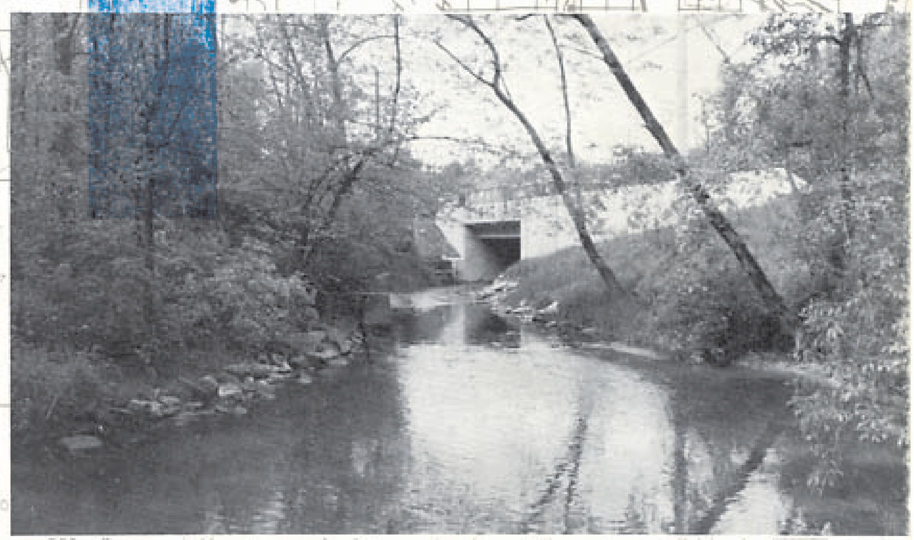
PLANNING REPORT NO. 36

A COMPREHENSIVE PLAN FOR THE OAK CREEK WATERSHED



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due Mr. Ronald J. Printz, SEWRPC Senior Water Resource Engineer, and Mr. Donald M. Reed, SEWRPC Principal Biologist, for their efforts in the conduct of this study and in the preparation of this report.

Planning Report No. 36

A COMPREHENSIVE PLAN FOR THE OAK CREEK WATERSHED

Prepared by the

Southeastern Wisconsin Regional Planning Commission
P. O. Box 769
Old Courthouse
916 N. East Avenue
Waukesha, Wisconsin 53187-1607

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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STATEMENT OF THE CHAIRMAN

This report documents the findings and recommendations of a three-year study of the serious and costly flooding, water pollution, and related land use problems of the Oak Creek watershed. The study was undertaken by the Regional Planning Commission in response to a formal request received from the Milwaukee Metropolitan Sewerage District. The conduct of the study was guided by the Oak Creek Watershed Committee, a Committee of 13 elected and appointed public officials and concerned citizens from throughout the watershed created by the Commission for this purpose. The study was intended to produce a comprehensive plan, a plan designed to assist the local, state, and federal units and agencies of government concerned in managing in a cost-effective and environmentally sound manner the water resources of this urbanizing 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, fishery development, and related land use plan elements; and presents a recommended comprehensive plan for the development of the watershed, including navigation improvements at the mouth of Oak Creek on the Lake Michigan shore. This report also specifically identifies the actions which must be taken by each of the units and agencies of government concerned to carry out the recommended plan over time. Full implementation of the recommended plan set forth herein will result in resolution of the costly and disruptive flooding, sandbar formation and navigation channel blockage, and water pollution problems of the Oak Creek watershed, will avoid the creation of new problems of this sort within the watershed, and will restore a more balanced warmwater and seasonal coldwater fishery within the watershed.

As is true of all of the Commission's plans, the Oak Creek watershed plan is entirely advisory to the local, state, and federal units of government concerned. The watershed plan is intended to provide a point of departure against which development proposals within the watershed can be evaluated by concerned officials and interested citizens as such proposals arise. 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 consideration and formal adoption of the plan and subsequent appropriate implementing action. Full implementation of the watershed plan will require the cooperative action of all of the units and agencies of government operating within the watershed.

In its continuing role of acting as a center for cooperative, areawide planning within southeastern Wisconsin, 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 Oak Creek watershed plan.

Respectfully submitted,

Anthony F. Balestrieri
Chairman

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Chapter I

INTRODUCTION

The Oak Creek watershed study is the seventh 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 for a proper appreciation of the Oak Creek 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 is also 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.

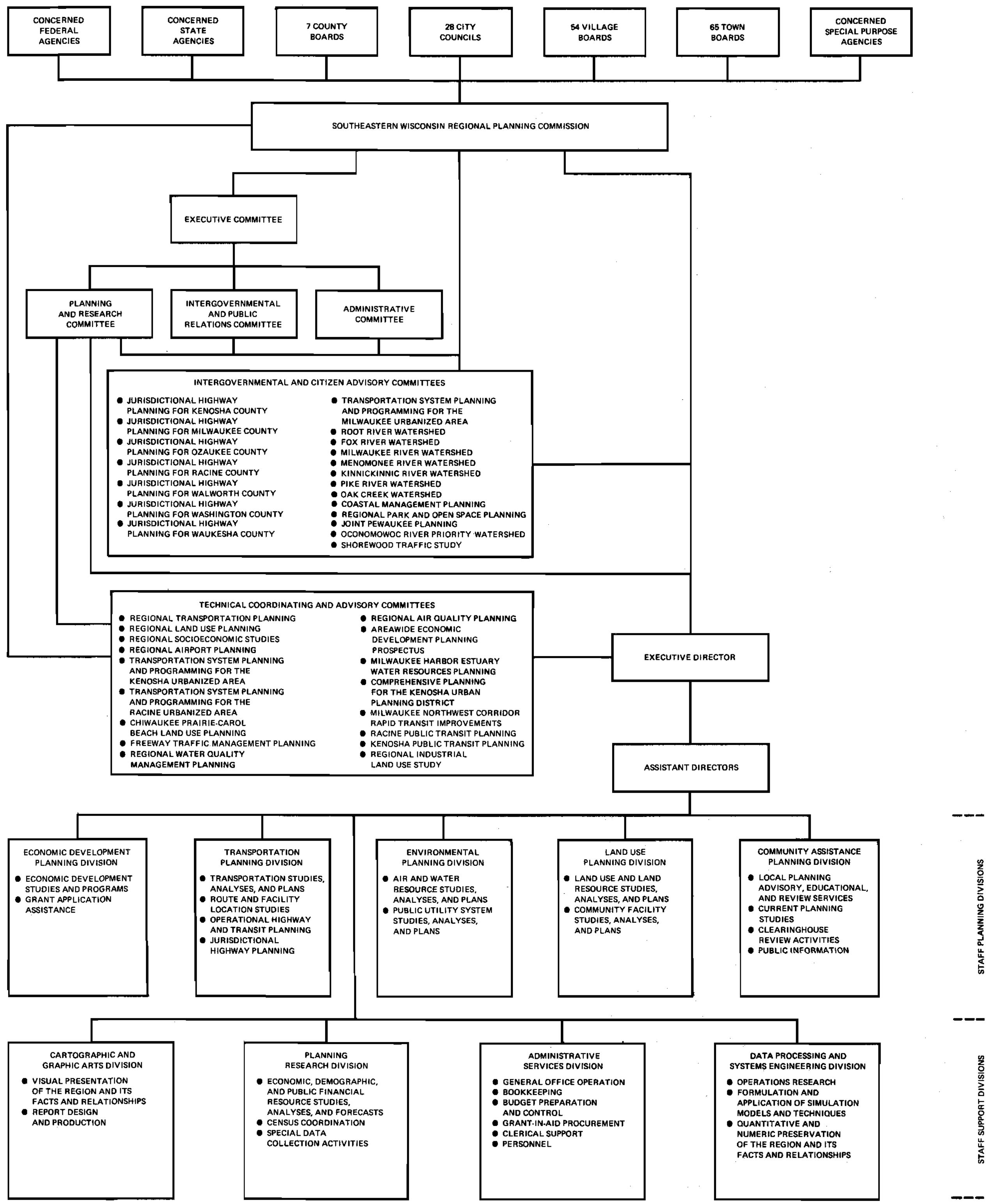
THE REGIONAL PLANNING COMMISSION

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) represents an attempt to provide the necessary areawide planning services for one of the largest 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 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 seven 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.

Figure 1

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION ORGANIZATIONAL STRUCTURE



Source: SEWRPC.

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 development 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. 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. About 37 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 37 percent of all the tangible wealth in the State as measured by equalized valuation, and represents the greatest wealth-producing area of the State, with about 39 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.

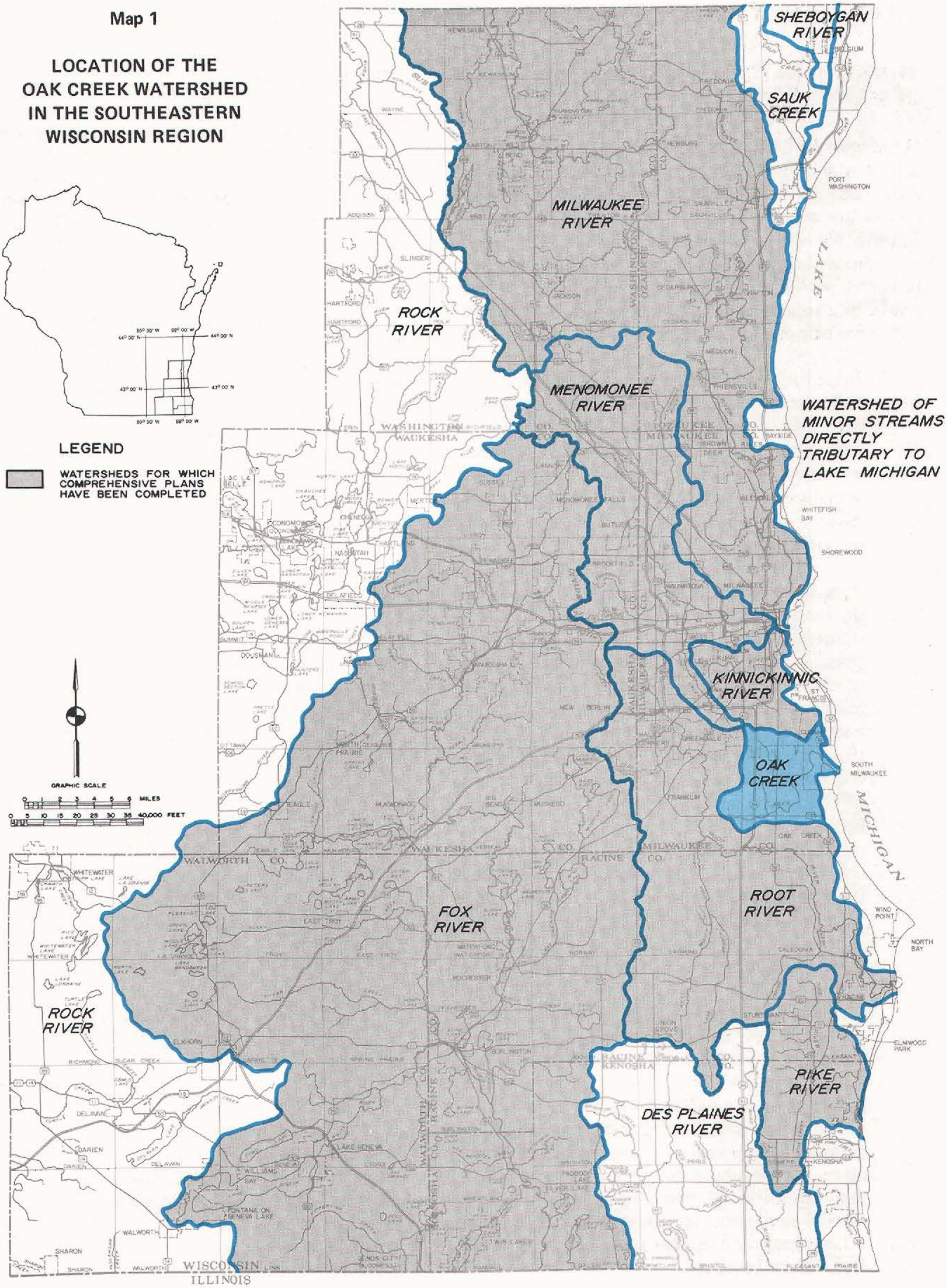
Geographically the Region is located in a relatively good position with regard to continued growth and development. It is bounded on the east by Lake Michigan, which provides an ample supply of fresh water for both domestic and industrial use, as well as being a recreational attraction and an integral 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. 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 Oak Creek 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 briefly review 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 Oak Creek watershed planning program.

Map 1

LOCATION OF THE OAK CREEK WATERSHED IN THE SOUTHEASTERN WISCONSIN REGION



The Oak Creek watershed is an integral part of the highly urbanized seven-county Southeastern Wisconsin Region. This Region, while comprising only 5 percent of the total area of the State, contains about 37 percent of the State's population, provides employment for about 39 percent of the State's labor force, and contains approximately 37 percent of the tangible wealth of the State. The Oak Creek watershed is the third smallest of the 11 major watersheds located wholly or partly within the Region. About 2.2 percent of the 1980 population of the Region resides within this urbanizing watershed, which comprises only about 1.0 percent of the area of the Region.

Source: SEWRPC.

Furthermore, water control facility recommendations contained within the Oak Creek 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 Oak Creek 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 subject of these guides include 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.

Other Regional and Subregional Work Programs

Additional regional planning programs undertaken by the Commission since its initial work effort, all directed toward the preparation of major elements of a comprehensive plan for the physical development of the Region, include among others: a regional land use and transportation planning program, completed in 1966, with the resulting plans being revised in 1978; a library system planning program, completed in 1974; a regional sanitary sewerage system planning program, completed in 1974; a regional housing planning program, completed in 1975; a regional airport system planning program, completed in 1976; a regional park, outdoor recreation, and related open space study, completed in 1977; a transportation planning program for the elderly and handicapped, completed in 1978; and a regional air quality maintenance planning program, completed in 1980. In addition, watershed planning programs were completed for the Root, Fox, Milwaukee, Menomonee, Kinnickinnic, and Pike River watersheds; jurisdictional highway system planning programs for all seven constituent counties were completed; and transit development planning programs were completed for the Kenosha and Racine urbanized areas. The Commission has also completed more detailed urban development plans for certain subareas of the Region, including the Kenosha and Racine Planning Districts.

Areawide Water Quality Management Planning Program

In July 1979 the Commission completed an areawide water quality management planning program that has particularly important implications for the Oak Creek watershed study. The areawide water quality management planning program updated and refined previous water quality and water quality-related plan elements such as the regional sanitary sewerage system plan and earlier comprehensive watershed plans. At the same time this planning program extended those previous water quality and related plan elements to the portions of the Region not then covered with watershed plans and updated all the plan recommendations to the new plan design year 2000. The areawide water quality management plan consists of the following five major elements: 1) an element addressing land use; 2) an element addressing elimination of pollution from point sources; 3) an element addressing elimination of pollution from nonpoint sources; 4) an element addressing the handling, recycling, and disposal of sewage sludge; and 5) an element addressing water quality monitoring. The plan includes the designation of wastewater treatment and water quality management agencies. The findings and recommendations of the areawide water quality management plan are set forth in SEWRPC Planning Report No. 29, A Regional Wastewater Sludge Management Plan for Southeastern Wisconsin, and SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for

Southeastern Wisconsin: 2000. This plan was adopted by the Commission on July 12, 1979, and by the Wisconsin Department of Natural Resources on July 25, 1979. The Governor approved and certified the plan to the U. S. Environmental Protection Agency on December 3, 1979. Progress toward implementation of the plan is documented in the Commission's annual reports.

THE OAK CREEK WATERSHED STUDY

The Oak Creek watershed study is the seventh comprehensive watershed planning program to be undertaken by the Commission. The watershed encompasses approximately 27 square miles, or 1.0 percent of the seven-county planning area, and about 2.2 percent of the population of the Southeastern Wisconsin Region resides within the watershed. The problems of this watershed typify those found in areas experiencing changing land use patterns and water resource-related problems, and have a direct affect on the property and general welfare of the residents of the watershed.

Milwaukee Metropolitan Sewerage District

The Milwaukee Metropolitan Sewerage District is a special-purpose unit of government governed by a commission. Geographically, the Milwaukee Metropolitan Sewerage District includes all of Milwaukee County except the City of South Milwaukee. The primary responsibility of the District is to provide for adequate collection and transmission of domestic, industrial, and other sanitary sewage to and into the intercepting sewer system, and the treatment of the sewage. The District, which exists pursuant to the provisions of Section 66.88 et sec. of the Wisconsin Statutes (Chapter 282, Laws of 1982), has the authority to improve any watercourse within the County by deepening, widening, or otherwise changing the watercourse as may be necessary to carry off surface waters or drainage waters. Accordingly, the District will be an important agency in the implementation of any recommended flood control measures within the Oak Creek watershed, since the Oak Creek watershed is located entirely in Milwaukee County.

Initiation of the Oak Creek Watershed Study

On April 6, 1979, the Milwaukee Metropolitan Sewerage District formally requested the Southeastern Wisconsin Regional Planning Commission (SEWRPC) to investigate the need for a comprehensive study of the Oak Creek watershed—a study looking to the ultimate resolution of the flooding, water pollution, and related problems existing within that watershed and affecting the property and general welfare of its residents. This request recognized that these problems can best be resolved within the context of a cooperative, long-range, comprehensive watershed planning effort, involving all of the units and agencies of government concerned. Accordingly, on June 7, 1979, the Commission acted to create the Oak Creek Watershed Committee, comprised of 12 public officials and citizen leaders from within the watershed, and charged that Committee with assisting the Commission in its study of the water-related problems of the watershed.

The Oak Creek Watershed Committee held its organizational meeting on September 24, 1979, and commenced immediately to prepare a prospectus for the required comprehensive watershed planning program.[1] The membership of the Oak Creek Watershed Committee is listed in Appendix A.

The Committee identified and described in the prospectus the four serious resource-related problems within the watershed that require areawide study and resolution: 1) flooding, stormwater drainage, and attendant damages; 2) water pollution; 3) changing land use, as related to flooding and stormwater drainage and to water pollution; and 4) deterioration and destruction of the natural resource base, particularly the loss of important natural areas and wildlife habitat. The Committee completed the prospectus on October 22, 1979, and urged 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 March 6, 1980, was published, and, in accordance with the advisory role of the Commission, was transmitted on February 15, 1980, to the governmental agencies concerned for their consideration and action. A formal agreement governing the conduct of the study was entered into between the Milwaukee Metropolitan Sewerage District, the City of South Milwaukee, and the Commission on November 15, 1982, and work on the study was initiated on January 3, 1983. The total study cost of $144,700

[1] *See Oak Creek Watershed Planning Program Prospectus, SEWRPC, December 1979.*

was, as agreed upon in the aforementioned agreement, apportioned between the Milwaukee Metropolitan Sewerage District and the City of South Milwaukee with the District contributing $142,747[2] and South Milwaukee contributing $1,953.

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 began in January 1983.

Study Objectives

The primary objective of the Oak Creek watershed planning program, as set forth in the prospectus, is to help abate the serious water resource and water resource-related problems of the Oak Creek basin by developing a workable plan to guide the staged development of multi-purpose water resource facilities and related resource conservation and management programs for the watershed. To be effective, this plan 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 decision-making on both land and water resource development within the watershed so that, through such development, 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 Oak Creek watershed, including measures for the mitigation of existing flood and storm water drainage problems and elements for the minimization of future flood problems.

2. Prepare a plan for surface water quality management for the Oak Creek watershed, incorporating measures to abate existing pollution problems and elements intended to prevent future pollution problems. Local refinement and detailing of sanitary sewer service areas, as well as other local actions to implement the adopted regional water quality management plan, will be incorporated and properly reflected in the watershed planning process.

3. Prepare a plan for public open space preservation, including measures for the preservation and enhancement of the remaining woodlands, wetlands, and fish and wildlife habitat of the watershed.

4. 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 for the Lake Michigan Estuary of Oak Creek

The entire Oak Creek watershed, from its headwater areas to its confluence with Lake Michigan, was included in the comprehensive watershed planning program for purposes of the flood control and floodland management and related land use plan elements of the study. Primary attention with respect to the water pollution element of the study was focused on that part of the watershed lying upstream of the Oak Creek estuary which extends from the mouth of Oak Creek on the Lake Michigan shore approximately 0.3 mile to a location just upstream of the first Oak Creek Parkway bridge above the mouth of the stream, as shown on Map 2. Because of the complex nature of the effect of this estuary on water quality, it is the Commission's position that it be studied separately from the free-flowing portions of the Oak Creek stream system.[3] The Oak Creek Parkway bridge was

[2] *In addition to contributing monies directly to the Oak Creek watershed study, the Milwaukee Metropolitan Sewerage District also provided funding in the amount of $84,000 for the preparation of one inch equals 100 foot scale, two-foot contour interval topographic maps based upon a monumented survey control network, as recommended by the Regional Planning Commission, of all that part of the Oak Creek watershed lying in the City of Milwaukee and a portion of the City of South Milwaukee. The necessary large-scale maps were already available for all of that portion of the Oak Creek watershed located within the Cities of Franklin, Oak Creek, and Greenfield, and for a portion of the watershed located within the City of South Milwaukee.*

[3] *See Lake Michigan Estuary and Direct Drainage Area Subwatersheds Planning Program Prospectus, SEWRPC, September 1978, p. 53.*

selected as the upstream terminus of the Lake Michigan estuary because reverse currents have been observed up to this point; and Lake Michigan backwater effects are minimal upstream of the bridge. The watershed study, accordingly, includes the estuary primarily with respect to park and open space planning and flood flows and stages, including the effects of Lake Michigan on such flows and stages.

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, a consultant, and Commission staff, along with the designated responsibilities of these agencies, consultants, and staff in the conduct of major elements of the planning study.

A comprehensive watershed planning program necessarily covers a broad spectrum of related governmental and private development programs, and thus no agency, whatever its function or authority, can operate independently in the conduct of a watershed 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 Oak Creek Watershed Committee, which, as already noted, was established in September 1979. 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 is intended to assist the Commission in determining and coordinating public 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.

Map 2

THE LAKE MICHIGAN ESTUARY SUBWATERSHED FORMED BY THE CONFLUENCE WITH OAK CREEK

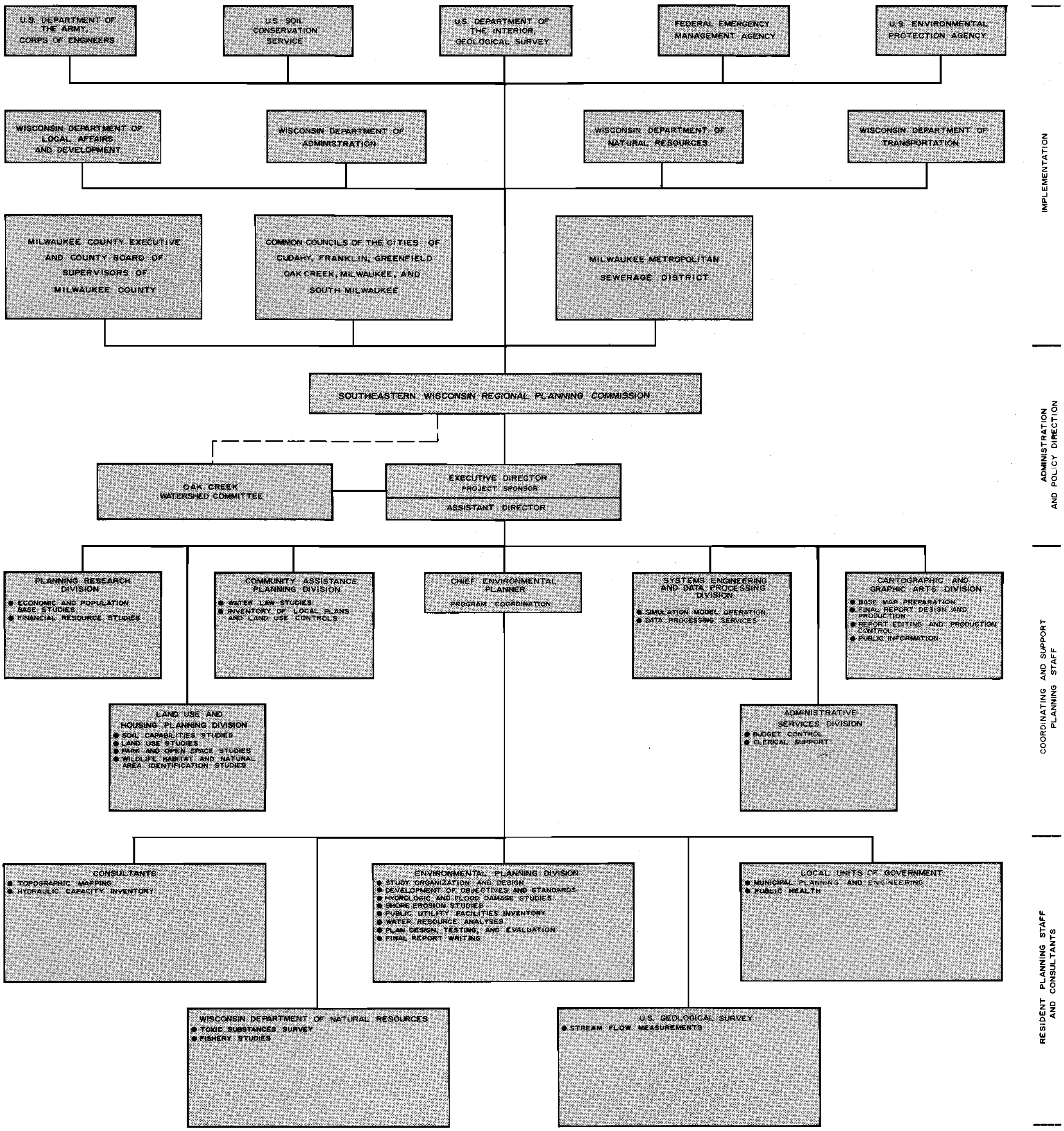
Oak Creek joins the Lake Michigan estuary within the City of South Milwaukee before discharging to Lake Michigan. The estuary extends approximately 0.3 mile up Oak Creek, to a location just upstream of the Oak Creek Parkway bridge in the City of South Milwaukee. It is the Commission position that, because of the complexity of the estuary, a water quality study of the estuary should be made separately from a study of the free-flowing portion of Oak Creek not affected by backwater from Lake Michigan. The watershed study, accordingly, includes the estuary primarily with respect to other planning considerations such as park and open space planning and floodland management.

Source: SEWRPC.

The watershed planning work program has been conducted by the resident Commission staff, supplemented as needed by contractual services provided by a consulting engineering firm. 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

Figure 2

ORGANIZATIONAL STRUCTURE FOR THE OAK CREEK WATERSHED PLANNING PROGRAM



Source: SEWRPC.

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 professional and supporting staff were supplemented with the services of a specialist in the area of surveying and mapping. A contractual agreement was executed with the firm of Alster-Ayers & Associates, Inc., of Madison, Wisconsin, for the provision of physical data and related vertical control servey information on selected hydraulic structures in the watershed.

Scheme of Presentation

The major findings and recommendations of the Oak Creek 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, 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 presents alternative plan elements for 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 for 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 Oak Creek 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.

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 adaptation 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, Kinnickinnic, and Pike Rivers, and Oak Creek 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 identify the specific problems of the Oak Creek watershed and to recommend 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 stormwater 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 they can, nevertheless, have major effects on watershed problems. 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 unit for water resources planning, 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. However, the meaning of the term watershed may be expanded to include planning concepts 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 Oak Creek, must exhibit if it is to form a rational unit for comprehensive water resources planning. 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 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 underlying the unique nature of the Commission's 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 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 urbanizing 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 critical in urbanizing areas such as the Oak Creek watershed. In such urbanizing areas, as opposed to more sparsely settled rural watersheds, the overall quality of the environment becomes highly dependent on present and future land use activities and supporting public facilities, and the viable options remaining for environmental protection and enhancement are limited.

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 Oak Creek watershed, the initial concern with environmental protection is centered on 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 ultimate resolution of these problems will require many important public policy determinations. These determinations must be made in recognition 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 two-fold: 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, the 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, Menomonee, Kinnickinnic, and Pike River watershed studies, and provide the foundation for the planning process applied in the Oak Creek 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 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 solutions within the watershed 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 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 testing and evaluation, and 7) plan selection and adoption. Plan implementation, although necessarily beyond the foregoing planning process, must be considered throughout the process if the plans are to be realized.

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 adaptation 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.

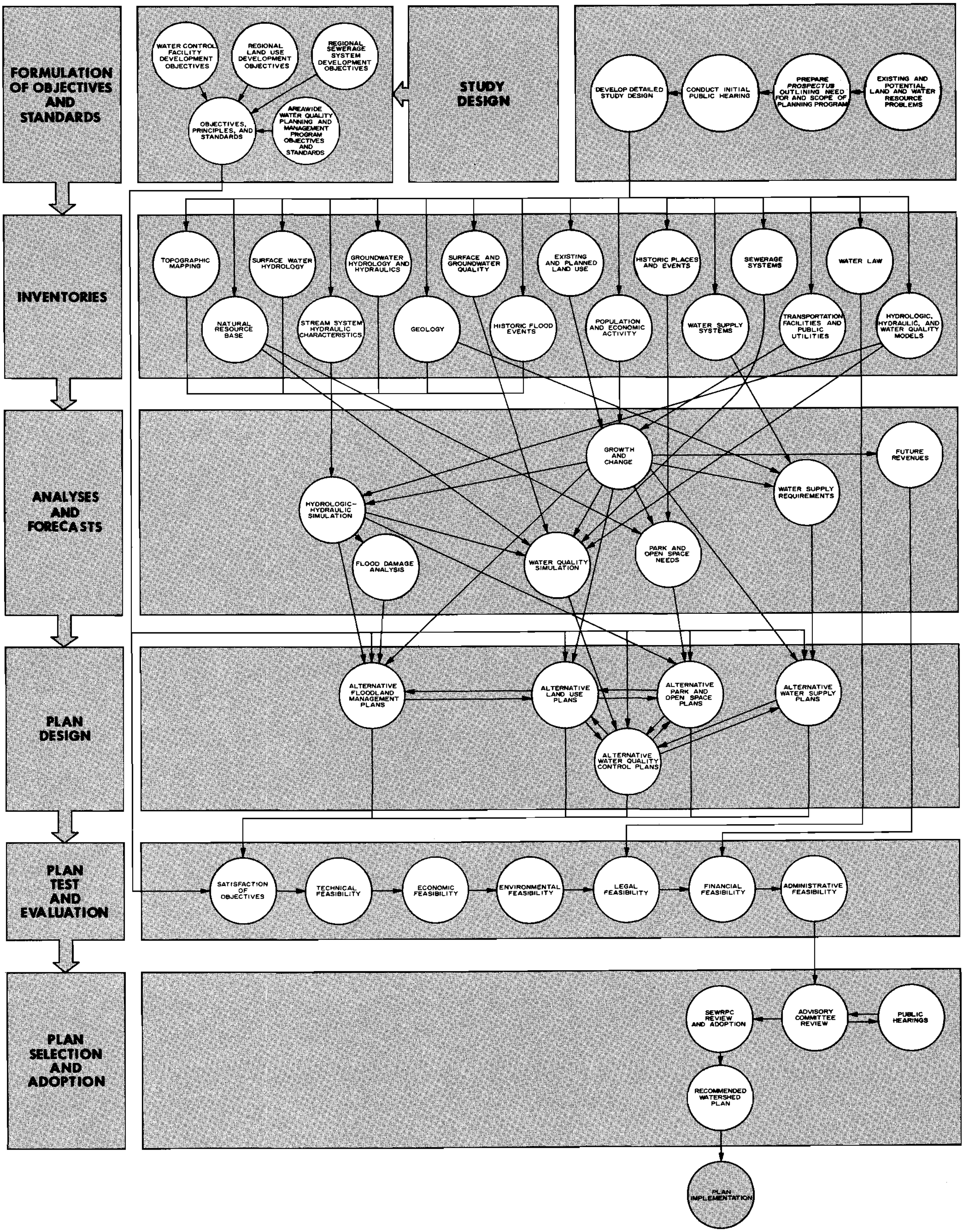
Study Design

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 Oak Creek watershed study were set forth in the Oak Creek Watershed Planning Program Prospectus prepared by the Oak Creek 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. The prospectus 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.

Figure 3

GENERAL STEPS IN A COMPREHENSIVE WATERSHED PLANNING PROGRAM



Source: SEWRPC.

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 Oak Creek 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 Oak Creek 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 testing can a choice be made from among alternatives of a 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, testing, 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 Oak Creek 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 management planning program.

Inventory

Reliable basic planning and engineering data collected on a uniform, watershedwide 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.

The sound formulation of comprehensive watershed development plans requires that factual data be developed on topographic features, the quantity of surface and groundwater, 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 Oak Creek 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.

Analyses and Forecasts

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 the determination of future growth within the watershed 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 can be 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 must be planned for anticipated demand at some future point in time. In the planning of water control facilities, the design year is usually based on 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 Oak Creek watershed study, the necessary forecast period was set as approximately 20 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 to 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 the 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 feasiblity, 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 digital computer simulation programs to evaluate hydrologic-hydraulic responses under alternative plan elements to interagency meetings and public hearings. Plan testing 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 that the Oak Creek watershed study develop a land use plan representing a refinement of the adopted regional land use plan. This land use plan will be 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 will be 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 Oak Creek 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 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 way to achieve such involvement in the planning process, and to openly arrive 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.

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. 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 Oak Creek watershed, thereby establishing a factual base upon which the watershed planning process may proceed. This description of the watershed is presented in two major sections; the first describes the man-made features, and the second describes the natural resource base of the watershed.

DESCRIPTION OF THE WATERSHED: MAN-MADE FEATURES

The man-made features of a watershed 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 in terms of both historical development and existing (1980) conditions. The fourth and fifth sections describe the public utility and transportation facility systems within the watershed. A final section summarizes the information presented in these five sections.

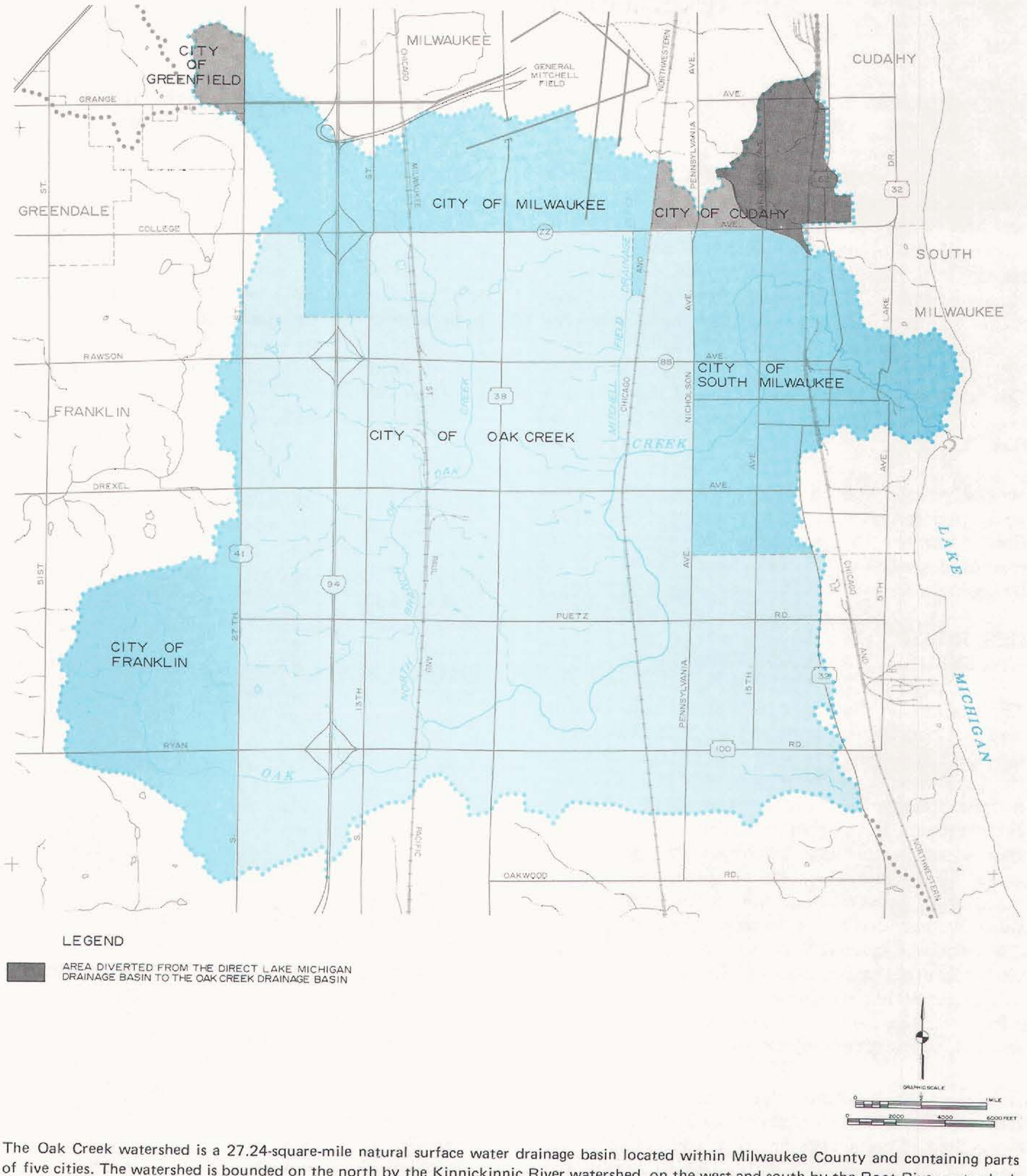
Regional Setting of Watershed and Political Boundaries

The Oak Creek watershed, as shown on Map 3, is a 27.24-square-mile surface water drainage basin that discharges to Lake Michigan in the City of South Milwaukee. In 1980, a 0.76-square-mile area was diverted from the direct Lake Michigan drainage basin to the Oak Creek drainage basin, the area diverted being shown on Map 3. This interbasin diversion increased the area of the Oak Creek drainage basin by 2.9 percent. The Oak Creek acts as an estuary of Lake Michigan from its mouth to the first Oak Creek Parkway bridge, a distance of about 0.3 mile. The Oak Creek watershed is the third smallest of the 11 major natural watersheds located wholly or partly within the Region. It comprises only about 1 percent of the total area of the Southeastern Wisconsin Region.

As shown on Map 3 and described in Table 1, the source of Oak Creek which, as a perennial stream, has a length of about 13.1 miles, is in Section 24, Town 5 North, Range 21 East in the City of Franklin. From its source near the intersection of Sherwood Drive and Southland Drive, the creek flows southerly for approximately 0.5 mile to just south of Ryan Road and thence easterly for approximately 4.4 miles to a point east of Shepard Avenue. The creek then flows northerly for approximately 5.2 miles to 15th Avenue and the Oak Creek Parkway, and then finally flows southeasterly for about 3.0 miles to its confluence with Lake Michigan.

Map 3

CIVIL DIVISIONS IN THE OAK CREEK WATERSHED



The Oak Creek watershed is a 27.24-square-mile natural surface water drainage basin located within Milwaukee County and containing parts of five cities. The watershed is bounded on the north by the Kinnickinnic River watershed, on the west and south by the Root River watershed, and on the east by areas directly tributary to Lake Michigan. Serious flooding problems exist within the watershed. Sound resolution of these problems requires a comprehensive study of the entire basin.

Source: SEWRPC.

Table 1

STREAMS SELECTED FOR DEVELOPMENT OF FLOOD STAGE PROFILES IN THE OAK CREEK WATERSHED

		Upstream Limit of Stream Designation by U. S. Public Land Survey		Stream Length[a] (miles)									
				Intermittent			Perennial			Combined			Community or Communities in Which Stream is Located
Stream Name	Tributary To	Intermittent	Perennial	Studied	Not Studied	Total	Studied	Not Studied	Total	Studied	Not Studied	Total	
Oak Creek	Lake Michigan	T5N, R21E SW¼ Section 13	T5N, R21E SW¼ Section 24	0.75	0.25	1.00	13.07	0.0	13.07	13.82	0.25	14.07	Cities of Franklin, Oak Creek, and South Milwaukee
North Branch of Oak Creek	Oak Creek	T6N, R22E NW¼ Section 31	T6N, R22E NE¼ Section 31	0.0	0.56	0.56	5.82	0.0	5.82	5.82	0.56	6.38	Cities of Milwaukee and Oak Creek
Mitchell Field Drainage Ditch	Oak Creek	T6N, R22E NW¼ Section 32	T6N, R22E SE¼ Section 33	0.90	0.57	1.47	2.41	0.0	2.41	3.31	0.57	3.88	Cities of Milwaukee and Oak Creek
Southland Creek	North Branch of Oak Creek	T5N, R21E SE¼ Section 13	--	1.77	0.24	2.01	--	--	--	1.77	0.24	2.01	Cities of Franklin and Oak Creek
Tributary to Southland Creek	Southland Creek	T5N, R22E SW¼ Section 18	--	0.73	0.50	1.23	--	--	--	0.73	0.50	1.23	City of Oak Creek
Tributary to Upper Oak Creek	Oak Creek	T5N, R21E SW¼ Section 13	--	0.55	0.26	0.81	--	--	--	0.55	0.26	0.81	City of Franklin

[a] *Total perennial and intermittent stream lengths determined from SEWRPC large-scale topographic maps and U. S. Geological Survey quadrangle maps.*

Source: SEWRPC.

The North Branch of Oak Creek which, as a perennial stream, has a length of about 5.8 miles, has its origin in Section 31, Town 6 North, Range 22 East in the City of Milwaukee just south of the IH 94 Mitchell Field Airport Spur Freeway interchange. From this origin, the stream flows southerly to its confluence with Oak Creek north of Ryan Road between 13th Street and Howell Avenue.

The third perennial stream in the Oak Creek watershed is the Mitchell Field drainage ditch which, as a perennial stream, has a length of about 2.4 miles. From its source east of the Mitchell Field north-south runway in Section 33, Town 6 North, Range 22 East in the City of Milwaukee the stream flows southerly to its confluence with Oak Creek north of Drexel Avenue.

In addition to the three perennial streams described herein, the stream system of the watershed includes a number of minor, intermittent watercourses. Information on these intermittent streams, as well as on the perennial streams, is provided in Table 1. The streams are shown on Map 3. The stream reaches for which detailed flood hazard data were developed are described in Chapter V.

Civil Divisions: Superimposed on the irregular watershed boundaries is a pattern of local political boundaries. As shown on Map 3, the watershed lies entirely within Milwaukee County and in parts of six cities. None of the minor civil divisions lie entirely within the watershed boundaries. The portions of the watershed lying within each of the six minor civil divisions are listed in Table 2. Geographic boundaries of the civil divisions are an important factor which must be considered in any areawide planning effort, like the Oak Creek watershed planning program, since the civil divisions form the basic foundation of the decision-making framework within which intergovernmental, environmental, and developmental problems must be addressed.

Special-Purpose Units of Government: The Milwaukee Metropolitan Sewerage District is a special purpose areawide unit of government having important responsibilities for the provision of sanitary sewer service and sewage treatment and for water pollution control and authorization for flood control throughout most of the watershed. The District provides sanitary sewer service to all the cities within the watershed except the City of South Milwaukee, which has its own sanitary sewerage system managed under the direction of

Table 2

AREAL EXTENT OF CIVIL DIVISIONS IN THE OAK CREEK WATERSHED: 1983

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	242.66	27.24	11.2	100.0
City				
Cudahy	4.74	0.99	20.9	3.6
Franklin	34.69	2.54	7.3	9.3
Greenfield	11.63	0.22	1.9	0.8
Milwaukee	96.65[a]	2.86	3.0	10.5
Oak Creek	28.41	17.39	61.2	63.9
South Milwaukee. . . .	4.85	3.24	66.8	11.9
Total	--	27.24[b]	--	100.0

[a] *Area within Milwaukee County is 96.63 square miles.*

[b] *The areas in this table were determined by map delineation and measurement. Some data used in this report have been determined by approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 27.24 square miles, or 17,436 acres. The watershed area as approximated by 111 quarter sections is 27.74 square miles, or 17,753 acres. The areas in this table differ somewhat from those set forth in Table 3 of the Oak Creek 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 stormwater drainage maps.*

Source: SEWRPC.

the City of South Milwaukee Sewerage Commission. The District also has water pollution abatement, drainage, and flood control responsibilities. The Metropolitan Sewerage District, with its service area encompassing approximately 88 percent of the Oak Creek watershed, is a particularly important agency in the Oak Creek 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 Management Responsibilities: Superimposed upon these local and special-purpose units of government are those state and federal governments having important responsibilities for resource conservation and management. These include the Wisconsin Department of Natural Resources; the University of Wisconsin-Extension; 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

An understanding of the size, characteristics, and spatial distribution of the population is basic to any watershed planning effort 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. 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 Oak Creek 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 and 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 and within the Region.

Demographic Base: For comprehensive watershed planning purposes, a demographic inventory should include consideration of population size, distribution, and composition.

Population Size: The 1980 resident population of the watershed was estimated at 39,700 persons, or about 4 percent of the population of Milwaukee County and about 2 percent of the population of the Region. As shown in Table 3 and Figure 4, the population of the watershed increased by 44 percent beween 1960 and 1970. During this same period, Milwaukee County experienced only a 2 percent increase, while the Region experienced a 12 percent increase. Between 1970 and 1980, the populations of the watershed and the Region increased by 9 percent and 1 percent, respectively, while the population of Milwaukee County decreased by 8 percent. The proportion of the total regional population which resides in the watershed increased from 1.6 percent in 1960 to 2.2 percent in 1980. The higher population growth rate of the watershed reflects the redistribution of population which has been occurring within the Region for many years. The Oak Creek watershed still contains substantial areas of rural lands, and, being located in the Milwaukee urbanized area, is subject to rapid urbanization. The public preference evidenced in the recent past for low-density residential development and the concomitant diffusion of urban development outward from the older metropolitan centers has resulted in high rates of population growth in areas contiguous to cities such as Milwaukee.

Population Distribution: The 1960, 1970, and 1980 resident population of the watershed is presented in Table 4 by civil division. The City of Oak Creek portion of the watershed, which comprises 64 percent by area of the Oak Creek watershed, experienced the largest increase in population from 1960 to 1980, with a gain of almost 6,000 persons. The proportion of the total resident population of the watershed located in the City of Oak Creek also increased— from about 28 percent in 1960 to about 33 percent in 1980. The portions

Table 3

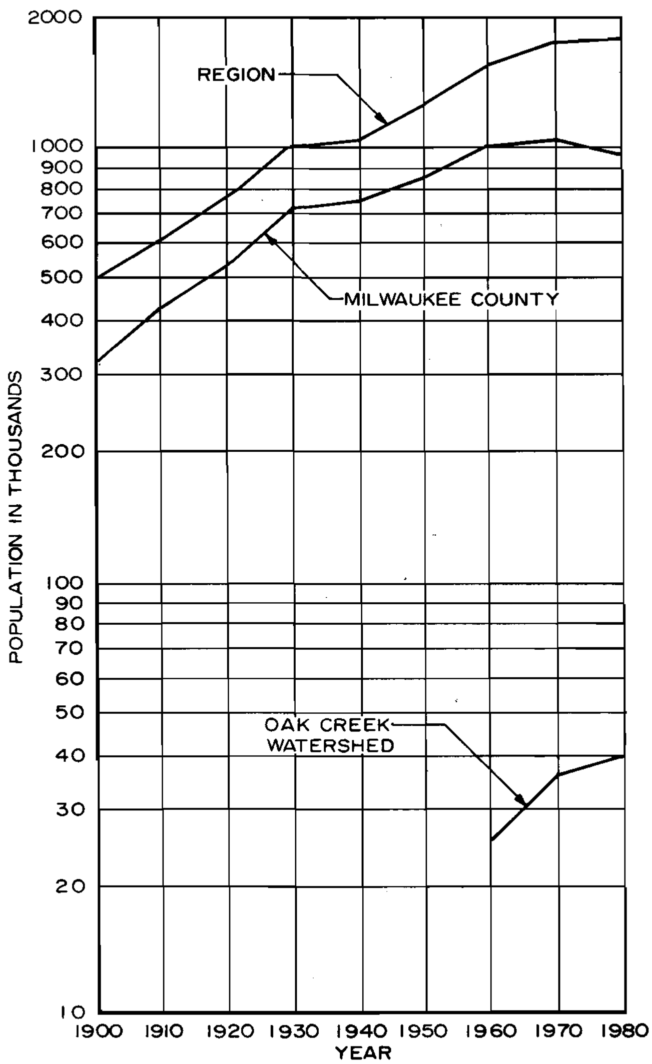
POPULATION IN THE OAK CREEK WATERSHED, MILWAUKEE COUNTY, AND THE REGION: SELECTED YEARS 1960-1980

Year	Population						Watershed Population As Percent of Regional Population
	Oak Creek Watershed		Milwaukee County		Southeastern Wisconsin Region		
	Number	Percent Change During Preceding Period	Number	Percent Change During Preceding Period	Number	Percent Change During Preceding Period	
1960	25,431	--	1,036,047	--	1,573,620	--	1.6
1970	36,498	44	1,054,249	2	1,756,083	12	2.1
1980	39,716	9	964,988	-8	1,764,919	1	2.2

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

Figure 4

POPULATION OF THE OAK CREEK WATERSHED, MILWAUKEE COUNTY, AND THE REGION: SELECTED YEARS 1900-1980



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

of the Cities of Milwaukee and South Milwaukee within the watershed showed decreases both in population and in their proportion of the total resident population of the watershed from 1970 to 1980. The populations of those portions of the Cities of Franklin and Greenfield within the watershed increased by more than 1,000 persons between 1960 and 1980, with slight increases in their proportions of the total watershed population. While the population of the watershed within the City of Cudahy increased significantly from 1970 to 1980, along with its proportion of the total watershed population, this may be attributed primarily to the additional land area of the City included in the 1980 watershed boundary because of stormwater drainage system changes in Cudahy. As already noted, between 1970 and 1980, 0.76 square mile of area in the City of Cudahy was diverted from the direct Lake Michigan drainage basin to the Oak Creek drainage basin.

As shown on Map 4, in 1980 most of the Oak Creek watershed had a density of fewer than 400 persons per gross square mile, reflecting the still predominantly rural character of the watershed. Only a small portion of the watershed in 1980 exhibited a population density in excess of 4,500 persons. These higher density areas included parts of the Cities of Cudahy, Greenfield, Milwaukee, and South Milwaukee.

From 1960 to 1980, the overall population density of the watershed increased by about 57 percent—from about 930 to about 1,460 persons per square mile. Table 5 presents the overall 1980 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 civil divisions.

Population Composition: In 1980 the median age of the resident population of the watershed was 29.4 years, while the median age of the resident population of Milwaukee County was about 30.0 years, and of the Region as a whole about 29.7 years. This differential reflects the still primarily rural nature of the watershed, for slightly younger age distributions are normally found in rural-urban fringe and rural areas. The average household size in the watershed in 1980 was 2.92 persons, while the average household size in Milwaukee County was 2.59 persons, and in the Region as a whole, 2.75 persons. This again reflects the primarily rural character of the watershed, for larger household sizes are normally more prevalent in rural and rural-urban fringe areas. In 1980, the average annual income for households within the watershed was estimated at $23,850, somewhat higher than the Milwaukee County average of $20,824, and the regional average of $22,756.

Economic Base: The Oak Creek watershed is located within the Milwaukee urbanized area and very near the Racine urbanized area. As such, its economic base cannot be differentiated in any meaningful way from that of the greater Milwaukee and Racine areas. The resident population of the watershed can readily commute to jobs located

Table 4

POPULATION IN THE OAK CREEK WATERSHED BY CIVIL DIVISION: 1960, 1970, and 1980

Civil Division[a]	1960		1970		1980[b]	
	Population	Percent of Watershed Population	Population	Percent of Watershed Population	Population	Percent of Watershed Population
City						
Cudahy	22	--[c]	475	1	2,412	6
Franklin . . .	1,598	6	1,956	5	2,857	7
Greenfield . .	394	2	545	2	1,461	4
Milwaukee . .	2,285	9	7,333	20	5,081	13
Oak Creek . .	7,067	28	10,054	28	13,015	33
South Milwaukee.	14,065	55	16,135	44	14,890	37
Total	25,431	100	36,498	100	39,716	100

[a] *The civil divisions in the watershed and the boundaries of these civil divisions have changed over time because of incorporations and annexations.*

[b] *Watershed boundary updated using large-scale topographic maps and stormwater drainage maps.*

[c] *Negligible.*

Source: SEWRPC.

outside the watershed, while other residents in the greater Milwaukee and Racine areas can readily commute to jobs located in the watershed. Some appreciation of the general character of the watershed can, nevertheless, be gained by examining the size and character of economic activities in the basin.

Figure 5 shows the relative concentration of jobs by eight major industrial categories in 1980 for the Oak Creek watershed, Milwaukee County, and the Region. Employment within the watershed in the eight major categories, estimated at 20,000 jobs, is concentrated in four major industry categories. Manufacturing provided the largest number of jobs, about 10,600, or about 53 percent of the total employment. Wholesale and retail trade, government services and education, and private services provided the next largest numbers of jobs, with about 19, 11, and 9 percent of the total, respectively. The other four major industry groups each provided 3 percent or less of the total jobs in the watershed. About 70 jobs, or less than 1 percent of the total, were provided by agriculture.

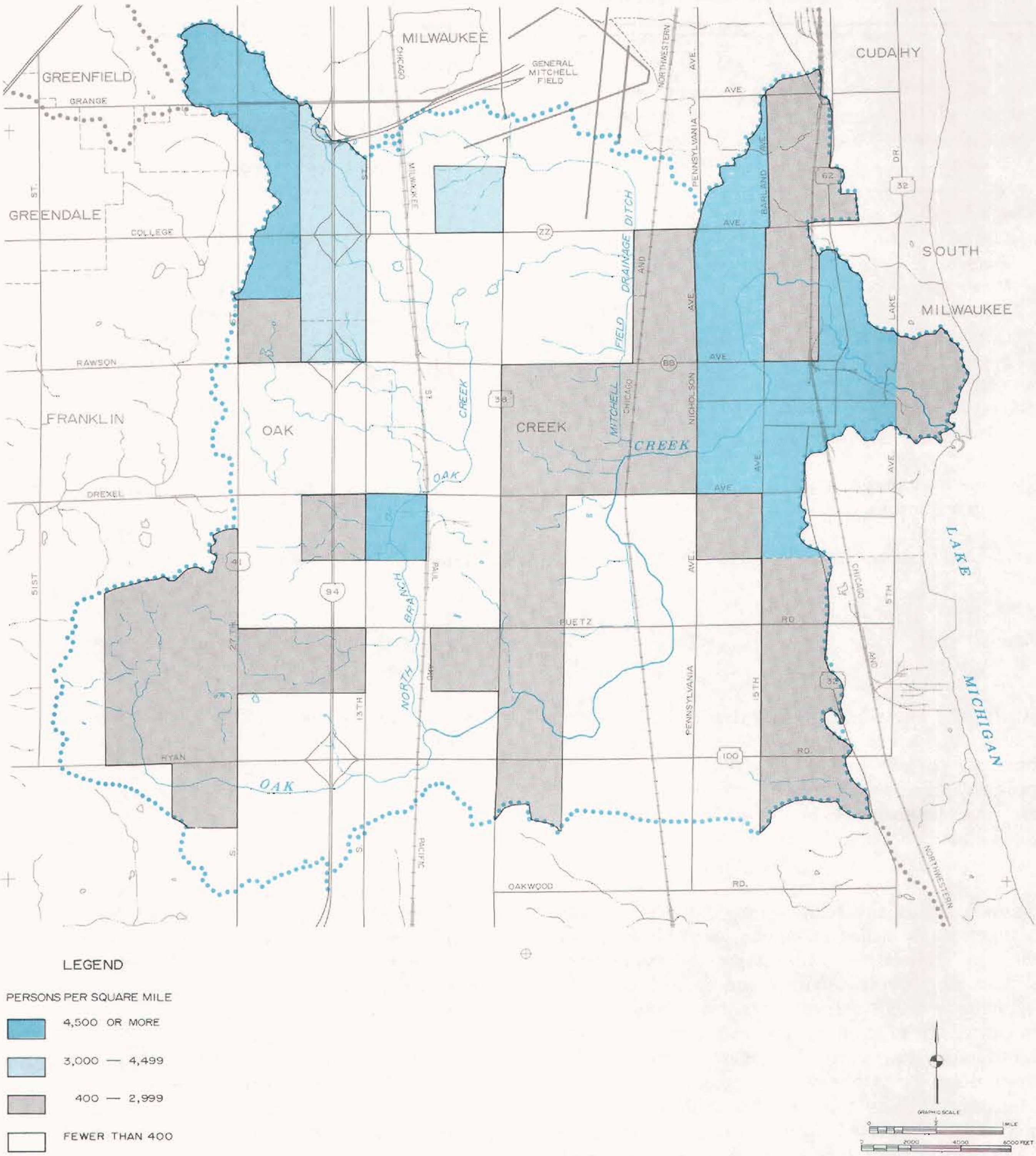
The relative concentration of jobs within manufacturing is presented in Figure 6 for the Oak Creek watershed, Milwaukee County, and the Region. The majority of manufacturing jobs are in the nonelectrical machinery category, which provided about 32 percent of all manufacturing employment within the watershed. The manufacture of electrical equipment and transportation equipment provided about 26 and 20 percent, respectively, of total manufacturing employment; other types of manufacturing each accounted for 7 percent or less of the total.

Land Use

An important concept underlying the watershed planning effort is that land use development must be adjusted to 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

Map 4

GROSS POPULATION DENSITY IN THE OAK CREEK WATERSHED: 1980



The 1980 resident population of the Oak Creek watershed is estimated at 39,700 persons. Gross population densities within the watershed range from fewer than 400 persons per square mile in the still rural areas of the watershed to more than 4,500 persons per square mile in the urbanized areas. From 1960 to 1980, the overall population density of the watershed increased from about 930 to about 1,460 persons per square mile, an increase of about 530 persons per square mile, or about 57 percent.

Source: SEWRPC.

Table 5

TOTAL POPULATION AND POPULATION DENSITY IN THE OAK CREEK WATERSHED: 1980

Civil Division	Population Within Watershed	Percent of Watershed Population	Area Included in Watershed (square miles)	Percent of Watershed Area Within Civil Division	Average Gross Population Density per Square Mile
City					
Cudahy	2,412	6.1	0.99	3.6	2,436
Franklin	2,857	7.2	2.54	9.3	1,125
Greenfield . . .	1,461	3.6	0.22	0.8	6,641
Milwaukee . . .	5,081	12.8	2.86	10.5	1,776
Oak Creek . . .	13,015	32.8	17.39	63.9	748
South Milwaukee. . .	14,890	37.5	3.24	11.9	4,596
Total	39,716	100.0	27.24	100.0	1,458

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

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.

Historical Development:[1] The first European settlers came to the watershed in 1835 by way of the military road that ran between Fort Dearborn at Chicago and Fort Howard at Green Bay. The settlement of what is now the City of South Milwaukee dates back to that year when Elihu Higgins of Massachusetts settled there. John Fowle, another early settler, spurred the development of the area by opening a tavern and stage station on the route between Chicago and Milwaukee. Oak Creek was designated a township in 1841 and held its first town meeting in 1842. The census of 1840 reported a population of 2,660 for the Town, of which South Milwaukee was then a part.

In addition to South Milwaukee, two unincorporated villages developed in the Town of Oak Creek: Carrolville on Lake Michigan and Oakwood on Oakwood Road between Howell Avenue and 13th Street. Carrollville was settled by Scotch-Irish immigrants who established St. Matthew's Catholic Church in 1841.

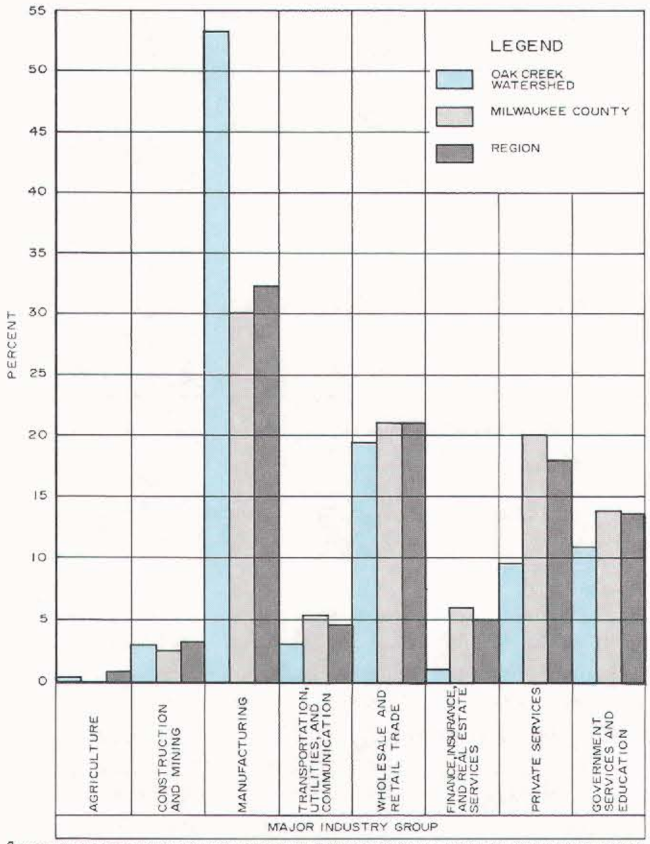
Oakwood was settled by German immigrants who established St. John's Lutheran Church at what is now S. 27th Street and Oakwood Road in 1843. In 1854, the Green Bay, Milwaukee & Chicago Rail Road Company, predecessor of the Chicago & North Western Transportation Company, laid tracks through the eastern section of the Town and opened a depot in South Milwaukee in 1855. Industry was attracted to the area. By the turn of the century, there were several factories in the area, including the United States Glue, the Galaway Coke, and the American Tar Products Companies. In 1856, Joseph Dibley opened a brickyard in South Milwaukee. In 1870, a second brickyard was opened that was so successful a pier was built to ship bricks throughout the Great Lakes region. The Wisconsin Union Railroad Company also constructed railway tracks through the Town in 1871, and was acquired in 1872 by the Milwaukee & St. Paul Railway Company, which eventually became today's Chicago, Milwaukee, St. Paul & Pacific Railroad Company (Milwaukee Road).

South Milwaukee remained a small unincorporated community until 1890, when the South Milwaukee Company was formed to promote industrial and residential development in the area. At the time of its incorporation in December 1892, the Village of South Milwaukee had a population of 512, eight

[1] *In addition to Commission inventories of historic places and events, the following reference was used in preparing the brief account of the historical development of the Oak Creek watershed: Department of Sociology of the University of Wisconsin-Milwaukee and Milwaukee Urban Observatory, The Milwaukee Metropolitan Fact Book: 1970, 1972.*

Figure 5

DISTRIBUTION OF TOTAL EMPLOYMENT[a] BY MAJOR INDUSTRY GROUP FOR THE OAK CREEK WATERSHED, MILWAUKEE COUNTY, AND THE REGION: 1980



[a]EXCLUDES SELF EMPLOYED, UNPAID FAMILY WORKERS, DOMESTICS, AND EMPLOYEES OF CHURCHES

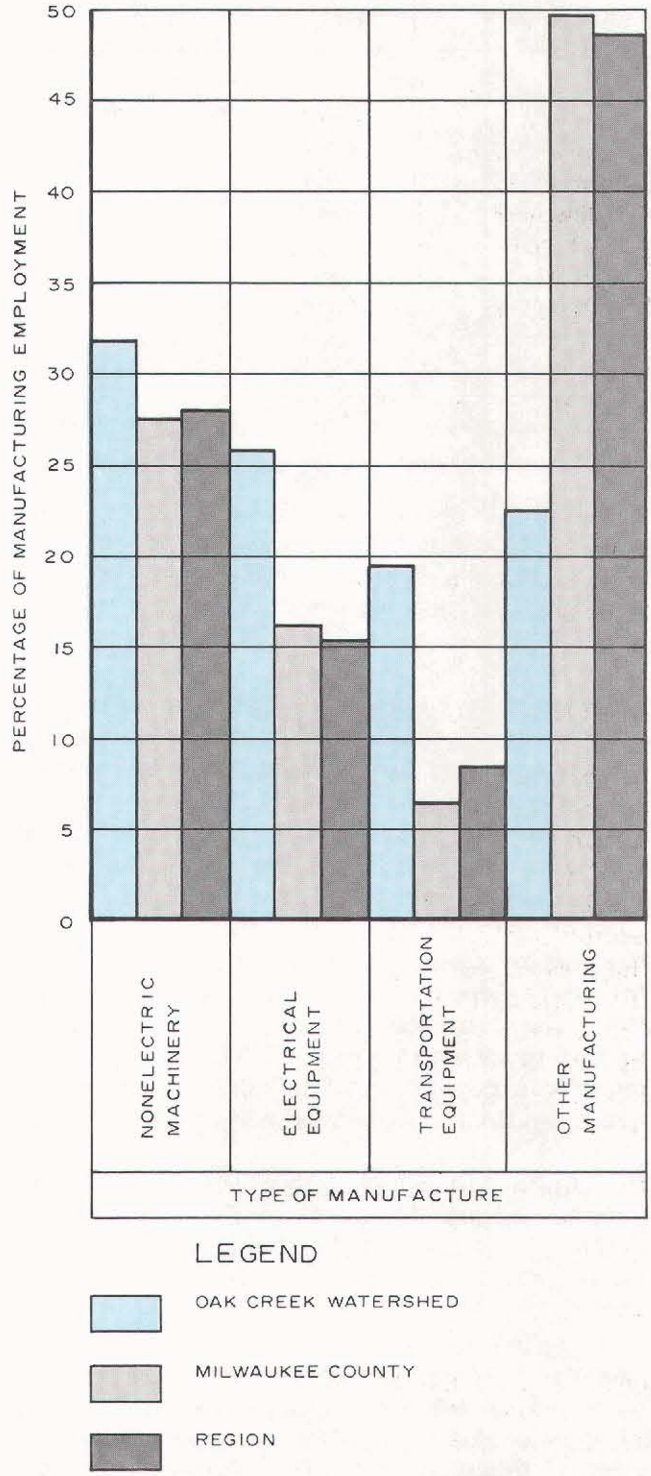
Source: U. S. Department of Industry, Labor and Human Relations and SEWRPC.

factories, and 53 businesses. Growth proceeded at a steady rate as German and Polish immigrants continued to be attracted to the area by the availability of work, and in 1897 a population of more than 1,500 permitted incorporation as a city. By 1900, population had increased to 3,392, and almost doubled to 6,072 in 1910. By 1970, the population had increased to a peak of 23,297, after which the population declined somewhat to 21,069 in 1980.

The earliest settlement in the Oak Creek watershed was the area which is now the City of South Milwaukee. Settlement of this area began in 1835. As shown on Map 5, most of the early urbanization within the watershed occurred in the City of South Milwaukee and was generally limited to this area until about 1950. At that time, the urbanized area

Figure 6

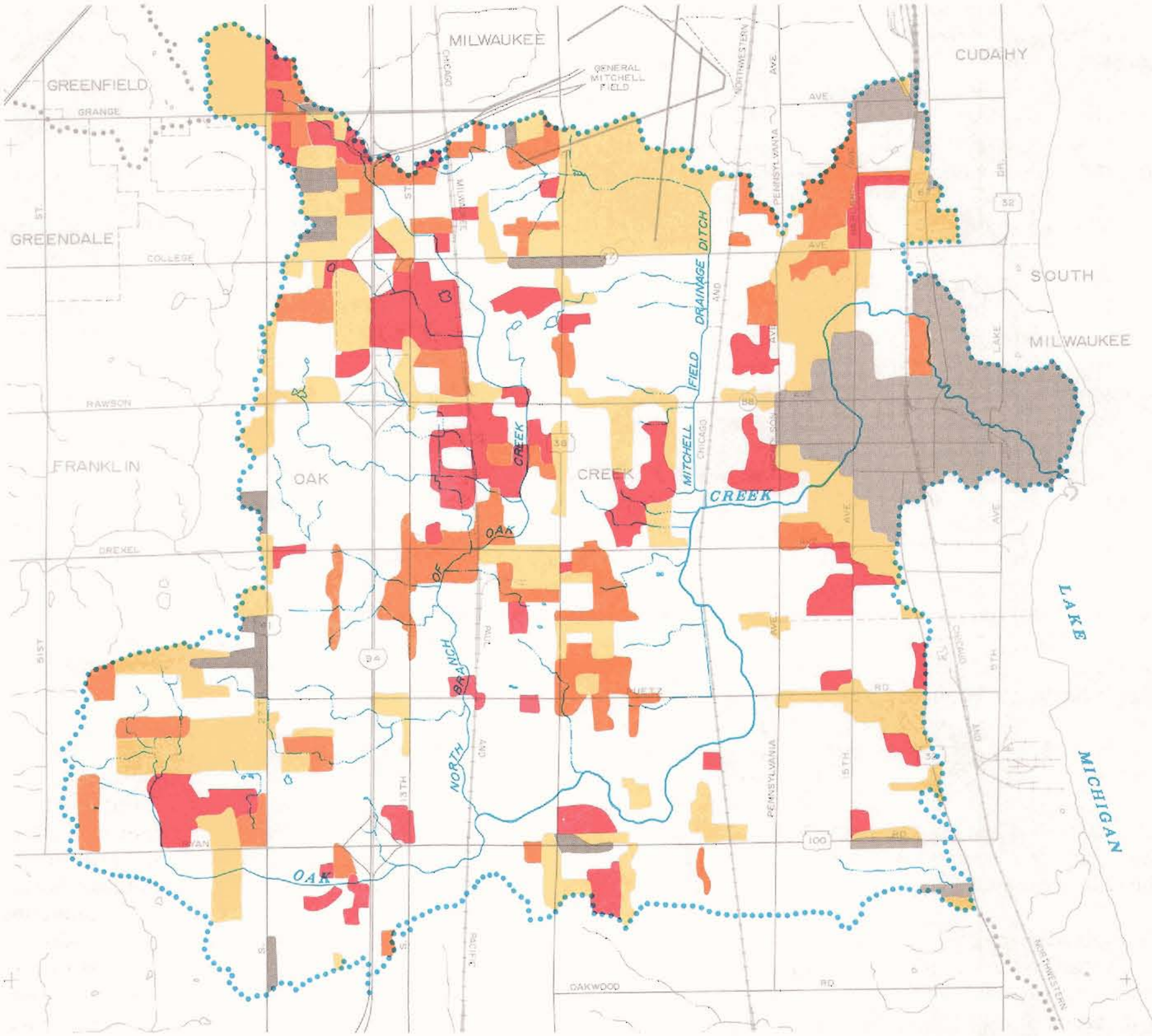
DISTRIBUTION OF MANUFACTURING EMPLOYMENT BY TYPE OF MANUFACTURING FOR THE OAK CREEK WATERSHED, MILWAUKEE COUNTY, AND THE REGION: 1980



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

Map 5

HISTORICAL URBAN GROWTH IN THE OAK CREEK WATERSHED: 1950-1980



LEGEND

1950	
1963	
1970	
1980	

Urban development occurred first within the watershed in the vicinity of the City of South Milwaukee, and until about 1950 remained concentrated in that City. By 1963, however, urban development had occurred not only in the South Milwaukee area but in scattered small areas throughout the watershed, and urban land uses constituted approximately 24 percent of the total area of the watershed. By 1980, approximately 47 percent of the total area of the watershed was in urban use.

Source: SEWRPC.

of the watershed totaled approximately 2.2 square miles, or about 8 percent of the total area of the watershed. By 1963, urbanization had begun to occur in small areas throughout the Oak Creek watershed and totaled approximately 6.6 square miles, or about 24 percent of the total area of the watershed. Between 1963 and 1980, approximately 4.3 square miles of additional land were converted from rural to urban use within the watershed, bringing the total in urban use to 10.9 square miles, or about 40 percent of the total area of the watershed.

Buildings and sites of historical interest and archaeological sites known to be located in the watershed are shown on Map 6 and listed in Table 6. Local historical societies in the watershed were contacted in an effort to identify historic sites of local interest. Information regarding the existance of archaeological sites was provided by the State Historical Society of Wisconsin. Of special interest is the Painesville Chapel, which is located in the City of Franklin, and the South Milwaukee Passenger Depot, both of which have been listed on the National Register of Historic Places. Comprehensive planning within the watershed should seek the protection and restoration of these historic sites and structures, thereby preserving their inherent cultural values.

Existing Land Use: The generalized existing land use pattern within the Oak Creek watershed is shown on Map 7 and the existing land uses are quantified in Table 7. Figure 7 graphically depicts the types and relative amounts of land uses within the watershed in 1963 and 1980.

As indicated in Table 7, about 15 square miles of the watershed area, or 53 percent of the total area of the watershed, was still in rural use in 1980, with agriculture and related open uses occupying about 13 square miles, or about 45 percent of the total watershed area. In 1980, urban land uses occupied about 13 square miles, or about 47 percent of the total area of the watershed, of which residential land use accounted for over five square miles, or over 19 percent of the total watershed area. Also of significance is the transportation, communication, and utilities land use category which accounted for over five square miles, or about 19 percent of the total watershed area. From 1963 to 1980, approximately 3.6 square miles, or 13 percent of the watershed, was converted from rural to urban use, resulting in a rate of urbanization of about 0.2 square mile per year.

Public Utility Base

Sanitary Sewer Service: In 1980, approximately 15.2 square miles or about 56 percent of the total area of the watershed, was provided with sanitary sewer service, serving a resident population of about 37,700 persons, or about 95 percent of the total resident population of the watershed, as shown on Map 8.

The sanitary sewage from the Cities of Cudahy, Franklin, Greenfield, Milwaukee, and Oak Creek is collected and transmitted for treatment and disposal to the Jones Island and South Shore treatment plants, located outside the watershed on the shore of Lake Michigan, and owned and operated by the Milwaukee Metropolitan Sewerage District. In the future, sewer service is proposed to be provided to the entire developable area of these cities.

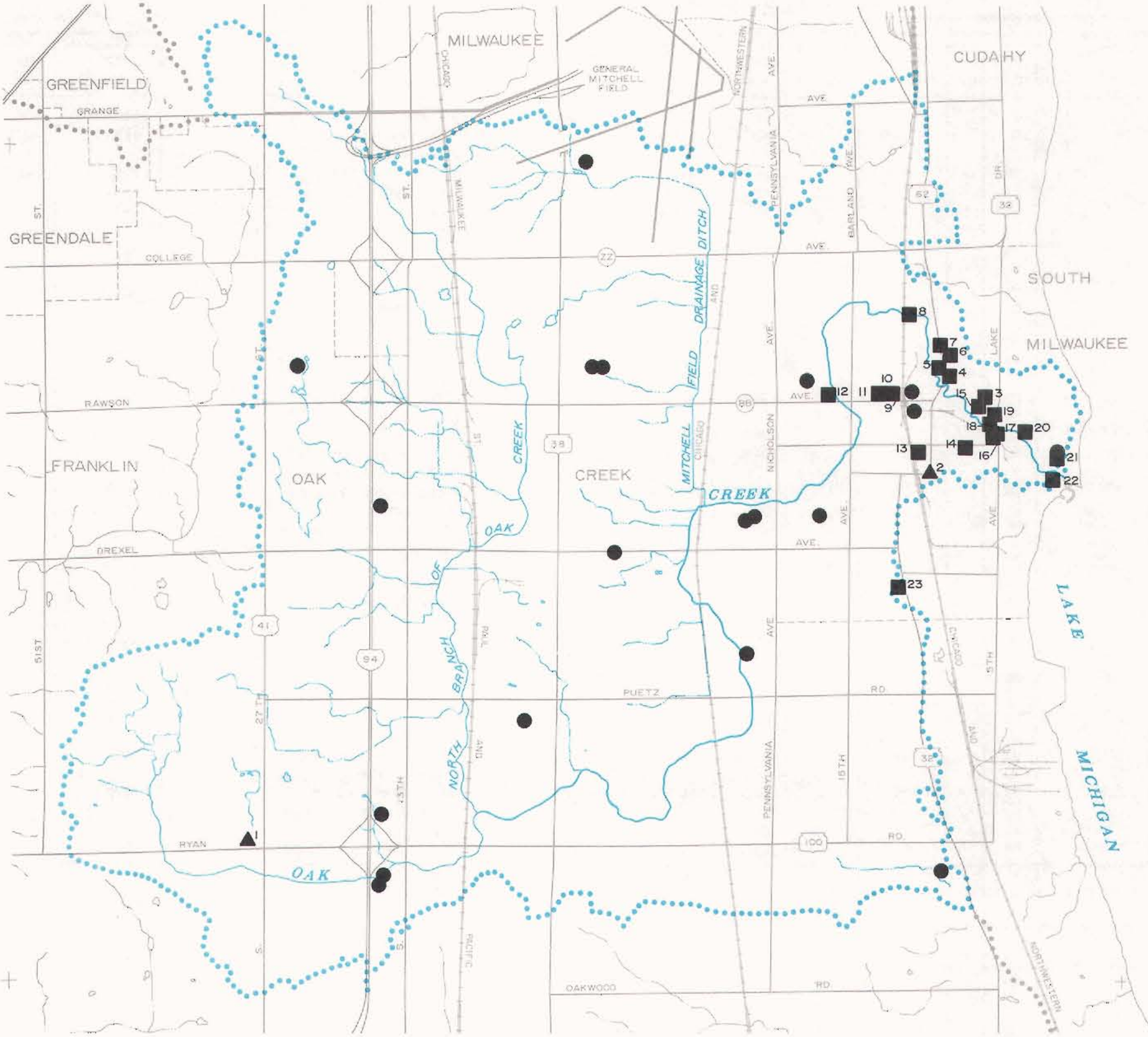
The City of South Milwaukee is the only municipality in Milwaukee County which is not a part of the Milwaukee Metropolitan Sewerage District. Sewage from the City of South Milwaukee is treated at a municipal sewage treatment plant located on the Lake Michigan shoreline about one mile north of the South Shore sewage treatment plant of the Milwaukee-Metropolitan Sewerage Commissions.

Water Supply Service: The Oak Creek watershed is served by four public water supply systems. The service areas of these systems—owned and operated by the City of Oak Creek Water and Sewer Utility, the Cudahy Water Department, the Milwaukee Water Works, and the South Milwaukee Water Utility—and of the one privately operated system—the Howell Avenue Estates Subdivision in the City of Oak Creek— are shown on Map 9. The four public water supply systems operate independent water supply systems. The Milwaukee Water Works provides retail service to the City of Greenfield, while the City of Oak Creek Water and Sewer Utility provides retail service to a portion of the City of Franklin. These four public utilities supply approximately 35,800 persons, or about 90 percent of the total resident population of the watershed, and all four utilize Lake Michigan as the sole source of water supply. The privately operated system utilizes the shallow dolomite aquifer as the source of supply.

Electric Power Service and Gas Service: Electric power is available to all portions of the watershed, such power being supplied by the Wisconsin

Map 6

HISTORICAL AND ARCHAEOLOGICAL SITES IN THE OAK CREEK WATERSHED: 1984



LEGEND

▲ HISTORICAL SITES LISTED ON THE NATIONAL REGISTER OF HISTORIC PLACES

■ HISTORICAL SITES OF LOCAL INTEREST

● ARCHAEOLOGICAL SITES KNOWN TO EXIST

3 REFERENCE NUMBER (SEE TABLE 6)

NOTE: THE ARCHAEOLOGICAL SITES SHOWN ON THIS MAP DO NOT HAVE A REFERENCE NUMBER IN TABLE 6 AS NO INFORMATION OTHER THAN THEIR LOCATION IS AVAILABLE

A number of sites and buildings of historic interest such as churches, homes, and natural areas, as well as archaeological sites, are located within the watershed. Preservation of the best remaining historical sites, structures, and archaeological sites should be given careful consideration in planning for, and development or redevelopment of, the watershed.

Source: State Historical Society of Wisconsin, South Milwaukee Historical Society, and SEWRPC.

Table 6

HISTORICAL SITES IN THE OAK CREEK WATERSHED: 1984

Site No.	Township (N)	Range (E)	Section	Quarter Section	County	City, Village, or Town	Site Name	Level of Significance	Year Constructed	Year Listed
1	05	21	24	SE ¼	Milwaukee	Franklin	Painesville Chapel	Local[a]	1851-1852	1977
2	05	22	11	NE ¼	Milwaukee	South Milwaukee	South Milwaukee Passenger Depot	Local[a]	1893	1978
3	05	22	2	SE ¼	Milwaukee	South Milwaukee	Home of Alfred Fowle	--[b]	1950	--
4	05	22	2	SE ¼	Milwaukee	South Milwaukee	Site of Higgins Inn	--[b]	1835	--
5	05	22	2	SE ¼	Milwaukee	South Milwaukee	Site of William Shaw Log Cabin	--[b]	--	--
6	05	22	2	SE ¼	Milwaukee	South Milwaukee	Site of First School in Area	--[b]	1841	--
7	05	22	2	SE ¼	Milwaukee	South Milwaukee	Site of Postmaster E. D. Phillips' Home	--[b]	--	--
8	05	22	2	NW ¼	Milwaukee	South Milwaukee	Site of Twin Arch Stone Bridge	--[b]	--	--
9	05	22	2	SW ¼	Milwaukee	South Milwaukee	Home of George and Delila Watrons Whitmore	--[b]	1850	--
10	05	22	2	SW ¼	Milwaukee	South Milwaukee	Home of George and Marietta Rawson Hook	--[b]	1892	--
11	05	22	2	SW ¼	Milwaukee	South Milwaukee	St. Mark's Cemetery	--[b]	1864	--
12	05	22	3	SE ¼	Milwaukee	South Milwaukee	Site of Saw Mill Built by the Father of M. H. Howes	--[b]	1838	--
13	05	22	11	NW ¼	Milwaukee	South Milwaukee	Chicago & North Western Railway Depot	--[b]	1902	--
14	05	22	11	NE ¼	Milwaukee	South Milwaukee	Home of the South Milwaukee Historical Society, Inc.	--[b]	1892	--
15	05	22	11	NE ¼	Milwaukee	South Milwaukee	Home of Delos and Mamie Fowle	--[b]	1850	--
16	05	22	11	NE ¼	Milwaukee	South Milwaukee	Wooden Trestle Bridge	--[b]	--	--
17	05	22	11	NE ¼	Milwaukee	South Milwaukee	The Site of Mill Dam	--[b]	1840	--
18	05	22	11	NE ¼	Milwaukee	South Milwaukee	Home of John F. and Emily Ahrens	--[b]	1840	--
19	05	22	11	NE ¼	Milwaukee	South Milwaukee	Home of John and Sarah Fowle	--[b]	1864	--
20	05	22	12	NW ¼	Milwaukee	South Milwaukee	Home of Dr. Henry and Appolonia Wood Fowle	--[b]	1851	--
21	05	22	12	NE ¼	Milwaukee	South Milwaukee	Home of Horace and Ellen Thompson Fowle	--[b]	1859	--
22	05	22	12	SE ¼	Milwaukee	South Milwaukee	Site of a Brick Yard Once Run by John and Horace Fowle and Horace Wells	--[b]	1870	--
23	05	22	14	NW ¼	Milwaukee	South Milwaukee	Home of Jeremiah McCreedy	--[b]	1876	--

[a] *Listed on the National Register of Historic Places.*

[b] *Identified by the South Milwaukee Historical Society.*

Source: State Historical Society of Wisconsin, South Milwaukee Historical Society, and SEWRPC.

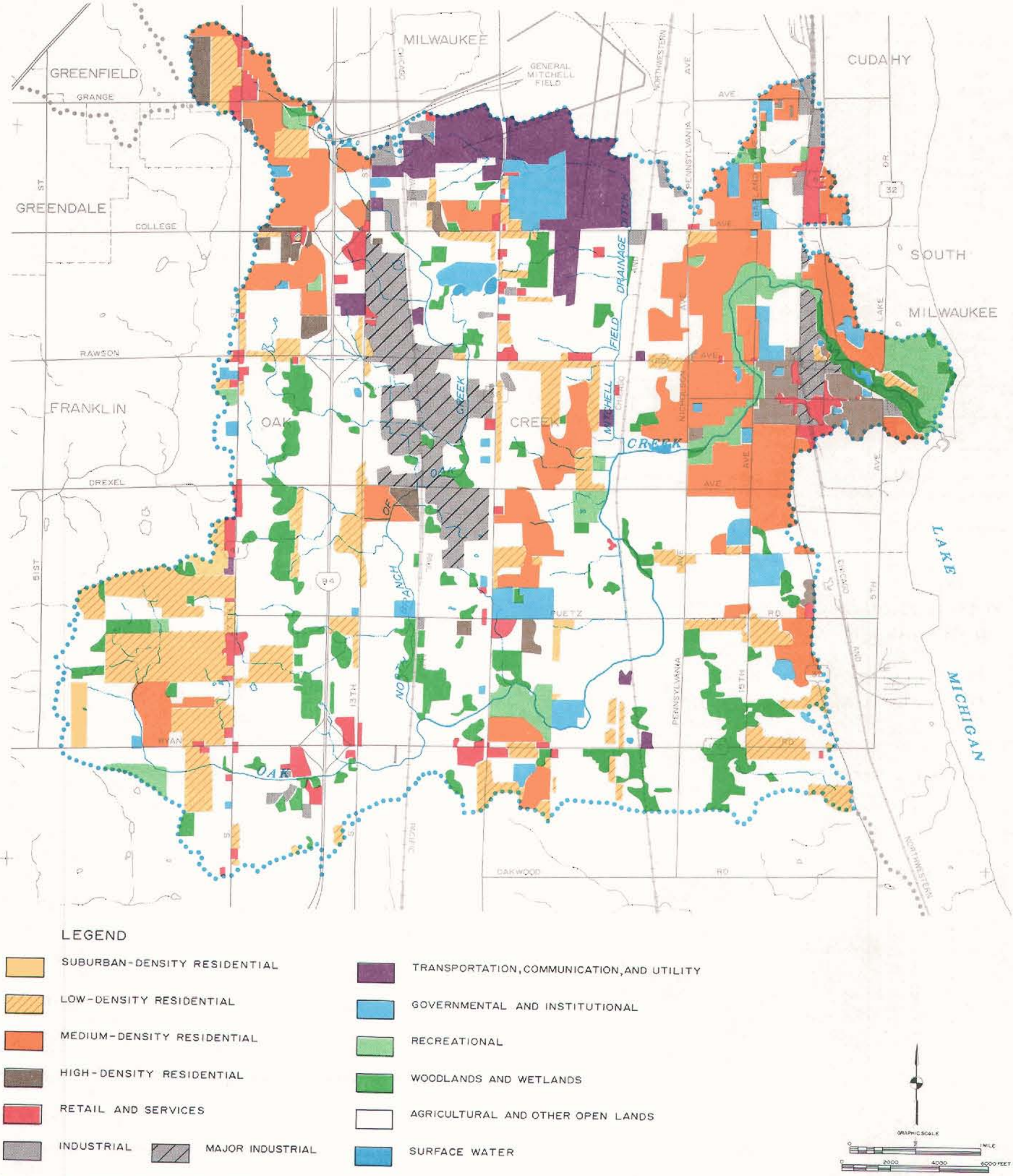
Electric Power Company, which is authorized to operate throughout the watershed. Natural gas service is also available to all portions of the watershed. The Wisconsin Natural Gas Company is authorized to provide service to the entire watershed with the exception of that portion of the City of Milwaukee between S. 6th Street and S. 27th Street lying within the watershed which is served by the Wisconsin Gas Company.

Transportation

Highways: As shown on Map 10, the Oak Creek watershed is served by an extensive street and highway system. There are 250.2 miles of streets and highways within the watershed. Of this total, 60.7 miles, or 24 percent, are classified as arterial streets and highways, and of these, 5.7 miles, or 9 percent, consist of freeway facilities. 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 is important to the watershed planning program because it could have adverse effects on surface water quality. For example, as discussed in Chapter VII of this report, rainfall- or snowmelt-induced washoff of

Map 7

GENERALIZED EXISTING LAND USE IN THE OAK CREEK WATERSHED: 1980



Rural land uses within the Oak Creek watershed presently occupy about 15 square miles, or about 53 percent of the total watershed area. Agriculture and related open uses occupy about 13 square miles, or about 45 percent of the total watershed area. Urban land uses occupy about 13 square miles, or about 47 percent of the total watershed area, of which residential land use accounts for over five square miles, or over 19 percent of the total watershed area. From 1963 to 1980, approximately 3.6 square miles, or about 13 percent of the watershed, was converted from rural to urban use, resulting in a rate of urbanization of about 0.2 square mile per year.

Source: SEWRPC.

Table 7

LAND USE IN THE OAK CREEK WATERSHED: 1963, 1970, 1975, and 1980

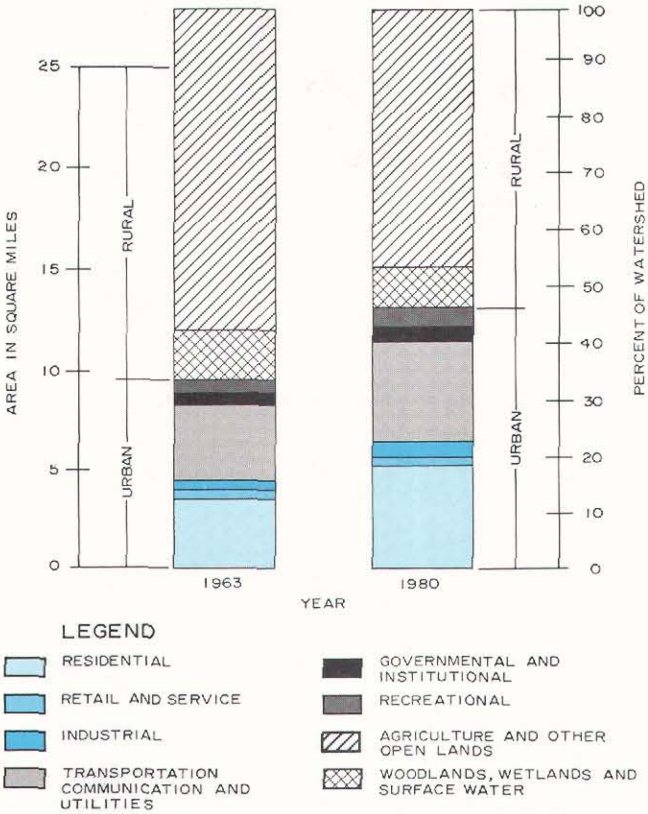
Land Use Category	1963			1970			1975			1980		
	Area (square miles)	Percent of Watershed	Percent of Major Category	Area (square miles)	Percent of Watershed	Percent of Major Category	Area (square miles)	Percent of Watershed	Percent of Major Category	Area (square miles)	Percent of Watershed	Percent of Major Category
Urban												
Residential	3.92	14.1	41.1	4.82	17.4	41.6	5.03	18.1	41.8	5.35	19.3	40.6
Retail and Services	0.25	0.9	2.6	0.29	1.0	2.5	0.29	1.0	2.4	0.33	1.2	2.5
Industrial	0.45	1.6	4.7	0.59	2.1	5.1	0.68	2.4	5.7	0.77	2.8	5.8
Transportation, Communication, and Utilities	3.84	13.9	40.3	4.43	16.0	38.3	4.62	16.7	38.3	5.29	19.0	40.3
Governmental and Institutional	0.52	1.9	5.4	0.61	2.2	5.3	0.63	2.3	5.2	0.66	2.4	5.0
Recreational	0.56	2.0	5.9	0.83	3.0	7.2	0.80	2.9	6.6	0.77	2.8	5.8
Urban Total	9.54	34.4	100.0	11.57	41.7	100.0	12.05	43.4	100.0	13.17	47.5	100.0
Rural												
Woodlands, Wetlands, and Surface Water	2.33	8.4	12.8	2.06	7.4	12.7	2.14	7.7	13.6	2.06	7.4	14.1
Agricultural and Other Open Lands	15.87	57.2	87.2	14.11	50.9	87.3	13.55	48.9	86.4	12.51	45.1	85.9
Rural Total	*18.20*	*65.6*	*100.0*	*16.17*	*58.3*	*100.0*	*15.69*	*56.6*	*100.0*	14.57	52.5	100.0
Total	27.74[a]	100.0	--	27.74[a]	100.0	--	27.74[a]	100.0	--	27.74[a]	100.0	--

[a] *This figure represents the total area of the watershed as determined by approximating the watershed boundary by U. S. Public Land Survey quarter section. The actual measured watershed total is 27.24 square miles.*

Source: SEWRPC.

Figure 7

DISTRIBUTION OF URBAN AND RURAL LAND USE IN THE OAK CREEK WATERSHED: 1963 AND 1980



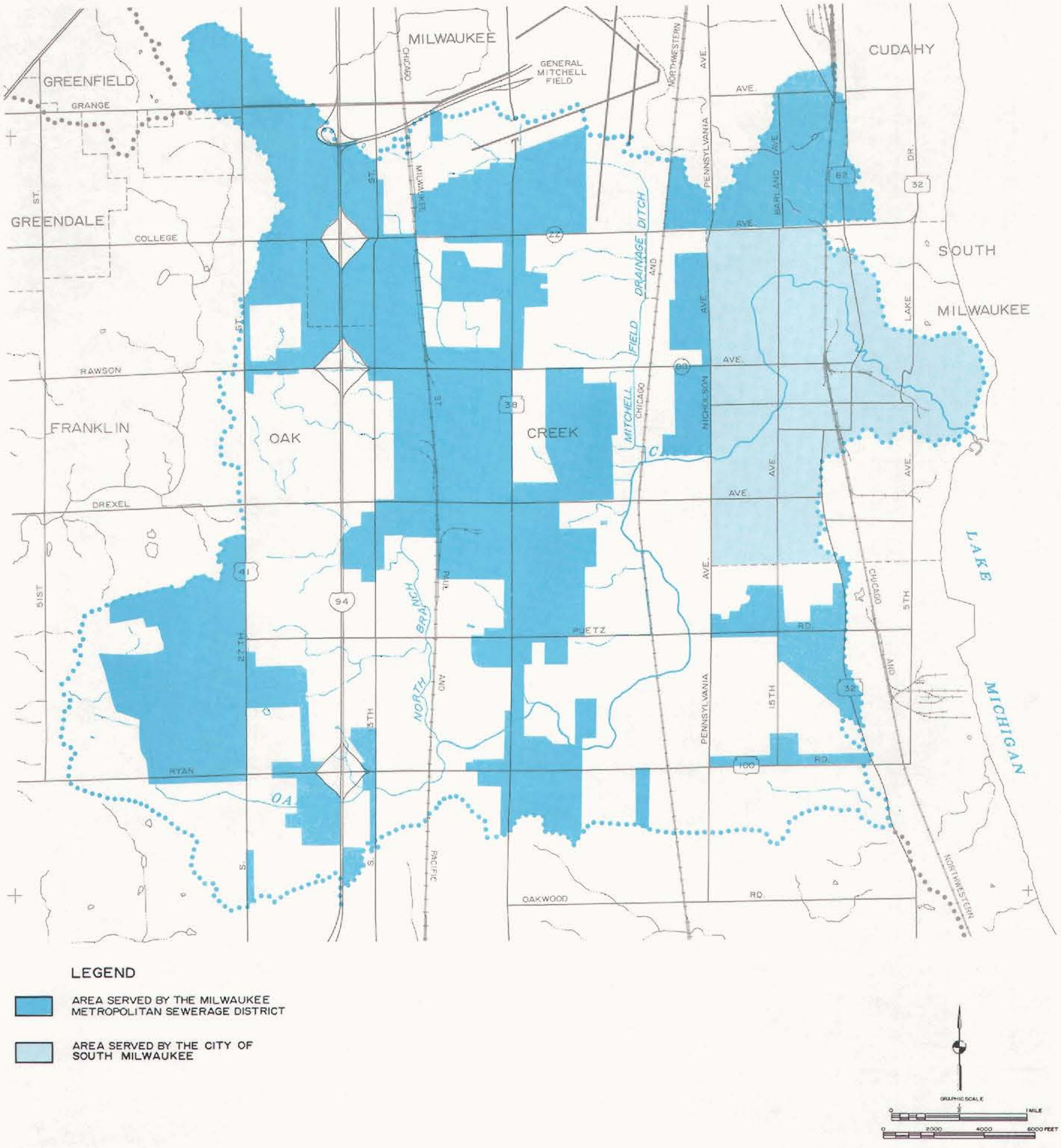
Source: SEWRPC.

substances from the urban land surface, including from street and highway pavements, may have a harmful effect on the rivers and streams of the watershed.

Bus Service: The transportation needs of the resident population of the watershed are largely determined by the distribution of residential development in relation to centers of employment, shopping, and other activities in the greater Milwaukee area. These transportation needs, 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 eastern portion of the 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 College Avenue public transit station located in the City of Milwaukee at IH 94 and W. College 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.

Map 8

SANITARY SEWER SERVICE AREAS IN THE OAK CREEK WATERSHED: 1980

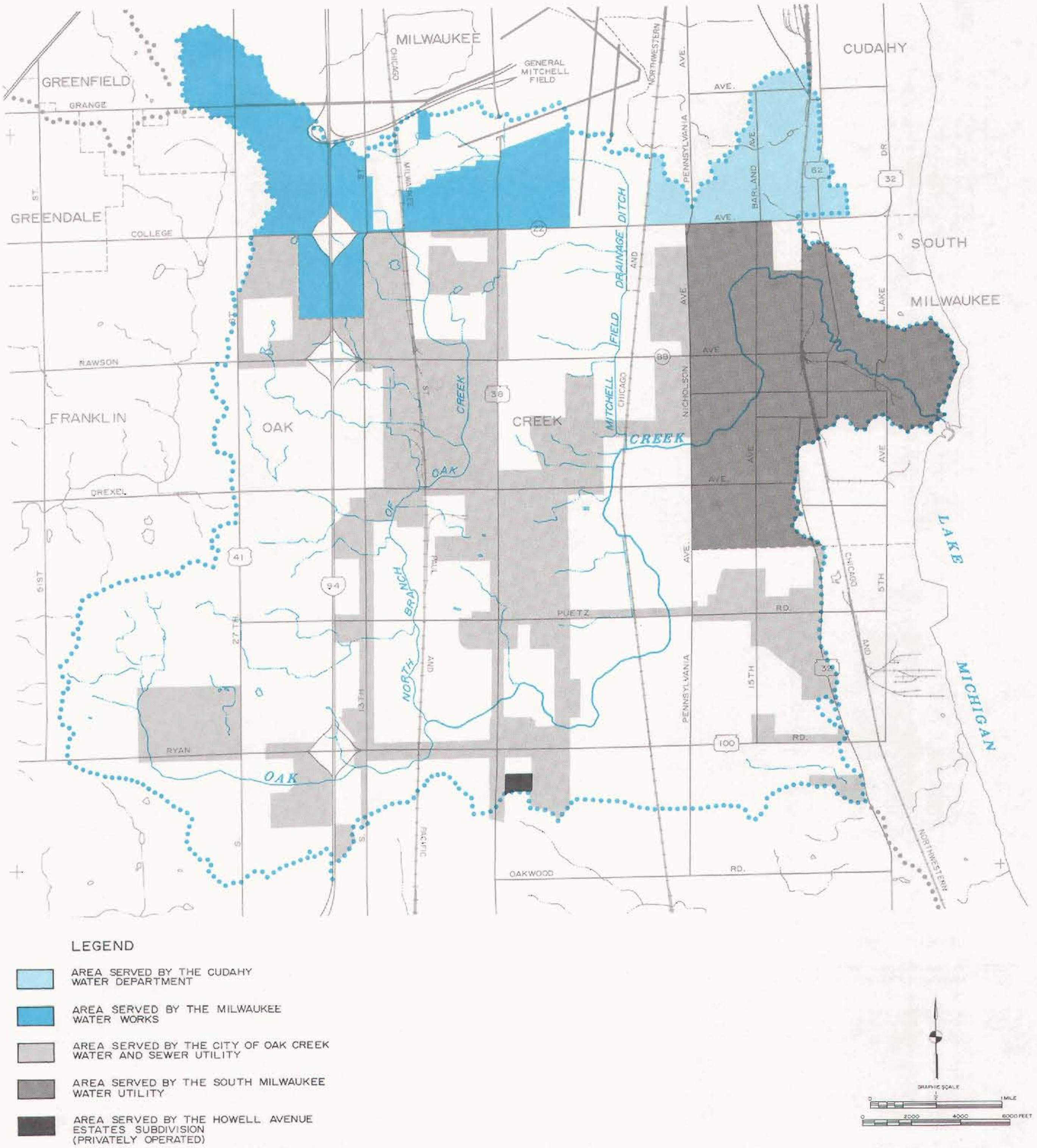


Two sanitary sewerage systems or portions thereof serve a total area of 15.2 square miles within the watershed, or about 56 percent of the total area of the watershed, and a total population of about 37,700 persons, or approximately 95 percent of the total resident population of the watershed.

Source: SEWRPC.

Map 9

PUBLIC AND PRIVATE WATER SUPPLY SERVICE AREA IN THE OAK CREEK WATERSHED: 1983

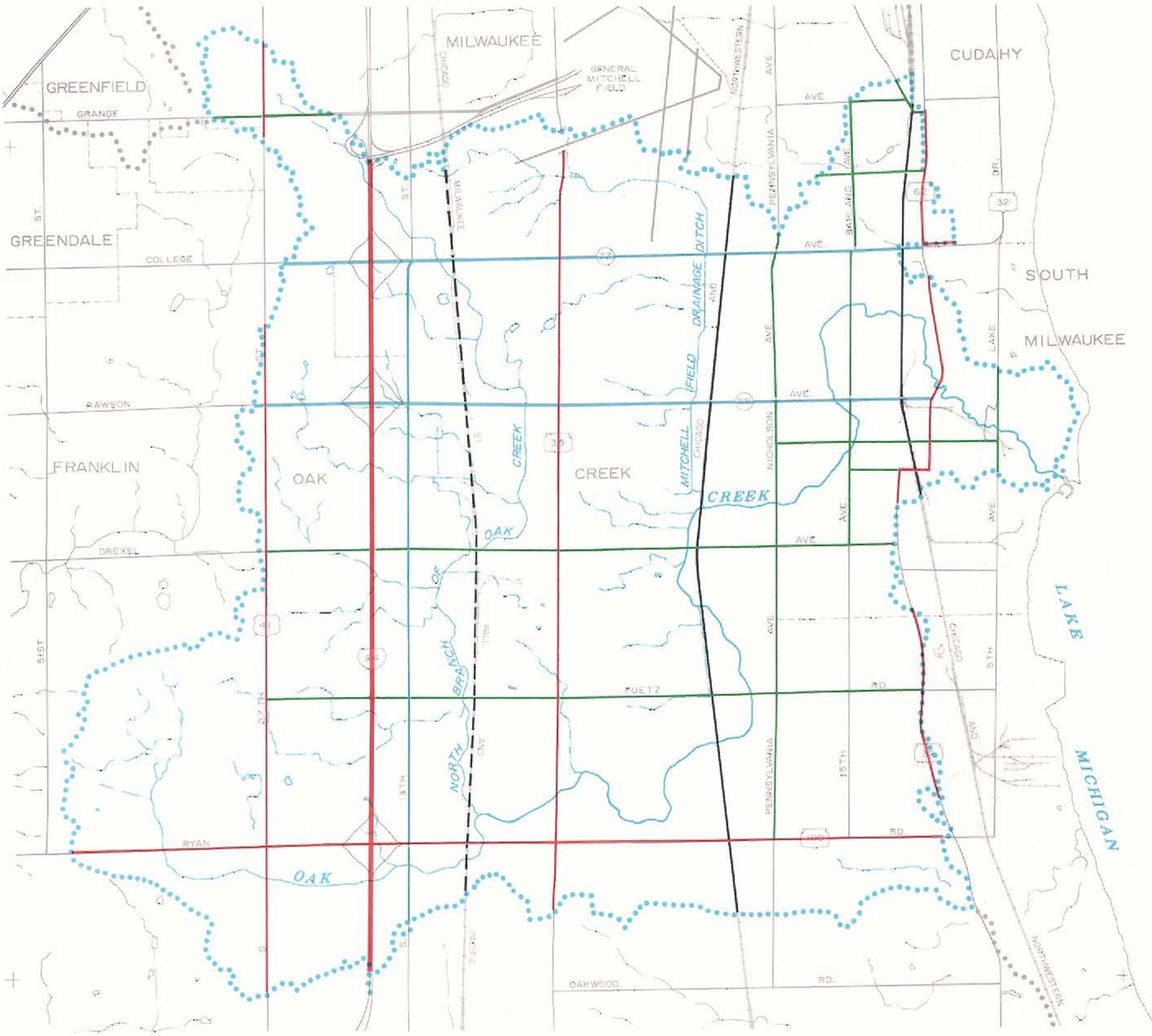


Four public water supply systems and one private system serve the urban areas of the Oak Creek watershed. The Milwaukee Water Works and the City of Oak Creek Water and Sewer Utility provide retail service to the City of Greenfield and a portion of the City of Franklin, respectively. The four public utilities located in the watershed utilize Lake Michigan as the sole source of water supply.

Source: SEWRPC.

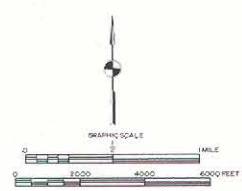
Map 10

ARTERIAL STREET AND HIGHWAY AND TRUNKLINE RAILWAY FACILITIES IN THE OAK CREEK WATERSHED: 1983



LEGEND

- STATE TRUNK ARTERIAL HIGHWAY (FREEWAY)
- STATE TRUNK ARTERIAL HIGHWAY (NONFREEWAY)
- COUNTY TRUNK ARTERIAL HIGHWAY
- LOCAL TRUNK ARTERIAL STREET AND HIGHWAY
- CHICAGO & NORTHWESTERN TRANSPORTATION COMPANY
- CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD COMPANY



The Oak Creek watershed is served by a well-developed surface transportation system. Passenger transportation is primarily by highway, with goods movement by both rail and highway. Both the Chicago & North Western Railway and the Chicago, Milwaukee, St. Paul & Pacific Railroad traverse the watershed in a north-south direction.

Source: SEWRPC.

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 in the watershed at Howell Avenue and Drexel Avenue, Howell Avenue and Ryan Road, and Ryan Road and STH 32.

Railway Service: Railway 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 Amtrak Passenger Station in Milwaukee to the north and Sturtevant and Chicago to the south. The Amtrak Passenger Station, which is located north of the watershed near the confluence of the Menomonee and Kinnickinnic Rivers, is 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 Transportation Company. As shown on Map 10, railroad lines emanate from the lower Menomonee River industrial valley of the City of Milwaukee and traverse the Oak Creek watershed in northsouth directions.

Airport: As shown on Map 10, General Mitchell Field, the southern portion of which lies within the Oak Creek watershed, is the only airport in the basin. More importantly, General Mitchell Field is the only airport providing scheduled air carrier service in the seven-county Planning Region, and as such is an important determining factor in the physical development of both the watershed and the Region.

The development of Mitchell Field began in 1926 when Milwaukee County 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 it was officially renamed General Mitchell Field. By 1983, the airport had expanded to about 2,100 acres and was served by nine major scheduled airlines, including Republic, United, Eastern, Northwest, Continental, Ozark, Midwest Express, Frontier, and TWA. In addition, Mitchell Field is served by six scheduled regional "commuter" airlines, including Alliance, Midstate, Mississippi Valley, Simmons, Air Wisconsin, and Delta Connection. A total of 3,296,763 passengers were handled on 74,448 air carrier flights during 1982, and total aircraft operations approximated 160,000. Of the total airport site, 810 acres, or 38 percent, are located within the Oak Creek watershed.

Future recommendations concerning the development of the airport and its environs are bound to concern residents of the watershed, since a large portion of the airport is contained within the basin. Existing airport operation 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 and the subsequent airport master plan include major passenger terminal renovation, the extension of runways and acquisition of 149 acres of additional land for clear zone protection, and the elimination of land use conflicts in the most severe noise impact areas. An airport noise abatement plan was adopted in 1983 by Milwaukee County and is currently being implemented. This should reduce noise impacts in large portions of the watershed.

DESCRIPTION OF THE WATERSHED: NATURAL RESOURCE 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 the elements comprising the natural resource base and their interrelationships, human 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, as relevant and practical, 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 these components of the natural resource base are described in this chapter, some are considered in more detail in later chapters. For example, this chapter provides an overview of the surface water resources of the watershed, while the findings of a detailed 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 [2]

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 large annual range in weather characteristics, particularly in winter and spring when distinct weather changes normally occur every three to five days. These temporal weather changes consist of marked variations in temperature, 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 the Oak Creek watershed in particular. It is common, for example, for midday summer temperatures in shoreline areas to drop abruptly to a temperature level $10^{o}F$ lower than that of inland areas because of cooling lake breezes generated by air rising from the warmer land surfaces. However, this Lake Michigan temperature influence is generally limited to that portion of the watershed lying within a few miles of the shoreline.

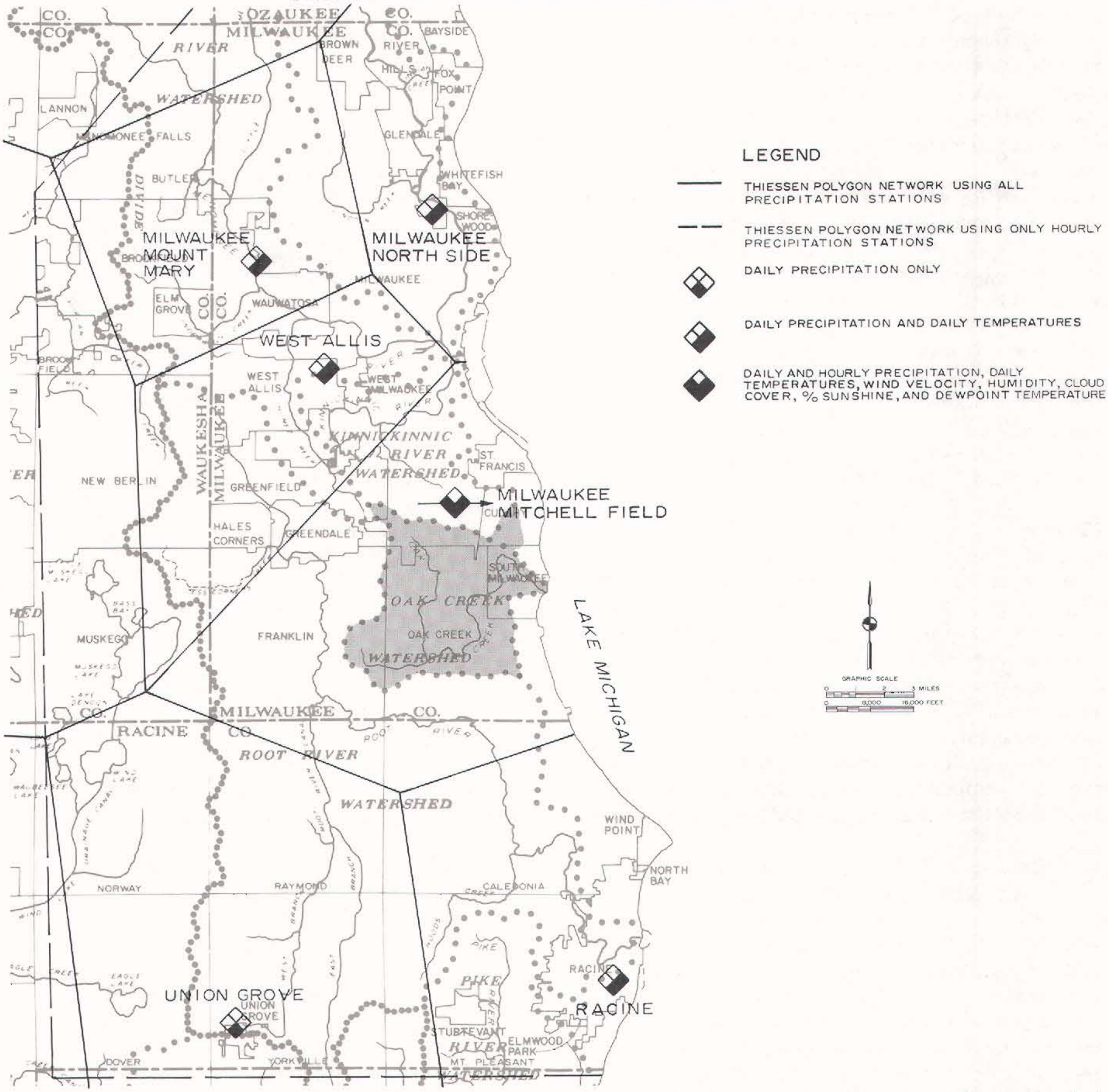
Map 11 and Table 8 show the location of six meteorological stations near the Oak Creek watershed, as well as the availability of temperature and other meteorological data. As shown on the map, the stations were used to construct a Thiessen polygon network which was used to associate land areas with specific meteorological data. The Oak Creek watershed is located entirely within the Thiessen polygon for the National Weather Service station at Mitchell Field, which is located immediately north of the watershed. Accordingly, the records of this station were used to characterize the climatologic and meteorologic conditions in the watershed. Additional information about this station is presented in Chapter VIII.

Temperature: Watershed temperatures, which exhibit a large annual range, are relevant to 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 the self-purification of streams are temperature dependent, since reaction rates approximately

[2] *Unless otherwise indicated, climatic and weather descriptions and data presented herein 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.*

Map 11

METEOROLOGICAL STATIONS OF THE NATIONAL WEATHER SERVICE NEAR THE OAK CREEK WATERSHED: 1983



The Thiessen polygon network constructed for the six 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 meteorlogical conditions in the Oak Creek watershed and for operating the water resources simulation model used to calculate streamflow and streamwater quality.

Source: National Weather Service and SEWRPC.

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 also

Table 8

METEOROLOGICAL DATA OBSERVATION STATIONS NEAR THE OAK CREEK WATERSHED

Station Identification		Location			
Name	Index Number	County	City or Village	Current Location	Data Recorded
Milwaukee-Mitchell Field	5479	Milwaukee	City of Milwaukee	FAA Building Mitchell Field	Hourly precipitation, daily temperatures, wind velocity, humidity, cloud cover, percent sunshine, and dewpoint temperature
Milwaukee-Mount Mary	5474	Milwaukee	City of Milwaukee	Mount Mary College	Daily precipitation and temperature
Milwaukee-North Side	5477	Milwaukee	City of Milwaukee	Discontinued December 1978	Daily precipitation and temperature
Racine	6922	Racine	City of Racine	Wastewater Treatment Plant	Daily precipitation and temperature
Union Grove	8723	Racine	Village of Union Grove	Wastewater Treatment Plant	Daily precipitation
West Allis	9046	Milwaukee	City of West Allis	Allis Chalmers Company	Daily precipitation and temperature

Source: SEWRPC.

highly dependent on temperature. For example, a stream at or near freezing temperatures can hold about 15 milligrams per liter (mg/l) of dissolved oxygen, but the dissolved oxygen solubility of surface waters of that same stream on a hot 80°F day will be 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 because of accelerated reaction rates while the oxygen supply is at its annual minimum because of solubility limitations associated with high temperatures.

Data for the air temperature observation station near the Oak Creek watershed—Milwaukee at Mitchell Field—are presented in Table 9. Monthly temperature data are presented in Figure 8. The air temperature and precipitation data used to develop the tables and figures presented in this and subsequent sections of this chapter are for various periods of record ranging from 16 years to 140 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 watershed temperature and precipitation characteristics. The temperature data illustrate how watershed air temperatures lag approximately one month behind summer and winter solstices during the annual cycle, with the result being 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 station for July and August, range from the 69°F to 71°F. Average daily maximum temperatures within the watershed for these two months range from 78°F to 80°F, whereas average

Table 9

AIR TEMPERATURE CHARACTERISTICS FOR MILWAUKEE AT MITCHELL FIELD 1951-1980

Month	Average Daily Maximum[a]	Average Daily Minimum[a]	Mean[b]
January	26.0	11.3	18.7
February	30.1	15.8	23.0
March	39.2	24.9	32.1
April	53.5	35.6	44.6
May	64.8	44.7	54.8
June	75.0	54.7	64.9
July	79.8	61.1	70.5
August	78.4	60.2	69.3
September	71.2	52.5	61.9
October	59.9	41.9	50.9
November	44.7	29.9	37.3
December	32.0	18.2	25.1
Year	54.6	37.6	46.1

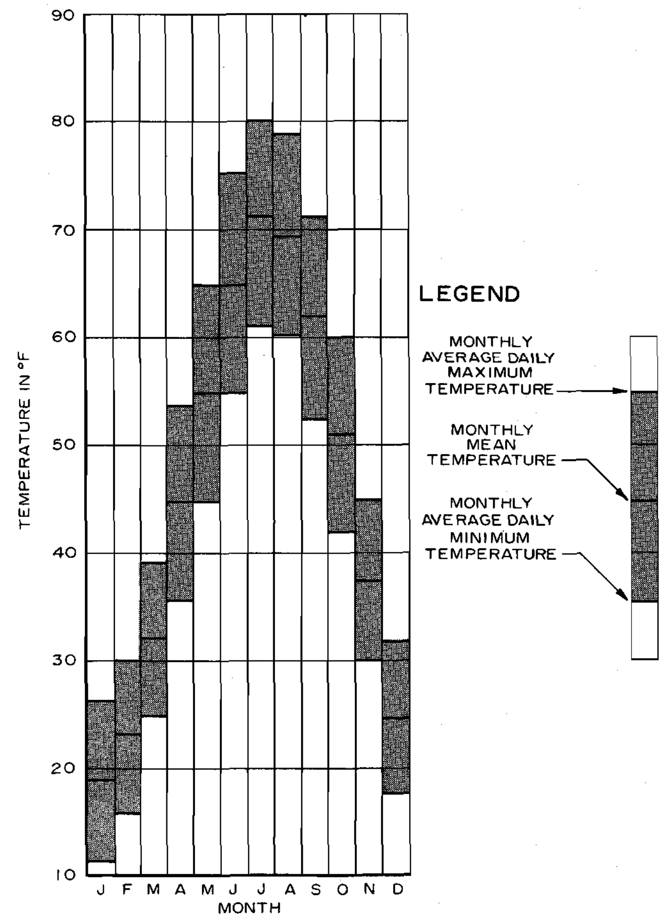
[a] *The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compile an average for each month in the indicated period of record; the results are then averaged for all months in the period of record.*

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

Source: National Climatic Center and SEWRPC.

Figure 8

AIR TEMPERATURE CHARACTERISTICS FOR MILWAUKEE AT MITCHELL FIELD: 1951-1980



Source: National Climatic Center and SEWRPC.

daily minimum temperatures vary from 60°F to 61°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 will be less than those recorded by the meteorological stations, particularly during the summer months.

Winter temperatures for the watershed, as measured by monthly means for January and February, range from 19°F to 23°F. Average daily maximum temperatures within the watershed for these two months vary from 26°F to 30°F, whereas average daily minimum temperatures range from 11°F to 16°F.

Extreme high and low temperatures in the watershed, based on recorded data for Milwaukee at the Mitchell Field weather station, range from a high of 101°F recorded in July 1955 to a low of -24°F recorded in January 1963. The growing season, which is defined as the number of days between the last 32°F frost in spring and the first freeze in fall, normally begins 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. Rainfall events may 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

Table 10

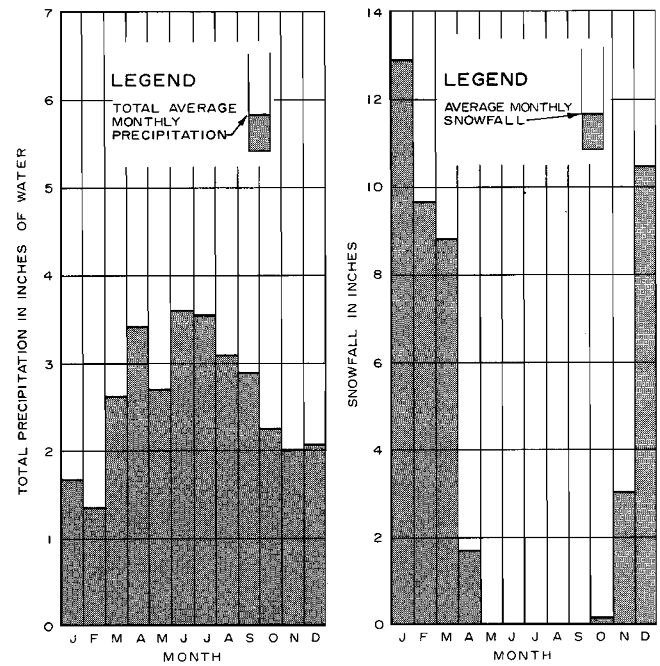
PRECIPITATION CHARACTERISTICS FOR MILWAUKEE AT MITCHELL FIELD

Month	Average Total Precipitation (1951-1980)	Average Snow and Sleet (1941-1981)
January	1.64	12.8
February	1.33	9.6
March	2.58	9.0
April	3.37	1.7
May	2.66	Trace
June	3.59	0.0
July	3.54	0.0
August	3.09	0.0
September	2.88	Trace
October	2.25	0.1
November	1.98	3.1
December	2.03	10.5
Year	30.94	46.8

Source: National Climatic Center and SEWRPC.

Figure 9

PRECIPITATION CHARACTERISTICS FOR MILWAUKEE AT MITCHELL FIELD



Source: National Climatic Center and SEWRPC.

plants. Such surcharging of separate sanitary sewerage systems is caused by the entry of excessive quantities of rain, snowmelt, and groundwater into 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 and snowfall data for the Mitchell Field observation station are presented in Table 10. Monthly total precipitation and snowfall observations are presented graphically in Figure 9. The table and figure illustrate the type of precipitation and the amount that normally occurs near the watershed.

The average annual total precipitation in the watershed and immediate surroundings, based on data for the Mitchell Field station, is 30.9 inches, expressed as water equivalent, while the average annual snow and sleet measured as snow and sleet is 46.8 inches.

Average total monthly precipitation for the watershed, based on data for the Mitchell Field weather station, ranges from a low of 1.33 inches in February to a high of 3.59 inches in June. The principal snowfall months are December, January, February, and March, when average monthly snowfalls are 10.5, 12.8, 9.6, and 9.0 inches, respectively, and during which time 90 percent of the average annual snowfall may be expected to occur. Snowfall is the predominant form of precipitation during these months, totaling approximately 55 percent of the total precipitation expressed as water equivalent. Approximately 18 inches, or 58 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 46.8 inches is equivalent to 4.7 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-third to one-half of the 30.9-inch average annual precipitation leaves the watershed as streamflow, the remaining precipitation being lost from the watershed primarily as evapotranspiration.[3]

Extreme precipitation event data through 1976 for four long-term weather stations—Milwaukee at Mitchell Field, Waukesha, Racine, and West Bend—are presented in Table 11. Inasmuch as these

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

Table 11

EXTREME PRECIPITATION EVENTS FOR SELECTED LONG-TERM STATIONS NEAR THE OAK CREEK WATERSHED

Observation Station		Period of Precipitation Records Except Where Indicated Otherwise	Total Precipitation (water equivalent)											
			Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County		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[a]	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[f]	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. Army Corps of Engineers, and SEWRPC.

long-term records are for stations located reasonably near the Oak Creek watershed, data from these stations may be considered representative of the extreme precipitation events that have occurred within the watershed.

Annual precipitation within the watershed and the immediate surroundings has varied from a low of approximately 17 inches, or about 56 percent of the area average, to a high of approximately 50 inches, or about 63 percent above the average. Annual seasonal snowfall has varied from a low of approximately five inches, or about 11 percent of the area average, to a high of approximately 109 inches, or about 133 percent above the average. The maximum monthly precipitation at the four stations is 13.17 inches, recorded at West Bend in August 1924, and the maximum monthly 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 as 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 factors influencing 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.

Table 12 indicates the snow depth in southeastern Wisconsin as measured during the 16-year period from 1961 through 1977 and published in Snow and Frost in Wisconsin, a 1978 Wisconsin Agriculture Reporting Service report. 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 data presented in Table 12 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 there is at least a 0.50 probability of having one inch or more of snow cover in southeastern Wisconsin. Furthermore, during January and February, there is least a 0.25 probability of having five or more inches of snow on the ground. During March, the month in which severe spring snowmelt-rainfall flood events are most likely to occur, there is at least a 0.38 probability of having one inch or more of snow on the ground.

By using Table 12, the probability that a given snow cover will exist or be exceeded at any given time can be estimated, and thus the data in the table can 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 0.25 probability of having one inch or more of snow cover on November 30 of any year, whereas there is a much higher probability, 0.75, of having that much snow cover on January 15.

Table 12

SNOW COVER PROBABILITIES IN SOUTHEASTERN WISCONSIN BASED ON DATA FOR THE PERIOD 1961-1977

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	
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	30	4	0.25	0	0.00	0	0.00	0	0.00	2.4	0.7
December	15	8	0.50	4	0.25	0	0.00	0	0.00	5.0	2.6
	31[f]	11	0.69	3	0.19	0	0.00	0	0.00	3.8	3.5
January	15	12	0.75	7	0.44	3	0.19	0	0.00	6.6	5.0
	31	10	0.62	8	0.50	3	0.19	0	0.00	7.6	4.9
February	15	13	0.81	6	0.38	4	0.25	0	0.00	6.4	5.3
	28	12	0.75	4	0.25	1	0.06	1	0.06	4.6	3.6
March	15	6	0.38	2	0.12	1	0.06	1	0.06	5.9	2.3
	31	6	0.38	2	0.12	0	0.00	0	0.00	3.7	1.5

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

[b] *Number of occurrences is the number of times during the 16-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 16, 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 16; that is, the number of observation times.*

[f] *Records not available for the first four years (1961-1964) of analysis.*

Source: Wisconsin Agriculture Reporting Service and SEWRPC.

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 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 as a result of frost actions. The design and construction of sanitary sewers is based on similar considerations.

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, and thus 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.

Data on frost conditions for the Region are available on a bi-weekly basis for the months of November to April as shown in Table 13 and are based upon data for a 16-period of record extending from 1961 through 1977, as set forth in the report Snow and Frost in Wisconsin, published in 1978 by the Wisconsin Agriculture Reporting Service. These data are provided for representative locations on a bi-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 13 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 depth occurred throughout the Planning Region. Frost depths of over 36 inches 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 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 nine 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 of frost depth may be expected.

Table 13

AVERAGE FROST DEPTH IN SOUTHEASTERN WISCONSIN: NOVEMBER TO APRIL

Month and Day	Nominal Frost Depth (inches)[a]
November 30	1
December 15	3
December 31	4
January 15	9
January 31	12
February 15	14
February 28	15
March 15	13
April 7	7
April 15	3

[a] Based on 1961-1977 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 minimum values.

Source: Wisconsin Agriculture Reporting Service, Snow and Frost in Wisconsin, October 1978.

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 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 of 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 Oak Creek watershed.

Based on the limited pan evaporation data available, pan evaporation for the watershed and environs averages about 29 inches annually, with about 24 inches occurring from May through October. During this period, pan evaporation exceeds precipitation. However, pan evaporation is not indicative of total evaporation in the watershed because the area of surface waters in the watershed is much smaller than the total watershed area.

Wind: Over the seasons of the year, prevailing winds in the Region follow a clockwise, directional pattern, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities in the Oak Creek watershed may be expected to be less than 5 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. Information on expected sky cover in the form of the expected percent of clear, partly cloudy, and cloudy days each month is also summarized in Figure 10. These daylight and sky cover data are useful in planning outdoor construction and maintenance work, and 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 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 between sunrise and sunset 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. Furthermore, 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 about equally divided between partly cloudy and clear.

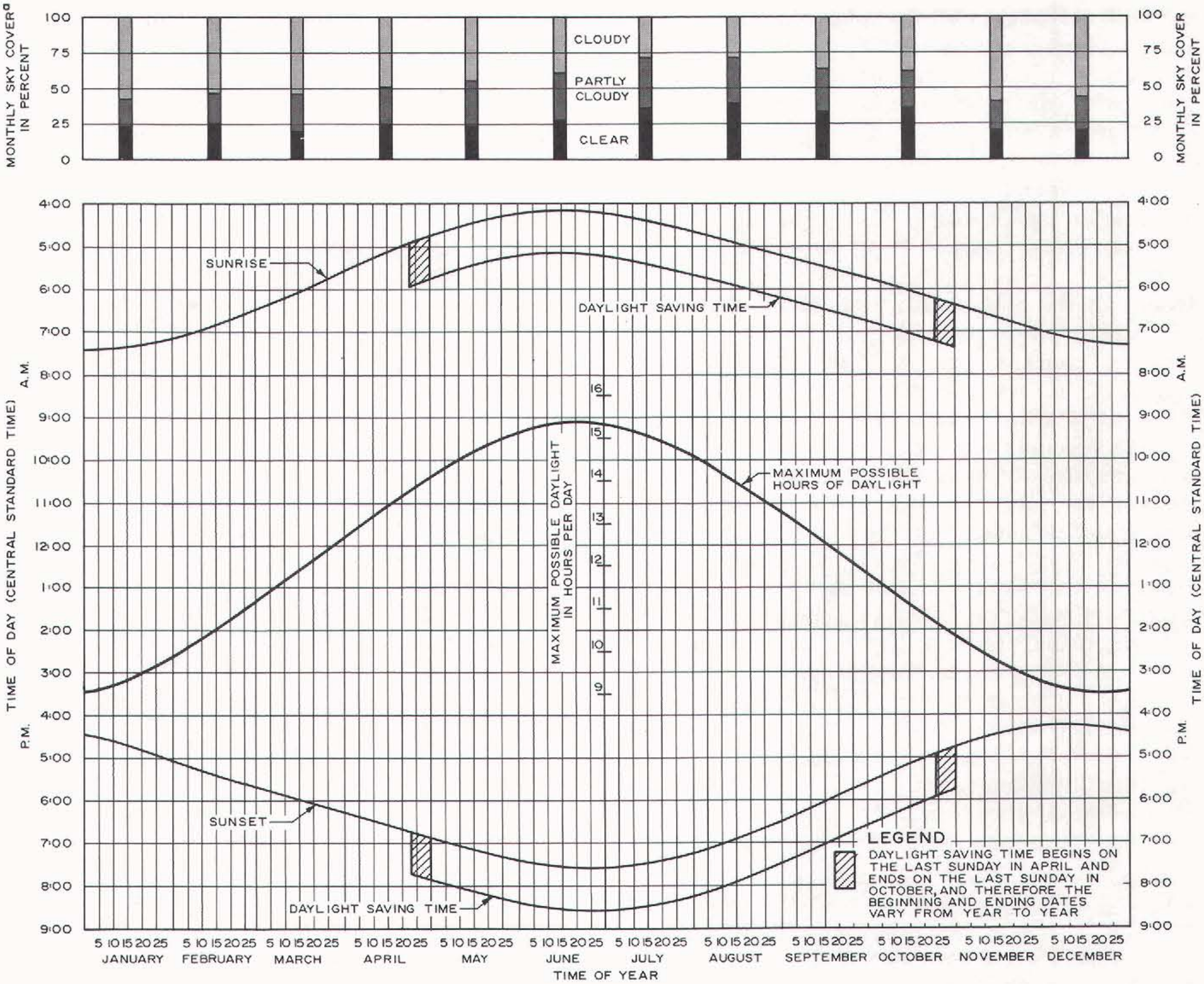
Physiography

As already noted, the Oak Creek watershed encompasses an area of approximately 27.24 square miles. The watershed is roughly rectangular in shape, being 4.5 miles wide in an east-west direction, and 5.5 miles long in a north-south direction. Also as noted, the area of the watershed was increased by 0.76 square mile in 1980 when the drainage basin lands in the City of Cudahy originally directly tributary to Lake Michigan were diverted into the watershed.

Topographic and Physiographic Features: The variation in elevation within the watershed is shown on Map 12. Watershed physiographic features, or surficial land forms, have been determined largely by the underlying bedrock and the overlying glacial deposits of the watershed. Land slopes in the watershed are classified into three major groups: slight—0 to 6 percent, moderate—6 to 12 percent, and steep—greater than 12 percent. As shown on Map 13, approximately 89 percent of the watershed is characterized as having slight slopes, 2 percent as having moderate slopes, and 1 percent as having steep slopes. Approximately 8 percent of the watershed is classified as made land for which slope data are not available. The Niagara cuesta on which the watershed lies is a gently eastward sloping bedrock surface. The elevation of the surface of the watershed is asymmetrical as shown on Map 12, with the eastern border of the watershed being generally lower in elevation—by about 80 to 140 feet—than the western border. Glacial deposits overlying the bedrock formations form the surface topography of the watershed, consisting primarily of gently sloping ground

Figure 10

SUNRISE, SUNSET, AND SKY COVER IN THE OAK CREEK 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 THESE MONTHLY DATA FOR THE LARGE GEOGRAPHIC REGION RELATIVE TO THE OAK CREEK 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 OBSCURING 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.

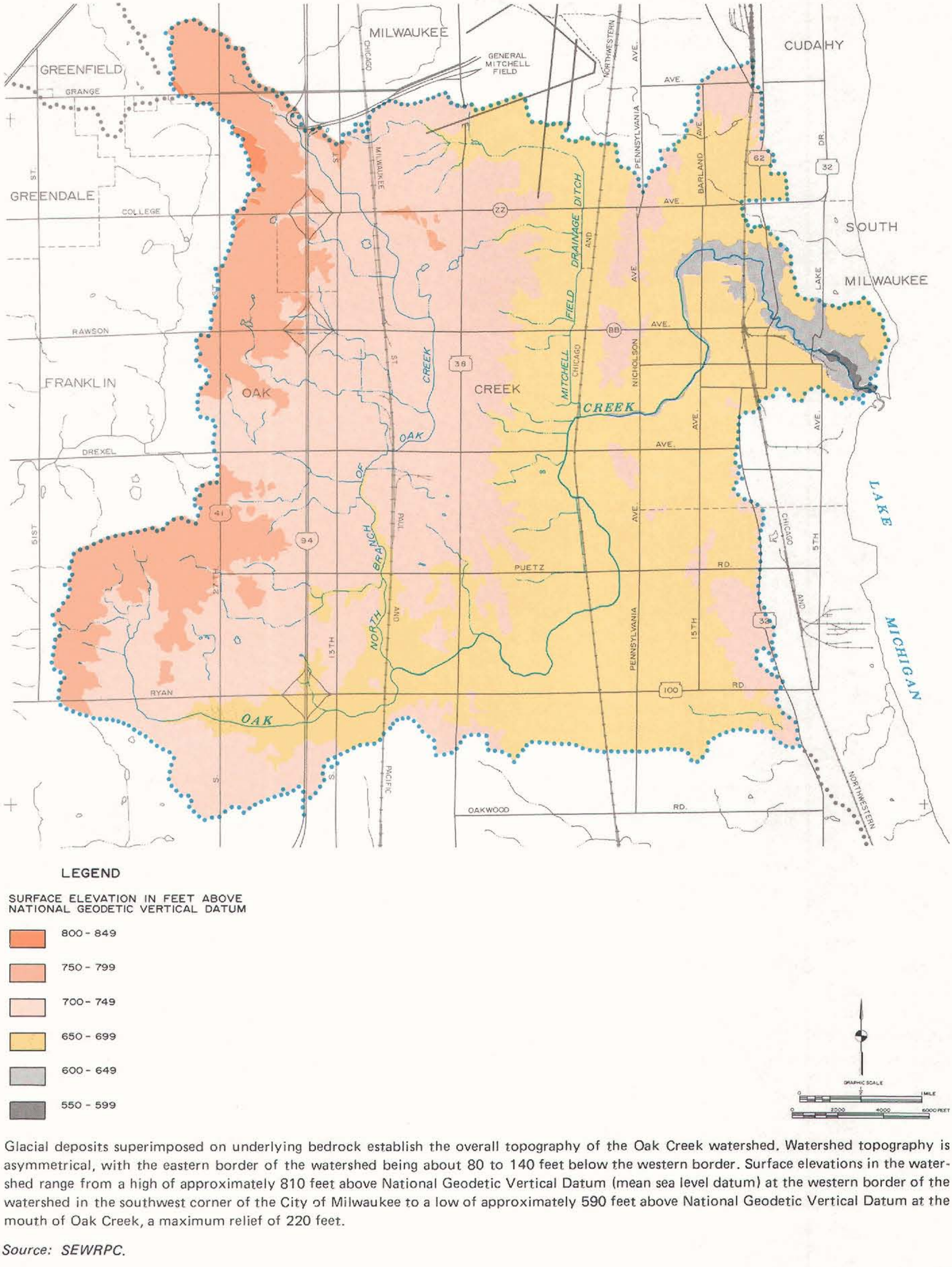
Source: Adapted by SEWRPC from National Weather Service and U. S. Naval Observatory Data.

moraine—heterogeneous material deposited on the glacial ice. Surface elevations within the watershed range from a high of approximately 810 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) along the western border of the watershed to approximately 590 feet above National Geodetic Vertical Datum at the mouth, a maximum relief of 220 feet.

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. Large-scale topographic mapping at a scale of 1 inch equals 100 feet with a two-foot contour interval prepared to SEWRPC standards is available for the entire watershed (see Map 14). The sources of mapping, dates, and other selected information are presented in Table 14. The referenced mapping together with 1 inch equals 400

Map 12

TOPOGRAPHIC CHARACTERISTICS OF THE OAK CREEK WATERSHED

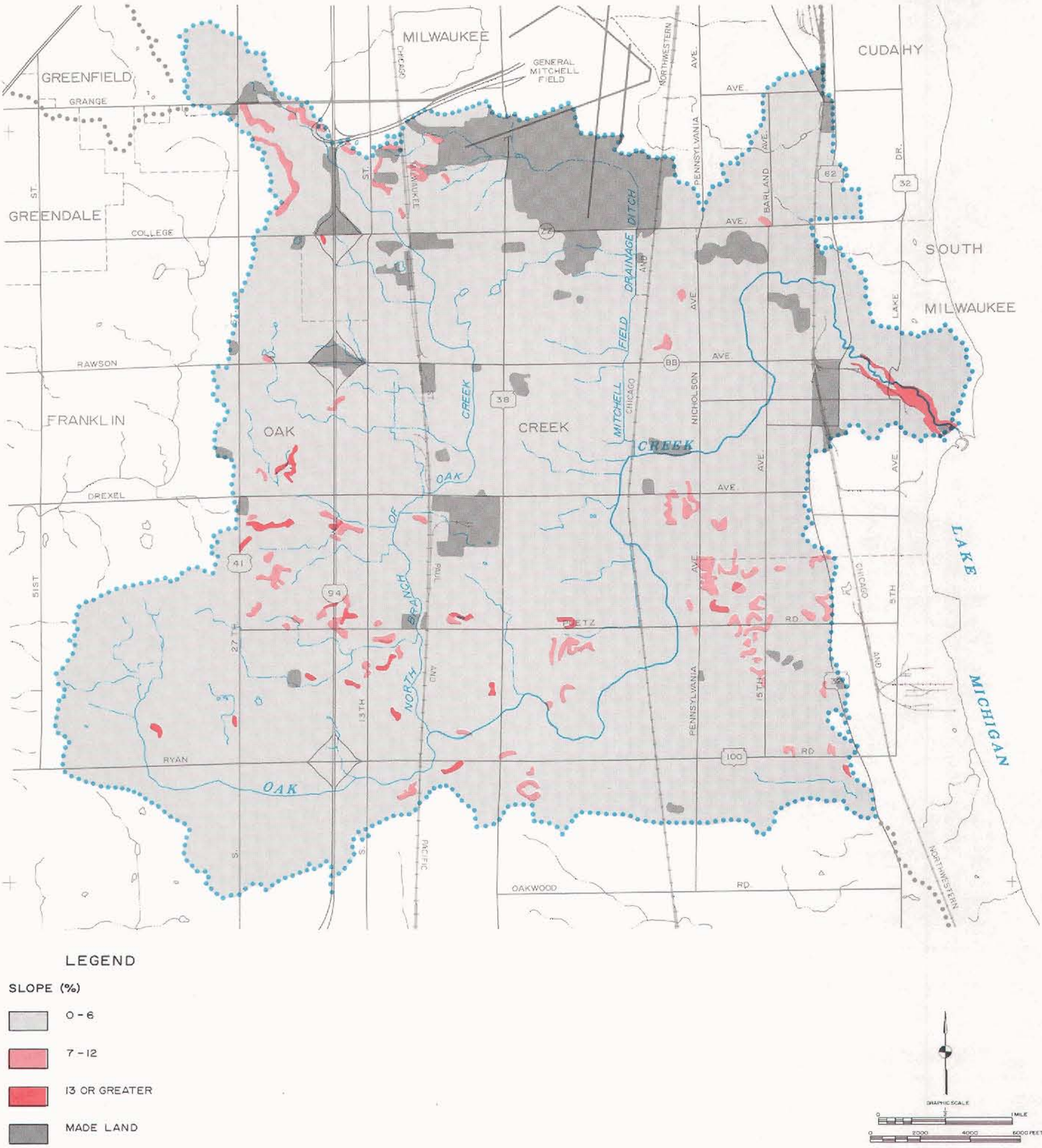


Glacial deposits superimposed on underlying bedrock establish the overall topography of the Oak Creek watershed. Watershed topography is asymmetrical, with the eastern border of the watershed being about 80 to 140 feet below the western border. Surface elevations in the watershed range from a high of approximately 810 feet above National Geodetic Vertical Datum (mean sea level datum) at the western border of the watershed in the southwest corner of the City of Milwaukee to a low of approximately 590 feet above National Geodetic Vertical Datum at the mouth of Oak Creek, a maximum relief of 220 feet.

Source: SEWRPC.

Map 13

LAND SURFACE SLOPES IN THE OAK CREEK WATERSHED



Approximately 89 percent of the Oak Creek watershed area is characterized as having slight slopes, 2 percent as having moderate slopes, and about 1 percent as having steep slopes. Approximately 8 percent of the watershed is classified as made land for which slope data are not available.

Source: SEWRPC.

foot scale aerial photographs were used extensively in the watershed planning process and should be valuable during implementation of the Oak Creek watershed plan.

Surface Drainage : The Oak Creek watershed drains in a generally easterly direction to Lake Michigan. The watershed adjoins the Kinnickinnic River watershed on the north, the Root River watershed on the south and west, and lands that drain directly to Lake Michigan on the east. Comprehensive watershed plans have been completed and adopted by the Commission for the Kinnickinnic River and Root River watersheds.

The surface drainage characteristics of the watershed are 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 glaciation superimposed on the bedrock and partly to the extensive channel modifications and other results of urbanization that are evident throughout the watershed. The configuration of the stream network in the watershed was described earlier in this chapter, being shown on Map 3 and described in Table 1.

Geology [4]

The geology of the Oak Creek 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 were 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 Oak Creek watershed consist predominantly of, in ascending order, 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 15, which summarizes the stratigraphy of the Oak Creek 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 foot per 100 feet). The relationship between the geologic units and the three aquifer systems underlying the watershed is also set forth in Table 15.

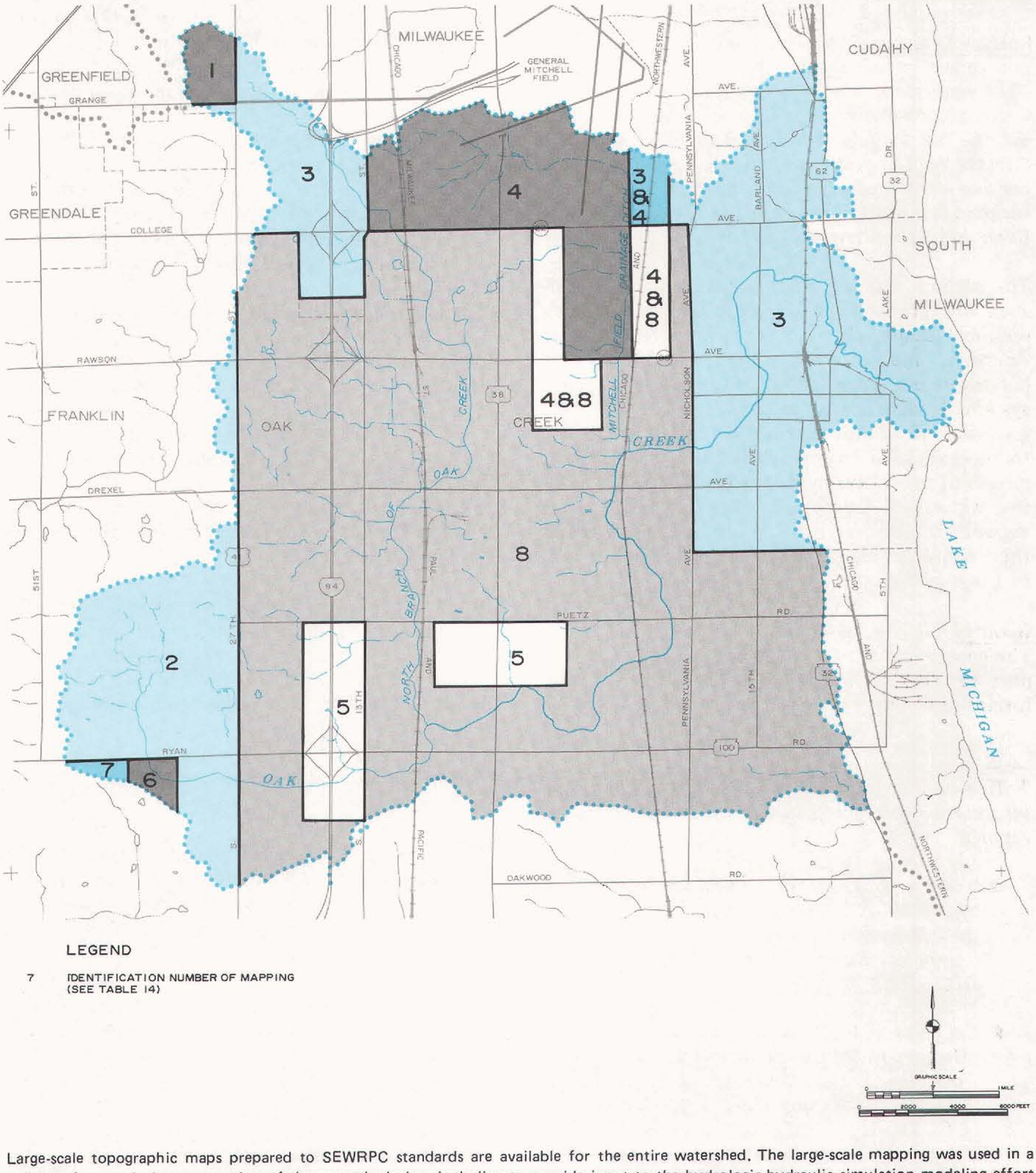
Precambrian Rock Units: Precambrian crystalline rocks thousands of feet thick form the basement on which younger rocks were deposited. Little is known of their origin, but in wells near the watershed that reach the Precambrian basement, the

[4] *This summary of watershed geology is based on 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.*
- *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.*
- *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.*
- *Martha J. Ketelle, "Hydrogeologic Considerations in Liquid Waste Disposal with a Case Study in Southeastern Wisconsin," SEWRPC Technical record, Volume 3, No. 3, September 1971.*
- *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, SEWRPC Technical Report No. 16, April 1976.*

Map 14

AVAILABILITY OF LARGE-SCALE TOPOGRAPHIC MAPPING FOR THE OAK CREEK WATERSHED: 1983



Large-scale topographic maps prepared to SEWRPC standards are available for the entire watershed. 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 in the evaluation of sites for alternative water-related public facilities and utilities. The extensive amount of large-scale mapping available should be valuable during the plan implementation process.

Source: SEWRPC.

Table 14

SELECTED INFORMATION PERTAINING TO LARGE-SCALE TOPOGRAPHIC MAPPING[a] IN THE OAK CREEK WATERSHED: 1983

Identification Number on Map 14	Civil Division	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	J. C. Zimmerman Corporation	City of Greenfield	1975	1977[b]
2	City of Franklin	Western Air Maps	City of Franklin	1963	1964
3	Cities of Cudahy, Milwaukee, and South Milwaukee	Owen Ayres & Associates, Inc.	SEWRPC	1980	1980-1981
4	Cities of Cudahy, Milwaukee, and Oak Creek	Aero-Metric Engineering, Inc.	Milwaukee County	1980	1981
5	City of Oak Creek	Wisconsin Department of Transportation, Division of Highways	Wisconsin Department of Transportation, Division of Highways	1970	1971
6	City of Franklin	Aero-Metric Engineering, Inc.	SEWRPC	1983	1983
7	City of Franklin	Alster & Associates, Inc.	City of Franklin	1963	1970
8	City of Oak Creek	Alster & Associates, Inc.	City of Oak Creek	1961[c]	1961[c]

[a] *All the mapping is two-foot contour interval at a scale of 1 inch equals 100 feet using SEWRPC-recommended procedures as described in SEWRPC Technical Report No. 7, Horizontal and Vertical Survey Control in Southeastern Wisconsin.*

[b] *Updates have been made by the City of Greenfield through 1980.*

[c] *All of these maps were updated between 1976 and 1978 except those for the following quarter sections in Township 5 North, Range 22 East: SW of Section 7; SE of Section 15; NW and SW of Section 18; NW and SW of Section 19; SW of Section 23; NW and SW of Section 25; NW of Section 26; SE and SW of Section 29; SW of Section 30; NE and SE of Section 32; and NE and NW of Section 35.*

Source: SEWRPC.

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 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 150 feet, whereas the Mount Simon sandstone has a thickness in excess of 800 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 Formation, has a thickness of between 150 and 200 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 between 50 and 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 dolo-

Table 15

STRATIGRAPHY OF THE OAK CREEK 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	50-300	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	150-200	Sandstone	
Cambrian	Eau Claire Sandstone	150	Sandstone, siltstone, and shale	--
	Mount Simon Sandstone	800+	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 the 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, and the confined sandstone aquifer is sometimes referred to as the deep aquifer.

Source: U. S. Geological Survey and SEWRPC.

mite was eroded prior to deposition of the glacial till so as to exhibit an overall downward slope which generally follows the present drainage pattern of the watershed.

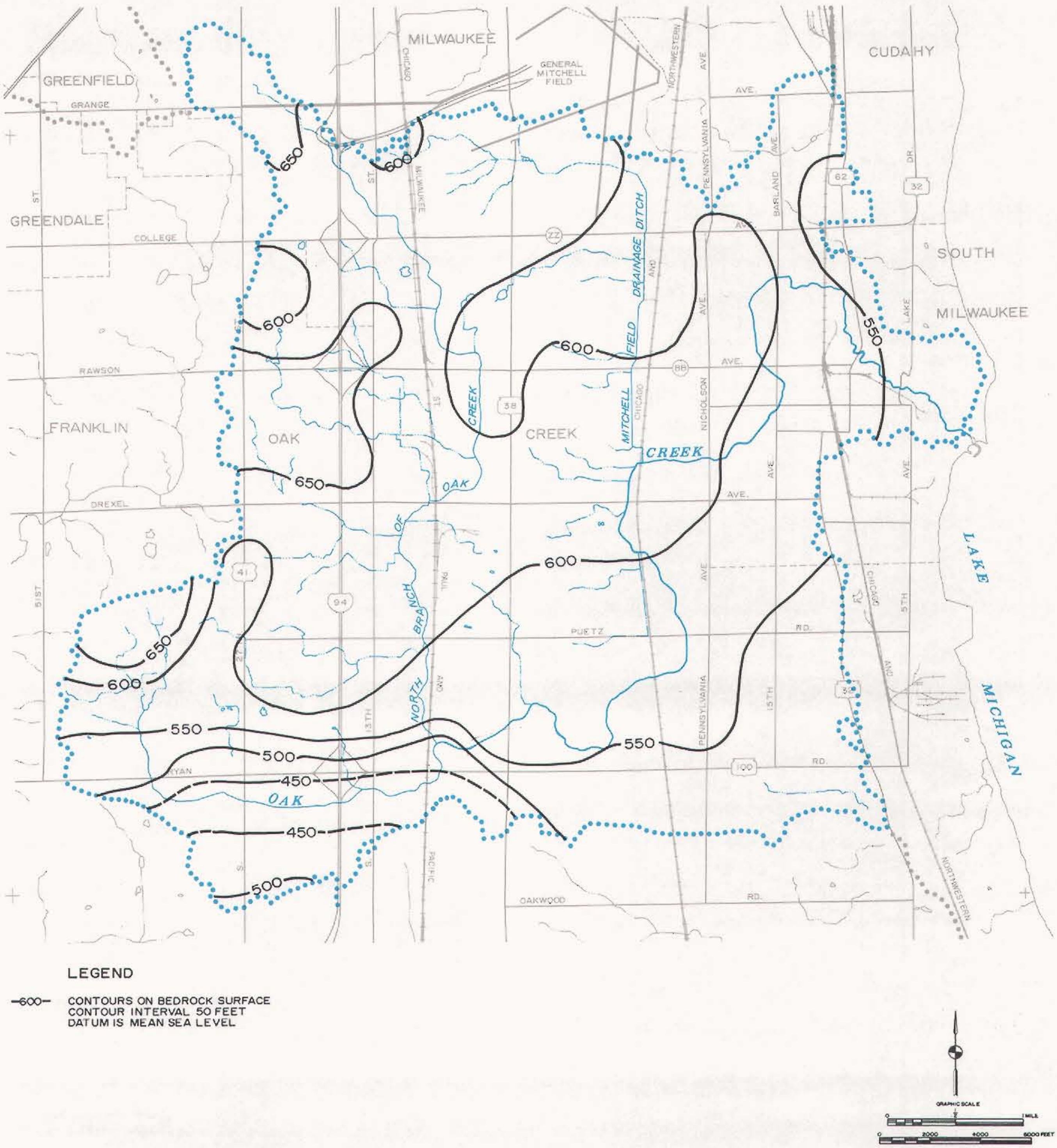
Quaternary Deposits: Unconsolidated deposits of boulders, gravel, sand, silt, and clay overlie the sedimentary rocks. These were deposited during the Pleistocene Age by continental glaciers that last covered the wastershed about 11,000 years ago. The deposits can be classified according to their origin 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 of glacial meltwater. Local deposits of stratified drift may exist in the watershed in the form of sand and gravel. As shown on Map 16, the thickness of the unconsolidated deposits in the Oak Creek watershed is variable, ranging from 100 to 250 feet.

Holocene materials consist of recent alluvium and marsh deposits. They are found 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 pits 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, gravel, and dolomite operations could

Map 15

TOPOGRAPHY OF THE SURFACE OF THE BEDROCK IN THE OAK CREEK WATERSHED

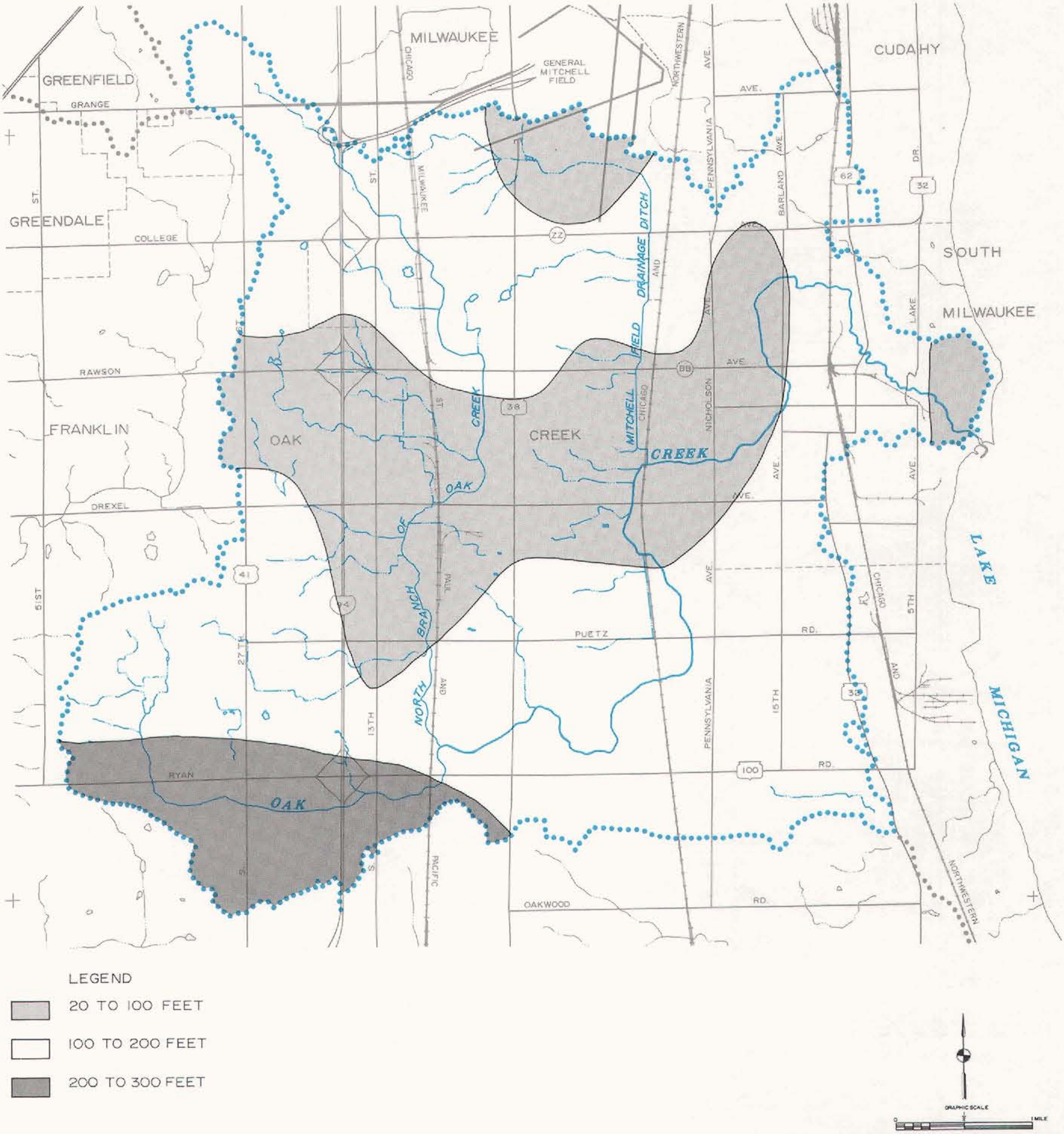


The surface of both the bedrock and the dolomite aquifer is located from 100 to 250 feet beneath the ground surface of the Oak Creek watershed. This bedrock surface dips generally downward in an easterly direction across the watershed at about 25 feet per mile. Topographic variations on the surface of 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 THE GLACIAL DEPOSITS IN THE OAK CREEK 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 variable throughout the basin. The thickness of glacial deposits is an important factor in the planning for and design of subsurface utilities and facilities because it determines whether such facilities will be constructed above or within the underlying bedrock.

Source: U. S. Geological Survey and SEWRPC.

complement contiguous public recreational areas or private residential, commercial, or industrial development. Those depressions that are in an urban setting may also serve as stormwater 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 the Oak Creek watershed. There are 14 abandoned sand and gravel pits distributed throughout the watershed. These are shown on Map 17.

Soils

The nature of the soils within the Oak Creek 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 Oak Creek 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 not only has 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 also has provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes. Detailed soils data are available for the entire area of the Oak Creek watershed. These data were utilized in the watershed planning program in the hydrologic modeling, the identification of areas having limitations for urban development utilizing onsite waste disposal systems and for development utilizing public sanitary sewer service, the identification of prime agricultural lands, and the delineation of primary environmental corridors.

Vegetation

Watershed vegetation at any given time is determined by a variety of factors, including climate, topography, occurrence of fire, soils, proximity to bedrock, drainage, and the activities of man. Because of the temporal and spatial variability of these factors and the sensitivity of different forms of vegetation to these factors, the watershed vegetation has been a changing mosaic of different types.

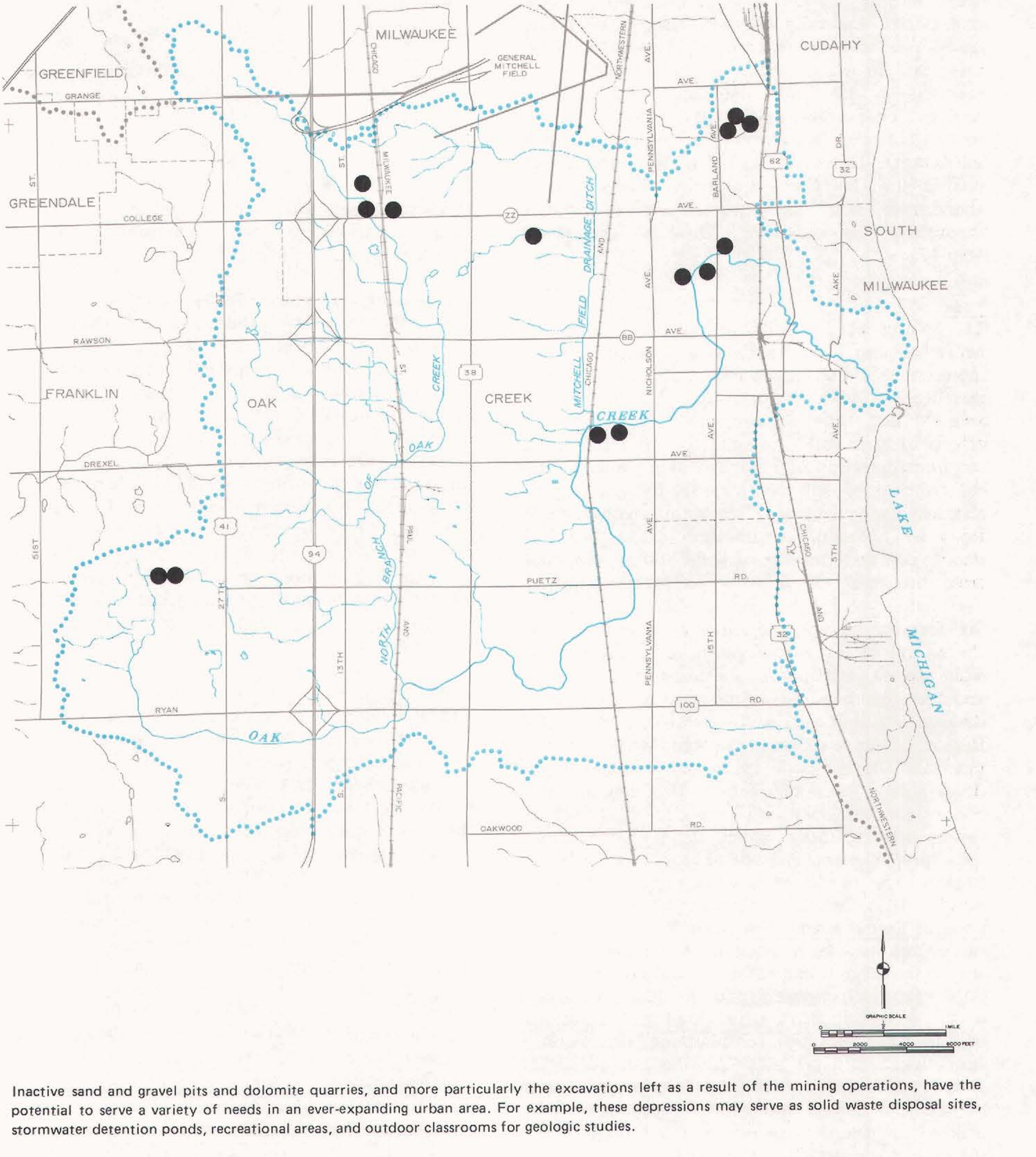
The terrestrial vegetation in the watershed occupies sites which may be subdivided into two broad classifications: wetland and woodland. Wetlands are defined as areas that are inundated or saturated by surface water or groundwater at a frequency, and with a duration sufficient to support—and that under normal circumstances do support—a prevalence of vegetation typically adapted for life in saturated soil conditions. Woodlands are defined as areas one acre or more in size having 17 or more deciduous trees per acre, each measuring at least four inches in diameter at breast height and having 50 percent or more tree canopy coverage. In addition, coniferous tree plantations and reforestation projects are identified as woodlands by the Commission.

The location, extent, type, and quality of wetland and woodland areas are key determinants of the environmental quality of the watershed. Such areas can, for example, support a variety of outdoor recreational activities. They offer aesthetic values, contributing to the beauty and visual diversity of the landscape and functioning as visual and acoustic shields or barriers. Such areas, and the vegetation contained within them, serve important ecological functions, since they are typically—on a unit area basis—the biologically most productive areas of the watershed; provide continuous wildlife range and sanctuary for native biota; and help to maintain surface water quality by functioning as sediment and nutrient traps. Finally, certain woodland and wetland areas can provide excellent outdoor laboratories for educational and research activities.

Presettlement Woodlands and Wetlands: Prior to the arrival of European settlers, the vegetation of the watershed was predominantly southern mesic

Map 17

ABANDONED SAND AND GRAVEL PITS IN THE OAK CREEK WATERSHED: 1983



Inactive sand and gravel pits 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 an ever-expanding urban area. For example, these depressions may serve as solid waste disposal sites, stormwater detention ponds, recreational areas, and outdoor classrooms for geologic studies.

Source: SEWRPC.

forest, lowland hardwood forest, and open marsh and southern sedge meadow. The southern mesic forest was composed of a variety of upland deciduous hardwoods such as sugar maple, basswood, red oak, and American beech. The lowland hardwood forest areas were predominantly composed of American elm, green ash, black ash, and black willow. Finally, the open marshes and southern sedge meadows were composed of cat-tails, sedges, and bluejoint grass. The presettlement distribution pattern of these three general categories of plant communities in the Oak Creek watershed is shown on Map 18. The southern mesic forest encompassed about 88 percent of the watershed area; the lowland hardwood forest encompassed about 3 percent of the watershed area; and the open marshes and southern sedge meadows encompassed about 9 percent of the watershed area. The map is based on information gathered as part of the U. S. Public Land Survey conducted within the watershed just prior to settlement of the watershed by Europeans in the 1830's. For example, a land surveyor's field notebook contains the following description of the lands between U. S. Public Land Survey Sections 15 and 22, Township 5 North, Range 22 East: "Land rolling good 2nd rate-marsh excepted-Timber: red and white oak, sugar maple." These same notes also provide the following description of the lands between U. S. Public Land Survey Sections 22 and 27, Township 5 North, Range 22 East: "Mostly swamp and marsh."

The three general categories of plant communities which historically existed in the watershed can be further divided into six plant community types for comparison to the remnant natural plant communities now existing in the watershed:

1. Dry-mesic upland hardwood forest containing red and white oaks, shagbark hickory, and sugar maple similar to the woodlands now found in Falk Park woods and portions of the Michael F. Cudahy Nature Preserve located in the City of Oak Creek.

2. Mesic upland hardwood forest containing sugar maple, basswood, and American beech similar to the woodlands now found in the Rawson Park woods and portions of the Michael F. Cudahy Nature Preserve located in the Cities of South Milwaukee and Oak Creek, respectively.

3. Lowland zones of wet to wet-mesic hardwood forest containing American elm, black willow, and green ash such as the stands still existing along the lower reaches of Oak Creek in the Oak Creek Parkway located in the City of South Milwaukee.

4. Small lowland areas of shrub carr containing red osier dogwood, willows, and other shrubs similar to the wetland areas now found south of Puetz Road between S. 20th Street extended and IH 94 in the City of Oak Creek.

5. Small lowland areas of southern sedge meadow like the wetland areas now found adjacent to Puetz Road between USH 41 and IH 94 in the City of Oak Creek.

6. Small lowland zones of shallow marsh like the wetland areas now found south of Violet Drive between CTH V and IH 94 in the City of Oak Creek.

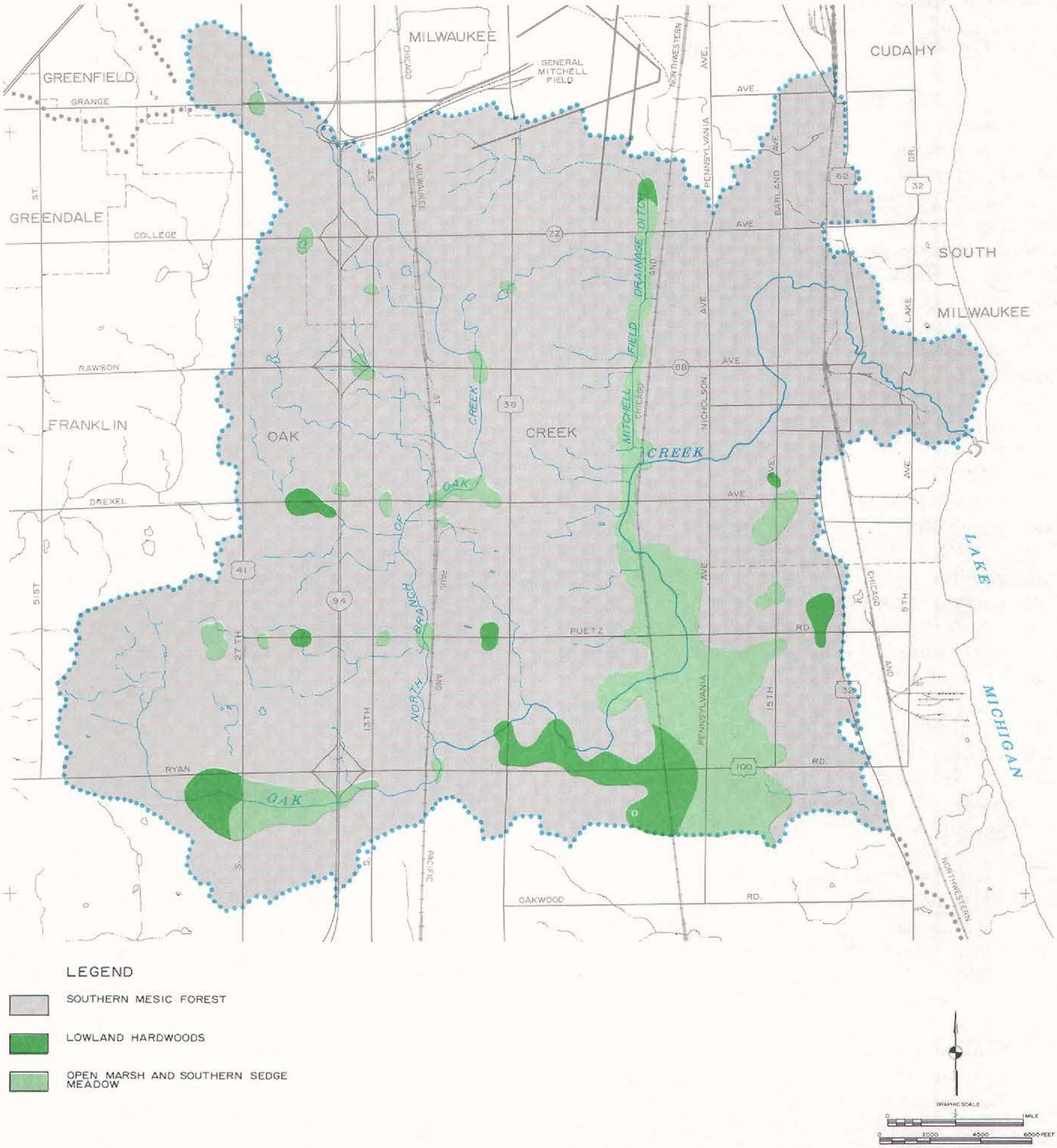
Inventories, including onsite field inspection, of the remaining natural areas which contain examples of the presettlement landscape within the Oak Creek watershed were conducted by the Wisconsin Department of Natural Resources, Scientific Areas Preservation Council staff in 1976 and 1981 for Milwaukee County. In addition, the Commission staff conducted a systematic review of its files, pertinent literature, Commission 1980 large-scale aerial photography of the watershed, and a poll of area biologists and resource managers to determine if any additional natural areas were located within the watershed. The findings of this natural area inventory effort are summarized below.

Two natural areas not already protected through public ownership encompassing about 78 acres, or about 0.4 percent of the total area of the watershed, and three natural areas presently protected by public ownership encompassing about 136 acres, or less than 0.8 percent of the total area of the watershed, were identified and rated as shown on Map 19 and in Table 16. Based on the current condition, each natural area was classified into one of the following four categories:

1. SA, State Scientific Area--State scientific areas are defined as those natural areas, geological sites, or archaeological sites identified as being of at least statewide significance and which have been so designated by the Wisconsin Department of Natural Resources, Scientific Areas Preservation Council. No such areas have been designated within the watershed.

Map 18

GENERALIZED PRESETTLEMENT VEGETATION IN THE OAK CREEK WATERSHED

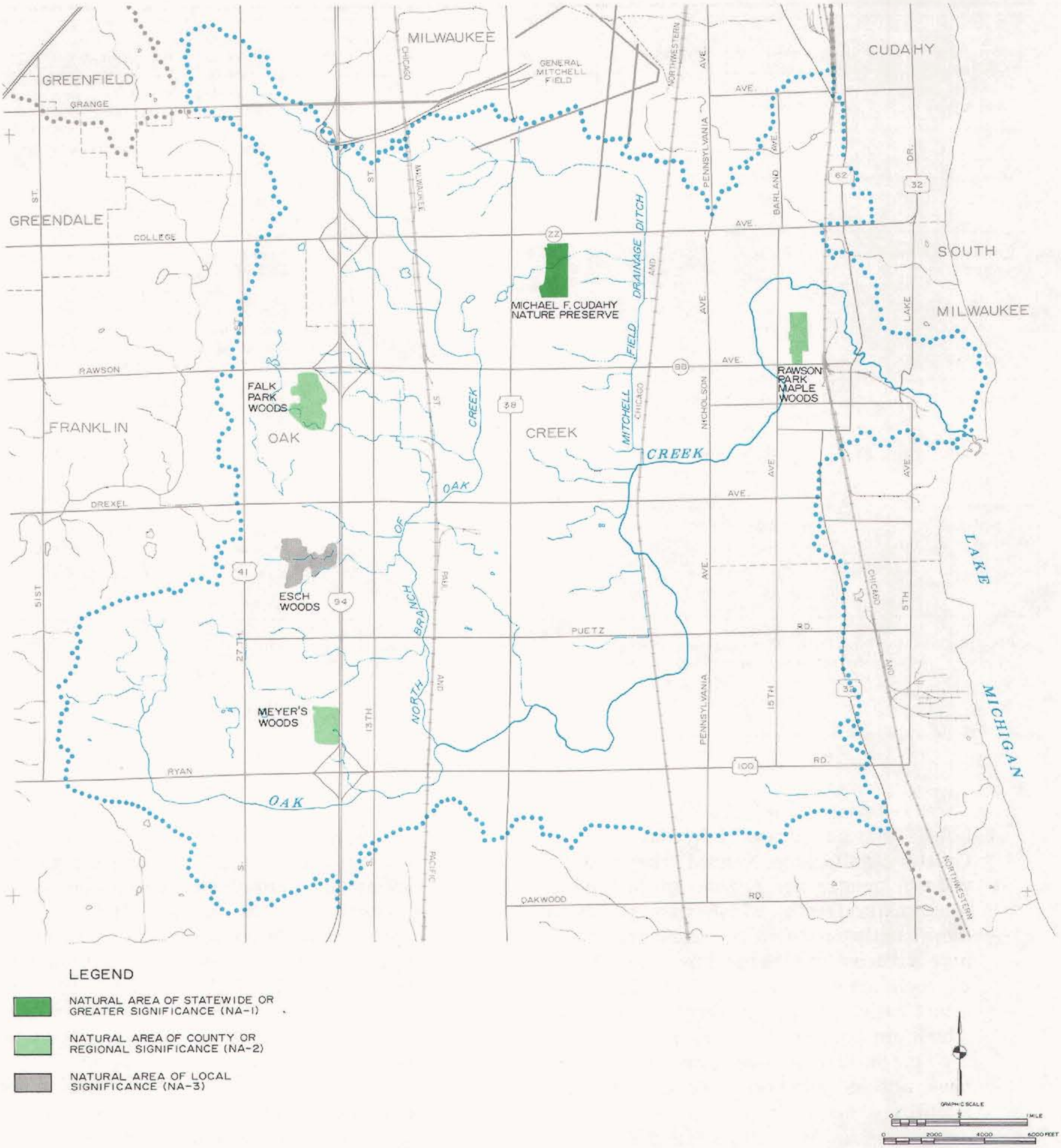


The presettlement distribution pattern of plant communities in the Oak Creek watershed can be represented by the three generalized categories shown above. About 88 percent of the watershed was classified as southern mesic forest; about 3 percent as lowland hardwood forest; and about 9 percent as open marshes and southern sedge meadows.

Source: SEWRPC.

Map 19

KNOWN NATURAL AREAS IN THE OAK CREEK WATERSHED: 1980



Inventories, including onsite field inspection, of the remaining natural areas within the Oak Creek watershed indicate that two natural areas not already protected through public ownership and three natural areas presently protected by public ownership exist within the watershed. To the extent practicable, these small remnants of the once extensive and diverse presettlement vegetation of the Oak Creek watershed should be protected and maintained in an essentially natural state.

Source: SEWRPC.

Table 16

KNOWN NATURAL AREAS IN THE OAK CREEK WATERSHED: 1983

Name	Location	Owner	Acreage	Classification Code	Description
Michael F. Cudahy Nature Preserve	T5N, R22E Section 4	Milwaukee County	60	NA-1	A remnant mixed hardwood stand containing sugar maple, beech, and red and white oaks and in part old growth, with a rich herbaceous layer and several local, rare, and endangered species
Meyers Woods	T5N, R22E Section 19	Private	30	NA-2	A southern mesic hardwood forest remnant containing sugar maple, basswood, red oak, and beech
Rawson Park Maple Woods	T5N, R22E Section 2	Milwaukee County	25	NA-2	A good stand of southern mesic hardwoods dominated by beech and sugar maples. The woods receive a considerable amount of use for field study by South Milwaukee High School students. Extensive trail development presently threatens the ground layer flora, which includes a Wisconsin endangered species
Falk Park Woods	T5N, R22E Section 7	Milwaukee County	51	NA-2	A good-quality stand of southern dry-mesic hardwoods dominated by white oak with red oak, sugar maple, basswood, white ash, and black cherry. A rich herbaceous layer is present. Past disturbances include selective cutting and some grazing
Esch Woods	T5N, R22E Section 18	Private	48	NA-3	A small but good stand of beech and sugar maples. Good size distribution; light logging in distant past. Black haw (Viburnum prunifolium) occurs here. Residential encroachment presently threatens the area

Classification Code: NA-1—Natural area of statewide or greater significance but not presently designated as State Scientific Area.
NA-2—Natural area of county or regional significance.
NA-3—Natural area of local significance.

Source: Wisconsin Department of Natural Resources and SEWRPC.

2. NA-1, Natural Areas of Statewide or Greater Significance--Natural areas of statewide or greater significance are defined as those natural areas which have not been significantly modified by man's activity or have sufficiently recovered from the effects of such activity so as to contain nearly intact native plant and animal communities which are believed to be representative of the presettlement landscape, but which have not as yet been classified as state scientific areas.

3. NA-2, Natural Areas of Countywide or Regional Significance—Natural areas of countywide or regional significance are defined as those natural areas which have been slightly modified by man's activities or which have insufficiently recovered from the effects of such activities but still contain good examples of native plant and animal communities representative of the presettlement landscape. These natural areas are of lesser significance because the degree of their quality is less than what would be defined as ecologically ideal and there is evidence of past or present disturbances such as logging, grazing, water level changes as a result of ditching or filling, or pollution; the area may contain very common plant or animal community types in the Region, in which case only the best examples would qualify for state scientific area recognition; or the area may be too small. These natural areas may serve local communities as educational sites, passive recreation areas, and ecological zones which lend a degree of naturalness to

their surroundings. In addition, these natural areas, if protected in an undisturbed condition, may be expected to increase in value over time. Therefore, some of these areas may, in the future, become natural or scientific areas of statewide significance.

4. NA-3, Natural Areas of Local Significance—Natural areas of local significance are defined as those natural areas which have been significantly modified by man's activities but have, nevertheless, retained a modest amount of natural cover. Such natural areas are suitable for local educational use, and their exclusion from a natural area survey would be considered an oversight. Natural areas of local significance may reflect the patterns of former vegetation or serve as examples of the influence of human settlement on vegetation. These natural areas may also be expected to increase in value if protected in an undisturbed condition.

Classification of an area into one of the foregoing categories is based upon consideration of the diversity of plant and animal species and community types present; the expected structure and integrity of the native plant or animal community; the extent of disturbance from man's activities such as logging, grazing, water level changes, and pollution; the commonness of the plant and animal communities present; any unique natural features within the area; the size of the area; and the area's educational value.

The natural areas in the Oak Creek watershed were also classified by the dominant type or types of vegetation present. The six categories used above to describe presettlement vegetation were used to classify the existing vegetation. Based on the vegetation classification, southern mesic hardwood forest is the dominant type of vegetation in the remaining natural areas of the watershed, occupying about 540 acres, or 3.1 percent of the total area of the watershed. Table 17 compares the presettlement and current vegetative pattern of the watershed. Clearly, only small remnants of the once extensive and diverse presettlement vegetation of the Oak Creek watershed remain. To the extent practicable, these remnants should be protected and maintained in an essentially natural state.

<u>Existing Woodlands</u>: As noted above, woodlands are defined as those upland areas one acre or more in size having 17 or more deciduous trees per acre, each measuring at least four inches in diameter at breast height and having 50 percent or more tree canopy coverage. In addition, coniferous tree plantations and reforestation projects are identified as woodlands. It is important to note that all lowland wooded areas, such as wet to wet-mesic hardwoods, have for watershed planning purposes been classified as wetlands, and are described in the following section of this chapter. As shown on Map 20, woodlands in the Oak Creek watershed presently cover 830 acres, or less than 5 percent of the total area of the watershed. Distributed in small stands throughout the watershed, these woodlands provide an attractive natural resource of immeasurable value. These woodlands accentuate the beauty of the stream system and the topography of the watershed, and are essential to the maintenance of the overall environmental quality of the environment in the watershed.

A demand for the remaining woodland areas may be expected within the watershed, especially for residential development. Real estate interests tend to acquire scenic woodland areas for such development and this trend may be expected to accelerate. Severe damage to woodland areas has resulted where developers have subdivided woodland tracts into small urban lots and removed trees to develop subdivisions. Remaining trees have often been seriously weakened through the loss of a large portion of the root system. It is important to note that woodlands can be substantially preserved during land subdivision through careful construction practices, as well as good subdivision layout and design. However, in the absence of good planning and plan implementation there is no guarantee that such preservation will take place.

The overall quality of life within the watershed will be greatly influenced by the quality of the environment as measured in terms of clean air, clean water, scenic beauty, and natural diversity. Woodlands contribute to clean air and water and to the maintenance of a diversity of plant and animal life in association with human life. The existing woodlands of the watershed which required a century or more to develop can be destroyed through mismanagement within a comparatively short period of time. Accordingly, careful attention should be given in the urban planning and development process to the preservation and proper manage-

Table 17

PRESETTLEMENT AND CURRENT VEGETATIVE PATTERNS IN THE OAK CREEK WATERSHED

Vegetation Type	1836		1980		Change	
	Acres	Percent of Watershed	Acres	Percent of Watershed	Acres	Percent Loss
Southern Mesic Forest	15,348	88.0	540	3.1	-14,808	96
Lowland Hardwood	505	2.9	90	0.5	-415	82
Open Marsh and Southern Sedge Meadow	1,583	9.1	41	0.2	-1,542	97
Total	17,436	100.0	671	3.8	-16,765	96

Source: SEWRPC.

ment of the remaining woodlands of the Oak Creek watershed as an important element of the natural resource base.

Existing Wetlands: As noted above, wetlands are defined as areas that are inundated or saturated by surface water or groundwater at a frequency, and with a duration sufficient to support—and that under normal circumstances do support—prevalence of vegetation typically adapted for life in saturated soil conditions. Such vegetation typically includes sedges, cat-tails, red osier dogwood, and willows. All remaining wetlands within the watershed have been identified by the Southeastern Wisconsin Regional Planning Commission and are shown on Map 20. Wetlands within the Oak Creek watershed include shallow marsh, southern sedge meadow, shrub carr, fresh (wet) meadow, and southern wet and wet-mesic hardwood forests. Wetlands in the watershed presently cover 459 acres, or less than 3 percent of the total area of the watershed.

Water and wetland areas probably provide the singularly most important landscape feature within the watershed and can serve to enhance all proximate uses. Their contribution to resource conservation and recreation within the watershed is immeasurable. Recognizing the desirable attributes of wetland areas, continued efforts should be made to protect this resource by discouraging costly—both in monetary and environmental terms—wetland draining, filling, and urbanization. Wetlands have an important set of common natural functions that make them ecologically and environmentally valuable resources. Below is a summary of the resource values of wetlands within the Oak Creek watershed:

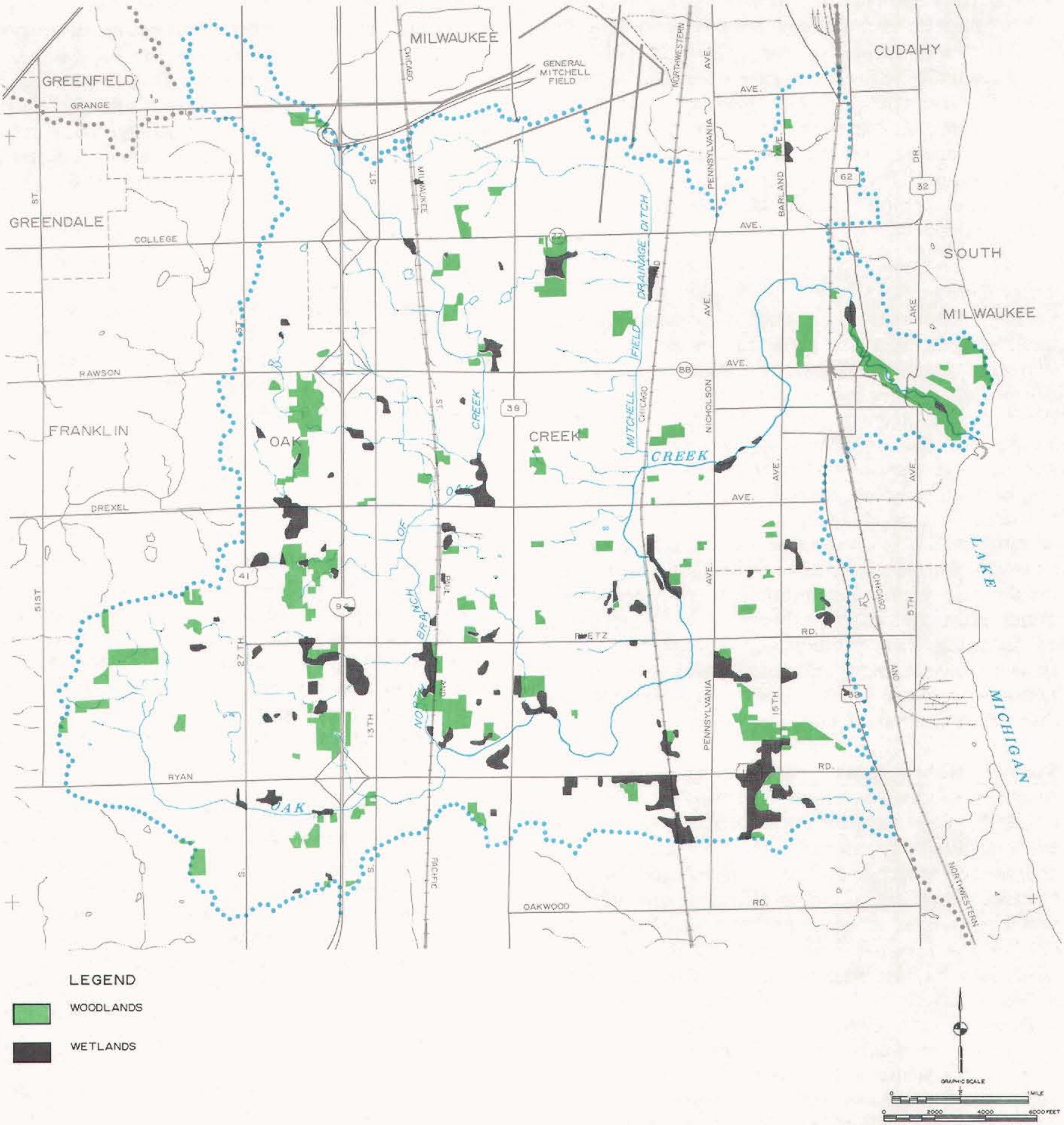
1. Wetlands affect the quality of water. Aquatic plants change inorganic nutrients such as phosphorus and nitrogen into organic material, storing it in their leaves or in the peat which is composed of plant remains. The stems, leaves, and roots of these plants also slow the flow of water through the wetland, allowing the silt and other sediment to settle out. Wetlands thus help to protect downstream water resources from siltation and pollution.

2. Wetlands influence the quantity of water. They act to retain water during dry periods and to hold it back during wet weather, thereby stabilizing streamflows and controlling flooding. At a depth of 12 inches, an acre of marsh is capable of holding more than 325,000 gallons of water, and thus helps protect communities against flooding.

3. Wetlands may serve as groundwater recharge and discharge areas.

Map 20

WOODLANDS AND WETLANDS IN THE WATERSHED: 1980



Woodlands in the Oak Creek watershed presently cover a total combined area of 830 acres, or less than 5 percent of the total area of the watershed. Distributed in small stands throughout the watershed, these woodlands provide an attractive natural resource of immeasurable value. These woodlands accentuate the beauty of the stream system and the topography of the watershed and are essential to the maintenance of the overall environmental quality of the watershed. Water and wetland areas probably provide the singularly most important landscape features within the watershed and can serve to enhance all proximate uses. Their contribution to resource conservation and recreation within the watershed is immeasurable, and they contribute both directly and indirectly to the watershed's economy. Recognizing the many environmental attributes of wetland areas, continued efforts should be made to protect this resource by discouraging costly—both in monetary and environmental terms—wetland draining, filling, and urbanization.

Source: SEWRPC.

4. Wetlands are important resources for overall ecological health and diversity. They provide essential breeding, nesting, resting, and feeding grounds and provide escape cover for many forms of fish and wildlife. The water present in the wetland is also attractive to upland birds and other animals. These functions give wetlands recreational, research, and educational values; support activities such as trapping, hunting, and fishing, and add aesthetic value to the community.

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 Oak Creek 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 Oak Creek watershed study.

Surface Water Resources: The surface water resources of the Oak Creek watershed, as identified in 1980, consist almost entirely of streams. Lakes are conspicuously absent, with the remainder of the surface water being made up of small ponds, flooded gravel pits, and wetlands. These surface water resources, in combination and individually, are far less abundant comparatively in the watershed than in the Region as a whole. As already noted, wetlands in the watershed account for only 459 acres, or 3 percent of the total area of the watershed, compared with 10 percent within the Region as a whole. Ponds and other surface water are present in an even smaller proportion, totaling only 27 acres, or less than 1 percent of the total area of the watershed, compared with 2 percent for the Region as a whole. 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 base flow of the streams. Agricultural drain tiles also contribute to this base flow. The streams also periodically receive surface water runoff from rainfall and snowmelt. This runoff, superimposed on the base flow, 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 12.5[5] inches of water spread over the watershed, amounting to about one-third 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 21.3 lineal miles of such perennial streams, as listed in Table 1. The detailed study of portions of the perennial stream system within the watershed constitutes 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 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 meandering 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 to be an integral part of a natural stream system.

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

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 themselves be subject to flood damage, should be prohibited in the floodway.

The floodplain fringe is that portion of the regulatory floodplain lying outside 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 that could be 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.

The problems of flooding and attendant damages in the Oak Creek watershed have been a matter of concern for many years. The flooding problem in the Oak Creek watershed has been documented in the federal flood insurance study reports for the Cities of Franklin,[6] Oak Creek,[7] and South Milwaukee.[8] Each report included data on historic flooding and on existing condition flood flows and stages, as well as a delineation of the floodlands. However, none of these studies contain alternative and recommended flood control plans for the watershed as a whole. It is, therefore, the purpose of this comprehensive watershed study to define the precise nature of the existing and probable future flood control problems of the watershed, identify the causes of those problems, propose alternative solutions thereto, and recommend the best solution from among the alternatives, together with the most effective means for carrying out that solution.

Existing flood problems can be best described in terms of information describing reported historic floods. Such information, valuable to problem definition, is presented in Chapter VI. Floodland management alternatives from which an integrated water resource management plan for the watershed can be synthesized are presented in Chapter XII, which includes a review and evaluation of the technical, economic, financial, legal, and administrative feasibility and political acceptability of each alternative. The recommended floodland management element of the comprehensive plan for the Oak Creek watershed, along with the basis for the plan synthesis and an analysis of the attendant costs, is presented in Chapter XIV.

Groundwater Resources: The Oak Creek watershed is richly endowed with groundwater resources. In the still rural portions of the watershed, the domestic water supply is provided by the groundwater reservoir. As already noted, Lake Michigan is

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6 *Federal Insurance Administration, City of Franklin, Wisconsin, Flood Insurance Study, July 1981.*

7 *Federal Insurance Administration, City of Oak Creek, Wisconsin, Flood Insurance Study, March 1978.*

8 *Federal Insurance Administration, City of South Milwaukee, Wisconsin, Flood Insurance Study, November 1979.*

the source of the public water supply provided to the urban areas of the watershed. Gradual discharge from the groundwater reservoir supplies the baseflow to Oak Creek and its tributaries.

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 1,900 feet in portions of the watershed. There are three major aquifers in the Oak Creek 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 to surface water resources and other elements of the planning study are discussed in subsequent chapters of this report.

Fish and Wildlife Resources

Fish and wildlife are desirable because of their educational, recreational, and aesthetic value, and their importance in the ecological system. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the watershed.

Fishery: The distribution and abundance of fish in rivers and streams may be used as an indication of both short- and long-term changes in water quality and general instream ecological conditions. There are several advantages to using fish life as an indicator of the water quality and general ecological health of a stream system. First, fish occupy the top of the aquatic food chain and their presence, therefore, implies the presence of many other types of plants and animals upon which they feed. Second, fish live continuously for generations in a water body and, therefore, over time come to reflect the condition of that water body. Finally, fish have been well studied, therefore, more accurate identification of species and more complete descriptions of their life histories are available than for other aquatic species, permitting relationships between fish and their environment to be well assessed.

The information about the specific population of fish in a stream system that is used as an indicator of water quality and ecological conditions must be compared to information concerning the natural population of fish in a clean and ecologically sound stream system. Several characteristics of the fish population of a clean and sound environment are important in such a comparison. These characteristics include the presence of fish species from all parts of the food chain, including the herbivorous or forage fish and several levels of predator fish; the presence of a high diversity of species; and a distribution of age classes reflecting a viable breeding population. Particular aquatic habitats should contain representative fish species—e.g., riffle areas should contain some combination of darters, daces, and certain species of minnows.

The fish species should be spread among the pollution intolerant, tolerant, and very tolerant, with the intolerant species dominating in the clean water conditions. Knowing those characteristics of the natural fish population which may be expected to exist in a clean and healthy environment, one may make comparisons with existing and historic populations and thereby assess the degree of deviation from the undisturbed native condition. Thus, typically, a natural undisturbed fish population has species in each of the three classifications, with the intolerant species, however, being the most numerous. Any deviation may be attributed to the physical and water quality alterations in the habitat caused by the activities of man in the watershed tributary to the stream channel system, as well as to man-made changes to the stream channel system itself.

The use of fish as indicators of prevailing water quality conditions has been an important analytical tool for water quality evaluation in past watershed studies. Fish species may be categorized on the basis of their tolerance to pollution. However, the ranking of fish species on a pollution tolerance scale does not provide a precise species-by-species hierarchy of pollution tolerance and, therefore, an indication of water quality conditions. Rather, such a ranking is intended to generally group species according to their tolerance to pollution. Generally, this pollution tolerance is related to dissolved oxygen concentrations, although turbidity, siltation, temperature, pH, and toxic substances such as ammonia and pesticides are also important factors in determining tolerance. Fish classified as very tolerant can withstand large variations in water quality conditions and may, therefore, be expected to be found in both clean and heavily polluted waters. Fish classified as tolerant can withstand smaller variations in water quality conditions than can very tolerant fish, and may, therefore, be expected to be found in clean and moderately polluted waters. Fish classified as intolerant, relative to other categories, can exist in only a very restricted range of water quality conditions and, therefore, may be expected to inhabit only clean waters. Generally, the presence of intolerant fish species indicates good water quality conditions, with high dissolved oxygen levels, low turbidity, pH values within a 6.0 to 9.0 standard units range, water temperatures which do not exceed the natural daily and seasonal fluctuations, and no toxic substances present. Insofar as a stream network is a dynamic system and fish are mobile animals, less tolerant fish species occasionally may find and temporarily reside in localized niches that are of higher quality than the overall quality of a particular reach of a stream system.

Historic Findings. Data from historic fish surveys of the Oak Creek system are useful in assessing the overall change in the fish populations and, therefore, in water quality conditions. In most cases where intolerant fish species have been significantly reduced or eliminated, significant alteration in the stream habitat may be assumed, such as channelization; draining of connected wetlands; runoff of fertilizers, sediment, pesticides, and other toxic substances from both rural and urban lands; and the discharge of both municipal and industrial wastes.

Historic data from six fishery surveys were evaluated and used to assess the changes over time that have occurred in the fishery of the Oak Creek watershed. Table 18 lists the fish species and shows the number of individual species collected in the watershed since 1910. Figure 11 illustrates the spatial distribution of these species at each collecting site on the stream system.

The earliest recorded fish survey of the Oak Creek watershed was conducted by S. Graenicher on October 2, 1910, for the Milwaukee Public Museum. The specific collection site is unknown and was simply reported as "Oak Creek." Although only three species of fish were identified in the collection, they are significant because one species is considered pollution intolerant—blacknose dace. This fish species is no longer found in the watershed.

The best historic appraisal of the natural fish fauna of Oak Creek comes from a survey conducted in 1924 by C. L. Turner at a site "one mile southwest of South Milwaukee" as the stream channel existed in 1924. Figure 11 shows the approximate collection site location between stream miles 4 and 5. At that time 14 species of fish were collected, of which five were found to be pollution intolerant—blacknose dace, blacknose shiner, brassy minnow, Iowa darter, and least darter; six tolerant—Johnny darter, common shiner, golden shiner, creek chub, bluntnose minnow, and green sunfish; and three very tolerant—central mudminnow, white sucker, and black bullhead. The distribution of fish species among the three pollution tolerance categories indicates that a healthy fishery existed at that time in Oak Creek.

For nearly 50 years, since 1924, no documented fish surveys were conducted in the Oak Creek watershed. In 1973, personnel from the Milwaukee Public Museum obtained collections from three sites along the main stem of Oak Creek and found less than half the number of species reported in 1924. Their findings included three pollution tolerant species—creek chub, brook stickleback, and green sunfish; and three very tolerant species—central mudminnow, fathead minnow, and white sucker. No intolerant species were reported.

In September 1975, the Wisconsin Department of Natural Resources conducted a fish survey of Oak Creek as part of a statewide fish distribution study. Five sites were surveyed in the watershed: three sites along the main stem of Oak Creek, one site along the Mitchell Field drainage ditch, and one site along the North Branch of Oak Creek. A total of 10 species were collected from the watershed, of which five were found to be pollution tolerant—emerald shiner, sand shiner, creek chub, brook stickleback, and green sunfish—and five very tolerant—central mudminnow, goldfish, fathead minnow, white sucker, and black bullhead. Again, no intolerant species were reported. Two of the species—emerald shiner and sand shiner—were represented by single individuals and were collected in the estuary portion of the watershed; as such, they may not represent a viable breeding population but rather an itinerant population from the near-shore waters of Lake Michigan.

Table 18

HISTORICAL FISH SURVEYS CONDUCTED IN OAK CREEK WATERSHED: 1910-1981

Fish Species According to Their Relative Tolerance to Pollution	Date of Survey and Number of Individuals Collected					
	October 2, 1910	July 11, 1924	March 22, 1973	September 5-8, 1975	September 6, 1980	August 18 and 31, 1981
Very Tolerant						
Central mudminnow (Umbra limi)	--	3	1	114	124	9
Goldfish[a] (Carassius auratus)	--	--	--	1	1	10
Carp[a] (Cyprinus carpio)	--	--	--	--	5	8
Fathead minnow (Pimephales promelas)	5	--	22	243	751	184
White sucker (Catostomus commersoni)	--	18	22	98	97	14
Black bullhead (Ictalurus melas)	--	1	--	1	--	--
Tolerant						
Johnny darter (Etheostoma nigrum)	2	99	--	--	--	--
Emerald shiner[b] (Notropis atherinoides)	--	--	--	1	--	--
Sand shiner[b] (Notropis stramineus)	--	--	--	1	--	--
Common shiner (Notropis cornutus)	--	6	--	--	--	--
Golden shiner (Notemigonus crysoleucas)	--	4	--	--	17	--
Creek chub (Semotilus atromaculatus)	--	32	24	337	77	--
Bluntnose minnow (Pimephales notatus)	--	25	--	--	--	--
Brook stickleback (Culaea inconstans)	--	--	78	237	1,556	--
Green sunfish (Lepomis cyanellus)	--	1	4	22	4	102
Pumkinseed (Lepomis gibbosus)	--	--	--	--	--	2
Largemouth bass (Micropterus salmoides)	--	--	--	--	1	1
Intolerant						
Blacknose dace (Rhinichthys atratulus)	1	5	--	--	--	--
Blacknose shiner (Notropis heterolepis)	--	59	--	--	--	--
Brassy minnow (Hybognathus hankinsoni)	--	3	--	--	--	--
Iowa darter (Etheostoma exile)	--	1	--	--	--	--
Least darter (Etheostoma microperca)	--	99	--	--	--	--
Total Number of Species Collected	3	14	6	10	10	8
Total Number of Individuals Collected	8	356	151	1,055	2,635	330

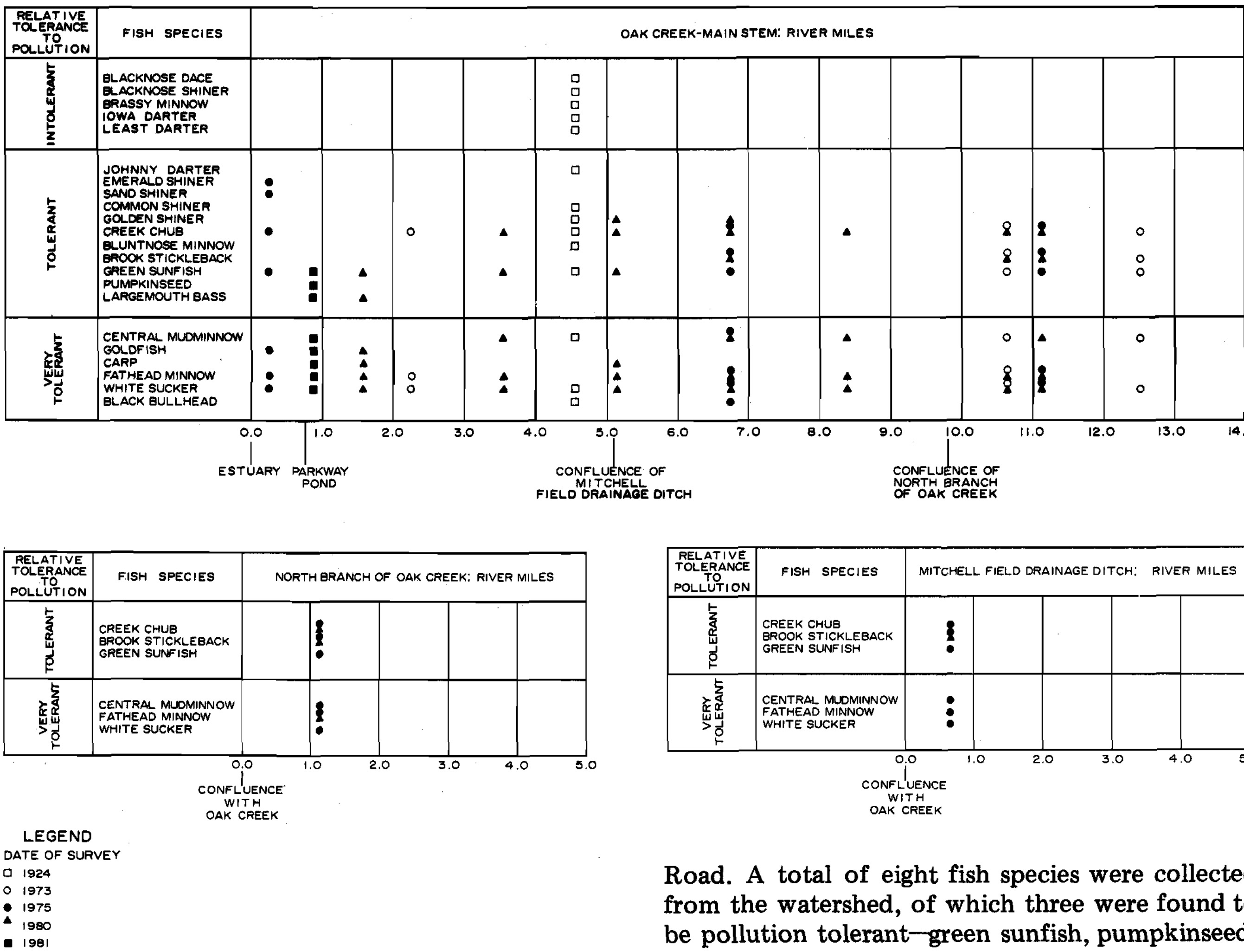
[a] *Introduced species.*

[b] *Anadromous fish species from Lake Michigan.*

Source: SEWRPC.

Figure 11

HISTORICAL SPATIAL DISTRIBUTION OF FISH IN THE OAK CREEK WATERSHED: 1924-1981



Source: SEWRPC.

A more comprehensive fish survey was conducted by the Commission staff in September 1980. Nine survey sites were established in the watershed: seven sites along the main stem of Oak Creek, one site along the Mitchell Field drainage ditch, and one site along the North Branch of Oak Creek. A total of 10 species were collected from the watershed, of which five were found to be pollution tolerant—largemouth bass, golden shiner, creek chub, brook stickleback, and green sunfish—and five very tolerant—central mudminnow, goldfish, carp, fathead minnow, and white sucker. No intolerant species were reported.

In August 1981, the Wisconsin Department of Natural Resources conducted fish surveys with electrofishing gear and minnow seines of the Parkway Pond located behind the dam near Mill Road. A total of eight fish species were collected from the watershed, of which three were found to be pollution tolerant—green sunfish, pumpkinseed, and largemouth bass—and five very tolerant—central mudminnow, goldfish, carp, fathead minnow, and white sucker. The largemouth bass, a gamefish species, was represented by a single individual and clearly does not indicate the presence of a breeding population in the pond.

In addition to the species reported in the survey, the following species have been reported from the estuary area near Lake Michigan: coho salmon, chinook salmon, rainbow trout, brown trout, brook trout, and longnose sucker. All six fish species are intolerant of pollution and only enter the stream during spring or fall spawning season when oxygen levels are relatively high. Spawning, however, is unsuccessful because of the generally poor water quality conditions and lack of suitable spawning habitat. In order for salmonids to reproduce, they must have clean gravel substrate with groundwater upwellings or cold, interstitial stream flows. This upwelling of groundwater or interstitial flow keeps the salmonid eggs well oxygenated and removes metabolic waste and silt. Those conditions are not met in Oak Creek at the present time. Furthermore, the presence of a dam one mile from the lake precludes any fish migration even if upstream conditions were favorable for spawning.

One documented fish kill has occurred in the Oak Creek watershed. On January 21, 1980, a gasoline spill near 10th and Rawson dumped an estimated 2,500 to 4,000 gallons into the creek. An estimated 80 percent of the fishery located downstream of the spill were killed, the total kill being estimated to have ranged from 500 to 5,000 fish. Fish species identified included rainbow and brown trout, coho salmon, creek chub, white sucker, carp, central mudminnow, and other forage species.

Existing Fishery: Commission personnel inventoried the fish population of the Oak Creek watershed stream system in June 1983 in order to determine the current status of the watershed fishery. These field studies, combined with instream habitat assessments and pollution controlability analyses, were intended to provide a basis for analyzing the potential for further fishery development within the watershed stream system.

Survey Procedures: The fish survey was accomplished using a one-quarter-inch mesh seine at each of the 14 stations distributed throughout the watershed surface water system. The fish survey stations were selected to be representative of the major streams in the watershed, to encompass the full spectrum of natural to channelized conditions, and to provide a basis with which historic fish collections could be compared. The location of the 14 stations is shown on Map 21. Table 19 provides information on the stations, such as channel width, flow, depth, and water conditions. All of the fish captured at each fish survey station were identified by species and counted. The fish survey process proceeded in an upstream direction and the fish were netted after disrupting the bottom habitat and stream bank vegetation. All captured fish are preserved as part of the collection of the University of Wisconsin-Waukesha Center.

Inventory Findings: As indicated in Table 20 and Appendix B, a total of 653 fish representing eight species were taken at the 14 stations during the fish survey which was conducted on June 16 and 17, 1983. The four most common species found in order of decreasing abundance were the creek chub, brook stickleback, central mudminnow, and fathead minnow. Figure 12 indicates, in summary form, the fish species captured at the 14 fish survey stations, as well as the number of each species, and the approximate position of each species on a pollution tolerance scale.

Of the total 653 fish, 421, or 64 percent, were classified as being tolerant to pollution, and the remaining 232, or 36 percent, were considered very tolerant. No intolerant species were captured anywhere in the Oak Creek watershed during the survey.

Clearly, the Oak Creek watershed no longer supports a healthy and diverse fishery when compared with the 1924 fishery conditions; of the 14 species reported in 1924, 75 percent of the total population represented species intolerant to pollution. Insofar as fish populations serve as an index of stream water quality conditions, the dominance of tolerant and very tolerant fish in the watershed stream system is a manifestation of the poor water quality and habitat conditions that presently exist, and in the past existed, in the watershed as documented in Chapter VII of this report.

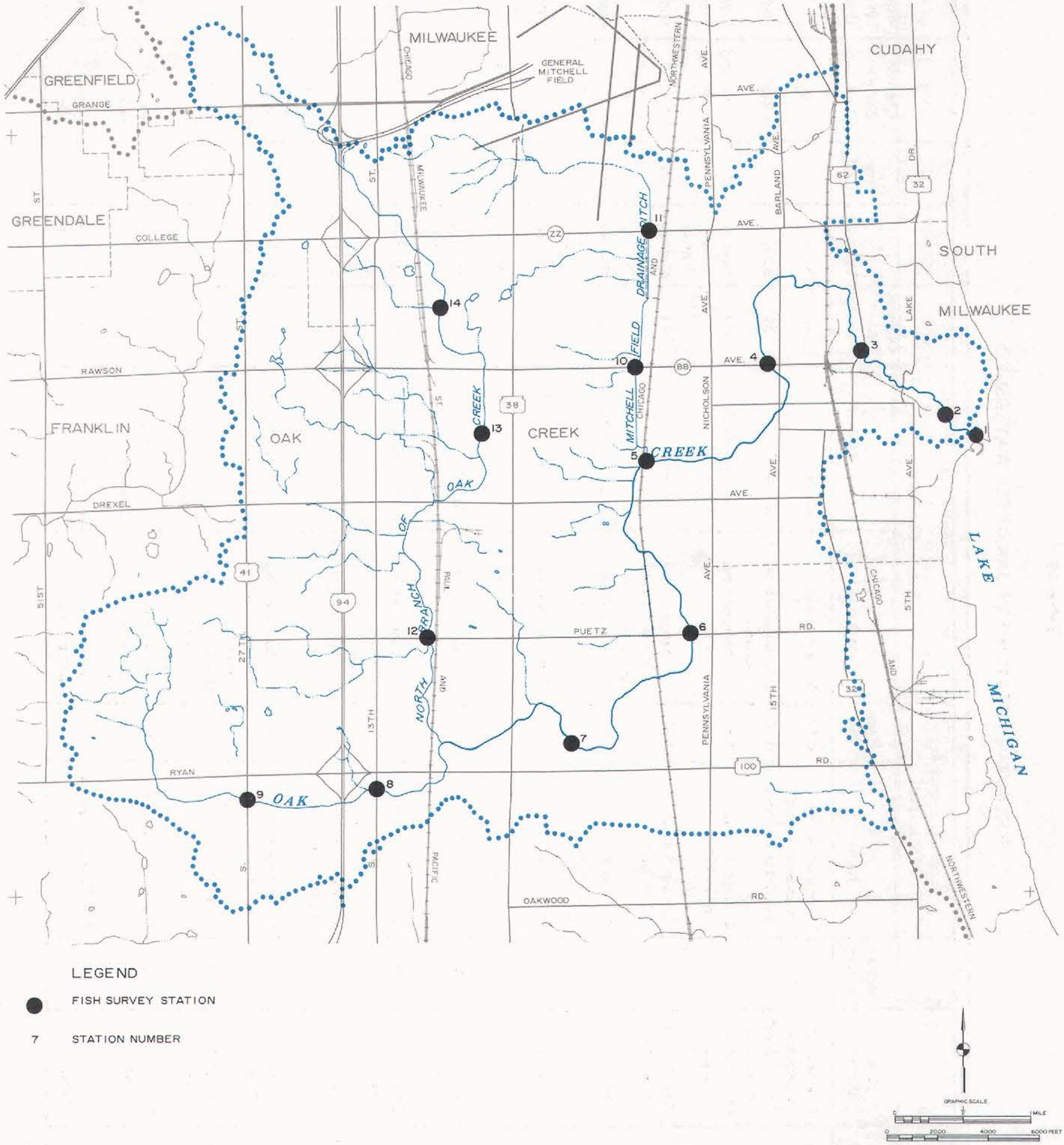
Of the eight species of fish captured at the 14 instream stations, only the black crappie and green sunfish are considered to be of any sport fishing value. Considering the watershed as a whole, fish of these two species accounted for only 0.3 percent of the total number of fish that were captured during the instream fish survey. This clearly indicates that the Oak Creek stream system—exclusive of the Lake Michigan estuary and stream reach below the dam portion—presently supports no significant recreational fishery.

Although fish sampling stations were rather uniformly distributed over the watershed, the number of fish captured at the stations was not uniformly distributed. For example, of the 653 fish taken at the 14 instream stations, 235—or 36 percent—were collected at one station—Fish Survey Station No. 6, located on Oak Creek at Puetz Road. The relatively large number of fish captured at this station does not, however, mean that there is a desirable fishery in that portion of the watershed, since about 58 percent of the fish taken at this station were categorized as being very tolerant to pollution.

A reach-by-reach comparison of the number and type of fish captured during both present and past fish surveys indicates a striking spatial variation in

Map 21

LOCATION OF FISH SURVEY STATIONS IN THE OAK CREEK WATERSHED: JULY 1983



Data from historic fish surveys of the Oak Creek system are useful in assessing the overall change in the fish population and, therefore, in water quality conditions. In most cases where intolerant fish species have been significantly reduced or eliminated, significant alteration in the stream habitat may be assumed, such as channelization; draining of connected wetlands; runoff of fertilizers, sediment, pesticides and other toxic substances from both rural and urban lands; and the discharge of both municipal and industrial wastes. Historic data from six fishery surveys were evaluated and used to assess the changes over time that have occurred in the fishery of the Oak Creek watershed.

Source: SEWRPC.

Table 19

FISH SURVEY STATIONS IN OAK CREEK WATERSHED

Watercourse	Civil Division	Station Number	Stream Crossings At Or Near Station		Vegetal Condition		Channel Width (feet)	Current	Temp. (°C)	Channel Bottoms Conditions	Observed Water Quality
			Name	River Mile	On Banks	In-Stream					
Oak Creek-Main Stem	City of South Milwaukee	1	Pedestrian Bridge near Boat Launch	0.14	None (sea wall)	None	48	None	--	Sand	Turbid
	City of South Milwaukee	2	Oak Creek Parkway	0.35	Overhanging trees (sea wall)	None	34	Slow	22	Rubble	Turbid
	City of South Milwaukee	3	Chicago Avenue (STH 32)	1.61	Overhanging trees	None (shaded)	38	Moderate to fast (riffle)	23	Gravel and rubble	Slightly turbid
	City of South Milwaukee	4	Rawson Avenue (CTH BB)	3.62	Overhanging trees and reed canary grass	Scattered Anacharis	44	Moderate to fast	25	Sand, gravel, and rubble	Slightly turbid
	City of Oak Creek	5	Chicago & North Western Railway	5.25	Shrubs and reed canary grass	Algae on rocks	22	Moderate to fast (riffle)	19	Sand, gravel, and rubble	Clear
	City of Oak Creek	6	Puetz Road	6.83	Reed canary grass	Anacharis	10	Moderate	21	Silt and sand	Very turbid
	City of Oak Creek	7	Shepard Avenue	8.41	Overhanging trees	None (shaded)	24	Moderate	18	Silt, sand, and gravel	Turbid
	City of Oak Creek	8	S. 13th Street (CTH V)	10.69	Overhanging trees	Scattered filamentous algae (shaded)	20	Moderate to slow	18	Muck	Turbid
	City of Franklin	9	S. 27th Street (USH 41)	11.70	Overhanging trees and reed canary grass	None (shaded)	21	Stagnant	22	Silt	Turbid
Mitchell Field Ditch	City of Oak Creek	10	Rawson Avenue (CTH BB)	0.80	Overhanging willows (ditched)	Anacharis (shaded)	22	Moderate	19	Silt, sand, and fine gravel	Clear
	City of Milwaukee	11	College Avenue (CTH ZZ)	1.83	Overhanging trees and reed canary grass	Anacharis and filamentous algae	20	Stagnant to slow	27	Silt and clay	Turbid
North Branch	City of Oak Creek	12	Puetz Road	0.92	Overhanging trees and reed canary grass	Anacharis and filamentous algae	22	Slow	24	Sand and silt	Turbid
	City of Oak Creek	13	Marquette Avenue	3.04	Cat-tails and bullrush	Potamogeton pectinatus and Anacharis	22	Stagnant to slow	24	Silt and sand	Clear
	City of Oak Creek	14	MATC-South Campus	4.20	Overhanging trees and shrubs	None (shaded)	6	Moderate to fast	21	Silt and clay	Clear

Source: SEWRPC.

Table 20

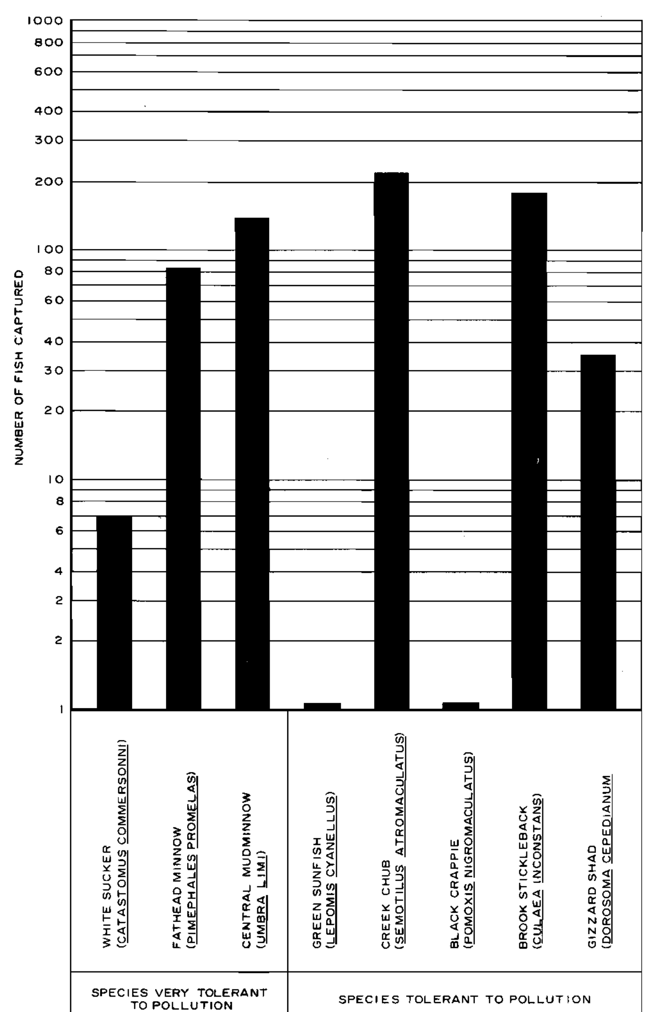
RESULTS OF FISH SURVEY IN THE OAK CREEK WATERSHED: JUNE 1983

Stream	Number of Stations	Very Tolerant		Tolerant		Intolerant		Subtotal			
		Species	Population	Species	Population	Species	Population	Number of Species	Species per Station	Population	Population per Station
Lower Oak Creek	4	1	1	4	53	--	--	5	1.25	54	14
Middle Oak Creek	3	3	144	2	189	--	--	5	1.67	333	111
Upper Oak Creek	2	1	6	1	15	--	--	2	1.00	21	11
Mitchell Field Ditch	2	2	47	2	70	--	--	4	2.00	117	59
North Branch of Oak Creek	3	1	34	2	94	--	--	3	1.00	128	43
Watershed Total	14	3	232	5	421	--	--	8	0.57	653	47

Source: SEWRPC.

Figure 12

RESULTS OF FISH SURVEY CONDUCTED IN THE OAK CREEK WATERSHED: JUNE 1983



Source: SEWRPC.

fishery characteristics. Lower Oak Creek, which is defined as that portion of the main stem of Oak Creek between its confluences with the Mitchell Field drainage ditch and Lake Michigan, yielded between 27 fish at Fish Survey Station No. 1 and one fish at Fish Survey Station No. 3. The 54 fish collected in the lower reaches of the main stem of Oak Creek are distributed among four pollution tolerant species—green sunfish, creek chub, black crappie, and gizzard shad—and one very tolerant species—fathead minnow. Figure 11 indicates that the July 1924 survey identified five pollution intolerant fish species—blacknose dace, blacknose shiner, brassy minnow, Iowa darter, and least darter—while fish surveys conducted in 1973, 1975, 1980, and 1981 found no intolerant fish species in lower Oak Creek. It should be noted that brown trout, rainbow trout, and coho salmon were recorded at this reach of Oak Creek after the January 21, 1980 fish kill. However, these three intolerant fish species are anadromous species from Lake Michigan and, therefore, do not represent part of the Oak Creek watershed resident fishery. In addition to the six intolerant fish species, five tolerant species— common shiner, golden shiner, creek chub, bluntnose minnow, and green sunfish—and three very tolerant species—central mudminnow, white sucker, and black bullhead—were collected during the July 1924 survey, for a total of 14 species at a single survey station located "one mile southwest of South Milwaukee" on the Oak Creek main stem.

The 1973 and 1975 surveys identified four tolerant species—emerald shiner, sand shiner, creek chub, and green sunfish—and three very tolerant species—goldfish, fathead minnow, and white sucker—for a total of seven fish species in lower Oak Creek. The 1980 and 1981 surveys identified four tolerant species—creek chub, green sunfish, pumpkinseed, and largemouth bass—and five very tolerant species—central mudminnow, goldfish, carp, fathead minnow, and white sucker—for a total of nine fish species in lower Oak Creek. The known diversity, then, has been reduced by between five and seven species of fish. Most notable is the shift from a balanced fishery dominated by the intolerant fish species to an unbalanced fishery dominated by very tolerant fish species. It should be further noted that this comparison involves five survey locations in 1973, 1975, 1980, and 1981, and a single survey location in 1924. It is likely that additional collection sites during the July 1924 survey would have recovered additional species. During the approximately 50-year interval between the 1924 and 1973 surveys, significant alterations have occurred in Oak Creek. It is also apparent that a significant change occurred between the time of the 1980 and 1981 fish surveys and the time of the 1983 fish survey as six fish species failed to be recaptured in lower Oak Creek in the 1983 survey.

Middle Oak Creek, which is defined as that portion of Oak Creek which encompasses the main stem between its confluences with the North Branch and the Mitchell Field drainage ditch, yielded between 235 fish at Fish Survey Station No. 6 and 35 fish at Fish Survey Station No. 5. The 333 fish collected in the middle reaches of the main stem of Oak Creek are distributed among two pollution tolerant species—creek chub and brook stickleback—and three very tolerant species—white sucker, fathead minnow, and central mudminnow. Figure 11 indicates that historical records for this portion of the Oak Creek watershed date back to 1975. In 1975, seven species of fish were recorded in the middle reaches of Oak Creek: three tolerant species—green sunfish, creek chub, and brook stickleback—and four very tolerant species—black bullhead, white sucker, fathead minnow, and central mudminnow. In 1980, two species of fish were added to the 1975 list: one tolerant species—golden shiner—and one very tolerant species—carp. No intolerant species were recorded in the middle reaches of Oak Creek since 1975. The loss of four species of fish, two tolerant species—green sunfish and golden shiner—and two very tolerant species—black bullhead and carp—in this reach of Oak Creek since 1980 also may represent a seasonal variation in the fish population, as well as a further decline in water quality conditions in the middle reaches of the Oak Creek main stem.

Upper Oak Creek, which is defined as that portion of the main stem of Oak Creek above its confluence with the North Branch of Oak Creek, yielded 11 fish at Fish Survey Station No. 8 and 10 fish at Fish Survey Station No. 9. The 21 fish collected in the upper reaches of the main stem of Oak Creek are distributed between a single pollution tolerant species—brook stickleback—and a single very tolerant species—fathead minnow. Figure 11 indicates that historical records for this portion of the Oak Creek watershed date back to 1973. In 1973, six species of fish were recorded in the upper reaches of Oak Creek. Subsequent fish surveys, in 1975 and 1980, identified the same fish species in this reach as were found in the original 1973 fish survey: three tolerant species—creek chub, brook stickleback, and green sunfish—and three very tolerant species—central mudminnow, fathead minnow, and white sucker. No intolerant species have been recorded in the upper reaches of Oak Creek since 1973. The loss of four species of fish, two tolerant species—green sunfish and creek chub—and two very tolerant species—white sucker and central mudminnow—since 1973 may represent a seasonal variation in the fish population, as well as a further decline in water quality conditions in the upper reaches of the Oak Creek watershed.

The sampling of the Mitchell Field drainage ditch portion of the Oak Creek watershed yielded 18 fish at Fish Survey Station No. 10 and 99 fish at Fish Survey Station No. 11. The 117 fish collected in the Mitchell Field drainage ditch are distributed among two pollution tolerant species—brook stickleback and creek chub—and two very tolerant species—central mudminnow and fathead minnow. Figure 11 indicates that historical records for the Mitchell Field drainage ditch date back to 1975. In 1975, six species of fish, three tolerant species—brook stickleback, creek chub, and green sunfish—and three very tolerant species—central mudminnow, fathead minnow, and white sucker—were recorded in the Mitchell Field drainage ditch. However, in 1980, only a single tolerant species—brook stickleback—was collected. No intolerant species have been recorded in the Mitchell Field drainage ditch since 1975. The loss of two species of fish, one tolerant species—green sunfish—and one very tolerant species—white sucker—in this portion of the Oak Creek watershed since 1975 may also represent a seasonal variation in the fish population, as well as a further decline in water quality conditions of the Mitchell Field drainage ditch.

The North Branch, which enters the main stem of Oak Creek downstream of the Chicago, Milwaukee, St. Paul & Pacific Railroad crossing, yielded between 112 fish at Fish Survey Station No. 12 and four fish at Fish Survey Station No. 14. The 128 fish collected in the North Branch of Oak Creek are distributed among two pollution tolerant species—brook stickleback and creek chub—and a single very tolerant species fathead minnow. Figure 11 indicates that historical records for this portion of the Oak Creek watershed date back to 1975. In 1975, six species of fish, three tolerant species—brook stickleback, creek chub, and green sunfish—and three very tolerant species—central mudminnow, fathead minnow, and white sucker—were recorded as present in the North Branch of Oak Creek. In 1980, only three species of fish, two tolerant species—brook stickleback and creek chub—and a single very tolerant species—fathead minnow—were collected. No intolerant species have been collected in the North Branch of Oak Creek since 1975. The loss of three species of fish, one tolerant species—green sunfish—and two very tolerant species—central mudminnow and white sucker—in the North Branch since 1975 represents a decline in water quality conditions.

As stated above, a healthy fish fauna should have a diversity of species spread over all three categories of pollution tolerance, with intolerant species being the most numerous. Furthermore, there should be representative fish species from several links in the food chain. In this regard, no large predator fish were found during the survey; the stream system's fishery is unbalanced in favor of small, pollution tolerant and very tolerant forage species.

These data conform with the historical perspective reported above in that no resident intolerant species have been collected during the last 10 years, indicating the unsuitable habitat changes and deteriorated water conditions which have occurred in the 50-year period between 1924 and 1973. This was a time of intensive agricultural, industrial, commercial, and housing developments within the watershed and suggests a strong cause and effect relationship. Siltation, stream realignment and channelization, the draining of wetlands, the use of pesticides and fertilizers, and excessive organic loading all have contributed to the loss of fish and other aquatic life in Oak Creek since 1924.

Similar conclusions regarding the polluted nature of the surface waters of the Oak Creek watershed can be reached from a survey of benthic organisms that inhabit the bottom sediments of the stream system. The findings of a benthic survey conducted by the Wisconsin Department of Natural Resources in October 1975 correspond with the findings of the recent fish surveys. Most of the benthic organisms were in the tolerant or very tolerant categories, and the population densities and diversity were low, which would indicate polluted conditions in the stream system.

The 1975 Wisconsin Department of Natural Resources Milwaukee River Basin Assessment for Milwaukee County indicates that toxic substances have been released into the stream system in the past. Also, in 1975 and 1976, there were five reported toxic substance spills; three were industrial spills and two were of commercial origin. Toxic levels of heavy metals such as zinc, mercury, chromium, and copper have been found in certain stream sediments in the Oak Creek watershed. These metals are known to cause death of fish and other small animals. Their action, however, may often be subtle, such as simply reducing reproduction capabilities and, thus, causing a slow, gradual loss of fish and other aquatic species from the stream system.

The nature of the stream bottom is also important in determining the abundance and distribution of fish species and their food items. Generally, gravelly or rocky bottoms provide more surface area for food items. Also, such sites are usually areas of faster water, causing silt to be flushed away and preventing animals and attached algae from being smothered. Certain fish species are naturally found in such areas—darters, stonerollers, suckers, and daces—taking advantage of the good food supply and clear, well-oxygenated water. Habitat observations (see Table 19) during the 1983 survey indicate that there are suitable gravel-rocky riffle areas in the Oak Creek main stem stream reaches between the Chicago & North Western Railway (C&NW) and the estuary. While these sites looked promising when first approached, they proved to be completely devoid of the expected riffle area fish species. It is known from the 1924 survey (Figure 11) that these riffle area fish species did indeed exist at one time in this stream reach.

Fish survey stations located upstream of the C&NW crossing had bottom substrates composed of sand, silt, or clay, with slow water movement, much less conducive to riffle species but adequate for a number of other fish species such as minnows and sunfishes—but again, the expected fish associations were not found. It is probable that gravel riffles existed in the upper reaches of the stream as well, but excessive siltation caused by erosion, stream realignment and channelization, and surface runoff has buried them. As a result, the natural complement of fish species characteristic of other southeastern Wisconsin streams does not occur in Oak Creek.

An assessment of the historical fish collection records and the 1983 fish survey of the Oak Creek watershed stream system indicates a highly degraded fishery. The records show a 1924 "natural" fish population in which 43 percent of the fish species are intolerant to polluted conditions. However, 50 years later, no intolerant resident fish species occur, the population being composed entirely of tolerant and very tolerant fish. In addition, the reduction in the total number of different fish species, or diversity of fish, from 14 species in 1924 to eight species in 1983 reflects a change in stream condition from a clean water environment, with many different niches for fish species to fit into a balanced system, to a polluted condition that can support only a few pollution tolerant species.

This destruction of a balanced fish population has been caused by numerous adverse stream and watershed conditions created by human activity. They include:

1. The draining and filling of wetlands, which contributed to a loss of fish spawning, nursery, and feeding areas.

2. The channelization and realignment of the stream system to accommodate flood flows, which created a uniform environment where once there may have been great stream heterogeneity in the form of alternating riffles, pools, and runs. The uniform bottom type and water velocities limit the kinds of fish and reduce their food supply.

3. Increased runoff from agricultural lands, roadsides, and construction sites which contributes silt and sedimentation to the stream, thereby filling pools, covering gravel beds and plants, clogging the gills of aquatic organisms, increasing turbidity, and interfering with the mating and feeding behavior of fish.

4. A reduction of the water quality conditions, particularly dissolved oxygen levels, brought on by nutrient enrichment, municipal wastewater flow relief devices, industrial discharges, urban runoff, and accidental spills of toxic chemicals.

5. The four-foot railroad bridge support on the North Branch, the dam in the Oak Creek Parkway, and the sandbar across the estuary. These obstructions prevent natural migration of fish species up and down the stream system, and into and out of Lake Michigan. This affects reproductive habits and the natural dispersal of fish. Recruitment of new species into depauperate areas is hampered or entirely prevented by these obstructions. Should water quality improve in the Oak Creek stream system, there is presently no way the fishery will restore itself naturally as long as these obstructions are in place.

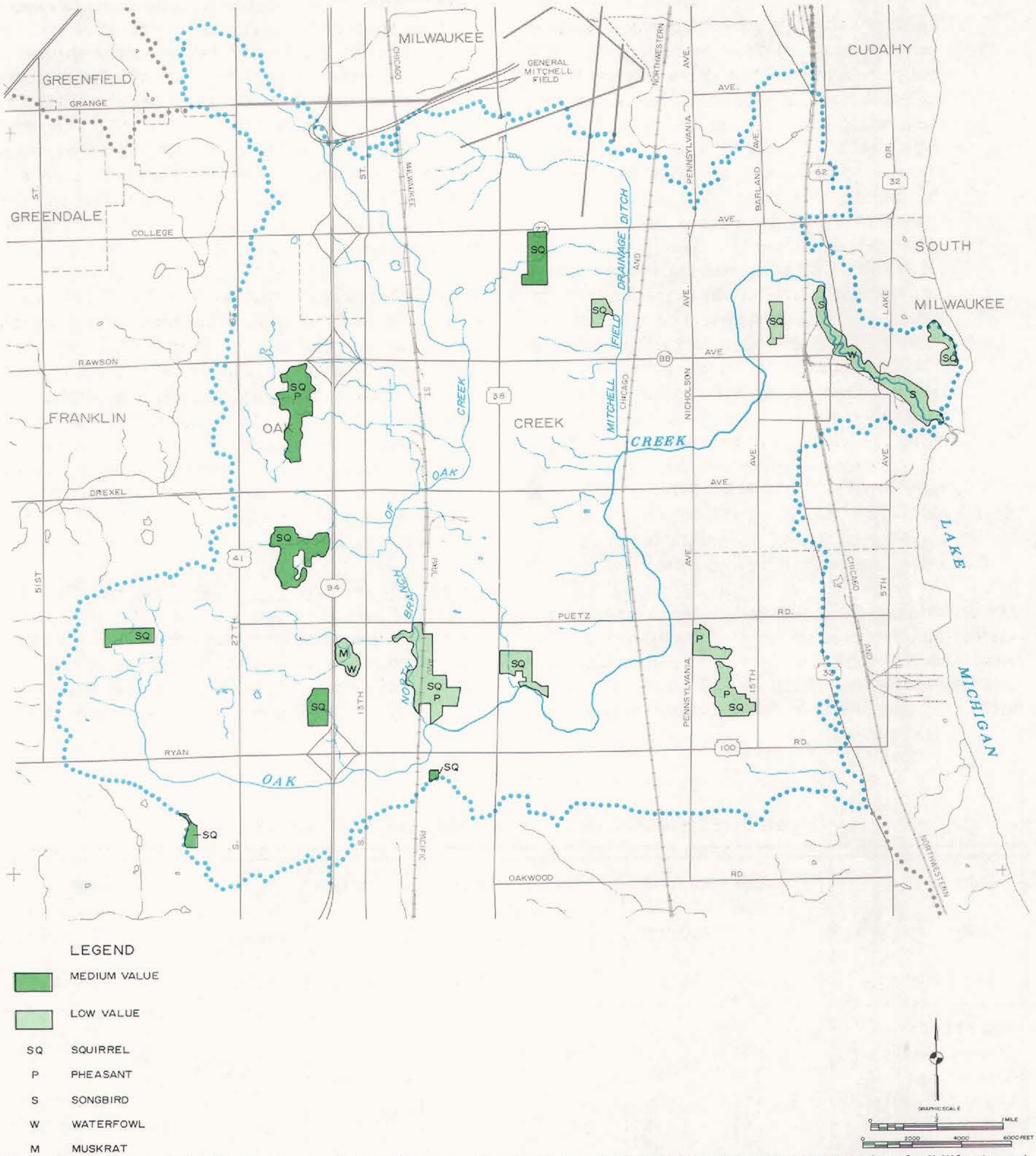
Wildlife Habitat: Since the settlement of the Oak Creek watershed by Europeans, there has been a sharp decrease in the variety and quantity of wildlife. This is a loss to observers and photographers of wildlife and affects the health and diversity of the total environment. Wildlife habitat areas were initially inventoried for the Commission by the Bureau of Research personnel of the Wisconsin Department of Natural Resources in 1963. This initial inventory was updated in 1970. In addition to providing a qualitative and quantitative description of the existing wildlife resources of the watershed, this inventory provided a basis for identifying those wildlife habitat areas that should, under the land use element of both the regional land use plan and the Oak Creek watershed plan, be preserved and protected. The findings of the wildlife inventory are summarized below.

A total of 587 acres of wildlife habitat were identified within the watershed and value rated, as shown on Map 22. Each wildlife habitat area was categorized into one of the following three value ratings:

1. High-Value Wildlife Habitat Areas—High-value wildlife habitat areas contain a good diversity of wildlife, are of adequate size to meet all of the habitat requirements for the species concerned, and are generally

Map 22

WILDLIFE HABITAT IN THE OAK CREEK WATERSHED: 1980



Since the settlement of the Oak Creek watershed by Europeans, there has been a sharp decrease in the variety and quantity of wildlife. A total of 587 acres of wildlife habitat were identified within the watershed, of which 333 acres, or about 57 percent, are in the low-value category. The remaining 254 acres, or about 43 percent, are identified as medium-value wildlife habitat. There are no high-value wildlife habitat areas within the watershed.

Source: SEWRPC.

located in proximity to other wildlife habitat areas. There are no high-value wildlife habitat areas within the watershed.

2. Medium-Value Wildlife Habitat Areas—Medium-value wildlife habitat areas generally lack one of the three criteria for a high-value wildlife habitat area. However, they retain a good plant and animal diversity. The Michael F. Cudahy Nature Preserve, Meyers Woods, and Falk Park woods located in the City of Oak Creek are examples of medium-value habitat areas.

3. Low-Value Wildlife Habitat Areas—Low-value wildlife habitat areas are remnant in nature in that they generally lack two or more of the three criteria for a high-value wildlife habitat area, but may, nevertheless, be important if located in proximity to medium- and/or high-value wildlife habitat areas, if they provide corridors linking higher value wildlife habitat areas, or if they provide the only available range in the area. The Rawson Park woods located in the City of South Milwaukee is typical of a low-value wildlife habitat area.

The factors considered in assigning value ratings to wildlife habitat areas were: diversity of animal and plant species, territorial requirements of the species, vegetative composition and structure, proximity to other wildlife habitat areas, and disturbance. The wildlife habitats in the Oak Creek watershed were also classified according to the principal wildlife type to which the habitats were suited. The wildlife types include deer, pheasant, waterfowl, muskrat-mink, songbird, squirrel, and mixed habitat. These designations were applied to help characterize a particular wildlife habitat area as meeting the requirements of the indicated species. This classification does not, however, imply that the named species is the only or even the most numerous or most important species in that particular habitat. For example, an area designated as a deer habitat may provide squirrel and songbird habitat as well.

Table 21 indicates that in the Oak Creek watershed, 333 acres, or about 57 percent of the wildlife habitat areas remaining in the watershed, are in the low-value category. A total of seven medium-value wildlife habitat areas, encompassing a total area of 254 acres, remain in the watershed, located predominantly in the upper reaches of the watershed between IH 94 and the western boundary of the watershed. As already noted, there are currently no high-value wildlife habitat areas in the Oak Creek watershed.

Game and Nongame Wildlife Species: The foregoing section described the quantity and quality of the remaining wildlife habitat in the Oak Creek watershed. The following section explicitly decribes the remaining wildlife of the watershed. The wildlife population of the watershed consists

Table 21

WILDLIFE HABITAT IN THE OAK CREEK WATERSHED: 1980

Municipality	High Value		Medium Value		Low Value		Total	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
City of Cudahy	--	--	--	--	--	--	--	--
City of Franklin	--	--	35	6	--	--	35	6
City of Greenfield	--	--	--	--	--	--	--	--
City of Milwaukee	--	--	--	--	--	--	--	--
City of Oak Creek	--	--	219	37	215	37	434	74
City of South Milwaukee	--	--	--	--	118	20	118	20
Watershed Total	--	--	254	43	333	57	587	100

Source: SEWRPC.

of fish, amphibians, reptiles, birds, and mammals. Each of these classes of the animal kingdom as represented in the watershed is described below, with the exception of fish, which are described in an earlier section of this chapter.

Game species of wildlife include those for which there generally are established hunting or trapping seasons with rules which regulate the numbers and types of individuals of harvest and methods by which they may be harvested. It is noted that harvesting of game species is prohibited in certain areas because of the proximity of large human populations, such as in the Oak Creek watershed, and the safety hazards associated with the discharge of firearms. Besides being harvested, these animals also provide aesthetic values which are enjoyed by both hunters and nonhunters. Examples of these types of animals are white-tailed deer, cottontail rabbit, red fox, many species of migratory waterfowl, and many species of fish. Nongame species of wildlife include those for which there are laws which preclude their harvest. The principal value of these species is their aesthetic appeal which is enjoyed by the hunting and nonhunting segments of the population. Examples of these types of animals are songbirds, birds of prey, and endangered or threatened species of fish, reptiles, amphibians, birds, and mammals.

Although a field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the Oak Creek watershed study, it is possible by using existing information such as the records of the Milwaukee County Public Museum and by polling naturalists and wildlife managers familiar with the watershed to prepare a list of the amphibians, reptiles, birds, and mammals which should be found in the watershed under existing conditions. The collation of the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to have existed, and to exist, in the southern portion of Milwaukee County; associating these lists with the historic and remaining habitat areas, as inventoried; and then projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed. The net result of the application of this technique is a better understanding of which species were once present in the watershed, which species are normally present under existing conditions, and which species could be expected to be lost as urbanization proceeds within the watershed. It should be noted that this procedure does not account for the transient species which would be found in the watershed only on rare occasions.

Amphibians and Reptiles: Although often unseen and unheard, amphibians and reptiles are vital components of the ecologic system of an environmental unit like the Oak Creek watershed. Amphibians native to the watershed include frogs, toads, and salamanders. Turtles and snakes are reptiles common to the Oak Creek watershed. Table 22 lists the nine amphibian and 15 reptile species normally present in the Oak Creek watershed and identifies those species most sensitive to urbanization.

Most amphibians and reptiles have definite habitat requirements which are adversely affected by certain agricultural land management practices, as well as by advancing urban development. One of the major threats to the maintenance of amphibian populations in a changing environment is the destruction of breeding ponds. Many types of frogs and salamanders return to the same breeding site year after year, even if the pond is not there, in which case they cannot breed. When an area is being filled and developed some ponds must be selectively saved if amphibians are to be maintained. Toads are somewhat of an exception in this respect in that they can better adapt to the changes in environment which normally accompany urbanization than can other species of amphibians.

Another major consideration in the maintenance of both amphibians and reptiles is the protection of migration routes. Many species annually traverse distances of a mile or more from wintering sites to breeding sites to summer foraging grounds. The same pathways may be used each year, and if species are to be maintained in the watershed, these pathways must be preserved. Protection of the environmental corridors of the watershed can assist in this respect.

Certain amphibians and reptiles are particularly susceptible to changes in food sources brought about by urbanization. Populations of the western fox snake and eastern milk snake, for example, are very likely to be reduced over time in the watershed because of the potential reduction of the species of rodents upon which they prey.

Birds: A large number of birds representing many species, ranging in size from large game birds to small songbirds, are found in the Oak Creek watershed. Table 23 lists those birds that would normally be expected to occur in the watershed. Each bird is classified as to whether it is likely to

Table 22

AMPHIBIANS AND REPTILES LIKELY TO OCCUR IN THE OAK CREEK WATERSHED: 1980

Scientific (family) and Common Name	Species Reduced or Dispersed with Full Watershed Urbanization	Species Lost with Full Watershed Urbanization
Amphibians		
Necturidae		
Mudpuppy	X	--
Ambystomatidae		
Blue-Spotted Salamander	--	X
Eastern Tiger Salamander	X	--
Bufonidae		
American Toad	X	--
Hylidae		
Northern Spring Peeper	--	X
Eastern Gray Treefrog	--	X
Western Chorus Frog	X	--
Ranidae		
Green Frog	X	--
Northern Leopard Frog	--	X
Reptiles		
Chelydridae		
Common Snapping Turtle	X	--
Kinosternidae		
Musk Turtle (stinkpot)	X	--
Emydidae		
Midland Painted Turtle	X	--
Western Painted Turtle	X	--
Blanding's Turtle[a]	--	X
Colubridae		
Northern Water Snake	X	--
Northern Brown Snake	X	--
Red-Bellied Snake	X	--
Eastern Garter Snake	X	--
Chicago Garter Snake	X	--
Prairie (Plains) Garter Snake	X	--
Butler's Garter Snake	X	--
Eastern Smooth Green Snake	--	X
Western Fox Snake	--	X
Eastern Milk Snake	--	X

NOTE: The technique used in collating the amphibian and reptile species involved associating known county records with the historic and remaining habitat areas in the watershed.

[a] *Identified as threatened in Wisconsin.*

Source: SEWRPC.

breed within the watershed, visits the watershed during the annual migration periods, or spends winter within the watershed.

Game birds which are likely to occur in the watershed include the pheasant, woodcock, common snipe, rail, duck, coot, and geese. The fall pheasant population within the watershed is irregularly distributed, but moderate populations live in the larger existing habitats. These populations are a factor of both the available habitat and the lack of hunting pressure in the watershed.

There is a significant population of waterfowl near the estuary portion of the watershed, especially mallards and teal. Larger numbers of waterfowl move through during migration when most of the regional species may also be present. The Oak Creek estuary constitutes an important wintering area for migratory waterfowl such as oldsquaw, bufflehead, goldeneye, and scaup. The open water present during the mid-winter period provides a resting area and source of food for those waterfowl species which spend the nonbreeding portion of their annual life cycle in the Region. Other species of water-based birds which may occur in the watershed include herons, sandpipers, gulls, plovers, and terns. Most of the waterfowl, shore birds, and wading birds may be expected to be found in and adjacent to the Oak Creek estuary. The numbers and diversity of the migratory gamebirds which occur in the watershed can be attributed to migration patterns associated with the Mississippi flyway, in which the watershed is located, as well as more localized migration corridors which coincide with the Lake Michigan shoreline.

Because of the mixture of lowland and upland woodlots, meadows, and agricultural lands still present in the watershed, along with the favorable summer climate, the watershed supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, whip-poor-wills, woodpeckers, nuthatches, and flycatchers, as well as several other species, serve as major insect predators. In addition to their ecological roles, birds such as robins, red-winged blackbirds, orioles, cardinals, and mourning doves, as well as those species mentioned above, serve as subjects for bird watchers and photographers.

Not all birds are viewed as an asset from an ecological, economic, or social point of view. With the advance of urbanization and, therefore, the loss of natural habitat, conditions have become less compatible for the more desirable bird species. House sparrows, starlings, grackles, and pigeons have replaced the more desirable birds in certain areas of the watershed because of their great tolerance for and adaptability to urban conditions.

Mammals: A variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the American pygmy shrew occur in the Oak Creek watershed. Table 24 lists 32 mammals likely to occur in the watershed.

The larger mammals still fairly common in the less densely populated areas of the watershed include white-tailed deer, cottontail rabbit, gray squirrel, woodchuck, muskrat, mink, weasel, raccoon, red fox, skunk, and opossum. The first three are often considered game mammals, while the balance are classified as fur-bearing mammals.

White-tailed deer generally occur in the larger wooded areas in the southern and western portions of the watershed. The open meadows and croplands adjacent to the woodlots, as well as the shrub carrs, are also utilized by deer. Human population and associated activities create a stress condition for the deer population. Deer populations and urban conditions are incompatible. When deer wander or are forced into residential, commercial, or industrial areas, they typically exhibit panic, running wildly and presenting a threat to people, property, and themselves. Foraging deer sometimes cause damage to gardens, or ornamental trees, croplands, and orchards. Deer and automobile collisions often occur on the fringes of urban areas and are another example of the stress conditions that exist when deer inhabit urban fringe areas.

The cottontail rabbit is abundant throughout the watershed even in urbanized areas. Although rabbit hunting is prohibited throughout the watershed, the abundance and activity patterns of rabbits often result in their being one of the most widely viewed mammals in the watershed. However, large populations may cause local problems for gardeners in some areas of the watershed. There is also an abundance of gray squirrels in the watershed. The gray squirrel is found primarily in woodlots and wooded residential sections. Trees of some maturity are required by gray squirrels because natural cavities in such trees are needed both for the rearing of young and for winter protection. Gray squirrels also construct leaf nests called drays which are used throughout the year for cover and nursery areas for the young.

Although there are no data available on the actual number of fur-bearing mammals in the watershed, muskrat and mink populations are believed to be relatively low because of the limited extent of the remaining wetlands. Muskrats may be attracted to any significant water area in the watershed, including wetlands, small ponds, creeks, and drainage ditches, all of which may provide suitable habitat. The familiar muskrat house contributes a certain amount of interest to the landscape and is often used by other wildlife. Waterfowl may make use of the houses for nesting, and mink and raccoon occasionally use muskrat houses as denning areas. Preservation and improvement of muskrat habitat would, therefore, benefit waterfowl, mink, and the raccoon.

The raccoon is associated with the woodland areas, and large populations are reported within the Oak Creek watershed. Much of the raccoon's food, however, is water-based so it makes considerable transient use of wetland areas. Scavenging raccoons can become pests in wooded environments that contain urban fringe development.

The red fox is more characteristic of mixed habitat and farmland areas, and good populations are known to occur in and adjacent to the watershed. Occasionally, red fox will wander into more urban portions of the watershed. Most people are tolerant of the fox because of its aesthetic appeal, while others, less well-informed, consider it a threat to other wildlife.

Southern woodchucks are commonly found in the watershed. They prefer the edges of brushy woodlands, particularly near open fields and croplands. The woodchuck is an extensive burrower. Abandoned woodchuck burrows are often occupied by other mammals, such as cottontail rabbits or skunks, and even red fox. The woodchuck's diet consists mainly of green vegetable material. Because of its diet, some farmers have reported crop damage in some portions of the watershed.

Skunks and opossums are common watershed fur-bearers. Both of these mammals inhabit woodland areas bordering farmlands and urban fringe development and venture into wetlands in search of food.

Small mammals relatively common in the watershed include the short-tailed shrew, striped ground squirrel or gopher, meadow vole, white-footed mouse, and little brown bat. These small mammals, with the exception of bats, are commonly associated with meadows, fence rows, and utility and transportation rights-of-way. They vary in their

Table 23

BIRDS LIKELY TO OCCUR IN THE OAK CREEK WATERSHED

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Podicipedidae			
Pied-Billed Grebe	--	--	X
Ardeidae			
Least Bittern	--	--	X
Great Blue Heron	--	--	X
Green-Backed Heron[a]	X	--	X
Black-Crowned Night-Heron	--	--	X
Yellow-Crowned Night-Heron	R?	--	R
Anatidae			
Tundra Swan	--	--	X
Canada Goose	--	--	X
Wood Duck[a]	X	--	X
Green-Winged Teal	--	--	X
American Black Duck	--	X	X
Mallard[b]	X	X	X
Northern Pintail	--	--	X
Blue-Winged Teal[a]	X	--	X
Northern Shoveler	--	--	X
American Wigeon	--	--	X
Redhead	--	--	X
Ring-Necked Duck	--	--	X
Greater Scaup	--	--	X
Lesser Scaup	--	--	X
Old Squaw	--	--	X
Common Goldeneye	--	R	X
Bufflehead	--	R	X
Cathartidae			
Turkey Vulture	--	--	X
Accipitridae			
Osprey	--	--	X(E)
Bald Eagle	--	--	R(E)
Northern Harrier	--	R	X
Sharp-Shinned Hawk	--	X	X
Cooper's Hawk	--	R(T)	X(T)
Northern Goshawk	--	R	X
Red-Shouldered Hawk	--	R(T)	X(T)
Broad-Winged Hawk	--	--	X
Red-Tailed Hawk[a]	R	X	X
Rough-Legged Hawk	--	X	X
Falconidae			
American Kestrel[b]	X	X	X
Merlin	--	--	X
Peregrine Falcon	--	--	R(E)
Phasianidae			
Ring-Necked Pheasant[b] (introduced)	X	X	NA
Rallidae			
Virginia Rail[a]	R	--	X
Sora[a]	R	--	X
Common Moorhen	--	--	R
American Coot	--	--	X
Gruidae			
Sandhill Crane	--	--	R
Charadriidae			
Black-Bellied Plover	--	--	X
Lesser Golden-Plover	--	--	X
Semipalmated Plover	--	--	X
Killdeer[b]	X	--	X
Scolopacidae			
Greater Yellowlegs	--	--	X
Lesser Yellowlegs	--	--	X
Solitary Sandpiper	--	--	X
Spotted Sandpiper[b]	X	--	X
Upland Sandpiper	--	--	X
Ruddy Turnstone	--	--	X
Red Knot	--	--	R
Sanderling	--	--	X
Semipalmated Sandpiper	--	--	X
Pectoral Sandpiper	--	--	X
Dunlin	--	--	X
Common Snipe	R	R	X
American Woodcock[a]	X	--	X
Wilson's Phalarope	--	--	X
Laridae			
Ring-Billed Gull	--	X	X
Herring Gull	--	X	X
Caspian Tern	--	--	X
Common Tern	--	--	X(E)
Forster's Tern	--	--	X(E)
Black Tern	--	--	X
Columbidae			
Rock Dove	X	X	NA
Mourning Dove	X	X	X
Cuculidae			
Black-Billed Cuckoo[a]	X	--	X
Yellow-Billed Cuckoo[a]	X	--	X
Stirigidae			
Eastern Screech-Owl[b]	X	X	NA
Great Horned Owl[a]	X	X	NA
Snowy Owl	--	R	R
Barred Owl[a]	R?	R	NA
Long-Eared Owl	--	R	R
Short-Eared Owl	--	X	X
Northern Saw-Whet Owl	--	--	X
Caprimulgidae			
Common Nighthawk	X	--	X
Whip-poor-will	--	--	X
Apodidae			
Chimney Swift	X	--	X
Trochilidae			
Ruby-Throated Hummingbird	X	--	X
Alcedinidae			
Belted Kingfisher[b]	X	--	X
Picidae			
Red-Headed Woodpecker[b]	X	R	X
Red-Bellied Woodpecker[b]	R	X	NA
Yellow-Bellied Sapsucker	--	R	X
Downy Woodpecker[b]	X	X	NA
Hairy Woodpecker[b]	X	X	NA
Northern Flicker[b]	X	R	X
Tyrannidae			
Olive-Sided Flycatcher	--	--	X
Eastern Wood-Pewee[b]	X	--	X
Yellow-Bellied Flycatcher	--	--	X
Acadian Flycatcher	--	--	X
Alder Flycatcher	--	--	X
Willow Flycatcher[a]	X	--	X
Least Flycatcher	--	--	X
Eastern Phoebe[a]	X	--	X
Great Crested Flycatcher[b]	X	--	X
Eastern Kingbird[b]	X	--	X
Alaudidae			
Horned Lark[a]	X	X	X
Hirundinidae			
Purple Martin[b]	X	--	X
Tree Swallow[b]	X	--	X
Northern Rough-Winged Swallow	X	--	X
Bank Swallow[a]	X	--	X
Cliff Swallow[a]	X	--	X
Barn Swallow[a]	X	--	X
Corvidae			
Blue Jay	X	X	X
American Crow	X	X	X
Paridae			
Black-Capped Chickadee[b]	X	X	X
Tufted Titmouse	R?	R	NA
Sittidae			
Red-Breasted Nuthatch	--	X	X
White-Breasted Nuthatch	X	X	NA
Certhiidae			
Brown Creeper	--	X	X

Table 23 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Troglodytidae			
Carolina Wren	--	--	R
House Wren	X	--	X
Winter Wren	--	--	X
Sedge Wren[a]	R	--	X
Marsh Wren[a]	R	--	X
Musicapidae			
Golden-Crowned Kinglet	--	X	X
Ruby-Crowned Kinglet	--	--	X
Blue-Gray Gnatcatcher[a]	R	--	X
Eastern Bluebird[a]	R	--	X
Veery[a]	R?	--	X
Gray-Cheeked Thrush	--	--	X
Swainson's Thrush	--	--	X
Hermit Thrush	--	--	X
Wood Thrush[b]	X	--	X
American Robin	X	X	X
Mimidae			
Gray Catbird	X	--	X
Northern Mockingbird	--	R	R
Brown Thrasher[b]	X	--	X
Motacillidae			
Water Pipit	--	--	X
Bombycillidae			
Bohemian Waxwing	--	R	--
Cedar Waxwing	X	X	X
Laniidae			
Northern Shrike	--	R	X
Sturnidae			
European Starling	X	X	X
Vireonidae			
White-Eyed Vireo	--	--	R
Solitary Vireo	--	--	X
Yellow-Throated Vireo[a]	--	X	--
Warbling Vireo	X	--	X
Philadelphia Vireo	--	--	X
Red-Eyed Vireo[b]	X	--	X
Emberizidae			
Blue-Winged Warbler[a]	R	--	X
Golden-Winged Warbler	--	--	X
Tennessee Warbler	--	--	X
Orange-Crowned Warbler	--	--	X
Nashville Warbler	--	--	X
Northern Parula	--	--	X
Yellow Warbler[b]	X	--	X
Chestnut-Sided Warbler[a]	R?	--	X
Magnolia Warbler	--	--	X
Cape May Warbler	--	--	X
Black-Throated Blue Warbler	--	--	X
Yellow-Rumped Warbler	--	--	X
Black-Throated Green Warbler	--	--	X
Blackburnian Warbler	--	--	X
Pine Warbler	--	--	X
Palm Warbler	--	--	X
Bay-Breasted Warbler	--	--	X
Blackpoll Warbler	--	--	X
Cerulean Warbler	--	--	X
Black-and-White Warbler[a]	R?	--	X
American Redstart[a]	R?	--	X
Prothonotary Warbler	--	--	R
Ovenbird[a]	R	--	X
Northern Waterthrush	--	--	X
Louisiana Waterthrush	--	--	R
Kentucky Warbler	--	--	R
Connecticut Warbler	--	--	X
Mourning Warbler[a]	R	--	X
Common Yellowthroat[b]	X	--	X
Hooded Warbler	--	--	X
Wilson's Warbler	--	--	X

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Emberizidae (continued)			
Canada Warbler[a]	R?	--	X
Yellow-Breasted Chat	--	--	R
Scarlet Tanager[a]	X	--	X
Northern Cardinal	X	X	NA
Rose-Breasted Grosbeak[b]	X	--	X
Indigo Bunting[b]	X	--	X
Dickcissel	--	--	R
Rufous-Sided Towhee[a]	X	--	X
American Tree Sparrow	--	X	X
Chipping Sparrow	X	--	X
Clay-Colored Sparrow	--	--	X
Field Sparrow[a]	X	--	X
Vesper Sparrow[a]	--	--	X
Savannah Sparrow[a]	X	--	X
Grasshopper Sparrow	--	--	X
Henslow's Sparrow[a]	X	--	X
LeConte's Sparrow	--	--	R
Fox Sparrow	--	R	X
Song Sparrow[b]	X	X	X
Lincoln's Sparrow	--	--	X
Swamp Sparrow[a]	X	R	X
White-Throated Sparrow	--	R	X
White-Crowned Sparrow	--	--	X
Harris' Sparrow	--	--	R
Dark-Eyed Junco	--	X	X
Lapland Longspur	--	R	X
Snow Bunting	--	R	X
Bobolink[a]	X	--	X
Red-Winged Blackbird[b]	X	X	X
Eastern Meadowlark[a]	X	R	X
Western Meadowlark[a]	R	--	X
Yellow-Headed Blackbird	--	--	X
Rusty Blackbird	--	R	X
Brewer's Blackbird	--	--	X
Common Grackle	X	X	X
Brown-Headed Cowbird[b]	X	X	X
Orchard Oriole	R	--	R
Northern Oriole	X	--	X
Fringillidae			
Pine Grosbeak	--	R	--
Purple Finch	--	X	X
Red Crossbill	--	R	R
White-Winged Crossbill	--	R	R
Common Redpoll	--	X	X
Pine Siskin	--	X	X
American Goldfinch	X	X	X
Evening Grosbeak	--	R	X
Ploceidae			
House Sparrow	X	X	NA

Breeding: Nesting species (nonnesting species present in summer are not included)
Wintering: Present January-February
Migrant: Spring and/or fall transient

X - *present, not rare*
R - rare
V - vagrant (not regularly occurring in southeastern Wisconsin)
NA - not applicable
(T) - threatened species in Wisconsin
(E) - endangered species in Wisconsin (bald eagle also U. S. threatened, peregrine falcon also U. S. endangered)
? - seasonal status uncertain

[a] *Species lost as breeding birds with full watershed urbanization.*

[b] *Species reduced in numbers as breeding birds with full watershed urbanization.*

Source: SEWRPC.

Table 24

MAMMALS LIKELY TO OCCUR IN THE OAK CREEK WATERSHED: 1980

Scientific (family) and Common Name
Didelphidae
Virginia Opossum
Soricidae
Cinereous Shrew
Smoky Shrew
American Pigmy Shrew
Short-Tailed Shrew
Vespertilionidae
Little Brown Bat
Silver-Haired Bat
Big Brown Bat
Red Bat
Hoary Bat
Leporidae
Mearn's Cottontail
Sciuridae
Southern Woodchuck
Striped Ground Squirrel (gopher)
Ohio Chipmunk
Minnesota Gray Squirrel
Western Fox Squirrel
Red Squirrel
Southern Flying Squirrel
Cricetidae
Prairie Deer Mouse
Northern White-Footed Mouse
Meadow Vole
Common Muskrat
Muridae
Norway Rat (introduced)
House Mouse (introduced)
Zapodidae
Meadow Jumping Mouse
Canidae
Eastern Red Fox
Gray Fox
Procyonidae
Upper Mississippi Valley Raccoon
Mustelidae
New York Long-Tailed Weasel
Upper Mississippi Valley Mink
Northern Plains Skunk
Cervidae
Northern White-Tailed Deer

Source: SEWRPC

importance from insect predators and food sources for larger mammals and raptors—hawks and owls—to pests in croplands, gardens, and lawns.

Overview: As a result of urban and agricultural activity and the associated decrease in woodlands, wetlands, prairies, and other natural areas, wildlife habitat in the Oak Creek watershed has been seriously depleted. The habitat that remains generally consists of land parcels that have not to date been considered suitable for cultivation or urban development. Much of the remaining habitat has been modified or has been deteriorated, and some of these remaining habitat areas are being increasingly encroached upon by encircling 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 mammal species once abundant in the watershed have diminished in type and quantity wherever intensive urbanization and agricultural land uses have occurred. Certain wildlife species, such as some songbirds, have the capacity to exist in small islands of undeveloped land within the urban and agricultural land complex or to adapt to this type of landscape, but this characteristic is not generally shared by most wildlife.

In order to maintain, and even increase, the existing remnants of wildlife populations within the watershed, the required amount, type, and pattern of habitat must be achieved, and a land use pattern must be established within the watershed that preserves the remaining valuable wildlife habitat. It is necessary to remember that all wildlife species are dependent on each other in one way or another. 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 may remain.

Potential Values: Although little remains of the natural wildlife habitat that once existed within the watershed and, consequently, little remains of the wildlife that once inhabited this area, that which does remain has the potential to significantly contribute to the quality of life in the watershed. If selected wildlife habitat areas are protected and properly managed, or if new wildlife habitat areas are created, sufficient wildlife populations can be maintained within the watershed to provide significant aesthetic, ecological, educational and research, and recreational value.

Observation Value: Wildlife habitat areas, with their usual variety and richness of vegetal types, have an inherent aesthetic value in the watershed. This aesthetic value is heightened if the wildlife habitats are in proximity to urban development and can, therefore, provide a welcome and restful visual contrast to the urban scene. The aesthetic impact of wildlife habitat areas is enhanced by the observation of the various forms of wildlife—fish amphibians, reptiles, birds, and mammals—that may inhabit those areas. Some forms of wildlife, such as birds, are readily seen and heard by even the most casual observers, whereas the viewing of other forms may require more careful examination and study.

Through thoughtful planning and management, some of the aesthetic benefits of wildlife and their habitat can be made an integral part of the watershed, as illustrated by the Michael F. Cudahy Nature Preserve, and the Falk and Rawson County Park woods. Opportunities for similar aesthetic experiences could be provided in the portions of the watershed west of IH 94 and along the stream reaches located adjacent to Oak Creek between 15th Avenue and S. 13th Street (CTH V). These portions of the watershed contain a variety of low- and medium-value wildlife habitat areas, most of which are in private ownership. However, these areas could be protected through an appropriate combination of zoning and public acquisition to form an interconnected network of linear wildlife habitat areas.

Ecological Function: As already noted, all wildlife species within the ecosystem of the watershed and its environments are interdependent. This means that the loss of one species—through destruction of its particular ecological niche—has an adverse effect on certain other wildlife species even though the ecological niche of those species may remain intact. From a narrow human perspective, a quality environment might be one in which certain "desirable" wildlife species such as songbirds exist but which is devoid of "troublesome" members of the animal community such as insect pests. However, it is generally not possible to have the benefit of the most "desirable" elements of the wildlife community without also accepting the less desirable elements.

The ecological importance of the woodlands and wetlands of the watershed and the wildlife residing in such areas was noted earlier in this chapter and will not be discussed further here. These woodland and wetland areas, however, constitute the biologically most productive areas of the watershed, and are important to the maintenance of diversity in watershed biota because of their ecological control function. Open space linkages must, however, be preserved between the best wildlife habitat areas, and the environmental corridor concept is particularly important in this respect. If adequately protected and properly managed, the remaining wildlife habitat in the watershed has the potential to provide the minimum elements needed to maintain a relatively healthy ecologic system.

Education and Research Function: Wildlife populations in the context of their natural habitat are valued by educators, naturalists, and researchers as objects of observation and study. The remaining wildlife and wildlife habitat of the Oak Creek watershed have the potential to meet the educational needs of watershed residents if selected sites throughout the basin are protected through public or private acquisition for that purpose.

Recreation-Related Values: The presence of wildlife contributes to the enjoyment of certain outdoor recreational activities. There is opportunity for the development of a limited recreational fishery in some of the watershed stream system provided that the adopted water use objectives and supporting standards are achieved. Bird watching and photography may be readily enjoyed by residents of the urban and urbanizing Oak Creek watershed provided that sufficient habitat is preserved.

Park and Open Space Sites

An inventory of existing park and open space sites in the Oak Creek watershed was conducted under the watershed planning program. This inventory indicated that there were a total of 34 park and open space sites within the watershed, totaling 1,686 acres (2.63 square miles), or about 9 percent of the total area of the watershed.[9] The spatial distribution of existing parks and open space sites is shown on Map 23. Of the total 34 sites, or 1,686

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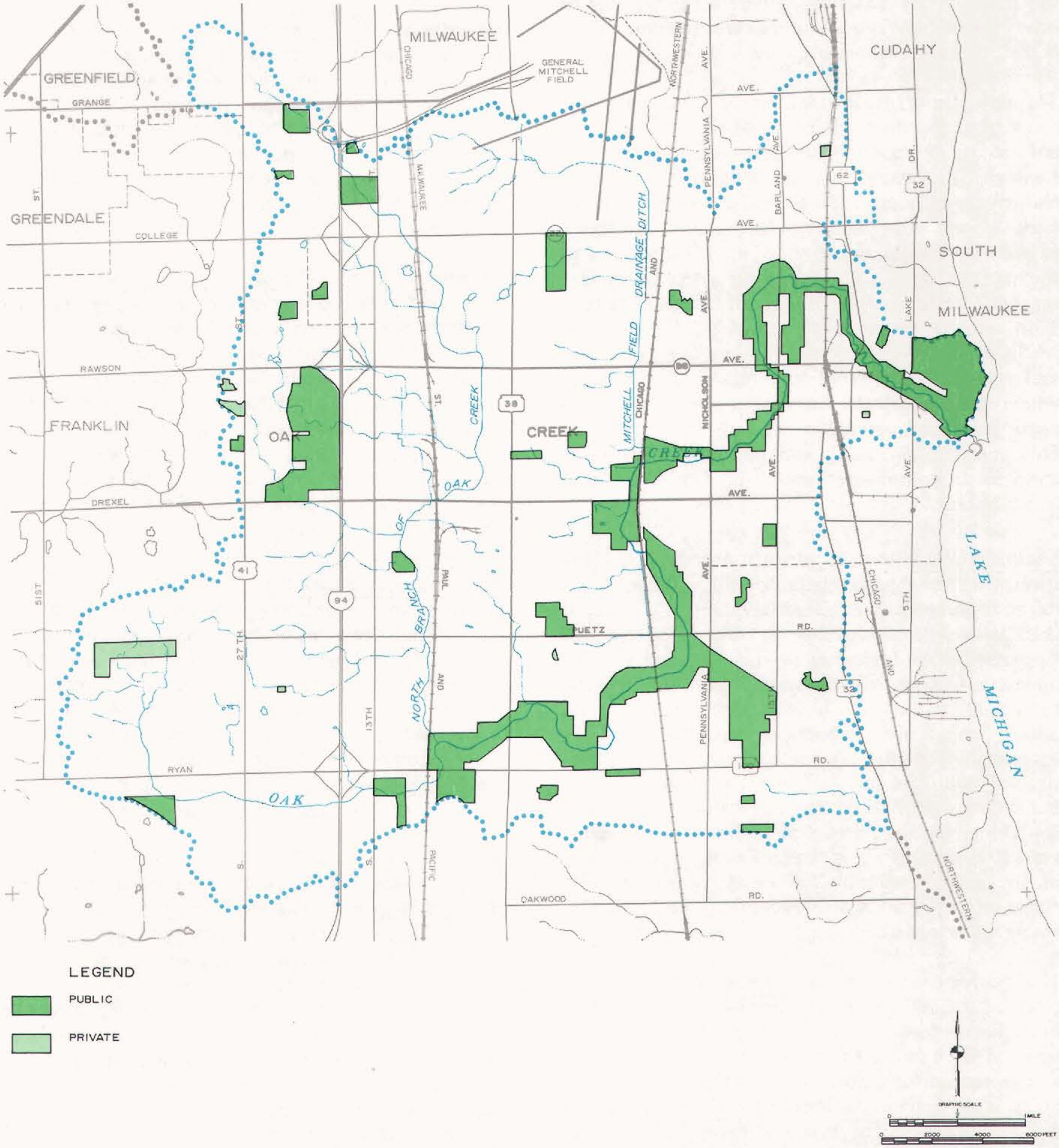
[9] *The 2.63 square miles of existing park and open space sites in the watershed as inventoried under the Oak Creek watershed planning program is 1.86 square miles, or 242 percent, greater than the 0.77 square mile of recreational land inventoried in 1980 under the Commission's continuing land use study. This difference is 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 recreation in the latter inventory. For example, a woodland owned by Milwaukee County and contained within a county park was considered part of a park and open space site in the park and open space sites inventory, but was not so included in the land use inventory because the use was identified as "woodland" rather than "recreation."*

Map 23

EXISTING PARK AND OPEN SPACE SITES IN THE OAK CREEK WATERSHED: 1980



A total of 34 park and open space sites encompassing 1,686 acres exist in the Oak Creek watershed. About 95 percent of this land is owned by public entities such as the County and cities. The remainder are owned by nonpublic entities.

Source: SEWRPC.

acres, public ownership accounts for 27 sites covering 1,610 acres, or 95 percent of the total acreage. Nonpublic ownership accounts for the remaining seven sites encompassing 76 acres, or 5 percent of the total acreage. Of the 1,610 acres of park and open space sites in public ownership, 1,353 acres, or about 84 percent, are owned by Milwaukee County.

Environmental Corridors

One of the most important tasks completed under the regional planning effort has been the identification and delineation of those areas of the Region in which concentrations of recreational, aesthetic, ecological, and cultural resources occur, resources which 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 shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, or organic soils; and 7) rugged terrain and high-relief topography. While the foregoing elements comprise the integral parts of the natural resource base, there are five additional elements which, although not 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 recreational, aesthetic, ecological, and cultural value: 1) existing park and open space sites; 2) potential park and open space sites; 3) historic sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

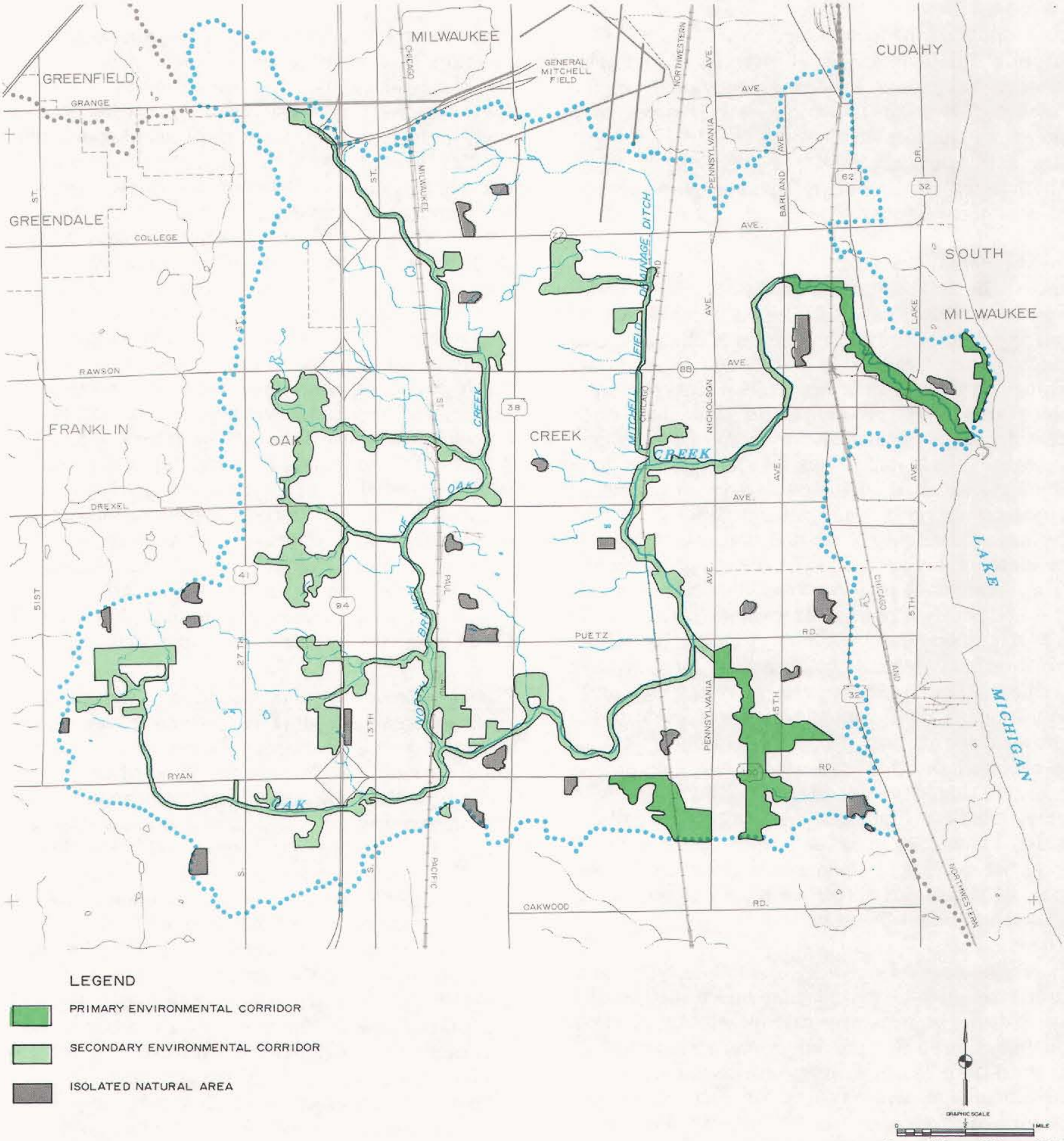
The delineation of these 12 natural resource and natural resource-related elements on a map results in a pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of such important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors connect with primary environmental corridors, and are at least 100 acres in size and one mile in length.

In any consideration of the importance of environmental corridors to the overall ecological health of an area, it is important to point out that because of the many interacting relationships existing between living organisms and their environment, the deterioration or destruction of one important element of the environment may lead to a chain reaction of further deterioration and destruction of other elements. The drainage of wetlands, for example, may have far-reaching effects since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater which serves as a source of domestic, municipal, and industrial water supply and upon which low flows of rivers and streams may depend. Similarly, the destruction of woodland cover may result in soil erosion, stream siltation, more rapid runoff, and increased flooding, as well as the loss of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects must eventually lead to serious deterioration of the underlying and supporting natural resource base and of the overall quality of the environment for life. The need to maintain the integrity of the remaining environmental corridors within the Oak Creek watershed should thus be apparent.

Primary Environmental Corridors: The primary environmental corridors in the Oak Creek watershed are located along the lower reaches of the main stem of Oak Creek in the Cities of Oak Creek and South Milwaukee, and in an area encompassing the larger remaining wetlands and woodlands in the southeastern corner of the watershed in the City of Oak Creek. These primary environmental corridors contain most of the remaining valuable woodlands, wetlands, and wildlife habitat areas in the watershed; are, in effect, a composite of the best individual elements of the natural resource base; and have truly immeasurable environmental and recreational value. The protection of the primary environmental corridors from intrusion by incompatible rural and urban uses, and thereby from degradation and destruction, should be one of the principal objectives of the watershed planning program. The primary environmental corridors should be considered inviolate; their preservation in an essentially open, natural state—including park and open space uses, limited agricultural uses, and country estate-type residential uses—will serve to maintain a high level of environmental quality in the watershed, protect its natural beauty, and provide valuable recreation opportunities. As indicated on Map 24, about 447 acres, or 3 percent of the total watershed area, are encompassed within the primary environmental corridors.

Map 24

ENVIRONMENTAL CORRIDORS IN THE OAK CREEK WATERSHED: 1980



Environmental corridors encompass almost all of the remaining valuable woodlands, wetlands, and wildlife habitat areas in the watershed, as well as many of the streams and associated undeveloped shorelands and floodlands; the significant topographic and geologic formations; and important ecological, recreational, historic, and cultural resources of the watershed. Primary environmental corridors in the watershed include a wide variety of these important resources and are located along the lower reaches of the main stem of Oak Creek in the cities of Oak Creek and South Milwaukee, and in an area encompassing the larger remaining wetlands and woodlands in the southeastern corner of the watershed in the City of Oak Creek. Secondary environmental corridors, which generally are less diverse and smaller in size than the primary environmental corridors, also include important resources and are located in the upper reaches of the main stem of Oak Creek, along the North Branch of Oak Creek, along the Mitchell Field Drainage Ditch, and along several intermittent streams tributary to Oak Creek and the North Branch of Oak Creek. The preservation of the natural resources encompassed within the environmental corridors and the protection of such corridors from intrusion by incompatible rural and urban uses, and thereby from degradation and destruction, should be one of the principal objectives of the watershed planning program. In addition to the primary and secondary environmental corridors, other pockets of important natural resources exist within the watershed. Such pockets of isolated natural areas—which may provide the only available wildlife habitat in an area, which provide good locations for local parks and nature study areas, and which lend unique aesthetic character and natural diversity to an area—should also be preserved and protected whenever possible.

Source: SEWRPC.

A comparison of the area of primary environmental corridor land as a percentage of the area of the watershed with the percentage of primary environmental corridor land in the County and the Region indicates that a relatively small area of the watershed has been classified as primary environmental corridor. About 6 percent of the total area of Milwaukee County is in primary environmental corridor, and about 17 percent of the total area of the Region is in primary environmental corridor. The importance of preserving the remaining primary environmental corridor lands in the Oak Creek watershed in natural, open uses is thus apparent.

Secondary Environmental Corridors: The secondary environmental corridors in the Oak Creek watershed are located along the upper reaches of the main stem of Oak Creek upstream of the primary environmental corridors along Oak Creek, along the North Branch of Oak Creek, and along several intermittent streams tributary to Oak Creek and the North Branch of Oak Creek. These secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural or urban purposes. Secondary environmental corridors facilitate surface water drainage, maintain "pockets" of natural resource features, and provide corridors for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. Such corridors are also important to the maintenance of environmental quality and should be preserved in an essentially open, natural state. As indicated on Map 24, about 1,152 acres, or 6 percent of the watershed, are encompassed within secondary environmental corridors. About 2 percent of the total area of Milwaukee County is in secondary environmental corridor, and about 3 percent of the total area of the Region is in secondary environmental corridor.

Isolated Natural Areas: In addition to the primary and secondary environmental corridors, smaller concentrations of natural resource base elements exist within the watershed area. Although these concentrations are isolated from the environmental corridors by urban development or agricultural uses, they may have important natural values. Isolated natural areas may provide the only available wildlife habitat in an area, provide good locations for local parks and nature study areas, and lend unique aesthetic character or natural diversity to an area. These isolated natural areas should also be protected and preserved in their natural state whenever possible. Isolated areas within the watershed are shown on Map 24. About 222 acres, or 1 percent of the watershed area, are encompassed within isolated natural areas that are five acres or greater in size. About 2 percent of the total area of Milwaukee County is in isolated natural areas, and about 2 percent of the total area of the Region is in isolated natural areas.

SUMMARY

The Oak Creek 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 Oak Creek 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 27.24-square-mile Oak Creek watershed comprises about 1 percent of the total area of the Southeastern Wisconsin Region and is the third smallest of the 11 distinct watersheds located wholly or partly within the Region. The watershed lies in one county and six cities.

The 1980 resident population of the watershed was estimated at 39,700 persons, or about 2 percent of the total population of the Region. From 1960 to 1970, the population growth rate of the watershed was significantly higher than that of Milwaukee County and the Region. From 1970 to 1980, the population growth rate was slightly higher than that of the Region, and substantially higher than that of Milwaukee County, which actually lost population over this decade. Population densities within the watershed range from fewer than 400 persons per gross square mile in the still rural areas of the watershed, to more than 4,500 persons per gross square mile in the urbanized areas. The median age in the watershed--29.4 years--is somewhat lower than that in the County and the Region, whereas household size—2.92 persons—and household income—$23,850—are higher than in the County and the Region.

The Oak Creek watershed is located within the Milwaukee urbanized area and very near the Racine urbanized area. As such, its economic base cannot be differentiated in any meaningful way from that of the greater Milwaukee and Racine areas. The residents of the watershed can readily commute to jobs located outside the watershed, while other residents of the greater Milwaukee and Racine areas can readily commute to jobs located in the watershed.

Total employment in the watershed in eight major industrial groups was estimated at 20,000 jobs in 1980. Of that total, about 10,600 jobs, or 53 percent, are provided in the manufacturing sector. Of that sector total, 3,400 jobs, or 32 percent, are provided in the nonelectrical machinery category.

Urban development first occurred within the watershed in the vicinity of the City of South Milwaukee and, until about 1950, remained concentrated in that city. By 1963, however, urban development had occurred not only in the South Milwaukee area but in scattered small areas throughout the watershed, and urban land uses constituted approximately 24 percent of the total area of the watershed. By 1980, approximately 47 percent of the total area of the watershed was in urban use, with residential being the predominant urban use, occupying about five square miles, or 19 percent of the total watershed area. As of 1980, approximately 15 square miles, or about 53 percent of the watershed area, were still in rural land uses, with agriculture and other open lands being the predominant rural use, occupying about 13 square miles, or about 45 percent of the total watershed area.

The watershed's public utility base is composed of its sanitary sewerage, water supply, electric power, and gas service systems. Adequate supplies of both electric power and natural gas are available to all areas of the watershed. Two sanitary sewerage districts or portions thereof serve about 56 percent of the total area of the watershed and approximately 95 percent of the total resident population of the watershed. The three sewage treatment plants serving the watershed discharge treated effluent to Lake Michigan. Four public water supply systems serve the urban areas of the Oak Creek watershed. The four public water supply systems which supply approximately 35,800 persons, or about 90 percent of the total resident population of the watershed, all utilize Lake Michigan as the sole source of supply.

The watershed is well served by an extensive all-weather arterial street and highway system. Two types of bus service are available in the watershed: urban mass transit and intercity bus service, urban mass transit service being provided by the Milwaukee County Transit System. Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrak passenger service over a line of the Chicago, Milwaukee, St. Paul & Pacific Railroad Company (Milwaukee Road) between Milwaukee and Chicago. General Mitchell Field is the only airport in the watershed and has the distinction of being the only airport in the Region providing scheduled air carrier service. About 810 acres the total airport site, or 38 percent of the total area of the airport, lies within the Oak Creek watershed.

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 Oak Creek watershed planning effort.

Because of its midcontinental location, far removed from the moderating effect of the oceans, the Oak Creek 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. Lake Michigan also has a moderating effect on the climate because of its proximity to the watershed. Air temperatures in the watershed range from a daily average of about 19°F in January to 71°F in July. Watershed temperature extremes have ranged from a low of about -24°F to a high of approximately 101°F.

Average annual precipitation within the watershed is 30.9 inches expressed as water equivalent, and average monthly amounts range from a low of 1.33 inches in February to a high of 3.59 inches in June. The average annual snowfall is 46.8 inches which, when converted to its water equivalent, constitutes 15 percent of the total annual precipitation. About 90 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 has total precipitation, with the annual snowfall ranging from a low of five inches to a high of approximately 109 inches.

With respect to snow cover, there is a 0.25 to 0.50 probability of having five or more inches of snow on the ground during January and February. A minimum of nine or more inches of frost penetration 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. The direction of prevailing winds follows a clockwise pattern over the seasons of the year, being northwesterly 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 22 to a maximum of 15.4 hours on about June 21. 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. Watershed topography is asymmetrical, with the eastern edge of the watershed being lower—by 80 to 140 feet—than the western edge of the basin. Surface elevations within the watershed range from a high of approximately 810 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) in the western portions of the watershed to a low of approximately 590 feet above National Geodetic Vertical Datum at the mouth of Oak Creek, a maximum relief of about 220 feet.

Surface drainage within the watershed is highly 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 channel modifications and other results of urbanization in the basin.

The geology of the Oak Creek watershed is a complex system of various layers and ages of rock formations. These formations slope gently down toward the east, and consist predominantly of, in ascending order, 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 their associated aesthetic, recreational, and economic values. There are 21.3 lineal miles of perennial streams within the watershed. Inasmuch as there are no major lakes of 50 acres or more in size in the watershed, these streams along with minor ponds and wetlands constitute the entire surface water resources of the watershed.

Extensive groundwater resources underlie the Oak Creek 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 1,900 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 the rural areas of the watershed, while the gradual discharge from the groundwater reservoir supplies the baseflow to Oak Creek and its tributaries.

Since the early settlement of the Oak Creek watershed, there has been a sharp decrease in the variety and quantity of wildlife because of the decrease in woodlands, wetlands, and other natural areas. Most of the remaining wildlife habitat areas are located between IH 94 and the western boundary of the watershed. The remaining fish and wildlife resources are particularly significant to the Oak Creek watershed because of the recreational, educational, and aesthetic value they impart.

There are 34 existing park and open space sites within the watershed, totaling 1,686 acres, or about 9 percent of the total area of the watershed. Of this total, 27 sites encompassing 1,610 acres, or 95 percent of the total acreage, are in public ownership.

The delineation of selected natural resource and natural resource-related elements in the watershed produces an essentially linear pattern of narrow, elongated areas which have been termed environmental corridors by the Regional Planning Commission. As of 1980, primary and secondary environmental corridors encompassing the best remaining elements of the natural resource base—including the surface waters, associated shorelands and floodlands, and the best remaining woodlands, wetlands, wildlife habitat areas, and existing and potential park sites—together with isolated natural areas occupied 1,821 acres in the watershed, or 10 percent of the watershed area. This compares with 10 percent for Milwaukee County and 22 percent for the Region as a whole. The preservation of the remaining environmental corridors and isolated natural areas in essentially natural, open uses is necessary to the maintenance of a high level of environmental quality in the Oak Creek watershed.

Chapter IV

ANTICIPATED GROWTH AND CHANGE IN THE WATERSHED

INTRODUCTION

In any planning effort, forecasts are required of all future conditions which are considered beyond the scope of the plans to be prepared, but which may affect either the design of the plans or the implementation of the plans over time. The future demands on the resources of a watershed are determined primarily by the size and spatial distribution of the future population and economic activity levels in the watershed. Although the spatial distribution of future population and economic activity can be influenced by public land use regulation, and although upper limits can be set on population and economic activity levels through such regulation, the control of changes in population and economic activity levels lies largely beyond the scope of governmental activity, at least at the regional and local levels. Neither the levels of population and employment within an area such as the Oak Creek watershed, nor the rates of change in these levels, can be prescribed in a watershed plan. Rather, such levels and changes will be a function of the relative attractiveness of the watershed, and of the Region of which the watershed is an integral part, to development relative to other watersheds within the Region and to other regions of the United States. In the preparation of the comprehensive plan for the Oak Creek watershed, therefore, future population and economic activity levels had to be forecast. These forecasts could then be converted to future demands for land within the watershed, and land and water use plans prepared to meet these demands. These land and water use plans, in turn, provided a basis for the preparation of supporting water resource management and related facility plans.

BASIS OF POPULATION AND ECONOMIC ACTIVITY LEVEL FORECASTS

It is important to note that the population and employment forecasts presented in this chapter were not independently prepared for the watershed study but were based upon forecasts prepared for, and used in, the preparation of other regional plan elements, including areawide land use, transportation, and sewerage system plans. This use of forecasts prepared for comprehensive, areawide planning purposes helped to assure consistency between the watershed plan and other long-range, areawide plan elements.

The population, employment, and land use demand forecasts selected as the basis for the preparation of the comprehensive watershed plan were based upon regional forecasts developed using an alternative futures approach. Under this approach, alternative futures were postulated for the Region considering potential changes in the key external factors affecting the development of the Region, including the cost and availability of energy, individual and family lifestyles, and the ability of the Region to compete with other regions of the United States for development. The range of population and economic activity levels attendant to these alternative futures was believed to represent reasonable extremes of future development conditions within the Region. Alternative land use patterns were then developed for each of these extremes in order to provide a range of spatial distribution of population and economic activity levels within the Region.

Two of the resulting four alternative futures—the "optimistic growth centralized development" future and the "optimistic growth decentralized development" future—envision modest growth in resident population and economic activity levels within the Region. One of these futures envisions that this growth will be accommodated in a centralized manner, with new urban development occurring largely at medium densities and contiguous to, and outward from, the existing urban centers of the Region. The other envisions that much of this growth will be accommodated in a decentralized manner, with new urban development occurring at low densities in a highly diffused pattern well beyond the limits of the existing centers of the Region. The other two futures envision only slight growth in economic activity and an actual decline in resident population levels. One of these two futures—the "pessimistic growth centralized development" future, envisions that any redistribution of population and employment will be accommodated in a centralized manner. The other of these futures—the "pessimistic growth decentralized development" future, envisions that any redistribution of population and employment will be accommodated in a decentralized manner. These alternative futures are more fully described in SEWRPC Technical Report No. 25, Alternative Futures for Southeastern Wisconsin.

Tables 25 and 26 summarize the population and employment changes which may be expected in the Southeastern Wisconsin Region, Milwaukee County, and the Oak Creek watershed under each of these four alternative futures. It was determined by the watershed committee that the future population and employment levels envisioned under the optimistic growth centralized development alternative would be used in the watershed planning. The use of this alternative future represents the most conservative approach—within reasonable limits—to the watershed planning process. This alternative future, as already noted, envisions a modest increase in population and economic activity levels within the Region and a slight increase in population and economic activity levels in Milwaukee County. This future, however, also envisions substantial growth in population and economic activity levels within the Oak Creek watershed and, therefore, represents a reasonable extreme of land use development which could occur in the watershed over the next two decades. In addition, this future would have the greatest effect on water quality and flooding conditions within the watershed. Moreover, the spatial distribution of population and economic activity under this future is based upon adopted regional and local land use development objectives, and is consistent with federal and state policies which seek to promote more centralized urban development patterns and protect environmentally significant areas and prime agricultural lands.

Table 25

POPULATION IN THE REGION, MILWAUKEE COUNTY, AND THE OAK CREEK WATERSHED: EXISTING 1950, 1960, 1970, AND 1980 AND PROJECTED YEAR 2000

Area	Existing 1950	Existing 1960	Existing 1970	Existing 1980	Projected Year 2000			
					Pessimistic Growth		Optimistic Growth	
					Decentralized Development Pattern	Centralized Development Pattern	Decentralized Development Pattern	Centralized Development Pattern
Region	1,240,618	1,573,620	1,756,083	1,764,919	1,690,000	1,690,000	2,219,300	2,219,300
Milwaukee County . . .	871,047	1,036,041	1,054,249	964,988	700,000	830,000	898,500	1,049,600
Oak Creek Watershed. .	18,173	25,431	36,498	39,716	41,700	49,900	50,100	72,600

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

Table 26

EMPLOYMENT IN THE REGION, MILWAUKEE COUNTY, AND THE OAK CREEK WATERSHED: EXISTING 1970 AND 1980 AND PROJECTED YEAR 2000

Area	Existing 1970	Existing 1980	Projected Year 2000			
			Pessimistic Growth		Optimistic Growth	
			Decentralized Development Pattern	Centralized Development Pattern	Decentralized Development Pattern	Centralized Development Pattern
Region	741,600	815,500	887,000	887,000	1,016,000	1,016,000
Milwaukee County	507,100	547,900	525,300	552,300	523,400	593,600
Oak Creek Watershed. . .	9,300	20,000	17,900	18,000	28,000	27,300

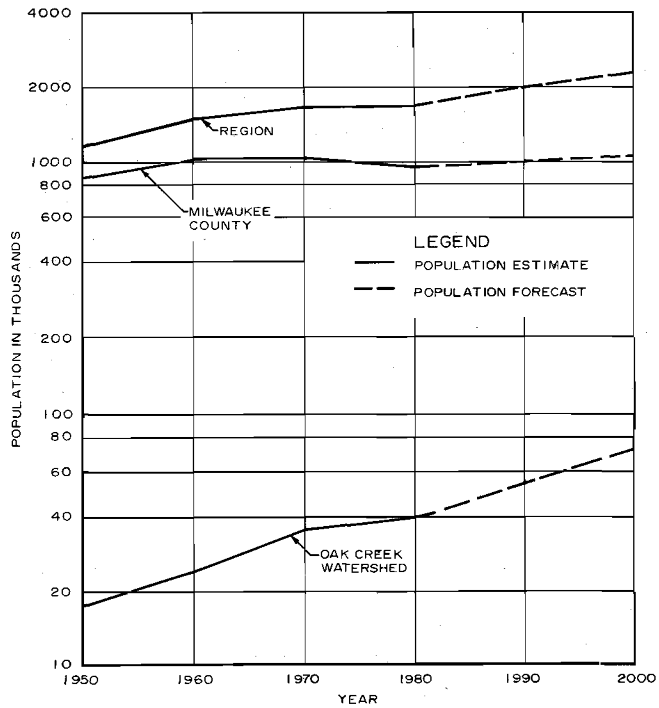
Source: Wisconsin Department of Industry, Labor and Human Relations and SEWRPC.

POPULATION GROWTH

The regional population forecast selected as a basis for the watershed planning effort anticipates that the resident population of the Region will reach a level of 2.22 million persons by the year 2000, as indicated in Table 27 and Figure 13. This would represent an increase of about 454,000 persons, or about 26 percent, over the 1980 level of about 1.76 million persons. This anticipated population increase—equivalent to about 23,000 persons per year from 1980 to 2000—is substantially more than the actual rate of increase of 18,200 persons per year experienced from 1960 to 1970 but substantially less than the actual rate of increase of 33,300 persons per year experienced from 1950 to 1960. It is also substantially more than the actual rate of increase of approximately 880 persons per year experienced from 1970 to 1980. The 1983 resident population of the Region is estimated to be 1,748,200 persons, or 1 percent less than the 1980 population level. The county population forecast, based upon normative areawide land use development objectives, envisions a reversal of historic trends. Under the forecast, the population of the County would increase slightly from a resident population level of about 965,000 in 1980 to about 1,050,000 in 2000, an increase of about 85,000 persons, or about 9 percent. The resident population of the County actually decreased by about 89,300 persons, or about 8 percent, from 1970 to 1980, having peaked at a level of 1,054,249 persons in 1970. The 1983 resident population of the County is estimated to be 945,000 persons, a decrease of about 108,200 persons, or about 10 percent, from the 1970 level.

Figure 13

POPULATION TRENDS AND FORECASTS FOR THE REGION, MILWAUKEE COUNTY, AND THE OAK CREEK WATERSHED: 1950-2000



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

Table 27

ANTICIPATED POPULATION CHANGE FOR THE REGION, MILWAUKEE COUNTY, AND THE OAK CREEK WATERSHED: SELECTED YEARS 1950-2000

Year	Southeastern Wisconsin Region	Milwaukee County	Oak Creek Watershed	Watershed Population as Percent of Regional Population
1950	1,240,618	871,047	18,173	1.5
1960	1,573,620	1,036,041	25,431	1.6
1970	1,756,083	1,054,249	36,498	2.1
1980	1,764,919	964,988	39,716	2.3
1990	1,992,100	1,007,300	56,200	2.8
2000	2,219,300	1,049,600	72,600	3.3
1980-2000 Percent Change	25.7	8.8	82.9	--

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

The population of the Oak Creek watershed increased steadily from a level of about 18,200 persons in 1950 to about 39,700 persons in 1980. Based upon the alternative future selected as a basis for the watershed planning, the population of the watershed may be expected to increase from the 1980 level of 39,700 persons to 72,600 persons in the plan design year 2000. This represents an increase of 32,900 persons, or 83 percent, over the 1980 population level.

The 83 percent increase in population anticipated for the watershed exceeds the increase anticipated for the County, and for the Region as a whole. This higher rate of growth for the watershed reflects the substantial increase in resident population anticipated in the areas of the Region peripheral to the larger urban centers, such as Milwaukee. As a result of these envisioned higher growth rates, the proportion of the regional population in the Oak Creek watershed may be expected to increase from about 2 percent in 1980 to about 3 percent in the plan design year, as indicated in Table 27.

Table 28

ANTICIPATED EMPLOYMENT FOR THE REGION AND THE OAK CREEK WATERSHED: SELECTED YEARS 1970-2000

Year	Southeastern Wisconsin Region	Oak Creek Watershed	Watershed Employment as a Percent of Regional Employment
1970	741,600	9,300	1.3
1980	884,200	20,000	2.3
1990	950,100	23,650	2.5
2000	1,016,000	27,300	2.7
1980-2000 Percent Change	14.9	36.5	--

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

EMPLOYMENT GROWTH

Economic activity, as measured in terms of employment opportunities, is not linked functionally to watershed patterns within southeastern Wisconsin. Rather, the forces determining economic activity originate and are sustained over the entire urbanizing Region. Employment levels in the Oak Creek watershed are, under the alternative future selected as a basis for the watershed planning, envisioned to increase substantially between 1980 and the plan design year, exceeding the growth rate forecast for the Region as a whole. This higher rate of growth in employment reflects the substantial increase in economic activity levels anticipated in the areas of the Region peripheral to the larger urban centers, such as Milwaukee. As shown in Table 28, employment opportunities within the watershed are expected to increase from 20,000 jobs in 1980 to about 27,300 in the plan design year 2000, an increase of about 36 percent. In contrast, a 15 percent increase in employment is anticipated within the Region as a whole during this time period.

LAND USE DEMAND

Because of the anticipated population increase of 32,900 persons and anticipated increase in employment of 7,300 jobs between 1980 and the year 2000 in the Oak Creek watershed, the continued conversion of land from rural to urban use may be expected to be required within the watershed. Between 1963 and 1980, approximately 3.3 square miles of land were converted from rural to urban use within the watershed, increasing the proportion of the total area of the watershed in urban use from 34 percent in 1963, or about 9.5 square miles, to 46 percent in 1980, or about 12.8 square miles. Under the alternative future selected as a basis for watershed planning, the conversion of an additional 5.6 square miles of land from rural to urban use may be expected between 1980 and the plan design year 2000, an increase of about 59 percent in urban use. By the plan design year, then, approximately 18.4 square miles, or about 66 percent, of the approximately 27.7-square-mile watershed—as determined by U. S. Public Land Survey quarter section approximation—would be in urban use.

SUMMARY

The population and economic activity levels selected as the basis for the Oak Creek watershed planning effort envision substantial increases in watershed population and employment. The resident population of the watershed may be expected to increase from the 1980 level of 39,700 persons to about 72,600 persons by the year 2000, an increase of 32,900 persons, or about 83 percent. Employment in the watershed may be expected to increase from the 1980 level of 20,000 jobs to about 27,300 jobs by the year 2000, an increase of 7,300 jobs, or about 36 percent. These changes in resident population and employment levels within the watershed are based upon an alternative future for the Region, of which the watershed is a part, which envisions modest population and employment growth and a centralized pattern of future land use development. This future provides the highest population and economic activity levels which can be reasonably expected to occur within the watershed by the plan design year. The anticipated growth in population and employment will require the conversion of an additional 5.6 square miles of land from rural to urban use within the watershed between 1980 and 2000, increasing the total amount of land in urban use within the watershed from 12.8 square miles, or 46 percent of the watershed, in 1980, to 18.4 square miles, or about 66 percent of the total area of the watershed, by the year 2000. Of the alternative futures considered, the alternative future selected as a basis for the watershed planning effort would have the greatest influence on water quality and flooding conditions within the watershed and provides, therefore, a conservative approach to the planning and design of water quality and flood control facilities.

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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 should 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 Oak Creek 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 hydrologic-hydraulic system of the Oak Creek watershed, with emphasis upon the behavioral characteristics of that system pertinent to comprehensive watershed planning. An understanding of this system is important to the watershed planning process inasmuch as the system and its behavior 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 close interdependence between the various elements of the hydrologic and hydraulic system of a watershed, any planned modification to, or development of, one of these elements must consider the potential effects on the other elements. 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 ultimately abated.

Digital computer simulation was used in the Oak Creek watershed study to accomplish the necessary integrated analysis of the hydrologic-hydraulic system of the watershed. The primary purpose of inventorying and analyzing the hydrologic and hydraulic data and information as presented in this chapter was to provide the data 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 Oak Creek watershed vary greatly with 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 Oak Creek 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 Oak Creek 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 Oak Creek 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 Oak Creek 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 is lost 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 the 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 some of the elements of the hydrologic budget. Quantitative measurements, or estimates, compiled for the Oak Creek watershed include precipitation, streamflow, evaporation, and groundwater levels; but the records of each of the 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 Oak Creek watershed can be developed considering only the surface and shallow groundwater supplies. In its simplest form, then, the long-term hydrologic budget for the Oak Creek 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, and based upon records from 1940 through 1983, the average annual precipitation over the watershed is 30.9 inches. Streamflow records collected from October 1, 1963, through September 30, 1983, at

[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 the plants, is transformed to the vapor state, and returned to the atmosphere. Evapotranspiration is the sum of the two processes.*

the U. S. Geological Survey gaging station on Oak Creek, in South Milwaukee (station number 04087204), indicate that the average annual discharge at that location is about 21.1 cubic feet per second, which is equivalent to 11.5 inches of water spread uniformly over the land surface of the watershed upstream from the gaging station. Substitution of these values for precipitation and runoff into the simplified hydrologic budget equation indicates an average annual evapotranspiration of 19.4 inches. On an average annual water-year basis, therefore, about 63 percent of the precipitation that falls on the Oak Creek watershed is returned to the atmosphere by the evapotranspiration process, while the remaining 37 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 Oak Creek 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: As already noted, the average annual total precipitation for the Oak Creek watershed based on data from the Milwaukee Mitchell Field observation station located near the watershed is 30.9 inches, whereas the average annual snow and sleet fall is 46.8 inches measured as snow and sleet. The location of this station and the availability of temperature and other meteorological data for other stations surrounding the watershed are shown on Map 11 and listed in Table 8 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 C 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 Oak Creek watershed is about 29 inches and, therefore, approximately equal to the average annual precipitation of 30.9 inches. The average annual evapotranspiration, as calculated in the hydrologic budget for the watershed, is about 19.4 inches. The 11.5-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

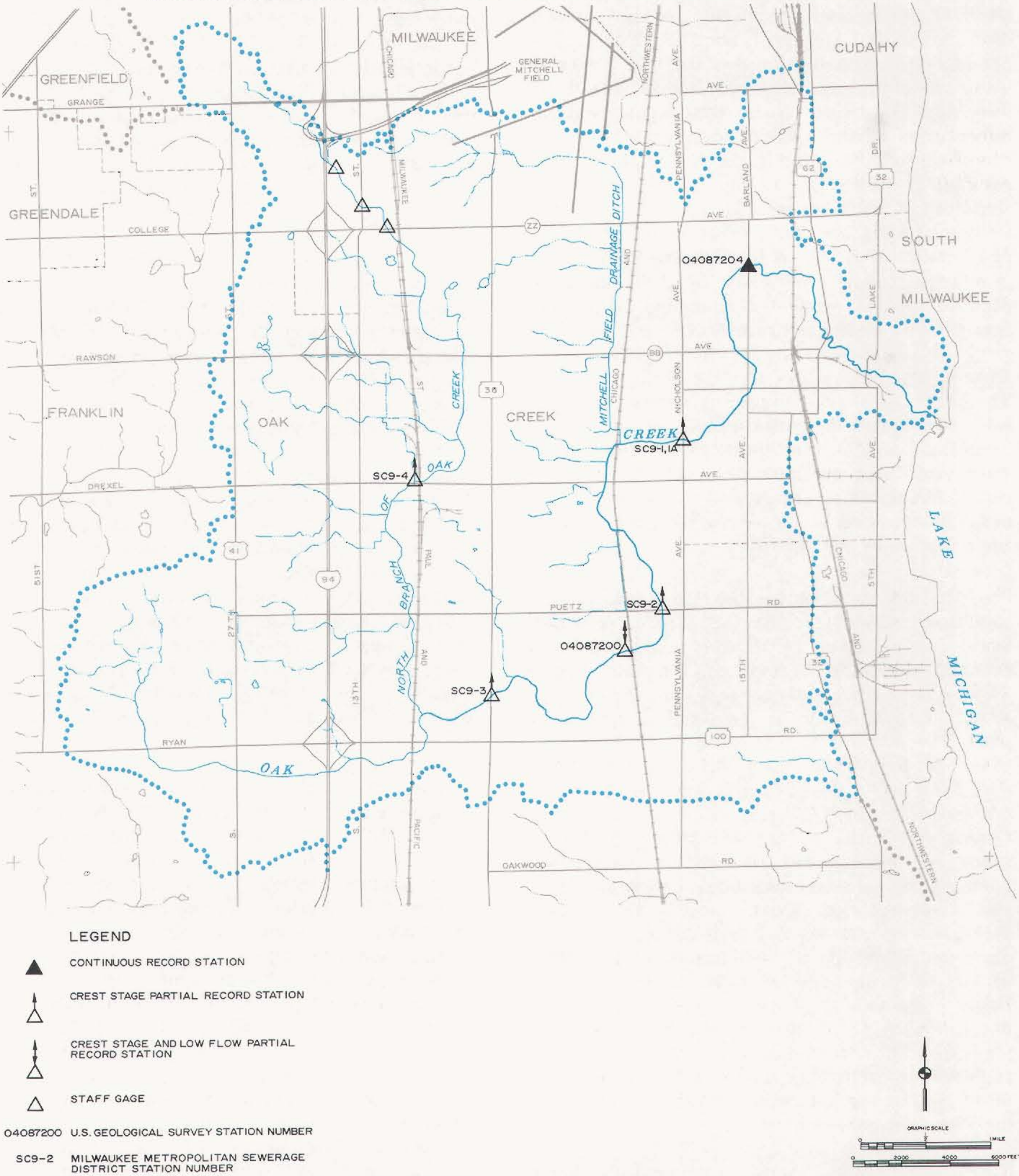
Surface water in the Oak Creek watershed is composed almost entirely of streamflow since, as indicated in Chapter III, there are no major lakes—that is, lakes of 50 acres or more in surface area—located within the watershed. Small ponds, which have a combined surface area of 27 acres, comprise the remainder 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 is, therefore, amenable to relatively precise measurement of its total quantity. As shown on Map 25 and as listed in Table 29, four types of stream stage and discharge monitoring stations have been constructed and are, or have been, operated in the watershed by the U. S. Geological Survey, the Milwaukee Metropolitan Sewerage District, and the City of Milwaukee.

Streamflow generally is not measured directly at discharge monitoring stations but is usually derived from measurements of "stage," that is, of water surface elevation at monitoring 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 each subarea, multiplying the velocity times the area for each subarea to obtain subarea discharge, and summing the discharges for all subareas to obtain the total discharge. Stage is determined by various types of indicators, with the readings made 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

Map 25

STREAM STAGE AND DISCHARGE STATIONS IN THE OAK CREEK 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 is, therefore, amenable to relatively accurate and precise measurement of the total quantities involved. As shown above, four types of stream stage and discharge monitoring stations have been installed and are, or have been, operated in the watershed.

Source: SEWRPC.

Table 29

STREAMFLOW GAGING IN THE OAK CREEK WATERSHED

Station Number	Station Site	Period of Record	Continuous Recorder	Crest Stage Gage	Staff Gage	Data Source
04087200	Oak Creek at Nicholson Road	June 1958 - continuing		X	X	1,2,3
04087204	Oak Creek at 15th Avenue	October 1963 - continuing	X			1,2,3
SC9-1	Oak Creek at S. Pennsylvania Avenue (downstream side)	September 11, 1967 - continuing		X		4
SC9-1A	Oak Creek at S. Pennsylvania Avenue (upstream side)	April 25, 1979 - continuing		X		4
SC9-2	Oak Creek at E. Puetz Road	September 7, 1967 - continuing		X		4
SC9-3	Oak Creek at S. Howell Avenue	January 4, 1972 - continuing		X		4
SC9-4	North Branch of Oak Creek at W. Drexel Avenue	April 15, 1971 - February 25, 1981		X		4
--	North Branch of Oak Creek at W. College Avenue	October 27, 1975 - continuing			X	5
--	North Branch of Oak Creek at S. 13th Street	October 27, 1975 - continuing			X	5
--	North Branch of Oak Creek at W. Ramsey Avenue and S. 15th Street	October 27, 1975 - continuing			X	5

Data Sources:

1. *Duane H. Conger, Techniques for Estimating Magnitude and Frequency of Floods for Wisconsin Streams, U. S. Geological Survey Water-Resources Investigations, Open-File Report 80-1214, Madison, Wisconsin, 1981.*

2. *B. K. Holmstrom, Low-Flow Characteristics of Streams in the Lake Michigan Basin, Wisconsin, U. S. Geological Survey Water-Resources Investigations Open-File Report 81-1193, Madison, Wisconsin, 1982.*

3. *U. S. Geological Survey, Water Resources Data for Wisconsin, U. S. Geological Survey Water Data Report, published yearly since 1961.*

4. *Milwaukee Metropolitan Sewerage Commission, 735 N. Water Street, Milwaukee, Wisconsin 53202.*

5. *City of Milwaukee, Department of Sewer Engineering, 841 N. Broadway. Milwaukee, Wisconsin 53202.*

Source: SEWRPC.

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: Two 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 annual 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 on Oak Creek in the Oak Creek Parkway downstream from the 15th Avenue bridge in the City of South Milwaukee since October 1963. (USGS Gage No. 04087204) This station monitors flow from a 25.0 square-mile drainage area which comprises 92 percent of the total area of the 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 and discharges that actually occur.

One crest-stage gaging station is also currently being operated on Oak Creek at Nicholson Road in the City of Oak Creek (Station No. 04087200) by the USGS in cooperation with the Wisconsin Department of Transportation. This station monitors streamflow from a 13.8 square-mile area comprising about 51 percent of the watershed area. Low-flow measurements have been obtained at this site for the water years 1958 through 1977.

Crest-stage and low-flow gaging data are summarized in USGS reports.[3] Table 29 lists the sites in the Oak Creek watershed where streamflow data have been collected by the USGS, describes the type of data collected at each site, defines the period of record, and identifies publications containing the data for each site.

Milwaukee Metropolitan Sewerage Commissions' Crest Stage Gages: A total of five crest stage gages were operated in the Oak Creek watershed by the Milwaukee Metropolitan Sewerage District as of 1984. These flood crest monitoring stations were installed in 1967, 1971, 1972, and 1979 and their locations are shown on Map 25. In general, one or more flood crest measurements have been made at each of the five stations during each of the years for which the stations have been in existence.

Peak flood stage data from these five gages were used, as discussed in Chapter VI, "Flood Characteristics and Problems," to develop historic flood stage profiles of the Oak Creek 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: As shown on Map 25, three staff gages are maintained by the City of Milwaukee in the City of Milwaukee, as of 1984. This network of staff gages is monitored by field personnel during and after flood events. In general, one or more flood stage measurements have been made at each of the three City of Milwaukee stations during each of the years that these stations have been in existence.

Seasonal Distribution of Peak Stages: Flood stages recorded at the two U. S. Geological Survey gaging stations in the Oak Creek watershed were used to evaluate the seasonal distribution of annual flood peaks. The seasonal distribution of the recorded peak discharges are shown in Figure 14.

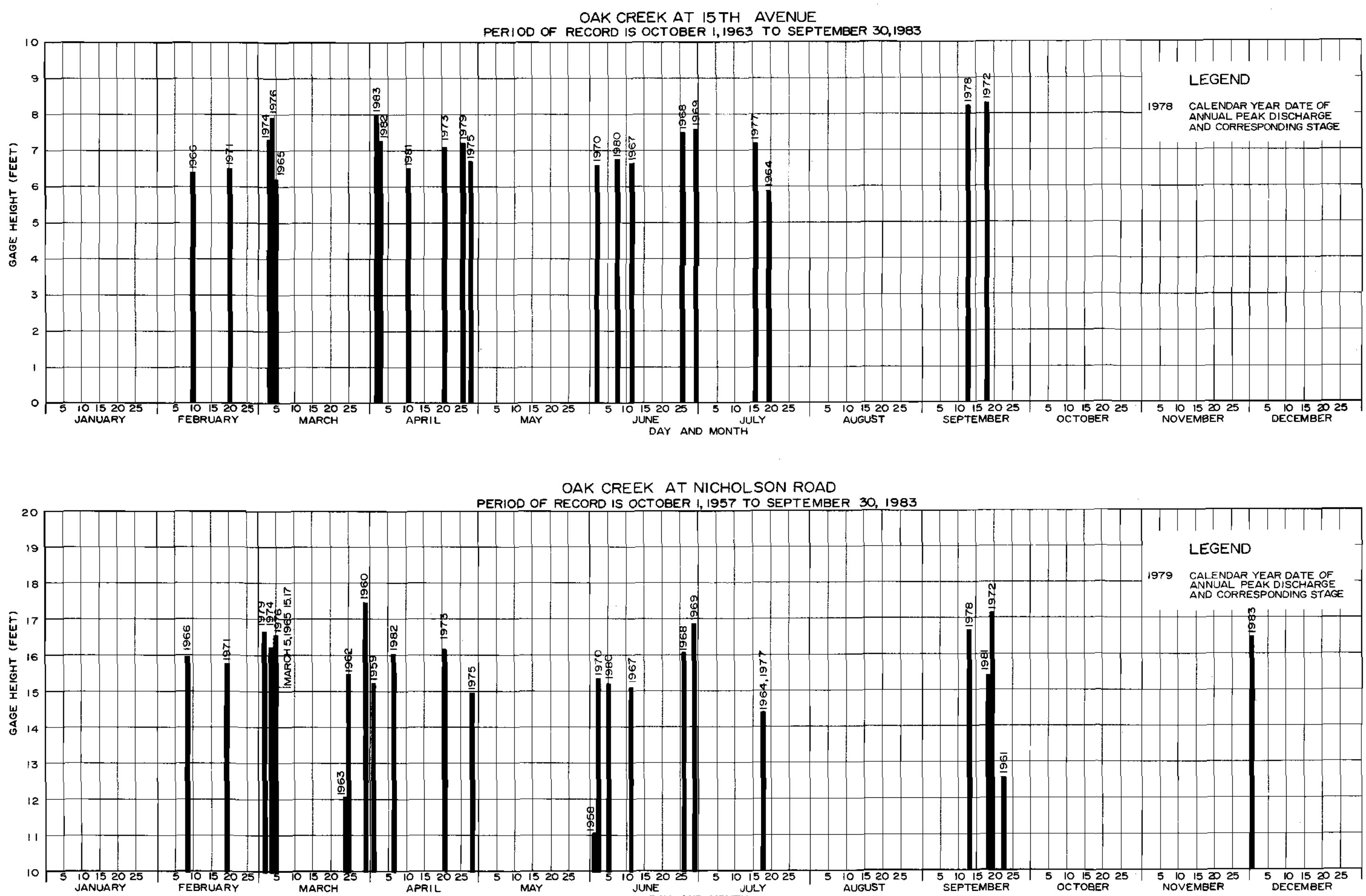
The 20-year record for the station downstream from the 15th Avenue bridge—which has a drainage area of 25.0 square miles—indicates that the occurrence of highwater events is not limited to any one season, with annual peaks having occurred during the months of February through September. The low frequency of occurrence of annual

[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 One, Inventory Findings and Forecasts, October 1976, pp. 104-109.*

[3] *Duane H. Conger, Techniques for Estimating Magnitude and Frequency of Floods for Wisconsin Streams, U. S. Geological Survey Water Resources Investigations Open-File Report 80-1214, Madison, Wisconsin, 1981; B. K. Holmstrom, Low-Flow Characteristics of Streams in the Lake Michigan Basin, Wisconsin, U. S. Geological Survey Water Resources Investigations Open-File Report 81-1193, Madison, Wisconsin, 1982.*

Figure 14

SEASONAL DISTRIBUTION OF ANNUAL PEAK DISCHARGES FOR OAK CREEK AT SOUTH MILWAUKEE (04087204) AND FOR OAK CREEK NEAR SOUTH MILWAUKEE (04087200)



U. S. Geological Survey and SEWRPC.

peaks in the months of November, December and January is typical of watersheds in southeastern Wisconsin. The months of March, April, and June apparently were the most active flood runoff periods in the Oak Creek watershed between 1964 and 1983, with 68 percent of the recorded annual peaks having occurred in these months.

The 25 years of record available for the station on Oak Creek at Nicholson Road—which has a drainage area of 13.8 square miles—support this conclusion, with 68 percent of the recorded annual peaks also having occurred in the months of March, April, and June.

A review of the Oak Creek data record indicated a similarity with the seasonal distribution of peak stages for the predominantly rural Milwaukee River watershed. Sixty-six years of gaging record for the Milwaukee River at Milwaukee indicate that 67 percent of the annual peaks occurred in the months of March, April, and June, as compared to 68 percent for Oak Creek for the same months for the 20-year period of record. However, the longer term Milwaukee River data also indicate that a relatively high number of annual peaks occurred in February. Including the February data in the analysis, it was found that 80 percent of the annual peaks in the Milwaukee River watershed occurred in what appear to be two distinct periods, February through April and the month of June. The Oak Creek data for the period 1964-1983 contained only two annual peaks in the month of February. However, the Milwaukee River data also show only one February annual peak during the same period. Therefore, based on the above analyses, it appears that for the Oak Creek watershed, two flooding seasons may exist. The period February through April may be classified as a high runoff period because of the effects of snow accumulation and frozen ground in February and March, and the effects of snowmelt or rainfall on near-saturated soils in March and April when the drying effects of transpiration are still minimal and when air and surface temperatures still inhibit evaporation. Frequent severe thunderstorms occurring in the month of June but before the peak period of summer evapotranspiration may explain the relatively frequent occurrence of major floods during June as compared to July and August, two months of potentially more severe precipitation, but periods of heavy foliation and evapotranspiration losses of soil moisture.

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 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 the increase in efficiency of drainage systems associated with the urbanization process increase runoff volumes and decrease runoff times. These two effects of urbanization are additive, with the result that 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 tend to show a rapid rise in runoff hydrographs subsequent to the beginning of rainfall events compared to the rate of rise of runoff hydrographs in rural basins of similar size. The primary significance of the rapid response of flood flow hydrographs to rainfall events in highly urbanized watersheds is that very little time is available to warn riverine area residents of impending flood damage and disruption.

Because significant urbanization may be expected to occur in the Oak Creek watershed, the impacts of such urbanization upon flood flows and stages and response time have been evaluated in the watershed planning effort. This evaluation is described in the analysis of alternative plans, set forth in Chapter XII of this report.

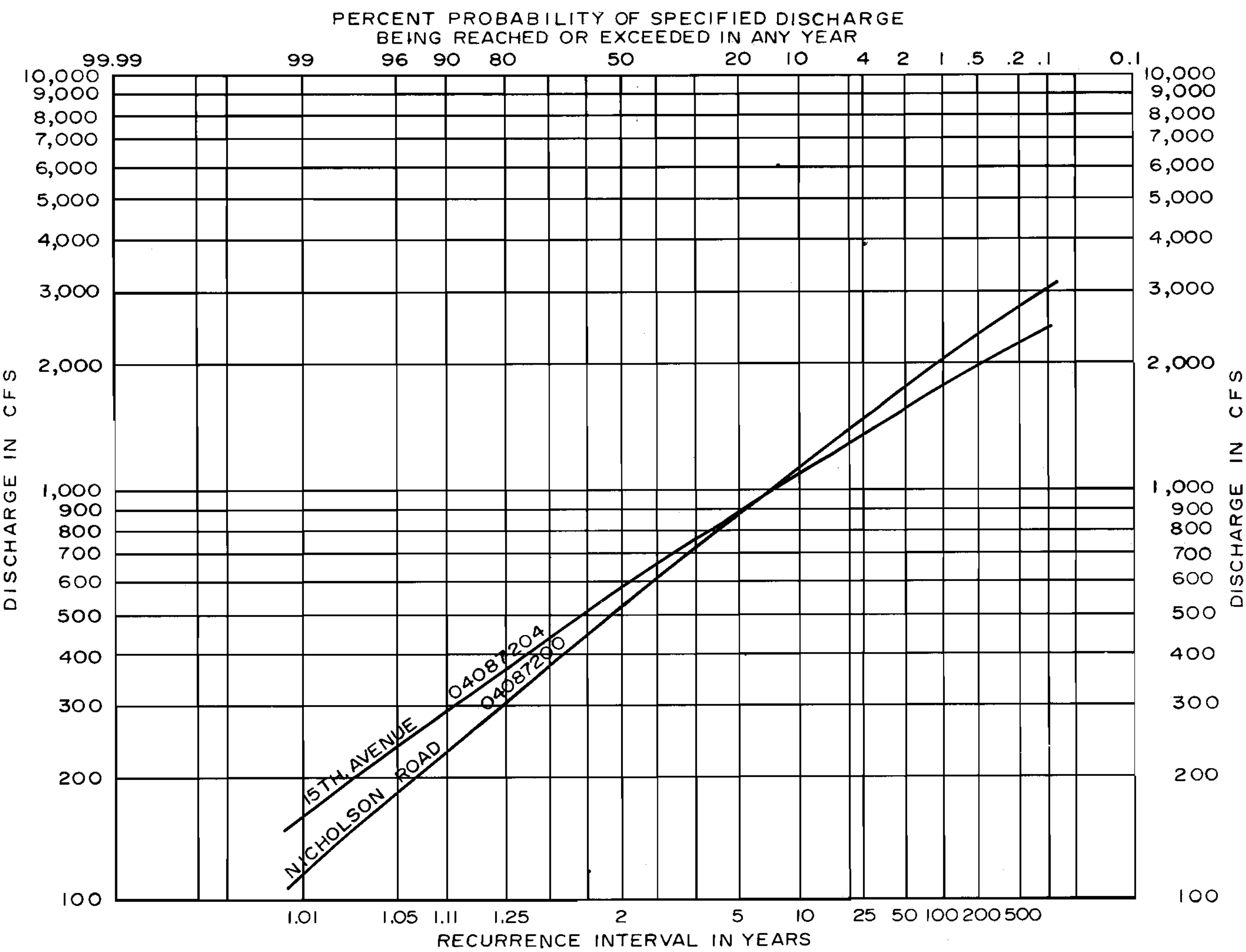
High-Flow Discharge-Frequency Relationships: The most important hydrologic characteristics of floods for watershed planning purposes are the frequency of occurrence, the peak rate of discharge, the volume of runoff, and the duration and timing of the event. Frequency—or "probability"—of occurrence is defined as the chance of occurrence, in any year, of a flood equal to 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 equaled 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.

A long and continuous record of river discharge is the best basis for determining flood discharge-frequency relationships. Discharge records for the Oak Creek at the 15th Avenue bridge encompass the period since October 1964, and for the crest-stage gaging station on Oak Creek at Nicholson Road, the period since 1958. These records, in combination with historic flood stage data, were invaluable 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 Oak Creek at 15th Avenue, at Nicholson Road, and for other locations throughout the watershed for the 44-year period from 1940 through 1983 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 X, "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 relationships for Oak Creek at the 15th Avenue and Nicholson Road bridges is shown in Figure 15.

Whereas Figure 15 presents the discharge-frequency relationship for instantaneous peak discharges under existing conditions in the watershed, Figure 16 shows high-flow discharge-frequency relationships under existing conditions in the watershed at the 15th Avenue bridge for periods of 1, 7, 30, and 120 days. These relationships also were developed using simulated streamflows and the log Pearson Type III method of statistical analysis. For a specified discharge, these curves facilitate estimating the probability that a specified high streamflow will be maintained or exceeded for a given period of time during any water year. For example, the probability of maintaining an average flow of 50 cubic feet per second (cfs) or more for a seven-day period in any water year is about 96 percent, while the probability of maintaining that average flow for 30 days is a lower 70 percent, and for 120 days an even lower 18 percent.

Figure 15

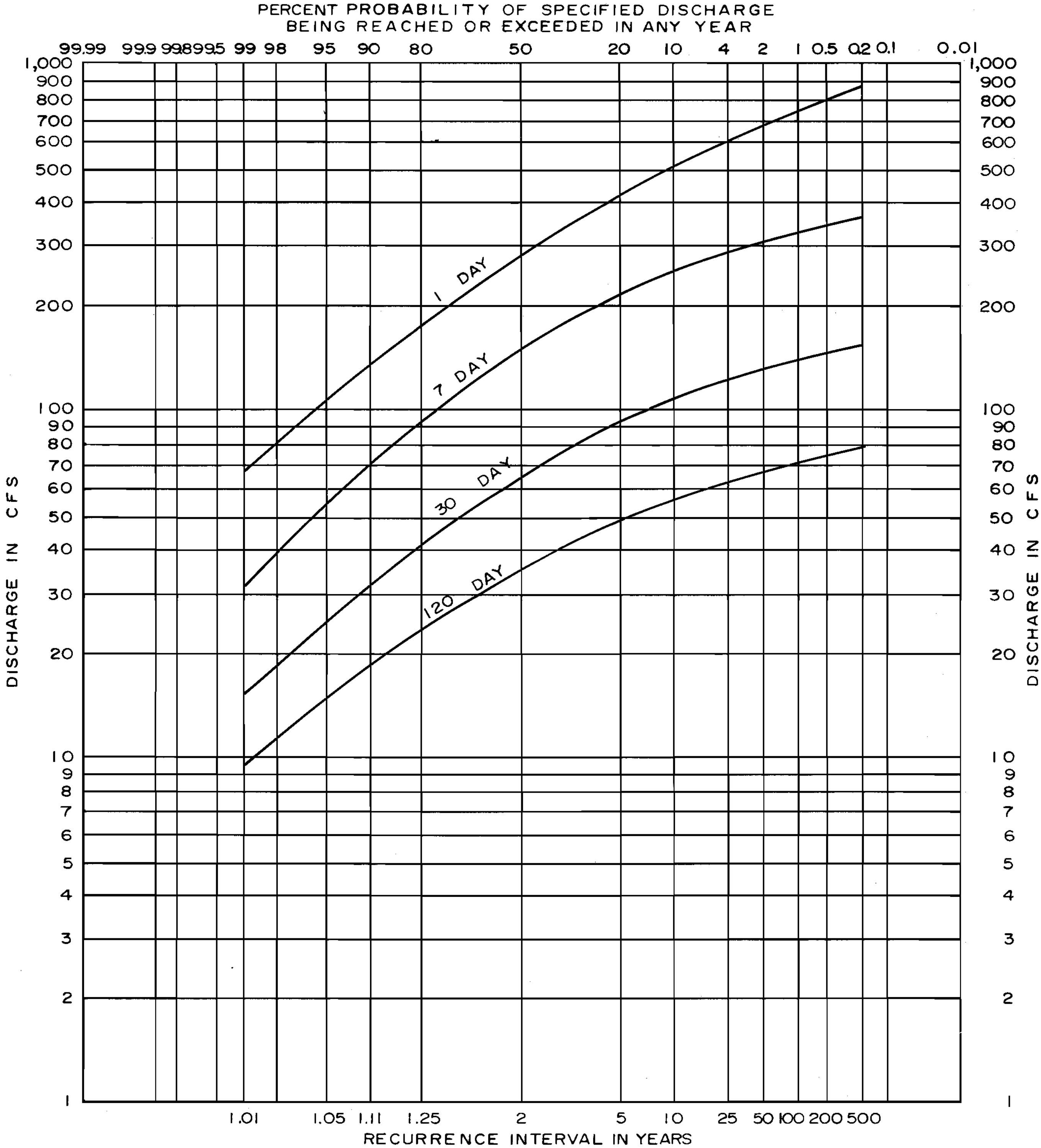
DISCHARGE-FREQUENCY RELATIONSHIPS FOR OAK CREEK IN SOUTH MILWAUKEE AT 15TH AVENUE (04087204) AND FOR OAK CREEK NEAR SOUTH MILWAUKEE AT NICHOLSON ROAD (04087200): EXISTING LAND USE, CHANNEL, AND FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

Figure 16

HIGH-FLOW DISCHARGE-FREQUENCY RELATIONSHIPS FOR OAK CREEK AT 15TH AVENUE (04087204): EXISTING LAND USE, CHANNEL, AND FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

Low-Flow Discharge-Frequency Relationships: Figure 17 shows low-flow discharge-frequency relationships for Oak Creek at the 15th Avenue bridge for periods of 1, 7, 30, and 120 days. Simulated discharges for the 44-year period from 1940 through 1983 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 streamflow equivalent to the minimum average seven-day flow expected to occur once on the average of every 10 years. The seven day-10 year low flow for Oak Creek at the 15th Avenue bridge as obtained from Figure 17 approximates zero cfs.[4] However, the minimum flow possible is actually about 0.1 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 and channel development conditions based on simulated hourly streamflows for Oak Creek at the 15th Avenue bridge for the 44 water years from 1940 through 1983. The hourly simulated flows, on which the Oak Creek flow duration relationship is based, range from a low of 0.1 cfs from industrial discharges to a high of 1,600 cfs on June 22, 1940. Since the flow duration curve is based on all hourly flows in the simulated period, it is an effective means of summarizing streamflow characteristics.

Flow duration curves are most frequently used as an aid in forecasting the availability of specified rates of flow. For example, the flow duration curve for Oak Creek at the 15th Avenue bridge indicates that an hourly flow of 5 cfs has been, and may be expected to be, exceeded 52 percent of the time under existing land use-floodland development conditions, whereas much higher hourly discharges of 47 cfs and 330 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 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 Oak Creek watershed planning program is directed primarily at 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 are not discussed in this report with the exception of a brief treatment of the potentiometric surface of deep and shallow aquifers.

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 Oak Creek watershed. Intergranular pore openings in rocks

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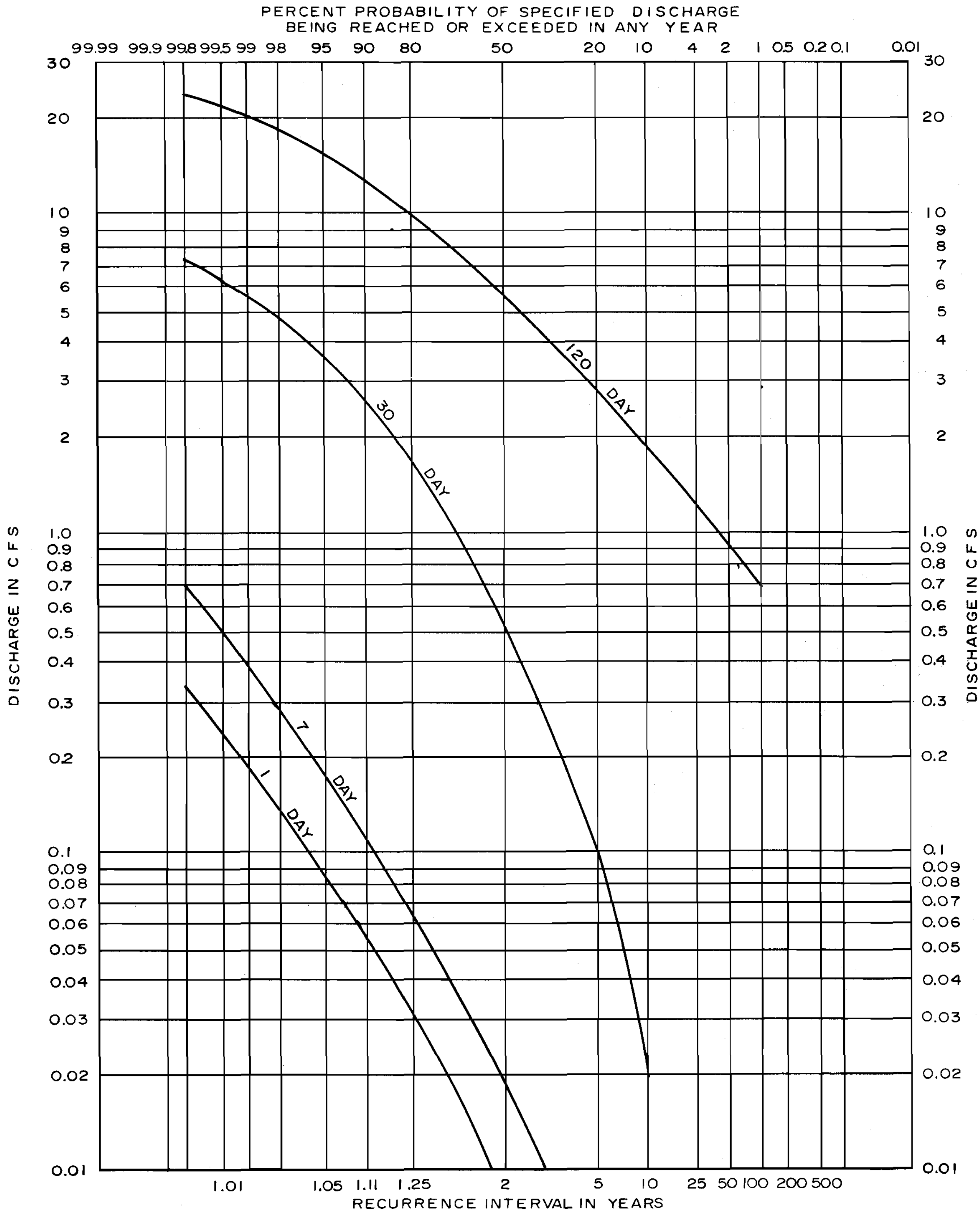
[4] *Figure 17 is based upon the results of the hydrologic-hydraulic simulation modeling. As noted in Chapter VIII of this report, flows from point sources of pollution were not included in the hydrologic-hydraulic simulation model since the amount of flow was considered insignificant with respect to major flood flows.*

[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 17

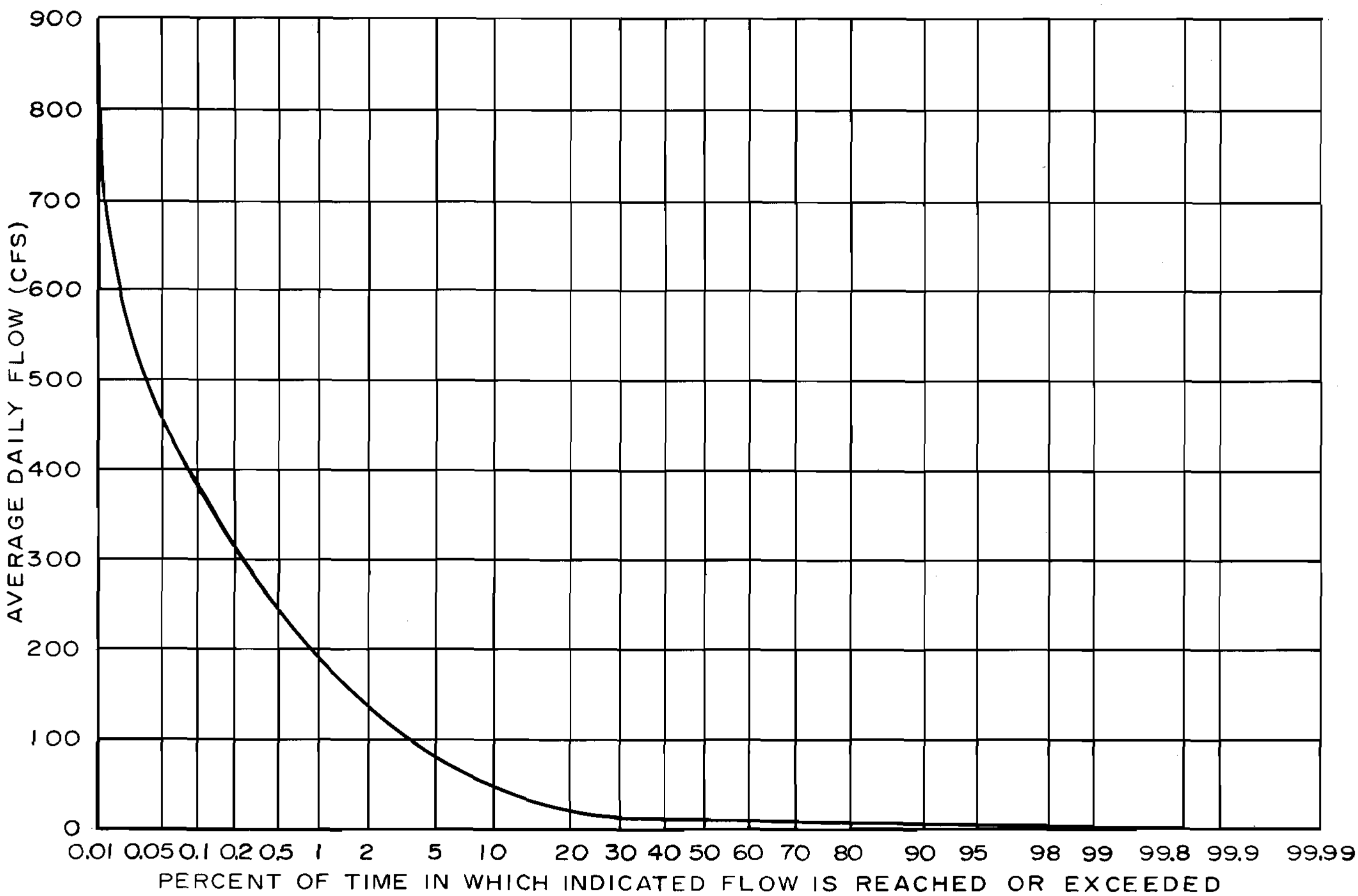
LOW-FLOW DISCHARGE FREQUENCY RELATIONSHIPS FOR OAK CREEK AT 15TH AVENUE (04087204): EXISTING LAND USE, CHANNEL, AND FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

Figure 18

FLOW DURATION RELATIONSHIPS FOR OAK CREEK IN SOUTH MILWAUKEE AT 15TH AVENUE (04087204): EXISTING LAND USE, CHANNEL, AND FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

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 fractures 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 Oak Creek 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 the 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 and from 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 materials.

Hydrologic Characteristics by Aquifer: There are three principal aquifers underlying the Oak Creek 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 15 of Chapter III. Hydrologic characteristics of each of the three principal aquifers are discussed below.

The Sandstone Aquifer: In the Oak Creek 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 destruction of the well by caving of the formation.

The surface of the sandstone aquifer is located approximately 600 to 700 feet beneath the ground surface of the Oak Creek watershed. The sandstone aquifer dips gently downward in an easterly direction at a slope of about 20 feet per mile (about 0.4 foot per 100 feet). The thickness of the sandstone aquifer beneath the watershed is known to exceed 1,100 feet. Assuming an average porosity of 15 percent, it is estimated that at least 3.1 million acre-feet of water are contained within that portion of the aquifer lying immediately beneath the Oak Creek watershed. This volume of water would be sufficient to cover the entire watershed to the depth of 180 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. Second, 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. Third, 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. The elevation of the potentiometric surface ranges from a high of between 450 and 480 feet above National Geodetic Vertical Datum (Mean Sea Level Datum).

The direction of groundwater movement in the sandstone aquifer is defined by the potentiometric surface of the aquifer. Groundwater in the sandstone aquifer beneath the Oak Creek watershed flows in a generally northerly direction toward the City of Milwaukee.

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 Oak Creek watershed in excess of 300 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 26 indicates the potentiometric surface for the combined dolomite aquifer and glacial deposits. 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 130 to 200 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.

<u>The Dolomite Aquifer</u>: The dolomite aquifer underlies the entire Oak Creek 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 it generally slopes downward from west to east. Further, there is a low-lying area underlying the southwestern portion of the watershed probably due to erosion prior to deposition of the overlying glacial till. The aquifer has a thickness of approximately 300 to 350 feet and dips gently downward in an easterly direction at about 20 feet per mile (about 0.4 foot per 100 feet). Recharge to the dolomite aquifer is primarily from infiltration of precipitation through overlying glacial deposits. The entire 300- to 350-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 285,000 acre-feet of water exist beneath the Oak Creek watershed in the dolomite aquifer. This quantity of water would be sufficient to cover the entire watershed to a depth of 16 feet.

The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 26, 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 westerly edge of the watershed to a low of about 580 feet near the watershed outlet at the confluence with Lake Michigan. Movement is down the hydraulic gradient toward Lake Michigan.

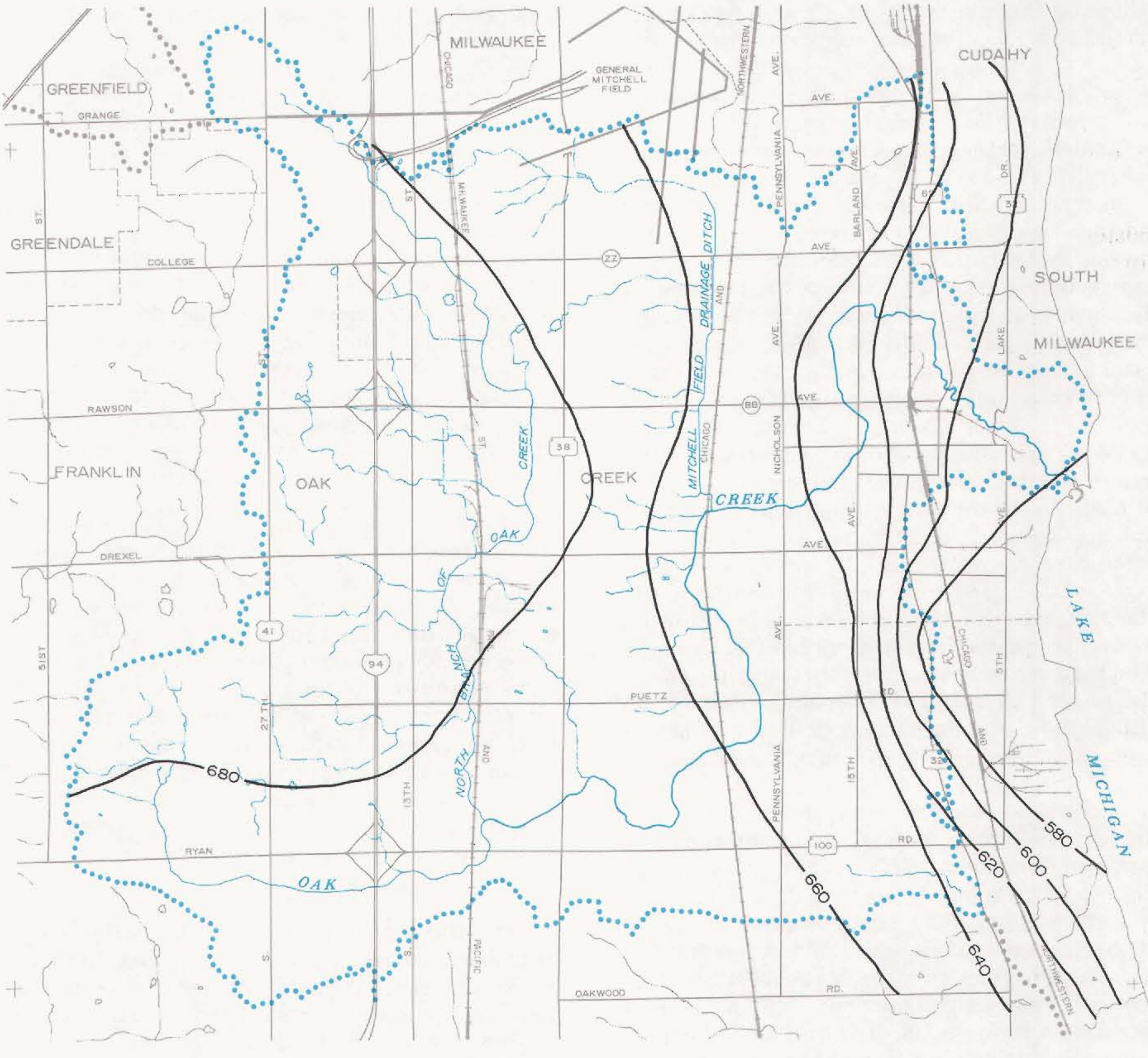
<u>The Sand and Gravel Aquifer</u>: The sand and gravel aquifer consists of stratified, unconsolidated glacial and alluvial sand and gravel deposits. As shown on Map 16 in Chapter III, the thickness of the unconsolidated deposits forming the sand and gravel aquifer varies from 20 to 300 feet in the Oak Creek watershed. The thickness of the zone of saturation, however, varies from about 130 to 10 feet, with an average value of about 80 feet. Assuming an average porosity of 30 per cent, about 420,000 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 about 25 feet.

Direct infiltration of precipitation is a major source of recharge to 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 toward streams and pumping areas. The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 26, 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

Map 26

GENERALIZED POTENTIOMETRIC SURFACE OF THE DOLOMITE AQUIFER AND GLACIAL DEPOSITS IN THE OAK CREEK WATERSHED



LEGEND

620 ELEVATION OF THE POTENTIOMETRIC SURFACE OF THE SHALLOW AQUIFER IN FEET ABOVE NATIONAL GEODETIC DATUM, CONTOUR INTERVAL 20 FEET

NOTE: THIS MAP WAS DEVELOPED USING WELL WATER LEVEL RECORDS FROM DIFFERENT YEARS AND SEASONS

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 toward 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.

U. S. Geological Survey and SEWRPC.

where the water table is shallow, by plant transpiration during growing seasons, and by filtration to the dolomite aquifer. Groundwater seepage into the surface water system, primarily from glacial deposits, is estimated to be 5.8 inches annually under existing land use-floodland development conditions.[6] This is approximately 87 percent of the total dry-weather flow of streams in the watershed; the remaining 0.9 inch, or 13 percent, comes from municipal and industrial point source discharges.

Map 27 shows the estimated depth to seasonal high water in the sand and gravel aquifer for the Oak Creek 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 was 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 36 percent of the watershed area. The seasonal high water may be expected to be between 10 and 30 feet beneath the land surface for 69 percent of the watershed area.

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 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 Oak Creek 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 Oak Creek watershed. Inasmuch as there are no major lakes in the Oak Creek 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 Man-Made Features and Natural Resource Base."

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 Oak Creek 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 intervals.

Selected Reaches: Stream reaches studied were selected by the Oak Creek Watershed Committee on the basis of historic and anticipated flooding problems as determined by deliberations with local officials and citizens of the watershed, by previous data availability, and by availability of funding.

It should be noted that the stream reaches selected for study are independent of the perennial or intermittent nature of the streams as defined on U. S. Geological Survey quadrangle maps. The perennial or intermittent classification of a stream, particularly in an urban area, was considered to be of no consequence since it 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.

Parts of six streams within the Oak Creek watershed were selected for hydrologic-hydraulic simulation leading to the development of detailed flood hazard information. Factors included discharge-frequency relationships under existing and probable future development of floodland and nonfloodland areas as well as corresponding flood stage profiles and areas of inundation. These streams are shown on Map 28 and consist of: 1) the main stem of Oak Creek in the Cities of Franklin, Oak Creek, and South Milwaukee; 2) the North Branch of Oak Creek in the Cities of Milwaukee and Oak Creek;

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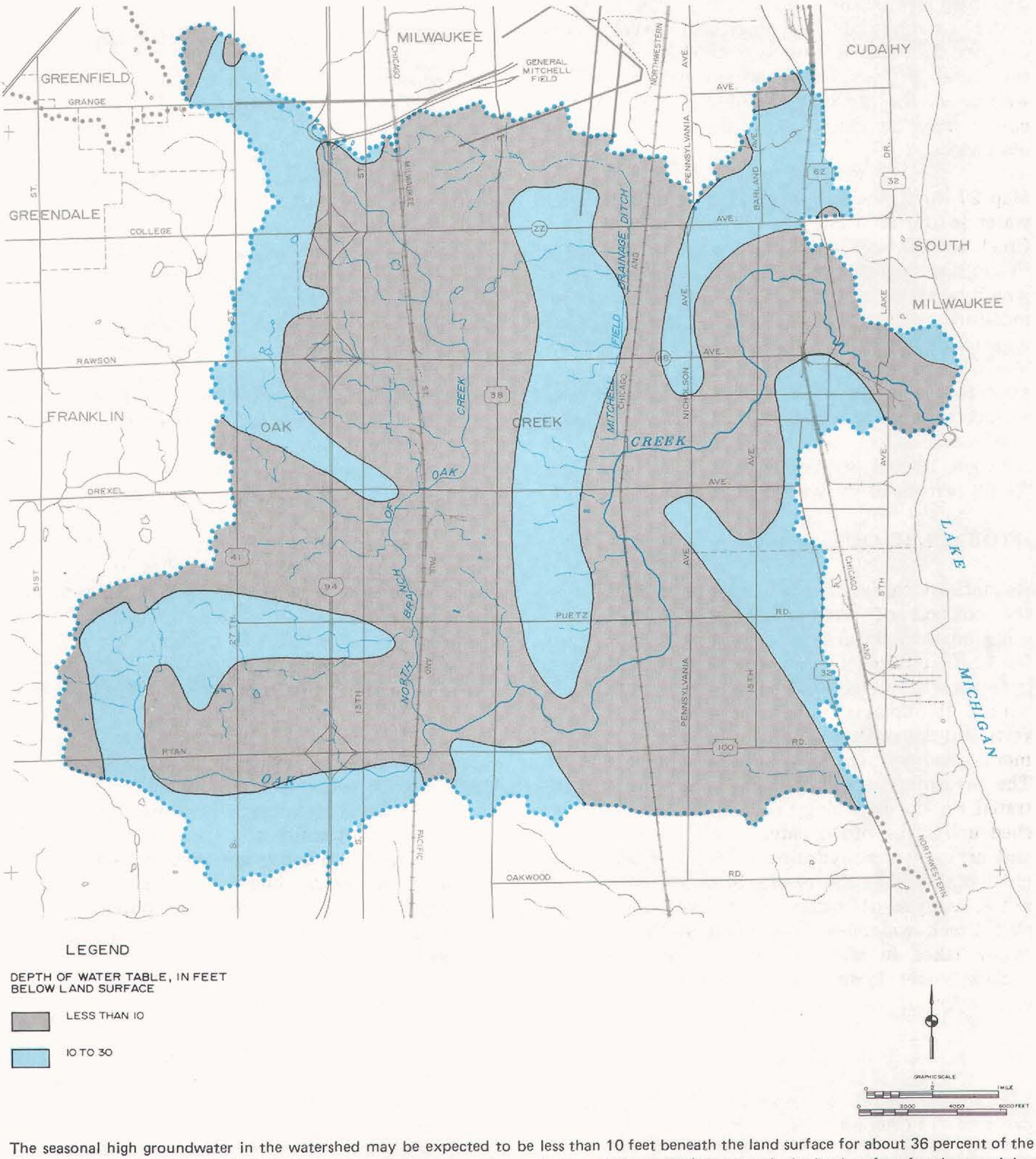
[6] *Determined using the hydrologic-hydraulic model described in Chapter VIII.*

[7] *Map 27 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 27

SEASONAL HIGH GROUNDWATER IN THE OAK CREEK WATERSHED

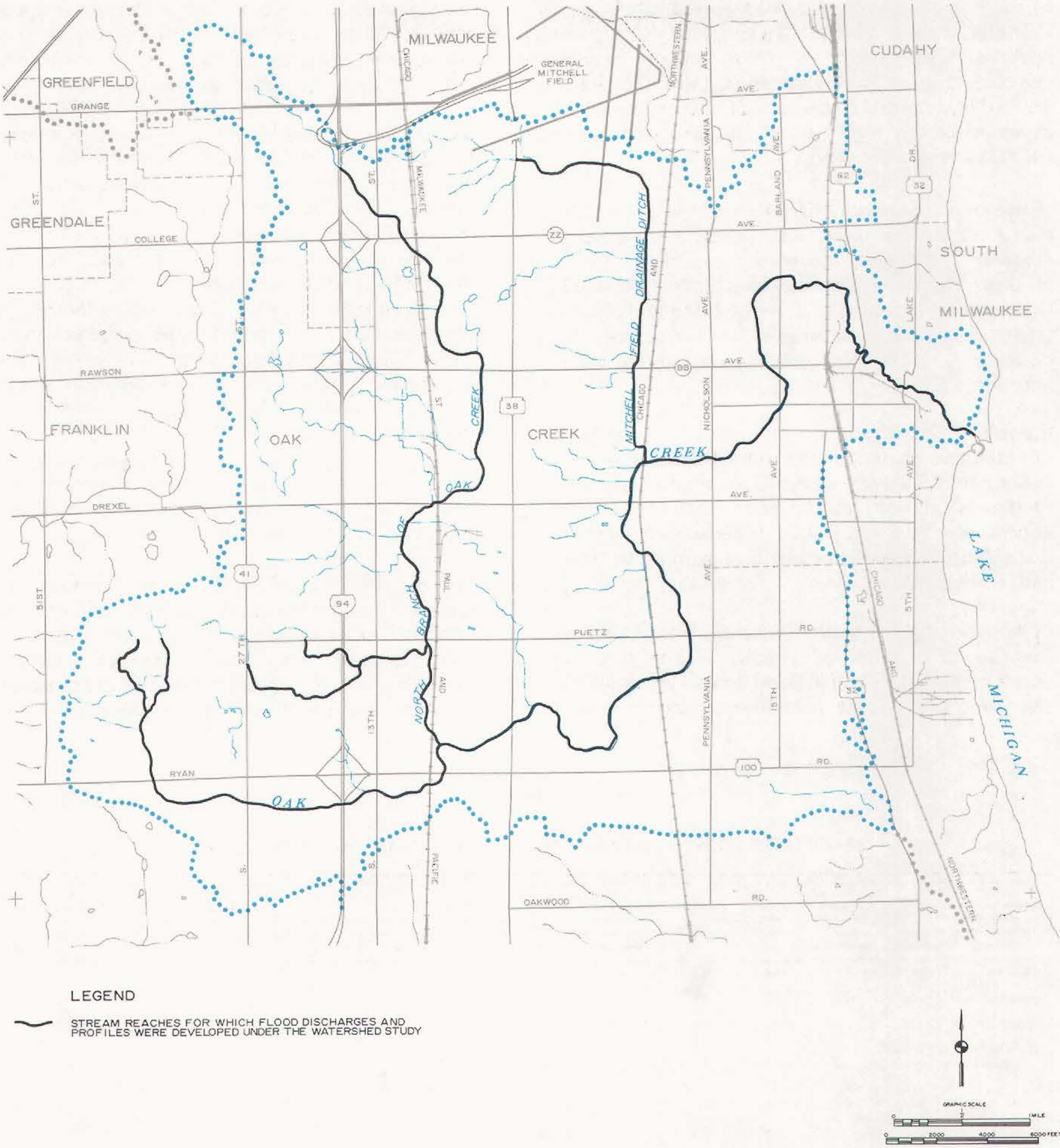


The seasonal high groundwater in the watershed may be expected to be less than 10 feet beneath the land surface for about 36 percent of the watershed area. The seasonal high groundwater may be expected to be between 10 and 30 feet beneath the land surface for the remaining 64 percent of the watershed area. As would be expected, seasonal high groundwater is closest to the land surface in topographically low areas, such as those along Oak Creek and its major tributaries.

Source: U. S. Geological Survey and SEWRPC.

Map 28

STREAM REACHES IN THE OAK CREEK WATERSHED SELECTED FOR PREPARATION OF FLOOD HAZARD INFORMATION



A total 26 miles of stream in the Oak Creek watershed were selected for development of detailed flood hazard information. A detailed inventory was conducted of the 26 miles to determine the storage and conveyance characteristics of the floodlands and the hydraulic capacity of all bridges, culverts, dams, and drop structures.

Source: SEWRPC.

3) the Mitchell Field Drainage Ditch in the Cities of Milwaukee and Oak Creek; 4) Southland Creek in the City of Oak Creek; 5) the tributary to Southland Creek in the City of Oak Creek; and 6) the tributary to Upper Oak Creek in the City of Franklin. Tables 30 and 31, and Map 31 present selected information on these stream reaches and the tributary drainage areas. As indicated in Table 30, detailed flood hazard information was developed for a total of 26.0 miles of streams in the Oak Creek watershed.

Subsequent to the identification of the above 26.0 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 sills.

Floodland Characteristics: Included in the category of floodland characteristics are the magnitude and variation of channel slope, floodplain 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 26.0 miles of 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, determined from SEWRPC structure drawings; field surveyed channel cross sections; and stream channel contour crossings shown on the large-scale topographic mapping of the watershed. All of these data were collected and collated as part of the watershed hydraulic structure inventory.

Channel slopes are irregular, with the steepest slopes being on the Upper Oak Creek and generally flatter slopes on the Middle Oak Creek, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch. The slopes on the Lower Oak Creek are generally steep from the Lake Michigan shoreline to the Chicago & North Western Railway right of way, and then are generally flatter. All other hydraulic factors being equal or similar, steep channel slopes result in high streamflow velocities and shorter runoff times, whereas flat slopes produce lower velocities and longer runoff times. Channel slopes in the Oak Creek, North Branch of Oak Creek, and the Mitchell Field Drainage Ditch range from 4.1 to 19.2 feet per mile, whereas much steeper slopes occur in the smaller tributaries, ranging from 25.4 to 37.1 feet per mile.

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 at points between

Table 30

SELECTED HYDRAULIC DATA FOR THE OAK CREEK WATERSHED: 1984

Stream Reach for Which Flood Stage Profiles Were Developed	Length (miles)	Elevation Difference in Feet from Mouth to Upstream End	Stream Slope (feet/mile)	Bridges and Culverts			Dams and Sills			All Structures		Major Channel Modifications		
				Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Miles	Percent
Lower Oak Creek	5.14	74.6	14.5	16	5	21	2	--	2	18	5	23	2.54	49
Middle Oak Creek	4.66	19.2	4.1	10	--	10	--	--	--	10	--	10	0.76	16
Upper Oak Creek	4.02	77.4	19.2	20	2	22	4	--	4	24	2	26	2.09	52
Mitchell Field Drainage Ditch	3.31	35.6	10.8	9	--	9	--	--	--	9	--	9	3.31	100
North Branch of Oak Creek	5.82	62.8	10.8	21	1	22	2	--	2	23	1	24	3.37	58
Southland Creek	1.77	45.0	25.4	8	--	8	--	--	--	8	--	8	0.13	7
Tributary to Southland Creek	0.73	21.9	30.0	1	--	1	--	--	--	1	--	1	--	--
Tributary to Upper Oak Creek	0.55	20.4	37.1	8	--	8	--	--	--	8	--	8	--	--
Total	26.00	--	--	93	8	101	8	--	8	101	8	109	12.20	47

Source: SEWRPC.

Table 31

SELECTED HYDROLOGICAL DATA FOR THE OAK CREEK WATERSHED: 1980

Subwatershed		Area			Total Area Tributary To Downstream-Most Point		Subbasins				1980 Rural Land Use					
											Woodlands, Wetlands and Surface Water		Agricultural and Other Open Lands		Total Rural	
Number	Name	Acres (1980)	Square Miles (1980)	Percent of Watershed	Acres	Square Miles	Number	Largest (square miles)	Smallest (square miles)	Mean Area (square miles)	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed
1	Lower Oak Creek	3,219.98	5.031	18.0	17,436.24	27.242	5	1.58	0.62	1.01	194.97	6.1	692.09	21.5	887.06	27.6
2	Middle Oak Creek	4,183.57	6.537	24.0	11,767.12	18.385	4	2.80	0.74	1.63	640.03	15.3	2,299.32	55.0	2,939.35	70.3
3	Upper Oak Creek	2,433.23	3.801	14.0	2,433.23	3.801	4	1.39	0.71	0.95	136.80	5.6	1,333.71	54.8	1,470.51	60.4
4	North Branch Oak Creek	5,150.32	8.047	30.0	5,150.32	8.047	7	2.30	0.35	1.15	406.77	7.9	2,398.96	46.6	2,805.73	54.5
5	Mitchell Field Drainage Ditch	2,449.14	3.826	14.0	2,449.14	3.826	4	1.28	0.72	0.96	89.23	3.6	1,082.88	44.2	1,172.11	47.9
Total		17,436.24	27.24	100.0	17,436.24	27.24	24	2.80	0.35	1.14	1,467.80	8.4	7,806.96	44.8	9,274.76	53.2

Subwatershed		1980 Urban Land Use													
		Residential		Retail and Service		Industrial		Transportation, Communication and Utility Facilities		Governmental and Institutional		Recreational		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	Lower Oak Creek	1,146.45	35.6	59.51	1.8	110.85	3.4	596.54	18.5	151.62	4.7	267.95	8.3	2,332.92	72.5
2	Middle Oak Creek	589.67	14.1	19.74	0.5	12.64	0.3	389.15	9.3	104.38	2.5	128.64	3.1	1,244.22	29.7
3	Upper Oak Creek	559.39	23.0	27.85	1.1	13.50	0.6	316.85	13.0	5.48	0.2	39.65	1.6	962.72	39.6
4	North Branch Oak Creek	941.79	18.3	76.56	1.5	268.01	5.2	980.00	19.0	51.68	1.0	26.55	0.5	2,344.59	45.5
5	Mitchell Field Drainage Ditch	242.72	9.9	28.09	1.1	73.45	3.0	805.69	32.9	124.57	5.1	2.51	0.1	1,277.03	52.1
Total		3,480.02	20.0	211.75	1.2	478.45	2.7	3,088.23	17.7	437.73	2.5	465.30	2.7	8,161.48	46.8

Source: SEWRPC.

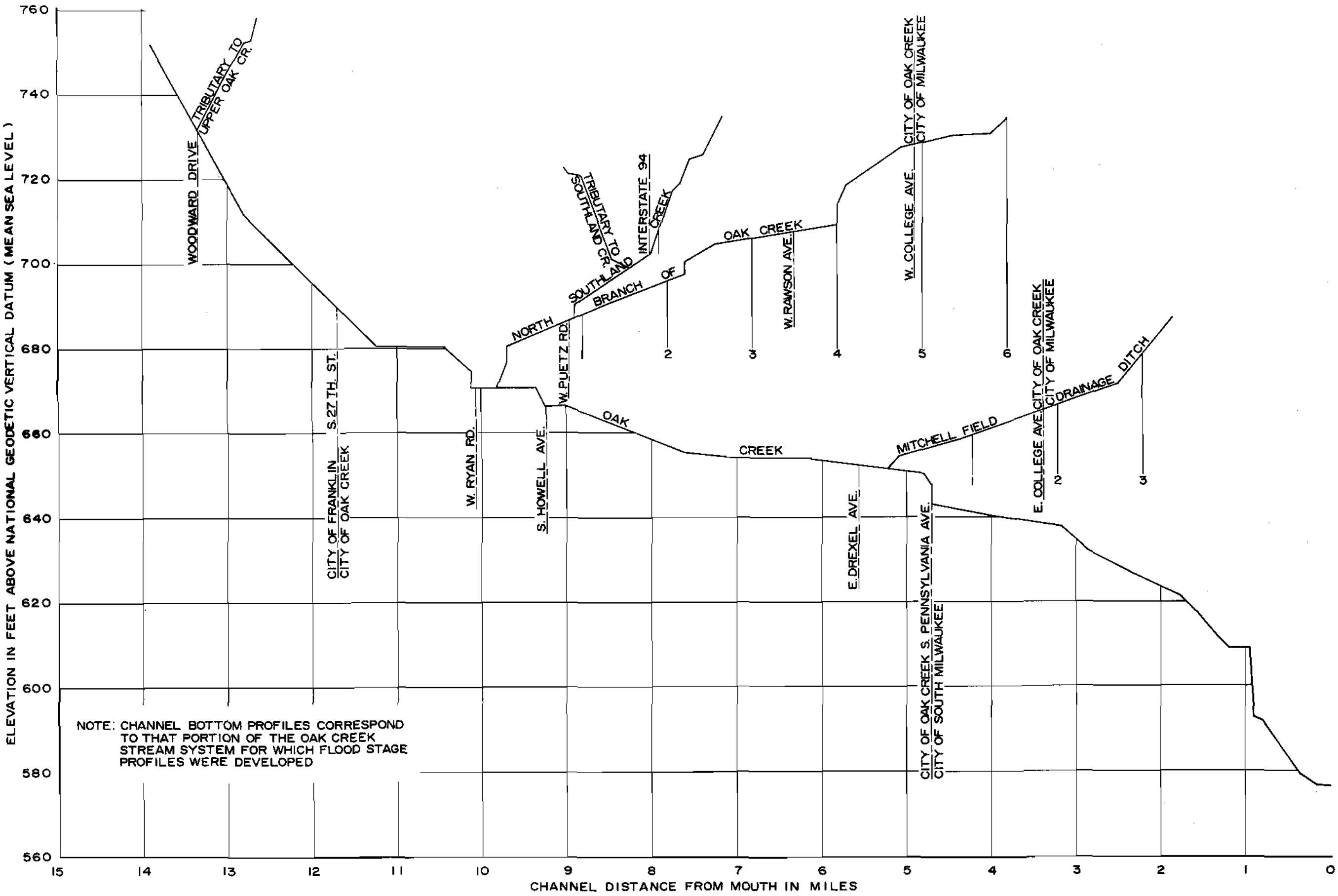
the bridges, culverts, dams, and sills at which channel bottom elevations were not determined by field surveys. Channel bottom elevations for these intermediate locations—as obtained from the channel bottom profiles and in some cases field-surveyed channel cross sections—were required for the development of floodland cross sections as discussed below. This procedure was used on all the streams studied under the Oak Creek 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 extent of lateral inundation for a given flood discharge. Approximately 534 floodland cross sections at an average spacing of 260 feet were developed for the 26.0 miles of stream studied in the Oak Creek watershed 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, since the latter are intended to represent the configuration of the riverine area near and around the structures. 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 numeric 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 the available large-scale topographic maps and field-surveyed cross sections obtained under the watershed study. Channel bottom elevations for some cross sections were obtained from the channel profiles prepared under the study. Map 29 indicates the primary source of floodland cross-section data by river reach throughout the 26.0 miles of stream for which

Figure 19

CHANNEL BOTTOM PROFILES FOR OAK CREEK AND SELECTED TRIBUTARIES



Source: SEWRPC.

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.

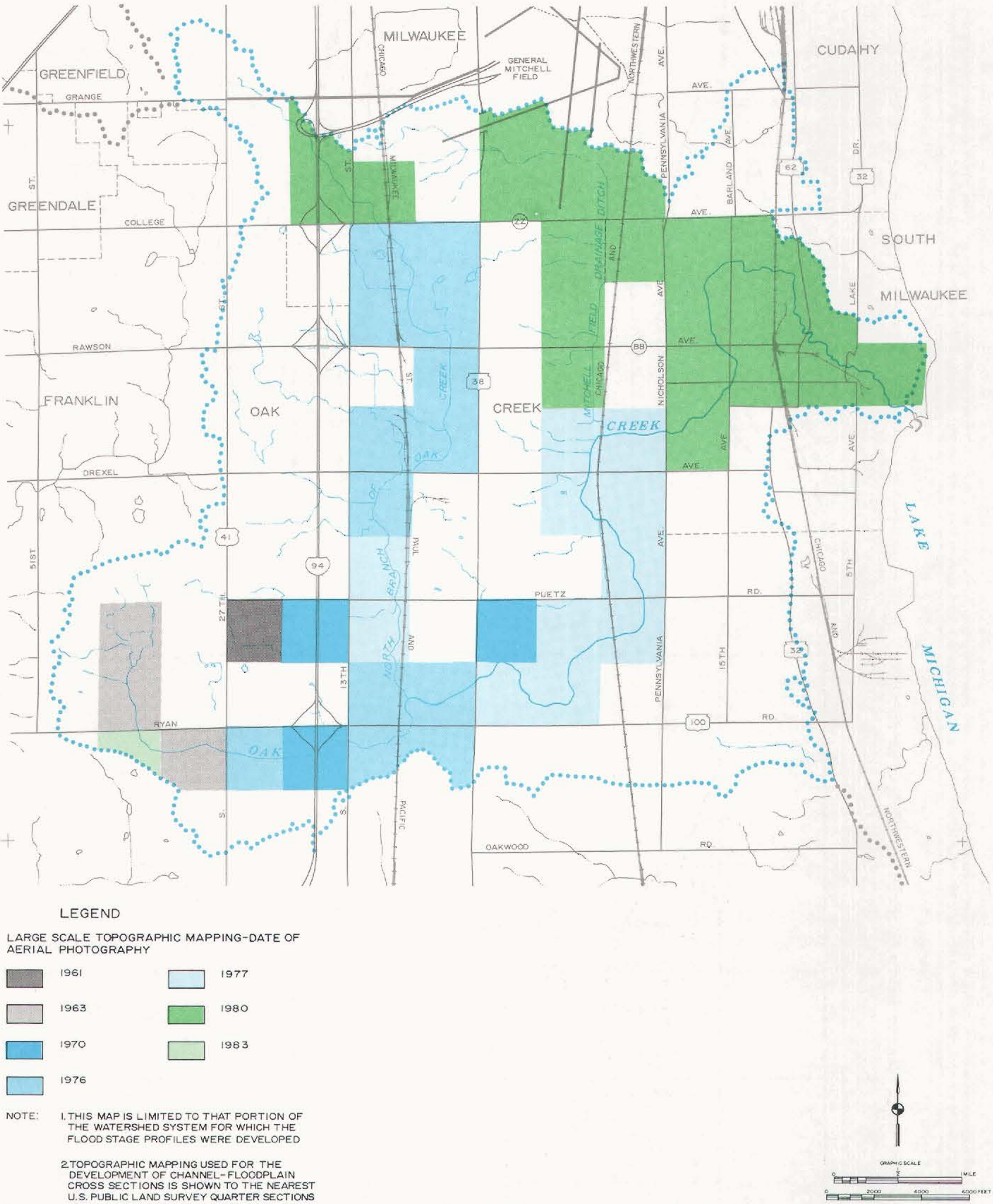
Numerous factors were considered in the selection of the location, length, and orientation of the floodland cross sections. These factors included nonhydraulic plan preparation and implementation as well as strictly hydraulic considerations.

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 abrupt changes in cross-sectional area or shape of the channel, or abrupt changes in natural floodplain roughness, and 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, which was done 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.

Map 29

SOURCES OF CROSS SECTION DATA FOR CHANNEL AND FLOODPLAIN IN THE OAK CREEK WATERSHED

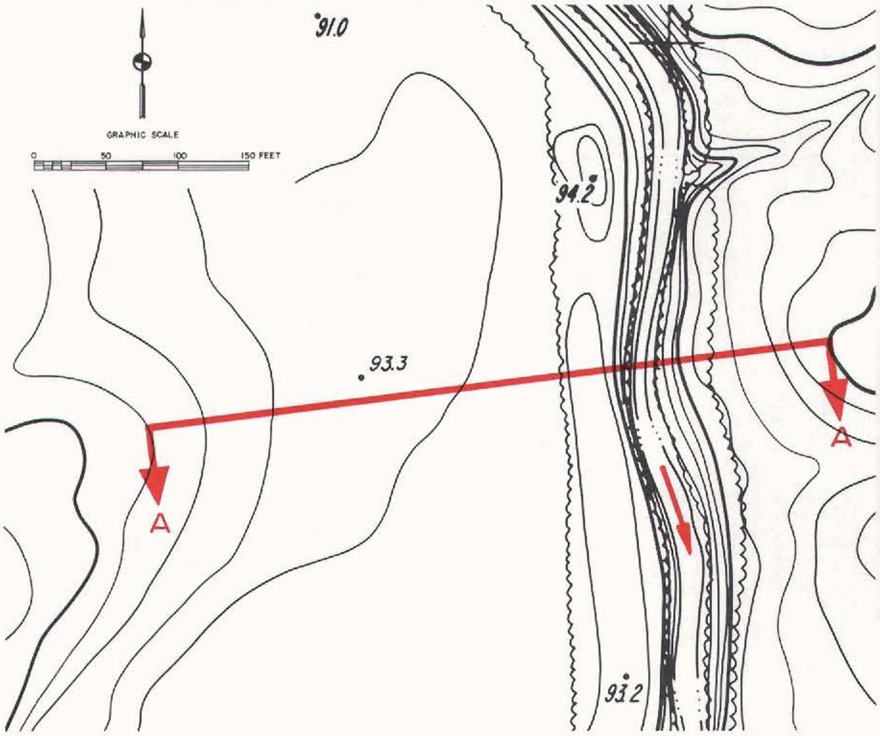


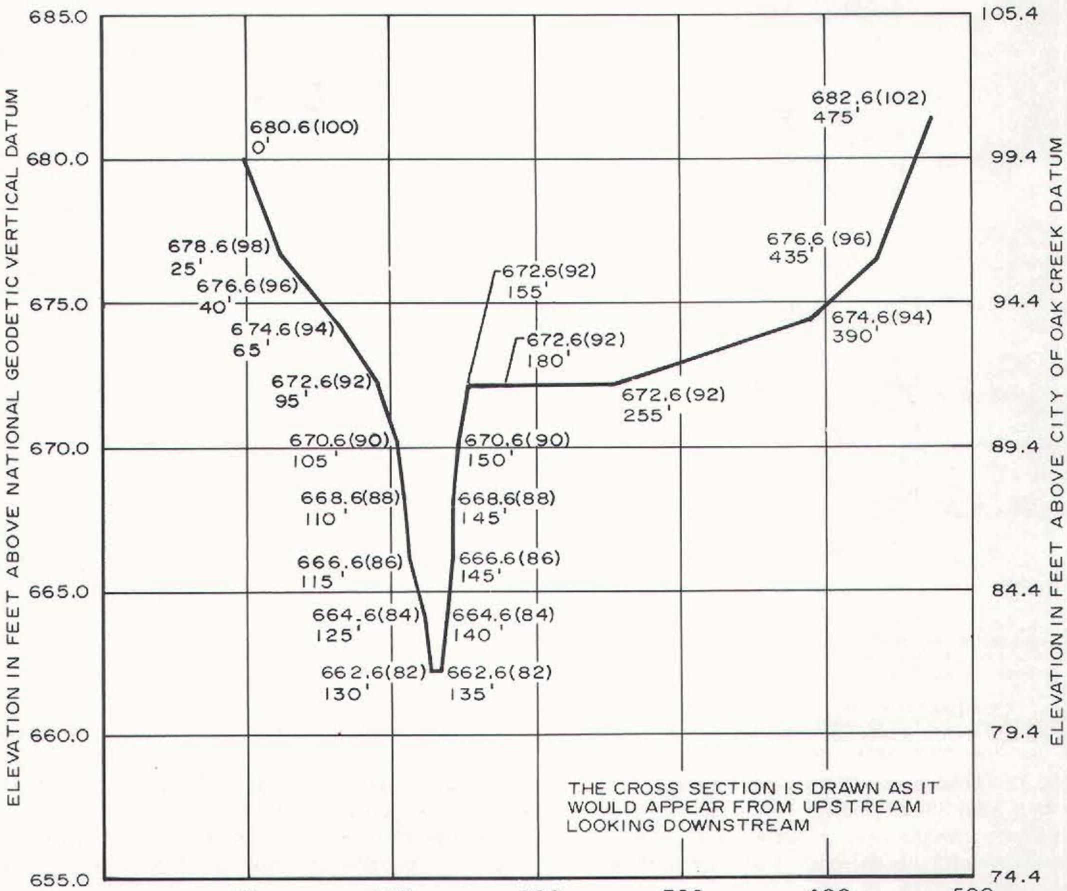
Approximately 530 floodland cross-sections at an average spacing of 260 feet were developed for the 26 miles of stream modeled under the Oak Creek watershed study. The floodland cross-sections were developed from the several sources shown above, which include large-scale topographic maps of the riverine areas. Floodland cross-sections are used to determine the hydraulic characteristics of the stream channel and floodplains, characteristics that determine flood stage and the extent of lateral inundation for a given flood discharge.

Source: SEWRPC.

Figure 20

TYPICAL CROSS SECTION OF CHANNEL AND FLOODPLAIN IN THE OAK CREEK WATERSHED





Source: SEWRPC.

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 sections 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. Thus, the carrying capacity of the channel and its floodplain diminishes as the value of the roughness coefficient increases. 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 floodplains; and the sinuosity or degree of meandering of the channel.

Floodland Manning roughness coefficients were assigned on the basis of field examination of the 26.0 miles of stream in the watershed for which detailed flood hazard information was to be developed. Values were estimated on the basis of the various factors summarized in Table 32, 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 hydrologichydraulic model used in the watershed planning program.

Channel Modifications: Channel modifications—or channelization, as it is commonly termed—usually include one or more of the following changes to the natural stream channel: channel straightening; channel deepening with ensuing lowering of the channel profile; channel widening; placement of a concrete invert and sidewalls; removal of dams, sills, or other obstructions to flow; 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, which 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 decreased floodplain storage and 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.

Channelization is also employed with artificial subsurface drainage for agricultural drainage purposes to lower high groundwater tables beneath fields near streams to improve soil moisture conditions for crops and for the operation of farm machinery. Such channelization may also be beneficial for flood control purposes because of the increase in channel size attendant to channel deepening. However, channelization for agricultural drainage purposes, as for urban drainage purposes, can cause increased flood flows and stages in downstream reaches.

A large portion of the stream system of the Oak Creek watershed has been intentionally modified for flood control and agricultural drainage purposes. Of the 26.0 miles of stream system in the watershed selected for development of detailed flood hazard data, about 12.2 miles, or 47 percent, are known to have undergone some type of major man-made channel modification. The channel modifications, for the most part, have been made over a long period of time, presumably by numerous public and private parties, and consequently adequate records are not available to identify all of the stream reaches so modified.

Artificial Subsurface Drainage: Artificial subsurface drainage is a factor primarily affecting the low-flow regimen of a watershed and is often closely associated with channel improvement. Large portions of the Oak Creek watershed have such poor surface drainage under natural conditions that it has been deemed necessary to install tile underdrains to permit efficient agricultural operations. Because of the individual manner in which, and the long period of time over which, such drainage improvements have been installed, it is not possible to determine precisely the total tile-drained area. Tile outfalls observed at numerous locations in the watershed indicate that artificial subsurface drainage of agricultural lands is widespread in the basin. Tile-drained areas are often, though not always, associated with channel improvement. This is because straightening and

Table 32

MANNING ROUGHNESS COEFFICIENTS APPLIED TO THE CHANNEL AND FLOODPLAINS OF THE OAK CREEK WATERSHED

Channel Condition			Roughness Coefficient Component[a]	Floodplain Condition		Roughness Coefficient Minimum	Roughness Coefficient Normal	Roughness Coefficient Maximum
Material Involved	Concrete		0.013					
	Earth		0.020	Pasture	Short grass	0.025	0.030	0.035
	Rock cut		0.025		High grass	0.030	0.035	0.050
	Fine gravel	n_1	0.024	Cultivated Areas	No Crop	0.020	0.030	0.040
	Coarse gravel		0.028		Mature row crops	0.025	0.035	0.045
Degree of Irregularity	Smooth		0.000		Mature field crops	0.030	0.040	0.050
	Minor		0.005	Brush	Scattered brush, heavy weeds	0.035	0.050	0.070
	Moderate	n_2	0.010		Light brush and trees, in winter	0.035	0.050	0.060
	Severe		0.020		Light brush and trees, in summer	0.040	0.060	0.080
Relative Effect of Obstructions	Negligible		0.000		Medium to dense brush, in winter	0.045	0.070	0.110
	Minor		0.010-0.015		Medium to dense brush, in summer	0.070	0.100	0.160
	Appreciable	n_3	0.020-0.030	Trees	Dense willows, summer, straight	0.110	0.150	0.200
	Severe		0.040-0.060		Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
Vegetation	Low		0.005-0.010					
	Medium		0.010-0.025		Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
	High	n_4	0.025-0.050		Heavy stand of timber a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
	Very high		0.050-0.100					
Degree of Meandering	Minor		1.000		Same as above, but with flood stage reaching branches	0.100	0.120	0.160
	Appreciable	k	1.150					
	Severe		1.300					

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

Source: V. T. Chow, Open Channel Hydraulics, (New York: McGraw-Hill, 1959), Chapter 5.

deepening of natural channels is often required to provide adequate outlets for the agricultural drain tiles.

The effect of artificial drainage on the flow regimen of a watershed is particularly difficult to analyze, because the effect of the drainage is not to reduce the surface water storage, but rather to increase the capacity for temporary soil water storage during the growing season. The net result may generally be expected to increase the total volume of streamflow due to a reduction of evapotranspiration losses. In the spring, when ice and snow conditions cause blocking of the drainage courses, there is probably little overall effect on natural flow conditions. During the frost-free months, however, when tile underdrains are fully operable, it is probable that areas that have been tiled to eliminate poor surface drainage, or to lower a high groundwater table, will exhibit a decrease in peak surface runoff due to the increased storage made available in the dewatered soil profile, but will result in the ultimate release of a greater volume of flow. However, for the more infrequent, high-intensity, short-duration rainfall events during which soil infiltration capacity is the limiting factor, it is doubtful that tiling in the Oak Creek watershed has a significant influence on peak rates of runoff.

Map 30 shows the lineal extent of known man-made channel modifications within the Oak Creek watershed on the stream system selected for development of detailed flood hazard data. The following two types of channelization were observed in the Oak Creek watershed:

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.

2. Major channelization: Continuous and extensive deepening, widening, and straightening, possibly with major relocations. Extensive application of concrete or masonry to channel bottom and/or side slopes and walls. Channel modifications are readily apparent to the casual observer.

The 26.0 miles of the watershed stream system selected for hydrologic-hydraulic simulation contain, as shown in Table 30, about 12.2 miles of known major channel modifications, or about 47 percent of the stream system selected for development of detailed flood hazard data. It is difficult to identify with certainty all of those stream reaches in the minor channelization category since various degrees of channel modifications are located throughout the Oak Creek watershed, which suggests that widespread mitigation of flood damage to riverine area agricultural and urban development along with agricultural subsurface drainage have been the primary motivations for channel modifications in the Oak Creek 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, generally 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.

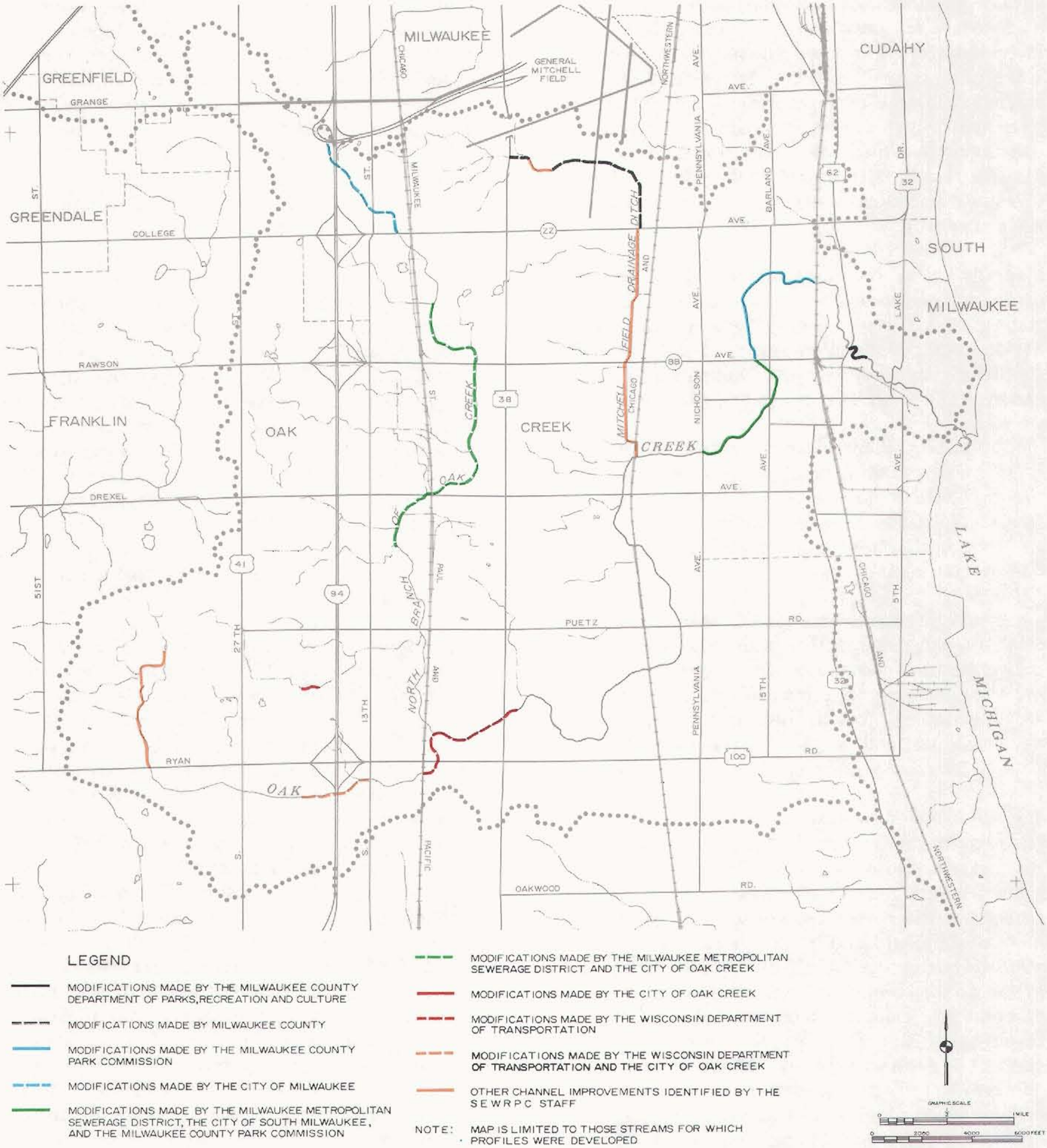
The effects of channel improvement projects are the reverse of the effect of other structural flood control measures, such as reservoirs, which are designed to impede flow, decrease velocity, and cause backwater effects. Channel improvements accelerate flow, increase velocity, and reduce upstream backwater 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 rates 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 improvement of the floodwater 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 Oak Creek 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 historic data are lacking, it is not possible to make a meaningful quantitative evaluation of the overall effect which the existing channel improvement projects have had on the history of the flow regimen of the stream system of the watershed.

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, particu-

Map 30

CHANNEL MODIFICATIONS IN THE OAK CREEK WATERSHED



A large portion of the stream system of the Oak Creek watershed has been intentionally modified for flood control and agricultural drainage purposes. For example, of the 26 miles of stream system in the watershed selected for development of detailed flood hazard information, about 12.2 miles, or 47 percent, have undergone some type of man-made channel modification. Most of the streams selected for development of flood hazard data have experienced various degrees of channel modification.

Source: SEWRPC.

larly with respect to localized effects. The constriction caused by an inadequately designed bridge or culvert under flood discharge conditions can result 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 1983, the 26.0 lineal miles of Oak Creek watershed stream system selected for hydrologic-hydraulic modeling were crossed, as shown on Map 31, by 101 bridges and culverts having an average spacing of 0.25 mile. While the hydraulic submodel of the hydrologic-hydraulic simulation model, as described in Chapter VIII, has the capability of accommodating any number or type of bridges or culverts, 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 increase flood stages 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 railway approaches as well as the 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 compared 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. Two examples of this type of hydraulically insignificant structure are shown in Figure 21.

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 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. No examples of this type of hydraulically insignificant structure were found in the Oak Creek watershed.

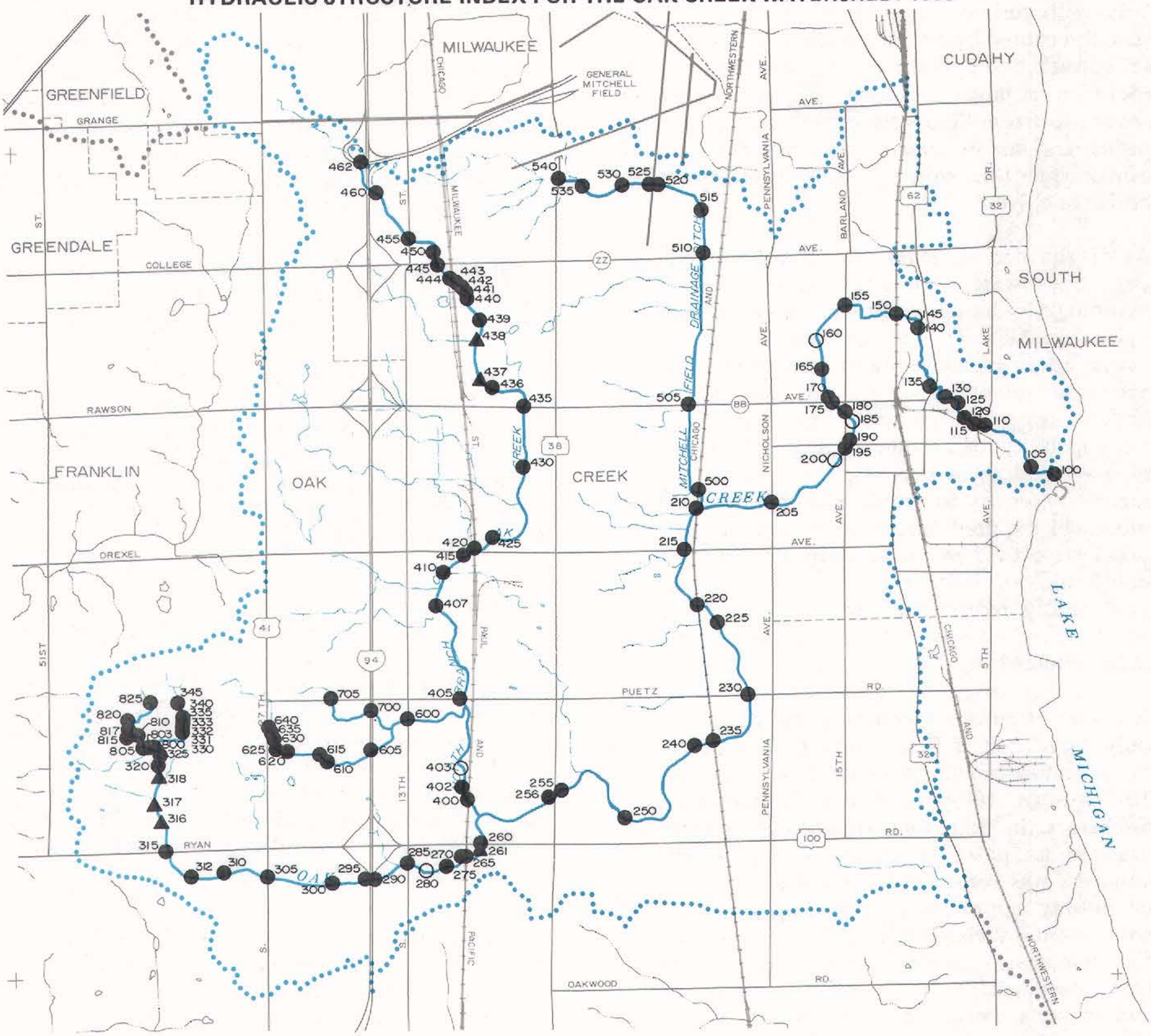
Hydraulically significant bridges and culverts generally are characterized by relatively small waterway openings in combination with approaches that are constructed well above the elevation of the floodplain. Such structures function as dams and have the potential for obstructing streamflow during major flood events. As shown in Figure 22, examples of hydraulically significant structures include the Forest Hill Avenue and Chicago, Milwaukee, St. Paul & Pacific Railroad crossings of the Oak Creek main stem.

Based on field reconnaissance, 93, or 92 percent, of the 101 bridges or culverts on that portion of the Oak Creek 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 31 and the number of structures on each of the selected stream reaches is set forth in Table 30. The average spacing of these hydraulically significant structures is 0.28 mile.

To meet the input data needs of the hydraulic submodel, it was necessary to obtain detailed data on these 93 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 93 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 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

Map 31

HYDRAULIC STRUCTURE INDEX FOR THE OAK CREEK WATERSHED: 1983



LEGEND

BRIDGES AND CULVERTS

● INVENTORIED UNDER THE WATERSHED STUDY AND EXPLICITLY INCLUDED IN HYDROLOGIC-HYDRAULIC SIMULATION

○ INVENTORIED UNDER THE WATERSHED STUDY BUT EXCLUDED FROM THE HYDROLOGIC-HYDRAULIC SIMULATION BECAUSE IT IS HYDRAULICALLY INSIGNIFICANT

DAMS AND SILLS

▲ INVENTORIED UNDER THE WATERSHED STUDY AND EXPLICITLY INCLUDED IN HYDROLOGIC-HYDRAULIC SIMULATION

STRUCTURE NUMBER

314

REACHES SELECTED FOR DEVELOPMENT OF FLOOD STAGE PROFILES

NOTE: THIS MAP IS LIMITED TO HYDRAULIC STRUCTURES ON THOSE PORTIONS OF THE WATERSHED STREAM SYSTEM FOR WHICH FLOOD STAGE PROFILES WERE DEVELOPED

GRAPHIC SCALE

0 1 MILE

0 2000 4000 6000 FEET

One dam, seven sills, and 101 bridges and culverts were inventoried during the course of the Oak Creek watershed study. Data obtained from this inventory were used to identify those sills, control 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, 93 bridges and culverts, one dam, and seven sills were identified for later incorporation into the water resources simulation model, as described in Chapter VIII.

Source: SEWRPC.

Figure 21

EXAMPLES OF HYDRAULICALLY INSIGNIFICANT RIVER CROSSINGS IN THE OAK CREEK WATERSHED

FOOTBRIDGE OVER OAK CREEK

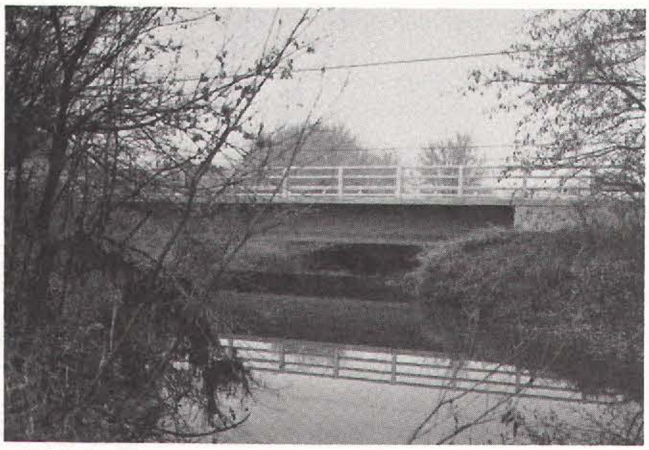
Source: SEWRPC.

FOOTBRIDGE OVER THE NORTH BRANCH OF OAK CREEK

Source: SEWRPC.

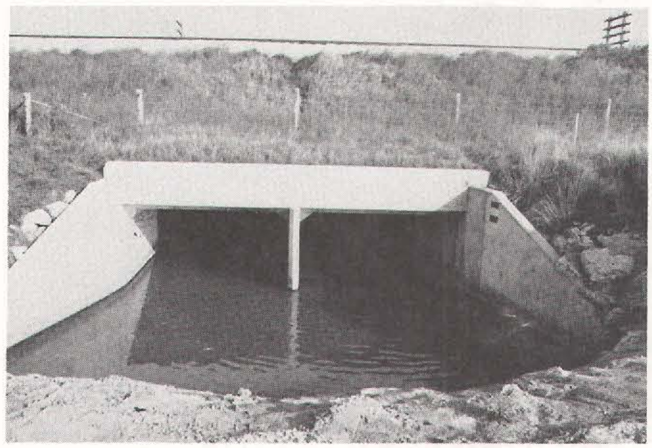
Figure 22

EXAMPLES OF HYDRAULICALLY SIGNIFICANT RIVER CROSSINGS IN THE OAK CREEK WATERSHED



FOREST HILL AVENUE CROSSING OF OAK CREEK

Source: SEWRPC.



CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD CROSSING OF OAK CREEK

Source: SEWRPC.

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 93 hydraulically significant bridges and culverts, which, in addition to providing information about the waterway opening, facilitated the drawing of channel bottom profiles.

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 Oak Creek watershed.

Dams and Sills: In addition to the 101 bridges and culverts located on that portion of the Oak Creek watershed stream system selected for development of detailed flood hazard information, there is one dam and seven dam-like structures, herein called sills, for a total of 109 hydraulic control structures. The dam is on Oak Creek in the Oak Creek Parkway and is used to control the pool level in a pond upstream.

The sills, four of which are located on Upper Oak Creek, two on the North Branch of Oak Creek, and one on Lower Oak Creek, and the dam were determined by field examination to be hydraulically significant using criteria similar to those applied to bridges and culverts. The locations of the dam and the sills are shown on Map 31. Of the

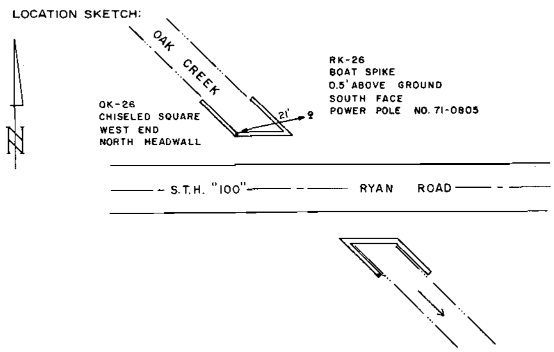
Figure 23

TYPICAL RECORD OF A VERTICAL CONTROL STATION ALONG THE OAK CREEK WATERSHED STREAM SYSTEM: 1983

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
RECORD OF VERTICAL CONTROL STATION
OAK CREEK WATERSHED PLANNING PROGRAM

SECTION 24 T 5 N, R 21 E, MILWAUKEE COUNTY, WISCONSIN
BENCH MARK NO. OK-26 ELEVATION 714.090'
REFERENCE BENCH MARK NO. RK-26 ELEVATION 712.163'
VERTICAL DATUM: MEAN SEA LEVEL, 1929 ADJUSTMENT
VERTICAL CONTROL ACCURACY: SECOND ORDER STRUCTURE NO. 315

LOCATION SKETCH:



DETAILED DESCRIPTION: ABOUT 0.2 MILE WEST OF THE SOUTH 1/4 CORNER OF SECTION 24,T5N,R21E, ABOUT 0.7 MILE WEST OF SOUTH 27TH STREET(U.S.H. "41").

DATE OF SURVEY: DECEMBER 1983 S - REGISTERED LAND SURVEYOR

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Source: SEWRPC.

109 hydraulic structures located on the stream system, a total of 101, or about 93 percent, were determined to be hydraulically significant.

The vertical survey control network discussed above was extended to the hydraulically significant dam and sills, and channel bottom elevations were determined at each structure. Detailed information on the physical characteristics of the dam and sills was obtained by field survey. Cross section drawings were prepared for the dam and the sills prior to coding the data for use in the hydrologic-hydraulic modeling.

SUBWATERSHEDS AND SUBBASINS IN THE OAK CREEK 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 30 and 31, respectively, and subwatershed and subbasin areas are set forth in Table 33.

Subwatersheds

The Oak Creek watershed may be considered to be a composite of five subwatersheds, as shown on Map 32, each of which is defined as the area directly tributary to all or portions of the six stream reaches selected for application of hydrologic-hydraulic simulation culminating in the development of detailed flood hazard data. These subwatersheds are: 1) the Upper Oak Creek subwatershed, which encompasses 3.801 square miles, or 14.0 percent of the total watershed area; 2) the North Branch of Oak Creek subwatershed, which encompasses 8.047 square miles, or 29.5 percent of the total watershed area; 3) the Middle Oak Creek subwatershed, which encompasses 6.537 square miles, or 24.0 percent of the total watershed area; 4) the Mitchell Field Drainage Ditch subwatershed, which encompasses 3.826 square miles, or 14.1 percent of the total watershed area; and 5) the Lower Oak Creek subwatershed, which encompasses 5.031 square miles, or 18.4 percent of the total watershed area.

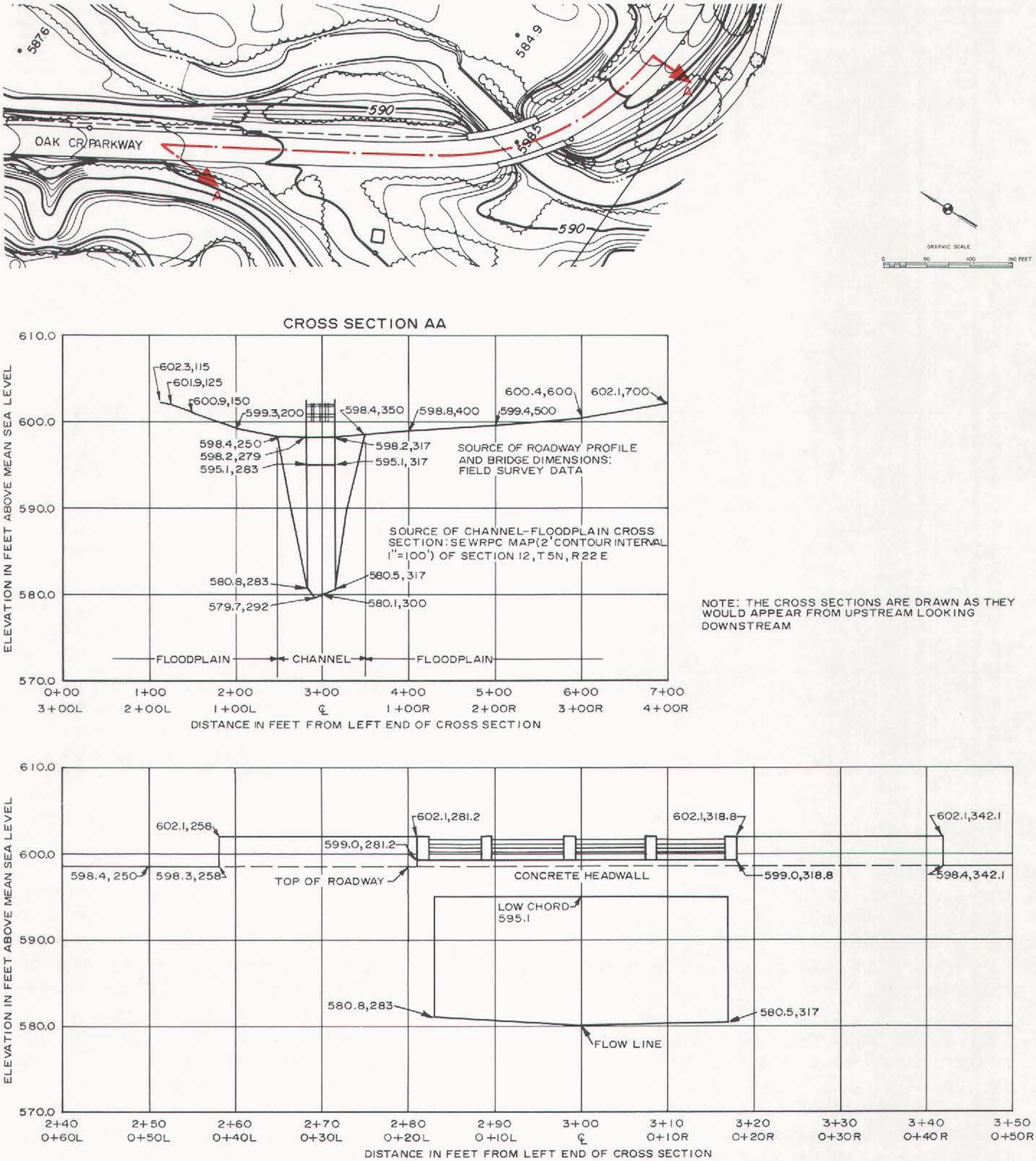
Channel modifications are known to have occurred in 49 percent of the stream reaches selected for development of flood hazard information in the Lower Oak Creek subwatershed, 16 percent in the Middle Oak Creek subwatershed, and 46 percent in the Upper Oak Creek subwatershed. Channel modifications are also known to have occurred in 42 percent of the stream reaches selected for development of flood hazard information in the North Branch Oak Creek subwatershed and 92 percent in the Mitchell Field Drainage Ditch subwatershed.

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 hydrologic subbasins. Hydrologic subbasins are the basic "building blocks" for simulating the hydrologic-hydraulic response of the watershed land surface. As shown on Map 33, a total of 24 subbasins was delineated in the watershed, ranging in size from 0.351 to 2.798 square miles, and having an average area of 1.135 square miles. These

Figure 24

TYPICAL DRAWING OF A HYDRAULIC STRUCTURE IN THE OAK CREEK WATERSHED



Source: SEWRPC.

Table 33

AREAS OF SUBWATERSHEDS AND SUBBASINS IN THE OAK CREEK WATERSHED

Subwatersheds				Subbasins		
Number	Name	Area (square miles)	Total Area Tributary to Subwatershed Discharge Point (square miles)	Identification	Area (square miles)	Total Area Tributary to Subbasin Discharge Point (square miles)
1	Lower Oak Creek	5.031	27.242	LOC-20	1.584	23.795
				LOC-21	1.083	24.878
				LOC-22	0.620	25.498
				LOC-23	0.894	26.392
				LOC-24	0.850	27.242
2	Middle Oak Creek	6.537	18.385	MOC-12	1.114	12.962
				MOC-13	0.738	13.700
				MOC-14	2.798	16.498
				MOC-15	1.887	18.385
3	Upper Oak Creek	3.801	3.801	UOC-1	0.710	0.710
				UOC-2	0.746	1.456
				UOC-3	1.391	2.847
				UOC-4	0.954	3.801
4	North Branch Oak Creek	8.047	8.047	NBOC-5	0.711	0.711
				NBOC-6	0.860	0.860
				NBOC-7	0.351	1.211
				NBOC-8	0.626	2.548
				NBOC-9	2.303	4.851
				NBOC-10	1.863	6.714
				NBOC-11	1.333	8.047
5	Mitchell Field Drainage Ditch	3.826	3.826	MFDD-16	0.877	0.877
				MFDD-17	0.948	1.825
				MFDD-18	1.281	3.106
				MFDD-19	0.720	3.826

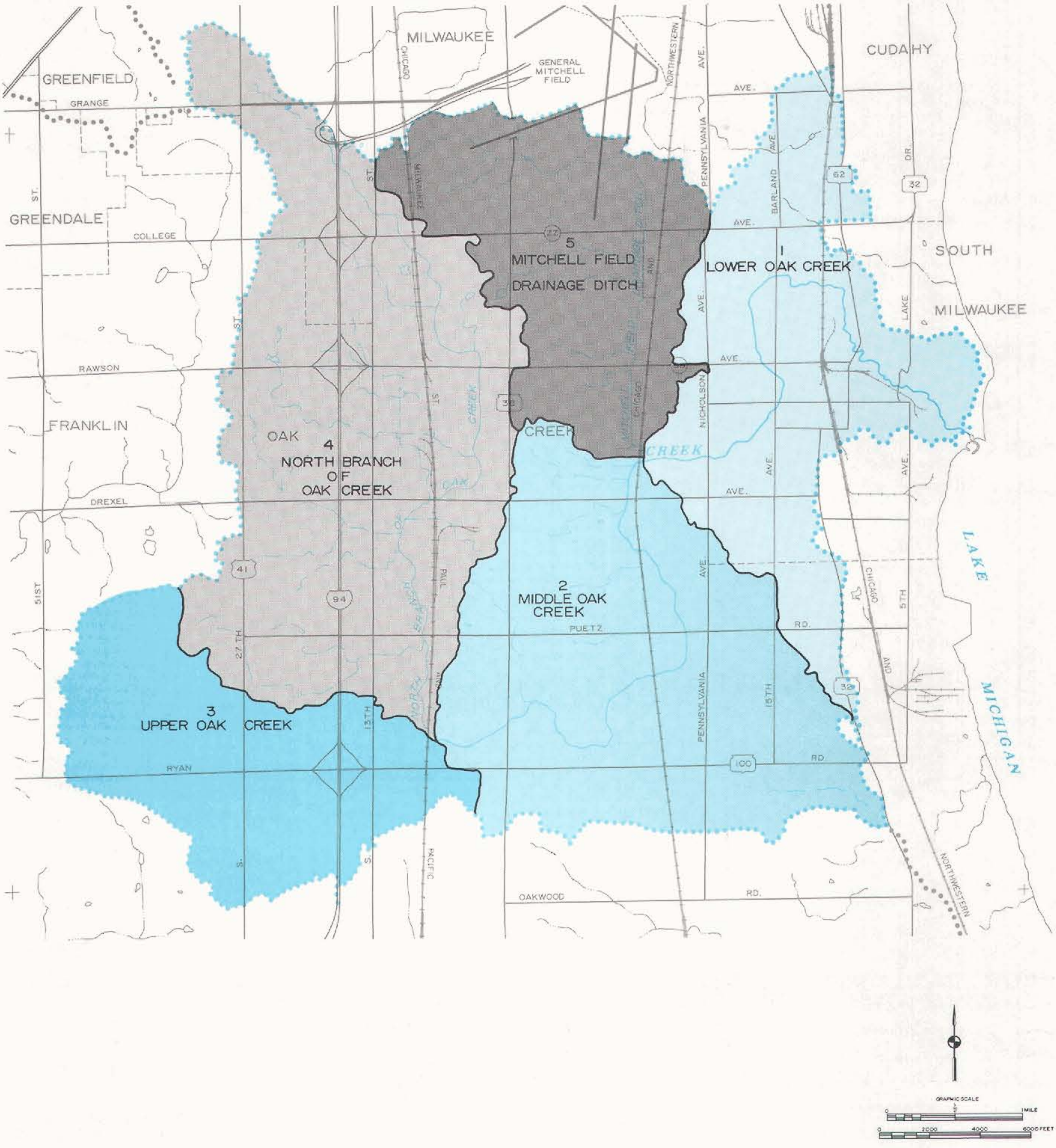
Source: SEWRPC.

subbasins were delineated using topographic mapping, supplemented with street grade data and information on the location, configuration, and elevation of storm sewer systems as available and necessary.

A number of factors were considered in the 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, such delineations may be useful in subsequent extensions and refinements of the Oak Creek watershed plan. The boundaries of subbasins were selected to reflect land use, vegetative 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, or long or high railroad and roadway embankments, also entered into selection of the discharge point to be delineated for some subbasins. Subbasins were delineated to terminate at streamflow and water quality monitoring stations, near 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 to areas of special

Map 32

SUBWATERSHEDS IN THE OAK CREEK WATERSHED

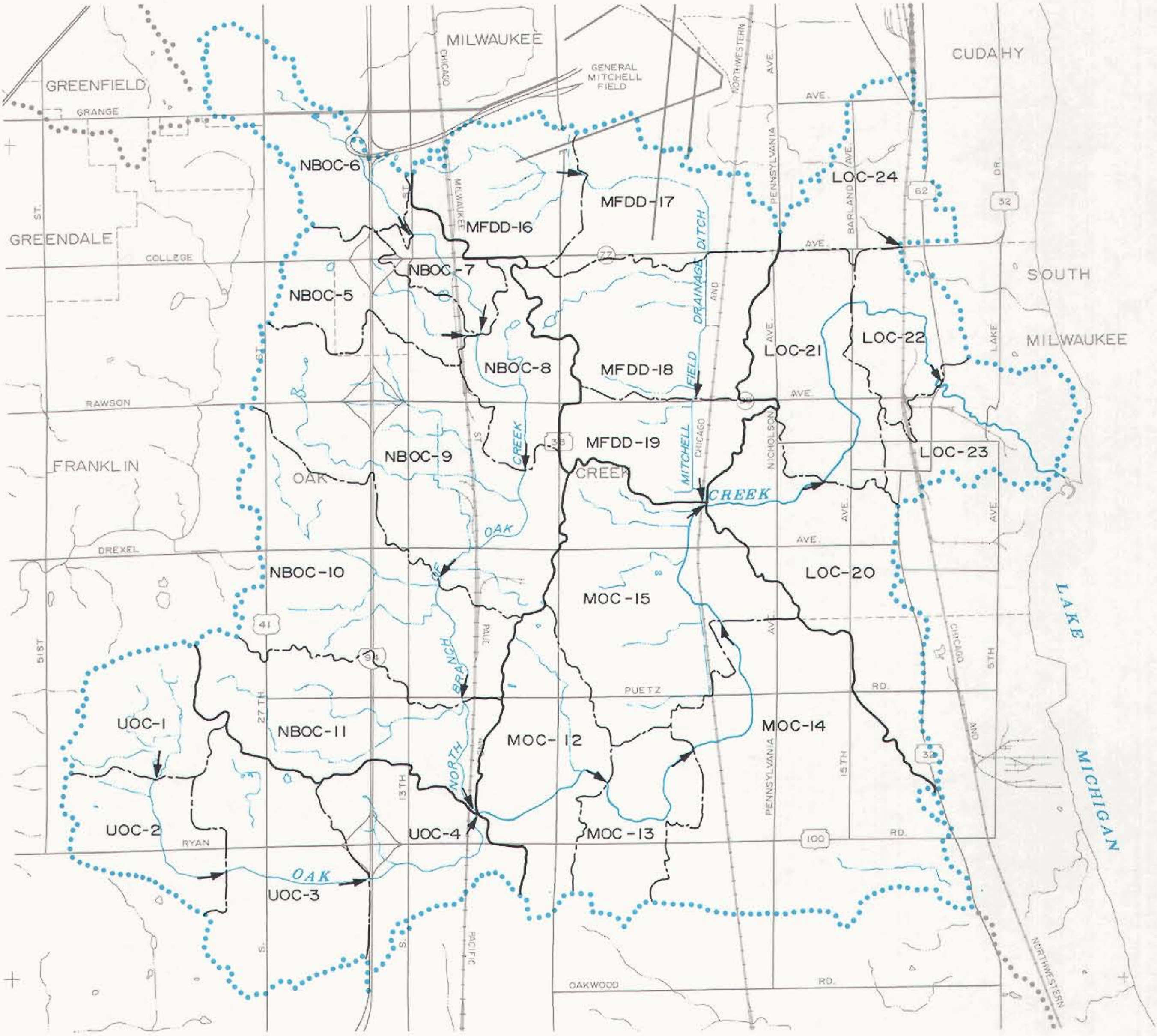


Five subwatersheds were delineated within the Oak Creek watershed with areas of 3.80, 6.54, 5.03, 8.05, and 3.83 square miles for the Upper Oak Creek, Middle Oak Creek, Lower Oak Creek, North Branch of Oak Creek, and Mitchell Field Drainage Ditch subwatersheds, respectively. In addition to providing 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 Oak Creek watershed.

Source: SEWRPC.

Map 33

SUBBASINS OF THE OAK CREEK WATERSHED



LEGEND

•••••	OAK CREEK WATERSHED BOUNDARY AS DELINEATED BY SEWRPC USING FIELD CHECKS AND LARGE SCALE MAPPING AND STORM AND COMBINED SEWER SYSTEM MAPS WHERE AVAILABLE
———	SUB-WATERSHED BOUNDARY
—·-·	SUB-BASIN BOUNDARY
MFDD	IDENTIFICATION OF SUB-WATERSHEDS
	LOC LOWER OAK CREEK
	MFDD MITCHELL FIELD DRAINAGE DITCH
	MOC MIDDLE OAK CREEK
	NBOC NORTH BRANCH OAK CREEK
	UOC UPPER OAK CREEK
LOC-20	SUB-BASIN IDENTIFICATION CODE
➞	SUB-BASIN DISCHARGE POINT
NOTE:	SUB-BASIN BOUNDARIES REVISED DECEMBER 1983 FOR OAK CREEK WATERSHED PLANNING PROGRAM

GRAPHIC SCALE 0 1 MILE; 0 2000 4000 6000 FEET

A total of 24 subbasins were delineated within the Oak Creek watershed for purposes of hydrologic-hydraulic simulation, ranging in size from 0.35 to 2.80 square miles and having an average area of 1.14 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.

concern for watershed management, such as those areas subject to urbanization or to other significant land use changes.

SUMMARY

This chapter describes those elements of the hydrologic-hydraulic system of the Oak Creek watershed which constitute the framework within which all the water resource-related problems of the watershed must be analyzed and resolved. Included in the description of the hydrology of the watershed are 1) data on precipitation, evapotranspiration, and other aspects of the hydrologic budget; 2) data on the volume and timing of runoff as revealed by stream gaging records; and 3) 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 the dams, bridges, culverts and other hydraulic structures in the watershed.

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 potential management 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 30.9 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the basin. The average annual runoff approximates 11.5 inches and the annual evapotranspiration loss total is about 19.4 inches.

Streamflow and flood stage records available for the Oak Creek stream system reveal that for predominantly rural areas two periods during the year are the most likely to produce major flooding. Historically, the period February through April and the month of June have produced about 80 percent of the annual flood peaks in the rural areas of the Oak Creek watershed. In contrast, highly urbanized watersheds which contain relatively large amounts of impervious surface area, extensive stormwater drainage systems, and channelization works exhibit a more uniform annual distribution of flooding events somewhat similar to the annual distribution of major rainfall events which can be expected, for the most part, during all months of the year with the possible exception of the months of December and January.

Approximately 26.0 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 101 hydraulically significant dams, bridges, culverts, and sills on that portion of the stream system, and for 534 floodland cross sections, all of these data being required as input to the hydrologic-hydraulic simulation 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 at least 200 feet. Groundwater in the deep sandstone aquifer beneath the watershed moves in a generally northerly direction toward Milwaukee. Flow in the dolomite and sand and gravel aquifers tends to be more varied but exhibits an overall movement toward Lake Michigan.

The Oak Creek watershed may be considered as a composite of five subwatersheds, namely the Upper Oak Creek, North Branch of Oak Creek, Middle Oak Creek, Mitchell Field Drainage Ditch, and Lower Oak Creek subwatersheds having areas of 3.80, 8.05, 6.54, 3.83, and 5.03 square miles, respectively. Hydrologic-hydraulic information, including land use, channel slopes, hydraulic structure, and channel modification data, was inventoried and analyzed for each of these subwatersheds.

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Chapter VI

HISTORIC FLOOD CHARACTERISTICS AND PROBLEMS

INTRODUCTION

Flooding of the stream system of the Oak Creek 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. In some cases channel improvements have aggravated flooding problems downstream.

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 significant proportions as urban land use has increased. Some of the present flood risk can be ascribed to the 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. Because the Oak Creek watershed is not yet fully urbanized, 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 urbanizing 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," is directed primarily at the inventory and analysis of flood problems along the 26.0 miles of stream channels in the Oak Creek watershed selected for development of detailed flood hazard data and attendant flood control plans, as shown on Map 28. The Oak Creek watershed plan is intended to provide recommendations for resolution of existing flood problems along these selected stream channel reaches and prevention of future flood problems in the associated riverine areas. The watershed planning process is not intended to address the resolution of stormwater 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 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.

Stormwater inundation is defined herein as the localized ponding of stormwater runoff which occurs when such runoff moving toward 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.

Stormwater inundation and riverine area flooding, as defined herein, differ in several significant ways. While stormwater inundation involves water moving downslope toward 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 stormwater inundation are small—generally less than one square mile. Flooding generally occurs along major perennial streams, whereas stormwater inundation is associated with intermittent channels or man-made drainageways or drainage swales. In contrast to areas experiencing flooding, areas experiencing stormwater inundation tend to be a discontinuous, 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 stormwater inundation requires detailed analysis of local topography and local street and associated building grades and of local stormwater 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.

Stormwater problems are not necessarily synonymous with stormwater inundation. Stormwater problems, and the demand for works and measures to control stormwater runoff as it moves toward the natural and man-made drainageways, are created only when urban development occurs without proper regard for stormwater runoff conveyance and storage needs. Such local problems in urban design are to be differentiated from the areawide problems referred to as flooding—associated with the movement of waters away from a channel, and up onto adjacent lands. Thus, the analysis of local stormwater drainage problems is not addressed in the comprehensive watershed planning studies conducted by the Commission generally, and is therefore beyond the scope of the Oak Creek watershed study specifically, as agreed by the Oak Creek Watershed Committee during preparation of the Oak Creek Watershed Planning Program Prospectus.

USES OF HISTORIC FLOOD INFORMATION

The collection, collation, and analysis of 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 Oak Creek watershed were known at the outset of the watershed study, the location and extent of all such areas within the watershed were not known for existing land use and channel conditions. Nor was such information available for probable future land use conditions and therefore adequate as a basis for the development of alternative flood control plans. One important use of historic flood information in the watershed study was the 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 to cause significant monetary flood damages.

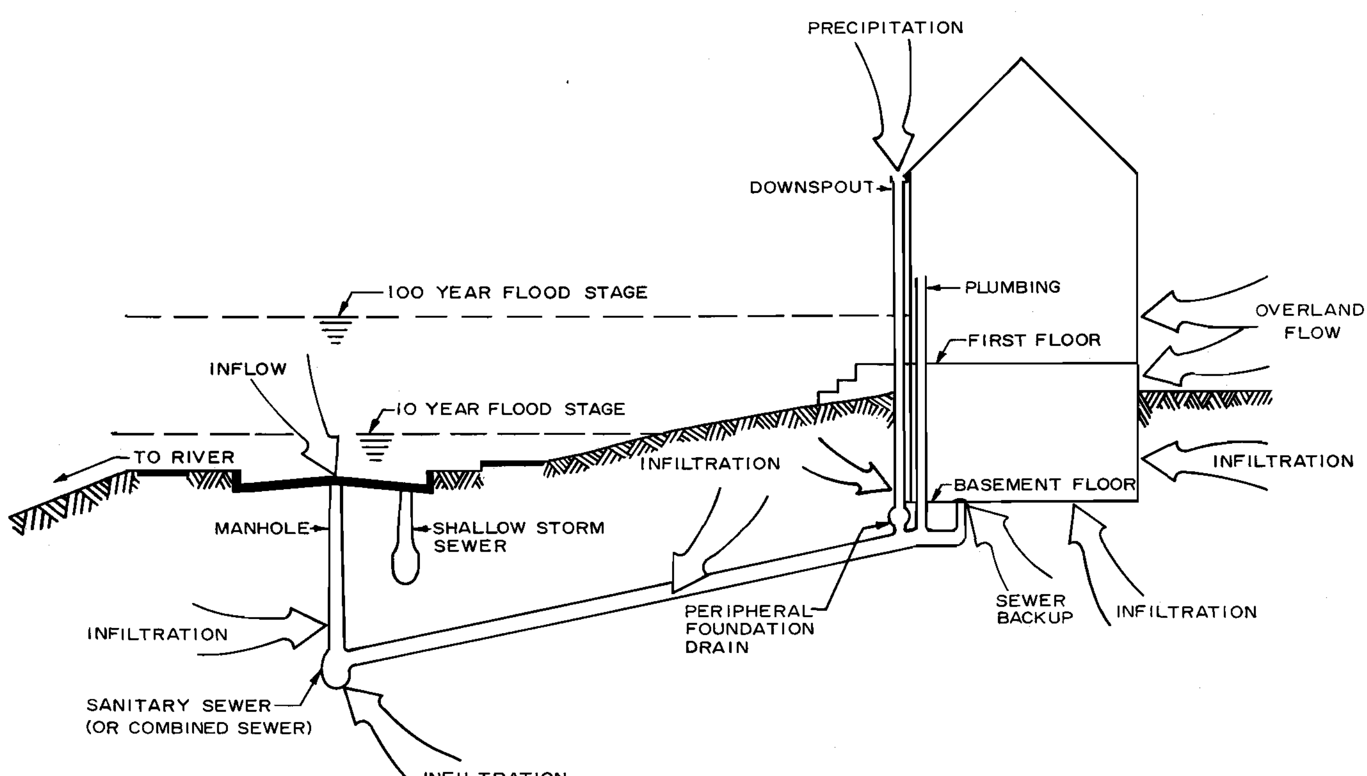
Determination of the Cause of Flood Damage

Flood damages in rural areas are caused primarily by the inundation of crops, and, to a lesser extent, by the inundation of roadways, agricultural buildings, and agricultural drainage systems. Historic floods have caused a wide range of agricultural damage in the watershed, including damage to and destruction of crops. Crop damage and destruction are dependent upon the date of flood occurrence, the duration and depth of flooding, the floodwater velocity, and the type of crop. Early spring floods can delay planting, not only during the flooding periods but also afterwards, when field conditions may be too wet for the operation of farm machinery, resulting in an effectively shorter growing season and attendant reductions in agricultural production and farm income.

Flood damages in urban areas are caused primarily by the inundation of buildings and, to a lesser extent, by the inundation of roadways and utilities. Residential, commercial, and industrial buildings 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 structure foundations, 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—

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.

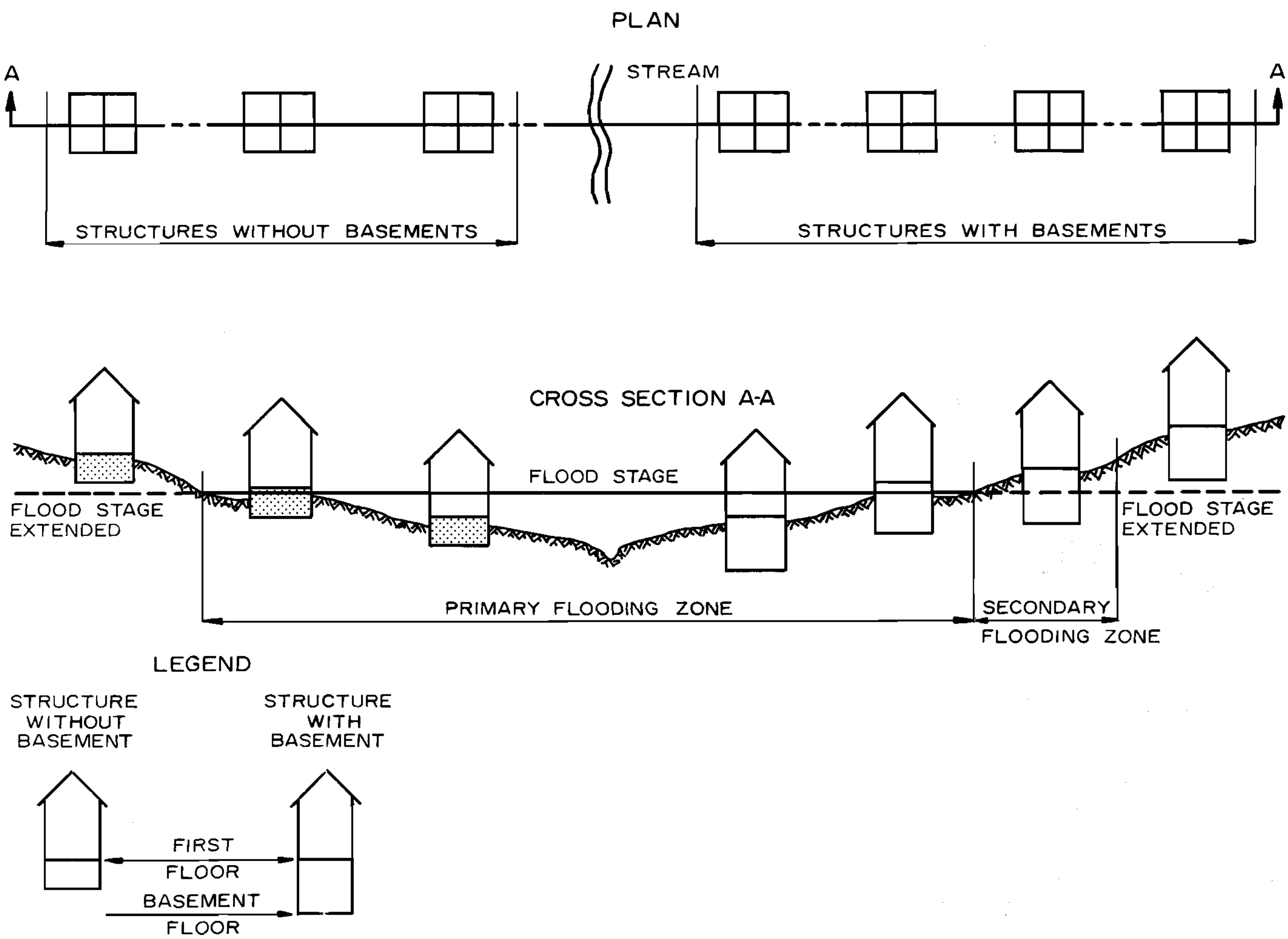
additional floodwater may enter the basement of the structure through basement doors, windows, and other structural openings. If flood stages rise high enough, floodwaters similarly may gain access to the first or main floor of a structure. In addition to the inundation damage to the structure and its 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 via the hydraulic connections between the inundated area—the area of primary flooding—and basements that are provided 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. According to officials of the communities located within the watershed, secondary flooding either has not been, or is no longer considered to be, a significant problem. Therefore, damages attributed to secondary flooding were not included in the flood damage estimates determined under this study. 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

Figure 26

PRIMARY AND SECONDARY FLOOD ZONES



Source: SEWRPC.

application of a mathematical simulation model. Sound engineering practice 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 representation of watershed hydrology and hydraulics. As described in Chapter VIII, "Water Resource Simulation Model," 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: 1) on the types of agricultural land flooded, including specific crops potentially inundated; 2) on the types of structures affected; 3) on the elevation of the ground at the structure and on the elevation of the first floor; 4) on the existence or absence of a basement; and 5) on the market value of the structure and land excluding contents. Damage to structure contents is determined as described later in this chapter under "Determination of Indirect Damages."

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 aforementioned uses of historic flood information all 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 immediately 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 of 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, objective 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. 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 research effort employing a variety of procedures and information sources was required to develop the account of historic flooding in the Oak Creek watershed presented in this chapter. The inventory of historic flooding was initiated by reviewing engineering and planning reports previously prepared by governmental agencies and private consulting firms and addressed to flood problems in all or parts of the watershed. Records for the single continuous record streamflow gaging station and the six crest stage gages located in the Oak Creek watershed were obtained and analyzed to identify flood dates since June 1958.[1] These dates were supplemented by dates of major historic flood events in the nearby Menomonee River watershed as documented in the Commission's comprehensive planning study for that watershed. In addition, synthetic streamflows generated for the Oak Creek watershed by application of the Commission's continuous process hydrologic-hydraulic simulation model were also utilized for identification of major flood events since 1940.

This initial review of published reports and data was followed by a review of newspapers and newspaper files. Although a long period of history was considered in this review, information could be assembled on each of only a few historic floods. The principal sources of information for this review were past issues of The Milwaukee Journal, The Oak Creek Pictorial, and The South Milwaukee Voice-Journal. Paralleling the review of these newspapers, the Commission staff contacted officials of various organizations, including officials of the Milwaukee Metropolitan Sewerage District, the City Engineers from the Cities of Franklin, Milwaukee, Oak Creek, and South Milwaukee, the Airport Engineer for General Mitchell Field, and officials of the Wisconsin Air National Guard and the Milwaukee County Historical Society.

[1] *A crest stage gage is located at the Nicholson Road crossing of Oak Creek and has been in operation since 1958; a continuous record streamflow gaging station is located on Oak Creek at 15th Avenue and has been in operation since October 1963. Both of these gages are operated by the U. S. Geological Survey in cooperation with the Milwaukee Metropolitan Sewerage District and the Southeastern Wisconsin Regional Planning Commission. In addition, there are four crest stage gages on Oak Creek operated by the Milwaukee Metropolitan Sewerage District. These gages are located at S. Howell Avenue, E. Puetz Road, and two at S. Pennsylvania Avenue. These gages have been operated since January 1972, September 1967, and April 1979, respectively. A fifth gage was operated by the District at the Drexel Avenue crossing on the North Branch of Oak Creek but was removed when this bridge was replaced in 1981. It has provided a period of record from April 1971 to February 1981.*

ACCOUNTS OF HISTORICAL FLOODS

Method of Presentation

The historical flood information for the Oak Creek 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 herein as those known to have caused relatively heavy widespread flooding, significant damage to property, and disruption of normal community activities. Eight major flooding periods were identified beginning with the June 22, 1917, flood and extending through the September 13, 1978, flood. Although the disruption associated with each major flood may have been of several days duration, the flood event is herein identified by the date on which the highest, or peak, flood stage was known, or believed, to have occurred.

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 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.

Although historical high water marks for major floods 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 a stream system, no definitive data on such marks could be discovered in the historic flood inventory. However, photographs and reports concerning the extent of flooding for particular events within the Oak Creek watershed were compared to flood stages and flood inundation maps generated by data from the Commission hydrologic-hydraulic simulation submodel for similar recurrence interval floods, and relatively good agreement was found, thereby verifying the validity of the simulated flood data.

The flood stages and flood inundation maps generated by data from the Commission's hydrologic-hydraulic simulation submodel were also compared to similar data presented in the federal flood insurance studies for the Cities of South Milwaukee, Oak Creek, and Franklin.[2] Table 34 provides a comparison of peak flood discharges and stages. A graphic summary of the comparison with respect to areas of inundation is provided on Map 34. Observed differences between these data from the two sources may be attributed to actual changes in the channels, bridges, or culverts; to the availability of additional and more current hydraulic structure data for the Commission's hydrologic-hydraulic simulation analyses; and to the differences in techniques used to determine peak flood discharges for the watershed. Discharges used in the federal flood insurance studies were based upon a statistical analysis of the stream gage records for the gages at S. 15th Avenue and at Nicholson Road, as opposed to the use of the hydrologic submodel described in Chapter VIII. For stream reaches where very similar hydraulic structure data and flood flows were used by both agencies, good agreement was found, thereby further verifying the validity of the Commission's simulated flood data.

Flood of June 22, 1917

In a 24-hour period from June 22 to June 23, 1917, a total of 5.8 inches of rain was recorded by the U. S. Weather Bureau station at Milwaukee.[3] This was the largest 24-hour rainfall amount ever recorded by that station. Due to a lack of streamflow data, either recorded or simulated, it is not possible to estimate the recurrence interval of the resulting flood. Newspaper accounts indicate that there was extensive flood damage to the stonework below the Oak Creek Parkway dam as well as to a portion of Mill Road north of the dam. Water was reported running over Rawson Avenue to the west of the bridge over Oak Creek. Farmers also reported extensive damage to newly planted crops.

Flood of June 23, 1940

In a 60-hour period from June 21 to June 24, 1940, a total of 5.97 inches of rain was recorded by the U. S. Weather Bureau station at Milwaukee. Of this total, 4.49 inches, or 75 percent, fell on June 22. The resulting flood was reported to be the worst since the 1917 event and had an estimated recurrence interval of about 50 years. The parkway drive along the Oak Creek Parkway lagoon, the intersection of 16th and Michigan Avenues, and Drexel Avenue west of Howell Avenue were reported flooded. Many basements were reported flooded on the west side of South Milwaukee. Hundreds of acres of truck gardens and field crops were inundated, with crop damages estimated in the thousands of dollars.

Flood of March 30, 1960

From March 29 through March 30, 1960, a total of 2.57 inches of rain was registered at the U. S. Weather Bureau station at Milwaukee. Though that was not a particularly heavy rainfall, localized areas of intense rainfall along with an unusually high snowmelt resulted in major flooding throughout the watershed. The resulting flood had an estimated recurrence interval of about 40 years. Streams throughout the watershed, already swollen from two days of melting snow, overflowed their banks and choked roads with water as the rain occurred. The crest of the flood along Oak Creek was reached on the night of March 30 and the morning of March 31.

The flood flow in Oak Creek washed out the road on the east side of the Manitoba Avenue bridge between 14th and 15th Avenues in South Milwaukee. Other inundated roads included the Oak Creek parkway drive east of Chicago Avenue and at the Chicago & North Western Railway underpass, and the intersection of 15th and Michigan Avenues. A watershed committee member, Mr. Norbert S. Theine, reported that as an Assistant City Engineer of the City of Oak Creek, he had made a field inspection of the watershed during this flood event and had found that all roads in the City of Oak Creek portion of the watershed crossing Oak Creek were inundated and impassible except STH 32.

About 300 calls were received by the South Milwaukee Police Department, most of them reporting flooded basements and asking for assis-

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[2] *Federal Emergency Management Agency, Federal Insurance Administration, Flood Insurance Study, City of Franklin, Wisconsin, July 1981; U. S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Oak Creek, Wisconsin, March 1978; Federal Emergency Management Agency, Federal Insurance Administration, Flood Insurance Study, City of South Milwauakee, Wisconsin, November 1979.*

[3] *The U. S. Weather Station at Milwaukee, a first order station, was located in the central business district of Milwaukee, a distance of about 6.5 miles from the watershed, from 1879 to 1941; at General Mitchell Field, a distance of about one-half mile from the watershed, from 1941 to the date of this report.*

Table 34

COMPARISON OF PEAK FLOOD DISCHARGES AND STAGES DEVELOPED FROM THE COMMISSION'S HYDROLOGIC-HYDRAULIC SIMULATION SUBMODEL TO THOSE PRESENTED IN THE FEDERAL FLOOD INSURANCE STUDIES FOR THE CITIES OF FRANKLIN, OAK CREEK, AND SOUTH MILWAUKEE: EXISTING LAND USE AND CHANNEL-FLOODPLAIN CONDITIONS

River Mile	Location	100-Year Recurrence Interval Discharge (cfs)		100-Year Recurrence Interval Stage (feet above NGVD)	
		Commission[a]	Federal Flood Insurance Study	Commission[a]	Federal Flood Insurance Study
	Oak Creek				
0.35	Downstream First Oak Creek Parkway Bridge	1775[b]	1960	586.3	587.2
	Upstream First Oak Creek Parkway Bridge	1775	1960	587.4	588.2
0.88	Downstream Second Oak Creek Parkway Bridge	1775	1960	599.4	599.6
	Upstream Second Oak Creek Parkway Bridge	1775	1960	601.1	601.6
0.94	Downstream Mill Road Bridge	1775	1960	603.1	601.8
	Upstream Mill Road Bridge	1775	1960	--	--
0.95	Oak Creek Parkway Dam	1760	1960	617.5	616.8
1.18	Downstream Third Oak Creek Parkway Bridge	1760	1960	617.4	616.8
	Upstream Third Oak Creek Parkway Bridge	1760	1960	617.7	616.9
1.32	Downstream Fourth Oak Creek Parkway Bridge	1760	1960	618.4	619.7
	Upstream Fourth Oak Creek Parkway Bridge	1760	1960	620.0	621.0
1.61	Downstream Chicago Avenue Bridge	1760	1960	623.4	625.3
	Upstream Chicago Avenue Bridge	1760	1960	625.7	625.8
2.14	Downstream Fifth Oak Creek Parkway Bridge	1760	1960	632.3	633.9
	Upstream Fifth Oak Creek Parkway Bridge	1760	1960	632.9	635.4
2.35	Downstream Chicago & North Western Railway	1760	1960	637.1	637.1
	Upstream Chicago & North Western Railway	1760	1960	638.0	637.2
2.84	Downstream 15th Avenue Bridge	1765	1960	641.5	641.4
	Upstream 15th Avenue Bridge	1765	1960	642.5	642.6
3.37	Downstream Pine Street Bridge	1765	1960	646.9	647.2
	Upstream Pine Street Bridge	1765	1960	647.4	647.4
3.62	Downstream Rawson Avenue Bridge	1765	1960	649.4	649.2
	Upstream Rawson Avenue Bridge	1765	1960	649.9	649.4
3.66	Downstream 16th Avenue Bridge	1765	1960	649.9	649.4
	Upstream 16th Avenue Bridge	1765	1960	650.0	649.7
3.76	Downstream 15th Avenue Bridge	1765	1960	650.2	650.0
	Upstream 15th Avenue Bridge	1765	1960	650.4	650.1
4.01	Downstream Milwaukee Avenue Bridge	1765	1960	650.8	650.9
	Upstream Milwaukee Avenue Bridge	1765	1960	651.1	651.4
4.06	Downstream 15th Avenue Bridge	1765	1960	651.1	651.4
	Upstream 15th Avenue Bridge	1765	1960	651.2	651.6
4.71	Downstream S. Pennsylvania Avenue Bridge	1775	1960	652.4	653.8
	Upstream S. Pennsylvania Avenue Bridge	1775	1960	653.7	658.5
5.25	Downstream Chicago & North Western Railway	1500	1550	661.2	661.0
	Upstream Chicago & North Western Railway	1500	1550	661.5	661.4
5.56	Downstream E. Drexel Avenue Bridge	1500	1550	662.0	662.2
	Upstream E. Drexel Avenue Bridge	1500	1550	662.6	662.6

Table 34 (continued)

River Mile	Location	100-Year Recurrence Interval Discharge (cfs)		100-Year Recurrence Interval Stage (feet above NGVD)	
		Commission[a]	Federal Flood Insurance Study	Commission[a]	Federal Flood Insurance Study
	Oak Creek (continued)				
6.06	Downstream Chicago & North Western Railway	1500	1280	663.3	663.8
	Upstream Chicago & North Western Railway	1500	1280	663.5	663.8
6.25	Downstream E. Forest Hill Avenue Bridge	1500	1280	663.7	664.3
	Upstream E. Forest Hill Avenue Bridge	1500	1280	663.8	664.3
6.83	Downstream E. Puetz Road Bridge	1500	1280	664.1	664.7
	Upstream E. Puetz Road Bridge	1500	1280	664.4	665.0
7.34	Downstream Chicago & North Western Railway	2080[c]	1280	665.0	665.3
	Upstream Chicago & North Western Railway	2080	1280	665.5	665.3
7.44	Downstream S. Nicholson Road Bridge	2080	1280	666.0	665.6
	Upstream S. Nicholson Road Bridge	2080	1280	666.7	665.8
8.41	Downstream S. Shepard Avenue Bridge	2080	1280	670.6	669.2
	Upstream S. Shepard Avenue Bridge	2080	1280	671.2	669.8
9.22	Downstream S. Howell Avenue Bridge (northbound)	2080	1280	677.2	675.3
	Upstream S. Howell Avenue Bridge (southbound)	2080	1280	677.6	675.5
10.06	Downstream W. Ryan Road Bridge	1030	535	680.9	678.5
	Upstream W. Ryan Road Bridge	1030	535	682.0	678.9
10.24	Downstream Chicago, Milwaukee, St. Paul & Pacific Railroad	1030	535	682.1	679.2
	Upstream Chicago, Milwaukee, St. Paul & Pacific Railroad	1030	535	684.8	685.0
10.69	Downstream S. 13th Street Bridge	1030	535	690.7	688.2
	Upstream S. 13th Street Bridge	1030	535	691.7	688.3
10.97	Downstream I-94 (northbound)	790	470	691.9	689.1
	Upstream I-94 (southbound)	790	470	691.9	689.2
11.23	Downstream S. 20th Street Bridge	790	470	692.0	689.4
	Upstream S. 20th Street Bridge	790	470	692.8	691.7
11.70	Downstream S. 27th Street Bridge	570	360	694.2	693.4
	Upstream S. 27th Street Bridge	570	360	695.1	693.5
11.97	Downstream S. 31st Street Bridge	410	320	698.4	697.2
	Upstream S. 31st Street Bridge	410	320	699.2	698.3
12.52	Downstream W. Ryan Road Bridge	410	320	710.3	708.7
	Upstream W. Ryan Road Bridge	410	320	715.4	712.2
13.18	Downstream W. Southland Drive	210	204	731.2	731.6
	Upstream W. Southland Drive	210	204	733.0	733.2

Table 34 (continued)

River Mile	Location	100-Year Recurrence Interval Discharge (cfs) Commission[a]	Federal Flood Insurance Study	100-Year Recurrence Interval Stage (feet above NGVD) Commission[a]	Federal Flood Insurance Study
	North Branch of Oak Creek (continued)				
0.10	Downstream Chicago, Milwaukee, St. Paul & Pacific Railroad	1670	930	683.5	682.2
	Upstream Chicago, Milwaukee, St. Paul & Pacific Railroad	1670	930	686.8	684.9
0.92	Downstream W. Puetz Road	1450	800	696.1	684.0
	Upstream W. Puetz Road	1450	800	698.0	695.3
2.00	Downstream Wildwood Drive	930	598	705.3	703.5
	Upstream Wildwood Drive	930	598	705.3	703.5
2.21	Downstream W. Drexel Avenue	930	598	705.4	703.8
	Upstream W. Drexel Avenue	930	598	706.1	705.6
2.25	Downstream Chicago, Milwaukee, St. Paul & Pacific Railroad	880	598	706.0	706.1
	Upstream Chicago, Milwaukee, St. Paul & Pacific Railroad	880	598	709.3	707.3
2.41	Downstream S. Sixth Street	880	598	709.4	707.8
	Upstream S. Sixth Street	880	598	709.9	708.6
3.04	Downstream W. Marquette Avenue	520	440	713.8	710.4

[a] *Flood discharges and stages which were developed for all of the stream reaches studied are listed in Appendix D for existing land use and channel conditions, and in Appendix E for year 2000 land use and existing channel conditions.*

[b] *The change in the magnitude of the flood discharge values for the 4.71-mile stream reach between the mouth of Oak Creek and the S. Pennsylvania Avenue bridge is 20 cfs. In order to simplify the hydraulic modeling, a single discharge value of 1780 cfs was used to calculate stages. The use of a single discharge value does not significantly affect the accuracy of the resulting flood stages because the actual change in flood discharge is small.*

[c] *Because of the relatively large floodplain area associated with this stream reach, large amounts of floodwater are temporarily retained, thus causing a significant reduction in the peak flood discharges further downstream.*

Source: SEWRPC.

tance. Reports of water levels above the first floor were rare, however. All available pumping equipment had to be pressed into operation during the flood. Many areas of the City of Oak Creek were inundated, with a number of farm buildings and homes surrounded by water. At E. Drexel Avenue, firemen used a rowboat to rescue three people stranded on their rooftop.

Flood of June 11, 1967

Over a six-day period from June 7 to June 12, 1967, rainfall totaling 4.43 inches was recorded at the U. S. Weather Bureau station at Milwaukee. Although the recorded streamflows indicate this event to have an estimated recurrence interval of only about two years, some flooding did occur. The major disruption due to this event occurred on the evening of June 12 at the intersection of 17th Avenue and Pine Street in the City of South Milwaukee, where flooding to depths of three to five feet occurred. According to the South Milwaukee Engineering Department, this was caused by flood waters from Oak Creek backing up through a storm sewer outfall. In addition to this sewer backup, many low-lying farm fields were reported flooded.

Flood of June 26, 1968

Late June of 1968 brought a series of storms to the Oak Creek watershed, with the U. S. Weather Bureau station at Milwaukee reporting 5.26 inches of rain from June 21 to June 27, 1968. The resulting flood had an estimated recurrence interval of about three years. Streets were reported flooded throughout the watershed, including Wildwood Drive over the North Branch of Oak Creek and E. Forest Hill Avenue (see Figures 27 and 28). There were also many reports of flooded basements.

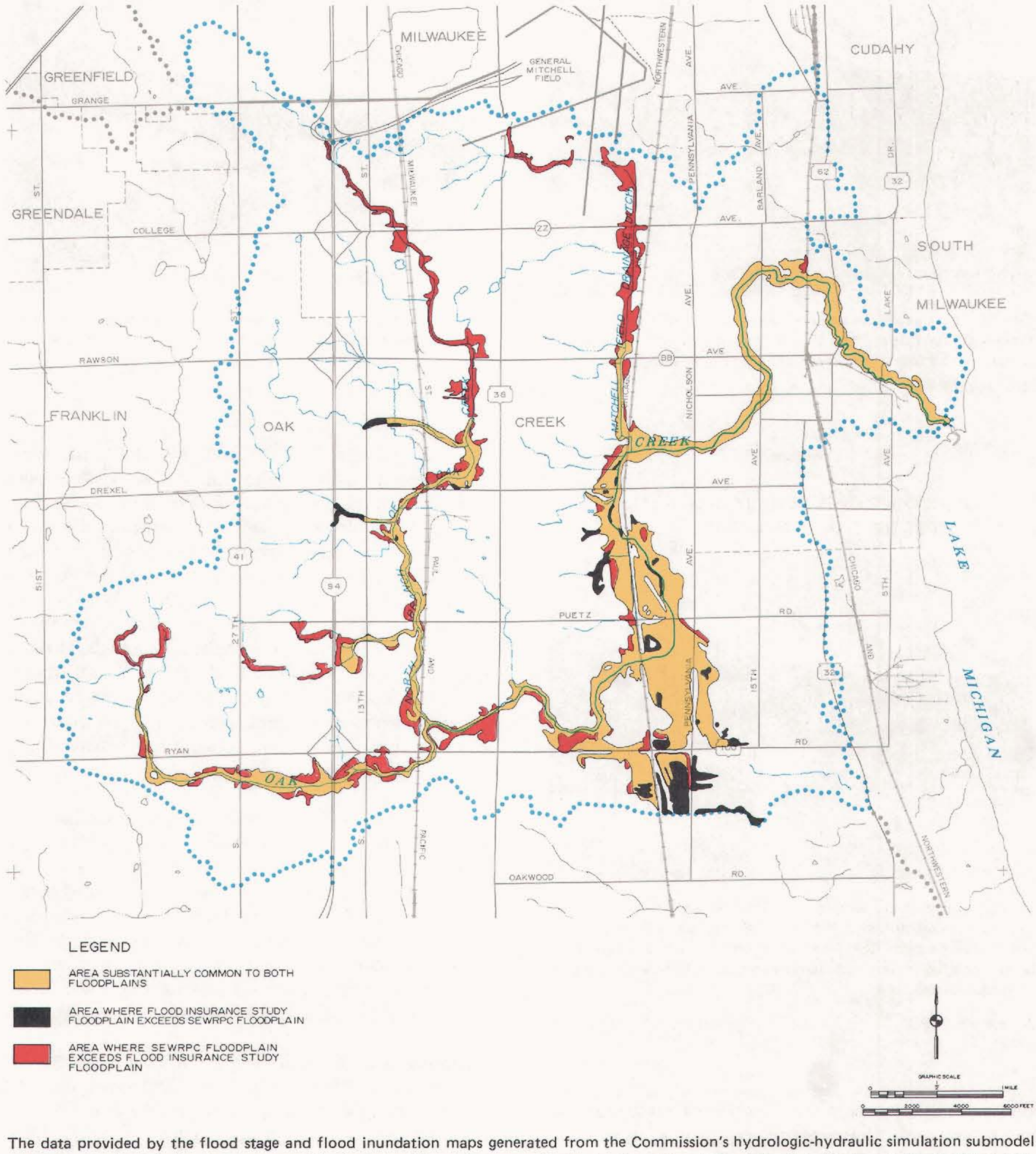
In rural areas, hundreds of acres of land were flooded. Fields of corn and other vegetables were drowned out in waters which in some places were up to waist level in depth.

Flood of September 18, 1972

From September 16 through September 21, 1972, 3.81 inches of rain was measured at the U. S. Weather Bureau station at Milwaukee. The bulk of this rain fell from 3:00 p.m. on September 17 to 6:00 a.m. on September 18, when a total of 2.31 inches was recorded. This storm was preceded by two and one-half months of unusually

Map 34

COMPARISON OF THE 100-YEAR RECURRENCE INTERVAL FLOODPLAIN AS DELINEATED BY THE SEWRPC OAK CREEK WATERSHED STUDY TO THOSE PRESENTED IN THE FEDERAL FLOOD INSURANCE STUDIES FOR THE CITIES OF FRANKLIN, OAK CREEK, AND SOUTH MILWAUKEE

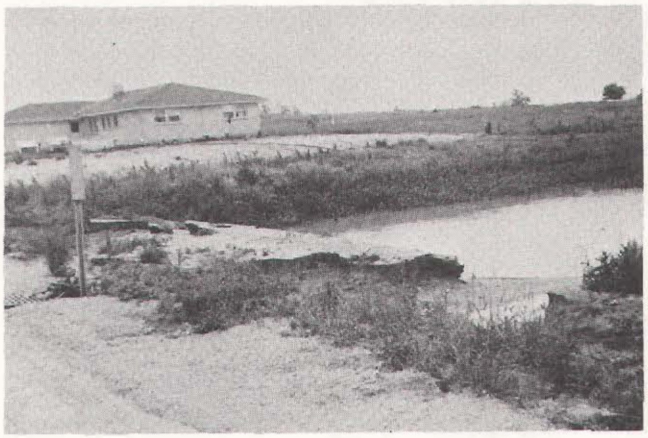


The data provided by the flood stage and flood inundation maps generated from the Commission's hydrologic-hydraulic simulation submodel were compared to similar data presented in the federal flood insurance studies for the cities of Franklin, Oak Creek, and South Milwaukee. Observed differences between these data from the two sources may be attributed to actual changes in the channels, bridges, or culverts; to the availability of additional and more current hydraulic structure data for the Commission's hydrologic-hydraulic simulation analyses; and to differences in techniques used to determine peak flood discharges for the watershed.

Source: SEWRPC.

FIGURE 27

OVERTOPPING OF THE WILDWOOD DRIVE BRIDGE OVER THE NORTH BRANCH OF OAK CREEK: JUNE 26, 1968



The left photograph was taken at about 9:00 a.m. on June 26 and shows Wildwood Drive being overtopped by floodwaters from the North Branch of Oak Creek. The right photograph was taken the following morning, after the floodwaters had receded. Evident in this picture is the erosion caused to the shoulder of the road by the floodwaters.

Source: SEWRPC.

Figure 28

FLOODING OF E. FOREST HILL AVENUE WEST OF OAK CREEK: JUNE 27, 1968

This photograph was taken at about 11:00 a.m. on June 27 and shows the inundation of E. Forest Hill Avenue about 50 feet west of the bridge over the Oak Creek main stem. Significant damage to crops occurred in this area as hundreds of acres of farmland were reported flooded.

Source: SEWRPC.

wet weather, causing the Oak Creek watershed to be in a very flood-prone condition when the September 17 rains occurred. The resulting flood had an estimated recurrence interval of about six years.

Various accounts describing damage and losses exist. Sewers were heavily taxed and in some cases were not capable of handling the high flows. Residents along Marion Avenue in South Milwaukee saw sewer manhole covers lifted due to excessive hydraulic pressure. Streets were reported to have been flooded to depths up to three feet. Among the streets flooded were 15th, Marion, Menomonee, and Pennsylvania Avenues in South Milwaukee; and Nicholson Road, E. Ryan Road, and E. Forest Hill Avenue in Oak Creek. By the time the cleanup was over, eight truckloads of mud had been removed from streets in the southwest area of the City of South Milwaukee.

Damage to buildings was in the thousands of dollars. Floodwaters entered buildings through basement windows. The South Milwaukee Fire Department received about 50 phone calls asking for help in pumping out flooded basements, and that Department estimated that there were hundreds of flooded basements in all. Most of the problems with basement flooding occurred in the southwest area of South Milwaukee.

Farmers also experienced problems due to the heavy rains. Fields were heavily rutted, turning some acreages into quagmires. Because of the damages resulting from this flood event, the U. S. Small Business Administration declared Milwaukee County a disaster area and, therefore, eligible for federal assistance.

Flood of April 21, 1973

Between April 18 and April 22, 1973, 3.30 inches of rainfall were recorded at the U. S. Weather Bureau station at Milwaukee, with 3.09 inches falling between 10:00 p.m. on April 20 and 1:00 a.m. on April 22. This storm was preceded by a heavy snowfall and subsequent snowmelt which occurred earlier in the month. Although severe flooding problems were reported in many parts of the Region, relatively few damages were reported in the Oak Creek watershed, where the resulting flood had an estimated recurrence interval of about four years.

The most prevalent problem was flooding of streets, including E. Puetz Road and E. Ryan Road. The Pine Street bridge was closed due to failing abutment walls. Although flooding was reported in the usual low spots in the watershed, damage to buildings was minimal, with about 12 reports of flooded basements.

Flood of September 13, 1978

From September 11 to September 14, 1978, 4.19 inches of rainfall were recorded at the U. S. Weather Bureau station at Milwaukee. Although no serious flooding was reported, a peak discharge of 1,020 cubic feet per second was recorded at the continuous record gaging station at 15th Avenue in South Milwaukee. This is the largest streamflow recorded at that gage since it was placed into operation in 1963. The estimated recurrence interval for this flow was about 10 years. Few flood problems were reported, however, probably in part due to the recently completed channel improvements between Rawson Avenue and Pennsylvania Avenue in South Milwaukee. This reach had been the site of some of the most severe urban flooding problems in previous years.

HISTORICAL FLOODING: SOME OBSERVATIONS

One of the uses of historical 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 Oak Creek 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 historical 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 in the watershed.

The principal types of damage experienced in the Oak Creek watershed have been damage to croplands and damage to structures—private residences and commercial buildings—and to their contents as a result of overland and attendant secondary flooding. It is estimated that, under existing land use and channel conditions, 22 structures located on nine properties may be expected to experience-direct flooding during a 100-year recurrence interval flood. Nearly all of the flood damages are associated with 17 of these structures located on four properties. Bridges and culverts and sections of roadways have been damaged by the erosive action of rapidly moving floodwaters so as to require extensive repair.

A costly type of disruption associated with major flood events in the Oak Creek watershed has been the interruption of business activities, not only during the flood events but also during the post-flood 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 that have been inundated at a relatively low place, 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 historical flood record assembled for the Oak Creek watershed indicates that floods cause physical damage to croplands and 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.

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. Although there are no known instances of the loss of life in association with flooding in the Oak Creek watershed, flood events in the watershed are potentially hazardous to people in or near the riverine areas. This is 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 Oak Creek 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 may still be 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. Not only are these forces large, but they probably would be applied abruptly and unexpectedly to persons trapped in the floodwaters.

The threat to human life is severe in the Oak Creek watershed for three reasons. First, part of the watershed is highly urbanized and, therefore, many people—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 storm and floodwater conveyance system that has been developed to serve urban areas of the watershed, flood discharges and stages in some stream reaches rise rapidly with little advance warning. Third, much of the watershed stream system has been subjected to major channelization. These hydraulically efficient sections will normally exhibit 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. 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 may be more difficult because of the relatively steep banks of the improved channels which in some cases are relatively free of vegetation and therefore relatively smooth.

With the exception of increasing public awareness of the danger, little can be done in most cases to mitigate the threats to human life presented by high velocity flows in channelized reaches. 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, historical evidence accumulated for the Oak Creek watershed, supplemented with hydraulic analyses completed under the watershed study, indicates that major flood events can pose a serious threat to human life. This risk is heightened in highly urbanized portions of the watershed because of the proximity of people to the riverine areas, the "flashy" nature of some of the streams, and the high velocities and steep banks characteristic of channelized reaches.

While the threat of flooding to human life can be readily illustrated by reference to historical 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 urbanized areas of the 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 contaminated, flood-borne sand, silt, and other materials and debris from their houses 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 LOSES 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 35.

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, stormwater systems, sanitary sewer systems, and other utilities; the cost of restoring damaged park and recreational lands; and the cost of replanting as well as the cost of losing all or part of the first crop.

Table 35

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 road 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.

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; 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 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—direct, indirect, and intangible—may, therefore, be further subdivided into public-sector losses as shown in Table 35. 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 historical flood events known to have occurred within the watershed and described the severity of each flood event and, in some cases, the reaches of the stream affected, and the types of damage and disruption that occurred. In most cases, though, little such historical information was available. The relative magnitude of recorded peak flood discharges was also noted. 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 upstream 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 Oak Creek watershed study was the average annual flood damage risk expressed in 1984 dollars. Average annual flood risk was computed for flood-prone reaches to provide a monetary value that could be used, wholly or in part, as an annual quantity 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.

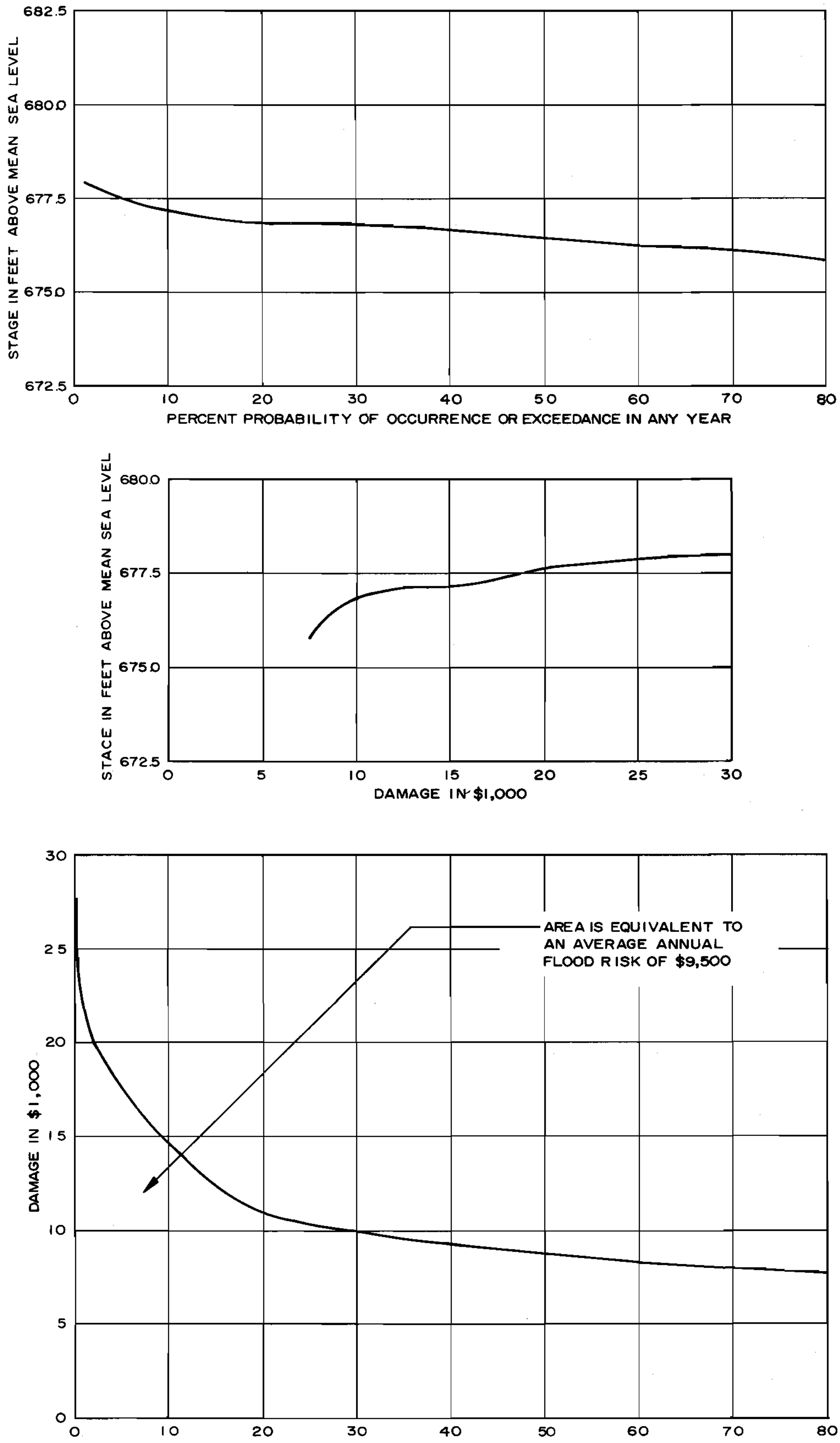
Methodology Used to Determine Average Annual Flood Risks

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 illustrated in Figure 29, 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 29. 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 long-term 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.

Figure 29

EXAMPLE OF DETERMINATION OF AVERAGE ANNUAL FLOOD RISK FOR A RIVER REACH



Source: SEWRPC.

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 the presence of bridges, culverts, and other structures—all of which are to some extent determined by the activities of man—plus 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.

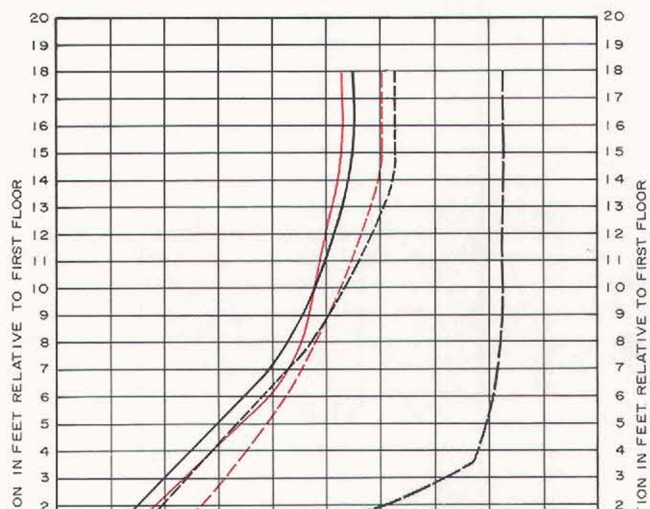
Figure 29 shows an example of a stage-probability curve synthesized for a stream reach in the Oak Creek watershed.

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 35. 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 100-year recurrence interval flow stage. Figure 29 presents an example of a synthesized stage-damage curve for a reach.

Synthesis of reach stage-damage relationships requires the use of depth-damage relationships for the various type structures, facilities, croplands, and activities likely to be present in or to occur in floodlands. A depth-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. The depth-damage relationships for five types of structures used in the Oak Creek watershed study area are shown in Figure 30. These depth-damage relationships were developed by the Commission staff using Federal Insurance Administration tables published in 1970 and revised in 1974 and 1975. The depth-damage relationships for croplands were provided by the U. S. Soil Conservation Service (SCS) and have been used by the SCS in cost-benefit studies of proposed flood control structures in agricultural areas in southeastern Wisconsin. The SCS damage data include consideration of the net value of appropriate replacement crops, which in turn is affected by the timing of the flood event. Depth-damage data for corn, oats, hay, and pasture are shown in Table 36. Damage to truck farm vegetable crops for any depth of flooding was assumed to be total. The depth-damage curves do not take into account the duration of flooding,

Figure 30

DEPTH-DAMAGE CURVES FOR SELECTED STRUCTURES



Source: Federal Insurance Administration and SEWRPC.

Table 36

DEPTH-DAMAGE DATA FOR CROPS IN THE OAK CREEK WATERSHED

Crop	Gross Value per Acre	Flood Depth (feet)	Percent Damage[a] per Month						
			April	May	June	July	August	September	October
Alfalfa[b]	$200	0-1	--	41	33	22	13	6	--
		1-3	--	47	45	28	19	9	--
		>3	--	63	49	33	22	13	--
Corn[c]	$275	0-1	--	15	32	25	15	9	6
		1-3	--	12	42	43	27	15	11
		>3	--	17	51	59	34	21	21
Oats[d]	$138	0-1	36	40	53	44	28	--	--
		1-3	36	40	63	55	38	--	--
		>3	36	40	66	60	44	--	--
Pasture[e]	$ 40	0-1	--	30	35	30	25	35	25
		1-3	--	35	50	45	40	50	40
		>3	--	45	65	60	45	65	55
Vegetables[f]	$875[g]	N/A[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]

NOTE: N/A indicates data not available.

[a] *Percent damage also includes the costs and return on planting and harvesting appropriate alternate crops after a damaging flood event occurs.*

[b] *Gross value of alfalfa hay based upon yield of 4.5 tons per acre at a value of $44.50 per ton.*

[c] *Gross value of corn based upon yield of 130 bushels per acre at a value of $2.12 per bushel.*

[d] *Gross value of oats based upon yield of 65 bushels per acre at a value of $1.43 per bushel, plus a yield of 60 bales of straw per acre at a value of $0.75 per bale.*

[e] *Gross value of pasture as feed based upon 120 cow-pasture days at $40 per cow per acre.*

[f] *Acreage data and depth damage data for each specific vegetable crop in the Oak Creek watershed were not available for evaluation of flood damage by crop. Because flooding can occur at any time during the growing season and because many vegetable crops will not tolerate flood inundation depths as shallow as even one foot, it was assumed that any vegetable crop experiencing any degree of flood inundation would be totally destroyed.*

[g] *Gross value of vegetables estimated based upon value per acre of onions equals $1,019, lettuce equals $1,832, carrots equals $1,416, sweet-corn equals $191, snap beans equals $367, cucumbers equals $907, green lima beans equals $315, cabbage equals $630, and potatoes equals $1,270.*

Source: U. S. Soil Conservation Service and SEWRPC.

assuming, in effect, that if inundation occurs, damages will be incurred. This is a realistic assumption for the urban structure damages where inundation for even very short periods of time will damage such costly components as electrical motors, controls, and equipment; furnishings; and interior decorating. In agricultural areas this assumption may be expected to provide a good approximation of actual damages, since many crops may be damaged by very short periods of inundation, although some crops must be inundated for some length of time to be totally destroyed.

Determination of Indirect Damages: The above depth-damage relationships reflect the direct damage to each of the various types of structures or croplands as the function of the depth of inundation. Indirect damages, which can be a significant reaction 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.[4] Indirect flood damage costs due to road overtopping were based upon the incremental increase in travel distance on detour routes and upon the duration of road overtopping when depths exceeded 0.3 foot for free weir flow conditions. Durations were determined using hydrographs generated by the hydrological simulation model for the Oak Creek watershed developed by the Commission.

Average Annual Flood Risks: The above methodology was used to compute average annual flood risks for selected reaches in the Oak Creek watershed under existing and hypothetical future floodland development-land use conditions. 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. For existing land use and channel conditions, the average annual flood damage for the Oak Creek watershed was determined to be $30,000, and the damages caused by the 10-, 50-, and 100-year recurrence interval flood events were determined to be $56,000, $249,000, and $344,000, respectively. The minimum annual flood damage was determined to be $14,000 based on the occurrence of the mean annual flood. The mean annual flood is the flood of a particular magnitude which is expected to be reached or exceeded in any given year.

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.

[4] *R. W. Kates, "Industrial Flood Losses: Damage Estimation in the Lehigh Valley," the University of Chicago, Department of Geography, Research Paper No. 98, 1965, pp. 15 to 17.*

Flood damage and disruption in the Oak Creek 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 the natural floodlands of the watershed, and the flood flow behavior of the stream system of the watershed.

Historical 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 stormwater inundation problems which are beyond the scope of the Oak Creek watershed planning program. Flood problems are defined, for purposes of this report, 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 includes both overland and secondary flooding. In contrast, stormwater inundation problems are defined as damaging inundation which occurs when stormwater 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 historical records indicated the occurrence of eight major flooding periods in the Oak Creek watershed in the recent past. 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 June 22, 1917; June 23, 1940; March 30, 1960; June 11, 1967; June 26, 1968; September 18, 1972; April 21, 1973; and September 13, 1978. Information about the cause and effect of each of these floods was derived by a research process consisting of the following sequential steps: initial reconnaissance of published reports and data, review of newspaper accounts and newspaper files, examination of library and historical society holdings, and contact with community and agency officials. In addition, streamflow and crest gaging records collected in the watershed since 1958, supplemented by synthetic streamflow records generated throughout the watershed by the application of the Commission simulation model since 1940, were utilized to identify the occurrence and magnitude of major floods and the cause thereof.

Findings of the research into historical flood problems leads to the conclusion that flood problems in the urbanized portions of the Oak Creek watershed are relatively minor compared to flood damages in agricultural areas. The majority of the urban flood damages have been concentrated in the southwest area of the City of South Milwaukee. Major channel improvements made to Oak Creek between Rawson Avenue and Pennsylvania Avenue have done much to alleviate flooding in this area. It is important to note, however, that the design flood selected for the Oak Creek watershed planning program is the 100-year recurrence interval event as it would occur under year 2000 planned 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, as described in Chapter XII of this report, to quantify flood problems likely to occur in the watershed under year 2000 planned land use and floodland development conditions, and to identify flood-prone areas. Based upon these studies, it is anticipated that under a no-action alternative substantial increases in flood damages may be expected to occur in both urban and rural areas of the watershed due to increased runoff rates and volumes attributable to the effects of urbanization. Because until recently the Oak Creek watershed has been primarily rural in nature, relatively few residences have been flooded in the past, compared to the highly urbanized watersheds in southeastern Wisconsin. However, uncontrolled urbanization and lack of adequate floodplain management could result in significant increases in flooding damage, not only to existing but also to future residential development in the watershed.

In addition to the quantitative data derived from the inventory of historical flooding, two observations emerge regarding the characteristics of flooding in the Oak Creek watershed. First, the historical 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 who actually occupy the floodlands. Second, the analysis of historical flooding indicates that rainfall, as opposed to snowmelt or rainfall-snowmelt combinations, has been the principal cause of major floods in the Oak Creek watershed. This is particularly significant because it means that, with the exception of the winter season, major floods can occur at any time of the year in the Oak Creek watershed 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.

Flood loss refers to the net effect of historical 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—and they may be classified by whether the private or public sector is affected.

Average annual flood damage risk expressed in monetary terms was selected as the quantitative, uniform means of expressing flood severity in the Oak Creek watershed. These values were derived from damage-probability curves developed for selected reaches under existing, planned, and other floodland and nonfloodland development conditions. The average annual flood damage in the watershed is estimated to be $30,000 for existing land use conditions. Of this total, $16,000 represents agricultural damages and $12,000 represents structure and contents damage, with the remainder representing public and private recreation area damages and miscellaneous direct and indirect damages. A major flood in the watershed could be expected to result in flood damages totaling about $344,000.

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Chapter VII

SURFACE WATER QUALITY CHARACTERISTICS AND PROBLEMS

INTRODUCTION

A basic premise of the Commission watershed studies is that the activities of man within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in an urbanizing area such as the Oak Creek 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 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 Oak Creek watershed planning program in particular, must include an evaluation of historic, present, and anticipated 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 Oak Creek 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 Commission-recommended 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 two decades; 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, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the watershed study.

The focus of this chapter is on surface water quality characteristics and problems. Two related topics addressed in previous Commission comprehensive watershed studies are water supply from both surface and subsurface sources and groundwater quality characteristics and problems. The topics of groundwater quality and water supply are treated in this report only to the extent that they provide information about the development potential of 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 Oak Creek watershed planning program which are set forth in Chapter I and, briefly restated, are to: 1) prepare a floodland management plan, 2) prepare a surface water quality management plan, 3) prepare a plan for public open space preservation, and 4) 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 Oak Creek Watershed Planning Program Prospectus, which identified four water resource-related problems in the watershed: flooding, pollution of surface waters, deterioration of the natural resource base, and changing land use. The inventory and analysis phases of the watershed planning program did not identify any serious problems in the areas of groundwater quality and water supply within the Oak Creek watershed.

The elimination of water supply as a major area of concern in the Oak Creek watershed planning program does not compromise the systems analyses conducted under the planning program, since the water supply and wastewater disposal systems do not interact significantly with the surface water system of the watershed. As indicated in Chapter III of this report, most of the population of the Oak Creek watershed is served by public water supply systems utilizing Lake Michigan as a source. After use, this water is discharged to sanitary sewerage systems through which the used water is transported to the shoreline of Lake Michigan for treatment before being returned to the Lake. Only in relatively small areas of the watershed where sanitary sewerage systems are not present is wastewater discharged to onsite disposal systems. Therefore, the water supply and disposal systems of the watershed are not in any major way a part of the hydrologic-hydraulic system of the watershed. Consequently, the water supply and sanitary sewerage systems are essentially physically separate from the surface and groundwater systems.

Even if groundwater problems—particularly groundwater quantity problems—do develop in the Oak Creek 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 watershed as small as the Oak Creek 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.

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 surface water resource are significantly affected by its quality, and each potential use requires a certain level of water quality. The uses which can be made of the surface water resource may also be affected by the physical characteristics of the channels and by modifications in those characteristics such as may result, for example, from the installation of concrete linings. Such physical limitations, however, were considered in establishing the water use objectives under the areawide water quality management planning effort. If channel linings are recommended under this plan for flood control purposes, the water use objectives established under that planning effort would have to be reevaluated.

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 so concentrated 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, wastewater disposal, 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 metals and other inorganic and organic elements or compounds in industrial wastes, domestic sewage, or runoff, some of which may be toxic to humans and to 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 and other aquatic 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 the oxygen supply in 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 a 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 aquatic life, interfere with navigation, impede agricultural drainage, and increase flood stages.

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, nutrient, 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 Oak Creek 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, may not be considered polluted when its water is 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 Indicators

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 indicators 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 indicators, however, are normally useful in evaluating wastewater quality and natural surface water quality and in indicating pollution. Selected indicators were employed in the Oak Creek 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 indicators 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 indicators were: temperature, dissolved solids, suspended solids, specific conductance, turbidity, hydrogen ion concentration (pH), chloride, dissolved oxygen, biochemical oxygen demand (BOD), total and fecal coliform bacteria, phosphorus and nitrogen forms, aquatic flora and fauna, heavy metals, pesticides, and polychlorinated biphenyls (PCB's).[1]

Wet and Dry Weather Conditions: An Important Distinction

A distinction is drawn in this chapter between instream water quality during dry weather (base flow) conditions and during wet weather conditions. In general, a water quality sample was assumed 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 if such rainfall was recorded on the day of sampling in those cases where the precise time of sampling is not known. Some water samples satisfying the general dry weather criteria were found not to represent dry weather water quality because flow was significantly higher than base flow at the time of sampling. These higher flows probably reflected delayed surface runoff from, and "interflow" discharge from, higher groundwater to the stream caused by earlier precipitation events. Therefore, samples taken from these high flows were not used

[1] *For a more complete discussion of most of the cited indicators, including their significance in evaluating water quality, see Chapter V of SEWRPC Technical Report No. 17, Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, June 1978.*

in the dry weather water quality analysis. Dry weather instream water quality is assumed to reflect 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 land surface 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 dominant sources of pollution addressed in pollution abatement efforts. 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 Oak Creek 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 land surface runoff during wet weather conditions are becoming increasingly important in terms of their impacts on water quality. Wet weather conditions are likely to be as critical in terms of adverse water quality conditions as dry weather conditions are in the Oak Creek watershed because of the absence of major point sources of pollution. Therefore, every effort was made to obtain and report wet weather instream water quality conditions in the Oak Creek 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 43-year period from 1940 through 1982 indicates that there are an average of 64 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 17 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 Oak Creek 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 Oak Creek 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 "recreational use, maintenance of warmwater fish and aquatic life, and minimum standards" water use objectives established under the adopted areawide water quality planning program for the Oak Creek system in conformance with the national water quality objectives cited in Public Law 92-500 have been used (see Table 77 of this report). The standards are intended to permit use of the surface waters of the Oak Creek watershed for full body contact recreation and to support warmwater fish and aquatic life. The water use objectives and supporting water quality standards set forth in Table 77 specify a minimum dissolved oxygen level, a maximum temperature, a fecal coliform count level, 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,[2,3] the water use objectives and standards incorporate recommended maximum or minimum levels for other water quality parameters.

[2] *U. S. Environmental Protection Agency, Quality Criteria for Water, EPA Report No. 440/9-76-003, Washington, D. C., 1976.*

[3] *National Academy of Sciences, National Academy of Engineering, Water Quality Criteria 1972, EPA Report No. R3-73-033, Washington D. C., 1974.*

Criteria have been recommended by the U. S. Environmental Protection Agency (EPA) for metals, polychlorinated biphenyls (PCB's), and pesticides, and those recommeded criteria are used by the Wisconsin Department of Natural Resources in administering the Wisconsin Pollutant Discharge Elimination System. These recommended criteria are presented later in this chapter in conjunction with the data available for the Oak Creek watershed regarding metals, PCB's, and pesticides.[4]

SURFACE WATER QUALITY STUDIES: PRESENTATION AND INTERPRETATION OF DATA

A variety of data sources, based primarily on field studies, are available for use in assessing the historic and existing water quality in the surface waters of the Oak Creek watershed. Each of the 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 as a basis for this chapter, along with selected water quality data from these sources, is set forth in Table 37, and sampling station locations are shown on Map 35. From these water quality data, conclusions are drawn as to the nature and, to the extent possible, the cause of surface water pollution in the Oak Creek 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 25 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 decades. However, the conclusions are based primarily on data obtained over the past decade.

Wisconsin Department of Natural Resources Basin Surveys: 1954, 1968-1969, and 1976

As part of a statewide water quality monitoring program, the Wisconsin Department of Natural Resources and its predecessor agencies have conducted three "basin surveys" of the Oak Creek watershed. 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 of the Wisconsin Department of Natural Resources and its predecessor agencies:

1. Report on 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.

2. 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.

3. Southeastern Wisconsin River Basins—Milwaukee County River Basins Report; Southeast District, Wisconsin Department of Natural Resources; 1976 (unpublished).

In addition to the three basin surveys, the Wisconsin Department of Natural Resources conducted a water quality evaluation of the Oak Creek watershed in 1979 using the Hilsenoff Biotic Index. The findings of that evaluation are presented herein, along with the findings of the basin surveys.

Findings of the 1954 Basin Survey: Table 38 presents the water quality data obtained under the 1954 basin survey. Water quality samples were taken at 13 locations along Oak Creek, as shown on Map 35, during the survey period. The sample data indicate that the dissolved oxygen characteristics of the stream were extremely variable. This variability may be largely attributed to temporal and spatial variations in streamflow, channel geometry, water temperature, and cloud cover in the watershed. Flow conditions in the stream can range from stagnant during hot dry weather to full channel flow conditions during cold, wet weather, resulting in a wide range of hydraulic conditions, oxygen saturation levels, and re-aeration rates. Dissolved oxygen levels were generally high during cold or wet weather conditions and lower during dry weather conditions. Temporal and spatial variations in cloud cover affect the rate of photosynthesis by aquatic plants and consequently the rate of oxygen production by these plants. Large,

[4] *"Environmental Protection Agency, Water Quality Criteria Documents; Availability," Federal Register, Vol. 45, No. 231, November 28, 1980; and "Water Quality Criteria; Request for Comments," Federal Register, Vol. 49, No. 26, February 7, 1984.*

Although it was recognized that the final watershed plan could recommend stream water use objectives different from the federally mandated "fishable-swimmable" stream water use objectives in the Oak Creek watershed, it was deemed appropriate to use the federal objectives and corresponding standards as a point of departure and a basis for evaluating the surface water quality conditions in the Oak Creek watershed. The comparative analyses set forth herein and in Chapter XIII are intended to provide the information needed to determine if the "fishable-swimmable" water use objectives are, as a practical matter, achievable and, if not, to recommend the 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 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 conditions occurred during periods of low flow. However, more recent studies, including those conducted by the Commission under its areawide water quality management planning program, 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 pollutants build up 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 are conducted of the results of the continuous water quality simulation modeling to determine the percent of time a given standard may be expected to be exceeded 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 the survival of aquatic organisms—dissolved oxygen, temperature, ammonia nitrogen, residual chlorine, and pH. A 90 percent compliance level was selected for those parameters—phosphorus and fecal coliform—which do not directly affect aquatic organisms, but which are important indirect factors and are primarily related to recreational use. The analyses indicated that if these compliance levels were met during periods other than those marked by extreme low-flow conditions, the duration of a violation could be expected to be relatively short and the intensity of a violation could be expected to be relatively low, and, therefore, desirable forms of aquatic life should not be adversely affected. This probabilistic approach to water quality standards interpretation is considered to be a supplement to the currently practiced method of evaluating the achievement of standards during low-flow conditions which approximate the 7 day average-1 in 10 year recurrence interval low flow.

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, the standards were applied to all available water quality samples for comparative purposes.

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 samples analyzed 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.

The observed fecal coliform bacteria concentrations could not be precisely compared to the specified standards 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 counts per 100 milliliters (ml) based on not fewer than five samples per month, nor a monthly geometric mean of 400 counts per 100 ml in more than 10 percent of all samples during 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 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.

Table 37

SUMMARY OF WATER QUALITY SAMPLING IN THE OAK CREEK WATERSHED: 1952-1983

Data Source	Documentation	Date	Streams Sampled	Number of Stations	Sampling Time, Period, Frequency	Temperature	Suspended Solids	Volatile Suspended Solids	Specific Conductance	Biochemical Oxygen Demand	Dissolved Oxygen	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen	Total Nitrogen	Dissolved Phosphorus
Wisconsin Department of Natural Resources	Report on an investigation of the 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	Oak Creek	14	2 to 9 visits, May 21, 1953 through September 18, 1953	X	--	--	--	X	X	--	--	--	--	--	--
Wisconsin Department of Natural Resources	Report on an investigation of pollution of the Milwaukee River, its tributaries, and Oak Creek conducted during 1968 and 1969	May 27, 1969	Oak Creek	13	1 to 3 visits, March 6, 1968 through September 3, 1968	X	--	--	--	X	X	--	--	--	--	--	--
Wisconsin Department of Natural Resources	A Drainage Basin Report, 1976 (unpublished)	--	Oak Creek	4	May 27, 1975 through April 12, 1976	X	X	X	--	X	X	X	X	X	X	--	X
Southeastern Wisconsin Regional Planning Commission	SEWRPC water quality studies: 1964-1965 and 1968-1975	1966	Oak Creek	2	January 29, 1964 through February 4, 1965	X	--	--	X	--	X	X	--	--	--	--	--
		1978		2	April 18, 1968 through August 25, 1975	X	--	--	X	--	X	X	X	X	X	X	X
Southeastern Wisconsin Regional Planning Commission	Index site water quality data	--	Oak Creek	1	34 samples September 7, 1976 through October 5, 1976	X	--	--	X	X	X	X	X	X	X	X	--
Wisconsin Department of Natural Resources	Drainage basin surveys of toxic and hazardous substances 1975-1976	1978	Oak Creek	4	May 27, 1975 through April 12, 1976	--	--	--	--	--	--	--	--	--	--	--	--
Wisconsin Department of Natural Resources	DNR file data	1979	Oak Creek	4	Spring 1979/ Fall 1979	--	--	--	--	--	--	--	--	--	--	--	--

Data Source	Documentation	Date	Streams Sampled	Number of Stations	Sampling Time, Period, Frequency	Soluble Reactive Phosphorus	Total Phosphorus	Phosphate Phosphorus	Chloride	Total Volatile Solids	Fecal Coliform	Coliform	ph	Bottom Organisms	Cadmium	Chromium	Copper	Lead	Mercury
Wisconsin Department of Natural Resources	Report on an investigation of the 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	Oak Creek	14	2 to 9 visits, May 21, 1953 through September 18, 1953	--	--	--	--	--	--	X	X	X	--	--	--	--	--
Wisconsin Department of Natural Resources	Report on an investigation of pollution of the Milwaukee River, its tributaries, and Oak Creek conducted during 1968 and 1969	May 27, 1969	Oak Creek	13	1 to 3 visits, March 6, 1968 through September 3, 1968	--	--	--	--	--	--	X	X	X	--	--	--	--	--
Wisconsin Department of Natural Resources	A Drainage Basin Report, 1976 (unpublished)	--	Oak Creek	4	May 27, 1975 through April 12, 1976	--	X	--	X	X	X	--	X	X	--	--	--	--	--
Southeastern Wisconsin Regional Planning Commission	SEWRPC water quality studies: 1964-1965 and 1968-1975	1966	Oak Creek	2	January 29, 1964 through February 4, 1965	--	--	--	X	--	--	X	X	--	--	--	--	--	--
		1978		2	April 18, 1968 through August 25, 1975	--	X	--	X	--	X	X	X	--	--	--	--	--	--
Southeastern Wisconsin Regional Planning Commission	Index site water quality data	--	Oak Creek	1	34 samples September 7, 1976 through October 5, 1976	X	X	X	X	--	X	--	--	--	--	--	--	--	--
Wisconsin Department of Natural Resources	Drainage basin surveys of toxic and hazardous substances 1975-1976	1978	Oak Creek	4	May 27, 1975 through April 12, 1976	--	--	--	--	--	--	--	--	--	--	X	X	X	X
Wisconsin Department of Natural Resources	DNR file data	1979	Oak Creek	4	Spring 1979/ Fall 1979	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 37 (continued)

Data Source	Documentation	Date	Streams Sampled	Number of Stations	Sampling Time, Period Frequency	Nickel	Zinc	PCB	DDT	DDE	DDD	Aldrin	Heptachlor	Heptachlor Epoxide	Lindane	Dieldrin	Methoxychlor	Phthalate	Atrazine	Simazine
Wisconsin Department of Natural Resources	Report on an investigation of the 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	Oak Creek	14	2 to 9 visits, May 21, 1953 through September 18, 1953	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wisconsin Department of Natural Resources	Report on an investigation of pollution of the Milwaukee River, its tributaries, and Oak Creek conducted during 1968 and 1969	May 27, 1969	Oak Creek	13	1 to 3 visits, March 6, 1968 through September 3, 1968	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wisconsin Department of Natural Resources	A Drainage Basin Report, 1976 (unpublished)	--	Oak Creek	4	May 27, 1975 through April 12, 1976	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Southeastern Wisconsin Regional Planning Commission	SEWRPC water quality studies: 1964-1965 and 1968-1975	1966' 1978	Oak Creek	2 2	January 29, 1964 through February 4, 1965 April 18, 1968 through August 25, 1975	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
Southeastern Wisconsin Regional Planning Commission	Index site water quality data	--	Oak Creek	1	34 samples September 7, 1976 through October 5, 1976	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wisconsin Department of Natural Resources	Drainage basin surveys of toxic and hazardous substances 1975-1976	1978	Oak Creek	4	May 27, 1975 through April 12, 1976	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Wisconsin Department of Natural Resouces	DNR file data	1979	Oak Creek	4	Spring 1979/ Fall 1979	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Source: Wisconsin Department of Natural Resources and SEWRPC.

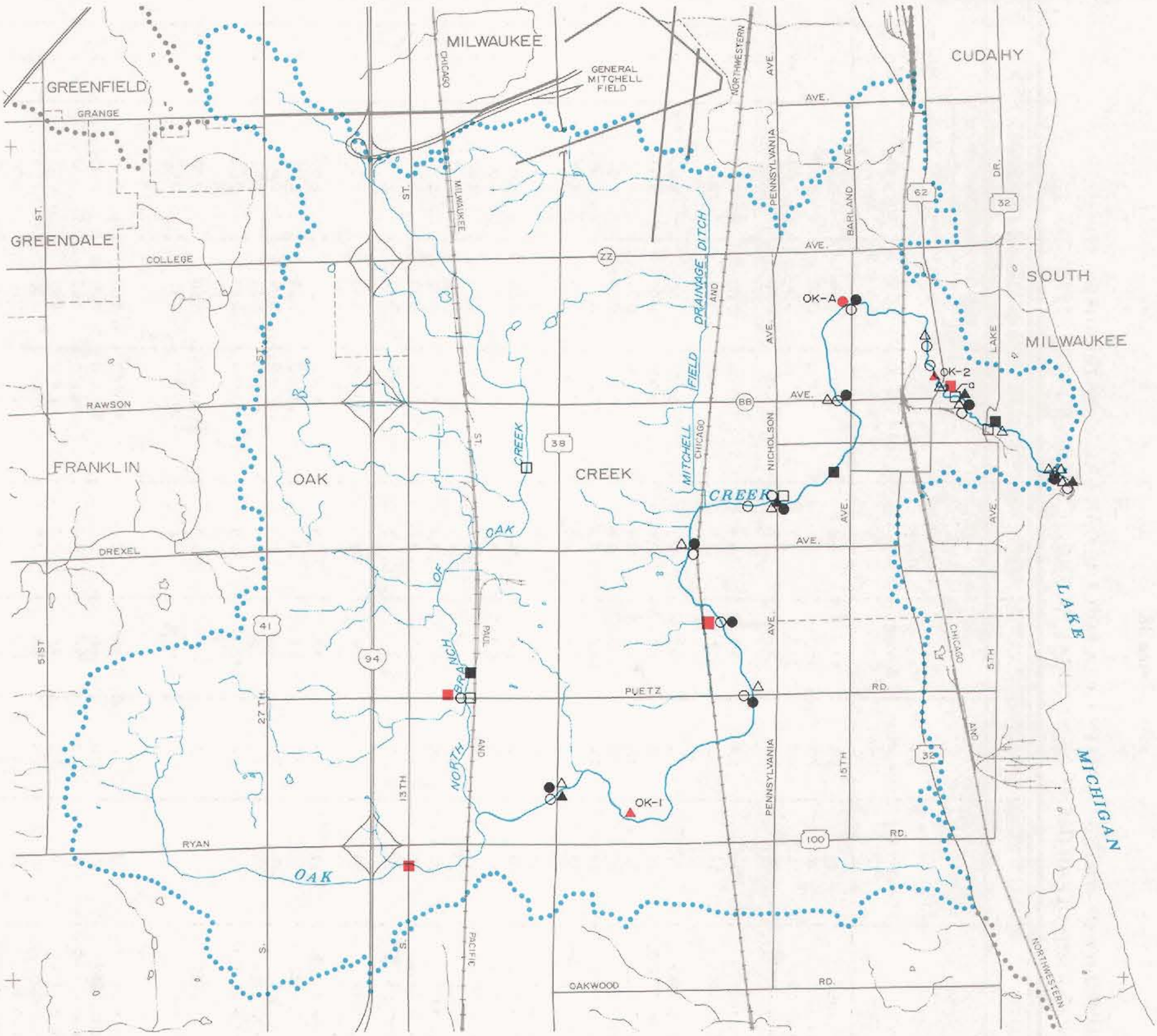
rapid changes in dissolved oxygen concentrations can, thus, be caused solely by changes in cloud cover which affect the rate of photosynthesis. Dissolved oxygen levels in Oak Creek were generally above the present minimum standard of 5 milligrams per liter (mg/l). High total coliform counts—in excess of 100,000 counts per 100 ml—were observed on two or more sampling days at seven stations throughout the watershed. These high total coliform counts suggest that the fecal coliform level of 400 colonies per 100 ml was probably exceeded in many samples. The high coliform counts could be attributed to the discharge of sanitary sewage into the surface waters from sanitary sewer overflows. Table 38 indicates that the existing standards for temperature and pH presented in Table 77 were not violated during the study period.

Biological data were collected at four stations along Oak Creek during the study period, the locations of which are shown on Map 35. As indicated in Table 39, the greatest diversity of benthic fauna species and those species characteristic of the best water quality were recorded at the sampling station at S. Howell Avenue.[5] The benthic community in the downstream portions of the main stem of Oak Creek was characteristic of a polluted stream. The polluted conditions may be

[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 a relatively few pollutant-tolerant species.*

Map 35

STREAMWATER QUALITY SAMPLING STATIONS IN THE OAK CREEK WATERSHED



LEGEND

- △ 1953 BASIN SURVEY – CHEMICAL
- ▲ 1953 BASIN SURVEY – BIOLOGICAL
- ○ 1969 BASIN SURVEY – CHEMICAL
- ● 1969 BASIN SURVEY – BIOLOGICAL
- □ 1976 BASIN SURVEY – CHEMICAL
- ■ 1976 BASIN SURVEY – BIOLOGICAL
- ▲ SEWRPC CONTINUED WATER QUALITY MONITORING PROGRAM 1968 – 1975
- ● SEWRPC MONITORING FOR THE AREAWIDE WATER QUALITY MANAGEMENT PLAN 1976–1977
- ■ 1979 WISCONSIN DEPARTMENT OF NATURAL RESOURCES BIOLOGICAL SURVEY
- a SEDIMENT SITE ONLY

GRAPHIC SCALE: 0 – 1 MILE; 0 – 2000 – 4000 – 6000 FEET

A variety of data sources are available for use in assessing the historic and existing water quality in Oak Creek 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 the SEWRPC monitoring for the areawide water quality management plan.

Source: SEWRPC.

Table 38

SUMMARY OF WATER QUALITY DATA FOR THE OAK CREEK WATERSHED— THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1952-1953

Oak Creek Sampling Stations								Concurrent and Antecedent Moisture Conditions as Indicated by Precipitation Observations		Characterization of Sampling Conditions	
								Daily Precipitation in Inches			
Location	River Mile	Date	Temperature (°C)	pH (standard units)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Total Coliform Count (MFCC per 100 ml)	On Day 1 and	Before Day 2 Sampling	Dry Weather[a]	Wet Weather
S. Howell Avenue Bridge	9.0	May 21, 1953	21	8.3	12.7	2.8	1,000	0.19	0.00	--	X
		June 23, 1953	26	8.3	16.1	3.1	10,000	0.00	0.00	X	--
		August 20, 1953	25	8.2	13.9	2.1	100	0.00	0.00	X	--
		September 18, 1953	20	7.7	7.6	2.5	1,000	0.46	0.00	--	X
Puetz Road Bridge	6.8	June 23, 1953	25	8.8	17.7	5.4	1,000	0.00	0.00	X	--
		August 20, 1953	24	7.9	13.0	2.5	100	0.00	0.00	X	--
Drexel Avenue Bridge	5.6	August 13, 1952	21	7.4	4.8	2.2	10,000	0.00	0.00	X	--
		September 4, 1952	20	7.5	8.1	0.6	10,000	0.00	0.00	X	--
		October 3, 1952	11	7.5	6.2	3.0	10,000	0.00	0.00	X	--
		June 23, 1953	21	7.5	9.3	2.8	100,000	0.00	0.00	X	--
		August 20, 1953	19	7.5	4.8	3.3	100,000	0.00	0.00	X	--
		September 18, 1953	19	7.6	8.0	2.2	10,000	0.46	0.00	--	X
Pennsylvania Avenue Bridge	4.7	July 31, 1952	21	7.5	4.0	3.9	10,000	0.00	0.00	X	--
		August 13, 1952	22	7.5	5.0	4.2	100,000	0.00	0.00	X	--
		September 4, 1952	18	7.5	8.0	3.2	10,000	0.00	0.00	X	--
		October 3, 1952	11	7.5	6.2	2.2	1,000	0.00	0.00	X	--
		May 21, 1953	20	8.2	11.3	4.7	10,000	0.19	0.00	--	X
		June 23, 1953	20	7.5	7.4	1.9	1,000	0.00	0.00	X	--
		August 20, 1953	20	7.5	5.5	3.8	10,000	0.00	0.00	X	--
		September 18, 1953	19	7.5	7.5	2.5	1,000	0.46	0.00	--	X
Rawson Avenue at 16th Street	3.6	July 31, 1952	22	7.7	7.4	2.2	10,000	0.00	0.00	X	--
		August 13, 1952	23	7.8	6.9	3.1	100,000	0.00	0.00	X	--
		September 4, 1952	21	7.8	9.5	2.2	1,000	0.00	0.00	X	--
		October 3, 1952	11	7.8	8.9	1.6	1,000	0.00	0.00	X	--
		June 23, 1953	25	7.8	8.3	5.1	100,000	0.00	0.00	X	--
		August 20, 1953	23	8.1	7.8	3.3	100,000	0.00	0.00	X	--
		September 18, 1953	22	8.4	12.3	1.9	10,000	0.46	0.00	--	X
Sanitary Sewer Overflow Walnut Street and Park Drive	1.9	August 13, 1952	--	7.2	--	146.0	10,000,000	0.00	0.00	X	--
		May 21, 1953	--	7.3	--	113.0	10,000,000	0.19	0.00	--	X
N. Chicago Avenue Bridge	1.6	July 31, 1952	22	7.8	7.8	3.6	100,000	0.00	0.00	X	--
		August 13, 1952	22	8.0	7.0	3.9	100,000	0.00	0.00	X	--
		September 4, 1952	20	7.8	8.6	4.0	10,000	0.00	0.00	X	--
		October 3, 1952	13	7.8	9.4	1.7	10,000	0.00	0.00	X	--
		June 23, 1953	21	7.8	8.0	4.8	10,000	0.00	0.00	X	--
		August 20, 1953	20	8.1	9.0	1.5	10,000	0.00	0.00	X	--
		September 18, 1953	19	7.8	8.3	3.5	10,000	0.46	0.00	--	X

Table 38 (continued)

Oak Creek Sampling Stations: Location	River Mile	Date	Temperature (°C)	pH (standard units)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Total Coliform Count (MFCC per 100 ml)	Concurrent and Antecedent Moisture Conditions as Indicated by Precipitation Observations: Daily Precipitation in Inches: On Day 1 and	Before Day 2 Sampling	Characterization of Sampling Conditions: Dry Weather[a]	Wet Weather
First Bridge on Oak Creek Parkway Upstream of Dam	1.2	July 31, 1952	22	7.8	7.8	2.8	1,000	0.00	0.00	X	--
		August 13, 1952	23	7.8	6.8	3.1	10,000	0.00	0.00	X	--
		September 4, 1952	24	8.1	8.8	0.6	1,000	0.00	0.00	X	--
		October 3, 1952	17	8.0	9.0	1.1	1,000	0.00	0.00	X	--
		May 21, 1953	21	8.2	8.6	4.2	1,000	0.19	0.00	--	X
		June 23, 1953	24	7.8	8.9	1.3	1,000	0.00	0.00	X	--
		August 20, 1953	26	8.1	9.3	1.6	1,000	0.00	0.00	X	--
		September 18, 1953	24	8.1	9.2	1.4	1,000	0.46	0.00	--	X
Second Bridge on Park Drive Upstream of Creek Mouth	0.9	August 13, 1952	22	8.0	8.2	3.9	100,000	0.00	0.00	X	--
		August 20, 1952	22	7.6	8.0	3.6	10,000	0.28	0.00	--	X
Sanitary Sewer Overflow at Creek Crossing	0.2	August 13, 1952	--	9.3	--	266.0	100,000	0.00	0.00	X	--
		May 21, 1953	--	9.3	--	314.0	1,000	0.19	0.00	--	X
First Bridge on Park Drive Upstream of Creek Mouth	0.4	July 31, 1952	22	7.7	4.9	38.7	10,000,000	0.00	0.00	X	--
		August 13, 1952	22	8.4	5.0	49.9	1,000,000	0.00	0.00	X	--
		August 20, 1952	21	7.4	3.5	28.2	10,000,000	0.28	0.00	--	X
		September 4, 1952	23	8.1	8.5	4.5	100,000	0.00	0.00	X	--
		October 3, 1952	15	7.8	10.1	3.6	10,000	0.00	0.00	X	--
		May 21, 1953	21	8.2	4.2	8.6	1,000	0.19	0.00	--	X
		June 23, 1953	26	8.2	11.2	1.4	1,000	0.00	0.00	X	--
		August 20, 1953	24	7.5	9.2	2.5	1,000	0.00	0.00	X	--
		September 18, 1953	22	8.3	11.6	2.5	1,000	0.46	0.00	--	X
Sanitary Sewer Overflow 10 Yards Downstream of First Bridge on Park Drive Upstream of Creek Mouth	0.2	July 31, 1952	--	7.4	--	63.9	1,000,000	0.00	0.00	X	--
		August 13, 1952	--	7.6	--	120.0	10,000,000	0.00	0.00	X	--
		September 18, 1953	30	7.1	--	27.5	1,000	0.46	0.00	--	X
		January 14, 1954	--	7.7	--	2.8	--	0.00	0.00	X	--
Foot Bridge 50 Feet Upstream of Creek Mouth	0.01	July 31, 1952	22	7.6	3.2	27.3	1,000,000	0.00	0.00	X	--
		August 13, 1952	22	8.2	3.5	44.7	1,000,000	0.00	0.00	X	--
		August 20, 1952	21	7.4	0.4	26.1	1,000,000	0.28	0.00	--	X
		September 4, 1952	21	7.5	6.2	3.5	100,000	0.00	0.00	X	--
		October 3, 1952	--	7.5	7.1	2.9	1,000	0.00	0.00	X	--
		May 21, 1953	18	7.6	3.8	34.4	10,000,000	0.19	0.00	--	X
		June 23, 1953	23	8.0	9.9	3.0	1,000	0.00	0.00	X	--
		August 20, 1953	22	7.5	7.7	4.1	1,000	0.00	0.00	X	--
		September 18, 1953	18	7.4	7.0	3.9	10,000	0.46	0.00	--	X

[a] *Precipitation of 0.10 inch or less on day of sampling.*

Source: Committee on Water Pollution.

Table 39

BENTHIC ORGANISM DATA FROM THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1953

Stream	Station Location	River Mile	Date	Bottom Type	Current	Benthic Organisms: Intolerant: Number of Species	Intolerant: Number of Individuals Per Square Foot	Tolerant: Number of Species	Tolerant: Number of Individuals Per Square Foot	Very Tolerant: Number of Species	Very Tolerant: Number of Individuals Per Square Foot	Total: Number of Species	Total: Number of Individuals Per Square Foot	Station Interpretation
Oak Creek	S. Howell Avenue Bridge	9.0	1953	Sand, silt	Sluggish	2	24	5	332	2	124	9	480	Clean
	Pennsylvania Avenue Bridge	4.7	1953	Gravel	Sluggish	1	2	4	191	1	178	6	371	Unbalanced
	First Bridge on Park Drive Upstream of Dam	0.4	1953	Silt	Swift	0	--	0	--	1	4,260	1	4,260	Polluted
	Foot Bridge 50 Feet Upstream of Creek Mouth	0.01	1953	Silt	Sluggish	0	--	0	--	1	7,190	1	7,190	Polluted

Source: Committee on Water Pollution and SEWRPC.

attributed to both nonpoint source pollution and the discharge of sanitary sewage into the surface waters from sanitary sewer overflows.

Findings of the 1968-1969 Survey: Table 40 presents the water quality data obtained in the 1968-1969 basin survey. Water quality samples were taken at 12 locations, as shown on Map 35, along Oak Creek during the survey period. As shown in Table 40, the sample data indicate that the dissolved oxygen levels, while variable, were generally above the existing minimum standard of 5 mg/l. Exceedingly high total coliform counts—in excess of 1,000,000 colonies per 100 ml—were observed at six stations throughout the watershed. These high counts suggest that generally excessive levels of total coliform bacteria existed throughout the lower reaches of Oak Creek. Table 40 indicates that the existing standards for temperature and pH presented in Table 77 were generally not violated during this sampling period.

Biological samples were collected at nine stations along Oak Creek during the study period, the locations of which are shown on Map 35. As indicated in Table 41, the benthic fauna species recorded were primarily tolerant to very tolerant of pollution, indicating degraded water quality conditions in the main stem of Oak Creek.

Findings of the 1975-1976 Survey: Table 42 presents the water quality data obtained under the 1976 basin survey. Water quality samples were taken at four stations, two of which were located on the main stem of Oak Creek and two of which were located on the North Branch of Oak Creek, as shown on Map 35. As shown in Table 42, the sample data indicate that dissolved oxygen levels were nearly always above the existing minimum standard of 5 mg/l. Fecal coliform counts occasionally exceeded the existing standard and were observed to be as high as 59,000 membrane filter fecal coliform counts (MFFCC) per 100 ml. Water temperatures below the Grant Park dam were higher than those observed at the other sampling stations during the spring and summer; however, temperature standards were not violated during the sampling period. Table 42 also indicates that standards for pH and un-ionized ammonia nitrogen were not violated, but that the Commission-recommended standard for total phosphorus was frequently exceeded.

Biological samples were collected at two stations during the survey period, the locations of which are shown on Map 35. As indicated in Table 43, the macroinvertebrates recorded were primarily tolerant to very tolerant of pollution, and the diversity of species collected was relatively low.

In addition, the survey included the collection of phytoplankton, periphyton, and fish samples. Phytoplankton levels were found to be relatively low, with chlorophyll-a levels ranging up to 2.3 micrograms per liter (ug/l). The majority of periphyton sampled in the Oak Creek watershed belonged to pollution-tolerant genera, including Gomphonema, Nitzschia, and Navicula. The periphyton were generally in poor physiological condition. Periphyton chlorophyll-a levels were found to range up to 74.8 milligrams per square meter (mg/m^2). Nine fish species were collected in the main stem and six fish species were collected in the tributary streams to Oak Creek. Although the Oak Creek main stem has a substantial fish population, high turbidity and siltation limits the types and population of fish in the watershed.

Findings of the 1979 Hilsenoff Biotic Index Evaluation: Table 44 presents the biotic index data obtained for four sampling stations in 1979. As shown in the table, the index values can range

Table 40

SUMMARY OF WATER QUALITY DATA FOR THE OAK CREEK WATERSHED FROM THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1968-1969

Oak Creek Sampling Stations: Location	Oak Creek Sampling Stations: River Mile	Date	Temperature (°C)	pH (standard units)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Total Coliform Count (MFCC per 100 ml)	Concurrent and Antecedent Moisture Conditions as Indicated by Mitchell Field Precipitation Observations — Daily Precipitation in Inches: On Day 1 and	Before Day 2 Sampling	Characterization of Sampling Conditions: Dry Weather[a]	Wet Weather
S. Howell Avenue Bridge	9.0	March 6, 1968	0	7.6	11.2	4.0	28,000	0.00	0.05	X	--
		September 3, 1968	20	7.8	7.2	2.1	14,000	0.00	0.00	X	--
Puetz Road Bridge	6.8	March 6, 1968	0	7.4	11.8	5.5	10	0.00	0.05	X	--
		September 3, 1968	20	7.7	8.3	2.1	6,800	0.00	0.00	X	--
Forest Hill Avenue Bridge	6.2	March 6, 1968	0	7.4	10.4	3.7	3,100	0.00	0.05	X	--
		September 3, 1968	21	7.7	6.3	1.0	40,000	0.00	0.00	X	--
Sewage Treatment Plant Lagoon Outfall.	6.0	March 6, 1968	5	7.4	0.0	73.0	3,900,000	0.00	0.05	X	--
		September 3, 1968	26	8.4	15.5	40.0	3,900,000	0.00	0.00	X	--
Drexel Avenue Bridge	5.6	March 6, 1968	4	7.4	4.3	34.0	3,500,000	0.00	0.05	X	--
		September 3, 1968	21	7.8	6.7	8.2	1,300,000	0.00	0.00	X	--
Pennsylvania Avenue Bridge	4.7	March 6, 1968	4	7.4	2.9	14.0	5,200,000	0.00	0.05	X	--
		September 3, 1968	23	8.3	9.8	23.0	600,000	0.00	0.00	X	--
Rawson Avenue Bridge	3.6	March 6, 1968	2	7.4	3.8	12.0	--	0.00	0.05	X	--
		March 13, 1968	--	--	--	--	200,000	0.00	0.00	X	--
		September 3, 1968	22	8.4	15.2	15.0	58,000	0.00	0.00	X	--
15th Avenue Bridge. . . .	2.8	March 6, 1968	2	7.6	9.3	8.9	--	0.00	0.05	X	--
		March 13, 1968	--	--	--	--	82,000	0.00	0.00	X	--
		September 3, 1968	23	8.3	17.2	26.0	26,000	0.00	0.00	X	--
Upstream of Bucyrus-Erie Corporation Outfall	1.5	March 6, 1968	5	7.6	7.8	5.5	7,430,000	0.00	0.05	X	--
		March 13, 1968	--	--	--	--	320,000	0.00	0.00	X	--
		September 3, 1968	--	--	--	15.0	5,200	0.00	0.00	X	--
Bucyrus-Erie Corporation Outfall . . .	1.4	March 6, 1968	9	7.8	12.2	0.6	10	0.00	0.05	X	--
First Bridge Upstream of Dam	1.2	March 6, 1968	7	7.8	10.0	4.3	7,380,000	0.00	0.05	X	--
		March 13, 1968	--	--	--	--	34,000	0.00	0.00	X	--
		September 3, 1968	23	6.6	10.4	13.0	20,000	0.00	0.00	X	--
Mouth of Oak Creek . . .	0.0	March 6, 1968	6	7.8	11.6	3.2	7,250,000	0.00	0.05	X	--
		March 13, 1968	--	--	--	--	44,000	0.00	0.00	X	--
		September 3, 1968	23	7.9	9.6	9.5	32,000	0.00	0.00	X	--

[a]*Precipitation of 0.10 inch or less on day of sampling.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 41

BIOLOGICAL STATION DATA SUMMARY FOR THE OAK CREEK WATERSHED: 1968

Oak Creek Sampling Station						Organic Pollution Tolerances						
						Intolerant		Tolerant		Very Tolerant		
Location	River Mile	Survey Date	Waste Source	Bottom Type	Current	Species	Population	Species	Population	Species	Population	Remarks
Howell Avenue Bridge	9.0	3-12	None known	Rock, sand, and gravel	Riffle	2	55	5	62	1	1	Filamentous algae present
Puetz Road Bridge	6.8	3-12	None known	Sand and gravel	Moderate	1	4	8	156	2	1,930	--
Forest Hill Avenue Bridge	6.2	3-12	None known	Sand, silt, and leaves	Sluggish	1	1	5	136	2	360	Organic debris on bottom
Drexel Avenue Bridge	5.6	3-12	Oak Creek Lagoon	Sand, gravel, and silt	Sluggish	0	0	2	148	2	53	Slimes and organic debris on bottom
Nicholson Avenue Bridge	4.5	3-12	Oak Creek Lagoon	Sand gravel, and silt	Moderate	0	0	1	5	2	2,598	--
Rawson Avenue Bridge	3.6	3-12	Oak Creek Lagoon	Rock sand and gravel	Riffle	0	0	0	0	1	143	Filamentous algae present
15th Avenue Bridge	2.8	3-12	Storm sewer	Sand and gravel	Riffle	0	0	2	2	2	347	Filamentous algae present
Park Drive Bridge above Dam	1.2	4-23	Storm sewer	Rock, sand, and gravel	Riffle	0	0	2	43	1	41	Very fast water, filamentous algae present
Park Drive Bridge above Confluence with Lake Michigan	0.4	4-23	Storm sewer	Rock, sand, and silt	Riffle	0	0	0	0	1	74	Filamentous algae present and organic ooze on bottom

Source: Wisconsin Department of Natural Resources.

Table 42

SUMMARY OF WATER QUALITY DATA FOR THE OAK CREEK WATERSHED FROM THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1975-1976

Stream	Oak Creek Sampling Stations		Date	Temperature (°C)	pH (standard units)	Dissolved Oxygen (mg/l)	BOD (mg/l)		Organic Nitrogen (mg/l)	Ammonia Nitrogen (mg/l)	Un-ionized Ammonia (mg/l)	Nitrite-Nitrate Nitrogen (mg/l)	Total Phosphorous (mg/l)	Dissolved Ortho-Phosphorous (mg/l)	Fecal Coliform (MFFCC per 100 ml)	Total Solids (mg/l)	Total Volatile Solids (mg/l)	Suspended Solids (mg/l)	Volatile Suspended Solids (mg/l)	Chloride (mg/l)	Time	Flow (cfs)
	Location	River Mile					5-day	6-day														
North Branch of Oak Creek	Puetz Road Bridge	0.9[a]	May 27, 1975	17.0	7.7	5.7	4.0	--	0.70	0.11	0.002	0.03	0.17	0.12	30	722	182	6	2	--	0930	1
			June 16, 1975	18.0	7.9	9.0	--	4.3	0.65	0.20	0.006	0.87	0.09	0.05	2,300	594	166	38	5	--	1320	4
			July 8, 1975	26.5	8.4	11.5	3.7	--	0.46	0.03	0.005	0.02	0.08	0.03	490	504	124	7	5	125	1302	1
			August 5, 1975	24.2	8.0	7.9	3.7	--	1.21	0.20	0.012	0.40	0.13	0.06	2,500	500	118	31	8	--	1251	2
			September 15, 1975	13.0	7.9	7.7	--	5.7	11.30	0.09	0.002	0.01	0.09	0.03	210	674	182	6	2	--	1107	1
			October 13, 1975	16.2	8.0	8.0	--	4.1	2.42	0.13	0.005	0.01	0.15	0.06	110	362	98	4	4	--	1216	1
			November 10, 1975	9.0	7.5	8.1	--	3.7	1.82	0.25	0.002	0.37	0.16	0.03	4,900	446	70	88	6	75	1007	3
			December 8, 1975	0.0	7.8	13.2	--	5.8	3.60	0.47	0.003	0.40	0.11	0.03	220	904	130	20	7	--	1030	1
			January 27, 1976	0.0	7.2	8.3	6.1	--	5.60	0.93	0.001	0.19	0.11	0.01	40	2,378	220	6	3	--	1250	1
			February 16, 1976	1.0	7.8	10.6	--	4.3	0.92	0.38	0.003	1.50	0.15	0.06	280	1,290	218	36	6	513	1230	10
			March 22, 1976	2.0	6.4	8.3	--	2.5	0.89	0.14	0.001	0.35	0.09	0.06	10	1,104	236	11	7	--	1020	2
			April 12, 1976	11.0	8.4	16.6	--	4.1	0.51	0.04	0.002	0.12	0.04	0.01	10	920	216	3	3	--	1340	3
Oak Creek	Pennsylvania Avenue Bridge	4.7	May 27, 1975	13.0	8.3	11.5	5.5	--	1.14	0.09	0.005	0.11	0.09	0.01	320	830	190	18	6	--	1100	6
			June 16, 1975	17.0	7.8	7.2	--	5.5	0.82	0.27	0.006	1.65	0.17	0.06	6,700	624	184	80	7	--	1333	27
			July 8, 1975	25.0	8.3	12.7	6.5	--	1.01	0.02	0.002	0.04	0.09	0.008	330	778	170	10	10	155	1332	3
			August 5, 1975	24.0	8,1	10.0	5.3	--	1.51	0.08	0.006	0.11	0.12	0.01	2,000	598	178	26	10	--	1315	7
			September 15, 1975	15.0	8.1	8.7	--	6.1	0.58	0.04	0.002	0.01	0.09	0.01	400	672	176	10	5	--	1201	1
			October 13, 1975	14.2	7.8	8.6	--	5.7	2.61	0.18	0.004	0.01	0.10	0.001	2,000	762	186	10	8	--	1048	4
			November 10, 1975	10.5	7.2	7.2	--	3.7	0.84	0.12	0.001	0.43	0.15	0.06	4,900	396	72	46	5	54	1022	9
			December 8, 1975	1.0	7.8	12.3	--	2.8	0.72	0.38	0.003	0.75	0.06	0.03	460	1,092	168	9	7	--	1045	1
			January 27, 1976	0.0	7.4	7.5	3.3	--	2.40	1.00	0.003	0.36	0.07	0.02	290	1,448	164	4	2	--	1320	1
			February 16, 1976	1.2	7.8	10.2	--	3.1	0.86	0.44	0.003	2.30	0.19	0.07	460	1,024	170	75	7	325	1430	34
			March 22, 1976	4.0	6.5	11.4	00	3.3	1.15	0.18	0.001	1.88	0.07	0.03	90	956	166	8	6	--	1046	11
			April 12, 1976	10.0	8.4	17.1	--	4.9	0.86	0.05	0.003	0.72	0.06	0.001	30	828	168	9	9	--	1445	12
Oak Creek	Second Bridge Downstream of Grant Park Dam	0.4	May 27, 1975	21.0	8.2	10.8	3.7	5.2	0.83	0.10	0.008	0.06	0.07	0.02	100	754	180	6	2	--	1130	6
			June 16, 1975	17.0	7.9	7.8	--	--	0.74	0.29	0.009	1.55	0.20	0.11	4,400	562	140	60	5	--	1400	37
			July 8, 1975	26.5	8.4	9.0	4.0	--	0.71	0.02	0.003	0.05	0.10	0.02	510	608	140	4	3	100	1401	8
			August 5, 1975	25.5	8.4	8.8	4.5	--	2.15	0.04	0.006	0.03	0.08	0.01	140	570	170	11	6	--	1420	7
			September 15, 1975	15.0	8.4	9.6	--	3.7	0.50	0.04	0.003	0.03	0.09	0.02	200	492	98	5	2	--	1216	6
			October 13, 1975	17.0	8.3	9.8	--	4.1	0.74	0.07	0.005	0.06	0.11	0.05	60	480	96	4	4	--	1111	2
			November 10, 1975	12.0	7.8	9.7	--	3.1	0.73	0.14	0.002	0.22	0.14	0.05	800	436	100	28	4	62	1057	6
			December 8, 1975	2.0	8.1	13.6	--	2.8	0.69	0.23	0.003	0.70	0.04	0.02	60	780	118	6	6	--	1100	12
			January 27, 1976	0.0	8.2	13.7	3.7	--	0.43	0.37	0.006	0.48	0.06	0.02	40	962	126	3	1	--	1405	2
			February 16, 1976	1.3	--	11.8	--	5.3	0.96	0.46	--	1.94	0.26	0.12	650	980	160	122	22	313	1511	35
			March 22, 1976	5.0	6.5	11.8	--	2.9	1.62	0.13	0.001	1.57	0.05	0.01	200	928	162	11	6	--	1130	5
			April 12, 1976	9.0	8.4	13.2	--	5.7	0.64	0.03	0.002	0.56	0.06	0.01	320	750	156	8	8	--	1540	16
North Branch of Oak Creek	Marquette Street Bridge	3.0[a]	May 27, 1975	18.0	7.7	7.9	3.7	--	0.64	0.17	0.003	0.02	0.25	0.130	100	504	170	9	2	--	--	--
			June 16, 1975	18.0	7.8	8.8	--	4.6	0.60	0.11	0.003	0.84	0.20	0.130	2,000	490	110	45	4	--	--	--
			July 8, 1975	26.0	8.2	11.0	2.8	--	0.55	0.06	0.006	0.04	0.08	0.045	50	366	100	4	4	75	--	--
			August 5, 1975	24.5	7.9	4.9	12.0	--	8.29	0.08	0.004	0.12	0.17	0.022	59,000	292	60	56	12	--	--	--
			September 15, 1975	13.0	7.7	4.0	--	3.7	0.95	0.27	0.004	0.01	0.11	0.040	50	494	110	26	6	--	--	--
			October 13, 1975	13.4	7.7	13.4	--	3.3	0.53	0.12	0.002	0.01	0.10	0.018	1,400	370	72	47	12	--	--	--
			November 10, 1975	10.0	7.5	7.3	--	3.7	0.80	0.07	0.001	0.37	0.25	0.076	8,300	378	76	94	14	62	--	--
			December 8, 1975	0.2	7.7	12.2	--	2.5	0.55	0.37	0.002	0.68	0.06	0.026	2,100	1,050	142	13	6	625	--	--
			February 16, 1976	0.5	7.6	10.0	--	14.0	1.43	0.59	0.002	1.34	0.12	0.029	230	1,458	174	27	8	--	--	--
			March 22, 1976	2.0	6.3	12.7	--	2.5	0.58	0.15	0.001	0.08	0.05	0.016	10	1,248	224	11	11	--	--	--
			April 12, 1976	13.0	8.0	17.6	--	6.7	1.76	0.11	0.003	0.13	0.04	0.012	410	992	270	11	11	--	--	--

[a] *Measured upstream from the confluence of the North Branch with Oak Creek main stem.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 43

MACROINVERTEBRATE DATA SUMMARY FOR THE OAK CREEK WATERSHED: 1975

Stream	Location	River Mile	Organic Pollution Tolerances					
			Intolerant		Tolerant		Very Tolerant	
			Species	Population (number per square foot)	Species	Population (number per square foot)	Species	Population (number per square foot)
North Branch of Oak Creek	Puetz Road Bridge . . .	0.9[a]	9	39	17	281	9	188
Oak Creek	Fourth Bridge Upstream of Mouth . .	1.3	--	--	9	209	11	235

[a]*Measured upstream from confluence of the North Branch with the Oak Creek main stem.*

Source: Wisconsin Department of Natural Resources.

Table 44

HILSENOFF BIOTIC INDEX VALUES FOR THE OAK CREEK WATERSHED: 1979

Stream	Sampling Station	River Mile	Hilsenoff Value[b]	
			Spring 1979	Fall 1979
North Branch of Oak Creek	Puetz Road Bridge.	0.9[a]	3.14	3.30
Oak Creek	13th Street Bridge	10.7	4.00	4.89
	Forest Hill Avenue Bridge.	6.2	3.55	4.03
	Fourth Bridge Upstream from Mouth	1.3	3.24	3.80

[a] *Measured upstream from the confluence of the North Branch with the Oak Creek main stem.*

[b] *Hilsenoff Values:*
0 to 1.75: excellent water quality; no organic pollution.
1.76 to 2.25: very good water quality; slight organic pollution.
2.26 to 2.75: good water quality; some organic pollution.
2.76 to 3.50: fair water quality; significant organic pollution.
3.51 to 4.25: poor water quality; very significant organic pollution.
4.26 to 5.00: very poor water quality; severe organic pollution.

Source: Wisconsin Department of Natural Resources.

from 0 to 5, with the lower values indicative of the best and the higher values reflecting the worst water quality conditions. This Biotic Index was developed to evaluate the severity of organic pollutants in streams throughout Wisconsin, and is based on a set of recognized tolerance values for benthic or bottom-dwelling macroinvertebrates. As shown in Table 44, the lowest values, as measured by this index, were recorded on the North Branch of Oak Creek at Puetz Road, and the higher values were recorded on the main stem of Oak Creek at the 13th Street bridge.

SEWRPC Water Quality Study: 1964-1965

During the 14-month period from January 1964 through February 1965, the Regional Planning Commission conducted an extensive stream water quality sampling program during which almost 4,000 water samples were collected at 87 sampling stations established in 43 streams in the Region. Under this program, samples were taken at two stations in the Oak Creek watershed—on Oak Creek at Shepard Avenue and on Oak Creek at STH 32—the sampling stations being identified as Ok-1 and Ok-2, respectively. The samples were taken under

Table 45

WATER QUALITY CONDITIONS OF OAK CREEK AND ITS TRIBUTARY: 1964-1965

Station Sampled	Parameter	Numerical Value			Number of Analyses
		Maximum	Average	Minimum	
Oak Creek (Ok-1, Ok-2)	Chloride (mg/l)	135	80	30	16
	Dissolved Solids (mg/l)	755	605	375	16
	Dissolved Oxygen (mg/l) . . .	13.7	10.9	6.4	25
	Total Coliform Count (MFCC/100 ml).	33,000	8,500	500	25
	Temperature (^{o}F)	77	48	32	24

Source: SEWRPC.

dry weather conditions on a monthly basis from April 1964 to February 1965. The samples were analyzed for selected chemical, physical, and biological characteristics to determine the then-existing condition of stream water quality in relation to pollution sources, land use, and population distribution and concentration. The study procedure and results are presented in SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin. For purposes of this analysis, comparisons were made assuming that similar low flows occurred during the months of August and September, and that the streams were likely to exhibit similar dry weather, low-flow water quality conditions. Supplemental data are also available for the low-flow periods of 1964-1966 at four additional stations located along the main stem of Oak Creek—Oak Creek at Forest Hill (Ok-1a), Oak Creek at Drexel Avenue (Ok-lb), Oak Creek at Pennsylvania Avenue (Ok-lc), and the mouth of Oak Creek at Grant Park (Ok-ld)—as collected by the Milwaukee Metropolitan Sewerage Commissions.

Findings of the Study: Table 45 presents a synopsis of dry weather water quality conditions in Oak Creek as determined by the Regional Planning Commission in the 1964-1965 sampling. Water quality conditions for dissolved oxygen, dissolved solids, biochemical oxygen demand, temperature, total coliform bacteria, pH, specific conductance, and chloride, as determined by both the Regional Planning Commission and the MMSD, are set forth below.

Dissolved Oxygen: During the 1964-1965 sampling period, the dissolved oxygen levels in the watershed were found to range from 6.4 mg/l to 13.7 mg/l, with an average of 10.9 mg/l. Although no samples taken at stations Ok-1 or Ok-2 exhibited an oxygen concentration of below 5.0 mg/l, substandard levels were recorded on 11 occasions during the 1964 summer months at the four Milwaukee Metropolitan Sewerage District (MMSD) stations. Surprisingly, the substandard levels recorded at the MMSD stations were not detected at station Ok-2, 2.2 miles downstream, thus indicating that this stream reach may have undergone natural recovery, thereby increasing dissolved oxygen levels.

Although there were no public or private sewage treatment facilities discharging to the stream system of the watershed, the upstream substandard dissolved oxygen levels can be attributed to raw sewage being discharged through sanitary sewer overflows into the stream system during periods of significant precipitation. In addition, runoff from both urban and rural land uses may have contributed to sporadic reductions in dissolved oxygen levels during periods of wet weather. In most cases, however, dissolved oxygen levels were found to be high throughout the upstream and middle reaches of the watershed, with readings of 13.4 mg/l and 10.3 mg/l at stations Ok-1 and Ok-2, respectively, during the August low-flow period in 1964. This is indicative of low amounts of organic loading on this stream system, and the supersaturated dissolved oxygen levels probably indicate the effects of plant growth on the water quality.

Biochemical Oxygen Demand: During the 1964-1965 sampling period, the five-day biochemical oxygen demand (BOD_5) in Oak Creek was found to range from 0.5 mg/l to 9.9 mg/l. The lowest value was recorded at station Ok-1 in May 1964 and the highest at station Ok-2 in August 1964. Higher values, in the range of 10.0 mg/l to 21.5 mg/l, were noted in the supplemental MMSD samples and were probably associated with precipitation on the day of sampling or within the 24-hour period preceding the sampling. Lower levels of biochemical oxygen demand were found at the farthest upstream station, Ok-1, with gradually increasing levels occurring at each successive station moving downstream through stations MMSD-Ok-1a, MMSD-Ok-1b, MMSD-Ok-1c, and Ok-2. This indicates increasing biochemical oxygen demand levels in the stream reaches tributary to the more intensively urbanized land uses. Biochemical oxygen demand levels are more sensitive to the effect of rainfall in streams draining urban areas than in similar streams draining rural areas because of the relatively large proportion of impervious area drained and the numerous sources of organic material. Consequently, at times of heavy rainfall, urban areas may contribute heavily contaminated runoff directly or indirectly to the surface water system. At station MMSD-Ok-2a, biochemical oxygen demand levels were found to be considerably reduced, falling to levels of 1.0 mg/l because of the dilution effect of Lake Michigan.

Temperature: During the 1964-1965 sampling period, the temperature of Oak Creek was found to range from 32° F to 77° F. For the period June through September 1964, the temperature averaged 58° F and 67° F at stations Ok-1 and Ok-2 respectively. These temperature variations may be attributed primarily to seasonal changes. Consequently, the discharges of cooling water into the main stem or the tributaries of Oak Creek from the Appleton Electric Company and Bucyrus Erie Company located in the City of South Milwaukee; the Harley-Davidson Motor Company located in the City of Oak Creek; and the Ladish Company located in the City of Cudahy apparently did not increase the normal temperature of the stream water above the prescribed standard of 89° F.

Total Coliform Bacteria: During the 1964-1965 sampling period, coliform levels in Oak Creek were found to vary from 500 membrane filter coliform counts (MFCC) per 100 ml to 33,000 MFCC/100 ml, with the highest count occurring at station Ok-2 on September 23, 1964. On the same day, a reading of 22,000 MFCC/100 ml was recorded at station Ok-1. The MMSD stations exhibited ranges from as low as 100 MFCC/100 ml to as high as 168,000 MFCC/100 ml. Elevated readings occurred generally during periods of wet weather. The coliform counts observed in fall and early winter of the 1964-1965 sampling period at sampling station Ok-2, reflecting the more urbanized areas of the watershed, were generally higher than the coliform counts observed upstream at sampling station Ok-1, which is associated with the more rural areas of the watershed. This same pattern was also noted during summers of some later years of sampling for fecal coliform.

Fecal coliform bacteria measurements were not a part of the 1964 water quality benchmark survey conducted by the Commission. Thus, it is difficult to estimate the levels of fecal coliform organisms within the total coliform concentration. Generally, however, increased total coliform counts indicate elevated fecal coliform readings. The MMSD conducted fecal coliform samplings in 1964 at the Grant Park station, MMSD-Ok-2a, at the mouth of Oak Creek. Although dilution from Lake Michigan waters would tend to reduce the fecal coliform counts at this station, ranges of from 20 to 1,400 fecal coliform counts per 100 ml were recorded. These levels indicate the presence of fecal coliform bacteria contamination in Oak Creek from several possible sources, including runoff from animal feeding operations, from areas served by malfunctioning onsite sewage disposal systems, and from sanitary sewer overflows and urban runoff.

Hydrogen Ion Concentration (pH): During the 1964-1965 sampling period, the pH values at all sampling stations in the Oak Creek watershed ranged from 7.3 to 9.1 standard units. The recommended maximum of 9.0 standard units, as prescribed by the Department of Natural Resources for the maintenance of fish and aquatic life, was exceeded four times, once at station MMSD-Ok-1a, twice at station MMSD-Ok-1c, and once at station MMSD-Ok-2a, with readings of 9.1 at each station. It is difficult to assess the origin of these elevated pH levels, although industrial waste discharges are the most likely cause.

Specific Conductance: During the 1964-1965 sampling period, the specific conductance of the surface waters of the Oak Creek watershed was found to range from 544 to 1,020 µmhos per centimeter at 25° C. The specific conductance is an approximate measure of the dissolved ions present in water, the increased specific conductance normally being due to the presence of increased amounts of such substances as sulfates, bicarbonates, and chlorides. As anticipated, higher specific conductance levels were evident during the spring runoff because of the greater concentrations of dissolved solids from the residue of winter street and highway salting operations. During the late spring, summer, and early fall months, specific conductance levels returned to normal at stations Ok-1 and Ok-2.

Chloride: During the 1964-1965 sampling period, the observed chloride concentrations for the Oak Creek watershed ranged from 7 mg/l to 135 mg/l, with the average values for Oak Creek being 77 mg/l. The levels of chloride concentration were typically elevated during the winter months at all stations except the MMSD-Ok-2a at Grant Park as a result of runoff contaminated with road salt. This exception reflects the dilution of the stream water with Lake Michigan water at that location.

Concluding Statement: The 1964-1965 dry weather survey indicated that water quality conditions consistently satisfied the temperature standards established for the surface waters of the Oak Creek watershed. The sample data, however, indicated that the dissolved oxygen standard, pH standard, and fecal coliform standard were occasionally to frequently violated. The violation of these standards can be primarily attributed to excessive nonpoint source pollution loading to the streams and to the discharge of sanitary sewage from sewer overflows.

SEWRPC Continuing Water Quality Monitoring Program: 1968-1975

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 stream water quality study and, accordingly, the monitoring network included the two Oak Creek watershed sampling stations. During 1968 and 1969, the SEWRPC stream water quality monitoring program involved twice-yearly sampling at all stations during periods of both 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. Additional data are available for low-flow periods in 1965 and 1966 from samples taken by the Milwaukee Metropolitan Sewerage District at stations Ok-1a, Ok-1b, Ok-1c, and Ok-2a.

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, for one sample obtained during the 24-hour period the samples were analyzed for the following four parameters: fecal coliform, nitrate nitrogen, nitrite nitrogen, and dissolved phosphorus.

In order to obtain regional information on additional water quality indicators, the Commission and the Wisconsin 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, ammonia 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 an increased interest in both the oxygen demand exerted by ammonia nitrogen and the toxic effect of ammonia nitrogen.

Thus, the stream water quality monitoring program, as revised in 1972, 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: A summary of the data collected by the Commission staff for the two sampling stations in the Oak Creek watershed—Ok-1 and Ok-2—for the period 1968 through 1975 is set forth in Tables 46 and 47.

Dissolved Oxygen: During the low-flow sampling periods for the years 1968 through 1975, the dissolved oxygen levels in the Oak Creek stream

Table 46

WATER QUALITY CONDITIONS OF OAK CREEK AT SAMPLING STATION OK-1: 1968-1975

Parameter	Recommended Level/Standard[a]	Numerical Value			Number of Analyses	Number of Times the Recommended Standard/Level Was Not Met
		Maximum	Average	Minimum		
Chloride (mg/l)	--	221.000	141.745	27.000	22	--
Dissolved Oxygen (mg/l)	5.0[b]	13.1	7.0	1.5	30	3[h]
Ammonia-N (mg/l)	0.02[c]	0.440[i]	0.249[i]	0.030[i]	8	0[j]
Organic-N (mg/l)	--	0.980	0.721	0.180	8	--
Total-N (mg/l)	--	1.750	1.233	0.290	8	--
Specific Conductance (umhos/cm at 25°C)	--	1,720.0	1,235.0	775.0	30	--
Nitrite-N (mg/l)	--	0.050	0.024	0.002	12	--
Nitrate-N (mg/l)	0.3	0.430	0.212	0.040	12	4
Soluble Orthophosphate-P (mg/l)	--	0.176	0.079	0.010	12	--
Total Phosphorus (mg/l)	0.1	0.160	0.102	0.020	8	5
Fecal Coliform (MFFCC/100 ml)	200-400[d]	1,200	508	130	12	7[g]
Temperature (°F)	89.0[e]	81.0	73.4	66.5	30	0
Hydrogen Ion Concentrations (standard units)	6.0-9.0[f]	8.2	8.0	7.6	22	0

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

[b] *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.*

[c] *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 or greater, and has been recommended by the EPA as a water quality standard for the protection of fish and other aquatic life of the types found in the natural waters of the Region.*

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

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

[g] *The value of 400 was used in determining the number of times the standard was not met.*

[h] *The concentrations were below the water quality standard of 5.0 mg/l for dissolved oxygen.*

[i] *Data are reported as total ammonia.*

[j] *Violations were determined by relating un-ionized and total ammonia as put forth in Quality Criteria for Water, EPA-440/9-76-003.*

Source: SEWRPC.

system ranged from 1.5 mg/l to 13.1 mg/l at stations Ok-1 and Ok-2 and the three MMSD stations at Forest Hill Road, Drexel Avenue, and Pennsylvania Avenue. The average dissolved oxygen concentrations at stations Ok-1 and Ok-2 were 7.0 and 7.1 mg/l, respectively. Lower dis-

Table 47

WATER QUALITY CONDITIONS OF OAK CREEK AT SAMPLING STATION OK-2: 1968-1975

Parameter	Recommended Level/Standard[a]	Numerical Value			Number of Analyses	Number of Times the Recommended Standard/Level Was Not Met
		Maximum	Average	Minimum		
Chloride (mg/l)	--	211.000	87.061	48.000	22	--
Dissolved Oxygen (mg/l)	5.0[b]	9.6	7.1	4.1	30	1[h]
Ammonia-N (mg/l)	0.02[c]	0.270[i]	0.144[i]	0.030[i]	8	0[j]
Organic-N (mg/l)	--	1.320	0.767	0.210	8	--
Total-N (mg/l)	--	3.460	1.518	0.510	8	--
Specific Conductance (umhos/cm at 25°C)	--	1,160.0	899.4	609.0	30	--
Nitrite-N (mg/l)	--	0.100	0.030	0.004	12	--
Nitrate-N (mg/l)	0.3	1.770	0.459	0.100	12	8
Soluble Orthophosphate-P (mg/l)	--	0.312	0.099	0.010	12	--
Total Phosphorus (mg/l)	0.1	0.230	0.102	0.050	8	3
Fecal Coliform (MFFCC/100 ml)	200-400[d]	1,800	490	150	12	3[g]
Temperature (°F)	89.0[e]	80.0	73.3	67.0	30	0
Hydrogen Ion Concentrations (standard units)	6.0-9.0[f]	89.0	8.0	7.8	22	0

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

[b] *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.*

[c] *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 or greater, and has been recommended by the EPA as a water quality standard for the protection of fish and other aquatic life of the types found in the natural waters of the Region.*

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

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

[g] *The value of 400 was used in determining the number of times the standard was not met.*

[h] *The concentrations were below the water quality standard of 5.0 mg/l for dissolved oxygen.*

[i] *Data are reported as total ammonia.*

[j] *Violations were determined by relating un-ionized and total ammonia as put forth in Quality Criteria for Water, EPA-440/9-76-003.*

Source: SEWRPC.

solved oxygen levels were, however, observed in 1975 than in any of the prior sampling years, indicating that the water quality conditions had declined during the sampling period. The data indicate that during low-flow conditions, the 5.0 mg/l standard was violated at the Commission sampling station only three times, all on August 25, 1975. The decrease in dissolved oxygen in August 1975 can be attributed to the rainfall which occurred over the four days prior to sampling, during which time two inches of rainfall were recorded at the General Mitchell Field weather station, located 3.5 miles north of station Ok-2. Based on the sampling results, there appears to be a more pronounced reduction in dissolved oxygen levels after intensive rainfall events at sampling stations Ok-1, MMSD-Ok-1a, and MMSD-Ok-1b, which are located closer to the agricultural subbasin of the watershed, than at the more urbanized downstream stations MMSD-Ok-1c and Ok-2. This may be attributed to organic loadings associated with stormwater runoff from agricultural lands.

A comparison of the dissolved oxygen concentrations recorded in April and August of the years 1964, 1968, and 1969 indicates consistently higher dissolved oxygen levels in April of each year than during the August low-flow periods. The lower flow and higher temperatures, coupled with the organic loadings from agricultural and urban runoff, probably account for the lower dissolved oxygen concentrations in the August samples.

Chloride: Chloride concentrations in Oak Creek were observed to range from 27 mg/l to 221 mg/l at the two Commission stations from 1964 through 1975. The majority of the readings exceeded the normal background levels of chloride concentrations in the groundwater of 7 mg/l for the Oak Creek watershed area. A comparison of the chloride concentrations for April and August of 1968 indicates generally higher chloride concentrations in April at both stations. When the average chloride concentrations for August 1968 through 1975 are compared for both stations, a decreasing trend over time is noted. The chloride concentrations exhibited decreases at both stations over the eight-year sampling period. These results are consistent with what might be expected, since the winter salting operations of the Milwaukee County Highway Department and the local units of government decreased during the same period because of the installation of computerized salting machines, which use less salt. Decreasing levels of chloride within the Oak Creek watershed may also be attributed to a reduced number of livestock operations as a result of urbanization, elimination of malfunctioning domestic onsite sewage disposal systems as a result of rapidly expending sewer service areas, and the gradual elimination of sewage overflow relief devices by the Cities of Oak Creek and South Milwaukee.

Fecal Coliform Bacteria: Fecal coliform bacteria counts observed at the Commission sampling stations from 1968 through 1975 ranged from 70 to 13,000 MFFCC/100 ml. It is difficult to assess any trends because of the lack of fecal coliform data for the years prior to 1968 and because of the fluctuations of fecal coliform values as a result of varied precipitation. Milwaukee Metropolitan Sewerage District data available for August 1965 and 1966 for sampling stations MMSD-Ok-1a, Ok-1b, and Ok-1c indicate very high counts ranging from 1,200 to 1,900 MFFCC/100 ml in 1965 and lower counts ranging from 400 to 700 MFFCC/100 ml in 1966. The fecal coliform levels recorded at sampling station Ok-2, located in the more urbanized portion of the watershed, were more sensitive to the flow rates on the sampling dates than were the levels recorded at sampling station Ok-1, located in the more rural portion of the watershed.

Unlike the other watersheds within the Region, where probable sources of fecal contamination can be identified, the Oak Creek watershed had few probable sources at the time of the sampling. Livestock operations, of which two were known to exist within the watershed in 1975, and malfunctioning septic systems are the probable major sources of fecal contamination within this watershed during dry weather. Runoff from livestock operations contribute fecal coliform primarily to surface waters during wet weather. Malfunctioning septic systems can contribute fecal coliform bacteria to surface and groundwater during periods of both dry and wet weather because a system's tendency to malfunction may not be dependent on saturated soil conditions but rather on the inability of the system and associated seepage bed to process wastes properly. The three sanitary sewerage system flow relief devices that have discharged raw sewage into the streams during times of sewer surcharge may have been the source of high fecal coliform levels during wet weather. In addition, fecal material from pets or other warm-blooded animals within the watershed, when washed off during precipitation events, may have contributed to the high levels. Generally, the data indicate that the overall levels of water quality in the main stem of Oak Creek have improved somewhat—

especially at sampling station Ok-1—since 1968, on the basis of fecal coliform levels observed in August during the years 1968 through 1975.

Hydrogen Ion Concentration (pH): As indicated in Tables 46 and 47, the pH values of the stream system in the Oak Creek watershed have generally been within the range of 6.0 to 9.0 standard units prescribed for the maintenance of warmwater fish and aquatic life. The pH was within the 1973 adopted standards for all of the samples taken at sampling stations Ok-1 and Ok-2. No apparent trend in pH was observed in the samples collected over the 10-year period. Normal ranges for pH of 7.9 to 8.2 standard units were also recorded at sampling stations MMSD-Ok-1a, Ok-1b, and Ok-1c in 1965 and 1966.

Specific Conductance: Specific conductance, a measure of total dissolved ions in water, was found to range from 544 to 1,720 μmhos per centimeter at 25° C at the two Commission sampling stations on the days of sampling between 1964 and 1975. The highest specific conductance value was found at station Ok-1 on August 11, 1970, and was preceded by four days of rainfall of sufficient intensity to have carried major amounts of dissolved solids into the watercourse. The direct relationship observed between dissolved ion concentrations and antecedent rainfall is supported by the increased values of specific conductance in April, which were observed to be higher than the August readings in 1968 and 1969. The increased concentrations of dissolved ions in the April samples may be attributed to spring runoff and the flushing action which accompanies snowmelt and heavy rainfall. However, the August samples seemed to indicate a decrease in specific conductance over the eight-year sampling period.

Temperature: As indicated in Tables 46 and 47, the temperature of the stream water of the watershed has remained below the 89° F standard established for fish and aquatic life. No trend in temperature variation was observed from August 1964 through 1975, although seasonal fluctuations were noted.

Soluble Orthophosphate and Total Phosphorus: Water samples collected from the two Commission sampling stations during August of the years 1968 through 1975 were analyzed for soluble orthophosphate concentrations. A range of 0.01 to 0.38 mg/l of soluble orthophosphate, measured as phosphorus, was found during the eight sampling years at the two stations. From 1972 through 1975, the water samples also were analyzed for total phosphorus, and a range of 0.02 to 0.23 mg/l as P was found. The ratio of soluble orthophosphate to total phosphorus was found to be approximately 1 to 1; however, at times the ratio was found to range from 0.5 to 1.0. This high ratio of soluble orthophosphate to total phosphorus indicated that most of the phosphorus is in the form readily available for the growth of aquatic flora. Although not enough samples were analyzed to characterize the trends in total phosphorus concentrations over time, it is evident from the data that the concentrations are higher than required for excessive algal growth. It is generally believed that a level of 0.10 mg/l of total phosphorus is sufficiently low to prevent nuisance growth of algae and other aquatic plants. Eight of the 16 water samples collected from Oak Creek exhibited total phosphorus levels equal to or higher than 0.10 mg/l.

The phosphorus data, along with the earlier-cited chloride data, are indicative of the presence of several sources of pollution from both point and nonpoint sources within the watershed. The increase in phosphorus with the increase in flow in the rural areas may indicate that part of the phosphorus loading is due to agricultural runoff. Conversely, in the urban areas, point source contamination from sanitary sewerage system flow relief devices, industrial wastewater discharges, and stormwater discharges may contribute significantly to the phosphorus loadings of the surface waters of the Oak Creek watershed.

Total phosphorus loadings from the watershed were determined utilizing flow data from the U. S. Geological Survey continuous stage recorder gage at sampling station Ok-2, and measured sample data. Total phosphorus loadings to the watershed as determined from land use information are discussed in Chapter VI of Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975. Both the technical report data and the measured data are presented in the following section on nonpoint sources of pollution.

Nitrogen: The total nitrogen concentrations in the water samples collected during August of the years 1972 through 1975 were found to range from 0.29 to 3.46 mg/l as N. Of this total, 0.6 to 2.8 percent was found to be in the form of nitrite nitrogen, 7.8 to 10 percent in the form of ammonia nitrogen, 51 to 60 percent in the form of nitrate nitrogen, and

38 to 62 percent in the form of organic nitrogen. The concentrations of ammonia nitrogen at the sampling stations ranged from 0.03 to 0.44 mg/l as N. The highest concentrations were found at sampling station Ok-1 in 1974 and 1975. These elevated levels could indicate the effects of agricultural cropping operations.

Nitrate nitrogen concentrations in the Oak Creek watershed were found to range from 0.04 to 2.1 mg/l as N. The major source of nitrate nitrogen in the Oak Creek watershed is probably agricultural operations.

Organic nitrogen in the Oak Creek watershed ranged from 0.18 to 1.32 mg/l on the sampling days in 1972 through 1975. Organic-nitrogen levels remained high over the last four years of sampling, with 75 percent of the values ranging upward from 0.50 mg/l. Generally, the total nitrogen loadings increased with flow. The four years of data are insufficient for identifying a trend in the total nitrogen loading of Oak Creek. However, the nitrogen data, when considered along with the chloride and total phosphorus data, do indicate that significant sources of pollution existed within the watershed which were probably diffuse in nature.

Concluding Statement: The Commission's continuing water quality monitoring program for 1968 through 1975 indicated that water quality conditions in the Oak Creek watershed had deteriorated since 1968. When comparing the 1975 water quality data to the applicable 1976 DNR-adopted standards, dissolved oxygen concentrations and fecal coliform counts were found not to meet the minimum standards for recreational use and the maintenance of warmwater fish and other aquatic life. In addition, the level of total phosphorus was higher than the recommended level adopted by the Commission, and the levels of ammonia nitrogen exceeded the established maximum standard of 0.4 mg/l for streams on two occasions at station Ok-1.

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 effects on animal and human life of certain substances not formerly considered in water quality management studies. Because of this growing awareness, the available data on the levels of these toxic and hazardous substances in the streams and lakes of the Region as obtained under the Wisconsin Department of Natural Resources drainage basin study programs were assembled by the Commission under the areawide water quality management program. Such data applicable to the Oak Creek watershed are presented below.

Toxic and Hazardous Substances—Background: The general category of toxic and hazardous materials consists of the three subcategories: metals, pesticides, and polychlorinated biphenyls (PCB's). All of these materials tend to accumulate in the environment as a result of man's activities. Metals such as cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc 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 were formerly used principally in the electrical industry in capacitors and transformers and in the production of papers used for printed self-copying forms not requiring carbon paper.

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 populations. Reported adverse effects of metals, pesticides, and PCB's on humans include liver and kidney disorders, carcinogenic effects, nervous system damage, skin lesions, and disruption of reproductive processes. PCB's can also affect reproduction in animals and can cause physical and mental disabilities which impede survival. 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.

Metals, pesticides, and PCB's may potentially be transported into the surface waters of the Oak Creek watershed directly via stormwater runoff as well as through industrial and municipal wastewater outfalls or by groundwater discharge if groundwater were to become contaminated with these materials. Potential diffuse sources of heavy metals, pesticides, and PCB's in the Oak Creek watershed include 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 discharges of sanitary sewerage system flow relief devices.

Findings of the Study: Dry weather metal, PCB, and pesticide concentrations found in the selected surface water quality samples taken by the Wisconsin Department of Natural Resources from sampling stations located on Oak Creek from May 1975 through April 1976 are summarized in Table 48. In addition, the results of two sediment samples collected from two locations on Oak Creek are presented in Table 49.

Surface Waters: Generally, the data presented in Table 48 do not indicate the presence of a toxic substances pollution problem in the surface waters of the Oak Creek watershed. Of the seven metals for which data are available, mercury was the only one found to occur in the watershed in concentrations in excess of the U. S. Environmental Protection Agency (EPA)-recommended standard. Two samples out of a total of 48 samples analyzed had mercury levels above the recommended standard. It is important to note that in the above analysis for mercury, the lowest level of mercury which the laboratory conducting the test was able to detect was 0.2 microgram per liter, (μg/l), which is higher than the recommended standard 0.05 μg/l. Therefore, the actual mercury concentration present in the remaining 46 samples, while lower than 0.2 μg/l, could still be higher than the recommended level of 0.05 μg/l. In addition, one sample out of a total of 10 samples analyzed for PCB's exceeded the EPA-recommended standard. As with mercury, the sensitivity of the tests used to analyze the samples for the presence of PCB's was significantly higher than the recommended standard level of 0.001 μg/l. Therefore, it is difficult to assess the actual number of samples in excess of the recommended standard in the surface waters of this basin.

With regard to observed concentrations of the pesticides for which criteria have been recommended—namely, DDT, DDE, DDD, Aldrin, Heptachlor, Heptachlor Epoxide, Lindane, Dieldrin, Methoxychlor, and Phthalate—the limited data available indicate that there are no violations of the EPA-recommended standards.

Sediment: The available data on the presence of toxic substances in the bottom sediments of the Oak Creek watershed are presented in Table 49. Analysis of the subject bottom sediments indicated that detectable levels of cadmium, zinc, and PCB's were present.

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 one location within the Oak Creek 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 at selected locations in the Region for a continuous period of time encompassing periods of both dry weather low flow and wet weather high flow. 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—a predecessor to the model used under the Oak Creek watershed planning program.

The sampling station utilized during this monitoring program was located at the 15th Avenue bridge crossing of Oak Creek—River Mile 2.8—in the City of South Milwaukee. This is also the site of a U. S. Geological Survey continuous stage recorder gage established in 1963. The location of the sampling site is shown on Map 35.

As shown in Figure 31, stream water quality determinations for the station were made at approximately one-day intervals for the period of September 7 and through October 5, 1976. In addition, on those days on which runoff occurred as the result of rainfall events, several water quality samples were taken for the purpose of preparing instream pollutographs. A significant rainfall event

Table 48

SUMMARY RESULTS OF AVAILABLE DATA FOR TOXIC AND HAZARDOUS MATERIALS IN SELECTED WATER QUALITY SAMPLES FROM THE OAK CREEK WATERSHED

Location	Date	Cadmium µg/l		Chromium µg/l		Copper µg/l		Lead µg/l		Mercury µg/l		Nickel µg/l		Zinc µg/l		Polychlorinated Biphenyls (PCB's) µg/l	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Oak Creek Puetz Road West of Howell	05/27/75-04/12/76	0.1(1)	< 0.2(11)	6.(3)	< 3.(10)	4.5(7)	< 4.(6)	6.(9)	< 3.(4)	0.3(1)	< 0.2*(12)	--	< 20.(13)	50.(8)	<20.(5)	--	< 0.1*(3)
Oak Creek Marquette Street	05/27/75-04/12/76	--	< 0.2(11)	12.(1)	< 3.(10)	6.8(8)	< 3.(3)	14.(9)	< 3.(2)	0.3(1)	< 0.2*(10)	--	< 20.(11)	80.(9)	< 20.(2)	--	< 0.1*(2)
Oak Creek Parkway 0.3 Miles Below Dam (Mill Road)	05/27/75-04/12/76	--	< 0.2(12)	11.(6)	< 3.(6)	5.(9)	< 3.(3)	6.(7)	< 3.(5)	--	< 0.2*(12)	--	< 20.(12)	17.(4)	< 20.(8)	0.36(1)	< 0.1*(2)
Oak Creek Pennsylvania Avenue	05/27/75-04/12/76	--	< 0.7(12)	33.(8)	< 3.(4)	5.8(5)	< 3.(7)	5.(6)	< 3.(6)	--	< 0.2*(12)	--	< 20.(12)	30.(8)	< 20.(4)	--	< 0.1*(2)

Location	Date	DDT µg/l		DDE µg/l		DDD µg/l		Aldrin µg/l		Heptachlor µg/l		Heptachlor Epoxide µg/l		Lindane µg/l		Dieldrin µg/l		Methoxychlor µg/l		Phthalate µg/l		Atrazine[c] µg/l		Simazine[c] µg/l	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Oak Creek Puetz Road West of Howell	05/27/75-04/12/76	--	<0.02*(3)	--	<0.01(3)	--	<0.01(3)	--	<0.005*(3)	--	<0.005*(3)	--	< 0.03*(3)	--	<0.005(3)	--	<0.01*(3)	--	<0.04*(3)	--	--	--	--	--	--
Oak Creek Marquette Street	05/27/75-04/12/76	--	<0.02*(3)	--	<0.01(3)	--	<0.02(3)	--	<0.005*(3)	--	<0.005*(3)	--	<0.005*(3)	--	< 0.01(3)	--	<0.01*(3)	--	<0.08*(3)	--	< 0.2(1)	--	--	--	--
Oak Creek Parkway 0.3 Miles Below Dam (Mill Road)	05/27/75-04/12/76	--	<0.02*(3)	--	< 0.01(3)	--	<0.02(3)	--	< 0.005*(3)	--	<0.005*(3)	--	< 0.01*(3)	--	<0.005(3)	--	<0.01*(3)	--	<0.08*(3)	--	--	--	--	--	--
Oak Creek Pennsylvania Avenue	05/27/75-04/12/76	--	< 0.02*(2)	--	<0.01(2)	--	<0.02(2)	--	< 0.005*(2)	--	<0.005*(2)	--	< 0.01*(2)	--	<0.003(2)	--	< 0.01*(2)	--	<0.08*(2)	--	< 0.2(2)	--	--	--	--

[a] *Average of determinate sample results (number of samples averaged).*

[b] *Indeterminate sample results (number of samples averaged). Asterisk (*) indicates those sample results of less than detectable (sensitivity) limits of the laboratory analysis.*

[c] *No recommended criteria established.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 49

SUMMARY RESULTS OF AVAILABLE DATA FOR TOXIC AND HAZARDOUS MATERIALS IN SELECTED SEDIMENT SAMPLES FROM THE STREAMS OF THE OAK CREEK WATERSHED

Location	Dates of Sampling	Cadmium mg/kg		Chromium mg/kg		Copper mg/kg		Lead mg/kg		Mercury mg/kg		Nickel mg/kg		Zinc mg/kg		Polychlorinated Biphenyls (PCB's) mg/kg	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Marquette at Oak Creek	02/16/76	0.5	--	9.3	--	42	--	80	--	0.025	--	15	--	500	--	250	--
Parkway at Oak Creek	02/16/76	0.75	--	25.0	--	39	--	128	--	0.095	--	10	--	120	--	34,000	--

[a] *Average of determinate sample results (number of samples averaged).*

[b] *Indeterminate sample results (number of samples averaged).*

Source: Wisconsin Department of Natural Resources and SEWRPC.

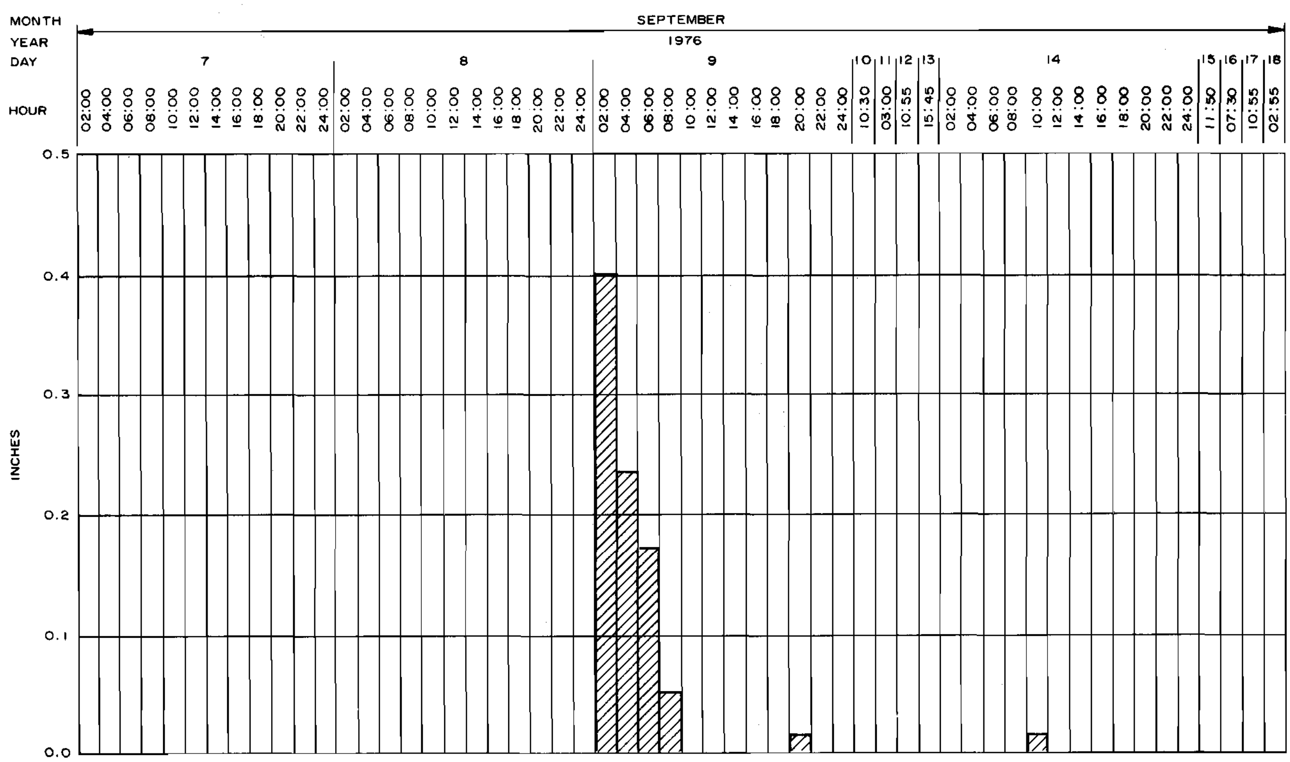
occurred on October 4 and 5, when about 1.38 inches of rainfall fell on the watershed during a 28-hour period from about 9:00 p.m. on October 4 to 12:00 p.m. on October 5. Such a rainfall event may be expected to occur one or more times each year.

The data collected at the station in the Oak Creek watershed during September and October of 1976 are different from the data collected in all the other monitoring efforts reported herein for two reasons. First, most of the data collected under other studies were single samples collected generally during dry weather conditions and, although some limited wet weather data were available, they generally were not sufficient to characterize the water quality impacts of runoff events. The 1976 data include both water quantity and quality information for rainfall runoff events, thus permitting a characterization of the water quality

Figure 31

SURFACE WATER QUALITY (DRY AND WET WEATHER) OF OAK CREEK AT 15TH AVENUE (RM 2.84): SEPTEMBER 7-OCTOBER 5, 1976

HOURLY PRECIPITATION: MILWAUKEE (MITCHELL FIELD)



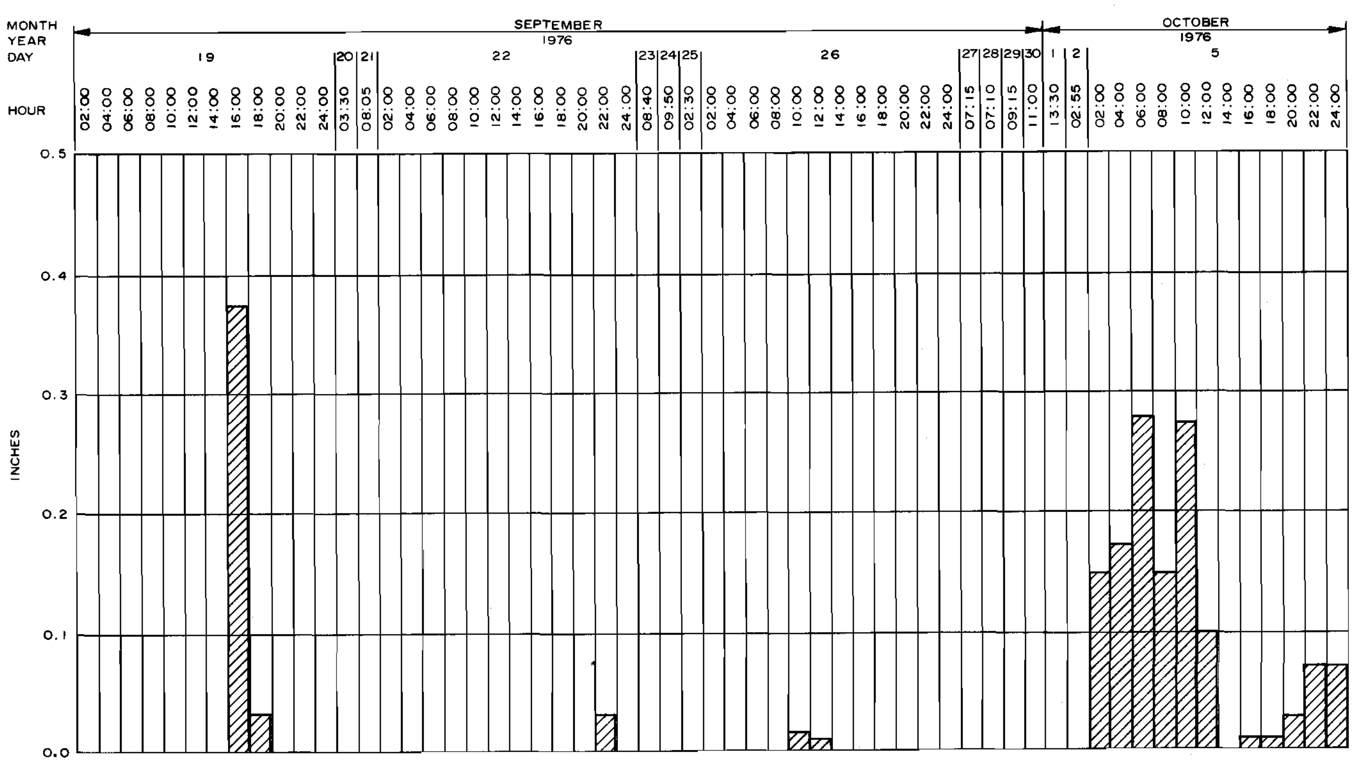
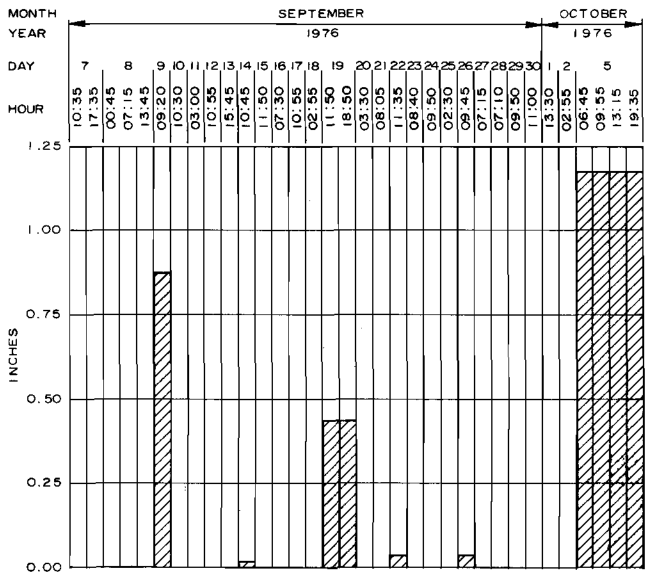
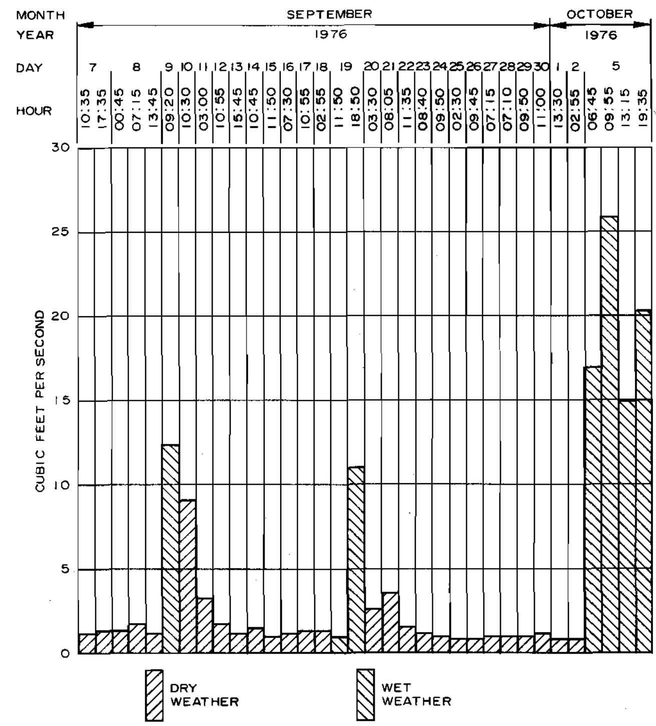


Figure 31 (continued)

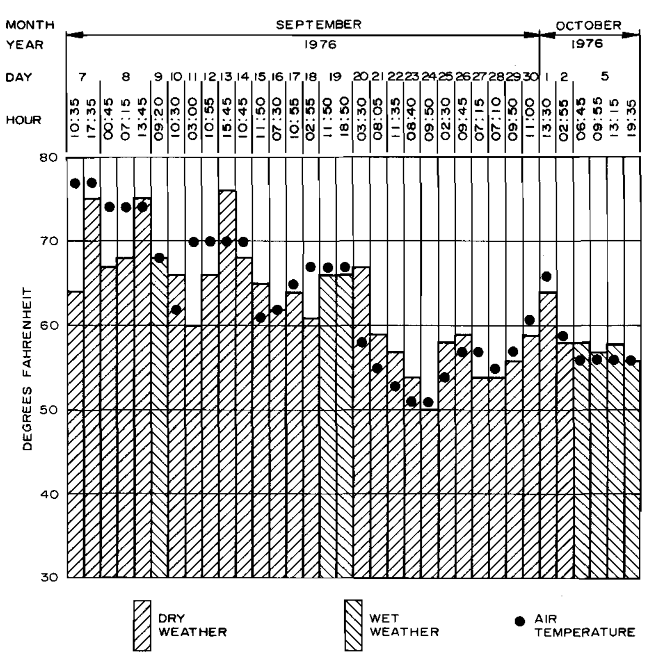
DAILY PRECIPITATION: MILWAUKEE (MITCHELL FIELD)



STREAMFLOW: OK-A



AIR AND WATER TEMPERATURE: OK-A



DISSOLVED OXYGEN: OK-A

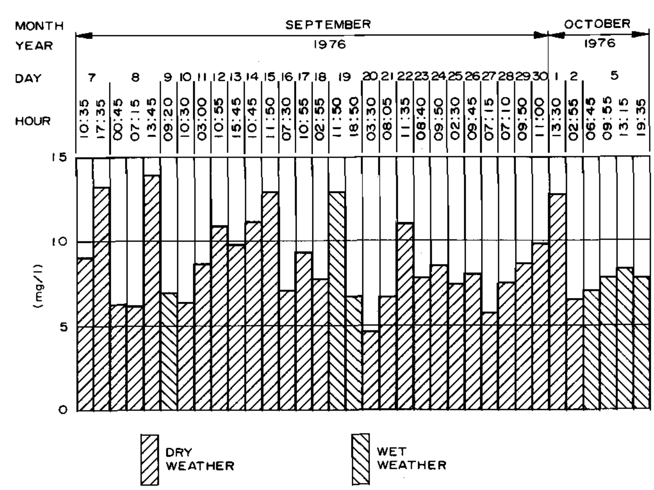
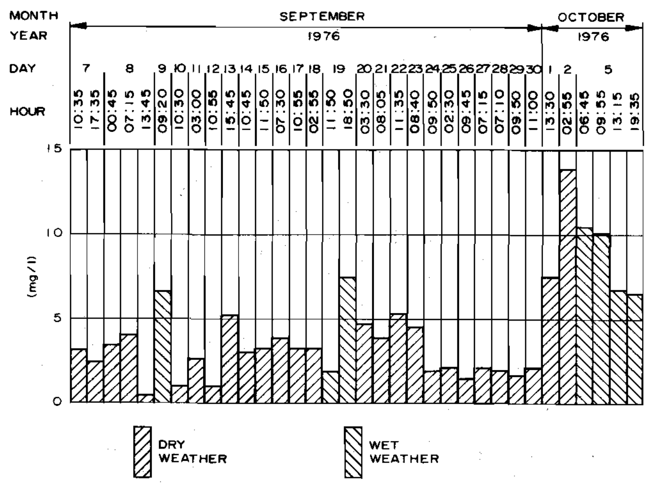
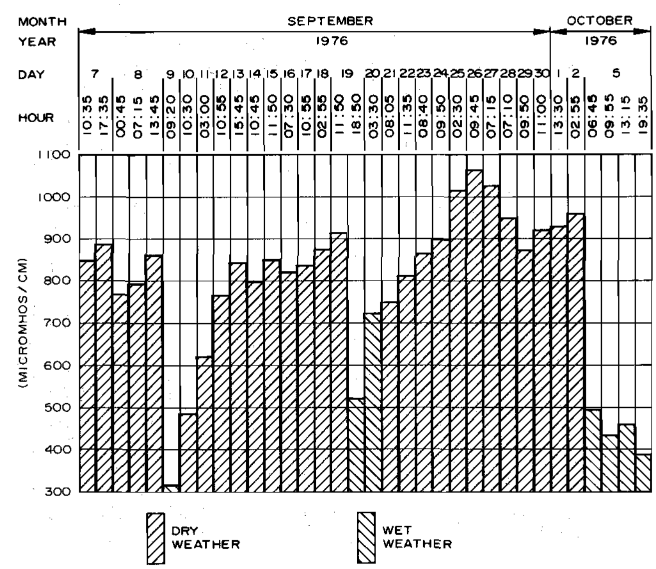


Figure 31 (continued)

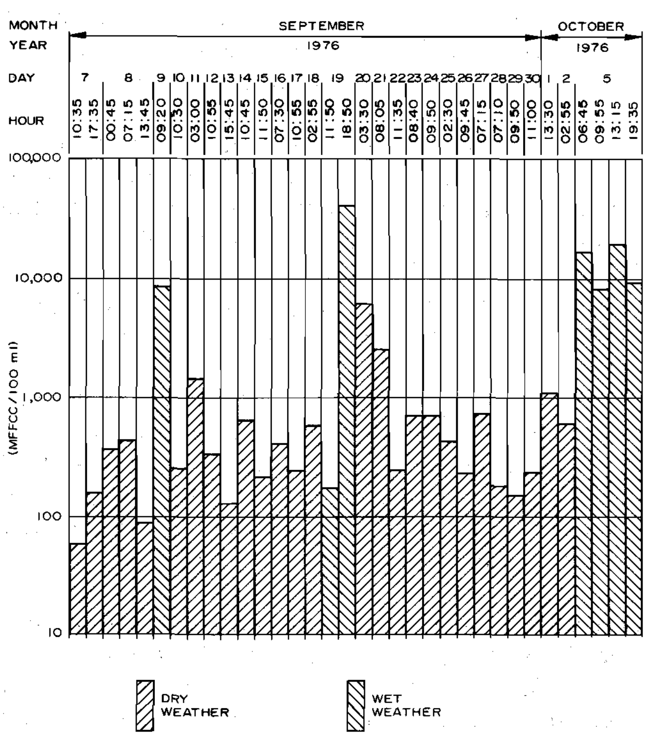
BIOCHEMICAL OXYGEN DEMAND: OK-A



SPECIFIC CONDUCTANCE: OK-A



FECAL COLIFORM: OK-A



CHLORIDE: OK-A

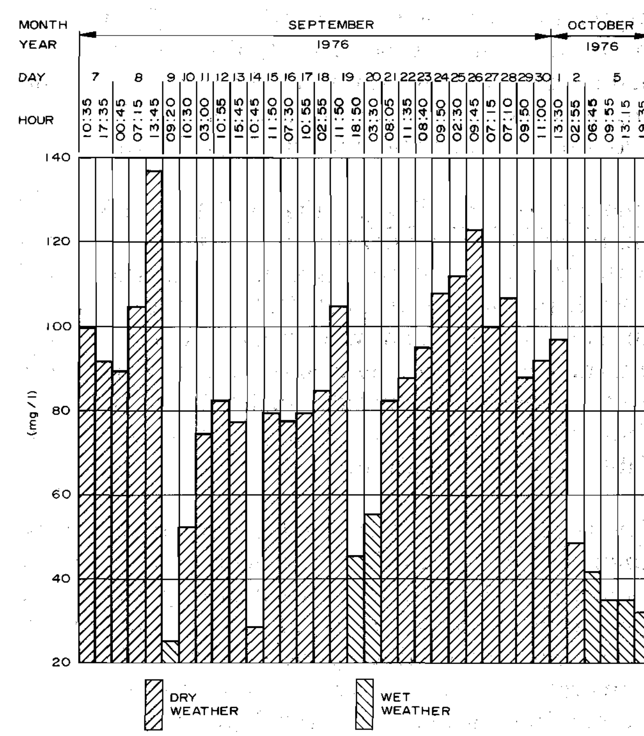
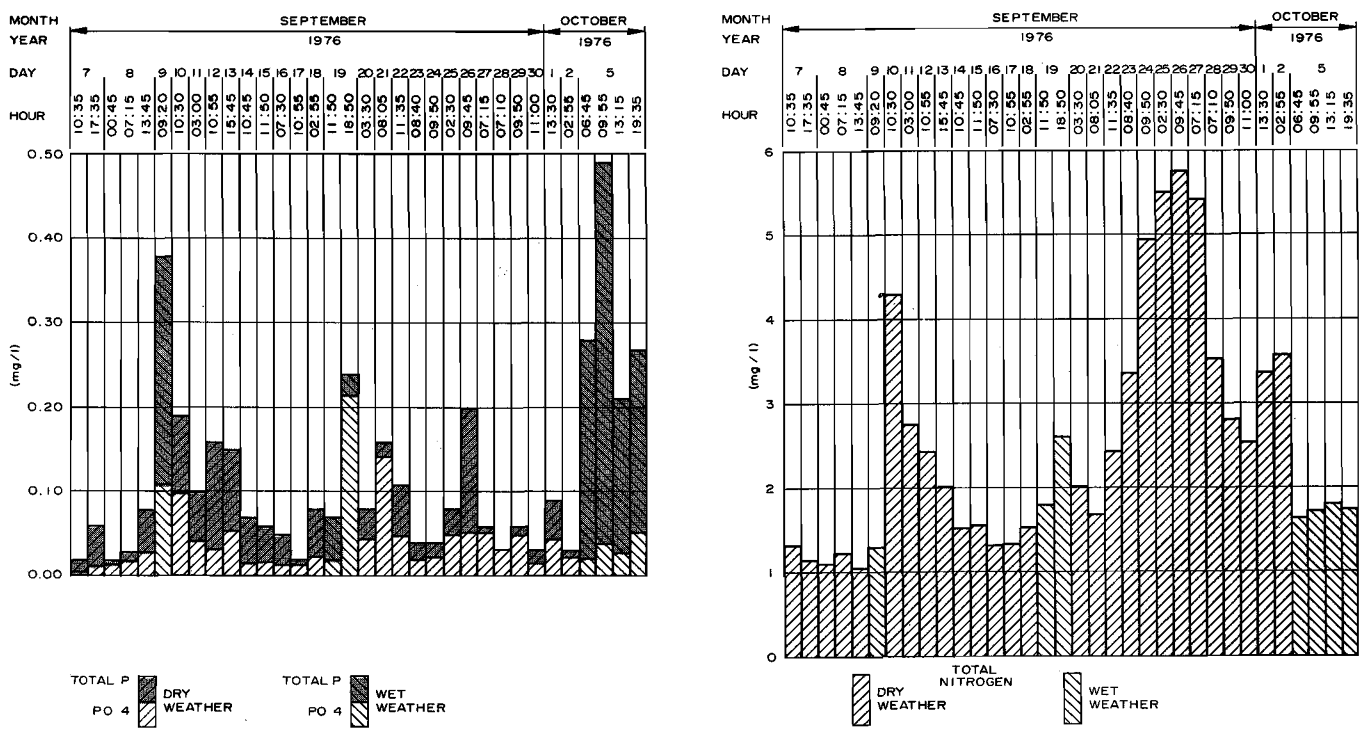


Figure 31 (continued)

PHOSPHORUS: OK-A

NITROGEN: OK-A



Source: Wisconsin Department of Natural Resources and SEWRPC.

impact of such events. Second, the 1976 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 in response to varying meteorological conditions.

Findings of the Study: Figure 31 is a graphic summary of water quantity and quality conditions in the Oak Creek at 15th Avenue during the period from September 7 through October 5 of 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 50 for this station.

Temperature: All of the water temperature measurements were less than the maximum allowable 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 slightly lower than the coincident air temperatures.

Dissolved Oxygen: All of the dissolved oxygen level measurements—except a measurement taken on September 20, 1976, when the dissolved oxygen was 4.6 mg/l—were above the minimum standard of 5.0 mg/l, with an average dry weather concentration of 8.8 mg/l.

Dissolved oxygen level concentrations were not significantly depressed during rainfall runoff events at the station, suggesting that the oxygen demand exerted by organic matter washed from the land surface was offset by oxygen entrained in the stormwater runoff, or that the reaction time was

Table 50

DRY AND WET WEATHER CONCENTRATIONS AND TRANSPORT FOR SELECTED POLLUTANTS IN THE OAK CREEK WATERSHED AT THE 15TH AVENUE BRIDGE—OK-A: SEPTEMBER 7-OCTOBER 5, 1976

1976 Sampling Dates for OK-A	Sampling Condition	Parameter, Transport, and Concentration[a]					
		Biochemical Oxygen Demand	Fecal Coliform	Chloride	Phosphate Phosphorus	Total Phosphorus	Total Nitrogen
		Pounds per Day (mg/l)	Colonies per Day (MFFCC per 100 ml)	Pounds per Day (mg/l)	Pounds per Day (mg/l)	Pounds per Day (mg/l)	Pounds per Day (mg/l)
September 7	Dry	14.95 (2.8)[b]	2.76×10^{10} (112.7)[b]	515.50 (95.8)[b]	0.05 (0.01)[b]	0.22 (0.04)[b]	6.75 (1.25)[b]
September 8	Dry	14.96 (2.8)[b]	7.95×10^{9} (325)[b]	588.37 (109.4)[b]	0.10 (0.02)[b]	(0.19) (0.04)[b]	4.24 (1.16)[b]
September 9	Wet	440.30 (6.6)	2.64×10^{12} (8,700)	1,734.5 (26.0)	7.20 (0.108)	25.35 (0.38)	88.70 (1.33)
September 10	Dry	49.23 (1.0)	5.83×10^{10} (260)	2,609.0 (53.0)	4.87 (0.09)	9.35 (0.19)	212.17 (4.31)
September 11	Dry	46.86 (2.6)	1.23×10^{11} (1,500)	1,351.7 (75)	0.77 (0.043)	1.80 (0.10)	50.10 (2.78)
September 12	Dry	9.68 (1.0)	1.50×10^{10} (340)	803.8 (83)	0.32 (0.033)	1.55 (0.16)	23.82 (2.46)
September 13	Dry	36.37 (5.2)	4.14×10^{9} (130)	545.5 (78)	0.38 (0.055)	1.05 (0.15)	14.27 (2.04)
September 14	Dry	26.15 (3.0)	2.62×10^{10} (660)	252.7 (29)	0.15 (0.017)	0.61 (0.07)	13.42 (1.54)
September 15	Dry	19.97 (3.2)	6.25×10^{9} (220)	499.3 (80)	0.11 (0.018)	0.37 (0.06)	9.92 (1.59)
September 16	Dry	26.58 (3.8)	1.37×10^{10} (430)	545.5 (78)	0.10 (0.015)	0.35 (0.05)	9.37 (1.34)
September 17	Dry	24.96 (3.2)	8.88×10^{9} (250)	624.1 (80)	0.11 (0.014)	0.16 (0.02)	10.61 (1.36)
September 18	Dry	24.96 (3.2)	2.13×10^{10} (600)	663.1 (85)	0.19 (0.024)	0.62 (0.08)	12.25 (1.57)
September 19	Wet	37.00 (6.9)[a]	1.09×10^{13} (36,261.8)[b]	277.3 (51.5)[b]	1.06 (0.20)[b]	1.20 (0.22)[b]	13.73 (2.55)[b]
September 20	Dry	64.84 (4.6)	3.92×10^{11} (6,100)	789.3 (56)	0.65 (0.046)	1.13 (0.08)	28.61 (2.03)
September 21	Dry	73.60 (3.8)	2.29×10^{11} (2,600)	1,607.5 (83.0)	2.75 (0.142)	3.10 (0.16)	32.93 (1.70)
September 22	Dry	45.32 (5.2)	9.92×10^{9} (250)	767.0 (88.0)	0.43 (0.049)	0.96 (0.11)	21.44 (2.46)
September 23	Dry	30.77 (4.4)	2.26×10^{10} (710)	664.4 (95.0)	0.15 (0.021)	0.28 (0.04)	23.64 (3.38)
September 24	Dry	11.14 (1.8)	2.00×10^{10} (710)	668.2 (108.0)	0.15 (0.024)	0.25 (0.04)	30.62 (4.95)

Table 50 (continued)

1976 Sampling Dates for OK-A	Sampling Condition	Parameter, Transport, and Concentration[a]					
		Biochemical Oxygen Demand	Fecal Coliform	Chloride	Phosphate Phosphorus	Total Phosphorus	Total Nitrogen
		Pounds per Day (mg/l)	Colonies per Day (MFFCC per 100 ml)	Pounds per Day (mg/l)	Pounds per Day (mg/l)	Pounds per Day (mg/l)	Pounds per Day (mg/l)
September 25	Dry	10.76 (2.0)	1.08×10^{10} (440)	602.6 (112.0)	0.27 (0.050)	0.43 (0.08)	29.64 (5.51)
September 26	Dry	7.53 (1.4)	5.63×10^{9} (230)	661.7 (123.0)	0.28 (0.053)	1.08 (0.20)	30.99 (5.76)
September 27	Dry	12.37 (2.0)	2.08×10^{10} (740)	618.7 (100.0)	0.32 (0.052)	0.37 (0.06)	33.53 (5.42)
September 28	Dry	11.14 (1.8)	5.07×10^{9} (180)	662.0 (107.0)	0.26 (0.032)	0.19 (0.03)	21.90 (3.54)
September 29	Dry	9.90 (1.6)	4.23×10^{9} (150)	544.5 (80.0)	0.30 (0.049)	0.37 (0.06)	17.45 (2.82)
September 30	Dry	13.99 (2.0)	7.60×10^{9} (240)	643.5 (92.0)	0.11 (0.015)	0.21 (0.03)	17.90 (2.56)
October 1	Dry	39.81 (7.4)	2.70×10^{10} (1,100)	521.9 (97.0)	0.24 (0.044)	0.48 (0.09)	18.24 (3.39)
October 2	Dry	74.20 (13.8)	1.49×10^{10} (610)	263.6 (49.0)	0.12 (0.022)	0.16 (0.03)	19.31 (3.59)
October 5	Wet	34.80 (6.46)[b]	5.66×10^{12} (12,199)[b]	192.3 (35.7)[b]	0.18 (0.033)[b]	1.79 (0.33)[b]	9.35 (1.74)[b]
Summary of Dry Weather Data	Minimum	7.53 (1.0)	2.76×10^{9} (112)	252.7 (29.0)	0.05 (0.01)	0.16 (0.02)	6.75 (1.16)
	Maximum	74.20 (13.8)	3.92×10^{11} (6,100)	2,609.0 (123.0)	4.87 (0.142)	9.35 (0.20)	212.17 (5.76)
	Average	29.20 (3.48)	4.51×10^{10} (787.0)	751.8 (85.2)	0.549 (0.039)	1.05 (0.08)	28.90 (2.85)
Summary of Wet Weather Data	Minimum	34.80 (0.46)	2.98×10^{11} (8,700)	192.3 (26.0)	0.18 (0.033)	1.20 (0.22)	13.73 (1.33)
	Maximum	440.30 (6.9)	1.09×10^{13} (36,261.8)	1,734.5 (51.5)	7.2 (0.02)	23.35 (0.38)	86.70 (2.55)
	Average	170.70 (6.66)	6.40×10^{12} (19,053.6)	734.7 (37.7)	2.81 (0.114)	9.45 (0.31)	37.26 (1.87)
Ratio Between Average Daily Wet Weather and Average Daily Dry Weather Transport and Concentration for Each Parameter		5.85 1.91	142.00 24.21	0.98 0.44	5.12 2.92	9.00 3.87	1.29 0.66

[a] *Values in parentheses indicate concentration.*

[b] *For days that multiple samples were collected, the concentrations are flow weighted.*

Source: SEWRPC.

too brief for significant dissolved oxygen reduction to occur. 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.[6]

Biochemical Oxygen Demand: The average dry weather biochemical oxygen demand (BOD) found at the sample station was 3.48 mg/l. The sample results indicated that the biochemical oxygen demand in the surface waters is influenced by runoff events. For example, the average concentration of biochemical oxygen demand during wet weather conditions was almost double that during dry weather conditions and the average loading during wet weather conditions was about six times the average loading during dry weather conditions. The increase in biochemical oxygen demand probably would be even more dramatic during snowmelt events because of the fall and winter accumulation of leaves, street litter, animal droppings, and vegetative ground cover.

Fecal Coliform Bacteria: About 44 percent of the dry weather samples for fecal coliform at the sampling station were in excess of the recommended level of 400 MFFCC per 100 ml. The sample station indicated a significant increase in fecal coliform bacteria following storm events, with all but one of the wet weather samples being in excess of the recommended level.

Specific Conductance and Chloride: The monitoring data indicate that during dry weather periods, specific conductance was relatively uniform at the sampling station, averaging 847 micromhos per centimeter. The sample data indicated a slight reduction of the specific conductance and chloride concentration during and following storm events at the sample location.

Phosphorus: As already noted, the recommended phosphorus standard of 0.10 mg/l is the recognized level below which nuisance growths of algae and other aquatic plants are not expected to occur in flowing streams. About 22 percent of the dry weather total phosphorus determinations made at the sample station exceeded this standard and 83 percent of the wet weather samples were found to exceed this standard. The average dry weather total phosphorus concentration was found to be 0.08 mg/l, with an average wet weather total phosphorus concentration of 0.31 mg/l. The data indicate that the instream total phosphorus concentration may be expected to increase significantly during both rainfall- and snowmelt-induced runoff events.

Nitrogen: Total nitrogen loadings were observed to be higher during wet weather conditions than during dry weather conditions. For example, the average total nitrogen loading during dry weather conditions was about 28.9 pounds per day, whereas the average total nitrogen loading during wet weather conditions was about 37.27 pounds per day. The data indicate that total nitrogen loadings may be expected to increase during rainfall or snowmelt events, but not as sharply as would other water parameters such as biochemical oxygen demand, fecal coliform bacteria, and total phosphorus.

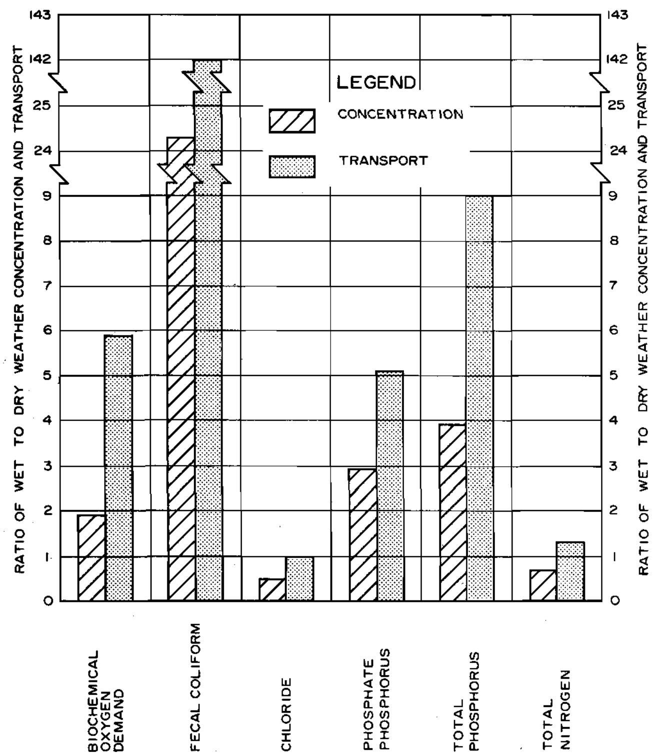
Dry and Wet Weather Concentration and Transport: The concentration of pollutants in stream waters as measured in, for example, milligrams per liter at any place and time, establishes the suitability for fish and aquatic life, recreational use, and aesthetic enjoyment. The transport of potential pollutants as measured, for example, in pounds per day at the mouth of a watershed, ultimately determines 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 32 provides ratios between dry and wet weather conditions for 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 from September 7, 1976, through October 5, 1976. This graphic summary illustrates the significant difference between dry and wet weather surface water quality conditions, as set forth in greater detail in Table 50

[6] *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.*

Figure 32

RATIO OF WET TO DRY WEATHER CONCENTRATION AND TRANSPORT FOR SELECTED POLLUTANTS IN OAK CREEK AT THE 15TH AVENUE BRIDGE—OK-A (RM 2.84): SEPTEMBER 7-OCTOBER 5, 1976



NOTE: ON DAYS THAT MULTIPLE SAMPLES WERE COLLECTED, THE CONCENTRATIONS ARE FLOW WEIGHTED

Source: Wisconsin Department of Natural Resources and SEWRPC.

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 and nitrogen.

Concentration: The instream concentration of four of the six parameters at the sample station increased during wet weather conditions. The concentrations ranged from 1.91 times the average dry weather concentration for biochemical oxygen demand to 24.21 times the average dry weather concentration for fecal coliform bacteria. These levels occurred in spite of the eight-fold increase in streamflow from 1.8 cubic feet per second (cfs) on dry weather days to 14.6 cfs on wet weather days. Therefore, the substantial increase in the available dilution water was more than offset by the increased quantity of substances carried into the surface waters for these four parameters by direct runoff occurring as overland flow through the storm sewer system, or from the inflow of shallow groundwaters. Instream chloride and nitrogen concentrations did not change significantly from wet weather to dry weather conditions.

Transport: The instream transport of the five indicators increased on the wet weather day to a level ranging from 1.29 times the average dry weather transport for total nitrogen to 142.00 times the dry weather transport for fecal coliform. As shown in Figure 32, the ratios of wet to dry weather transport are greater than the ratios of wet to dry weather concentrations.

Concluding Statement: The September and early October 1976 surveys at one sample location in the Oak Creek watershed indicated water quality conditions satisfying the established temperature standards in all instances. The dissolved oxygen standard was violated only once following a rainfall event. About 44 percent of the dry weather fecal coliform samples were greater than 400 MFFCC/100 ml, and 22 percent of the dry weather total phosphorus concentrations exceeded the established standard. All of the wet weather—rainfall and snowmelt—fecal coliform and phosphorus concentrations exceeded the standards.

The instream concentrations of biochemical oxygen demand, fecal coliform bacteria, phosphate, and total phosphorus were found to be up to 25 times greater during a rainfall runoff event than during dry weather periods. The data suggest that violations of the instream water quality standards for these constituents in the Oak Creek watershed are more likely to occur during wet weather conditions than during dry weather conditions. The average daily transport of biochemical oxygen demand, fecal coliform bacteria, phosphate, and total phosphorus to Lake Michigan was up to 142 times greater during a rainfall runoff event than during dry weather periods.

Concluding Remarks—
Surface Water Quality Studies

Certain observations may be made and conclusions drawn from the available water quality data. Dry and wet weather water quality conditions in the watershed may be identified and an overall assessment made as to the degree to which established water quality standards are satisfied. More particularly, the following observations and conclusions are based on the historic monitoring studies in the Oak Creek watershed, supplemented with analyses of data drawn from studies of other watersheds.

- Substandard water quality conditions, associated with high concentrations of pollutants, are more likely to occur during wet weather conditions than during dry weather conditions and are attributable to: 1) the accumulation of pollutants on the land surface between rainfall and snowmelt events, and the subsequent transport from the land surface of pollutants to the stream system by rainfall and snowmelt runoff; and 2) the resuspension of polluted streambed sediments by the high stream velocities which occur during runoff periods. It has been noted, however, that the increased oxygen-demanding substances are initially offset by the high dissolved oxygen content of runoff waters, by increased aeration due to turbulence, and by other factors affecting the surface water system as shown by a consistent increase in dissolved oxygen concentrations during and immediately following precipitation activity.

- 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 land flow, through storm sewer and channel systems, or from shallow subsurface groundwater inflow. The known exceptions are the concentrations of nitrogen and chloride, which did not exhibit a marked increase during the rainfall events which were recorded in October 1976.

- Based upon data collected during September and October 1976, the ratio of wet weather to dry weather transport is significantly greater than the ratio of wet weather to dry weather concentration. That is, wet weather conditions generally have a much greater impact on the mass of pollutants transported from the watershed to Lake Michigan than on the concentration of pollutants being transported.

- The temperature standard, which specifies that surface water temperatures be less than or equal to 89° F, appears to be met virtually all of the time in the Oak Creek 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 met virtually all 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 mg/l, appears to be met about 96 percent of the time during both dry and wet weather conditions in downstream reaches of the Oak Creek watershed. This suggests that the oxygen demand exerted by organic matter washed from the land surface during rainfall and snowmelt runoff events is initially offset by oxygen entrained in the stormwater runoff. However, in the past there has been an adverse impact on dissolved oxygen levels in the downstream portions of Oak Creek as a result of the occasional discharge of sanitary sewage from three sanitary sewer overflows in the watershed. The pollutant loadings from these overflows are to be abated by mid-1984 as a result of sewer rehabilitation projects in the Cities of Oak Creek and South Milwaukee. The oxygen concentrations in runoff are maintained or enhanced by the higher stream re-aeration coefficients which generally occur during high-flow periods.

- The fecal coliform standard, which specifies a fecal coliform count not exceeding 400 MFFCC/100 ml, appears to be exceeded in the watershed about 44 percent of the time during dry weather conditions and virtually all of the time during wet weather conditions.

- The total phosphorus standard of 0.1 mg/l appears to be satisfied about 78 percent of the time during dry weather conditions but is violated approximately 80 percent of the time during wet weather conditions within the watershed.

- Measured ammonia nitrogen, stream temperature, and pH are used to determine the instream concentration of un-ionized ammonia. Sample data collected on Oak Creek in August from 1972 through 1975 indicated no violations of the ammonia nitrogen standard.

- Ammonia nitrogen concentrations and concentrations of other nitrogen forms may be expected to increase or decrease during wet weather conditions, depending on the magnitude of the base flow nitrogen concentration, which could be significantly higher or lower than the nitrogen concentration of surface runoff.

- Chloride concentrations in the surface waters of the Oak Creek watershed are generally higher than those found in more rural watersheds of southeastern Wisconsin. Chloride in the surface waters is attributable to the use of chloride compounds for street deicing during the winter. Chlorides may also be contributed by leachate from solid waste landfills. 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 effect 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. Landfill leachate contributions may be important during low streamflow conditions.

- The concentrations of metals in the Oak Creek watershed were found to be generally within the limits of the recommended standards based on the limited data available. However, one sample did indicate a possible excessive instream concentration of mercury, recording a level of 0.3 µg/l; the recommended standard is 0.05 µg/l.

- The available sample data were not adequate to establish the presence of a PCB pollution problem because the recommended PCB standard of 0.001 mg/l is much lower than the current determinant capability of laboratory procedures—0.05 mg/l.

- The benthic community of the Oak Creek watershed is composed primarily of large populations of pollution-tolerant species, a condition generally indicative of polluted conditions.

- Of the eight potential types of surface water pollution—toxic, organic, nutrient, pathogenic, thermal, sediment, radiological, and aesthetic—all but thermal and radiological pollution are known to exist to some degree in the Oak Creek watershed.

- The surface waters of the Oak Creek watershed generally do not meet the established water use objectives. Although the levels of some critical parameters such as pH and temperature are met essentially all of the time, levels of other parameters such as dissolved oxygen, phosphorus, and fecal coliform are in excess of recommended standards at least some of the time.

- Violations of the water quality standards for the warmwater fishery water use objective have been documented in the surface waters of the Oak Creek watershed. These violations are related to dissolved oxygen levels caused by oxygen-demanding materials in bottom sediments, as well as organic and ammonia nitrogen in sewage treatment plant discharges during periods of low flow.

- The recreational water use objective is not met in the Oak Creek watershed primarily because of the fecal coliform bacteria present in the surface waters, and also because of the nutrient concentrations in excess of the recommended standards, which provide the potential for aquatic weed growth.

POLLUTION SOURCES

An evaluation of water quality conditions in the Oak Creek watershed must include an identification, characterization and, where feasible, quantification of known pollution sources. This identification, characterization, and quantification is intended to aid in determining the probable causes 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 sewer system overflows, industrial wastewater discharges, and urban and rural stormwater runoff.

The schematic representation of the average annual volume of water passing through various paths in the hydrologic cycle of the Oak Creek watershed is shown in Figure 33. The hydrologic budgets were prepared using the hydrologic simulation model described in Chapter VIII of this report, supplemented with municipal, private, and industrial point source discharge data collated from the Wisconsin Pollutant 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 33. For example, pollutants discharged from storm sewer outfall points will be transported as wet weather flow and surface runoff to the stream system. Nonpoint source pollutants will move along both the wet weather and dry weather—groundwater—routes from their point of origin to the stream system.

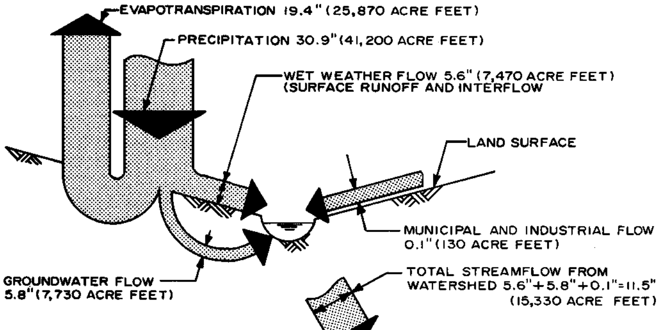
Point Source Pollution

Point source pollution is defined as pollution which is discharged to the surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, including portable pumps, sewage treatment plant discharges, and industrial discharges. The point sources existing within the watershed as of 1984 are located on Map 36.

Sanitary Sewerage System Flow Relief Points: Raw sanitary sewage can enter the surface water system of a watershed either directly from sanitary sewer overflows or indirectly via flow relief devices to separate storm sewer systems. This direct or indirect conveyance of sanitary sewage to the surface water system of a watershed occurs

Figure 33

AVERAGE ANNUAL HYDROLOGIC BUDGET FOR THE OAK CREEK WATERSHED: 1983 CONDITIONS



Source: SEWRPC.

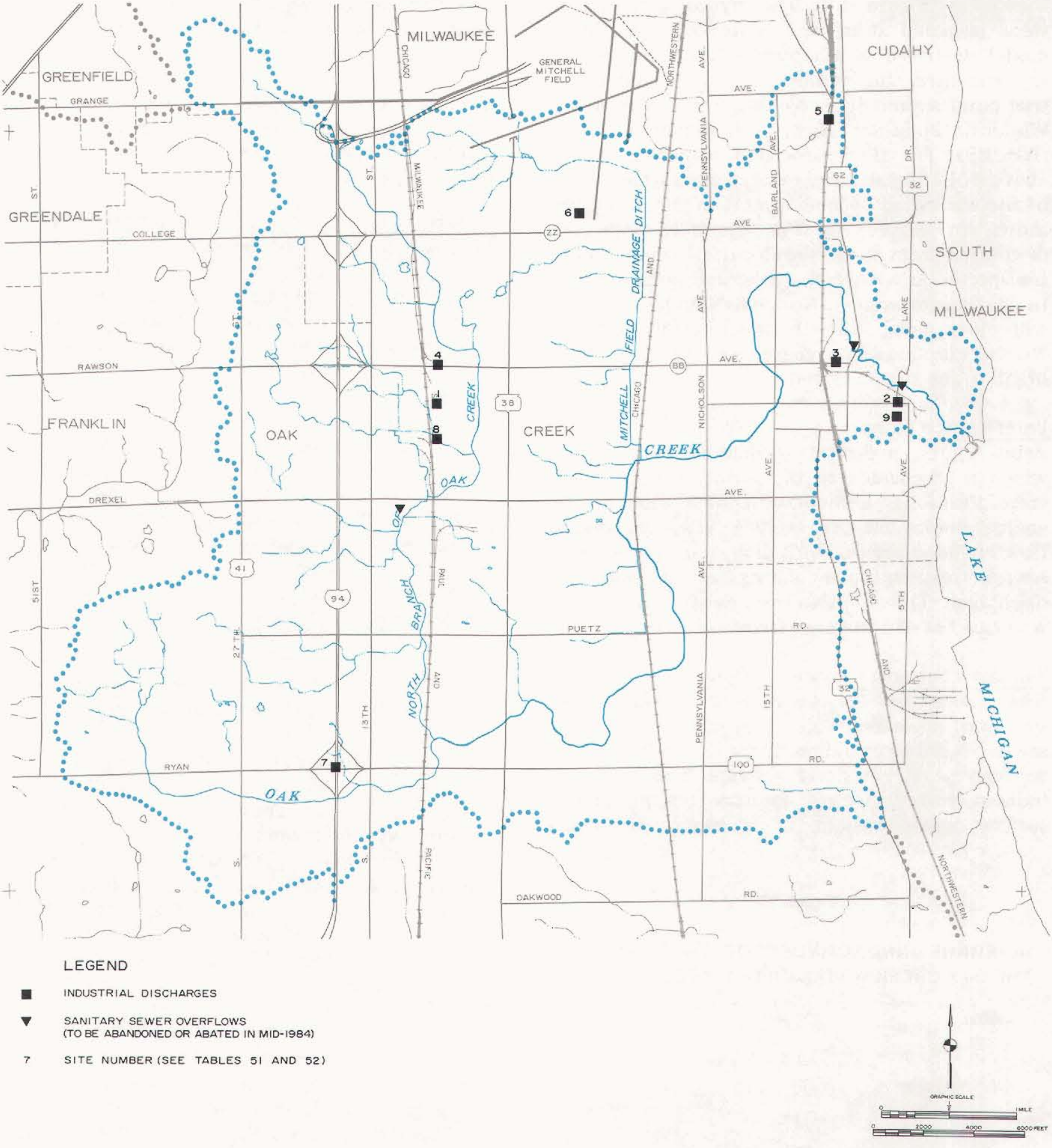
through various types of flow relief devices as a result of one or more of the following conditions: inadequate sanitary sewage conveyance facilities, excessive infiltration and inflow of clear water during wet weather conditions, and mechanical and/or power failures at sanitary sewage pumping facilities. In order to prevent damage to residential dwellings or the mechanical elements of the conveyance system due as a result of the aforementioned system failures, a sanitary sewerage flow relief device is provided.

Number and Location of Flow Relief Devices in the Watershed: As of early 1984, three sanitary sewerage system relief devices—or overflows—were located in the watershed. The locations of these relief devices are shown on Map 36. The flow relief device located at the pumping station near the intersection of Wildwood Drive and Wake Forest Drive in the City of Oak Ceek was abandoned in April 1984 as a result of a sewer system rehabilitation project in the City. This device was a bypass which permitted the trunk sewer entering the sewage pumping station to be discharged by gravity to Oak Creek during periods of power outage, equipment failure, or insufficient pumping capacity. The pumping station was abandoned with the construction of a larger and deeper trunk sewer.

There were two known flow relief devices in the City of South Milwaukee, one of which was located at the N. Chicago Avenue pumping station near where N. Chicago Avenue crosses Oak Creek and one of which was located at the Ravine pumping station near the intersection of 3rd Avenue and Marquette Avenue. These two devices were also bypasses which permitted the trunk sewers entering the sewage pumping stations to discharge by gravity to Oak Creek during periods of power outage, equipment failure, or insufficient pumping capacity. As a result of the sewer system rehabilitation project being conducted by the City of South Milwaukee, these two bypasses will, by mid-1984, be used only in extreme emergencies such as equipment failure, when the pumping station would be inoperable. The improvements to these two pumping stations include both standby pumping and power equipment. Thus, the bypasses are expected to be utilized very infrequently, if ever. Consequently, the water quality evaluations as well as the hydraulic and hydrologic analyses in this report do not include either the flows or the associated pollutant loadings which would occur if these bypasses were to continue to operate.

Map 36

KNOWN POINT SOURCES OF POLLUTION IN THE OAK CREEK WATERSHED: 1983



A total of 12 known point sources of pollution existed in the Oak Creek watershed in 1983. These consisted of three sanitary sewer flow relief devices which discharge raw sewage to the stream system during wet weather, and pumping facilities and outfalls which discharge mostly noncontact cooling waters from nine industrial sources. By mid-1984, the use of the two sanitary sewer flow relief devices located in the City of South Milwaukee will be limited to extreme emergencies such as equipment failure at the pumping station, while the other sanitary sewer flow relief device will be completely abandoned following sanitary sewer rehabilitation.

Source: SEWRPC.

Municipal Sewage Treatment Facilities: There are no municipal sewage treatment facilities discharging, or proposed to discharge, to the surface waters of the Oak Creek watershed.

Industrial Discharges: Industrial wastewater consisting primarily of cooling and process water is discharged directly or indirectly to the surface water system of the Oak Creek watershed at 16 locations. This industrial wastewater enters Oak Creek 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: Table 51 summarizes by receiving stream and civil division the number of industrial wastewater outfalls in the watershed and their respective discharge characteristics. Map 36 indicates the location of these wastewater outfalls in the watershed. Table 51 indicates that nine industrial establishments with a total of 16 wastewater outfalls discharge noncontact spent cooling waters, boiler blowdown water, aircraft washwater, oil-contaminated stormwater, stormwater, and sludge tank decant water. Table 52 presents a summary of the quantity and quality of the outflow of these discharges. The 16 industrial wastewater outfalls discharge directly to the surface waters of the Oak Creek watershed.

Quantity and Quality of Industrial Discharges: The data presented on the 16 industrial discharges in Table 51 are for 1983, and indicate that the average annual discharge rate contributed by industrial sources to the surface waters of the Oak Creek watershed is 1.02 million gallons per day, equivalent to 0.77 inch of water annually over the surface of the watershed. The average annual flow from the Oak Creek watershed, including point sources discharge, is equivalent to 12.5 inches of water over the surface of the watershed. Thus, the contribution of the 16 industrial plant discharges is equivalent to about 6 percent of the total average annual discharge of the watershed.

The concentrations of pollutants in and the quantity of discharge from the 16 industrial point sources exhibit significant variations. As shown in Table 52, the industrial discharges from seven outfalls are comprised of clean, noncontact cooling waters and do not constitute a water pollution problem. The discharges from four outfalls convey oil-contaminated wastewaters but these wastewaters undergo pretreatment by means of an oil separator prior to discharge to Oak Creek. Consequently, these discharges should not constitute a serious source of pollution. The remaining five outfalls discharge a combination of boiler blowdown and cooling waters, aircraft washwater, sludge tank decant waters, and process waters from industrial operations but should not constitute a serious source of water pollution. Thus, the annual pollutant load contributed by the 16 outfalls in the watershed is small compared to the annual pollutant load contributed by other sources in the basin. Where pretreatment is being provided, such discharges could be a more serious source of water pollution if the pretreatment facilities were improperly maintained and operated and thereby malfunctioned.

Nonpoint Source Pollution

Definition and Characteristics: Nonpoint source pollution, also referred to as diffuse source pollution, consists of various discharges of pollutants to the surface waters which cannot be readily identified as point sources. Nonpoint 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 sources of pollution is somewhat arbitrary since a nonpoint 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, nonpoint 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.

Nonpoint source pollution is similar in composition 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 increas-

Table 51

KNOWN INDUSTRIAL WASTEWATER OUTFALLS IN THE OAK CREEK WATERSHED BY RECEIVING STREAM AND CIVIL DIVISION: 1983

Name	Receiving Stream	Civil Division	Number of Outfalls	Reported Average Annual Hydraulic Discharge Rate (gallons/day)	Temperature (°F)	Reported Wastewater Discharge Characteristics[a]				
						Suspended Solids (mg/l)	Oil and Grease (mg/l)	BOD_5 (mg/l)	pH (Standard Units)	Total Phosphorus (mg/l)
Applied Plastics Company, Inc.	North Branch of Oak Creek via storm sewer	City of Oak Creek	1	4,500	63.0[b]	10.5	5.0[b]	5.5	6.95[b]	N/A
Appleton Electric Foundry Division[c] Outfall 001	Oak Creek via storm sewer	City of South Milwaukee	2	72,000	65.3	N/A	0.25	N/A	N/A	N/A
Outfall 002				92,000	59.5	N/A	0.25	N/A	N/A	N/A
Bucyrus-Erie Company Outfall 001	Oak Creek via storm sewer	City of South Milwaukee	4	22,600	72.8	N/A	N/A	N/A	N/A	N/A
Outfall 002				8,600	66.1	7.55	N/A	N/A	7.4	N/A
Outfall 005				223,600	N/A	5.8	N/A	N/A	7.69	N/A
Industrial Fuel	North Branch of Oak Creek via storm sewer		2	1,000	N/A	18.5	N/A	N/A	N/A	N/A
Ladish Company[d]	Oak Creek via storm sewer	City of Cudahy	1	535,000	52.8	0.0	N/A	N/A	N/A	N/A
U. S. Air Force Reserve 440th TAW[e] General Mitchell Field Outfall 001 Outfall 002 Outfall 003	Mitchell Field drainage ditch	City of Milwaukee	3	--	--	--	--	--	--	--
Union Oil Ryan Road Truckstop[e]	Oak Creek via storm sewer	City of Oak Creek	1	--	--	--	--	--	--	--
Western Machine Company[f]	Oak Creek via storm sewer	City of Oak Creek	1	--	--	--	--	--	--	--
South Milwaukee Water Utility[e]	Oak Creek via storm sewer	City of South Milwaukee	1	--	--	--	--	--	--	--

NOTE: N/A indicates data not available.

[a] *Based on 1983 industrial effluent forms on file with the Wisconsin Department of Natural Resources as required under Section NR 101 of the Wisconsin Administrative Code.*

[b] *Monitoring requirements for these parameters were dropped in May 1983.*

[c] *Values are based on quarterly monitoring.*

[d] *Values based on data obtained in April-June and October-December.*

[e] *Insufficient data available to determine average wastewater discharge characteristics.*

[f] *No monitoring of discharge required.*

Source: SEWRPC.

Table 52

CHARACTERISTICS OF INDUSTRIAL DISCHARGES IN THE OAK CREEK WATERSHED: 1983

	Number of Outfalls by Type of Discharge[a]						
	Cooling Water	Boiler Blowdown	Aircraft Washwater	Stormwater	Oil-Contaminated Stormwater	Sludge Tank Decant Water	Other[b]
Applied Plastics Company, Inc.	1	--	--	--	--	--	--
Appleton Electric Foundry Division	2	--	--	--	--	--	--
Bucyrus-Erie Company	2	--	--	1	--	--	1
Industrial Fuel.	--	1	--	--	1	--	--
Ladish Company[c]	1	--	--	--	--	--	--
U. S. Air Force Reserve 440th TAW General Mitchell Field	--	--	1	--	2	--	--
Union Oil Ryan Road Truckstop	--	--	--	--	1	--	--
Western Machine Company	1	--	--	--	--	--	--
South Milwaukee Water Utility	--	--	--	--	--	1	--

[a] Based on Wisconsin Pollutant Discharge Elimination System information on file with the Wisconsin Department of Natural Resources.

[b] Process water from wet scrubber and shaker operation.

[c] The Ladish Company is permitted to discharge through 13 outfalls, only one of which is tributary to the Oak Creek watershed.

Source: SEWRPC.

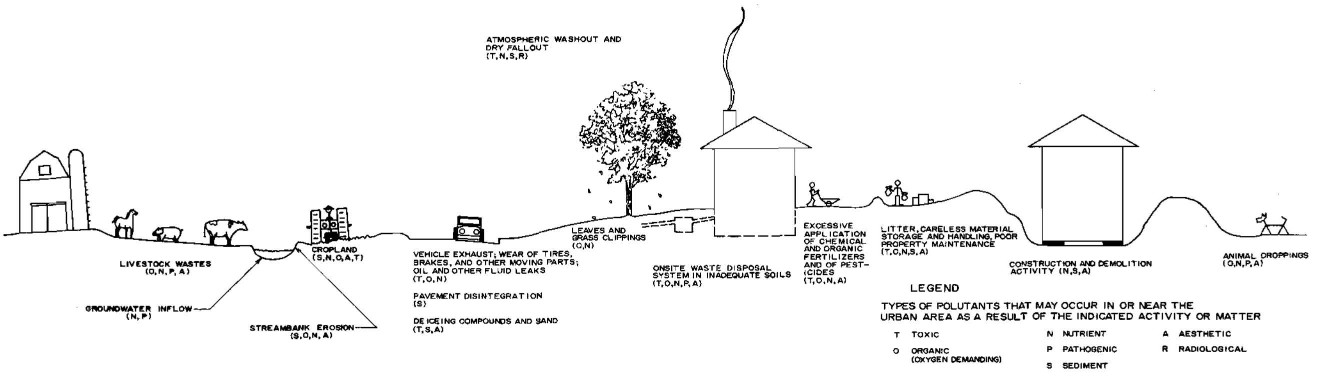
ing concern in water resources planning and engineering as efforts to abate point source pollution become increasingly successful. The control of nonpoint source pollution is a necessary step in the process of improving surface waters to render such waters suitable for full recreational use and a healthy fishery.

Nonpoint source pollution generally differs from point source pollution in one important respect: nonpoint 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 nonpoint 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 34). The following activities of man, or effects of man's activities, result in nonpoint 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) improper management of livestock wastes; 8) excessive use of fertilizers and pesticides; 9) debris, careless material storage and handling, and poor property maintenance; 10) construction and demolition activity; 11) application of deicing salts and sand; 12) stream bank erosion; and 13) domestic and wild animal litter.

With respect to spatial distribution, the entire 27.2-square-mile surface of the Oak Creek watershed is a potential source of nonpoint source pollution. The following discussion addresses the types of nonpoint sources of water pollution in the Oak Creek watershed, based on the results of the examination of the available data sources and the application of several analytical techniques.

Figure 34

NONPOINT SOURCES OF WATER POLLUTION



Source: SEWRPC.

Residential Land Use: The concentration of people, domestic structures, and activities in residential areas and the alteration of the natural drainage and infiltration characteristics results in the production and release of nonpoint source water pollutants. Runoff from lawns, rooftops, driveways, sidewalks, and unused land is channeled through drainageways and streets and is transported directly, as overland flow, or indirectly, through storm sewerage systems, to surface waters. Pollutant sources associated with residential land uses include street debris, fertilizers, pesticides, pet wastes, garbage and litter, vegetation, degraded surface coatings such as paint particles, and detergent. Surface runoff from precipitation events and from urban activities within residential areas, such as lawn sprinkling or automobile washing, release pollutants to the environment.

Commercial Land Use: The high percentage of impervious area and attendant high runoff rates, together with the accumulation of litter and debris, make commercial land a significant contributor of nonpoint source pollutants. Rainfall and snowmelt runoff from rooftops, parking lots, buildings, alleys, streets, loading docks and work areas, and adjacent sidewalks and open areas contribute sediment, oxygen-demanding substances, dissolved substances, nutrients, toxic and hazardous substances, oil, grease, bacteria, and viruses to the streets and storm sewers which drain the commercial areas and discharge into the streams of the Oak Creek watershed. Another source of runoff is the washing of debris from work areas, sidewalks, and areas adjacent to storage areas in order to present a clean and orderly appearance to commercial customers.

Industrial Land Use: Runoff from industrial spills, production and distribution sites, automobile salvage yards, loading docks and work areas, material storage sites, industrial buildings and adjacent streets, parking lots, rooftops, lawns, sidewalks, and open areas transports fuels, oil, grease, wood, metals, paper, plastic, salt, sand and gravel, organic substances, fly ash, petroleum and chemical products, corrosives, waste chemicals, brush, garbage, rubber, acids, glass, ceramics, paint particles, glue, and solvents to streets, storm sewers, and large collector sewers. Many industrial operations do not have the indoor or covered storage capacity to house raw materials awaiting processing, and therefore store the materials in outdoor bins or designated areas exposed to natural weathering processes, breakage, leakage, erosion, oxidation, heat, cold, and moisture which increase the degradation of the material and the potential for its removal and transport to surface waters by storm runoff or snowmelt.

Transportation Activities: Transportation activities contribute significant amounts of pollutants to surface waters in the Oak Creek watershed as goods and people are moved by rail, air, bus, truck, or car. The terminals, transportation routes, and service and maintenance areas are all sites of pollutant buildup and potential release. Motor vehicle pollutants accumulate on freeways and expressways, highways, streets, and parking lots. Motor vehicles deposit fuel, oil and grease, hydraulic fluids, coolants, exhaust emissions—particulates and gases, tire rubber, litter, metals, asbestos, and nutrients on streets. Deicing salts, pavement debris, vegetation debris, animal wastes, litter, fertilizers, pesticides, chemicals, and material from adjacent land also accumulate on streets. Because the transportation-related urban surfaces are impervious and designed to drain very quickly, they play a particularly important role in the transport of pollutants.

Deicing Salt Usage: Initially, salts were used in conjunction with abrasives such as sand or ashes to facilitate travel on snowy and icy highways. In the winter of 1956-1957, the Wisconsin Highway Commission initiated a "bare pavement" winter maintenance program, which required liberal and frequent applications of "straight" salt in order to provide, wherever possible, consistently dry and therefore safer driving surfaces. Sodium chloride is the most commonly used deicing salt. The deicing salts dissolve to form solutions with lower freezing points than the freezing point for water. The application of deicing salts on highways during the winter may significantly affect the quality of runoff water. The salt applied to the highway must either be carried by surface runoff or must infiltrate the ground surface. Improper or excessive salt application may lead to groundwater or surface water contamination, soil contamination, damage to plants, damage to wildlife, increased corrosion, and possible human toxicity in extreme circumstances.

Recreational Activities: Certain outdoor recreational activities, which utilize large areas of the land and water, may constitute nonpoint sources of pollution by contributing pollutants to stormwater runoff and snowmelt that are then carried to surface waters. Normally, outdoor recreational sites include large areas of land which are relatively well stabilized and act either as relatively modest sources of pollutants, or as pollutant-trapping mechanisms. For example, grass buffer strips along streams serve to remove pollutants from stormwater runoff and snowmelt through the sedimentation, filtration, and nutrient uptake effects of the vegetative cover. However, outdoor recreational sites may also include space and impervious areas for the conduct of such recreational pursuits as tennis, swimming, and boating. Consequently, recreational areas may be sources of nonpoint pollution. The amount of pollutants contributed will depend upon such factors as the types of recreational facilities provided, the location and size of vegetated buffer areas and zones, the amount of fertilizers and pesticides used, the land management methods applied, the drainage efficiency of the site, and the location of the site with respect to adjacent lakes or streams. However, well-designed and -managed recreational lands may serve as a means of resolving other, more severe nonpoint source pollution problems.

Construction Activities: The development and redevelopment of residential, commercial, industrial, transportation, and recreational areas within the Oak Creek watershed can cause significant quantities of pollutants to be contributed to streams. Construction activities generally involve soil disturbance and destruction of stable vegetative cover; changes in the physical, chemical, and biological properties of the land surface; and attendant changes in the hydrologic and water quality characteristics of the site as an element of the natural system of surface and groundwater movement. The clearing and grading of construction sites subjects the soil to high erosion rates. Potential pollutants from construction activities include soil particles; pesticides; petroleum products, such as oils, grease, gasoline, and asphalt; solid waste materials, such as paper, wood, metal, rubber, garbage, and plastic; construction chemicals such as paints, glues, solvents, sealants, acid, and concrete; and soil additives such as lime, fly ash, and salt. The transportation of pollutants from construction sites to natural waters is by direct runoff of stormwater and snowmelt, leaching and groundwater infiltration, wind, soil slippage or landslide, and mechanical transfer on vehicles.

Onsite Sewage Disposal Systems: As of 1980, the sanitary and household wastewaters from approximately 1,670 persons, or about 4 percent of the total resident population of the watershed, were treated and disposed of through the use of onsite sewage disposal systems. An onsite sewage disposal system may be a conventional septic tank system, a mound system, or holding tank. It was reported in SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, that approximately 50 percent of the septic systems in some areas of the Southeastern Wisconsin Region are connected to agricultural drainage tiles or ditches, with nearly all of the septic wastes from these systems being directly discharged to drainage channels and surface waters. Failure of an onsite sewage disposal system occurs when the soils surrounding the seepage area will no longer accept or properly stabilize the effluent, when the groundwater rises to levels which will no longer allow for uptake of liquid effluent by the soils, or when age or lack of proper maintenance cause the system to malfunction. Hence, onsite sewage disposal system failure may result from installation in soils with severe limitations for system use, improper design or installation of the system, or inadequate maintenance.

Solid Waste Disposal Sites: Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed sanitary landfill and the variety of operations that are referred to as refuse dumps—especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A sanitary landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of sanitary landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to avoid leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

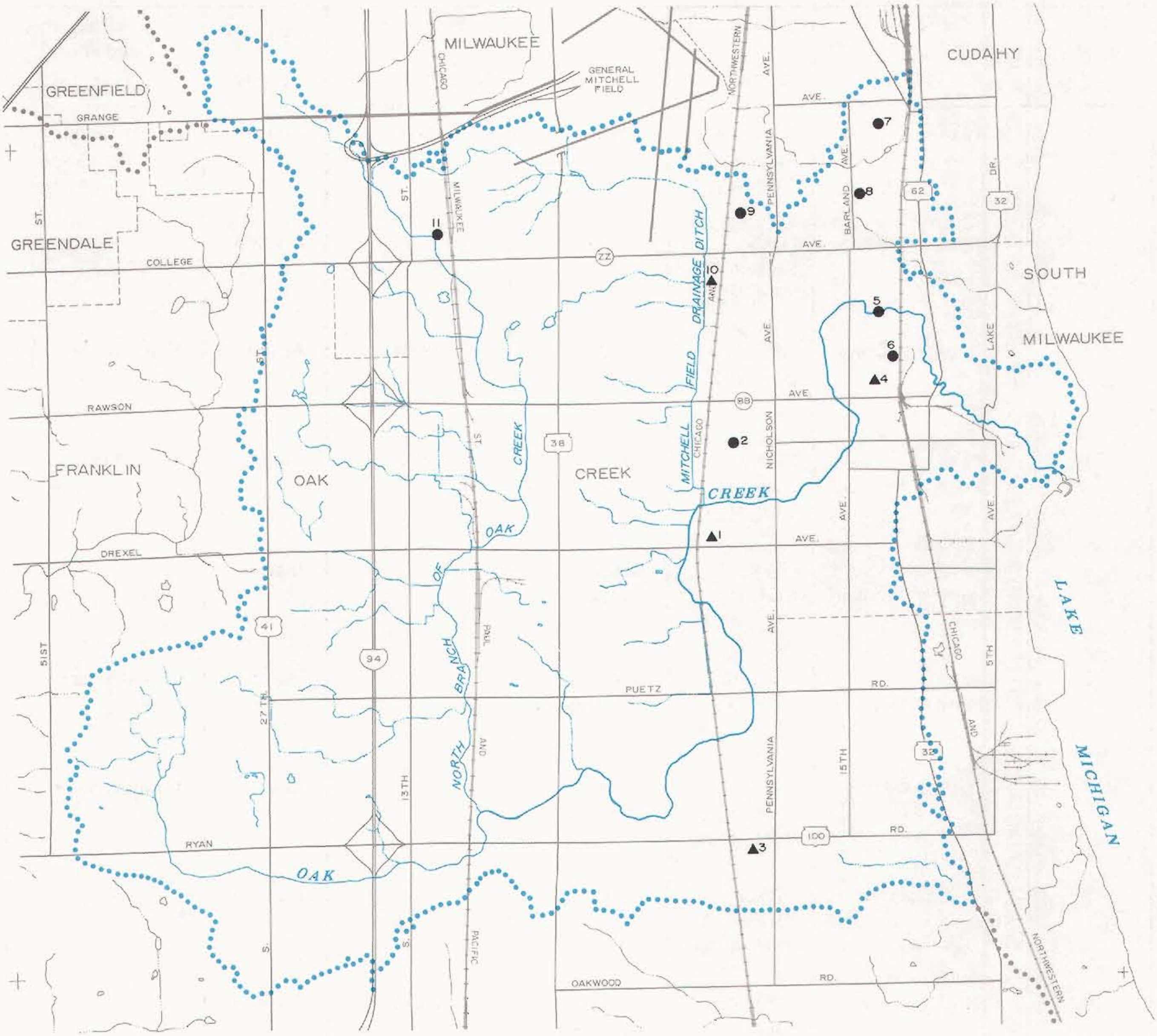
In order for a landfill to produce leachate there must be some source of water moving through the fill material. Possible sources include precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the sanitary landfill, the production of leachates in a well-designed and -managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 32 inches, which is typical of the Oak Creek watershed, could produce from 170,000 to 430,000 gallons of leachate per year per acre of landfill if the facility is not properly located, designed, and operated.

In 1984 there were four active and seven inactive sanitary landfill operations located within the Oak Creek watershed, as shown on Map 37 and in Table 53. A review of Wisconsin Department of Natural Resources water quality monitoring and surveillance program records indicates that the Department monitors groundwater quality at the DeRosso landfill and at the Falk Corporation landfill on a quarterly basis to determine whether pollutants from leachate are entering the groundwater. The pollutant indicators monitored include chemical oxygen demand, specific conductivity, and chlorides. Individual pollutants such as mercury or other metals are not tested for directly, unless the pollutant indicators show a potential for the presence of such pollutants in the groundwater. As of January 1984, the groundwater quality monitoring program had not indicated leachate movement into the groundwater, nor violations of the federal drinking water quality standards in the groundwater around the sites.

Livestock Operations: The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. As of 1983, there were two livestock operations in the Oak Creek watershed comprising a total of about 75 head of dairy cows. Animal manure, composed of feces, urine, and sometimes bedding materials, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Most farm animals within the Oak Creek watershed are raised and managed in barnyards or feedlots. A feedlot is defined as a relatively small—generally less than five acres in size—confined land area, such as a fenced barnyard or a fenced portion of a pasture, for raising large numbers of livestock—generally 25 to 200 head—primarily by importing feed, as opposed to using pasture grazing. Operators usually rely on the occasional export of accumulated manure and bedding materials from the so-called feedlots which are generally denuded of vegetative cover, and are therefore subject to high rates of erosion and pollutant release. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can contaminate water by surface runoff, infiltration to the groundwater, and volatilization to the atmosphere. Some livestock also wade in streams and trample stream bottoms, contributing manure directly to the stream and accelerating stream bank erosion. During the warmer seasons of the year the manure is often scattered on cropland and pasture-

Map 37

LANDFILL SITES IN THE OAK CREEK WATERSHED



LEGEND

▲ ACTIVE LANDFILL

● INACTIVE LANDFILL

7 SITE NUMBER (SEE TABLE 53)

In 1984, there were four active and seven inactive sanitary landfills located within the Oak Creek watershed. Groundwater quality is monitored by the Wisconsin Department of Natural Resources at the De Rosso landfill and at the Falk Corporation landfill. As of January 1984, no leachate movement into the groundwater was reported, around these sites, nor were violations of the federal drinking water quality standards in the groundwater.

Source: SEWRPC.

Table 53

LANDFILL SITES IN THE OAK CREEK WATERSHED: 1984

Number on Map	Civil Division	Location	Operator	Wisconsin DNR License Number	Status	Solid Waste Type
1	City of Oak Creek	SW¼, SW¼ Section 10 T5N, R22E	City of Oak Creek	0414	Active	Construction and demolition
2	City of Oak Creek	NW¼ Section 10 T5N, R22E	--	--	Inactive	--
3	City of Oak Creek	NE¼, NW¼ Section 27 T5N, R22E	Gordon DeRosso	1979	Active	Foundry sand
4	City of South Milwaukee	SW¼ Section 2 T5N, R22E	Falk Corporation	1872	Active	Noncombustible general refuse
5	City of South Milwaukee	NW¼ Section 2 T5N, R22E	Bucyrus-Erie Corporation	--	Inactive	--
6	City of South Milwaukee	NE¼, SW¼ Section 2 T5N, R22E	Bucyrus-Erie Corporation	--	Inactive	Foundry sand
7	City of Cudahy	NW¼ Section 35 T6N, R22E	Ladish Corporation	--	Inactive	Foundry sand
8	City of Cudahy	SW¼ Section 35 T6N, R22E	--	--	Inactive	--
9	City of Cudahy	W½, SW¼ Section 34 T6N, R22E	City of Milwaukee	0428	Inactive	--
10	City of Milwaukee	NW¼ Section 3 T5N, R22E	City of Milwaukee	0428	Active	Construction and demolition
11	City of Milwaukee	SW¼ Section 32 T6N, R22E	--	--	--	--

Source: Wisconsin Department of Natural Resources and SEWRPC.

land where the waste material is likely to be taken up by the vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Crop Production: Cropland can have an adverse effect upon water quality within the Oak Creek watershed, contributing sediments, nutrients, organic matter, and pesticides in runoff to streams. The extent of water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. The topographic, hydrographic, meteorologic, and hydrologic conditions within the watershed are also important factors. For example, just as inadequate handling of animal wastes from a confined feeding operation will pollute the stream system, excessive fertilizer, pesticide, and herbicide usage also has the potential to damage the water resources. Crops grown in the Oak Creek watershed include row crops, such as corn and soybeans; small grains, such as wheat and oats; hay, such as clover, alfalfa, timothy, and canary grass; vegetables, such as potatoes, onions, peas, sweet corn, cabbage, and tomatoes; and specialty crops, such as sod. Row and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Since the early 1930's, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic material entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality.

Woodlands: A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Oak Creek watershed.

Atmospheric Sources: Streams are subjected directly to the deposition of pollutants from the atmosphere via dry fallout and precipitation washout. Man's activities and the physical environment influence air pollutant concentrations, dispersal, and fallout rates. Air pollutants in the form of smoke, dust, soot, fly ash, fumes, mist, odors, seeds, pollen, spores, and contaminated precipitation fall directly on surface waters and are direct sources of nutrients, sediments, oxygen-demanding substances, metals, and chemicals. Some air pollutants present no threat to water quality, but others are significant contributors to water quality degradation. Oxides of nitrogen may react with sodium, potassium, and other metals to form soluble nitrates which, when washed out of the atmosphere by rain, may contribute to the fertility of surface waters. Phosphorus adsorbed on fine clay and silt-sized particles may be transported by wind erosion and deposited in surface waters. In cases where ice covers a body of water, the various deposits still occur, but are stored until spring thaw. Direct contribution to surface water systems is of special concern because there is no intervening filtration by the land surface. The deposit of contaminants from the air to the water environment may be indirect, resulting from the transport, transformation, and storage of contaminants on land. This may introduce a substantial time delay between the time when a contaminant reaches the land and the time when the contaminant shows up in the water. The storage of air contaminants deposited on land also provides opportunity for the transformation of the contaminants into other chemical forms prior to their reaching the waterways. The indirect transfer of air pollutants to streets and through drainageways, storm sewers, and surface runoff is considered to be an element of the pollutant loadings from the sources discussed above.

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, metals, polychlorinated biphenyls (PCB's), and other unique organic materials.

Table 54 indicates that six accidental spills occurred within the Oak Creek watershed in 1982, as reported to the Wisconsin Department of Natural Resources. These data are presented 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 1982 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.

It is important to note that since 1976, Milwaukee County has 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 the tributary to Oak Creek.

Stream Processes: Instream processes also affect the pollution transport loading of a stream. The tremendous amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, stream bank and bed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as a particle trap or filter. On an annual basis or on a long-term basis, streams may exhibit a net deposition, a net erosion, or no net change in internal sediment transport, depending on the tributary land uses, watershed hydrology, precipitation, and geology. It was reported in SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, that from 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may be contributed by stream bank erosion. In general, increased stream urbanization may be expected to result in increased stream flow rates and volumes, with potential increases in stream bank erosion and bottom scour, and flooding problems. These effects may be mitigated by utilization of proper stormwater management practices.

Existing Stormwater Drainage Systems: Stormwater drainage facilities are defined, for purposes of this report, as conveyances—including, but not limited to, subsurface pipes and conduits, ditches,

Table 54

KNOWN HAZARDOUS SPILLS OCCURRING IN THE OAK CREEK WATERSHED: 1982

Date	Source of Spill	Type of Spill	Quantity	Receiving Water
March 29, 1982	Unknown	Unidentified gray liquid	Unknown	Oak Creek
June 26, 1982	Unknown	Oil	Unknown	Oak Creek
August 17, 1982	Unknown	Gasoline	Unknown	Oak Creek
September 15, 1982	Unknown	Unidentified green liquid	Unknown	Oak Creek
September 21, 1982	Abandoned gas stations	Oil	200-300 gallons	--[a]
November 24, 1982	Unknown	Oil	25 gallons	Oak Creek

[a] *This spill was contained before any material entered Oak Creek.*

Source: Wisconsin Department of Natural Resources.

channels, and appurtenant inlet, outlet, storage, and pumping facilities—located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying such runoff to natural watercourses for disposal. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible.

In the Oak Creek watershed, the stormwater drainage systems provide the means by which a portion of the nonpoint source pollutants reach the surface water system. Therefore, the extent and characteristics of the existing stormwater drainage system are pertinent to an understanding of the nonpoint source pollution problem. Because of the direct relationship between urban stormwater drainage systems and surface water quality, the Commission's areawide water quality management planning program included an inventory of the existing urban stormwater drainage systems within the Region. The results of that inventory, as well as of more recent inventory data, for the Oak Creek watershed are presented in summary form below.[7]

Inventory Findings: The five known existing stormwater drainage systems which serve portions of the subareas of the Oak Creek watershed are shown on Map 38. These include the systems operated by the Cities of Cudahy, Franklin, Milwaukee, Oak Creek, and South Milwaukee. Together, these systems have a combined tributary drainage area within the watershed of about 10.42 square miles, or about 38 percent of the total area of the watershed. Included within this stormwater drainage area are a total of 173 known stormwater outfalls. There are three known stormwater storage facilities in the watershed. The total annual average discharge from these outfalls is estimated to be 1,221 million gallons occurring in 70 events. The combined maximum discharge rate for these outfalls is estimated to be 3,379 cubic feet per second (cfs) for a two-year recurrence interval rainfall event and 4,610 cfs for a five-year recurrence interval rainfall event. Pertinent characteristics of each system are summarized in Table 55. The location and configuration of the major stormwater drainage conduits, as well as of the outlets and estimated tributary areas of the five stormwater drainage systems within the Oak Creek watershed, are shown on Map 38.

Nonpoint Source Pollutant Loads: Nonpoint source pollutant loads in the Oak Creek watershed were estimated by the unit load analysis method for estimating drainage channel loads and by using measured pollutant concentrations and a water quality simulation model for estimating the load of pollutants transported to the mouth of Oak Creek.[8]

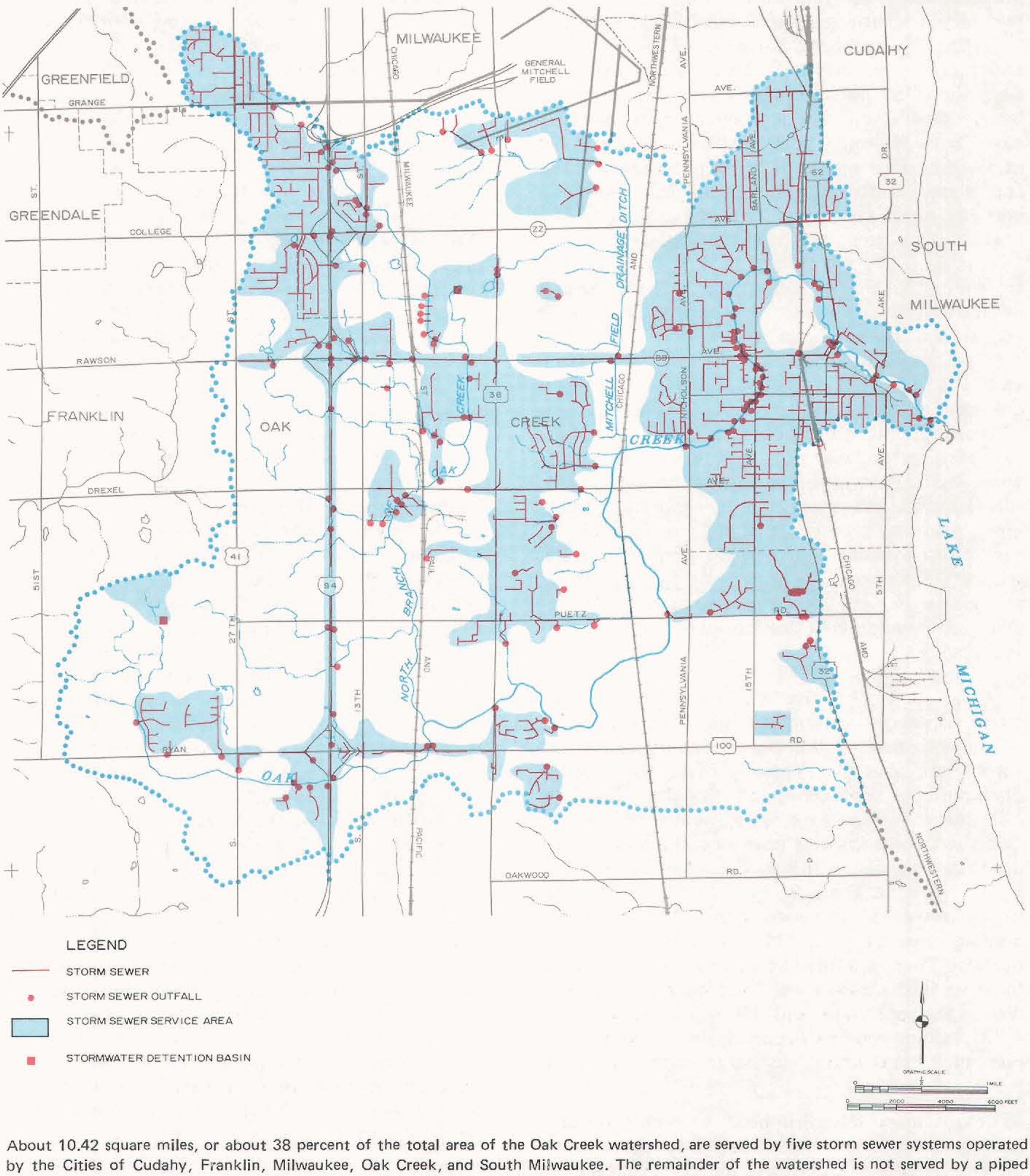
Unit Load Analysis: A preliminary analysis of the relative magnitude of nonpoint source pollutant loadings from the various land use-cover combinations comprising the Oak Creek watershed was conducted under the Regional Planning Commission's areawide water quality management planning program. That analysis was based on unit loading rates for various pollutants and land use-cover combinations. Certain 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 unit loading rates used in the areawide water quality management plan have been revised, where necessary, to reflect more recent study results and are set forth in Table 56. The analysis provides an estimate of gross pollutant loads from nonpoint sources in the Oak Creek watershed, as well as a means of identifying the most important sources of each pollutant, by quantifying the drainage channel pollutant load; i.e., the overbank-delivered pollutant loads to the perennial and intermittent streams of the Oak Creek watershed. The results of this analysis are summarized in Table 57. Estimated pollutant loads from point sources, although insignificant in the Oak Creek watershed, are also presented to provide a comparison of point source loads and nonpoint source loads. Annual pollutant loadings are estimated for total nitrogen, total phosphorus, biochemical oxygen demand, fecal coliform organisms, and sediment.

[7] *For a detailed description of the procedure used to inventory urban stormwater 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: 1975.*

[8] *See Chapter V of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975.*

Map 38

KNOWN URBAN STORM SEWER SYSTEMS IN THE OAK CREEK WATERSHED



About 10.42 square miles, or about 38 percent of the total area of the Oak Creek watershed, are served by five storm sewer systems operated by the Cities of Cudahy, Franklin, Milwaukee, Oak Creek, and South Milwaukee. The remainder of the watershed is not served by a piped stormwater drainage system, but drainage is instead carried overland by roadside ditches and natural swales to the major stream system of the watershed.

Source: SEWRPC.

Table 55

AREA SERVED BY AND SELECTED CHARACTERISTICS OF EXISTING STORMWATER DRAINAGE SYSTEMS IN THE OAK CREEK WATERSHED

Location of Public Stormwater Conveyance System	Estimated Tributary Area		Number of Stormwater Outfalls in System Discharging to Surface Waters	Size Range of Outfalls in System (diameter in inches)	Summation of Drainage Districts		
					Total Estimated Annual Discharge Volume (million gallons)	Estimated Maximum Stormwater Discharge Rates	
	Acres	Square Miles				2-Year Recurrence Interval Event (cubic feet per second)	5-Year Recurrence Interval Event (cubic feet per second)
City of Cudahy	489	0.76	1	72	88	280	390
City of Franklin. . . .	34	0.05	3	30 to 36	3	16	22
City of Milwaukee . .	403	0.63	24	15 to 60	83	262	349
City of Oak Creek. . .	3,845	6.01	94	12 to 66	703	1,721	2,330
City of South Milwaukee . .	1,898	2.97	51	12 to 102	344	1,100	1,519
Total	6,669	10.42	173	12 to 102	1,221	3,379	4,610

Source: SEWRPC.

The drainage channel pollutant loads can be expected to be different from the actual transport from the watershed, because material processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The drainage channel pollutant loading rates and, therefore, the total drainage channel pollutant loads set forth in Table 57 are representative of the annual quantities of potential pollutants moved from small areas of the Oak Creek watershed into localized drainage swales and channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system to the watershed outlet.

Based on data set forth in Table 57, urban sources of pollution are estimated to contribute 44 percent of the nitrogen, 63 percent of the phosphorus, 79 percent of the biochemical oxygen demand, 71 percent of the fecal coliform organisms, and 56 percent of the sediment which pollute the Oak Creek system. The contribution from urban point sources is relatively insignificant—less than 0.1 percent of total pollutants. Nonpoint sources account for essentially all of the urban pollutant loadings.

Of the pollutant loads from all sources within the watershed, rural pollution sources contribute an estimated 56 percent of the nitrogen, 37 percent of the phosphorus, 21 percent of the biochemical oxygen demand, 29 percent of the fecal coliform organisms, and 44 percent of the sediment. There are no rural point sources of pollution, since none of the livestock operations in the watershed are of sufficient size to fall within the definition of a point source under the normal state or federal guidelines. Livestock feeding operations—including the disposal of manure on croplands—contribute about 3 percent of the nitrogen, 5 percent of the phosphorus, 8 percent of the biochemical oxygen demand, 45 percent of the fecal coliform organisms, and 0.4 percent of the sediment attributed to rural sources. The remainder of the estimated rural pollution load, or 97 percent of the nitrogen, 95 percent of the phosphorus, 92 percent of the biochemical oxygen demand, 55 percent of the fecal coliform organisms, and virtually all of the sediment, is contributed by other rural nonpoint sources—namely, stormwater runoff from rural land uses and atmospheric loadings to surface waters.

Transport Load Analyses: To determine the amount of pollutants actually being transported downstream in the watershed, two pollutant transport analyses were conducted. The first analysis measured suspended solids, biochemical

Table 56

SUMMARY OF REPORTED POLLUTANT CHANNEL LOADING RATES FROM NONPOINT SOURCES USED IN THE UNIT LOADING ANALYSIS

Category of Nonpoint Pollution Sources	Rate of Pollutant Loadings[a] (given in pounds/acre/year except for fecal coliform organisms, given in counts/acre/year; and onsite sewage disposal systems, given in load/capita/year and livestock operations, given in load/animal unit/year)				
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Fecal Coliform Organisms	Sediment
Urban					
Residential Land Use	4.0	0.32	24.3	1.6×10^{10}	545
Commercial Land Use	9.0	0.75	97.6	3.3×10^{10}	745
Industrial Land Use	8.4	0.70	36.9	6.2×10^{10}	977
Construction and Extractive Activities and Landfills	60.0	45.0	120.0	Negligible	33,125
Transportation					
Freeways and Highways	23.4	1.4	159.0	6.7×10^{10}	7,800
Airports	12.0	2.7	17.6	Negligible	3,200
Recreation					
Parks	2.3	0.06	1.3	3.6×10^{9}	420
Golf Courses	4.4	0.20	1.3	Negligible	420
Onsite Sewage Disposal Systems (pounds or counts/capita/year)	5.7	1.32	81.6	1.0×10^{11}	28
Rural					
Livestock Operations (pounds or counts/animal unit/year)	28.4	6.6	111.2	6.4×10^{11}	700
Orchards	2.3	0.14	4.6	6.6×10^{8}	251
Pastures	4.6	0.29	9.7	Included in Livestock Load	420
Woodlands	2.3	0.14	4.6	6.6×10^{8}	251
Air Pollution to Surface Waters	8.9	0.5	162.0	Negligible	665
Row Crops	23.1	2.7	20.7		6,900
Small Grain	4.7	0.13	9.6	Included Livestock Load	3,200
Hay	0.9	0.09	9.6		3,200
Vegetables	23.1	2.7	30.0		10,000
Sod	0.9	0.09	2.1		700

[a] *The literature sources from which the loading rates were developed and a description of the procedures used to estimate loading rates are presented in SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, except that the sediment loads from construction, extractive, and transportation activities, and the phosphorus load from row crops, were derived from the Model Enhanced Unit Loading (MEUL) method, as set forth in SEWRPC Planning Report No. 35, A Comprehensive Plan for the Pike River Watershed.*

Source: SEWRPC.

oxygen demand (BOD_5), total nitrogen, and total phosphorus concentrations in Oak Creek and the application of a technique developed in the International Joint Commission's The IJC Menomonee River Watershed Study. The technique involves applying a stratified random sampling method to distinquish between wet weather and dry weather estimates of pollutant transport in order to estimate annual loads from the watershed. This transport analysis thus provides a measure of the observed stream transport loads.[9]

[9] *International Joint Commission, The IJC Menomonee River Watershed Study, Volume 5, Simulation of Pollutant Loadings and Runoff Quality, EPA-905/4-7-79-029-E, December 1979.*

Table 57

UNIT LOAD ANALYSIS FOR THE OAK CREEK WATERSHED: 1980

Source	Loads Presented in Pounds per Year, Except for Sediment Presented in Tons per Year, and Fecal Coliform Organisms Presented in Counts x 10^{10} per year									
	Total Nitrogen		Total Phosphorus		Biochemical Oxygen Demand		Fecal Coliform Organisms		Sediment	
	Load	Percent	Load	Percent	Load	Percent	Load	Percent	Load	Percent
Urban Point Sources										
Municipal Sewage Treatment Plants	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Private Sewage Treatment Plants	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Combined Sewer Overflow	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Industrial Discharges	0	0.0	<100	0.0	100	0.0	0	0.0	<10	0.0
Sanitary Sewer Flow Relief Devices[a]	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Urban Point Source Totals	0	0.0	<100	0.0	100	0.0	0	0.0	<10	0.0
Urban Nonpoint Sources										
Residential	16,200	7.5	1,300	3.5	98,600	13.6	6,500	12.3	1,100	4.7
Commercial[b]	7,800	3.6	600	1.6	84,500	11.7	2,900	5.4	320	1.4
Industrial	4,500	2.1	400	1.1	19,700	2.7	3,300	6.2	260	1.1
Transportation	33,700	15.6	3,200	8.5	191,900	26.5	7,700	14.5	5,380	23.0
Construction[c]	21,200	9.9	15,900	42.5	42,300	5.8	0	0.0	5,840	24.9
Recreation	1,200	0.6	<100	0.0	700	0.1	200	0.4	110	0.5
Septic Tank Systems	9,500	4.4	2,200	5.9	136,200	18.8	17,000	32.1	20	0.1
Urban Nonpoint Source Totals	94,100	43.7	23,600	63.1	573,900	79.2	37,600	70.9	13,030	55.7
Urban Source Totals	94,100	43.7	23,600	63.1	574,000	79.2	37,600	70.9	13,030	55.7
Rural Nonpoint Sources										
Agricultural	105,200	48.9	12,300	32.8	108,300	14.9	--[d]	--	9,740	41.6
Open Land	10,600	5.0	700	1.9	22,300	3.1	8,300	15.7	480	2.0
Woodland	1,900	0.9	100	0.3	3,800	0.5	100	0.2	100	0.5
Atmospheric Loadings to Surface Waters	200	0.1	<100	0.0	4,400	0.6	0	0.0	10	0.0
Livestock Operations	3,100	1.4	700	1.9	12,200	1.7	7,000	13.2	40	0.2
Rural Nonpoint Source Totals	121,000	56.3	13,800	36.9	151,000	20.8	15,400	29.1	10,370	44.3
Nonpoint Source Totals	215,100	100.0	37,400	100.0	724,900	100.0	53,000	100.0	23,400	100.0
Total Sources	215,100	.100.0	37,400	100.0	725,000	100.0	53,000	100.0	23,400	100.0

[a] *The annual discharge from sanitary sewer flow relief devices is less than 1 million gallons.*

[b] *Includes loadings from utility and communication facility land use.*

[c] *Includes loadings from urban land under construction, extractive activities, and landfills.*

[d] *Included in livestock operations' load of fecal coliform organisms.*

Source: SEWRPC.

The second pollutant transport analysis involved the application of the Wisconsin Urban Runoff Model, developed under the Nationwide Urban Runoff Program study in Milwaukee County, to simulate pollutant loadings.[10] The model was used to estimate storm event loadings of suspended solids, volatile suspended solids, nitrogen, phosphorus, and lead to surface waters in the watershed. Groundwater inputs, winter pollutant loadings, and instream processes were not simulated.

Table 58 presents the sources of data used for the measured transport analysis based on streamflow and pollutant concentration measurements in

[10] *Southeastern Wisconsin Regional Planning Commission and Wisconsin Department of Natural Resources, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, Volume II, Feasibility and Application of Urban Nonpoint Source Water Pollution Abatement Measures, 1983.*

Table 58

SOURCES OF DATA USED IN THE OAK CREEK MEASURED TRANSPORT ANALYSIS

Parameter	SEWRPC Technical Report No. 17 1968-1975	SEWRPC Index Site Sampling Program 1976	Wisconsin Department of Natural Resources Monthly Sampling Program	U. S. Geological Survey Streamflow Monitoring Program 1963-1975
Streamflow	--	--	--	X
Nitrogen	X	X	--	--
Phosphorus	X	X	--	--
BOD_5	--	X	--	--
Suspended Solids	--	--	X	--

Source: SEWRPC.

Oak Creek near the 15th Avenue bridge. Streamflow data were available from the U. S. Geological Survey for the years 1963 through 1975 as part of its routine sampling program. Total phosphorus, total nitrogen, and BOD_5 measurements were available from SEWRPC Technical Report No. 17, Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, and from the Commission's index site water quality sampling program conducted in 1976. Suspended solids concentration data were available from the Wisconsin Department of Natural Resources monthly sampling program. In Oak Creek, near the 15th Avenue bridge, it is estimated from these instream measurements that 149,000 pounds of total nitrogen, 9,000 pounds of total phosphorus, 237,000 pounds of BOD_5, and 2.9 million pounds of suspended solids are transported annually.

As already noted, the use of the Wisconsin Urban Runoff Model provides an alternative means of estimating pollutant transport loads. The model was developed, calibrated, and verified with the use of extensive monitoring data collected under the Nationwide Urban Runoff Program study in Milwaukee County. The model simulates storm runoff pollutant loadings as a function of the imperviousness of the land surface, the land surface slope, street and traffic conditions and pollutant loading rates, soil data, weather data, and wet and dry atmospheric loadings. For the Oak Creek watershed, application of the Wisconsin Urban Runoff Model resulted in simulated annual pollutant transport loads of about 4.2 million pounds of suspended solids, 85,000 pounds of total nitrogen, 11,300 pounds of total phosphorus, and 1,400 pounds of lead.

Sediment Rating Curve-Flow Duration Curve Method: The sediment rating curve-flow duration curve method is a technique for measuring sediment transport loads, or yield. Three steps are involved in applying the sediment rating curve-flow duration curve method. The first and second steps involve construction of a suspended sediment rating curve and development of a flow duration curve for the watershed. The third step combines the information embodied in the two curves to obtain annual sediment yield, and the application of an appropriate adjustment for bed load.

Development of a 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 (cfs) 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 a stream as a function of discharge.

A total of 15 pairs of suspended sediment transport-daily discharge values were used to construct the sediment ratings curve for the Oak Creek. The suspended sediment and streamflow data were available from the U. S. Geological Survey for Oak

Creek at 15th Avenue. The sediment rating curve for Oak Creek is presented in graphic form in Figure 35, as is an equation representing the transport-discharge relationship for the 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; the basin size and slope; the stormwater drainage system characteristics; and the extent and nature of construction activities. Because the aggregate mathematically fitted relationship shown in Figure 35 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. This relationship should thus provide a reasonably accurate estimate of average annual suspended sediment yield.

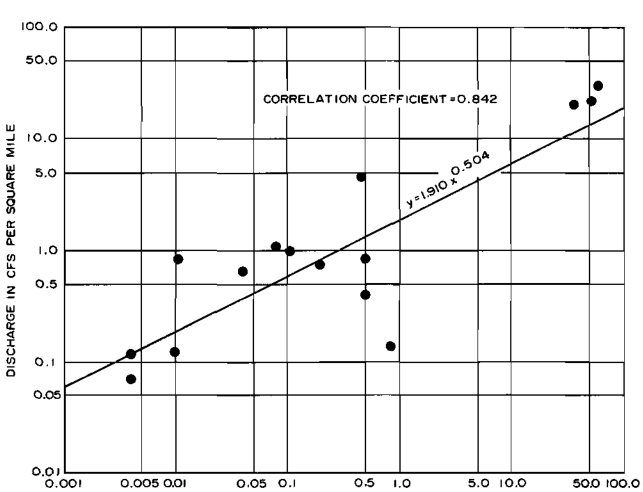
Development of Flow Duration Curve: A flow duration curve is a cumulative frequency curve indicating the percentage of time that a specified discharge may be expected to be equaled or exceeded. Measured streamflow data from the period of October 1963 through September 1983 were used to generate existing condition average daily discharges for Oak Creek at 15th Avenue. These discharges were statistically analyzed to develop the flow duration curve shown in Figure 36.

Combination of Sediment Rating and Flow Duration Relationships: As already noted, 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 35 was combined with the flow duration curve shown in Figure 36 using the tabular procedure set forth in Table 59.

Daily discharge rates were divided into 21 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

Figure 35

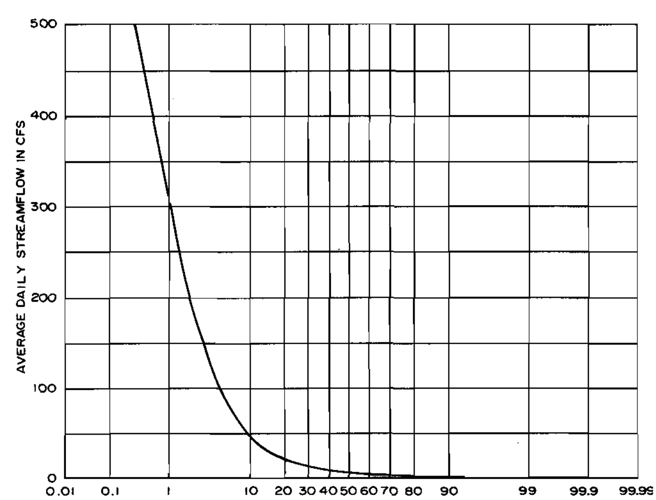
RELATIONSHIP BETWEEN SEDIMENT TRANSPORT AND DISCHARGE FOR THE OAK CREEK WATERSHED



Source: U. S. Geological Survey and SEWRPC.

Figure 36

FLOW DURATION CURVE FOR OAK CREEK AT 15TH AVENUE (RM 2.84) BASED ON MEASURED DATA FROM OCTOBER 1963-SEPTEMBER 1983



Source: SEWRPC.

Table 59

ESTIMATED AVERAGE ANNUAL SUSPENDED SEDIMENT YIELD FOR THE OAK CREEK WATERSHED AT 15TH AVENUE

Average Daily Discharge Range (cubic feet per second)	Days Within Flow Range		Sediment Transport	
	Percent of Year[a]	Number of Days per Year	Tons per Square Mile per Day[b]	Tons per Square Mile per Year
0-1	0.81	3.0	0.0001	<0.01
1-2	6.08	22.2	0.0010	0.02
2-3	12.73	46.5	0.0026	0.12
3-4	10.43	38.1	0.0052	0.20
4-5	8.76	32.0	0.0085	0.27
5-6	5.97	21.8	0.0128	0.28
6-7	5.30	19.3	0.0177	0.34
7-8	4.57	16.7	0.0234	0.39
8-9	3.61	13.2	0.0301	0.40
9-10	2.85	10.4	0.0375	0.39
10-20	18.60	67.9	0.0930	6.32
20-30	6.35	23.2	0.2565	5.95
30-40	2.93	10.7	0.4995	5.34
40-50	2.10	7.7	0.8228	6.34
50-75	2.92	10.7	1.5786	16.89
75-100	1.29	4.7	3.0766	14.46
100-200	2.77	10.1	8.9656	90.55
200-300	0.93	3.4	24.7034	83.99
300-400	0.45	1.6	48.1678	77.07
400-500	0.27	0.9	79.3048	71.37
more than 500	0.28	0.9	97.7424	87.97
Annual Total	100.0	365.0	--	468.67

[a] *From flow duration relationship set forth in Figure 36.*

[b] *From sediment rating relationship as a function of discharge, as set forth in Figure 35.*

Source: U. S. Geological Survey and SEWRPC.

year that each flow class occurred and the corresponding sediment transport rate as determined from Figure 35.

As shown in Table 59, the suspended sediment load per square mile of the Oak Creek watershed is estimated at 468.7 tons per year. Increasing this value 10 percent to account for the bedload, the total average sediment yield per unit area of the watershed is estimated at 515.6 tons per square mile per year. Applying this unit sediment yield to the 25.0-square-mile portion of the watershed upstream of 15th Avenue, which consititutes 92 percent of the total watershed area, produces a total average annual sediment yield from that portion of the watershed of about 12,890 tons. Applying the unit sediment load of 515.6 tons per square mile per year to the entire Oak Creek watershed produces a total average annual sediment yield of about 14,024 tons.

The sediment yield data set forth in Table 59 also illustrate the importance of stormwater runoff flows in generating sediment yields. Over 88 percent of the annual sediment yield is generated during streamflows exceeding 100 cubic feet per second, which occur only about 4.7 percent of the time.

Table 60 compares the sediment yields estimated by the application of the sediment rating curve-flow duration curve method for the Milwaukee River, Menomonee River, Kinnickinnic River, Root River, Fox River, and Oak Creek watersheds. The comparison indicates that smaller watersheds tend to have higher sediment yields on a unit-area basis than larger watersheds have. The reported average suspended sediment yield for the seven-county Southeastern Wisconsin Region, excluding bedload, is about 50 tons per square mile per year.[11]

Comparison of Transport Loads: A comparison of estimated transport loads is set forth in Table 61. The simulated transport loads for suspended solids, nitrogen, and phosphorus estimated using the Wisconsin Urban Runoff Model are similar to the measured transport loads. The suspended sediment load estimated using the sediment rating curve method is over five times higher than the simulated and measured suspended solids loads. In streams with high sand and silt loadings, high flow velocities, and stream bank erosion, suspended sediment measurements are usually substantially higher than suspended solids measurements. The suspended sediment concentration consists of the entire amount of solids filtered from a water sample, whereas the suspended solids concentration generally excludes many larger sized particles which settle rapidly in the sample container. Oak Creek may thus transport relatively large amounts of larger sized particles which are included in the suspended sediment measurements, but not in the suspended solids measurements.

Comparison of Simulated Transport Loads to Drainage Channel Loads: The simulated transport and drainage channel loading estimates were utilized in order to provide a comparability check on the estimates of the major pollutant sources in the watershed. The unit loading analysis set forth above provides drainage channel pollutant loads; i.e., the overbank-delivered pollutant loads to the perennial and intermittent streams and drainage systems of the Oak Creek watershed. The application of the Wisconsin Urban Runoff Model to the watershed provides watershed transport loads; i.e., the loads transported to the downstream end of the watershed. Estimates of both drainage channel and transport loads are useful to an understanding of the pollution sources and condi-

Table 60

COMPARISON OF ESTIMATED SEDIMENT YIELDS IN SELECTED WATERSHEDS OF SOUTHEASTERN WISCONSIN

Watershed	Drainage Area of Sediment Sample Site (square miles)	Sediment Yield (tons per square mile per year)
Oak Creek	25	515.6
Kinnickinnic River . .	20	450.0
Pike River	39	237.0
Menomonee River. . .	123	97.5
Root River.	187	96.3
Milwaukee River . . .	686	61.1
Fox River	868	20.2

Source: SEWRPC.

Table 61

COMPARISON OF ESTIMATED TRANSPORT LOADS FOR THE OAK CREEK WATERSHED

Pollutant	Transport Load (thousands of pounds per year)		
	SEWRPC-Measured Transport Analysis[a]	Simulated Transport Analysis[b]	Sediment Rating Curve Method
Suspended Sediment . . .	--	--	25,500
Suspended Solids	2,930	4,160	--
Volatile Suspended Solids	--	685	--
BOD_5	237	--	--
Total Nitrogen.	149	85	--
Total Phosphorus	9	11	--
Total Lead	--	1.4	--

[a]*Estimated loadings represent pollutant transport in Oak Creek at the 15th Avenue bridge. Includes pollutant loadings from point sources, nonpoint sources, and stream bank erosion.*

[b]*Loadings were estimated using the Wisconsin Urban Runoff Model. Includes nonpoint source loadings only; point source loadings and stream bank erosion are not simulated by the model.*

Source: SEWRPC.

[11] *S. M. Hindall, Measurement and Prediction of Sediment Yields of Wisconsin Streams, U. S. Geological Survey Water Resources Investigation, 1976, pp. 54-75.*

tions in a watershed, and a comparison of these two loading estimates provides an insight into the factors affecting nonpoint source pollutant load contributions to the streams and the transport of these pollutants through the stream system. The drainage channel pollutant loads are an important measure of relative pollutant loading conditions throughout an entire watershed. Transport loading estimates are important when considering information on total pollutant loading to a downstream point, such as the mouth of Oak Creek at Lake Michigan.

Since the Wisconsin Urban Runoff Model develops watershed transport load estimates for nonpoint source pollutants on the basis of the land uses in a watershed, the urban and rural nonpoint source proportions of the total estimated loads were compared with the unit load analysis results. Table 62 summarizes the results of the application of the model to the Oak Creek watershed and compares resultant transport loads to the watershed drainage channel pollutant loads generated by the application of the unit loading rates. Point source load estimates are combined with the

Table 62

SUMMARY COMPARISON OF ESTIMATED DRAINAGE CHANNEL LOADINGS AND SIMULATED TRANSPORT LOADINGS OF POLLUTANTS IN THE OAK CREEK WATERSHED: 1980

Source	Parameter	Unit Load Analysis Drainage Channel Loads[a] Estimated Load	Unit Load Analysis Drainage Channel Loads[a] Percent of Total	Simulated Transport Loads[b] Estimated Load	Simulated Transport Loads[b] Percent of Total
Urban Point	Phosphorus (pounds per year)	100	--[c]	100	--[c]
	Nitrogen (pounds per year)	0	--[c]	0	--[c]
	Sediment (tons per year)	10	--[c]	10	--[c]
Urban Nonpoint	Phosphorus (pounds per year)	23,600	63	3,600	32
	Nitrogen (pounds per year)	94,100	44	33,500	40
	Sediment (tons per year)	13,030	56	1,370[d]	33
Urban Source Totals	Phosphorus (pounds per year)	23,700	63	3,600	32
	Nitrogen (pounds per year)	94,100	44	33,500	40
	Sediment (tons per year)	13,040	56	1,370[d]	33
Rural Nonpoint	Phosphorus (pounds per year)	13,800	37	7,700	68
	Nitrogen (pounds per year)	121,000	56	51,300	60
	Sediment (tons per year)	10,370	44	2,790[d]	67
Total Nonpoint Sources	Phosphorus (pounds per year)	37,400	100	11,300	100
	Nitrogen (pounds per year)	215,100	100	84,800	100
	Sediment (tons per year)	23,400	100	4,160[d]	100
Total Sources	Phosphorus (pounds per year)	37,500	100	11,300	100
	Nitrogen (pounds per year)	215,100	100	84,800	100
	Sediment (tons per year)	23,410	100	4,160[d]	100

[a] *These drainage channel pollutant loads represent pollutant contributions from very small drainage areas. Only a portion of these loads would be delivered to the major stream channel and to the mouth of Oak Creek.*

[b] *The simulated loadings were estimated using the Wisconsin Urban Runoff Model. Since the model does not include a component for point source loads, these loads, although insignificant in the Oak Creek watershed, were added to obtain a total loading comparison. The model-simulated loads represent the portion of the total watershed load transported to the mouth of Oak Creek.*

[c] *Less than one-tenth of 1 percent.*

[d] *The Wisconsin Urban Runoff Model estimates suspended solids loadings, which represent only a portion of the total sediment loading to a waterway.*

Source: SEWRPC.

model-simulated nonpoint source load estimates to estimate total pollutant transport from the watershed. Point source loadings, however, were found to be relatively insignificant in the Oak Creek watershed.

Review of the results of these two different analytical methods indicates that the results are reasonably consistent. Comparisons were made for total urban nonpoint source and total rural nonpoint source watershed loads. The comparison of loads for each individual detailed land use category was not deemed appropriate since the two methods of estimating loads were developed independently at a systems level of accuracy, and on the basis of research study reports from different time periods, thus reflecting changes in the state-of-the-art of pollutant load estimating. Accordingly, it was concluded that comparisons of load proportions at the most detailed level of land use categories were not warranted.

As could be expected, the model results indicate total phosphorus, totai nitrogen, and sediment transport load quantities from nonpoint sources which are lower than the drainage channel pollutant load quantities. The transport loads from nonpoint sources, as estimated by the model, represent 30 percent, 39 percent, and 18 percent of the drainage channel pollutant loads of phosphorus, nitrogen, and sediment, respectively. The transport loads are expected to be lower than the drainage channel pollutant loads because only a portion of the total amount of pollutants contained in stormwater runoff—i.e., drainage channel pollutant loads—is transported to the mouth of the river—i.e., transport loads.

Urban nonpoint sources contribute a somewhat higher portion of the total drainage channel loads of phosphorus and sediment than do rural nonpoint sources. Urban nonpoint sources contribute 63 percent and 56 percent of the total drainage channel loads of phosphorus and sediment, respectively, but only 32 percent and 33 percent of the simulated transport loads of phosphorus and sediment. Urban nonpoint sources contribute a higher portion of the total drainage channel loads because channel loadings from construction site, extractive activities, and landfill erosion are relatively high, accounting for 67 percent of the total phosphorus load and 45 percent of the sediment load contributed by urban nonpoint sources. Construction site and related erosion accounted for only 55 percent and 26 percent of the total urban nonpoint source simulated transport loadings of total phosphorus and sediment, respectively. Large amounts of sediment and sediment-associated pollutants which are eroded from construction sites thus may be deposited in streets, ditches, and streams without being transported to the mouth of Oak Creek. Thus, Table 62 indicates that while urban nonpoint sources—primarily construction site and related erosion—accounted for the majority of the drainage channel loadings of phosphorus and sediment, these urban sources contributed a smaller portion of the transport loadings at the mouth of Oak Creek because much of the pollutant loads contributed by construction site and related erosion may be deposited in the stormwater drainage system, therefore not reaching the mouth of the creek.

Pollution Sources: Overview

Figure 37 provides a graphic summary of the average annual loads of selected pollutants to the stream network of the Oak Creek watershed from point and nonpoint sources, as determined in the unit load analysis. The following observations may be made and conclusions drawn based on the identification, characterization, and quantification of pollution sources:

- Sanitary sewage enters the surface water system of the watershed through two overflows located in the City of South Milwaukee. A third overflow located in the City of Oak Creek was abandoned in April 1984 as a result of a sewer system rehabilitation project in the City of Oak Creek. The two overflows located in the City of South Milwaukee will also be abated by mid-1984 as a result of a sewer system rehabilitation project being conducted in that City. Consequently, the water quality evaluations in this report do not include the pollutant loadings from these bypasses.

- There are no municipal sewage treatment plants discharging to the surface waters of the Oak Creek watershed.

- Nine industrial establishments which discharge wastewaters through 16 outfalls are known to exist in the watershed and constitute a minor component of the hydraulic budget of the basin, accounting for only 6 percent of the total average annual flow from the basin. These 16 industrial outfalls all normally discharge spent cooling waters, a combination of cooling and boiler blowdown water, aircraft washwater, oil-contaminated stormwater, stormwater, and sludge tank decant water. The average annual pollutant contribution from these sources is insignificant, accounting for less than 0.1 percent of the total load of all pollutants evaluated.

- Nonpoint source pollution includes materials washed from the atmosphere, land surface, or subsurface by rainfall, snowmelt, or seepage waters and conveyed to surface waters. The majority of potential pollutants accumulated on or near the land surface may be traced to a variety of man's activities or to the effects of man's activities. Nonpoint sources account for essentially all of the total annual pollutant load to the surface waters of the Oak Creek watershed.

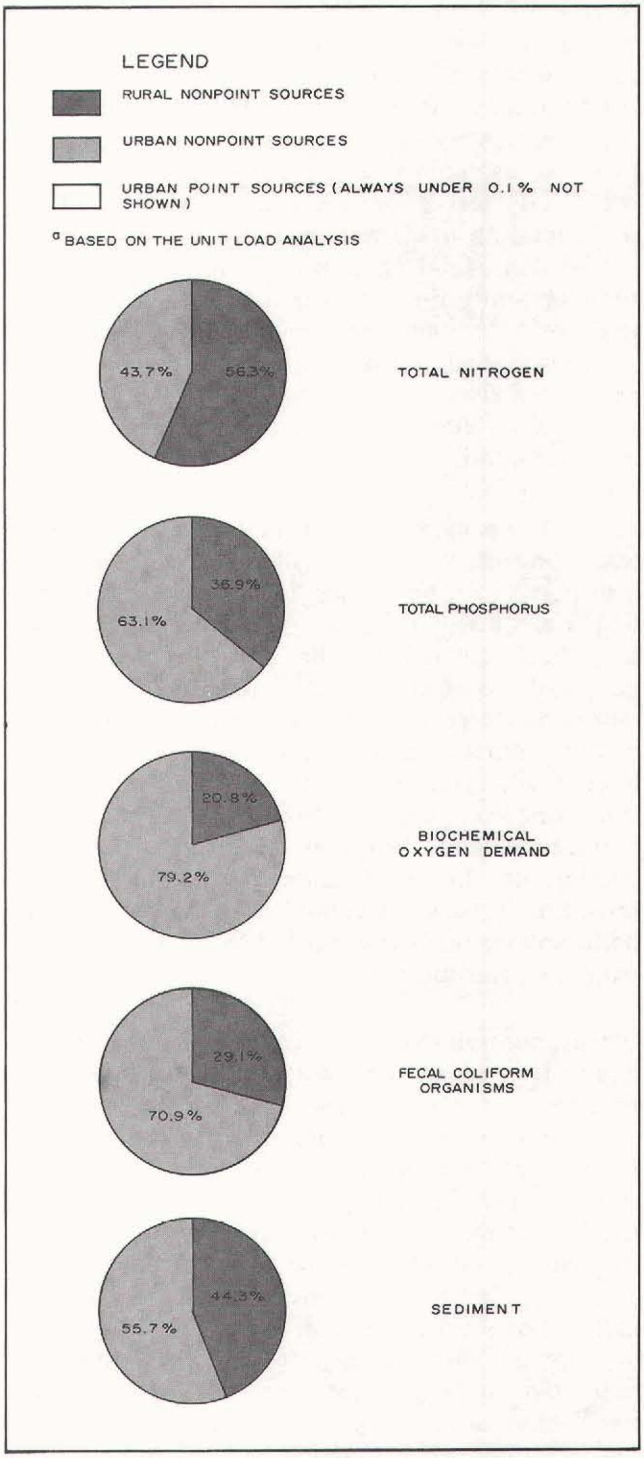
- Of the total nonpoint source pollutant load to the watershed, as estimated using the unit load analysis, urban nonpoint sources are estimated to contribute about 44 percent of the nitrogen, about 79 percent of the biochemical oxygen demand, about 63 percent of the phosphorus loading, about 71 percent of the fecal coliform organisms, and about 56 percent of the sediment load. Rural nonpoint sources account for the remaining 56 percent of the nitrogen, 21 percent of the biochemical oxygen demand, 37 percent of the phosphorus, 29 percent of the fecal coliform, and 44 percent of the sediment.

- During dry weather conditions, the recommended temperature, pH, dissolved oxygen, and ammonia nitrogen standards are met virtually all of the time. The phosphorus and fecal coliform standards recommended for Oak Creek are violated about 22 percent and 44 percent of the time, respectively, during dry weather conditions.

- During wet weather conditions, the established temperature, pH, dissolved oxygen, and ammonia nitrogen standards are met nearly all of the time. However, the recommended phosphorus and fecal coliform standards are violated more than 80 per-

Figure 37

SUMMARY OF AVERAGE ANNUAL POLLUTANT LOADINGS FROM SOURCES IN THE OAK CREEK WATERSHED: 1980[a]



Source: SEWRPC.

cent of the time during wet weather, indicating that major contributions of these pollutants are related to nonpoint sources.

- Pollutant sources identified in the Oak Creek watershed can be categorized into point sources, urban nonpoint sources, and rural nonpoint sources. Known point sources of pollution include two sanitary sewerage flow relief devices and 10 industrial sources which have 18 outfalls. Nonpoint sources of pollution include materials washed from the atmosphere, and the land surface or subsurface, by rainfall, snowmelt, or seepage waters. In urban areas, these pollutants are conveyed to the surface waters directly or, as in many cases in the Oak Creek watershed, via one of the five storm sewer systems located in the watershed. As of 1980, urban land uses comprised about 46 percent of the Oak Creek watershed, with the approximately 5.4 square miles of residential land use accounting for about 42 percent of the total urban land. Other major sources of urban nonpoint pollutants in the watershed were the approximately 1.1 square miles of commercial land use and 0.8 square mile of industrial land use, and the septic tanks which served about 1,670 persons. The approximately 0.5 square mile of land under construction, used for extractive activities or for landfills, is also a major source of nonpoint source pollutants. Rural lands comprised about 54 percent of the watershed, with pollutant loadings from the 13.1 square miles of agricultural and open land and the estimated 110 livestock animal unit equivalents being the most significant rural pollutant sources.

SUMMARY

The activities of man and the occurrences of nature affect and are affected by the quality of surface water. In a watershed such as the Oak Creek watershed, the effects of human activities on water quality tend to overshadow the 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 Oak Creek watershed have been and are polluted, and identifies the sources of that pollution.

The term "water quality" encompasses the physical, chemical, and biological characteristics of water. Water is deemed to be polluted when foreign substances caused by, or related to, human activities are in such form and concentration 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. The parameters used in analyzing water quality conditions in the Oak Creek watershed include temperature, dissolved solids, suspended solids, specific conductance, turbidity, hydrogen ion concentration (pH), chloride, dissolved oxygen, biochemical oxygen demand, total and fecal coliform bacteria counts, phosphorus and nitrogen forms, aquatic flora and fauna, metals, pesticides, and polychlorinated biphenyls (PCB's).

Water quality standards supporting water use objectives for the watershed surface water system provide a scale against which historic and existing water quality can be judged. For purposes of the comparative water quality analysis set forth in this chapter, the water quality standards corresponding to the "recreational use, maintenance of warmwater fish and aquatic life, and minimum standards" objectives established under the areawide water quality management 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 ground-

water discharged to the stream plus the continuous or intermittent discharge of various point sources, such as industrial cooling or process waters. While instream water quality during wet weather conditions includes the above discharges, the dominant influence—particularly during major rainfall or snowmelt events—is the load from soluble and insoluble substances washed into the streams by stormwater runoff. This runoff moves from the land surface to the stream waters via overland routes, such as drainage ditches and streets and highway ditches and gutters, or via the underground storm 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 17 percent of the days in a given year in the Oak Creek watershed.

A variety of data sources, based primarily on field studies and dating back to 1954, were used to assess the historic and existing water quality of surface water in the Oak Creek watershed. Most of the historic water quality monitoring information available for the watershed represents dry weather conditions, with some information being available on wet weather conditions and relatively little information being available on either dry or wet-weather condition concentrations of such more exotic pollutants as metals, pesticides, and polychlorinated biphenyls (PCB's).

The past studies have shown that high concentrations of pollutants are more likely to occur during wet weather conditions in the Oak Creek watershed than during dry weather conditions. The ratio of measured wet weather to measured dry weather pollutant concentrations ranges from 0.44 to 24.21. The ratio of wet weather to dry weather pollutant transport values ranges from 0.98 to 142 and, generally, is significantly greater than the ratio of wet weather to dry weather concentrations. That is, as may be expected, wet weather conditions generally have a greater impact on pollutant transport from the watershed than on pollutant concentrations, since, in general, wet weather causes a significantly greater increase in flow than in pollutant concentration.

During dry weather conditions, the recommended temperature and pH, dissolved oxygen, and ammonia nitrogen standards appear to be satisfied in the Oak Creek system virtually all of the time. In contrast, the phosphorus and fecal coliform standards are violated 22 percent and 44 percent of the time, respectively, during dry weather conditions.

During wet weather conditions, the established temperature, pH, dissolved oxygen, and ammonia nitrogen standards appear to be satisfied nearly all of the time. The recommended phosphorus and fecal coliform standards appear to be violated most of the time.

The magnitude and extent of toxic and hazardous substance contamination of the Oak Creek watershed cannot be determined from the limited data available.

The benthic community in the watershed is composed of large populations of pollutant-tolerant species, a situation indicative of polluted conditions.

Of the eight potential types of surface water pollution, all but thermal and radiologic pollution are known to exist to at least some degree in the Oak Creek watershed. The quality of the surface waters of the Oak Creek watershed generally does not support warmwater fishery and aquatic life objectives, nor does it generally support recreational use objectives.

Commission inventories indicate that as of 1980, point source contributions of pollutants were relatively insignificant, and both urban and rural nonpoint sources were major contributors of pollutants.

Point source pollutant loads in the Oak Creek watershed were estimated by utilizing measured data obtained under the Wisconsin Pollution Discharge Elimination System. Pollutant loads from nonpoint sources were estimated using a unit load analysis and a water quality simulation model. Based on the unit load analysis, urban nonpoint sources of pollution are estimated to contribute 44 percent of the nitrogen, 63 percent of the phosphorus, 79 percent of the biochemical oxygen demand, 71 percent of the fecal coliform, and 56 percent of the sediment which are discharged to drainage channels in the Oak Creek watershed. Of the total pollutant loads, rural nonpoint pollutant sources contribute the remaining 56 percent of the nitrogen, 37 percent of the phosphorus, 21 percent of the biochemical oxygen demand, 29 percent of the fecal coliform organisms, and 44 percent of the sediment.

As an alternative to the unit load analysis, which estimates drainage channel pollutant loads from very small drainage areas, methods can be used to estimate transport loads at the mouth of the watershed. These methods indicate the proportions of the drainage channel pollutant loads which are actually delivered to the mouth of the watershed. The simulated transport loads represent 39 percent of the nitrogen, 30 percent of the phosphorus, and 18 percent of the sediment included in the drainage channel pollutant loadings as estimated by the unit load analysis.

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Chapter VIII

WATER RESOURCE SIMULATION MODEL

INTRODUCTION

Quantitative analyses of watershed hydrology, hydraulics, and water quality under existing and alternative future conditions are a fundamental requirement of any sound, comprehensive watershed planning effort. Of particular interest in watershed planning are: 1) those aspects of the hydrology and hydraulics of the watershed which affect peak flood discharges and stages and are, therefore, of concern in floodland management; and 2) those aspects which affect water quality conditions, such as periods of critically low streamflows or of pollutant washoff from the land surface, and are, therefore, of concern in water quality management.

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, and the rate at which pollutants are either assimilated within, or transported from, the watershed.

Recently developed water resources planning and 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 analyses of hydrology, hydraulics, and water quality under existing and alternative future conditions required in a sound planning effort.

The purpose of this chapter is to describe the Water Resource Simulation Model—actually a combined hydrologic, hydraulic, and water quality model—used in the Oak Creek 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] The voluminous input and output data attendant to the modeling effort could not all be included in this report; however, the data not included are available in Commission files.

It is important to emphasize that the model used in the Oak Creek watershed planning program, or more specifically the mathematical computations and logic decisions executed during the operation of that model, is no more and no less sophisticated or valid than the operations which could, with sufficient personnel and time, be accomplished manually. The only advantage of digital

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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 further 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 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.*

computer simulation over manual computations is the rapidity of the computer 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 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 processes 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, however, it would have been impractical to manually execute the computations necessitated in even a single application of the model used in the Oak Creek watershed study.

MODEL USED IN THE OAK CREEK WATERSHED PLANNING PROGRAM

Model Selection Criteria

For comprehensive watershed planning, the mathematical simulation model should be able to:

1. Simulate hydrologic, hydraulic, and water quality conditions in both rural and urban areas;

2. Compute flood discharges and stages for a wide range of recurrence intervals, including the 100-year recurrence interval, with sufficient accuracy for use in delineating floodland regulatory districts and areas and for designing and evaluating alternative flood control measures and works;

3. 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;

4. 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;

5. Incorporate the hydrologic and hydraulic effects of alternative structural flood control works, such as channelization, dikes and floodwalls, and storage impoundments;

6. Permit assessment of the impact on surface water quality of discharges from point sources of pollution such as municipal and industrial discharges; and

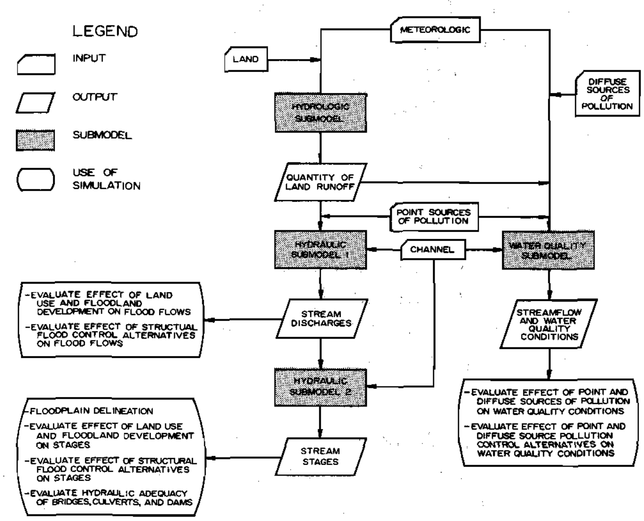
7. Permit assessment of the impact on surface water quality of diffuse, or nonpoint, sources of pollution, such as organic materials and plant nutrients washed from the land surface or leached out of soil profiles.

Model Selection

Figure 38 graphically illustrates the overall structure of the model selected by the Commission for use in its water resources planning programs; identifies four 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.

Figure 38

HYDROLOGIC-HYDRAULIC-WATER QUALITY MODEL USED IN THE OAK CREEK WATERSHED PLANNING PROGRAM



Source: SEWRPC

The Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel are three computer programs originally contained within a program package known as "Hydrocomp Simulation Programming".[4] These submodels, which were available on a proprietary basis through the consulting firm, Hydrocomp, Inc., had been under development since the early 1960's, when pioneering work in hydrologic-hydraulic modeling was initiated at Stanford University.[5] The Hydrocomp program submodels—that is, the Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel—are all continuous process submodels and were installed on the Regional Planning Commission computer system in 1974. These submodels were used, among other applications, in the Commission's Menomonee River, Kinnickinnic River, and Pike River watershed studies and in the Commission areawide water quality management planning program, including under the latter the simulation of water quality conditions in the Oak Creek watershed.[6] Indeed, the modeling results obtained under the areawide water quality management planning program served as the basis for the water quality related analyses conducted under the Oak Creek watershed study.

In early 1984, a new computer program was installed on the Regional Planning Commission computer system to replace the original Hydrocomp program package. This program, called "Hydrological Simulation Program-Fortran" (HSPF), was obtained from the U. S. Environmental Protection Agency and represents a refined version of the original Hydrocomp program package.[7] The HSPF program was used for flood control related analyses conducted under the Oak Creek watershed.

The submodel identified as Hydraulic Submodel 2 is the U. S. Army Corps of Engineers Program called "Water Surface Profiles."[8] This discrete event, steady state model was provided to the Commission 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,[9] and has been operable on the Commission computer system since 1974.

Each of the four submodels is described briefly below. These separate descriptions 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 factor is the nature and use of the land.

The basic conceptual unit on which the Hydrologic Submodel operates is called the hydrologic land segment type. A hydrologic land segment type is

[4] See Hydrocomp, Inc., Hydrocomp Simulation Programming Operations Manual, 4th Edition, January 1976; and Hydrocomp, Inc., Hydrocomp Water Quality Operations Manual, April 1977.

[5] *See 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.*

[6] *See Southeastern Wisconsin Regional Planning Commission, A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, February 1979.*

[7] *U. S. Environmental Protection Agency, Environmental Research Laboratory, Hydrological Simulation Program—Fortran, User's Manual for Release 8.0, Athens, Georgia, April 1984.*

[8] *U. S. Army Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L202A, HEC-2, Water Surface Profiles Users Manual, Davis, California, September 1982.*

[9] *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.*

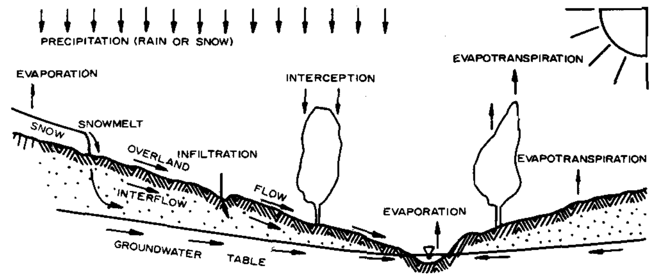
defined as a unique combination of meteorological characteristics, such as precipitation and temperature; land characteristics, such as the proportion of land surface covered by impervious surfaces; soil type; and slope. A strict interpretation of this definition results in a virtually infinite number of unique hydrologic land segment types within even a small watershed because of the large number of possible combinations of meteorological characteristics, land characteristics, and soils which exhibit a continuous, as opposed to discrete, spatial variation throughout the watershed. To apply the concept, the study area is divided into hydrologic land segments. A hydrologic land segment is defined as a surface drainage unit which exhibits a runoff pattern characteristic of a unique hydrologic land segment type. Thus the practical, operational definition of a hydrologic land segment is a surface drainage unit consisting of a subbasin or a combination of subbasins that are represented by a particular hydrologic land segment type. The hydrologic land segments were defined so that a travel time of approximately one hour for flow through the segment was provided, and so that simulated output data could be obtained at sites where historic water quality sampling data were already available, or at points located upstream or downstream of known sources of pollution. As described later in this chapter, four hydrologic land segment types and 27 hydrologic land segments were identified within the Oak Creek watershed for modeling existing conditions.

The hydrologic processes explicitly simulated within the Hydrologic Submodel are shown in Figure 39. 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 40. 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 63 identifies eight categories of historic meteorological data sets, seven of which

Figure 39

PROCESSES SIMULATED IN THE HYDROLOGIC SUBMODEL



Source: Hydrocomp, Inc., and SEWRPC.

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 Oak Creek watershed land surface are described later in this chapter.

Table 64 identifies the 22 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, along with point and groundwater discharges as produced by the Hydrologic Submodel, to combine the two, and to route[10] them 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.

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[10] *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 40

INTERDEPENDENCE BETWEEN PROCESSES IN THE HYDROLOGIC AND WATER QUALITY SUBMODELS

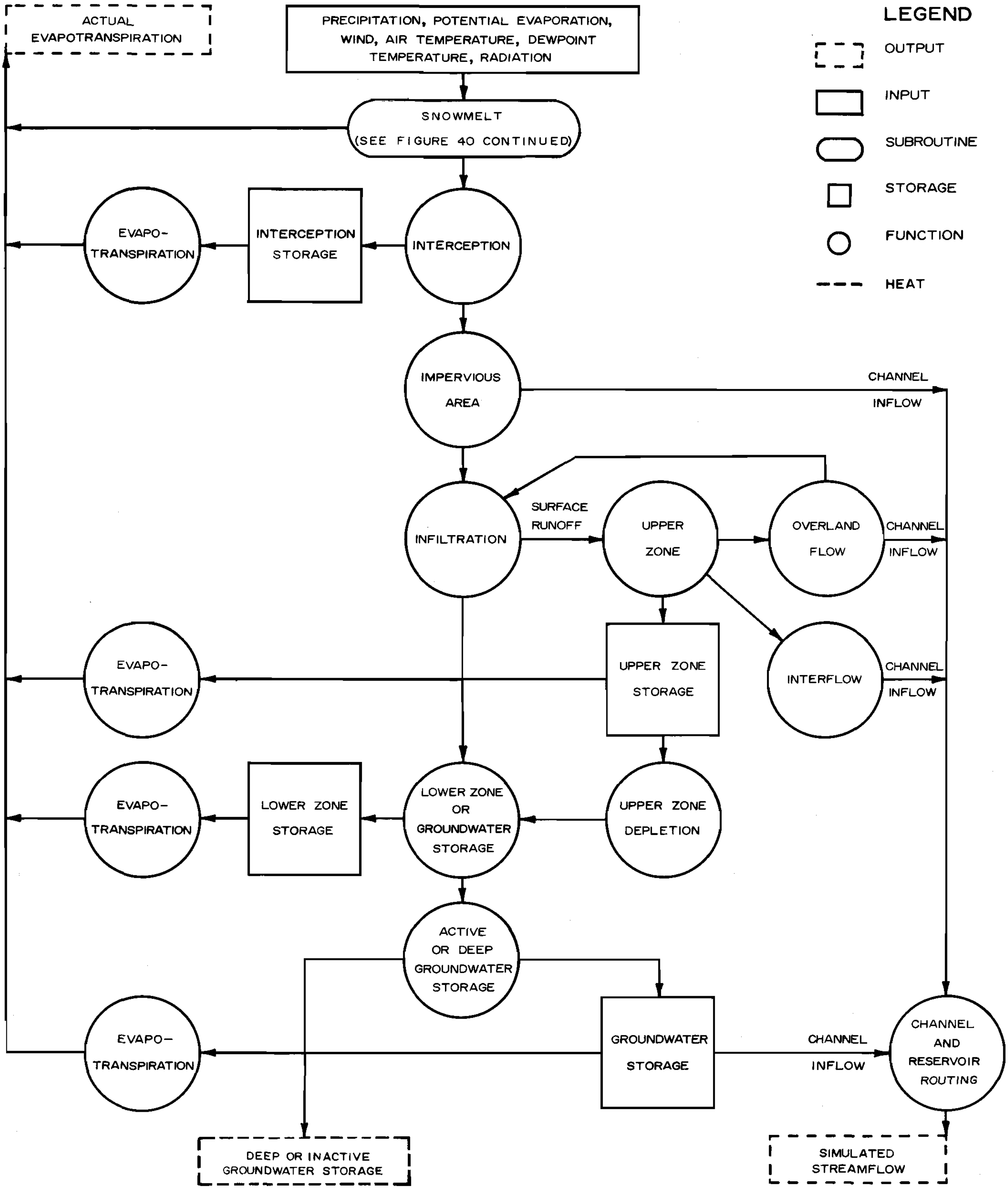
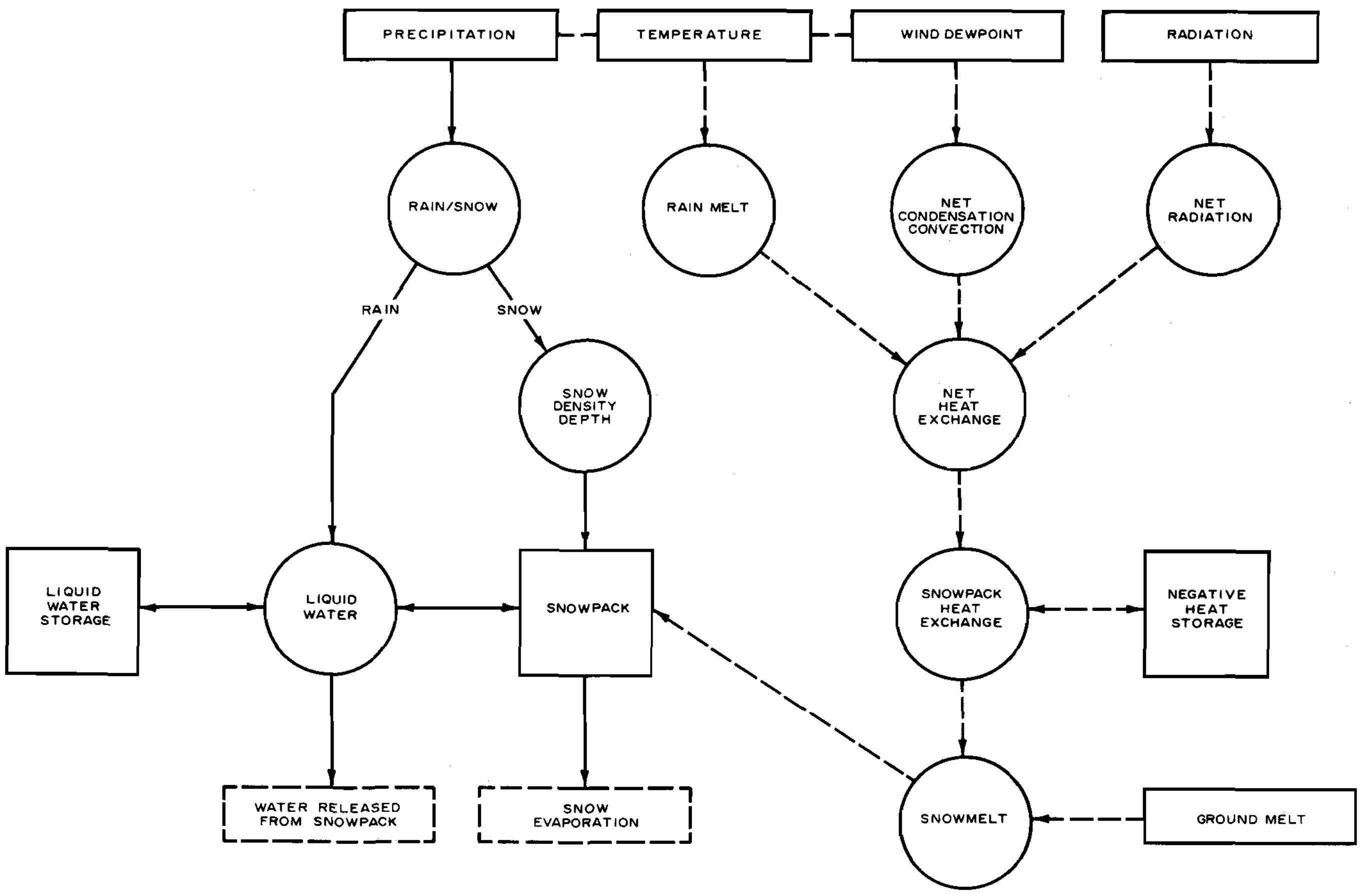


Figure 40 (continued)

FLOWCHART FOR SNOWMELT SUBROUTINE



Source: Hydrocomp, Inc., and SEWRPC.

Statistical analyses performed on the resulting continuous series of discharges yield the various recurrence interval flood discharges that are 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.

Hydraulic Submodel 1 was also used as a discrete event simulation model, which involved utilizing, as input to the model, data characterizing discrete rainfall events which produce the various recurrence interval floods, operating the model at a five-minute computational time interval, and generating as output the corresponding instantaneous peak discharges from the resulting hydrographs. This version of Hydraulic Submodel 1 was necessary for use on the headwater reaches of the Oak Creek, North Branch of Oak Creek, and Mitchell Field Drainage Ditch because of the tendency for the small watercourses involved to experience a rapid rise and fall of floodwaters and thus to pose the possibility of the instantaneous peak discharge not being correctly simulated because the model could be operated at too large a computational time interval in the other mode. More specifically, selected total rainfall amounts for specified duration rainfall events—as shown in Figure C-2 of Appendix C—were distributed over their respective durations at five-minute time intervals and thus applied to generate the simu-

Table 63

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	°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]	°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/cm² or 3.97 x 10^{-3} BTU/cm². 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/cm²/day or 3.97 x 10^{-3} BTU/cm²/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 64

PARAMETERS REQUIRED FOR EACH HYDROLOGIC LAND SEGMENT TYPE SIMULATED WITH THE HYDROLOGIC SUBMODEL

Parameter		Definition or Meaning	Unit	Primary Source of Numerical Values[a]
Number	Symbol			
1	CEPSC	Maximum interception storage	Inches	Extent and type of vegetation as determined from aerial photographs and field examination
2	UZSN	Nominal transient groundwater storage in the upper soil zones	Inches	A function of LZSN and therefore determined primarily by calibration
3	LZSN	Nominal transient groundwater storage in the lower soil zones	Inches	Related to annual precipitation but determined primarily by calibration
4	DEEPER	Decimal fraction of the groundwater recharge that percolates to deep or inactive groundwater storage	None	--[b]
5	LZETP	Decimal fraction of land segment with shallow groundwater subject to direct evapotranspiration	None	Soils and topographic data
6	INFILT	Nominal infiltration rate	None	Calibration
7	INTFW	Index of interflow	None	Calibration
8	LSUR	Average length of overland flow	Feet	Topographic maps
9	SLSUR	Average slope of overland flow	None	Topographic maps
10	NSUR	Manning roughness coefficient for overland flow	None	Field reconnaissance
11	IRC	Interflow recession rate	None	Hydrograph analysis
12	AGWRC	Groundwater recession rate	None	Hydrograph analysis
13	CCFACT	Adjust theoretical snowmelt equations to field conditions	None	--[b]
14	SNOWCF	Adjust snowfall measurements to account for typical catch deficiency	None	--[c]
15	RDCSN	Density of new snow at $0^{\circ}F$	None	--[b]
16	SHADE	Decimal fraction of land segment with forest cover	None	Aerial photographs
17	MGMELT	Groundmelt rate attributable to conduction of heat from underlying soil to snow	Inches/day	--[b]
18	MWATER	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]
19	COVIND	Water equivalent of snowpack when segment is completely covered by snow	Inches	--[b]
20	SNOEVP	Adjust theoretical snow evaporation equations to field conditions	None	--[b]
21	MELEV	Mean elevation of segment	Feet Sea Level Datum	Topographic map
22	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, Volume One, 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 (New York: McGraw-Hill, 1975).*

Source: U. S. Environmental Protection Agency.

lated instantaneous peak flood discharge for the specified recurrence interval event.[11] Hydraulic Submodel 1 was thus operated at a five-minute computational time interval for each duration rainfall event, which produced several hydrographs and corresponding instantaneous peak discharges for the various duration rainfall events. The largest instantaneous peak discharge obtained from the various duration rainfall events for the particular recurrence interval flood was chosen for use in Hydraulic Submodel 2.

In addition to maintaining a continuous accounting of inflow to the stream system, Hydraulic Submodel 1 performs routing calculations for land segments—a land segment being either a channel reach and its tributary drainage area, or an impoundment and its tributary drainage area—by employing the conservation of mass principle and basic hydraulic laws.

Routing 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 land segment with the values selected so as to encompass the entire range of physically possible water surface elevations. As simulated by the reservoir routing algorithm, a volume of flow enters the land segment during a particular time increment with the origin of the flow being discharge from a land segment immediately upstream. The incremental volume of flow is added to that already in the land segment 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 land segment during the time increment. The volume of water stored in the land segment 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 land segment at the end of each time increment. Any number of stage-discharge relationships may be utilized for a given existing or potential lake or reservoir site, facilitating the simulation of a variety of potential outlet works and operating procedures.

[11] See Michael L. Terstriep and John B. Stall, "The Illinois Drainage Area Simulator, ILLUDAS," Illinois State Water Survey, Bulletin 58, Urbana, 1974.

Hydraulic Submodel 2: The primary function of Hydraulic Submodel 2 is to determine the flood stages attendant to the flood flows of specified recurrence intervals 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 principle is satisfied. The above iterative computational process is then repeated for successive upstream floodland reaches. The 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 the 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 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.

Water Quality Submodel: The principal function of the Water Quality Submodel as used in the Oak Creek 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 nonpoint 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 in 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 in Figure 38, operation of the Water Quality Submodel requires the input of six data sets—meteorological, land, channel, diffuse sources of pollution, point sources of pollution, and output from the Hydrologic Submodel or the quantity of runoff. Table 63 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 of the Water Quality Submodel are similar to the data required for Hydraulic Submodel 1. In addition, nonhydraulic channel data must be provided, consisting primarily of water quality parameters and such coefficients as the maximum benthic algae concentration and the deoxygenation coefficient for each reach.

The basic conceptual unit upon which the Water Quality Submodel operates is called the water quality land segment type. A water quality land segment type is defined as an area of land which exhibits a unique combination of meteorological characteristics such as precipitation and temperature, land characteristics such as the proportion of land surface covered by impervious surfaces, soil type slope, vegetative cover, and land management practices such as contour plowing on agricultural land and street sweeping in urban areas. A strict interpretation of this definition results in a virtually infinite number of unique water quality land segment types even within a small watershed because of the large number of possible combinations of the above-mentioned characteristics within a watershed that exhibit continuous, as opposed to discrete, spatial variations throughout the watershed. To apply the concept, the study area is divided into water quality land segments. A water quality land segment is defined as a surface drainage unit which exhibits the pollutant runoff characteristic of a unique water quality land segment type. Thus, the practical, operational definition of a water quality land segment is a surface drainage unit consisting of a subbasin, or a combination of subbasins, which can be considered to be represented by a particular water quality land segment type.

Water quality land segment types and water quality land segments are refinements of hydrologic land segment types and hydrologic land segments in that they incorporate the pollutant runoff characteristics of the land. For a given hydrologic land segment, the different types of land management practices that affect pollutant runoff will produce different water quality response but the same hydrologic response. Thus, several water quality land segments may have to be identified within a single hydrologic land segment.

A set of nonpoint pollution source data is required for each constituent that is to be modeled on each hydrologic-water quality land segment type. Each set of data contains monthly land loading rates of 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 nonpoint source data set for each land segment also contains the concentration of the constituent 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 constituents 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 describing 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 nonpoint source constituents 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 constituent 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 indicated in Figure 41.

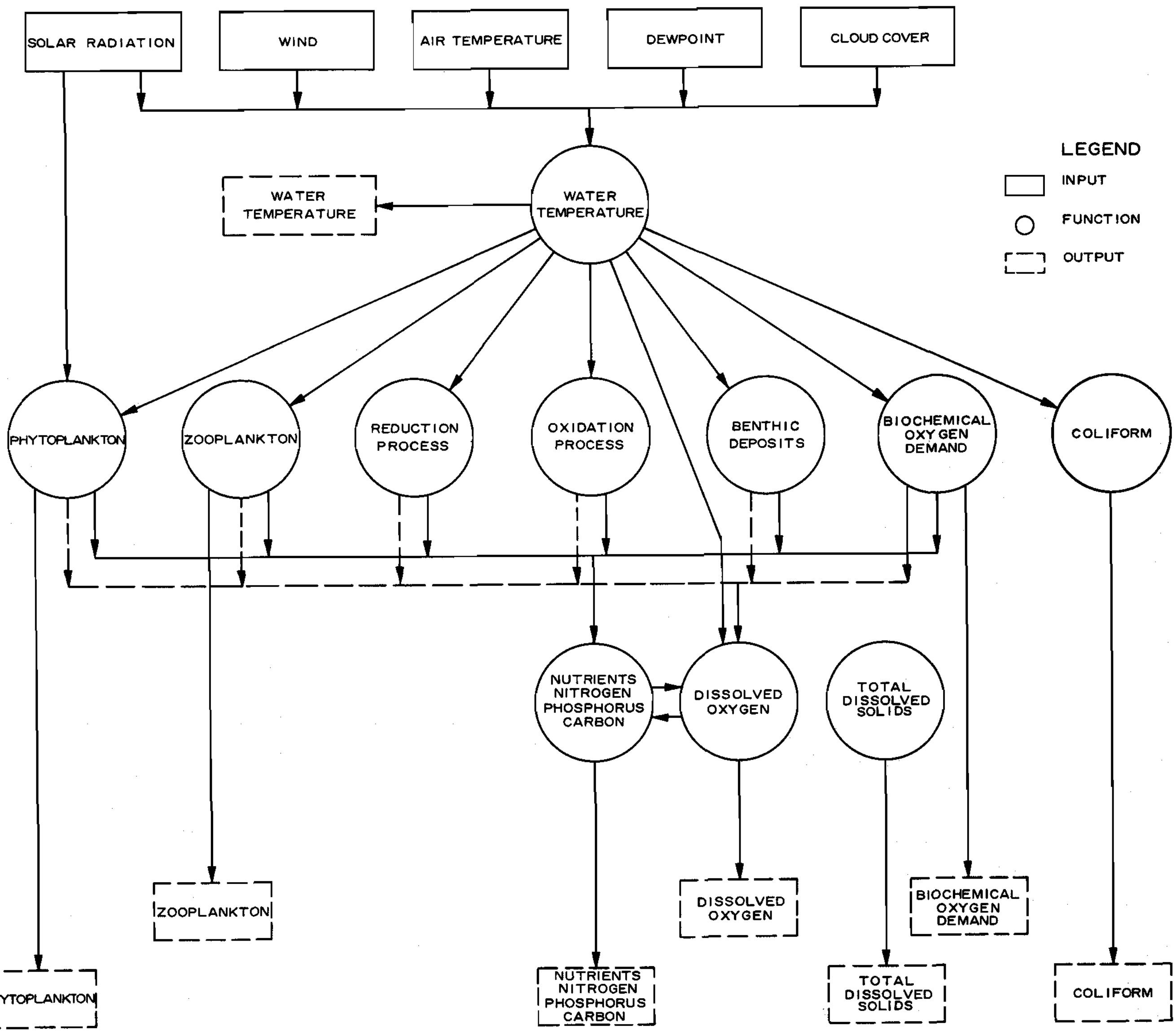
DATA BASE DEVELOPMENT

The largest single work element in the preparation and application of the hydrologic-hydraulic-water quality 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 Oak Creek watershed is a file of information that quantitatively depicts the characteristics or condition of the surface water system of the watershed.

As shown schematically in Figure 38, application of the model requires the development of an input data base composed of the following five distinct categories of information: meteorological conditions data, land data, channel data, diffuse sources of pollution data, and point sources of pollution data. Each of the five data categories provides input to at least one of the four submodels. Of the five input data sets, the meteorological data set is the largest because it consists of 40 years of daily or hourly information for each of the eight historic meteorological data types. The meteorological data set is also the most critical since 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.

Figure 41

INTERDEPENDENCE OF PROCESSES IN THE WATER QUALITY SUBMODEL



Source: Hydrocomp, Inc., and SEWRPC.

With respect to their origin, the data in the base are largely historic; they are based on existing records of past observations and measurements. For example, the bulk of the meteorological data in the base are historic because they are assembled from National Weather Service (NWS) records. Some of the data in the base are original because 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 because 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 since they were computed from historic percent sunshine measurements because of the absence of long-term historic radiation observations in or near the watershed and because of the impracticality of developing long-term original solar radiation data.

A distinction should be drawn between model input data and model calibration data. The five 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 calibration. The principal types of calibration data are streamflow, flood stage, and water quality.

Each of the five 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 63, 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, and daily cloud cover. Map 11 in Chapter III shows six 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. Since the entire watershed lies within the Milwaukee Mitchell Field polygon, this station was used as the source of all required meteorological data sets.

The process used to develop the meteorological data sets for the model is schematically depicted in Figure 42. Much of the meteorologial data base development was completed under other Regional Planning Commission work programs. The principal work element completed under the Oak Creek watershed planning program was an extension of the termination date of the meteorologic data base. Meteorological data sets were developed for the 44-year period from 1940 through September 1983. 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 in Figure 38, land data are needed to operate the Hydrologic Submodel, the output of which influences the four other submodels. Table 64 identifies the 22 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 land 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 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 stormwater drainage system. However, the above four characteristics were selected for use as both the most basic and the most representative.

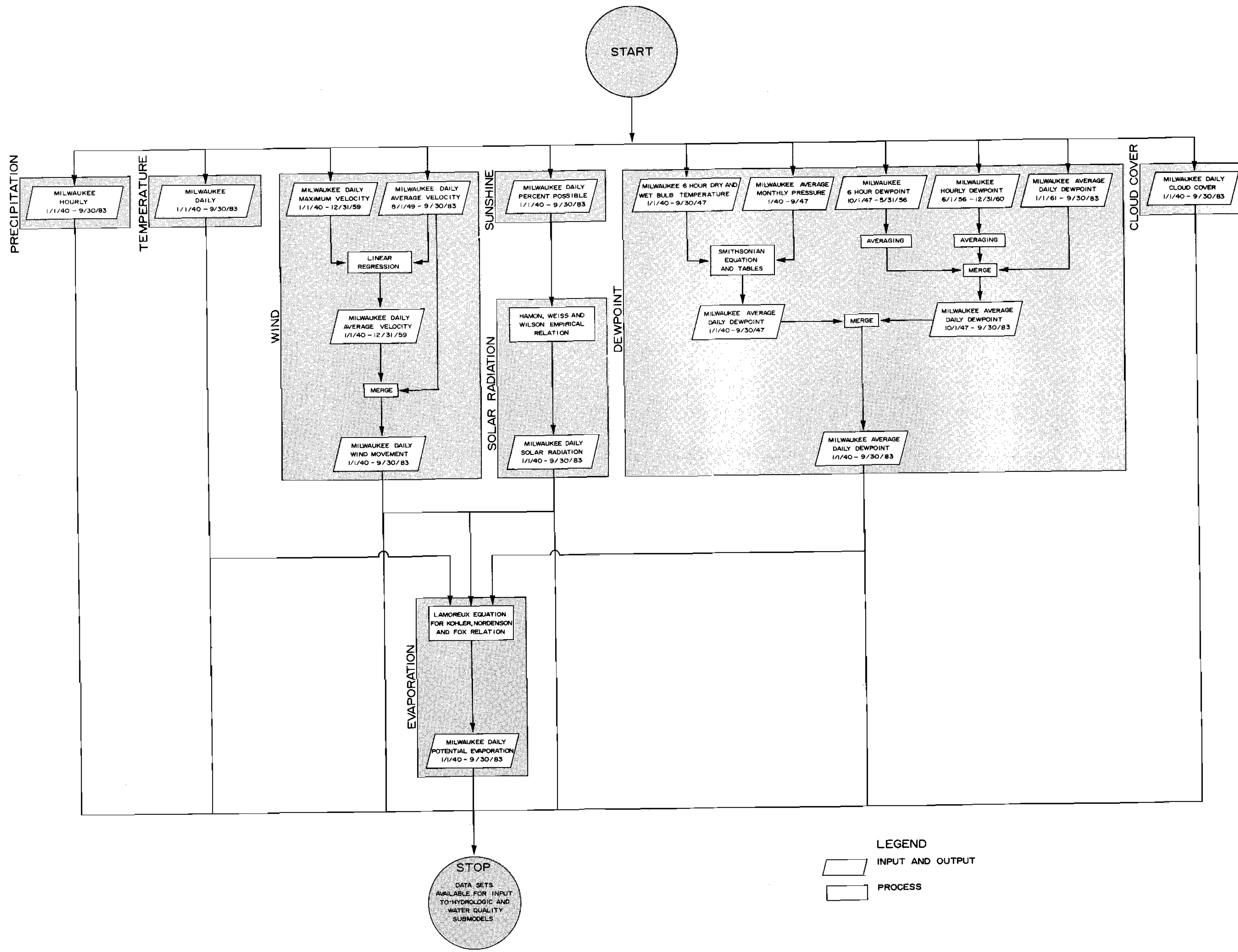
Identification of Hydrologic Land Segment Types: The process used to identify hydrologic land segment types in the watershed began with the subdivision of the watershed into subbasins using the procedure described in Chapter V. As shown on Map 33 in Chapter V, a total of 24 subbasins were delineated ranging in size from 0.35 to 2.80 square miles. These subbasins provided the basic "building blocks" for the identification of hydrologic land segment types and, subsequently, of hydrologic-water quality land segment types in the watershed.

Influence of Meteorological Stations: As noted earlier in this chapter, and as shown on Map 11 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 nearby meteorological stations. Since the Oak Creek watershed is located entirely within the Milwaukee Mitchell Field polygon, all subbasins were associated with this station, which is most likely to be representative of the meteorological processes affecting the subbasins.

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 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,

Figure 42

PROCESS USED TO DEVELOP METEOROLOGICAL DATA SETS FOR THE MODEL



Source: SEWRPC

which generate large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage. The Oak Creek watershed was determined to be primarily covered with Hydrologic Group C soils.

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 inch equals 2000 feet scale, two-foot contour interval topographic maps available for the entire watershed and 1 inch equals 2000 feet scale U. S. Geological Survey quadrangle maps. The slope analysis indicated that no areas of steep slope were present in the watershed, with slopes of less than 4 percent dominating. Based on the analysis of slopes throughout the watershed and previous slope sensitivity studies,[12] it was determined that the use of slopes in the determination of required land segment types was not warranted.

Land Use and Cover: The combination of land use and cover—which most often reflects man's influence on the hydrologic processes in that land use-cover—is largely the result of man's activities, particularly in the Oak Creek watershed. 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 0.5 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 amounts 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.

[12] *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.*

Table 65 lists the four imperviousness categories defined for the purpose of identifying hydrologic land segment types in the Oak Creek watershed. These four imperviousness categories encompass the full spectrum of existing and probable future conditions in the watershed. The imperviousness categories were selected by first determining the relative area of each of 11 land use-cover classifications within each of the watershed subbasins using 1 inch equals 400 feet scale 1980 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 and using a percent imperviousness assigned to each of the 11 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.

Resulting Hydrologic Land Segment Types and Hydrologic Land Segments: Application of the above process yielded a total of four different hydrologic land segment types in the Oak Creek watershed. The four hydrologic land segment types used to represent the land surface of the Oak Creek watershed for hydrologic-hydraulic simulation are defined in Table 66 in terms of their hydrologic soil grouping, imperviousness, and proximity to a meteorological station.

It should be noted that the land segment types reflecting imperviousness as a feature of different urban and rural land cover types, coupled with urban drainage efficiency as characterized in the hydrologic submodel, serve to distinguish between the effects on stormwater runoff of lands having various types and densities of urban development. The imperviousness of different urban and rural land cover types is incorporated into the Hydrologic Submodel in the following manner. The Hydrologic Submodel includes two individual subroutines which simulate runoff from pervious and impervious surfaces. The total runoff for a particular land segment usually consists of runoff from both pervious and impervious surfaces. However, a distinction is made in the program input between the impervious surface runoff that flows onto a pervious surface, and that which is directly connected to the stream system. A portion of the impervious surface runoff of a land segment may be designated as inflow to the pervious surface and thus may contribute to the total pervious

Table 65

IMPERVIOUSNESS CATEGORIES IN THE OAK CREEK WATERSHED
AS DEFINED FOR THE HYDROLOGIC SUBMODEL

Identification Number	Description	Range of Percent Imperviousness	Typical Corresponding Land Use Cover Combinations
1	Low Imperviousness	9-20	Low-density residential with supporting urban uses and associated land cover.
2	Low to Medium Imperviousness	21-33	Low- to medium-density residential with supporting urban uses and associated land cover.
3	Medium Imperviousness	34-45	Medium-density residential with supporting urban uses and associated land cover.
4	High Imperviousness	46-65	High-density residential with supporting urban uses and associated land cover.

Source: SEWRPC.

Table 66

HYDROLOGIC LAND SEGMENT TYPES REPRESENTATIVE OF THE OAK CREEK WATERSHED

Identification Number of Hydrologic Land Segment Type	Most Influential Meteorological Station	Hydrologic Soil Type	Impervious Category				Subbasins in Watershed Represented by Land Segment Type	
	Milwaukee Mitchell Field	C Soil	Low	Low to Medium	Medium	High	Number	Percent of Total
1	X	X	X	--	--	--	10	42
2	X	X	--	X	--	--	8	33
3	X	X	--	--	X	--	5	21
4	X	X	--	--	--	X	1	4
Total	--	--	--	--	--	--	24	100

Source: SEWRPC.

surface runoff. The remaining impervious surface runoff is then designated as direct inflow to the stream system. The drainage efficiency of a particular hydrologic land segment type can be represented in the hydrologic submodel by specifying the length of overland flow. In an urban area provided with an engineered storm sewer system, the length of overland flow is the average distance which storm water runoff must travel before reaching a street gutter, storm sewer inlet, or drainage channel. This length is much shorter in urban than in rural areas, and serves to increase the peak rate of runoff.

Thus the simulation model has the capability of differentiating between the rate of runoff from various densities of urban use, as well as between the rate of runoff from urban as opposed to rural land. This capability is particularly important in the preparation of a watershed plan which is to serve as a basis for integrating land use and flood control planning and development. The integrated plans can identify those areas of the watershed which are in urban use and those which are recommended to be converted from rural to urban use over the plan design period; and can calculate peak flood flows to be used in delineating flood hazard areas and in determining the hydraulic capacity of flood control works, recognizing the increases in flood flows that will accompany the planned land use conversion. Future conversions of land from rural to urban use in locations and at densities different from, and in amounts greater than, those envisioned in the land use plan can be required to provide sufficient storage in the drainage system to maintain the post-development peak rate of runoff at the predevelopment level.

The spatial distribution of the four hydrologic land segment types in the watershed under 1980 conditions is depicted on Map 39. The map also shows the 27 hydrologic land segments; that is, surface drainage units as actually 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—an area considered to be represented by a particular hydrologic land segment type.

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 22 land-related parameters required for each of the land segment types. Table 64 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 those of the Oak Creek watershed, information taken from hydrology references, and calibration—under the Oak Creek 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,[13] is discussed later in this chapter.

[13] *LZSN, UZSN, INFILTRATION, and INTERFLOW.*

Channel Data

Channel conditions, including slope and cross-section, are important determinants of the hydraulic behavior of a stream system. As indicated in Figure 38, 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 are based on data assembled for Hydraulic Submodel 2.

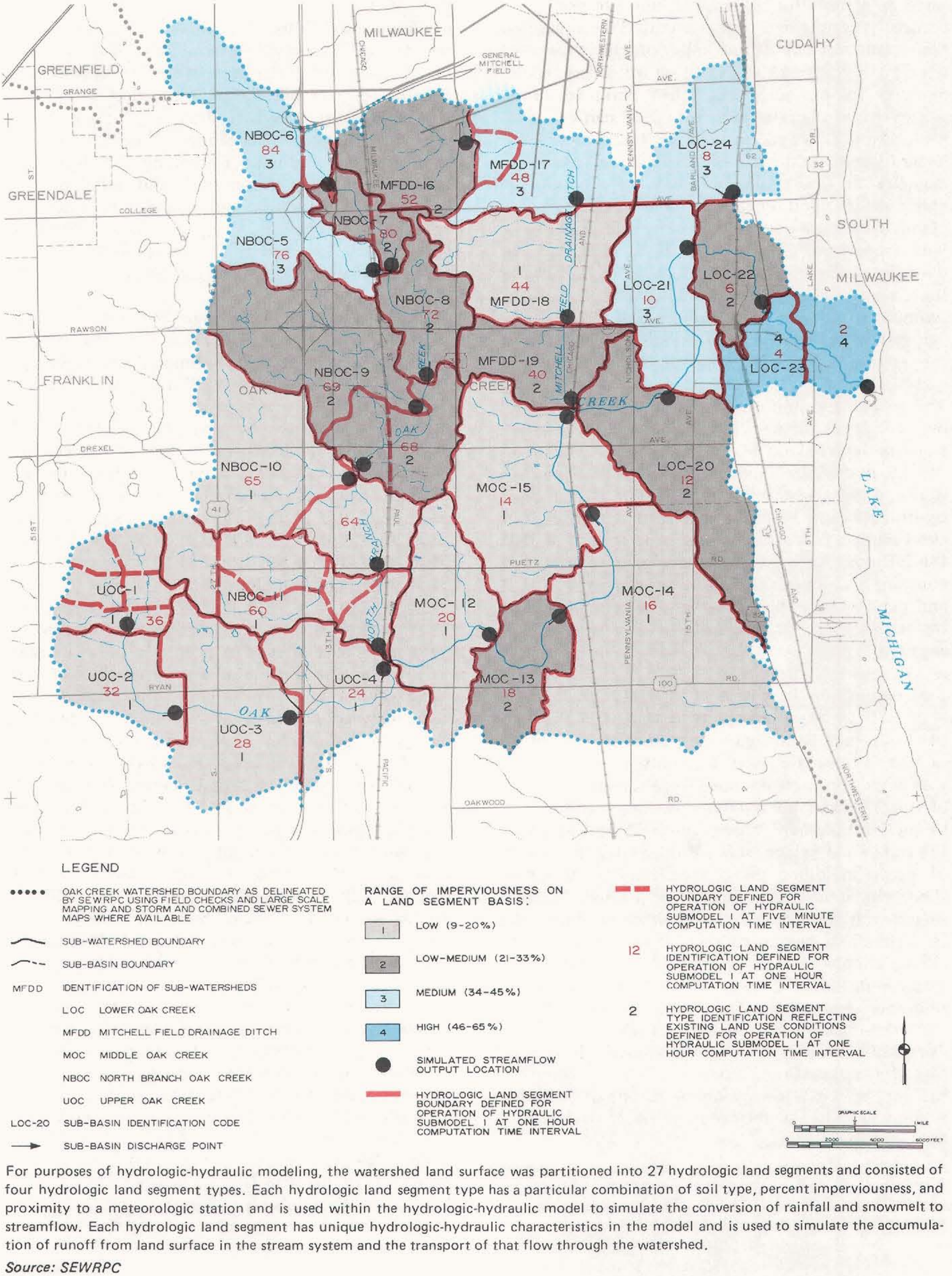
Channel Data for Hydraulic Submodel 2: The following four types of channel data are required as input to Hydraulic Submodel 2: discharge; channel-floodplain cross-sections, including the distance between cross-sections; Manning roughness coefficients for the channel and each floodplain; and hydraulic structure—bridge, culvert, and dam—data. Hydraulic structure data 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 required discharges were obtained using two modeling procedures. For points in the watershed with accumulated drainage areas of approximately eight square miles or greater, the required discharges were obtained as a result of operating Hydraulic Submodel 1 at a one-hour computational time interval over the 44-year simulation period for which recorded meteorological data were available—January 1, 1940 through September 30, 1983—and performing discharge frequency analyses on the 44 simulated annual instantaneous peak discharges using the log Pearson Type III technique.[14] The frequency analyses yield flood discharges of a known recurrence interval at various points throughout the watershed stream system. For points in the watershed with accumulated drainage areas of less than approximately eight square miles, a discrete event modeling procedure was used to obtain the required discharges as was described in the section on Hydraulic Submodel 1 presented earlier in this chapter. These procedures were used to obtain 10-year, 50-year, and 100-year recurrence interval dis-

[14] *See "Guidelines for Determining Flood Flow Frequency," Bulletin No. 17, United States Water Resources Council, Washington, D. C., March 1976.*

Map 39

REPRESENTATION OF THE OAK CREEK WATERSHED FOR HYDROLOGIC-HYDRAULIC SIMULATION



For purposes of hydrologic-hydraulic modeling, the watershed land surface was partitioned into 27 hydrologic land segments and consisted of four hydrologic land segment types. Each hydrologic land segment type has a particular combination of soil type, 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 hydrologic land segment has unique hydrologic-hydraulic characteristics in the model 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

charges which were input to the Hydraulic Submodel 2, which in turn was used to compute the corresponding flood stage 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 260 feet and physical descriptions of 101 hydraulically significant structures, was obtained for about 26.0 miles of stream selected for simulation.

Channel Data for Hydraulic Submodel 1: As noted earlier in this chapter, a stage-discharge-cumulative storage table must be provided along with the surface area for each hydrologic land segment. The process used to develop the stage-discharge-cumulative storage tables was initiated by subdividing the approximately 26.0 miles of stream system selected for simulation into reaches and assigning tributary areas to the reaches, thus creating hydrologic land segments. The first step in this process is to insure that there is exactly one channel reach associated with each hydrologic land segment. This is a requirement of the model, since the channel reach provides the mechanism whereby runoff from the land surface is intercepted, aggregated with flows from upstream hydrologic land segments, and then routed downstream through the stream system. The second step in hydrologic land segment identification is determination of the minimum allowable reach length within a hydrologic land segment, 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 a one-hour computational time interval used in modeling, the minimum reach length should be about one mile. The third and final criterion used to identify hydrologic land segments is that each reach within a hydrologic land segment be relatively homogeneous with respect to floodland cross-sectional shape, channel slope, and channel-floodplain roughness coefficients. Hydrologic land segments 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 approximately 26.0 miles of stream system into 27 hydrologic land segments, as shown on Map 39. Each has an average reach length of about 1.0 mile, which was appropriate for operation of Hydraulic Submodel 1 at a one-hour computational time interval. For operation of the model at a five-minute computational time interval for small drainage areas as described in the section on Hydraulic Submodel 1 presented earlier in this chapter, it was necessary to further partition certain portions of the watershed into hydrologic land segments of shorter reach lengths, as shown on Map 39, appropriate for the shorter computational time interval.

After subdivision of the stream system into hydrologic land segments, channel cross-sections representative of each hydrologic land segment were identified. 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 hydrologic land segment. A stage-discharge-cumulative storage table was then developed using this cross-section. It should be noted that conveyance was used as the basis for determining a representative cross-section for each hydrologic land segment, which included consideration of the Manning roughness coefficient for the respective stream reach. A stage-discharge-cumulative storage table was prepared for each stream system configuration—for example, existing condition or proposed channel improvement—that was to be simulated.

Channel Data for Water Quality Submodel: Hydraulic channel data required for the Water Quality Submodel are almost identical to the data described above for Hydraulic Submodel 1, the major difference being that Hydraulic Submodel 1 allows only one land segment type to be associated with each hydrologic land segment whereas the Water Quality Submodel accepts up to three land segment types per hydrologic land segment.

Nonhydraulic channel data must also be provided for the stream reach within each hydrologic water quality land segment. These 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 the 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.

Point Source Data

Figure 38 illustrates how point source data are input to the Hydraulic Submodel 1 and to the Water Quality Submodel. Point source input data for the Water Quality Submodel consisted of monthly discharge values plus monthly water quality values for four point sources in the watershed as shown on Map 40 and in Table 67. Point source discharge data were not input to the Hydraulic Submodel 1 since these values were considered insignificant with respect to peak flood discharges.

Nonpoint Source Data

Figure 38 illustrates how nonpoint source data are input to the Water Quality Submodel, along with meteorologic, point source, channel data, and output from the hydrologic submodel. The choice of initial numerical values for some nonpoint 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 Oak Creek watershed[15] and previous Commission staff experience. Some of these values were subsequently adjusted during the calibration process to improve the correlation between observed and simulated water quality. A set of land surface loading rates shown in Table 68 was established for each of the 19 hydrologic water quality land segments in the watershed. Map 41 indicates how the Oak Creek watershed was subdivided into hydrologic water quality land segments for water quality simulation.

Calibration Data

The six categories of data discussed above—meteorological, land, channel, riverine area structure, point pollution source, and nonpoint pollution source—constitute the total input data required to operate the four submodels. Of equal importance are calibration data. Although not needed to operate the model, these are necessary for the calibration of the model. These data, which are derived strictly from field measurements, include recorded actual 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 is thus calibrated.

Streamflow Data: The principal source of historic streamflow information in the watershed is the streamflow measurements made by the U. S. Geological Survey (USGS) from October 1, 1963, to September 30, 1983, at the continuous record-

[15] *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 of the Metropolitan Area Cedar-Green River Basins, Washington, Part II: Urban Drainage, December 1974, p. 86.*

Table 67

SELECTED INFORMATION ON POINT SOURCES REPRESENTED IN THE WATER QUALITY SUBMODEL: 1975

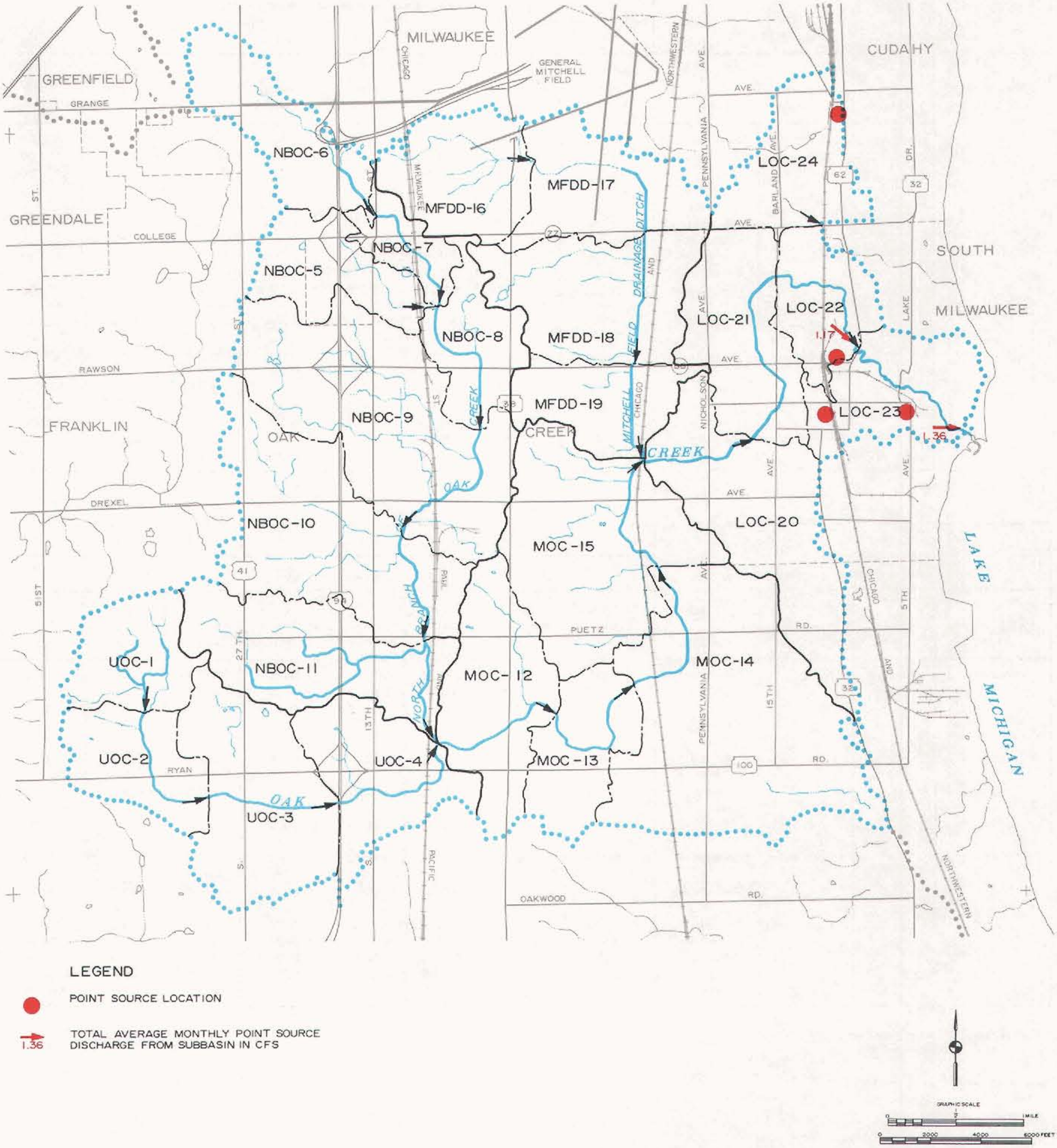
Quantity	Point Source Discharge Location (Subbasin)	Name[a]	Flow (cfs)	Water Temperature (^{o}C)	Five-Day Biochemical Oxygen Demand (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Oxygen (mg/l)	Chloride (mg/l)
1	22	Ladish Company	1.2	21	1.0	336	7.96	--
3	23	Appleton Electric Company Electric Lighting Division Appleton Electric Company Foundry and Bucyrus Erie Company	1.4	19	12.0	251	8.29	60

[a] *Data are included in this table for only those point sources which were determined to have a discharge which would be significant from a quality perspective. Other point source flows and loads reported in Chapter VII were found to be insignificant. The flows represent an increase in present loadings to reflect industrial growth. In addition, the impact of the existing lower flows was anlayzed, with the results indicating that such flows would not be expected to have significant adverse water quality impacts.*

Source: SEWRPC.

Map 40

POINT SOURCES INCLUDED IN THE WATER QUALITY SUBMODEL FOR THE OAK CREEK WATERSHED



Point sources of discharge to Oak Creek 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 four significant point sources were identified in the watershed.

Source: SEWRPC

Table 68

LAND SURFACE POLLUTANT LOADING RATES REPRESENTED IN THE WATER QUALITY SUBMODEL

Hydrologic-Water Quality Land Segment Type				Average Annual Land Surface Loading Rates (mg/l)[a] Impervious Surface							
Meteorological Station	Soil Type	Impervious Category	Land Use	Biochemical Oxygen Demand	Ammonia Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Phosphate Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform
Milwaukee	Dominate C	Rural	Row Crop	0.140	0.0100	0.0150	0.020	0.005	0.300	5.0	400.00
			Grain Crop	0.134	0.0100	0.0150	0.020	0.005	0.300	5.0	400.00
			Hay	0.140	0.0100	0.0150	0.020	0.005	0.300	5.0	400.00
			Vegetable and Other Agricultural	0.140	0.0100	0.0175	0.020	0.005	0.300	5.0	400.00
			Other Open Land	0.140	0.0100	0.0150	0.020	0.005	0.300	5.5	400.00
			Other Recreation	0.103	0.0100	0.0040	0.020	0.0068	0.300	5.0	10.00
		Low	Residential	0.135	0.0100	0.0490	0.020	0.005	0.300	5.0	400.00
		Medium	Residential	0.140	0.0100	0.0490	0.020	0.005	0.300	5.0	400.00
		High	Residential	0.140	0.0100	0.0490	0.020	0.005	0.300	5.0	400.00
			Commercial	0.140	0.0100	0.0150	0.020	0.005	0.300	4.8	400.00
			Industrial	0.140	0.0100	0.0150	0.020	0.005	0.300	5.0	800.00
			Highway	0.285	0.0200	0.0300	0.040	0.005	0.300	5.0	800.00
			Airfield	0.285	0.0400	0.0600	0.080	0.005	0.300	5.0	800.00

Hydrologic-Water Quality Land Segment Type				Average Annual Land Surface Loading Rates (mg/l)[a] Pervious Surface							
Meteorological Station	Soil Type	Impervious Category	Land Use	Biochemical Oxygen Demand	Ammonia Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Phosphate Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform
Milwaukee	Dominate C	Rural	Row Crop	3.896	0.0140	0.0196	0.0045	0.0015	0.001	10.0	0.13
			Grain Crop	0.787	0.0072	0.0039	0.0010	0.0004	0.001	10.0	0.13
			Hay	0.200	0.0140	0.0010	0.0002	0.0002	0.001	10.0	50.00
			Vegetable and Other Agricultural	3.896	0.0140	0.0196	0.0045	0.0015	0.001	10.0	0.13
			Other Open Land	0.019	0.0026	0.0113	0.0030	0.0020	0.006	14.0	10.00
			Other Recreation	0.200	0.0232	0.0080	0.0045	0.0022	0.001	10.0	10.00
		Low	Residential	0.010	0.0020	0.0010	0.0040	0.0042	0.006	12.0	36.00
		Medium	Residential	0.071	0.0257	0.0010	0.0066	0.0130	0.300	17.0	46.00
		High	Residential	0.146	0.0257	0.0015	0.0130	0.0225	0.054	40.0	95.00
			Commercial	0.460	0.2000	0.0020	0.010	0.040	0.010	40.0	100.00
			Industrial	0.390	0.200	0.0025	0.0068	0.030	0.008	110.0	170.00
			Highway	0.035	0.0257	0.0010	0.040	0.005	0.050	40.0	800.00
			Airfield	0.035	0.0514	0.0020	0.080	0.003	0.050	40.0	800.00

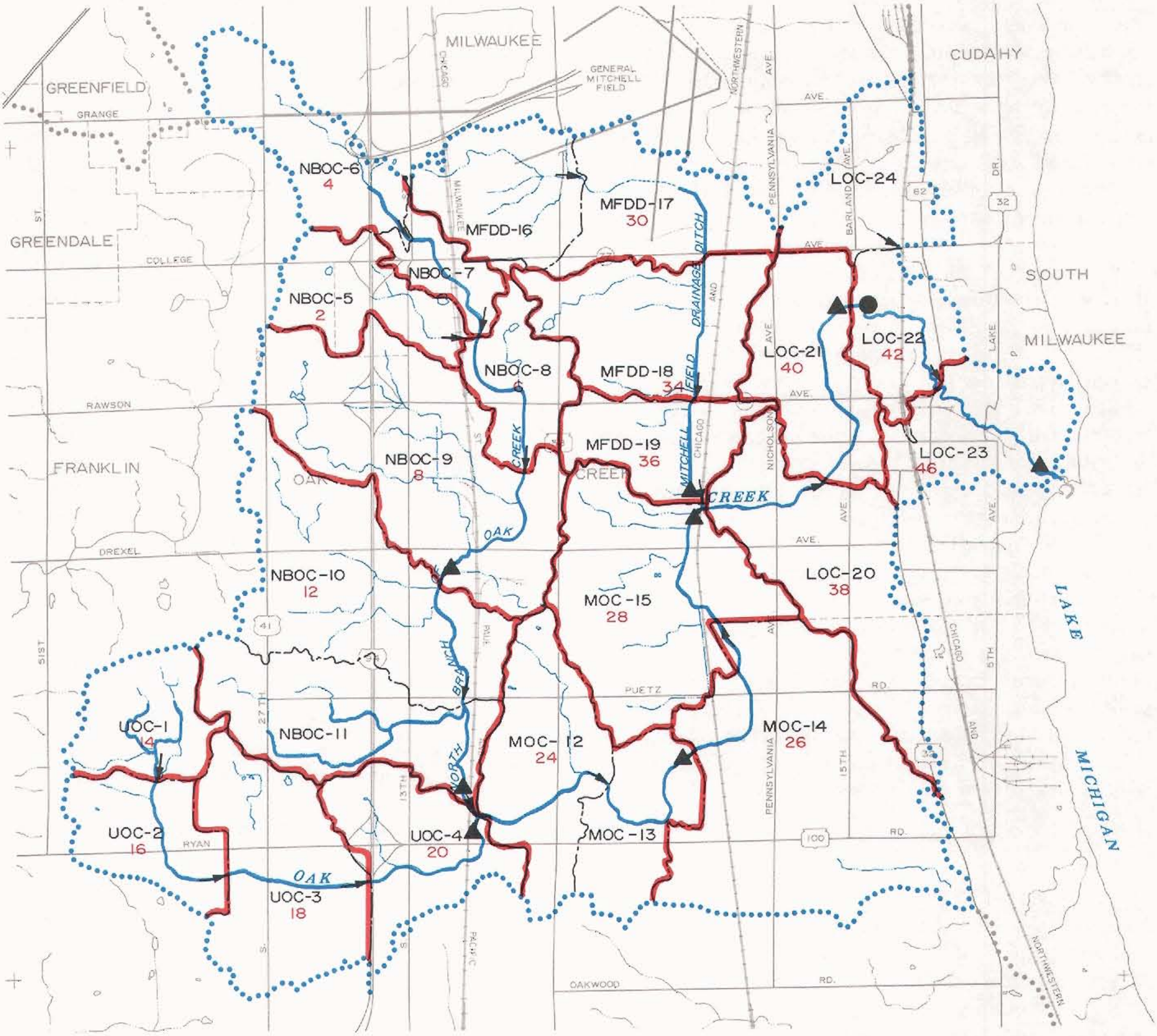
[a] *Except fecal coliforms, which are in MFFCC per 100 ml.*

Source: SEWRPC.

ing gage on Oak Creek at 15th Avenue in the City of South Milwaukee. This streamflow information was supplemented with streamflow information obtained at a crest-stage partial-record station also maintained by the U. S. Geological Survey. This station is located on Oak Creek at Nicholson Road and provided data on annual maximum discharges beginning in 1958.

Map 41

REPRESENTATION OF THE OAK CREEK WATERSHED FOR WATER QUALITY SIMULATION



LEGEND

- ••••• OAK CREEK WATERSHED BOUNDARY AS DELINEATED BY SEWRPC USING FIELD CHECKS AND LARGE SCALE MAPPING AND STORM AND COMBINED SEWER SYSTEM MAPS WHERE AVAILABLE
- SUB-WATERSHED BOUNDARY
- SUB-BASIN BOUNDARY
- MFDD IDENTIFICATION OF SUB-WATERSHEDS
  - LOC LOWER OAK CREEK
  - MFDD MITCHELL FIELD DRAINAGE DITCH
  - MOC MIDDLE OAK CREEK
  - NBOC NORTH BRANCH OAK CREEK
  - UOC UPPER OAK CREEK
- LOC-20 SUB-BASIN IDENTIFICATION CODE
- → SUB-BASIN DISCHARGE POINT
- HYDROLOGIC WATER QUALITY LAND SEGMENT BOUNDARY
- 24 HYDROLOGIC WATER QUALITY LAND SEGMENT IDENTIFICATION NUMBER
- ▲ SIMULATED WATER QUALITY OUTPUT LOCATION
- ● WATER QUALITY SAMPLING SITE

GRAPHIC SCALE: 0 – 1 MILE; 0 – 2000 – 4000 – 6000 FEET

For purposes of water quality modeling, the watershed stream system was partitioned into 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 hydrologic-water quality land segment, 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

Flood Stage Data: Information on historic high water levels was provided by public officials, consulting engineers, private citizens, and the staff of the Regional Planning Commission. This information 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 was 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, 1976, to October 5, 1976, at the 15th Avenue bridge crossing of Oak Creek in the City of South Milwaukee. 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. Each of these water quality determinations was 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 Oak Creek 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 Oak Creek watershed planning program is shown in Figure 43. 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.

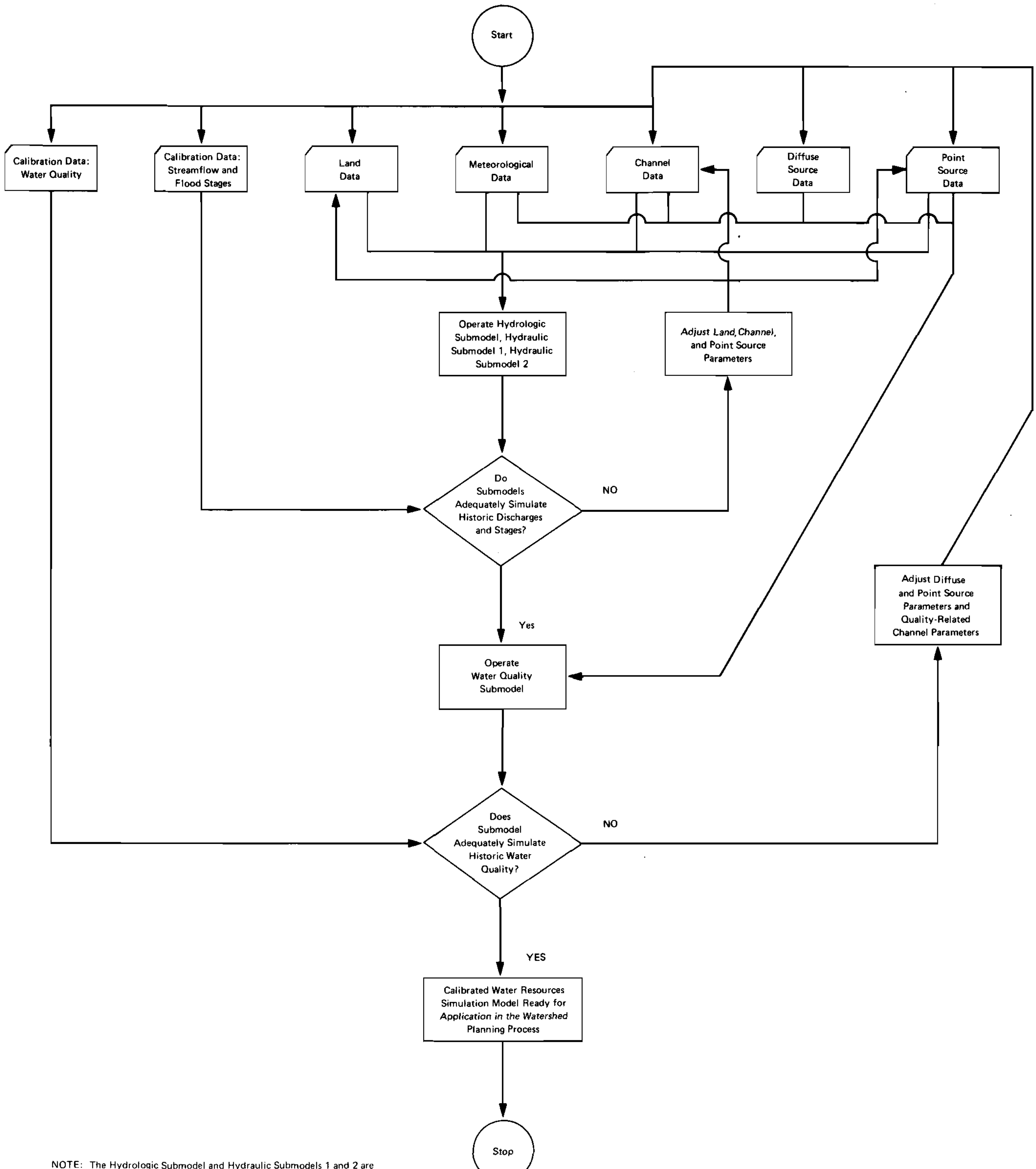
Successful calibration and testing of the first three submodels are of utmost importance because output from these submodels has direct bearing on the testing and evaluation of the floodland management elements of the watershed plan. Furthermore, the validity of results from the Water Quality Submodel is determined, in part, by the quality of the output of the Hydrologic Submodel and Hydraulic Submodel 1.

Hydrologic-Hydraulic Calibration for the Oak Creek Watershed Planning Program Hydrologic Submodel and Hydraulic Submodel 1: Meteorological 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 22 parameters for each of the hydrologic land segment types was strongly influenced by parameter values established under previous Commission water resources-related planning efforts. This was feasible since, as noted above, combinations of soil type, slope and land use-cover present in the Oak Creek watershed are similar to those in other watersheds and subwatersheds on which calibration work had been previously conducted by the Commission staff.

The Hydrologic Submodel and Hydraulic Submodel 1 were operated during the 20-year period from October 1963 through September 1983 for the 24.9-square-mile area—91 percent of the total area of the watershed—tributary to the continuous streamflow recording gage on Oak Creek, located at 15th Avenue in the City of South Milwaukee. The actual calibration interval for this operation was the period extending from October 1, 1962 through September 30, 1983, which allowed a one-year period for model initiation and start-up purposes.

Figure 43

CALIBRATION PROCESS USED FOR HYDROLOGIC-HYDRAULIC -WATER QUALITY MODELING

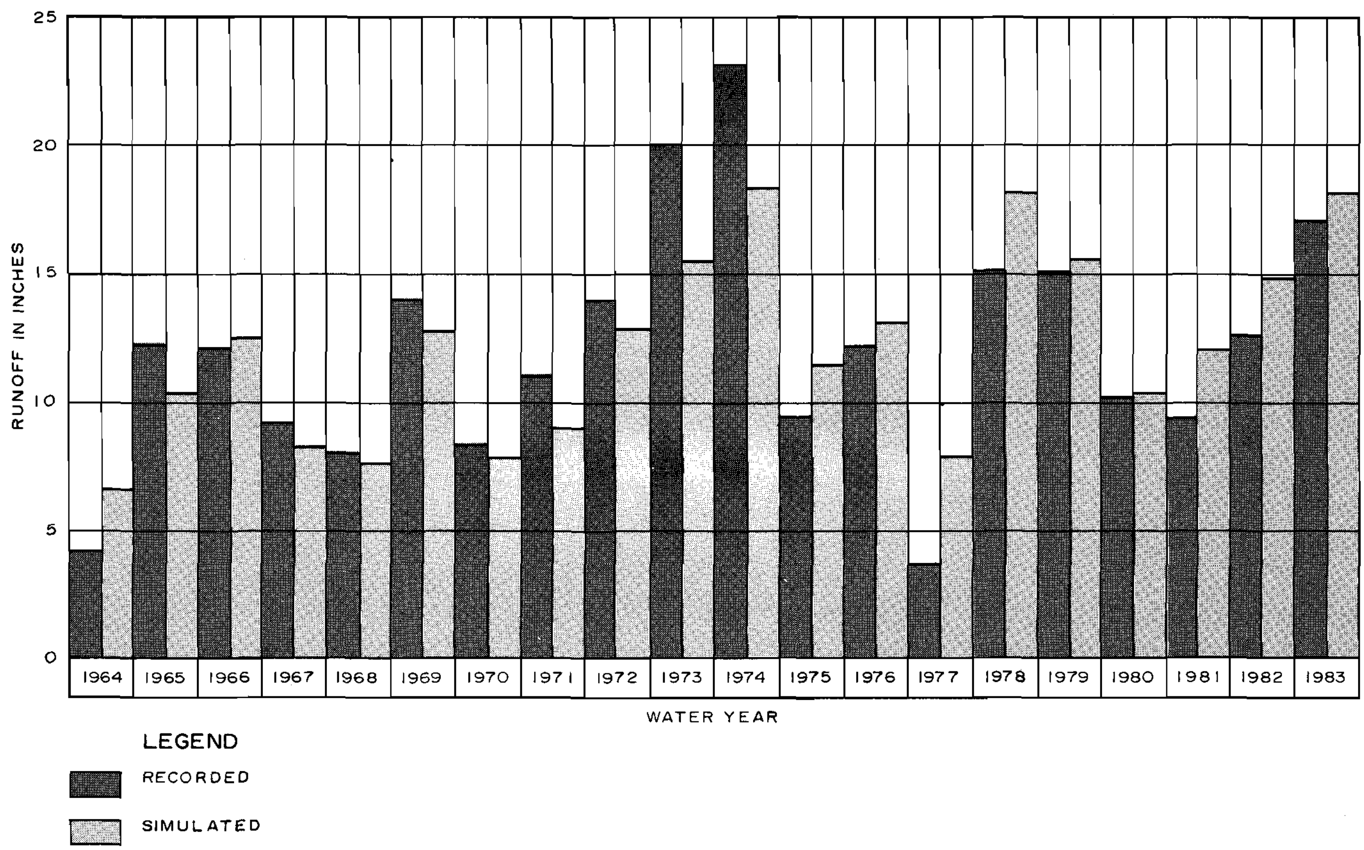


NOTE: The Hydrologic Submodel and Hydraulic Submodels 1 and 2 are calibrated first, followed by calibration of the Water Quality Submodel.

Source: SEWRPC

Figure 44

RECORDED AND SIMULATED ANNUAL RUNOFF VOLUMES FOR OAK CREEK AT THE 15TH AVENUE GAGE: OCTOBER 1, 1963-SEPTEMBER 30, 1983



Source: SEWRPC.

The results obtained in the calibration process for the Oak Creek gaging station are presented below through a comparison of recorded and simulated annual and monthly runoff volumes, recorded and simulated flow-duration curves, and recorded and simulated hydrographs for major runoff events:

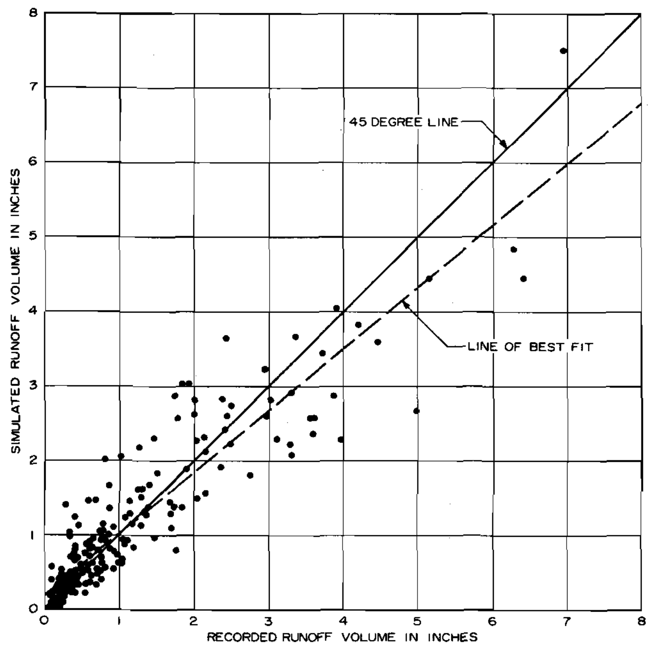
- Figure 44 presents a graphic comparison of recorded and simulated annual runoff volumes for the 20-year calibration period. Simulated annual runoff volumes range from 26 percent below to 103 percent above recorded values. The simulated cumulative annual runoff volume for the 20-year period is 240.01 inches, as compared to the 237.69-inch cumulative recorded annual runoff volume for that same period. In general, simulated annual volumes are within about 20 percent of the recorded values.

- Recorded and simulated monthly runoff volumes are compared in Figure 45. The monthly runoff data points are seen to be 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 20-year period for which recorded discharge data are available are shown in Figure 46. 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 exhibit adequate agreement.

Figure 45

LINEAR CORRELATION BETWEEN RECORDED AND SIMULATED MONTHLY RUNOFF VOLUMES FOR OAK CREEK AT THE 15TH AVENUE GAGE: OCTOBER 1, 1963-SEPTEMBER 30, 1983



Source: SEWRPC.

- Recorded and simulated hydrographs for four runoff events drawn from various times of the year are shown in Figure 47. 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 adequate agreement.

- Recorded and simulated peak flow values from the two highest runoff events occurring each water year since October 1963 are compared in Figure 48. These data are also seen to be grouped about a 45-degree line, indicating a tendency to exhibit the desired one-to-one correlation between the recorded and simulated peak flow values. An additional line shown in Figure 48 represents the line of best fit through the points plotted for all the selected runoff events. The line closely approximates a 45-degree line, which suggests that the Hydraulic Submodel, in conjunction with the Hydrologic Submodel, is adequately simulating peak discharges without significant bias.

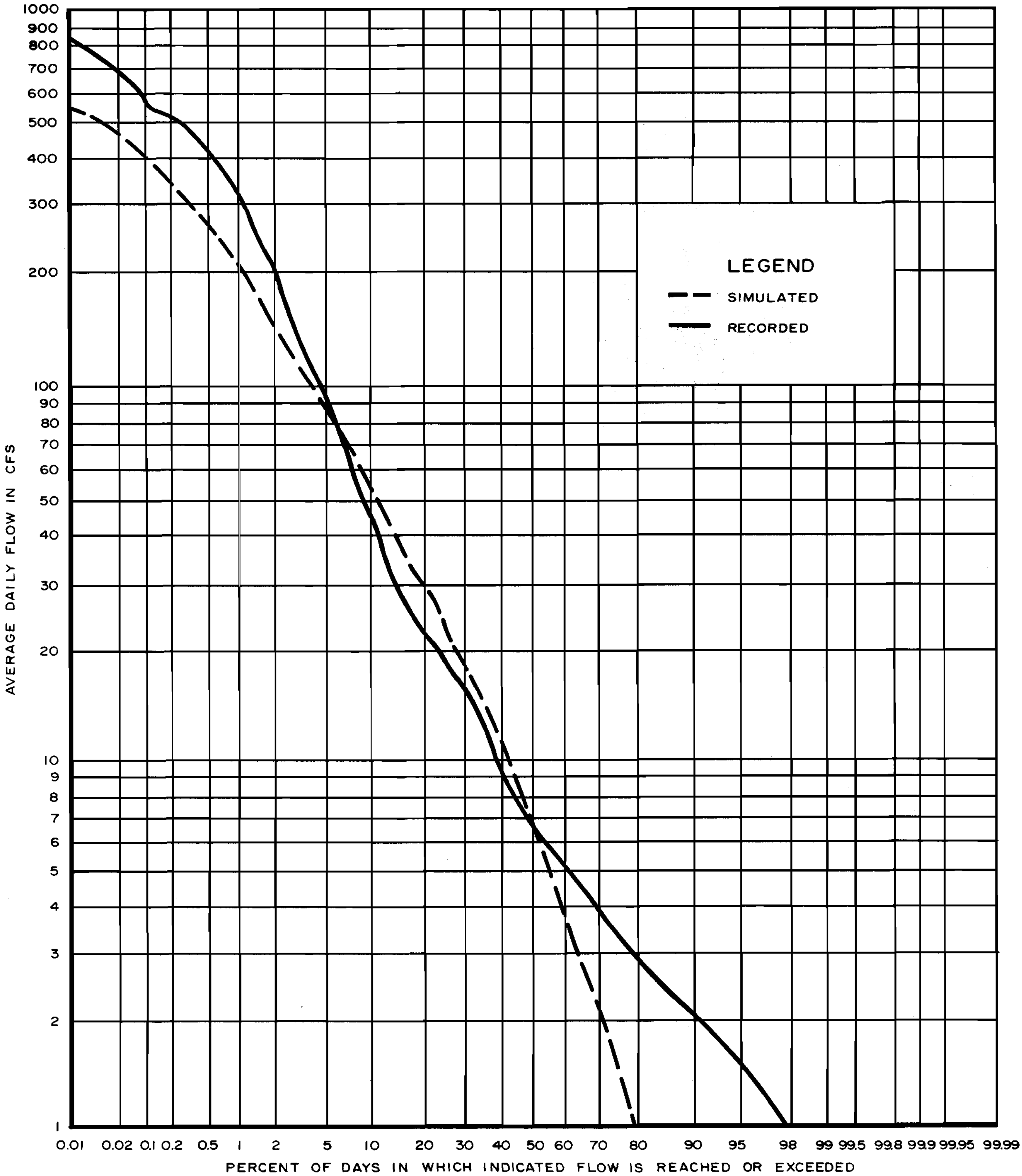
Over-simulation or under-simulation of flood discharge may be attributable to spatial variations in the amount of rainfall occurring over the watershed. That is, even though the precipitation observation station used to provide input data is located near the watershed, and even though the watershed is small, it is possible for portions of the basin to receive precipitation amounts, especially during brief events such as thunderstorms, that are significantly different from those recorded at the observation station. Over-simulation or under-simulation may also be attributable to variations in the time at which a particular runoff event begins. It is unlikely that precipitation will begin throughout the watershed at exactly the same time at which it begins at the observation station.

Over-simulation of flood discharges during early spring months or under-simulation during winter months may sometimes be attributable to the hydrologic submodel itself. The model, in simulating certain kinds of winter runoff events, may compute too much infiltration, thus somewhat under-simulating the actual runoff. The model may also, in simulating certain kinds of early spring runoff events, compute too little infiltration, thus somewhat over-simulating the actual runoff. However, improper simulation of certain runoff events due to the reasons noted above should not adversely affect overall long-term hydrologic-hydraulic modeling results. This is so because over the relatively long 44-year simulation period used in the Oak Creek watershed study, positive and negative simulation errors tend to compensate, thus resulting in a relatively uniform frequency distribution of simulated annual peak discharges. This simulated frequency distribution should closely approximate the actual distribution for the 44-year period. Therefore, the simulated flood frequency curves are also expected to closely approximate actual flood frequency relationships even though simulation error for some individual flood events may exist.

Hydraulic Submodel 2: After successful calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on the Oak Creek watershed, and subsequent development of flood discharges as discussed earlier in this chapter, Hydraulic Submodel 2 was calibrated against historic flood stage

Figure 46

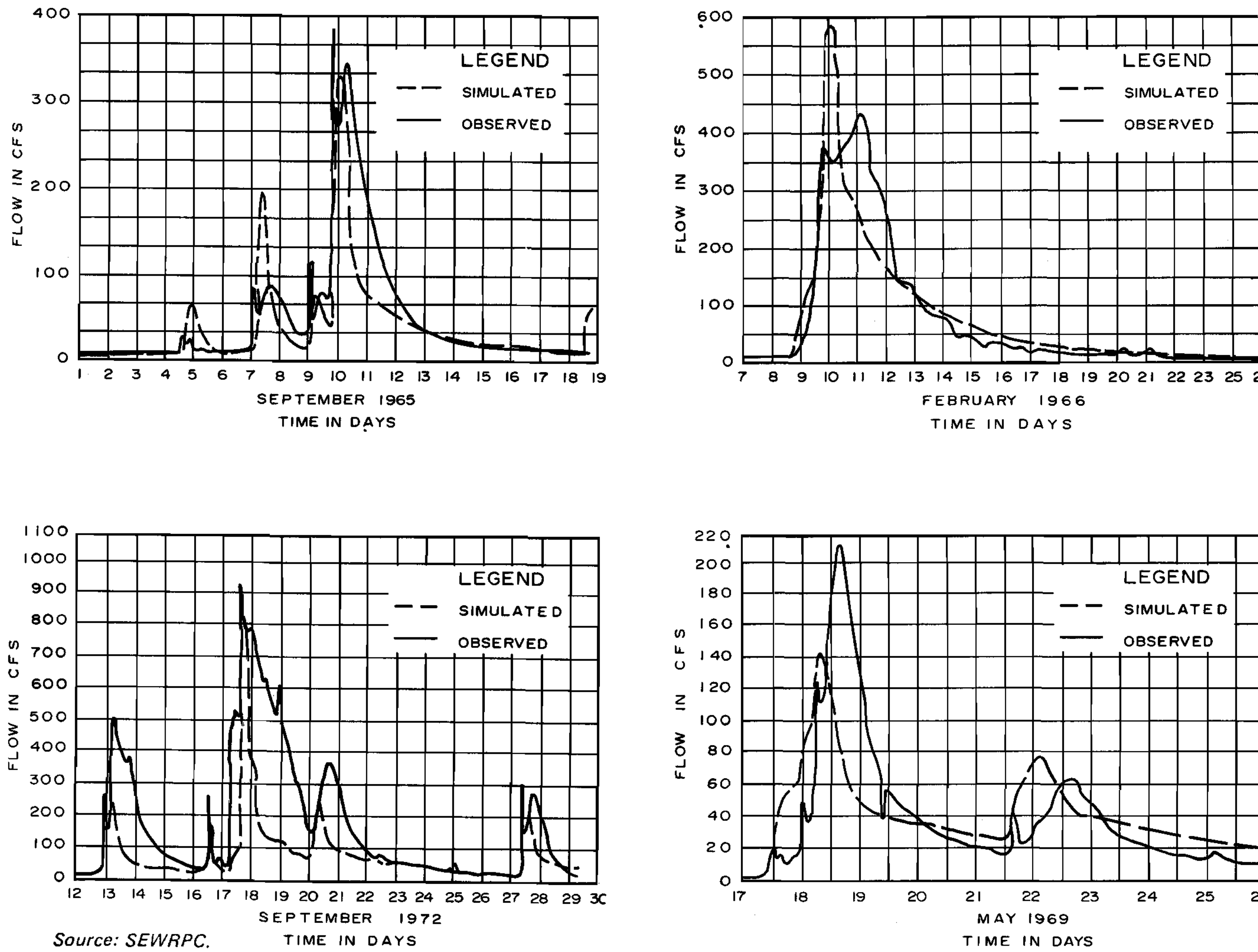
RECORDED AND SIMULATED FLOW DURATION CURVES FOR OAK CREEK



Source: SEWRPC.

Figure 47

RECORDED AND SIMULATED HYDROGRAPHS FOR OAK CREEK AT THE 15TH AVENUE GAGE FOR SELECTED EVENTS: OCTOBER 1964-SEPTEMBER 1983



Source: SEWRPC.

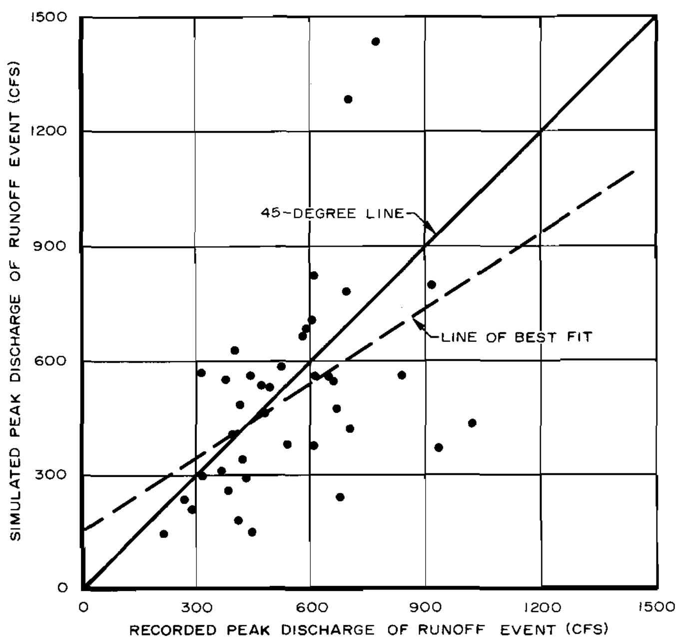
information utilizing the developed flood discharges. The historic flood inventory described in Chapter VI resulted in the acquisition of historic high water data for streams in the Oak Creek watershed.

The calibration process involved comparing the plotted 10-, 50-, and 100-year flood stage profiles obtained using Hydraulic Submodel 2 to historic high water marks. The relative position of the recorded and simulated flood stages was examined for consistency. For example, because the 1978 flood was determined to be approximately a 10-year recurrence interval event, a close correlation would be expected between existing land use-floodland development 10-year recurrence interval flood stage profiles obtained from Hydraulic Submodel 2 and actual high water marks obtained during or immediately after that event.

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.

Figure 48

LINEAR CORRELATION BETWEEN RECORDED AND SIMULATED PEAK DISCHARGES FOR 39 SELECTED RUNOFF EVENTS FOR OAK CREEK AT 15TH AVENUE: OCTOBER 1963-SEPTEMBER 1983



Source: SEWRPC.

Water Quality Calibrations on the Oak Creek Watershed

As noted at the beginning of this chapter, water quality simulation modeling for the Oak Creek watershed was completed under the Commission areawide water quality management planning program. Under that program, the Water Quality Submodel was calibrated, using the results of the stream water index sampling program conducted under the areawide water quality management planning program. The fall calibration period, September 7, 1976, to October 6, 1976, provided the primary data for calibration of the Water Quality Submodel at the sampling station. The calibration process consisted of comparison of the observed water quality and the model results for the sampling location. After achieving successful calibration with emphasis on six parameters—temperatures, dissolved oxygen, phosphate phosphorus, the nitrogen forms, fecal coliform counts, and carbonaceous biochemical oxygen demand—the remaining simulated parameters—chlorides and total dissolved solids—were examined for reasonableness. After minor adjustments were made in the nonpoint loading rates for chlorides and total dissolved solids, the model produced acceptable results for the calibration period. A comparison of recorded values to simulated values for selected water quality indicators in Oak Creek at the 15th Avenue gage for a portion of the calibration period is presented in Figure 49. The comparison indicates that the model yields acceptable results with respect to the selected indicators shown on the figure.

SUMMARY

Quantitative analyses of streamflow and water quality conditions under existing and possible alternative future conditions is a fundamental requirement of any sound 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 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 Oak Creek watershed planning program. The various submodels comprising the model were selected from available computer programs so that the composite model would meet the watershed study needs as specified by seven criteria. The Water Resource Simulation Model used in the Oak Creek watershed planning program consists of the following four submodels: the Hydrologic Submodel, Hydraulic Submodel 1, Hydraulic Submodel 2, and the Water Quality 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. The basic conceptual unit on which this submodel operates is the hydrologic land segment type. A hydrologic land segment type is defined as a land drainage unit exhibiting a unique combination of meteorological characteristics, such as precipitation and temperature; land characteristics, such as the proportion of land surface covered by impervious surfaces; soil types; and slopes. 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 type. Meteorologic and land data constitute the two principal types of input for

Figure 49

RECORDED AND SIMULATED WATER QUALITY DATA FOR OAK CREEK AT THE 15TH AVENUE GAGE: SEPTEMBER 17, 1976-SEPTEMBER 26, 1976

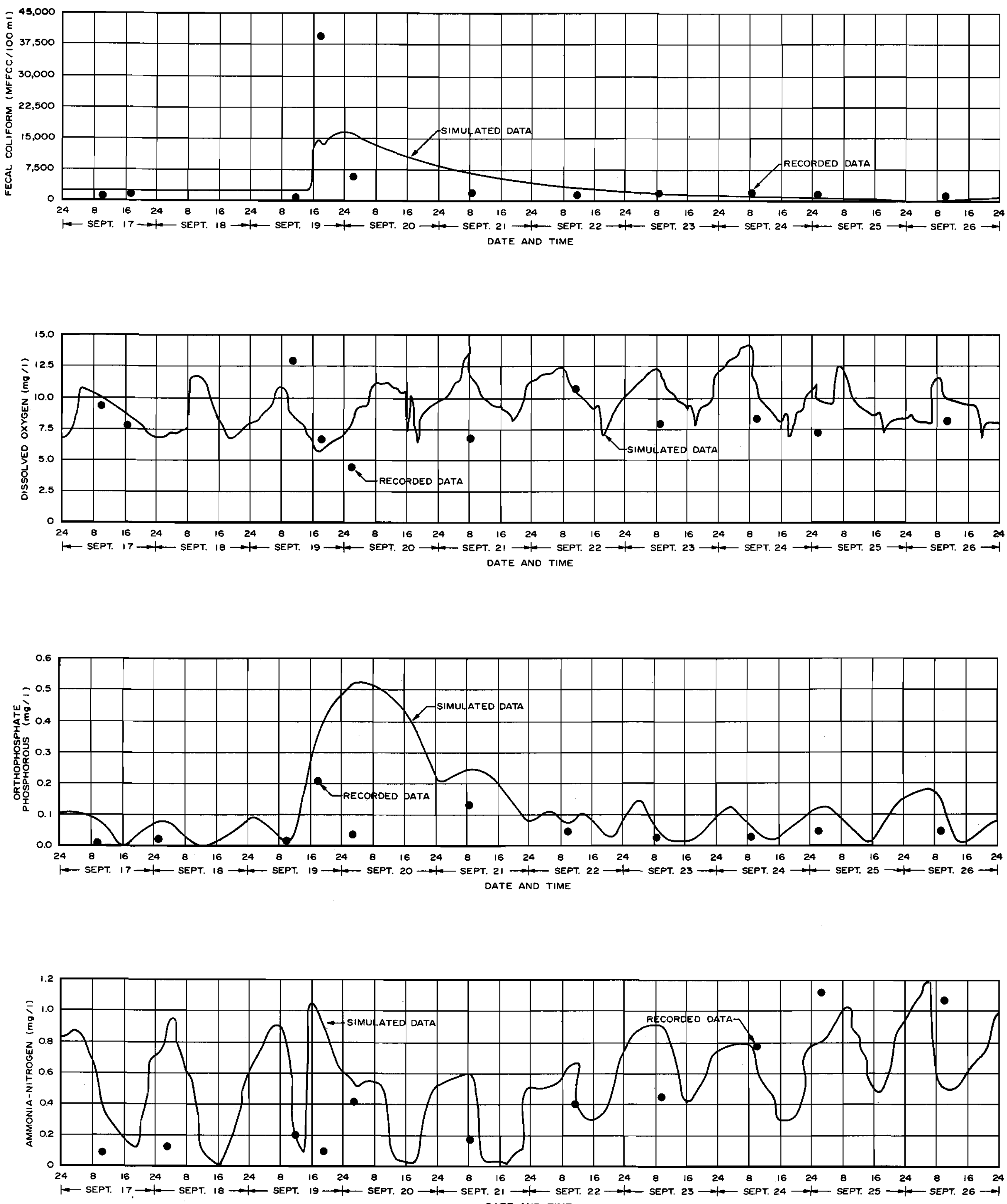
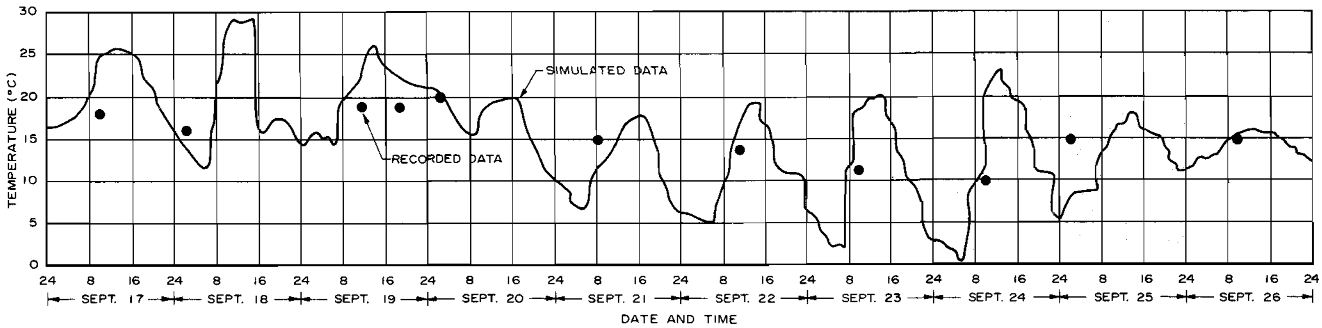
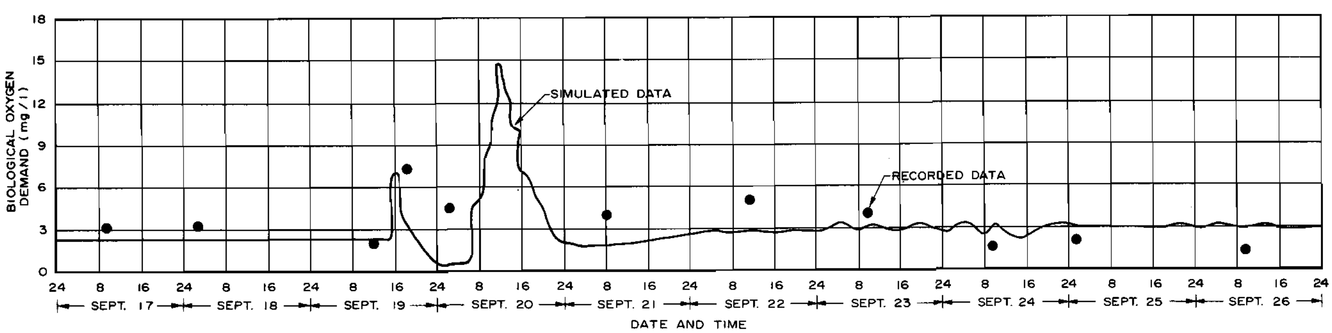


Figure 49 (continued)





Source: SEWRPC.

operation of the Hydrologic Submodel. The key output from the submodel consists of a continuous series of runoff quantities for each hydrologic 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 rivers and streams of the watershed. Application of this submodel requires that the stream system be divided into land segments, a land segment being either a channel reach and its tributary drainage area, or an impoundment and its tributary drainage area. Input for Hydraulic Submodel 1 consists of a stage-discharge-cumulative storage table for each land segment, 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.

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 nonpoint and point pollution 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 or nonpoint source data, and point source data. The meteorological data set is the largest because it contains 44 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 under the Commission areawide water quality management planning program, and data from other sources such as the National Weather Service, as well as data collected under the watershed study itself.

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 significant differences are 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 simulation model were streamflow 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 streamflows at the stream gaging station on Oak Creek at 15th Avenue in the City of South Milwaukee and by comparing simulated stages to historic stages available at locations throughout the watershed.

The Water Quality Submodel was then calibrated to the surface water system of the Oak Creek 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 of concern to agricultural, commercial, manufacturing, conservation, and government interests. The rights to the availability and use of water are, accordingly, of vital concern to a host 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 may be expected to 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[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 are set forth in SEWRPC Technical Report No. 2 (2nd Edition), Water Law in Southeastern Wisconsin.

This chapter summarizes a portion of the more detailed information concerning water law set forth in the technical report. For a more 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, consult SEWRPC Technical Report No. 2 (2nd Edition). The major purpose of this chapter is to summarize the salient legal factors bearing on the water-related problems of the Oak Creek 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.

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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).*

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 and a discussion of the development and operation of harbors. More detailed consideration is given to those aspects of water law that relate more specifically to the problems of the Oak Creek watershed, including inventory findings on state water regulatory permits and state water pollution abatement orders and permits.

WATER QUALITY MANAGEMENT

Because the Oak Creek 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 Oak Creek 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.

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 and 1977, enacted into law on October 18, 1972, and August 8, 1977, respectively. 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 Oak Creek watershed are discussed below. Under the new federal law, state governors are required to hold public hearings every three years to review 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 technology. A 1977 amendment to the Act extended this deadline to July 1, 1983, and a 1982 amendment to the Act further extended the deadline to 1988 for those communities unable to meet the 1983 deadline because of reductions in federal funds or other reasons beyond the community's control. In addition to these uniform or national effluent limitations, the Act 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 and 1977, 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 discharge 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 relating to data collection and reporting. For facilities other than publicly owned treatment works, Section 301 of the Act requires for each class of point sources the application no later than July 1, 1983, of the best available technology economically achievable 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 to 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 Processes: 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 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 the revision of plans;

adequate authority for intergovernmental cooperation; adequate steps for implementation, including schedules of compliance with 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 envisioned largely 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 and 1977, 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.

Any areawide plan prepared under the Section 208 planning process must include the identification of both point and nonpoint sources of water pollution and the identification of cost-effective measures which will abate the pollution from those sources. The plans must also identify the appropriate "management agency" responsibilities for implementation. 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.[3]

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. Following preparation of a detailed study design and after receiving a planning grant from the U. S. Environmental Protection Agency, the Commission started the planning program in July 1975. The program was continued through the July 12, 1979, formal adoption of the plan by the Commission. The plan adoption followed a series of public meetings and hearings, and is fully documented in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin, Volume One, Inventory Findings, Volume Two, Alternative Plans, and Volume Three, Recommended Plan. The plan was approved by the Wisconsin Natural Resources Board on July 25, 1979, by the Governor on December 3, 1979, and by the U. S. Environmental Protection Agency on April 30, 1980.

In general, the Section 208 water quality planning and management program for southeastern Wisconsin was used to update, extend, and refine the previous studies and plans completed by the Commission, and in so doing to meet fully the requirements of the Federal Water Pollution Control Act. Furthermore, the Commission has determined that the water quality plan recommendations set forth in the adopted Section 208 regional water quality management planning program will be fully integrated into and coordinated with the recommendations to be formulated under the Oak Creek 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

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[3] *The legal requirements are described in more detail in Chapter VI of SEWRPC Planning Report No. 20, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings.*

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 sewerage works has been set at 75 percent of the construction costs until October 1, 1984. From October 1, 1984, and thereafter, funding has been set at 55 percent of the construction costs provided the Act continues to be reauthorized. 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 Resources (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 groundwater and surface waters of the State. The only substantive water quality management authority not located in the 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 DNR which directly bear upon water quality management and, hence, upon the preparation of those elements of the Oak Creek 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 for each region in the State. The seven-county Southeastern Wisconsin Planning Region lies entirely within the eight-county Southeast District of the Department. This section of the statutes also stipulates that the Department should 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 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 requires that the Wisconsin Department of Natural Resources prepare and adopt water use objectives and supporting water quality standards that apply to all surface waters of the State. Such authority is essential if the State is to meet the requirements of the Federal Water Pollution Control Act. Water use objectives and supporting water quality standards were initially adopted for interstate waters in Wisconsin on June 1, 1967, and for intrastate waters on September 1, 1968. On October 1, 1973, the Wisconsin Natural Resources Board adopted revised water use objectives and supporting water quality standards which were set forth in Wisconsin Administrative Code Chapters NR 102, 103, and 104. On October 1, 1976, Administrative Code Chapter NR 104 was further revised. The Department of Natural Resources is currently in the process of revising water use objectives and supporting water quality standards in accordance with Section 24 of the U.S. Environmental Protection Agency 1981 Municipal Wastewater Treatment Construction Grant Amendments. The results and recommendations of this watershed study are intended to assist the Department in these revisions.

Water quality standards have been promulgated by the Department for the following major water uses in southeastern Wisconsin: recreational use, public water supply, warmwater fish and aquatic life, coldwater fish and aquatic life, intermediate fish and aquatic life, and marginal aquatic life. In addition, two variance categories—as set forth in NR 104.06(2)(a) and NR 104.06(2)(b) of the Wisconsin Administrative Code—have been established by the Department within southeastern Wisconsin. There are also minimum standards which apply to all waters. The existing water use objectives for all stream channels studied within the Oak Creek watershed are shown on Map 42, and applicable water quality standards for all water uses designated in southeastern Wisconsin are set forth in Table 69. 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."[4]

Minimum Standards: All surface waters must meet certain conditions at all times and under all flow conditions. The Wisconsin Administrative Code states that:

"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 the 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.

(c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in the 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."[5]

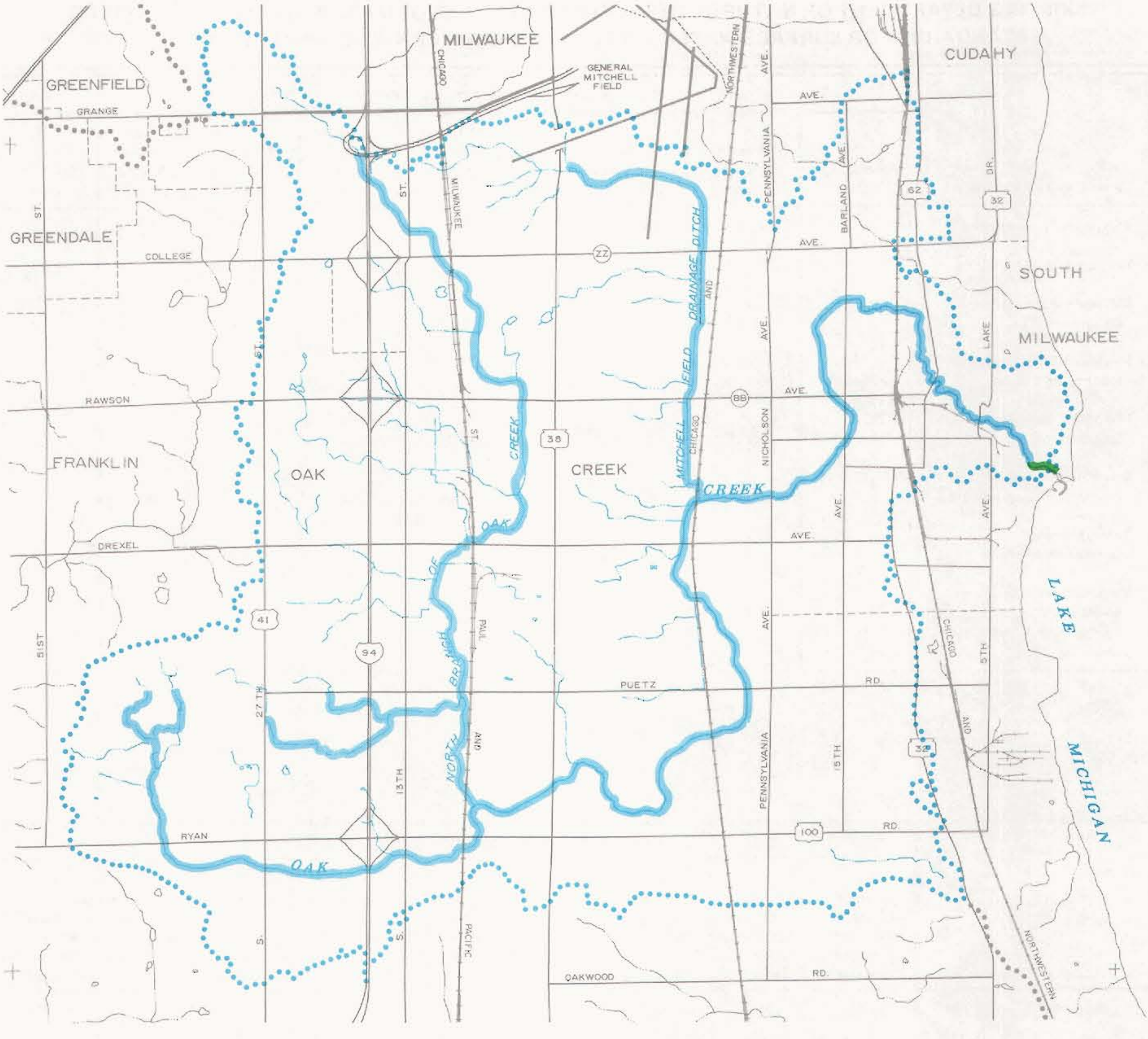
Recreational Use: Waters to be used for recreational purposes should be aesthetically attractive, free of substances that are toxic upon ingestion or irritating to the skin upon contact, and void of pathogenic organisms. The two conditions are satisfied if the water meets the minimum standards for all waters as previously described, whereas the

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

[5] *Wisconsin Administrative Code Chapter NR 102.02.*

Map 42

WATER USE OBJECTIVES FOR SURFACE WATERS IN THE OAK CREEK WATERSHED ADOPTED BY THE WISCONSIN NATURAL RESOURCES BOARD: 1982



LEGEND

COLDWATER FISH AND AQUATIC LIFE STANDARDS RELATED TO THE PROTECTION OF SPAWNING SALMONIDS TO BE MET WHEN SALMONID SPAWNING RUNS ARE IN PROGRESS

WARMWATER FISHERY AND AQUATIC LIFE, RECREATIONAL USE, AND MINIMUM STANDARDS

NOTE: DNR WATER USE OBJECTIVE CLASSIFICATIONS ARE SHOWN ON THIS MAP FOR ALL STUDIED STREAMS IN THE OAK CREEK WATERSHED. THE DNR ADOPTED STANDARDS APPLY TO ALL SURFACE WATERS OF THE STATE, AND THE WARMWATER FISHERY AND AQUATIC LIFE AND RECREATIONAL USE CLASSIFICATION APPLIES TO ALL STREAMS NOT SPECIFICALLY DESIGNATED OTHERWISE

Water use objectives and supporting water quality standards for all surface waters in the Oak Creek watershed are established by the Wisconsin Department of Natural Resources and are reviewed and revised, as appropriate, at least every three years under the provision of the Federal Water Pollution Control Act, as amended. In accordance with the national goal of having water quality suitable for "protection and propagation of fish, shellfish, and wildlife and . . . for recreation in and on the water," all of the streams within the Oak Creek watershed, with the exception of the estuary, are presently designated for maintenance of warmwater fish and aquatic life and for recreational use. The Oak Creek estuary is designated for the maintenance of a spawning salmonid fishery and aquatic life, and for recreational use.The existing DNR water use objectives shown above served as a point of departure for the development of the water use objectives and supporting water quality standards recommended in the Commission's areawide water quality management planning program, the results of which constitute the basic water quality management elements of the Oak Creek watershed plan. The SEWRPC-recommended water use objectives and supporting standards which were used in the development of the comprehensive plan for the Oak Creek watershed are set forth on Map 44 and in Table 77 in Chapter X of this report.

Source: SEWRPC.

Table 69

EXISTING DEPARTMENT OF NATURAL RESOURCES WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR SURFACE WATERS IN THE SOUTHEASTERN WISCONSIN REGION: 1982

Water Quality Parameter	Individual Water Use Objectives Applicable to Surface Waters								
	Recreational Use	Variance NR104.06 (2)(a)	Variance NR104.06 (2)(b)	Public Water Supply	Warmwater Fish and Aquatic Life	Coldwater Fish and Aquatic Life	Intermediate Fish and Aquatic Life[q]	Marginal Aquatic Life[p]	Minimum Standards[a]
Maximum Temperature (°F)[o]	--	89[b,e]	89[b,c,e]	--	89[b,e]	--[b,d,e]	89[b,e]	89[b,e]	--
pH Range (S. U.)	--	6.0-9.0[f]	6.0-9.0[f]	--	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	--
Minimum Dissolved Oxygen (mg/l)	--	2.0[e]	2.0[e]	--	5.0[e]	6.0[e]	3.0[e]	1.0[e]	--
Maximum Fecal Coliform (counts per 100 ml)	200-400[g]	1,000-2,000[h]	1,000[i]	200-400[g]	--	--	--	200-400[g]	--
Maximum Total Residual Chlorine (mg/l)	--	0.01	0.01	--	0.01	0.002	0.5	0.5	--
Maximum Un-ionized Ammonia-Nitrogen (mg/l)	--	0.04	0.04	--	0.04	0.02	--	0.04	--
Total Ammonia Nitrogen (mg/l)	--	--	--	--	--	--	3/6[f]	--	--
Maximum Total Dissolved Solids (mg/l)	--	--	--	500-750[k]	--	--	--	--	--
Other	--	--[n]	--[n]	--[l]	--[n]	--[m,n]	--[n]	--[n]	--

Water Quality Parameter	Combinations of Water Use Objectives Applicable to Surface Waters						
	Variance NR104.06 (2)(a) and Minimum Standards[a]	Variance NR104.06 (2)(b) and Minimum Standards[a]	Marginal Aquatic Life, Recreational Use, and Minimum Standards[a]	Intermediate Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Warmwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life Recreational Use, Public Water Supply and Minimum Standards[a]
Maximum Temperature (°F)[o]	89[b,e]	89[b,c,e]	89[b,e]	89[b,e]	89[b,e]	--[b,d,e]	--[b,d,e]
pH Range (S. U.)	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]
Minimum Dissolved Oxygen (mg/l)	2.0[e]	2.0[e]	1.0[e]	3.0[e]	5.0[e]	6.0[e]	6.0[e]
Maximum Fecal Coliform (counts per 100 ml)	1,000-2,000[h]	1,000[i]	200-400[g]	200-400[g]	200-400[g]	200-400[g]	200-400[g]
Maximum Total Residual Chlorine (mg/l)	0.01	0.01	0.5	0.5	0.01	0.002	0.002
Maximum Un-ionized Ammonia-Nitrogen (mg/l)	0.04	0.04	0.04	--	0.04	0.02	0.02
Total Ammonia Nitrogen (mg/l)	--	--	--	3/6[j]	--	--	--
Maximum Total Dissolved Solids (mg/l)	--	--	--	--	--	--	500-750[k]
Other	--[n]	--[n]	--[n]	--[n]	--[n]	--[m,n]	--[l,m,n]

Table 69 (continued)

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

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

[c]Maximum temperatures shall not exceed 89°F at any time at the edge of mixing zones established by the Department of Natural Resources under NR102.03(4).

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

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

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

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

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

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

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

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

[l]The intake water supply shall be such that, by appropriate treatment and adequate safeguards, it will meet the established drinking water standards.

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

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

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

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

After a review of the ecological and environmental impact of thermal discharges in excess of a daily average of 500 million British thermal units (BTUs) per hour, mixing zones are established by the Department of Natural Resources. Any plant or facility for which the construction 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 and 1977, or regulations promulgated thereto.

[p]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 NR104.02(3)(b).)

[q]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 NR104.02(3)(a).)

Source: Wisconsin Department of Natural Resources.

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.

Variances NR 104.06(2)(a) and NR 104.06(2)(b): These variance categories apply to streams for restricted use downstream from an area of intense urban development or where wastewater has a predominant influence. The significant characteristics of these categories are a maximum fecal coliform level of 1,000 counts per 100 milliliters (ml) based on no fewer than five samples per month, or of 2,000 counts per 100 ml in more than 10 percent of all samples during any month; and a minimum dissolved oxygen level of 2.0 milligrams per liter (mg/l). The 2,000 counts per 100 ml maximum standard for fecal coliform organisms does not, however, apply to variance category NR 104.06(2)(b). The variance categories are 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 for 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 Department standards for raw water to be used for water supply include maximum limits on dissolved solids and fecal coliform.

Warmwater Fish and Aquatic Life: As indicated in Table 69, this objective is intended to result in water quality conditions adequate to support the maintenance of warmwater fish and aquatic life. The most significant standards supporting this category are an 89° F maximum temperature and a minimum dissolved oxygen level of 5.0 mg/l.

Coldwater Fish and Aquatic Life: Standards for water to be used for the preservation and enhancement of coldwater 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 Department standards for the maintenance of coldwater fish and aquatic life are set forth in Table 69. This category requires that no significant artificial temperature increases be exhibited where natural trout reproduction occurs, and requires a minimum dissolved oxygen level of 7.0 mg/l during the spawning season.

Intermediate Fish and Aquatic Life: This water use objective is applied to streams which do not support a balanced aquatic community. This intermediate fish and aquatic life objective is one of the variance categories provided by Wisconsin Administrative Code NR 104.02(3). The most significant standards supporting this objective are a maximum temperature of 89° F and a minimum dissolved oxygen level of 3.0 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 protected. The most significant standards supporting this objective, as shown in Table 69, are a maximum temperature of 89° F and a minimum dissolved oxygen level of 1.0 mg/l.

Application of the Water Use Objectives to the Oak Creek Watershed: The application of the nine basic categories of water use objectives require 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 streamflow 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 streamflow conditions at or above the 7 day-10 year low flow.

The water use objectives established in 1982 by the Wisconsin Department of Natural Resources for the surface waters of the Oak Creek watershed are recreational use, maintenance of warmwater fish and aquatic life, and minimum standards. In addition, coldwater fish and aquatic life standards for the protection of spawning salmonids are to be met in the Oak Creek estuary when salmonid spawning runs are in progress. The established water use objectives apply to all perennial streams in the watershed, which include the main stem of Oak Creek, the North Branch of Oak Creek, and the Mitchell Field drainage ditch. The state-adopted water use objectives are identical to the Regional Planning Commission-recommended objectives except regarding the Oak Creek estuary; the Commission recommends further study in order to determine water use objectives for the estuary.

Water Pollution Abatement Programs: Section 144.24 of the Wisconsin Statutes authorizes the Wisconsin Department of Natural Resources to provide financial assistance for the construction of point source pollution abatement facilities necessary for the protection of state waters. Under this program, communities can receive up to 60 percent of the construction costs of eligible projects for which the planning and design have been completed, but which are unable to obtain a federal construction grant. This program also provides funds for the replacement or rehabilitation of private and small commercial onsite septic systems. The state grant for such projects is limited to $3,000 for each residence or small commercial establishment served, or to 60 percent of the total project cost, whichever is less. As a condition for obtaining a grant under this program, the government unit responsible for the regulation of onsite private sewage treatment systems must submit an application for participation to the Wisconsin Department of Natural Resources. In the Oak Creek watershed, only the City of Franklin has completed this application procedure, and residents in Franklin are thus eligible to receive state funding in partial support of septic tank system rehabilitation.

Section 144.25 of the Wisconsin Statutes authorizes the Department of Natural Resources to provide financial assistance for the control of nonpoint sources of pollution. Under this program, priority watersheds are identified on the basis of the need and local support for nonpoint source water pollution abatement to achieve water quality objectives and supporting water quality standards. A plan is prepared for the selected watersheds which identifies the nonpoint source projects which will be eligible for state funding. Individual projects, termed local priority projects, can also be funded outside the priority watersheds when judged to be effective nonpoint source pollution control projects. State funding ranges from 50 to 70 percent of the total project capital cost, depending upon the type of project. In the Oak Creek watershed, state funds were granted to the Milwaukee County Department of Parks, Recreation and Culture in 1981, 1982, and 1983 under the local priority project program for stream bank erosion protection measures in the Oak Creek Parkway through the City of South Milwaukee.

Water Pollution Abatement Orders: Section 144.025(2)(c) of the Wisconsin Statutes authorizes the Department of Natural Resources 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 for 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 Code.

Section 144.025(2)(d) of the Wisconsin Statutes authorizes the Department to issue 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. Such orders may prescribe a specific 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 waters 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, 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 property 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, 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 the 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. 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, groundwater. Rules relating to the pollutant discharge elimination system are set forth in Chapter NR 200 of the Wisconsin Administrative Code.

The following types of discharges require permits:

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 agricultural uses 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 Pollutant Discharge Elimination 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 a major vehicle for achievement of the basic goal of meeting 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 the installation of private septic tank sewage disposal systems. Such systems often contribute to the pollution of surface water and groundwater. 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 plat layout. 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. The Department also may prohibit the installation or use of septic tanks in any area of the State where, based on Department findings, 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.

Wisconsin Environmental Policy Act: In April 1972, the Wisconsin Legislature created Section 1.11 of the Wisconsin Statutes concerning 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 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 action.

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.

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 countywide 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 providing broad grant of authority to general-purpose units of local government, the Wisconsin Statutes currently provide for the creation of four types of special-purpose units of government through which water pollution can be abated and water quality protected. These are: 1) metropolitan sewerage districts; 2) utility districts; 3) joint sewerage systems; and 4) cooperative action by contract.

Milwaukee Metropolitan Sewerage District: The Milwaukee Metropolitan Sewerage District was established under the provisions of Section 59.96 of the Wisconsin Statutes. Until April 1982, it operated under the direction 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 operated and existed pursuant to the provisions of Section 59.96 of the Wisconsin Statutes. In 1982, this two-commission arrangement was replaced with a single commission established under the provisions of Sections 66.88 through 66.918 of the Wisconsin Statutes. This legislation made the District a special-purpose unit of government with independent tax authority administered by an 11-member commission, the Milwaukee Metropolitan Sewerage Commission.

The District has the power to plan and construct treatment plants, main sewers, and pumping works for the collection, transmission, and treatment of house, industrial, and other sanitary sewage. The District has the power to promulgate and enforce reasonable rules for the supervision, protection, management, and use of the entire sewerage system. The District may also improve any watercourse within the District and any watercourse outside the District which flows from 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. In the case where the District improves a watercourse outside the District, it may contract with the local units of government that own or control the land through which that watercourse flows for payment of that part of the cost of the improvements outside the District. This watercourse improvement work is subject to the issuance of a permit by the Wisconsin Department of Natural Resources under Section 30.20 of the Wisconsin Statutes. In addition to improving watercourses, the District may design, construct, and maintain storm sewers and other drainage facilities.

Prior to 1984, the District included all of the cities and villages within the County of Milwaukee except the City of South Milwaukee, which elected not to become part of the District. During 1984, the Milwaukee Metropolitan Sewerage District took the steps necessary to remove certain areas in the southern portions of the cities of Oak Creek and Franklin from the District, as shown on Map 43. Those areas were removed which are not expected to be provided with public sanitary sewer service within a 10-year planning period. Through its Commission, the District may from time to time again add portions or all of these areas to the District.

Also through its Commission, the District may enter into contracts with municipalities in the same general drainage areas and adjacent to the District to furnish sanitary sewer service to those municipalities. The term "same general drainage area" has been defined by the Commission 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. The Commission has the power to inspect all sewers and sewerage systems which drain into the District's main or intercepting sewers. Furthermore, it has 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 Milwaukee 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 or intercepting sewers owned by the District.

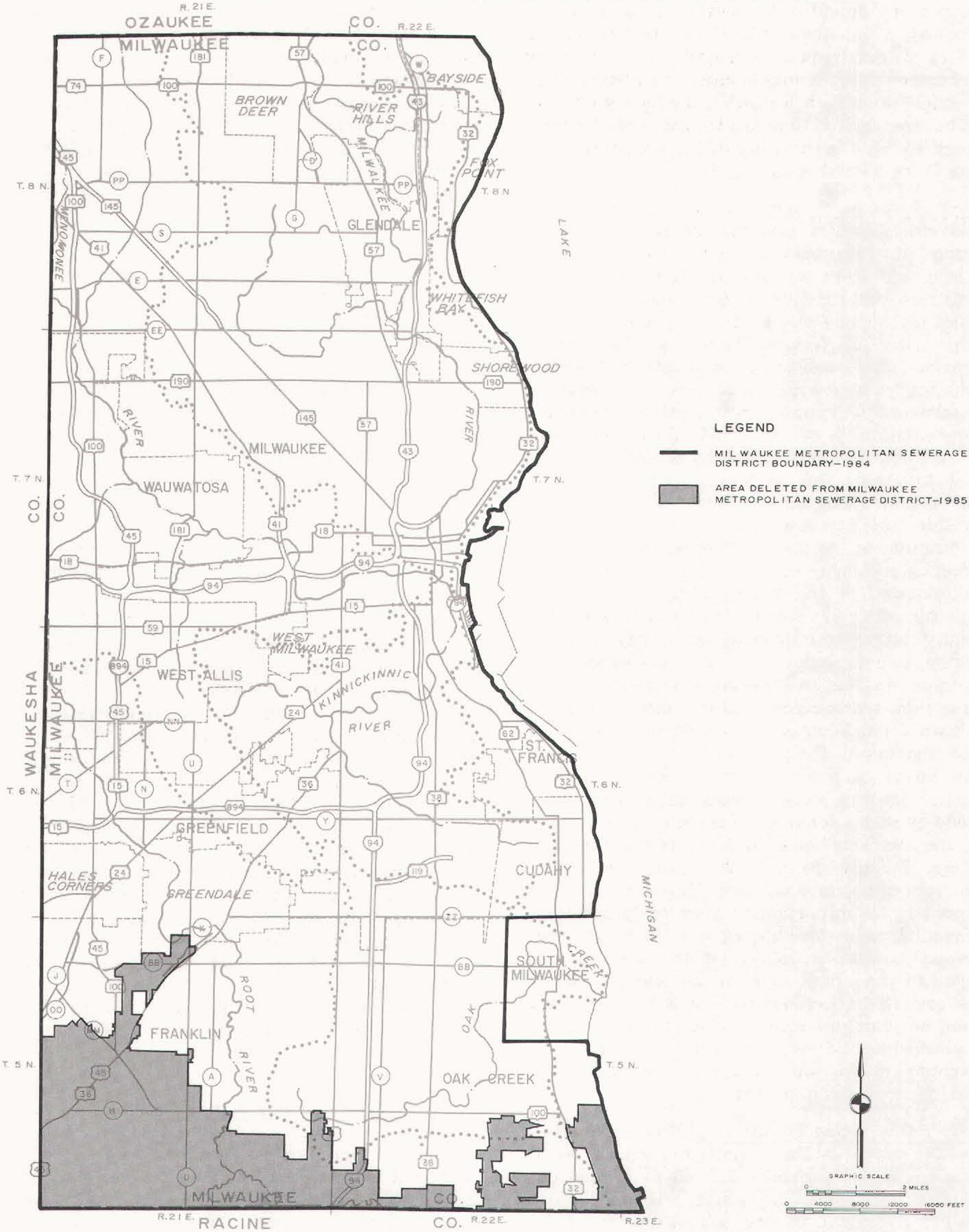
With regard to watercourse improvements, the District, through its Commission and predecessor agency, has engaged in a broad program of improving watercourses by widening, deepening, or otherwise changing watercourses so as to accommodate the expected flow of stormwaters and surface drainage waters from the area within the District and from the areas surrounding the District. In connection with this work, unauthorized waste discharges to watercourses may be 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 stormwaters and drain waters.

While there are statutory provisions for the creation of other kinds of metropolitan sewerage districts outside Milwaukee County, and while such provisions have importance in other watersheds of the Southeastern Wisconsin Region, such provisions have no practical importance in the Oak Creek watershed because of the existing authority of the Milwaukee Metropolitan Sewerage District and the City of South Mlwaukee relative to the provision of sewage treatment. Accordingly, from a practical point of view, metropolitan sewerage districts other than the Milwaukee Metropolitan Sewerage District are not of significance to the implementation of the areawide water quality management plan in the Oak Creek watershed or to the Oak Creek 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

Map 43

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT BOUNDARIES: 1985



During 1984, the Milwaukee Metropolitan Sewerage District took the necessary steps to remove from the District certain areas in the southern portions of the Cities of Franklin and Oak Creek which are not expected to be provided with public sanitary sewer service within a 10-year planning period. Some or all of these areas may again be added to the District as sewer service is extended into these areas.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

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. There are no known utility districts existing in the Oak Creek watershed as of 1984.

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 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 plan, construct, and maintain in the area sewerage facilities for the collection, transmission, and treatment of sewage. Such a 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 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 the same may be taken to the circuit court of the county in which the aggrieved governmental unit is located. There were no joint sewerage systems in the Oak Creek watershed as of 1984, and given the governmental structure in the watershed none are likely to be needed or created in the future.

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 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.

Private Steps for Water Pollution Control

The foregoing discussion deals exclusively with the water pollution control machinery available to units and agencies of government. However, direct action may also be taken by private individuals or organizations to effectively abate water pollution. There are two legal categories of private individuals who can seek direct action for water pollution control: 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 its 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 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. A master in chancery or a "master in litigation" is a person or agency which is brought in as a court technical expert to supply expertise on a particular issue or topic. 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 is 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 the rights of riparians. The Wisconsin Supreme Court set forth a potentially far-reaching conclusion in Muench v. Public Service Commission[6] 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 of 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 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 for 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

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[6] *261 Wis. 492, 53 N.W. 2d 514 (1952).*

standard, limitation, or prohibition of 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 to the alleged violator. When issuing final orders in any action under this section the courts may award the costs of litigation to any party.

FLOODLAND REGULATION AND CONSTRUCTION OF FLOOD CONTROL FACILITIES

Effective abatement of flooding can be achieved only through a comprehensive approach to the problem. Certainly, physical protection from flood hazards through the construction 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.

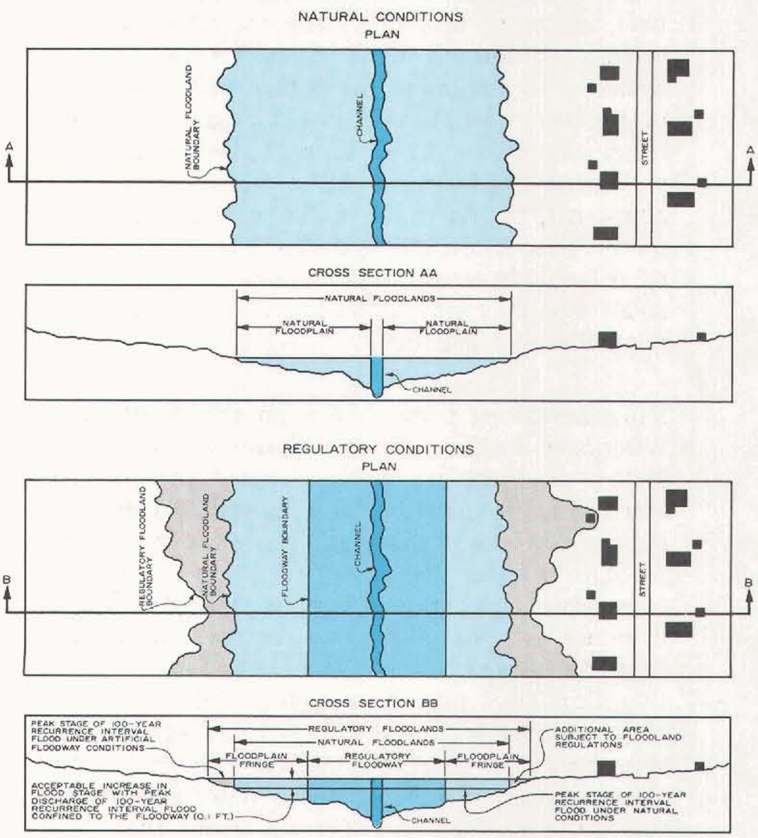
Definition of Floodlands

The precise delineation of floodlands is essential to the sound, effective, and legal administration of floodland regulation. This is particularly true in rapidly urbanizing areas such as the Oak Creek 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. For example, 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 50). 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, with each delineation relating to a corresponding specified flood recurrence interval. The Commission has, therefore, recommended that the natural

Figure 50

FLOODLAND COMPONENTS UNDER NATURAL AND REGULATORY CONDITIONS



Source: SEWRPC.

floodplains of a river or stream be specifically defined as those being confined to 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—which includes the channel—that will safely convey the 100-year recurrence interval flood discharge, with small upstream and downstream stage increases allowed, generally limited in Wisconsin to 0.1 foot if the stage increase does not increase the flood damage potential. Increases greater than 0.1 foot are permissible only when supported by appropriate legal arrangements with the affected local units of government and private property owners. 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 or beyond the floodway. Because the use of a regulatory floodway may result in increases in the stage of a flood of a specified recurrence 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 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 Oak Creek watershed study for Oak Creek and its major tributaries.

Principles of Floodland Regulation

Certain legal principles must be recognized in the development of land use regulations designed to implement a comprehensive watershed plan. With respect to the floodland areas of the watershed, these 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. Any such structures, 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 restricting 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 Regulations in Floodlands

Based upon the above principles and the definition of floodplains, the Commission has proposed that the local units of government within the 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, 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 line, consistent with the appropriate floodway zoning ordinance. A Wisconsin Department of Natural Resources permit is required for the deposit of material or the 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 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 regulation in Wisconsin is further governed by rules promulgated by the Federal Emergency Management Agency (FEMA). In essence, floodland regulation in Wisconsin is a partnership between the local, state, and federal levels of government.

State Floodplain Management Program: 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. However, 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 by the State from the county, city, or village. 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 construction 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 the 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 Federal Emergency Management Agency (FEMA). FEMA was given broad authority to conduct all types of studies relating to the 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 landowners 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 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 FEMA that it wishes to participate in the program, FEMA 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, FEMA 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 FEMA. Such rates can be federally subsidized if the actuarial rates are such that widespread participation in the program would be unlikely. 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 acquires 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:

1. Evaluate the potential effects of any actions the agency may take in a floodplain;

2. Ensure that the agency's planning programs and budget requests reflect consideration of flood hazards and floodplain management;

3. Identify any proposed action to take place in a floodplain in any new requests for appropriations from the Office of Management and Budget;

4. Consider floodplain management when formulating or evaluating any water resource use appropriate to the degree of hazard involved; and

5. 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 Insurance Act of 1968, and the Federal 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 manmade 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.

With respect to the Oak Creek watershed, this limitation may be overcome by delegation of the planning tasks to SEWRPC and attendant designation of the plan implementation tasks to various existing units of government. The Milwaukee Metropolitan Sewerage District, as already noted, has the authority to construct flood control facilities throughout the District and on watercourses which flow from within the District and, therefore, may make improvements to Oak Creek through the City of South Milwaukee. Such improvements may include deepening, widening, or other changes which in the judgment of the Commission are necessary to properly carry off surface or drainage waters. The District has historically engaged in a program of improving watercourses so as to accommodate the expected flow of stormwater and surface drainage waters from the areas involved. In particular, as noted in Chapter V of this report, the District, in cooperation with the City of South Milwaukee and the predecessor agency to the Milwaukee County Department of Parks, Recreation and Culture, has improved the drainage characteristics of Oak Creek through channelization of segments of the main stem of Oak Creek from Rawson Avenue upstream to Nicholson Avenue. In addition, the District has removed material from the bed of selected portions of the North Branch of Oak Creek between Puetz Road and Drexel Avenue in the City of Oak Creek. From 1981 through 1983, the Milwaukee County Department of Parks, Recreation and Culture installed about 1,000 feet of gabions along the Oak Creek channel banks just downstream of Chicago Avenue for erosion control. In the 1950's, the predecessor agency to that Department widened and deepened the Oak Creek channel from Rawson Avenue downstream to the Chicago & North Western Railway bridge. In addition, channel improvements have been carried out by the City of Oak Creek in conjunction with the Milwaukee Metropolitan Sewerage District, by the Wisconsin Department of Transportation, and by the City of Franklin. These improvements are shown on Map 30.

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.[7] 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.

SPECIFIC LEGAL CONSIDERATIONS AND INVENTORY FINDINGS IN THE OAK CREEK WATERSHED

Inventories were conducted of 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. A discussion of these legal considerations and how they apply to the Oak Creek watershed is presented below.

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 conducted under the Oak Creek watershed study of all water regulation permits issued by the Department of Natural Resources in the Oak Creek watershed.

[7] *64 Wis. 2d 6, 218 N.W. 2d 734 (1974).*

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 to be in the public interest. It was determined that there were no bulkhead lines in the Oak Creek watershed as of 1983.

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 66.894(8) 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 Oak Creek watershed lies within Milwaukee County and partly within the Milwaukee Metropolitan Sewerage District, jurisdiction over that watershed vis-a-vis improvements to that watershed is exercised by the Milwaukee Metropolitan Sewerage Commission.

Other Water Regulatory Permits: In a search of the records of the Wisconsin Department of Natural Resources, permits were found for the Oak Creek watershed for the following types of water-related activities: placement of structures and deposits in navigable waters (Wisconsin Statutes Section 30.12); dredging (Wisconsin Statutes Section 30.20); and the installation of high-capacity wells (Wisconsin Statutes Section 144.025 (2)(c). These permits are listed in Table 70. With regard to flood control facilities, Section 30.12 of the Wisconsin Statutes requires that a Wisconsin Department of Natural Resources permit be obtained for the placement of structures and deposits, including concrete lining and rip-rap, in the bed of a navigable stream.

State Water Pollution Abatement Orders and Permits

An inventory was conducted of all effluent discharge permits and of all outstanding pollution abatement orders in the Oak Creek watershed. The following section presents the results of that inventory.

Effluent Discharge Permits: As noted earlier in this chapter, a new Wisconsin pollutant discharge elimination system permit structure was established by the Wisconsin Department of Natural Resources pursuant to Chapter 147 of the Wisconsin Statutes. A permit is required for all industrial and municipal waste discharges. The inventory revealed that to date (1983) a total of nine industrial waste discharge permits have been applied for and/or issued in the Oak Creek watershed and two municipal waste discharge permits have been applied for and/or issued. Pertinent characteristics pertaining to each of these permits are set forth in Tables 71 and 72 respectively.

Pollution Abatement Orders: In addition to the inventory of effluent discharge permits, an inventory was conducted to determine if outstanding pollution abatement orders in the Oak Creek watershed existed. It was determined that no such orders have been issued in the watershed. It should be noted that pollution abatement orders related to point source discharge are no longer enforced owing to the recent pollutant discharge elimination system permit structure.

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 United States, 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. It was determined that one permit has been issued in the Oak Creek watershed to the Milwaukee County Department of Parks, Recreation and Culture for the placement of gabions along the banks of the Oak Creek main stem for erosion control. In addition, five applications were reviewed by the Corps of Engineers for the placement of utility lines across the Oak Creek main stem and north branch. Permits were not issued for these activities since they are already given blanket approval under nationwide permits.

Table 70

STATE WATER REGULATORY PERMITS IN THE OAK CREEK WATERSHED: 1983

Statute	Permit Number	Description
Section 30.12	3-SE-81-00727.000	Wisconsin Electric Power Company—Placement of rip-rap on banks of Mitchell Field drainage ditch
	3-SE-81-00704.000	Milwaukee County Parks Department—Placement of rip-rap on banks of Oak Creek
Section 30.20	3-SE-77-00022.000	Wisconsin Natural Gas Company—Removal of materials from the bed of Oak Creek
	3-SE-78-00024.000	City of Oak Creek—Removal of materials from the bed of Oak Creek
	3-SE-82-00032.000	City of Oak Creek—Removal of materials from the bed of Oak Creek
	3-SE-82-00033.000	City of Oak Creek—Removal of materials from the bed of Oak Creek
	3-SE-76-00440.000	Wisconsin Telephone Company—Removal of materials from the bed of Oak Creek
	3-SE-76-00441.000	Wisconsin Telephone Company—Removal of materials from the bed of Oak Creek
	3-SE-82-00039.000	Milwaukee Metropolitan Sewerage District—Removal of materials from the bed of the North Branch of Oak Creek
	3-SE-82-00040.000	Milwaukee Metropolitan Sewerage District—Removal of materials from the bed of the North Branch of Oak Creek
	3-SE-82-00041.000	Milwaukee Metropolitan Sewerage District—Removal of materials from the bed of the North Branch of Oak Creek
	3-SE-82-00042.000	Milwaukee Metropolitan Sewerage District—Removal of materials from the bed of the North Branch of Oak Creek
Section 144.025	19-702	Gene Tehan—Installation of high-capacity well in the City of Oak Creek

Source: SEWRPC.

Table 71

INDUSTRIAL WASTE DISCHARGE PERMITS ON FILE WITH THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES FOR DISCHARGES IN THE OAK CREEK WATERSHED: 1983

Permittee	Location		Type of Discharge	Pretreatment (if known)	Receiving Stream	Permit Number
	Address	Civil Division				
Appleton Electric Company Lighting Products Division	2201 12th Avenue	City of South Milwaukee	Cooling water, boiler blowdown	None	Oak Creek	WI-0028312-3
Appleton Electric Company Foundry Division	2105 5th Avenue	City of South Milwaukee	Cooling water	None	Oak Creek	WI-0033481-2
Applied Plastics Company, Inc.	7320 S. 6th Street	City of Oak Creek	Cooling water	None	North Branch of Oak Creek	WI-0041700-3
Bucyrus-Erie Company	1100 Milwaukee Avenue	City of South Milwuakee	Cooling water, wet scrubber discharge, stormwater drainage	Settling lagoon	Oak Creek	WI-0001058-4
Industrial Fuel	610 W. Rawson Avenue	City of Oak Creek	Boiler blowdown, washwater	Settling tank, oil, and water separator	Groundwater absorption pond	WI-0040428-2
Ladish Company	5481 S. Packard Avenue	City of Cudahy	Cooling water, stormwater drainage	None	Oak Creek	WI-0000728-3
South Milwaukee Water Utility	2005 10th Avenue	City of South Milwaukee	Decant water from holding tank	Settling	Oak Creek	WI-0045497-1
Western Machine Company	7665 S. 6th Avenue	City of Oak Creek	Cooling water	N/A	North Branch of Oak Creek	WI-0043796-1
U. S. Air Force Reserve 440TAW	General Mitchell Field 300 E. College Avenue	City of Milwaukee	Washwater, stormwater drainage	Oil and water separator	Mitchell Field Drainage Ditch	WI-0045195-1

NOTE: N/A indicates data not available.

Source: SEWRPC.

Floodland Regulation and Flood Insurance Eligibility

By 1984, all of the communities within the Oak Creek watershed had adopted floodplain zoning ordinances, and every community in the watershed was participating in the federal flood insurance program. Any proposed relocation of streams or channels must comply with the local ordinances. If changes proposed result in increases of greater than 0.1 foot to the 100-year recurrence interval floodplain elevations, appropriate legal arrangements would have to be made with the affected property owners, and the local community's floodplain maps amended to identify this change.

Local Water-Related Regulatory Matters

An inventory was conducted under the Oak Creek watershed study of other local ordinances relating to water quality and water use. This inventory indicated that the rules of the Milwaukee Metropolitan Sewerage District prohibit the discharge of stormwater 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 District require that every municipality contributing sanitary sewage to the metropolitan sewerage system adopt effective ordinances prohibiting the discharge of excessive clear water into the sanitary sewerage system. The inventory further revealed that 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 have

Table 72

MUNICIPAL WASTE DISCHARGE PERMITS IN THE OAK CREEK WATERSHED: 1983

Permittee	Location	Type of Discharge	Receiving Stream	Permit Number
City of South Milwaukee	One at 3rd Avenue at Michigan Avenue-Ravine Pump Station, and one at N. Chicago Avenue at Oak Creek	Sanitary sewer overflows	Oak Creek	WI-0028819-2
Oak Creek Sewer and Water Utility	Wildwood Drive at Wake Forest Drive	Sanitary sewer overflow	North Branch of Oak Creek	WI-0032212-1

Source: SEWRPC.

adopted rules and regulations, which are presently undergoing revision, for the Department of Parks, Recreation and Culture (formerly the Milwaukee County Park Commission) 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 County, no person shall fish the waters of the parks or the parkways. In addition, no person shall, without the express written permission of the County, place upon the lagoons, rivers, or any of the waters under the control of the County any float, boat, or other wood craft, nor may one land or go upon any of the islands of the lagoons or rivers or 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 also be found to be in the interest of public health, safety, and welfare. Under this basic statutory authorization, it would appear that any municipality in the Oak Creek 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 Oak Creek watershed study did not reveal the existence of any such boating regulations in the watershed.

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 following salient findings having particular importance for planning in the Oak Creek watershed:

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 and 1977, 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 Oak Creek 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 perennial streams in the Oak Creek watershed were adopted by the Wisconsin Natural Resources Board in 1973 and revised in 1976. These include recreational use and the maintenance of warmwater fish and aquatic life, and minimum standards. In addition, coldwater fish and aquatic life standards related to the protection of spawning salmonids shall be met in the Oak Creek estuary when salmonid spawning runs are in progress. The adopted regional water quality management plan recommends maintaining the water use objectives in the Oak Creek watershed as warmwater fishery and aquatic life, recreational use, and minimum standards except in the Oak Creek estuary. That plan recommends further study of the Oak Creek estuary before establishing any water use objective.

In addition to granting broad 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 four types of special-purpose units of government through which water pollution can be abated and water quality protected: the Milwaukee Metropolitan Sewerage District, utility districts, joint sewerage systems, and cooperative action by contract. With respect to the provision of sewage treatment and related trunk sewers, the Milwaukee Metropolitan Sewerage District serves the entire Oak Creek watershed except that portion of the watershed in the City of South Milwaukee, which operates its own sewage treatment plan.

Flood control facilities may be constructed throughout the Oak Creek watershed by the Milwaukee Metropolitan Sewerage District. The District has historically engaged in a limited program of improving watercourses in the watershed. In addition, the predecessor agency to the Milwaukee County Department of Parks, Recreation and Culture improved portions of the Oak Creek channel on its own, and cooperated with the City of South Milwaukee and the Milwaukee Metropolitan Sewerage District to improve another portion of the Oak Creek channel. The construction of flood control facilities incorporating the placement of structures or deposits in the bed of a navigable stream is regulated under Section 30.12 of the Wisconsin Statutes, and requires a permit from the Wisconsin Department of Natural Resources. Interbasin water diversions are regulated by several legal doctrines, including the common-law riparian doctrine, state consent, and Section 30.18 of the Wisconsin Statutes.

Inventories were conducted in the Oak Creek watershed of 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. A total of 13 state water regulatory permits were found to have been issued in the watershed under Chapters 30 and 144 of the Wisconsin Statutes. A total of 11 state effluent discharge permits have been issued in the watershed, of which a total of nine are industrial waste discharge permits. One permit has been issued in the Oak Creek watershed by the U. S. Department of the Army, Corps of Engineers, for stream bank protection. All six of the communities within the watershed have adopted floodplain zoning ordinances, and all of the communities are participating in the federal flood insurance program.

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Chapter X

WATERSHED DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS

INTRODUCTION

The formulation of development objectives and supporting standards is one of the most important steps in the Commission 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 Oak Creek Watershed Committee, the composition of which is described 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 Oak Creek watershed. Others were formulated specifically for 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 comparisions between such subelements. The description of these criteria and procedures in this chapter is intended to provide an understanding by all concerned of the level of detail entailed in the watershed plan preparation, as well as of the need for refinement of some aspects of that plan prior to implementation.

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 not only must be logically sound and related in a demonstrable and measurable way to alternative physical development proposals, but must 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, a number of regional development objectives relating to land use, housing, transportation, sewerage, water quality management, air quality management, flood control, and recreation and open space preservation. These objectives, together with their supporting principles and standards, are set forth in previous Commission planning reports. Some of these objectives and standards are directly applicable to the Oak Creek watershed planning effort, and are hereby recommended for adoption as development objectives for the watershed.

Land Use Development Objectives

Seven of the eight regional land use development objectives adopted by the Commission under its regional land use planning program are directly applicable to the Oak Creek watershed planning effort.[1] These are:

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

2. A spatial distribution of the various land uses which will result in 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 in terms of both 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 and Water Quality Management Planning Objectives

All five of the water quality management objectives adopted by the Commission under its regional water quality management planning effort are directly applicable to the Oak Creek watershed planning effort. These are:

1. The development of land management and water quality control practices and facilities—inclusive 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 need for sanitary and industrial wastewater disposal and the need for stormwater runoff control generated by the existing and proposed land uses.

2. The development of land management and water quality control practices and facilities—inclusive of sanitary sewerage systems—

[1] *The other land development objective is the preservation of land areas for agricultural uses in order to provide for certain 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 the shape and order of urban development.*

so as to meet the recommended water use objectives and supporting water quality standards as set forth on Map 44 and in Table 77.

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

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

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

Park and Open Space Objectives

Two of the seven park and open space objectives adopted by the Commission under its regional park and open space planning program are directly applicable to the Oak Creek 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.

Water Control Facility Development Objectives

Two of the specific water control facility development objectives adopted by the Commission under its other comprehensive watershed planning programs are applicable to the Oak Creek watershed planning effort.[3] These are:

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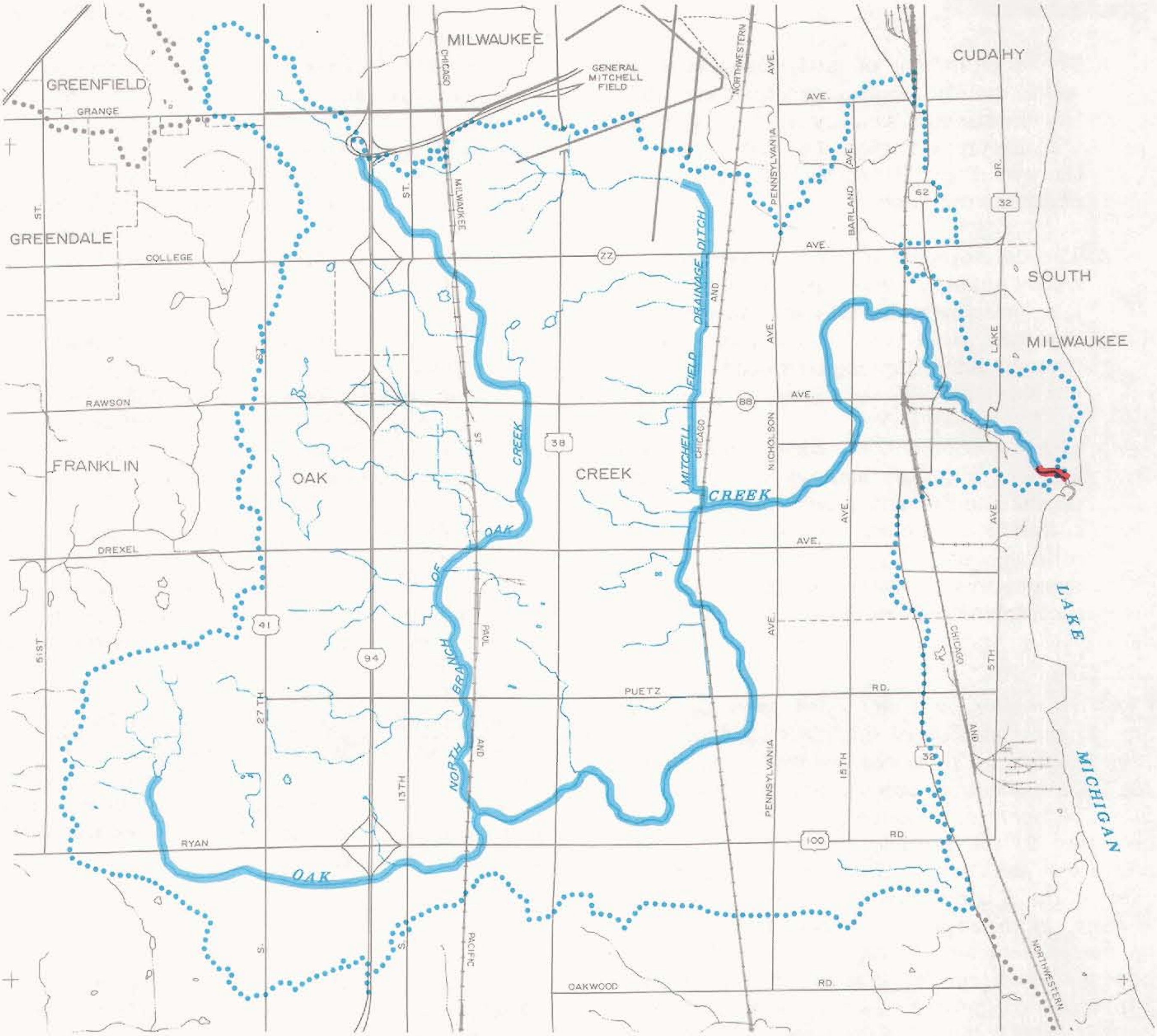
[2] *The other five park and open space objectives are: 1) the provision of sufficient outdoor recreation facilities to allow the resident population of the Region adequate opportunity to participate in intensive nonresource-oriented outdoor recreation activities; 2) the provision of sufficient outdoor 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; 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, consistent with safe and enjoyable lake use and the maintenance of good water quality; and 5) the efficient and economical satisfaction of outdoor recreation and related open space needs, meeting all other objectives at the lowest possible cost. While these objectives are applicable to the watershed planning program, they should be applied at the local level as a joint effort by county agencies, school districts, and local community recreation agencies.*

[3] *The other two 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 water control facility objective is not applicable to the Oak Creek watershed planning program since there are no major lakes in the watershed. The groundwater objective is not applicable to the Oak Creek watershed planning program since the study prospectus did not identify groundwater quantity or quality as being significant problems in this watershed.*

Map 44

PRELIMINARY RECOMMENDED WATER USE OBJECTIVES FOR SURFACE WATERS IN THE OAK CREEK WATERSHED: 2000

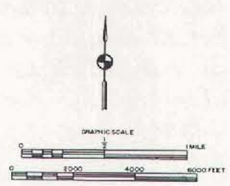


LEGEND

WARMWATER FISHERY AND AQUATIC LIFE, RECREATIONAL USE, AND MINIMUM STANDARDS

LAKE MICHIGAN ESTUARY; COMMISSION RECOMMENDED WATER USE OBJECTIVES DEPENDENT UPON FURTHER DETAILED STUDY

NOTE: EXCEPT FOR THE LAKE MICHIGAN ESTUARY, THIS MAP IDENTIFIES THE PRELIMINARY RECOMMENDED WATER USE OBJECTIVES ONLY FOR THE PERENNIAL STREAMS. THE WARMWATER FISHERY AND AQUATIC LIFE, RECREATIONAL USE, AND MINIMUM STANDARDS CLASSIFICATION WOULD ALSO APPLY TO ALL INTERMITTENT STREAMS.



Under the regional water quality management planning program, analyses were conducted to determine the feasibility of achieving a level of water quality that would make all surface waters "fishable and swimmable" as envisioned by the U. S. Congress in Public Law 92-500. The results of these analyses indicated that all of the streams analyzed in the Oak Creek watershed could be brought to "fishable and swimmable" standards.

Source: SEWRPC.

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 point and nonpoint source pollution abatement measures 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 land use, sanitary sewerage system and water quality management, park and open space, and water control facility development objectives are 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 objective. These principles and standards, as they apply to watershed planning and development, are set forth in Tables 73, 74, 75, and 76, 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 selected portions of the Oak Creek watershed stream system for warmwater fishery and aquatic life, recreational use, and minimum standards. These currently adopted water use objectives and the supporting standards are set forth on Map 43 and in Table 69 in Chapter IX.

Preliminary recommended water use objectives are shown on Map 44 and are identical to those set forth in Chapter II of Volume Two, Alternative Plans, of SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, with the exception of objectives for the Mitchell Field Drainage Ditch which was not identified in that plan. The preliminary recommended water use objectives for Oak Creek, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch include the support of warmwater fish and aquatic life and full recreational use. A comparison of the preliminary recommended water use objectives with the water use objectives established by the Wisconsin Department of Natural Resources indicates that these objectives are identical with the exception of those for the Oak Creek estuary. As shown on Map 44, recommended water use objectives for the Oak Creek estuary are to be determined based on the results of further study, while the water use objectives used in practice by the Wisconsin Department of Natural Resources for the Oak Creek estuary include the support of a salmon fishery and full recreational use, based upon the fact that salmon are known to exist in the estuary at least at some times of the year. The water quality standards supporting these preliminary recommended water use objectives are set forth in Table 77. These recommendations are in conformance with the national water use objectives cited in Public Law 92-500, which call for the attainment wherever possible of water quality which is sufficient to support the protection and propagation of fish, shellfish, and other wildlife, and for the support of human recreation in and on the waters. Analyses conducted in development of the adopted regional water quality management plan indicate that the attainment of these "fishable-swimmable" water use objectives and the supporting water quality standards is feasible and realistic if the significant water pollution sources in the Oak Creek watershed are properly abated.

It should be noted that the planning standards herein recommended for adoption fall into two groups: comparative and absolute. The comparative standards, by their very nature, can be applied only through a comparison of alternative plan proposals. Absolute standards can be applied individually to each alternative plan proposal since they are expressed in terms of maximum, minimum, or desirable values. The standards set forth herein should serve as aids not only in the development, test, and evaluation of 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

Table 73

LAND USE DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE OAK CREEK 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, anticipated year 2000 persons-per-dwelling-unit averages were used. These averages range from a minimum of 2.6 persons per dwelling unit in Milwaukee County to a maximum of 3.5 persons per dwelling unit in Ozaukee and Washington Counties with an anticipated average of 2.9 persons per dwelling unit for the Region as a whole in 2000. According to the 1970 federal census, the average number of persons per dwelling unit ranged from a minimum of 3.0 persons per dwelling unit in Milwaukee County to a maximum of 3.7 persons per dwelling unit in Ozaukee and Waukesha Counties with an average of 3.2 persons per dwelling unit for the Region as a whole. In 1975, it is estimated that the average number of persons per dwelling unit ranged from a minimum of 2.8 persons per dwelling unit in Milwaukee County to a maximum of 3.6 persons per dwelling unit in Ozaukee and Waukesha Counties with an average of 3.0 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

(Table 73 continued)

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; reduce storm water runoff by providing area for floodwater impoundment and storage; contribute to groundwater supplies; trap soil particles suspended in runoff and thus reduce stream sedimentation; protect shoreland areas from erosion; 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: dry, dry-mesic, mesic, wet-mesic, and wet. 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.

(Table 73 continued)

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.

(Table 73 continued)

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.

(Table 73 continued)

h. Available adequate storm water management 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 management 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 management 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:

(Table 73 continued)

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.

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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.*

(Table 73 continued)

[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 inundated or saturated by surface- or groundwater at a frequency and with a duration sufficient to support—and that under normal circumstances do support—a prevalence of vegetation typically adapted for life in saturated soil conditions and encompassing an area of one acre or more.

[o] The term woodland, as used herein, is defined as those areas one acre or more in size having 17 or more deciduous trees per acre, each measuring at least four inches in diameter at breast height and having 50 percent or more tree canopy coverage. In addition, coniferous tree plantations and reforestation projects are identified as woodlands by the Commission. It should be noted that all lowland wooded areas, such as tamarack swamps, are also classified as wetlands.

[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.

Source: SEWRPC.

Table 74

WATER QUALITY MANAGEMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE OAK CREEK WATERSHED

OBJECTIVE NO. 1

The development of land management and water quality control practices and facilities—inclusive 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 need for sanitary and industrial wastewater disposal and the need for storm water runoff control generated by the existing and proposed land uses.

PRINCIPLE

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

STANDARDS

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

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

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

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

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

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

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

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

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

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

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

(Table 74 continued)

OBJECTIVE NO. 2

The development of land management and water quality control practices and facilities—inclusive of sanitary sewerage systems—so as to meet the recommended water use objectives and supporting water quality standards as set forth on Map 44 and in Table 77.

PRINCIPLE

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

STANDARDS

1. The level of treatment to be provided at each sewage treatment plant industrial wastewater outfall 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 on Map 44 and in Table 77.

2. The type and extent of storm water treatment or associated preventive land management practices to be applied within a hydrologic unit should be determined by water quality analyses directly related to the established water use objectives for the receiving surface water body. These analyses should demonstrate that the proposed treatment level or land management practices will aid in achieving the water quality standards supporting each major water use objective as set forth on Map 44 and in Table 77.

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

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

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

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

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

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

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

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

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

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

13. No pollutants should be discharged by sanitary or industrial sewage treatment plants in amounts which would preclude the achievement of the recommended water use objectives or the supporting standards as set forth on Map 44 and in Table 77.

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

(Table 74 continued)

OBJECTIVE NO. 3

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

PRINCIPLE

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

STANDARDS

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

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

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

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

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

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

7. There should be no discharge of heavy metals, pesticides, industrial chemicals, or other substances in quantities known to be toxic or hazardous to fish or other aquatic life.

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

OBJECTIVE NO. 4

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

(Table 74 continued)

PRINCIPLE

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

STANDARDS

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

2. The sum of storm water control facility and related land management practice operating and capital investment costs should be minimized through proper storm water management planning and design.

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

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

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

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

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

8. Clear water infiltration and inflows to the sanitary sewerage system should be reduced to the cost-effective level.

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

OBJECTIVE NO. 5

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

PRINCIPLE

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

(Table 74 continued)

STANDARDS

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

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

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

4. Each designated management group should have legal authority, financial resources, technical capability, and practical autonomy sufficient to assure the timely accomplishment of its responsibilities in the achievement of the recommended water use objectives and supporting standards as set forth on Map 44 and in Table 77.

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

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

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

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

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

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

Source: SEWRPC.

Table 75

OUTDOOR RECREATION AND OPEN SPACE PLANNING OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE OAK CREEK 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:

Site Type	Size (gross acres)	Publicly Owned General Use Sites							
		Parks				Schools[a]			
		Minimum Per Capita Public Requirements (acres per 1,000 persons)[d]	Typical Facilities	Maximum Service Radius (miles)[b]		Minimum Per Capita Public Requirements (acres per 1,000 persons)[f]	Typical Facilities	Maximum Service Radius (miles)[c]	
				Urban[e]	Rural			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]	--

(Table 75 continued)

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.

STANDARD

All remaining nonurban lands within the designated primary environmental corridors in the Region should be preserved in their natural state.

(Table 75 continued)

B. PRIME AGRICULTURAL LANDS

PRINCIPLE

Prime agricultural lands constitute the most productive farmlands in the Region and, in addition to providing food and fiber, 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.

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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.*

[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.*

[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.*

(Table 75 continued)

[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. Recreation lands at the neighborhood level should most desirably be provided through a joint community-school district venture, with the facilities and recreational land are 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 76

WATER CONTROL FACILITY DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE OAK CREEK 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, consistent with the land use element of the comprehensive watershed plan and with any storm water management plans. 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

(Table 76 continued)

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]

11. All water control facilities should be compatible with existing local storm water management plans and as flexible as practical to accommodate future local storm water management planning.

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 recreational use, a warmwater fishery, other aquatic life, and a salmon fishery.

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.

(Table 76 continued)

STANDARDS

1. All waters shall meet those water quality standards set forth in Table 77 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.

3. Flood control and storm water management facilities should be designed to minimize the negative impacts on fish and other aquatic life and to support the water use objectives set forth on Map 44 and in Table 77.

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[a] *Although Commission watershed studies conducted prior to the Kinnickinnic River watershed study 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 was reduced in the Kinnickinnic River and Pike River watershed reports in order to be consistent with 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.In 1985, the Wisconsin Department of Natural Resources Board approved revisions to the Wisconsin Administrative Code which provide for a maximum computed increase in flood stage of 0.01 foot, or, in effect, permit no increase in flood stage.

[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.

Table 77

PRELIMINARY RECOMMENDED WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR STREAMS IN THE OAK CREEK WATERSHED: 2000[a]

Water Quality Parameters	Warmwater Fishery and Aquatic Life, Recreational Use, and Minimum Standards[b]
Maximum Temperature (°F)	89[c]
pH Range (standard units)	6.0-9.0[d]
Minimum Dissolved Oxygen (mg/l)	5.0
Maximum Fecal Coliform (counts per 100 ml)	200-400[e]
Maximum Total Residual Chlorine (mg/l)	0.01
Maximum Un-ionized Ammonia Nitrogen (mg/l)	--[f]
Maximum Total Phosphorus (mg/l)	0.1
Other	--[g]

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

[b]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]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.

[d]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.

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

[f] The following criteria shall apply for un-ionized ammonia nitrogen (NH_3-N):

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

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

where:

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

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

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

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

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

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

where:

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

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

These un-ionized ammonia nitrogen criteria may be modified, if appropriate, to reflect local site specific conditions and to protect only those fish and aquatic life species or age or size classes that occur, or are desired, within a certain water body. Such site-specific modifications shall be conducted in conformance with the guidelines set forth in U. S. Environmental Protection Agency, Guidelines for Deriving Numerical Aquatic Site-Specific Criteria by Modifying National Criteria, Office of Research and Development, Draft, December 1982. These site-specific criteria modifications, however, should be used with caution because of a relative scarcity of toxicity information on less sensitive fish and aquatic life species.

[g]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, the Federal Register, Part V, Environmental Protection Agency, "Water Quality Criteria Documents, Availability," November 28, 1980; Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976; and Water Quality Criteria, 1972, EPA-R3-73,003, National Academy of Sciences, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of 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.

Source: Wisconsin Department of Natural Resources and SEWRPC.

management facilities must constitute integral parts of a total system. It is not possible through application of these objectives and standards alone, however, to assure such system integration, since the objectives and standards cannot be used to determine the effect of individual facilities and controls on each other or on the system as a whole. This requires the application of planning and engineering techniques developed for this purpose—such as hydrologic, hydraulic, and water quality simulation—to quantitatively test the performance of the proposed facilities as part of a total system, thereby permitting adjustment of the spatial distribution and capacities of the facilities 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 that such conflict will require resolution through compromise; such compromise is an essential part of any design effort. The degree to which the recommended Oak Creek watershed plan meets the adopted objectives and standards is discussed in Chapter XIV of this report.

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 them here.

Rainfall Intensity-Duration-Frequency Relationships

If local stormwater control and 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 C. The curves in Figure C-1 and the equations in Table C-1 are directly applicable to urban stormwater control system design using the rational formula,[4] with the equations being intended primarily for incorporation into digital computer programs used in stormwater control system analysis and design.

The curves in Figure C-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 C-3 and C-4, respectively. The relationships presented in Figure C-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 Oak Creek 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

[4] *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.*

slope, and soil type, are presented in Appendix C, Figure C-5, and Table C-2.[5] 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 Oak Creek watershed study according to the log Pearson Type III method of analyses as recommended by the U. S. Water Resources Council[6] and as specified by the Wisconsin Department of Natural Resources.[7] In the absence of suitable, long-term flow records at all points of interest or concern within the watershed, the discharge-frequency analyses were applied to simulated annual peak discharges 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 to compute the monetary flood damages and calculate the economic benefits associated with alternative floodland management measures.

Design Flood

The design flood adopted for the Oak Creek 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 selection 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 from 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 the costs and benefits of alternative flood control plans can be analyzed along with the advantages and disadvantages of various levels and combinations of police power regulations, public acquisition, and public construction for flood damage abatement and prevention. 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, is estimated to have had a recurrence interval of 100 years; the two largest floods of record for the Milwaukee River watershed, as measured near the watershed outlet at Milwaukee, are 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, is estimated to have had a recur-

[5] *Ibid.*

[6] *United States Water Resources Council, Guidelines for Determining Flood Flow Frequency, Bulletin No. 17 of the Hydrology Committee, Washington, D. C., March 1976.*

[7] *"Wisconsin's Floodplain Management Program," Wisconsin Administrative Code, Chapter NR 116, Register, July 1977, No. 259.*

rence interval of 37 years; the largest flood of record for the Root River watershed, as determined in Racine at the watershed outlet, is estimated to have had a recurrence interval of 100 years; the large flood of April 21, 1973, in the Kinnickinnic River watershed is estimated to have had a recurrence interval of about 60 years as recorded at S. 7th Street in the City of Milwaukee; and the largest flood of record for the Pike River watershed, as determined in Kenosha at the mouth of the river, is estimated to have had a recurrence interval of 60 years. For regulatory purposes, the use of a flood event that is similar in terms of peak flood stages and 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 an 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 as, 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. Because of the large cross-sectional area of flow made available on the relatively broad floodplains characteristic of the streams of the Planning Region, 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 those of the latter. The differences between the stages of a 25- or 50-year recurrence interval flood event and of 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. The 100-year recurrence interval flood was recommended for use by federal agencies for floodplain management purposes in 1969[8] by the U. S. Water Resources Council, an organization composed of representatives of federal offices and agencies concerned with water resource problems. This recommendation, in effect,

[8] *U. S. Water Resources Council, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies, Washington, D. C., September 1969.*

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 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 originally recommended by the Commission, is now mandatory within Wisconsin.

Digital Computer Utilization

Digital computers were used extensively in the conduct of the Oak Creek 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. The digital computer was used extensively in the Oak Creek 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 by participating engineers, planners, and technicians. Because successful computer operation requires that all desired operations be completed 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 alpha-numerical 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 watershed-wide basis.

Third, through computer usage, the basic watershed study data and information are 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.

Economic Evaluation

The concepts of economic analysis and economic selection are vital to the public planning process. A sound economic analysis of benefits and costs should be an important guide to planners and decision-makers in the selection of the most suitable plan from an array of alternatives. All decisions concerning monetary expenditures, either private or public, are implicitly based on an evaluation of benefits and costs. This is not to imply that a formal economic analysis is conducted of every expenditure. However, decision-making process does consider whether the benefit received would be worth the amount paid. Benefits are not necessarily quantifiable 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 alternative benefits that could be received for alternative expenditures within the limits of available resources. Alternative benefits are compared, either objectively or subjectively, and the one which is considered to give the greatest value for its cost is selected. Again, the benefits may be purely intangible; but the decision-making process itself implies an evaluation of which alternative is considered to be worth the most. When investment for future benefits is considered, one alternative that should always be considered is the benefit that could be received from investment in the money market. This benefit is expressed in the prevailing interest rate.

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." The monetary value of a benefit 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 cost, 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 of an alternative, since the amount of public funds available or potentially available, and public attitudes toward a particular plan element, must be considered in selecting from 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.

The benefits that could be achieved through implementation of a comprehensive plan for the Oak Creek watershed include floodland management; recreational opportunities; the provision of efficient community utilities and facilities; the enhancement of property values; and the preservation of recreational, scenic, cultural, and ecological values. Costs which could be incurred in implementation of the watershed plan include construction and land acquisition costs, and the income foregone as a result of the 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. For example, because of its subjective interpretation of benefits and costs, the community may 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. The benefits of one project may be realized earlier than are 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 for a one dollar benefit at some time in the future has a value of less than one dollar today. The variation in the 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 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 Oak Creek 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 Oak Creek watershed alternative plans.

Using a 6 percent interest rate, 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 $1.00. However, the total present worth of the benefits for the 50-year period, from year one through 50, 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 Oak Creek 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 the aesthetic factors derived from natural beauty and a pleasant environment. Intangibles also include benefits, such as improved efficiencies in community utilities and facilities, that have monetary values 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; and expenditures for engineering, legal work, and project administration. The costs of structural facilities were calculated using 1984 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 1984 market prices for land in the Oak Creek 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 in 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 receipt of the project. The financial analysis determines whether or not the prospective available funds are adequate to cover all 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 in continued planning. Staging developments may also allow an element to be deferred until increased demands raise its benefit-cost ratio. In planning for staged development, however, consideration must be given to the possibilities of higher costs in the future and unavailability of land. In any development, staging also serves to lower risks incurred because of unavailability of data during preparation and partial implementation of initial plans.

SUMMARY

The formulation of objectives and standards 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 into, previously adopted regional development objectives, supplemented only as required to meet the specific needs of the Oak Creek watershed planning program. The development objectives adopted for the watershed plan consist of seven of the eight adopted regional land use planning objectives, all of the five adopted water quality management planning objectives, two of the seven adopted regional park and open space planning objectives, and two of the four water control facility objectives adopted under previous Commission comprehensive watershed planning studies.

In addition to presenting and discussing the objectives, principles, and standards adopted for the Oak Creek watershed, this chapter presents the engineering design criteria and analytic procedures used in the watershed study. These criteria and procedures were used to synthesize an Oak Creek 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 the design flood selected 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.

Chapter XI

RECOMMENDED LAND USE PLAN AND PARK AND OPEN SPACE PLAN FOR THE WATERSHED

INTRODUCTION

The demographic and economic base and the existing land use pattern of the Oak Creek watershed were described in Chapter III of this report. Forecasts of probable future population and economic activity levels, together with attendant demands for various land uses within the watershed, were set forth in Chapter IV. Under the alternative future selected for use in the watershed planning effort, the resident population of the watershed would increase from the 1980 level of about 39,700 persons to a year 2000 level of about 70,000 persons, an increase of about 76 percent over the 20-year period. Similarly, employment within the watershed would increase from the 1980 level of about 20,000 jobs to a year 2000 level of about 27,300 jobs, an increase of about 36 percent. This growth in population and employment would require the conversion of an additional 11.1 square miles of land within the watershed from rural to urban uses, increasing the amount of land devoted to urban use from about 13.2 square miles in 1980 to about 24.3 square miles in 2000, an increase of about 84 percent. The demand for urban land will have to be satisfied primarily through the conversion of a large portion of the remaining agricultural and other open lands of the watershed to urban uses. This conversion, if unplanned or poorly planned, and if not properly related to the natural resource base, may be expected to further intensify the developmental and environmental problems of the watershed.

It is therefore important that new urban development within the watershed be properly related to soil capabilities, to the wetlands and woodlands of the watershed, to the floodlands of the streams and watercourses of the watershed, and to established utility systems. If the intensification of developmental and environmental problems is to be avoided and the serious problems of flooding and water pollution already existing within the Oak Creek watershed are to be abated, new urban development within the watershed must assume a pattern which is more carefully adjusted to the ability of the underlying and sustaining natural resource base to support such development. A land use plan must, therefore, constitute a major element of any comprehensive plan for the development of the Oak Creek watershed. This land use plan element, although emphasizing the riverine areas of the watershed, must cover the entire watershed, and should represent the basic approach to resolution of the growing developmental and environmental problems of the watershed. The land use plan element and any structural water control facility and water quality management plan elements for flood control and pollution abatement should be mutually supportive in that land use development will determine to a considerable extent the loading on the water control and water quality management facilities, while those facilities will, in turn, influence land use development, particularly in the riverine areas of the watershed.

REGIONAL LAND USE PLAN

Because in a large urbanizing region such as southeastern Wisconsin, the socioeconomic factors that determine growth operate on an areawide basis, transcending both political and natural watershed boundaries, a land use plan for a watershed within such a region must be set within the framework of an areawide—or regional—land use plan. The watershed land use plan recommended herein is accordingly set within the context of, and reflects the concepts contained in, the adopted regional land use plan for the design year 2000. That 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 plan seeks to encourage the centralization of urban development to the greatest degree practicable; to encourage new urban development to occur in locations and at densities consistent with the economical provision of public centralized sanitary sewer, water supply, and mass transit facilities and services; and to encourage new urban development to occur only in areas which are covered by soils well suited to urban use and which are not subject to special hazards such as flooding.

Importantly, the plan seeks to protect and preserve in essentially natural, open uses the primary environmental corridors of the Region. These environmental corridors, while constituting only about 17 percent of the total area of the Region, encompass almost all of the best remaining woodlands, wetlands, wildlife habitat areas, surface waters, and associated undeveloped floodlands and shorelands; areas covered by organic soils; areas of rough topography and significant geological formations; sites having scenic, scientific, and cultural value; areas of groundwater recharge and discharge; and the best remaining potential park and related open space sites. Protection and preservation of the primary environmental corridors is considered essential to the protection and wise use of the natural resource base; to the preservation of the cultural heritage and natural beauty of the Region; and to the enrichment of the physical, intellectual, and spiritual development of the resident population. Such protection and preservation is also necessary to avoid the intensification of existing developmental and environmental problems, such as flooding and water pollution, and to avoid the creation of new problems of this type. The topography, soils, and flood hazards in these corridors, moreover, make them poorly suited to intensive urban development of any kind, but well suited to recreational and conservancy uses.

While the adopted regional land use plan forms the basis for the watershed land use plan as herein presented, it should be noted that in the preparation of the watershed land use plan, the regional land use plan was refined and detailed to more precisely reflect the flood hazards existing in the riverine areas of the watershed as determined under the watershed planning program, to reflect recent local development decisions regarding major trunk sewer locations, and, to the extent practicable, to reflect the proposals contained in existing community and neighborhood development plans and plan implementation ordinances.[1] The regional land use development objectives which the regional land use plan is designed to meet are set forth in SEWRPC Planning Report No. 25 and were judged to remain valid and attainable within the context of the more detailed watershed development plan. These objectives, principles, and standards were refined and detailed under the watershed planning effort as described in Chapter X of this report.

REGIONAL PARK AND OPEN SPACE PLAN

Following completion and adoption of the year 2000 regional land use plan in December 1977, the Regional Planning Commission in 1978 completed and adopted a regional park and open space plan. This plan is fully documented in SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, and contains recommendations which, while fully consistent with the recommendations in the adopted regional land use plan, represent refinements of those recommendations and, as such, should also provide a part of the basic framework for the watershed land use plan.

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 contains recommendations for the preservation of the remaining primary environmental corridors of the Region through appropriate combinations of public acquisition and land use regulation. The outdoor recreation element is composed of two components: a resource-oriented outdoor recreation component containing recommendations for the location, size, and development of large parks and recreation corridors within the Region, and an urban-oriented recreation component containing recommendations concerning the location, size, expansion, and development of community and neighborhood parks within the urban areas of the Region. The recommendations of the regional park and open space plan were incorporated into the land use plan for the Oak Creek watershed plan, with refinements as necessary to reflect the most

[1] *The following local land use and related plans were also utilized in the preparation of the watershed land use plan: Barton-Aschman Associates, Inc., Comprehensive Plan, 1973, City of Oak Creek, 1973; Maynard W. Meyer & Associates, Master Plan Report for the City of South Milwaukee, 1963; unpublished neighborhood unit development plans for the Southwood and Franklin Neighborhoods in the City of Franklin; SEWRPC Community Assistance Planning Report No. 15, Off-Airport Land Use Development for General Mitchell Field and Environs: 1977; Amendment to the Regional Transportation Plan—2000, Lake Freeway South Corridor, as adopted by the SEWRPC 1981; and the zoning ordinances and zoning district maps adopted by the municipalities within the watershed.*

recent public actions concerning the acquisition and development of park and open space sites within the watershed.[2]

WATERSHED LAND USE PLAN

As already noted, the regional land use and park and open space plans for the design year 2000 form the basis for the recommended land use plan for the Oak Creek watershed. The watershed land use plan would 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, meeting to the extent practicable both the demands of the urban land market and the design standards developed for the updated regional land use plan. Under the regional land use plan, the allocation of future land uses within each county of the Region is based on the demand for land which may be expected to be created by the forecast resident population and employment growth within each county through the plan design year 2000. 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 the Region and watershed that are covered by soils well suited to such development, that are not subject to special hazards such as flooding, and that can be readily provided with gravity drainage sanitary sewer, public water supply, and urban public transit services.

The land use plan emphasizes continued reliance on 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 the intensification of developmental and environmental problems within the Region and the watershed. This land use plan is shown in graphic summary form on Map 45 and in Figure 51, and is more specifically described in the following sections of this chapter.

In order to meet the needs of the expected resident population and employment, the amount of land devoted to urban use within the watershed, as indicated in Table 78, is projected to increase from the 1980 total of about 13.2 square miles, or about 47 percent of the total area of the watershed, to about 24.3 square miles, or about 87 percent of the total area of the watershed, by year 2000. It is important to note that the 13 percent of the watershed remaining in rural use would be comprised of woodlands, wetlands, and floodlands proposed to be permanently preserved through joint state-local zoning or public acquisition. Thus, the watershed land use plan as presented herein may be regarded as an "ultimate" plan, as well as a plan for the design year 2000. The demand for urban land will have to be satisfied primarily through the conversion of a large portion of the remaining agricultural and other open lands of the watershed from rural to urban uses. Such rural land uses may thus be expected to decline collectively from about 14.6 square miles in 1980 to about 3.5 square miles in the year 2000, a decrease of about 76 percent between 1980 and 2000. Under the land use plan, then, the Oak Creek watershed would take on an essentially fully developed character by the plan design year 2000.

In 1980, about 56 percent of the total area of the watershed and approximately 95 percent of the total resident population of the watershed were served by public sanitary sewerage facilities. By the plan design year, all the urban areas within the watershed are proposed to be served by public sanitary sewerage facilities.

Residential Land Use

As indicated in Table 78, about 5.35 square miles, or about 19 percent of the total area of the watershed, are presently devoted to residential use. About 5 square miles is proposed to be added to the existing stock of residential land in the watershed between the years 1980 and 2000. This new urban development is proposed to occur primarily at medium residential population densities, with lot sizes ranging from approximately 6,000 square feet to about one-half acre per dwelling unit, and with gross residential population densities ranging from about 3,300 to 9,200 persons per square mile.

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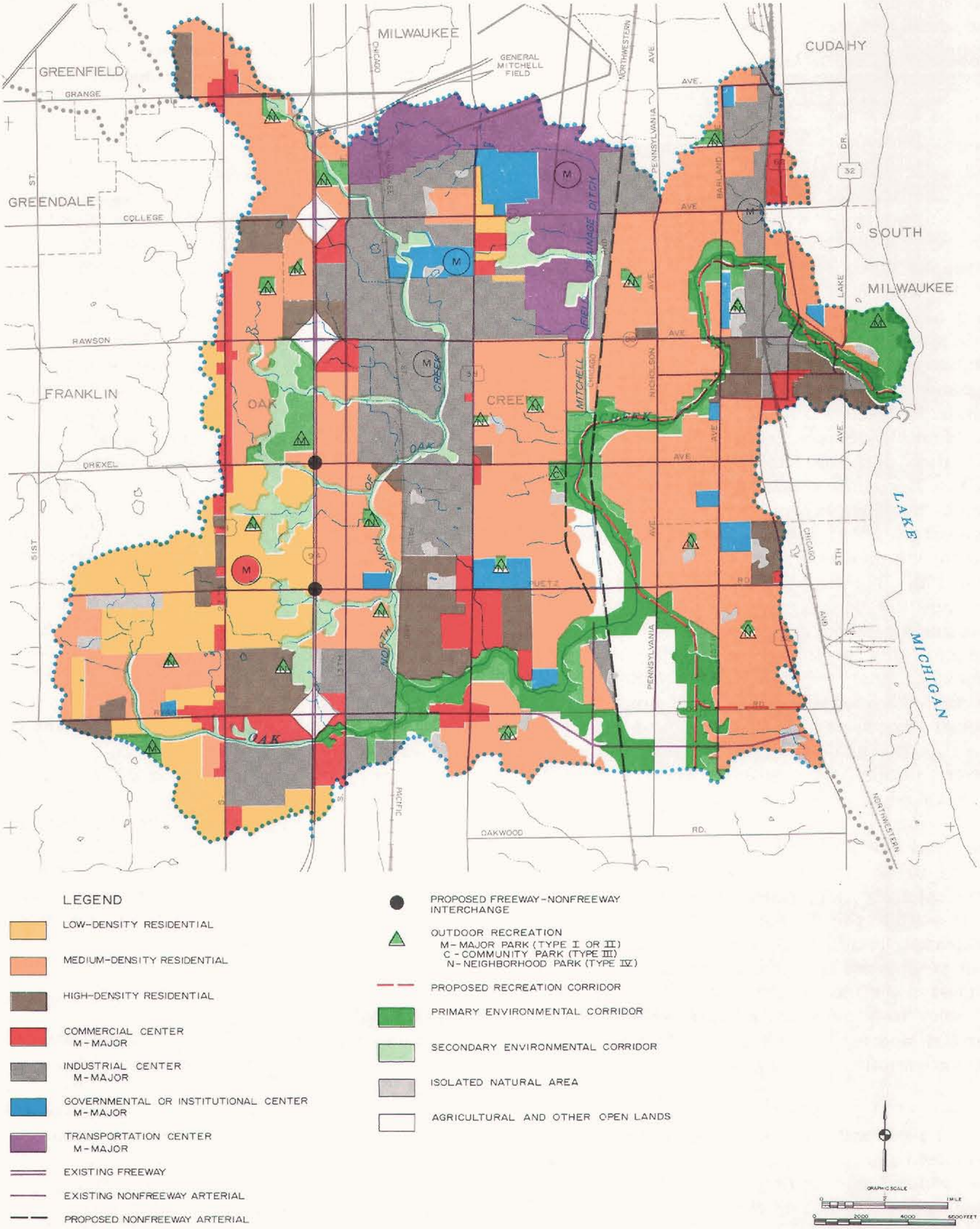
[2] *Local park and open space plans, as well as the local land use plans identified in footnote 1, were also utilized in the preparation of the park and open space element of the land use plan for the watershed. Such local plans included: City of Oak Creek Plan Commission, Practical Environmental Preservation, a revised parks master plan for the City of Oak Creek, 1980; and Milwaukee County Park Commission, Guide for Growth, 1978.*

Map 45

RECOMMENDED LAND USE AND PARK AND OPEN SPACE PLAN FOR THE OAK CREEK WATERSHED: 2000

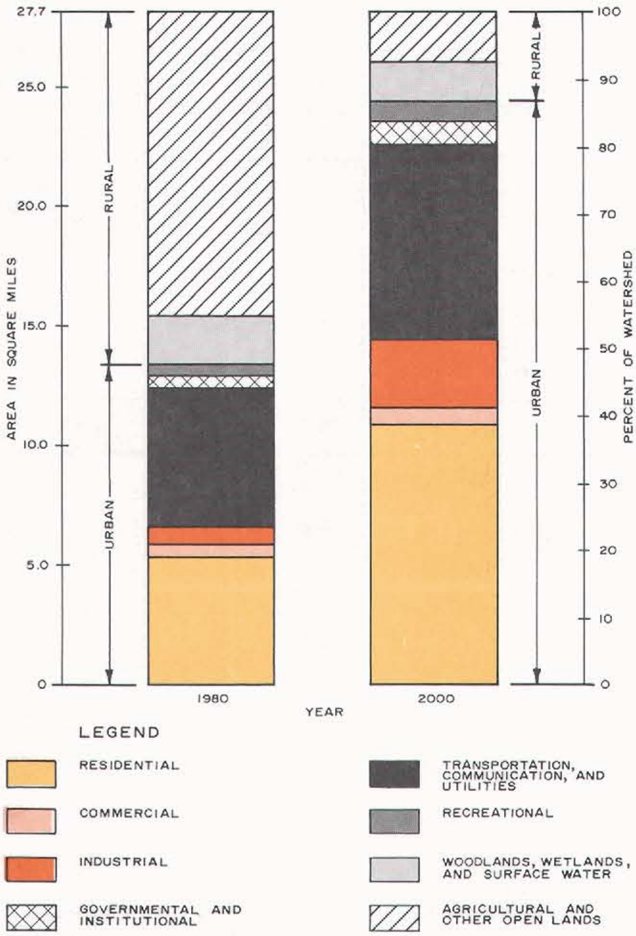


The regional land use plan for the year 2000 forms the recommended land use base for the Oak Creek watershed. The land use plan for the watershed would meet the social, physical, and economic needs of the future watershed population by allocating sufficient land to each of the various major land use categories to satisfy the known and anticipated demand for each use. About 13.2 square miles, or 47 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 the conversion of about 11.1 square miles of land to urban use by the year 2000. 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 Oak Creek watershed are the protection and preservation of important natural resource features, the restoration of wetlands within existing and proposed county-owned parkway lands, and the provision of additional park sites and facilities.

Source: SEWRPC.

Figure 51

EXISTING AND PROPOSED LAND USE
IN THE OAK CREEK WATERSHED



Source: SEWRPC.

Retail Service Land Use

In addition to neighborhood, community, and highway-oriented commercial areas, one regional commercial center—the Oak Creek Center—is proposed to be located in the watershed. Under the recommended land use plan, this center would be located between Puetz Road and Drexel Avenue west of IH 94 (see Map 45). Under the Oak Creek watershed plan, the total amount of land used for commercial purposes is proposed to be increased by about 0.82 square mile—from about 0.33 square mile in 1980 to about 1.15 square mile in 2000, an increase of about 248 percent.

Industrial Land Use

Land devoted to industrial activity would be located primarily in two regional industrial centers—the existing Cudahy-South Milwaukee regional industrial center located along and in the vicinity of the more easterly of the two Chicago & North Western Transportation Company railway lines through the watershed; and the Oak Creek regional industrial center proposed to be located south of General Mitchell Field near the intersection of IH 94 and Rawson Avenue (see Map 45). Under the Oak Creek watershed plan, the amount of land used for industrial purposes is proposed to be increased by 2.26 square miles—from 0.77 square mile in 1980 to 3.03 square miles in 2000, an increase of about 293 percent.

Governmental and Institutional Land Use

In addition to the neighborhood and the community governmental and institutional centers, one regional center—the Milwaukee Area Technical College south campus—is located in the watershed. This center is located north of Rawson Avenue and west of Howell Avenue in the north-central portion of the watershed (see Map 45). In addition, as indicated in Table 78, the land use plan envisions a total increase of approximately 0.19 square mile in governmental and institutional land uses, an increase of about 29 percent over the plan design period.

Transportation, Communication, and Utility Land Uses

Transportation and related activities are inherently large consumers of land and, along with residential lands, represent the most extensive type of urban development in the watershed. Under the adopted regional transportation plan, some additional major transportation facilities would be provided in the watershed by the plan design year 2000. A limited access surface arterial highway is proposed to be located along the more westerly of the two Chicago & North Western Transportation Company railway lines through the watershed. Two additional freeway interchanges along IH 94 in the watershed are proposed to be provided—one at Drexel Avenue and the other at Puetz Road. In addition, as shown on Map 45, other new arterial highway segments, including the relocation of a portion of STH 100, would be developed under the plan. A parkway drive is also proposed to be provided within and adjacent to Milwaukee County-owned parkway lands, ultimately providing a parkway drive connecting the Oak Creek Parkway in South Milwaukee to the Root River Parkway in Racine County. The remaining transportation lands proposed in the watershed would be provided to meet the need for additional land access, collector, and arterial streets to serve planned urban development to the design year. As

Table 78

EXISTING AND PROPOSED LAND USE IN THE OAK CREEK WATERSHED: 1980 AND 2000

Land Use Category	Existing 1980			Planned Increment		Total 2000		
	Area (square miles)	Percent of Major Category	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Major Category	Percent of Watershed
Urban								
Residential	5.35	40.6	19.3	5.02	93.8	10.37	42.7	37.4
Retail and Services	0.33	2.5	1.2	0.82	248.5	1.15	4.8	4.1
Industrial	0.77	5.8	2.8	2.26	293.5	3.03	12.5	10.9
Transportation, Communication, and Utilities	5.29	40.3	19.0	2.54	48.0	7.83	32.2	28.2
Governmental and Institutional	0.66	5.0	2.4	0.19	28.8	0.85	3.5	3.1
Recreational	0.77	5.8	2.8	0.28	36.4	1.05	4.3	3.8
Urban Total	13.17	100.0	47.5	11.11	84.4	24.28	100.0	87.5
Rural								
Woodlands, Wetlands, and Surface Water	2.06	14.1	7.4	-0.58	-28.2	1.48	42.8	5.3
Agricultural and Other Open Lands	12.51	85.9	45.1	-10.53	-84.2	1.98	57.2	7.2
Rural Total	14.57	100.0	52.5	-11.11	-76.2	3.46	100.0	12.5
Watershed Total	27.74	--	100.0	--	--	27.74	--	100.0

Source: SEWRPC.

indicated in Table 78, transportation, communication, and utility land uses in the watershed may be expected to increase by about 2.54 square miles, or by about 48 percent, over the plan design period.

Recreational Land Use

As indicated in Table 78, the plan envisions recreational land uses in the watershed to increase by about 0.28 square mile, or by 36 percent—from 0.77 square mile in 1980 to 1.05 square miles in 2000. One major undeveloped county-owned park—Falk Park—is located in the west-central portion of the watershed. In addition, small parts of two existing regional parks owned by Milwaukee County—Grant Park and Oakwood Park—are located within the watershed (see Map 45), and an undeveloped regional park owned by Milwaukee County—Bender Park—is located about one-half mile from the southeastern corner of the watershed on Lake Michigan in the City of Oak Creek. A more detailed description of recommended park and open space reservation and development actions is presented in a later section of this chapter.

Rural Land Uses

The recommended increases in urban land uses in the watershed would result in a corresponding decrease in rural land uses, including woodlands, wetlands, and agricultural and other open land. The existing stock of such land within the watershed would decrease significantly from about 14.57 square miles in 1980 to about 3.46 square miles in 2000. Thus, by the year 2000, only about 13 percent of the total area of the watershed would remain in rural land uses. As indicated in Table 78, woodlands, wetlands, and surface water combined covered a total of 2.06 square miles in the watershed in 1980. Generally, the Commission recommends that such natural resource features be preserved in natural open uses, especially when such features are located within the environmental corridors. However, certain commitments by local units of government within the watershed—including the loss of such lands envisioned on locally approved subdivision platting layouts and official maps, and in local zoning ordinances and zoning district maps—would result in the loss of about 0.58 square mile, or about 28 percent, of such lands in the watershed. The remaining 1.48 square miles would be preserved and protected in essentially natural open uses.

As further indicated in Table 78, there were about 12.51 square miles of agricultural and other open lands in the watershed in 1980. Of this total, about 10.53 square miles, or about 84 percent, would be converted to urban uses. As shown on Map 45, the remaining 1.98 square miles are located primarily in the southern and southeastern portion of the watershed and generally consist of lands used for agricultural purposes within the 100-year recurrence interval flood hazard area along Oak Creek.

OPEN SPACE PRESERVATION PLAN ELEMENT

The proposed land use plan for the Oak Creek watershed recommends the preservation in essentially natural, open uses of almost all of the environmental corridors and isolated natural areas remaining in the watershed. In addition, the plan recommends the restoration of wetland vegetation on certain lands currently used for agricultural purposes within existing and proposed county-owned parkway boundaries. The recommendations directed at the preservation of primary environmental corridors, secondary environmental corridors, and isolated natural areas, and at the restoration of wetlands in the watershed are presented below.

Primary Environmental Corridors

The existing primary environmental corridors in the Oak Creek watershed encompass about 447 acres, or about 3 percent of the total area of the watershed. In comparison, 17 percent of the Region is in primary environmental corridor. As indicated in Chapter III of this report, these corridors are located along the lower reaches of the main stem of Oak Creek in the City of South Milwaukee, and in an area encompassing a large concentration of wetlands and woodlands in the southeastern corner of the watershed in the City of Oak Creek. The existing Oak Creek Parkway encompasses a significant proporation of the existing primary environmental corridor lands in the watershed and serves to protect and preserve these lands. It is accordingly recommended that these public parkway lands, encompassing 229 acres, or 51 percent of primary envronmental corridors within the watershed, continue to be used for resource preservation and limited recreational purposes as indicated in Table 79. It is further recommended that an additional 188 acres, or an additional 42 percent, of the primary environmental corridor lands in the watershed be publicly acquired so that almost all of the remaining primary environmental corridor lands in the watershed would be protected through public ownership. About 30 acres, or about 7 percent of the existing environmental corridor lands, are proposed to be converted to urban use, reflecting committed local planning and zoning decisions. Of these 30 acres, five acres, or about 17 percent, are wetlands. Such wetlands are all located outside state-identified shoreland and floodplain areas, and thus are not subject to regulation under Chapter NR 117 of the Wisconsin State Statutes. The additional 188 acres of the existing primary environmental corridor lands would be acquired for public use over the plan design period at an estimated cost of $500,000, expressed in 1980 dollars. Actual costs of acquisition of the corridor lands could be expected to range from about $500 per acre for wetlands to about $14,000 per acre for uplands.

As further indicated in Table 79, it is recommended that certain lands owned by Milwaukee County and lands proposed to be acquired by the County as part of the Oak Creek Parkway be restored to wetland vegetation, thereby restoring and re-creating primary environmental corridor lands. Specifically, all those lands located within the 100-year recurrence interval flood hazard area along Oak Creek and certain adjacent lands covered by soils characteristic of wetlands within the existing or proposed parkway boundaries, including lands currently classified as secondary environmental corridors and isolated natural areas, are recommended to be so restored. Under this proposal, about 258 acres of secondary environmental corridor—204 acres currently in public ownership and 54 acres proposed for public acquisition—would be converted to primary environmental corridor. In addition, 12 acres of isolated natural area lands—4 acres currently in public ownership and 8 acres proposed for public acquisition—would be converted to primary environmental corridor. Finally 309 acres of other open lands—249 acres currently in public ownership and 60 acres proposed for public acquisition—would be converted to primary environmental corridor under this proposal. In total, 579 acres—including 457 acres of existing county-owned lands and 122 acres of lands proposed for county ownership—would be restored to primary environmental corridor. The

Table 79

EXISTING AND PROPOSED ENVIRONMENTAL CORRIDORS, ISOLATED NATURAL AREAS, AND OTHER OPEN LANDS IN THE OAK CREEK WATERSHED: 1980-2000

Classification and Status of Open Lands	Primary Environmental Corridor (acres)			Secondary Environmental Corridor (acres)			Isolated Natural Areas (acres)			Other Open Lands[a] (acres)		
	Public	Private	Total	Public	Private	Total	Public	Private	Total	Public	Private	Total
Existing 1980 Area	229	218	447	320	832	1,152	43	179	222	274	977	1,251
Proposed Changes to Open Lands: 1980-2000												
Areas Proposed to be Converted to Urban Uses (local planning and zoning decision).		-30	-30		-188	-188		-32	-32	-25	-385	-410
Primary Environmental Corridors Proposed for Public Acquisition	+188	-188	--									
Secondary Environmental Corridors Proposed to be Converted to Primary Environmental Corridors . .	+258	--	+258	-204	-54	-258						
Isolated Natural Areas Proposed to be Converted to Primary Environmental Corridors	+12		+12				-4	-8	-12			
Other Open Lands Proposed to be Converted to Primary Environmental Corridors	+309		+309							-249	-60	-309
Secondary Environmental Corridors Proposed to Converted to Isolated Natural Areas.					-64	-64		+64	+64			
Total Year 2000 Area	996	--	996	116	526	642	39	203	242	--	532	532

[a]*Lands located within the 100-year recurrance interval flood hazard area and/or covered by soils poorly suited to urban development even with public sanitary sewer service.*

Source: SEWRPC.

122 acres proposed for county ownership would be acquired over the plan design period at an estimated cost of $440,000, expressed in 1980 dollars.

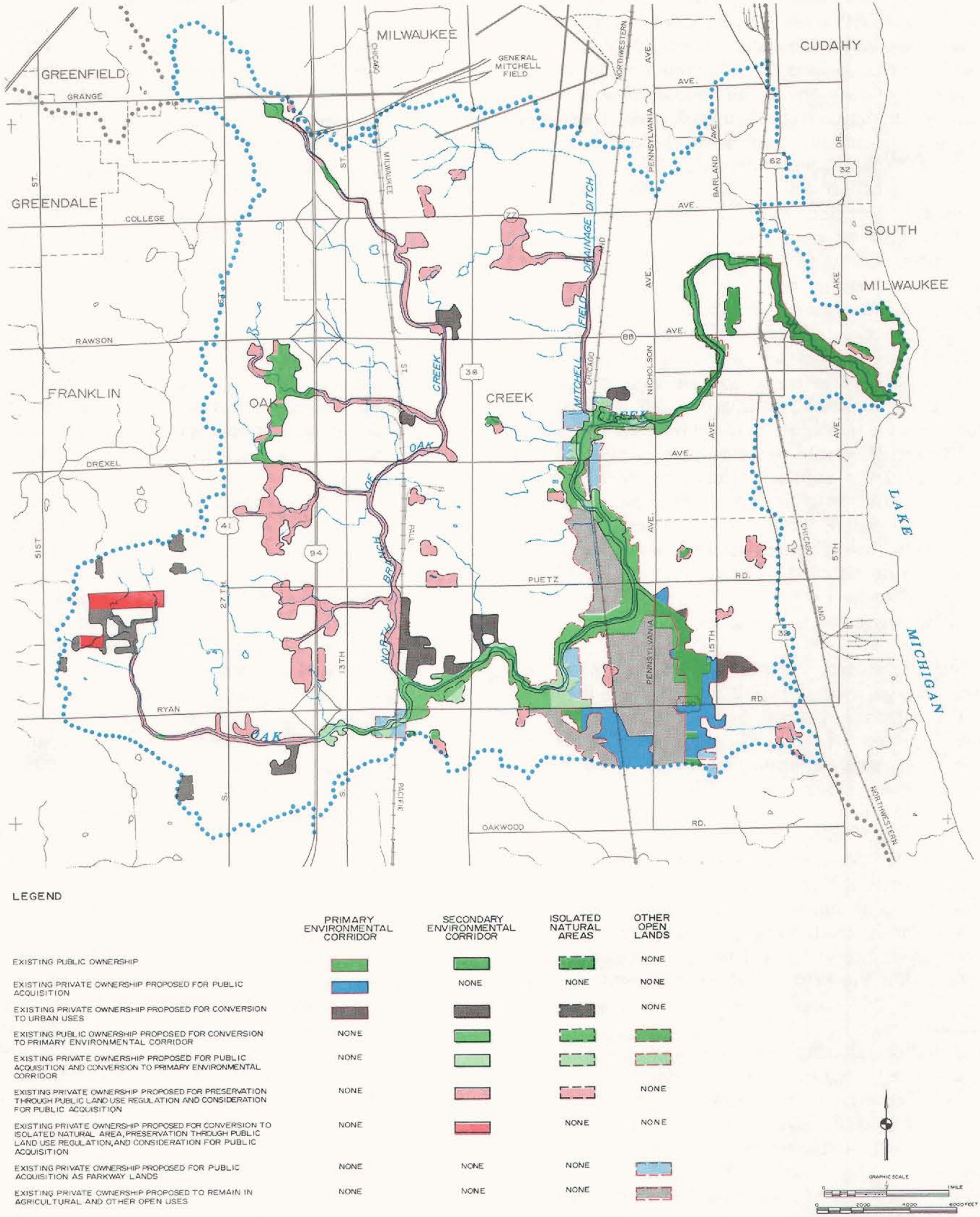
As indicated in Table 79, a total of 996 acres, or almost 6 percent of the total area of the watershed, would be encompassed within the primary environmental corridors by the plan design year. All of this corridor area would be protected by public ownership. Of this total, 229 acres, or 23 percent, were primary environmental corridors in 1980 and were owned as public parkway; 188 acres, or 19 percent, were primary environmental corridors in 1980 and were proposed for preservation through acquisition for public parkway purposes; and 579 acres, or 58 percent, were areas subject to flood hazard or covered by soils poorly suited to any urban use located within existing or proposed county-owned parkway lands and proposed for restoration to primary environmental corridor (see Maps 45 and 46).

Secondary Environmental Corridors

The existing secondary environmental corridors in the Oak Creek watershed are located along the upper reaches of the main stem of Oak Creek upstream from the primary environmental corridors along Oak Creek, along the North Branch of Oak Creek, and along several intermittent streams tributary to Oak Creek and the North Branch of Oak Creek. It is recommended that the secondary environmental corridor lands which are presently held in public park and open space use be maintained in such ownership. Those secondary environmental corridor lands not presently held in public park and related open space use are recommended to be considered for preservation and protection through interim land use regulation and ultimate public acquisition in open uses as may be needed for local parks, drainageways, and stormwater detention or retention basins. It is important to note in this respect that, in urban areas, secondary environmental corridor lands may serve as particularly suitable locations for these uses. Thus, public acquisition of secondary environmental corridor lands may be appropriate, particularly when the opportunity is presented to incorporate such corridors into urban stormwater detention areas, associated drainageways, and neighborhood parks.

Map 46

EXISTING AND PROPOSED ENVIRONMENTAL CORRIDORS, ISOLATED NATURAL AREAS, AND OTHER OPEN LANDS IN THE OAK CREEK WATERSHED: 1980-2000



The land use plan for the Oak Creek watershed recommends the protection and preservation of the important remaining natural resource features in the watershed, especially those features within the primary environmental corridors. In addition, the plan recommends the restoration of wetlands within existing and proposed county-owned parkway lands. Specifically, of the 447 acres of primary environmental corridors existing in the watershed in 1980, about 30 acres, or about 7 percent, would be converted to urban uses, reflecting committed local planning and zoning decisions, while the remaining 417 acres, or about 93 percent, would be preserved in natural open uses. In addition, about 579 acres of open land subject to flood hazard within existing or proposed county-owned parkway lands would be restored to wetlands and reclassified as primary environmental corridor. Thus, by the plan design year 2000, 996 acres, or about 6 percent of the watershed, would be encompassed within the primary environmental corridors. In addition, by the plan design year 2000, 642 acres, or about 4 percent of the watershed, would be encompassed within secondary environmental corridors, and 242 acres, or about 1 percent of the watershed, would be encompassed within isolated natural areas.

Source: SEWRPC.

As shown in Table 79, of the 1,152 acres of secondary environmental corridors in the watershed, about 320 acres, or 28 percent, were held in public park and open space uses in 1980. As in the case of the primary environmental corridors, certain secondary environmental corridor lands are proposed to be converted to urban uses in order to recognize local planning and zoning decisions. Under the Oak Creek watershed plan, then, about 188 acres, or 16 percent of the secondary environmental corridors existing in the watershed in 1980, would be converted to urban uses by the year 2000. Of these 188 acres of secondary environmental corridor proposed to be converted to urban use, 30 acres, or about 16 percent are wetlands. Six acres, or about 3 percent, of such wetlands are located within state-identified shoreland or floodplain areas, and thus are subject to regulation pursuant to Chapter NR 117 of the Wisconsin State Statutes. The remaining 644 acres, or 56 percent, would be initially protected through public land use regulation, and, as more detailed drainage and neighborhood unit planning and design proceeded, would be considered for public acquisition through purchase and/or dedication. If in such more detailed planning such corridor lands are found to be not needed for a public use, they could be converted to urban use.[3]

As already noted, certain existing and proposed park and parkway lands located within the 100-year recurrence interval flood hazard area or in areas covered by soils characteristic of wetland vegetation and adjacent to lands classified as secondary environmental corridors are proposed to be restored to wetland vegetation. The restored wetlands and adjacent secondary environmental corridors would meet the size, length, and natural resource criteria for primary environmental corridors. Thus, as indicated in Table 79, about 258 acres of lands classified as secondary environmental corridors in the watershed in 1980—including 204 acres within the existing Milwaukee county-owned Oak Creek Parkway and 54 additional acres on other lands proposed for county acquisition in the watershed—would be reclassified as primary environmental corridors as a result of the wetlands restoration effort. As further indicated in Table 79, about 64 acres, or about 5 percent of the existing secondary environmental corridors in the watershed, would be converted to isolated natural areas, reflecting local planning and zoning decisions. Finally, then, a total of 642 acres, or about 4 percent of the watershed, would be encompassed within secondary environmental corridors by the plan design year (see Maps 45 and 46).

Isolated Natural Areas

In addition to the primary and secondary environmental corridors, other, smaller concentrations of natural resource base elements exist within the watershed. These concentrations are isolated from the remaining environmental corridors by urban development or agricultural uses, and, although separated from the environmental corridor network, may have important natural values. It is recommended that such areas be preserved in essentially natural, open uses to the extent practicable. Those isolated natural areas currently held in public outdoor recreation and open space use are recommended to be maintained in such use, while the remaining isolated natural areas are recommended to be protected through public land use regulation. It is important to note that in urban areas these isolated natural areas may serve as particularly suitable locations for local urban park and open space lands; and public acquisition of isolated natural areas may be appropriate, particularly when the opportunity is presented to incorporate such areas into urban drainageways, stormwater retention or detention areas, or neighborhood parks. As indicated in Table 79, of the 222 acres of isolated natural areas in the watershed in 1980, 43 acres, or 19 percent, were held in public ownership, and the remaining 179 acres, or 81 percent, were in private ownership. As further indicated in Table 79, 32 acres, or 14 percent of the existing isolated natural areas, are proposed to be converted to urban use, reflecting local planning and zoning decisions. It should be noted that none of the 32 acres of isolated natural areas proposed to be converted to urban use are wetlands. In addition, as previously noted, about 64 acres of secondary environmental corridor would be converted to isolated natural area land and 12 acres of isolated natural area land would be converted to primary environmental corridor under the plan. As indicated in Table 79, then, about 242 acres, or about 1 percent of the watershed, would be

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[3] *Milwaukee County has an ongoing program of adjusting county park boundaries by selling "excess" county park or parkway lands which are determined to be not needed for recreational or environmental preservation purposes. The sale of such lands would not be considered to conflict with this watershed plan provided that such lands are not needed for county park or parkway purposes and do not contain significant natural resource features such as woodlands, wetlands, or floodland areas.*

encompassed within isolated natural areas by the plan design year. These lands would be initially protected through public land use regulation, and, as more detailed drainage and neighborhood unit planning and design proceeded, would be considered for public acquisition through purchase and/or dedication. If in such more detailed plans such areas are found to be not needed for a public use, they could be converted to urban use (see Maps 45 and 46).

Other Open Lands

There are large areas of land in the watershed located within the 100-year recurrence interval flood hazard area and/or covered by soils characteristic of wetlands; such areas are poorly suited to urban use even with sanitary sewer service. As indicated in Table 79, these areas encompassed about 1,251 acres in 1980. Under the Oak Creek watershed plan, about 410 acres, or 33 percent of these lands, would be converted to urban use in order to recognize local planning and zoning decisions, and, as previously noted, 309 acres, or 25 percent, would be converted to primary environmental corridor. The remaining 532 acres, or 42 percent of such lands, are proposed to remain in agricultural and other private open uses (see Maps 45 and 46).

OUTDOOR RECREATION PLAN ELEMENT

The outdoor recreation plan element of the Oak Creek watershed plan is composed of: 1) a resource-oriented outdoor recreation component containing recommendations concerning the number and location of large parks and recreation corridors; and 2) an urban-oriented outdoor recreation component containing recommendations to guide the public provision of needed local parks.

Large Parks and Recreation Corridors

Type I and Type II parks are defined by the Commission as large, public, general-use outdoor recreation sites which provide opportunities for such activities as camping, golfing, picnicking, and swimming; which have a large area; and which contain significant natural resource amenities. Type II parks are defined to range in area from 100 to 249 acres, while Type I parks are 250 acres or larger 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 more limited variety of recreational facilities than do Type I parks and have a smaller area devoted to any given activity.

In 1980 there were two Type I parks located partially within the watershed: Grant Park and Oakwood Park. As shown on Map 45, Grant Park is located in the City of South Milwaukee on the eastern border of the watershed, and Oakwood Park is located in the City of Franklin on the southwestern border of the watershed. The plan recommends the continued maintenance of these sites. In addition, it is recommended that Falk Park, a 216-acre undeveloped site owned by Milwaukee County, be developed as a Type II park as the need becomes evident. Under this proposal, a variety of facilities for resource-oriented activities would be provided at an estimated cost of $250,000. The plan also recommends the completion of the acquisition of the Oak Creek Parkway. As already noted, about 310 acres of primary environmental corridor lands currently held in private ownership are proposed for county acquisition as part of the Oak Creek Parkway—including 188 acres of lands classified as primary environmental corridors in 1980 and 122 acres of land proposed to be acquired, restored to wetlands during the plan implementation period, and reclassified as primary environmental corridors. In addition, under the plan about 86 acres of open lands would be acquired for parkway purposes at an estimated cost of $430,000. These lands have been proposed for acquisition by Milwaukee County to effect complete parkway development.

A recreation corridor is defined by the Commission as a publicly owned ribbon of land at least 15 miles long located through areas of scenic, scientific, historic, or natural interest that contains trails marked and maintained for such activities as hiking and biking. As shown on Map 45, a recreation corridor segment is proposed to be located along the main stem of Oak Creek from its mouth at the eastern end of the watershed upstream a distance of about seven miles, and would connect with a recreation corridor proposed to be located along the Root River in Milwaukee and Racine Counties. In addition, a one-mile recreation corridor segment would link the Oak Creek recreation corridor to Bender Park. Thus, approximately eight miles of recreation corridor providing trails for such activities as hiking and biking would be provided within the Oak Creek watershed at an estimated development cost of $180,000. It should be noted that the recreation corridor segments would be located primarily within the county-owned Oak Creek Parkway or on lands proposed for county acquisition under the open space preservation plan; therefore, no additional land acquisition costs would be incurred for the provision of these recreational facilities.

Urban Parks and Facilities

In contrast to Type I and Type II parks, Type III and Type IV general-use outdoor recreation sites depend more upon the characterists of the urban area to be served than on the underlying natural resource base amenities. Type III general-use sites, by definition, range in size from 25 to 99 acres, while Type IV general-use sites are 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, 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.

In 1980, there was one Type III general-use outdoor recreation site located within the watershed—Abendschein Park, a 53-acre site owned by the City of Oak Creek (see Map 45) providing a hardball diamond and playfield area. Under the outdoor recreation plan element, additional outdoor recreation facilities would be provided at this site. As shown on Map 45, there were two fully developed Type IV parks in the watershed—Carrollton Park, owned by the City of Oak Creek and Rawson Park, owned by Milwaukee County and located in the City of South Milwaukee—and eight Type IV parks proposed for additional development in the watershed. Six of these sites—Chapel Hills Park, Green Lawn Park, Manor Marquette Park, Miller Park, Shepard Hills Park, and Willow Heights—are owned by the City of Oak Creek. The other two undeveloped Type IV sites—Johnstone Park and an as yet unnamed county park site known as Park Site No. 65—are located in the City of Oak Creek and owned by Milwaukee County. Under the outdoor recreation plan element, the two developed Type IV parks would be maintained for outdoor recreation use, while additional outdoor recreation facilities would be provided at the eight undeveloped Type IV parks in the watershed as the need becomes evident. As shown on Map 45, the outdoor recreation plan element recommends the provision of four additional park sites in the Oak Creek watershed. These sites would be located in the southwestern portion of the watershed—one in the City of Franklin and three in the City of Oak Creek—in areas proposed to be converted to urban development by the plan design year 2000. The total acquisition cost of these parks and of the proposed acquisition of additional land at an existing park is estimated at $480,000.

The regional park and open space plan also includes recommendations concerning the type and quantity of urban outdoor recreation facilities which should be provided to meet the existing and probable future recreation needs of residents of urban areas. In comparison to the resource-oriented recreation sites and facilities, nonresource-oriented facilities—including baseball diamonds, basketball courts, ice skating rinks, playfields, playgrounds, softball diamonds, and tennis courts—rely less heavily on natural resource amenities; generally serve a larger number of people; are provided 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 Oak Creek watershed would be developed on existing or proposed additional Type III and Type IV parklands. Although the type and quantity of these facilities proposed for the watershed would be determined through a joint effort by the school districts and local community recreation agencies based on a more detailed study of community and neighborhood needs, facility development costs were estimated using the regional park and open space plan. The total cost of urban park facility development in the Oak Creek watershed is estimated at $1,268,000. This estimate includes the development costs for intensive nonresource-oriented facilities—for example, restroom facilities and parking spaces—directly related to the recommended facilities for the one Type III, eight undeveloped, and four proposed new Type IV sites within the watershed.

SUMMARY

This chapter has presented a recommended land use plan and park and open space plan for the watershed. The salient recommendations of these plan elements may be summarized as follows:

1. Under the recommended land use plan, the amount of land devoted to urban use within the watershed would increase from the 1980 total about 13.2 square miles, or about 47 percent of the total area of the watershed, to about 24.3 square miles, or about 87 percent of the total area of the watershed, by the plan design year 2000. About 5.0 square miles, or about 45 percent of the 11.1-square-mile increase in urban lands anticipated in the watershed, would be devoted to the residential land

uses; while 2.5 square miles, or about 23 percent of the anticipated increase in urban land, would be devoted to transportation, communication, and utility uses, and 2.3 square miles, or about 21 percent, would be devoted to industrial land uses. The remaining 1.3 square miles, or about 11 percent of the 11.1-square-mile increase in urban land uses anticipated, would be devoted to retail, service, governmental, institutional, and recreational land uses. Thus, in the plan design year, residential land uses would comprise 10.4 square miles, or about 37 percent of the total area of the watershed; transportation, communication, and utility uses 7.8 square miles, or about 28 percent; industrial land uses 3.0 square miles, or about 11 percent; retail and service uses 1.2 square miles, or about 4 percent; governmental and institutional uses 0.9 square mile, or about 3 percent; and park and outdoor recreational uses 1.0 square mile, or about 4 percent.

2. The increase in urban land uses in the watershed by the plan design year 2000 would result in a corresponding decrease in rural land uses. Under the recommended land use plan for the watershed, the existing stock of rural land would decrease from 14.6 square miles, or 53 percent of the total area of the watershed, in 1980, to about 3.5 square miles, or 13 percent of the total area of the watershed, in the plan design year 2000. About 10.5 square miles, or 94 percent of the 11.1-square-mile decrease in rural land uses anticipated in the watershed, would be converted through the conversion of agricultural and other open lands to urban uses. About 0.6 square mile, or about 6 percent of the 11.1-square-mile decrease in rural land, would be converted through the conversion of woodland or wetland areas to urban uses. Thus, in the plan design year, agricultural and other open lands would comprise 2.0 square miles, or about 7 percent of the total area of the watershed; and woodlands, wetlands, and surface water 1.5 square miles, or about 6 percent of the total area of the watershed.

3. Primary environmental corridors in the Oak Creek watershed encompassed 447 acres, or about 3 percent of the total area of the watershed, in 1980. Under the watershed plan about 30 acres, or about 7 percent, of the existing primary environmental corridor lands would be converted to urban uses, reflecting committed local planning and zoning decisions; while 579 acres of land subject to flood hazard and covered by soils poorly suited to urban uses and located within existing or proposed county-owned parkway lands—including 258 acres of land currently classified as secondary environmental corridor, 12 acres of land currently classified as isolated natural areas, and 309 acres of other open lands—would be restored to wetlands and reclassified as primary environmental corridors. Thus, by the plan design year 2000, 996 acres, or about 1.5 square miles—about 6 percent of the total area of the watershed—would be encompassed within primary environmental corridors. The plan further recommends that the 310 acres of existing or proposed primary environmental corridors currently in private ownership be acquired for public use. Such lands would be acquired over the plan design period at an estimated cost of $940,000, expressed in 1980 dollars.

4. Secondary environmental corridors in the watershed encompassed 1,152 acres, or about 6 percent of the total area of the watershed, in 1980. Under the watershed plan about 188 acres, or 16 percent, of the existing secondary environmental corridor lands would be converted to urban uses, reflecting committed local planning and zoning decisions; while 258 acres of such lands would be converted to primary environmental corridors and 64 acres would be converted to isolated natural areas. Thus, by the year 2000, 642 acres, or almost 4 percent of the total area of the watershed, would be encompassed within secondary environmental corridors. The remaining secondary environmental corridors should initially be protected through public land use regulation. If, as more detailed drainage and neighborhood unit planning and design proceed, such corridors are found to be needed for urban stormwater retention or detention areas, associated drainageways, and neighborhood parks, they should be acquired through purchase or dedication. If such corridor

lands are found to be not needed for public purposes, they may be converted to urban use.

5. Isolated natural areas within the watershed encompassed 222 acres, or about 1 percent of the total area of the watershed, in 1980. Under the watershed plan about 32 acres, or 14 percent, of existing isolated natural area lands would be converted to urban uses, reflecting committed local planning and zoning decisions; while 12 acres of such lands would be converted to primary environmental corridors. Over the plan design period, 64 acres of secondary environmental corridors would be converted to isolated natural areas. Thus, by the plan design year 2000, about 242 acres, or about 1 percent of the total area of the watershed, would be encompassed within isolated natural areas. The remaining isolated natural areas should initially be protected through public land use regulation. If, as more detailed drainage and neighborhood unit planning and design proceed, such areas are found to be needed for urban stormwater retention or detention areas, associated drainageways, and neighborhood parks, they should be acquired through purchase or dedication. If such areas are found to be not needed for public purposes, they may be converted to urban use.

6. Of those lands located in primary environmental corridors and proposed to be converted to urban use, about five acres, or about 17 percent, consist of wetlands. Of those lands located in secondary environmental corridors and proposed to be converted to urban use, about 30 acres, or about 16 percent, consist of wetlands. None of the isolated natural areas proposed to be converted to urban use contain wetlands. Of the wetland areas proposed to be converted to urban use, only six acres, or about 17 percent, are located within shoreland or floodland areas and are thus subject to regulation pursuant to Chapter NR 117 of the Wisconsin Statutes.

7. Other open lands in the watershed—that is, lands located within the 100-year recurrence interval flood hazard area and/or covered by soils poorly suited for urban uses—encompassed 1,251 acres, or about 7 percent of the total area of the watershed, in 1980. Under the watershed plan about 410 acres, or 33 percent of such open lands, would be converted to urban uses, reflecting committed local planning and zoning decisions; while 309 acres of such lands would be converted to primary environmental corridor lands. Thus, by the year 2000, about 532 acres, or about 3 percent of the total area of the watershed, would be encompassed in other open lands.

8. Portions of two parks of areawide significance—Grant Park and Oakwood Park—were located within the watershed in 1980. The watershed plan recommends the continued maintenance of these parks, as well as the development of one additional major park—Falk Park, a 216-acre undeveloped park site owned by Milwaukee County. The plan also recommends the public acquisition of about 86 acres of open lands for parkway purposes, and the provision of eight miles of recreational corridor lands to provide opportunities for hiking, biking, and ski touring activities within the watershed. The total cost for the development of the major park site, acquisition of additional parkway lands, and provision of recreational corridors would be about $860,000, expressed in 1980 dollars.

9. In 1980 three neighborhood and community parks—Abendschein, Carrollton, and Rawson Parks—were located in the watershed. The watershed plan recommends the continued maintenance of these parks, as well as the provision of outdoor recreation facilities at eight publicly owned, but as yet undeveloped, neighborhood parks in the watershed. The plan also recommends the acquisition and development of four additional neighborhood park sites within the watershed. The total acquisition and development costs of such neighborhood and community parks, including the park support facilities such as restrooms and parking, would be about $1,748,000, expressed in 1980 dollars.

The watershed land use plan would 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 plan seeks to protect and enhance the natural resource base of the watershed by allocating new urban development only to those areas that are covered by soils well suited to such development; that are not subject to special hazards such as flooding; and that can be readily provided with gravity drainage sanitary sewer, public water supply, and urban mass transit services. Adoption and implementation of this plan element would promote the wise use of the natural resource base, preserve the cultural heritage and natural beauty of the watershed, and help to enrich the physical, intellectual, and spiritual development of the resident population, as well as avoid the intensification of existing developmental and environmental problems, such as flooding and water pollution or the creation of new problems of this type. The plan will also permit the design of surface water quality management and drainage and flood control facilities to proceed on a sound basis within the watershed.

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Chapter XII

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES

INTRODUCTION

The inventory and analysis phases of the Oak Creek watershed planning program identified certain water resource and related problems, including flooding and water pollution. As stated in Chapter I, the primary purpose of the Oak Creek 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, more attractive, and more economic pattern. This pattern should be properly related to the underlying and sustaining natural resource base so as to avoid the intensification of existing and the creation of new developmental and environmental problems in the watershed.

The purpose of this chapter is to present alternative floodland management measures from which a recommended floodland management plan for the watershed can be synthesized. The structural and nonstructural floodland management alternatives described herein should be considered as adjuncts to the basic land use development proposals advanced in Chapter XI, and were designed 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 alternative is subjected to several levels of review and evaluation, including technical, economic, financial, legal, and administrative feasibility and political acceptability. 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 planned land use changes. Alternative structural floodland management measures are then described for the various stream reaches of the watershed. Bridge and culvert alteration or replacement for transportation purposes throughout the watershed is discussed, followed by a description of the 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 needs and other socioeconomic needs of the resident population of a watershed. Floodland management is intended to eliminate loss of life, lessen danger to human health and safety, minimize monetary damage to private and public property, reduce the cost of utilities and services, and minimize disruption in community affairs. A broader goal is the enhancement of the overall quality of life of the watershed residents by the protection of those environmental values—recreational, aesthetic, ecological, and cultural—normally associated with, and concentrated in, riverine areas.

The 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 Oak Creek watershed is specifically intended to achieve the land use development, sanitary sewerage system development, and water control facility development objectives and their supporting standards as set forth in Chapter X.

The techniques of floodland management may be broadly divided into two categories—structural measures and nonstructural measures. Structural measures include floodwater storage facilities such as reservoirs and impoundments; diversion facilities such as dikes and channels; 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 conservation, recreation, and other open space uses; floodland use regulations; land use controls outside the floodlands; structure floodproofing; structure removal; channel maintenance; flood insurance; lending institution policies; realtor policies; community utility policies; and emergency programs. Table 80 lists the structural and nonstructural floodland management measures which may apply, individually or in combinations, to the stream network of the Oak Creek watershed, and summarizes the 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, being preventative, are generally more effective in riverine areas that have not yet been converted to flood damage-prone development even though they have the potential for such development.

Structural Measures

Each of the five structural floodland management measures set forth in Table 80 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 either to detain floodwaters upstream of flood-prone areas for subsequent gradual release—as is the case with a detention pond—or to retain floodwaters for gradual release and evaporation or for groundwater recharge—as is the case with a retention pond—thereby substantially decreasing downstream discharges and flood stages and associated flood damages. A key factor in the application of this alternative is the existence of sites having sufficient floodwater storage volume upstream of all, or a significant portion of, the flood-prone riverine areas, and which thereby can 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, 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 is their potential for mitigating flooding in several downstream reaches, in contrast with most other structural floodland management measures which provide only 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, the large land area required, the potentially adverse water quality conditions within the impoundment, and the false sense of security regarding 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 the subwatershed and, despite the legal problems that may be involved, outside the 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. 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.

Table 80

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES CONSIDERED IN THE OAK CREEK WATERSHED PLANNING PROGRAM

Alternative		Function	Comment
Major Category	Name		
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 by use 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, or, to control selected practices by which existing urban or rural lands are managed	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	- -
	Community education programs	To inform and educate citizens regarding personal and private actions by property owners and residents which 1) may adversely affect flood flows and stages or 2) could favorably affect or prevent changes in flood flows and stages in the watershed	May have relationship to aesthetic, recreational, urban utility, or water quality aspects of water resources management in the watershed
	Flood insurance	To minimize monetary loss or reduce monetary impact on structure owner	Premiums may be subsidized or actuarially determined

Table 80 (continued)

Alternative		Function	Comment
Major Category	Name		
Nonstructural (continued)	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 tiles; 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

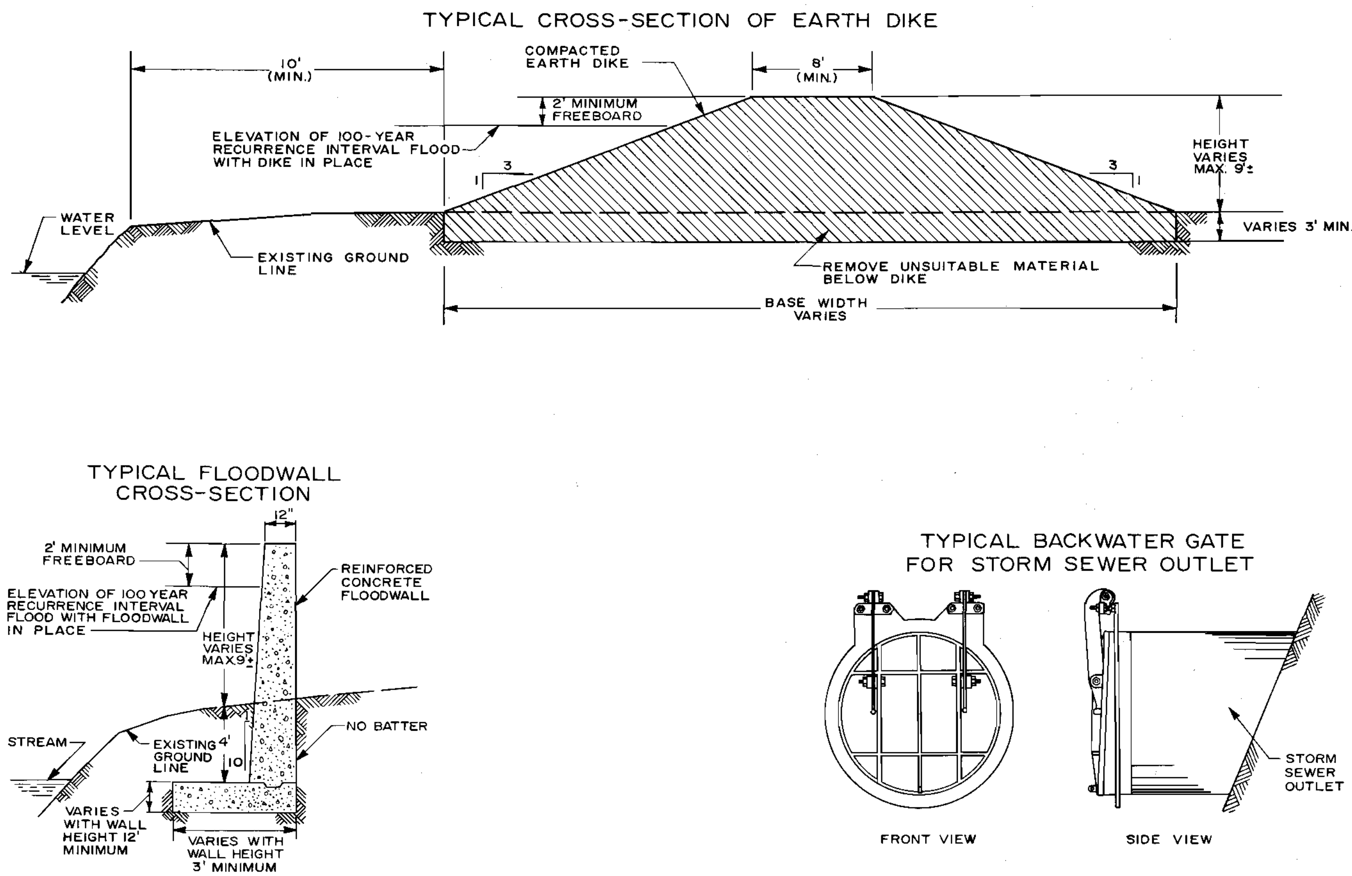
Source: SEWRPC.

Dikes and Floodwalls: Earthen dikes and concrete or sheet steel floodwalls, like those shown in Figure 52, 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 than the former.

In order to be effective in reducing flooding, dikes and floodwalls must normally be supplemented by the installation of backwater gates—at elevations approximating the 100-year recurrence interval river flood stage—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. A stormwater drainage system, which typically includes street stormwater inlets and storm sewer outfalls, normally provides for the conveyance of stormwater runoff from developed urban areas to a recovery stream. During major flood events, however, high river levels may in some areas reverse the operation of the stormwater drainage system, thus negating its function, and resulting in the movement of floodwaters from the river into developed riverine areas, thereby producing unwanted inundation and attendant monetary damages and inconvenience. Backwater gates prevent such flow reversal by functioning as valves that normally pass the stormwater 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.

Figure 52

TYPICAL EARTH DIKE, CONCRETE FLOODWALL, AND BACKWATER GATE



Source: SEWRPC.

While backwater gates, operating as described above, will prevent the movement of floodwaters from the river, they may, depending on topographic conditions, create local flooding problems attributable to the accumulation of stormwater runoff which does not have access to the river because of the closed storm sewer outfall. Areas susceptible to this problem may be protected through the provision of temporary or permanent pumping facilities to convey the impounded stormwater 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 higher than the "natural" condition stage as a result of the lateral constriction imposed on the stream by the dikes and floodwalls, and this design-condition stage 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 of protecting development from flood inundation by local action. It must be recognized, however, that there are serious negative aspects of dikes and floodwalls, including the potential for increasing upstream flood stages as a result of the hydraulic constriction imposed on the stream, and the possibility that a series of successive dike-floodwall projects along a stream may substantially reduce the natural floodwater storage capability of the river reach and thereby increase downstream discharges and associated stages. Other significant negative characteristics of dikes and floodwalls include the potentially high capital costs; the potentially high aesthetic cost, or penalty, normally associated with the placement of these high, long structures in the riverine areas, particularly if the areas protected are devoted primarily to residential land use; and the false sense of security against flood dangers that may be engendered by the presence of the dikes or floodwalls.

Channel Enclosure and Modification: Channel enclosure refers to the installation of large underground conduits along or near the alignment of major stream reaches intended to convey floodwaters through an area so as to substantially reduce overland flooding and sanitary sewer backup. 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: 1) straightening, deepening, and widening; 2) placement of a concrete invert and partial sidewalls; and 3) 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 meandering loops—of the existing channel. 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 intensive 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 stormwater runoff to the relocated channel.

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 application of this 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 the 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 action can be taken locally to provide relief to a flood-prone area. Significant negative features include negative environmental impacts, including aesthetic impacts, maintenance, and the possibility of aggravating downstream discharges and stages resulting from the loss of floodwater storage capacity in a long channelized or enclosed reach.

Bridge and Culvert Alteration or Replacement: Existing or new highway and railway bridges and culverts, or modifications to existing bridges and culverts, may, by virtue of the conveyance provided, significantly affect upstream and downstream flood stages and aggravate existing, or create new, flood hazards. Futhermore, increased regulatory flood stages attendant to bridge and culvert construction or reconstruction must be 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 transportation system by inundating highways or railway bridges or their approaches, thereby rendering the facilities impassable during major floods.

The purpose of bridge and culvert removal, alteration, or replacement is to avoid or minimize the adverse effects of bridges and culverts on floodflow characteristics and the adverse effects of flood flows on the functioning of the related transportation facilities. These adverse effects are eliminated by increasing the size of the waterway opening or otherwise substantially altering the crossing, or by replacing it. The usefulness of this structural alternative in a watershed is contingent upon identifying those bridges and culverts that produce major backwater effects as a result of 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 most cases 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 system maintenance and improvement process.

Nonstructural Measures

Each of the 12 nonstructural floodland management measures presented in Table 80 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.

Reservation of Floodlands for Conservation, Recreation, and Other Open Space Uses: Comprehensive land use planning recognizes that there is a need for active and passive recreational and open space lands readily accessible to residents of the metropolitan area. Floodlands may 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, and improve the accessibility of the recreation areas to the urban population.

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 such recreational uses as cross-country hiking and skiing trails. The principal advantage of this floodland management alternative is its definitiveness and legal incontestability, whereas the key disadvantage is the public cost. Public acquisition of floodland areas for recreational and related open space uses 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 governmental unit or agency for public maintenance and use. The land developer may be receptive to the idea of dedicating the floodlands and adjacent environmental corridors to a local governmental unit or agency since floodlands are not well suited for residential development, not only because of flooding, but also because of limiting soils, difficulties in supplying and maintaining utilities, 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.

In addition to preventing additional flood-prone development, minimizing the aggravation of upstream and downstream flood problems, and providing prime and readily accessible outdoor recreational land, the reservation of floodlands for recreational and open space uses also may be expected to have a significant and favorable impact on the value of residential property in proximity to the riverine-area parkways. A study was conducted by the Commission under its regional park and open space planning program of the effects of public open space land on residential values.[1] The emphasis was upon the extent to which residential property values may be influenced by proximity to public open space areas. Information for the study was compiled through 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 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 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 open space 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 the police powers granted them by state legislatures. Such regulations are ordinarily intended to mitigate flood damage 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, floodlands in Wisconsin are governed primarily by the rules and regulations adopted by

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[1] *Chapter X of SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, November 1977.*

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 Statutes. The principal advantages of floodland regulations are that they control the manner in which new development occurs in riverine areas, and also control selected practices by which existing urban or rural lands are managed. 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 modified in 1977 to require that floodways be delineated so as to essentially not cause any increase in the regulatory or 100-year recurrence interval flood stage.[2]

Although stipulation of an essentially "no-stage increase" floodway eliminates or reduces some of the 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 may lead to the destruction of the environmental corridors of a watershed, since it encourages floodland fill with development outside the floodway limits, but within environmentally critical areas. Floodland and other land use recommendations can be made more effective for environmental corridor protection as well as for flood damage mitigation. For example, more comprehensive floodland regulations in rural areas may simply designate a floodland district for which all flood-prone development is excluded, or may incorporate a floodway, a developable floodplain fringe, and an undevelopable conservancy district.

Control of Land Use Outside the Floodlands: In a watershed, it is important to regulate the manner in which urban development occurs outside 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 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.[3] 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 stormwater runoff from that development is controlled.

Community Education Programs: It is important that the public be fully aware of how the actions of property owners can affect flood flows and stages. Private actions, such as the dumping of debris in a stream channel by property owners and residents, may adversely affect flood flows and stages upstream. Also, localized channelization or the removal of obstructions to flow may increase the flood flows and stages downstream. Proper actions by property owners and residents, however—taken within the framework of a water resources management plan for the watershed—may serve to reduce an existing flooding problem or prevent a future problem, thereby reducing the degree of action necessary by local units of government and minimizing the public financial burden.

Structure Floodproofing: As discussed in Chapter VI 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 reduce flood damages significantly. This approach is referred to as floodproofing, and may be more specifically defined as a combination of physical

[2] *"Wisconsin's Flood Plain Management Program," Wisconsin Administrative Code, Chapter NR 116, July 1977. As of July 1985, the Code did not actually prohibit any stage increase but specified that any increase in stage could not exceed 0.1 foot. A revised version of Chapter NR 116 became effective in March 1986 limiting this increase to 0.01 foot.*

[3] *For a graphic demonstration of the potential impact of land use changes outside 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, October 1976, pp. 72-97.*

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:[4] 1) techniques for preventing entry of floodwaters; 2) techniques for ensuring 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 raising—that is, elevating—the structure such that the first floor—or other most 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 it causes will continue to occur.

Prevention of Floodwater Entry: A variety of floodproofing measures and techniques can be used to prevent the entry of floodwaters. Sanitary sewer backup through basement floor drains may be prevented by the 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. 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 blocks[5] 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 the structure.

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[4] *For more detailed descriptions of floodproofing measures and estimate 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.*
- *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.*
- *William K. Johnson, Physical and Economic Feasibility of Nonstructural Floodplain Management Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center and Institute for Water Resources, May 1977.*
- *William D. Carson, Estimating Costs and Benefits for Nonstructural Flood Control Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center, October 1975.*

[5] *The Wisconsin Uniform Dwelling Code provides that doors and windows must have a minimum openable area of 3.5 percent of the net floor area unless mechanical ventilation providing at least one air exchange per hour is provided. 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.*

Generally speaking, the concrete block basements widely used in residential construction in southeastern Wisconsin are not capable of withstanding the hydrostatic forces associated with complete saturation of the soil surrounding the buildings.[6] A possible alternative, therefore, to preventing floodwater from entering the basement of such structures is intentionally flooding the basement with clean water prior to the inflow of floodwater, thereby maintaining the structural integrity of the basement 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.

Maintenance of Utilities and Services and Protection of Contents: Another category of floodproofing measures applicable to structures consists of techniques designed to ensure the maintenance of utilities and other services needed for the building to function immediately after, and possibly during, a flood event, and to protect structural contents. This second set 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 floor level, surrounded by low walls to prevent the 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 using waterproof electrical fixtures in flood-prone areas of the structure. Some mechanical and electrical equipment may be protected by removing critical water-vulnerable components—for example, the blower motor on a forced air heating unit—prior to entry of the floodwaters.

[6] *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.*

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 such contents. Flood-vulnerable contents could be temporarily moved out of the buildings, be moved to higher floors, or be temporarily elevated on supports or shelves.

Some of the above floodproofing measures are contingent upon receiving adequate forewarning—at least several hours—of the 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 small, heavily urbanized basins that are 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 other most 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 structure that remain below the design flood stage.

Basic floodproofing measures like those discussed above are generally considered feasible for most nonresidential structures—such as businesses, commercial buildings, and schools—even if the design flood stage is above the first floor elevation. However, such measures generally are not 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.

The total capital cost of elevating a structure is dependent on the extent to which the structure is elevated, but includes fixed costs that are independent of the height to which the structure is raised. Examples of fixed costs include the costs of placing beams or other supports beneath the structure, disconnecting utilities, and replacing shrubs, whereas examples of the variable costs include the cost of vertical extensions to the basement walls, and of the fill required to raise the yard grade. 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 to be $4,900 in 1984 dollars. 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 to be $42,500 in 1984 dollars, assuming that the building is raised four feet, and increases by about $3,900 for each additional foot that the structure is raised. While the costs of floodproofing by 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 flood damage. A significant negative aspect of floodproofing is the very real possibility that it will be applied without adequate professional engineering guidance, possibly leading to major damage to the structure and posing a threat to 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 community, thereby leaving a significant demand for flood relief—a demand that will focus 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.

Finally, it should be noted that buildings which have been floodproofed are not exempt from federal requirements regarding the purchase of flood insurance. Buyers of homes which have been floodproofed but still lie within flood-prone areas are required to purchase flood insurance when obtaining a loan from a federally insured lending institution.

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 of 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 the tax base to a community as a result of removing taxable property. It should be noted, however, that while there may be such a loss, 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 service; 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 the 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 have three positive effects on flooding and stormwater inundation problems. First, periodic stream channel cleaning and maintenance are important to maintaining the integrity of the flood stage profiles developed under the watershed planning program. As noted in Chapter VIII of this report, hydraulic and hydrologic 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 of the hydraulic system inventory. Second, periodic cleaning and maintenance of the stream channels is needed to maintain the channel bottom profile at an elevation below the invert of existing or planned storm sewer and stormwater channel outfalls in urban areas and drainage tile and drainage ditch outfalls in rural areas. Failure to clean and maintain the channels 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 stormwater inundation of urban areas and of cropland. Third, cleaning and maintenance of the watershed channel system are important to reduce the probability that buoyant objects and debris 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. It should be noted that the implementation of nonpoint source pollution controls can serve to reduce the amount of sediment and debris in the streams and, therefore, can reduce the costs of channel maintenance. Also, since the removal of sediment from a stream channel may be considered to be dredging by the Wisconsin Department of Natural Resources, a permit for such dredging activities may be required.

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 effect 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; this accumulation could result in flood stages higher than those presented in this report. The 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,[7] the Village of Elm Grove in the Menomonee River watershed,[8] and the Village of Pewaukee in the Fox River watershed.[9] These studies have all indicated that channel cleaning and maintenance will not, in itself, have any significant effect on peak flood stages.

Flood Insurance: The overriding objective of the national Flood Insurance Program is to encourage the purchase of flood insurance by individual landowners to reduce the 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

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[7] *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.*

[8] *Chapter IV of SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, October 1976, pp. 116-117.*

[9] *Chapter III of SEWRPC Community Assistance Planning Report No. 14, A Floodland Management Plan for the Village of Pewaukee, September 1977, pp. 100-101.*

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.

As of December 31, 1984, all of the communities in the Oak Creek watershed were participating in the federal Flood Insurance Program. Such participation can provide 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 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. Therefore, a very close tie exists between two of the nonstructural floodland management 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 flood-prone status of property has 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 determining 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 J. Lucey of Wisconsin on November 26, 1973, real estate brokers, salesmen, or their agents are strongly urged to inform potential purchasers of property about 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. Regulations concerning the responsibility of realtors to inform potential buyers about any adverse conditions, such as flood hazards, are listed in the Wisconsin Administrative Code, Chapter R624.

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 and utilities such 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, a sewer alignment that parallels and lies near 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 Oak Creek 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 appropriate local units of government and other agencies in the Oak Creek 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. Sanitary sewer construction in flood-prone areas also entails higher treatment costs since increased clearwater infiltration and inflow problems 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 measures,[10] such as the installation of remote

[10] *William K. Johnson, Physical and Economic Feasibility of Nonstructural Floodplain Management Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center and Institute for Water Resources, May 1977.*

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, broadcasting of emergency messages to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, use of a siren warning system employing a special pattern to indicate that flooding is occurring, preplanning road closures and evacuation of residents, and the mobilization of portable pumping equipment to relieve the surcharge of sanitary sewers.

HYDROLOGIC-HYDRAULIC CONSEQUENCES OF PLAN YEAR 2000 LAND USE

The purpose of developing and calibrating a mathematical water resource simulation model under the Oak Creek watershed planning program, as described in Chapter VIII of this report, was to provide a tool for quantitatively analyzing the hydrologic, hydraulic, and water quality characteristics and performance of the watershed under existing and future land use conditions. The results of applying the hydrologic and hydraulic submodels to the entire watershed for three critical watershed land use and channel/ floodplain conditions are described below. Additional model applications to portions of the watershed and its stream system for plan design and evaluation purposes are discussed in Chapter VIII, as well as in subsequent sections of this chapter.

Procedure

The hydrologic and hydraulic simulation submodels were applied to the entire watershed for three combinations of land use and channel/ floodplain conditions in order to quantify the probable impact of future urban development on flood flows and stages in the Oak Creek watershed. These three conditions were:

1. Existing (1980) land use and existing channel and floodplain conditions—under which about 46 percent of the total area of the watershed was in urban land uses and about 54 percent in rural land uses;

2. Year 2000 planned land use and existing channel and floodplain conditions—under which about 88 percent of the total area of the watershed would be in urban land uses and about 12 percent in rural land uses. This planned land use pattern was that described in Chapter XI, with the exception, however, that no land within the 100-year recurrence interval flood hazard area would be developed for urban use; and

3. Year 2000 planned land use and existing channel conditions with some development permitted in the floodplain fringe areas—the same basic planned land use condition as under condition two, but assuming the development for urban use of certain lands lying within the 100-year recurrence interval flood hazard area—or floodplain—but outside the floodway. This planned land use pattern was identical to that presented in Chapter XI.

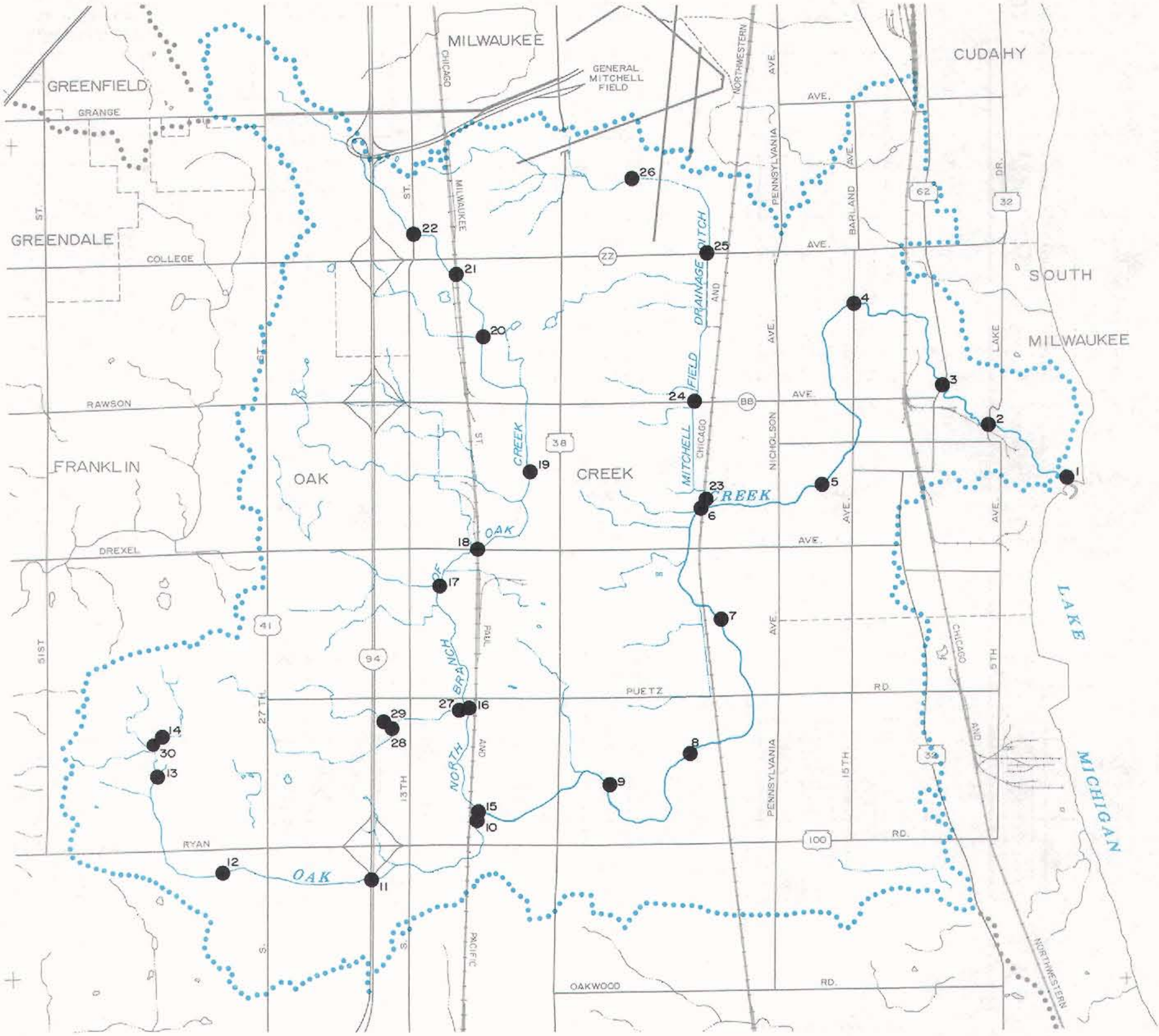
The hydrologic and hydraulic submodels were applied to each of the three combinations of land use and channel/floodplain conditions in accordance with the procedures described in Chapter VIII. Utilizing the submodels, flood flows were computed for 42 selected locations on the stream system of the watershed—16 on Oak Creek, 9 on the North Branch of Oak Creek, 6 on the Mitchell Field Drainage Ditch, and 11 on the remaining tributaries studied, all as shown on Map 39 in Chapter VIII. Thirty locations were selected for comparison of flood flows under the three land use and channel/floodplain conditions, as shown on Map 47.

Discharge-frequency relationships at selected locations were chosen as the best means of comparing and contrasting the hydrologic-hydraulic response of the watershed to the three combinations of land use and channel/floodplain conditions, inasmuch as discharge-frequency relationships are concise representations of the watershed or subwatershed flood flow characteristics.

The hydraulic response of the watershed to the three combinations of land use and channel/ floodplain conditions was determined by computing and contrasting the 100-year recurrence interval flood stages for each condition. The impact of the three combinations of land use and channel/floodplain conditions was also quantified by computing and comparing the average annual monetary flood risks for selected flood-prone reaches under existing (1980) and plan year 2000 development conditions. These comparisons are presented in subsequent sections of this chapter.

Map 47

EFFECTS OF CHANGING LAND USE ON 100-YEAR FLOOD FLOWS IN THE OAK CREEK WATERSHED



LEGEND

● LOCATION SELECTED FOR COMPARISON OF FLOOD FLOWS UNDER EXISTING AND YEAR 2000 PLANNED LAND USE CONDITIONS (NUMBERS ON MAP CORRESPOND TO FIGURES ON FOLLOWING PAGES)

LAND USE CONDITION

A EXISTING 1980

B PLAN YEAR 2000 WITHOUT FLOODPLAIN DEVELOPMENT

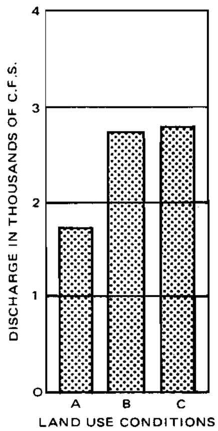
C PLAN YEAR 2000 WITH FLOODPLAIN LIMITED DEVELOPMENT

Analysis conducted under the watershed study indicates that relative to existing land use and channel and floodplain conditions, 100-year recurrence interval flood flows in the watershed under year 2000 planned land use and existing channel and floodplain conditions may be expected to increase by up to 69 percent at 30 locations in the watershed, with an average increase of about 35 percent. Under year 2000 planned land use and existing channel conditions but with limited floodplain development, these flows may be expected to increase by up to 78 percent, with an average increase of about 41 percent (see Table 81).

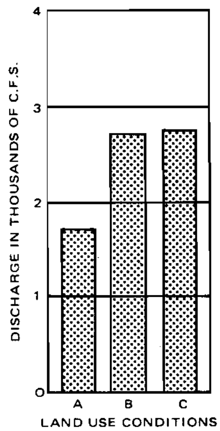
Source: SEWRPC.

Map 47 (continued)

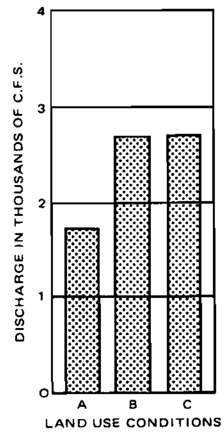
1
R.M. 0.00
OAK CREEK AT THE CONFLUENCE WITH LAKE MICHIGAN



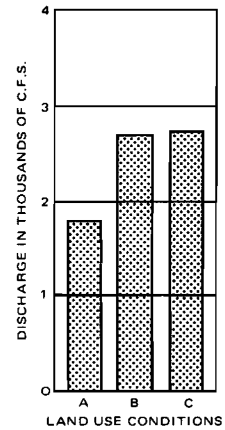
2
R.M. 0.95
OAK CREEK UPSTREAM OF PARKWAY DAM



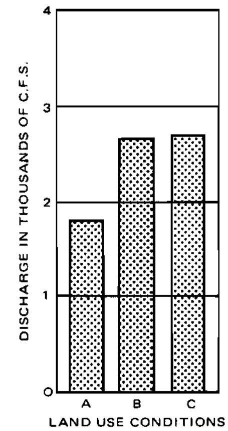
3
R.M. 1.61
OAK CREEK UPSTREAM OF CHICAGO AVENUE



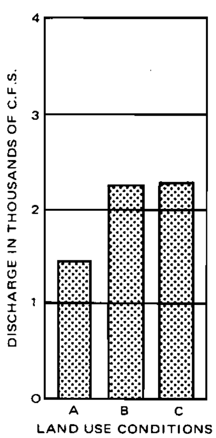
4
R.M. 2.84
OAK CREEK UPSTREAM OF 15TH AVENUE



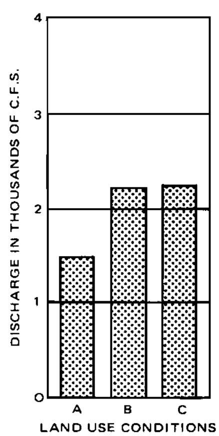
5
R.M. 4.36
OAK CREEK UPSTREAM OF MARQUETTE BOULEVARD EXTENDED



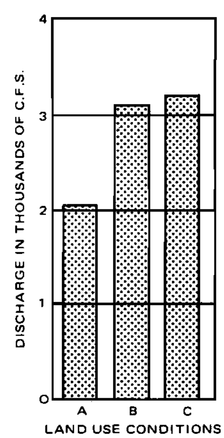
6
R.M. 5.23
OAK CREEK UPSTREAM OF CONFLUENCE OF MITCHELL FIELD DRAINAGE DITCH



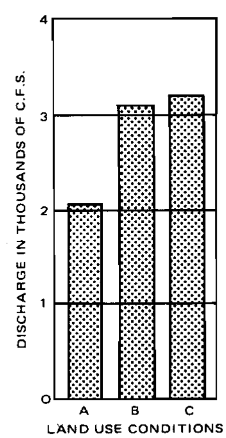
7
R.M. 6.25
OAK CREEK UPSTREAM OF E. FOREST HILL AVENUE



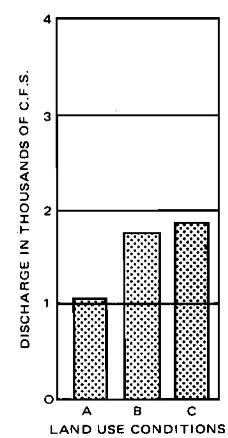
8
R.M. 7.52
OAK CREEK UPSTREAM OF ABANDONED CHICAGO NORTH SHORE AND MILWAUKEE RAILWAY



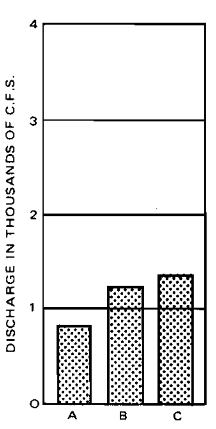
9
R.M. 8.75
OAK CREEK UPSTREAM OF S. SHEPARD AVENUE



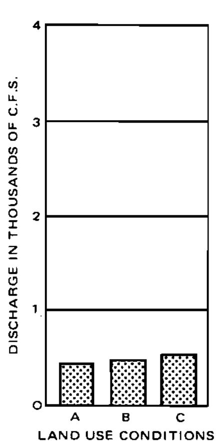
10
R.M. 9.84
OAK CREEK UPSTREAM OF CONFLUENCE OF NORTH BRANCH OF OAK CREEK



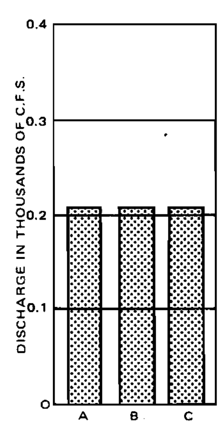
11
R.M. 10.97
OAK CREEK UPSTREAM OF I-94



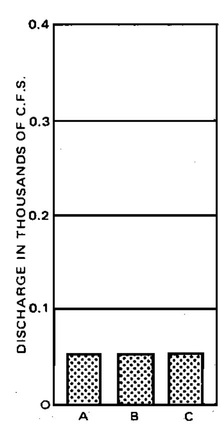
12
R.M. 11.97
OAK CREEK UPSTREAM OF S. 31ST STREET



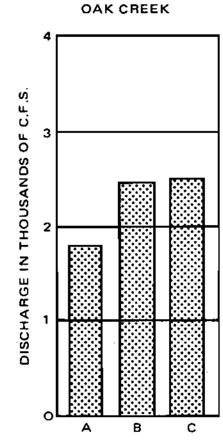
13
R.M. 13.07
OAK CREEK DOWNSTREAM OF W. SOUTHLAND AVENUE



14
R.M. 13.32
OAK CREEK UPSTREAM OF W. WOODWARD DRIVE

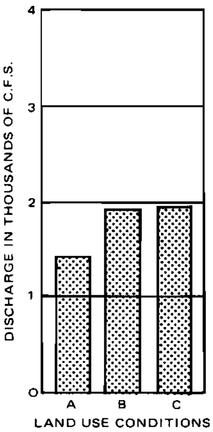


15
R.M. 0.00
NORTH BRANCH OF OAK CREEK AT THE CONFLUENCE WITH OAK CREEK

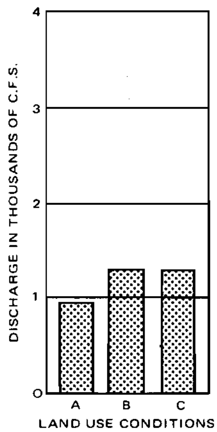


Map 47 (continued)

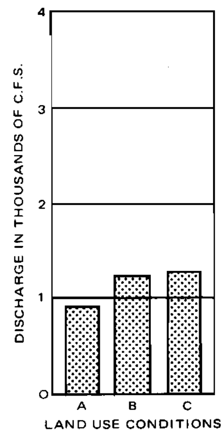
16
R.M. 0.88
NORTH BRANCH OF OAK CREEK DOWNSTREAM OF W. PUETZ ROAD



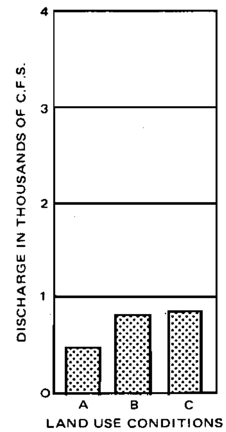
17
R.M. 1.86
NORTH BRANCH OF OAK CREEK DOWNSTREAM OF WILDWOOD DRIVE



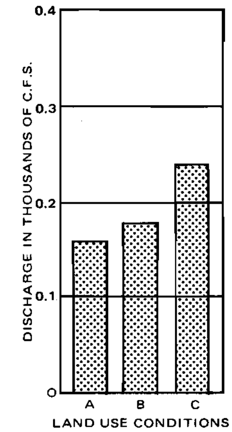
18
R.M. 2.25
NORTH BRANCH OF OAK CREEK UPSTREAM OF CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD



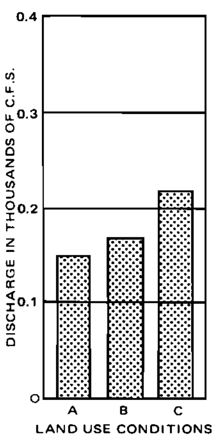
19
R.M. 3.04
NORTH BRANCH OF OAK CREEK UPSTREAM OF W. MARQUETTE AVENUE



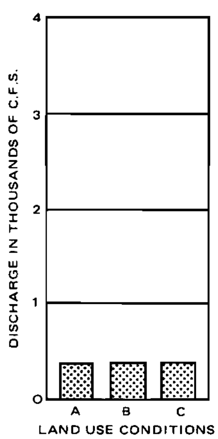
20
R.M. 4.22
NORTH BRANCH OF OAK CREEK AT THE MATC SOUTH CAMPUS



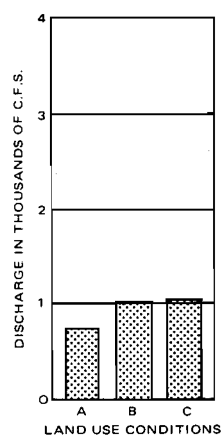
21
R.M. 4.75
NORTH BRANCH OF OAK CREEK UPSTREAM OF CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD



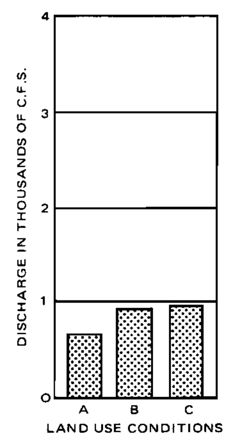
22
R.M. 5.21
NORTH BRANCH OF OAK CREEK UPSTREAM OF CTH V/S. 13TH STREET



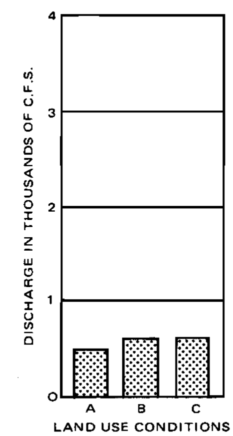
23
R.M. 0.00
MITCHELL FIELD DRAINAGE DITCH AT THE CONFLUENCE WITH OAK CREEK



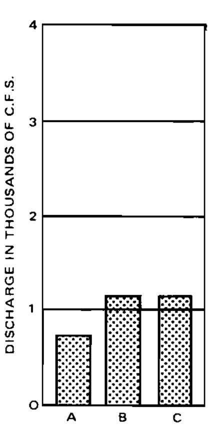
24
R.M. 0.80
MITCHCELL FIELD DRAINAGE DITCH UPSTREAM OF CTH BB/ W. RAWSON AVENUE



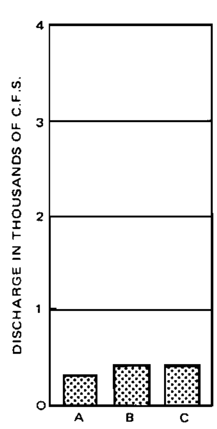
25
R.M. 1.83
MITCHELL FIELD DRAINAGE DITCH UPSTREAM OF CTH ZZ/ W. COLLEGE AVENUE



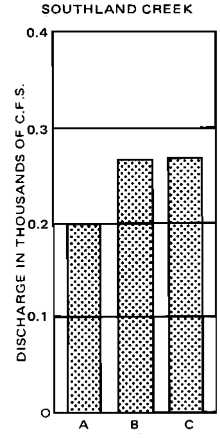
26
R.M. 2.73
MITCHELL FIELD DRAINAGE DITCH UPSTREAM OF PRIVATE DRIVE



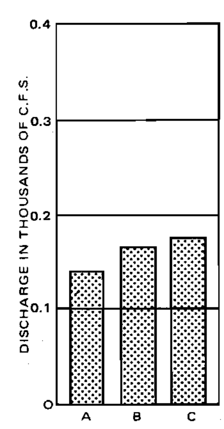
27
R.M. 0.00
SOUTHLAND CREEK AT THE CONFLUENCE WITH NORTH BRANCH OF OAK CREEK



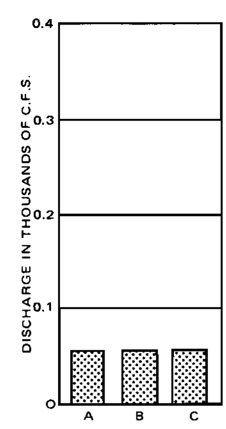
28
R.M. 0.71
SOUTHLAND CREEK UPSTREAM OF THE CONFLUENCE OF THE TRIBUTARY TO SOUTHLAND CREEK



29
R.M. 0.00
TRIBUTARY TO SOUTHLAND CREEK AT THE CONFLUENCE WITH SOUTHLAND CREEK



30
R.M. 0.00
TRIBUTARY TO UPPER OAK CREEK AT THE CONFLUENCE WITH OAK CREEK



Land Use Considerations

The year 2000 land use plan for the Oak Creek watershed, as described in Chapter XI, calls for portions of the 100-year recurrence interval floodplain to be developed for urban use. Such development serves to reduce the floodwater storage capacity of the floodplain, thus increasing downstream discharges and associated flood stages. Although it is generally undesirable to exacerbate downstream flooding problems in this manner, a watershed plan must recognize to the maximum extent practicable local land use plans and attempt to incorporate them. Since the land use plan detailed in Chapter XI does incorporate the salient features of the local plans which include some urban development in the floodplains of the watershed, it was necessary to quantify the impacts that such development may be expected to have on flood discharges and stages throughout the watershed. To assess these impacts, it was necessary to consider the plan year 2000 land use pattern both with and without intrusion of urban land uses into the floodplain fringe areas.

For the purposes of the study, the discharges and stages developed under condition two described above were used as the base condition for comparison of alternative floodland management measures. Insofar as such structural and nonstructural measures would serve to reduce flood problems in the watershed to levels below those presented by the base condition, they were considered further for inclusion in a final watershed plan.

Hydrologic-Hydraulic Response of the Watershed to Plan Year 2000 Land Use Pattern

The 10-, 50-, and 100-year recurrence interval discharge-frequency data for the three combinations of land use and channel/floodplain conditions are presented in Table 81. The discharge-frequency relationships, shown graphically in Figures 53 through 57, quantitatively demonstrate the hydrologic-hydraulic impacts of existing and planned land use patterns. The following discussion draws on the results of the watershedwide simulation modeling to identify the locations at which significant changes in flood discharges and stages may be expected to occur, and to indicate the magnitude and significance of those impacts.

Discharge-Frequency Relationships: Figures 53 through 57 are typical of the discharge-frequency relationships that exist, and may be expected to exist, within the watershed under the three land use development conditions investigated. It may be noted that the three discharge-frequency curves at each location are approximately parallel, with a tendency, however, for the curves to converge as the severity of flood event increases. If the discharge-frequency curves for any two land use and channel/floodplain conditions at a given location on the stream system were indeed parallel, then a constant ratio of flood flows would exist between the two conditions. A convergence of the discharge-frequency curves for increasing recurrence intervals indicates that the ratio of flood flows for the two conditions decreases for the more infrequent flood events. Therefore, the relative impact of land use conditions on flood flows and stages tends to be somewhat less for the severe flood events—as indicated by a decrease in the ratios of the flood flows shown in Table 81. This is to be expected, because the rainfall and rainfall-snowmelt associated with the more severe flood events saturate the pervious portions of the watershed, causing those areas to behave in a manner characteristic of impervious areas.

Hydrologic-Hydraulic Impact of Year 2000 Planned Land Use Conditions Without Development in the Floodplain

There is concern over the possible hydrologic-hydraulic consequences of the incremental urban development associated with the year 2000 land use plan. More specifically, it is necessary to know how much larger flood flows may be and how much higher attendant flood stages may be under year 2000 planned land use and floodplain development conditions throughout the watershed relative to discharges and stages under existing conditions.

Based upon the results of the hydrologic modeling at the 30 sites listed in Table 81, the increases in the 10-year recurrence interval flood discharge between existing and year 2000 planned land use—excluding development from the floodplains of the stream system—and existing channel/floodplain conditions may be expected to range from a low of 19 percent—160 cubic feet per second (cfs) to 190 cfs—at S. 31st Street on Oak Creek, to a high of 150 percent—400 cfs to 1,000 cfs—on Oak Creek upstream of the confluence with the North Branch of Oak Creek, with an average increase of 70 percent for the watershed. Similarly, the increases in the 100-year recurrence interval flood discharge between existing and year 2000 planned land use and existing channel/floodplain conditions may be expected to range from a low of 7 percent—410 cfs to 440 cfs—at S. 31st Street on Oak Creek, to a high of 69 percent—520 cfs to

Table 81

HYDROLOGIC EFFECT OF CHANGING LAND USE IN THE OAK CREEK WATERSHED

Location			Recurrence Interval (years)	Existing (1980) Condition Discharge (cfs)	Year 2000 Planned Land Use Without Floodplain Development		Year 2000 Planned Land Use With Floodplain Development	
Stream	River Mile	Description			Discharge (cfs)	Relative to Existing Conditions (ratio)	Discharge (cfs)	Relative to Existing Conditions (ratio)
Oak Creek	0.00	Confluence with Lake Michigan	10 50 100	1,140[a] 1,590[a] 1,770[a]	1,900[a] 2,520[a] 2,780[a]	1.7 1.6 1.6	1,910[a] 2,540[a] 2,810[a]	1.7 1.6 1.6
	0.95	At Parkway Dam	10 50 100	1,130[a] 1,580[a] 1,760[a]	1,890[a] 2,510[a] 2,770[a]	1.7 1.6 1.6	1,900[a] 2,520[a] 2,790[a]	1.7 1.6 1.6
	1.61	At Chicago Avenue	10 50 100	1,130[a] 1,580[a] 1,760[a]	1,880[a] 2,490[a] 2,750[a]	1.7 1.6 1.6	1,890[a] 2,510[a] 2,770[a]	1.7 1.6 1.6
	2.84	At 15th Avenue	10 50 100	1,090[a] 1,560[a] 1,770[a]	1,830[a] 2,430[a] 2,680[a]	1.7 1.6 1.5	1,840[a] 2,440[a] 2,700[a]	1.7 1.6 1.5
	4.36	Upstream of Marquette Boulevard Extended	10 50 100	1,080[a] 1,560[a] 1,780[a]	1,820[a] 2,410[a] 2,660[a]	1.7 1.5 1.5	1,830[a] 2,420[a] 2,680[a]	1.7 1.6 1.5
	5.23	Upstream of Confluence of Mitchell Field Drainage Ditch	10 50 100	840 1,290 1,500	1,480 2,010 2,240	1.8 1.6 1.6	1,500 2,030 2,270	1.8 1.6 1.6
	6.25	At E. Forest Hill Avenue	10 50 100	850 1,290 1,500	1,480 2,010 2,240	1.7 1.6 1.5	1,500 2,030 2,270	1.8 1.6 1.5
	7.52	At Abandoned Chicago North Shore & Milwaukee Railroad	10 50 100	1,130 1,780 2,080	2,040 2,790 3,120	1.8 1.6 1.5	2,080 2,870 3,220	1.8 1.6 1.6
	8.75	Upstream of S. Shepard Avenue	10 50 100	1,130 1,780 2,080	2,040 2,790 3,120	1.8 1.6 1.5	2,080 2,870 3,220	1.8 1.6 1.6
	9.84	Upstream of Confluence of North Branch of Oak Creek	10 50 100	400 790 1,030	1,000 1,540 1,740	2.5 2.0 1.7	1,030 1,620 1,830	2.6 2.0 1.8
	10.97	At IH 94	10 50 100	310 600 790	640 1,050 1,210	2.1 1.8 1.5	690 1,140 1,330	2.2 1.9 1.7
	11.97	At S. 31st Street	10 50 100	160 310 410	190 360 440	1.2 1.2 1.1	200 390 490	1.2 1.3 1.2
	13.07	Downstream of W. Southland Drive	10 50 100	100 170 210	--[b] --[b] --[b]	1.0 1.0 1.0	--[b] --[b] --[b]	1.0 1.0 1.0
	13.32	Upstream of W. Woodward Drive	10 50 100	20 40 50	--[b] --[b] --[b]	1.0 1.0 1.0	--[b] --[b] --[b]	1.0 1.0 1.0
North Branch of Oak Creek	0.00	Confluence with Oak Creek	10 50 100	710 1,400 1,670	1,200 1,990 2,280	1.7 1.4 1.4	1,210 2,000 2,320	1.7 1.4 1.4
	0.88	Downstream of W. Puetz Road	10 50 100	650 1,190 1,450	1,120 1,680 1,900	1.7 1.4 1.3	1,130 1,750 1,940	1.7 1.5 1.3

Table 81 (continued)

Location			Recurrence Interval (years)	Existing (1980) Condition Discharge (cfs)	Year 2000 Planned Land Use Without Floodplain Development		Year 2000 Planned Land Use With Floodplain Development	
Stream	River Mile	Description			Discharge (cfs)	Relative to Existing Conditions (ratio)	Discharge (cfs)	Relative to Existing Conditions (ratio)
North Branch of Oak Creek (continued	1.86	Downstream of Wildwood Drive	10 50 100	500 800 930	940 1,190 1,260	1.9 1.5 1.4	940 1,190 1,260	1.9 1.5 1.4
	2.25	At Chicago, Milwaukee, St. Paul & Pacific Railroad	10 50 100	430 750 880	880 1,130 1,180	2.0 1.5 1.3	890 1,130 1,190	2.1 1.5 1.4
	3.04	At W. Marquette Avenue	10 50 100	260 430 520	540 790 880	2.1 1.8 1.7	560 820 900	2.2 1.9 1.7
	4.22	At the MATC-South Campus	10 50 100	100 140 160	120 160 180	1.2 1.1 1.1	150 220 240	1.5 1.6 1.5
	4.75	At Chicago, Milwaukee, St. Paul & Pacific Railroad	10 50 100	80 140 150	100 150 170	1.2 1.1 1.1	120 200 220	1.5 1.4 1.5
	5.21	At CTH V/S. 13th Street	10 50 100	170 330 370	190 350 390	1.1 1.1 1.0	190[c] 350[c] 390[c]	1.1 1.1 1.0
Mitchell Field Drainage Ditch	0.00	Confluence with Oak Creek	10 50 100	350 590 730	580 880 1,020	1.7 1.5 1.4	580 900 1,050	1.7 1.5 1.4
	0.80	At CTH BB/W. Rawson Avenue	10 50 100	320 560 680	560 820 930	1.8 1.5 1.4	560 830 950	1.8 1.5 1.4
	1.83	At CTH ZZ/W. College Avenue	10 50 100	310 450 520	450 560 620	1.4 1.2 1.2	450[c] 560[c] 620[c]	1.4 1.2 1.2
	2.73	At Private Drive	10 50 100	330 600 740	640 1,010 1,180	1.9 1.7 1.6	640[c] 1,010[c] 1,180[c]	1.9 1.7 1.6
Southland Creek	0.00	Confluence with North Branch of Oak Creek	10 50 100	80 270 350	180 370 450	2.2 1.4 1.3	180 370 450	2.2 1.4 1.3
	0.71	Upstream of the Confluence of the Tributary to Southland Creek	10 50 100	50 160 200	110 220 270	2.2 1.4 1.4	110 220 270	2.2 1.4 1.4
Tributary to Southland Creek	0.00	Confluence with Southland Creek	10 50 100	40 100 140	80 150 170	2.0 1.5 1.2	80 150 180	2.0 1.5 1.2
Tributary to Upper Oak Creek	0.00	Confluence with Oak Creek	10 50 100	20 50 60	--[b] --[b] --[b]	1.0 1.0 1.0	--[b] --[b] --[b]	1.0 1.0 1.0

[a]*The change in the magnitude of the flood discharge values downstream of the confluence with the Mitchell Field Drainage Ditch does not always vary significantly from one output location to the next. For this reason, as well as to simplify the hydraulic modeling, discharge values were not changed at every output location in the calculation of flood stages. Therefore, the discharge values listed in this table may vary from those listed in Appendices D, E, and F.*

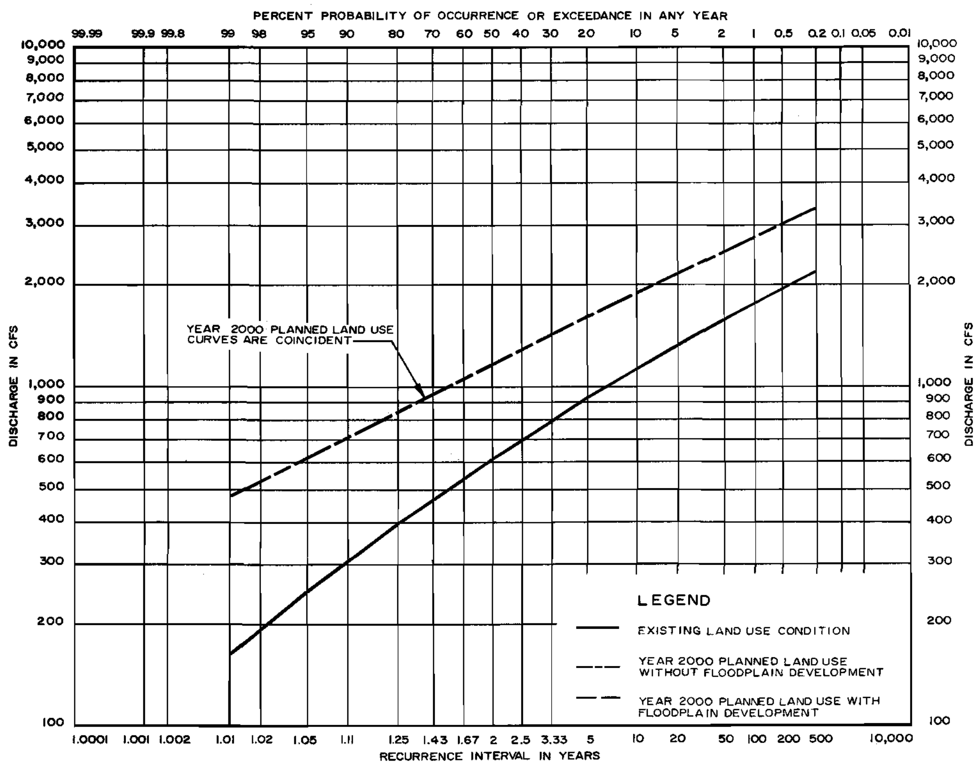
[b]*No change in land use.*

[c]*No loss of floodwater storage upstream of this location.*

Source: SEWRPC.

Figure 53

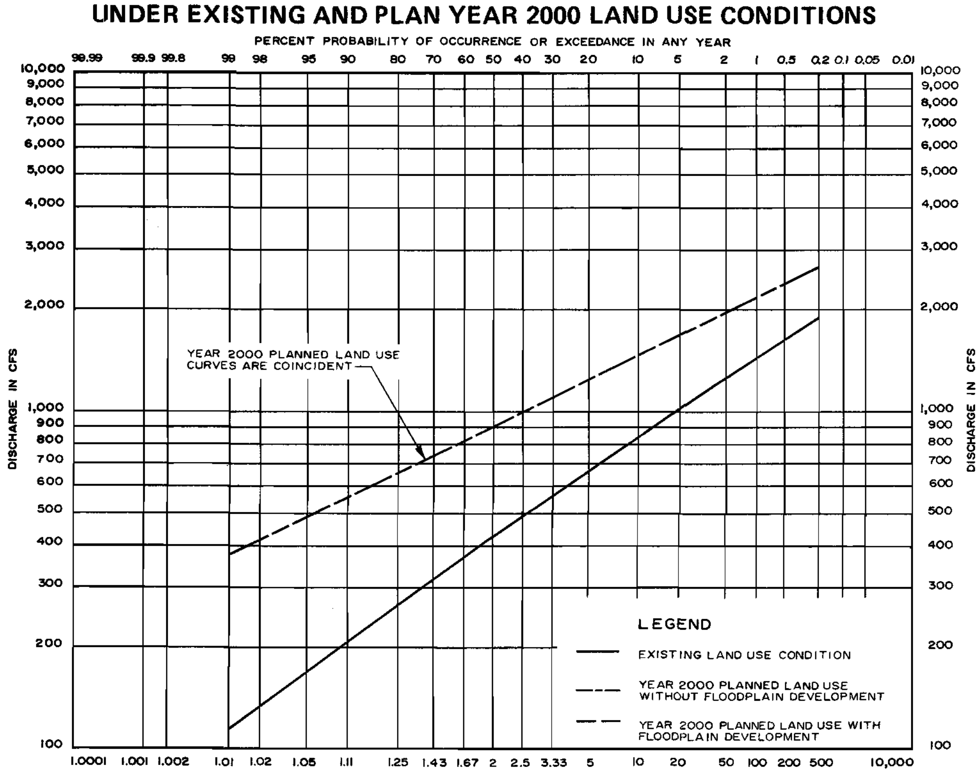
SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR OAK CREEK AT THE CONFLUENCE WITH LAKE MICHIGAN UNDER EXISTING AND PLAN YEAR 2000 LAND USE CONDITIONS



Source: SEWRPC.

Figure 54

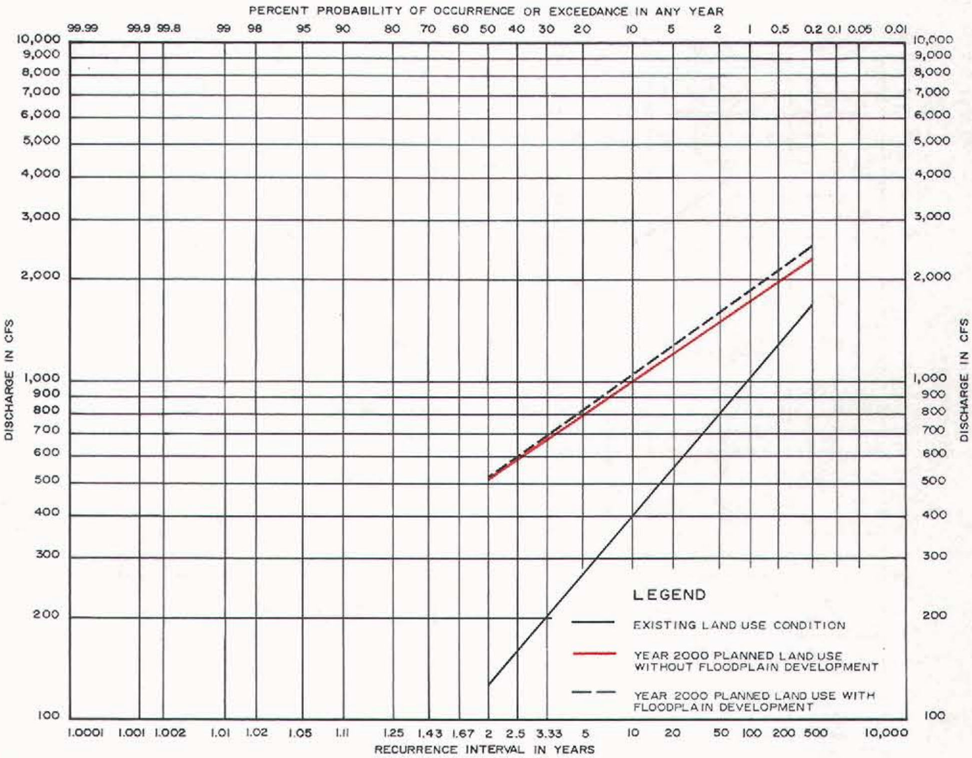
SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR OAK CREEK UPSTREAM OF THE CONFLUENCE OF MITCHELL FIELD DRAINAGE DITCH UNDER EXISTING AND PLAN YEAR 2000 LAND USE CONDITIONS



Source: SEWRPC.

Figure 55

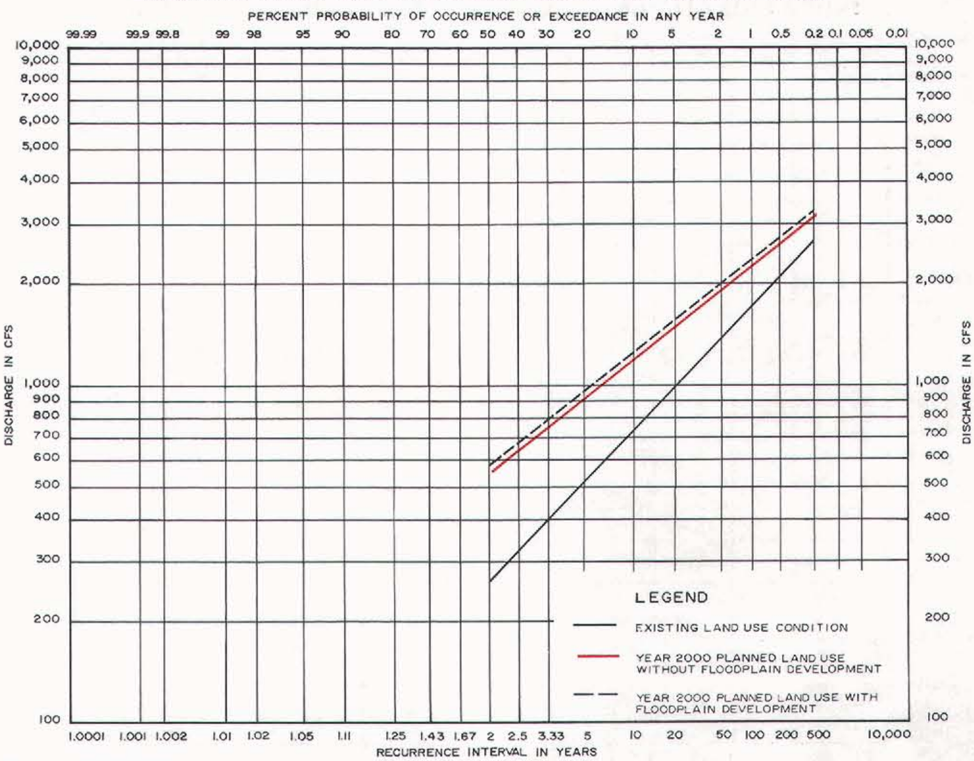
SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR OAK CREEK UPSTREAM OF THE CONFLUENCE OF NORTH BRANCH OF OAK CREEK UNDER EXISTING AND PLAN YEAR 2000 LAND USE CONDITIONS



Source: SEWRPC.

Figure 56

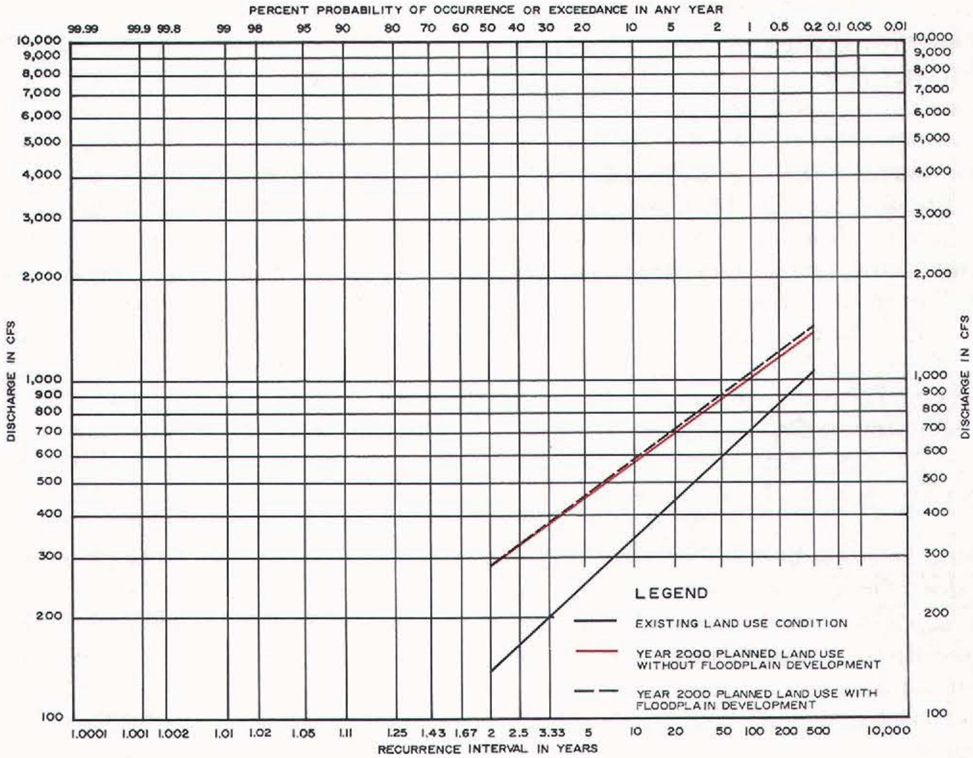
SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR NORTH BRANCH OF OAK CREEK AT THE CONFLUENCE WITH OAK CREEK UNDER EXISTING AND PLAN YEAR 2000 LAND USE CONDITIONS



Source: SEWRPC.

Figure 57

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR MITCHELL FIELD DRAINAGE DITCH AT THE CONFLUENCE WITH OAK CREEK UNDER EXISTING AND PLAN YEAR 2000 LAND USE CONDITIONS



Source: SEWRPC.

880 cfs—at W. Marquette Avenue on the North Branch of Oak Creek, with an average increase of 35 percent for the watershed.

Hydrologic-Hydraulic Impact of Year 2000 Planned Land Use With Development in the Floodplain

The impact that development in the floodplain fringe would have on flood flows in the watershed can be determined by comparing discharge-frequency values for the watershed under year 2000 planned land use and existing channel/floodplain conditions with those that would exist under year 2000 planned land use and existing channel conditions but with development of floodplain fringe areas. The comparison also illustrates the impact which development in accordance with the land use plan described in Chapter XI may be expected to have on flood flow characteristics.

Based upon the results of the hydrologic modeling at the 30 sites listed in Table 81, the increases in the 10-year recurrence interval flood discharge between year 2000 planned land use and existing channel conditions but excluding development in the floodplain fringe areas and such planned land use conditions with development in the floodplain fringe areas may be expected to range from a low of 0 percent on Southland Creek at the confluence with the North Branch of Oak Creek, to a high of 25 percent—120 cfs to 150 cfs—at the MATC-South Campus on the North Branch of Oak Creek, with an average increase of 3 percent for the watershed. The increases in the 10-year recurrence interval flood discharge between existing land use and channel/floodplain conditions and year 2000 planned land use and existing channel conditions with floodplain fringe development may be expected to range from a low of 25 percent—160 cfs to 200 cfs—at S. 31st Street on Oak Creek, to a high of 158 percent—400 cfs to 1,030 cfs—on Oak Creek upstream of the confluence with the North Branch of Oak Creek, with an average increase of 74 percent for the watershed.

For the 100-year recurrence interval flood, the increases in discharge between year 2000 planned land use and existing channel conditions without floodplain fringe development and with floodplain fringe development may be expected to range from a low of 0 percent on Southland Creek at the confluence with the North Branch of Oak Creek, to a high of 33 percent—180 cfs to 240 cfs—at the MATC-South Campus on the North Branch of Oak Creek, with an average increase of 4 percent for the watershed. The increases in the 100-year recurrence interval flood discharge between existing land use and channel/ floodplain conditions and year 2000 planned land use and existing channel conditions with floodplain fringe development may be expected to range from a low of 5 percent—370 cfs to 390 cfs—at S. 13th Street on the North Branch of Oak Creek, to a high of 78 percent—1,030 cfs to 1,830 cfs—on Oak Creek upstream of the confluence with the North Branch, with an average increase of 41 percent for the watershed.

Hydrologic-Hydraulic Impact of Diversion Pipe along Drexel Avenue

In addition to studying the impacts of changing land use on flood discharges and stages in the Oak Creek watershed, an investigation was made of the impact on flood discharges and stages of an existing diversion pipe located along Drexel Avenue between the North Branch of Oak Creek and the Oak Creek main stem. The purpose of this pipe is to convey floodwaters from the North Branch of Oak Creek to the Oak Creek main stem, thereby reducing the peak flood discharges along the North Branch of Oak Creek south of W. Drexel Avenue. A comparison of the simulated flood discharges along the North Branch of Oak Creek with and without the diversion pipe is provided in Table 82. As indicated in this table, elimination of this diversion pipe would serve to increase the 100-year recurrence interval peak flood discharge on the North Branch of Oak Creek by as much as 12 percent under existing land use and channel conditions; by as much as 6 percent under plan year 2000 land use—excluding development from the floodplains of the stream system—and existing channel/floodplain conditions; and by as much as 8 percent under plan year 2000 land use—including limited development in the floodplain fringe areas—and existing channel conditions. Because of the timing of the peak discharges on the North Branch of Oak Creek and the main stem of Oak Creek, the diversion pipe has an insignificant impact on peak flood discharges and stages along the main stem of Oak Creek.

SELECTION OF FLOOD-PRONE REACHES

In order to develop the floodland management element of the comprehensive plan for the Oak Creek watershed, the existing and probable future flood-prone reaches within the watershed must be identified, and alternative floodland management measures developed and evaluated for those reaches which have or may be expected to have severe flood problems. A two-step approach was used to determine the stream reaches for which alternative floodland management measures were to be developed. The first step involved the hydrologic-hydraulic simulation of flood flows and stages under existing land use and channel and floodplain conditions to identify existing flood-prone reaches and areas. The results of this step were checked against the findings of the historic flood damage survey conducted under the watershed study. The second step involved the hydrologic-hydraulic simulation of flood flows and stages under plan year 2000 land use and existing channel and floodplain conditions, including in the latter, however, any locally committed flood control measures to identify those areas in the watershed which may be expected to be flood damage-prone under plan year 2000 land use conditions without implementation of any further floodland management measures. The results of this two-step approach and of the subsequent design and evaluation of alternative flood damage-abatement measures are described in the following sections of this chapter on a watershedwide basis.

ALTERNATIVE FLOODLAND MANAGEMENT PLANS FOR THE OAK CREEK WATERSHED

The Flood Problem

The hydrologic-hydraulic simulation of the Oak Creek watershed under existing land use and channel and floodplain conditions indicates that there is the potential for modest flood damage to both crops and structures in the watershed. The potential for crop damage is spread throughout much of the watershed, while the majority of the structure damage potential is concentrated along Oak Creek between its confluence with the Mitchell Field Drainage Ditch and with the North Branch of Oak Creek, and the North Branch of Oak Creek. It is estimated that under a 100-year recurrence interval flood, 22 structures located on nine properties would be damaged.

Table 82

IMPACT OF DREXEL AVENUE DIVERSION PIPE ON FLOOD DISCHARGES ALONG THE NORTH BRANCH OF OAK CREEK

Location		Recurrence Interval (years)	Existing (1980) Condition Discharge (cfs)			Year 2000 Planned Land Use Without Floodplain Development Discharge (cfs)			Year 2000 Planned Land Use With Floodplain Development Discharge (cfs)		
River Mile	Description		With Diversion	Without Diversion	Percent Increase	With Diversion	Without Diversion	Percent Increase	With Diversion	Without Diversion	Percent Increase
0.00	Confluence with Oak Creek	10	710	730	3	1,200	1,270	6	1,210	1,320	9
		50	1,400	1,480	6	1,990	2,010	1	2,000	2,100	5
		100	1,670	1,670	0	2,280	2,300	1	2,320	2,380	2
0.88	Downstream of W. Puetz Road	10	650	670	3	1,120	1,210	8	1,130	1,260	12
		50	1,190	1,320	11	1,680	1,720	2	1,750	1,810	3
		100	1,450	1,550	7	1,900	1,910	0	1,940	2,000	3
1.86	Downstream of Wildwood Drive	10	500	520	4	940	970	3	940	1,020	8
		50	800	940	18	1,190	1,240	4	1,190	1,300	9
		100	930	1,040	12	1,260	1,300	3	1,260	1,340	6
2.25	Upstream of Chicago, Milwaukee, St. Paul & Pacific Railroad	10	430	460	7	880	940	7	890	1,000	12
		50	750	900	20	1,130	1,200	6	1,130	1,250	11
		100	880	990	12	1,180	1,250	6	1,190	1,280	8
3.04	Upstream of W. Marquette Avenue	10	260	260	0	540	540	0	560	560	0
		50	430	430	0	790	790	0	820	820	0
		100	520	520	0	880	880	0	900	900	0

Source: SEWRPC.

Under year 2000 planned land use and existing channel and floodplain development conditions, the potential for crop damage would exist only along Oak Creek between E. Forest Hill Avenue and S. Shepard Avenue. This is because, under planned land use conditions, all lands currently in agricultural use and subject to flooding, except those along the reach noted, would be converted to urban use, including parkway use along the flood-prone reaches of the channel. Structure damages would be concentrated along the same reaches under both planned land use conditions and existing land use conditions. It is estimated that 30 structures—all currently existing—located on 16 properties would incur flood damages under a 100-year recurrence interval flood event under planned land use and existing channel conditions. This increase in the number of structures subject to flood damage would not be due to the construction of new structures in the flood hazard area, but to increases in flood flows and stages as land use in the watershed changed from rural to urban.

The average annual monetary damages attributable to flood damages to crops and structures may be expected to approximate $15,600 and $14,300, respectively, under existing land use, channel, and floodplain conditions; and about $25,200 and $72,800, respectively, under year 2000 planned land use and existing channel and floodplain conditions. If, however, additional urban development were permitted to occur in the flood hazard area, even higher monetary flood risks could be expected to be incurred. Under existing land use, channel, and floodplain conditions, flood damages to crops and structures of about $84,200 and $259,600, respectively, may be expected to be incurred during a 100-year recurrence interval flood event; and of about $32,700 and $23,500, respectively, during a 10-year recurrence interval flood event. Under year 2000 planned land use and existing channel and floodplain conditions, flood damages to crops and structures of about $80,600 and $571,800, respectively, may be expected to be incurred during a 100-year recurrence interval flood event; and of $43,400 and $179,500, respectively, during a 10-year recurrence interval flood event. These existing and potential flood damages are relatively small compared to such damages in other watersheds in the Region. This may be attributed to the fact that the Oak Creek watershed is smaller than most of the major watersheds in the Region; to the fact that much of the watershed is still undeveloped, including the riverine areas, and thus flood damage-prone urban development can still be kept out of the flood hazard area; and to the fact that historic flood damage-prone urban development, such as that once existing in the City of South Milwaukee, has been cleared and the cleared land used for parkway purposes.

No Action Alternative

One alternative course of action for addressing the flood problems of the Oak Creek watershed is to do nothing—that is, to recognize the inevitability of flooding in the watershed, but to decide not to mount a collective, coordinated program to abate the flood damages. Under this alternative, one of two flood damage situations would remain, depending on which of the two land use development policies for the year 2000 previously described is adopted within the watershed. As previously stated, 30 structures may be expected to experience flood damages under a 100-year recurrence interval flood under either future land use condition. If it is assumed that new urban development will be allowed to occur within the floodplain fringe areas—that is, within the flood hazard area but outside the floodway—with all new structures being placed on fill or otherwise protected from flood damage, then under year 2000 land use and existing channel conditions, the average annual flood damages in the watershed may be expected to approximate $103,000. If it is assumed that no further development of flood hazard-prone areas within the watershed will be permitted, the average annual flood damages in the watershed may be expected to approximate $98,000. Under either condition, damage to crops would be minor and concentrated in the southeast portion of the watershed. There are no monetary benefits associated with this "do nothing" alternative, and the average annual cost would be equivalent to the average annual flood damages. Table 83 summarizes the estimated costs of this alternative.

Structure Floodproofing, Elevation, and Removal Alternative

A structure floodproofing, elevation, and removal alternative flood control plan was prepared and evaluated to determine if such a structure-by-structure approach would be a technically feasible and economically sound solution to the urban flood damage problems within the Oak Creek watershed. For analytical purposes, the 100-year recurrence interval flood stage under 2000 planned land use and existing channel conditions with floodplain fringe development was used to estimate the number of existing flood-prone structures to be floodproofed, elevated, or removed and the approximate costs involved.

In the case of residential structures, 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 have the first floor raised to an elevation of at least two feet above the 100-year recurrence interval flood stage to provide adequate freeboard. For aesthetic reasons, structure elevation was limited to a maximum of four feet. Structures which would have to be elevated more than four feet were considered for removal.

Floodproofing was assumed to be feasible for all nonresidential structures provided the flood stage was not more than seven feet above the first floor elevation. The floodproofing costs were assumed to be a function of the depth of water over the first floor.

As shown on Map 48, of the 30 structures which are expected to incur flood damage, 22 would have to be floodproofed, 6 would have to be elevated, and 2 would have to be removed under this alternative. Future flood damage to the existing structures in the watershed would be virtually eliminated by these measures. The potential for damage to crops in the watershed would remain, however. Table 83 sets forth the number and type of structures to be floodproofed, elevated, or removed and summarizes the estimated costs and benefits.

Assuming that these structure floodproofing measures would be fully implemented, and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost of this alternative is estimated at $50,000. This cost consists of the amortization of the $788,000 capital cost—$463,000 for floodproofing, $193,000 for structure elevation, and $132,000 for structure removal. The average

Table 83

PRINCIPAL FEATURES, COSTS, AND BENEFITS OF THE FLOODLAND MANAGEMENT ALTERNATIVES FOR THE OAK CREEK WATERSHED

Alternative			Economic Analysis[a]											
Number	Name	Description	Technically Feasible	Capital Cost: Item	Capital Cost (thousands)	Annual Amortized Capital Cost (thousands)	Annual Operation and Maintenance Cost (thousands)	Total[b] Annual Cost (thousands)	Annual[b] Benefits (thousands)	Excess of Annual Benefits Over Costs (thousands)	Benefit-Cost Ratio	Benefit-Cost Ratio Greater than 1.0	Nontechnical and Noneconomic Considerations: Positive	Nontechnical and Noneconomic Considerations: Negative
1	No Action-No development in floodplain area	- -	Yes	- -	$ - -	$ - -	$ - -	$ 98[c]	$ - -	$ - -	- -	No	- -	Continue to incur average annual flood damages of $98,000
2	No Action-Development in floodplain fringe area only	- -	Yes	- -	- -	- -	- -	103[c]	- -	- -	- -	No	- -	Continue to incur average annual flood damages of $103,000
3	Structure floodproofing elevation, and removal	a. Floodproof up to 22 residential and commercial structures b. Elevate up to six residential structures c. Remove up to two residential structures	Yes	Floodproofing Elevating Removal Subtotal	463 193 132 788	50	- -	50	78	28	1.56	Yes	Immediate partial flood relief at discretion of property owners Most of the costs would 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. Partial resolution of flood problem
4	Major Channelization 1	a. 16.2 miles of major channelization b. Modification or replacement of 26 bridges	Yes	Major channelization Bridge modification and replacement Subtotal	16,047 6,083 22,130	1,394	15	1,409	93	-1,316	0.07	No	Consistent with commitment of communities within the watershed as reflected by the location, size, and grade of existing storm sewers and bridges	Aesthetic impact of concrete lining, partial resolution of flood problem
5	Major Channelization 2	a. 16.2 miles of major channelization b. Replacement of 41 bridges	Yes	Major channelization Bridge replacement Subtotal	18,084 10,822 28,906	1,821	15	1,836	103	-1,733	0.06	No	Consistent with commitment of communities within the watershed as reflected by the location, size, and grade of existing storm sewers and bridges	Aesthetic impact of concrete lining
6	Major Channelization 3	a. 4.3 miles of major channelization b. Replacement of 12 bridges	Yes	Major channelization Bridge replacement Subtotal	1,142 4,799 5,941	375	4	379	34	- 345	0.09	No	Consistent with locally committed plans for development of industrial parks and residential neighborhood in City of Oak Creek	Partial resolution of flood problem
7	Decentralized Storage	Provide onsite detention storage facilities	Yes	Onsite detention facilities Land cost Subtotal	4,580 450 5,030	317	234	551	73	- 478	0.13	No	Potential to retain public open space. Impact on instream water quality	No assurance of long-term commitment by local units of government to require onsite detention facilities. Difficult to apply to small-scale development proposals. Partial resolution of flood problem.
8	Centralized Storage	Construction of five detention storage reservoirs	Yes	Reservoirs and outlet culverts Earthen embankment Land acquisition Subtotal	612 12 99 723	46	18	64	58	- 6	0.91	No	Potential to retain public open space	Partial resolution of flood problem

Table 83 (continued)

Alternative			Economic Analysis[a]											
Number	Name	Description	Technically Feasible	Capital Cost: Item	Capital Cost (thousands)	Annual Amortized Capital Cost (thousands)	Annual Operation and Maintenance Cost (thousands)	Total[b] Annual Cost (thousands)	Annual[b] Benefits (thousands)	Excess of Annual Benefits Over Costs (thousands)	Benefit-Cost Ratio	Benefit-Cost Ratio Greater than 1.0	Nontechnical and Noneconomic Considerations: Positive	Nontechnical and Noneconomic Considerations: Negative
9	Combination of Major Channelization and Floodproofing	a. 6.4 miles of major channelization b. 3.7 miles of channel deepening and shaping c. Replacement of 19 bridges d. Floodproof, elevate, or remove up to 24 structures	Yes	Major channelization	$ 1,676	$ 583	$ 10	$ 593	$ 92	$ -501	0.16	No	Consistent with locally committed plans for development of industrial parks and residential neighborhood in City of Oak Creek. Provides sufficient outlet for existing storm sewers	Partial resolution of flood problem
				Channel deepening and shaping	401									
				Bridge replacement	6,541									
				Structure floodproofing, elevation, and removal	347									
				Subtotal	8,965									
10	Combination of Major Channelization, Channel Deepening and Shaping, Centralized Storage, Structure Floodproofing, and Elevation	a. 6.4 miles of major channelization b. 3.7 miles of channel deepening and shaping c. Replacement of eight bridges d. Construction of five detention basins e. Floodproof or elevate up to 18 structures	Yes	Major channelization	1,574	386	28	414	98	- 316	0.24	No	Consistent with locally committed plans for development of industrial parks and residential neighborhood in City of Oak Creek. Provides sufficient outlet for existing storm sewers. Potential to retain public open space	Partial resolution of flood problem
				Channel deepening and shaping	401									
				Bridge replacement	3,317									
				Detention basins	723									
				Structure floodproofing and elevation	107									
				Subtotal	6,122									
11	Combination of Minimum Channelization and Structure Floodproofing, Elevation, and Removal	a. 5.7 miles of major channelization b. 3.7 miles of channel deepening and shaping c. Replacement of 11 bridges d. Floodproof, elevate, or remove up to 26 structures	Yes	Major channelization	1,076	318	9	327	93	- 234	0.28	No	Consistent with locally committed plans for development of industrial parks and residential neighborhood in City of Oak Creek. Provides sufficient outlet for existing storm sewers	Partial resolution of flood problem
				Channel deepening and shaping	401									
				Bridge replacement	3,049									
				Structure floodproofing, elevation, and removal	521									
				Subtotal	5,047									
12	Combination of Channel Deepening and Shaping, and Structure Floodproofing, Elevation, and Removal	a. 2.4 miles of channel deepening and shaping b. Replacement of two bridges c. Floodproof, elevate, or remove up to 29 structures	Yes	Channel deepening and shaping	207	64	1	65	78	13	1.20	Yes	Immediate partial flood relief at discretion of property owners Provides sufficient outlet for a storm sewer outfall which is currently below channel grade and eliminates a negative channel slope between IH 94 and S. 27th Street	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. Partial resolution of flood problem
				Bridge replacement	110									
				Structure floodproofing, elevation, and removal	692									
				Subtotal	1,009									

[a] *Economic analyses are based on an annual interest rate of 6 percent and a 50-year amortization period and project life.*

[b] *Annual benefits and costs used in the benefit-cost analysis include only the direct benefits derived from the abatement of monetary flood damages, and the direct costs attendant to implementation of the flood control measures, including capital and operation and maintenance costs. Environmental and recreational benefits and costs were not addressed in the benefit-cost analysis since these represent intangible benefits and costs and, therefore, cannot be readily quantified.*

[c] *The total cost of this alternative consists of the average annual monetary flood damages.*

Source: SEWRPC.

annual flood damage abatement benefit was estimated at $78,000 per year, yielding a benefit-cost ratio of 1.56. Therefore, the structure floodproofing, elevation, and removal alternative plan as described herein was found to be both technically and economically feasible.

Major Channelization Alternatives

Three alternatives utilizing major channel modifications were developed and analyzed for the Oak Creek watershed to determine if such measures would provide technically and economically sound solutions to existing and future flood problems, as well as to accommodate existing local development and stormwater drainage plans. The purpose of the first two alternatives was two-fold: 1) to help abate the existing and future flood damages; and 2) to provide an adequate outlet for existing urban stormwater drainage systems which, as designed and built, may experience a loss of required hydraulic capacity as a result of the inverts of the outlets being at an elevation below the existing streambed, or as a result of surcharging from the receiving stream to which the outlets discharge.

Many of the storm sewer outfalls in the watershed have been designed to match the recommended future channel invert set forth in the 1967 report prepared for the Milwaukee Metropolitan Sewerage District by Klug & Smith Company entitled, Report on Oak Creek Flood Survey on Entire Basin for the Metropolitan Sewerage Commission of the County of Milwaukee. That report recommends major channel modifications for much of the Oak Creek watershed stream system, and its recommendations have been incorporated by the District and other state and local units and agencies of government into the design of bridges, channel improvements, and urban stormwater drainage systems. This has resulted in one existing storm sewer outfall entering the stream system with an invert elevation below the elevation of the existing channel bottom. An additional 21 storm sewer outfalls enter the stream system with invert elevations at, or within two feet of, the elevation of the existing channel bottom. Finally, an additional 151 storm sewer outfalls enter the stream system with invert elevations more than two feet above the elevation of the channel bottom. The locations of the 22 outfalls which enter the stream with invert elevations less than two feet above the channel bottom are shown on Map 49. The locations of all of the storm sewer outfalls in the watershed are also shown on Map 36 in Chapter VII. Those outfalls with invert elevations below the channel bottom and within two feet of that bottom may be expected to experience loss of capacity which may cause drainage problems due to storm sewer surcharging.

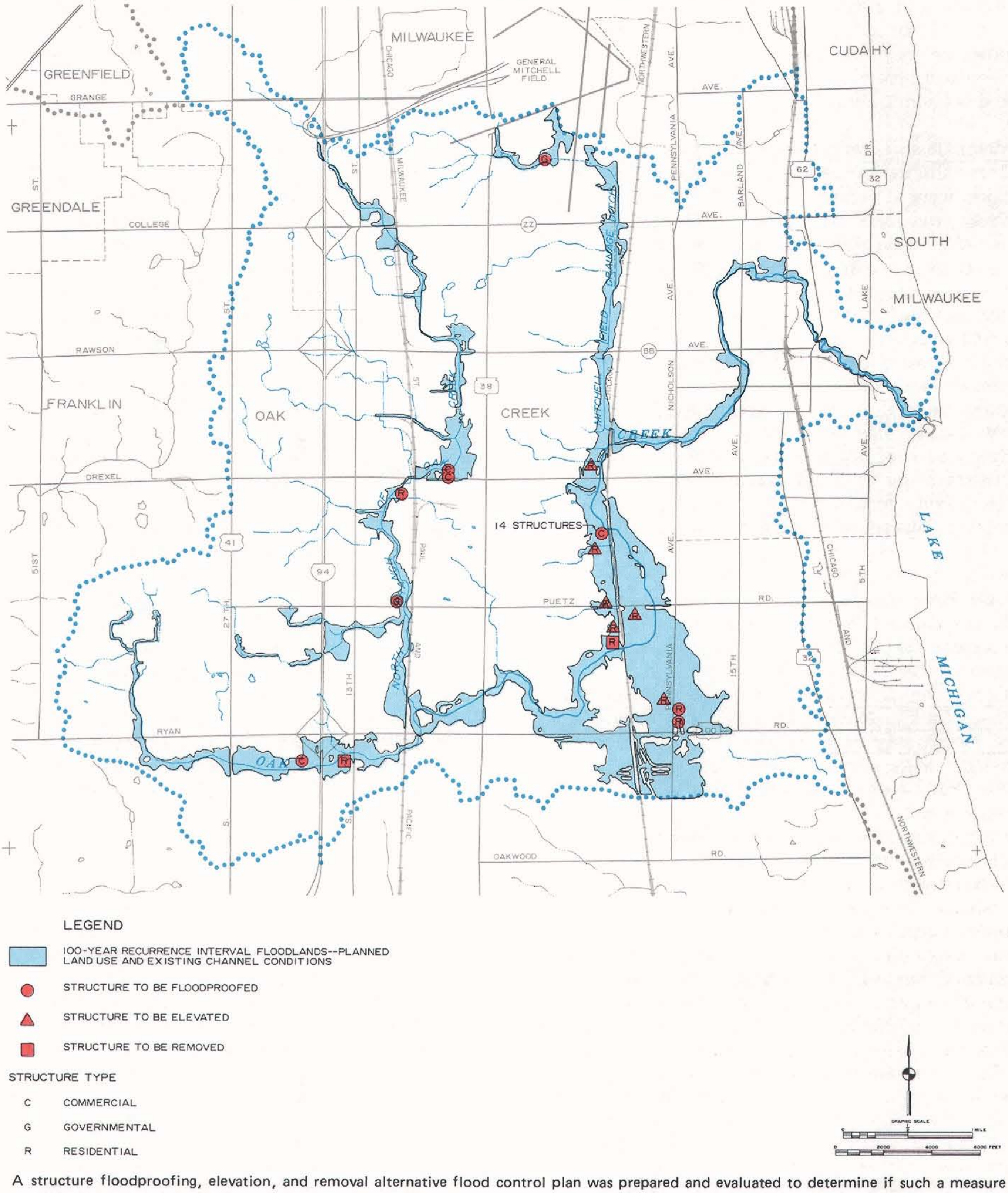
The third alternative considered was designed to accommodate the development of two locally committed industrial parks in the City of Oak Creek, one located along Oak Creek between IH 94 and S. 27th Street, and one located along the North Branch of Oak Creek between W. Drexel Avenue and W. Rawson Avenue. This alternative is also designed to accommodate a locally committed residential development along the North Branch of Oak Creek, downstream of Wildwood Drive.

Major Channelization Alternative 1: The first flood control alternative utilizing major channel improvements is shown on Map 50, and the physical characteristics and estimated costs and benefits of this project are set forth in Table 83. The design of the modified channel under this alternative—including the alignment, grade, and channel bottom widths—is based upon the recommended channel improvements outlined in the Klug & Smith report referenced above except along two stream reaches where channel improvements have been made which do not follow that design. These reaches are located along Oak Creek between E. Rawson Avenue and S. Pennsylvania Avenue, and between S. Howell Avenue and the confluence with the North Branch of Oak Creek. For those stream reaches which were not included in the Klug & Smith report, the channel alignment and bottom widths used were based on preliminary designs developed by the City of Oak Creek Engineering Department.

Under this alternative, major channel modifications would be required along Oak Creek starting at the upstream end of the parkway impoundment in the City of South Milwaukee and continuing upstream to S. 27th Street—a distance of 9.8 miles. The proposed channel would have a bottom width ranging from 16 to 42 feet, with side slopes of one on two for the lower half of the channel cross-section, and of one on three for the upper half of the channel cross-section. The lower half of the channel would be concrete-lined and the top half turf-lined. This channel cross-section geometry is consistent with that proposed by the Milwaukee Metropolitan Sewerage District for the reach of Oak Creek between E. Rawson Avenue and S. Pennsylvania

Map 48

STRUCTURE FLOODPROOFING, ELEVATION, AND REMOVAL ALTERNATIVE FOR THE OAK CREEK WATERSHED

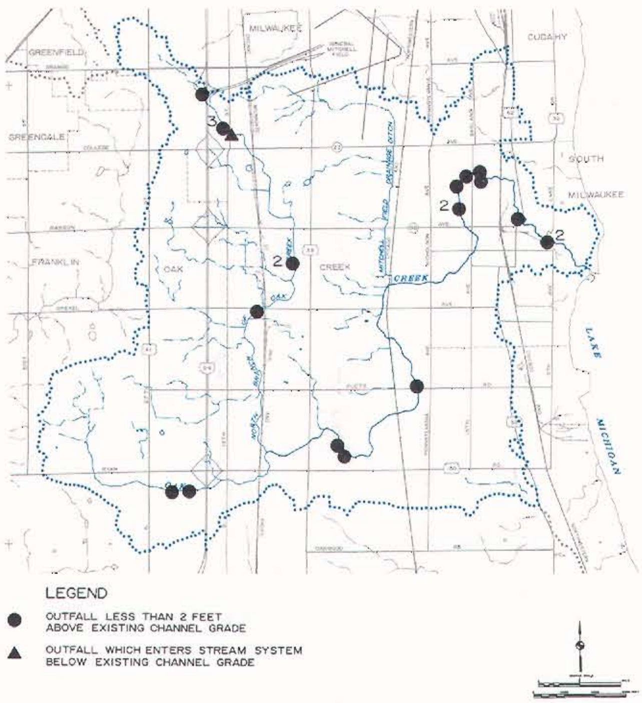


A structure floodproofing, elevation, and removal alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, 22 structures would have to be floodproofed, six structures would have to be elevated, and two structures would have to be removed. Residual crop damages amounting to $25,000 on an average annual basis would remain in the watershed. This alternative was found to be both technically feasible and to have a benefit cost ratio of greater than one.

Source: SEWRPC.

Map 49

EXISTING STORM SEWER OUTFALLS IN THE OAK CREEK WATERSHED WHICH ENTER THE STREAM SYSTEM WITHIN TWO FEET OF THE EXISTING CHANNEL GRADE



Many of the existing storm sewers in the Oak Creek watershed have been designed under the assumption that major channelization of the stream system would occur. This has resulted in one storm sewer outfall being set at an elevation which is below the existing channel grade, with another 21 storm sewer outfalls being set at elevations at or within two feet of the existing channel grade. This situation may result in surcharging of those storm sewers which drain to these 22 outfalls.

Source: SEWRPC.

Avenue. Major channel modifications would also be required along the North Branch of Oak Creek from its confluence with Oak Creek upstream to W. Ramsey Avenue, a distance of 5.6 miles, and along the Mitchell Field Drainage Ditch from its confluence with Oak Creek upstream to W. Rawson Avenue, a distance of 0.8 mile. The proposed channel geometry would be the same as that for Oak Creek, with bottom widths of eight feet for the North Branch of Oak Creek and 24 feet for the Mitchell Field Drainage Ditch. In addition, this alternative includes widening and shaping of the channel of the Mitchell Field Drainage Ditch along the Wisconsin Air National Guard property. These improvements would begin at the upstream end of the south runway culvert and continue upstream for approximately 800 feet. The proposed channel would be turf-lined with a bottom width of 10 feet and side slopes of one on three.

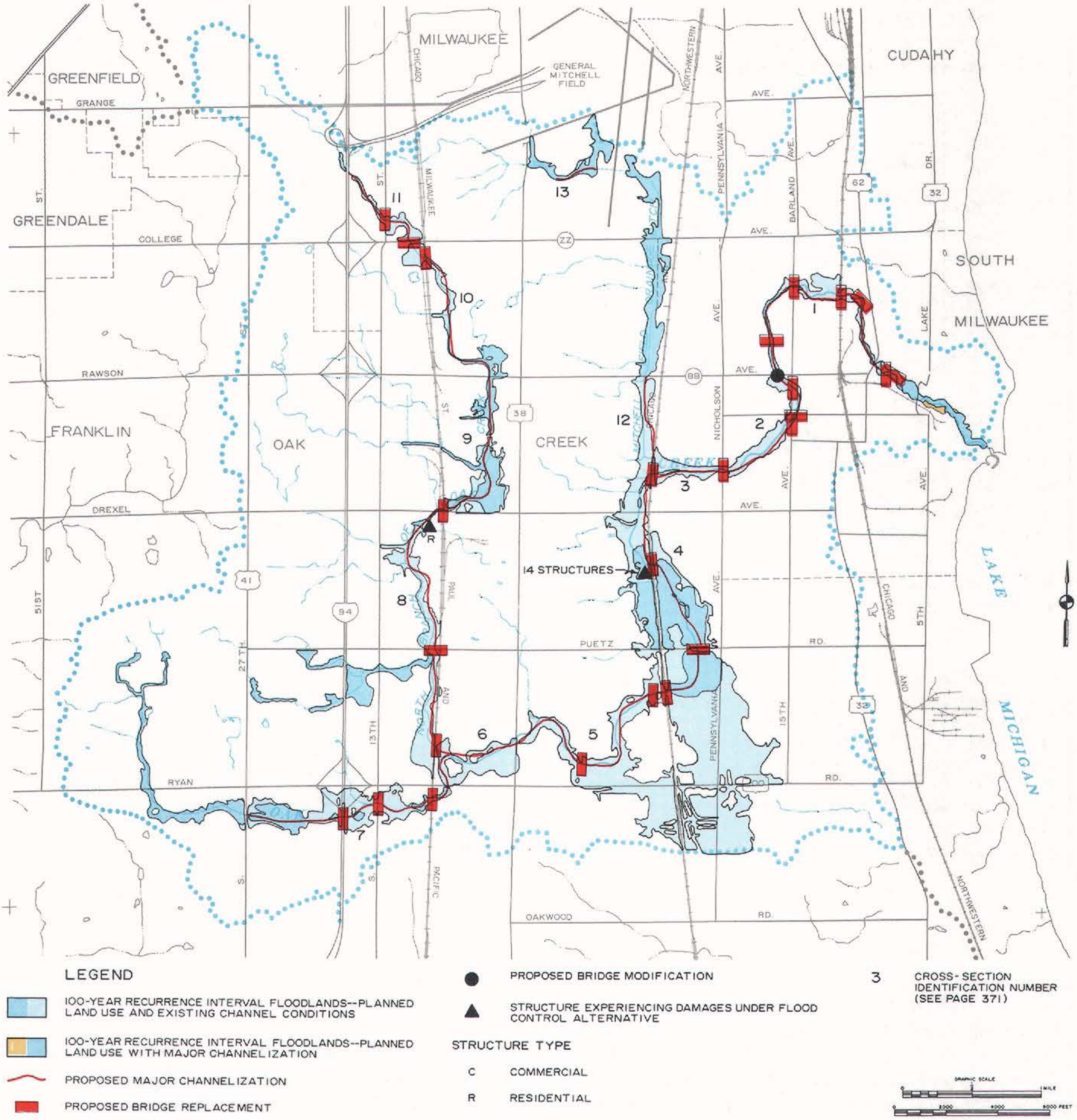
This alternative plan element also includes the replacement of 25 bridges as listed in Table 84—19 on Oak Creek and six on the North Branch of Oak Creek. No bridge replacement would be required on the Mitchell Field Drainage Ditch. It should be noted that of the 25 bridges to be replaced, 12 are designated for reconstruction for highway capacity purposes under the year 2000 regional transportation system plan as set forth in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000. Therefore, the cost of replacing these 12 bridges was not included in the cost analysis of the alternative flood control plan elements.

In addition to these bridge replacements, modifications would be required in the design of the proposed E. Rawson Avenue replacement bridge which is scheduled for construction in the fall of 1985. The new bridge is proposed to consist of three 10-feet-wide by 10-feet-high concrete box culverts. The hydrologic-hydraulic analyses of this alternative indicate that this structure would cause an excessive amount of backwater, resulting in added flood damages in the City of South Milwaukee. Preliminary findings indicate that the waterway opening of this bridge would need to be increased by an area equivalent to three 11-feet-wide by 10-feet-high box culverts.

It should be noted that the flood flows estimated under this alternative are somewhat higher than those estimated under the Klug & Smith study. One reason for these differences is that the earlier study used a 50-year recurrence interval storm as the design storm, while this study uses a 100-year recurrence interval event as the design storm. Second, the techniques used in the development of the design flows for the Klug & Smith study did not reflect the loss of storage and the improved hydraulic efficiency associated with implementation of a major channelization alternative. The simulation modeling techniques which were utilized in this study more fully reflect these effects. For example, the earlier study estimated design flood flows at the Oak Creek parkway impound-

Map 50

MAJOR CHANNELIZATION ALTERNATIVE 1 FOR THE OAK CREEK WATERSHED

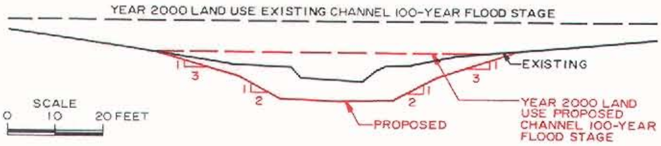


A major channelization alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, the Oak Creek channel would be deepened and enlarged beginning at the upstream end of the parkway impoundment in the City of South Milwaukee and extending upstream to S. 27th Street—a distance of 9.8 miles; the North Branch of Oak Creek would be deepened and enlarged beginning at its confluence with Oak Creek and extending upstream to W. Ramsey Avenue—a distance of 5.6 miles; and the Mitchell Field Drainage Ditch would be deepened and enlarged beginning at its confluence with Oak Creek and extending upstream to E. Rawson Avenue—a distance of 0.8 mile. In addition, 25 bridges would be replaced to accommodate the deeper and larger channel. Under this alternative, residual flood damages amounting to $10,000 on an average annual basis would remain in the watershed. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

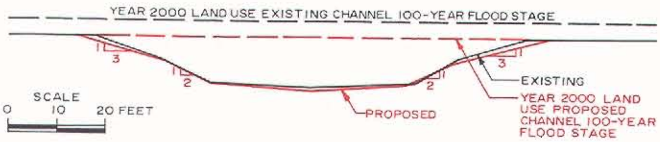
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN PARKWAY LAGOON AND E. RAWSON AVENUE



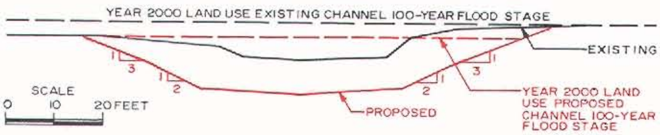
2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN E. RAWSON AVENUE AND S. PENNSYLVANIA AVENUE



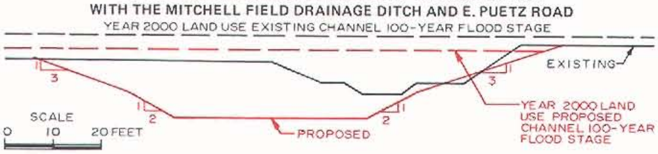
3

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. PENNSYLVANIA AVENUE AND THE CONFLUENCE WITH THE MITCHELL FIELD DRAINAGE DITCH



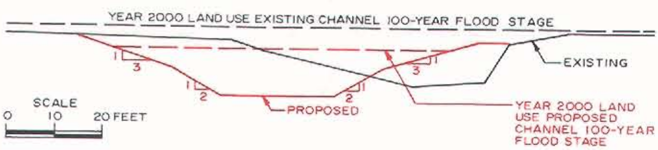
4

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN THE CONFLUENCE WITH THE MITCHELL FIELD DRAINAGE DITCH AND E. PUETZ ROAD



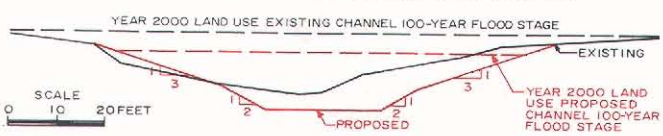
5

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN E. PUETZ ROAD AND S. HOWELL AVENUE



6

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. HOWELL AVENUE AND THE CONFLUENCE WITH THE NORTH BRANCH OF OAK CREEK



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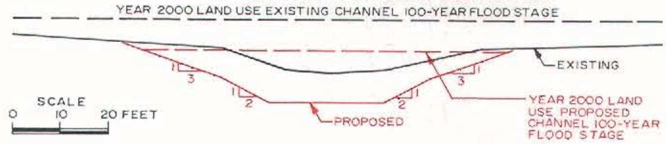
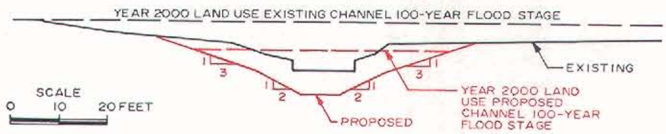
TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN THE CONFLUENCE WITH THE NORTH BRANCH OF OAK CREEK AND S. 27TH STREET



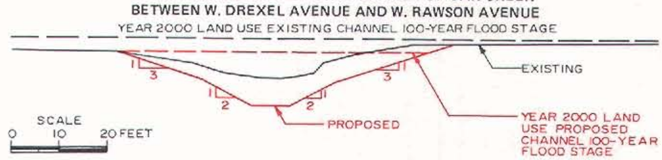
8

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN THE CONFLUENCE WITH OAK CREEK AND W. DREXEL AVENUE



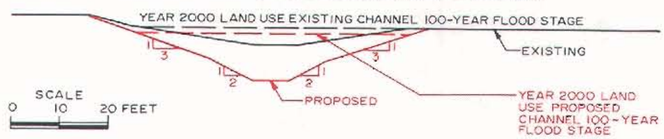
9

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. DREXEL AVENUE AND W. RAWSON AVENUE



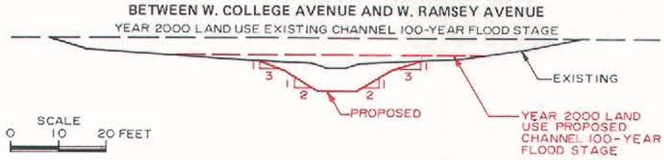
10

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. RAWSON AVENUE AND W. COLLEGE AVENUE



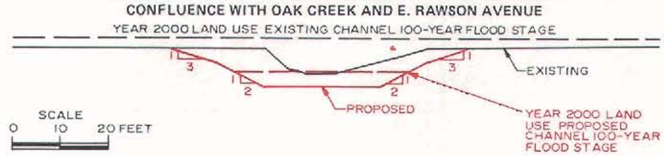
11

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. COLLEGE AVENUE AND W. RAMSEY AVENUE



12

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH BETWEEN THE CONFLUENCE WITH OAK CREEK AND E. RAWSON AVENUE



13

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH UPSTREAM FROM AIRPORT RUNWAY

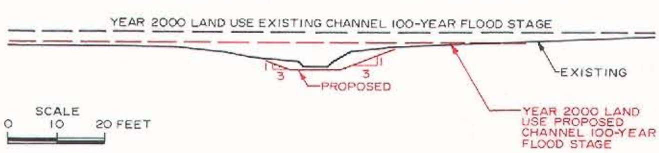


Table 84

BRIDGES TO BE REPLACED UNDER ALTERNATIVES REQUIRING CHANNELIZATION WITHIN THE OAK CREEK WATERSHED

Structure Name	Stream	River Mile	To be Replaced Under Regional Transportation Plan	Major Channelization Alternative 1	Major Channelization Alternative 2	Major Channelization Alternative 3	Combination of Major Channelization Channel Deepening and Shaping, Structure Floodproofing, Elevation, and Removal	Combination of Major Channelization Channel Deepening and Shaping, Centralized Storage, Structure Floodproofing and Removal	Combination of Minimum Channel Modification and Structure Floodproofing, Elevation, and Removal	Combination of Channel Deepening and Shaping, and Structure Floodproofing, Elevation, and Removal
2nd Parkway Bridge . . .	Oak Creek	0.88	--	--	X	--	--	--	--	--
Mill Road		0.94	--	--	X	--	--	--	--	--
3rd Parkway Bridge. . . .		1.18	--	X	X	--	--	--	--	--
4th Parkway Bridge. . . .		1.32	--	X	X	--	--	--	--	--
Chicago Avenue		1.61	--	--	X	--	--	--	--	--
5th Parkway Bridge. . . .		2.14	--	X	X	--	--	--	--	--
C&NW Railway		2.35	--	X	X	--	--	--	--	--
15th Avenue.		2.84	X	X	X	--	--	--	--	--
Pine Street		3.37	--	X	X	--	--	--	--	--
E. Rawson Avenue		3.62	--	--	X	--	--	--	--	--
16th Avenue.		3.66	--	--	X	--	--	--	--	--
15th Avenue.		3.76	X	X	X	--	--	--	--	--
Milwaukee Avenue		4.01	--	X	X	--	--	--	--	--
15th Avenue.		4.06	X	X	X	--	--	--	--	--
S. Pennsylvania Avenue .		4.71	X	X	X	--	--	--	--	--
C&NW Railway		5.25	X	X	X	--	X	X	X	--
E. Drexel Avenue		5.56	--	--	X	--	--	--	--	--
C&NW Railway		6.06	X	X	X	--	X	X	X	--
E. Forest Hill Avenue. . .		6.25	--	--	X	--	--	--	--	--
E. Puetz Road.		6.83	X	X	X	--	--	--	--	--
C&NW Railway		7.34	X	X	X	--	--	--	--	--
S. Nicholson Road		7.44	X	X	X	--	--	--	--	--
S. Shepard Avenue		8.41	--	X	X	--	X	X	X	--
S. Howell Avenue		9.23	--	--	X	--	--	--	--	--
W. Ryan Road.		10.06	--	--	X	X	X	--	--	--
CMSTP&P Railroad. . . .		10.24	--	X	X	X	X	--	--	--
S. 13th Street		10.69	X	X	X	X	X	X	X	--
IH 94.		10.98	--	X	X	X	X	X	X	--
S. 20th Street		11.24	--	--	X	X	X	--	--	--
CMSTP&P Railroad. . . .	North Branch of Oak Creek	0.10	--	X	X	X	X	--	X	--
W. Puetz Road.		0.92	X	X	X	X	X	X	X	--
Wildwood Drive		2.00	--	--	X	X	X	--	--	--
W. Drexel Avenue.		2.21	--	--	X	X	X	--	--	--
CMSTP&P Railroad. . . .		2.25	--	X	X	X	X	X	X	--
S. 6th Street		2.41	--	--	X	X	X	--	--	--
W. Marquette Avenue. . .		3.04	--	--	X	X	X	--	--	--
W. Rawson Avenue		3.51	--	--	X	--	X	--	--	--
S. 6th Street		3.86	--	--	X	--	--	--	--	--
CMSTP&P Railroad. . . .		4.75	--	X	X	--	X	X	X	X
W. College Avenue		4.91	X	X	X	--	X	X	X	X
S. 13th Street		5.21	--	X	X	--	X	X	X	--

Source: SEWRPC.

ment in the City of South Milwaukee of 2,740 cfs and 5,000 cfs for the 10-year and 50-year recurrence interval storm events, respectively, under future land use and existing channel conditions assuming full urbanization of the watershed. Under this study, these design flood flows were estimated to be 1,900 cfs and 2,500 cfs for the 10-year and 50-year recurrence interval events, respectively, and 2,800 cfs for the 100-year recurrence interval event, all assuming planned land use and existing channel conditions. Under planned land use and channel conditions, the estimated flow rates under this study are 4,800 cfs and 7,100 cfs for the 10-year and 50-year recurrence interval events, respectively, and 8,200 cfs for the 100-year recurrence interval event.

The results of the hydrologic-hydraulic simulation modeling conducted for this alternative indicate that the 100-year recurrence interval flood flow would not be contained within the modified channel proposed in the Klug & Smith report along certain stream reaches. The areas of residual flood damages associated with this alternative are indicated on Map 50; these damages may be expected to total about $10,000 on an average annual basis.

Utilizing an annual interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this major channelization alternative is estimated at $1,409,000. This cost consists of the amortization of the $22,130,000 capital cost of the major channelization and bridge replacement entailed, and $15,000 in annual operation and maintenance costs. This cost does not reflect the purchase price of land required for the proposed channel modifications. The alignment of the proposed channel is mainly within parkway lands or existing drainage rights-of-way; therefore, land costs were considered minimal. The average annual flood abatement benefit is estimated at $93,000, resulting in a benefit-cost ratio of 0.07. This major channelization alternative, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above the channel bottom, or from the realignment of the channel to coincide with local development plans.

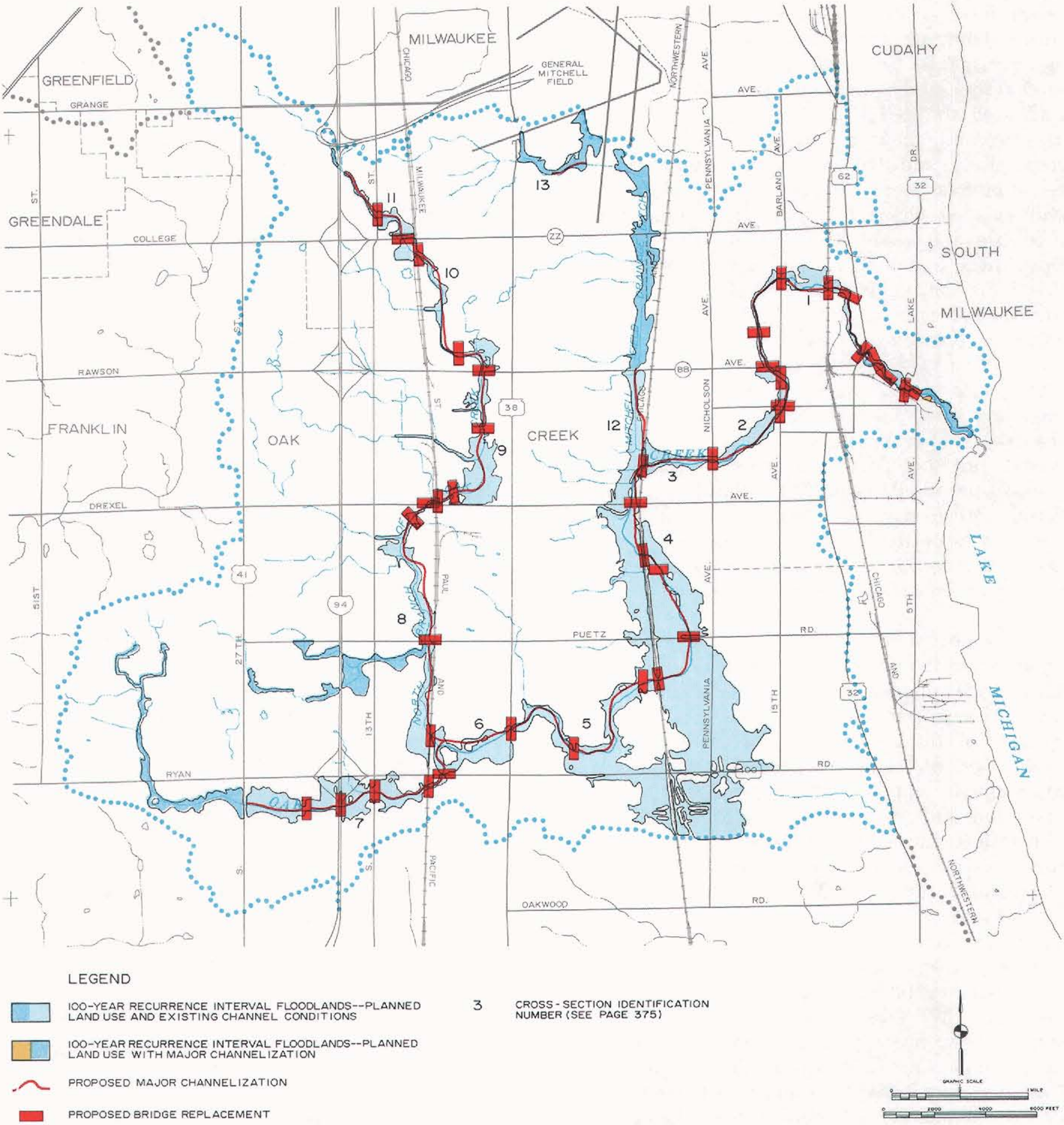
Major Channelization Alternative 2: The second major channelization flood control alternative is essentially the same as the first alternative, except that the channel is designed to contain the 100-year recurrence interval flood discharge while providing a minimum of two feet of freeboard. Major channel modifications would be required along Oak Creek between the parkway impoundment in the City of South Milwaukee and S. 27th Street, a distance of 9.8 miles; along the North Branch of Oak Creek from its confluence with Oak Creek to W. Ramsey Avenue, a distance of 5.6 miles; and along the Mitchell Field Drainage Ditch from its confluence with Oak Creek to E. Rawson Avenue, a distance of 0.8 mile. This alternative is shown on Map 51, and the physical characteristics and estimated costs and benefits are set forth in Table 83. Under this alternative, the proposed channel would need to be widened and/or deepened beyond that proposed in the Klug & Smith report. For some reaches the proposed channel would need to be widened an additional 10 to 36 feet, while the channel bottom would need to be lowered an additional two feet. For the reach of the Mitchell Field Drainage Ditch along the Wisconsin Air National Guard property, no further channel widening was considered under this alternative. Any further effort to confine the design flood discharge to the channel at this location would require the replacement of the south runway culvert, since the backwater created by this culvert results in a flood stage higher than the proposed channel banks. Since the channel improvements called for under the first channelization alternative would result in the elimination of the structure damages in this area, no further consideration was given to replacing the runway culvert.

In addition to the required widening and lowering of the channel bottom, 16 additional bridges would need to be replaced under this alternative. These bridges are listed in Table 84. Of the 41 bridges requiring replacement under this alternative, 12 are designated for reconstruction for highway capacity purposes under the year 2000 regional transportation system plan as set forth in SEWRPC Planning Report No. 25, and therefore were not considered in the cost analysis of this alternative.

Utilizing an annual interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this channel modification alternative is estimated at $1,836,000, consisting of the amortization of the $28,906,000

Map 51

MAJOR CHANNELIZATION ALTERNATIVE 2 FOR THE OAK CREEK WATERSHED



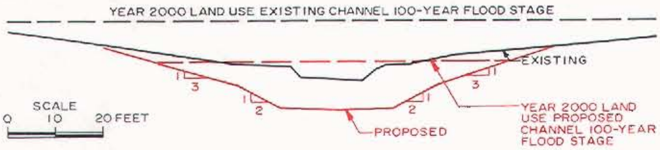
A second major channelization alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, the Oak Creek channel would be deepened and enlarged beginning at the parkway dam in the City of South Milwaukee and extending upstream to S. 27th Street—a distance of 9.8 miles; the North Branch of Oak Creek would be deepened and enlarged beginning at the confluence with Oak Creek and extending upstream to W. Ramsey Avenue—a distance of 5.6 miles; and the Mitchell Field Drainage Ditch would be deepened and enlarged beginning at the confluence with Oak Creek and extending upstream to E. Rawson Avenue—a distance of 0.8 mile. In addition, 41 bridges would be replaced to accommodate the larger channel. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

Map 51 (continued)

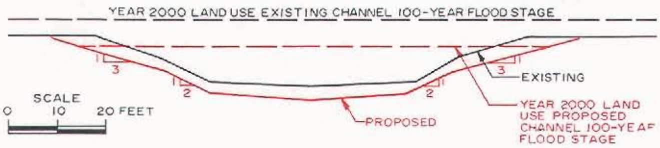
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN PARKWAY LAGOON AND E. RAWSON AVENUE



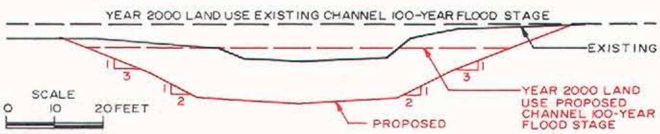
2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN E. RAWSON AVENUE AND S. PENNSYLVANIA AVENUE



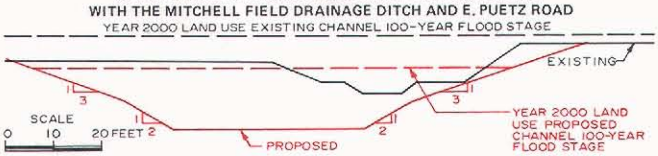
3

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. PENNSYLVANIA AVENUE AND THE CONFLUENCE WITH THE MITCHELL FIELD DRAINAGE DITCH



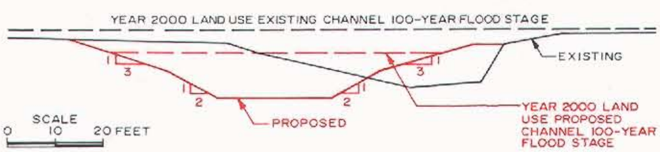
4

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN THE CONFLUENCE WITH THE MITCHELL FIELD DRAINAGE DITCH AND E. PUETZ ROAD



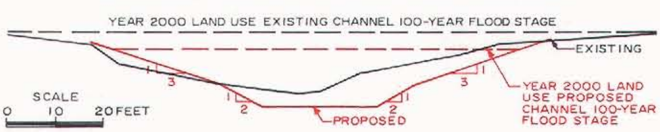
5

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN E. PUETZ ROAD AND S. HOWELL AVENUE



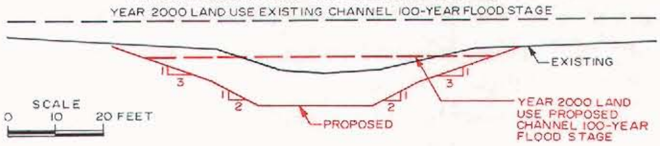
6

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. HOWELL AVENUE AND THE CONFLUENCE WITH THE NORTH BRANCH OF OAK CREEK



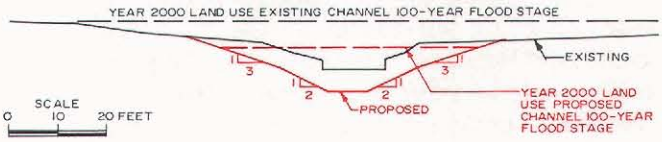
7

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN THE CONFLUENCE WITH THE NORTH BRANCH OF OAK CREEK AND S. 27TH STREET



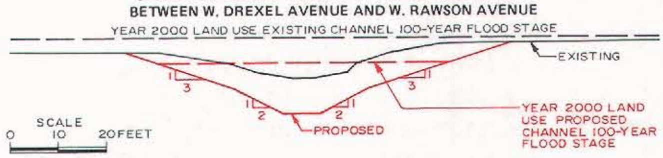
8

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN THE CONFLUENCE WITH OAK CREEK AND W. DREXEL AVENUE



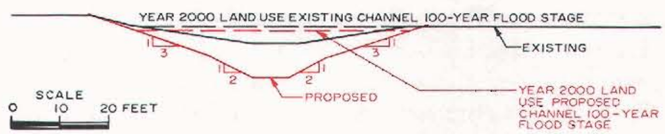
9

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. DREXEL AVENUE AND W. RAWSON AVENUE



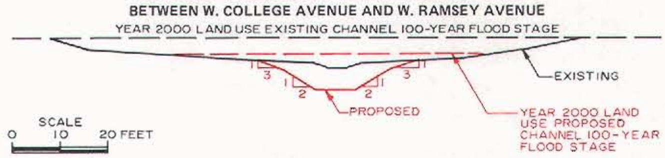
10

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. RAWSON AVENUE AND W. COLLEGE AVENUE



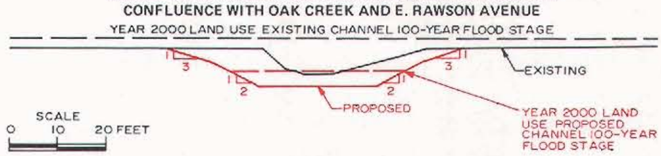
11

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN W. COLLEGE AVENUE AND W. RAMSEY AVENUE



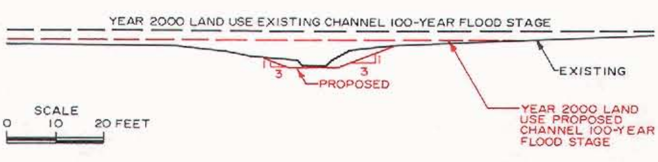
12

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH BETWEEN THE CONFLUENCE WITH OAK CREEK AND E. RAWSON AVENUE



13

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH UPSTREAM FROM AIRPORT RUNWAY



capital cost of major channelization and bridge replacement, and $15,000 in annual operation and maintenance costs. This cost does not reflect the purchase price of land required for the proposed channel since the alignment of the proposed channel is mainly within parkway lands or existing drainage rights-of-way. The average flood abatement benefit is estimated at $103,000, resulting in a benefit-cost ratio of 0.06. Thus, this major channelization alternative plan, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above the existing channel bottom, or from the realignment of the channel to coincide with local development plans.

Major Channelization Alternative 3: The third flood control alternative utilizing major channelization is shown on Map 52, and the physical characteristics and estimated costs and benefits attendant to this alternative are set forth in Table 83. Under this alternative, major channel modifications would be carried out along only a portion of Oak Creek beginning at the Chicago, Milwaukee, St. Paul & Pacific Railroad (Milwaukee Road) and extending upstream to S. 27th Street—a distance of about 1.5 miles. Peak flood discharges and channel slopes would be less under this alternative than under the first two channelization alternatives, thereby resulting in lower velocities along the modified channel reaches and allowing the use of turf lining in place of concrete lining. The proposed channel would have a bottom width of 20 feet with side slopes of one on three. Major channel modifications would also be required along the North Branch of Oak Creek beginning about 960 feet downstream of the confluence with Southland Creek and extending upstream to W. Rawson Avenue—a distance of about 2.8 miles. This proposed channel would also be turf-lined and have a bottom width of 20 feet with side slopes of one on three.

This alternative plan would require the replacement of five bridges on Oak Creek and seven bridges on the North Branch of Oak Creek. These bridges are listed in Table 84. Of these 12 bridges, two are designated for reconstruction for highway capacity purposes, and therefore were not considered in the cost analysis for this alternative.

The hydrologic-hydraulic analyses conducted under this alternative indicates that the reduction in floodwater storage created by the channel modifications would serve to increase stages downstream of the Oak Creek modification a distance of about 10.2 miles, with the increases over this length varying from 0.1 to 0.5 foot. Stages would also be increased downstream of the North Branch modification for a distance of about 0.7 mile, with the increases over this length varying from 0.1 foot to 1.1 feet. Chapter NR 116 of the Wisconsin Administrative Code requires that flooding easements be obtained from all property owners affected by any increase of more than 0.1 foot in the 100-year recurrence interval flood profile.[11] Accordingly, such flooding easements would have to be obtained under this alternative for that reach from the mouth of Oak Creek to the beginning of the major channel improvements.

Under this alternative, flood damage to crops and structures totaling $26,000 and $43,000, respectively, on an average annual basis would remain in the watershed. The locations of these residual damages are shown on Map 52.

Utilizing an annual interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative is estimated at $379,000, consisting of the amortization of the $5,941,000 capital cost of the channel improvements and bridge replacements, and $4,000 in annual operation and maintenance costs. These costs do not reflect the purchase price of land required for the proposed channel alignments since most of the channel would be within existing drainage rights-of-way or within parkway lands. The average annual flood abatement benefit is estimated at $34,000, resulting in a benefit-cost ratio of 0.09. Thus, this channel enlargement alternative, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits associated with this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above

[11] *A revised version of Chapter NR 116 became effective in March 1986 limiting this increase to 0.01 foot.*

the channel bottom, or from the realignment of the channel in accordance with local development plans.

Decentralized Storage Alternative

An alternative flood control plan consisting of decentralized—or offstream, onsite—storage was considered. This alternative is shown on Map 53, with the physical characteristics and estimated costs and benefits being set forth in Table 83. This alternative assumes that all of the communities in the watershed will adopt policies requiring that onsite stormwater detention facilities be provided as land is converted from rural to urban use in order to ensure that stormwater runoff from developing areas will not exceed such runoff under predevelopment conditions. Such a policy would serve to limit peak flood discharges to those under the existing land use conditions in the watershed. In addition, the construction of onsite storage facilities could reduce the costs of local urban stormwater facilities, as well as provide some water quality benefits, by limiting the amount of urban nonpoint source pollution entering the stream system.

Under this alternative plan, a large number of relatively small detention basins were assumed to be installed throughout the watershed to serve new development. For cost estimation purposes, it was assumed that 90 such basins, each with a size of from one to two acres and serving about 80 acres of tributary drainage area, would be installed. It was recognized that other types of facilities such as infiltration trenches could also be used to minimize stormwater flows, and that the best type of facility would have to be determined on the basis of site-specific analyses. The estimated cost of this alternative did not, however, include a credit for reductions in the size and cost of local stormwater conveyance facilities, since such reductions are uncertain in the absence of detailed system plans. The estimated cost of this alternative does include the cost of the up to 180 acres of land required for the detention basins. These land costs were included since the area occupied by these basins could, in the absence of a decentralized storage plan, be used for other purposes.

In considering a decentralized storage alternative, several negative aspects are encountered. First, the long-term commitment to a decentralized storage policy by any one local unit of government in the watershed, much less by all of the local units of government in the watershed, must be considered uncertain. While a local governing body may at any given time favor such a policy, there is no assurance that future governing bodies will be similarly inclined. Furthermore, it is unlikely that a decentralized storage policy could, as a practical matter, be applied to each and every increment of urban land development in the watershed. While such a policy may be relatively easy to apply to large-scale development, it is much more difficult to apply to smaller increments of land development. Accordingly, as a practical matter, it is likely that flood flows would increase as a result of urban development despite the best efforts of any local unit of government to apply a decentralized stormwater storage policy. Finally, such a policy does not address the flood problems associated with existing development conditions. These problems would still require the development of a more "conventional" flood control plan.

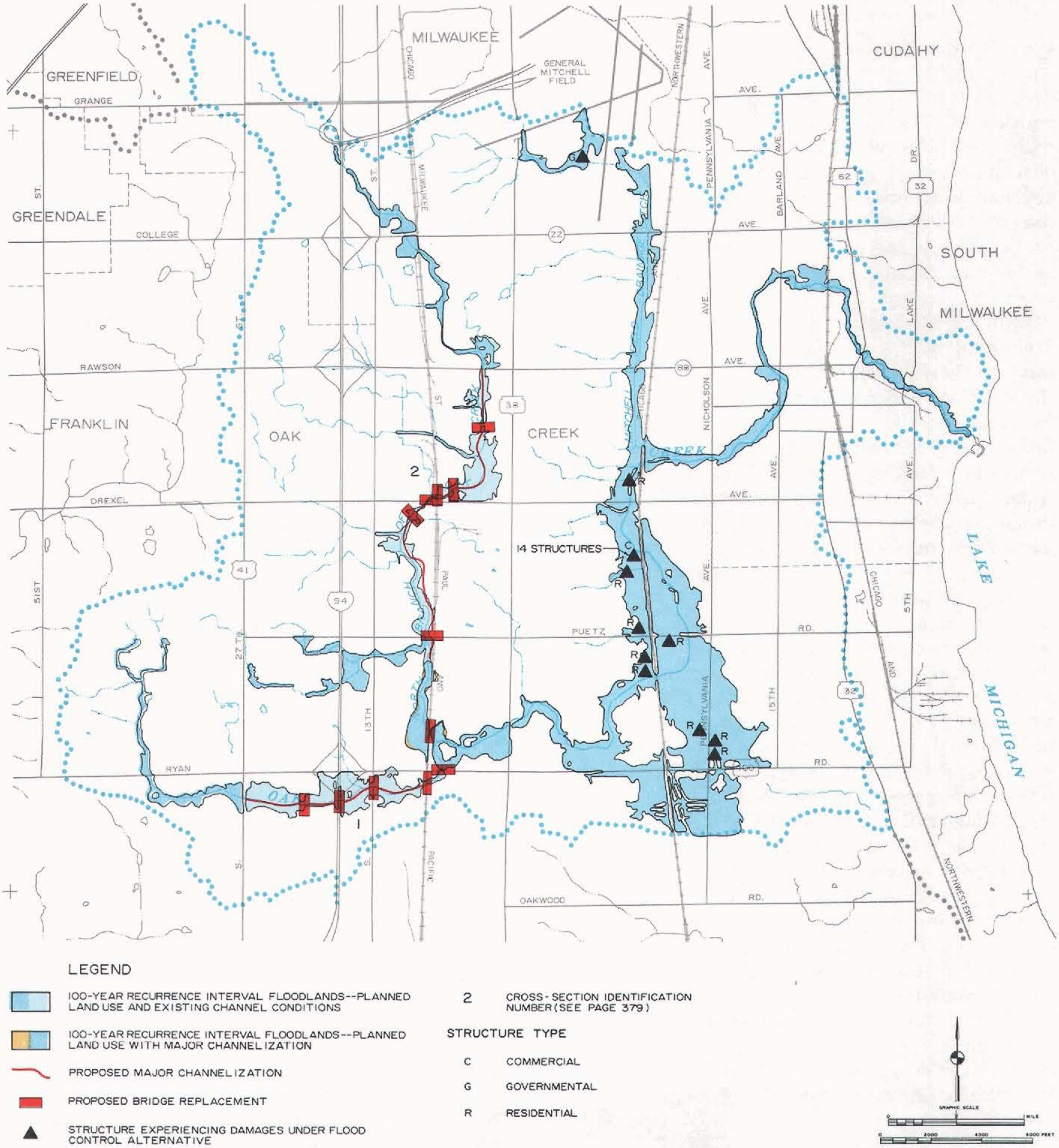
Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $551,000, consisting of the amortization of the $5,030,000 land costs and capital cost of the onsite detention facilities, and $234,000 in annual operation and maintenance costs. The average annual flood abatement benefit was estimated at $73,000, the difference between the potential average annual flood damage under existing land use and channel and floodplain conditions and year 2000 planned land use and existing channel conditions with floodplain fringe development. The benefit cost ratio was thus estimated at 0.13.

Centralized Storage Alternative

A centralized—or on-stream—detention storage alternative flood control plan was also prepared and evaluated. As shown on Map 54, this alternative consists of the construction of five on-stream detention basins at the following locations: 1) upstream of S. Howell Avenue on the Oak Creek main stem; 2) upstream of S. 27th Street on the Oak Creek main stem; 3) upstream of S. 31st Street on the Oak Creek main stem; 4) upstream of the first S. 6th Street crossing of the North Branch of Oak Creek—this being at the same location as the proposed sediment basin described in Chapter XIII; and 5) upstream of S. Howell Avenue on the Mitchell Field Drainage Ditch. These sites were selected because of their proximity to reaches with

Map 52

MAJOR CHANNELIZATION ALTERNATIVE 3 FOR THE OAK CREEK WATERSHED



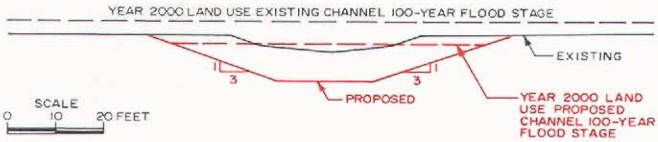
A third major channelization alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, the Oak Creek channel would be deepened and enlarged beginning at the Milwaukee Road railway right-of-way and extending upstream to S. 27th Street—a distance of about 1.5 miles; and the North Branch of Oak Creek would be deepened and enlarged beginning about 960 feet downstream of the confluence with Southland Creek and extending upstream to W. Rawson Avenue—a distance of about 2.8 miles. In addition, 12 bridges would be replaced. Under this alternative, residual flood damages amounting to $69,000 on an average annual basis would remain in the watershed. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

Map 52 (continued)

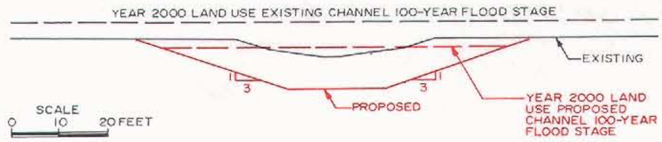
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK



2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK



potential flood damages and because basins at these sites would have the greatest potential impact on downstream peak flood discharges.

The results of the hydrologic-hydraulic simulation modeling conducted under this alternative indicate that some flood damage potential would remain under this alternative. The locations of the residual flood damages attendant to the 100-year recurrence interval flood event under year 2000 planned land use and existing channel conditions with floodplain fringe development are shown on Map 54 and amount to about $45,000 on an average annual basis.

Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $64,000, consisting of the amortization of the $723,000 land cost and capital cost of constructing the five detention basins, and $18,000 in annual operation and maintenance costs. The average annual flood abatement benefit is estimated at $58,000, resulting in a benefit-cost ratio of 0.91.

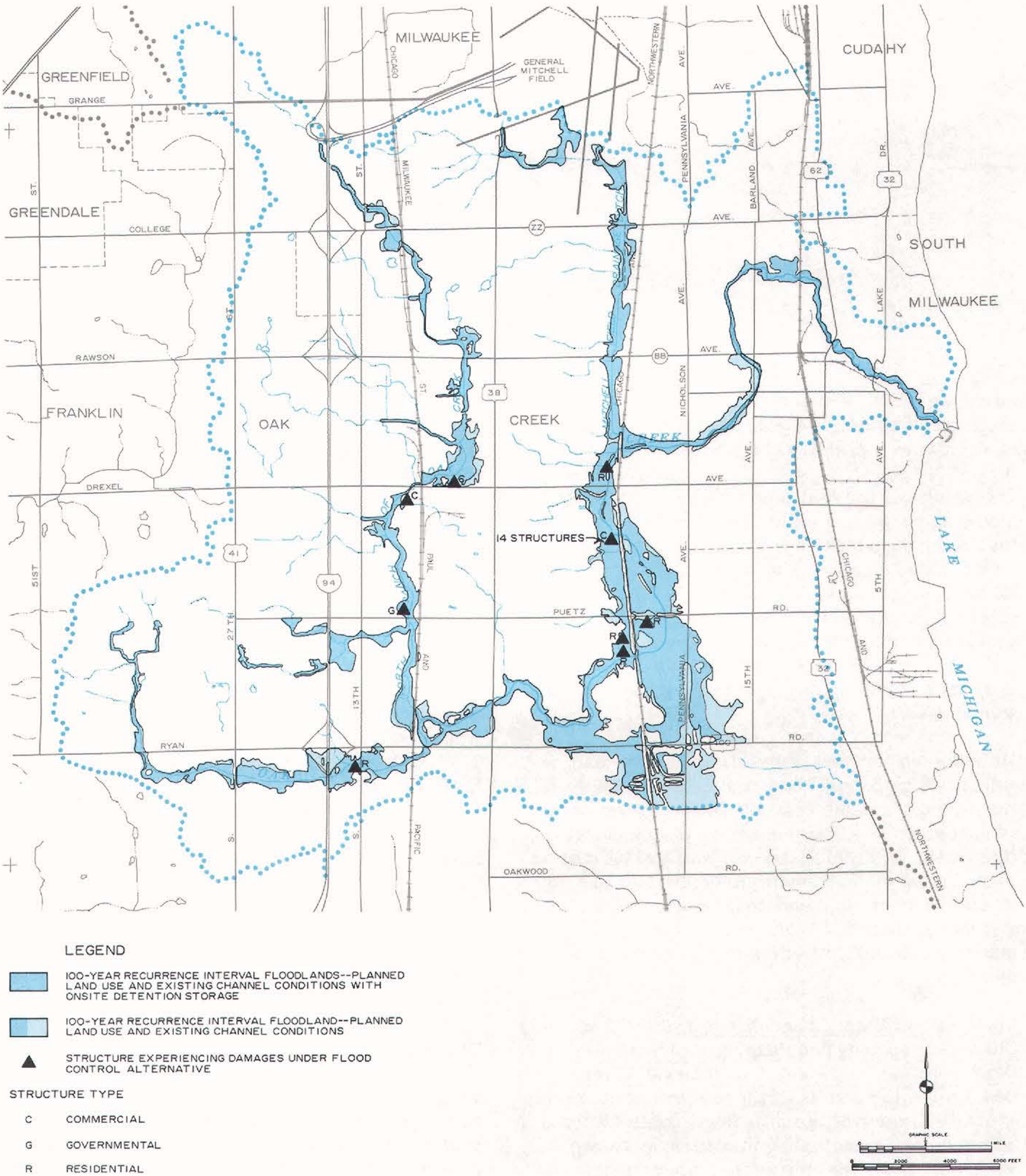
Combination Major Channelization, Channel Deepening and Shaping, and Structure Floodproofing, Elevation, and Removal Alternative

Based upon the results of the analyses of the flood control alternatives, a ninth flood control alternative was developed. This alternative is shown on Map 55, with the physical characteristics and estimated costs and benefits being set forth in Table 83. This alternative incorporates the major channel modifications described under the third major channelization alternative; that is, modifications would be carried out along Oak Creek from the Milwaukee Road railway crossing upstream to S. 27th Street, a distance of 1.5 miles; and along the North Branch of Oak Creek from about 960 feet downstream of the confluence with Southland Creek and extending upstream to W. Rawson Avenue, a distance of 2.8 miles. These channels would have bottom widths of 20 feet and side slopes of one on three, and be turf-lined. Major channel modifications would also be made along an additional 2.1 miles of the North Branch of Oak Creek from W. Rawson Avenue to W. Ramsey Avenue. In addition to these major channel modifications, deepening and shaping of the channel would be required along three stream reaches: 1) Oak Creek between S. Pennsylvania Avenue and E. Puetz Road, a distance of 2.1 miles; 2) Oak Creek extending from a point about 0.5 mile downstream of S. Shepard Avenue to a point about 0.3 mile upstream of S. Shepard Avenue, a distance of 0.8 mile; and 3) the Mitchell Field Drainage Ditch from its confluence with Oak Creek upstream to E. Rawson Avenue, a distance of 0.8 mile. In these reaches the streambed would be lowered an average of three feet in order to provide an adequate outlet for existing storm sewer outfalls.

The hydrologic-hydraulic analysis conducted under this alternative indicates that the loss of floodwater storage would result in an increase of 0.1 to 0.8 foot in the 100-year recurrence interval flood profile for Oak Creek downstream of the proposed channel modifications. The increase in the flood profile on the North Branch of Oak Creek is expected to range from 0.8 foot to 1.4 feet. Therefore, flooding easements would have to be obtained under this alternative for the Oak Creek

Map 53

DECENTRALIZED STORAGE ALTERNATIVE FOR THE OAK CREEK WATERSHED

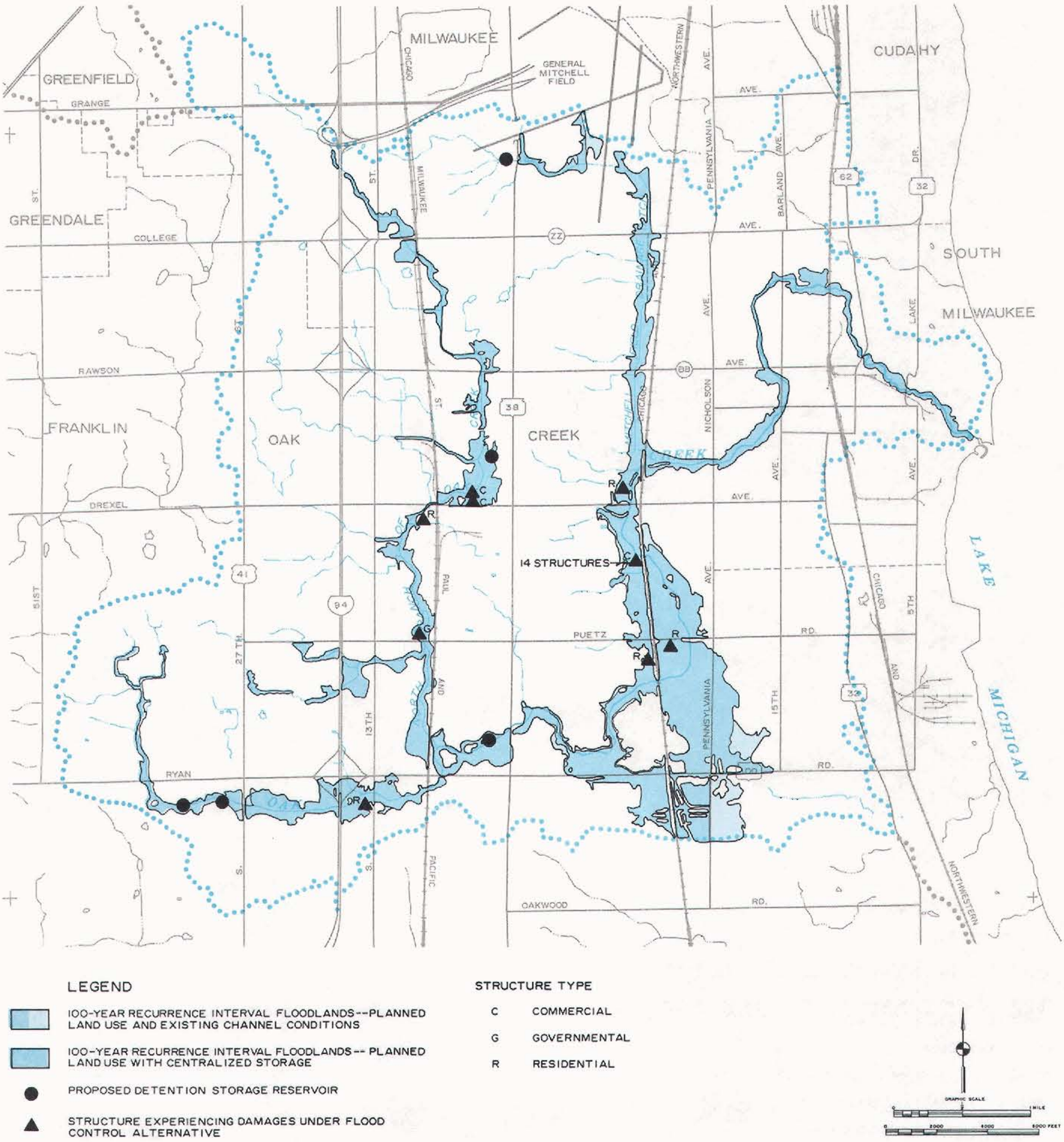


A decentralized storage alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, onsite detention storage facilities would be provided as land is converted from rural to urban uses. This alternative would not resolve the flood problems associated with existing development conditions. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

Map 54

CENTRALIZED STORAGE ALTERNATIVE FOR THE OAK CREEK WATERSHED

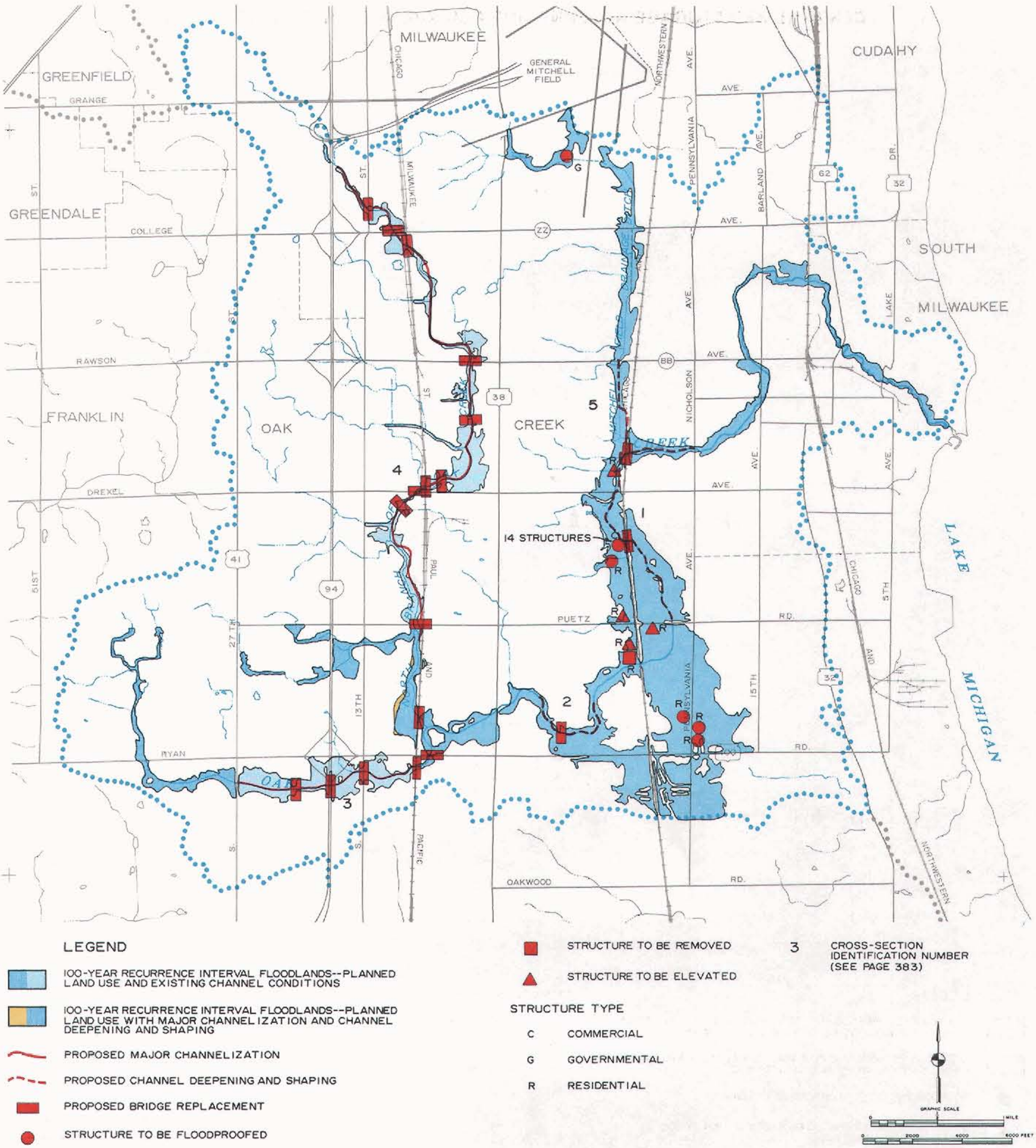


A centralized storage alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, five on-stream detention basins would be constructed at the following locations: 1) upstream of S. Howell Avenue on Oak Creek; 2) upstream of S. 27th Street on Oak Creek; 3) upstream of S. 31st Street on Oak Creek; 4) upstream of the first S. 6th Street crossing of the North Branch of Oak Creek; and 5) upstream of S. Howell Avenue on the Mitchell Field Drainage Ditch. Under this alternative, residual flood damages amounting to $45,000 on an average annual basis would remain in the watershed. While this alternative was found to be technically feasible, it was found to have a benefit cost ratio of less than one.

Source: SEWRPC.

Map 55

COMBINATION MAJOR CHANNELIZATION, CHANNEL DEEPENING AND SHAPING, AND STRUCTURE FLOODPROOFING, ELEVATION, AND REMOVAL ALTERNATIVE FOR THE OAK CREEK WATERSHED



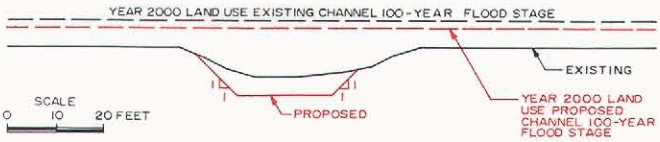
A combination major channelization, channel deepening and shaping, and structure floodproofing, elevation, and removal alternative flood control plan was prepared to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, major channel deepening and enlargement would be carried out along Oak Creek beginning at the Milwaukee Road right-of-way and extending upstream to S. 27th Street—a distance of 1.5 miles; and along the North Branch of Oak Creek beginning at a point 960 feet downstream from the confluence with Southland Creek and extending upstream to W. Ramsey Avenue—a distance of 4.9 miles. Minor deepening and shaping of the channel would be carried out along Oak Creek between S. Pennsylvania Avenue and E. Puetz Road—a distance of 2.1 miles; along Oak Creek from a point about 0.5 mile downstream of S. Shepard Avenue to a point about 0.3 mile upstream of S. Shepard Avenue—a distance of about 0.8 mile; and along the Mitchell Field Drainage Ditch from its confluence with Oak Creek upstream to E. Rawson Avenue, a distance of 0.8 mile. In addition, 19 bridges would be replaced. This alternative also includes the floodproofing of 19 structures, the elevation of four structures, and the removal of one structure. Residual damages amounting to $11,000 on an average annual basis would remain in the watershed. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

Map 55 (continued)

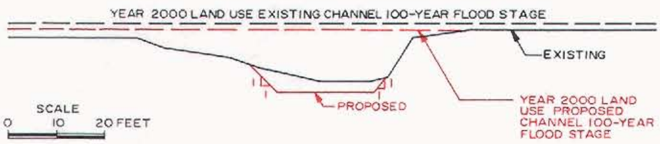
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. PENNSYLVANIA AVENUE AND E. PUETZ ROAD



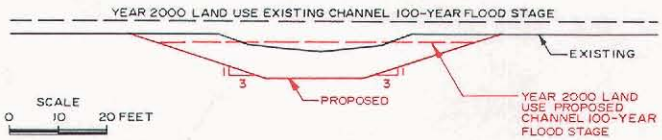
2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN RIVER MILE 7.89 AND RIVER MILE 8.76



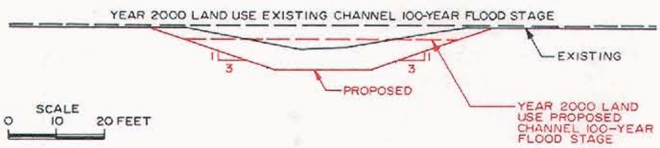
3

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN MILWAUKEE ROAD RAILROAD AND S. 27TH STREET



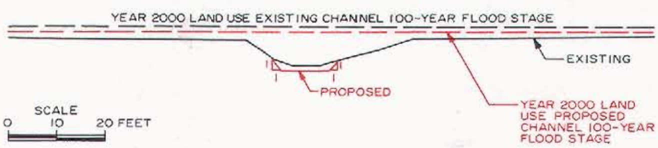
4

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK



5

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH



main stem and the North Branch of Oak Creek downstream of the proposed channel modifications. In order to alleviate the residual structure damages which would be expected to remain, this alternative includes the floodproofing of 19 buildings, elevation of four buildings, and removal of one building. Remaining flood damages under this alternative would be limited to crop damages with an estimated average annual cost of $11,000.

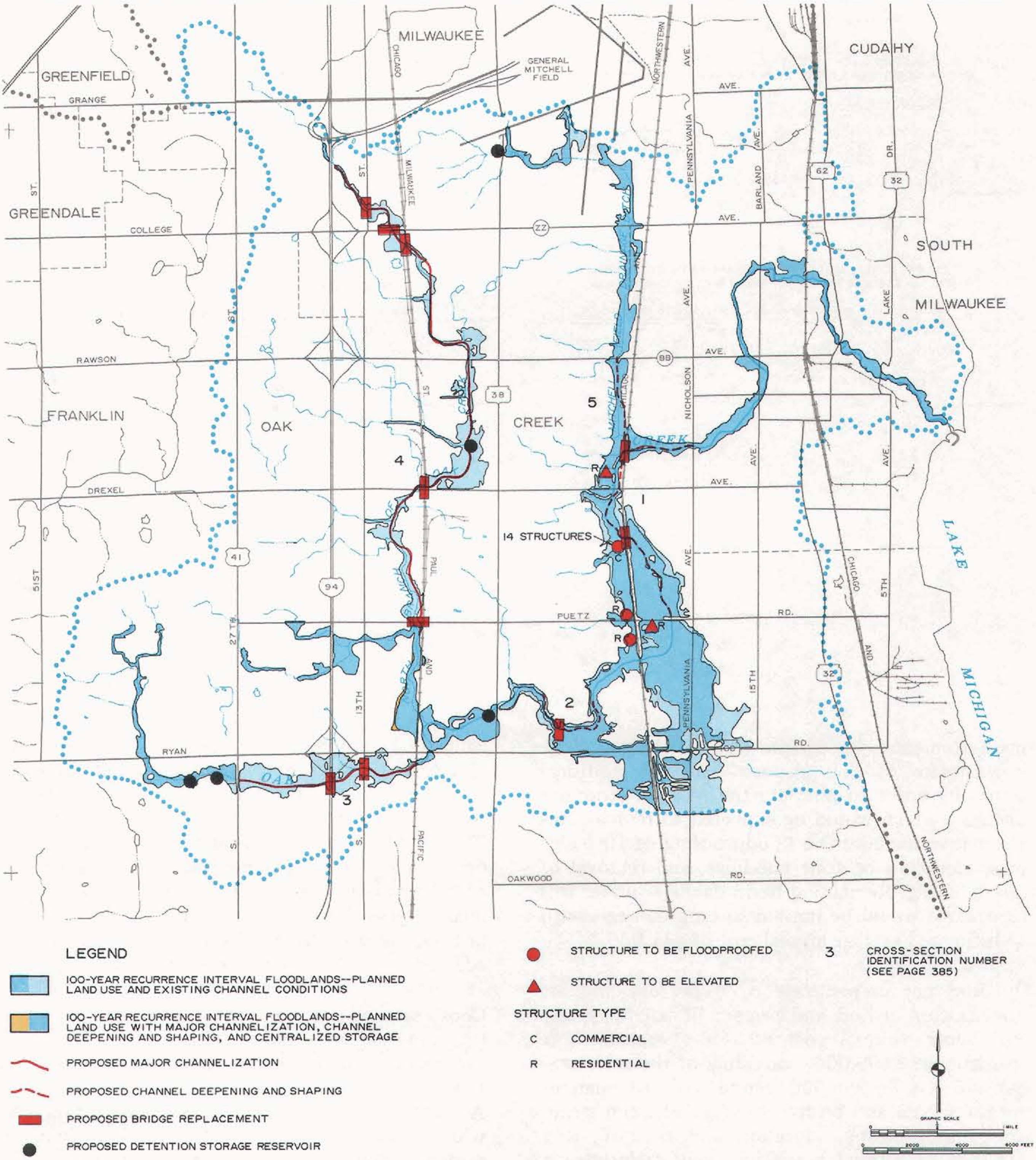
Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $593,000, consisting of the amortization of the $8,965,000 capital cost of channel improvements and bridge replacements, and structure floodproofing, elevation and removal, and $10,000 in annual operation and maintenance costs. These costs do not reflect the purchase price of land required for the proposed channel alignment since most of the channel would lie within parkway lands or existing rights-of-way. The average annual flood abatement benefit is estimated at $92,000, resulting in a benefit-cost ratio of 0.16. Thus, this combination of channel enlargement and structure floodproofing, elevation, and removal, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above the channel bottom, or from the realignment of the channel in accordance with local development plans.

Combination Major Channelization, Channel Deepening and Shaping, Centralized Storage, and Structure Floodproofing and Elevation Alternative

A second flood control alternative was developed which combines several of the flood control elements described in previous alternatives. This flood control alternative is shown on Map 56, with the physical characteristics and estimated costs and benefits attendant to this alternative being set forth in Table 83. Under this alternative, major channel modifications would be made along Oak Creek from the Milwaukee Road railway crossing

Map 56

COMBINATION MAJOR CHANNELIZATION, CHANNEL DEEPENING AND SHAPING, CENTRALIZED STORAGE, AND STRUCTURE FLOODPROOFING AND ELEVATION ALTERNATIVE FOR THE OAK CREEK WATERSHED



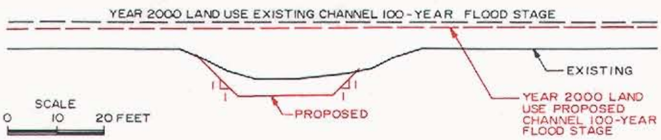
A combination major channelization, channel deepening and shaping, centralized storage, and structure floodproofing and elevation alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, major channel deepening and enlargement would be carried out along Oak Creek between the Milwaukee Road right-of-way and S. 27th Street–a distance of 1.5 miles; and along the North Branch of Oak Creek between a point 960 feet downstream of the confluence with Southland Creek and W. Ramsey Avenue–a distance of 4.9 miles. Minor channel deepening and shaping would be carried out along Oak Creek between S. Pennsylvania Avenue and W. Puetz Road–a distance of 2.1 miles; along Oak Creek between a point 0.5 mile downstream of S. Shepard Avenue and a point about 0.3 mile upstream of S. Shepard Avenue–a distance of 0.8 mile; and along the Mitchell Field Drainage Ditch between its confluence with Oak Creek and E. Rawson Avenue–a distance of 0.8 mile. These channel modifications would require the replacement of 10 bridges. In addition, five on-stream detention basins would be constructed: 1) upstream of S. Howell Avenue on Oak Creek; 2) upstream of S. 27th Street on Oak Creek; 3) upstream of S. 31st Street on Oak Creek; 4) upstream of the first S. 6th Street crossing of the North Branch of Oak Creek; and 5) upstream of S. Howell Avenue on the Mitchell Field Drainage Ditch. Finally, this alternative includes the floodproofing of 16 structures and the elevation of two structures. Residual damages under this alternative amount to $5,000 on an average annual basis. While technically feasible, this alternative was found to have a benefit-cost ratio of less than one.

Source: SEWRPC.

Map 56 (continued)

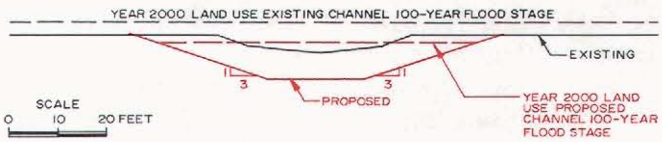
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. PENNSYLVANIA AVENUE AND E. PUETZ ROAD



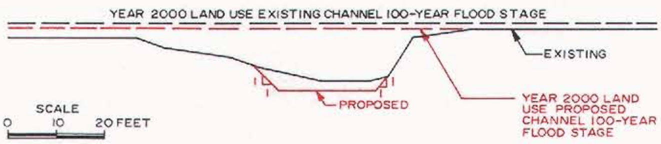
3

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN MILWAUKEE ROAD RAILROAD AND S. 27TH STREET



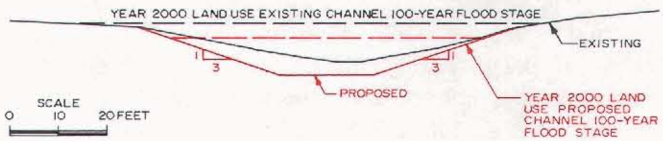
2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN RIVER MILE 7.89 AND RIVER MILE 8.76



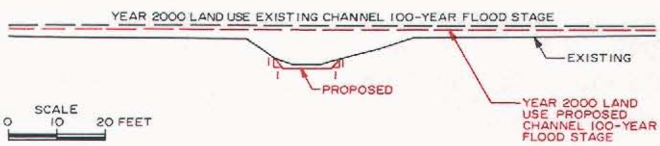
4

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK



5

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH



upstream to S. 27th Street, a distance of 1.5 miles; and along the North Branch of Oak Creek from about 960 feet downstream of the confluence of Southland Creek and extending upstream to W. Ramsey Avenue, a distance of 4.9 miles. These channels would be turf-lined and would have a bottom width of 20 feet and side slopes of one on three. Channel deepening and shaping would also be required along: 1) Oak Creek between S. Pennsylvania Avenue and E. Puetz Road, a distance of 2.1 miles; 2) Oak Creek from a point 0.5 mile downstream of S. Shepard Avenue to a point 0.3 mile upstream of S. Shepard Avenue, a distance of 0.8 mile; and 3) the Mitchell Field Drainage Ditch from its confluence with Oak Creek upstream to E. Rawson Avenue, a distance of 0.8 mile. In these reaches the streambed would be lowered an average of three feet.

In addition to the above channel improvements, five centralized, or on-stream, detention basins would be constructed at the following locations: 1) upstream of S. Howell Avenue on Oak Creek; 2) upstream of S. 27th Street on Oak Creek; 3) upstream of S. 31st Street on Oak Creek; 4) upstream of the first S. 6th Street crossing of the North Branch of Oak Creek; and 5) upstream of S. Howell Avenue on the Mitchell Field Drainage Ditch.

This alternative plan includes the replacement of five bridges on Oak Creek and five bridges on the North Branch of Oak Creek, as listed in Table 84. Since the installation of the detention basins would result in lower peak flood discharges, fewer bridge replacements are required under this alternative than under the "combination" alternative discussed above. Of the 10 bridges to be replaced, five are designated for reconstruction for highway capacity purposes and therefore were not considered in the cost analysis for this alternative.

Residual structure damages in the watershed would be alleviated under this alternative by the floodproofing of 16 buildings and the elevation of two buildings. Remaining flood damages under this alternative would be limited to crop damages with an estimated average annual cost of $5,000.

Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $403,000, consisting of the amortization of the $6,122,000 land costs of the detention basins and capital cost of channel improvements, bridge replacements, and detention basins, and of structure floodproofing, elevation, and removal, and $28,000 in annual operation and maintenance costs. These costs do not reflect the purchase price of land required for the proposed channel alignment since most of the channel would lie within parkway lands or existing drainage rights-of-way. The average annual flood abatement benefit is estimated at $98,000, resulting in a benefit-cost ratio of 0.24. Thus, this combination of channel enlargement, centralized detention, and structure floodproofing, elevation, and removal, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above the channel bottom, or from the realignment of the channel in accordance with local development plans.

Combination Minimum Channel Modification and Structure Floodproofing Elevation, and Removal Alternative

A flood control alternative was developed for the watershed which incorporates the minimum amount of channel modifications required to provide an adequate outlet for the existing storm sewer outfalls. This alternative would allow for the implementation of local neighborhood and industrial park development plans. This alternative is shown on Map 57, with the physical characteristics and estimated costs and benefits being set forth in Table 83. Under this alternative, channel deepening and shaping would occur along 1) Oak Creek between S. Pennsylvania Avenue and E. Puetz Road, a distance of 2.1 miles; 2) Oak Creek from a point 0.5 mile downstream of S. Shepard Avenue to a point about 0.3 mile upstream of S. Shepard Avenue, a distance of 0.8 mile; and the Mitchell Field Drainage Ditch from its confluence with Oak Creek to E. Rawson Avenue, a distance of 0.8 mile. Further channel modifications made along Oak Creek and the North Branch of Oak Creek would be designed to contain flood discharges up to and including a 10-year recurrence interval event, as opposed to a 100-year recurrence interval event which was used under the other alternatives. Major channelization would be made along Oak Creek from the Milwaukee Road railway crossing south of W. Ryan Road upstream to S. 27th Street, a distance of 1.5 miles. The proposed channel would be turf-lined with a bottom width of 10 feet and one on three side slopes. Major channel modifications would also be made along two reaches on the North Branch of Oak Creek: 1) from a point 960 feet downstream of W. Puetz Road upstream to W. Rawson Avenue, a distance of 2.8 miles; and 2) from the sheet pile spillway located west of the United Parcel Service distribution center upstream to W. Ramsey Avenue, a distance of 1.4 miles. The proposed channel would also be turf-lined, with a bottom width of 10 feet and one on three side slopes.

Because of the loss of floodwater storage under this alternative, stage increases in the 100-year recurrence interval flood of 0.1 to 0.7 foot along the main stem of Oak Creek and of 0.1 to 1.0 foot along the North Branch of Oak Creek may be expected. Therefore, under State law flood easements would be required along the main stem of Oak Creek and along the North Branch of Oak Creek downstream from the proposed channel modifications.

This alternative plan includes the replacement of five bridges on Oak Creek and six bridges on the North Branch of Oak Creek, as listed in Table 84. Of these 11 bridges, five are designated for reconstruction for highway capacity purposes and therefore were not considered in the cost analysis for this alternative.

Under this alternative, residual structure damages which would be expected to remain would be alleviated by the floodproofing of 21 buildings, elevation of four buildings, and removal of one building. Remaining flood damages would thus be limited to crop damages having an estimated average annual cost of $10,000.

Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $327,000, consisting of the amortization of the $5,047,000 capital cost of channel improvements, bridge replacements, and structure floodproofing, elevation, and removal, and $9,000 in annual operation and maintenance costs. These costs do not reflect the purchase price of lands required for the proposed channel alignment since most of the channel would lie within parkway lands or existing drainage rights-of-way. The average annual flood abatement benefit is estimated at $93,000, resulting in a benefit-cost ratio of 0.28. Therefore, this combination of channel enlargement and structure floodproofing, elevation, and removal, while technically feasible, was found to have a benefit-cost ratio of substantially less than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of adequate outlets for the storm sewer outfalls located less than two feet above the channel bottom, or from the realignment of the channel in accordance with local development plans.

Combination Channel Deepening and Shaping, and Structure Floodproofing, Elevation, and Removal Alternative

An alternative flood control plan consisting of limited channel deepening and shaping and structure floodproofing, elevation, and removal was prepared and evaluated for the watershed. This plan is shown in graphic form on Map 58. The physical characteristics and estimated costs and benefits attendant to this alternative are summarized in Table 83. Under this plan, channel deepening and shaping would occur along Oak Creek from River Mile 10.30 upstream to S. 27th Street, a distance of 1.4 miles. Within this reach, the streambed would be lowered an average of three feet in order to provide an adequate outlet for existing storm sewer outfalls, and also to eliminate the negative channel slope between IH 94 and S. 20th Street. Between River Mile 10.30 and IH 94, the channel would have a bottom width of 10 feet with side slopes of one on three, similar to the existing side slopes in this reach. Between IH 94 and S. 27th Street, the channel would have a bottom width of 10 feet with side slopes of one on three in order to facilitate maintenance of the channel through the industrial park. Overland flooding may still be expected to occur during major runoff events along this reach of channel deepening. Flows associated with minor runoff events having recurrence intervals of two years or less would, however, be confined to the channel for most of the reach through the planned industrial park between IH 94 and S. 27th Street.

Channel deepening and shaping would also be required along the North Branch of Oak Creek starting at the steel sheet pile spillway located west of the United Parcel Service distribution center and extending upstream to S. 13th Street, a distance of 1.0 mile. Within this reach, the streambed would be lowered an average of three feet in order to provide an outlet for a storm sewer outfall which is currently below the streambed. The proposed channel would have a bottom width of 10 feet with side slopes of one on two to one on five, similar to the existing side slopes in this reach. Overland flooding would still be expected to occur through this reach during major runoff events. More frequent events having recurrence intervals of two years or less would, however, be confined to the channel for that reach beginning at the north end of the MATC-South Campus, and extending upstream to S. 13th Street.

Under this alternative plan, two bridges on the North Branch of Oak Creek would be replaced as listed in Table 84. One of these bridges is designated for reconstruction for highway capacity purposes and therefore was not considered in the cost analysis for this alternative.

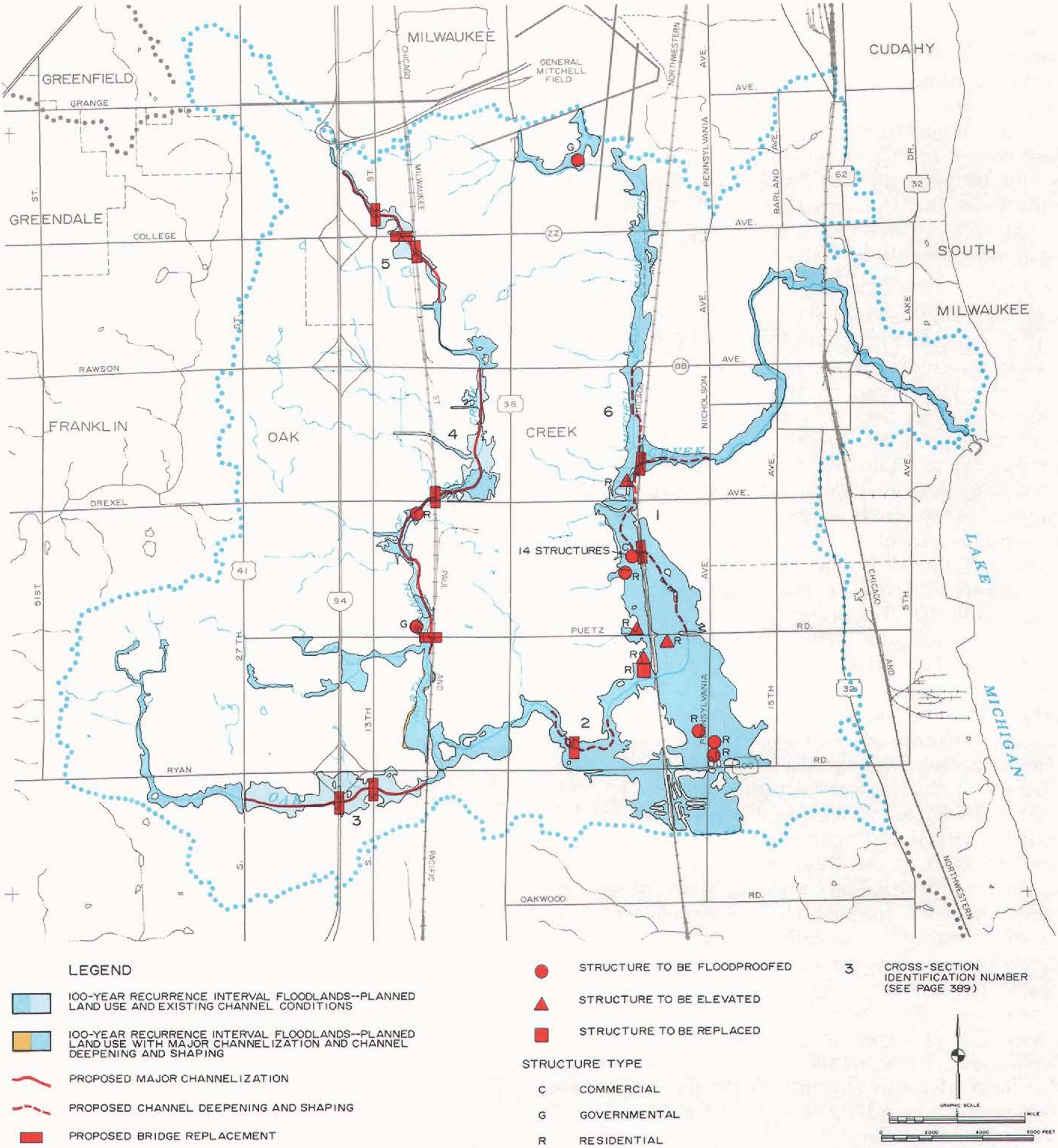
Under this alternative, structure damages would be alleviated by the floodproofing of 21 buildings, elevation of six buildings, and removal of two buildings. Remaining flood damages would be limited to crop damages having an estimated average annual cost of $25,000.

Utilizing an interest rate of 6 percent and an amortization period and project life of 50 years, the average annual cost of this alternative was estimated at $65,000, consisting of the amortization of the $1,009,000 capital cost of channel modification, bridge replacement, and structure floodproofing, elevation, and removal, and $1,000 in annual operation and maintenance costs for the Oak Creek channel through the proposed industrial park between IH 94 and S. 27th Street and for the North Branch channel between College Avenue and S. 13th Street—this reach currently being maintained by the City of Milwaukee. The average annual flood abatement benefits are estimated at $78,000, resulting in a benefit-cost ratio of 1.20. Therefore, this alternative was found to be technically feasible and to have a benefit-cost ratio of greater than one. The monetary benefits assigned to this alternative do not include benefits derived from the provision of an outlet for the storm sewer outfall located below the channel bottom.

As part of this flood control alternative, three subalternatives were considered for providing an adequate outlet for the storm sewer with its outfall located below the existing channel invert: 1) raising the storm sewer so that the outfall from this sewer matches the existing channel invert; 2) construction of a new storm sewer

Map 57

COMBINATION MINIMUM CHANNEL MODIFICATION AND STRUCTURE FLOODPROOFING, ELEVATION, AND REMOVAL ALTERNATIVE FOR THE OAK CREEK WATERSHED



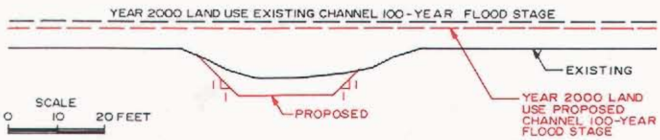
A combination minimum channel modification and structure floodproofing, elevation, and removal alternative flood control plan was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, major channel deepening and enlargement would be carried out along Oak Creek from the Milwaukee Road right-of-way to S. 27th Street—a distance of 1.5 miles; along the North Branch of Oak Creek from a point 960 feet downstream of the confluence with Southland Creek to W. Rawson Avenue—a distance of 2.8 miles; and along the North Branch of Oak Creek from the steel sheet pile spillway located west of the United Parcel Service distribution center to W. Ramsey Avenue—a distance of 1.4 miles. Minor channel deepening and shaping would be carried out along Oak Creek between S. Pennsylvania Avenue and E. Puetz Road—a distance of 2.1 miles; along Oak Creek between a point 0.5 mile downstream of S. Shepard Avenue to a point 0.3 mile upstream of S. Shepard Avenue—a distance of 0.8 mile; and along the Mitchell Field Drainage Ditch between its confluence with Oak Creek and E. Rawson Avenue—a distance of 0.8 mile. In addition, 11 bridges would be replaced. Finally, this alternative includes the floodproofing of 21 structures, the elevation of four structures, and the removal of one structure. Residual flood damages amounting to $10,000 on an average annual basis would remain in the watershed. While technically feasible, this alternative was found to have a benefit-cost ratio of significantly less than one.

Source: SEWRPC.

Map 57 (continued)

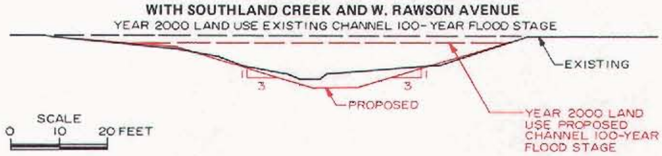
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN S. PENNSYLVANIA AVENUE AND E. PUETZ ROAD



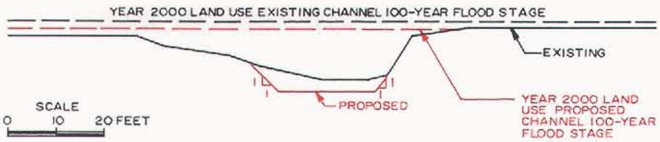
4

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEN THE CONFLUENCE WITH SOUTHLAND CREEK AND W. RAWSON AVENUE



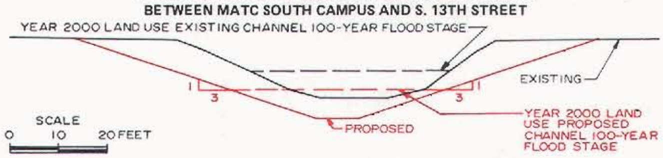
2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN RIVER MILE 7.89 AND RIVER MILE 8.76



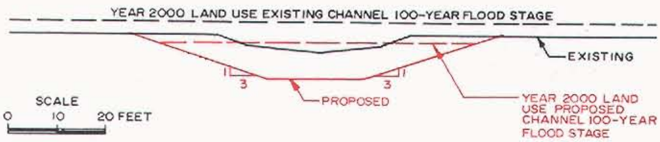
5

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK BETWEEN MATC SOUTH CAMPUS AND S. 13TH STREET



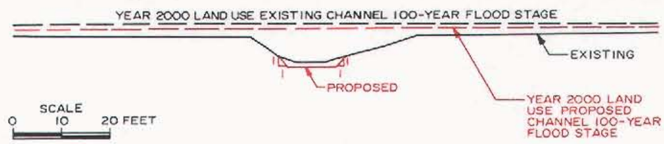
3

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK BETWEEN MILWAUKEE ROAD RAILROAD AND S. 27TH STREET



6

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE MITCHELL FIELD DRAINAGE DITCH BETWEEN THE CONFLUENCE WITH OAK CREEK AND E. RAWSON AVENUE



parallel to the North Branch of Oak Creek channel which would convey the flow from the restricted sewer to a point downstream where an adequate outlet can be achieved; and 3) provision of a pumping station at the outlet of the sewer.

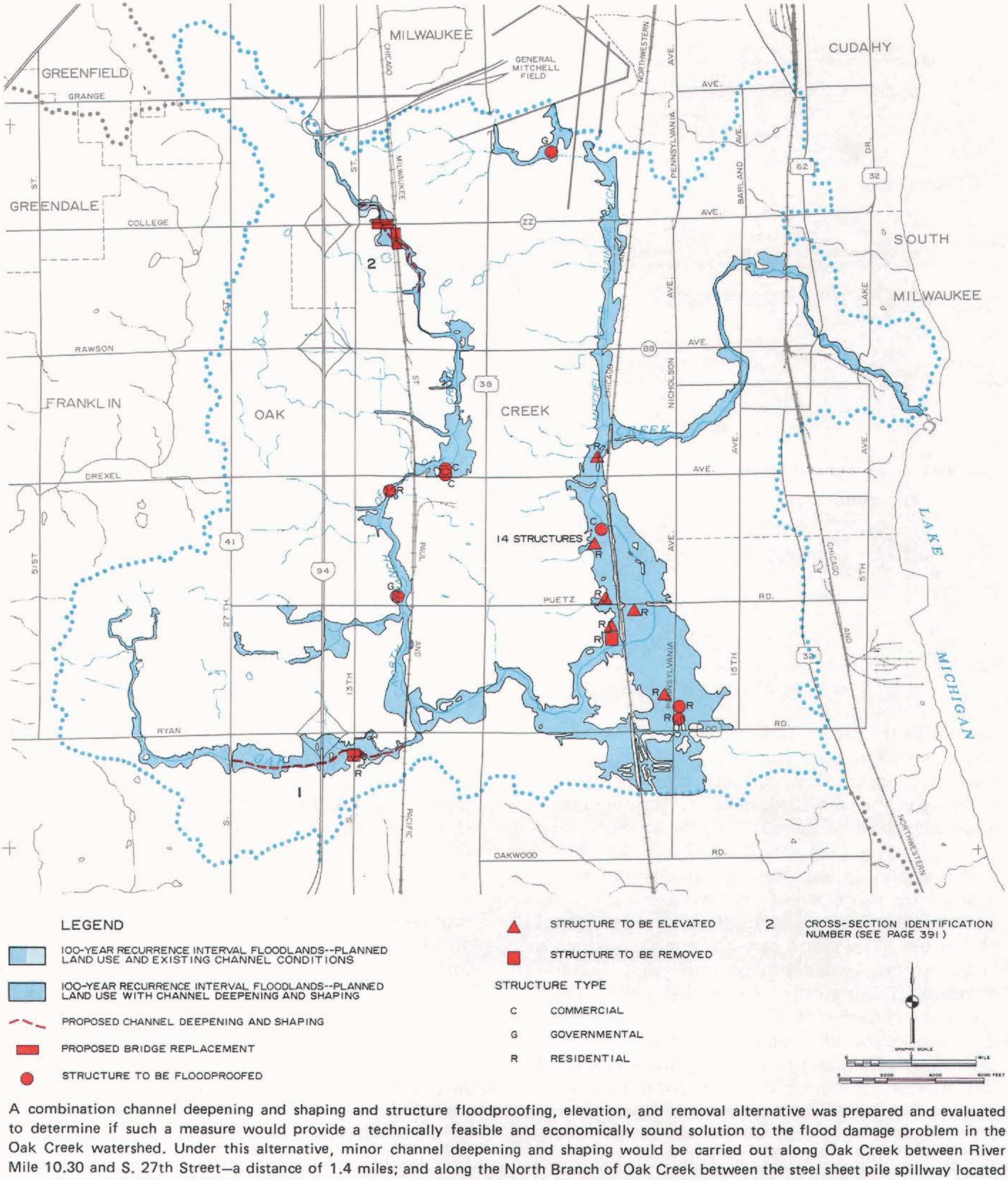
The sewer elevation subalternative would require raising the storm sewer which enters the North Branch of Oak Creek at S. 13th Street a minimum of 3.6 feet. The storm sewer is constructed at the minimum required depth of cover and, therefore, elevation of this storm sewer would not be practical. If the elevation of this sewer could be achieved, the cost entailed would be about $120,000. Besides being impractical, this subalternative would not alleviate the poor drainage conditions which exist in the North Branch of Oak Creek between W. College Avenue and the private bridge located at River Mile 4.67. These drainage conditions occur under periods of low flow and are caused by the negative channel slopes in this stream reach. Because of these problems, this subalternative was not considered further.

The parallel storm sewer subalternative which was analyzed under this alternative provides for the laying of approximately 0.8 mile of 54-inch-diameter pipe along the east side of the North Branch of the Oak Creek channel between S. 13th Street and the private bridge at River Mile 4.35. This intercepting sewer is shown in Figure 58. This sewer would have sufficient capacity to accommodate runoff from rainfall events having recurrence intervals of up to and including five years. The cost of providing the intercepting sewer is estimated at $410,000. This subalternative would not alleviate the problem of poor drainage in the stream channel because of the negative slope in the channel. Because of the relatively high cost of this subalternative, and the fact that the channel would continue to have standing water under low-flow periods, the laying of the intercepting storm sewer was not considered further.

The final subalternative considered consists of the installation of a lift station at the outlet of the restricted storm sewer. The cost of installing this

Map 58

COMBINATION LIMITED CHANNEL DEEPENING AND SHAPING AND STRUCTURE FLOODPROOFING, ELEVATION, AND REMOVAL ALTERNATIVE FOR THE OAK CREEK WATERSHED

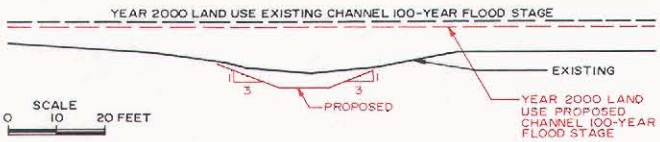


A combination channel deepening and shaping and structure floodproofing, elevation, and removal alternative was prepared and evaluated to determine if such a measure would provide a technically feasible and economically sound solution to the flood damage problem in the Oak Creek watershed. Under this alternative, minor channel deepening and shaping would be carried out along Oak Creek between River Mile 10.30 and S. 27th Street—a distance of 1.4 miles; and along the North Branch of Oak Creek between the steel sheet pile spillway located west of the United Parcel Service distribution center and S. 13th Street—a distance of 1.0 mile. Two bridges would be replaced under this alternative. In addition, this alternative includes the floodproofing of 21 structures, the elevation of six structures, and the removal of two structures. Residual flood damages amounting to $25,000 on an average annual basis would remain in the watershed. This alternative was found to be technically feasible and to have a benefit-cost ratio of greater than one.

Source: SEWRPC.

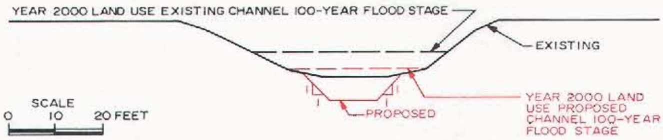
1

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK



2

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK



lift station is estimated at $350,000, with annual operation and maintenance costs estimated at $2,500. This subalternative would not alleviate poor drainage conditions in the channel reach described above. Because of the relatively high cost of this subalternative, as well as the fact that poor drainage conditions would remain in the channel reach described above, the installation of a lift station was not considered further.

Concluding Statement

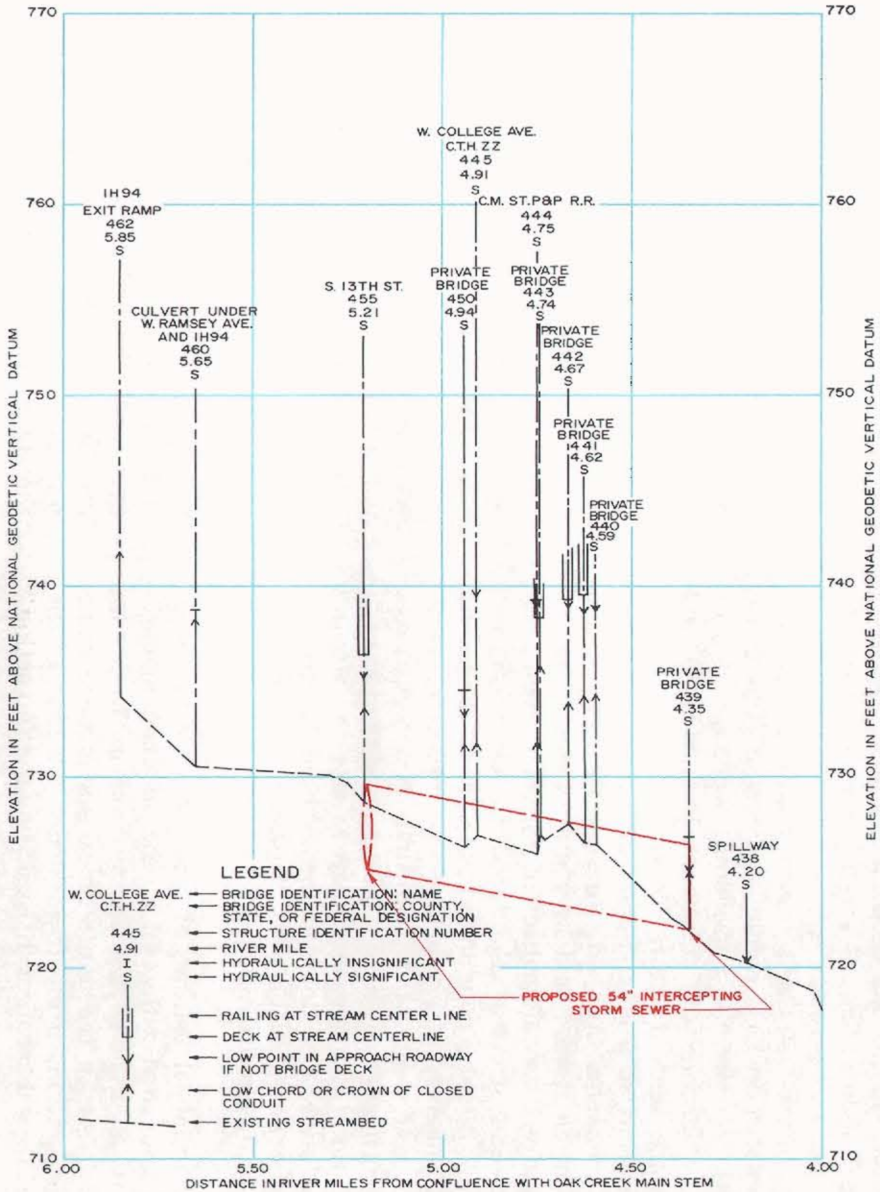
Five different structural floodland management alternatives—three channel modification alternatives, one decentralized detention storage alternative, and one centralized detention storage alternative—and one nonstructural measure—structure floodproofing, elevation, and removal—were examined as possible solutions to the flood problems of the Oak Creek watershed. Four additional alternatives which combine several of the above measures were also considered: a combination of major channelization, channel deepening and shaping, and structure floodproofing, elevation, and removal; a combination of major channelization, channel deepening and shaping, centralized detention storage, and structure floodproofing and elevation; a combination of minimal channelization and structure floodproofing, elevation, and removal; and a combination of channel deepening and shaping, and structure floodproofing, elevation, and removal. In addition, two alternatives which involve essentially no action were discussed. The flood damages attendant to the "no action" alternatives provide an important basis for analyses of the potential benefits associated with each of the other alternatives.

The principal features of, and the costs and benefits associated with, each of the floodland management alternatives are summarized in Table 83, together with the nontechnical and noneconomic considerations likely to influence selection of the most desirable approach. Excluding the "no action" approach, all of the above alternatives were found to be technically feasible. However, only two alternatives were found to have benefit-cost ratios of greater than one: structure floodproofing, elevation, and removal; and the combination of channel deepening and shaping, and structure floodproofing, elevation, and removal. Of the remaining eight alternatives, six were found to have sufficient intangible benefits to be maintained as viable alternatives. Two alternatives—Major Channelization Alternative 1 and Major Channelization Alternative 2—were eliminated from further consideration because the high costs of these alternatives far outweighed the benefits.

Even though the structure floodproofing, elevation, and removal alternative was found to be technically feasible and resulted in the highest benefit-cost ratio of the alternatives considered, it was rejected as the recommended plan for several reasons. Adoption and implementation of this alternative would not provide adequate outlets for the 21 storm sewer outfalls which enter the stream channel with invert elevations less than two feet above the channel bottom, thus constraining the hydraulic capacity of the tributary sewers. More importantly, this alternative would not provide an outlet for the storm sewer outfall which currently enters the stream system below the channel invert. This alternative also would not provide for the realignment of certain channel reaches in accordance with locally committed development plans. Since implementation of this alternative would be on an individual, voluntary basis, full implementation may not occur and residual flood damages may remain. Also, overland flooding may be expected to continue to occur in certain areas, periodically closing some streets to automobile traffic as well as resulting in yard and street damages and cleanup costs. Finally, some floodproofing measures may be applied by property owners without adequate professional advice, thereby resulting in continued structure damage.

Figure 58

PROFILE ILLUSTRATION OF INTERCEPTING STORM SEWER FOR A PORTION OF NORTH BRANCH OF OAK CREEK



Source: SEWRPC.

Also eliminated from further consideration was the third major channelization alternative, as well as the alternative calling for a combination of major channelization, channel deepening and shaping, and structure floodproofing, elevation, and removal, and the alternative calling for a combination of major channelization, channel deepening and shaping, centralized detention storage, and structure floodproofing and elevation. The desirable intangible benefits of these alternatives—provision of adequate storm sewer outlets as well as a channel alignment which is consistent with locally committed development plans—can be achieved with other alternatives having more favorable benefit-cost ratios—specifically, the combination minimal channelization and structure floodproofing, elevation, and removal alternative.

The decentralized detention storage alternative was eliminated from further consideration for several reasons. In addition to having a benefit-cost ratio of significantly less than one, this alternative would not abate the flood problems associated with existing development conditions. Also, a stable, long-term commitment to a decentralized storage policy by all of the local units of government in the watershed is uncertain. Furthermore, it is unlikely that a decentralized storage policy could, as a practical matter, be applied to every increment of urban land development. Accordingly, flood flows would probably continue to increase as urban development proceeds within the watershed under this alternative.

Although the centralized detention storage alternative has a benefit-cost ratio of close to one, this alternative would not provide an adequate outlet for the 22 storm sewer outfalls with invert elevations less than two feet above the existing channel bottom, nor does it provide a channel alignment consistent with locally committed development plans. Also, this alternative would not abate all of the structure damages which may be expected to occur in the watershed under future development conditions. Accordingly, this alternative was also eliminated from further consideration.

Even though the combination minimal channelization and structure floodproofing, elevation, and removal alternative would provide the desired intangible benefits as well as eliminate structure flood damages in the watershed, the high cost of this alternative precluded its further consideration.

After due consideration of the various technical and economic features and intangible aspects of the alternative floodland management measures, the Advisory Committee recommended that the alternative calling for a combination of channel deepening and shaping and structure floodproofing, elevation, and removal be adopted to resolve existing and future flood problems in the Oak Creek watershed. This alternative is recommended for several reasons. First, this alternative has a benefit-cost ratio of greater than one. Second, structure flood damages in the watershed would be eliminated. Third, this alternative would provide an outlet for the storm sewer outfall which currently enters the stream system below the channel invert. In making its decision to recommend this alternative, the Committee recognized that it would not provide as adequate an outlet for existing storm sewer outfalls which are located at elevations less than two feet above the channel bottom as would certain other alternatives; nor provide for the realignment of the channel in accordance with local development plans. Because this alternative would not provide a channel large enough to contain the 100-year recurrence interval flood flow, a total of 12 lots located within platted industrial and residential areas would continue to be located within the 100-year recurrence interval floodway and, therefore, be considered unsuitable for development. These lots include two in the planned industrial park located along Oak Creek downstream of S. 27th Street, three in the planned industrial park located along the North Branch of Oak Creek north of W. Drexel Avenue, and seven in the planned Willow Heights Subdivision located along the North Branch of Oak Creek, south of W. Drexel Avenue. The market value of these lots in 1985 was estimated at $110,000. Channel improvements to protect these lots would cost $5,941,000.

Since the recommended flood control alternative does not include significant channel modifications within the watershed, some concern was expressed by representatives of the City of Oak Creek that development would be hampered in those areas which are poorly drained. Current plans by the City of Oak Creek Engineering Department envision the construction of drainage systems that would discharge to a lowered channel network. In response to this matter, the Advisory Committee recommended that the watershed plan include the conduct of stormwater management studies. These studies would determine existing and possible future drainage problems on a subwatershed basis.

The studies would then investigate options to alleviating these problems, including the use of low-head conduits for drainage systems, the implementation of onsite storage practices, and, only if absolutely essential, further modifications to receiving streams.

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 may be subject to closure during major flood events, thereby adversely affecting the operation of the highway transportation system. In order to identify flood-prone reaches of the watershed, bridges that may cause or aggravate existing flood problems must be identified. The purpose of this section is to identify those bridges and culverts that may be expected to interfere with the operation of the highway and railroad transportation systems during major flood events by virtue of inadequate hydraulic capacity and overtopping of the approach roads or of the structure.

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 the resultant disruption of traffic by floodwaters. The categories and designated flood events are:

1. Land access 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 railways—a 100-year recurrence interval flood discharge.

It is evident that the severity of the flood recommended 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 stream crossing—that is, the classification as a land access collector street, arterial street and highway, or freeway or expressway—is recommended in the adopted design year 2000 regional transportation system 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 systems can function properly.

The existing bridges and culverts in the watershed that have substandard capacity during major flood events were identified using the information contained within the hydrologic-hydraulic summary tables set forth in Appendices D, E, and F in combination with the bridge standards. As set forth in Table 85, 18 bridges and culverts may be expected to have substandard hydraulic characteristics under plan year 2000 land use and existing channel conditions. It is recommended that when these bridges are modified or replaced by local or state highway agencies or by railroads as a part of highway and railroad improvement programs, the crossings be designed to provide adequate hydraulic capacity in accordance with recommended standards. Of the total number of substandard bridges and culverts, eight are located on land access and collector streets where the 10-year recurrence interval standard is applicable, and 10 are located on arterial streets and highways other than freeways and expressways where the 50-year recurrence interval standard is applicable.

The location and design of all new bridges and culverts, as well as the design of replacements of or modifications to existing bridges or culverts, should be based upon the applicable objectives and standards as set forth in Chapter X of this report. Of particular importance is the standard requiring all new or replacement bridges and culverts to be designed to accommodate the 100-year recurrence interval peak flood discharge under plan year 2000 land use conditions without raising the corresponding peak flood stage by more than 0.1 foot above the peak stage established in the adopted comprehensive watershed plan. This provision is intended to ensure that 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.

Table 85

STREAM CROSSINGS IN THE OAK CREEK WATERSHED HAVING SUBSTANDARD HYDRAULIC CAPACITIES

Structure Identification[a]					Recommended Design Frequency (years)	Hydraulic Inadequacy	
Stream	Number[b]	Name	River Mile	Civil Division		Approach Road Overtopped	Bridge Deck Overtopped
Oak Creek	225	E. Forest Hill Avenue. .	6.25	City of Oak Creek	50	X	X
	230	E. Puetz Road	6.83	City of Oak Creek	50	X	--
	240	S. Nicholson Road . . .	7.44	City of Oak Creek	50	X	--
	250	S. Shepard Avenue . . .	8.41	City of Oak Creek	10	X	--
	260	W. Ryan Road.	10.06	City of Oak Creek	50	X	--
	285	S. 13th Street	10.69	City of Oak Creek	50	X	X
	300	S. 20th Street	11.24	City of Oak Creek	10	X	X
	345	W. Puetz Road.	13.79	City of Franklin	50	X	X
North Branch of Oak Creek	405	W. Puetz Road.	0.92	City of Oak Creek	50	X	X
	410	Wildwood Drive	2.00	City of Oak Creek	10	X	X
	425	S. 6th Street.	2.41	City of Oak Creek	10	X	X
	430	W. Marquette Avenue. .	3.04	City of Oak Creek	10	X	X
Mitchell Field Drainage Ditch	510	E. College Avenue. . . .	1.83	Cities of Milwaukee and Oak Creek	50	X	--
Southland Creek	620	S. 26th Street	1.57	City of Oak Creek	10	X	--
	625	W. Grays Lane.	1.69	City of Oak Creek	10	X	--
	640	S. 27th Street	1.77	Cities of Franklin and Oak Creek	50	X	X
Tributary to Southland Park	705	W. Puetz Road.	0.73	City of Oak Creek	50	X	X
Tributary to Upper Oak Creek	820	Maple Crest Drive	0.30	City of Franklin	10	X	--

[a] This table identifies public bridges and culverts which, when considered in conjunction with their approach roadways, have substandard hydraulic capacities under plan year 2000 land use and existing 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 31, Chapter V.

Source: SEWRPC.

RECOMMENDED NONSTRUCTURAL FLOODLAND MANAGEMENT MEASURES

Of the 12 nonstructural floodland management measures set forth in Table 80 and discussed earlier in this chapter, two have been considered as specific alternatives for the abatement of flood damages in the Oak Creek watershed. An additional three are particularly effective for minimizing the aggravation of existing problems and for preventing the development of future flood hazards. The seven 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 alleviate the monetary flood losses incurred by owners of flood-prone property, and may substantially reduce the threat to life and health of residents of flood-prone areas. The following section describes the recommended application of the three primary nonstructural floodland management measures—reservation of open floodlands for recreational and related open space uses, floodland use regulation, and channel maintenance—and of the seven secondary measures.

Primary Measures

Reservation of Floodlands for Recreation and Related Open Space Uses: The land use plan element of the watershed plan recommends, as described in Chapter XI, the preservation in essentially natural open uses of 1.6 square miles of primary environmental corridor in the Oak Creek watershed. These corridor lands follow the alignment of Oak Creek and encompass most of the floodlands along the main stem. In addition, the land use plan recommends the preservation of about one square mile of secondary environmental corridor. These corridor lands generally follow the alignment of the upper reaches of Oak Creek, the North Branch of Oak Creek, the Mitchell Field Drainage Ditch, and Southland Creek. 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 lands for these purposes constitute important means of implementing the recommended watershed plan. It is accordingly recommended that the use of floodland areas for outdoor recreation and related open space activities be encouraged not only to implement the recommended land use plan, but also to minimize the aggravation of existing flood problems and the development of new flood problems in the watershed.

The Wisconsin Floodplain Management Program: State Statutes require that all counties, cities, and villages 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 communities in the watershed, all but the Cities of Cudahy and Greenfield contain existing or potential flood hazard areas. All of these communities have adopted floodland or floodland-related regulations such as wetland, conservancy, or floodplain zoning to protect the floodlands of the watershed from further encroachment by flood-prone rural and urban land uses. All of these zoning ordinances have been approved by the Wisconsin Department of Natural Resources. It is recommended that the required floodland and floodland-related land use regulations be designed not only to accommodate existing development, but to preserve the floodwater conveyance and storage capacity of the floodlands in order to conserve the floodwater storage and conveyance capacity of the existing floodlands, abate future flood hazards and monetary flood damages, reduce the hazard 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. This would require the regulation of 0.8 square mile of land designated for open space uses in the land use plan, as well as of the designated primary environmental corridors. Floodways should not be delineated, and the entire floodplains should be preserved in essentially natural, open uses. Only where existing or committed development may warrant should floodways be delineated and any filling and further development of the floodplain fringe area be permitted.

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 the flood stage profiles developed under the watershed planning program; 2) maintain the channel invert below the invert of existing and planned stormwater outfalls to allow such outfalls 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 the conveyance capacity of the bridges and culverts. It is recommended that the operations of the responsible governmental units and agencies be designed to include the conduct of such channel maintenance.

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 Program also provides a way of reducing monetary flood losses to the property owner. It is therefore in the best interest of the communities in the Oak Creek watershed to participate in the federal Flood Insurance Program.

While the ultimate decision to purchase flood insurance remains with the 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 Federal Emergency Management Agency 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 flood damages. The community or unit of government must also submit assurances of future compliance with sound floodland management practices, including resolutions indicating that flood problems will be continuously monitored and that such problems will be considered in all official actions affecting floodland use.

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 and Oak Creek. Both of these communities, as well as the other four communities in the watershed, have elected to participate in the federal Flood Insurance Program. Insurance rate studies have been completed for all six communities in the watershed.

Because of the availability of large-scale topographic mapping over the entire watershed, the analyses conducted under the Oak Creek watershed planning program were more complete and detailed than those conducted under federal flood insurance studies. Therefore, it is recommended that the hydrologic-hydraulic data generated under the watershed planning program be used to update and amend the flood insurance studies as appropriate.

Lending Institution Policies: As a result of the federal 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 flood insurance needs to be purchased before a mortgage is granted 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 federal Flood Insurance Program, and that the principal source of flood hazard information within the Oak Creek watershed be that developed under the watershed planning program and available through the Regional Planning Commission.

Realtor Policies: 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 Oak Creek watershed be formulated such that the size, location, and use of those utilities and facilities is 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 Oak Creek watershed.

Land Use Controls Outside the Floodlands: As described in Chapter XI, about 11 square miles of open lands throughout the watershed are proposed for urban development under the land use plan. In preparing plans for the development of these areas and for the redevelopment of local areas, it is recommended that the potential hydrologic impact of the proposed development or redevelopment be considered in addition to the relationship of such development and redevelopment to soil capabilities, long-established and planned utility systems, and the natural resource base. The alternatives set forth in this chapter are designed to accommodate the plan year 2000 urban development set forth in the land use plan as described in Chapter XI. Development beyond that recommended in the land use plan has not been considered and, thus, onsite storage flood control measures would be needed to accommodate such development.

Emergency Programs: An emergency program to minimize the damage and disruption associated with flooding normally consists of a variety of measures that are tailored to the flood hazard characteristics of individual communities. It is particularly pertinent to note that historic data and simulation results indicate that the urban portions of the Oak Creek watershed are 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 urbanized areas of the Oak Creek watershed for selected recurrence intervals may be expected to be several times larger than those that would occur in the rural areas of similar size, soils, and topography. It is recommended, therefore, that in each watershed community where major flooding occurs, procedures be developed to provide floodland residents and other property owners with information about the location and extent of the flood hazard areas so that residents can take appropriate flood damage mitigation measures.

Community Education Programs: Public awareness of the possible effects on flood flows and stages of such actions as dumping of debris in a stream channel, localized channelization, and removal of obstructions to flow may serve to prevent an increase in flooding problems. It is recommended that residents of the Oak Creek watershed be informed of the existence of this comprehensive watershed plan through the news media. Public reaction to the plan should be solicited through a public hearing on the plan.

ACCESSORY FLOODLAND MANAGEMENT CONSIDERATIONS

During the Oak Creek watershed planning program, several issues emerged which, although not pertaining to the floodland management alternatives set forth in this chapter, did relate to the hydrology and hydraulics of the Oak Creek watershed. These matters were considered during the watershed planning process, and the resulting conclusions and recommendations are described below.

Maintenance of Stream Gaging Network

Since 1963 the U. S. Geological Survey (USGS) has operated, in cooperation with the Regional Planning Commission and the Milwaukee Metropolitan Sewerage District, a continuous stage recorder at the first 15th Avenue crossing of Oak Creek in the City of South Milwaukee. The USGS has also maintained, in cooperation with the Wisconsin Department of Transportation, a crest stage and low-flow partial record gage at the S. Nicholson Road crossing of Oak Creek in the City of Oak Creek. In addition to these two streamflow monitoring stations, a total of five crest stage gages are operated in the watershed by the Milwaukee Metropolitan Sewerage District, and a total of three staff gages are operated by the City of Milwaukee in the Milwaukee portion of the watershed.

By monitoring river flows and stages at points strategically located within the watershed, continuous-recording stream gaging stations, as well as partial record streamflow stations and crest stage stations, can provide critical data required for the rational management of the surface water resources of the watershed. Discharge-frequency relationships derived from data provided by continuous-recording stream gaging stations and by partial record stations, along with flood stage profiles from crest stage gages, can be used to periodically refine the hydrologic and hydraulic simulation submodels developed and used in the Oak Creek watershed study. Such stream gaging records are also useful in bridge and culvert design and in water quality management planning. It is accordingly recommended that the continuous recorder gage installed at the first 15th Avenue crossing of Oak Creek in the City of South Milwaukee continue to be operated. It is also recommended that the partial record station operated by the U. S. Geological Survey at the S. Nicholson Road crossing of Oak Creek in the City of Oak Creek continue to be operated, and that the Milwaukee Metropolitan Sewerage District and the City of Milwaukee continue to maintain crest stage or staff gage networks.

MAINTENANCE OF RECREATIONAL NAVIGATION AT MOUTH OF OAK CREEK

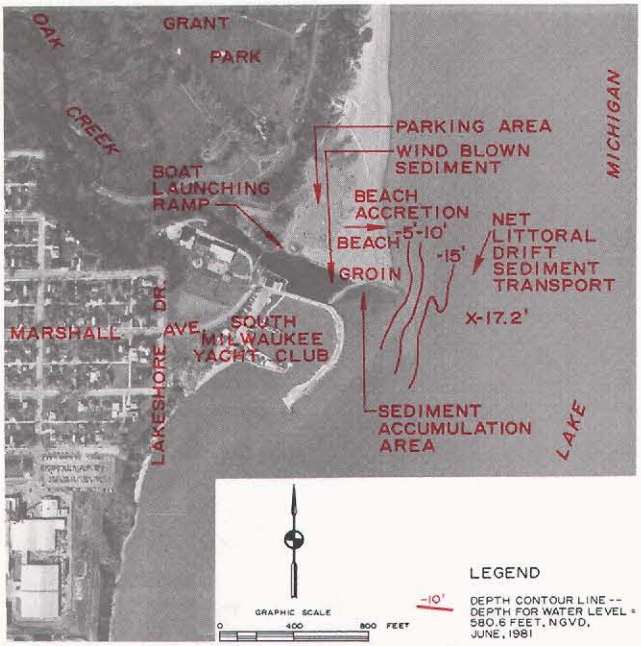
The use of a recreational boat launching ramp located at the mouth of Oak Creek in Grant Park is periodically denied by the formation of a sandbar at the mouth of the creek between the ramp and Lake Michigan. A number of studies of the problem with accompanying proposals for its resolution have been made and are summarized herein. These proposals were, for the most part, never implemented owing to perceived technical inadequacies, or to lack of funding. As part of the Oak Creek watershed study, the Commission reviewed the earlier studies and developed a potential solution to the problem that is different from those proposed previously. Four variations of this solution are presented below.

Description of the Study Area and Problem

Oak Creek enters Lake Michigan at Grant Park, which is owned and maintained by the Milwaukee County Department of Parks, Recreation and Culture. A parking facility for the launching ramp and for a swimming beach is located on the north bank of Oak Creek only a few hundred feet from Lake Michigan. The site of the launch facility is shown on Map 59.

Map 59

THE MOUTH OF OAK CREEK AT LAKE MICHIGAN



The use of a recreational boat launching ramp at the mouth of Oak Creek is periodically hampered by the formation of a sandbar at the mouth of Oak Creek between the boat launch and Lake Michigan. This sandbar formation began after the construction of two rubble-mound jetties at the mouth of Oak Creek in 1891.

Source: Milwaukee County Department of Parks, Recreation and Culture.

The north and south banks of Oak Creek were extended 600 and 300 feet, respectively, into Lake Michigan by the South Milwaukee Company in 1891 by construction of rubble-mound jetties 200 feet apart bounding a 12-foot-deep dredged channel. The updrift shoreline reportedly reacted to this development by moving 125 feet lakeward at the site by 1894, with shoaling within the mouth of Oak Creek occurring ever since.[12] Shoaling is so severe that boats frequently must be dragged across the bar between the launch facility and Lake Michigan. During low-flow periods, stagnant conditions have reportedly occurred in Oak Creek upstream of the sandbar, resulting in occasionally putrid water quality as well. Presently, about 5,000 cubic yards per year are dredged from the site by Milwaukee County in an attempt to maintain recreational navigation. Because the sand grains have been rounded by wave action, the material has been found unsuitable for use in general construction and thus is of little value.

[12] *County of Milwaukee, Interoffice Communication, December 11, 1973.*

In 1956, the South Milwaukee Yacht Club constructed a breakwater to protect the marina from the shoaling occurring at the mouth of Oak Creek.[13] Shoaling was attributed not only to littoral drift, but also to wind-blown sand from the large beach located just north of the creek. Snow fencing and other structures were used to impede movement of wind-blown sand into the creek with limited success. In 1984, a windbreak was constructed on the beach north of the creek in the form of a mound upon which shrubbery was planted. Although significant storage of sand was apparent on the north side of this structure, the shoaling problem at the mouth of Oak Creek remained severe.

Attempts to maintain a navigable channel by dredging have been made for many years, but with little success. The bar can form in a matter of hours during a Lake Michigan storm. On at least one occasion, a storm occurred on the day dredging was completed and the sandbar reformed again within hours.

Previous Studies

A number of studies and associated proposals have been made concerning the shoaling problem at the mouth of Oak Creek. At least six separately conceived marina plans have been presented to Milwaukee County since 1941.[14] In 1967, a report prepared by a consultant retained by Milwaukee County recommended either a marginal navigability program or a minimum wave protection program.[15]

Wind and wave records were analyzed to estimate net littoral drift. Net transport direction was found to be from north to south at a rate of about 10,000 cubic yards per year in the littoral zone. Aeolian transport was estimated to be about 4,000 cubic yards per year from the beach to the creek. Sediment transport from the Oak Creek watershed to the mouth was found to contribute little to the shoaling problem.

[13] *Milwaukee Sentinel, July 28, 1964.*

[14] *Milwaukee County, Interoffice Communication, "Grant Park Boat Launching Facility," September 27, 1972.*

[15] *Dames and Moore, "Report of Investigation, Sedimentation and Navigability of Oak Creek, Grant Park, South Milwaukee, Wisconsin," for the Milwaukee County Park Commission, 1967.*

The proposed marginal navigability program included grouting the north jetty to block sand movement and dredging, with spoils to be transported by slurry pipeline to the beach south of the creek. A windbreak composed of shrubbery was also recommended to impede aeolian transport. The proposed minimum wave protection program included an off-shore breakwater at a cost of about $284,000, with an estimated annual maintenance cost of $8,000.

In 1972, Milwaukee County staff proposed construction of a breakwater connected to an extension of the north jetty, the orientation thereof being from northwest to southeast.[16] The staff also proposed that a lagoon be dredged on the west side of the Grant Park beach north of the creek in which a marina would be constructed. In 1973, county staff proposed additional solutions to the problem.[17] One involved diverting Oak Creek through the South Milwaukee Yacht Club, with boats launched at the county ramp traveling through the Yacht Club to and from the lake. Another proposed closing the opening in the Yacht Club breakwater and creating another adjacent to the creek. A short breakwater connected near this opening would protect it from waves and also provide some protection to the launch area. Another suggestion was abandoning the launch ramp and letting the creek seek its natural course to the lake.

In 1981, Milwaukee County retained a consultant to determine the feasibility of extending the jetty on the north side of Oak Creek to trap sediment.[18] The study determined that sand accretion on the beach north of the creek is occurring at a rate of about 5,000 cubic yards per year, and confirmed earlier estimates of net littoral drift at the site of about 10,000 cubic yards per year to the south. Three segmented serial extensions of the north jetty were evaluated, each segment being 100 feet long. The sand storage life of each was estimated at six years with a total service life of 18 years, after which period sand accumulation in the creek would again commence unimpeded. Construction cost for the three-segment structure recommended in the report was $502,000. Segmented vegetative windbreaks were also recommended, as well as a comprehensive dredging analysis.

Milwaukee County retained a consultant to further study the problem, the results of which are contained in a report prepared in October 1983.[19] The study concluded that most of the sandbar formation was attributable to aeolian transport from the beach just north of the creek, with littoral drift also contributing significantly to the problem. The ultimate source of the sand was reportedly severe erosion of the bluffs downdrift from the breakwaters at Milwaukee. A detailed off-shore bathymetric survey found that natural protective off-shore longitudinal bars had been eroded, and the study recommended replacement with artificial bars. Two approaches were proposed, one being placement of artificial weedbeds made of plastic streamers to absorb wave energy and, consequently, to decrease littoral drift past the mouth of Oak Creek. The cost of this option was estimated at $70,000. The second approach was placement of an artificial bar off shore made of reinforced concrete units of a specified geometry. The cost of this option was estimated at $250,000. Control of wind-blown sand was proposed through placement of a vegetative windbreak. The launch area was proposed to be protected from waves through construction of an off-shore breakwater oriented from northeast to southwest. The cost of this structure was estimated in excess of $1 million.

In 1985, Milwaukee County retained a consultant to evaluate the suitability of spoil materials from deep tunnel construction in Milwaukee[20] for con-

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[16] *Milwaukee County Interoffice Communication, "Grant Park Boat Launching Facility," September 27, 1972.*

[17] *Milwaukee County, Interoffice Communication, December 11, 1973.*

[18] *Warzyn Engineering, Inc., "Analysis of Groin Extension, Oak Creek Entrance to Lake Michigan, Grant Park, South Milwaukee," report to Milwaukee County Department of Public Works, 1981, 13 pp.*

[19] *Edith M. McKee, "Geological Study, Lake Michigan at Mouth of Oak Creek in Grant Park, South Milwaukee, Wisconsin," prepared for the Milwaukee County Department of Parks, Recreation and Culture, 1983, 13 pp.*

[20] *Warzyn Engineering, Inc., "Addendum to Analysis of Groin Extension, Oak Creek Entrance to Lake Michigan," letter report to Milwaukee County Department of Parks, Recreation and Culture, August 7, 1985.*

trol of the sandbar at the mouth of Oak Creek. The study found that the spoil was not suitable for groin construction or creation of a stable fill area.

Navigation Channel Maintenance by Flushing

None of the proposed remedies to the sandbar problem at the mouth of Oak Creek provide an ideal solution. Extension of jetties, construction of breakwaters, and creation of artificial longshore bars will all deprive downdrift beaches of sand. All may provide shorter to longer periods of relief to boaters using the launch ramp at Grant Park. However, all will ultimately fail unless extensive dredging is performed periodically. Presently, Milwaukee County expends on the order of $35,000 annually for dredging. Even if the annual cost was acceptable relative to costs associated with other alternatives, dredging alone has been found unacceptable because of the unpredictable nature of shoaling which can occur at virtually any time. Thus, boaters find the launch facility undependable, and either launch elsewhere at some degree of inconvenience or decrease their boating on Lake Michigan.

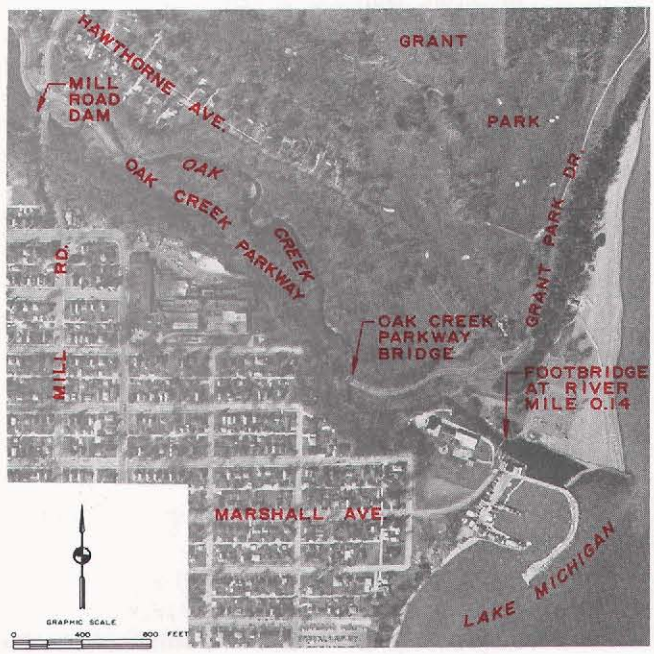
Because of the relatively high costs of the more dependable alternatives proposed to maintain navigation at the Grant Park launch facility, and because these solutions were not permanent in nature, the Commission considered other solutions which might both prove economical and reliable. Any successful solution must complement natural forces at work in the coastal environment rather than attempt to resist these forces. Downdrift beaches should not be deprived of sand by new artificial structures at the mouth of Oak Creek. At the same time, however, the sandbar must be controlled to maintain access to Lake Michigan. The solution arrived at was basic: Combine the natural resources of Oak Creek with existing artificial structures which are already paid for, and with new structures and appurtenances more specifically designed to resolve the problem.

Four alternatives similar in basic concept, but different in detail, were developed and are described in the following sections. All involve flushing sand from the mouth of the creek using either the natural flow of the stream or temporarily stored flow to be subsequently released for this purpose. The dam on Oak Creek near Mill Road in South Milwaukee is the location of one of the temporary storage sites. The Oak Creek Parkway bridge at River Mile 0.35 is the location of another. The third site is the footbridge at River Mile 0.14. The locations of these sites are shown on Map 60. A fifth alternative was considered which involved pumping water through diffusers placed along the channel bottom in order to suspend the accumulated sand, the suspended sand to be then washed out into the lake by streamflow.

Another alternative would involve abandoning the boat launch facility at Grant Park. A review of alternative public launch facilities in the vicinity of Grant Park revealed that the closest sites are at South Shore Park in the City of Milwaukee, about 5.5 miles to the north of Oak Creek, and in the City of Racine, about 11.5 miles to the south of Oak Creek. Both of these facilities charge a fee for boat launching, whereas boat launching at the Grant Park facility is currently free. A third boat launch facility has been proposed for construction at Bender Park in the City of Oak Creek, about 2.5 miles south of Oak Creek. This facility, however, is part of a long-range plan for development

Map 60

LOCATIONS OF ALTERNATIVE IMPOUNDMENT SITES EVALUATED FOR NAVIGATION CHANNEL FLUSHING POTENTIAL



Three alternatives were evaluated which involve storing water for use in flushing accumulated sand from the mouth of Oak Creek. These alternatives consist of: 1) storing water behind the existing Mill Road dam; 2) storing water behind a "dry" dam to be constructed at the first Oak Creek Parkway bridge; and 3) storing water behind a "dry" dam to be constructed at the footbridge located near the mouth of Oak Creek.

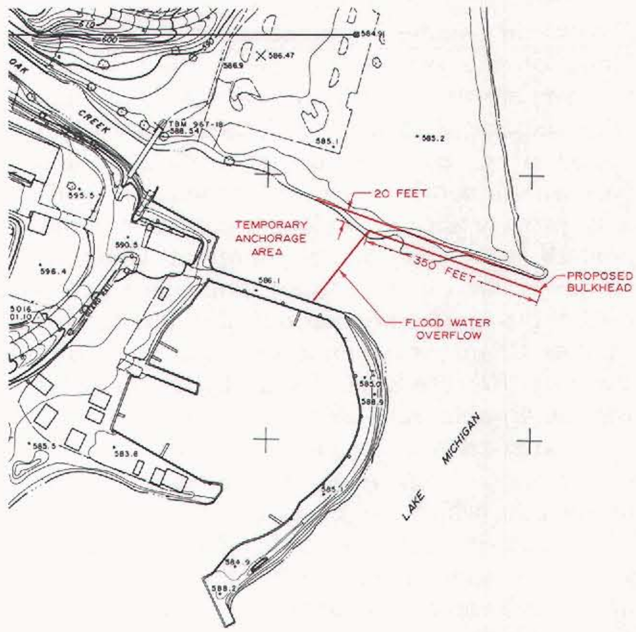
Source: SEWRPC.

of this park, and therefore does not present an immediate alternative to the Grant Park site. Since the Grant Park facility has proven to be popular with boaters when access to Lake Michigan has been readily available, and since it is the only boat launch facility in the immediate area, the Advisory Committee felt that abandoning this site would be publicly unacceptable. Therefore, abandonment of the Grant Park boat launch was dropped from further consideration.

Navigation Channel Geometry: Four feet is the approximate maximum depth of the Oak Creek lagoon at the Grant Park launch facility because of the presence of the water intake from Lake Michigan serving South Milwaukee. Four feet, therefore, was set as the design depth of any proposed navigation channel to Lake Michigan. Channel width was determined in part by the potential flushing ability of Oak Creek. A minimum width of 20 feet would allow passage of one boat at a time under most conditions, and two-way traffic would be possible under ideal conditions. To maintain a constant channel width, the existing jetty on the north side of the Creek would serve as one channel boundary, and a new parallel bulkhead would be installed 20 feet away to prevent sand from sliding into the channel from the south. The west end of the bulkhead would be connected to the breakwater on the south side of the channel to prevent sand encroachment from the lake and to force sandbar flushing flows through the navigation channel, as shown in Figure 59.

Figure 59

PROPOSED NAVIGATION CHANNEL PLAN VIEW



Source: SEWRPC.

Once the width of the channel is fixed, the depth will be determined by the velocity of the flow from Oak Creek and by the scour potential of the sandbar. The allowable velocity for design of a sand channel as determined by the U. S. Soil Conservation Service is that at which bottom particle motion is initiated. The velocity is dependent upon particle size, suspended sediment concentration, water depth, and channel alignment and bank slope. The allowable, or scour, velocities for the sands at the mouth of Oak Creek range from 2.0 to 2.6 feet per second (fps) for fine to coarse grain sizes in sediment laden flow. A design value of 2.6 fps was selected assuming that coarser sands are predominant. The corresponding design flow to scour a 20-foot-wide channel to an average depth of four feet is about 210 cubic feet per second (cfs). For a 25-foot width, the design flow would be 260 cfs, and for a 30-foot channel, 310 cfs. Thus, flow of these approximate magnitudes for given channel widths should be provided and then maintained for sufficient duration to scour the navigation channel to the desired depth of four feet.

The minimum elevation of the top of the bulkhead should be based on a design water level for Lake Michigan representative of boating season conditions to ensure that all flow released from the dam passes through the navigation channel. The maximum elevation should not be high enough to cause significant backwater upstream during major runoff events, nor so high as to force too much flow through the navigation channel, which could cause inordinate scour that could undermine the structures adjacent to the channel.

The design and construction of a 500-foot steel sheet pile bulkhead for the navigation channel for piles 15 feet long would cost about $140,000.

Flushing of Navigation Channel by Natural Flow of Oak Creek: An evaluation was made of the potential of storm runoff from the watershed to scour the sandbar at the mouth of Oak Creek. Only the very large runoff events which occur less than once a year have been observed to cause large-scale scour of the bar. The depth of the scour has not been measured and in some cases has obviously been much less than the desired navigation depth of four feet. This is because the existing channel width is about 200 feet, which prohibits development of velocities large enough to scour sand to an average depth of four feet.

Natural storm runoff from the watershed could scour the channel to a navigable depth if the channel width were reduced. Utilizing a minimum width of 20 feet for one-way small boat navigation, an analysis of streamflow records collected by the U. S. Geological Survey on Oak Creek at 15th Avenue in South Milwaukee from 1963 to 1983 indicated that an average of five runoff events each year are of sufficient magnitude to scour the bar to a navigable depth. However, there were two years during this period when only one such event occurred, and three years when 10 occurred. Therefore, some natural assistance exists but cannot be depended upon to occur when needed, and may occur when not needed. Consequently, flushing of the navigation channel by natural flow from Oak Creek, although helpful, may not provide a satisfactory solution to the problem. This alternative appears to be the most compatible with the recreational, biological, and water quality use objectives contained in this plan.

This alternative would entail only the cost of the construction of the navigation bulkhead, which, as noted in the previous section, would total $140,000.

Navigation Channel Flushing with Contents of Mill Road Dam Pool: A means must be developed to scour the navigation channel at will subsequent to bar formation by storm waves and by wind-blown sand. Using the water in the pool behind the Mill Road dam on Oak Creek in South Milwaukee to flush the sandbar into the lake was investigated as a possible means of providing immediate relief following each storm event forming a sandbar.

The dam at Mill Road (Figure 60) has a simple uncontrolled spillway and a 36-inch-diameter drain pipe used occasionally to drain the pool for maintenance purposes. The drain pipe is controlled by a manually operated sluice gate which is about 60 feet from the pipe inlet and about 70 feet from the outlet, which is at the upstream side of the Mill Road bridge and at the south end. Potentially, the sluice gate could be opened when the pool was full and the outrushing waters would scour a navigable channel at the mouth of the creek, provided the channel width were limited to 20 feet, and provided the dam outlet flow rate was not attenuated too much by channel storage between the dam and the mouth.

Figure 60

THE MILL ROAD DAM AT SOUTH MILWAUKEE

Source: SEWRPC.

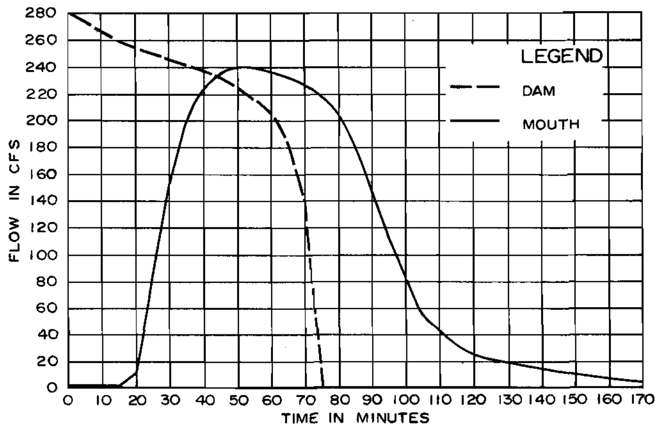
The maximum flow capacity of the drain pipe when the pool is at normal elevation was computed to be about 135 cfs, which appears to be inadequate to maintain a four-foot-deep navigation channel at the mouth of Oak Creek. A depth of about only two and one-half feet might be provided with a flow of 135 cfs. Therefore, to use the dam to flush the sandbar, additional outlet flow capacity may be necessary. If another 36-inch drain pipe were installed at the dam, the maximum outlet flow capacity would be about 270 cfs.

To more fully evaluate the effects of flushing using a dual-pipe outlet, the Hydrological Simulation Program-FORTRAN (HSPF), utilized to simulate the flows used for computation of flood profiles in the watershed, was modified and used to perform a detailed simulation of the reach between the dam and the mouth of the creek. The pool outlet hydrograph was simulated assuming instantaneous and simultaneous opening of sluice gates for two drain pipes. HSPF was then used to route the hydrograph through nine contiguous channel segments to the lake. The Oak Creek inflow to the pool was also included as part of the simulation for inflows ranging from 1.2 to 91 cfs. The simulation modeling indicated that the inflows have no significant effects upon the routed hydrograph at the mouth.

Figure 61 compares the simulated dam outlet hydrograph with the routed hydrograph at the mouth. The peak discharge decreased through the reach from 279 to 239 cfs, or 14 percent. The flow

Figure 61

COMPARISON OF SIMULATED HYDROGRAPHS AT THE DRAIN OUTLET OF THE MILL ROAD DAM AND AT THE MOUTH OF OAK CREEK



Source: SEWRPC.

rate at the mouth exceeded 200 cfs for 45 minutes, more than adequate time to scour the sandbar to a navigable depth. Time to drain the dam pool was about 80 minutes. About 20 minutes after the flow was released, it reached the mouth 0.94 mile downstream. About 120 minutes after release, flow was back to normal at the mouth.

Based on the simulation modeling, it appears that flushing of the sandbar using the Mill Road dam is technically feasible.

Within the main channel of Oak Creek from the dam downstream to the mouth, mean flow velocities associated with the release of flushing waters from the dam were computed using the HEC-2 water surface profile model developed for determination of flood stages. The velocities for 24 channel cross-sections averaged 3.6 feet per second (fps), and ranged from 1.9 to 6.4 fps. Average velocities greater than 4 fps occurred at River Miles 0.34, 0.42, 0.47, 0.61, 0.78, 0.81, 0.89, and 0.94. The addition of bank reinforcement in some of these reaches may be desirable to control channel erosion. However, such reinforcement should be added only if a relatively large number of flushing events are anticipated relative to the number of natural runoff events of equal or greater magnitude which occur annually.

While this alternative is technically feasible, there are a number of potentially negative environmental impacts and safety hazards associated with it. First, drainage of the pool behind the Mill Road dam would result in the scouring of anoxic sediments from the bottom of the pool which could result in dangerously low dissolved oxygen levels along with high concentrations of un-ionized ammonia in downstream reaches. In addition, there are a variety of heavy metals in these sediments which are potentially toxic to fish and other aquatic life. Periodic flushing of the pool and polluted sediments has, in the past, resulted in downstream fish kills. Draining the pool and operating the structure as a "dry" dam which would store water only when inflow exceeded drain pipe capacity would serve to reduce further buildup of these sediments. Frequent flushing and repeated inundation of the existing sediments, however, would prevent them from being stabilized by terrestrial vegetation and dewatering. Second, suspended solids scoured from behind the dam would be deleterious to fish respiratory systems and spawning behavior. Settleable solids would smother fish food organisms, productive riffle areas, and fill pool habitat. Third, the discharge from the pool may increase scour and bank erosion downstream, thereby destroying valuable fish habitat. These conditions would discourage the construction and maintenance of fish habitat structures needed to enhance a recreational sport fishery. Finally, witholding streamflow to fill the pool could result in the desiccation of the stream channel. This situation would exacerbate the natural low-flow and poor water quality conditions which occasionally limit fish and aquatic life downstream.

Operation of the structure as a dry dam would involve shutting the sluice gates each time a sandbar blocked the navigation channel at the mouth. After the pool was full the gates would be opened to flush the bar. The amount of time required to fill the pool is dependent on inflow rate from Oak Creek. Table 86 lists the fill times for a range of inflows. As indicated, the fill time ranges from about 1.5 hours for an inflow of 190 cfs, a daily mean flow exceeded 2 percent of the time at the USGS gaging station at 15th Avenue, to about 12.9 days for a flow of 0.9 cfs, which was exceeded 98 percent of the time during the monitoring period 1963-1983. The pool would be left empty between flushing events.

Safety measures required for operation of this structure as a flushing device would include surveillance of the pool area during filling to ensure that no people were present in the area, and also in the reach of Oak Creek between the dam and the lake prior to and during release of the pool contents.

Table 86

TIME TO FILL MILL ROAD DAM POOL FOR RANGE OF INFLOWS

Inflow (cubic feet per second)	Percent of Time Exceeded[a]	Pool Elevation (feet, NGVD)			
		607.0	609.0	611.0	612.0
		Fill Time (days)			
190	2	0.01	0.02	0.05	0.06
41.0	10	0.04	0.10	0.21	0.28
12.0	30	0.13	0.34	0.72	0.96
5.8	50	0.27	0.69	1.48	1.98
3.2	70	0.48	1.26	2.69	3.59
1.60	90	0.96	2.51	5.38	7.18
1.20	95	1.28	3.35	7.17	9.58
0.89	98	1.73	4.52	9.67	12.90

[a] *For period 1963-1983 at USGS gaging station at 15th Avenue.*

Source: U. S. Geological Survey and SEWRPC.

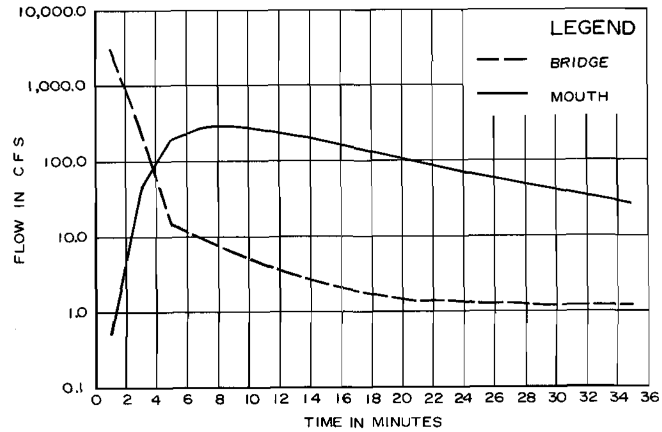
Presently, the dam acts as a migration barrier to fish. If operated as a dry dam, fish migration upstream of the dam would still be prevented owing to the size and orientation of the existing drain pipe. In the winter when flushing is unnecessary and fish migration is minimal, the structure could be operated as a "winter" dam to provide an ice skating and ice fishing area.

The design and construction costs of this alternative would be about $140,000 for the bulkhead in the navigation channel, and $10,000 for an additional 36-inch, 130-foot-long drain pipe at the dam and for a sluice gate. It is recommended, however, that construction of the navigation channel be completed first, followed by a test of the ability of the existing pool drain pipe to flush the channel to verify the need, if any, for additional outlet flow capacity.

Navigation Channel Flushing with Contents of Proposed Oak Creek Parkway Dry Dam: An alternative to utilization of the Mill Road dam pool to flush a 20-foot-wide navigation channel at the mouth of Oak Creek would be construction of a dry dam closer to Lake Michigan. There are three principal advantages to this alternative: 1) safety precautions would still be required but would be reduced because less area would require surveillance, 2) a structure more specifically suited to the purpose of flushing the sandbar could be designed and constructed, and 3) less time would be required for the pool filling and flushing operation.

Figure 62

COMPARISON OF SIMULATED HYDROGRAPHS AT THE OAK CREEK PARKWAY BRIDGE AT RIVER MILE 0.35 AND AT THE MOUTH OF OAK CREEK



Source: SEWRPC.

Figure 62 presents a comparison of hydrographs simulated by HSPF at the mouth and at the parkway bridge closest to the lake (River Mile 0.35); these hydrographs represent release of the contents of a pool about 8.5 feet deep at the bridge. Pool filling would require 44 percent of the amount of time needed to fill the pool of the Mill Road dam. The dam pool could be drained in about 10 minutes as determined by HSPF simulation, compared to 80 minutes for the Mill Road dam. About one minute after flow release, flow would reach the mouth 0.35 mile downsteam, compared to 20 minutes from Mill Road. About 55 minutes after release, flow would be nearly back to normal at the mouth, compared to about 120 minutes for the Mill Road site. The flow rate at the mouth would exceed 200 cfs for about 10 minutes using the new dam, and for about 45 minutes using the dual-drain-pipe flushing system of the Mill Road dam.

To construct the new dam, the downstream side of the existing bridge abutment (Figure 63) would be modified to accommodate a gate 8.5 feet high and about 36 feet long with a horizontal hinge along the bottom. The gate would lie on the channel bottom when not in use to allow free flow of water and fish migration. To flush the sandbar, the gate would be raised mechanically until flush with the face of the abutment. After the pool was full, the gate would be quickly opened to drain the pool. The procedure could be repeated as necessary to achieve the desired navigation depth.

Extremely high velocities would exist during the flushing operation in the reach extending about 700 feet downstream from the bridge, along with

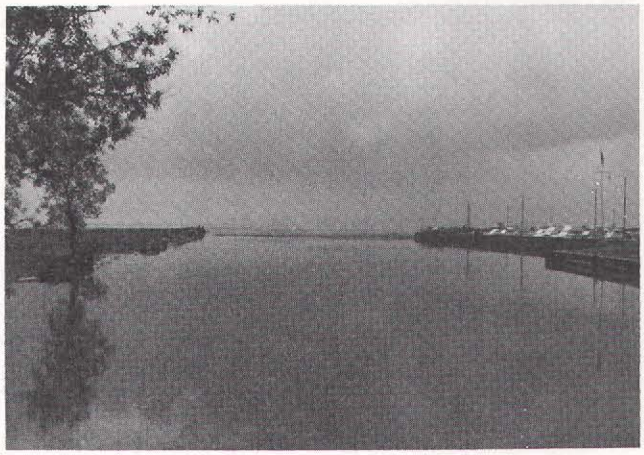
Figure 63

DOWNSTREAM SIDE OF OAK CREEK PARKWAY BRIDGE AT RIVER MILE 0.35

Source: SEWRPC.

Figure 64

LOOKING DOWNSTREAM FROM FOOTBRIDGE AT RIVER MILE 0.14



Source: SEWRPC.

some overbank flooding. Therefore, stream channel protection would be required for both the banks and the bed. This alternative shares many of the negative environmental impacts and safety hazards associated with the Mill Road dam flushing alternative. In addition, the construction of the 700-foot concrete channel would permanently destroy some fish and aquatic life habitat and the existing and potential recreational and biological uses associated with the unchannelized segment.

The design and construction costs of this alternative would be $140,000 for the bulkhead for the navigation channel, $35,000 for the gate on the dry dam at the bridge, and $100,000 for 700 feet of concrete lining of the channel downstream from the dam, for a total cost of $275,000.

Navigation Channel Flushing with Contents of Proposed Dry Dam Located at Footbridge at River Mile 0.14: To minimize the cost of protecting the channel of Oak Creek from scour caused by release of pool contents at the previously proposed dry dam at the Oak Creek Parkway bridge at River Mile 0.35, which would require about 700 feet of concrete lining, an alternative site was evaluated at the footbridge at River Mile 0.14. This site is near the proposed navigation channel, as indicated in Figure 64, and would be similarly modified by provision of a hinged gate at the downstream face of the bridge. The gate dimensions would be about 8 feet by 50 feet, compared to 8.5 feet by 36 feet at the parkway bridge. When closed, about four feet of water would be backed up at the dam site, compared to about 8.5 feet at the parkway bridge site. A concrete apron for scour protection at the downstream side of the bridge would be required instead of extensive concrete channel lining.

The design and construction costs of this alternative would be $55,000 for the gate of the dry dam and the concrete apron and $140,000 for the navigation channel bulkhead, for a total cost of $195,000.

Navigation Channel Clearing With Diffusers: A fifth alternative was evaluated which consists of pumping water through diffusers placed along the navigation channel in order to scour the sand, rather than using flow from Oak Creek—either naturally or artificially produced—to scour accumulated sand from the channel. Once suspended in the water column, the sand would be carried out into the lake by the natural streamflow of Oak Creek. The advantages of this alternative are: 1) fewer safety precautions would be required than for the "flushing" alternatives, and 2) this alternative would have fewer negative impacts on fish and fish habitat.

The diffuser system would consist of a network of pipes fitted with high pressure water jets and placed along the center and sides of the navigation channel. The size and location of the diffusers within the navigation channel would depend upon the size and location of the sandbar formation. In order to allow for fluctuations in the Lake Michigan water level, the diffusers would need to be designed so that their elevation could be adjusted, thereby ensuring that a four-foot depth is maintained in the navigation channel. Water would be supplied to the system by connecting to either the intake or the discharge pump at the City of South Milwaukee water treatment facility, which is located near the mouth of Oak Creek, or by adding a separate pump solely for this purpose. The intake pump currently in use at the water treatment plant can supply water at a rate of 10 million gallons per day (mgd) and at a pressure of 30 pounds per square inch (psi). Of this total, 3 mgd is required for plant use. The discharge pump currently in use at the water treatment plant is capable of providing a water pressure of 85 psi, but the capacity of the pump is limited to the 3 mgd required by the City of South Milwaukee. This lower discharge rate would require that the diffusers be used only during periods of low municipal water use, such as at night. A second pump on the intake pipe at the water treatment plant would be able to supply the required water for the diffusers at a higher pressure than would the intake pump currently in use. The addition of this pump would, however, increase the cost of this alternative.

One of the disadvantages of this alternative is that it is dependent on the flow in Oak Creek being sufficient to carry the suspended sand far enough into the lake to enable boats to enter and leave the navigation channel. If the streamflow is too low, deposition is likely to occur immediately upon the sand leaving the channel, obstructing the passage of boats.

In addition to carrying the sand a sufficient distance into the lake, the streamflow must be high enough to counteract the flow of water from Lake Michigan into the Oak Creek estuary caused by lake seiche. If the streamflow is too low, water flowing into the estuary from the lake would carry the sand upstream where it would again deposit in the Oak Creek channel. Water level records for the Milwaukee inner harbor indicate a typical seiche wave amplitude of about 0.5 foot with an average seiche period of about one hour. Assuming similar conditions exist in the Oak Creek estuary, the estimated average flow into and out of the estuary during the seiche period would be about 60 cfs, with a peak inflow of about 90 cfs. Therefore, a flow of at least 100 cfs would be required in Oak Creek if the diffusers were operated during the inflow portion of the seiche period. Review of the U. S. Geological Survey streamflow records for Oak Creek at 15th Avenue from 1963 to 1983 indicates that the mean daily flow exceeds 100 cfs an average of 17 times a year. However, only about four of these days, or 25 percent, occur during the months of May through September when boating activity is greatest. However, by operating the diffusers only during the outflow portion of the seiche period, this problem could be avoided. This would require careful monitoring of the water levels in the Oak Creek estuary to determine when the seiche wave has peaked and direction of flow is reversed.

The design and construction costs of this alternative would be $140,000 for the navigation bulkhead and $40,000 for the diffusers and conveyance pipe between the water treatment plant and the diffusers, for a total cost of $180,000. The cost for the diffusers and conveyance pipe is based on the diffusers covering a 20-foot length of the navigation channel. This is about one-half the average width of the present sandbar formation across the mouth of Oak Creek. As noted above, the size and cost of the diffusers will depend on the actual size of the sandbar formation within the navigation channel.

Concluding Statement

The recommended approach for maintenance of a recreational navigation channel at the mouth of Oak Creek would be stepwise in nature to allow for actual field testing of some of the alternatives described above. The purpose is two-fold: 1) to construct only the most critical components of the flushing system initially for field testing to determine if further steps are actually necessary; and 2) to temporally distribute the capital costs of implementation. Recommended alternatives should have minimal environmental impacts and safety hazards and be compatible with the plan's recreational, biological, and water quality objectives.

It is recommended that the proposed bulkhead forming and protecting the navigation channel be designed and constructed initially. Following construction, the behavior of the channel in response to Lake Michigan storms and flushing by natural runoff from Oak Creek should be observed to determine if boating accessibility to the lake is adequate. To complement this effort, it is recommended that the sand level on the beach just north of the channel be lowered to provide for wind-blown sand storage behind the jetty, and that minimal dredging be performed in the navigation channel if needed. These measures would have minimal environmental impacts on Oak Creek and minimal safety hazards. In addition, they are compatible with the plan's water quality, recreational, and biological use objectives.

If the proposed bulkhead program is not entirely successful, the next step would be to design either a dry dam at the River Mile 0.14 footbridge or a diffuser network to be placed within the navigation channel. If the design meets environmental and safety criteria, construction could proceed. Compared to other flushing alternatives, these alternatives have less potential for negative environmental impacts and safety hazards. They are also more compatible with the recommended water use objectives. The proposed flushing alternatives using the existing Mill Road dam and/or proposed parkway bridge "dry" dam have negative environmental impacts and safety hazards associated with them. In addition, they are not compatible with the recommended water use objectives.

POTENTIAL FOR FISHERY DEVELOPMENT

Review of fishery data collected under the watershed study indicates that the Oak Creek watershed presently supports a dominance of fish that are generally tolerant of the poor water quality conditions and degraded physical habitat provided by the stream channels. Certain reaches of the Oak Creek watershed stream system are nearly or entirely devoid of fish. Numerous adverse conditions have been created in the stream system by human activity in the watershed over the past 150 years, and particularly over the past 60 years, resulting in the destruction of a balanced fish population within the watershed. These adverse stream conditions are related to alterations both in water quality and in the physical habitat. The response of fish to such changes in their habitat over the short term may not always be as dramatically evident as a fish kill—although fish kills have occurred in the Oak Creek watershed—but in the long term the final result is the same. For example, adverse stream conditions may affect the natural reproduction of a fish species so that some individuals are lost each year. Over time, the cumulative effects are such that the fish species within the watershed is extirpated.

The water pollution abatement measures recommended in the watershed plan constitute the most basic fishery enhancement measures possible. Improvement in water quality conditions may be expected to be accompanied by an improved fishery, at least in those stream reaches physically able to sustain a fishery. Certain additional measures may be taken in order to prevent the further decline of the Oak Creek watershed fishery and, to the extent practicable, rehabilitate the warmwater fishery, as well as enhance a limited sport fishery within the watershed. These measures may be considered as accessory to the land use, park and open space, flood control, and water pollution abatement elements of the watershed plan.

In order to develop a set of management recommendations which will result in the maintenance and rehabilitation of a warmwater fishery within the Oak Creek watershed, it is necessary to identify the problems which have adversely affected the fishery of the watershed. Only by understanding these problems is it possible to consider the changes in land and water resources management that could result in improvement in the fish habitat. The specific problems which have resulted in the degradation of the fishery include:

1. The draining and filling of wetlands adjacent to the stream system, which has resulted in a loss of fish spawning, nursery, and feeding areas.
2. The ditching and realignment of stream channels, which has resulted in a uniform aquatic environment where there was once a heterogeneity in the form of alternating riffles, pools, and runs. This ditching and realignment has resulted in uniform bottom types and water velocities which limit the types of fish that can inhabit a stream system, and has thereby reduced the natural diversity.
3. Runoff from agricultural lands and construction sites which transports sediment into the stream system, filling pools, covering gravel beds and plants, clogging the gills of fish, increasing turbidity, interfering with the mating and feeding behavior of fish, and, through abrasive action, sometimes injuring fish.
4. Extreme fluctuations in streamflow, which create alternating scouring and stagnant conditions within the stream system.
5. Runoff waters containing pesticides and fertilizers from urban and rural lands, raw sewage from sanitary sewer system overflow devices, industrial discharges, and chemical spills which have caused a decline in water quality conditions.

6. The lack of instream vegetation and cover, which has prevented fish from finding shelter from predators and sudden floods. Some fish species may not carry on normal reproductive activities without proper cover. In addition, the lack of vegetative cover for other aquatic organisms may reduce the food resources available to fish, thereby affecting their growth and reproductive capacity.

7. The Oak Creek Dam, the Nicholson Avenue bridge spillway, the spillway located just south of Ryan Road, and the three concrete drop sills located in the Southwood Subdivision, as well as the occasional sandbars across the mouth of Oak Creek along the main stem of Oak Creek, the Milwaukee Road railway bridge spillway, and the two spillways just south of the Milwaukee Area Technical College-South Campus along the North Branch of Oak Creek. All of these structures inhibit the natural movement of fish up and down the stream system and into and out of Lake Michigan. These structures affect the reproductive habits and natural dispersal of fish species within the watershed. The recruitment of new fish species into depopulated areas may be hampered or entirely prevented by these obstructions.

8. As a result of the above-mentioned problems, the fish population of the Oak Creek watershed has reached a point where the natural source of "seed stock" necessary to restore the depopulated areas of the watershed is apparently lacking. Very tolerant fish such as fathead minnow and central mudminnows and tolerant fish such as creek chub and brook stickleback are able to survive in the stream system, but intolerant species such as darters, daces, and stonerollers are lacking.

In an urbanizing watershed such as Oak Creek, it may not be practicable to consider halting, much less reversing, the historic trends in some of these factors. For example, the ditching and realignment of stream channels may be expected to continue, and, indeed, is recommended in the plan for flood control and drainage purposes. Similarly, large fluctuations in streamflow cannot be avoided in an urbanizing watershed, where the stream system must serve urban stormwater drainage purposes. On the other hand, remaining wetlands in some reaches can be protected, pollution and sediment loadings can be reduced, and certain measures, such as the revegetation of stream banks, can be undertaken.

Based upon the Commission inventories of the fishery and related aquatic life, and of the physical features of the stream system, the Commission rated the various stream reaches of Oak Creek and its tributaries in terms of their aquatic habitat potential. As shown on Map 61, the following stream reaches, totaling 11.1 miles in length, or 52 percent of the total perennial stream length in the watershed, are considered potentially capable of supporting a balanced warmwater fishery and an anadromous, or seasonal, coldwater sport fishery:

- Oak Creek main stem between its confluence with Lake Michigan and its confluence with the North Branch of Oak Creek.
- North Branch of Oak Creek between Groveland Drive extended and its confluence with the main stem.

This conclusion assumes that physical barriers, such as dams, sills, weirs, and spillways, will be removed or altered to permit reestablishment of the fisheries in these stream reaches. Also shown on Map 61 are the following stream reaches, totaling 8.0 miles in length, or 38 percent of the total perennial stream length in the watershed, considered potentially capable of supporting a tolerant forage fishery and anadromous, or seasonal, coldwater sport fishery:

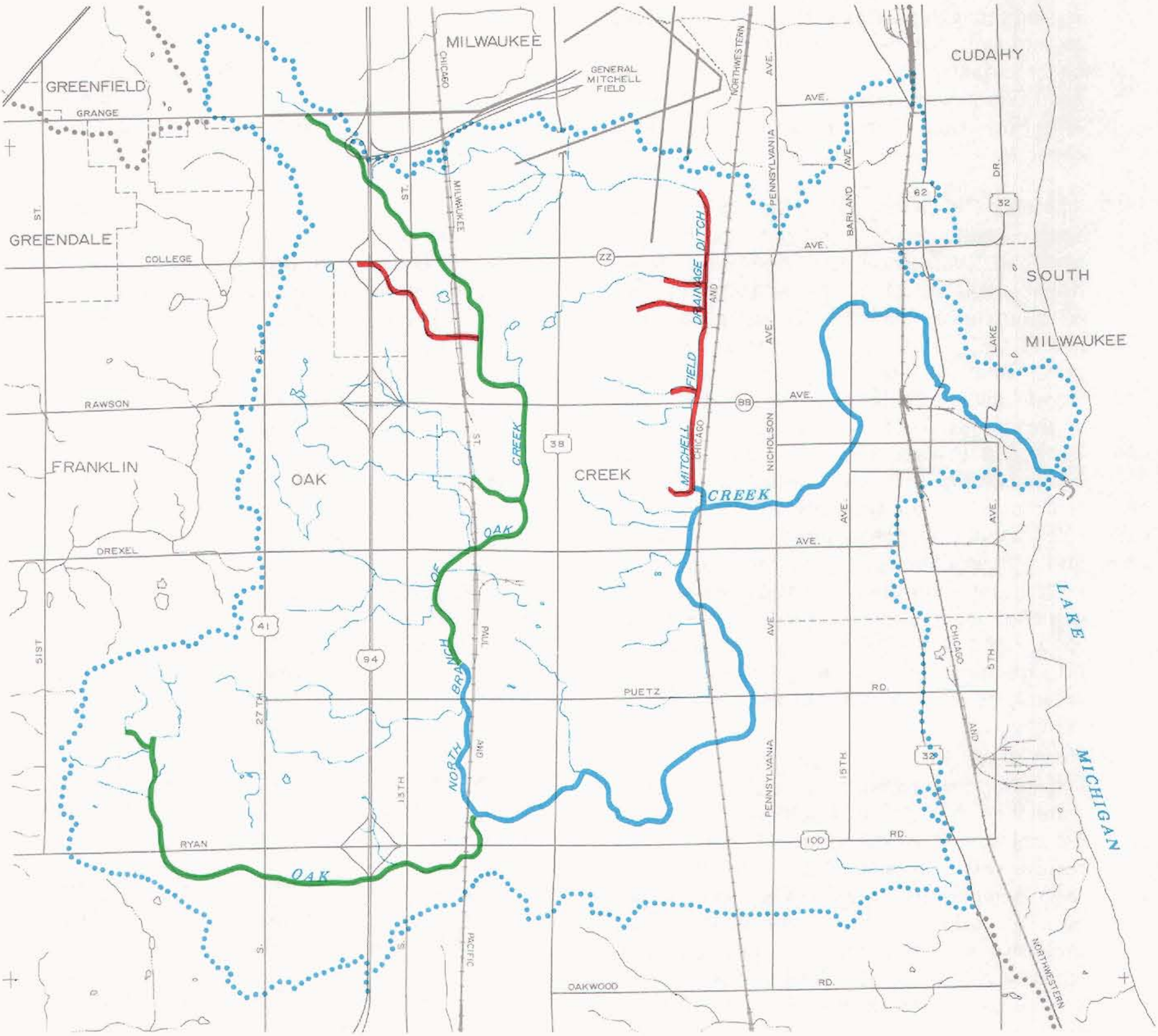
- Oak Creek main stem between its confluence with the North Branch of Oak Creek and Hilltop Lane extended.
- North Branch of Oak Creek between Groveland Drive extended and IH 94.

Finally, as set forth on Map 61, the remaining perennial stream reaches, totaling 2.2 miles in length, or 10 percent of the total perennial stream length in the watershed, are considered capable of supporting only a limited tolerant or very tolerant forage fishery as a result of the major irreversible cultural modifications to the land surface, channel characteristics, and low-flow conditions.

Two major characteristics of a good fishery are the presence of those species of fish necessary to provide recreational activity for people, and sufficient

Map 61

POTENTIAL FISHERY DEVELOPMENT BY STREAM REACH IN THE OAK CREEK WATERSHED



LEGEND

STREAM REACHES POTENTIALLY CAPABLE OF SUPPORTING A TOLERANT FORAGE FISHERY AND ANADROMOUS OR SEASONAL COLDWATER SPORT FISHERY

STREAM REACHES POTENTIALLY CAPABLE OF SUPPORTING A WARMWATER SPORT FISHERY AND ANADROMOUS OR SEASONAL COLDWATER SPORT FISHERY

STREAM REACHES CONSIDERED CAPABLE OF SUPPORTING LIMITED TOLERANT OR VERY TOLERANT FORAGE OR ROUGH FISH

A Commission inventory of the Oak watershed resulted in the rating of the stream reaches of the watershed in terms of their aquatic habitat potential. Of the 21.3 miles of perennial stream in the watershed, 11.1 miles, or 52 percent, were considered to be potentially capable of supporting a balanced warmwater fishery and anadromous, or seasonal, coldwater sport fishery; 8.0 miles, or 38 percent, were considered to be potentially capable of supporting a tolerant forage fishery and anadromous, or seasonal, coldwater sport fishery; and 2.2 miles, or 10 percent, were considered to be capable of supporting a limited tolerant or very tolerant forage fishery.

Source: SEWRPC.

diversity of other fish species to provide a food base and overall stability to the stream community. To promote such a good fishery, the following fish management measures should be considered as adjuncts to the land use, park and open space, flood control, and water pollution abatement plans for the watershed.

Alternative 1—Measures to Maintain a Minimum Fishery

The measures that would be required to develop and maintain a minimum fishery in the Oak Creek watershed are indicated on Map 62. These measures include modification of existing water conveyance structures and implementation of mitigation techniques to improve instream habitat for aquatic organisms.

More specifically, the dam located in the Oak Creek Parkway would be maintained in its present condition. That portion of Oak Creek below the dam would also be maintained in its present condition, and would continue to provide recreational opportunities for warmwater and seasonal coldwater sport fishing.

Designated reaches of the main stem of Oak Creek, including those reaches between 15th Avenue and Pennsylvania Avenue and between IH 94 and the Milwaukee Road Railroad bridge, and that portion of the North Branch of Oak Creek between S. 13th Street and Forest Hill Avenue extended, would be improved by application of instream mitigation measures. Such measures are intended to enhance instream water quality and habitat conditions for aquatic organisms by creating groupings of pools and riffles, and by diversifying bottom substrates, and include the placement of wing deflectors, use of scattered rocks, and stream bank improvement techniques such as bank undercuts and selective plantings. Sills or drop structures located at Pennsylvania Avenue and just south of Ryan Road on the Oak Creek main stem, those situated immediately south of the Milwaukee Area Technical College-South Campus, and the structure located under the Milwaukee Road bridge on the North Branch would be notched to allow the passage of fish during high streamflow periods. In addition, stream meanders would be created in portions of the instream mitigation areas. Based upon the foregoing modifications, a balanced warmwater and forage fishery could be maintained contingent upon the annual or biennial stocking of forage, pan, and other warmwater sport fish.

The upper reaches of the main stem and North Branch, as well as the entire Mitchell Field Drainage Ditch, would be maintained in their present condition as a limited forage fishery, and would continue to support species such as central mudminnow and fathead minnow.

The measures required to develop and maintain a minimum fishery in the Oak Creek watershed not encompassed in the water resources management and selected land use recommendations of the watershed plan are estimated to cost $387,000. These include the modification of the four sills and drop structures. The specific instream mitigation measures needed to maintain a minimum fishery should be developed within the context of a detailed fish management plan prepared by the Wisconsin Department of Natural Resources.

Alternative 2—Measures to Maintain an Extended Minimum Warmwater and Seasonal Coldwater Sport Fishery

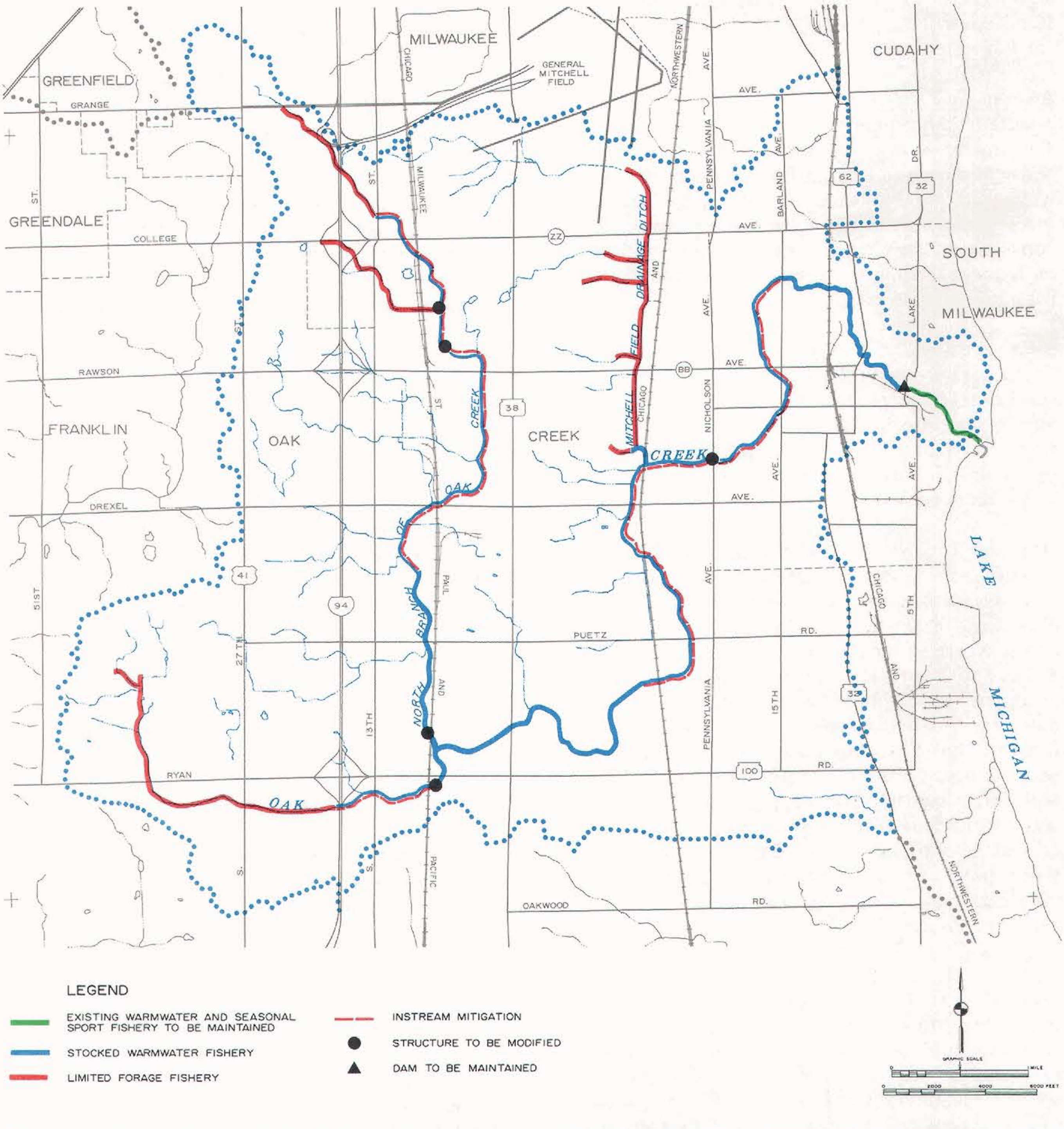
The measures that would be required to develop and maintain an extended minimum warmwater and seasonal coldwater sport fishery in the Oak Creek watershed are indicated on Map 63. Under this alternative, the dam located in the Oak Creek Parkway would be removed or modified by the addition of a fish ladder, similar to that shown in Figure 65, or the dam would be operated so that a pool exists only in the winter in order to facilitate the seasonal upstream movement of anadromous coldwater fish. That portion of Oak Creek below the dam would be maintained in its present condition as a warmwater and seasonal coldwater sport fishery.

The portion of Oak Creek between the dam and Pennsylvania Avenue would be developed as a stocked warmwater and seasonal coldwater sport fishery. To effect development of the fishery, instream habitat mitigation techniques would be implemented between 15th Avenue and Pennsylvania Avenue to improve habitat conditions for aquatic organisms. Mitigation techniques used would be similar to those recommended under Alternative 1. Annual or biennial stocking of forage, pan, and other warmwater sport fish may be necessary to maintain the desired fishery in these reaches.

The remaining reaches of Oak Creek, including the western portion of the main stem from Nicholson Avenue, the entire North Branch, and the entire

Map 62

MEASURES TO MAINTAIN A MINIMUM FISHERY

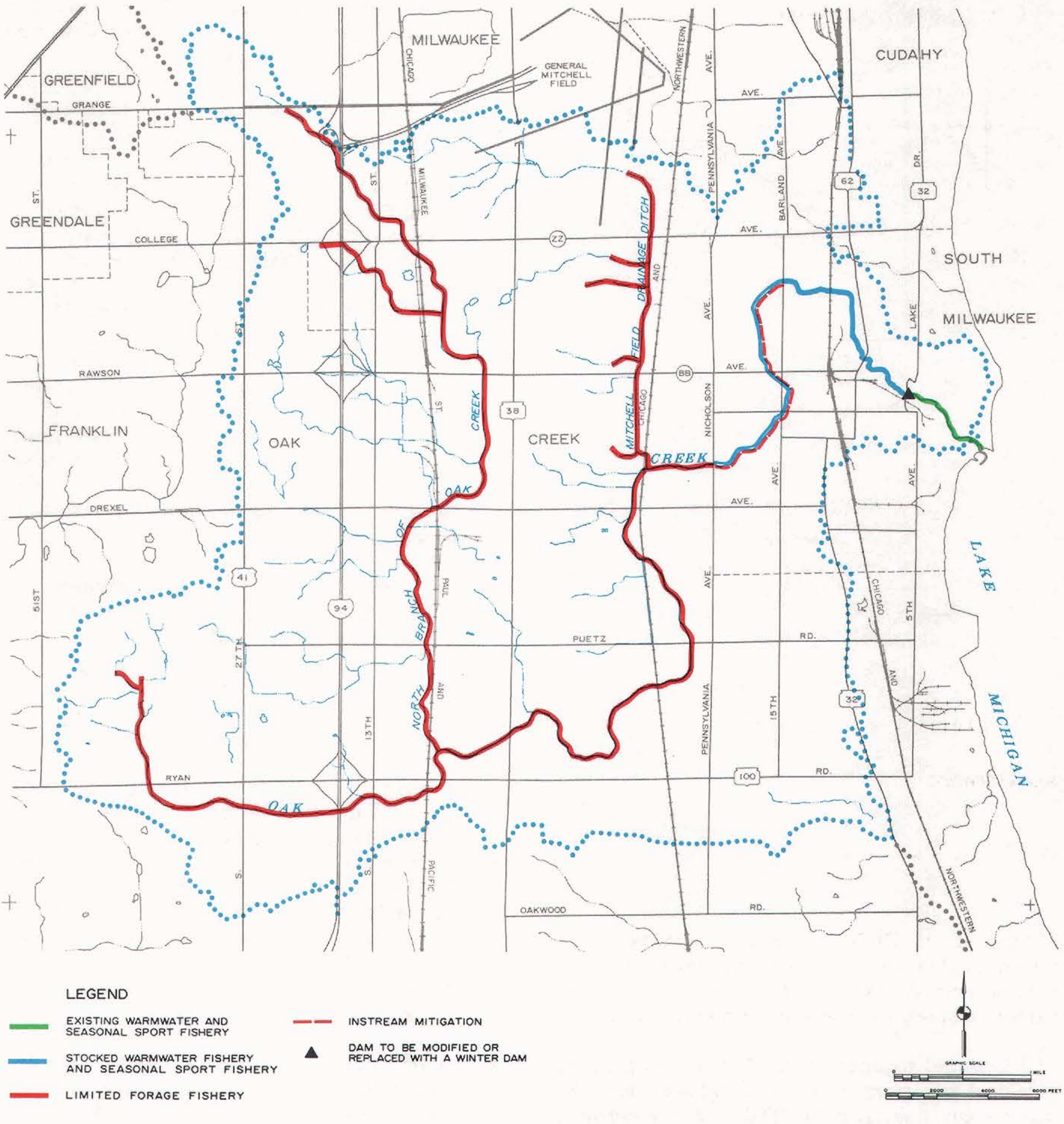


The measures that would be required to develop and maintain a minimum fishery in the Oak Creek watershed include the modification of five sill and drop structures by notching these structures to allow passage of fish during high streamflow periods; the application of instream habitat mitigation measures along 5.3 miles of Oak Creek and 3.6 miles of the North Branch of Oak Creek; and the annual or biennial stocking of forage, pan, and other warmwater sport fish.

Source: SEWRPC.

Map 63

MEASURES TO MAINTAIN AN EXTENDED MINIMUM WARMWATER AND SEASONAL COLDWATER SPORT FISHERY

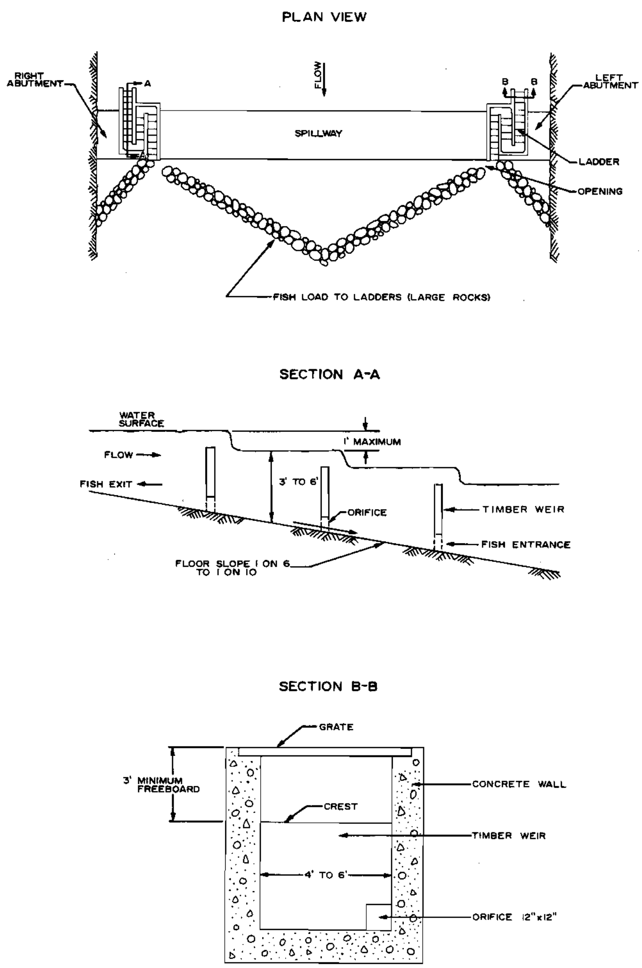


The measures that would be required to develop and maintain an extended minimum warmwater and seasonal coldwater sport fishery in the Oak Creek watershed include either the removal or the modification with a fish ladder of the Mill Road dam; the application of 1.9 miles of instream habitat mitigation measures along Oak Creek; and an annual or biennial stocking of forage, pan, and other warmwater sport fish.

Source: SEWRPC.

Figure 65

INSTALLATION OF A FISH LADDER AT THE OAK CREEK PARKWAY DAM



Source: SEWRPC.

Mitchell Field Drainage Ditch, would be maintained in their present condition and would support a limited forage and would, to a limited extent, support a seasonal coldwater sport fishery.

The measures required to develop and maintain an extended minimum warmwater and seasonal coldwater sport fishery in the Oak Creek watershed, encompassed in the water resources management and related land use recommendations of the watershed plan, are the fish ladder modifications at the dam estimated to cost $100,000, or operation of the dam so that a pool exists only in the winter, estimated to cost $5,000; and an annual or biennial fish stocking program, estimated to cost $3,000.[21] The specific instream mitigation measures needed to maintain an extended minimum warmwater and seasonal coldwater sport fishery should also be developed within the context of a detailed fish management plan prepared by the Wisconsin Department of Natural Resources.

Alternative 3—Measures to Maintain a Maximum Warmwater and Seasonal Coldwater Fishery

The measures that would be required to develop and maintain a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed are indicated on Map 64. Under this alternative, the dam located in the Oak Creek Parkway would be removed or modified by the addition of a fish ladder, similar to that shown in Figure 65. Modification of the dam would allow upstream migration of anadromous fish, thereby increasing the potential for seasonal recreational sport fishing in most reaches of the main stem and North Branch of Oak Creek. That portion of Oak Creek located downstream from the dam would continue to be maintained in its present condition and would continue to offer opportunities for warmwater and seasonal coldwater sport fishing.

Sills or drop structures located at Pennsylvania Avenue and just south of Ryan Road on the Oak Creek main stem, those situated immediately south of the Milwaukee Area Technical College-South Campus, and the structure located under the Milwaukee Road bridge on the North Branch would be removed or replaced with modified fish ladders, similar to that shown in Figure 66, to allow upstream and downstream movement of forage and game fish. Designated portions of the Oak Creek main stem and North Branch could then be developed as warmwater and seasonal coldwater sport fisheries. Instream habitat mitigation techniques similar to those recommended under the previous alternatives would be implemented on the main stem of Oak Creek between 15th Avenue and Pennsylvania Avenue, and between the Milwaukee Road bridge and IH 94. On the North Branch of Oak Creek, instream habitat rehabilitation measures would be implemented for the reach between S. 13th Street and Forest Hill Avenue extended. The instream mitigation measures, combined with the modification of existing sills and drop structures,

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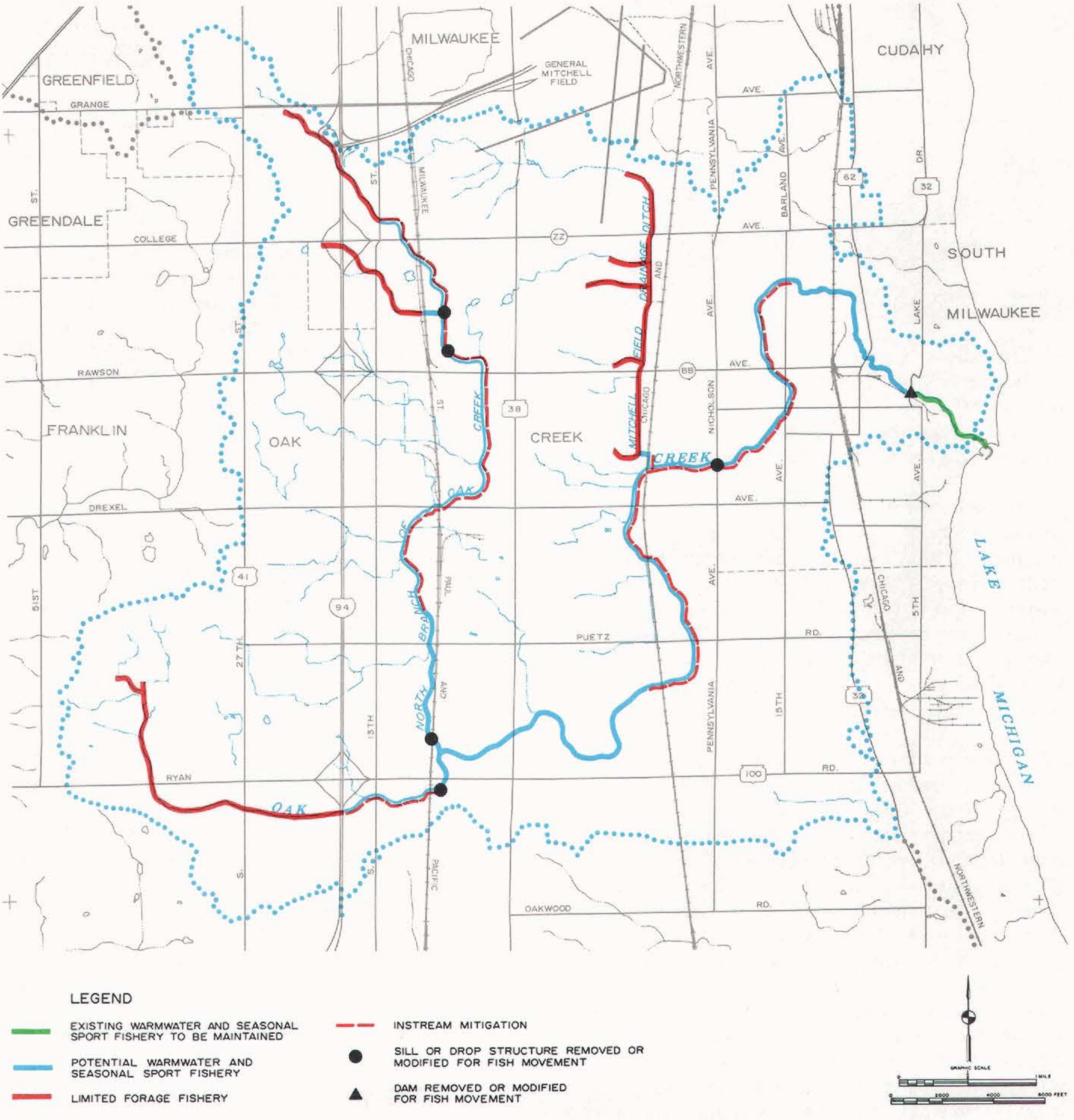
[21] *The cost of the fish stocking program will be borne by existing Wisconsin Department of Natural Resources fish management programs.*

Map 64

MEASURES TO MAINTAIN A MAXIMUM WARMWATER AND SEASONAL COLDWATER FISHERY

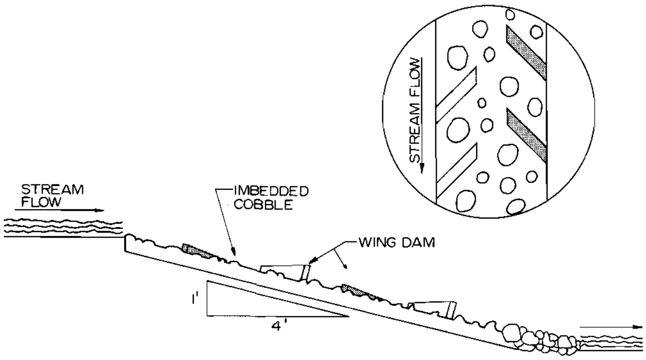


The measures that would be required to develop and maintain a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed include either the removal or the modification with a fish ladder of the Mill Road dam; the removal or installation of modified fish ladders at five sill or drop structures; the application of habitat mitigation measures along 5.3 miles of Oak Creek and along 3.6 miles of the North Branch of Oak Creek; and an initial stocking of selected forage and game fish species.

Source: SEWRPC.

Figure 66

MODIFIED FISH LADDER



Source: SEWRPC.

should allow forage, warmwater, and seasonal coldwater sport fish to repopulate designated reaches of Oak Creek. An initial stocking of selected forage and game fish species may be used to accelerate the repopulation process.

The remaining reaches of the main stem and North Branch of Oak Creek, as well as the Mitchell Field Drainage Ditch, would continue to support a limited forage fishery, and would provide limited seasonal sport fishing opportunities because of intermittent or low streamflows. To the extent that anadromous fish move into these reaches, limited additional fishing opportunities may be provided under this alternative.

The measures required to develop and maintain a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed not encompassed in the water resources management and related land use recommendations of the watershed plan are the fish ladder modifications at the dam, estimated to cost $100,000, or the removal of the dam, estimated to cost $20,000, or operation of the dam so that a pool exists only in the winter, estimated to cost $5,000; the removal or modification of the five sills and drop structures, estimated to cost $25,000; and an initial fish stocking program estimated to cost $3,000. Specific instream mitigation measures needed to maintain a maximum warmwater and seasonal coldwater fishery should be developed within the context of a detailed fish management plan prepared by the Wisconsin Department of Natural Resources.

Concluding Remarks—Fishery Development

Based upon a review of the alternatives considered, Alternative 3 was modified to take into account recommendations made by the Wisconsin Department of Natural Resources fish manager for the Lake Michigan area working in cooperation with the Commission staff.[22, 23] The modified Alternative 3 is presented herein as the recommended fish management plan for the Oak Creek watershed.

Recommended Plan—Measures to Maintain a Maximum Warmwater and Seasonal Coldwater Fishery: The measures that are required to develop and maintain a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed are summarized on Map 65. Under this alternative, it is recommended that the existing dam located in the Oak Creek Parkway be notched down to the streambed, as shown in Figure 67, to allow upstream migration of anadromous fish, thereby increasing the potential for seasonal sport fishing in most reaches of the main stem and North Branch of Oak Creek. Notching of the dam by providing a notch width of 40 feet at the top of the dam and 10 feet at the base of the dam would preserve the dam abutments while accommodating high- and low-flow events.

It is also recommended that the mill pond created by the dam be modified to improve the warm- and coldwater fishery potential of Oak Creek. Dam modification would require dredging a portion of the accumulated sediments behind the dam to normalize the streambed gradient and to re-create stream meanders. A portion of the bed of the former impoundment could be used in winter to provide an ice skating rink. The rink would have to be created by artificially irrigating the rink surface.

It is further recommended that the sill located on the main stem at Pennsylvania Avenue (Nicholson Avenue) be removed; and that the sill located on the main stem just south of Ryan Road, the two sills located on the North Branch immediately south of the Milwaukee Area Technical College-South Campus, and the sill located on the North Branch at the Milwaukee Road bridge be removed, or be provided with fish ladders, similar to that

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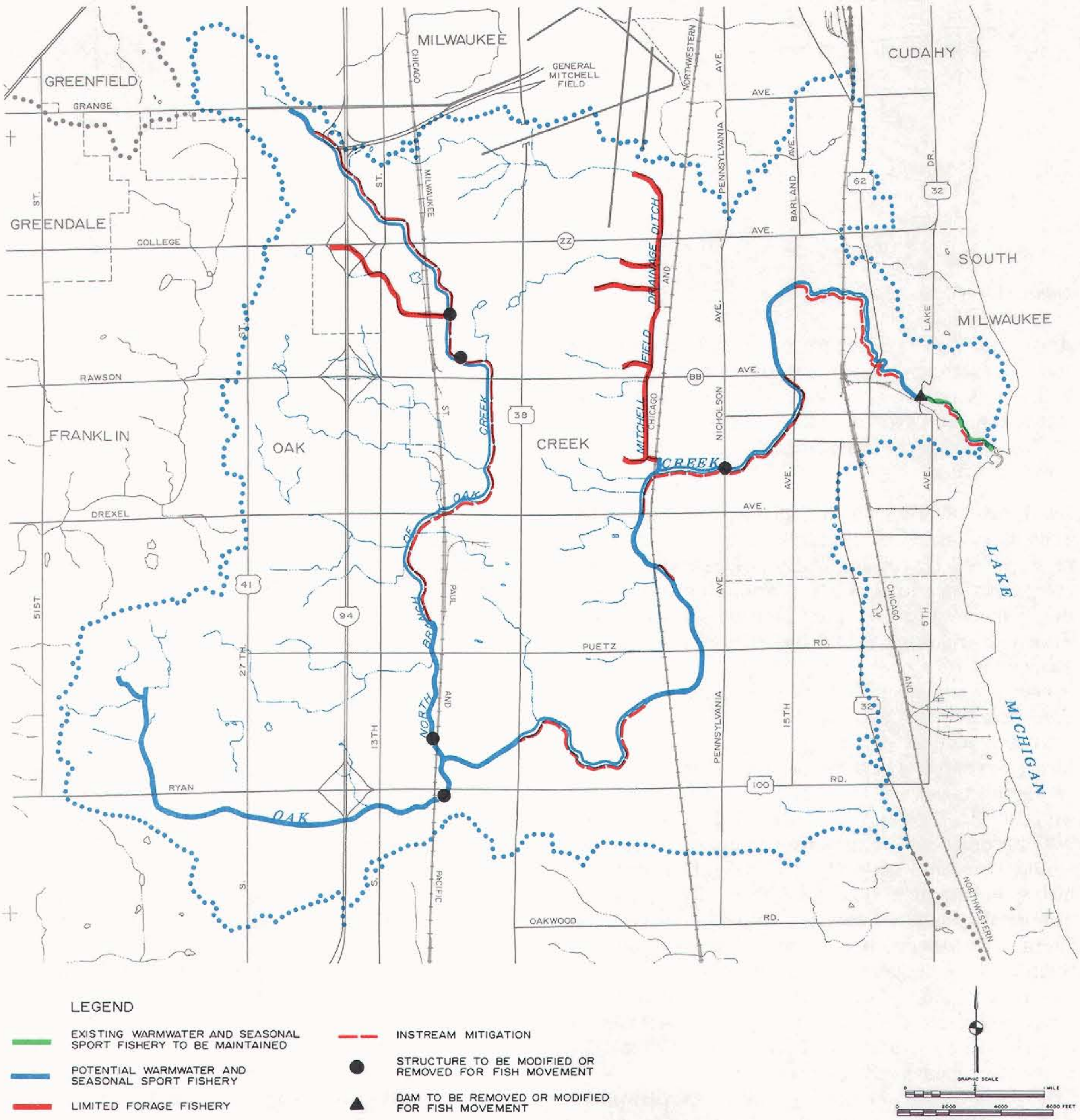
[22] *Ronald M. Bruch, "Development of an Anadromous Fishery in Oak Creek, Milwaukee County," January 21, 1986.*

[23] *Wisconsin Department of Natural Resources, "Stream Classification for Oak Creek," in draft Southeast District Water Resources Management file report, 1986.*

Map 65

RECOMMENDED MEASURES TO MAINTAIN A MAXIMUM WARMWATER AND SEASONAL COLDWATER FISHERY

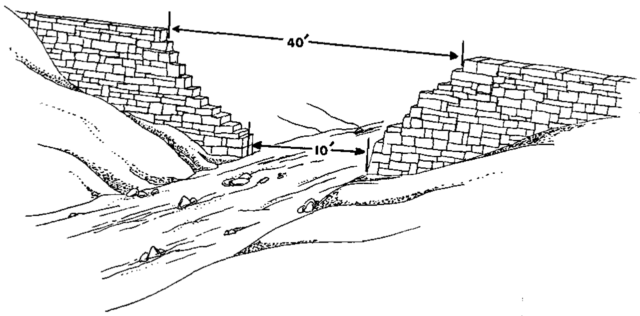


Based upon a careful physical and biological evaluation of the stream system of the watershed by the staffs of the Commission and the Wisconsin Department of Natural Resources, a set of recommended measures was formulated for the maintenance of a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed. These measures include notching the existing Mill Road dam and normalization of the stream grade through the reach occupied by the existing mill pond above the dam; the removal or installation of modified fish ladders at five sill or drop structures; the application of habitat mitigation measures along 5.7 miles of Oak Creek and 4.9 miles of the North Branch of Oak Creek; the application of stream bank stabilization measures; and an initial stocking of selected forage and game fish species.

Source: SEWRPC.

Figure 67

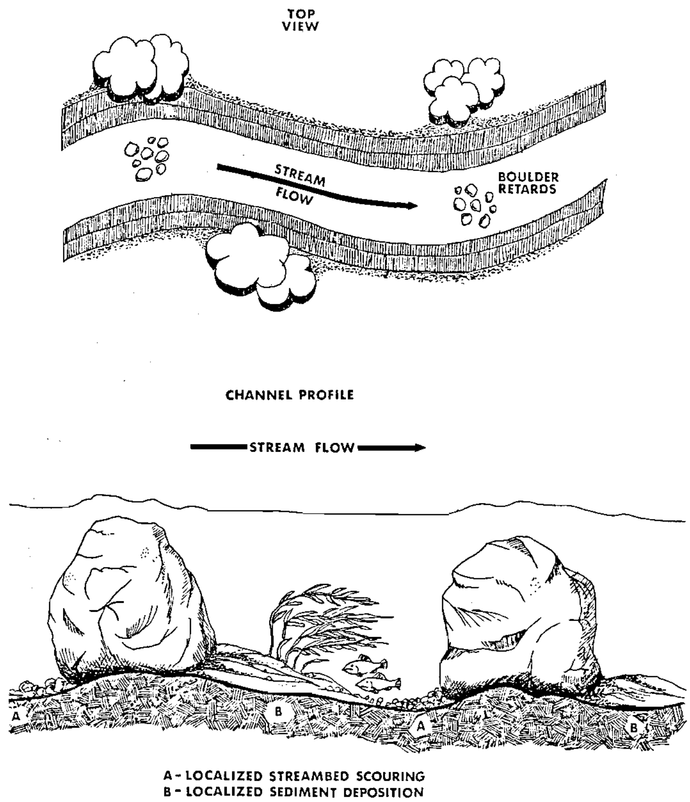
PROPOSED MODIFICATION
OF MILL ROAD DAM



Source: SEWRPC.

Figure 68

BOULDER RETARDS AS USED
FOR INSTREAM MITIGATION



Source: SEWRPC.

shown in Figure 66. This would allow upstream and downstream movement of forage and game fish. As a result, approximately 20 miles of the main stem and North Branch of Oak Creek could be developed as warmwater and seasonal coldwater sport fisheries.

As shown on Map 65, designated portions of the main stem and North Branch of Oak Creek would be improved by the application of instream habitat mitigation measures. Such measures should include the placement of boulder retards—such as those shown in Figure 68—on the streambed, and the placement of stone rip-rap at the toe of existing masonry and concrete bank protection structures. The boulder retards would serve to enhance instream habitat by modifying streamflow patterns, diversifying bottom substrates, and providing protective cover and resting areas for fish and other aquatic life. Rip-rap placement at the toe of existing masonry and concrete protection structures would serve to diversify and therefore enhance instream habitat conditions for aquatic organisms. The development of stands of emergent vegetation along the stream banks would be encouraged. Stands of emergent vegetation should also be encouraged along the channel bottom to provide improved habitat for certain aquatic invertebrates and fish and some forms of terrestrial wildlife. The floodland management impacts of other instream fish management measures, such as the placement of brush bundles, would have to be evaluated in relation to the hydraulic characteristics and objectives of the channel configuration.

Several stream bank stabilization measures are recommended under this alternative. Placement of stone rip-rap and wing deflectors is recommended for those reaches where stream bank erosion necessitates remedial action. These reaches are shown on Map 65. The placement of stone rip-rap and wing deflectors along stream banks where severe scouring is occurring, in addition to reshaping the stream banks to a more stable angle, would effectively mitigate excessive erosion while providing suitable instream and stream bank habitat. Such bank stabilization measures would also enhance recreational opportunities along Oak Creek by providing areas of improved access for recreational users. Additional stream bank stabilization measures in the form of prescribed plantings are also recommended. Plantings would contribute to stream bank stability and enhance terrestrial wildlife habitat for species using the Oak Creek riparian area as migratory habitat and as a connecting corridor between habitat areas of higher value.

The instream mitigation measures, combined with the notching of the dam and removal or modification of existing sills and drop structures, should allow forage, warmwater, and seasonal coldwater sport fish to repopulate designated reaches of Oak Creek. An initial stocking of selected forage and game fish species may be used to accelerate the repopulation process.

The remaining reaches of the North Branch of Oak Creek as well as the Mitchell Field Drainage Ditch would continue to support a limited forage fishery, and would provide limited seasonal sport fishing opportunities because of intermittent or low streamflows. To the extent that anadromous fish move into these reaches, limited additional fishing opportunities may be provided under this alternative.

The measures recommended to develop and maintain a maximum warmwater and seasonal coldwater fishery in the Oak Creek watershed would have the following estimated costs: notching of the dam and modification of the pond, $8,000; modification of the five sills and drop structures, $9,000; instream habitat improvement, $40,000; bank erosion control measures, $5,000; and an initial fish stocking program, $3,000. To the extent that the recommended measures are implemented, the potential for establishing a balanced warmwater and seasonal coldwater fishery within the Oak Creek watershed would be substantially improved.

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 the recommended floodland management plan element for the comprehensive plan for the Oak Creek 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 divided into two categories: structural measures and nonstructural measures. A total of six 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) bridge or culvert modification or replacement; 2) channel modification; 3) dikes; 4) detention reservoirs; 5) onsite storage; and 6) floodwater diversion. Twelve 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 the floodlands; 9) emergency programs; 10) structure floodproofing; 11) structure removal; and 12) community education programs. 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 preventive 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-hydraulic flood flow simulation model was used to quantitatively evaluate the impact of two different plan year 2000 land use conditions on the flood flow behavior of the Oak Creek watershed. The simulation model studies indicated that 100-year recurrence interval peak flood flows would increase up to 69 percent if no development were permitted in the floodplain, and up to 78 percent if development were allowed in some portions of the floodplain fringe.

In order to compare the cost of alternative floodland management measures, the flood damage susceptibility of a river reach must be quantified in monetary terms. Information derived from the historic flood survey, combined with the results of hydrologic-hydraulic simulation modeling, indicated that on an average annual basis, the monetary flood risks for the watershed total about $29,900 under existing land use and existing channel and floodplain conditions, and about $98,000 under plan year 2000 land use and existing channel and floodplain conditions. If additional urban development were permitted to occur in the floodplain fringe, even higher monetary flood risks could be expected to be incurred. Under existing land use, channel, and floodplain conditions, flood damage to crops and structures of about $84,200 and $259,600, respectively, may be expected to be incurred during a 100-year recurrence interval flood. Under plan year 2000 land use and existing channel and floodplain conditions, flood damages of about $80,600 and $571,800, respectively, may be expected to be incurred during a 100-year recurrence interval flood.

A total of 12 alternative floodland management measures—including two "no-action" alternatives—were developed and evaluated for resolution of the flood problems of the Oak Creek watershed. After due consideration of the various technical and economic features of these alternatives, the Watershed Committee recommended that the combination channel deepening and shaping and structure floodproofing, elevation, and removal alternative be used to resolve existing and probable future flood problems in the Oak Creek watershed. Utilizing an annual interest rate of 6 percent and an amortization period and project life of 50 years, the total average annual cost of this alternative is $65,000, consisting of the amortization of the $1,009,000 capital costs and $1,000 in annual operation and maintenance costs. Thus, the resulting benefit-cost ratio of this alternative is 1.20.

Eighteen bridges and culverts were identified in the watershed planning program that could be expected, by virtue of inadequate capacity and overtopping of the approach roads or of the structure, to interfere with the operation of the highway and railroad transportation system during major flood events under plan year 2000 conditions and existing channel conditions. Eight of these substandard bridges and culverts are located on land access and collector streets and ten are located on arterial streets and highways other than freeways and expressways. It is recommended that when these structures are modified or replaced as part of necessary highway and railway improvement programs, these crossings 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 to accommodate the 100-year recurrence interval flood discharge under plan year 2000 conditions without raising the corresponding peak stage by more than 0.1 foot above the peak stage established in the adopted comprehensive watershed plan.

Of the 12 nonstructural floodland management measures identified for possible application in the Oak Creek watershed, the following three were found to be particularly effective for minimizing the aggravation of existing problems and for preventing the 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, and 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 watershed land use plan, but also to minimize the aggravation of 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 the Oak Creek watershed floodlands, or new floodland regulations would have to be prepared by the communities in the watershed.

Although 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 provides a way of reducing monetary flood losses to the property owner. All of the communities located in the Oak Creek watershed which have been identified as having flood hazard areas have elected to participate in the federal Flood Insurance Program. Insurance rate studies for these communities have all been completed. It is recommended that hydrologic-hydraulic data generated under the watershed program be used to amend and update the flood insurance studies. 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 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 to 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 lcoation of new urban development. It is recommended that the policies of the governmental units and agencies responsible for such utilities and facilities within the watershed be designed to complement the floodland recommendations for the Oak Creek watershed and the recommended primary environmental corridor protection plan subelement.

Public awareness of the existence of a comprehensive watershed plan may serve to reduce or prevent flooding problems in the Oak Creek watershed. It is recommended that residents of the watershed be informed of the existence of this study through the news media and through a public hearing on the recommended plan.

The continuous stream gaging station and the partial record crest and staff gages located within the Oak Creek watershed provide critical data required for rational management of the surface water resources. Discharge-frequency relationships, flood stage profiles, and other information obtained from the hydrologic-hydraulic simulation model were developed and used in the Oak Creek watershed study. It is recommended that the continuous streamflow monitoring gage installed at the first 15th Avenue crossing of Oak Creek continue to be operated. It is also recommended that the crest stage and low-flow partial record station operated by the U. S. Geological Survey at S. Nicholson Road continue to be operated and that the Milwaukee Metropolitan Sewerage District and the City of Milwaukee continue to maintain the existing crest and staff gage network.

At the Grant Park boat launch at the mouth of Oak Creek, chronic sandbar formation seriously interferes with boat passage to and from Lake Michigan. An evaluation of this problem included a review of the previous studies of the problem and associated proposals, most of which were not implemented because of perceived technical inadequacies or lack of funding. A Commission analysis of the problem concluded that if a narrow navigation channel with fixed boundaries were constructed, either natural uncontrolled storm runoff from the watershed or flow controlled by impoundment could be used on an as-needed basis to flush sand from the channel to maintain navigable depths. It was recommended that the navigation channel be constructed to determine if natural runoff alone complemented by a minimal dredging effort would suffice for maintenance of recreational navigation. If not, it was recommended that either a dry dam be constructed on Oak Creek just upstream from the Grant Park boat launch specifically designed to temporally impound water to be used to flush the channel, or that a network of diffusers be installed within the navigation channel through which water would be pumped to flush the accumulated sand. The costs of these alternatives range from about $140,000 to $190,000.

Based on the fishery data collected under the watershed study, the Oak Creek watershed supports a dominance of fish that are generally tolerant of the poor water quality conditions and degraded physical habitat provided by the stream channels. Those problems which have contributed to the degradation of the fishery include: 1) the draining and filling of wetlands adjacent to the stream system; 2) the ditching and realignment of stream channels; 3) sediment runoff from agricultural lands and construction sites; 4) extreme fluctuations in streamflow; 5) runoff of pesticides and fertilizers from urban and rural lands; 6) the lack of instream vegetation and cover; 7) the presence of nine dams and spillways, as well as the occasional sandbar across the mouth of Oak Creek; and 8) the lack of appropriate "seed stock" necessary to restore the depopulated areas of the watershed. Based upon the inventories of the fishery and related aquatic life and existing physical habitat conditions, stream reaches were rated in terms of their aquatic habitat potential. Perennial stream reaches totaling 11.1 miles in length are considered potentially capable of supporting a balanced warmwater fishery and a seasonal coldwater sport fishery; perennial stream reaches totaling 8.0 miles in length are considered potentially capable of supporting a tolerant forage fishery and seasonal coldwater sport fishery; and perennial stream reaches totaling 2.2 miles in length are considered capable of supporting a limited tolerant or very tolerant forage fishery. In order to promote a good fishery in the watershed, four alternative fish management measures were considered. Based on these alternatives, it is recommended that the following measures be included in the watershed plan: 1) modification of the Oak Creek Parkway (Mill Road) dam by notching the existing structure down to the streambed to provide an opening of 40 feet at the top of the dam and 10 feet at the base of the dam; 2) dredging a portion of the accumulated sediments behind the Parkway dam to normalize the streambed gradient and to re-create stream meanders; 3) removal or modification of five sill and drop structures; 4) instream habitat mitigation measures; 5) stream bank stabilization measures; and 6) an initial fish stocking program.

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Chapter XIII

RECOMMENDED WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

The inventory and analysis phases of the Oak Creek watershed planning program identified flooding and water pollution as water resource problems in the watershed. The principal purpose of the watershed planning program is to develop a workable plan for the resolution of these problems. The purpose of this chapter is to present alternative plans for water pollution abatement, and to recommend the best plan from among these alternatives for incorporation into the comprehensive plan for the watershed. More specifically, this chapter analyzes the extent to which various alternative water pollution abatement measures may be expected to mitigate or eliminate the point and nonpoint source water pollution problems that exist within the watershed, 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 water quality standards, provides an important basis for alternative plan design and evaluation. An initial set of water use objectives and supporting water quality standards was presented in Chapter X of this report, together with other related objectives and standards. The formulation of objectives and standards may have to be an iterative process in which, as a result of plan design and evaluation, certain objectives initially proposed may have to be revised or discarded because their satisfaction has been proven unrealistic; new objectives may be suggested; and conflicts between inconsistent objectives may be balanced out. This formulation of objectives and standards must proceed hand in hand with plan design and evaluation.

The water quality management plan elements prepared under other Commission studies include recommendations for the abatement of the point and nonpoint sources of pollution within the Region and the Oak Creek watershed, such as sanitary sewer overflows, private wastewater treatment plant discharges, industrial wastewater discharges, malfunctioning septic tank system discharges, stormwater runoff from rural and urban lands, soil erosion, and livestock waste runoff. The water quality management measures described herein were designed and should be considered as refinements of these recommendations, and, importantly, as adjuncts to the basic land use development proposal advanced in Chapter XI to facilitate the attainment of regional and watershed development objectives.

It should again be noted that the water quality management plan element for the Oak Creek watershed, as described herein, is a system level plan and, as such, has three functions:

1. Identification of the type and sources of water pollution in the watershed;

2. Determination of the levels of abatement of those sources required to achieve the established water use objectives and supporting standards for the watershed; and

3. Evaluation of alternative means for achieving the required level of pollution abatement and identification of the best means considering technical practicality, economic feasibility, and environmental impact.

This chapter is organized in the following manner. The surface water quality problems of the watershed as identified in Chapter VII are first briefly reviewed, together with the sources of those problems. Next, the steps that have already been taken, or have been committed to be taken, for the resolution of these problems are described. Further measures required to resolve the remaining problems are then 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 the water quality problems are also briefly described, together with the available control measures.

BASIS FOR THE DEVELOPMENT AND ANALYSIS OF ALTERNATIVE WATER QUALITY MANAGEMENT PLAN ELEMENTS

In a combined urban and rural setting such as the Oak Creek watershed, man's activities significantly affect, and are affected by, the quality of surface waters. 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 the desired beneficial uses as expressed in stated water use objectives and standards. Thus, surface water use objectives and supporting water quality standards become an important basis for problem identification and plan design and evaluation.

Water Use Objectives

The recommended water use objectives and supporting water quality standards set forth in Chapter X of this report thus provide the basis for the analyses set forth in Chapter VII and in this chapter. Basically, these water use objectives seek the maintenance of a healthy warmwater fishery and full recreational use of the perennial streams of the watershed.

Accordingly, the water quality standards which support the designated water use objectives set forth in Table 74 in Chapter X appropriately specify a minimum dissolved oxygen level; a maximum temperature; a maximum fecal coliform count; a maximum residual chlorine level; maximum un-ionized ammonia nitrogen and phosphorus levels; and a required range in pH levels. In addition, by reference to other federal and state regulations, the water use objectives and standards incorporate maximum levels for certain other water quality indicators, including a broad range of toxic and hazardous substances.[1] Based upon the fishery inventory findings set forth in Chapter III, the channel modification alternatives set forth in Chapter XII, and the water quality analyses presented in this chapter, the water use objectives and supporting standards were reevaluated, as discussed below.

[1] *See U. S. Environmental Protection Agency, Quality Criteria for Water, EPA Report No. 440/9-76-003, Washington, D. C., 1976; National Academy of Sciences, National Academy of Engineering, Water Quality Criteria 1972, EPA Report No. R3-73-003, Washington, D. C., 1974; and Chapter NR 104 of the Wisconsin Administrative Code.*

Historically, in order to facilitate assessment of the potential effects of point sources of pollution, water quality standards were developed for application to specified periods of low flow, such as a 7 day-10 year low-flow condition. Under this historic approach, it was assumed that nonpoint sources of pollution had an insignificant effect on water quality conditions, and that the worst water quality conditions therefore occurred during periods of low flow. However, more recent studies, including those conducted by the Commission under its regional water quality management planning program, indicate that water quality standards may be violated not only during periods of low flow, but also during and following rainfall events occurring after long periods of dry weather during which pollutants build up on the land surface. This finding requires a new approach to the application of water quality standards—an approach which considers and assesses the proportion of the total time that water quality conditions may be expected to meet specified standards. Under this approach, statistical analyses are conducted on the results of water quality simulation modeling to determine the percent of time a given standard may be expected to be violated, including during periods of low flow. A 95 percent compliance level was selected for those parameters which directly affect aquatic organisms—dissolved oxygen, temperature, and residual chlorine. 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 coliform and phosphorus. For pH, a permitted range in values is established which should be met during all flow conditions. Standards for un-ionized ammonia nitrogen are established to protect against acute and chronic toxicity, and should also be met during all flow conditions.

The levels of pollution control which are technically practicable and economically sound also influence the extent to which the desired "fishable-swimmable" water use objectives can be achieved. Point source pollution control measures have historically been given high priority for resolution of surface water quality problems. Point source pollution control measures and practices are based upon a highly advanced technology. Moreover, point sources of pollution and the attendant effects on surface water quality conditions can be more readily and accurately quantified because of the manner in which the pollutants are introduced into the surface water systems. Nonpoint source pollution control measures and practices are based upon a less advanced technology. Moreover, nonpoint sources and the attendant effects on surface water conditions cannot be as readily or as accurately quantified as can point sources. Knowledge of the effectiveness of nonpoint source pollution control measures is limited, and the degree of pollution control which may be expected to be achieved by various methods must be estimated as accurately as possible from case studies.[2] Technically practicable control measures to reduce the pollutants released and carried by stormwater runoff vary in effectiveness from about a 5 percent reduction for some urban practices, including improved leaf and lawn clipping collection and disposal practices, to about a 50 percent reduction for some stormwater storage measures.

Historic Surface Water Pollution

A careful examination of available water quality data for the Oak Creek watershed, as described in Chapter VII of this report, indicates that water quality problems exist during both wet and dry weather conditions over much of the watershed. Of the eight possible categories of pollution, six—pathogenic, organic, nutrient, toxic, sediment, and aesthetic—are known to exist in the Oak Creek watershed. The other two categories of pollution—thermal and radiological—are not known to exist in the watershed.

The most serious type of surface water pollution present in the watershed is pathogenic pollution as indicated by the widespread occurrence of high fecal coliform bacteria counts. These fecal coliform counts, which are indicative of the presence of human and animal wastes, are attributable to point sources, such as discharges from sanitary sewerage system flow relief devices, and to both urban and rural nonpoint sources. Urban nonpoint source fecal coliform loadings are primarily contributed from pet waste and leakage from failing septic tank systems. Rural nonpoint source fecal coliform loadings are primarily contributed from animal wastes. Other less extensive pollution problems in the watershed include the presence of toxic and hazardous substances, depressed dissolved oxygen levels, and excessive nutrient concentrations, particularly phosphorus, under wet weather conditions.

Pollution Sources

Point sources of water pollution in the Oak Creek watershed include three municipal sanitary sewerage system flow relief devices and 18 industrial wastewater discharge outfalls. However, in 1980 these point sources were estimated to contribute less than 1 percent each of the nitrogen, phosphorus, biochemical oxygen demand, fecal coliform, and suspended solids contributed annually to the surface waters of the watershed.

Pollutant loading analyses conducted under the regional water quality management planning program, and confirmed under the watershed study, indicated that nonpoint sources of pollution—both rural and urban—accounted for the majority of pollutants that were transported to the surface water system. Commission inventories indicated that in 1980, more than 99 percent of the nitrogen, phosphorus, biochemical oxygen demand, fecal coliform, and suspended solids were contributed to the surface water system of the watershed by nonpoint sources of water pollution. These pollutant loadings occur during wet weather conditions, when surface water runoff acts to transport pollutants to the stream system of the watershed.

About 81 percent of the urban area, and 38 percent of the total area of the Oak Creek watershed, is provided with engineered stormwater drainage systems. Therefore, much of the direct runoff from urban areas enters the surface water system through storm sewer outfalls located along the streams and watercourses, with the remaining direct runoff entering the surface water systems through open stormwater channels, or as sheet flow—that is, overland flow not occurring in well-defined channels. Direct runoff from rural areas enters the surface water system through open stormwater channels or agricultural drainage systems, or as sheet flow. Water quality surveys indicate that high concentrations of pollutants, such as biochemical oxygen demand, nitrogen, phosphorus, and fecal coliform bacteria, are most likely to occur during wet weather conditions—that is, the conditions in which surface water runoff from urban and rural lands provide the dominant flow and pollutant loading to the river system.

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[2] *See SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative Plans, February 1979; and SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff, July 1977.*

The limited data available also indicate that excessive concentrations of toxic and hazardous substances, including mercury and PCB's, may exist in the surface water system of the Oak Creek watershed. The presence of toxic and hazardous materials is also supported by the fishery survey undertaken as part of the watershed study. That survey found a lack of aquatic life in stream reaches with characteristics that should otherwise support warmwater species if toxic or other stressful conditions were not present.

Toxic and hazardous materials have not been traced to any one particular source or group of sources in the watershed. Potential sources, however, include municipal and industrial wastewater discharges and nonpoint source contributions, such as excessive application of pesticides and herbicides in both rural and urban areas and washout and fallout of toxic material from the atmosphere. Such washout and fallout may include lead, chromium, mercury, and nickel. A potential also exists for transmission of toxic and hazardous substances from unconfined leachate that originates in solid waste disposal sites. There are 11 known abandoned landfill sites in the Oak Creek watershed, of which five are located immediately adjacent to the watershed stream system. These landfills have all been classified by the Wisconsin Department of Natural Resources as having been properly abandoned; however, the potential may still exist for surface and groundwater contamination from these sites.

Measures Already Underway, or Committed, to Resolve Pollution Problems

Substantial efforts have already been initiated to eliminate some of the major sources of water pollution and thereby abate the pollution problems of the Oak Creek watershed. These efforts are briefly described below and related to the pollution sources described above.

The regulation of point source pollution control sources is effected through the Wisconsin Pollutant Discharge Elimination System. As described in Chapter IX of this report, the Wisconsin 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 a state permit for the discharge of any pollutant into the waters of the State, including the groundwaters. More specifically, permits are required for discharges from municipal sewage treatment plants and associated collection systems, private wastewater treatment facilities, and industrial establishments. The permits may specify abatement requirements and provide a schedule of compliance, setting forth dates by which specific elements of the permit must be responded to. As noted in Chapter IX, the 18 industrial wastewater outfalls in the watershed are controlled through regulation under this system.

As already noted, there were three sanitary sewerage flow relief devices present in the watershed in 1983. The one existing flow relief device located in a portion of the City within the watershed was abandoned in April 1984 as a result of the sanitary sewer system rehabilitation projects in the City of Oak Creek. Furthermore, pollution from two additional flow relief devices in an area of the City of South Milwaukee within the watershed will be significantly reduced as a result of sanitary sewer system rehabilitation projects scheduled for completion in mid-1984. This rehabilitation work will eliminate the need for the operation of these devices in all but the most extreme circumstances; consequently, untreated sanitary sewage should only infrequently spill from these devices into the surface waters of the Oak Creek watershed.

With regard to nonpoint source pollution control, the U. S. Soil Conservation Service, working with the Milwaukee County Department of Parks, Recreation and Culture, designed and helped install approximately 1,000 feet of stream bank protection measures along the Oak Creek Parkway in the City of South Milwaukee from 1981 through 1983. The cost of these protection measures, $110,000, was shared by the Wisconsin Department of Natural Resources under the local priority project portion of the Wisconsin nonpoint source water pollution abatement program. Installation of these measures is expected to reduce the severe stream bank erosion in the areas treated and associated deposition of sediment into the stream, with an anticipated improvement in downstream water quality conditions.

ANALYSIS OF ALTERNATIVE WATER QUALITY MANAGEMENT PLAN ELEMENTS

Analytic Framework and Assumptions

A review of available data on water pollution problems and on pollution sources in the Oak Creek watershed, and efforts underway to abate or eliminate those sources, indicates that progress is being made toward eliminating certain sources of pollution in the Oak Creek watershed. In consideration of the basic pollution abatement program already in progress, the water quality analyses under the Oak Creek watershed planning program, including water quality simulation modeling studies, were conducted within the framework of the committed actions and related assumptions set forth below.

Industrial Wastewater Discharges: The water quality management element of the Oak Creek watershed plan assumes that pollutants that are transported through industrial wastewater outfalls to the surface water system of the watershed will be reduced to acceptable levels through the operation of the Wisconsin Pollutant Discharge Elimination System (WPDES). Currently, industrial discharges in the Oak Creek watershed consist of cooling, process, and backwash waters, as well as stormwater, that do not contain significant amounts of pollutants. Consequently, these discharges should not have significant adverse water quality impacts. Existing water quality conditions, however, indicate that there may be some unreported discharges which may be contributing to excessive concentrations of toxic and hazardous substances in the surface waters of the watershed. These excessive concentrations may also be caused by toxic and hazardous substances contained in stream bottom sediments. The estimated existing and year 2000 discharges from the existing industrial wastewater outfalls in the Oak Creek watershed are presented in Table 87. Year 2000 flows were estimated to be unchanged from existing flows based upon consideration of existing and projected employment levels for the industry groups represented. Those data indicate no appreciable employment increases in the industrial groups. The table also presents the maximum permitted pollutant concentrations in the wastewater as set forth in the WPDES permits.

Existing and Plan Year 2000 Land Use Conditions: The existing land use conditions and plan year 2000 land use conditions in the Oak Creek watershed, as described in Chapter III and Chapter XI of this report, provided the basis for estimating the extent and probable impacts on surface water quality conditions of land use changes in the watershed and, more importantly, for examining the nonpoint source pollution problem and alternate solutions thereto under the water quality management plan element.

Extent and Severity of Existing and Anticipated Future Water Quality Problems

The development, test, and evaluation of alternative water quality control measures requires an assessment of probable future, as well as existing, water quality problems in the watershed. The identification of the probable future pollution problems and attendant sources was based upon careful consideration of the historic data, projected industrial wastewater discharges, existing and planned land use patterns within the watershed, and the results of water quality simulation modeling studies. The historic water quality data provided information on various types of pollution which could not be assessed by the simulation studies, such as toxic substances and sediments. The presence of these substances may affect the beneficial use of the surface water resources. 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 recommended year 2000 land use plan, together with various alternative pollution control measures. The simulation model results were compared against the water quality standards supporting the intended water 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 principal purpose of developing and calibrating the water resource simulation model under the Oak Creek watershed study was to provide a tool for quantifying watershed hydrologic, hydraulic, and water quality conditions under existing and various possible future development conditions and management measures within the watershed. The water quality simulation work was conducted under the areawide water quality management planning program. That modeling work was reviewed and found to be suitable for use in the Oak Creek watershed planning program, a systems level planning effort. The results of the water quality simulation modeling are discussed below.

In using the water quality simulation model to analyze the impact of the year 2000 land use plan and alternative pollution abatement measures on water quality conditions, the watershed was represented by the existing stream channel system and year 2000 planned land use-floodland development conditions. The watershed land surface was

Table 87

EXISTING AND FORECAST YEAR 2000 INDUSTRIAL WASTEWATER DISCHARGE QUANTITIES IN THE OAK CREEK WATERSHED

Name	Receiving Stream	Civil Division	Number of Outfalls	Existing and Forecast Year 2000 Average Hydraulic Discharge (gallons per day)	Type of Wastewater	Wastewater Characteristics				
						Total Suspended Solids (mg/l)	BOD_5 (mg/l)	Temperature (°F)	pH (standard units)	Oil and Grease (mg/l)
Appleton Electric Company Foundry Division	Oak Creek	City of South Milwaukee	2	164,000	Noncontact cooling water	--	--	90	--	10
Applied Plastics Company, Inc.	North Branch of Oak Creek	City of Oak Creek	1	4,500	Process and contact cooling water	40	20	89	--	15
Bucyrus-Erie Company	Oak Creek	City of South Milwaukee	4	254,800	Noncontact cooling water and process water	40	--	89	6 to 9	--
Industrial Fuel	North Branch of Oak Creek	City of Oak Creek	2	1,000	Boiler blow-down water	40	--	--	--	15
Ladish Company	Oak Creek	City of Cudahy	1	535,000	Noncontact cooling water and stormwater	--	--	89,120	--	10
Peter Cooper Corporation	Oak Creek	City of Oak Creek	1	20	Noncontact cooling water	--	10	--	6 to 9	--
South Milwaukee Water Utility	Oak Creek	City of South Milwaukee	1	125,000	Filter backwash	40	--	--	--	--
Union Oil Ryan Road Truckstop	Oak Creek	City of Oak Creek	1	1,000	Wash water and storm runoff	--	--	--	--	15
U. S. Air Force Reserve 440 TAW	Oak Creek	City of Milwaukee	3	9,000	Wash water and storm runoff	30	--	--	6 to 9	20
Western Machine Company	North Branch of Oak Creek	City of Oak Creek	1	1,500	Cooling water	--	--	--	--	--

Source: Wisconsin Department of Natural Resources and SEWRPC.

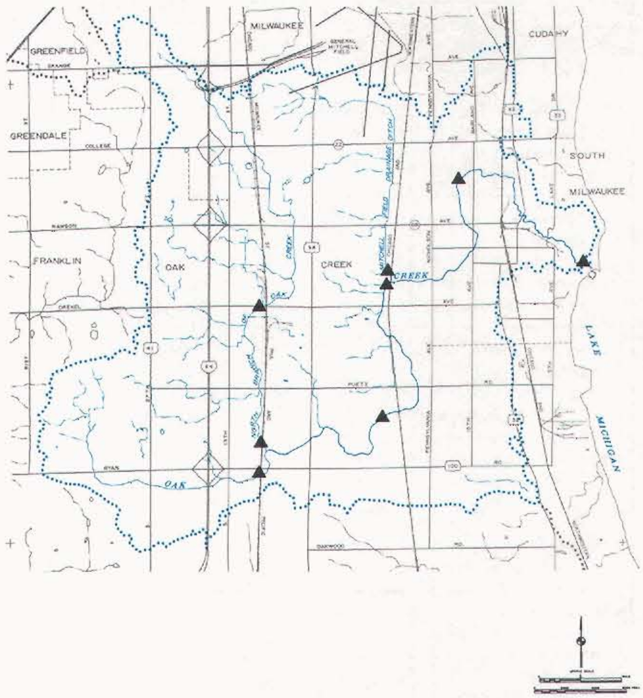
represented by 20 water quality land segments. Each of the 20 land segments was assigned one of 14 hydrologic water quality land segment types developed for the watershed—each type having specified land use, meteorological station, and hydrologic soil group characteristics. Water quality simulation results were obtained for eight locations within the watershed, as shown on Map 66. Input data base development and the calibration of the water quality submodel are described in Chapter VIII of this report. Streamflow was 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. This time period was selected as being representative of, and replicating the hydrologic characteristics of, a 10-year period, beginning in January 1965 and used in previous Commission studies as representative of hydrologic conditions in the Region.

To further define and quantify the water quality problems which exist in the Oak Creek watershed as described in Chapter VII of this report, the instream water quality conditions were simulated using input data representing the existing land use and channel conditions and industrial point source discharges. The simulation modeling results for the existing conditions provided a basis of comparison for the results of the simulation modeling of probable future conditions, and for determining the effects of future land use and channel conditions and alternative pollution abatement measures on water quality conditions.

Continuous water quality simulation produces sufficient water quality data to allow water quality condition-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 conditions, and to provide a comparison to water quality standards for existing conditions, as well as planned or projected future conditions.

Map 66

SIMULATED WATER QUALITY OUTPUT LOCATIONS IN THE OAK CREEK WATERSHED



For purposes of water quality simulation modeling, the watershed land surface was represented by 20 water quality land segments. Each of the 20 land segments was assigned one of 14 hydrologic water quality land segment types developed for the watershed—each type having specified land use, meteorological station, and hydrologic soil group characteristics. The water quality land segment types were the basis for simulating the transport of pollutants from the land surface to the stream system via surface runoff or groundwater flow. Characteristics of each land segment were used to simulate the accumulation and transport of both point and nonpoint source pollutants in the channel system and the resulting instream biological, chemical, and physical processes. The water quality simulation results are presented for eight locations, as shown on this map. Water quality simulation results are not presented for the Oak Creek estuary because accurate simulation of water quality conditions in the estuary requires further study of the complex hydraulic, water quality, and sediment interactions occurring in this environment.

Source: SEWRPC.

Simulation Results Under Existing and Plan Year 2000 Conditions: Review of the simulation model study results, as summarized in Table 88, verifies the conclusion derived from the inventory data that under existing conditions in the Oak Creek watershed, water quality generally does not meet recommended water use objectives and supporting water quality standards for warmwater fishery and aquatic life and recreational use. Existing condition simulation results indicate that fecal coliform and phosphorus levels generally do not meet recommended standards throughout the watershed. The standard for un-ionized ammonia nitrogen is violated in Oak Creek at 15th Avenue. Temperature, dissolved oxygen, and pH standards are met under existing conditions throughout the watershed. As shown on Map 67, the simulation model studies indicate that none of the 25 miles of streams

Table 88

SUMMARY OF SIMULATED WATER QUALITY CONDITIONS IN THE OAK CREEK WATERSHED UNDER EXISTING AND ALTERNATIVE FUTURE CONDITIONS

Water Quality Parameter and Alternative Condition[a,d]	Percent of Time Simulated Value Achieves the Recommended Standard							
	North Branch of Oak Creek Downstream from Drexel Avenue	North Branch of Oak Creek Upstream of Confluence with Oak Creek Main Stem	Oak Creek Upstream of Confluence with North Branch	Oak Creek at Chicago, North Shore & Milwaukee Railroad	Oak Creek at Chicago & North Western Railway	Oak Creek at 15th Avenue	Oak Creek at Confluence with Lake Michigan	Mitchell Field Drainage Ditch Upstream of Confluence with Oak Creek Main Stem
Temperature								
Existing	99	99	99	99	99	99	100	99
Year 2000	99	99	99	99	99	99	100	99
50 Percent Reduction	99	99	99	99	99	99	100	99
75 Percent Reduction	99	99	99	99	99	99	100	99
Dissolved Oxygen								
Existing	98	99	99	99	98	98	99	98
Year 2000	98	99	99	99	98	98	99	98
50 Percent Reduction	98	99	99	99	98	98	99	98
75 Percent Reduction	98	99	99	99	98	98	99	98
Phosphorus								
Existing	71[b]	71[b]	88[b]	76[b]	81[b]	72[b]	76[b]	78[b]
Year 2000	61[b]	67[b]	78[b]	70[b]	60[b]	70[b]	68[b]	72[b]
50 Percent Reduction	75[b]	81[b]	90[b]	82[b]	82[b]	83[b]	83[b]	88[b]
75 Percent Reduction	92	92	98	95	93	94	92	98
Un-ionized Ammonia Nitrogen								
Existing	--	--	--	--	--	--[c]	--	--
Year 2000	--	--	--	--	--	--[c]	--	--
50 Percent Reduction	--	--	--	--	--	--	--	--
75 Percent Reduction	--	--	--	--	--	--	--	--
Fecal Coliform								
Existing	2[b]	14[b]	14[b]	8[b]	16[b]	14	13[b]	38[b]
Year 2000	61[b]	64[b]	65[b]	61[b]	68[b]	61[b]	62[b]	50[b]
50 Percent Reduction	82[b]	82[b]	85[b]	85[b]	85[b]	84[b]	85[b]	82[b]
75 Percent Reduction	89[b]	90	91	91	91	90	88[b]	89[b]

[a] *The existing conditions represent 1975 conditions. The year 2000 condition represents plan year 2000 land use, recommended point source controls, and no nonpoint source pollution control. The 50 percent reduction alternative represents year 2000 planned land use conditions with recommended point source controls plus a 50 percent reduction in nonpoint source pollutant loading. The 75 percent reduction alternative represents year 2000 planned land use conditions with recommended point source controls plus a 75 percent reduction in nonpoint source pollutant loading.*

[b] *Indicates that the applicable standard is not achieved for the recommended percent of time.*

[c] *Indicates that the chronic toxic criteria for un-ionized ammonia nitrogen, which should be met by the average concentration over any 30-consecutive-day period, are violated. The acute toxic criteria for un-ionized ammonia nitrogen, which should never be exceeded, are not violated at any sites.*

[d] *The recommended range in pH values of a minimum of 6.0 standard units and a maximum of 9.0 standard units was not violated under existing or year 2000 conditions.*

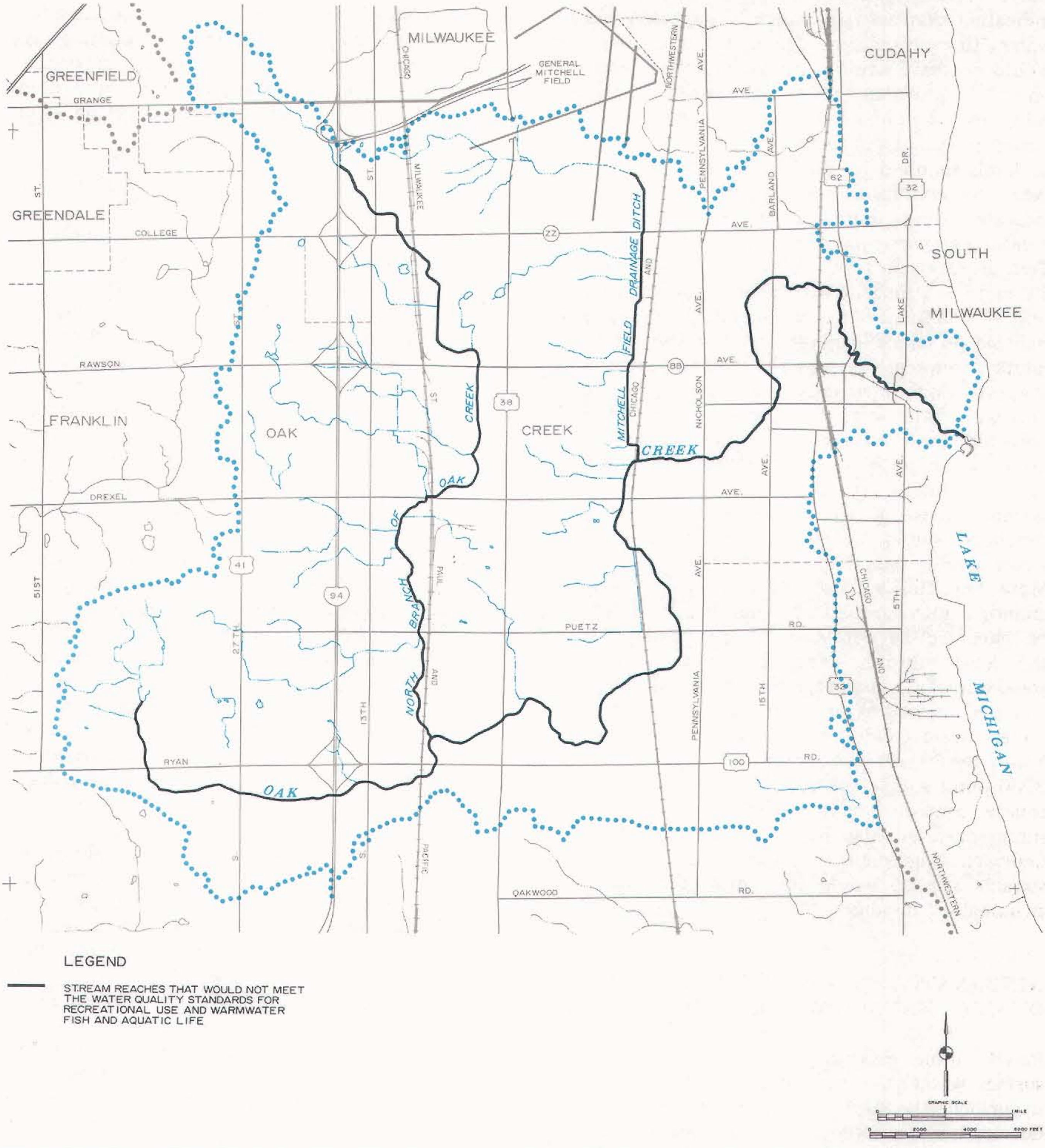
Source: SEWRPC.

studied meet all of the recommended water quality standards for the support of warmwater fish and aquatic life and recreational use.

The water quality conditions in the Oak Creek watershed were simulated under design year 2000 planned conditions including planned land use conditions, and assuming implementation of recommended point source abatement measures. The plan year 2000 conditions assume elimination of all sanitary sewerage system flow relief devices in the watershed, no changes in flow volumes from existing industrial waste discharges, and the provision of sanitary sewer service to all residents of the watershed, thus eliminating all pollution from septic tank systems. The continued discharges from industrial waste outfalls, consisting of process, cooling, and backwash waters with pollutant concentrations that would be limited in accordance with WPDES permit requirements, would not

Map 67

WATER QUALITY SIMULATION RESULTS FOR THE OAK CREEK WATERSHED: EXISTING (1975) LAND USE CONDITIONS AND FORECAST (2000) LAND USE CONDITIONS ASSUMING PLANNED POINT SOURCE POLLUTION ABATEMENT MEASURES



Water quality simulation modeling study data supported by water quality sampling data indicate that under existing conditions, none of the stream reaches within the watershed meet the water use objective and supporting water quality standards for recreational use and the support of warmwater fish and aquatic life. Under plan year 2000 land use conditions and with point source control, but without nonpoint source control, some improvement in water quality conditions, particularly in fecal coliform levels, may be expected. However, increased urbanization, with attendant increases in nonpoint source pollution contributions to the surface water system, may be expected to partially offset the reduced pollutant loadings from the elimination of point sources in the watershed. Consequently, water quality conditions would continue not to satisfy the initially recommended water quality standards.

Source: SEWRPC.

be expected to have an adverse water quality impact. A potential increase in industrial wastewater discharges was also analyzed, with the results indicating that even significantly increased wastewater flow discharges from industrial sources would not have significantly adverse water quality impacts, provided those discharges consisted primarily of noncontact cooling waters and contained pollutant concentrations that were limited to levels required by WPDES permits. Under plan year 2000 conditions, the simulation model studies indicate some improvement in water quality conditions, particularly in fecal coliform levels. The decrease in fecal coliform levels shown in Table 88 is primarily attributable to the elimination of malfunctioning septic tank systems. The reduced pollutant loadings from the elimination of sanitary sewerage system flow relief devices and the provision of sanitary sewer service to those portions of the watershed not presently sewered, however, may be partially offset by increased urbanization, with attendant increases in nonpoint source pollution contributions to the surface water system. Consequently, water quality conditions generally would not satisfy the recommended water quality standards, as shown in Table 88. More specifically, violations of the un-ionized ammonia nitrogen and phosphorus standards may be expected to continue, as may violations of the fecal coliform standard. The recommended standards for temperature, dissolved oxygen, and pH may be expected to continue to be met under future conditions. The water quality simulation results for future land use and plan year 2000 point source controls, but without nonpoint source control beyond existing levels, are also summarized on Map 67, which indicates that, as under existing conditions, none of the 25 miles of streams studied would fully meet the "fishable-swimmable" standards.

ALTERNATIVE NONPOINT SOURCE WATER QUALITY MANAGEMENT PLAN ELEMENTS

Based upon measured historic and simulated surface water quality conditions in the Oak Creek watershed, the problems to be addressed in the development of alternative water quality management measures include excessive fecal coliform counts, excessive nutrient concentrations, and the presence of toxic and hazardous substances. Historic water quality data and simulation results under existing conditions indicate fecal coliform bacteria to be the most prevalent and potentially dangerous form of water pollution in the watershed. These results indicate that the primary sources of fecal coliform bacteria are urban and rural nonpoint sources—in particular, malfunctioning septic tank systems—rather than point source contributions. For toxic and hazardous substances, the limited data indicate that unreported point source discharge of such substances may be occurring within the Oak Creek watershed.

Alternative Reductions in Nonpoint Source Loadings

A wide variety of management measures are available for controlling nonpoint sources of water pollution. The task of formulating a plan element for the abatement of these sources requires a somewhat different approach than would be used to formulate a plan element for point source pollution abatement. Different sets of physical measures for nonpoint source pollution abatement must be set forth for specific geographic subareas of the watershed. However, at the systems level of planning, the examination of alternative water pollution abatement plans must, as a practical matter, be limited to the degree of control necessary to meet the standards for each water quality analysis area. The development of site-specific practices requires detailed consideration of a great many factors, including land use, soils, subsurface characteristics, existing management practices, property ownership, property use and management goals, public works equipment and practices, investment policies, available technical and financial resources, and the extent to which, and methods whereby, public agencies may desire to seek plan implementation.

The development and evaluation of alternative nonpoint source control measures was accordingly accomplished by evaluating various levels of nonpoint source pollutant reductions upstream of each simulation output site under plan year 2000 land use conditions. Because of the site-specific nature of nonpoint sources, specific measures at specific locations cannot be recommended at the systems planning level. Rather, the level of reduction in pollutant loading needed to meet water use objectives and supporting water quality standards was identified. This required level of reduction in pollutant loading was used as the basis for the development of preliminary alternative combinations of nonpoint source control measures. The control measures were selected from the spectrum of possible management measures developed by the Commission under its regional water quality planning program, and evaluated in the Nationwide Urban Runoff Program study for Milwaukee County.[3]

Simulation Model Application Results: Simulation model studies were used to determine the impact on surface water quality conditions of the reductions in nonpoint source land surface loadings. The simulation model inputs representing plan year 2000 land use conditions and channel modifications were altered to represent the reduction in land surface loading rates and in the resultant runoff loadings. This was accomplished by reducing the pollutant loading rates for both impervious and pervious surfaces, as well as the concentrations of pollutants in subsurface flow, by a factor consistent with the reduction desired. The reduced subsurface flow concentrations accordingly reflected the expected reduction in the concentration of 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.

As already noted, the simulation of water quality conditions under existing land use, channel, and pollutant loading conditions indicated that standards for phosphorus and fecal coliform are currently violated throughout the watershed, as indicated in Table 88. In addition, the standard for un-ionized ammonia nitrogen is violated at one site—Oak Creek at 15th Avenue. The simulation of water quality conditions under plan year 2000 land use, existing channel, and point source abatement conditions indicated a continuation of substandard fecal coliform, phosphorus, and ammonia nitrogen levels.

As shown in Table 88, the simulation model studies indicated that a 50 percent reduction in nonpoint source pollutant loadings, applied to both the rural and urban areas of the watershed under plan year 2000 land use, channel, and point source abatement conditions, may be expected to result in significant reductions in fecal coliform bacteria, un-ionized ammonia nitrogen, and phosphorus levels. The simulation studies indicated that although water quality conditions may be expected to improve significantly, the standards for phosphorus and fecal coliform would continue to be violated. Assuming a 75 percent reduction in nonpoint source pollutant loadings, the simulation model studies indicated that the recommended standards for phosphorus and un-ionized ammonia nitrogen may be expected to be met, and that the standard for fecal coliform may be met at five of the eight simulation output sites. The violations of the fecal coliform standard indicated at the remaining three output sites were all minor, and the standard could accordingly be considered to be essentially met under this level of reduction throughout the watershed.

Based upon the results of the simulation modeling, the installation of measures designed to achieve a 75 percent reduction in pollutant loadings from nonpoint sources would be required in order to fully achieve the standards for fecal coliform bacteria and phosphorus. For un-ionized ammonia nitrogen, less than a 50 percent reduction in pollutant loadings from nonpoint sources would be required.

Other Considerations: The application of nonpoint source control measures may be expected to result in the reduction of constituents besides those represented in the water quality simulation model, including certain toxic substances and sediment which accumulate on the land surface and are washed off during rainfall or snowmelt events. Since some toxic substances are attached to fine soil particles, similar to the way in which phosphorus is attached, the reduction in toxic substances from nonpoint sources would likely be similar to the reduction in phosphorus, as shown in Table 88.. Much of the sediment transported in the Oak Creek watershed currently originates from agricultural areas where the soil is periodically exposed as a result of stream bank erosion, and at construction sites where the land surface has been disturbed. Agricultural soil conservation measures on the relatively small area of land expected to remain in agricultural use through the year 2000, stream bank protection measures, and construction erosion control measures can be effective in reducing sediment contributions from these sources. Reductions in excess of 50 percent may be achieved using these measures.

[3]*See SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff, 1977; and Wisconsin Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, Volume Two, Feasibility and Application of Urban Nonpoint Source Water Pollution Abatement Measures, Nationwide Urban Runoff Program, 1983.*

Alternative Nonpoint Source 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 relation to the available control measures. Measures must be selected to assure the necessary level of control at the least cost. Alternative groups of nonpoint source control measures that were evaluated for the Oak Creek watershed are summarized in Table 89. Costs of the nonpoint 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 in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff, 1977; and in Wisconsin Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, Volume Two, Feasibility and Application of Urban Nonpoint Source Water Pollution Abatement Measures, 1983.

The simulation model studies indicated that significant reductions in nonpoint source pollutant loadings will be needed to fully attain the water quality standards for fecal coliform bacteria, phosphorus, and un-ionized ammonia nitrogen. The purpose of this section of the chapter is to identify and briefly describe alternative nonpoint source control measures which may be used to achieve the required reductions in nonpoint sources of pollutants. Nonpoint source control measures are closely related to land use in that there is one set of control measures generally suitable for urban lands and another, quite different, set of nonpoint source control measures generally suitable for agricultural or rural lands. The alternative nonpoint source control plans for urban lands and rural lands set forth below would provide, as may be required, an approximate 25 percent or a 50 percent to 75 percent reduction in loadings of most pollutants.

Control of Urban Nonpoint Sources: Three alternative sets of nonpoint source water pollution control measures were considered for urban lands. The first, or minimum, set of measures consists of the basic land management measures which were recommended in the regional water quality management plan for application in all urban areas of the Region. The second set of measures consists of the minimum set together with certain additional measures, including centralized stormwater storage facilities. The third set of measures consists of the minimum set together with certain additional measures, including decentralized stormwater storage facilities.

The minimum urban nonpoint source control plan identified in Table 89 includes public education programs, litter and pet waste control, construction site erosion control, reduced use of fertilizers and pesticides, industrial and commercial material storage facility control, and minor changes in municipal street sweeping, leaf collection, and catch basin cleaning operations. In general, implementation of these measures may be expected to achieve an approximate 25 percent reduction in loadings of most pollutants from urban sources, although certain practices—such as construction site erosion control—would achieve substantially higher reductions in certain pollutants. In addition, the provision of sanitary sewer service to all developed areas of the watershed would eliminate pollutant loadings from malfunctioning septic tank systems. If only these minimum control measures were implemented in the Oak Creek watershed, the temperature, dissolved oxygen, and un-ionized ammonia nitrogen standards would be fully met in all major stream reaches. The fecal coliform and phosphorus standards, however, would be met only about 70 percent of the time, rather than the recommended 90 percent of the time. Oak Creek and its major tributaries could not, therefore, be considered to be fully suitable for recreational use, although the water quality conditions would support a warmwater fishery.

The additional urban nonpoint source control plans described in Table 89—one with centralized stormwater storage and one with decentralized stormwater storage—include the minimum measures plus stream bank protection; improved street maintenance; increased municipal street sweeping, leaf collection, and catch basin cleaning operations; and stormwater retention and storage and infiltration measures. These additional measures may be expected to achieve an approximate 50 to 75 percent reduction in all pollutant loadings from urban sources. With the implementation of these additional measures, the fecal coliform and phosphorus standards as well as the temperature, dissolved oxygen, and un-ionized ammonia nitrogen standards would be fully met, and the major streams would be fully suitable for recreational use.

Table 89

ALTERNATIVE GROUPS OF NONPOINT SOURCE WATER POLLUTION CONTROL MEASURES FOR THE OAK CREEK WATERSHED

Alternative Nonpoint Source Control Plan	Approximate Level of Pollution Control[a]	Measures to Control Nonpoint Source Pollution from Urban Areas[b]	Measures to Control Nonpoint Source Pollution from Rural Areas[b]
Minimum Nonpoint Source Control Measures	25 Percent	Public education programs; litter and pet waste control; restricted use of fertilizers and pesticides; construction site erosion control; critical area protection; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; industrial and commercial material storage facility control	Public education programs; fertilizer and pesticide management; critical area protection; crop residue management; conservation tillage; pasture management; contour plowing
Additional Nonpoint Source Control Measures with Centralized Stormwater Storage	50 to 75 Percent	Above minimum measures plus: increased street sweeping,[c] leaf collection, and catch basin cleaning; improved street maintenance and refuse collection and disposal; stream bank protection; centralized stormwater storage basins	Above minimum measures plus: crop rotation; contour stripcropping; grassed waterways; diversions; terraces; vegetative buffer strips; stream bank protection; stormwater storage
Additional Nonpoint Source Control Measures with Decentralized Stormwater Storage	50 to 75 Percent	Above minimum measures plus: increased street sweeping,[c] leaf collection, and catch basin cleaning; improved street maintenance and refuse collection and disposal; stream bank protection; onsite stormwater storage measures; parking lot stormwater storage measures; decentralized stormwater storage basins; stormwater infiltration facilities	Above minimum measures plus: crop rotation; contour stripcropping; grassed waterways; diversions; terraces; vegetative buffer strips; stream bank protection; stormwater storage

[a] *The required level of nonpoint source reduction is identified from the water quality analyses. The percent reduction refers to the portion of pollutant runoff from urban or rural land which can be controlled by the implementation of those practices. The level of control achieved varies substantially for different pollutants.*

[b] *Categories of measures are presented here for general analysis purposes only. Not all measures are applicable to, or recommended for, all parts of the Oak Creek watershed.*

[c] *Sweep all streets in urban areas more often in spring and in fall, require parking restrictions to permit access to curb areas, and sweep commercial and industrial areas more often than residential areas.*

Source: SEWRPC.

In order to achieve the required level of urban nonpoint source pollutant loading reductions, stormwater storage measures would need to be installed in the watershed. Stormwater storage measures have been shown to remove more than 75 percent of some pollutants. Urban nonpoint source control measures which do not include the storage of stormwater remove substantially less than 50 percent of uncontrolled pollutant loadings.

Thus, in order to achieve an overall 50 to 75 percent reduction in urban nonpoint source pollutant loadings, stormwater storage measures would need to be implemented in some portions of the watershed. Two alternative urban stormwater storage alternative plans were considered for the Oak Creek watershed: a centralized storage alternative plan and a decentralized storage alternative plan.

The centralized stormwater storage alternative plan, as shown on Map 68, would include the installation of three retention basins, ranging in surface area from six to eight acres and in total volume from 30 to 40 acre-feet. The basins, as designed for water quality improvement purposes, would have a fixed surface water elevation and volume. The basins thus would not store additional runoff during storm events. The basins could, however, be designed to store additional runoff and thereby act as flood control measures, this issue being addressed in Chapter XII.

Basin A would be located on the North Branch of Oak Creek in U. S. Public Land Survey Section 8, Township 5 North, Range 22 East, as shown on Map 69. This basin would have a surface area of approximately eight acres, and a total volume of about 40 acre-feet. The basin would have a tributary drainage area of about 2,700 acres which would be devoted primarily to industrial and residential land uses under plan year 2000 land use conditions.

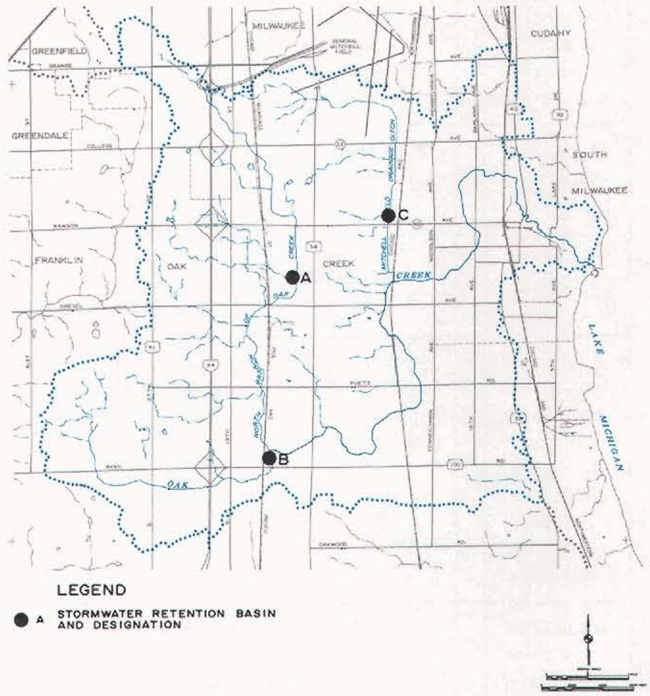
Basin B would be located on the main stem of Oak Creek in U. S. Public Land Survey Section 20, Township 5 North, Range 22 East, as shown on Map 70. The basin would have a surface area of about seven acres and a total volume of about 35 acre-feet. The basin would have a tributary drainage area of about 2,434 acres which would be devoted primarily to residential, commercial, and industrial use under plan year 2000 land use conditions.

Basin C would be located on the Mitchell Field Drainage Ditch in U. S. Public Land Survey Section 4, Township 5 North, Range 22 East, as shown on Map 71. The basin would have a surface area of about six acres and a total volume of about 30 acre-feet. The basin would have a tributary drainage area of about 1,988 acres which would be devoted primarily to transportation and industrial land uses under plan year 2000 land use conditions.

Together, these basins would treat runoff from a combined total drainage area of about 7,122 acres, or about 40 percent of the total area of the watershed. All of the basins would retain a permanent pool of water with a mean depth of about five feet. The basins would receive drainage from areas of the watershed having some of the highest nonpoint source pollutant loadings. If the retention basins were constructed prior to the planned urban development, they would also help to control sediment loadings from construction site erosion. Under the centralized basin plan, those stream reaches located above the proposed basins would not be expected to fully meet the recommended standards for phosphorus and fecal coliform. These stream reaches, as shown on Map 72, have a total length of about 7.6 miles, or about 36 percent of the total perennial stream length in the watershed. Use impairment would be slight, however, with both the phosphorus and fecal coliform standards being met from 70 to 80 percent of the time in these stream reaches, rather than the recommended 90 percent of the time. The temperature, dissolved oxygen, and un-ionized ammonia nitrogen standards would, moreover, be fully met so that fish and other aquatic life in these stream reaches would not be adversely affected.

Map 68

LOCATION OF STORMWATER RETENTION BASINS UNDER THE CENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN

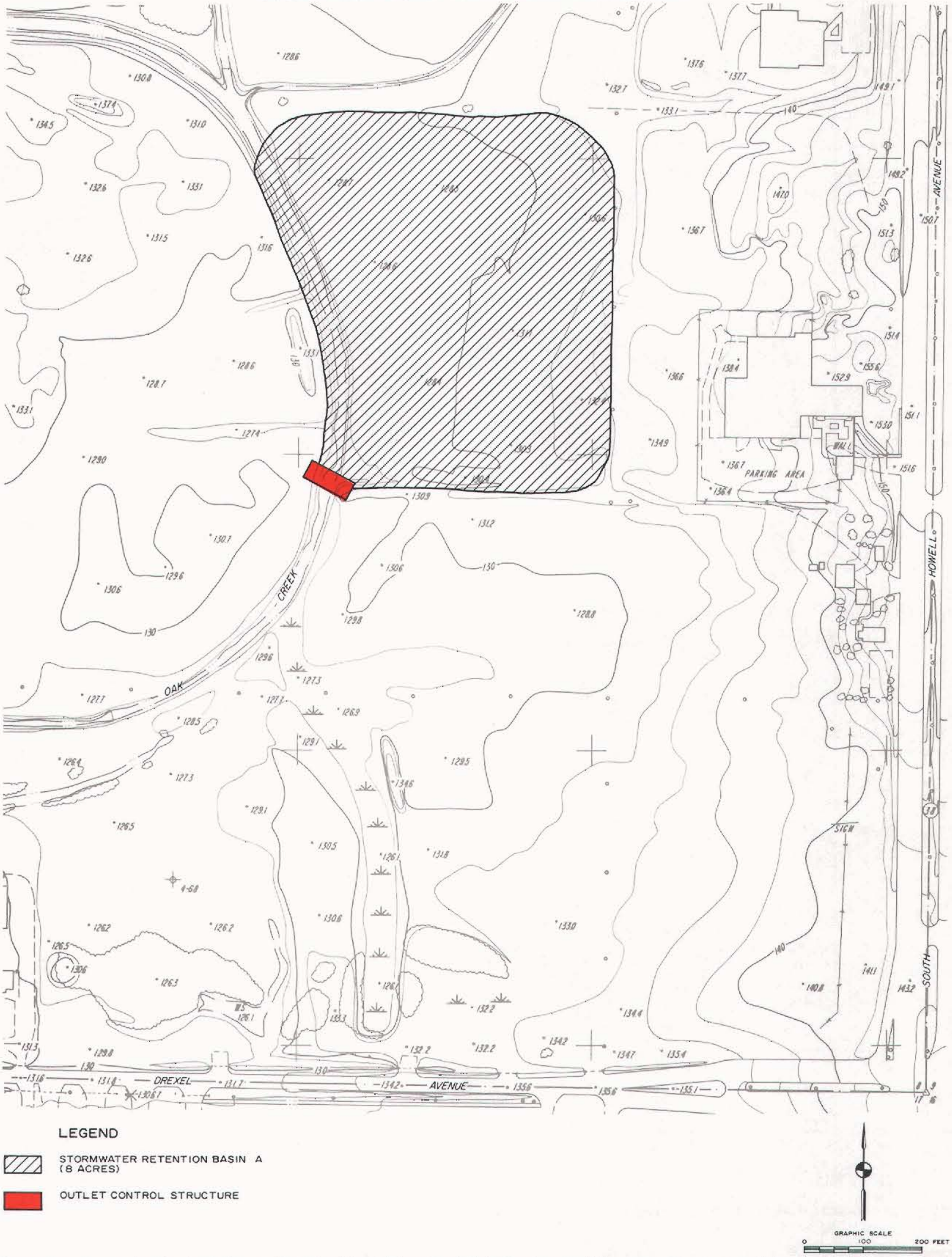


Under the centralized stormwater storage alternative plan, three stormwater retention basins, ranging in surface area from six to eight acres each, would be constructed. The basins would have a combined volume of about 105 acre-feet and a total tributary drainage area of about 7,122 acres, or about 40 percent of the total area of the watershed. The basins would be designed for water quality improvement purposes rather than for flood control.

Source: SEWRPC.

Map 69

STORMWATER RETENTION BASIN A UNDER THE CENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN

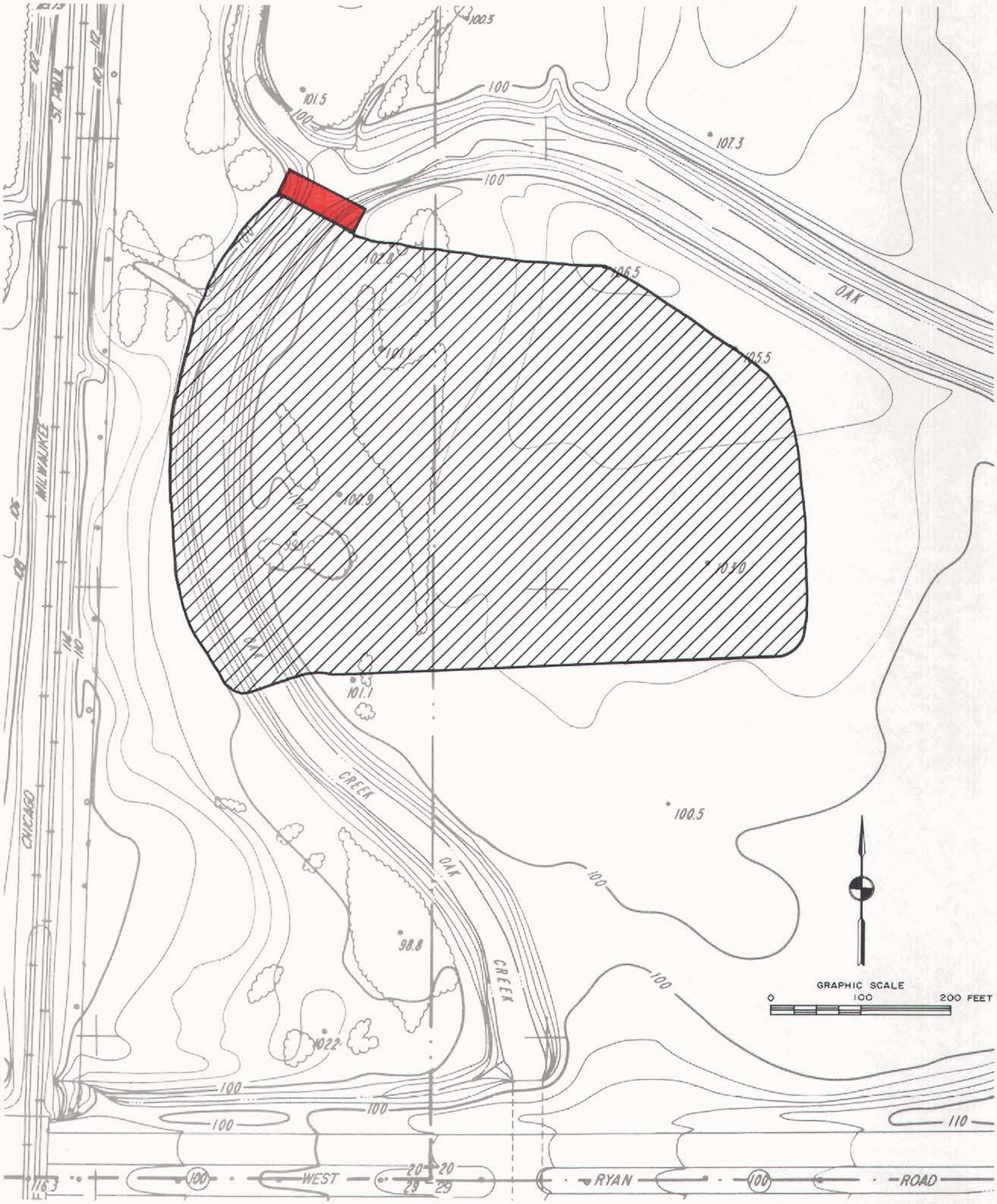


Stormwater retention basin A, located on the North Branch of Oak Creek, would have a surface area of about eight acres, a total volume of about 40 acre-feet, and a tributary drainage area of about 2,700 acres. The basin would remove pollutant loadings from the headwater drainage area of the North Branch of Oak Creek, which would primarily consist of industrial and residential land uses under year 2000 land use conditions.

Source: SEWRPC.

Map 70

STORMWATER RETENTION BASIN B UNDER THE CENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN



LEGEND

STORMWATER RETENTION BASIN B (7 ACRES)

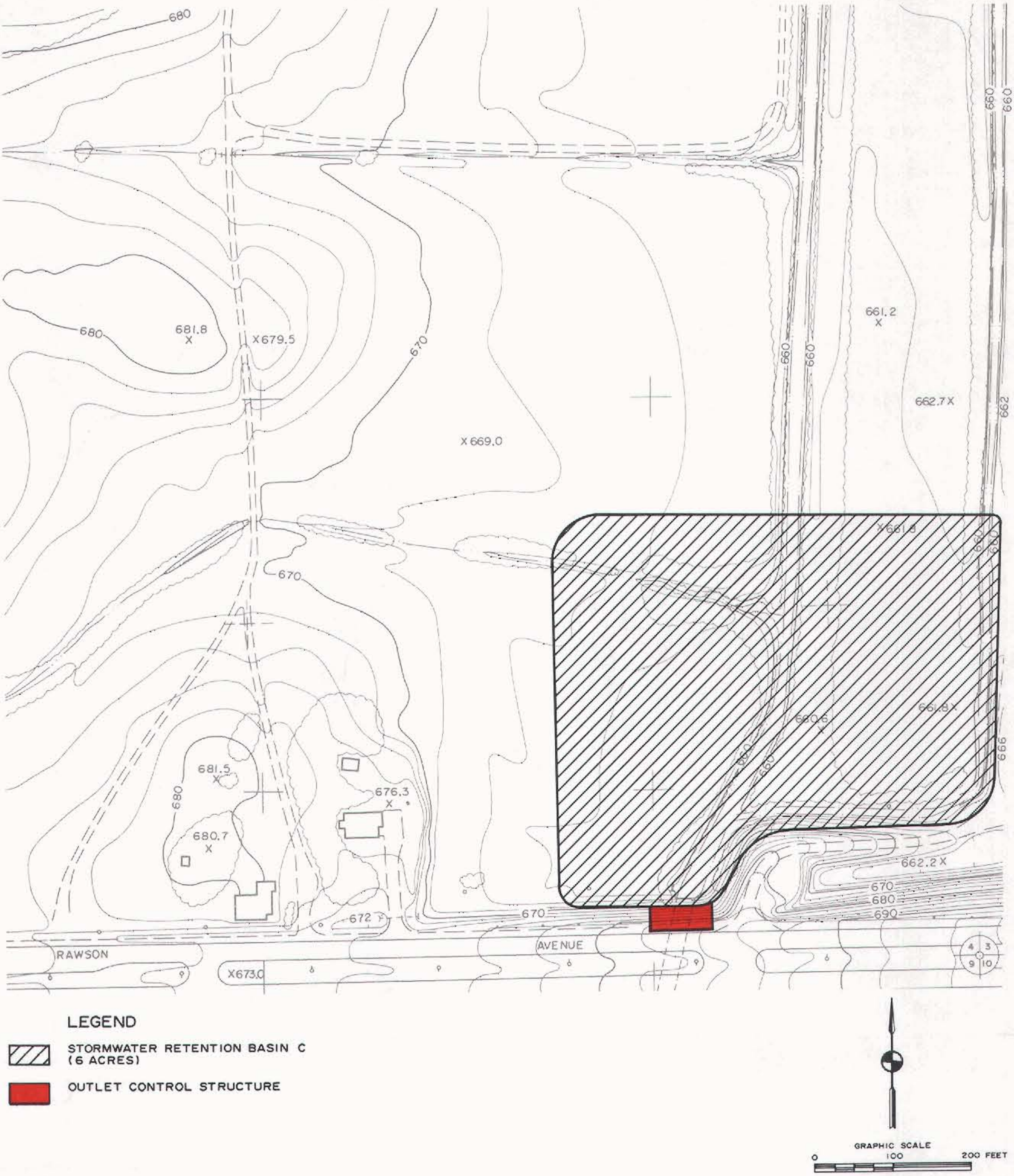
OUTLET CONTROL STRUCTURE

Stormwater retention basin B, located on the main stem of Oak Creek just upstream of the North Branch, would have a surface area of about seven acres, a total volume of about 35 acre-feet, and a tributary drainage area of about 2,434 acres. The basin would remove pollutant loadings from a drainage area expected to include a mix of residential, commercial, and industrial land use under plan year 2000 land use conditions.

Source: SEWRPC.

Map 71

STORMWATER RETENTION BASIN C UNDER THE CENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN

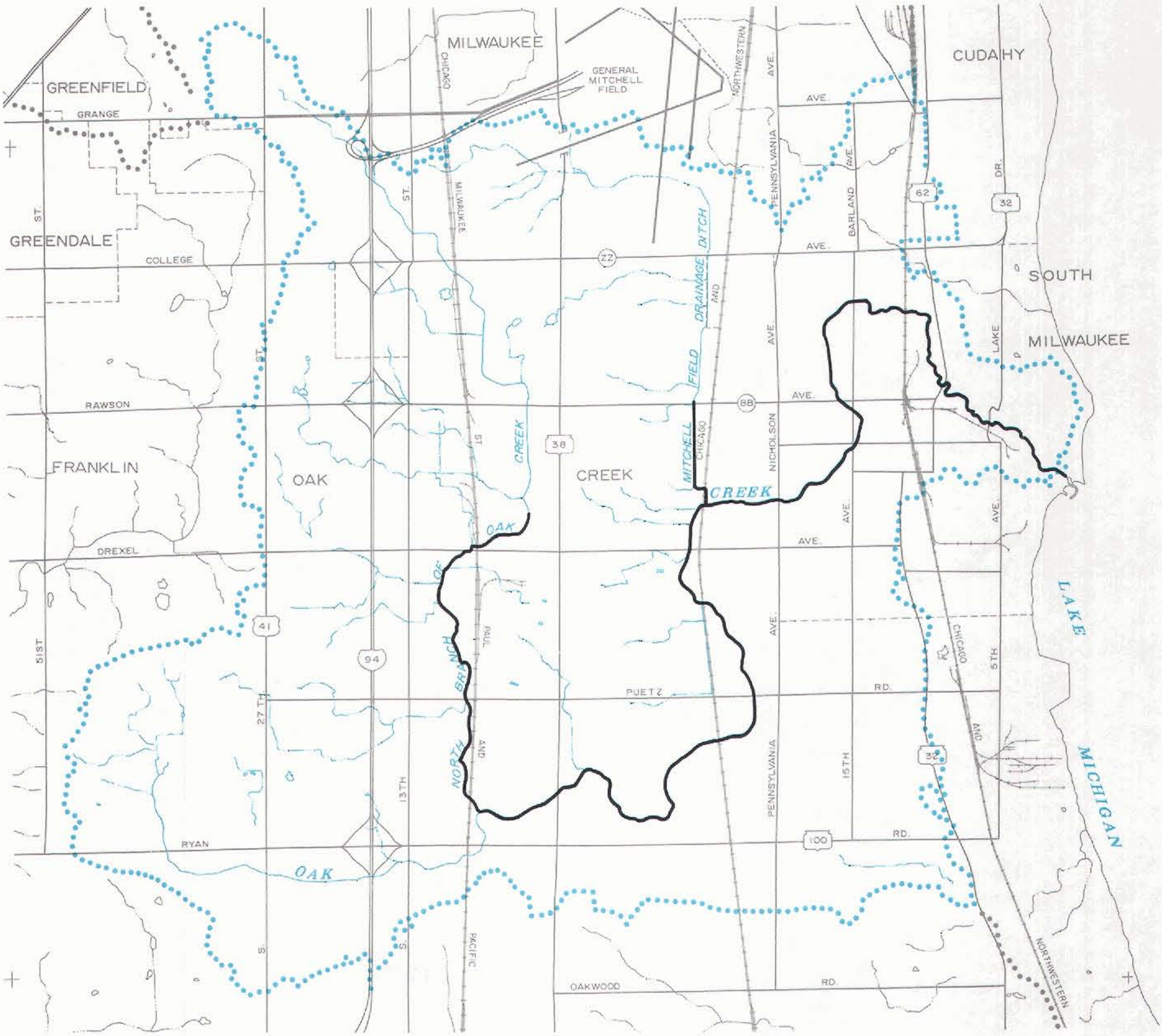


Stormwater retention basin C, located on the Mitchell Field Drainage Ditch upstream of Rawson Avenue, would have a surface area of about six acres, a total volume of about 30 acre-feet, and a tributary drainage area of about 1,988 acres. The basin would remove pollutant loadings from a drainage area which, under plan year 2000 land use conditions, is expected to include a portion of General Mitchell Field, and other transportation and industrial uses.

Source: SEWRPC.

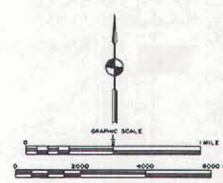
Map 72

ACHIEVEMENT OF STANDARDS FOR RECREATIONAL USE AND MAINTENANCE OF WARMWATER FISH UNDER THE CENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN



LEGEND

—— PERENNIAL STREAM REACHES WHICH WOULD BE EXPECTED TO MEET THE STANDARDS SUPPORTING RECREATIONAL USE AND THE MAINTENANCE OF WARMWATER FISH AND AQUATIC LIFE



Under the centralized stormwater storage alternative plan, about 13.7 stream miles, or about 64 percent of the perennial stream miles in the watershed, would be expected to meet all of the water quality standards supporting recreational use and the maintenance of warmwater fish and aquatic life. The remaining 7.6 miles of stream, or about 36 percent, located upstream of the three proposed stormwater retention basins, would be expected to continue to violate the standards for phosphorus and fecal coliform organisms.

Source: SEWRPC.

Under the decentralized stormwater storage alternative plan, smaller retention basins—ranging in size from one to two acres in surface area—would be constructed within the watershed. The retention basins would have individual total volumes ranging from 5 to 10 acre-feet. In addition to retention basins constructed specifically for this purpose, parking lots and other open onsite areas could be utilized for the storage or infiltration of stormwater. In order to treat stormwater runoff as under the centralized stormwater storage alternative, approximately 25 storage facilities would need to be constructed to serve nearly 50 percent of the total watershed. The specific location and design of these decentralized facilities would have to be based not only upon a site-specific analysis of the hydrology and pollution source characteristics of the subwatershed areas concerned, but upon specific urban development plans, including detailed land subdivision and development layouts.

The decentralized storage facilities would be located to receive drainage from areas with relatively high pollutant loadings, and the basins could also serve to reduce sediment loadings contributed by construction site erosion during urban development. The facilities could be located so that major perennial stream reaches would benefit from the high levels of pollutant removal. Accordingly, under the decentralized stormwater storage alternative plan, all 21.3 miles of perennial streams in the watershed could be expected to meet the recommended standards supporting recreational use and the maintenance of warmwater fish and aquatic life, as shown on Map 73.

Control of Rural Nonpoint Sources: In the recommended year 2000 land use plan for the Oak Creek watershed, as set forth in Chapter XI, only 421 acres are anticipated to remain in agricultural use in the year 2000. It is expected that those agricultural soil conservation measures which would entail a significant capital investment would be applied only to these 421 acres. No livestock operations are expected to be located within the watershed in the year 2000, so livestock waste controls are not proposed. Stream bank protection measures are proposed for both open land and agricultural land areas.

Two alternative sets of nonpoint source control measures were considered for rural lands. The first set of measures is referred to as minimum measures and includes basic agricultural soil conservation measures with a relatively low capital cost, which were recommended in the regional water quality management plan for all rural areas. The second set of measures is referred to as additional measures and would be required to achieve higher levels of reduction in rural nonpoint source pollutant loadings.

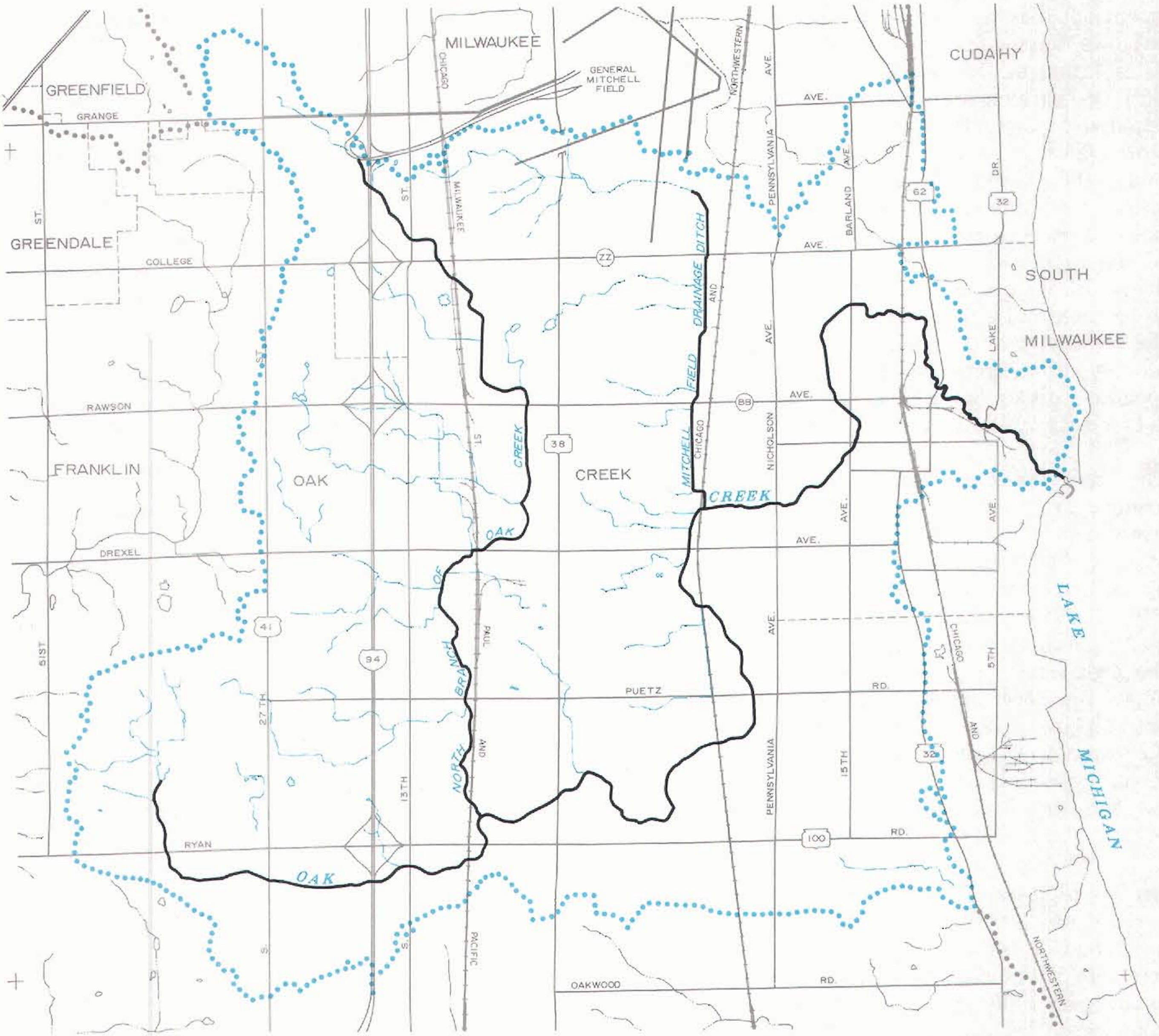
The minimum rural nonpoint source control measures identified in Table 89 include public education programs, fertilizer and pesticide management, critical area protection, crop residue managment, conservation tillage, pasture management, and contour plowing. These measures may be expected to result in an approximate 25 percent reduction in pollutant loadings from rural sources. If only these minimum practices were implemented in the Oak Creek watershed, rural nonpoint sources could contribute to continued violations of the phosphorus and fecal coliform standards, thereby precluding some recreational use.

The additional rural nonpoint source control measures identified in Table 89 include all of the above minimum measures plus crop rotation, contour strip-cropping, grassed waterways, diversions, terraces, vegetative buffer strips, stream bank protection, and stormwater storage. These additional measures may be expected to achieve an approximate 50 to 75 percent reduction in pollutant loadings from rural sources. With the implementation of these additional measures, rural nonpoint sources should be controlled sufficiently to help achieve the phosphorus and fecal coliform standards, thereby providing surface water quality conditions suitable for full recreational use.

Other Pollution Control Measures: Although reductions in nonpoint source loadings through the measures described above may provide the necessary surface water quality improvement for most pollutants, some additional control measures will be necessary in order to achieve the water use objectives for the Oak Creek watershed. These measures include additional source controls to eliminate toxic and hazardous substances from surface waters in the Oak Creek watershed in order to protect the development of a desired fishery. The implementation of the nonpoint source pollution control measures discussed above will provide some reduction of the pesticides and sediment-associated urban toxic substances broadly distributed over the land surface. Accidental spills with attendant intermittent discharges through surface runoff, as well as floor drains connected to

Map 73

ACHIEVEMENT OF STANDARDS FOR RECREATIONAL USE AND MAINTENANCE OF WARMWATER FISH AND AQUATIC LIFE UNDER THE DECENTRALIZED STORMWATER STORAGE ALTERNATIVE PLAN



LEGEND

PERENNIAL STREAM REACHES WHICH WOULD BE EXPECTED TO MEET THE STANDARDS SUPPORTING RECREATIONAL USE AND THE MAINTENANCE OF WARMWATER FISH AND AQUATIC LIFE

GRAPHIC SCALE
0 1 MILE
0 2000 4000 6000 FEET

Under the decentralized stormwater storage alternative plan, all of the 21.3 miles of perennial stream in the watershed would be expected to meet the water quality standards supporting recreational use and the maintenance of warmwater fish and aquatic life. This alternative plan would require the installation of approximately 25 one- to two-acre stormwater retention facilities within the watershed, which would treat stormwater runoff from nearly 50 percent of the total watershed.

Source: SEWRPC.

surface water and surface drainage systems, are other sources of toxic and hazardous substances which should be controlled. Spill prevention and control plans should be developed for all situations under which such spills could occur. Floor drains and drainage pumps in industrial facilities which collect grease, oil, chemicals, and other toxic and hazardous substances should be altered as necessary to eliminate discharge to storm sewers and surface watercourses. Possible alternatives include discharge to sanitary sewer systems for treatment at, and disposal through, public sewage treatment plants, pretreatment prior to discharge, or elimination of the discharge entirely through process modifications.

Costs: Capital costs and average annual operation and maintenance costs for the alternative nonpoint source control measures—minimum and additional are set forth in Table 90 for the 15-year planning period. Costs for additional measures are presented for both the centralized and decentralized stormwater storage alternative plans.

Implementation of the minimum nonpoint source control measures would have a total capital cost of about $5.1 million, almost all of which would be for urban measures, only $5,000 being for rural measures. Of the total urban capital cost, about $4.6 million, or about 92 percent, would be for construction site erosion control. This cost would be borne primarily by land developers and, ultimately, by new landowners. The minimum nonpoint source control measures would require an average annual operation and maintenance cost of about $125,000, of which $110,000, or 88 percent, would be for urban measures; the remaining $15,000, or 12 percent, would be for rural measures. Of the total urban average annual operation and maintenance cost, almost $70,000, or about 64 percent, would be for construction site erosion control.

Implementation of the additional nonpoint source control measures with centralized stormwater storage—which includes the minimum measures—would have a total capital cost of about $5.77 million, of which $5.84 million, or 99 percent, would be for urban measures and the remaining $65,000, or about 1 percent, would be for rural measures. About 80 percent of the total urban capital cost would be for construction site erosion control. The additional nonpoint source control measures with centralized stormwater storage would require an average annual operation and maintenance cost of about $220,000, of which about $195,000, or about 89 percent, would be for urban measures, and the remaining $25,000, or about 11 percent, would be for rural measures. About 36 percent of the urban annual operation and maintenance cost would be for construction site erosion control.

Implementation of the additional nonpoint source control measures with decentralized stormwater storage—including the minimum measures—would have a total capital cost of about $7.0 million, of which about $6.9 million, or about 99 percent, would be for urban measures and the remaining $65,000, or about 1 percent, would be for rural measures. About 67 percent of the total urban capital cost would be for construction site erosion control. The additional nonpoint source control measures with decentralized stormwater storage would require an average annual operation and maintenance cost of about $285,000, of which about $260,000, or about 91 percent, would be for urban measures, and the remaining $25,000, or about 9 percent, would be for rural measures. About 27 percent of the urban annual operation and maintenance cost would be for construction site erosion control.

In order to assist public officials, as well as concerned citizens, in evaluating the financial feasibility of the alternative nonpoint source control measures, the estimated costs were divided into public sector and private sector costs. Public sector and private sector costs are set forth in Table 91 for each of the alternative groups of nonpoint source control measures considered. Of the estimated total capital cost of $5.14 million for minimum nonpoint source control measures, about $1.16 million, or about 23 percent, would be required for projects in the public sector; the remaining $3.98 million, or about 77 percent, would be required for projects in the private sector. Of the estimated annual operation and maintenance cost of $125,000 for minimum nonpoint source control measures, about $48,000, or about 38 percent, would be required for public sector projects; the remaining $77,000, or about 62 percent, would be required for private sector projects.

For additional nonpoint source control measures with centralized stormwater storage, about $1.56 million, or about 27 percent of the capital cost of about $5.84 million, would be required for public sector projects, and about $4.28 million, or about

Table 90

ESTIMATED COST OF ALTERNATIVE NONPOINT SOURCE CONTROL MEASURES FOR THE OAK CREEK WATERSHED

Nonpoint Source Pollution Control Measures	Estimated Cost[a]	
	Total Capital (1986-2000)	Average Annual Operation and Maintenance
Urban		
Minimum Measures		
Construction Site Erosion Control.	$4,640,000	$ 70,000
Industrial and Commercial Material Storage Facility Control	500,000	10,000
Other Minimum Measures[b]	Minimal	30,000
Subtotal	$5,140,000	$110,000
Additional Measures		
Increased Street Sweeping, Leaf Collection, and Catch Basin Cleaning.	Minimal[c]	$ 40,000
Improved Street Maintenance and Refuse Collection.	Minimal	20,000
Stream Bank Protection	$ 100,000	5,000
Centralized Stormwater Storage[d]	530,000	20,000
Decentralized Stormwater Storage[e]	1,700,000	85,000
Subtotal with Centralized Storage (includes minimum)	$5,770,000	$195,000
Subtotal with Decentralized Storage (includes minimum)	$6,940,000	$260,000
Rural		
Minimum Measures		
Minimum Soil Conservation Measures[f]	$ 5,000	$ 15,000
Subtotal	$ 5,000	$ 15,000
Additional Measures		
Stream Bank Protection	$ 50,000	$ 5,000
Additional Soil Conservation Measures[g]	10,000	5,000
Subtotal (includes minimum)	$ 65,000	$ 25,000
Total Minimum Measures	$5,145,000	$125,000
Total Additional Measures with Centralized Stormwater Storage (includes minimum)	$5,835,000	$220,000
Total Additional Measures with Decentralized Stormwater Storage (includes minimum)	$7,005,000	$285,000

[a] *Capital costs expressed in January 1984 dollars: "Engineering News Record" Construction Cost Index of 4109. Operation and maintenance costs expressed in January 1984 dollars: U. S. Department of Labor Consumer Price Index for Wage Earners and Clerical Workers of 327.3.*

[b] *Other minimum urban control measures include public education programs; pet waste and litter control; fertilizer and pesticide use restrictions; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; and critical area protection.*

Table 90 Footnotes (continued)

[c] *Increased street sweeping, leaf collection, and catch basin cleaning would utilize the equipment needed to provide the existing normal level of service. The costs assume that no equipment purchases would be required to provide the increased level of service required for pollution control.*

[d] *Includes the use of three, six- to eight-acre stormwater retention basins.*

[e] *Includes the use of one- to two-acre stormwater storage basins, onsite storage measures, parking lot storage measures, and infiltration facilities.*

[f] *Minimum soil conservation practices include crop residue management, conservation tillage, pasture management, contour plowing, fertilizer and pesticide management, and critical area protection.*

[g] *Additional soil conservation practices include crop rotation, contour strip-cropping, grassed waterways, diversions, terraces, and vegetative buffer strips.*

Source: SEWRPC.

Table 91

PUBLIC SECTOR AND PRIVATE SECTOR ALTERNATIVE NONPOINT SOURCE CONTROL COSTS FOR THE OAK CREEK WATERSHED

Nonpoint Source Pollution Control Measures	Public Sector				Private Sector				Total	
	Total Capital (1986-2000)	Percent of Total	Annual Operation and Maintenance	Percent of Total	Total Capital (1986-2000)	Percent of Total	Annual Operation and Maintenance	Percent of Total	Total Capital (1986-2000)	Annual Operation and Maintenance
Urban Minimum Measures	$1,160,000	23	$ 48,000	44	$3,980,000	77	$ 62,000	56	$5,140,000	$110,000
Additional Measures with Centralized Stormwater Storage (includes minimum)	1,500,000	26	122,000	63	4,270,000	74	73,000	37	5,770,000	195,000
Additional Measures with Decentralized Stormwater Storage (includes minimum)	2,060,000	30	157,000	60	4,880,000	70	103,000	40	6,940,000	260,000
Rural Minimum Measures	$ 2,500	50	$ --	0	$ 2,500	50	$ 15,000	100	$ 5,000	$ 15,000
Additional Measures (includes minimum)	58,000	86	5,000	20	7,000	14	20,000	80	65,000	25,000
Total Minimum Measures	$1,162,500	23	$ 48,000	38	$3,982,500	77	$ 77,000	62	$5,145,000	$125,000
Total Additional Measures with Centralized Stormwater Storage	$1,558,000	27	$127,000	58	$4,277,000	73	$ 93,000	42	$5,835,000	$220,000
Total Additional Measures with Decentralized Stormwater Storage	$2,118,000	30	$162,000	57	$4,887,000	70	$123,000	43	$7,005,000	$285,000

Source: SEWRPC.

73 percent, would be required for private sector projects. The relatively high private sector capital costs would be incurred to control construction site erosion on private development land. About $127,000, or about 58 percent, of the total annual operation and maintenance cost of $220,000 for additional nonpoint source control measures with centralized stormwater storage would be required for projects in the public sector; the remaining $93,000, or 42 percent of the cost, would be required for projects in the private sector.

For additional nonpoint source control measures with decentralized stormwater storage, about $2.1 million, or about 30 percent of the capital cost of approximately $7.0 million, would be required for public sector projects, and about $4.9 million, or about 70 percent, would be required for private sector projects. Of the annual operation and maintenance cost of approximately $285,000 for additional measures with decentralized stormwater storage, about $162,000, or about 57 percent, would be for projects in the public sector, while the remaining $123,000, or about 43 percent, would be for projects in the private sector.

The estimated capital costs and operation and maintenance costs for the abatement of nonpoint sources, as well as for the abatement of point sources, are not included in the comprehensive watershed plan costs because the water quality management plan elements are set forth in the regional water quality management plan. The estimated pollution control measures needed and the associated costs have, however, been revised and updated for this comprehensive watershed plan.

WATER QUALITY MONITORING PROGRAM

As discussed in Chapter VII of this report, a variety of surface water quality monitoring programs have been carried out within the Oak Creek watershed. These monitoring programs include, but are not limited to, periodic basin surveys by the Wisconsin Department of Natural Resources, beginning in 1954; a Commission water quality study conducted from 1964 to 1965; a Commission continuous water quality monitoring program conducted from 1968 to 1976; and a survey of toxic and hazardous substances conducted by the Wisconsin Department of Natural Resources in 1975 and 1976.

A well-planned and executed water quality monitoring program can serve two important functions for the water quality management plan element of a comprehensive plan for the Oak Creek watershed. First, water quality monitoring can perform a surveillance function in that periodic sampling and analysis of the stream system can detect undesirable levels of pollutants 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 improvements in the water quality of the Oak Creek watershed as recommended plan elements are implemented. As part of the Commission's continuing regional water quality management planning program, a technical report for water quality monitoring in the Region is to be prepared, relying upon the guidance of a special advisory body having technical water quality monitoring expertise, and including members from potential financial support agencies.

RECOMMENDED NONPOINT SOURCE WATER QUALITY MANAGEMENT PLAN

Three alternative sets of nonpoint source water pollution control measures were considered for the Oak Creek watershed: minimum measures; minimum measures and certain additional measures including centralized stormwater storage; and minimum measures and certain additional measures including decentralized stormwater storage. The evaluation of the three sets of measures was based on costs, on the likelihood of successful installation and continued maintenance of the control measures, and on the level of pollutant loading reduction which could be expected to be achieved and the attendant degree to which the recommended water use objectives and supporting water quality standards could be expected to be met.

In order to provide water quality conditions which would be suitable for full recreational use, including swimming and wading, boating, and sight-seeing, in about 70 percent of the perennial stream miles within the Oak Creek watershed, the minimum and certain additional urban and rural nonpoint source control measures, including centralized stormwater storage, are recommended. These measures may be expected to reduce uncontrolled nonpoint source pollutant loadings by up to 75 percent in portions of the watershed. This pollutant loading reduction is expected to achieve the phosphorus and fecal coliform standards for the stream reaches shown on Map 72, thereby preventing the occurrence of nuisance growths of aquatic rooted plants and algae which could make these stream reaches unsuitable and undesirable for recreational use. Such recreational activities are an important and valuable use of the watercourses, especially within the extensive primary environmental corridor which borders Oak Creek, as shown on the land use plan set forth in Chapter XI. Implementation of the recommended nonpoint source water pollution control measures, however, is not expected to fully meet the recreational water use objectives for about 7.6 miles of stream, or about 36 percent of the total perennial stream miles in the watershed, also as shown on Map 72. Recreational use impairment in these stream reaches would be slight, however, with both the phosphorus and fecal coliform standards being met from 70 to 80 percent of the time in these stream reaches, rather than the recommended 90 percent of the time. Moreover, the temperature, dissolved oxygen and un-ionized ammonia nitrogen standards would be fully met so that fish and other aquatic life in these reaches would not be adversely affected.

The implementation of the recommended additional nonpoint source control measures with centralized stormwater storage would require a total capital cost of about $5.84 million. The recommended control measures would entail an average annual operation and maintenance cost of about $220,000.

The decentralized stormwater storage alternative plan would allow the recreational use objectives to be more fully met. This alternative plan would, however, entail an additional capital cost of about $1,170,000 and an annual operation and maintenance cost of about $65,000 above the recommended plan costs. Furthermore, because of the detailed second level, site-specific planning required for the decentralized alternative, it is unlikely that the necessary number of small storage measures—many of which would have to be installed by the private sector—would be successfully and properly constructed and maintained. A well-developed and -financed maintenance program is essential to ensure the continued pollutant removal effectiveness of stormwater storage measures.

Under the minimum nonpoint source control alternative plan, none of the perennial stream miles in the watershed would fully meet the recreational water use objectives. The phosphorus and fecal coliform standards could be expected to be met about 70 percent of the time, rather than the recommended 90 percent of the time. The minimum nonpoint source control alternative plan would have a capital cost of $690,000 and an annual operation and maintenance cost of $95,000 less than the recommended plan costs.

SUMMARY

A careful examination of the available water quality data for the Oak Creek watershed stream system for the period from 1964 through 1976 indicates that polluted conditions exist in virtually all of the watershed. Toxic, organic, nutrient, pathogenic, sediment, and aesthetic pollution are all known to exist in the surface waters of the Oak Creek watershed. These problems have been attributed to pollutant loadings from both point sources and nonpoint sources. Point sources of pollution are relatively insignificant in the watershed: In 1980, the three municipal sanitary sewerage flow relief devices and 18 industrial wastewater discharge outfalls in the watershed were estimated to contribute less than 1 percent of the nitrogen, phosphorus, biochemical oxygen demand, fecal coliform, and suspended solids loadings to surface waters in the watershed. Nonpoint sources were estimated to be the primary causes of water quality problems in the watershed, contributing over 99 percent of the total pollutant loadings.

Water quality simulation modeling analyses were conducted under both existing and future alternative land use, stream channel, and pollution abatement conditions. The modeling analyses indicated that Oak Creek currently violates recommended water quality standards for phosphorus, un-ionized ammonia nitrogen, and fecal coliform. The modeling results also indicated that under future land use and stream channel conditions, reductions in nonpoint source pollutant loadings would be required to achieve the recommended water quality standards.

Three alternative sets of nonpoint source control measures were developed and evaluated. The first set, minimum measures, would achieve an approximate 25 percent reduction in pollutant loadings. These measures would require a total capital cost of about $5.1 million and an average annual operation and maintenance cost of about $125,000. Almost all of the capital cost, and 88 percent of the annual operation and maintenance cost, would be for urban measures, with the remainder being required for rural measures. Approximately 92 percent of the urban capital cost and 64 percent of the urban operation and maintenance cost would be for construction site erosion control. These costs would primarily be borne by land developers. With the implementation of only the minimum nonpoint source control measures, the recommended phosphorus and fecal coliform standards would be achieved about 70 percent of the time, and none of the perennial streams in the Oak Creek watershed would be fully suitable for recreational use, although there would be no adverse effects on warmwater fish and aquatic life.

The second set of nonpoint source control measures, referred to as minimum and certain additional measures, including centralized stormwater storage, would achieve an approximate 50 to 75 percent reduction in pollutant loadings to about 13.7 stream miles, or about 64 percent of the total perennial stream miles in the watershed. These minimum and additional measures would require a total capital cost of about $5.8 million and an average annual operation and maintenance cost of about $220,000. About 99 percent of the capital cost and 89 percent of the annual operation and maintenance cost would be for urban measures, with the remainder being required for rural measures. Approximately 80 percent of the urban capital cost and about 36 percent of the urban operation and maintenance cost would be for construction site erosion control. The implementation of the minimum and certain additional nonpoint source control measures, including centralized stormwater storage, may be expected to achieve the recommended phosphorus and fecal coliform standards at least 90 percent of the time within 13.7 miles of stream, thereby providing for full recreational use. In the remaining 7.6 miles of stream, or 36 percent of the total stream miles, the phosphorus and fecal coliform standards would be met from 70 to 80 percent of the time. Recreational use impairment would be slight in these stream reaches, although fish and other aquatic life would not be adversely affected.

The third set of nonpoint source control measures, referred to as minimum and certain additional measures including decentralized stormwater storage, would achieve an approximate 50 to 75 percent reduction in pollutant loadings to all perennial stream reaches in the watershed. These minimum and additional measures would require a total capital cost of about $7.0 million and an average annual operation and maintenance cost of about $285,000. Over 99 percent of the capital cost and 91 percent of the annual operation and maintenance cost would be for urban measures, with the remainder being required for rural measures. Approximately 67 percent of the urban capital cost and about 27 percent of the urban operation and maintenance cost would be for construction site erosion control. The implementation of the minimum and certain additional nonpoint source control measures, including decentralized stormwater storage, would likely allow the achievement of the recommended phosphorus and fecal coliform standards at least 90 percent of the time throughout the watershed, thereby providing for full recreational use, as well as for the maintenance of warmwater fish and aquatic life.

Of the total capital cost for minimum nonpoint source control measures, about 23 percent would be required for projects in the public sector and about 77 percent would be required for projects in the private sector. About 27 percent of the capital cost for minimum and certain additional measures including centralized stormwater storage, and about 30 percent of the capital cost for minimum and certain additional measures including decentralized stormwater storage, would be required for public sector projects. Of the total annual operation and maintenance cost for minimum nonpoint source control measures, about 38 percent would be required for public sector projects and about 62 percent for private sector projects. For minimum and certain additional measures including centralized stormwater storage, about 58 percent of the annual operation and maintenance cost would be required for projects in the public sector and 42 percent for projects in the private sector. For minimum and certain additional measures including decentralized stormwater storage, about 57 percent of the annual operation and maintenance cost would be required for projects in the public sector and 43 percent for projects in the private sector.

Based on an analysis of costs, pollutant loading reductions, the expected achievement of water quality standards, and the likelihood of successful installation and maintenance of the control measures, it was recommended that minimum and certain additional nonpoint source pollution control measures, including centralized stormwater storage, be implemented in the Oak Creek watershed. The implementation of these measures would be expected to fully achieve the recommended water quality standards supporting recreational use and the maintenance of warmwater fish and aquatic life in about 13.7 miles of stream, or about 64 percent of the total 21.3 miles of perennial stream in the Oak Creek watershed. The remaining 7.6 miles of stream, or 36 percent, would have slight recreational use impairment, although fish and other aquatic life would not be adversely affected.

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Chapter XIV

RECOMMENDED COMPREHENSIVE PLAN

INTRODUCTION

The comprehensive plan for the Oak Creek watershed is comprised of three major elements: 1) a land use element, including a park and related open space preservation subelement; 2) a supporting floodland management element composed of structural and nonstructural subelements; and 3) a supporting water quality management element composed of point and nonpoint source pollution abatement subelements. The land use element refines and details the adopted regional land use plan and the adopted regional park and open space plan. The water quality management plan element is based upon and refines and details the adopted regional water quality management plan. The floodland management plan element was synthesized by selecting from among the alternatives considered the best floodland management measures. This selection was based upon careful evaluation of the tangible and intangible factors involved, with primary emphasis upon the degree to which the various alternatives met the established watershed development objectives in a cost-effective manner. A fourth plan element—development of a balanced fishery—is also a part of the comprehensive plan and represents that alternative which provides the best opportunity for fishery development.

This chapter describes the recommended comprehensive watershed development plan as synthesized from the best of the alternatives considered, discusses the basis for the synthesis, and analyzes the attendant costs. In addition, the chapter evaluates 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. It should be noted that this chapter describes the recommended plan as presented for public hearing. The public reaction to this plan and the subsequent action of the Oak Creek Watershed Committee to adjust the plan based upon the results of the public hearing are discussed in Chapter XVI of this report.

BASIS FOR PLAN SYNTHESIS

The watershed development objectives which the comprehensive plan for the Oak Creek 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 three preceding chapters describe the alternative plans considered for the resolution of the water-related problems of the watershed, and identify the best land use, floodland management, water quality management, and fishery development alternatives for inclusion in the comprehensive watershed plan. As already noted, this identification was based upon careful evaluation of the technical, economic, environmental, legal, financial, and administrative feasibility of the alternative plans, as well as on the basis of the ability of those plans to meet the applicable watershed development objectives and supporting standards. Figure 69 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 single 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 to the extent practicable toward the satisfaction of the development objectives. It should be noted that many of the alternative plan elements were specifically designed to satisfy certain 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 the adopted watershed development objectives.

RECOMMENDED PLAN

Based upon the results of the analyses of the ability of the various plan elements to satisfy the watershed development objectives and to exhibit an acceptable benefit-cost ratio, the specific plan elements set forth below are recommended for inclusion in the comprehensive plan for the Oak Creek watershed.

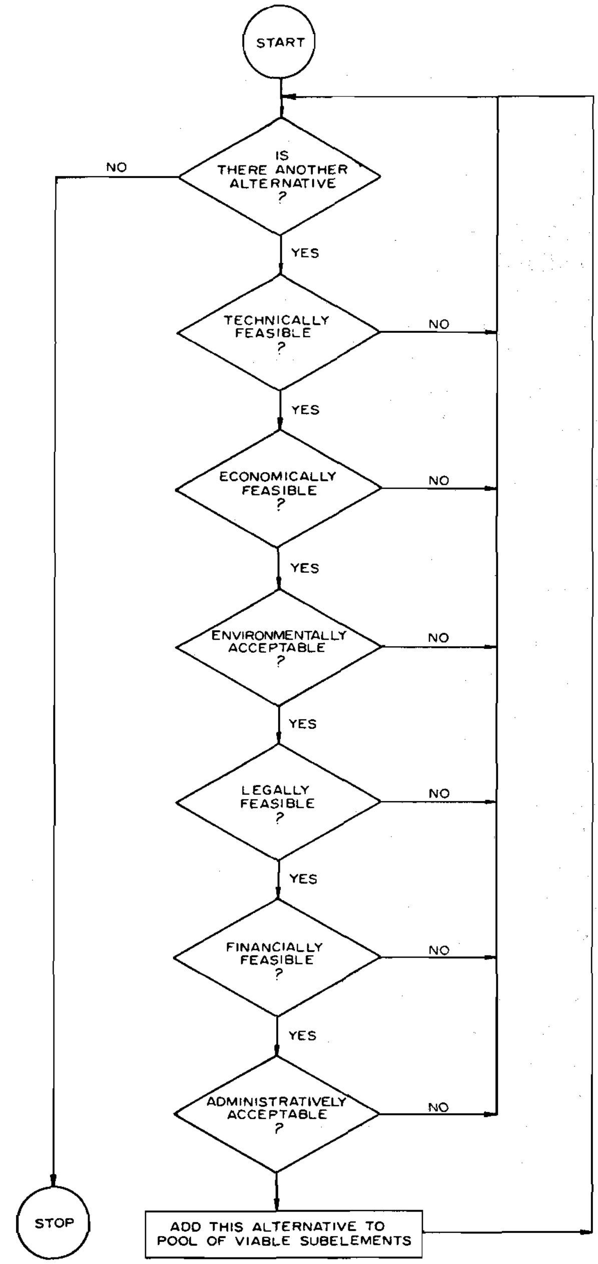
Recommended Land Use Plan Element

Overall Land Use: The adopted regional land use plan, as refined and detailed under the watershed study, is recommended for adoption as the land use element of the Oak Creek watershed plan (see Map 45 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 the spatial distribution of land uses within the watershed in order to achieve a safer, more healthful, more pleasant, and more efficient land use pattern while meeting the forecast land use demand. The land use plan emphasizes continued reliance on 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 the intensification of developmental and environmental problems within the Region and the watershed.

Urban Development: Forecasts indicate that the population of the Oak Creek watershed may be expected to increase from the 1980 level of about 39,700 persons to a plan design year 2000 level of about 72,600 persons, an 83 percent increase. Employment may be expected to increase from the 1980 level of about 20,000 jobs to a plan design year 2000 level of about 27,300 jobs, a 36 percent increase. Although the Oak Creek watershed is still largely in rural land uses, with about 15 square miles, or 53 percent of the watershed, devoted to such uses in 1980, an additional 11 square miles of land are forecast to be converted from rural to urban use over the next two to three decades, an 84 percent increase.

Figure 69

TEST AND EVALUATION OF A PLAN SUBELEMENT



Source: SEWRPC.

As indicated in Table 78 in Chapter XI of this report, the recommended land use plan proposes to add about 5.0 square miles 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 as well as growth of population within the watershed, and by decreasing household size and attendant need for additional dwelling units. This new urban development is proposed to occur primarily at medium population densities, with gross residential population densities ranging from about 3,300 to about 9,200 persons per square mile. The new residential development would be located in areas served, or proposed to be served, by a full range of public utilities and essential urban services. The remaining 6.1 square miles of land proposed to be converted from rural to urban use within the watershed by the year 2000 would be used for commercial, industrial, governmental and institutional, recreational, and transportation, communication, and utility land uses as required to meet the gross demand for land generated by the resident population and employment levels anticipated within the watershed.

Agricultural and Other Open Land Use: As already noted, the recommended land use plan for the watershed would require the conversion to urban use of about 11 square miles of land presently devoted to agricultural and other open land uses. The existing stock of such land within the watershed would accordingly decrease from about 15 square miles in 1980 to about four square miles in the year 2000, a decrease of about 76 percent.

Park and Open Space Plan: As discussed earlier in this report, a regional park and open space plan was completed and adopted by the Commission in 1978 and includes recommendations affecting the Oak Creek 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 open uses of all remaining primary environmental corridor lands within the Region and the watershed. Exceptions to this are a total of about 30 acres, or about 7 percent, of existing primary environmental corridor lands which are proposed to be converted to urban use within the watershed over the plan design period, reflecting committed local planning and zoning decisions. The preservation of the primary environmental corridors 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 Region and the watershed. As shown on Map 46 in Chapter XI of this report, the corridor lands to be preserved consist of about 417 acres located along the lower reaches of Oak Creek in the City of South Milwaukee, and in an area encompassing a large concentration of wetlands and woodlands in the southeastern area of the watershed in the City of Oak Creek. Of this total, about 229 acres, or about 51 percent, are already publicly owned. The plan recommends that the remaining 188 acres, or 42 percent, ultimately be publicly acquired through purchase or dedication. In addition to the preservation of 93 percent of the existing primary environmental corridor lands in the watershed, the land use plan element recommends the restoration of 579 acres of unused open lands to wetland vegetation, thereby restoring and re-creating primary environmental corridors. These lands are located within existing and proposed county-owned parkway boundaries and are shown on Map 46 in Chapter XI.

The outdoor recreation plan element for the Region and the watershed is composed of: 1) a resource-oriented outdoor recreation component containing recommendations as to the number and location of large parks and recreation corridors; and 2) an urban-oriented outdoor recreation component containing recommendations to guide the public provision of needed local parks. More specifically, as shown on Map 46 in Chapter XI, the outdoor recreation plan element recommends:

- Continued maintenance of Grant Park and Oakwood Park, as well as the Cudahy Nature Preserve.

- Development of Falk Park to provide for general-use outdoor recreational activities.

- Completion of the acquisition of lands for the Oak Creek Parkway. Approximately 400 acres of additional land would be required, to bring the total to about 1,420 acres.

- Development of opportunities for hiking, biking, and ski touring activities in about eight lineal miles of recreation corridor.

- Continued maintenance of three community and three neighborhood parks, provision of recreational facilities at eight publicly owned but undeveloped neighborhood parks, and acquisition and development of four additional neighborhood parks as needed. The latter would require a combined area of about 60 acres.

- Development of a recreational sport and forage fishery through implementation of the fishery development plan element.

The development and acquisition of the proposed parks and related open spaces, and the acquisition of the primary environmental corridor lands, would require the following costs: 1) $940,000 for the purchase of land for the preservation and restoration of primary environmental corridors; 2) $860,000 for the development of Falk Park, acquisition of additional parkway lands, and provision of recreational corridors; and 3) $1,748,000 for the acquisition and development of neighborhood parks. These costs are reflected in the total cost of the regional park and open space plan and are not, therefore, considered to be additional costs in the Oak Creek watershed plan. The recommended park and open space plan element would achieve the park, outdoor recreation, and open space preservation objectives and standards formulated under the watershed study, meeting the existing and anticipated future recreation needs within the watershed in an efficient and effective manner.

It should be noted that as of the end of 1985, the City of Oak Creek had completed development of several neighborhood parks as proposed in Chapter XI. In addition, in a recently completed park and open space plan for the City of Oak Creek, the City proposes the development of one additional neighborhood park in the watershed. This park, Camelot Park, located in the eastern portion of the watershed, is proposed to be approximately 12 acres in size and consists of six acres of land recently acquired by the City and six acres of land located in the Oak Creek Parkway proposed to be leased from the County. These recent changes necessitated the following revised recommendations for community and neighborhood maintenance and development of parks in the watershed: continued maintenance of three existing community parks—Abendschein, Copernicus, and Maitland Parks; continued maintenance of seven existing neighborhood parks—Chapel Hills, Cudahy, Manor Marquette, Miller, Rawson, Shepard Hills, and Willow Heights Parks; provision of additional facilities at five existing neighborhood parks—Camelot, Carollton, Green Lawn, Johnstone, and Riverton Meadows Parks; and acquisition and development of four additional neighborhood parks as needed, all as shown on Map 74.

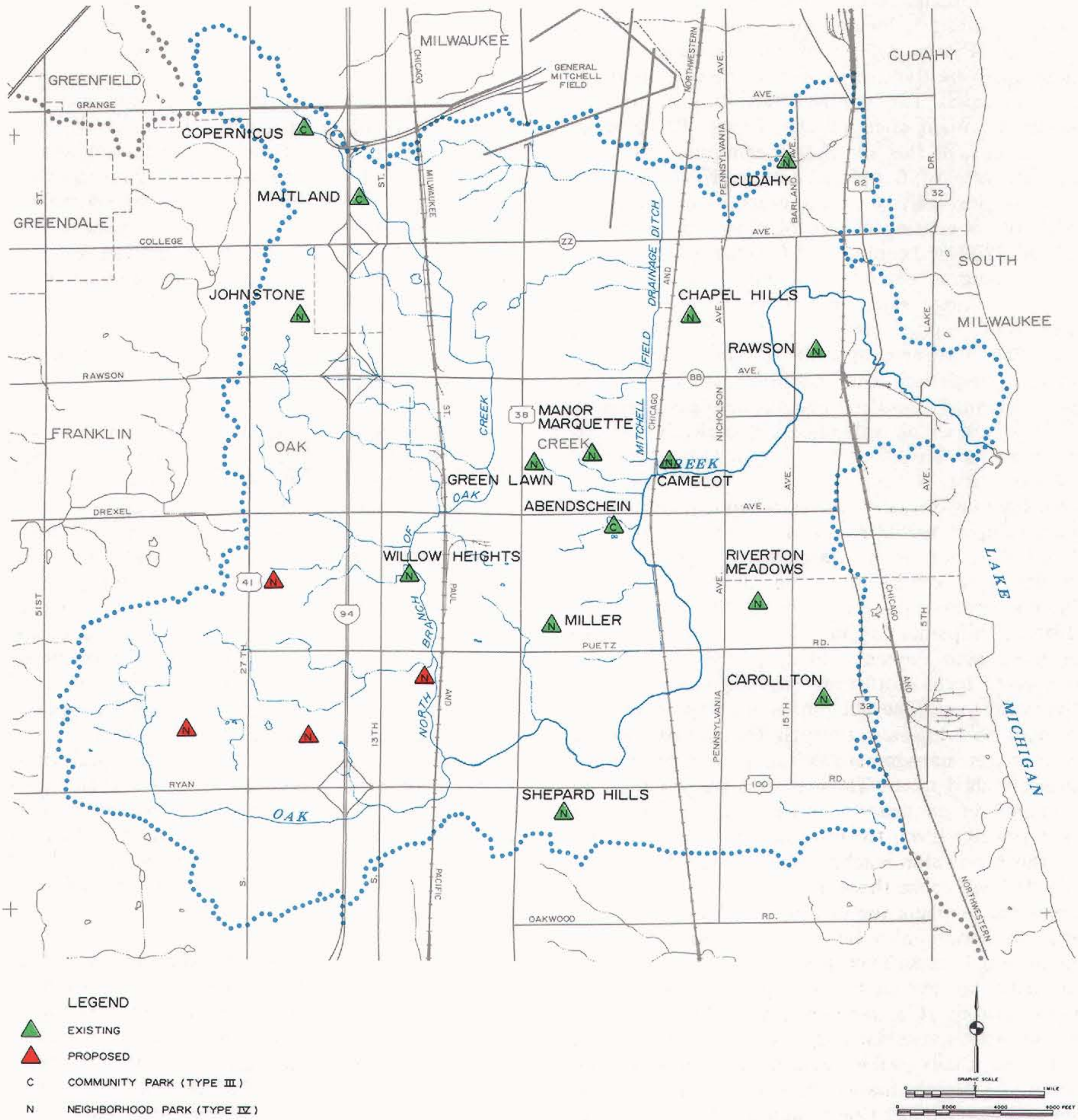
Recommended Floodland Management Plan Element

The recommended floodland management plan element for the Oak Creek watershed includes the application of both structural and nonstructural measures for the abatement of damages in flood-prone areas of the watershed, the improvement of stormwater drainage facilities, and the prevention of future flood-prone development. The basic nonstructural plan element consists of the land use development proposals contained in the land use element of the watershed plan. The extent and placement of incremental urban development over the next two decades is critical if the intensification of the existing and the creation of new flood damage problems in the watershed are to be avoided, since such extent and placement directly affect the hydrologic and hydraulic behavior of the watershed. In this respect, preservation of the primary environmental corridors is of particular importance and affects not only the hydrologic and hydraulic behavior of the stream system but also water quality conditions. Preservation of about 1,250 acres of floodlands in open uses lying outside the environmental corridors is also critical. These floodlands are envisioned to be retained primarily in agricultural use. These nonstructural floodland management plan elements are graphically summarized on Maps 45 and 46 in Chapter XI.

In addition to the land use development proposals, the plan recommends that the alternative calling for a combination of channel deepening and shaping and structure floodproofing, elevation, and removal be adopted to resolve existing and probable future flood problems in the watershed. This recommended alternative consists of the following components: 1) channel deepening and shaping of 1.4 miles of the Oak Creek channel between River Mile 10.30 and the S. 27th Street crossing, and of 1.0 mile of the North Branch of Oak Creek between the steel sheet pile spillway located west of the United Parcel Service distribution center and the S. 13th Street crossing; 2) the floodproofing of 21 buildings, the elevation of six buildings, and the removal of two buildings; and 3) the replacement of two bridges on the North Branch of Oak Creek. Of the 21 buildings recommended for floodproofing, 16 are located along the main stem of Oak Creek, consisting of two houses and 14 commercial buildings; four are located along the North Branch of Oak Creek, consisting of two commercial buildings, one apartment building,

Map 74

EXISTING AND PROPOSED COMMUNITY AND NEIGHBORHOOD PARKS IN THE OAK CREEK WATERSHED: 2000



As of 1985, the City of Oak Creek had completed the development of several neighborhood parks recommended in the preliminary watershed plan. In addition, a recently completed park and open space plan for the City of Oak Creek proposes the development of one additional neighborhood park, Camelot Park, in the eastern portion of the watershed, not envisioned in the preliminary watershed plan. These recent changes necessitated the following revised recommendations for community and neighborhood maintenance and development of parks in the watershed: continued maintenance of three existing community parks—Abendschein, Copernicus, and Maitland Parks; continued maintenance of seven existing neighborhood parks—Chapel Hills, Cudahy, Manor Marquette, Miller, Rawson, Shepard Hills, and Willow Heights Parks; provision of additional facilities at five existing neighborhood parks—Camelot, Carollton, Green Lawn, Johnstone, and Riverton Meadows Parks; and acquisition and development of four additional parks as needed.

Source: SEWRPC.

and one municipal garage; and one office and warehouse building is located along the Mitchell Field Drainage Ditch. All six of the buildings recommended to be elevated, as well as the two buildings recommended for removal, are houses located along the main stem of Oak Creek. The average annual cost of this alternative, computed using an interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at $65,000, consisting of the following: amortization of the $207,000 capital cost for channel deepening and shaping; amortization of the $110,000 capital cost for bridge replacement; amortization of the $692,000 capital cost for the floodproofing, elevation, and removal of 29 buildings; and $1,000 annual operation and maintenance costs. The recommended floodland management plan element for the Oak Creek watershed is graphically summarized on Map 75.

Implementation of this floodland management plan element would result in the abatement of all flood damages in the watershed caused by flood events up to and including the 100-year recurrence interval event under plan year 2000 land use conditions. Implementation of the floodland management plan element will not, however, serve to eliminate local stormwater drainage problems in the watershed. The abatement of those problems should be addressed through the preparation of stormwater management system plans prepared for subwatershed areas. These system plans should be prepared in an orderly and logical manner, with first priority given to those subwatersheds located in the headwater reaches of the watershed, since the drainage from those areas may have an impact on drainage plans for downstream subwatersheds. Priority should also be given to those subwatersheds which experience serious drainage problems, or may be expected to experience significant urbanization. It is recommended, therefore, that stormwater management system plans be prepared for Oak Creek subwatersheds in the following order: 1) North Branch of Oak Creek subwatershed, 2) Upper Oak Creek subwatershed, 3) Middle Oak Creek subwatershed, 4) Mitchell Field Drainage Ditch subwatershed, and 5) Lower Oak Creek subwatershed. These study areas are shown on Map 76. For those subwatersheds which are located in more than one community, it is recommended that the preparation of the stormwater management plans be a joint effort of the communities concerned.

The Oak Creek Watershed Committee gave careful consideration to the relationship between the recommended watershed land use plan and the recommended watershed flood control plan. As a matter of policy, the Watershed Committee recommended that all flood control works be designed based upon the flood flows and stages anticipated under the land use development conditions in the watershed land use plan. The Committee further recommended that as a matter of policy, new urban development should be permitted in those portions of the watershed not recommended for such development in the watershed land use plan only upon the condition that stormwater runoff from the developed land not exceed runoff under predevelopment conditions.

Impacts of Recommended Land Use and Floodland Management Plans on Flood Flows and Stages: Implementation of the recommended land use and floodland management plans may be expected to have a significant impact on flood flows and stages in the Oak Creek watershed. The impacts of plan implementation on the regulatory 100-year recurrence interval flood are given for selected locations along the stream system of the Oak Creek watershed in Table 92. Future urban land use development proposed for the watershed accounts for the increase in peak flood flows and stages. Along those stream reaches where channel deepening and shaping is recommended, peak flood stages may be expected to be lower than under planned land use development and existing channel conditions. More detailed data pertaining to peak flood flows and stages under planned land use and planned channel conditions are provided in Appendix F.

Bridge Replacement: It is recommended that bridges and culverts on the major stream system of the Oak Creek watershed that have inadequate hydraulic capacity, as manifested by overtopping of the approach roadways or of the structure itself, be eventually modified or replaced so as to eliminate interference with the operation of the highway and railroad transportation system. There are 101 bridges and culverts on the major stream system of the watershed. Of this total, 81, or 80 percent, are hydraulically adequate, as shown in Table 93, and need not be modified or replaced except as may be necessary for transportation purposes. A total of 18 of the crossings, or an additional 18 percent, are stream crossings that, while not included in the flood control recommendations noted above, are hydraulically inadequate and should be modified or replaced in the normal course of events as the transportation system is renewed. The remaining two crossings, or 2 percent, represent bridges and culverts specifically affected by the recommended flood control measures, and should be replaced in accordance with those recommendations. One of these two bridges is already designated for reconstruction under the regional transportation plan and therefore was not reflected in the costs of this watershed plan. The capital cost of replacing the remaining bridge is estimated at $110,000. The design of all new bridges within the watershed should be based upon the applicable objectives and standards set forth in Chapter X.

Floodland Regulations: It is recommended that the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee review and, as necessary, revise their floodland zoning regulations to reflect the updated flood hazard data and the floodland management concepts and recommendations set forth in this report. Such regulations should be explicitly designed to complement the recommended watershed land use plan element, as well as the structural and nonstructural flood control measures recommended in the plan. In general, those floodlands lying within the 100-year recurrence interval flood hazard lines under plan year 2000 conditions that are presently neither developed for urban use, nor committed to such development by the recordation of land subdivision plats and the installation of municipal improvements, should be zoned so as to prohibit incompatible urban development except where such development is envisioned under the recommended land use plan. Such encroachment is envisioned in about 240 acres of flood hazard area, or in about 10 percent of the total such area in the watershed.

Those urban land uses in the floodlands scheduled to be floodproofed, elevated, removed, or protected through structural flood control measures should be appropriately zoned, including the imposition of an overlay floodplain regulatory zone that will ensure that proper attention is given to the flood hazards on these sites as zoning and development decisions are made. Those lands which would be removed from the floodplain upon construction of the flood control improvements outlined in the plan should be zoned as floodplains until the recommended flood control works are put in place, whereupon the lands should be rezoned for appropriate urban development.

Channel Maintenance: It is recommended that a regular stream channel maintenance program be undertaken throughout the major stream system of the Oak Creek watershed. This would include the periodic removal of sediment deposits, heavy vegetation, and debris from all watercourses in the watershed, including bridge openings and culverts. Such a program is necessary to ensure the integrity of the existing and recommended stream bottom profile.

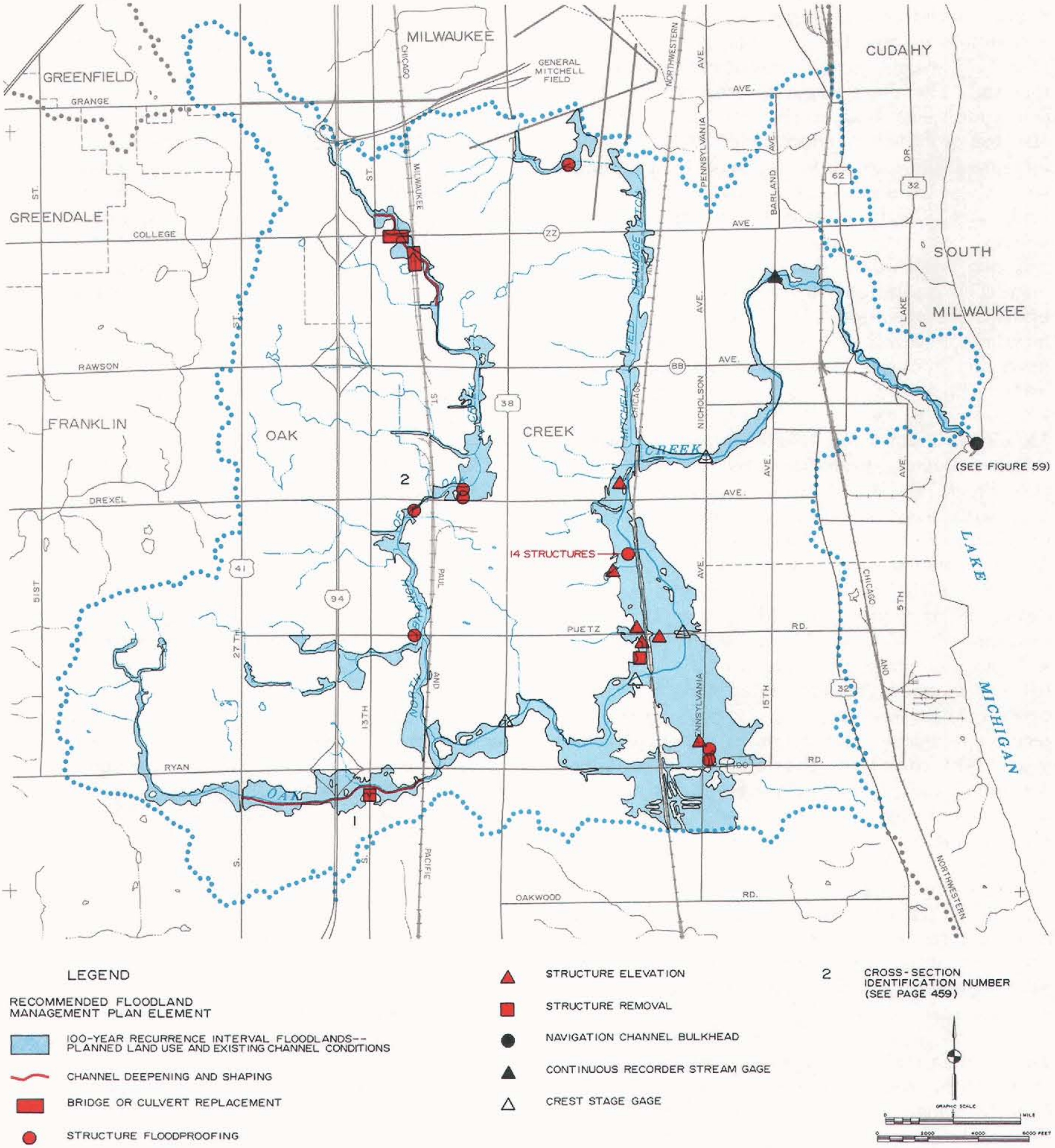
Flood Insurance: All of the civil divisions located wholly or partly within the watershed and designated by the Federal Emergency Management Agency (FEMA) as having flood hazard areas have taken the necessary steps to make their residents eligible to participate in the Federal Flood Insurance Program. Initial flood insurance studies have been completed by FEMA for all of the communities in the watershed. It is recommended that FEMA review the flood hazard data set forth in this report and revise, as necessary, the local flood insurance studies to reflect the new flood hazard data. It is further recommended that owners of property in flood-prone areas purchase flood insurance to provide some financial relief for losses sustained in floods that may occur prior to the completion of any recommended flood control works. Finally, as the flood control works are implemented, it is recommended that FEMA make necessary revisions to the flood insurance studies.

Lending Institution and Realtor Policies: It is recommended that lending institutions continue their practice of determining the flood-prone status of properties prior to mortgage transactions and that the principal source of flood hazard information be the Oak Creek watershed study. It is further 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 rules of the Wisconsin Real Estate Examining Board.

Community Utility Policies and Emergency Programs: It is recommended that the policies of the governmental units and agencies within the watershed responsible for the design, construction, operation, and maintenance of public utilities

Map 75

RECOMMENDED FLOODLAND MANAGEMENT PLAN ELEMENT FOR THE OAK CREEK WATERSHED: 2000

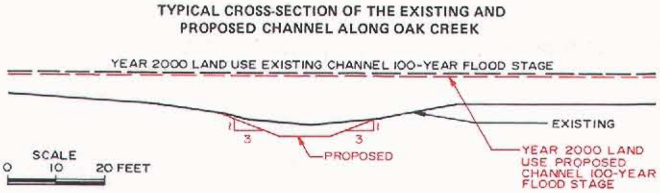


The recommended floodland management plan element for the Oak Creek watershed is comprised of both structural and nonstructural measures. Structural measures include channel deepening and shaping along about 1.4 miles of Oak Creek and along 1.0 mile of the North Branch of Oak Creek. Nonstructural measures include: 1) floodproofing of 21 buildings, elevation of six buildings, and removal of two buildings; 2) regulation of land use development both inside and outside the floodlands; 3) channel maintenance; 4) participation in the federal flood insurance program; 5) continuation of desirable lending institution and realtor policies concerning the sale of riverine area; 6) supportive community utility policies and emergency programs; and 7) maintenance of a basic stream gaging network. In addition to these measures, the recommended floodland management plan contains a provision for the maintenance of recreational navigation at the mouth of Oak Creek through the construction of a jetty parallel to the existing jetty located along the north side of the channel.

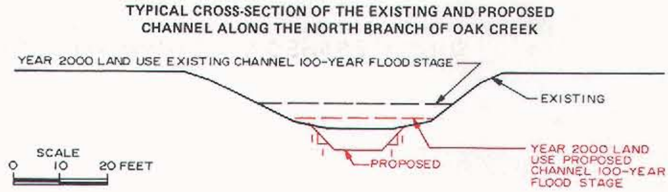
Source: SEWRPC.

Map 75 (continued)

1



2



and facilities—such as water supply and sewerage facilities, drainageways, and streets and highways—carry out those functions in a manner fully consistent with the land use and floodland regulation recommendations for the Oak Creek watershed. Although the hydrologically unpredictable "flashy" nature of flooding within the Oak Creek watershed renders a flood forecasting system impractical, it is recommended that each watershed community develop procedures to provide floodland residents and other property owners with timely information about floods in progress.

Maintenance of Stream Gaging Networks: The stream gaging stations in the Oak Creek watershed can provide data essential to the rational management of the surface waters of the basin. It is recommended that the continuous recorder on Oak Creek at the first 15th Avenue crossing in the City of South Milwaukee, the crest stage and low-flow gage on Oak Creek at Nicholson Road in the City of Oak Creek, and the four crest stage and three staff gage stations in the watershed continue to be operated.

Maintenance of Recreational Navigation at Mouth of Oak Creek: The use of the recreational boat launch ramp located at the mouth of Oak Creek in Grant Park is periodically denied by the formation of a sandbar at the mouth of the creek between the ramp and Lake Michigan. In order to alleviate this problem, it is recommended that a navigation channel be constructed at the mouth of Oak Creek and that this channel be maintained by the flushing of accumulated sand from it. This plan would be implemented in the following stages:

1. Provision of an approximately 20-feet-wide by four-feet-deep navigation channel at the mouth of Oak Creek through the construction of a jetty parallel to the north shore of the creek; lowering of the sand level on the beach north of the channel to an elevation of about two feet below the top of the jetty located on the north side of the Oak Creek channel; and performance of such minimal dredging of the navigation channel as may be necessary to maintain four feet of depth in the channel.

2. Design and construction of either a dry dam at or near the existing footbridge near River Mile 0.14, or a network of diffusers within the navigation channel. This would be done only if the implementation of step one does not yield adequate results.

Recommended Fishery Development Plan Element

Fishery data collected under the watershed study indicate that the Oak Creek watershed does not support a balanced fish population. In order to enhance the fishery resource in the watershed, it is recommended that the following measures be taken:

1. Modification of the Mill Road dam by notching the existing structure down to the streambed to provide an opening of 40 feet at the top of the dam and 10 feet at the base of the dam.

2. Dredging as may be necessary of a portion of the accumulated sediments behind the Mill Road dam to normalize the streambed gradient and to re-create stream meanders.

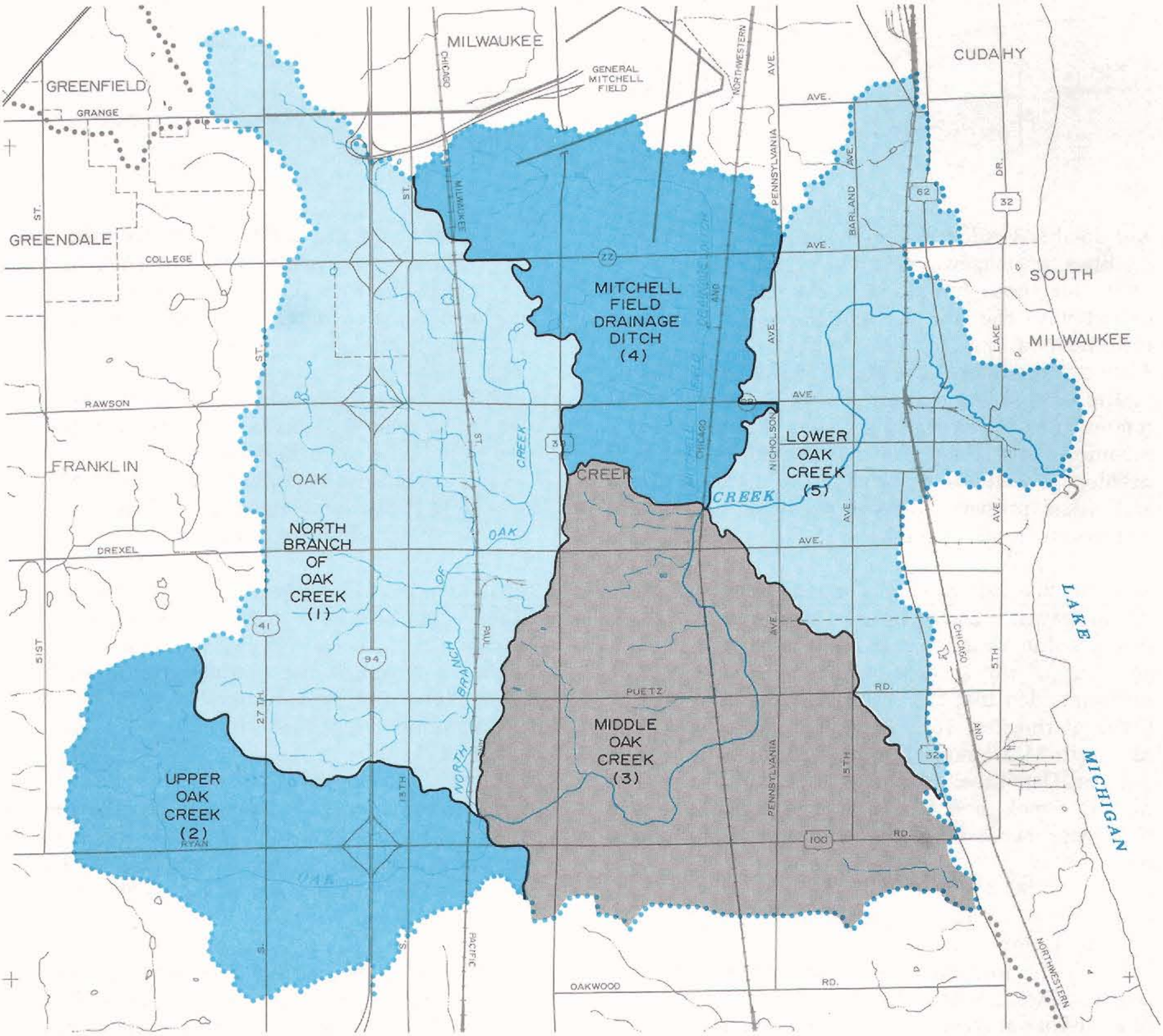
3. Removal or modification of five sill and drop structures.

4. Instream habitat mitigation measures, including placement of boulder retards and stone rip-rap, and encouraging the development of stands of emergent vegetation in the streambed.

5. Stream bank stabilization measures, including placement of stone rip-rap and wing deflectors as well as prescribed plantings.

Map 76

SUBWATERSHED LOCATIONS FOR STORMWATER MANAGEMENT SYSTEM PLANS



LEGEND

(3) PRIORITY FOR PREPARATION OF STORMWATER MANAGEMENT SYSTEM PLAN

MIDDLE OAK CREEK SUBWATERSHED IDENTIFICATION

The Oak Creek watershed plan recommends that stormwater management system plans be developed within the framework of the watershed plan to alleviate local drainage problems. These plans should be developed on a subwatershed basis, with priority being given to those areas in the headwater reaches of the watershed, as well as to those reaches which experience serious drainage problems or may be expected to experience significant urbanization.

Source: SEWRPC.

Table 92

100-YEAR RECURRENCE INTERVAL FLOOD DISCHARGES AND STAGES AT SELECTED LOCATIONS IN THE OAK CREEK WATERSHED: EXISTING LAND USE AND CHANNEL CONDITIONS AND PLANNED LAND USE AND CHANNEL CONDITIONS

Location	Existing Land Use and Channel Conditions		Planned Land Use and Channel Conditions	
	Peak Flood Discharge (cfs)	Peak Flood Stage (feet NGVD[a])	Peak Flood Discharge (cfs)	Peak Flood Stage (feet NGVD[a])
Oak Creek				
Confluence with Lake Michigan	1,780	582.1	2,810	583.4
Parkway Dam	1,780	617.5	2,810	618.5
Chicago Avenue	1,780	625.7	2,770	628.0
15th Avenue	1,780	642.5	2,700	644.6
Upstream of Marquette Boulevard Extended	1,780	651.7	2,700	655.5
Upstream of Confluence with Mitchell Field Drainage Ditch	1,500	661.2	2,270	662.4
East Forest Hill Avenue	1,500	663.7	2,270	666.2
Abandoned Chicago, North Shore & Milwaukee Railroad	2,080	666.7	3,220	668.1
South Shepard Avenue	2,080	673.7	3,220	675.1
Upstream of Confluence with North Branch of Oak Creek	1,030	680.7	1,830	682.4
IH 94	790	691.9	1,330	692.7
South 31st Street	410	699.2	490	699.9
Downstream of W. Southland Drive	210	725.6	- -[b]	726.0
Upstream of W. Woodward Drive	50	734.6	- -[b]	734.6
North Branch of Oak Creek				
Confluence with Oak Creek	1,670	680.5	2,320	682.3
Downstream of W. Puetz Road	1,450	694.6	1,940	695.5
Downstream of Wildwood Drive	930	705.1	1,260	705.8
Chicago, Milwaukee, St. Paul & Pacific Railroad	880	709.3	1,190	711.4
West Marquette Avenue	520	714.0	900	714.9
MATC-South Campus	160	724.6	240	725.6
Chicago, Milwaukee, St. Paul & Pacific Railroad	150	733.2	220	736.3
CTH V/S. 13th Street	370	733.4	390	733.4
Mitchell Field Drainage Ditch				
Confluence with Oak Creek	730	661.2	1,050	662.2
CTH BB/W. Rawson Avenue	680	665.9	950	667.0
CTH ZZ/W. College Avenue	520	673.2	620	674.0
Private Drive	740	680.4	1,180	680.7
Southland Creek				
Confluence with North Branch of Oak Creek	350	694.6	450	695.5
Upstream of Confluence of the Tributary to Southland Creek	200	704.8	270	705.8
Tributary to Southland Creek				
Confluence with Southland Creek	140	704.9	180	705.8
Tributary to Upper Oak Creek				
Confluence with Oak Creek	60	734.6	- -[b]	734.6

[a] *NGVD-National Geodetic Vertical Datum.*

[b] *No change in land use.*

Source: SEWRPC.

Table 93

BRIDGE REPLACEMENT/MODIFICATION RECOMMENDATIONS IN THE OAK CREEK WATERSHED PLAN

Structure Identification			Hydraulically Adequate—Replace or Modify as Necessary for Transportation Purposes	Hydraulically Inadequate—Replace or Modify as Transportation System is Renewed	Replace or Modify in Accordance With Flood Control Recommendations
Stream	Name	River Mile[a]			
Oak Creek	Pedestrian Bridge	0.14	X		
	1st Oak Creek Parkway Bridge	0.35	X		
	2nd Oak Creek Parkway Bridge	0.88	X		
	Mill Road	0.94	X		
	3rd Oak Creek Parkway Bridge	1.18	X		
	4th Oak Creek Parkway Bridge	1.32	X		
	Chicago Avenue/STH 32	1.61	X		
	5th Oak Creek Parkway Bridge	2.14	X		
	Pedestrian Bridge	2.24	X		
	Chicago & North Western Railway	2.35	X		
	15th Avenue	2.84	X		
	Pedestrian Bridge	3.18	X		
	Pine Street	3.37	X		
	E. Rawson and 16th Avenues	3.64	X		
	15th Avenue	3.76	X		
	Pedestrian Bridge	3.89	X		
	Milwaukee Avenue	4.01	X		
	15th Avenue	4.06	X		
	Pedestrian Bridge	4.18	X		
	S. Pennsylvania Avenue	4.71	X		
	Chicago & North Western Railway	5.25	X		
	E. Drexel Avenue	5.56	X		
	Chicago & North Western Railway	6.06	X		
	E. Forest Hill Avenue	6.25		X	
	E. Puetz Road	6.83		X	
	Chicago & North Western Railway	7.34	X		
	S. Nicholson Road	7.44		X	
	S. Shepard Avenue	8.41		X	
	S. Howell Avenue/STH 38	9.23	X		
	W. Ryan Road/STH 100	10.06		X	
	Chicago, Milwaukee, St. Paul & Pacific Railroad	10.24	X		
	Private Bridge	10.25	X		
	Private Bridge	10.46	X		
	Private Bridge	10.60	X		
	S. 13th Street/CTH V	10.69		X	
	Pedestrian Bridge	10.72	X		
	IH 94	10.98	X		
	S. 20th Street	11.24		X	
	S. 27th Street/STH 41	11.70	X		
	S. 31st Street	11.97	X		
	Private Bridge	12.23	X		
	W. Ryan Road/STH 100	12.52	X		
	W. Southland Drive	13.18	X		
	W. Woodward Drive	13.31	X		
	W. Glenwood Drive	13.58	X		
	Private Drive	13.60	X		
	Private Drive	13.62	X		
	Maple Crest Drive	13.64	X		
	Private Bridge	13.76	X		
	W. Puetz Road	13.79		X	

Table 93 (continued)

Structure Identification			Hydraulically Adequate—Replace or Modify as Necessary for Transportation Purposes	Hydraulically Inadequate—Replace or Modify as Transportation System is Renewed	Replace or Modify in Accordance With Flood Control Recommendations
Stream	Name	River Mile[a]			
North Branch of Oak Creek	Chicago, Milwaukee St. Paul & Pacific Railroad	0.10	X		
	Private Bridge	0.21	X		
	Private Bridge	0.34	X		
	W. Puetz Road	0.92		X	
	Private Bridge	1.71	X		
	Wildwood Drive	2.00		X	
	W. Drexel Avenue	2.21	X		
	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.25	X		
	S. 6th Street	2.41		X	
	W. Marquette Avenue	3.04		X	
	W. Rawson Avenue/CTH BB	3.51	X		
	S. 6th Street	3.86	X		
	Private Bridge	4.35	X		
	Private Bridge	4.59	X		
	Private Bridge	4.62	X		
	Private Bridge	4.67	X		
	Private Bridge	4.74	X		
	Chicago, Milwaukee, St. Paul & Pacific Railroad	4.75			X
	W. College Avenue/CTH ZZ	4.91			X
	Private Bridge	4.94	X		
	S. 13th Street/CTH V	5.21	X		
	W. Ramsey Avenue and IH 94	5.65	X		
	IH 94 Exit Ramp	5.85	X		
Mitchell Field Drainage Ditch	Chicago & North Western Railway	0.14	X		
	E. Rawson Avenue/CTH BB	0.80	X		
	E. College Avenue/CTH ZZ	1.83		X	
	Private Bridge	2.15	X		
	Private Bridge	2.73	X		
	Pedestrian Bridge	3.10	X		
	S. Howell Avenue/STH 38	3.31	X		
Southland Creek	S. 13th Street/CTH V	0.47	X		
	IH 94	0.88	X		
	S. 20th and S. 21st Streets	1.15	X		
	S. 26th Street	1.57		X	
	W. Grays Lane	1.69		X	
	S. 27th Street/STH 41	1.77		X	
Tributary to Southland Creek	IH 94	0.19	X		
	W. Puetz Road	0.73		X	
Tributary to Upper Oak Creek	Private Drive	0.02	X		
	Private Drive	0.04	X		
	Private Drive	0.05	X		
	W. Glenwood Drive	0.21	X		
	Private Drive	0.27	X		
	Private Drive	0.28	X		
	Maple Crest Drive	0.30		X	
	W. Puetz Road	0.55	X		

[a] *Distance in miles along stream channel upstream from mouth or confluence.*

Source: SEWRPC.

6. An initial fish stocking program.

Recommended Water Quality Management Plan Element

The adopted regional water quality management plan, as refined and detailed under the watershed study, is recommended for adoption as the water quality management element of the Oak Creek watershed plan. The plan contains recommendations for the abatement of pollution from industrial waste discharges; the control of pollution from nonpoint sources; and the development of a water quality monitoring program for the watershed.

Abatement of Pollution from Industrial Waste Discharges: The recommended water quality management plan element of the Oak Creek watershed plan proposes that the direct or indirect discharge of industrial wastes into Oak Creek and its tributaries be eliminated while allowing the continued discharge of clear water, such as spent cooling water, to the stream system. 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 Pollution from Nonpoint Sources: In order to reduce pollution from nonpoint sources, it is recommended that urban communities in the Oak Creek watershed use a judicious blend of public education programs, litter and pet waste control, proper use of fertilizers and pesticides, construction erosion control, critical area protection, improved timing and efficiency of street sweeping, leaf collection, catch basin cleaning, and industrial and commercial material storage facilities and runoff control. Provision of sanitary sewer service to all developed areas of the watershed is recommended to eliminate pollutant loadings from malfunctioning septic tank systems. In addition to these measures, it is recommended that retention basins be constructed at the following three locations: 1) along the North Branch of Oak Creek north of W. Drexel Avenue between S. Howell Avenue and S. 6th Street; 2) along Oak Creek immediately upstream of the confluence with the North Branch of Oak Creek; and 3) along the Mitchell Field Drainage Ditch, north of E. Rawson Avenue. These basins would be designed so as not to have a significant impact on flood flows and stages in the watershed.

It is recommended that nonpoint source pollution from rural areas be reduced by utilization of public education programs, fertilizer and pesticide management, critical areas protection, crop residue management, conservation tillage, pasture management, contour plowing, crop rotation, contour strip-cropping, grassed waterways, diversions, terraces, vegetative buffer strips, stream bank protection, and stormwater storage.

In order to achieve the water use objectives for the Oak Creek watershed, some additional control measures are recommended. These measures are meant to eliminate toxic and hazardous substances from surface waters in the watershed in order to protect the development of a desired fishery. It is recommended that accidental spill prevention and control plans be developed for all situations under which such spills could occur, and that floor drains and drainage pumps in industrial facilities which collect grease, oil, chemicals, and other toxic and hazardous substances be altered, as necessary, to eliminate discharge to storm sewers and surface watercourses. State regulations prohibit connecting the floor drains from any type of facility to storm sewers or to surface waters.

Development of Water Quality Monitoring Program: It is recommended that a water quality monitoring program be developed for the watershed to demonstrate and document changes in surface water quality attendant to plan implementation, and to help detect and locate illegal sources of pollution. The basis for such a monitoring program should be a technical report for water quality monitoring in the Region, which would be prepared under the guidance of a special advisory body having technical water quality monitoring expertise, and including members from potential financial support agencies.

IMPACT OF RECOMMENDED COMPREHENSIVE WATERSHED PLAN ON WATER USE OBJECTIVES

The watershed development objectives, principles, and standards used in the preparation of the comprehensive Oak Creek watershed plan are set forth in Chapter X of this report. One of the water quality management planning objectives relates directly to the Oak Creek watershed stream system. The initially recommended water use objectives are shown on Map 44 in Chapter X of this report. The water quality standards attendant to those water use objectives as they were established on a preliminary basis prior to preparing the watershed plan are set forth in Table 77 in Chapter X.

The initially recommended water use objectives were revised based upon an evaluation of the potential for fishery development, as discussed in Chapter XII of this report, and upon the anticipated water quality benefits of the recommended plan. The recommended water use objectives are summarized on Map 77. The map indicates that two reaches of the perennial stream network would not meet the objective of full recreational use under the recommended plan, and were therefore reclassified for warmwater fishery and aquatic life, limited recreational use, and minimum standards. These reaches are the main stem of Oak Creek upstream of the North Branch and the North Branch of Oak Creek upstream of the first S. 6th Street crossing. Also, because of fishery and water quality considerations, the Mitchell Field Drainage Ditch is designated for limited fishery and aquatic life, limited recreational use, and minimum standards. The standards attendant to these revised recommended water use objectives are set forth in Table 94.

COST ANALYSIS

In order to assist public officials in evaluating the recommended comprehensive Oak Creek watershed plan, a preliminary capital improvement program with attendant operation and maintenance costs was prepared which, if followed, would result in total watershed plan implementation by the year 2000. The schedule of capital and operation and maintenance costs for the recommended watershed plan is set forth in Table 95.

The schedule assumes a 15-year plan implementation period beginning in 1986 and extending through the year 2000. The capital cost of implementing the entire Oak Creek watershed plan is estimated at $10.6 million, representing an average annual capital expenditure over the 15-year period of nearly $710,000. Of this total, about $3.6 million, or about 34 percent, and representing an average annual expenditure of $236,500, is required to implement the park and open space element of the plan, including the acquisition of primary environmental corridor lands; about $5.8 million, or about 55 percent of the total and representing an average annual expenditure of $389,000, is required for implementation of the water quality management element of the plan; about $1.2 million, or about 11 percent of the total and representing an average annual expenditure of about $80,200, is required for implementation of the floodland management element of the plan; and about $65,000, or less than 1 percent and representing an average annual expenditure of about $4,300, is required for implementation of the fishery development element of the plan.

The total capital investment and operation and maintenance cost required for plan implementation may be expected to approximate $1.0 million on an average annual basis, or about $18.05 per capita per year over the 15-year plan implementation period. This per-capita cost is based on a resident watershed population of 56,000 persons—the average resident population in the watershed between the 1980 population level of 39,700 persons and the plan year 2000 population level of 72,600 persons. The average annual costs of implementation of the land use and park and open space element, the water quality management element, the floodland management element, and the fishery development element are estimated at, respectively, $302,800, or $5.41 per capita; $611,000, or $10.91 per capita; $92,800, or $1.66 per capita; and $4,300, or $0.07 per capita.

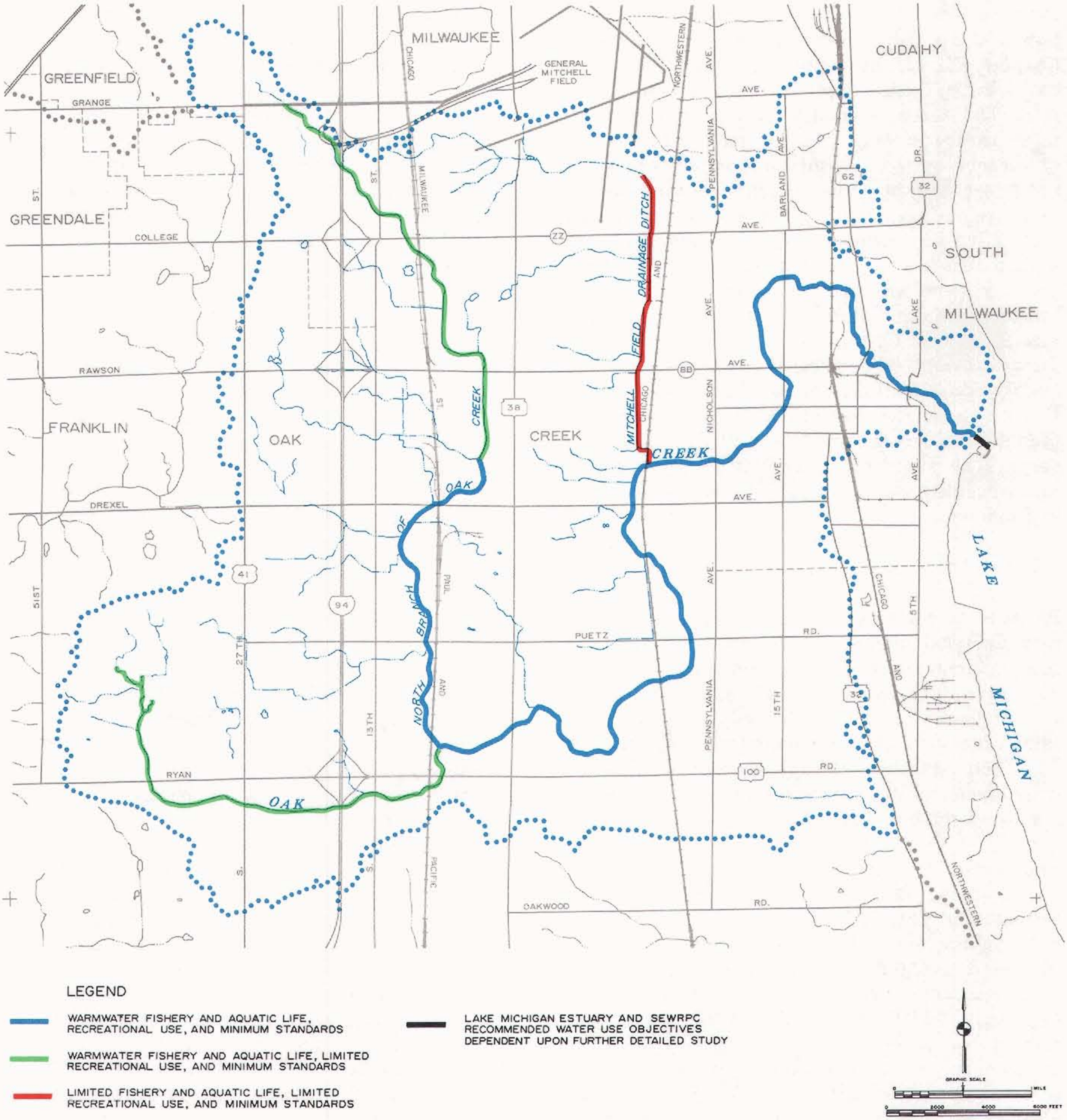
ABILITY OF THE RECOMMENDED COMPREHENSIVE PLAN TO MEET ADOPTED OBJECTIVES AND STANDARDS

The watershed development objectives and supporting standards were formulated early in the Oak Creek 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 Oak Creek watershed planning program consist of objectives and standards adopted under related areawide land use, park and open space, and water pollution abatement planning programs, supplemented with objectives and standards developed under the Oak Creek watershed planning program. The adopted watershed development objectives and supporting standards 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 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 96.

The relatively small number of standards that could not be met or which would be only partially met under the recommended comprehensive plan for the Oak Creek watershed, as indicated in

Map 77

RECOMMENDED WATER USE OBJECTIVES FOR SURFACE WATERS IN THE OAK CREEK WATERSHED: 2000



As a result of an evaluation of the potential for fishery development, and because of the anticipated water quality benefits of the recommended plan, it was necessary to revise the initially recommended water use objectives. The revised objectives include the maintenance of a warmwater fishery and full recreational use along the Oak Creek main stem from the first parkway bridge upstream to the confluence with the North Branch of Oak Creek, and along the North Branch of Oak Creek from its confluence with Oak Creek upstream to a point about 1,300 feet upstream of the first S. 6th Street crossing. Water use objectives providing for the maintenance of a warmwater fishery and limited recreational use are recommended along the Oak Creek main stem upstream of the confluence with the North Branch of Oak Creek, and along the North Branch of Oak Creek upstream of a point about 1,300 feet upstream of S. 6th Street. All other perennial stream reaches are recommended to meet standards for the maintenance of a limited fishery and limited recreational use.

Source: SEWRPC.

Table 96, support objectives that are inextricably related to the underlying natural resource base. The failure to meet those standards reflects the practically unavoidable effects on the natural resource base of the watershed of extensive agricultural development and increasing urbanization, effects not readily assimilated within the relatively small Oak Creek watershed. Nevertheless, adoption and implementation of the recommended watershed plan could result in substantial attainment of the adopted watershed development objectives, and thus 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 within the watershed.

CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE PLAN FOR THE OAK CREEK WATERSHED

Within the framework of the overriding goals of the Oak Creek 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 problems such as flooding, water pollution, diminishing quality of the natural resource base, and changing land use in the Oak Creek watershed; and 2) preventing the aggravation of existing or development of new environmental problems within the basin. This is because preparation of the recommended comprehensive plan for the Oak Creek watershed involved the conduct of extensive inventories; the 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 alternative; the preparation of a plan implementation strategy and capital and operation and maintenance expenditure schedule; and several years of deliberation by the Oak Creek 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 problems and the development of new problems. Because the comprehensive plan for the Oak Creek watershed seeks to identify those courses of action most likely to result in rational, cost-effective, and lasting solutions to the water resource problems of the watershed and the prevention of future problems, it is appropriate to identify and, where feasible, quantify the consequences of not adopting and implementing the recommendations of the comprehensive plan. The analysis of the consequences of not adopting and implementing the watershed plan has a negative aspect in that it identifies water resource problems that may be expected to occur or to be aggravated 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 plan.

The analysis of the likely consequences of not implementing the recommended comprehensive plan for the Oak Creek watershed is based primarily on two sources of information: 1) the data collected and the analyses conducted under the Oak Creek watershed planning program, and 2) empirical information derived from observation of the water resource problems that already exist within the seven-county Planning Region and which have been the subject of other Commission plan activities. The likely consequences of not implementing the recommended comprehensive plan for the Oak Creek watershed are summarized in Table 97. Within the overall framework of the three basic plan elements—the land use and park and open space plan element, the floodland management plan element, and the water quality management plan element—Table 97 identifies each plan subelement and some likely consequences of failure to implement those subelements.

SUMMARY

The various plan elements recommended to be adopted as integral parts of the comprehensive plan for the Oak Creek watershed have all been described separately in the preceding chapters of this report. This chapter presents a concise description of the overall recommended comprehensive plan for the Oak Creek watershed as that plan was synthesized from the best alternatives considered. The comprehensive plan consists of a land use and park and open space element, a water quality management element, a floodland management element, and a fishery development element.

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 the intensification

Table 94

FINAL RECOMMENDED WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR STREAMS IN THE OAK CREEK WATERSHED: 2000[a]

Water Quality Parameters	Warmwater Fishery and Aquatic Life, Recreational Use, and Minimum Standards[b]	Warmwater Fishery and Aquatic Life, Limited Recreational Use, and Minimum Standards[b]	Limited Fishery and Aquatic Life, Limited Recreational Use, and Minimum Standards[b]
Maximum Temperature (^{o}F)	89[c]	89[c]	89[c]
pH Range (standard units)	6.0-9.0[d]	6.0-9.0[d]	6.0-9.0[d]
Minimum Dissolved Oxygen (mg/l)	5.0	5.0	3.0
Maximum Fecal Coliform (counts per 100 ml)	200-400[e]	200-400[e]	200-400[e]
Maximum Total Residual Chlorine (mg/l)	0.014	0.014	0.014
Maximum Un-ionized Ammonia Nitrogen (mg/l)	- -[f]	- -[f]	- -[f]
Maximum Total Phosphorus (mg/l)	0.1	- -	- -
Other	- -[g]	- -[g]	- -[g]

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

[b] *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] *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^{o}F for streams.*

[d] *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.*

[e] *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.*

Table 94 Footnotes (continued)

[f] *The following criteria shall apply for un-ionized ammonia nitrogen (NH_3-N):*

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

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

where:

At water temperatures equal to or greater than $10^{\circ}C$, $f(T) = 1$

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

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

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

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

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

where:

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

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

These un-ionized ammonia nitrogen criteria may be modified, if appropriate, to reflect local site-specific conditions and to protect only those fish and aquatic life species or age or size classes that occur, or are desired, within a certain water body. Such site-specific modifications shall be conducted in conformance with the guidelines set forth in U. S. Environmental Protection Agency, Office of Research and Development, "Guidelines for Deriving Numerical Aquatic Site-Specific Criteria by Modifying National Criteria," draft, December 1982. These site-specific criteria modifications, however, should be used with caution because of a relative scarcity of toxicity information on less sensitive fish and aquatic life species.

[g] *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, the Federal Register, Part V, Environmental Protection Agency, "Water Quality Criteria Documents, Availability," November 28, 1980; Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976; and Water Quality Criteria, 1972, EPA-R3-73,003, National Academy of Sciences, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of 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.*

Source: SEWRPC.

Table 95

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED PLAN FOR THE OAK CREEK WATERSHED BY PLAN ELEMENT AND YEAR: 1986-2000

Calendar Year	Project Year	Land Use and Park and Open Space Element						
		Primary Environmental Corridor		Parks and Recreation Corridor		Subtotal		
		Land Acquisition	Operation and Maintenance	Land Acquisition and Development	Operation and Maintenance	Capital	Operation and Maintenance	Total
1986	1	$ 137,000	$ 2,000	$ 132,530	$ 4,800	$ 269,530	$ 6,800	$ 276,330
1987	2	137,000	4,000	132,530	9,600	269,530	13,600	283,130
1988	3	137,000	6,000	132,530	14,400	269,530	20,400	289,930
1989	4	137,000	8,000	132,530	19,200	269,530	27,200	296,730
1990	5	137,000	10,000	132,530	24,000	269,530	34,000	303,530
1991	6	137,000	12,000	182,530	33,800	319,530	45,800	365,330
1992	7	137,000	14,000	182,530	43,600	319,530	57,600	377,130
1993	8	137,000	16,000	182,530	53,400	319,530	69,400	388,930
1994	9	137,000	18,000	132,530	63,200	319,530	81,200	400,730
1995	10	137,000	20,000	132,530	73,000	319,530	93,000	412,530
1996	11	--	20,000	120,530	78,340	120,530	98,340	218,870
1997	12	--	20,000	120,530	83,680	120,530	103,680	224,210
1998	13	--	20,000	120,530	89,020	120,530	109,020	229,550
1999	14	--	20,000	120,530	94,360	120,530	114,360	234,890
2000	15	--	20,000	120,530	99,700	120,530	119,700	--
Watershed Total		$1,370,000	$210,000	$2,177,950	$784,100	$3,547,950	$994,100	$4,542,050
Annual Average		$ 91,300	$ 14,000	$ 145,200	$ 52,300	$ 236,500	$ 66,300	$ 302,800

NOTE: All costs are estimated in constant 1980 dollars.

Calendar Year	Project Year	Floodland Management Element								
		Channel Deepening and Shaping, and Bridge Replacement		Structure Floodproofing, Elevation, and Removal	Streamflow Gaging	Maintenance of Recreational Navigation		Subtotal		
		Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Total
1986	1	$ --	$ --	$138,400	$ 7,000	$ --	$ --	$ 138,400	$ 7,000	$ 145,400
1987	2	158,500	1,000	138,400	7,000	140,000	5,000	436,900	13,000	449,900
1988	3	158,500	1,000	138,400	7,000	--	5,000	296,900	13,000	309,900
1989	4	--	1,000	138,400	7,000	--	5,000	138,400	13,000	151,400
1990	5	--	1,000	138,400	7,000	55,000	5,000	193,400	13,000	206,400
1991	6	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1992	7	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1993	8	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1994	9	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1995	10	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1996	11	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1997	12	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1998	13	--	1,000	--	7,000	--	5,000	--	13,000	13,000
1999	14	--	1,000	--	7,000	--	5,000	--	13,000	13,000
2000	15	--	1,000	--	7,000	--	5,000	--	13,000	13,000
Watershed Total		$317,000	$14,000	$692,400	$105,000	$195,000	$70,000	$1,204,000	$189,000	$1,393,000
Annual Average		$ 21,100	$ 900	$ 46,100	$ 7,000	$ 13,000	$ 4,700	$ 80,200	$ 12,600	$ 92,800

Table 95 (continued)

Calendar Year	Project Year	Water Quality Management Element					
		Nonpoint Source Pollution Abatement		Water Quality Monitoring	Subtotal		
		Capital	Operation and Maintenance	Operation and Maintenance	Capital	Operation and Maintenance	Total
1986	1	$ 585,000	$ 203,000	$10,000	$ 585,000	$ 213,000	$ 789,000
1987	2	393,000	204,000	--	393,000	204,000	597,000
1988	3	393,000	205,000	--	393,000	205,000	598,000
1989	4	570,000	211,000	--	570,000	211,000	781,000
1990	5	393,000	212,000	--	393,000	212,000	605,000
1991	6	335,000	213,000	10,000	335,000	223,000	558,000
1992	7	486,000	224,000	--	486,000	224,000	710,000
1993	8	335,000	225,000	--	335,000	225,000	560,000
1994	9	335,000	226,000	--	335,000	226,000	561,000
1995	10	335,000	227,000	--	335,000	227,000	562,000
1996	11	335,000	228,000	10,000	335,000	238,000	573,000
1997	12	335,000	229,000	--	335,000	229,000	564,000
1998	13	335,000	230,000	--	335,000	230,000	565,000
1999	14	335,000	231,000	--	335,000	231,000	566,000
2000	15	335,000	232,000	--	335,000	232,000	567,000
Watershed Total		$5,835,000	$3,300,000	$30,000	$5,835,000	$3,330,000	$9,165,000
Annual Average		$ 389,000	$ 220,000	$ 2,000	$ 389,000	$ 222,000	$ 611,000

Calendar Year	Project Year	Fishery Development Element	
		Removal or Modification of Dam and Drop Structures, Instream Habitat Mitigation, Stream Bank Stabilization, Fish Stocking	
		Capital	Subtotal
1986	1	$ --	$ --
1987	2	17,000	17,000
1988	3	16,000	16,000
1989	4	16,000	16,000
1990	5	16,000	16,000
1991	6	--	--
1992	7	--	--
1993	8	--	--
1994	9	--	--
1995	10	--	--
1996	11	--	--
1997	12	--	--
1998	13	--	--
1999	14	--	--
2000	15	--	--
Watershed Total		$65,000	$65,000
Annual Average		$ 4,300	$ 4,300

Calendar Year	Project Year	Total		
		Capital	Operation and Maintenance	Total
1986	1	$ 992,930	$ 226,800	$ 1,219,730
1987	2	1,116,430	230,600	1,347,030
1988	3	975,430	238,400	1,213,830
1989	4	993,930	251,200	1,245,130
1990	5	871,930	259,000	1,130,930
1991	6	654,530	281,800	936,330
1992	7	805,530	294,600	1,100,130
1993	8	654,530	307,400	961,930
1994	9	654,530	320,200	974,730
1995	10	654,530	333,000	987,530
1996	11	455,530	349,340	804,870
1997	12	455,530	345,340	801,210
1998	13	455,530	352,020	807,550
1999	14	455,530	358,360	813,890
2000	15	455,530	364,700	820,230
Watershed Total		$10,651,950	$4,513,100	$15,165,050
Annual Average		$ 709,900	$ 300,900	$ 1,010,800

Source: SEWRPC.

Table 96

ABILITY OF THE RECOMMENDED COMPREHENSIVE PLAN FOR THE OAK CREEK WATERSHED TO MEET ADOPTED WATERSHED DEVELOPMENT OBJECTIVES AND STANDARDS

Objective Number	Objective Description	Standard		Degree to Which Standard is Met
LAND USE OBJECTIVES				
1	A balanced allocation of space to the various land use categories which meets the social, physical, and economic needs of the resident population in the Oak Creek watershed	Residential land allocation	High-density urban—eight net acres per 100 added dwelling units	Met[a]
			Medium-density urban—23 net acres per 100 added dwelling units	Met[a]
			Low-density urban—83 net acres per 100 added dwelling units	Met[a]
			Suburban—167 net acres per 100 added dwelling units	Met[a]
			Rural—500 net acres per 100 added dwelling units	Met[a]
		Park and recreation land allocation	Major—four net acres per 1,000 added persons	Met[a]
			Other—eight net acres per 1,000 added persons	Met[a]
		Industrial land allocation	Seven net acres per 100 added employees	Partially Met[a]
		Commercial land allocation	Major—one net acre per 100 added employees	Partially Met[a]
			Other—two net acres per 100 added employees	Partially Met[a]
		Governmental and institutional land allocation	Nine net acres per 1,000 added persons	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 various land uses which will result in the protection and wise use of the natural resources of the Oak Creek watershed 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 perennial streams in natural state	Met
			50 percent of shoreline of perennial streams in nonurban use	Met
			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	Met
		Woodlands	Protect 10 percent of watershed	Not Met
			Maintain five acres per 1,000 population	Met
		Wildlife	Maintain a wholesome habitat	Met

Table 96 (continued)

Objective		Standard	Degree to Which Standard is Met
Number	Description		
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 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 in terms of both physical characteristics and location	Regional industrial site requirements	Met[a]
		Regional commercial site requirements	Met[a]
		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 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 spatial location	Could be Met[b]
		Regional park spatial location	Met[a]
		Areas of scientific, cultural scientific, and educational value	Met[a]
PARK AND OPEN SPACE OBJECTIVES			
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 Oak Creek watershed adequate opportunity to participate in a wide range of outdoor recreation activities	Sufficient recreation sites to meet the recreation demand of population: Regional	Met
		Multicommunity	Met
		Community	Met
		Neighborhood	Met
		Recreation sites located within corridors	Met[d]
		Linear recreation corridor requirement	Met[d]
		Recreation corridor dimensions	Met[d]
		Travel distance to recreation corridors	Met[d]
		Resource-oriented recreation corridors	Met[d]

Table 96 (continued)

Objective		Standard	Degree to Which Standard is Met
Number	Description		
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
		Preserve all prime agricultural lands	Not Applicable
		Preserve agricultural lands adjoining recreation or educational sites	Partially Met
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
SANITARY SEWERAGE SYSTEM AND WATER QUALITY MANAGEMENT OBJECTIVES			
1	The development of land management and water quality control practices and facilities—inclusive 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 need for stormwater runoff control generated by the existing and proposed land uses	Sanitary sewer service to medium- and high-density urban development	Met[a]
		Sanitary sewer service to low-density development	Met
		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
		Sanitary sewer service restricted in areas of soils with very severe limitations for urban development	Met[a]
		Orderly extension of sanitary sewerage facilities	Could be Met
		Sizing of sewerage facility components in accordance with land use plan	Met
		Treatment and disposal of industrial wastes	Met
		Provision of stormwater management facilities to existing proposed urban areas	Met[c]
		Priority to prime agricultural lands for land management practices	Could be Met[c]
2	The development of land management and water quality control practices and facilities—inclusive of sanitary sewerage systems—so as to meet the recommended water use objectives and supporting water quality standards as set forth on Map 44 and in Table 77	Level of treatment at sewage treatment plant	Not Applicable
		Sewage treatment plant discharge	Not Applicable
		Standards for sewage treatment plants	Not Applicable
		Existing sewage treatment plants scheduled to be abandoned	Not Applicable
		Prohibition of sewage bypasses to storm sewers and waterways	Met
		Elimination of combined sewer overflows	Not Applicable
		Adequate design of sewage treatment plants	Not Applicable
		Interim sewage treatment plants	Not Applicable
		Best practicable treatment of sanitary sewage	Not Applicable
		Best available treatment of industrial sewage	Met[c]
		No nonconforming pollutant discharge	Met[c]
		Stormwater treatment and land management practices	Met[c]
		Stream fencing and feedlot runoff control	Met[c]
		Orderly transition of rural lands to urban uses	Met[c]

Table 96 (continued)

Objective		Standard	Degree to Which Standard is Met
Number	Description		
3	The development of land management and water quality control practices and facilities—inclusive of sanitary sewerage systems—that are properly related to and will enhance the overall quality of the natural and man-made environments	Location of new and replacement sewage treatment plants outside the 100-year recurrence interval floodplain	Not Applicable
		Floodproofing existing sewage treatment plants in the 100-year recurrence interval floodplain	Not Applicable
		Location of new and replacement sewage treatment and stormwater treatment and storage facilities for compatibility with existing and proposed development	Not Applicable
		Provision of aesthetically compatible new and replacement sewage treatment plants with buffer zones between existing and proposed development	Not Applicable
		Disposal of sewage treatment plant sludge	Not Applicable
		Proper location of pollutant storage facilities in relation to the 100-year recurrence interval floodplain	Not Applicable
		Elimination of discharges of metals, pesticides, and other toxic and hazardous substances	Could be Met[c]
		Nondegradation of existing water quality	Could be Met[c]
4	The development of land management and water quality control practices and facilities—inclusive of sanitary sewerage systems—that are economical and efficient, meeting all other objectives at the lowest possible cost	Minimize investment and operating costs of sanitary sewerage systems and stormwater control facilities and related land management practices	Could be Met
		Minimize number of sanitary sewerage system and sewage treatment facilities	Met
		Maximize feasible use of pollution control facilities	Met
		Use of new and improved materials and management practices	Could be Met
		Staged or incremental construction of sanitary sewerage facilities	Met
		Minimize land acquisition costs for new sewer construction	Met
		Minimize excessive clear water inflows and infiltration into sanitary sewerage system	Met
		Integrated design of sanitary and storm sewer systems	Could be Met
5	The development of water quality management institutions—inclusive of the governmental units and their responsibilities, authorities, policies, procedures, resources, and supporting revenue-raising mechanisms which are effective and locally acceptable, and which will provide a sound basis for plan implementation, including the planning, design, construction, operation, maintenance, repair and replacement of water quality control practices and facilities, inclusive of sanitary sewerage systems, stormwater management systems, and land management practices	Develop and establish system of user charges and industrial cost recovery for program support	Could be Met
		Maximum utilization of existing institutional structures	Met
		Water pollution control by local entities	Met
		Provide management groups with necessary resources	Could be Met

Table 96 (continued)

Objective		Standard		Degree to Which Standard is Met
Number	Description			
		WATER CONTROL OBJECTIVES		
1	An integrated system of drainage and flood control facilities and floodland management programs which will effectively reduce flood damage under the existing land use pattern of the watershed and promote the implementation of the 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 recurrence interval flood	Could be Met
			Arterial streets and highways—pass the 50-year recurrence interval flood	Could be Met
			Freeways and expressways—pass the 100-year recurrence interval flood	Could be Met
			Railroads—pass the 100-year recurrence interval flood	Could be Met
		New or replacement bridges and culverts shall pass the 100-year recurrence interval flood without raising the peak stage more than 0.1 feet		Could be Met
		Structure design shall maximize passage of ice flow and debris		Could be Met
		Certain new and replacement bridges and culverts shall pass the 100-year recurrence interval flood with two feet of freeboard		Could be Met
		Existing bridges and culverts to meet standards 1, 3, and 4 above		Not Met
		Channel improvements, dikes, and floodwalls should be restricted to the absolute minimum necessary		Met
		The height of dikes and floodwalls shall pass the 100-year recurrence interval flood with two feet of freeboard		Not Applicable
		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		Not Applicable
		All other water control facilities such as dams or diversion channels shall accommodate the 100-year recurrence interval flood		Not Applicable
		Public land acquisition to eliminate water control facilities shall encompass the entire 100-year recurrence interval floodplain		Partially 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		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 support recreational use	Satisfy established water quality standards which are applicable except during 1) extreme low-flow periods and 2) extreme conditions recognized in the probabilistic approach to water quality standards achievement		Met
		Flood control and stormwater management facilities designed to minimize negative impacts on fish and aquatic life and to support water use objectives.		Met

[a] *This standard has been met under the recommended land use plan and 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.*

[c] *This standard has been met under the recommended water quality management plan because it served as an input to the plan design process.*

[d] *This standard has been met under the recommended regional Park and Open Space plan because it served as an input to the plan design process.*

Source: SEWRPC.

Table 97

PROBABLE CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE PLAN FOR THE OAK CREEK WATERSHED

Plan Element	Plan Subelement	Probable Consequences of Failure to Implement Plan Recommendations
Land Use	Overall land use	● Increased cost of public utilities and services such as sanitary sewerage, water supply, transportation, and police and fire protection ● Essentially all of the negative consequences discussed below, since most are inextricably related to the land use plan
	Primary environmental corridor	● Loss of recreational, aesthetic, ecologic, and cultural values found in essentially natural unprotected riverine lands and associated woodland, wetland, and wildlife habitat areas
	Park and open space plan	● Loss of recreational, aesthetic, environmental, and cultural values in park and open space lands
	Recreational trails	● Prevention of full public use and enjoyment of primary environmental corridor lands
Floodland Management	Flood control measures for watershed	● Continuation of the average annual flood damage risk of $29,000 or more under existing conditions
	Bridge replacement (for transportation purposes)	● Interference with operation of highway and railroad facilities during flood events
	Land use controls	
	Floodland regulations	● Increased flood losses due to construction of new flood-prone structures ● Aggravation of upstream and downstream flood problems due to loss of conveyance and storage resulting in an increase in average annual flood damages ● Loss of critical portions of primary environmental corridors
	Control of land use outside floodlands	● Increased runoff to the stream system resulting in an increase in average annual flood damages
	Flood insurance	● Large monetary losses absorbed by owners of flood-prone structures and property
	Lending institution and realtor policies	● Acquisition 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
	Accessory considerations	
	Stream gaging network	● Lack of critical flow data on actual flood events for use in monitoring urbanization effects and in eventually refining simulation models
	Maintenance of recreational navigation at mouth of Oak Creek	● Continued problem of sandbar development resulting in inability to use Grant Park boat launch
Fishery Development	Development of Oak Creek fishery	● Lack of a balanced fish population ● Lack of a recreational sport and forage fishery ● Loss of funding for the navigational channel jetty and fishing pier for the handicapped ● Continuing water quality problems and nuisances within the Mill Road dam pond as a result of the maintenance of the pond environment ● Continued cost of dredging and dam maintenance for the Mill Road dam ● Loss of ecological, aesthetic, and educational values associated with a balanced fish and aquatic life community ● Loss of impetus for implementing additional watershed plan elements such as the water quality and park and open space plan elements

Table 97 (continued)

Plan Element	Plan Subelement	Probable Consequences of Failure to Implement Plan Recommendations
Water Quality	Industrial discharge abatement	● Localized pollution problems
	Sanitary sewer service to all new urban development	● Localized and instream hazards and localized objectional aesthetic conditions
	Elimination of malfunctioning onsite disposal systems	● Continued contamination of surface waters and groundwater with pathogenic pollution and continued nutrient loading and aesthetic pollution of streams
	Rural and urban nonpoint source pollution control measures	● Continued watershedwide surface water quality degradation during and immediately after runoff events, as well as during normal and low-flow periods
	Water quality monitoring program	● Lack of data for use in documenting impact of watershed development on water quality

Source: SEWRPC.

of existing and 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 the intensification of flood damage and water pollution problems. Primary environmental corridor preservation would be accomplished by public regulation and acquisition of corridor lands. In addition to recommending the preservation of the 417 acres of existing primary environmental corridor lands in the watershed, the plan recommends that 579 acres of publicly owned land and land proposed for public acquisition be restored to wetland vegetation. The recommended plan would accommodate a plan year 2000 population in the watershed of about 72,600 persons and a planned employment level of about 27,300 jobs. To accommodate the increase in population and employment, an additional 11 square miles of land would be converted from rural to urban use.

The overall land use plan element for the Oak Creek watershed is intended, in part, to minimize the aggravation of existing flood problems and help prevent future flood problems. Structural and nonstructural flood control measures are also recommended, where necessary, to resolve existing flooding problems and enhance the overall drainage system of the watershed. In particular, the floodland management plan element recommends channel deepening and shaping along 1.4 miles of Oak Creek and 1.0 mile of the North Branch of Oak Creek, as well as the floodproofing, elevation, or removal of up to 29 structures. Local drainage problems within the watershed are recommended to be addressed through stormwater management system plans to be prepared on a subwatershed basis.

In addition to the foregoing measures, the floodland management element of the plan includes recommended standards relative to bridge replacement to assure that major streets and highways remain operable during major flood events. Based upon the application of these standards, it was determined that, of the 101 bridges and culverts in the watershed, a total of 18 crossings are hydraulically inadequate. Two additional crossings are to be replaced under recommended flood control measures. Also included in the floodland management element are various supplemental measures intended to minimize the monetary losses associated with flooding, including participation in the federal Flood Insurance Program and continuation of desirable lending institution and realtor policies concerning the sale of riverine area properties.

Finally, the floodland management element includes two recommendations which, while not directly related to floodland management, relate to the hydrology and hydraulics of the watershed. The first recommendation is for the maintenance of a basic cooperative stream gaging program. The second recommendation is for a plan to alleviate the chronic sandbar formation problem at the mouth of Oak Creek. Specifically, this element recommends the construction of a navigation channel at the mouth of Oak Creek which would allow passage of small fishing and recreational boats. This construction would be supplemented by either minimal dredging or the flushing of accumulated sand with either water stored behind a dry dam to be located just upstream from the Grant Park boat launch or water pumped through diffusers placed within the navigation channel.

The fishery development element of the Oak Creek watershed plan calls for the following measures intended to improve the quality of the Oak Creek fish population: 1) notching the existing Mill Road dam down to the streambed to provide an opening of 40 feet at the top of the dam and 10 feet at the base of the dam; 2) dredging a portion of the accumulated sediment behind the Mill Road dam to normalize the streambed gradient and to re-create stream meanders; 3) removal or modification of five sill and drop structures; 4) instream habitat mitigation measures; 5) stream bank stabilization measures; and 6) an initial fish stocking program.

The recommended Oak Creek watershed plan incorporates those water quality management measures set forth in the adopted regional water quality management plan which are directly applicable to the Oak Creek watershed. These include the control of industrial waste discharges to the stream system, the institution of measures to control nonpoint source pollution from both rural and urban land surfaces, and the development of a water quality monitoring program for the watershed.

A preliminary schedule of capital and operating and maintenance costs was prepared which, if followed, would result in total watershed plan implementation by the year 2000. The capital cost of implementing the entire Oak Creek watershed plan is estimated at $10.6 million, representing an average annual capital expenditure over the 15-year period of nearly $710,000. Of this total, about $3.6 million, or about 34 percent and representing an average annual expenditure of $236,500, is required to implement the park and open space element of the plan, including the acquisition of primary environmental corridor lands; about $5.8 million, or about 55 percent of the total and representing an average annual expenditure of $389,000, is required for implementation of the water quality management element of the plan; about $1.2 million, or about 11 percent of the total and representing an average annual expenditure of about $80,200, is required for implementation of the floodland management element of the plan; and about $65,000, or less than 1 percent and representing an average annual expenditure of about $4,300, is required for implementation of the fishery development element of the plan.

The total capital investment and operation and maintenance cost required for plan implementation may be expected to approximate $1.0 million on an average annual basis, or about $18.05 per capita per year over the 15-year plan implementation period. This per-capita cost is based on a resident watershed population of 56,000 persons—the average resident population in the watershed between the 1980 population level of 39,700 persons and the plan year 2000 population level of 72,600 persons. The average annual cost of implementation of the land use and park and open space element, the water quality management element, the floodland management element, and the fishery development element are estimated, respectively, at $302,800, or $5.41 per capita; $611,000, or $10.91 per capita; $92,800, or $1.66 per capita; and $4,300, or $0.07 per capita.

The comprehensive plan was evaluated for its ability to meet the adopted watershed development objectives and standards. 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, more healthful, and more pleasant, as well as 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 Oak Creek 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 watershed plan implementation, the Oak Creek watershed will be susceptible to aggravation of the existing water resource problems and to the development of new problems.

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Chapter XV

PLAN IMPLEMENTATION

INTRODUCTION

The recommended comprehensive plan for the Oak Creek watershed, as described in Chapter XIV of this report, provides a design for the attainment of the watershed development objectives formulated under the Oak Creek 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 nonpoint source pollution abatement subelements.[1]

While the recommended comprehensive plan for the Oak Creek 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 intended as a guide for use in the implementation of the Oak Creek 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 Oak Creek 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 concerned 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 for implementation of the watershed plan are identified.

[1] *The recommended land use plan element, the floodland management plan element, and the water quality management plan element, as well as the process used to arrive at these elements and the alternatives considered, are described in Chapters XI, XII, and XIII, respectively.*

PRINCIPLES OF PLAN IMPLEMENTATION

The plan implementation recommendations contained in this chapter are, to the maximum extent possible, based upon and related to existing 1985 governmental programs and are predicated upon enabling legislation. Because of the ever-present possibility of unforeseen changes in economic conditions, state and federal legislation, case law decisions, governmental organizations, and tax and fiscal policies, it is not possible to declare once and for all time 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 not only must 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 in which to achieve the necessary plan implementation—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, state, and federal 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 Oak Creek 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 concerned can contribute substantially toward implementation of the recommended watershed plan.

With respect to 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 for structural flood control measures and pollution abatement 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 recreational facilities. The preparation of such detailed plans will require the continuing development of close working relationships between the Commission, the Milwaukee County Board, the local units of government concerned, and certain other agencies—in particular, the Milwaukee Metropolitan Sewerage District and 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 facilitate 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 and Construction Phases of the Public Works Development Process

The planning process used to prepare the Oak Creek 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 Oak Creek watershed plan requires an understanding of this three-phase process, the process is briefly described below. Although emphasis is placed on use of the process in preparing a comprehensive plan for the Oak Creek watershed and in the subsequent steps needed to advance that plan toward implementation, it is important to note that the three-phase 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, park and open space, 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 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 resource 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 land use in one portion of a watershed can markedly influence the environment in other areas of the watershed; for example, urban development and channel modifications can have a significant impact 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 the watershed. Therefore, the regional land use plan—as refined and detailed in the watershed planning process—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 is comprehensive in that a full spectrum of potential solutions to the water resource problems are considered during the public works development 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 technical, economic, environmental, and other features of the plan elements be analyzed in 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 by the implementing units and agencies of government concerned subsequent to the adoption of the areawide systems plan.

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 presumes that the optimum solution has been identified under the systems planning phase. Preliminary engineering concentrates on examining variations of the recommended solution and on examining the technical, economic, environmental, 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 contractors to submit bids for the project and to actually construct the recommended works. Engineers responsible for carrying out the final phase should also be responsible 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-phase public works development process does not always proceed in a simple, linear three-step fashion. 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.

Changing federal and state regulations and guidelines can disrupt the three-phase process. This is particularly true if a significant change in those regulations and guidelines occurs subsequent to the systems planning phase and prior to or during the preliminary engineering phase, thus necessitating an iteration to the systems planning phase to reconsider measures studied during that phase or to analyze additional measures as may be necessitated by regulation and guideline changes. During the passage of time between the systems planning phase and the 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 be rejected or encounter considerable opposition, necessitating an iteration 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 in terms of technical practicality, economic feasibility, and environmental impact. Superimposition 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 certain state and federal regulations, applications by state and local units of government for federal grants in partial support of the planning for, 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 agency. The comments and recommendations of the areawide planning agency must include information on the extent to which the proposed project is consistent with the comprehensive planning program for the region, and the extent to which such a project contributes to the fulfillment of such planning programs. The review comments and recommendations of the areawide planning agency are 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 reviews can be of material assistance in achieving implementation of the recommended Oak Creek 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 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 certified as being either 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 Oak Creek 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 completely advisory role of the Commission makes actual implementation of the recommended Oak Creek watershed plan entirely dependent upon action by local, areawide, state, and federal agencies of government. Examination of the various agencies that are available to implement the recommended watershed plan under existing enabling legislation 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 counties, cities, villages, and towns 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 public agencies in existence, it becomes 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.[2] The agencies are, for convenience, discussed by level of government; however, the interdependence between the various levels, as well as between agencies of government, and the need for close intergovernmental cooperation cannot be overemphasized. 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

[2] *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.*

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 Oak Creek 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 Oak Creek watershed plan. The Oak Creek 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 Oak Creek 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 Agencies: County government has considerable latitude available in forming agencies to perform the park and outdoor recreation and zoning and planning functions of the county. Counties may organize park commissions or park and planning commissions pursuant to Section 27.02 of the Wisconsin Statutes. 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, however, essentially the same no matter how an individual county chooses to organize these functions.

In Milwaukee County, the Milwaukee County Parks, Recreation and Culture Committee of the County Board is responsible for the acquisition, development, operation, and maintenance of parks and parkways. Staff services for park and parkway matters are provided by the County Department of Parks, Recreation and Culture, which reports to the referenced County Board Committee. Because Milwaukee County contains no unincorporated area, there is no county zoning authority, and neither the County Board Committee nor the Department carries out any related land use planning functions.

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. This requirement is met in the Oak Creek watershed through the Transportation and Public Works Committee of the Milwaukee County Board. 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 has important responsibilities with respect to the recommended construction and reconstruction of certain highway bridges within the Oak Creek watershed.

County Land Conservation Committees: In 1982 the State Legislature abolished the former system of county soil and water conservation districts. These districts, while closely allied with county government operations, were, in fact, separate governmental units. In place of that system, the county boards of supervisors are required to create within each county of the State a land conservation committee. In so doing, the State Legislature recognized that the county is the dominant local unit of government responsible for natural resource protection programs, and in particular for soil and water conservation programs.

The land conservation committees have a broad range of discretionary authority, including the development and adoption of standards and specifications for management practices to control erosion, sedimentation, and nonpoint sources of water pollution; the distribution and allocation of available federal and state cost-sharing funds for soil and water conservation; the conduct of research and educational information programs about soil and water conservation; the conduct of programs designed to prevent flood damage and drainage, irrigation, groundwater, and surface water problems; the provision of financial, technical, and other assistance to landowners; the acquisition of land and other interests and property; the acquisition of machinery, equipment, and supplies required to carry out various land conservation programs; and the construction, improvement, operation, and maintenance of structures needed for land conservation, flood prevention, and nonpoint source pollution control. In addition, land conservation committees are charged with the duty of preparing a long-range natural resource conservation plan for the county, including an erosion control plan and program. All of the activities of the land conservation committees are closely supervised by the county boards and subject to the fiscal resources made available by those boards.

Municipal Planning Agencies: Municipal planning agencies include city, village, and town 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 the Statutes.

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 Oak Creek watershed plan.

Milwaukee Metropolitan Sewerage District: The Milwaukee Metropolitan Sewerage Commission, which operates pursuant to Sections 66.88 through 66.918 of the Wisconsin Statutes, has the power to project, plan, and construct sewage treatment plants, main and intercepting sewers, and pumping and temporary disposal works for the collection and transmission of domestic, industrial, and other sanitary sewage within the Milwaukee Metropolitan Sewerage District. The District consists of all of Milwaukee County except the City of South Milwaukee and the southern portion of the Cities of Franklin and Oak Creek, and of those portions of the City of Milwaukee and Village of Bayside in Washington and Ozaukee Counties, respectively. The boundaries of the District are shown on Map 43 in Chapter IX. The Milwaukee Metropolitan Sewerage Commission, furthermore, may improve any watercourse within the District by deepening, widening, or otherwise changing the watercourse where such change is deemed necessary to carry off surface or drainage waters. Clearly, the District has important watershed plan implementation functions relative to flood control and pollution abatement.

Regional Planning Commission: Although not a plan implementation agency as such, 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 Oak Creek Watershed Committee, which should remain as an important public planning organization in the watershed.

State Level Agencies

The following state level agencies have either general or specific planning authority and hold certain plan implementation powers important to the adoption and implementation of the comprehensive Oak Creek watershed plan.

Wisconsin Department of Natural Resources (DNR): The DNR has broad authority and responsibility in the areas of park development, natural resources protection, water quality control, and water regulation. The DNR 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, and to acquire conservation and scenic easements. Pursuant to federal planning guidelines, the Secretary of the DNR is responsible for certifying areawide plans for water quality management to the U. S. Environmental Protection Agency (EPA). 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 noted in Chapter IX of this report, the responsibility for water pollution control in Wisconsin is centered in the Wisconsin Department of Natural Resources. The water pollution control authority and responsibilities of the DNR are set forth in Chapter 144 of the Wisconsin Statutes. Under this chapter, the DNR is given broad authority to prepare water use objectives and supporting water quality standards; to issue general and specific orders relating to water pollution abatement; to review and approve all plans and specifications for components of sanitary sewerage systems; to conduct research and demonstration projects on sewerage and waste treatment matters; to operate an examining program for the certification of sewage treatment plant operators; to order the installation of centralized sanitary sewerage systems; to review and approve the creation of joint sewerage systems and metropolitan sewerage districts; and to administer a financial assistance program for the construction of pollution prevention and abatement facilities. In addition, under Chapter 147 of the Wisconsin Statutes, the DNR is given broad authority to establish and carry out a pollutant discharge elimination program in accordance with the policy guidelines set forth by the U. S. Congress under the Federal Water Pollution Control Act Amendments of 1972. This legislation establishes a waste discharge permit system and provides that no permit may be issued by the DNR for any discharge from a point source of pollution that is in conflict with any areawide wastewater treatment and water quality management plan approved by the DNR. Also, under this legislation the DNR is given rule-making authority to establish effluent limitations, water quality limitations, performance standards related to classes or categories of pollution, and toxic and pretreatment effluent standards. All permits issued by the DNR must include the conditions that waste discharges must meet, as applicable; all effluent limitations, performance standards, effluent prohibitions, and pretreatment standards; and any other limitations which must be met to comply with the established water use objectives and supporting water quality standards as developed under areawide waste treatment management planning programs. As appropriate, the permits may require periodic water quality monitoring to determine compliance, and may include a timetable for appropriate action on the part of the owner or operator of any point waste discharge. This legislation, along with accompanying procedures, is the primary tool used by the Wisconsin Department of Natural Resources to achieve the water use objectives and supporting water quality standards.

The DNR 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 DNR 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 DNR 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 DNR has authority to require the abatement of water pollution; to administer state financial aid programs for water resource protection; to assign priority for federal aid applications for sewerage facilities; to review and approve water supply and sewerage systems; and to license well drillers and issue permits for high-capacity wells. With such broad authority for the protection of the natural resources of the State and the Region, the DNR will be extremely important to the implementation of nearly all of the major elements of the comprehensive Oak Creek watershed plan.

Wisconsin Department of Transportation (WisDOT): This Department is broadly empowered to provide the State with an integrated transportation system. The WisDOT is responsible for administering all state and federal aid for 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 WisDOT is also responsible for reviewing and approving changes in county trunk highway systems. As such, the WisDOT, along with the respective county highway committees of the county boards of supervisors concerned, can contribute to full implementation of the Oak Creek watershed plan.

Wisconsin Department of Agriculture, Trade and Consumer Protection: Under the Wisconsin Soil and Water Conservation Law, state level soil and water conservation responsibilities have been placed in the Wisconsin Department of Agriculture, Trade and Consumer Protection. Within that

Department, the law created a seven-member advisory Land Conservation Board. The Land Conservation Board reviews and comments on rules relating to soil and water conservation, administers the State's farmland preservation program, reviews all county erosion control plans and the annual county and long-range county land conservation plans, and generally advises the Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection and the University of Wisconsin on matters relating to soil and water conservation. As such, the Department and its Land Conservation Board will have plan implementation responsibilities relative to the Oak Creek watershed plan.

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 informational 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

The following federal level agencies administer federal aid and assistance programs that can have important implications for implementation of the recommended Oak Creek watershed plan because of their potential impact on the financing of both land acquisition and construction of specific facilities.

U. S. Environmental Protection Agency (EPA): The U. S. Environmental Protection Agency administers water quality management planning grants and sanitary sewerage facility construction grants. The latter can be particularly important to implementation of the water quality management element of the Oak Creek 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 EPA 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 EPA, 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 a continuing areawide water quality management planning program for southeastern Wisconsin.

U. S. 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 streamflow gaging program recommended in the Oak Creek watershed plan.

U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service: This agency administers the Federal Agricultural and Conservation Program (ACP). This program provides grants to rural landowners in partial support of carrying out approved land and water conservation practices. Grants from this program could contribute to implementation of the land use and water quality elements of the Oak Creek watershed plan.

U. S. 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 land conservation committees 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 contribute to implementation of the land management and treatment measures recommended in the Oak Creek watershed plan.

Federal Emergency Management Agency: The Federal Emergency Management Agency is the primary federal agency responsible for emergency matters, including flooding emergencies. The agency provides technical assistance programs to state and local governments to reduce or eliminate flood risks and administers programs to assist individuals and businesses in obtaining insurance protection against floods. In order to ensure that its residents are eligible for the purchase of flood insurance, local communities must ensure that their floodland zoning regulations meet the minimum standards set forth in rules published by the Federal Emergency Management Agency.

U. S. Army Corps of Engineers: The U. S. Army Corps of Engineers can conduct planning studies and construct flood control facilities as authorized by the U. S. Congress. There are two programs which could be used by the Corps to undertake plan implementation activities in the Oak Creek watershed. Under Section 205 of the Federal Flood Control Act of 1948, as amended, the Corps is authorized under its small continuing authorities program to contribute to the design and construction phases of certain flood control projects, provided the maximum cost to the Corps is $4 million or less. Projects to be undertaken under this program may be authorized by the Chief of Engineers. A second program, the general investigation program, requires explicit congressional authorization and appropriation. This type of program would be carried out in several phases, including a three-stage feasibility study followed by a construction phase. Both the feasibility study and the construction phase require explicit congressional approval, and implementation of projects under the program can require more than a decade to accomplish. There is no statutory limit to the funding which can be made available under this program. However, projects under both programs must be demonstrated to be economically feasible and environmentally sound.

While the structural flood control elements of the recommended Oak Creek watershed floodland management plan can be implemented by existing local units and agencies of government, the Corps of Engineers could participate in such implementation. This would require strong congressional, as well as local, support. Local implementation would be more certain and expeditious, but this certainty and expediency must be weighed by the governing bodies concerned against the financial support that may be available for plan implementation.

The Corps of Engineers also administers a regulatory program relating to the discharge of dredge and fill materials into the waters of the United States and adjacent wetlands. This program is administered pursuant to Section 404 of the Federal Water Pollution Control Act as amended in 1972. The administration of this program will have importance with respect to the land use, park and open space, floodland management, and water quality management elements of the Oak Creek watershed plan.

PLAN ADOPTION AND INTEGRATION

Upon adoption of the Oak Creek 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 Oak Creek 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 acknowledgement of the comprehensive watershed plan by the local legislative bodies and the existing local, areawide, state, and federal level agencies concerned is highly desirable to assure a common understanding among the several governmental levels and to enable their staffs to program the necessary implementation work. This acceptance or acknowledgement is, in some cases, required by the Wisconsin Statutes before certain planning actions can proceed. For example, such a requirement holds for city and village plan commissions created pursuant to Section 62.23 of the Wisconsin Statutes. In addition, formal plan adoption may be required for state and federal financial aid eligibility. A model resolution for adoption of the comprehensive plan for the Oak Creek watershed is provided in Appendix I. Adoption of the recommended Oak Creek watershed plan by any unit or agency of government pertains only to the statutory duties and functions of the adopting agencies, and does not and cannot in any way preempt or commit action by another unit or agency of government acting within its own area of functional and geographic jurisdiction.

Upon adoption or endorsement of the Oak Creek watershed plan by a unit or agency of government, it is recommended that the policy-making body of the unit or agency direct its staff to review in detail the plan elements of the comprehensive watershed plan. Once such review is completed, the staff can propose to the policy-making body for its consideration and approval the steps necessary to fully integrate the watershed plan elements into the plans and programs of the unit or agency of government.

Local Level Agencies

1. It is recommended that the Milwaukee County Board of Supervisors formally adopt the Oak Creek watershed plan by resolution, pursuant to Section 66.945(12) of the Wisconsin Statutes, after the issuance of a report and recommendation by the County Parks, Recreation and Culture Committee, the County Transportation and Public Works Committee, and the County Land Conservation Committee.

2. It is recommended that the Plan Commissions of the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee adopt the Oak Creek 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 upon such certification the governing bodies also adopt the recommended plan.

Areawide Agencies

1. It is recommended that the Milwaukee Metropolitan Sewerage Commission adopt the recommended Oak Creek watershed plan as the plan affects the work of that Commission.

State Level Agencies

1. It is recommended that the Wisconsin Natural Resources Board endorse the comprehensive Oak Creek watershed plan as an amendment to the previously endorsed regional water quality management plan, certify the plan as an amendment to the regional water quality management 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 Board, through its staff, coordinate the recommended Oak Creek watershed plan with those activities relating to water regulation and control; floodland, shoreland, and wetland zoning; and water quality management planning and water pollution abatement activities.

2. It is recommended that the Secretary of the Wisconsin Department of Transportation endorse the Oak Creek watershed plan and direct the Department staff to give due consideration to the plan in the exercise of its various responsibilities governing the construction and reconstruction of highway and attendant drainage facilities in the watershed.

3. It is recommended that the Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection, upon recommendation of the Land Conservation Board, endorse the Oak Creek watershed plan and direct the Department staff to give due consideration to the plan in the exercise of its various responsibilities governing farmland preservation and soil and water conservation.

Federal Level Agencies

1. It is recommended that the U. S. Environmental Protection Agency formally accept and endorse the Oak Creek watershed plan as an amendment to the regional water quality management plan upon certification as such by the State of Wisconsin.

2. It is recommended that the U. S. Geological Survey endorse the Oak Creek watershed plan and continue its cooperative stream gaging program within the watershed.

3. It is recommended that the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, formally acknowledge the Oak Creek watershed plan and utilize the plan recommendations in its administration of the federal agricultural and conservation program.

4. It is recommended that the U. S. Soil Conservation Service formally acknowledge the Oak Creek watershed plan and utilize the plan recommendations in the administration of its various soil and water conservation technical assistance programs.

5. It is recommended that the Federal Emergency Management Agency formally acknowledge the Oak Creek watershed plan and use the floodland data in that plan as a basis for reviewing and updating its series of federal flood insurance studies.

6. It is recommended that the U. S. Army Corps of Engineers formally acknowledge the Oak Creek watershed plan. It is further recommended that the Corps cooperate with any local or state units and agencies of government requesting assistance in the review, design, and construction of the floodland management elements of the recommended Oak Creek watershed plan. It is also recommended that the Corps of Engineers use the land use and environmental corridor elements of the plan in carrying out its regulatory program relative to the placement of fill and the conduct of other activities in wetlands.

SUBSEQUENT ADJUSTMENT OF THE PLAN

No plan can be permanent in all of its aspects or precise in all of its elements. The very definition and characteristics of areawide planning suggest that for an areawide plan, such as a comprehensive watershed plan, to be viable and of use to local, state, and federal units and agencies of government, the plan must 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 Oak Creek 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 the most effectively and efficiently, and therefore to assure timely adjustments of the watershed plan, it is recommended that all of the foresaid state, areawide, and local agencies having plan and plan implementation powers advise and transmit all subsequent planning studies, plan proposals and amendments, and plan implementation devices to the Regional Planning Commission for consideration. Of particular importance in this respect will be the continuing role of the Oak Creek Watershed Committee in intergovernmental coordination.

LAND USE PLAN ELEMENT IMPLEMENTATION

The implementation of the land use plan element—including the overall land use, open space preservation, and outdoor recreation components—of the comprehensive Oak Creek 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 elements 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 of flood damage mitigation will be achieved. 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 and parkway lands remaining within the watershed. Although all of the plan implementation recommendations are closely interrelated, this section has been divided for convenience into the following major subject areas: overall land use plan element, open space preservation plan element, and outdoor recreation plan element. The recommended implementation actions are summarized in Table 98, and a schedule of the capital and operation and maintenance costs of this plan element is set forth in Table 99.

Overall Land Use Plan Element

The overall land use plan element of the Oak Creek watershed plan is a refinement of the year 2000 regional land use plan, which in turn was included within the year 2000 regional water quality management plan. The overall land use plan element deals with land use both within and outside the riverine areas of the watershed.

Implementation of the overall land use plan element can best be accomplished through the adoption of the Oak Creek watershed plan and the implementation of that plan through local, state, and federal land use and related regulations. The following methods are suggested for use in this respect.

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. Within the Oak Creek watershed, zoning is the responsibility of the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee. In general, it is recommended that each of these communities review and, as necessary, revise their existing zoning ordinances and zoning district maps so as to implement the land use plan element of the Oak Creek watershed plan. The following suggestions are made to all zoning agencies within the watershed to assist them in this task.

Residential and Related Urban Areas: Not all of the areas shown as devoted to residential and other urban uses in the recommended watershed land use plan should be initially placed in urban land use districts. Only existing and platted but not yet fully developed residential areas and those areas that have immediate development potential that can be economically served by municipal utilities and facilities—in particular, sanitary sewerage and water supply facilities—should be placed in exclusive residential districts related to the development densities indicated on the recommended watershed land use plan.

The balance of the proposed residential land use areas should be placed in exclusive agricultural districts which would act as holding zones for future development. Such holding districts should be rezoned into the appropriate residential zoning district or supporting land use district, such as business or industrial districts, only when the community can economically and efficiently accommodate the proposed development. Certain residential areas may be initially zoned for very low-density "country estate" and related rural and outdoor recreational uses. All residential zoning, however, should be properly related to the inherent suitabilities of the underlying soil resource base.

Agricultural and Open Areas: Areas shown as agricultural and other open land in the recommended watershed land use plan should be placed in an exclusive agricultural use district which essentially permits only agricultural uses and which prohibits land division into parcels of less than 35 acres in size. Significant wetlands, woodlands, and wildlife habitat areas that may lie outside the environmental corridors but within the general agricultural and open space areas in the southeastern portion of the watershed should be placed in appropriate conservancy zoning districts.

Primary Environmental Corridors: The primary environmental corridors shown on the recommended watershed land use plan should be placed into one of several zoning districts as dictated by consideration of existing development; the character of the specific resource values to be protected within the corridor; and the attainment of the outdoor recreation, open space preservation, and resource base conservation objectives of the watershed plan. Prime wildlife habitat areas, wetlands, woodlands, and undeveloped floodlands lying in the corridors generally should be placed in conservancy districts. Existing and potential park sites lying in the corridors should be placed in park districts that permit the development of appropriate private and public recreational facilities.

Floodlands: Floodland regulations should be reviewed and updated as necessary in order to ensure the substantial maintenance in open uses of all undeveloped floodways and floodplains in the watershed. Either a basic floodland use district or an overlay floodland use district approach may be taken, depending upon local preference. In those cases where urban development already exists in the floodplain and where the watershed plan recommends structural measures for the abatement of flood damages, including structure floodproofing and elevation, and the undertaking of channel improvements, it will be necessary to identify

Table 98

SUMMARY OF MAJOR OAK CREEK WATERSHED PLAN ELEMENTS AND PRIMARY IMPLEMENTING GOVERNMENTAL UNITS AND AGENCIES

Action or Project	Responsible Unit of Government									
	Milwaukee County	City of Cudahy	City of Franklin	City of Greenfield	City of Milwaukee	City of Oak Creek	City of South Milwaukee	Milwaukee Metropolitan Sewerage District	Wisconsin Department of Natural Resources	U. S. Department of the Interior, Geological Survey
Plan Adoption/Endorsement	X	X	X	X	X	X	X	X	X	X
Land Use Element										
General Zoning Ordinance Review/Revision		X	X	X	X	X	X			
Floodland Zoning Ordinance Review/Revision			X		X	X	X			
Shoreland-Wetland Zoning Ordinance Review/Revision			X		X	X	X			
Park and Open Space Element										
Primary Environmental Corridor Land Acquisition	X									
Wetland Aquisition and Restoration	X									
Recreational Trail Development	X									
Falk Park Development	X									
Neighborhood Park Development	X		X			X				
Floodland Management Element										
Oak Creek Channel Modifications								X		
North Branch of Oak Creek Channel Modifications								X		
Structure Floodproofing					X	X				
Structure Removal								X		
Oak Creek Mouth Jetty	X								X	
Oak Creek Mouth Diffusers or Dry Dam	X								X	
Streamflow Gaging					X			X		X
Fishery Development Element	X						X		X[a]	
Water Quality Management Element										
Nonpoint Source Pollution Control	X	X	X	X	X	X	X			
Sedimentation Basin Construction	X									

[a] *The Wisconsin Department of Natural Resources is recommended as the lead agency.*

Source: SEWRPC.

floodway districts for selected stream reaches so as to permit the placement of this urban development into floodplain fringe overlay districts, thereby avoiding rendering such uses nonconforming and at the same time ensuring that appropriate regulations are in place attendant to any future development.

Sanitary Sewer Extension Review: The Wisconsin Department of Natural Resources must review and approve all locally proposed extensions of public sanitary sewer systems. It is recommended that the DNR review all such extensions against the basic land use recommendations of the Oak Creek watershed plan, ensuring that the development proposed to be served by extended sanitary sewers is compatible with the plan recommendations. Sanitary sewer extensions should not be approved in those instances where, for example, they are intended to serve urban development that might be located within primary environmental corridors.

Wetland Regulation: It is recommended that the DNR and the U. S. Army Corps of Engineers, in the administration of their various wetland regulatory programs, take into account the land use development, park and open space preservation and protection, and floodland management recommendations of the Oak Creek watershed plan. It should be noted that some plan recommendations would seek to preserve and protect existing wetlands, and others could result in the destruction of certain wetlands. It is accordingly recommended that the state and federal agencies concerned recognize the comprehensive nature of the Oak Creek watershed plan, making agency decisions on wetland regulation in a manner consistent with that plan. It is also recommended that the six communities in the watershed—all of which are now mandated by State law to enact protective wetland zoning for all wetlands five acres or more in size within shoreland areas—take steps to adopt local zoning regulations to protect wetlands in a manner consistent with the recommended plan.

Open Space Preservation Plan Element

Implementation of the foregoing recommendations will substantially contribute to implementation of the open space preservation plan element. In addi-

Table 99

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE PARK AND OPEN SPACE PLAN ELEMENT OF THE RECOMMENDED PLAN FOR THE OAK CREEK WATERSHED BY YEAR: 1986-2000

		Primary Environmental Corridor (Milwaukee County)		Falk Park Development (Milwaukee County)		Recreational Corridor Development (Milwaukee County)		Additional Urban Parks (Local Units of Government)		Total	
Calendar Year	Project Year	Acquisition[a]	Operation and Maintenance[b]	Development[c]	Operation and Maintenance[d]	Development[e]	Operation and Maintenance[f]	Acquisition and Development[g]	Operation and Maintenance[h]	Acquisition and Development	Operation and Maintenance
1986	1	$ 137,000	$ 2,000	$ --	$ --	$ --	$ --	$ 132,530	$ 4,800	$ 269,530	$ 6,800
1987	2	137,000	4,000	--	--	--	--	132,530	9,600	269,530	13,600
1988	3	137,000	6,000	--	--	--	--	132,530	14,400	269,530	20,400
1989	4	137,000	8,000	--	--	--	--	132,530	19,200	269,530	27,200
1990	5	137,000	10,000	--	--	--	--	132,530	24,000	269,530	34,000
1991	6	137,000	12,000	50,000	5,000	--	--	132,530	28,800	319,530	45,800
1992	7	137,000	14,000	50,000	10,000	--	--	132,530	33,600	319,530	57,600
1993	8	137,000	16,000	50,000	15,000	--	--	132,530	38,400	319,530	69,400
1994	9	137,000	18,000	50,000	20,000	--	--	132,530	43,200	319,530	81,200
1995	10	137,000	20,000	50,000	25,000	--	--	132,530	48,000	319,530	93,000
1996	11	--	20,000	--	25,000	36,000	540	84,530	52,800	120,530	98,340
1997	12	--	20,000	--	25,000	36,000	1,080	84,530	57,600	120,530	103,680
1998	13	--	20,000	--	25,000	36,000	1,620	84,530	62,400	120,530	109,020
1999	14	--	20,000	--	25,000	36,000	2,160	84,530	67,200	120,530	114,360
2000	15	--	20,000	--	25,000	36,000	2,700	84,530	72,000	120,530	119,700
Watershed Total		$1,370,000	$210,000	$250,000	$200,000	$180,000	$ 8,100	$1,747,950	$576,000	$3,547,950	$994,100
Annual Average		$ 91,300	$ 14,000	$ 16,700	$ 13,300	$ 12,000	$ 600	$ 116,500	$ 38,400	$ 236,500	$ 66,300

NOTE: All Costs are estimated in constant 1980 dollars.

[a] *Assumes that 10 percent of the recommended 396 acres of primary environmental corridor and parkway lands would be acquired in each of the first 10 years of plan implementation at an estimated average cost of $3,400 per acre.*

[b] *Based on an annual operation and maintenance cost of $50 per acre for primary environmental corridor land.*

[c] *Assumes that 20 percent of the 216-acre Falk Park site would be developed in each of the middle five years of plan implementation at an estimated average cost of $1,200 per acre.*

[d] *Based on an annual operation and maintenance cost of $500 per acre for major parkland.*

[e] *Assumes that 20 percent of the undeveloped 4.5-mile segment of the recommended seven-mile recreation corridor along the main stem of Oak Creek would be developed in each of the final five years of plan implementation at an estimated average cost of $40,000 per mile.*

[f] *Based on an annual operation and maintenance cost of $600 per mile for recreational trails.*

[g] *Assumes that acquisition and development costs for the 12 proposed urban parks would be evenly distributed over the 15-year plan implementation period.*

[h] *Based on an annual operation and maintenance cost of $750 per acre for urban parks.*

Source: SEWRPC.

tion to those recommendations, the plan recommends that those primary environmental corridor lands not already in public ownership be publicly acquired through whatever means possible, including purchase, dedication, or gift. Such lands total 188 acres in area and lie primarily in an area encompassing a large concentration of wetlands and woodlands in the southeastern area of the watershed in the City of Oak Creek. In addition, the plan recommends that certain lands currently used for agricultural purposes be restored to wetland vegetation, thereby restoring and re-creating primary environmental corridor lands. The plan recommends that those lands designated for restoration to wetland vegetation which are not already in public ownership be publicly acquired by purchase or dedication. Such lands total 122 acres in area also located in the southeastern area of the watershed in the City of Oak Creek. It is recommended that the Milwaukee County Department of Parks, Recreation and Culture gradually acquire the undeveloped primary environmental corridor lands and preserve such lands in their natural state. It is also recommended that the Department gradually acquire and restore those lands designated for restoration to wetland vegetation. This land acquisition recommendation was previously made in the regional park and open space plan.

Secondary environmental corridors in the watershed are located along the upper reaches of Oak Creek, along the North Branch of Oak Creek, along a portion of the Mitchell Field Drainage Ditch, and along several intermittent streams tributary to Oak Creek, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch. These corridors are important, since they serve as drainageways and, within developing urban areas, can provide urban open spaces and locations for local parks. It is recommended that the local municipalities involved appropriately zone secondary environmental corridor lands through the use of conservancy and floodland zoning and take such corridors into account in the land development process, perhaps incorporating such corridors into urban stormwater detention areas, associated drainageways, and neighborhood parks as may be required.

Outdoor Recreation Plan Element

The outdoor recreation plan element recommends that the Milwaukee County Department of Parks, Recreation and Culture continue to maintain Grant Park and Oakwood Park as large, multi-purpose outdoor recreational facilities, to maintain the Cudahy Nature Preserve, and to maintain Copernicus, Cudahy, Maitland, and Rawson Parks as neighborhood and community parks offering general-use outdoor recreational facilities. It is also recommended that that Department complete, as the demand becomes evident, the development of outdoor recreational facilities in Falk Park. Finally, it is recommended that that Department assume responsibility for the development of eight miles of recreation trail through environmental corridor lands—seven miles along Oak Creek between Lake Michigan and E. Fitzsimmons Road, and one mile between the Oak Creek recreational corridor and Bender Park.

In addition to the above recommendations, it is recommended that the Milwaukee County Department of Parks, Recreation and Culture or the City of Oak Creek continue to maintain six existing neighborhood and community parks, complete the development of five neighborhood parks, and acquire and develop three new neighborhood and community parks. It is also recommended that the Milwaukee County Department of Parks, Recreation and Culture or the City of Franklin acquire and develop one new neighborhood and community park.

FLOODLAND MANAGEMENT PLAN ELEMENT IMPLEMENTATION

The major floodland management recommendation of the Oak Creek watershed plan is the institution of sound floodland zoning regulations throughout the watershed and the acquisition for public park and open space use of primary environmental corridor lands along the lower reaches of Oak Creek and in the southeast area of the watershed. The application of floodland zoning was discussed in the previous section of this chapter. It is important to note, however, that the floodland zoning measures to be applied need to be coordinated with the implementation of the structural flood control measures described below. That is, the local zoning agencies need to apply appropriate floodland zoning to the existing floodlands in the watershed, particularly along Oak Creek and the North Branch of Oak Creek, based upon future land use and existing channel conditions until such time as the recommended channel improvements are undertaken. At that time, the floodland zoning regulations may be adjusted to reflect the improvements that have actually been put in place.

Implementation of the floodland management plan element also requires consideration of the structural and nonstructural measures for flood damage abatement, as well as consideration of bridge replacement, maintenance of stream channels and hydraulic structure waterway openings, flood insurance, lending institution and realtor policies, and the maintenance of a stream gaging network. The implementation of each of these items is discussed below and summarized on Table 98, and a schedule of the capital and operation and maintenance costs for this plan element is set forth in Table 100. The Milwaukee Metropolitan Sewerage District was, in 1986, in the process of developing flood control policy and system plans. The policy plan is intended to define the responsibility of the District for implementing flood control and drainage improvement projects.

Oak Creek Channel Modifications

It is recommended that the Cities of Milwaukee and Oak Creek ask the Milwaukee Metropolitan Sewerage Commission to make the needed channel improvements within the Oak Creek watershed and the Milwaukee Metropolitan Sewerage District. In particular, it is recommended that the Sewerage Commission carry out the recommended channel deepening and shaping along 1.4 miles of Oak Creek between River Mile 10.30 and the S. 27th Street crossing, and along 1.0 mile of the North Branch of Oak Creek between the steel sheet pile spillway located west of the United Parcel Service distribution center and the S. 13th Street crossing.

Structure Floodproofing, Elevation, and Removal

The recommended plan calls for structure floodproofing, elevation, and removal measures to be undertaken along Oak Creek and the North Branch of Oak Creek in the City of Oak Creek, and along the Mitchell Field Drainage Ditch in the City of Milwaukee. Structure floodproofing and elevation would be undertaken by the property owners directly affected, as, for example, by the Oak Creek Floral Company with respect to its greenhouses located along Oak Creek. It is recommended, however, that the professional services required to prepare plans for floodproofing and the

Table 100

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE FLOODLAND MANAGEMENT ELEMENT OF THE RECOMMENDED PLAN FOR THE OAK CREEK WATERSHED BY YEAR: 1986-2000

		Channel Deepening and Shaping, and Bridge Replacement (Milwaukee Metropolitan Sewerage District)		Structure Floodproofing, Elevation, and Removal (City of Oak Creek)	Structure Floodproofing (City of Milwaukee)	Streamflow Gaging (designated agencies)	Maintenance of Recreational Navigation (Milwaukee County)		Total	
Calendar Year	Project Year	Capital	Operation and Maintenance	Capital	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance
1986	1	$ - -	$ - -	$ 68,800	$69,600	$ 7,000	$ - -	$ - -	$ 138,400	$ 7,000
1987	2	158,500	1,000	138,400	- -	7,000	140,000[a]	5,000	436,900	13,000
1988	3	158,500	1,000	138,400	- -	7,000	- -	5,000	296,900	13,000
1989	4	- -	1,000	138,400	- -	7,000	- -	5,000	138,400	13,000
1990	5	- -	1,000	138,400	- -	7,000	55,000[b]	5,000	193,400	13,000
1991	6	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1992	7	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1993	8	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1994	9	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1995	10	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1996	11	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1997	12	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1998	13	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
1999	14	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
2000	15	- -	1,000	- -	- -	7,000	- -	5,000	- -	13,000
Watershed Total		$317,000	$14,000	$622,400	$69,600	$105,000	$195,000	$70,000	$1,204,000	$189,000
Annual Average		$ 21,100	$ 900	$ 41,500	$ 4,600	$ 7,000	$ 13,000	$ 4,700	$ 80,200	$ 12,600

[a] *Construction cost of navigation channel bulkhead.*

[b] *Construction cost of diffuser network or dry dam gate and concrete apron. This cost is included in the total cost of the recommended watershed plan. However, monitoring of the channel navigability at the mouth of Oak Creek following construction of the channel bulkhead may indicate that there is no need for a diffuser network or a dry dam to provide channel flushing.*

Source: SEWRPC.

elevation of individual buildings be made available, at no cost, to property owners by the two cities involved through the city engineers. In addition, it is recommended that the Cities of Milwaukee and Oak Creek review their local building ordinances to ensure that appropriate floodproofing regulations are included. In addition, it is recommended that these two Cities explore on behalf of the property owners directly affected any available state and/or federal aids for such floodproofing measures. With regard to the building which is recommended for removal located along Oak Creek west of S. 13th Street, it is recommended that this property be acquired by the Milwaukee Metropolitan Sewerage Commission and subsequently dedicated to the Milwaukee County Department of Parks, Recreation and Culture for parkway purposes.

Streamflow Gaging

It is recommended that the Milwaukee Metropolitan Sewerage Commission and the U. S. Geological Survey continue the cooperative effort involved in maintaining the existing continuous recorder stream gaging station on Oak Creek at 15th Avenue in the City of South Milwaukee. It is also recommended that the U. S. Geological Survey and the Wisconsin Department of Transportation continue to maintain the partial record peak-flow gage on Oak Creek at S. Nicholson Road. Finally, it is recommended that the Milwaukee Metropolitan Sewerage District and the City of Milwaukee maintain their networks of crest-stage and staff gages in the Oak Creek watershed.

Oak Creek Mouth Recreational Navigation

It is recommended that the Milwaukee County Parks, Recreation and Culture Committee authorize the Department of Parks, Recreation and Culture to construct a bulkhead running parallel to, and approximately 20 feet south of, the jetty located along the north side of the Oak Creek channel at its confluence with Lake Michigan. It is also recommended that the Department of Parks, Recreation and Culture undertake the dredging of this new navigation channel in order to maintain a depth of four feet. In the event that sandbar formation continues to occur frequently within the navigation channel, it is recommended that the Department of Parks, Recreation and Culture construct either a diffuser network within the recommended navigation channel or a dry dam in the vicinity of the footbridge located at River Mile 0.14, to provide water to flush the navigation channel.

Bridge Replacement

It is recommended that the Wisconsin Department of Transportation, the Milwaukee County Transportation and Public Works Committee, and any local units of government constructing or financing new bridges or replacing existing bridges over the stream channel system of the Oak Creek watershed design and construct such bridges in accordance with the water control facility objectives set forth in Chapter X of this report. It is further recommended that the highway agencies involved coordinate the replacement of any highway bridges with the agencies designated as being responsible for the construction of recommended channel improvements along Oak Creek and the North Branch of Oak Creek.

Flood Insurance

It is recommended that the communities in the watershed continue to participate in the Federal Flood Insurance Program. It is further recommended that the Federal Emergency Management Agency take the data and information developed under the Oak Creek watershed study into account in making revisions to the federal flood insurance studies that have been completed for the communities in the Oak Creek watershed. It is also recommended that owners of property in flood-prone areas purchase flood insurance for protection against losses sustained in future floods.

Lending Institution and Realtor Policies

It is recommended that lending institutions continue to determine the flood-prone status of properties prior to the granting of a mortgage. It is also recommended that real estate brokers and their agents continue to inform potential purchasers of property of any flood hazard which may exist at the site.

Maintenance of Stream Channels and Hydraulic Structure Waterway Openings

It is recommended that all governmental units and agencies in the watershed having jurisdiction over the highway and stream system carry out periodic cleaning and maintenance of both the stream channels and the bridge and culvert waterway openings. The stream channel maintenance responsibilities of the Milwaukee Metropolitan Sewerage District were in 1986 in the process of being defined under the District flood control policy plan.

FISHERY DEVELOPMENT PLAN ELEMENT

It is recommended that the Wisconsin Department of Natural Resources undertake the following measures recommended for the development and maintenance of a warmwater and seasonal coldwater fishery in the Oak Creek watershed.

1. Modify the Mill Road dam by notching the structure down to the streambed and also

dredge a portion of the accumulated sediments behind the dam to normalize the streambed gradient and to re-create stream meanders.

2. Remove or modify with fish ladders two sills located on the Oak Creek main stem at S. Pennsylvania Avenue and south of W. Ryan Road; and three sills on the North Branch of Oak Creek at the first Chicago, Milwaukee, St. Paul & Pacific railway crossing, immediately upstream of the second S. 6th Street crossing and immediately south of the MATC-South Campus.

3. Enhance the fishery habitat by the application of instream habitat mitigation measures.

4. Apply stream bank stabilization measures to selected reaches of the stream system.

5. Conduct an initial stocking of selected forage and game fish species.

The recommended implementation action discussed under this plan element is summarized in Table 98. A schedule of the capital and operation and maintenance costs of the fishery development plan element is set forth in Table 101.

Table 101

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE FISHERY DEVELOPMENT ELEMENT OF THE RECOMMENDED PLAN FOR THE OAK CREEK WATERSHED BY YEAR: 1986-2000

Calendar Year	Project Year	Fishery Development (Wisconsin Department of Natural Resources)	
		Capital	Total
1986	1	$ --	$ --
1987	2	17,000	17,000
1988	3	16,000	16,000
1989	4	16,000	16,000
1990	5	16,000	16,000
1991	6	--	--
1992	7	--	--
1993	8	--	--
1994	9	--	--
1995	10	--	--
1996	11	--	--
1997	12	--	--
1998	13	--	--
1999	14	--	--
2000	15	--	--
Watershed Total		$65,000	$65,000
Annual Average		$ 4,300	$ 4,300

Source: SEWRPC.

WATER QUALITY MANAGEMENT PLAN ELEMENT

The major water quality management recommendations of the Oak Creek watershed plan relate to the abatement of pollution from industrial waste discharges, the abatement of pollution from nonpoint sources, and the conduct of a water quality monitoring program. The recommended implementation actions discussed under this plan element are summarized in Table 98. A schedule of the capital and operation and maintenance costs of this plan element is set forth in Table 102.

Abatement of Pollution from Industrial Waste Discharges

It is recommended that the nine existing, and any future, industrial point sources of pollution discharging directly or indirectly to the Oak Creek watershed stream system be controlled. Discharge limitations for each outfall would be set by the Wisconsin Department of Natural Resources under the Wisconsin Pollutant Discharge Elimination System (WPDES).

Abatement of Pollution from Nonpoint Sources

The implementation of nonpoint source abatement measures can best be achieved through participation in the Wisconsin Nonpoint Source Water Pollution Abatement Program administered by the Wisconsin Department of Natural Resources. Under the program, a nonpoint source abatement plan is prepared for priority watersheds designated by the Department. Following the preparation of that plan, municipalities and landowners within the priority watershed are eligible for state funding for 50 to 70 percent of the capital cost of certain nonpoint source control measures. It is therefore recommended that the municipalities in the watershed cooperatively work with the Department toward the designation of the Oak Creek watershed as a priority watershed. It is also recommended that the nonpoint source abatement plan be coordinated with a stormwater management plan for the watershed. There are areas of urban development within the watershed which currently suffer from inadequate stormwater drainage. These drainage problems need to be addressed through the preparation of detailed subwatershed stormwater management plans.

Table 102

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE WATER QUALITY MANAGEMENT PLAN ELEMENT OF THE RECOMMENDED PLAN FOR THE OAK CREEK WATERSHED BY YEAR: 1986-2000

Calendar Year	Project Year	Nonpoint Source Pollution Abatement (designated management agencies)		Water Quality Monitoring (Wisconsin Department of Natural Resources)	Total	
		Capital	Operation and Maintenance	Operation and Maintenance	Capital	Operation and Maintenance
1986	1	$ 858,000	$ 203,000	$10,000	$ 585,000	$ 213,000
1987	2	393,000	204,000	- -	393,000	204,000
1988	3	393,000	205,000	- -	393,000	205,000
1989	4	570,000	211,000	- -	570,000	211,000
1990	5	393,000	212,000	- -	393,000	212,000
1991	6	335,000	213,000	10,000	335,000	223,000
1992	7	486,000	224,000	- -	486,000	224,000
1993	8	335,000	225,000	- -	335,000	225,000
1994	9	335,000	226,000	- -	335,000	226,000
1995	10	335,000	227,000	- -	335,000	227,000
1996	11	335,000	228,000	10,000	335,000	238,000
1997	12	335,000	229,000	- -	335,000	229,000
1998	13	335,000	230,000	- -	335,000	230,000
1999	14	335,000	231,000	- -	335,000	231,000
2000	15	335,000	232,000	- -	335,000	232,000
Watershed Total		$5,835,000	$3,300,000	$30,000	$5,835,000	$3,330,000
Annual Average		$ 389,000	$ 220,000	$ 2,000	$ 389,000	$ 222,000

Source: SEWRPC.

Subject to the guidelines and recommendations set forth in the nonpoint source abatement plan, 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, for urban areas, control of litter and pet waste; proper application of chemical and organic fertilizers and pesticides to lawns and shrubbery, and, for rural areas, minimum soil conservation practices. All critical areas of upland, shoreland, and stream bank erosion should be identified and protected in both urban and rural areas. It is also recommended that, through local building codes, builders be required to control soil erosion during demolition and construction activities, and that proper storage and runoff control be provided for all facilities handling materials that may be hazardous to the environment.

The University of Wisconsin-Extension should assist in educating the public about litter and pet waste control and fertilizer and pesticide application. The U. S. Soil Conservation Service should provide technical assistance in the development of specific nonpoint source pollution control measures by local communities. In addition, it is 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 that 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. It is further recommended that street deicing material be properly applied by the necessary agencies within the watershed to minimize the chloride loadings to the surface waters of the Oak Creek watershed. Finally, it is recommended that the Milwaukee County Land Conservation Committee design and construct three retention basins at the following locations:

1) along the North Branch of Oak Creek north of W. Drexel Avenue between S. Howell Avenue and S. 6th Street; 2) along Oak Creek immediately upstream of the confluence with the North Branch of Oak Creek; and 3) along the Mitchell Field Drainage Ditch north of E. Rawson Avenue.

Continuing Water Quality Monitoring Program

It is recommended that the Regional Planning Commission, in cooperation with the Wisconsin Department of Natural Resources and the major units of government in the Oak Creek watershed, develop and implement a continuing water quality monitoring program. Such a program would demonstrate and document the changes in surface water quality attendant to implementation of the Oak Creek watershed plan and would help detect, locate, and control future sources of pollution.

FINANCIAL AND TECHNICAL ASSISTANCE

Upon adoption of the various land use, park and open space, floodland management, and water quality management plan elements and any necessary schedules of capital costs and operation and maintenance expenditures, it becomes important for 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. In addition to using current tax revenue sources, such as property taxes, fees, fines, public utility earnings, highway aids, and state-shared taxes, the 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

Local units of government are normally authorized to borrow so as to effectuate their powers and discharge their duties. Chapter 67 of the Wisconsin Statutes generally empowers counties, cities, villages, and towns to borrow money and to issue municipal obligations not to exceed 5 percent of the equalized assessed valuation of their taxable property, with certain exceptions, including school bonds and revenue bonds. Such borrowing powers which are related directly to implementation of the comprehensive Oak Creek 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 and the construction of sewage treatment plants, and for park and related open space land acquisition and development.

3. The Milwaukee Metropolitan Sewerage District has borrowing authority under Sections 66.88 through 66.918 of the Wisconsin Statutes. As a special-purpose corporation, the District has the power to issue debt and levy taxes to carry out its duties as they relate to capital improvements.

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 and placed into a separate fund and to be paid out only upon order of the county park commission for the purchase of land and other commission expenses. Farm drainage boards, town sanitary districts, metropolitan sewerage districts, cities, and villages also have taxing and special assessment powers under Sections 88.06, 63.06, 60.39, 59.96(9), and 62.18(16) of the Wisconsin Statutes.

Community Development Block Grant 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 (HUD), provides Community Development Block Grants (CDBG's) 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 cities with populations in excess of 50,000 persons and to urban counties. In Milwaukee County, the City of Milwaukee and the City of West Allis receive entitlement funds, while Milwaukee County receives entitlement funds as an urban county. Milwaukee County carries out a number of countywide community development projects such as housing rehabilitation, senior citizen services, and public works projects with the CDBG funds, as well as providing CDBG funds to villages and cities within the County that have identified local projects for use of the funds.

State Water Pollution Prevention and Abatement Program

A 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 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. 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.

State Water Quality Nonpoint Source Control Grants Program

This program, an element of the Wisconsin Fund, is administered by the Wisconsin Department of Natural Resources to provide grants for urban and rural nonpoint source controls. Grants for eligible land management practices range from 50 to 70 percent of the cost of implementing the project.

Federal Agricultural Conservation Program

This program, administered by the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, provides grants to farmers for carrying out approved soil, water, woodland, and wildlife conservation practices.

Federal Water Resources Investigation Program

The U. S. Geological Survey administers a cooperative water resources investigation program that provides federal matching funds in amounts of up to 50 percent of the cost of projects under the program. This program provides funds for 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 approval of a particular project by the U. S. Congress. After feasibility studies and public hearings, the U. S. Army Corps of Engineers will undertake the construction of such flood control works as channel improvements, dikes and floodwalls, 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.

The U. S. Army Corps of Engineers can undertake flood control projects under two separate authorities. Under Section 205 of the Federal Flood Control Act of 1948 as amended, the Corps is authorized to contribute to the design and construction phases of relatively small-scale flood control projects, provided that the maximum cost to the Corps is $4 million or less. Projects eligible under this program can be authorized directly by the Chief of Engineers and, therefore, project implementation times are shorter than under the other Corps' program, typically 5 to 10 years. A second program, the general investigation program, requires explicit congressional authorization and appropriation. Projects under this program must be implemented in several phases over many years, including completion of a three-stage feasibility study followed by a construction phase. Projects under this program typically require from 20 to 30 years to fully implement. Under both Corps programs, the projects must be demonstrated to be economically feasible and environmentally sound. Flood control projects within the Oak Creek watershed are relatively small and could possibly be undertaken under the small-scale program of the Corps.

Technical Assistance

Certain federal, state, regional, and county agencies provide technical assistance upon request to local units of government in implementing watershed plans. 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. 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 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 Service, 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. 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 quality problems; fish management; and forest planting, protection, management, and harvesting. The Department 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 the development of parks and recreational facilities, resource development, and the development of water supply and sewage disposal facilities.

Areawide Agencies: The Southeastern Wisconsin Regional Planning Commission provides 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 land conservation committees are authorized to furnish technical assistance to landowners or occupiers and to any public or private agency in their efforts to prevent soil erosion and floodwater and sedimentation damage and to further water conservation and development.

SUMMARY

This chapter has described the various means available and recommended specific procedures for implementation of the recommended comprehensive Oak Creek watershed plan. The most important recommended plan implementation actions are summarized below by level of government.

Local Level

The local level agencies involved in implementation of the Oak Creek watershed plan are Milwaukee County and the Cities of Cudahy, Franklin, Greenfield, Oak Creek, Milwaukee, and South Milwaukee. The recommended actions for each of these units and agencies of government are presented below.

Milwaukee County: It is recommended that Milwaukee County, through its various committees, commissions, boards, and the County Board of Supervisors, act to implement the recommended watershed plan in the following manner:

1. That the County Board of Supervisors adopt the recommended Oak Creek watershed plan after the issuance of a report and recommendation by the County Parks, Recreation and Culture Committee, the County Transportation and Public Works Committee, and the County Land Conservation Committee as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the County Department of Parks, Recreation and Culture acquire over time through purchase, dedication, and gift, as may be timely and appropriate, the remaining undeveloped primary environmental corridor lands in the watershed;

3. That the County Department of Parks, Recreation and Culture acquire and restore those lands in the southeast area of the watershed designated for restoration to wetland vegetation;

4. That the County Department of Parks, Recreation and Culture continue to maintain

Grant and Oakwood Parks[3] as large, multipurpose outdoor recreational facilities, the Cudahy Nature Preserve, and Copernicus, Cudahy, Maitland, and Rawson Parks as neighborhood and community parks offering general-use outdoor recreational facilities;

5. That the County Department of Parks, Recreation and Culture complete, as the demand becomes evident, the development of outdoor recreational facilities at Falk Park;

6. That the County Department of Parks, Recreation and Culture design, construct, and maintain the recommended seven-mile recreation trail along the main stem of Oak Creek between Lake Michigan and E. Fitzsimmons Road, and the recommended one-mile recreation trail segment in the watershed between the Oak Creek trail and Bender Park;

7. That the County Department of Parks, Recreation and Culture, with Wisconsin Department of Natural Resources financial assistance, design, construct, and maintain the recommended bulkhead at the mouth of Oak Creek and, if necessary, either a diffuser network within the navigation channel or a dry dam in the vicinity of the footbridge located at River Mile 0.14, and also periodically maintain the Oak Creek channel at the bulkhead;

8. That the County Transportation and Public Works Committee, as the highway system under its jurisdiction is maintained and reconstructed over time, construct new and replace existing bridges over the Oak Creek stream channel system in accordance with the recommended water control facility objectives and standards;

9. That the County Land Conservation Committee assume the lead responsibility for nonpoint source water pollution control throughout the watershed; and

10. That the County Land Conservation Committee construct and maintain the three recommended sedimentation basins.

City of Cudahy: It is recommended that the City of Cudahy, through its various committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after a report and recommendation by the Board of Public Works and the City Plan Commission as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of Cudahy Zoning Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan; and

3. That as the designated management agency, the Board of Public Works assume the responsibilities for nonpoint source pollution.

City of Franklin: It is recommended that the City of Franklin, through its various committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after a report and recommendation by the Board of Public Works, the City Plan Commission,

[3] *Oakwood Park within the context of the Oak Creek watershed plan refers to the existing county-owned and -operated golf course, a portion of which lies within the Oak Creek watershed. Oakwood Park is about one mile east of the site of a proposed recreational impoundment known as Oakwood Lake. That impoundment, which was recommended in the Commission-adopted Root River watershed plan, is located in the Root River watershed. Responsibility for the development of this impoundment is expected to be placed with the Wisconsin Department of Natural Resources in the second generation regional park and open space plan, presently under preparation, as an integral part of the development of a state recreation area at this location.*

and the City Park Commission as a guide to land use, park and open space, floodland management, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of Franklin Zoning Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan;

3. That the City Park Commission acquire and develop, as the demand becomes evident, one new neighborhood park in the watershed; and

4. That as the designated management agency, the Board of Public Works assume the responsibilities for nonpoint source pollution control.

City of Greenfield: It is recommended that the City of Greenfield, through its various committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after the issuance of a report and recommendation by the Board of Public Works and the City Plan Commission as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of Greenfield Zoning Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan; and

3. That as the designated management agency, the Board of Public Works assume the responsibilities for nonpoint source pollution control.

City of Milwaukee: It is recommended that the City of Milwaukee, through its various departments, committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after the issuance of a report and recommendation by the City Plan Commission and the City Park and Recreation Commission as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of Milwaukee Zoning Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan;

3. That the City Plan Commission and the Common Council review the city building code to ensure that appropriate regulations dealing with structure floodproofing are included, and provide professional engineering assistance to landowners affected by the structure floodproofing recommendations of the plan;

4. That as the designated management agency, the Department of Public Works assume the responsibilities for nonpoint source pollution control; and

5. That the City continue to maintain its program of monitoring stream stages in the Oak Creek watershed.

City of Oak Creek: It is recommended that the City of Oak Creek, through its various committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after the issuance of a report and recommendation by the Department of Public Works and the City Plan Commission as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of Oak Creek Zoning

Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan;

3. That the City Plan Commission and the Common Council review the city building code to ensure that appropriate regulations dealing with structure floodproofing are included, and provide professional engineering assistance to landowners affected by the structure floodproofing recommendations of the plan;

4. That the City Park and Recreation Commission continue to maintain six community and neighborhood parks; complete the development of five neighborhood parks, three of which are leased from the County; and, as the demand becomes evident, develop and maintain three new neighborhood parks; and

5. That as the designated management agency, the Common Council assume the responsibilities for nonpoint source pollution control.

City of South Milwaukee: It is recommended that the City of South Milwaukee, through its various committees, commissions, boards, and the Common Council, act to implement the recommended watershed plan in the following manner:

1. That the Common Council adopt the recommended Oak Creek watershed plan after the issuance of a report and recommendation by the City Plan Commission and the City Park and Recreation Commission as a guide to land use, park and open space, floodland, and water quality management in the Oak Creek watershed;

2. That the City Plan Commission and the Common Council review and revise, as necessary, the City of South Milwaukee Zoning Ordinance to implement the recommendations set forth in the land use, floodland management, and water quality management elements of the Oak Creek watershed plan; and

3. That as the designated management agency, the Common Council assume the responsibilities for nonpoint source pollution control.

Areawide Level

Milwaukee Metropolitan Sewerage District: It is recommended that the Milwaukee Metropolitan Sewerage Commission, acting as the agent for the Milwaukee Metropolitan Sewerage District:

1. Adopt the recommended Oak Creek watershed plan, including the land use, floodland management, and water quality management elements;

2. Carry out the recommended channel modifications and structure removal or land purchases along Oak Creek and the North Branch of Oak Creek; and

3. Continue to maintain its program of monitoring stream stages in the Oak Creek watershed, including financially supporting the continuous stage recorder stream gage on Oak Creek at 15th Avenue.

State Level

The state level agencies involved in implementation of the Oak Creek watershed plan consist of the Wisconsin Departments of Natural Resources, Transportation, and Agriculture, Trade and Consumer Protection. The recommended actions for each of these state agencies are presented below.

Wisconsin Department of Natural Resources: It is recommended that the Wisconsin Department of Natural Resources:

1. Endorse the comprehensive Oak Creek watershed plan as an amendment to the previously endorsed areawide water quality management plan for the Southeastern Wisconsin Region and certify the plan as such through the Governor to the U. S. Environmental Protection Agency;

2. Direct the staff of the Department to integrate the watershed plan recommendations into its broad range of agency responsibilities and to assist in coordinating plan implementation over the next two decades. In particular, Department decisions with respect to the extension of locally proposed sanitary sewers, wetland regulation, and the regulation of industrial waste discharges should be made in a manner fully consistent with the recommended plan;

3. Cooperate with the Southeastern Wisconsin Regional Planning Commission and the local units of government in the watershed in designing and carrying out a continuing water quality monitoring program;

4. Undertake the development of a balanced fishery as recommended in the watershed plan; and

5. Provide financial assistance to the Milwaukee County Department of Parks, Recreation and Culture for the construction of the recommended bulkhead, as well as a handicapped fishing pier, at the mouth of Oak Creek.

Wisconsin Department of Transportation: It is recommended that the Wisconsin Department of Transportation:

1. Endorse the recommended Oak Creek watershed plan;

2. Continue to cooperate in the stream gaging program by financially supporting a partial record peak-flow gage on Oak Creek at S. Nicholson Road; and

3. Construct new and replace existing bridges over the Oak Creek stream channel system in accordance with the recommended water control facility objectives and standards as the highway system under its jurisdiction is maintained and reconstructed over time.

Wisconsin Department of Agriculture, Trade and Consumer Protection: It is recommended that the Wisconsin Department of Agriculture, Trade and Consumer Protection:

1. Endorse the Oak Creek watershed plan; and

2. Refer the plan to the Land Conservation Board and direct that Board to utilize the plan recommendations, as appropriate, in its various responsibilities governing farmland preservation and soil and water conservation.

Federal Level

The federal agencies involved or potentially involved in implementation of the Oak Creek watershed plan consist of the U. S. Environmental Protection Agency; the U. S. Geological Survey; the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service; the U. S. Soil Conservation Service; the Federal Emergency Management Agency; and the U. S. Army Corps of Engineers. The recommended actions for each of these federal agencies are presented below.

U. S. Environmental Protection Agency: It is recommended that the U. S. Environmental Protection Agency formally accept and endorse the Oak Creek watershed plan as an amendment to the regional water quality management plan upon certification as such by the Governor of the State of Wisconsin.

U. S. Geological Survey: It is recommended that the U. S. Geological Survey endorse the Oak Creek watershed plan and continue to work with the Regional Planning Commission and state and local units of government in conducting the cooperative stream gaging program in the watershed.

U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service: It is recommended that the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, formally acknowledge the Oak Creek watershed plan and utilize the plan recommendations in the administration of the federal agricultural and conservation program.

U. S. Soil Conservation Service: It is recommended that the U. S. Soil Conservation Service formally acknowledge the Oak Creek watershed plan and utilize the plan recommendations in the administration of its various technical assistance programs.

Federal Emergency Management Agency: It is recommended that the Federal Emergency Management Agency formally acknowledge the Oak Creek watershed plan and use the floodland data contained in the plan as a basis for reviewing and updating federal flood insurance studies.

U. S. Army Corps of Engineers: It is recommended that the U. S. Army Corps of Engineers formally acknowledge the Oak Creek watershed plan; assist, upon request, any local or state units and agencies of government in the review, design, and construction of the floodland management element of the recommended plan; and use the land use and environmental corridor elements of the plan in carrying out its regulatory program relative to the placement of fill in wetlands.

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Chapter XVI

SUMMARY AND CONCLUSIONS

This report presents the major findings and recommendations of the Southeastern Wisconsin Regional Planning Commission Oak Creek watershed planning program. The report 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 economic activity, population growth, and land use and water-related developmental and environmental problems. The report presents alternative plan elements relating to floodland management, water pollution abatement, and land use, and sets forth a recommended plan for the development of the watershed and the resolution of its existing flood damage and water pollution problems, and for the prevention of future flood damage and water pollution problems. The recommended plan is based upon regional and watershed development objectives adopted by the watershed committee. The plan contains specific recommendations for its implementation, along with analyses of ways in which to finance implementation.

STUDY ORGANIZATION AND PURPOSE

The Oak Creek watershed study, which resulted in the preparation of this report, is the seventh comprehensive watershed planning program to be undertaken by the Regional Planning Commission. This study was undertaken within the statutory authority of the Commission and upon the specific request of the Milwaukee Metropolitan Sewerage District. Funding for the study was provided by the Milwaukee Metropolitan Sewerage District and the City of South Milwaukee. The study was guided from its inception by the Oak Creek Watershed Committee, an advisory committee to the Commission composed of 13 local and state public officials, technicians, and concerned 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 Wisconsin Department of Natural Resources; and a private consultant engaged by the Commission, Alster-Ayres & Associates, Inc., photogrammetric and control survey engineers. The disciplines provided by the cooperating governmental agencies and the private consultant included groundwater and surface water hydrology and hydraulics, mathematical simulation modeling, fishery development, 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. Solutions to such areawide problems must, therefore, be sought on a watershed basis.

The primary purpose of the Oak Creek watershed planning program is to help abate the serious water resource and water resource-related problems of the watershed by developing a workable plan to guide the staged development of multi-purpose 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 the floodlands along the major waterways of the Oak Creek watershed, including measures for the mitigation of existing flood problems and for the minimization of future flood problems.

- Prepare a plan for surface water quality management within the Oak Creek watershed, incorporating measures to abate existing pollution problems and 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 on December 1, 1979.[1] To enhance the utility and effectiveness of the watershed plan in abating problems of flooding, water pollution, and changing land use within the watershed, the plan was developed to be amenable to cooperative adoption and joint implementation by all of the 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 Oak Creek 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 request. In addition to setting forth the findings and recommendations of the watershed study, this report 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 Oak Creek watershed is a surface water drainage unit approximately 27 square miles in areal extent lying in southeastern Milwaukee County. Oak Creek from its source in Section 13, Township 5 North, Range 21 East, in the City of Franklin flows southerly to a point just south of W. Ryan Road, and thence easterly to a point east of S. Shepard Avenue in the City of Oak Creek. The creek then flows northerly to 15th Avenue and the Oak Creek Parkway in the City of South Milwaukee, and then finally flows southeasterly to its confluence with Lake Michigan. Along its course, Oak Creek is joined by two major tributaries: the North Branch of Oak Creek and the Mitchell Field Drainage Ditch.

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 lies entirely within one county—Milwaukee—and partly within six cities—Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee. Table 2 in Chapter III indicates the area of each civil division within the watershed, the percent of the watershed area within each civil division, and the percent of each civil division area within the watershed. The population in the watershed by civil division is shown in Table 3 in Chapter III. 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 community services. The responsibility for providing sanitary sewer service and sewage treatment within the Oak Creek watershed rests with the Milwaukee Metropolitan Sewerage District and the cities within the watershed. The responsibility for nonpoint source water pollution control rests with the County and the cities within the watershed. The Sewerage District also has the authority to make channel and other improvements for drainage and flood control purposes within the watershed. The Milwaukee County Parks, Recreation and Culture Committee is responsible for providing park and related open space lands and facilities within the watershed. Certain state and federal government agencies, including, importantly, the Wisconsin Department of Natural Resources, also have important responsibilities for water resource management within the watershed.

Population and Economic Activity

The 1980 resident population of the watershed was estimated at 39,700 persons, or about 2 percent of the population of the Region. The resident population of the watershed may be expected to increase to about 72,600 persons by the year 2000, or almost double its 1980 resident population level.

Employment in the watershed is expected to increase during the next two decades at a rate greater than the rate of increase of the Region as a whole, reflecting a continued decentralization of economic activity from the established urban areas of the Region to suburban locations. Employment within the watershed in 1980 totaled about 20,000 jobs, and may be expected to increase to about 27,300 jobs by the year 2000, an increase of about 7,300 jobs, or about 36 percent, over the 20-year period.

Land Use

In 1980, as shown on Map 7 in Chapter III of this report, a little over half of the Oak Creek watershed was still devoted to rural land uses, with about 15 square miles, or 53 percent of the total watershed area, being in such uses. Agriculture and

[1] *See Oak Creek Watershed Planning Program Prospectus, SEWRPC, December 1979.*

related open uses were the predominant rural land uses in the watershed, occupying over 13 square miles, or about 47 percent of the total watershed area. In 1980 urban land uses within the watershed occupied about 13 square miles, or 47 percent of the total watershed area. The dominant urban land use categories were residential and transportation-communication-utility, which encompassed about 19 percent of the total watershed area and about 40 percent of the urban area of the watershed each.

Public Utility Service and Transportation Facilities
The public utility base of the watershed is well developed. In 1980, electric power was supplied throughout the watershed by the Wisconsin Electric Power Company. Natural gas service was supplied by the Wisconsin Natural Gas Company except in that portion of the City of Milwaukee between S. 6th and S. 27th Streets, which was served by the Wisconsin Gas Company. Sanitary sewer service was supplied by the Milwaukee Metropolitan Sewerage District and the City of South Milwaukee, which together in 1980 served about 95 percent of the total resident population of the watershed. Public water supply, utilizing Lake Michigan as a source, was also available throughout the watershed through four public water supply entities.

The Oak Creek watershed is served by a well-developed surface transportation system consisting of a particularly good network of all-weather streets and highways, and urban mass transit service. In 1980, the watershed was traversed by a network of railway lines, all of which provided freight service, and one of which also provided scheduled Amtrak passenger train service between Milwaukee and Chicago. General Mitchell Field, lying partly within the watershed, served as the major commercial airport for the Region.

Climate
The Oak Creek watershed has a climate characterized by a progression of markedly different seasons because of its midcontinental 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 19°F in January to 70°F in July, while the extremes range from a low of about -24°F to a high of approximately 101°F.

The average annual precipitation within the watershed is 30.94 inches, and the average total monthly precipitation ranges from a low of 1.33 inches in February to a high of 3.59 inches in June. The watershed receives, on the average, 46.8 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.

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 or about December 22, to a maximum of about 15 hours on or 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 may be expected to be cloudy, with the remainder about equally divided between partly cloudy and clear.

Physiography and Geology
The Oak Creek watershed is roughly rectangular in shape, with its major axis lying in an approximately north-south direction. The watershed has a total area of approximately 27 square miles, with a length—measured from the northern to southern extremities of the basin—of approximately 5.5 miles and a width of about 4.5 miles. The Oak Creek watershed is bounded on the north by the Kinnickinnic River watershed, on the west and south by the Root River watershed, and on the east by lands that drain directly to Lake Michigan and by the lake itself.

The Oak Creek begins its 14-mile route to Lake Michigan from its origin near the intersection of Acre Avenue and S. 36th Street in the southwest one-quarter of U. S. Public Land Survey Section 13, Township 5 North, Range 21 East, in the City of Franklin. From its source, the creek flows in a southerly direction for about 1.6 miles before turning east and flowing to a point east of S. Shepard Avenue in the City of Oak Creek. From there, the creek flows in a generally northerly direction to 15th Avenue and the Oak Creek Parkway in the City of South Milwaukee, where it turns southeast and flows to its confluence with

Lake Michigan. Oak Creek acts as an estuary of Lake Michigan from its mouth to about the first Oak Creek Parkway bridge, a distance of about 0.3 mile.

The North Branch of Oak Creek, the largest tributary to Oak Creek, begins its 6.3-mile route to Oak Creek from its point of origin at W. Grange Avenue in the northwest one-quarter of U. S. Public Land Survey Section 31, Township 6 North, Range 22 East, in the City of Milwaukee. From there it flows in a southerly direction to its confluence with Oak Creek north of W. Ryan Road between S. 13th Street and S. Howell Avenue. The third perennial stream in the watershed is the Mitchell Field Drainage Ditch which originates at S. 6th Street in the northeast one-quarter of U. S. Public Land Survey Section 32, Township 6 North, Range 22 East, in the City of Milwaukee. From its origin it flows in an easterly direction about 1.5 miles to a point east of the main north-south runway of General Mitchell Field, thence in a southerly direction for about 2.3 miles to its confluence with Oak Creek north of E. Drexel Avenue and east of the Chicago & North Western Railway. Several other streams are tributary to Oak Creek or the North Branch of Oak Creek, including the tributary to Upper Oak Creek, Southland Creek, and the tributary to Southland Creek. The stream system selected for detailed study totaled 26 miles, as shown on Map 28 in Chapter V.

The topography and physiographic features of the Oak Creek watershed 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 which form 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 810 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) along the western border of the watershed to approximately 590 feet above that datum at the mouth, a maximum relief of about 220 feet.

Wildlife and Wildlife Habitat

As a result of urban and agricultural development, woodlands, wetlands, and other natural areas which provide good wildlife habitat are limited within the Oak Creek watershed. Only about 587 acres of significant wildlife habitat remain within the watershed, of which about 57 percent is rated as having a relatively low value. The remaining wildlife habitat areas are particularly important because of the recreational, educational, and aesthetic values provided, and because of the element of naturalness and diversity that these areas impart to both the urban and rural environments of the watershed.

Existing and Potential Park, Outdoor Recreation, and Related Open Space Sites

A total of 34 existing park, outdoor recreation, and related open space sites lie within the watershed, encompassing a combined area of 1,686 acres, or about 9 percent of the total area of the watershed.

Environmental Corridors

The delineation of natural resource and related elements within the Region produces a pattern of narrow, elongated areas which have been termed "environmental corridors" by the Regional Planning Commission. As of 1980, primary environmental corridors in the watershed occupied 447 acres, or about 3 percent of the watershed area. In contrast, primary environmental corridors occupied about 17 percent of the entire seven-county Southeastern Wisconsin Region. Secondary environmental corridors occupied an additional 1,152 acres, or an additional 6 percent of the watershed. Isolated natural features occupied about 222 acres, or about 1 percent of the watershed area. The continued preservation of the primary environmental corridors in essentially natural, open 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 had important implications for water resources planning and management. Water use objectives and supporting water quality standards are now required for all of the navigable waters of the United States, and it is a national goal to restore and maintain these waters to and in a "fishable and swimmable" state. To meet this goal, the Act requires the establishment of specific effluent limitations for all point sources of water pollution. These limitations are to be enforced through a pollutant discharge permit system.

The 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.

Surface Water Hydrology and Hydraulics

Precipitation is the primary source of water entering the Oak Creek watershed, and averages about 31 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the watershed. The average annual runoff approximates 12 inches, and the annual evapotranspiration loss totals about 19 inches.

The streamflow and flood stage records available for the Oak Creek system reveal that two flooding seasons exist. The period February through April is a high runoff period because of the effects of snow accumulation and frozen ground in February and March, and the effects of snowmelt or rainfall on near-saturated soils in March and April when the drying effects of transpiration are still minimal and when air and surface temperatures still inhibit evaporation. The other period, in June, experiences frequent severe thunderstorms occurring before the peak period of summer evapotranspiration and heavy foliation.

The Oak Creek watershed may be divided into five subwatersheds, as shown on Map 32 in Chapter V. These subwatersheds are: 1) the Lower Oak Creek subwatershed which encompasses 5.03 square miles, or 18.4 percent of the total watershed area; 2) the Middle Oak Creek subwatershed, which encompasses 6.54 square miles, or 24 percent of the total watershed area; 3) the Upper Oak Creek subwatershed, which encompasses 3.80 square miles, or 14 percent of the total watershed area; 4) the North Branch of Oak Creek subwatershed, which encompasses 8.05 square miles, or 29.5 percent of the total watershed area; and 5) the Mitchell Field Drainage Ditch subwatershed, which encompasses 3.83 square miles, or 14.1 percent of the total watershed area. The streams studied included Oak Creek in the Lower and Middle Oak Creek subwatersheds; Oak Creek and the tributary to Upper Oak Creek in the Upper Oak Creek subwatershed; the North Branch of Oak Creek, Southland Creek, and the tributary to Southland Creek in the North Branch of Oak Creek subwatershed; and the Mitchell Field Drainage Ditch in the Mitchell Field Drainage Ditch subwatershed.

Pertinent hydrologic-hydraulic characteristics of the watershed—including land use, channel slopes, hydraulic structures, and channel modifications—were inventoried and analyzed. Approximately 26 lineal miles of stream within the watershed were selected for development of detailed flood hazard information, including discharge-frequency relationships, flood stage profiles, and areas of inundation for selected flood recurrence intervals. Detailed data were obtained for 101 hydraulically significant bridges, culverts, and sills—out of a total of 109 such structures on the stream system studied—and 534 floodland cross-sections were prepared for that portion of the stream system modeled under the watershed study.

Of the approximately 26 lineal miles of stream studied, about 12 miles, or 47 percent, had been significantly modified through man-made channel alterations by 1980, as shown on Map 30 in Chapter V. The modified stream reaches lie largely along Lower and Upper Oak Creek, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch.

Water Resources Simulation Model

Quantitative analysis of hydrologic, hydraulic, and water quality conditions under existing and alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Hydrologic-hydraulic-water quality simulation, accomplished with a set of interrelated digital computer programs, is an effective way to conduct the required quantitative analyses. The water resource simulation model developed from existing computer programs for use in the Oak Creek watershed planning effort consisted of four submodels: a hydrologic submodel, two hydraulic submodels, and a water quality submodel.

The principal function of the hydrologic submodel was to determine the volume and temporal distribution of runoff from the land to the stream system using meteorological and land data. The first hydraulic submodel 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. The second hydraulic submodel computes flood stages attendant to flood flows of specified recurrence intervals as determined using the first hydraulic submodel. This permits the ready preparation of flood stage profiles to be used in the delineation of flood hazard areas. The water quality submodel simulates, at selected locations on the surface water system, the time-varying concentrations, 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 into the water resources simulation model are approximations of complex natural phenomena; therefore, it is necessary to calibrate the model. Calibration consists of comparing simulated values, such as flood discharges or flood stages, with observed values of the same phenomena and, if a significant difference exists, making adjustments in the model so that it better simulates actual conditions. The hydrologic and hydraulic submodels were calibrated by comparing the simulated discharges and stages to measured discharges and stages at the stream flood and crest-stage gaging stations located on Oak Creek and the North Branch of Oak Creek, and by comparing simulation stages to historic flood data available at several other locations in the watershed. The water quality submodel was calibrated using data obtained from the Commission's extensive 1976 stream water quality monitoring program.

Flood Characteristics, Damage, and Risk

Research of the available historic records indicated the occurrence of eight major floods in the Oak Creek watershed since 1917. These floods, each of which caused significant damage to property as well as disruption of normal social and economic activities, occurred on June 22, 1917; June 23, 1940; March 30, 1960; June 11, 1967; June 26, 1968; September 18, 1972; April 21, 1973; and September 13, 1978. The June 23, 1940, flood was the largest flood of record, having a recurrence interval of about 50 years on Oak Creek at 15th Avenue. The flood of March 30, 1960, was the second largest flood of record on Oak Creek.

The principal types of damage experienced in the Oak Creek watershed have been damage to croplands and to structures—private residences and commercial buildings—and to their contents as a result of direct and secondary flooding. Bridges and culverts and sections of roadways have also been damaged by the erosive action of rapidly moving floodwaters so as to require extensive repair.

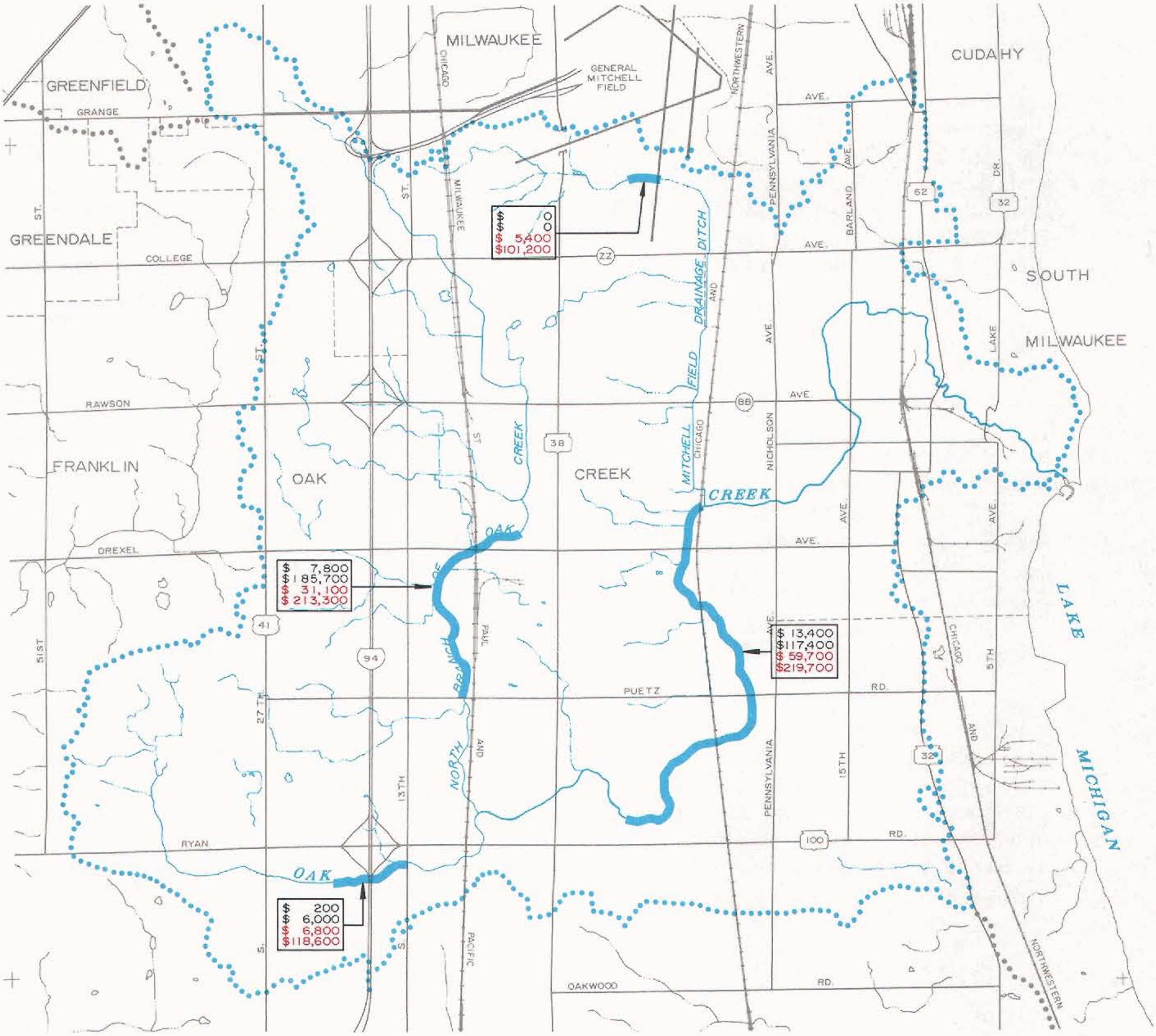
A costly type of disruption associated with major flood events in the Oak Creek watershed has been the interruption of business activities not only during the flood events but also during the post-flood cleanup and repair period. In the public sector, the routine operations of governmental units usually 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 arterial streets and highways by inundation or by damage to bridges. Although floodland recreational areas and facilities, such as ballfields, golf courses, and picnic grounds, typically incur little physical damage as a result of flooding, use is temporarily curtailed by inundation.

The stream reaches within the Oak Creek watershed having potential for the heaviest flood damages are shown on Map 78, along with the estimated average annual flood damages under both existing and probable future land use conditions and the damages for a flood having a recurrence interval of 100 years. For the watershed as a whole, the average annual flood damages under existing land use and channel conditions approximate $30,000. Damages from a 100-year recurrence interval flood over the entire watershed under existing land use and channel conditions approximate $344,000. The reaches of heaviest flood damage are the reach along Oak Creek between the confluence with the Mitchell Field Drainage Ditch and S. Shepard Avenue in the City of Oak Creek, where the average annual and 100-year recurrence interval flood damages under existing land use and channel conditions approximate $13,400 and $117,400, respectively; and the reach along the North Branch of Oak Creek between W. Puetz Road and about 1,800 feet upstream of the Chicago, Milwaukee, St. Paul & Pacific Railroad (Milwaukee Road), where the average annual and 100-year recurrence interval flood damages approximate $7,800 and $185,700, respectively. On an average annual basis over the entire watershed, flood damages may be expected to more than triple under planned land use and existing channel conditions.

For the watershed as a whole under existing land use and channel conditions, a total of 22 structures—six residential structures and 16 nonresidential structures—would be subject to flood damages under a 100-year recurrence interval flood event.

Map 78

EXISTING AND POTENTIAL AVERAGE ANNUAL AND 100-YEAR RECURRENCE INTERVAL FLOOD DAMAGES ALONG SELECTED STREAM REACHES IN THE OAK CREEK WATERSHED



LEGEND

SELECTED FLOOD DAMAGE REACH

ESTIMATED FLOOD DAMAGES

EXISTING

$ 13,400 AVERAGE ANNUAL
$117,400 100-YEAR RECURRENCE INTERVAL

FUTURE

$ 59,700 AVERAGE ANNUAL
$219,700 100-YEAR RECURRENCE INTERVAL

NOTE: ESTIMATED FUTURE FLOOD DAMAGES ASSUME YEAR 2000 PLANNED LAND USE CONDITIONS AND EXISTING CHANNEL CONDITIONS

The stream reaches in the Oak Creek watershed having the heaviest flood damage potential are shown above, along with the estimated average annual flood damages under both existing and probable future land use conditions, as well as such damages for a flood having a recurrence interval of about 100 years. For the watershed as a whole, the average annual flood damages under existing land use and channel conditions are estimated at $30,000. Damages from a 100-year recurrence interval flood over the entire watershed under existing land use and channel conditions are estimated at $344,000. On an average annual basis over the entire watershed, these damages could be expected to more than triple under planned land use and existing channel conditions.

Source: SEWRPC.

Under plan year 2000 land use and existing conditions, 30 structures may be expected to be affected by flooding—11 residential structures and 19 nonresidential structures.

Surface Water Quality and Pollution

The term "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 present in such a form and concentration as to render the water unsuitable for a desired beneficial use.

An assessment of a variety of data sources dating back to 1954 indicated that generally poor surface water quality conditions exist in the Oak Creek watershed. Many forms of pollution—toxic, organic, nutrient, pathogenic, sediment, and aesthetic—are known to exist in the watershed. The available studies indicate that the highest concentrations of pollution and the worst streamwater quality conditions are more likely to occur during periods of wet weather—that is, on days when 0.1 inch or more of precipitation occurs—and high streamflows than during periods of dry weather and low streamflows. This may be attributed to the accumulation of pollutants on the surface of the watershed between runoff events and the subsequent transport of those pollutants to the stream system during runoff. While the poor water quality conditions are associated with precipitation-induced events, the worst water quality conditions result from events having a recurrence interval of one year or less. Water quality problems and the loss of fish and other aquatic life habitat and recreational use associated with nonpoint source runoff are usually manifested during low-flow periods.

The most serious type of pollution present in the watershed is pathogenic, as evidenced by the widespread occurrence of high fecal coliform counts. Other, less extensive pollution problems include the presence of toxic and hazardous materials, and excessive nutrient concentrations, particularly phosphorus, under wet weather conditions.

Pollutant loading analyses conducted under the Commission areawide water quality management planning program, and confirmed under the watershed study, indicate that nonpoint sources of pollution—both rural and urban—account for the majority of pollutants that are transported to the surface water system. Commission inventories indicated that virtually all of the nitrogen, phosphorus, biochemical oxygen demand, fecal coliform organisms, and suspended solids are contributed to the surface water system of the watershed by these nonpoint sources of water pollution. These pollutant loadings will occur during wet weather conditions when surface water runoff acts to transport pollutants to the stream system of the watershed.

Point source water pollution contributions are relatively insignificant in the Oak Creek watershed. The sources of pollution identified as point sources consist of three municipal sanitary sewerage system flow-relief devices, and 16 industrial wastewater discharge outfalls. As of mid-1984, the three flow-relief devices had been either abandoned or abated.

About 38 percent of the total area of the Oak Creek watershed is provided with engineered urban stormwater drainage facilities. Therefore, much of the runoff from urban areas, which may be expected to be grossly polluted, enters the surface water system directly through storm sewer outfalls located along the major streams, with the remaining direct runoff entering the surface water system through open stormwater channels or as sheet flow—that is, overland flow not occurring in well-defined channels. Runoff from rural areas enters the surface water system through open stormwater channels or agricultural drainage systems, or as sheet flow. As already noted, water quality surveys indicate that high concentrations of pollutants, such as biochemical oxygen demand, nitrogen, phosphorus, and fecal coliform bacteria, are most likely to occur during wet weather conditions—that is, the conditions in which the surface water runoff from urban and rural lands provides the dominant flow and pollutant loading to the river system.

The limited data available also indicate that, with the possible exception of mercury and polychlorinated biphenyls (PCB's), excessive concentrations of toxic and hazardous substances do not exist in the surface water system of the Oak Creek watershed.

In 1980, the surface water quality conditions in the Oak Creek watershed did not satisfy the standards supporting the adopted water use objectives. Improvement of surface water quality in the Oak Creek 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 Oak Creek 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 within the Oak Creek basin by developing a workable plan to guide the staged development of multi-purpose 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 the 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 alternative floodland management and water quality management measures 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 basically envisions a future watershed environment that is safe, healthful, and attractive, as well as more orderly and efficient.

With respect to water use objectives, the Wisconsin Department of Natural Resources currently has assigned to the waters of the Oak Creek stream system water use objectives which provide for the maintenance of a warmwater fishery and full recreational use, as shown on Map 42 in Chapter IX of this report. The standards supporting these water use objectives are identified in Table 69 in Chapter IX.

In conformance with the national water quality objectives set forth in the Federal Water Pollution Control Act, all of the surface waters of the Oak Creek watershed were initially assigned water use objectives and supporting standards that would provide fully "fishable and swimmable" conditions. This would mean that the waters would be suitable for full body contact recreational use and would support a healthy warmwater fishery and related aquatic life. Given the recommendations contained in the plan relating to water quality and flood control and the practicality of maintaining a fishery in the watershed, however, the recommended water use objectives for the surface waters of the Oak Creek watershed—which are set forth on Map 77 in Chapter XIV—were changed from that initial idealized set. The main stem upstream of the North Branch of Oak Creek and the North Branch upstream of the first S. 6th Street crossing were classified for a warmwater fishery and limited recreational use. The Mitchell Field Drainage Ditch was classified for a limited fishery and limited recreational use. The water quality objectives and supporting standards providing for maintenance of a warmwater fishery and full recreational use were retained for the remaining perennial stream reaches in the watershed.

ALTERNATIVE PLANS

The comprehensive plan for the Oak Creek watershed was prepared within the context of an existing set of adopted regional plan elements, including, importantly, the adopted regional land use plan, regional park and open space plan, and regional water quality management plan. Accordingly, the major focus of the watershed study was on the floodland management and fishery development plan elements. The land use and park and open space element of the watershed plan constituted a refinement of the adopted regional land use and park and open space plans. The water quality management element similarly constituted a refinement of the adopted regional water quality management plan, although with some changes in the water use objectives.

In developing alternative floodland management plans, both structural and nonstructural measures were considered. Six structural floodland measures were identified for possible application either individually or in various combinations to specific flood-prone reaches of the watershed: 1) detention storage, 2) diking, 3) diversion, 4) bridge or culvert modification or replacement, 5) channelization, and 6) onsite storage. Twelve nonstructural measures were similarly identified: 1) reservation of floodlands for recreational and related open space uses, 2) floodland use regulation, 3) channel maintenance, 4) flood insurance, 5) lending institution policies, 6) realtor policies, 7) community utility policies, 8) emergency flood-warning programs, 9) regulation of land use outside the floodlands, 10) structure floodproofing and elevation, 11) structure removal, and 12) community education programs.

The various alternative structural floodland management plans prepared and evaluated under the Oak Creek watershed study are identified in Table 83 in Chapter XII. Including the two "no action" alternatives—one providing for no development in the floodplain and one providing limited development in the floodplain fringe—12 alternative floodland management plans were prepared and evaluated. Each of these alternatives was evaluated with the assistance of water resource simulation models, assuming plan year 2000 land use conditions and the effect of such conditions on the flood flow regimen of the stream system. The alternative plans are described and evaluated in Chapter XII of this report, including the benefit-cost ratios attendant to each alternative.

In determining the recommended fishery development plan, four alternative plans were developed as described in Chapter XII.

RECOMMENDED WATERSHED PLAN

A comprehensive watershed plan was synthesized from the previously proposed regional and subregional plan elements, as these elements were refined and detailed in the watershed study, and from the alternative floodland management and fishery development plans prepared under the watershed study. The plan consists of a land use and park and open space element; a floodland management element; a fishery development element; and a water quality management element. The plan, which is recommended for adoption as a guide to the physical development of the Oak Creek watershed, contains the following salient proposals.

Land Use and Park and Open Space Element

The recommended land use and park and open space element for the watershed was derived from the previously prepared and adopted regional land use and park and open space plans. This recommended plan element proposes the following measures:

1. The guidance of future land use development in the watershed through land use controls locally exercised to achieve the land use pattern shown on Map 45 in Chapter XI. By so guiding future development, the intensification of existing, and the creation of new, developmental and environmental problems would be avoided. Importantly, 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.

   The recommended plan would accommodate a resident population in the watershed of about 72,600 persons, an increase of about 32,900 persons over the 1980 level; and a planned employment of about 27,300 jobs, an increase of about 7,300 jobs over the 1980 level. To accommodate the increase in population and employment, an additional 11.1 square miles of land would be converted from rural to urban use between 1980 and 2000, bringing the total urban land to 24.3 square miles, or 89 percent of the total area of the watershed. New urban development in the watershed is proposed to occur primarily at medium population densities, with gross residential population densities ranging from about 3,000 to 9,000 persons per square mile. The new urban development would be located in areas served, or proposed to be served, by a full range of public utilities and essential urban services, particularly public sanitary sewer and water supply services.

2. The eventual public acquisition through purchase, dedication, or gift of the remaining primary environmental corridor lands in the watershed, with the exception of about 30 acres, or about 7 percent of the total corridor lands, which are proposed to be converted to urban use reflecting committed local planning and zoning decisions. The primary environmental corridors of the Oak Creek watershed total about 447 acres and are located generally along the lower reaches of Oak Creek in the City of South Milwaukee, and in an area encompassing a large concentration of wetlands and woodlands in the southeastern area of the watershed in the City of Oak Creek. Of the total corridor lands, 229 acres, or about 51 percent, are already in public ownership. Accordingly, the plan recommends that the remaining 188 acres, or 42 percent of the total corridor lands, be acquired for public use over time through purchase, dedication, or gift as urbanization in the watershed proceeds.

3. The restoration of 579 acres of agricultural and other open lands to wetland vegetation, thereby restoring and re-creating primary environmental corridors within the water-

shed. These lands are all located within existing and proposed county-owned parkway boundaries.

4. The completion of the acquisition of lands for the Oak Creek Parkway.

5. The development of eight miles of recreational trails through environmental corridor lands—seven miles along Oak Creek between Lake Michigan and E. Fitzsimmons Road, and one mile between the Oak Creek recreational corridor and Bender Park.

6. The continued provision of park and outdoor recreational facilities throughout the watershed, including the maintenance of Grant Park and Oakwood Park as large, multi-purpose outdoor recreational facilities; the development of outdoor recreational facilities at Falk Park; the continued maintenance of Abendschein, Copernicus, and Maitland Parks as community parks; the continued maintenance of seven existing neighborhood parks; the provision of additional recreational facilities at five publicly owned but only partially developed neighborhood parks; and the acquisition and development of four additional neighborhood parks as needed.

Floodland Management Plan Element

The recommended floodland management plan element for the Oak Creek watershed consists of a carefully selected combination of structural and nonstructural measures. As a matter of policy, the Watershed Committee recommended that the design of all structural flood control works be based upon anticipated flood flows and stages under land use development conditions as reflected in the watershed land use plan. Furthermore, the Committee recommended that, should any local unit of government subsequently determine to permit new urban development in those portions of the watershed not recommended for urban development in the watershed land use plan, such development be permitted only if onsite stormwater detention will be provided to assure that runoff from the developed land will not exceed runoff under predevelopment conditions; or if it is shown that the development will not increase downstream discharges and stages over those set forth in the watershed plan.

The recommended floodland management plan element contains both structural and nonstructural flood control measures to resolve existing problems. The basic nonstructural plan measures consist of the land use development proposals contained in the land use element of the watershed plan. The major structural measures consist of:

1. Deepening and shaping of 1.4 miles of the main stem of Oak Creek between River Mile 10.30 and S. 27th Street, all in the City of Oak Creek. Within this reach, the streambed would be lowered an average of three feet, resulting in average and maximum channel depths of 7.5 feet and 10 feet, respectively. The modified channel would be turf-lined, with a bottom width of 10 feet and side slopes of one on three, and would have a capital cost of about $163,000.

2. Deepening and shaping of 1.0 mile of the North Branch of Oak Creek channel between the steel sheet pile spillway located west of the United Parcel Service distribution center and S. 13th Street in the Cities of Oak Creek and Milwaukee. Within this reach the streambed would be lowered an average of three feet, resulting in average and maximum channel depths of 5.7 feet and 11 feet, respectively. The modified channel would be turf-lined, with a bottom width of 10 feet and side slopes ranging from one on two to one on five, similar to the existing side slopes in this reach, and would have a capital cost of about $44,000. Fish and other aquatic life habitat destroyed as a result of channel modifications should be mitigated through an approved rehabilitation plan.

3. The floodproofing of 21 buildings, of which 20 are in the City of Oak Creek and one is in the City of Milwaukee, at an estimated total capital cost of $367,000; the elevation of six buildings, all in the City of Oak Creek, at an estimated capital cost of $193,000; and the removal of two buildings, both in the City of Oak Creek, at an estimated cost of $132,000.

4. The replacement of two bridges on the North Branch of Oak Creek—the Milwaukee Road railway crossing at River Mile 4.75 at an estimated capital cost of $110,000; and the W. College Avenue crossing at River Mile 4.91. The capital cost of the latter bridge replacement was not reflected in the cost of the recommended flood control measures since this bridge is scheduled to be replaced for highway improvement purposes.

5. The development of stormwater management system plans for individual subwatersheds.

The total capital cost of these measures is estimated at $1,009,000, with an annual operation and maintenance cost of about $1,000.

In addition to the foregoing measures, the floodland management element of the plan includes recommended standards relative to channel improvement and bridge replacement to ensure that major streets and highways remain operable during flood events. The plan also includes several supplemental measures intended to minimize the monetary losses associated with flooding, including participation in the Federal Flood Insurance Program and continuation of desirable lending institution and realtor policies concerning the sale of riverine properties. The maintenance of a basic cooperative stream gaging program is also recommended.

Finally, the plan recommends that each of the units of government in the watershed carefully review their floodland zoning regulations to ensure that such regulations complement the recommended watershed land use plan element and are coordinated with the structural flood control measures recommended in the plan. In general, those floodlands lying within the 100-year recurrence interval flood hazard lines under year 2000 planned land use conditions that are presently neither developed for urban use, nor committed to such use by the recordation of land subdivision plats and the installation of municipal improvements, should be zoned so as to prohibit incompatible urban development. Those existing urban land uses in the floodlands scheduled to be floodproofed, elevated, or protected through structural flood control measures should be placed in a flood hazard district until implementation of the recommended flood control measures, at which time the lands should be appropriately rezoned.

Accessory Considerations—Floodland Plan Element: In addition to the flood control measures described above, the floodland management plan element contains measures which address the need to maintain recreational navigation at the mouth of Oak Creek. These measures are aimed at alleviating the problem of sandbar formation at the mouth of Oak Creek which at times interferes with the use of a public boat launch facility located in Grant Park. These measures are stepwise in nature and consist of the following:

1. Construction of a jetty south of, and parallel to, the north side of the mouth of the creek to define a 20-foot-wide by four-foot-deep navigation channel; lowering of the sand level on the beach north of the channel to an elevation which is two feet below the top of the existing jetty located along the north side of the mouth of the creek; and the performance of such minimal dredging of the navigation channel as may be required to maintain four feet of depth, given that the proposed channel confinement should keep the channel clear by the scouring action of the streamflows. The capital cost of these measures is estimated to total $140,000. These measures would have an annual operation and maintenance cost of about $5,000.

2. Design and construction of either a diffuser network within the navigation channel or a dry dam at or near the existing footbridge near River Mile 0.14, provided that the scouring action intended to be created by the jetty construction proves to be inadequate, and dredging of the navigation channel must be done too frequently. Water either pumped through the diffusers or stored behind the dam would be used to flush accumulated sand from the navigation channel. The capital cost of the diffuser network would approximate $40,000, while the capital cost of the dry dam would approximate $55,000. The diffuser network would have an annual operation and maintenance cost of about $3,000, while the dry dam would have an annual operation and maintenance cost of about $2,000.

Fishery Development Plan Element

The fishery development plan element for the Oak Creek watershed consists of the following measures which are aimed at developing a recreational fishery and a more balanced fish population in the watershed:

1. Modification of the Mill Road dam by notching the existing structure down to the streambed to provide an opening of 40 feet at the top of the dam and 10 feet at the base of the dam. This would eliminate the existing mill dam pond and restore this reach to a free-flowing stream.

2. Dredging a portion of the accumulated sediments behind the Mill Road dam to normalize the streambed gradient and to re-create stream meanders.

3. Removal or modification of five sill and drop structures, two of which are on the main stem of Oak Creek, and three of which are on the North Branch.

4. Instream habitat mitigation measures, including the placement of boulder retards and stone rip-rap, and encouraging the development of stands of emergent vegetation in the streambed.

5. Stream bank stabilization measures, including placement of stone rip-rap and wing deflectors, as well as prescribed plantings.

6. An initial fish-stocking program.

The capital cost for this plan element is estimated to total $65,000.

Water Quality Management Plan Element

Drawing from the previously adopted regional water quality management plan, the recommended watershed plan proposes the abatement of surface water pollution problems within the Oak Creek watershed through the following measures:

1. The elimination of the direct or indirect discharge of industrial wastes to the Oak Creek and its tributaries while allowing the continued discharge of clear water, such as spent cooling water, to the stormwater drainage system.

2. The abatement of pollution from nonpoint sources throughout the Oak Creek watershed through participation in the Wisconsin Nonpoint Source Pollution Abatement Program which is administered by the Wisconsin Department of Natural Resources. Designation as a priority watershed under this program would result in the preparation of a nonpoint source abatement plan for the Oak Creek watershed. Municipalities and landowners within the watershed would then be eligible for state funding which would pay for 50 to 70 percent of the capital cost of certain nonpoint source control measures. The nonpoint source abatement plan should be coordinated with detailed stormwater management plans designed to abate local stormwater drainage problems in the watershed.

   Subject to the guidelines and recommendations set forth in the nonpoint source abatement plan, it is recommended that the abatement of pollution from nonpoint sources be conducted through implementation of a combination of the following measures: proper material storage and runoff control on industrial and commercial sites; control of sediment and debris during demolition and construction activities; public education programs to promote proper use of fertilizers and pesticides; litter and pet waste control; the application of soil conservation practices on rural land; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; stream bank erosion control; provision of sanitary sewer service to all developed areas of the watershed; development of accidental hazardous spill prevention and control plans; and the alteration of floor drains and sump pumps in industrial facilities which collect toxic and hazardous substances to eliminate discharges to storm sewers and surface watercourses. State regulations prohibit the connection of building floor drains to storm sewers or surface waters.

3. Construction of three sediment retention basins, all in the City of Oak Creek: one on the North Branch of Oak Creek about 1,300 feet upstream of the first S. 6th Street crossing; one on Oak Creek upstream of the confluence with the North Branch of Oak Creek; and one on the Mitchell Field Drainage Ditch upstream of E. Rawson Avenue. These basins would be designed to maintain a permanent pool of water with a mean depth of five feet. The water surface area and volume of each basin would be: eight acres and 40 acre-feet, respectively, for the North Branch of Oak Creek basin; seven acres and 35 acre-feet, respectively, for the Oak Creek basin; and six acres and 30 acre-feet, respectively, for the Mitchell Field Drainage Ditch basin. Construction of these basins would result in water quality objectives being met in the Oak Creek main stem from the mouth upstream to the confluence with the North Branch of Oak Creek, a distance of about 9.8 miles; in the North Branch of Oak Creek from its confluence with Oak Creek upstream to the proposed basin, a distance of about 2.6 miles; and in the Mitchell Field Drainage Ditch from its confluence with Oak Creek upstream to E. Rawson Avenue, a distance of about 0.8 mile. These basins would be designed

solely for water quality improvement purposes and would not be expected to have significant flood control benefits. These basins should be designed so as to provide passage for fish migrations.

The capital cost of these three basins is estimated to total $530,000, with annual operation and maintenance costs approximating $20,000.

4. The undertaking of a cooperative, continuing water quality monitoring program.

COST ANALYSIS

In order to assist public officials in evaluating the recommended comprehensive Oak Creek watershed plan, a preliminary capital improvement program with attendant operation and maintenance costs was prepared which, if followed, would result in total watershed plan implementation by the year 2000.

The schedule of capital and operation and maintenance costs for the recommended watershed plan is set forth in Table 95 in Chapter XIV. This schedule assumes a 15-year plan implementation period beginning in 1986 and extending through the year 2000. The capital cost of implementing the entire Oak Creek watershed plan is estimated at $10.6 million, representing an average annual capital expenditure over the 15-year period of nearly $710,000. Of this total, about $3.6 million, or 34 percent, representing an average annual expenditure of $236,500, is required to implement the park and open space element of the plan, including the acquisition of primary environmental corridor lands; about $5.8 million, or 55 percent, representing an average annual expenditure of $389,000, is required for implementation of the water quality management element of the plan; about $1.2 million, or 11 percent of the total, representing an average annual expenditure of about $80,200, is required for implementation of the floodland management element of the plan; and about $65,000, or less than 1 percent of the total, representing an average annual expenditure of about $4,300, is required for implementation of the fishery development element of the plan.

Thus, the total capital investment and operation and maintenance cost required for plan implementation may be expected to approximate $1.0 million on an average annual basis, or about $18.05 per capita per year over the 15-year plan implementation period. This per-capita cost is based on a resident watershed population of about 56,000 persons—the anticipated average resident population in the watershed between the 1980 population level of about 39,700 persons and the plan year 2000 population level of about 72,600 persons. The average annual costs of implementation of the land use and park and open space element, water quality management element, floodland management element, and fishery development element are estimated at, respectively, $302,800, or $5.41 per capita; $611,000, or $10.91 per capita; $92,800, or $1.66 per capita; and $4,300, or $0.07 per capita.

The only significant, newly proposed projects and accompanying expenditures envisioned in the Oak Creek watershed plan are those associated with the floodland management and fishery development elements. The costs of the land use and park and open space element and of the water quality management element have been included in other regional plan elements, and do not represent new expenditures. The total cost, including both capital and operation and maintenance costs, of the recommended floodland management element of the watershed plan is about $1.4 million for the 15-year plan implementation period. Of this total, $560,000 represents the costs for structure floodproofing and elevation. Since these latter expenditures would occur on private property, it may be assumed that these measures would be undertaken by the private property owners concerned and would not involve any significant public expenditures. The remaining $840,000 for implementation of the floodland management measures represent public costs. This would amount to a public investment of about $56,000 on an average annual basis, or about $1.00 per capita per year over the 15-year plan implementation period. Of this total average annual public expenditure, $43,000, or $0.77 per capita per year, represents capital costs, while $13,000, or $0.23 per capita per year, represents operation and maintenance costs.

The total cost of the recommended fishery development element of the watershed plan is about $65,000, all of which represents public costs. This amounts to an expenditure of $4,300 on an average annual basis, or about $0.07 per capita per year over the 15-year plan implementation period. All of this total represents capital costs. There are no operation and maintenance costs associated with this plan element.

PLAN IMPLEMENTATION

Chapter XV of this report identifies the various plan implementation responsibilities by level and unit of government. Most of the major recommendations contained in the comprehensive Oak Creek watershed plan can be undertaken by the existing state, county, and local units of government.

At the local governmental level, plan implementation entities include Milwaukee County and the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee. On an areawide level, the implementation agency is the Milwaukee Metropolitan Sewerage District. At the state level, implementation entities include the Wisconsin Departments of Natural Resources, Transportation, and Agriculture, Trade and Consumer Protection. At the federal level, plan implementation entities include the U. S. Environmental Protection Agency, the U. S. Geological Survey, the Federal Emergency Management Agency, the U. S. Department of Agriculture, and potentially the U. S. Army Corps of Engineers.

Primary emphasis in implementation of the newly developed recommendations of the Oak Creek watershed plan—that is, those dealing with flood control—is based on actions by the Milwaukee Metropolitan Sewerage District and, to a lesser degree, the Cities of Milwaukee and Oak Creek. The listing of the detailed plan actions required to implement the watershed plan by level, unit, and agency of government is set forth on pages 492 through 501 of this report.

PUBLIC REACTION TO THE RECOMMENDED PLAN AND SUBSEQUENT ACTION OF THE OAK CREEK WATERSHED COMMITTEE

A formal public hearing was held on April 30, 1986, upon completion of the preliminary plan for the watershed. The hearing was conducted on behalf of the Regional Planning Commission by the Oak Creek Watershed Committee, with the Chairman of the Committee presiding. The purpose of the hearing was to present the preliminary findings and recommendations of the watershed study for review and consideration by public officials and interested citizens. The hearing was announced through news releases sent to all media serving the watershed area, through letters to the heads of the local units of government in the watershed, and through publication and distribution of a Commission Newsletter summarizing the preliminary findings and recommendations of the study.[2] The hearing was held at 7:30 p.m. on April 30, 1986, at South Milwaukee City Hall.

Minutes of the public hearing were published by the Commission and provided to both the Oak Creek Watershed Committee and the Regional Planning Commission for review and consideration prior to final adoption of the recommended plan.[3] Included in the public hearing document are the written comments submitted at or after the public hearing.

The record of the public hearing indicated a generally favorable reaction to the overall plan with one major exception, and with concerns being expressed by a number of individuals, organizations, and agencies with respect to five additional matters. The major exception to the generally favorable reaction to the plan involved the proposed removal of the Mill Road dam and attendant pond in order to allow the seasonal migration of fish into the upstream reaches of the watershed.

The five additional matters for which concerns were raised were as follows:

1. The extension of a sport fishery upstream of the Mill Road dam.
2. The navigation bulkhead proposed to be constructed at the mouth of Oak Creek.
3. Stormwater drainage problems in the City of Oak Creek.
4. Planned land use recommendations for areas in the City of Cudahy.
5. The status of an existing stormwater detention basin located in the City of Cudahy.

Each of these six areas of concern is discussed below, together with the Advisory Committee's response thereto. Changes to the preliminary plan as proposed by the Advisory Committee and presented in Chapter XIV of this report are specifically noted.

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[2] *See SEWRPC Newsletter, Vol. 26, No. 1, January-February, 1986.*

[3] *See Minutes of Public Hearing, A Comprehensive Plan for the Oak Creek Watershed, SEWRPC.*

Concerns Over Removal of the Mill Road Dam

The vast majority—22 out of 24—of the individuals and groups who addressed the Advisory Committee at the public hearing presented comments relating to the recommendation for the removal of the Mill Road dam in the City of South Milwaukee for the purpose of allowing fish migration into the upstream reaches of the watershed. Of those individuals and groups, all but three were in opposition to its removal. Comments which endorsed the removal of the dam for fish migration purposes were presented by representatives of the Wisconsin Wildlife Federation, the Milwaukee County Conservation Alliance, the South Milwaukee 1400 Fishing and Hunting Club, and the Milwaukee Audubon Society. The concerns presented related to the loss of a structure of historic significance; the potential loss of the aesthetic value of the pond formed by this dam; and the potential loss of certain recreational opportunities afforded by the dam and impoundment, including ice skating.

In response to these concerns and comments, the Commission staff examined two alternatives to the removal of the Mill Road dam relative to the fishery development plan element. The alternatives were developed in cooperation with the Wisconsin Department of Natural Resources, Lake Michigan Area Fish Manager. These alternatives consist of: 1) no modification to the dam, with the resulting sport fishery being limited to reaches downstream of the dam; and 2) construction of a "fish migration channel" to the north of the dam, which could act as an effective fish ladder.

Under the first alternative, the existing dam and pond would be maintained in their present state. Thus, the aesthetic benefits of the pond would be retained, as would use of the pond for ice skating. This alternative, however, would not allow for the passage of fish into the reaches upstream of the dam, and thus these stream reaches would not be developed into a seasonal coldwater fishery. Therefore, the coldwater fishery would be limited to the reach downstream of the dam. Periodic dredging of accumulated sediments would continue to be required in the pond. The capital cost of this alternative is estimated at $100,000 for an initial dredging of the pond, with an average annual cost of about $6,000 for maintenance dredging.

The second alternative considered consists of constructing a "fish migration channel" along the north side of the pond, following the alignment of the Oak Creek Parkway. Rather than passing through the site of the Mill Road dam, this new channel would exit the pond site at a point about 80 feet north of the dam. The channel would extend from a point 85 feet downstream of Mill Road to the first Oak Creek Parkway bridge located upstream of the existing pond. The alignment of this new channel is shown in Figure 70. The new channel would have a bottom width of five feet, with side slopes of one on two. The channel would have a depth ranging from about 15 feet at Mill Road to about 6.5 feet near the upstream end of the pond. A typical cross-section of the fish migration channel is shown in Figure 70. This channel would contain the stream during periods of low flow and for floods having a recurrence interval of up to two years. Under this alternative, a berm would be constructed along the new channel in order that the remaining area currently occupied by the pond could be used to maintain a smaller pond. In order to maintain an adequate pool elevation, to ensure an adequate level of water quality in the pond, and to maintain flow over the dam in periods of dry weather, water would need to be pumped into the pond either from a well or by connection to the raw water intake for the City of South Milwaukee water treatment plant. Proper precautions would need to be taken to prevent the seepage of water from the pond into the fish migration channel. This alternative would allow for the migration of fish into the upstream reaches of the watershed while maintaining the Mill Road dam and pond.

Under this alternative, it would be necessary for a second level planning effort to be conducted by the parties directly involved in the implementation—the Milwaukee County Department of Parks, Recreation and Culture, the Wisconsin Department of Natural Resources, and the City of South Milwaukee. This second level plan would provide a more detailed evaluation and refinement of this alternative, and, importantly, an opportunity for public review of the proposal.

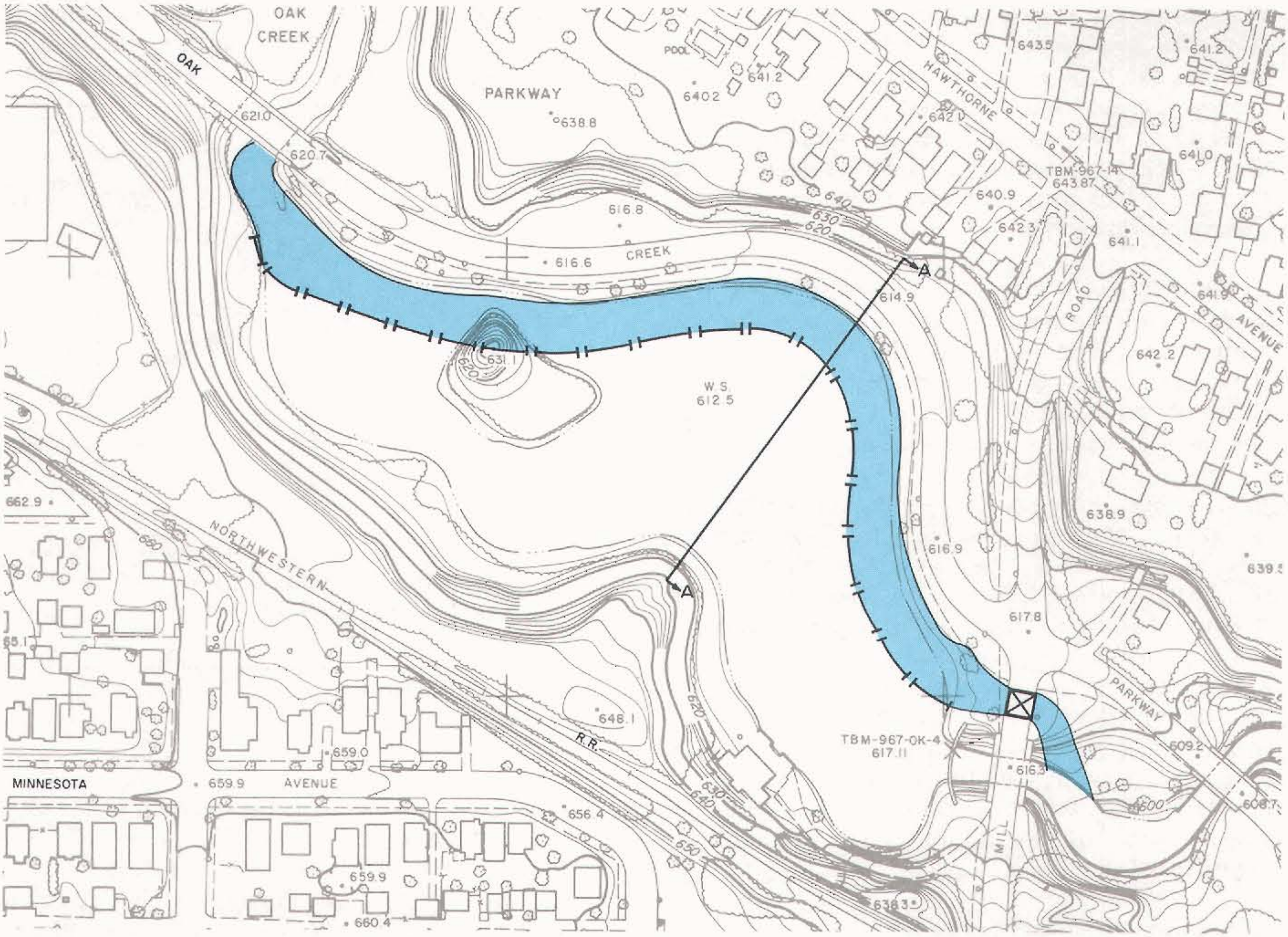
The capital cost of this alternative, including the construction of a culvert under Mill Road, is estimated at $250,000, with an annual operation and maintenance cost of about $7,000, including periodic maintenance dredging of the pond. The 100-year recurrence interval flood profile for Oak Creek under this alternative is shown in Table 103 and Figure 71.

Concerns over Extension of a Sport Fishery Upstream of the Mill Road Dam

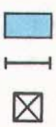
Six individuals, including four elected officials, expressed concern over the plan recommendation

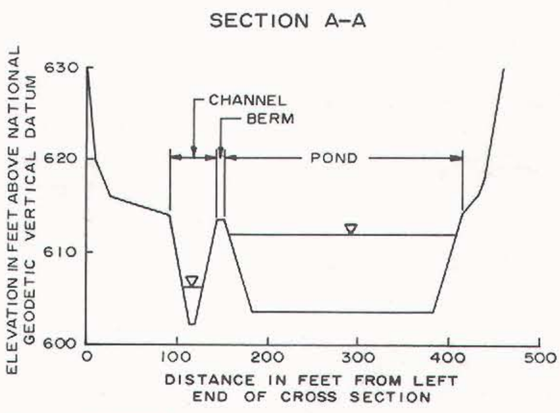
Figure 70

PROPOSED CHANNEL ALIGNMENT UNDER FISH MIGRATION CHANNEL ALTERNATIVE



LEGEND





Source: SEWRPC.

for extending the sport fishery upstream of the Mill Road dam. These concerns related to the problems of noise, litter, increased traffic, and trespassing on private lands which could result from the increased use of Oak Creek by fishermen. Local officials expressed concerns over the increased costs to the communities for policing the areas along Oak Creek. These individuals felt that the fishing opportunities available downstream of the Mill Road dam were sufficient to meet any reasonable demands.

Three individuals supported extending the fishery upstream of the dam. Those three persons represented the Wisconsin Wildlife Federation, the Milwaukee County Conservation Alliance, the South Milwaukee 1400 Fishing and Hunting Club, and the Milwaukee Audubon Society.

In response to these concerns, the Committee noted that, while the possibility for these problems to occur does exist, they could be minimized by the imposition of limits on fishing areas and on the hours when fishing would be allowed, and by the placement of signs clearly indicating where public property ends and private property begins. The Committee further noted that these problems relate not only to fishermen but also to any users of public parkways in the County. Thus, it was concluded that this issue itself should not preclude consideration of the establishment of a fishery upstream of the Mill Road dam.

Navigation Bulkhead Concerns

Comments expressing approval of the recommended navigation bulkhead for alleviating the sandbar at the mouth of Oak Creek were received from nine individuals. Howerever, three individuals were concerned that this bulkhead would not serve to fully eliminate the problem of sandbar formation at the mouth of Oak Creek. These individuals asked that consideration be given either to constructing a pair of jetties which would extend into Lake Michigan to the north and south of the mouth of the creek, or to extending the existing north jetty to the east and southeast in a "dogleg" fashion in order to control the deposition of sand at the mouth of the creek.

In response to these concerns, the Commission staff reconsidered the construction of jetties at the mouth of Oak Creek. The conclusion reached was that in order for the jetties to provide a long-term solution to the sandbar problem, they would need to be extended for several hundred feet into the lake. The cost of these jetties would be much higher than the cost of the recommended bulkhead. A 1981 study, which was prepared for the Milwaukee County Department of Parks, Recreation and Culture, recommended extending the existing north jetty 300 feet into Lake Michigan at a cost of $502,000. This alternative was discussed in Chapter XII of this report. The cost in 1984 dollars of providing two jetties, or a dogleg-shaped jetty, would exceed $1,000,000, in comparison to a capital cost of $140,000 for the measure recommended in the preliminary plan. In addition to having a much higher cost, the jetties would serve to trap sediments which are carried from north to south by Lake Michigan currents. By trapping these sediments, the jetties could deprive downdrift beaches of sand.

Table 103

100-YEAR RECURRENCE INTERVAL FLOOD STAGES ALONG OAK CREEK UNDER BOTH EXISTING AND FISH MIGRATION CHANNEL CONDITIONS (YEAR 2000 PLANNED LAND USE CONDITIONS)

Location	Flood Stage (feet NGVD[a])			
	River Mile	Existing Channel Conditions	Fish Migration Channel Conditions	Difference (feet)
	0.93	604.4	604.4	0.0
Mill Road	0.94	- -	- -	- -
Parkway Dam	0.95	- -	- -	- -
	0.96	618.5	614.5	-4.0
	1.01	618.5	614.5	-4.0
	1.04	618.5	614.5	-4.0
	1.10	618.5	615.9	-2.6
	1.17	618.5	615.9	-2.6
Third Oak Creek Parkway Bridge	1.18	- -	- -	- -
	1.20	619.2	616.8	-2.4
	1.29	619.8	619.8	0.0
Fourth Oak Creek Parkway Bridge	1.32	- -	- -	- -
	1.34	622.7	622.7	0.0

[a]NGVD-National Geodetic Vertical Datum.

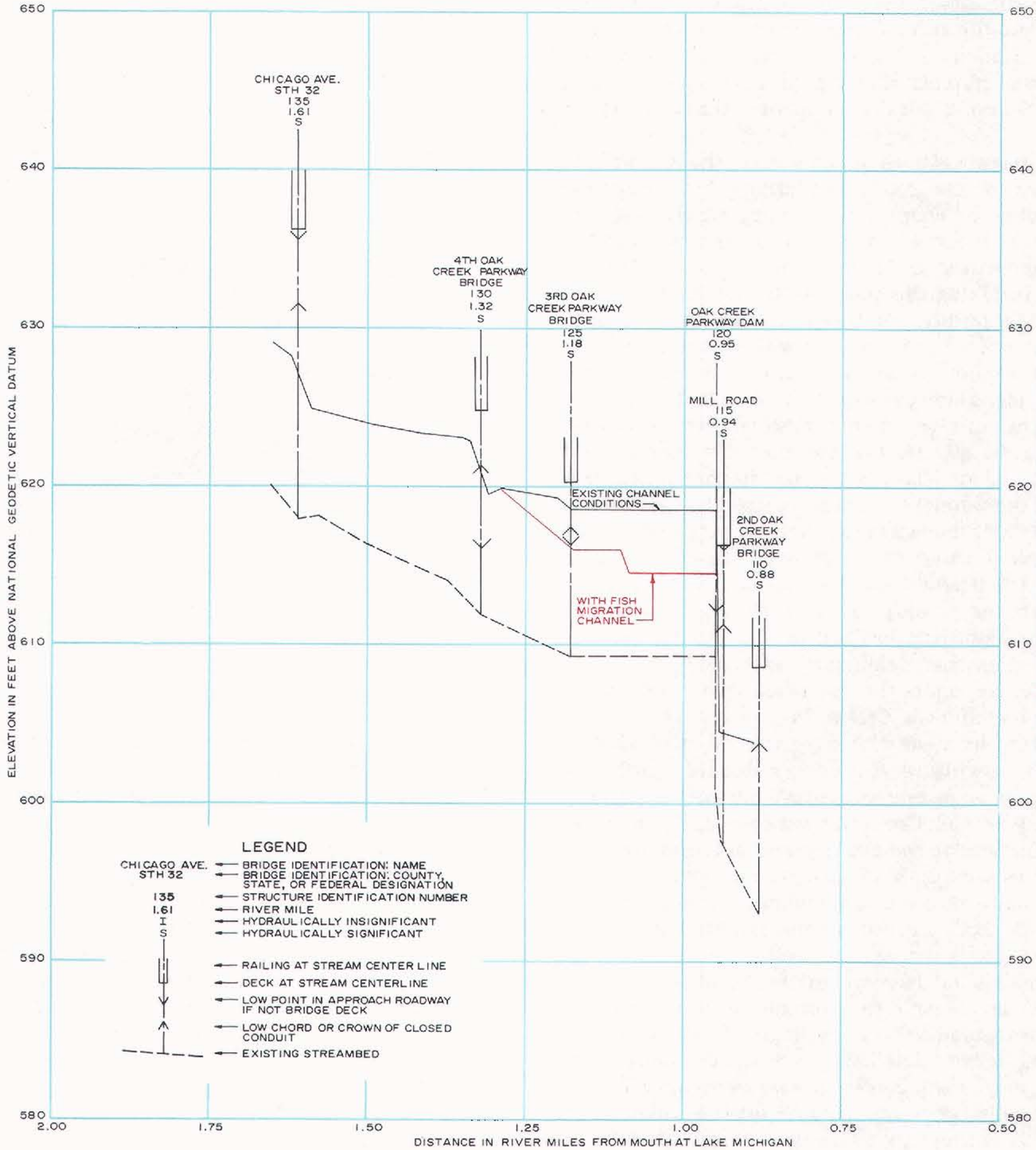
Source: SEWRPC.

Flood Control Plan and City of Oak Creek Stormwater Drainage Concerns

There was minimal discussion at the public hearing about the flood control plan. However, comments were presented by the Director of Community Development for the City of Oak Creek concerning present and anticipated future drainage problems within the City. In particular, these concerns were related to the lack of a recommendation in the watershed plan for extensive modifications to the

Figure 71

100-YEAR RECURRENCE INTERVAL FLOOD PROFILE FOR OAK CREEK FISH MIGRATION CHANNEL ALTERNATIVE



Source: SEWRPC.

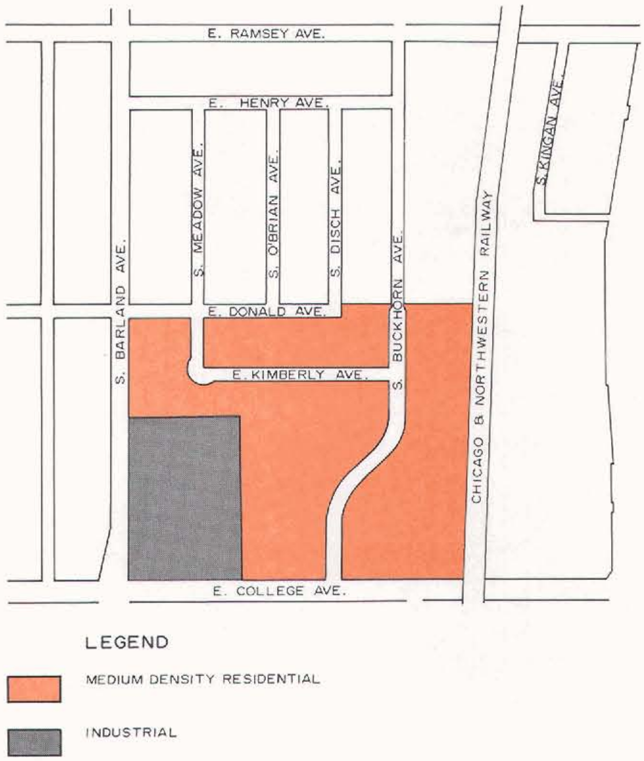
Oak Creek channel, such modifications having been previously recommended in a 1967 report prepared by Klug & Smith Company for the Milwaukee Metropolitan Sewerage District. It was indicated that officials of the City of Oak Creek felt that these modifications were necessary in order to provide an adequate outlet for the local stormwater drainage systems that would be needed to serve lands proposed for development within the City.

With respect to these concerns, the Committee reaffirmed its recommendation that only the 2.7 miles of channel deepening and shaping proposed in the preliminary plan as presented at the public hearing be included in the comprehensive plan. In taking this position, the Committee noted that the purpose of this watershed study was to resolve problems associated with overland flooding of the stream system, not stormwater management problems. Damage estimates relative to overland flooding of the stream system were not high enough to warrant the high cost of major channel modification. The Committee further noted that while the watershed plan recommends that detailed stormwater management plans be prepared for the watershed, there are no known areas of the watershed which could not be provided with adequate stormwater management facilities, given the channel configuration and land use pattern recommended in the preliminary watershed plan. More specifically, under the watershed study, the staff of the City of Oak Creek Engineering Department indicated six areas within the watershed which may experience future stormwater drainage problems. These six areas are concentrated within the Middle and Upper Oak Creek Subwatersheds. Upon review and analysis of the existing and potential drainage facilities serving these areas, it was concluded that it would be possible to adequately drain these areas without making major channel modifications.

In making its decision on the floodland management plan element, the Committee recognized that, not withstanding the findings of the watershed study, more detailed stormwater management plans may reveal certain stream segments where no technically or economically feasible alternatives exist to conveyance as a means of managing stormwater runoff locally. In these instances, additional channel modifications may be indicated. Such channel modifications may be incorporated into the watershed plan at a future date provided that it is demonstrated that: 1) there are indeed no feasible alternatives to the additional channelization; 2) the additional channelization would have no significant adverse impacts on downstream flood flows and stages; and 3) proper instream mitigation measures are provided, such as the use of turf-lined as opposed to concrete-lined channels.

Figure 72

CITY OF CUDAHY CHANGES TO RECOMMENDED LAND USE PLAN



Source: SEWRPC.

City of Cudahy Land Use Plan Element Concerns

Comments were received in a letter from the Director of Public Works for the City of Cudahy concerning the recommendations of the watershed land use plan element that certain lands in the City of Cudahy be zoned for industrial development. These lands are bordered by E. College Avenue on the south, S. Barland Avenue on the west, E. Donald Avenue on the north, and the Chicago & North Western Railway on the east. It was requested that these lands be shown in the watershed plan as recommended for residential development. In response to this request, the Committee agreed to change the designation of these lands from industrial to residential development, as shown in Figure 72. It should be noted that some of the lands within the area which are to retain the industrial land use designation are currently in institutional use.

Table 104

IMPACT OF CUDAHY DETENTION BASIN ON MITCHELL FIELD DRAINAGE DITCH FLOOD FLOWS AND STAGES (YEAR 2000 PLANNED LAND USE CONDITIONS)

Location	River Mile	10-Year Recurrence Interval Flood: Discharge (cfs) With Detention Basin	10-Year Discharge (cfs) Without Detention Basin	10-Year Stage (feet above NGVD[a]) With Detention Basin	10-Year Stage (feet above NGVD[a]) Without Detention Basin	100-Year Recurrence Interval Flood: Discharge (cfs) With Detention Basin	100-Year Discharge (cfs) Without Detention Basin	100-Year Stage (feet above NGVD[a]) With Detention Basin	100-Year Stage (feet above NGVD[a]) Without Detention Basin
Upstream of Confluence with Oak Creek	0.12	570	580	661.1	661.1	1,030	1,050	662.4	662.4
Chicago & North Western Railway	0.14	--	--	--	--	--	--	--	--
	0.15	570	580	661.1	661.1	1,030	1,050	662.7	662.7
	0.49	570	580	663.0	663.0	1,030	1,050	663.7	663.7
	0.77	570	580	664.9	664.9	1,030	1,050	665.8	665.8
E. Rawson Avenue	0.80	--	--	--	--	--	--	--	--
	0.82	560	560	665.3	665.3	940	950	666.9	667.0
	1.28	560	560	666.4	666.4	940	950	667.3	667.3
	1.82	560	560	672.1	672.1	940	950	673.1	673.1
E. College Avenue	1.83	--	--	--	--	--	--	--	--
	1.85	450	450	672.6	672.6	620	620	674.0	674.0

[a] *NGVD-National Geodetic Vertical Datum.*

Source: SEWRPC.

City of Cudahy Stormwater Drainage Basin Concerns

Comments were also received from the City of Cudahy Director of Public Works concerning a stormwater detention basin located on the Ace World Wide Moving & Storage Company property north of E. College Avenue and east of the Chicago & North Western Railway. This detention basin serves an area of about 47 acres tributary to the Mitchell Field Drainage Ditch. Construction of this basin had been requested by the City of Oak Creek in order to limit the stormwater runoff from this property to pre-development levels. It was requested by the City of Cudahy Director of Public Works that the Committee consider the continued need for this stormwater detention basin as it relates to the recommended watershed plan.

In response to this request, the Commission staff conducted an analysis of this stormwater detention basin and its impact on flood flows and stages along the Mitchell Field Drainage Ditch. Flood flows corresponding to both 10- and 100-year recurrence interval floods were simulated with and without the detention basin. The results of these simulations are provided in Table 104, and indicate that the detention basin provides for a reduction of up to 1 percent in the 10-year recurrence interval flood discharges along the Mitchell Field Drainage Ditch, and of up to 2 percent in the 100-year recurrence interval flood discharges. This reduction would not have a significant impact on flood stages along the Mitchell Field Drainage Ditch. Therefore, removal of the detention basin would not significantly increase flooding along the Drainage Ditch.

Concluding Remarks

Based upon the foregoing, the Advisory Committee made the following changes to the comprehensive plan for the Oak Creek watershed as that plan was presented at the public hearing:

1. The fishery development plan element was changed as it relates to the Mill Road dam and attendant pond by incorporating into the watershed plan the "fish migration" channel alternative. This alternative would leave the Mill Road dam in its present

location and condition while providing a bypass channel around the pond to accommodate the migratory movement of fish. The recommended alternative is shown in Figure 70, and the final fishery development plan is graphically summarized on Map 79. It is further recommended that, prior to the implementation of the fishery development plan, a second level plan be completed by the Wisconsin Department of Natural Resources, in cooperation with Milwaukee County and the City of South Milwaukee, the Department acting as lead agency in the planning effort. Such a plan is to include the following items:

- A description of subsurface conditions in the vicinity of the proposed facilities, including soil boring data as needed.
- Preliminary engineering plans for the proposed fish migration channel and the handicapped fishing pier at the mouth of Oak Creek.
- Recommendations for limitations on the times during which, and on the locations at which, fishing will be allowed in the watershed in order to alleviate potential regulatory problems.
- Recommendations as to how the fishery development plan should be funded.
- An opportunity for the public to participate in the second level planning process through the concerned local officials and through the holding of public informational meetings and a public hearing on the plan recommendations.

2. It was recommended that the floodland management plan recommendation for the preparation of stormwater management plans be supplemented to indicate that such plans may indicate that for certain stream reaches there are no technically or economically feasible alternatives to improving the conveyance capacity as a means of local stormwater management. In such instances, additional channel modifications may be necessary. Such channel modifications may be incorporated into the watershed plan provided it is demonstrated that: a) there are no feasible alternatives; b) the additional channelization would have no significant adverse impact on downstream flood flows and stages; and c) proper instream mitigation measures are provided.

3. The year 2000 planned land use map for the Oak Creek watershed was changed to reflect existing zoning in the City of Cudahy for an area bounded by E. College Avenue on the south, S. Barland Avenue on the west, E. Donald Avenue on the north, and the Chicago & North Western Railway on the east. The revised land use recommendation is shown in Figure 72.

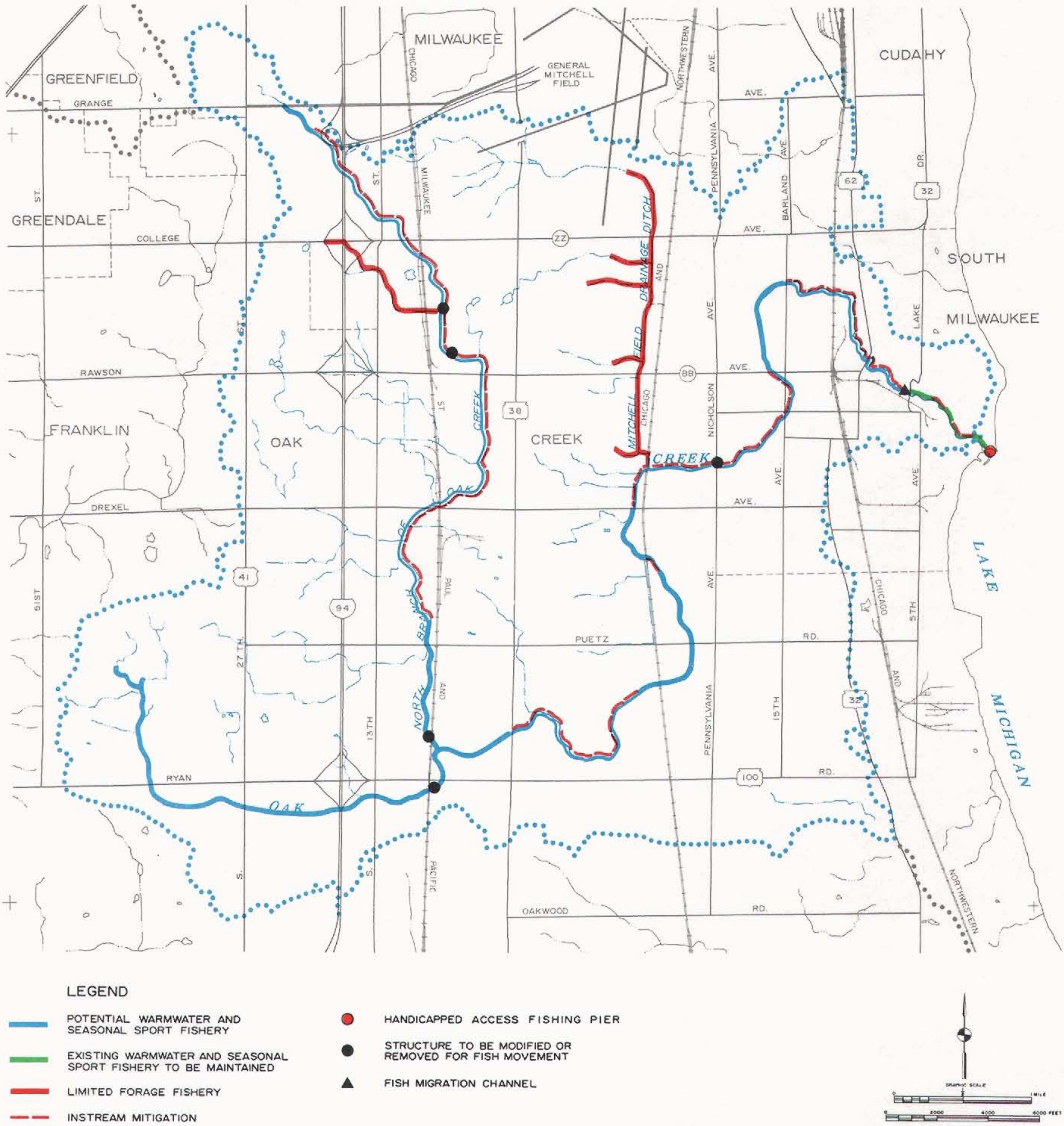
4. It was recommended that the City of Cudahy pursue with the City of Oak Creek the matter of abandoning a stormwater detention basin located on the Ace World Wide Moving & Storage Company property north of E. College Avenue and east of the Chicago & North Western Railway. In making this recommendation, the Advisory Committee recognized that analyses conducted under the watershed study indicated that abandonment of this basin would not have any significant effects on flood flows and stages along the Mitchell Field Drainage Ditch.

CONCLUSION

Adoption and implementation of the recommended comprehensive plan for the Oak Creek watershed may be expected to result in the substantial achievement of the adopted watershed development objectives and supporting standards. Consequently, 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, would minimize the development of new problems of this kind, and would enhance the potential biological and recreational use of the stream system. Failure to implement the watershed plan may be expected to result in the further intensification of developmental and environmental problems and potentially the creation of new problems which will be even more expensive to resolve.

Map 79

FINAL RECOMMENDED MEASURES TO MAINTAIN A MAXIMUM WARMWATER AND SEASONAL COLDWATER FISHERY



Because of the concerns expressed at the public hearing regarding the preliminary recommendation for the removal of the Mill Road dam and attendant pond, the Watershed Committee changed its recommendation concerning this feature of the plan. The final recommendation consists of the construction of a fish migration channel which would extend along the north side of the pond between a point about 80 feet downstream of Mill Road and the third Oak Creek Parkway bridge. The existing dam would remain intact, as would the pond except for that area required for the fish migration channel. The remaining features of the preliminary recommended fishery development element would not be changed. These features include: 1) the removal or modification with fish ladders of five sill and drop structures; 2) the application of upstream habitat mitigation measures along 10.6 miles of stream; 3) the application of stream bank stabilization measures; 4) an initial fish-stocking program; and 5) the construction of a handicapped access fishing pier at the mouth of Oak Creek. Implementation of the fishery development plan would not occur until after the completion of a second level plan which would include a public hearing on the plan.

Source: SEWRPC.

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APPENDICES

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Appendix A

OAK CREEK WATERSHED COMMITTEE

Norbert S. Theine Chairman	Administrator, City of South Milwaukee
Kurt W. Bauer Secretary	Executive Director, Southeastern Wisconsin Regional Planning Commission
John M. Bennett	City Engineer, City of Franklin
Thomas D. Borgwardt	Airport Engineer, General Mitchell Field
Ronald W. Kazmierczak	Assistant District Director, Southeast District, Wisconsin Department of Natural Resources
Richard A. Keyes	Environmental Engineer, Department of Public Works, Milwaukee County
Charles G. Lambert	Secretary, Milwaukee County Conservation Alliance
Edwin J. Laszewski, Jr.	City Engineer, City of Milwaukee
Patrick Marchese	Executive Director, Milwaukee Metropolitan Sewerage District
Paul E. Milewski	Director of Community Development, City of Oak Creek
David F. Schulz	Director, Department of Parks, Recreation and Culture, Milwaukee County
John D. St. John	Supervisor, Milwaukee County Board; Member, Milwaukee County Land Conservation Committee
Douglas R. Sleight	Member, South Milwaukee Yacht Club

Appendix B

RESULTS OF FISH SURVEY IN THE OAK CREEK WATERSHED BY STATION: JUNE 1983

Station Number	Stream	Species and Population According to Their Relative Tolerance to Organic Pollution														Total Number of Species	Total Population
		Very Tolerant					Tolerant							Intolerant			
		White sucker (Catastomus commersoni)	Fathead minnow (Pimephales promelas)	Central mudminnow (Umbra limi)	Population: Number	Population: Percent of Station Total	Green sunfish (Lepomis cyanellus)	Creek chub (Semotilus atromaculatas)	Black crappie (Pomoxis nigromaculatus)	Brook stickleback (Culaea inconstans)	Gizzard shad (Dorosoma cepedianum)	Population: Number	Population: Percent of Station Total	Population: Number	Population: Percent of Station Total		
1	Oak Creek-Main Stem	--	1	--	1	4	1	--	1	--	24	26	96	--	--	4	27
2	Oak Creek-Main Stem	--	--	--	--	--	--	--	--	--	13	13	100	--	--	1	13
3	Oak Creek-Main Stem	--	--	--	--	--	--	1	--	--	--	1	100	--	--	1	1
4	Oak Creek-Main Stem	--	--	--	--	--	--	13	--	--	--	13	100	--	--	1	13
5	Oak Creek-Main Stem	--	--	--	--	--	--	35	--	--	--	35	100	--	--	1	35
6	Oak Creek-Main Stem	3	--	134	137	58	--	26	--	72	--	98	42	--	--	4	235
7	Oak Creek-Main Stem	4	2	1	7	11	--	56	--	--	--	56	89	--	--	4	63
8	Oak Creek-Main Stem	--	--	--	--	--	--	--	--	11	--	11	100	--	--	1	11
9	Oak Creek-Main Stem	--	6	--	6	60	--	--	--	4	--	4	40	--	--	2	10
10	Mitchell Field Drainage Ditch	--	14	--	14	78	--	--	--	4	--	4	22	--	--	2	18
11	Mitchell Field Drainage Ditch	--	30	3	33	33	--	5	--	61	--	66	67	--	--	4	99
12	North Branch of Oak Creek	-	30	--	30	27	--	72	--	10	--	82	73	--	--	3	112
13	North Branch of Oak Creek	--	1	--	1	8	--	2	--	9	--	11	92	--	--	3	12
14	North Branch of Oak Creek	--	3	--	3	75	--	1	--	--	--	1	25	--	--	2	4
Total		7	87	138	232	36	1	211	1	171	37	421	64	--	--	8	653

Source: SEWRPC.

Appendix C

RAINFALL AND RUNOFF DATA FOR STORM WATER DRAINAGE AND FLOOD CONTROL FACILITY DESIGN

Table C-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	Equation[b]: 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 C-2

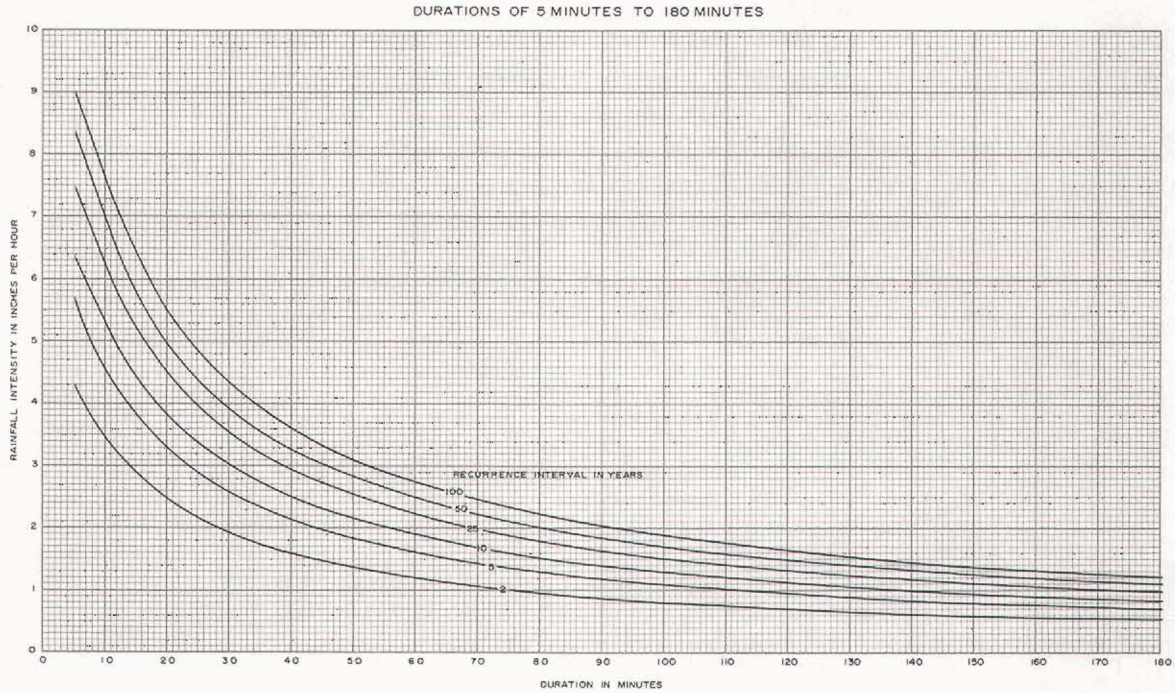
WEIGHTED RUNOFF COEFFICIENTS FOR USE IN THE RATIONAL FORMULA

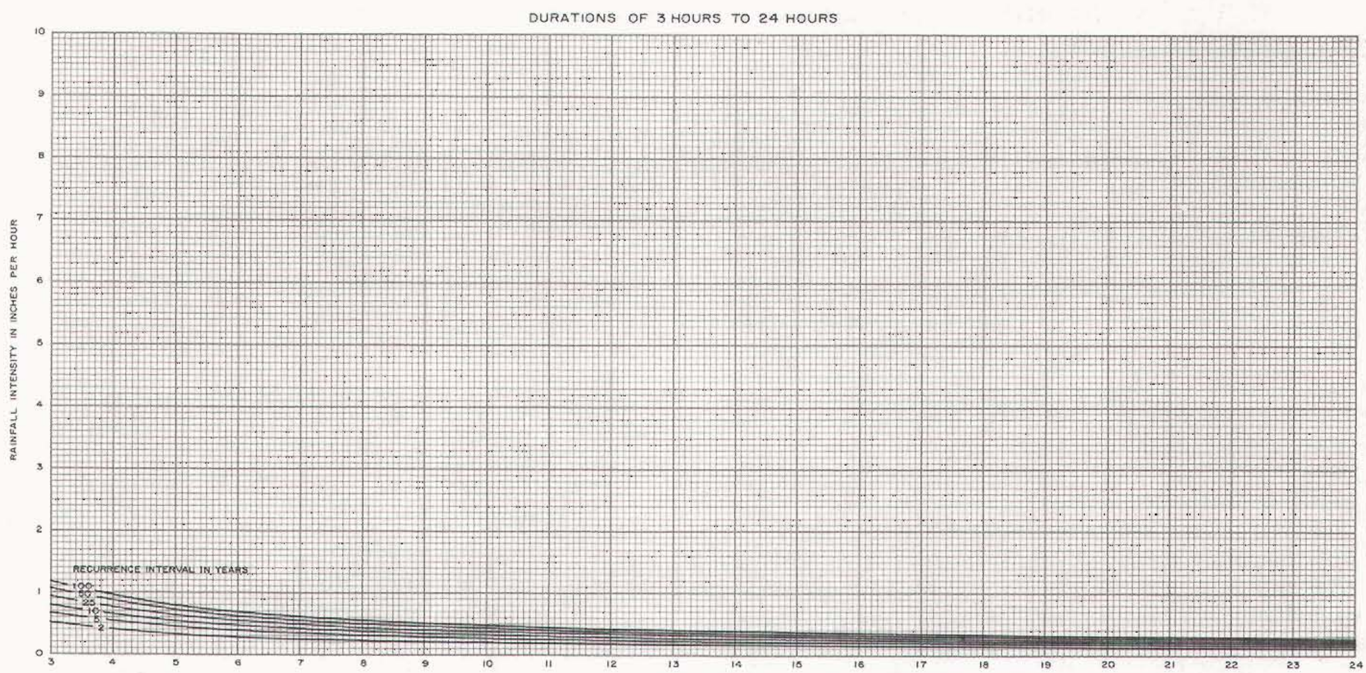
Land Use	Percent Impervious Area	Hydrologic Soil Group A: Slope Range (percent) 0 - 2	A: 2 - 6	A: 6 & Over	B: 0 - 2	B: 2 - 6	B: 6 & Over	C: 0 - 2	C: 2 - 6	C: 6 & Over	D: 0 - 2	D: 2 - 6	D: 6 & Over
Industrial.	90	0.67 0.85	0.68 0.85	0.68 0.86	0.68 0.85	0.68 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	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 C-1

POINT RAINFALL INTENSITY-DURATION-FREQUENCY CURVES FOR MILWAUKEE, WISCONSIN[a] (ARITHMETIC SCALES)



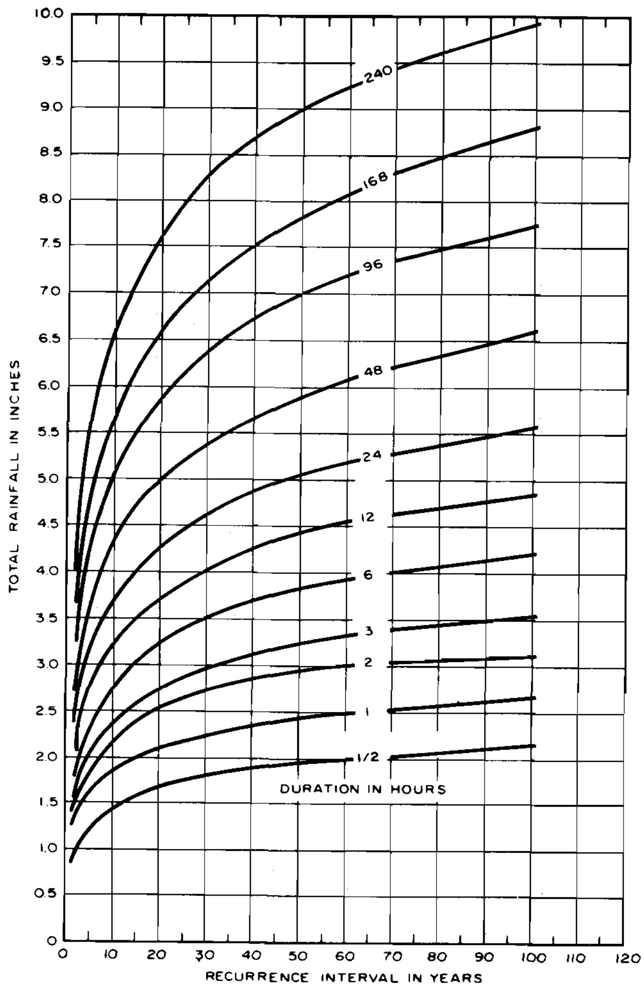


[a] *The curves are based on Milwaukee rainfall data for the 64-year period of 1903 to 1966. These curves are applicable within an accuracy of ± 10 percent to the entire Southeastern Wisconsin Planning Region.*

Source: SEWRPC.

Figure C-2

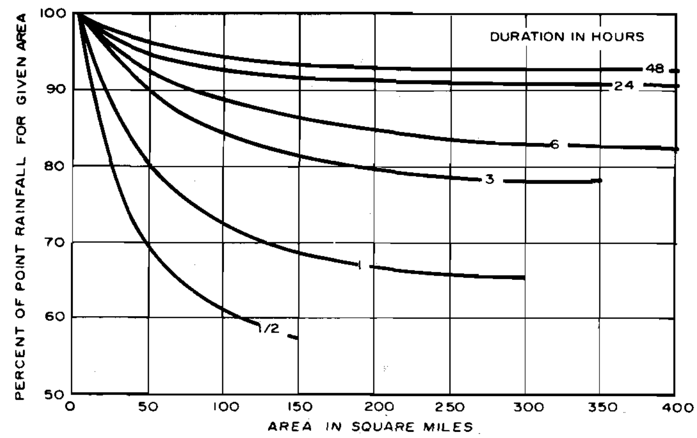
POINT RAINFALL DEPTH-DURATION-FREQUENCY RELATIONSHIPS IN THE REGION AND THE OAK CREEK WATERSHED



Source: National Weather Service and SEWRPC.

Figure C-3

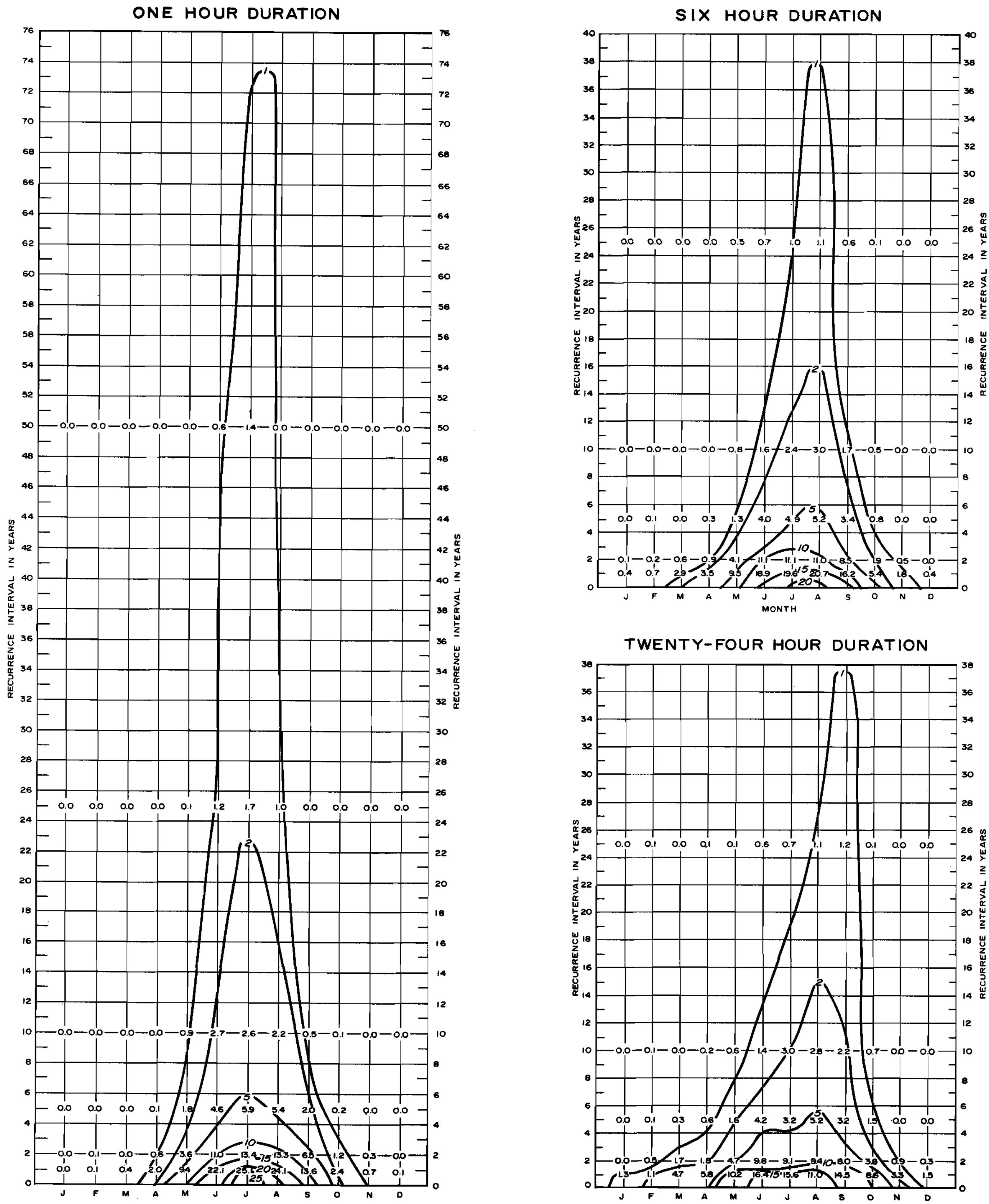
RAINFALL DEPTH-DURATION-AREA RELATIONSHIPS IN THE REGION AND THE OAK CREEK WATERSHED



Source: National Weather Service and SEWRPC.

Figure C-4

SEASONAL VARIATION OF RAINFALL EVENT DEPTH IN THE REGION AND THE OAK CREEK WATERSHED

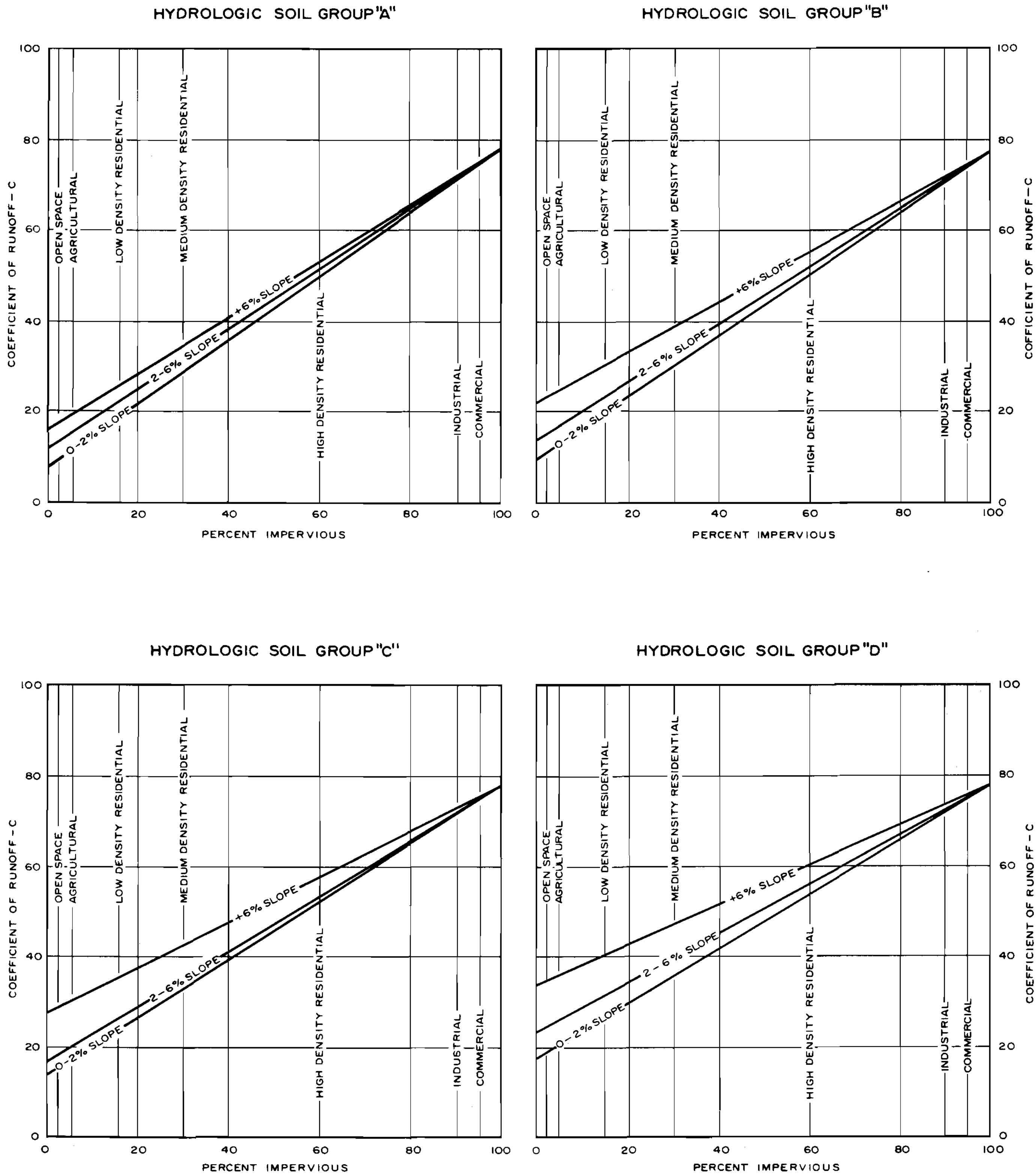


CURVE NUMBERS INDICATE THE PROBABILITY IN PERCENT OF OBTAINING A RAINFALL EVENT IN ANY MONTH OF A PARTICULAR YEAR WITH A DEPTH EQUAL TO OR GREATER THAN THE RAINFALL DEPTH CORRESPONDING TO A GIVEN RECURRENCE INTERVAL AS SHOWN IN FIGURE C-2.

Source: National Weather Service and SEWRPC.

Figure C-5

COEFFICIENT OF RUNOFF CURVES FOR HYDROLOGIC SOIL GROUPS



Source: SEWRPC.

Appendix D

HYDROLOGIC-HYDRAULIC SUMMARY FOR STRUCTURES ON OAK CREEK AND SELECTED MAJOR TRIBUTARIES: EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

Table D-1

HYDROLOGIC-HYDRAULIC SUMMARY—LOWER OAK 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
100	Pedestrian Bridge	0.14	1I	- -	- -	1,140	- -	- -	- -	- -	- -	1,590	- -	- -	- -	- -	- -	1,780	- -	- -	- -	- -	- -
105	1st Oak Creek Parkway Bridge	0.35	1S	10	Yes	1,140	585.5	585.0	0.5	- -	- -	1,590	586.8	586.0	0.8	- -	- -	1,780	587.4	586.3	1.1	- -	- -
110	2nd Oak Creek Parkway Bridge	0.88	1S	10	Yes	1,140	600.3	598.4	1.9	- -	- -	1,590	600.9	599.2	1.7	- -	- -	1,780	601.1	599.4	1.7	- -	- -
115	Mill Road	0.94	1S	50	Yes	1,140	602.4	602.0	0.4	- -	- -	1,590	603.4	602.8	0.6	- -	- -	1,780	603.8	603.1	0.7	- -	- -
120	Oak Creek Parkway Dam	0.95	2S	- -	- -	1,140	616.4	602.4	14.0	- -	- -	1,590	617.2	603.4	13.8	- -	- -	1,780	617.5	603.8	13.7	- -	- -
125	3rd Oak Creek Parkway Bridge	1.18	1S	10	Yes	1,140	616.4	616.4	0.0	- -	- -	1,590	617.2	617.2	0.0	- -	- -	1,780	617.7	617.4	0.3	- -	- -
130	4th Oak Creek Parkway Bridge	1.32	1S	10	Yes	1,140	618.2	617.3	0.9	- -	- -	1,590	619.4	618.0	1.4	- -	- -	1,780	620.0	618.4	1.6	- -	- -
135	Chicago Avenue/STH 32	1.61	1S	50	Yes	1,140	624.1	622.6	1.5	- -	- -	1,590	625.2	623.2	2.0	- -	- -	1,780	625.7	623.4	2.3	- -	- -
140	5th Oak Creek Parkway Bridge	2.14	1S	10	Yes	1,140	631.5	631.0	0.5	- -	- -	1,590	632.5	632.0	0.5	- -	- -	1,780	632.9	632.3	0.6	- -	- -
145	Pedestrian Bridge	2.24	1I	- -	- -	1,140	- -	- -	- -	- -	- -	1,590	- -	- -	- -	- -	- -	1,780	- -	- -	- -	- -	- -
150	Chicago & North Western Railway	2.35	1S	100	Yes	1,140	636.2	635.5	0.7	- -	- -	1,590	637.5	636.7	0.8	- -	- -	1,780	638.0	637.1	0.9	- -	- -
155	15th Avenue	2.84	1S	50	Yes	1,090	640.8	640.3	0.5	- -	- -	1,560	642.0	641.2	0.8	- -	- -	1,780	642.5	641.5	1.0	- -	- -
160	Pedestrian Bridge	3.18	1I	- -	- -	1,090	- -	- -	- -	- -	- -	1,560	- -	- -	- -	- -	- -	1,780	- -	- -	- -	- -	- -
165	Pine Street	3.37	1S	10	Yes	1,090	645.9	645.4	0.5	- -	- -	1,560	647.0	646.5	0.5	- -	- -	1,780	647.4	646.9	0.5	- -	- -
170 & 175	E. Rawson and 16th Avenues[g]	3.65	1S	50	Yes	1,090	648.2	648.0	0.2	- -	- -	1,560	649.4	649.1	0.3	- -	- -	1,780	650.0	649.6	0.4	- -	- -
180	15th Avenue	3.76	1S	50	Yes	1,090	648.5	648.4	0.1	- -	- -	1,560	649.8	649.6	0.2	- -	- -	1,780	650.3	650.2	0.1	- -	- -
185	Pedestrian Bridge	3.89	1I	- -	- -	1,090	- -	- -	- -	- -	- -	1,560	- -	- -	- -	- -	- -	1,780	- -	- -	- -	- -	- -
190	Milwaukee Avenue	4.01	1S	50	Yes	1,090	649.0	648.9	0.1	- -	- -	1,560	650.4	650.2	0.2	- -	- -	1,780	651.0	650.8	0.2	- -	- -
195	15th Avenue	4.06	1S	50	Yes	1,090	649.1	649.0	0.1	- -	- -	1,560	650.6	650.5	0.1	- -	- -	1,780	651.2	651.1	0.1	- -	- -
200	Pedestrian Bridge	4.18	1I	- -	- -	1,090	- -	- -	- -	- -	- -	1,560	- -	- -	- -	- -	- -	1,780	- -	- -	- -	- -	- -
205	S. Pennsylvania Avenue[h]	4.71	1S	50	Yes	1,090	652.3	650.4	1.9	- -	- -	1,560	653.2	651.8	1.4	- -	- -	1,780	653.7	652.4	1.3	- -	- -

[a] *Measured in miles above mouth at Lake Michigan.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of South Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.97 feet. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The bridges at E. Rawson and 16th Avenues were replaced in fall 1985 with a single structure. The new bridge is reflected in the flood stages listed in this table and on the profiles in Appendix G.*

[h] *There is a drop of about 4.0 feet in the streambed at the downstream side of the S. Pennsylvania Avenue bridge.*

Source: SEWRPC.

Table D-2

HYDROLOGIC-HYDRAULIC SUMMARY—MIDDLE OAK 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
210	Chicago & North Western Railway	5.25	1S	100	Yes	850	659.6	659.4	0.2	--	--	1,290	661.0	660.7	0.3	--	--	1,500	661.5	661.2	0.3	--	--
215	E. Drexel Avenue	5.56	1S	50	Yes	850	660.2	660.1	0.1	--	--	1,290	661.6	661.5	0.1	--	--	1,500	662.3	662.0	0.3	--	--
220	Chicago & North Western Railway	6.06	1S	100	Yes	850	661.4	661.4	0.0	--	--	1,290	662.7	662.5	0.2	--	--	1,500	663.3	663.1	0.2	--	--
225	E. Forest Hill Avenue	6.25	1S	10	No	850	662.0	661.7	0.3	0.3	--	1,290	663.0	662.9	0.1	1.3	0.2	1,500	663.6	663.5	0.1	1.9	0.8
230	E. Puetz Road	6.83	1S	50	Yes	850	662.8	662.7	0.1	--	--	1,290	663.8	663.5	0.3	--	--	1,500	664.3	663.9	0.4	--	--
235	Chicago & North Western Railway	7.34	1S	100	Yes	1,130	664.2	664.0	0.2	--	--	1,780	665.0	664.7	0.3	--	--	2,080	665.5	665.0	0.5	--	--
240	S. Nicholson Road	7.44	1S	50	No	1,130	664.8	664.6	0.2	--	--	1,780	666.3	665.5	0.8	1.1	--	2,080	666.7	666.0	0.7	1.5	--
250	S. Shepard Avenue	8.41	1S	10	No	1,130	669.6	669.3	0.3	--	--	1,780	670.9	670.3	0.6	0.3	--	2,080	671.2	670.6	0.6	0.6	--
255	S. Howell Avenue/ Northbound STH 38	9.22	1S	50	Yes	1,130	675.9	675.7	0.2	--	--	1,780	677.0	676.8	0.2	--	--	2,080	677.6	677.2	0.4	--	--
256	S. Howell Avenue/ Southbound STH 38	9.24	1S	50	Yes	1,130	675.9	675.9	0.0	--	--	1,780	677.0	677.0	0.0	--	--	2,080	677.6	677.6	0.0	--	--

[a]*Measured in miles above mouth at Lake Michigan.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table D-3

HYDROLOGIC-HYDRAULIC SUMMARY—UPPER OAK 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
260	W. Ryan Road/STH 100	10.06	1S	50	No	400	679.1	679.0	0.1	0.5	--	790	681.0	680.3	0.7	2.4	--	1,030	682.0	680.9	1.1	3.4	--
261	Spillway	10.12	2S	--	--	400	679.1	679.1	0.0	--	--	790	681.0	681.0	0.0	--	--	1,030	682.0	682.0	0.0	--	--
265	Chicago, Milwaukee, St. Paul & Pacific Railroad	10.24	1S	100	Yes	400	682.2	679.2	3.0	--	--	790	682.2	681.1	1.1	--	--	1,030	682.3	682.0	0.3	--	--
270	Private Bridge	10.25	1S	--	--	400	683.6	682.2	1.4	1.8	1.8	790	684.4	682.2	2.2	2.6	2.6	1,030	684.8	682.3	2.5	3.0	3.0
275	Private Bridge	10.46	1S	--	--	400	686.3	685.4	0.9	--	--	790	689.0	686.6	2.4	--	--	1,030	690.4	687.0	3.4	0.6	--
280	Private Bridge	10.60	1I	--	--	400	--	--	--	--	--	790	--	--	--	--	--	1,030	--	--	--	--	--
285	S. 13th Street/CTH V	10.69	1S	50	Yes	400	688.2	688.0	0.2	--	--	790	690.2	689.6	0.6	--	--	1,030	691.7	690.7	1.0	--	--
286	Pedestrian Bridge	10.72	1I	--	--	400	--	--	--	--	--	790	--	--	--	--	--	1,030	--	--	--	--	--
290	IH 94 Northbound	10.97	1S	100	Yes	310	688.6	688.5	0.1	--	--	600	690.5	690.5	0.0	--	--	790	691.9	691.9	0.0	--	--
295	IH 94 Southbound	10.99	1S	100	Yes	310	688.6	688.6	0.0	--	--	600	690.6	690.5	0.1	--	--	790	691.9	691.9	0.0	--	--
300	S. 20th Street	11.24	1S	10	Yes	310	689.3	688.8	0.5	--	--	600	692.3	690.7	1.6	0.3	0.3	790	692.8	692.0	0.8	0.8	0.8
305	S. 27th Street/STH 41	11.70	1S	50	Yes	220	693.4	693.0	0.4	--	--	430	694.7	693.8	0.9	--	--	570	695.1	694.2	0.9	--	--
310	S. 31st Street	11.97	1S	10	Yes	160	697.0	697.0	0.0	--	--	310	698.4	698.0	0.4	--	--	410	699.2	698.4	0.8	--	--
312	Private Bridge	12.23	1S	--	--	160	702.4	702.0	0.4	--	--	310	703.6	702.6	1.0	--	--	410	704.2	702.7	1.5	0.2	0.2
315	W. Ryan Road/STH 100	12.52	1S	50	Yes	160	711.3	709.1	2.2	--	--	310	713.2	710.0	3.2	--	--	410	715.4	710.3	5.1	--	--
316	Concrete Drop Sill	12.69	2S	--	--	160	713.5	713.5	0.0	--	--	310	714.4	714.4	0.0	--	--	410	715.7	715.6	0.1	--	--
317	Concrete Drop Sill	12.90	2S	--	--	160	718.5	718.5	0.0	--	--	310	720.0	720.0	0.0	--	--	410	720.8	720.6	0.2	--	--
318	Concrete Drop Sill	13.07	2S	--	--	100	723.6	723.6	0.0	--	--	170	725.0	725.0	0.0	--	--	210	725.6	725.6	0.0	--	--
320	W. Southland Drive	13.18	1S	10	Yes	100	731.7	730.6	1.1	--	--	170	732.5	731.0	1.5	--	--	210	733.0	731.2	1.8	--	--
325	W. Woodward Drive	13.31	1S	10	Yes	50	733.8	733.6	0.2	--	--	90	734.4	734.0	0.4	--	--	110	734.6	734.2	0.4	--	--
330	W. Glenwood Drive	13.58	1S	10	Yes	10	743.4	741.8	1.6	--	--	30	744.6	742.0	2.6	--	--	40	744.8	742.1	2.7	0.2	0.2
331	Private Drive	13.60	1S	--	--	10	745.0	743.4	1.6	--	--	30	745.8	744.6	1.2	0.3	0.3	40	745.8	744.8	1.0	0.3	0.3
332	Private Drive	13.62	1S	--	--	10	745.7	745.0	0.7	--	--	30	746.4	745.8	0.6	0.3	0.3	40	746.5	745.8	0.7	0.4	0.4
333	W. Maple Crest Drive	13.64	1S	10	Yes	10	746.0	745.7	0.3	--	--	30	746.8	746.4	0.4	--	--	40	746.8	746.5	0.3	--	--
335	Reservoir Outlet	13.65	1S	--	--	10	747.3	746.0	1.3	--	--	30	747.8	746.8	1.0	--	--	40	747.9	746.8	1.1	--	--
340	Private Bridge	13.76	1S	--	--	20	748.6	747.3	1.3	--	--	50	748.6	747.8	0.8	--	--	60	748.6	747.9	0.7	--	--
345	W. Puetz Road	13.79	1S	50	No	20	750.9	748.8	2.1	--	--	50	752.6	749.0	3.6	0.1	0.1	60	752.6	749.0	3.6	0.1	0.1

[a]*Measured in miles above mouth at Lake Michigan.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek and City of Franklin Vertical Datums = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table D-4

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO UPPER OAK CREEK: EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
800	Private Drive	0.02	1S	- -	- -	20	735.6	733.8[g]	1.8	- -	- -
803	Private Drive	0.04	1S	- -	- -	20	736.1	735.6	0.5	- -	- -
805	Private Drive	0.05	1S	- -	- -	20	736.6	736.1	0.5	- -	- -
810	W. Glenwood Drive	0.21	1S	10	Yes	20	742.6	740.8	1.8	- -	- -
815	Private Drive	0.26	1S	- -	- -	20	745.0	742.7	2.3	- -	- -
817	Private Drive	0.28	1S	- -	- -	20	745.2	745.0	0.2	- -	- -
820	W. Maple Crest Drive	0.30	1S	10	No	20	746.4	745.2	1.2	0.1	0.1
825	W. Puetz Road	0.55	1S	50	Yes	3	753.8	753.0	0.8	- -	- -

Number	50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
800	50	735.9	734.4	1.5	- -	- -	60	736.0	734.6	1.4	- -	- -
803	50	736.3	735.9	0.4	- -	- -	60	736.4	736.0	0.4	- -	- -
805	50	737.0	736.3	0.7	- -	- -	60	737.1	736.0	1.1	0.1	0.1
810	50	743.7	741.1	2.6	- -	- -	60	744.2	741.2	3.0	0.1	0.1
815	50	745.0	743.8	1.2	- -	- -	60	745.0	744.2	0.8	- -	- -
817	50	745.4	745.0	0.4	- -	- -	60	745.5	745.0	0.5	- -	- -
820	50	746.4	745.4	1.0	0.1	0.1	60	746.4	745.5	0.9	0.1	0.1
825	8	754.1	753.4	0.7	- -	- -	10	754.3	753.5	0.8	- -	- -

[a]Measured in miles above confluence with Oak Creek.

[b]Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c]A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d]The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e]City of Franklin Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.

[f]Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

[g]The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the tributary to Upper Oak Creek.

Source: SEWRPC.

Table D-5

HYDROLOGIC-HYDRAULIC SUMMARY—NORTH BRANCH OAK 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
400	Chicago, Milwaukee, St. Paul & Pacific Railroad[g]	0.10	1S	100	Yes	710	683.8	681.2	2.6	- -	- -	1,400	685.9	683.1	2.8	- -	- -	1,670	686.8	683.6	3.2	- -	- -
402	Private Bridge	0.21	1S	- -	- -	710	686.8	685.1	1.7	2.0	0.2	1,400	687.4	686.9	0.5	2.6	0.8	1,670	687.9	687.7	0.2	3.1	1.3
403	Private Bridge	0.34	1I	- -	- -	710	- -	- -	- -	- -	- -	1,400	- -	- -	- -	- -	- -	1,670	- -	- -	- -	- -	- -
405	W. Puetz Road	0.92	1S	50	Yes	650	694.3	694.0	0.3	- -	- -	1,190	696.8	695.6	1.2	- -	- -	1,450	698.0	696.1	1.9	0.2	0.1
407	Private Bridge	1.71	1S	- -	- -	650	702.8	702.7	0.1	1.7	1.7	1,190	704.0	703.9	0.1	2.9	2.9	1,450	704.4	704.4	0.0	3.2	3.2
410	W. Wildwood Drive	2.00	1S	10	Yes	500	703.6	703.6	0.0	- -	- -	800	704.9	704.8	0.1	1.3	1.3	930	705.3	705.3	0.0	1.7	1.7
415	W. Drexel Avenue	2.21	1S	50	Yes	500	703.9	703.7	0.2	- -	- -	800	705.5	705.0	0.5	- -	- -	930	706.1	705.4	0.7	- -	- -
420	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.25	1S	100	Yes	430	706.4	703.9	2.5	- -	- -	750	708.5	705.4	3.1	- -	- -	880	709.3	706.0	3.3	- -	- -
425	S. 6th Street	2.41	1S	10	Yes	430	707.0	706.4	0.6	- -	- -	750	709.4	708.6	0.8	0.9	0.8	880	709.9	709.4	0.5	1.4	1.3
430	W. Marquette Avenue	3.04	1S	10	No	260	712.4	712.1	0.3	0.4	0.4	430	713.6	713.4	0.2	1.6	1.6	520	714.0	713.8	0.2	2.0	2.0
435	W. Rawson Avenue/ CTH BB	3.51	1S	50	Yes	260	712.9	712.9	0.0	- -	- -	430	714.1	714.0	0.1	- -	- -	520	714.6	714.4	0.2	- -	- -
436	S. 6th Street	3.86	1S	10	Yes	260	715.2	714.8	0.4	- -	- -	430	716.3	715.9	0.4	- -	- -	520	716.8	716.3	0.5	- -	- -
437	Spillway	3.90	2S	- -	- -	260	716.1	715.2	0.9	- -	- -	430	716.8	716.3	0.5	- -	- -	520	717.0	716.8	0.2	- -	- -
438	Spillway	4.20	2S	- -	- -	260	723.4	723.3	0.1	- -	- -	430	724.1	724.0	0.1	- -	- -	520	724.4	724.3	0.1	- -	- -
439	Private Bridge	4.35	1S	- -	- -	100	725.3	724.2	1.1	0.4	- -	140	725.4	724.7	0.7	0.5	- -	160	725.5	725.0	0.5	0.6	- -
440	Private Bridge	4.59	1S	- -	- -	100	729.5	728.8	0.7	- -	- -	140	730.1	729.3	0.8	- -	- -	160	730.4	729.4	1.0	- -	- -
441	Private Bridge	4.62	1S	- -	- -	100	729.8	729.5	0.3	- -	- -	140	730.5	730.1	0.4	- -	- -	160	730.8	730.4	0.4	- -	- -
442	Private Bridge	4.67	1S	- -	- -	100	730.4	730.0	0.4	- -	- -	140	731.0	730.6	0.4	- -	- -	160	731.4	730.9	0.5	- -	- -
443	Private Bridge	4.74	1S	- -	- -	100	730.5	730.4	0.1	- -	- -	140	731.1	731.1	0.0	- -	- -	160	731.4	731.4	0.0	- -	- -
444	Chicago, Milwaukee, St. Paul & Pacific Railroad	4.75	1S	100	Yes	80	731.0	730.5	0.5	- -	- -	140	732.6	731.1	1.5	- -	- -	150	733.2	731.4	1.8	- -	- -
445	W. College Avenue/ CTH ZZ	4.91	1S	50	Yes	125	731.0[h]	731.0[h]	0.0	- -	- -	235	732.6[h]	732.6[h]	0.0	- -	- -	260	733.2[h]	733.2[h]	0.0	- -	- -
450	Private Bridge	4.94	1S	- -	- -	170	731.0[h]	731.0[h]	0.0	- -	- -	330	732.6[h]	732.6[h]	0.0	- -	- -	370	733.2[h]	733.2[h]	0.0	0.1	- -
455	S. 13th Street	5.21	1S	50	Yes	170	731.6	731.0[h]	0.6	- -	- -	330	733.0	732.6[h]	0.4	- -	- -	370	733.3	733.2[h]	0.1	- -	- -
460	W. Ramsey Avenue and IH 94 Box Culvert	5.65	1S	100	Yes	240	735.2	734.1	1.1	- -	- -	360	736.5	734.9	1.6	- -	- -	400	736.9	735.1	1.8	- -	- -
462	IH 94 Exit Ramp	5.85	1S	- -	- -	240	739.0	736.7	2.3	- -	- -	360	740.4	737.3	3.1	- -	- -	400	740.8	737.6	3.2	- -	- -

[a] *Measured in miles above confluence with Oak Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *There is a drop of about 4.0 feet in the streambed at the downstream side of the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge.*

[h] *The flood stage indicated represents the water surface elevation due to the backwater from the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge at River Mile 4.75.*

Source: SEWRPC.

Table D-6

HYDROLOGIC-HYDRAULIC SUMMARY—MITCHELL FIELD DRAINAGE DITCH: 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
500	Chicago & North Western Railway	0.14	1S	100	Yes	350	659.4[g]	659.4[g]	0.0	- -	- -	590	660.9	660.7[g]	0.2	- -	- -	730	661.5	661.2[g]	0.3	- -	- -
505	E. Rawson Avenue/ CTH BB	0.80	1S	50	Yes	320	664.4	664.3	0.1	- -	- -	560	665.4	665.0	0.4	- -	- -	680	665.9	665.3	0.6	- -	- -
510	E. College Avenue/ CTH ZZ	1.83	1S	50	Yes	310	671.3	671.1	0.2	- -	- -	450	672.6	672.1	0.5	- -	- -	520	673.2	672.5	0.7	- -	- -
515	Private Bridge	2.15	1S	- -	- -	310	673.6	672.7	0.9	0.8	0.8	450	674.3	673.7	0.6	1.5	1.5	520	674.7	674.1	0.6	1.9	1.9
520	Airport Runway Culvert	2.60	1S	- -	- -	240	677.5	674.3	3.2	- -	- -	310	680.3	674.9	5.4	0.5	- -	310	680.3	675.2	5.1	0.5	- -
525	Private Bridge	2.74	1S	- -	- -	330	677.5[h]	677.5[h]	0.0	0.8	- -	600	680.3[h]	680.3[h]	0.0	3.6	1.7	740	680.3[h]	680.3[h]	0.0	3.6	1.7
530	Pedestrian Bridge	2.80	1S	- -	- -	330	678.3	677.5[h]	0.8	- -	- -	600	680.3[h]	680.3[h]	0.0	1.3	- -	740	681.0	680.3[h]	0.7	2.0	0.4
535	Private Bridge	3.10	1S	- -	- -	330	686.9	684.1	2.8	2.0	1.8	600	687.0	684.8	2.2	2.1	1.9	740	687.2	685.1	2.1	2.3	2.1
540	S. Howell Avenue/ STH 38	3.31	1S	50	Yes	330	690.2	688.8	1.5	- -	- -	600	691.7	689.7	2.1	- -	- -	740	692.5	690.0	2.5	- -	- -

[a]Measured in miles above confluence with Oak Creek.

[b]Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c]A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d]The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e]City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.

[f]Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

[g]The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the Mitchell Field Drainage Ditch.

[h]The flood stage indicated represents the water surface elevation due to the backwater from the airport runway culvert.

Source: SEWRPC.

Table D-7

HYDROLOGIC-HYDRAULIC SUMMARY—SOUTHLAND 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
600	S. 13th Street/CTH V	0.47	1S	50	Yes	80	700.9	700.9	0.0	- -	- -	270	703.5	702.7	0.8	- -	- -	350	704.4	703.0	1.4	- -	- -
605	IH 94	0.88	1S	100	Yes	50	704.5	702.8	1.7	- -	- -	160	705.5	704.5	1.0	- -	- -	200	706.2	705.1	1.1	- -	- -
610 & 615	Culvert Between S. 20th Street and S. 21st Street[g]	1.23	1S	10	Yes	50	723.5	717.2	6.3	- -	- -	160	724.8	718.5	6.3	- -	- -	200	725.2	718.8	6.4	- -	- -
620	S. 26th Street	1.57	1S	10	Yes	50	728.5	728.0	0.5	- -	- -	160	730.1	729.1	1.0	0.6	0.4	200	730.2	729.3	0.9	0.7	0.5
625	W. Grays Lane	1.69	1S	10	No	50	732.3	729.5	2.8	0.7	- -	160	732.7	730.4	2.3	1.1	- -	200	732.8	730.5	2.3	1.2	- -
630	Parking Lot Culvert	1.70	1S	- -	- -	50	735.2	732.3	2.9	0.3	0.3	160	735.8	732.7	3.1	0.9	0.9	200	735.9	732.8	3.1	1.0	1.0
635	Parking Lot Culvert	1.72	1S	- -	- -	50	735.3	735.2	0.1	2.1	2.1	160	735.9	735.8	0.1	2.7	2.7	200	736.0	735.9	0.1	2.8	2.8
640	S. 27th Street/STH 41	1.77	1S	50	No	40	735.4	735.3	0.1	- -	- -	120	737.0	735.9	1.1	0.2	0.2	140	737.1	736.0	1.1	0.3	0.3

[a]Measured in miles above confluence with the North Branch of Oak Creek.

[b]Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c]A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d]The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e]City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.

[f]Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

[g]The Southland Creek channel was enclosed in a culvert between S. 20th Street and a point 290 feet upstream of S. 21st Street in the fall of 1984. This culvert is reflected in the flood stages listed in this table and on the profiles in Appendix G.

Source: SEWRPC.

Table D-8

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO SOUTHLAND 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[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
700	IH 94	0.19	1S	100	Yes	40	704.8	702.8	2.0	- -	- -	100	705.4	704.2[g]	1.2	- -	- -	140	705.7	704.8[g]	0.9	- -	- -
705	W. Puetz Road	0.73	1S	50	No	30	724.8	723.3	1.5	0.1	0.1	90	725.1	724.1	1.0	0.4	0.4	100	725.1	724.5	0.6	0.4	0.4

[a] *Measured in miles above confluence with Southland Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The flood stage indicated represents the water surface elevation of Southland Creek at the confluence with the tributary to Southland Creek.*

Source: SEWRPC.

Appendix E

HYDROLOGIC-HYDRAULIC SUMMARY FOR STRUCTURES ON OAK CREEK AND SELECTED MAJOR TRIBUTARIES: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Table E-1

HYDROLOGIC-HYDRAULIC SUMMARY—LOWER OAK CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
100	Pedestrian Bridge	0.14	1I	--	--	1,910	--	--	--	--	--	2,540	--	--	--	--	--	2,810	--	--	--	--	--
105	1st Oak Creek Parkway Bridge	0.35	1S	10	Yes	1,910	587.7	586.6	1.1	--	--	2,540	589.3	587.6	1.7	--	--	2,810	589.9	588.0	1.9	--	--
110	2nd Oak Creek Parkway Bridge	0.88	1S	10	Yes	1,910	601.3	599.6	1.7	--	--	2,540	602.9	600.4	2.5	--	--	2,810	603.9	600.7	3.2	--	--
115	Mill Road	0.94	1S	50	Yes	1,910	604.0	603.3	0.7	--	--	2,540	605.3	603.9	1.4	--	--	2,810	605.7	604.4	1.3	--	--
120	Oak Creek Parkway Dam	0.95	2S	--	--	1,910	617.6	604.0	13.6	--	--	2,540	618.3	605.3	13.0	--	--	2,810	618.5	605.7	12.8	--	--
125	3rd Oak Creek Parkway Bridge	1.18	1S	10	Yes	1,910	617.9	617.6	0.3	--	--	2,540	618.9	618.3	0.6	--	--	2,810	619.2	618.5	0.7	--	--
130	4th Oak Creek Parkway Bridge	1.32	1S	10	Yes	1,910	620.3	618.6	1.7	--	--	2,540	622.0	619.3	2.7	--	--	2,810	622.7	619.5	3.2	--	--
135	Chicago Avenue/STH 32	1.61	1S	50	Yes	1,890	626.1	623.5	2.6	--	--	2,510	627.5	624.5	3.0	--	--	2,770	628.0	624.9	3.1	--	--
140	5th Oak Creek Parkway Bridge	2.14	1S	10	Yes	1,890	633.1	632.5	0.6	--	--	2,510	634.2	633.5	0.7	--	--	2,770	634.7	633.9	0.8	--	--
145	Pedestrian Bridge	2.24	1I	--	--	1,890	--	--	--	--	--	2,510	--	--	--	--	--	2,770	--	--	--	--	--
150	Chicago & North Western Railway	2.35	1S	100	Yes	1,890	638.3	637.4	0.9	--	--	2,510	639.6	638.5	1.1	--	--	2,770	640.0	638.9	1.1	--	--
155	15th Avenue	2.84	1S	50	Yes	1,840	642.7	641.6	1.1	--	--	2,440	644.0	642.4	1.6	--	--	2,700	644.6	642.7	1.9	--	--
160	Pedestrian Bridge	3.18	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
165	Pine Street	3.37	1S	10	Yes	1,840	647.6	647.0	0.6	--	--	2,440	648.6	648.0	0.6	--	--	2,700	448.9	648.3	0.6	--	--
170 & 175	E. Rawson and 16th Avenues[g]	3.65	1S	50	Yes	1,840	650.4	649.7	0.7	--	--	2,440	652.3	650.7	1.6	--	--	2,700	653.1	651.1	2.0	--	--
180	15th Avenue	3.76	1S	50	Yes	1,840	650.8	650.6	0.2	--	--	2,440	653.0	652.5	0.5	--	--	2,700	654.0	653.3	0.7	1.0	--
185	Pedestrian Bridge	3.89	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
190	Milwaukee Avenue	4.01	1S	50	Yes	1,840	651.4	651.2	0.2	--	--	2,440	653.6	653.2	0.4	--	--	2,700	654.8	654.2	0.6	0.3	--
195	15th Avenue	4.06	1S	50	Yes	1,840	651.6	651.4	0.2	--	--	2,440	653.7	653.6	0.1	--	--	2,700	655.2	654.8	0.4	1.0	--
200	Pedestrian Bridge	4.18	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
205	S. Pennsylvania Avenue[h]	4.71	1S	50	Yes	1,840	653.8	652.7	1.1	--	--	2,440	654.7	654.6	0.1	--	--	2,700	655.9	655.8	0.1	--	--

[a] *Measured in miles above mouth at Lake Michigan.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of South Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.97 feet. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The bridges at E. Rawson and 16th Avenues were replaced in fall 1985 with a single structure. The new bridge is reflected in the flood stages listed in this table and on the profiles in Appendix G.*

[h] *There is a drop of about 4.0 feet in the streambed at the downstream side of the S. Pennsylvania Avenue bridge.*

Source: SEWRPC.

Table E-2

HYDROLOGIC-HYDRAULIC SUMMARY—MIDDLE OAK CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
210	Chicago & North Western Railway	5.25	1S	100	Yes	1,500	661.4	661.1	0.3	--	--	2,030	662.5	662.1	0.4	--	--	2,270	662.9	662.4	0.5	--	--
215	E. Drexel Avenue	5.56	1S	50	Yes	1,500	662.1	662.0	0.1	--	--	2,030	663.6	663.0	0.6	--	--	2,270	664.1	663.4	0.7	--	--
220	Chicago & North Western Railway	6.06	1S	100	Yes	1,500	663.3	663.0	0.3	--	--	2,030	664.6	664.2	0.4	--	--	2,270	665.8	664.8	1.0	--	--
225	E. Forest Hill Avenue	6.25	1S	10	No	1,500	663.5	663.4	0.1	1.8	0.7	2,030	664.8	664.8	0.0	3.1	2.0	2,270	665.9	665.9	0.0	4.2	3.1
230	E. Puetz Road	6.88	1S	50	No	1,500	664.3	663.9	0.4	--	--	2,030	665.6	665.0	0.6	0.6	--	2,270	666.2	666.0	0.2	1.2	--
235	Chicago & North Western Railway	7.34	1S	100	Yes	2,080	665.5	665.0	0.5	--	--	2,870	666.6	665.8	0.8	--	--	3,220	667.2	666.4	0.8	--	--
240	S. Nicholson Road	7.44	1S	50	No	2,080	666.7	666.0	0.7	1.5	--	2,870	667.6	667.0	0.6	2.4	--	3,220	668.0	667.6	0.4	2.8	--
250	S. Shepard Avenue	8.41	1S	10	No	2,080	671.0	670.4	0.6	0.4	--	2,870	671.6	670.9	0.7	1.0	--	3,220	671.8	671.1	0.7	1.2	--
255	S. Howell Avenue/ Northbound STH 38	9.22	1S	50	Yes	2,080	677.6	677.2	0.4	--	--	2,870	678.5	677.9	0.6	--	--	3,220	678.9	678.2	0.7	0.2	--
256	S. Howell Avenue/ Southbound STH 38	9.24	1S	50	Yes	2,080	677.6	677.6	0.0	--	--	2,870	678.7	678.5	0.2	--	--	3,220	679.2	678.9	0.3	0.5	--

[a]*Measured in miles above mouth at Lake Michigan.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table E-3

HYDROLOGIC-HYDRAULIC SUMMARY—UPPER OAK CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
260	W. Ryan Road/STH 100	10.06	1S	50	No	1,030	682.0	680.9	1.1	3.6	--	1,620	684.5	682.2	2.3	5.9	0.3	1,830	685.0	682.7	2.3	6.4	0.8
261	Spillway	10.12	2S	--	--	1,030	682.0	682.0	0.0	--	--	1,620	684.5	684.5	0.0	--	--	1,830	685.0	685.0	0.0	--	--
265	Chicago, Milwaukee, St. Paul & Pacific Railroad	10.24	1S	100	Yes	1,030	682.1	682.1	0.0	--	--	1,620	684.8	684.5	0.3	--	--	1,830	685.4	685.0	0.4	--	--
270	Private Bridge	10.25	1S	--	--	1,030	684.8	682.1	2.7	3.0	3.0	1,620	685.9	684.8	1.1	4.1	4.1	1,830	686.4	685.4	1.0	4.6	4.6
275	Private Bridge	10.46	1S	--	--	1,030	690.2	687.2	3.0	0.4	--	1,620	691.3	688.4	1.9	1.5	0.3	1,830	691.5	688.7	2.8	1.7	0.5
280	Private Bridge	10.60	1I	--	--	1,030	--	--	--	--	--	1,620	--	--	--	--	--	1,830	--	--	--	--	--
285	S. 13th Street/CTH V	10.69	1S	50	No	1,030	691.5	690.5	1.0	--	--	1,620	692.4	691.5	0.9	0.5	0.5	1,830	692.5	691.7	0.8	0.6	0.6
286	Pedestrian Bridge	10.72	1I	--	--	1,030	--	--	--	--	--	1,620	--	--	--	--	--	1,830	--	--	--	--	--
290	IH 94 Northbound	10.97	1S	100	Yes	690	691.7	691.7	0.0	--	--	1,140	692.6	692.6	0.0	--	--	1,330	692.7	692.7	0.0	--	--
295	IH 94 Southbound	10.99	1S	100	Yes	690	691.8	691.7	0.1	--	--	1,140	692.6	692.6	0.0	--	--	1,330	692.8	692.7	0.1	--	--
300	S. 20th Street	11.24	1S	10	No	690	692.7	691.8	0.9	0.7	0.7	1,140	693.2	692.7	0.5	1.2	1.2	1,330	693.3	692.9	0.4	1.3	1.3
305	S. 27th Street/STH 41	11.70	1S	50	Yes	400	694.5	694.0	0.5	--	--	700	696.1	694.7	1.4	--	--	840	696.7	695.0	1.7	0.4	--
310	S. 31st Street	11.97	1S	10	Yes	200	697.8	697.8	0.0	--	--	390	699.3	698.5	0.8	--	--	490	699.9	698.8	1.1	0.3	--
312	Private Bridge	12.23	1S	--	--	200	702.8	702.2	0.6	--	--	390	704.1	702.7	1.4	0.1	0.1	490	704.8	702.8	2.0	0.8	0.8
315	W. Ryan Road/STH 100	12.52	1S	50	Yes	200	711.9	709.4	2.5	--	--	390	714.9	710.3	4.6	--	--	490	717.6	710.5	7.1	--	--
316	Concrete Drop Sill	12.69	2S	--	--	200	713.8	713.8	0.0	--	--	390	715.3	715.3	0.0	--	--	490	717.6	717.6	0.0	--	--
317	Concrete Drop Sill	12.90	2S	--	--	200	719.0	719.0	0.0	--	--	390	720.6	720.6	0.0	--	--	490	721.1	721.1	0.0	--	--
318	Concrete Drop Sill	13.07	2S	--	--	100	724.0	724.0	0.0	--	--	170	725.5	725.5	0.0	--	--	210	726.0	726.0	0.0	--	--
320	W. Southland Drive	13.18	1S	10	Yes	100	731.7	730.6	1.1	--	--	170	732.5	731.0	1.5	--	--	210	733.0	731.2	1.8	--	--
325	W. Woodward Drive	13.31	1S	10	Yes	50	733.8	733.6	0.2	--	--	90	734.4	734.0	0.4	--	--	110	734.6	734.2	0.4	--	--
330	W. Glenwood Drive	13.58	1S	10	Yes	10	743.4	741.8	1.6	--	--	30	744.6	742.0	2.6	--	--	40	744.8	742.1	2.7	0.2	0.2
331	Private Drive	13.60	1S	--	--	10	745.0	743.4	1.6	--	--	30	745.8	744.6	1.2	0.3	0.3	40	745.8	744.8	1.0	0.3	0.3
332	Private Drive	13.62	1S	--	--	10	745.7	745.0	0.7	--	--	30	746.4	745.8	0.6	0.3	0.3	40	746.5	745.8	0.7	0.4	0.4
333	W. Maple Crest Drive	13.64	1S	10	Yes	10	746.0	745.7	0.3	--	--	30	746.8	746.4	0.4	--	--	40	746.8	746.5	0.3	--	--
335	Reservoir Outlet	13.65	1S	--	--	10	747.3	746.0	1.3	--	--	30	747.8	746.8	1.0	--	--	40	747.9	746.8	1.1	--	--
340	Private Bridge	13.76	1S	--	--	20	748.6	747.3	1.3	--	--	50	748.6	747.8	1.6	--	--	60	748.6	747.9	0.7	--	--
345	W. Puetz Road	13.79	1S	50	No	20	750.9	748.8	2.1	--	--	50	752.6	749.0	3.0	0.1	0.1	60	752.6	749.0	3.6	0.1	0.1

[a]*Measured in miles above mouth at Lake Michigan.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek and City of Franklin Vertical Datums = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table E-4

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO UPPER OAK CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
800	Private Drive	0.02	1S	- -	- -	20	735.6	733.8[g]	1.8	- -	- -
803	Private Drive	0.04	1S	- -	- -	20	736.1	735.6	0.5	- -	- -
805	Private Drive	0.05	1S	- -	- -	20	736.6	736.1	0.5	- -	- -
810	W. Glenwood Drive	0.21	1S	10	Yes	20	742.6	740.8	1.8	- -	- -
815	Private Drive	0.27	1S	- -	- -	20	745.0	742.7	2.3	- -	- -
817	Private Drive	0.28	1S	- -	- -	20	745.2	745.0	0.2	- -	- -
820	W. Maple Crest Drive	0.30	1S	10	No	20	746.4	745.2	1.2	0.1	0.1
825	W. Puetz Road	0.55	1S	50	Yes	3	753.8	753.0	0.8	- -	- -

	50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
800	50	735.9	734.4	1.5	- -	- -	60	736.0	734.6	1.4	- -	- -
803	50	736.3	735.9	0.4	- -	- -	60	736.4	736.0	0.4	- -	- -
805	50	737.0	736.3	0.7	- -	- -	60	737.1	736.0	1.1	0.1	0.1
810	50	743.7	741.1	2.6	- -	- -	60	744.2	741.2	3.0	0.1	0.1
815	50	745.0	743.8	1.2	- -	- -	60	745.0	744.2	0.8	- -	- -
817	50	745.4	745.0	0.4	- -	- -	60	745.5	745.0	0.5	- -	- -
820	50	746.4	745.4	1.0	0.1	0.1	60	746.4	745.5	0.9	0.1	0.1
825	8	754.1	753.4	0.7	- -	- -	10	754.3	753.5	0.8	- -	- -

[a] *Measured in miles above confluence with Oak Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Franklin Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the tributary to Upper Oak Creek.*

Source: SEWRPC.

Table E-5

HYDROLOGIC-HYDRAULIC SUMMARY—NORTH BRANCH OAK CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
400	Chicago, Milwaukee, St. Paul & Pacific Railroad[g]	0.10	1S	100	Yes	1,210	685.3	682.7	2.6	- -	- -	2,000	687.8	684.0	3.8	- -	- -	2,320	689.3	684.4	4.9	- -	- -
402	Private Bridge	0.21	1S	- -	- -	1,210	687.2	686.4	0.8	2.4	0.6	2,000	688.7	688.6	0.1	3.9	2.1	2,320	689.9	689.8	0.1	5.1	3.3
403	Private Bridge	0.34	1I	- -	- -	1,210	- -	- -	- -	- -	- -	2,000	- -	- -	- -	- -	- -	2,320	- -	- -	- -	- -	- -
405	W. Puetz Road	0.92	1S	50	No	1,130	696.4	695.4	1.0	- -	- -	1,750	698.6	696.6	2.0	0.8	0.7	1,940	699.0	696.9	2.1	1.2	1.1
407	Private Bridge	1.71	1S	- -	- -	1,130	703.9	703.8	0.1	2.8	2.8	1,750	704.9	704.8	0.1	3.8	3.8	1,940	705.1	705.0	0.1	4.0	4.0
410	W. Wildwood Drive	2.00	1S	10	No	940	704.8	704.8	0.0	1.2	1.2	1,190	705.8	705.7	0.1	2.2	2.2	1,260	706.0	706.0	0.0	2.4	2.4
415	W. Drexel Avenue	2.21	1S	50	Yes	940	705.6	705.0	0.6	- -	- -	1,190	707.0	705.9	1.1	- -	- -	1,260	707.3	706.2	1.1	- -	- -
420	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.25	1S	100	Yes	890	709.4	705.6	3.8	- -	- -	1,130	710.9	706.9	4.0	- -	- -	1,190	711.4	707.3	4.1	- -	- -
425	S. 6th Street	2.41	1S	10	No	890	710.0	709.4	0.6	1.5	1.4	1,130	711.0	711.0	0.0	2.5	2.4	1,190	711.5	711.5	0.0	3.0	2.9
430	W. Marquette Avenue	3.04	1S	10	No	560	714.0	713.8	0.2	2.0	2.0	820	714.7	714.5	0.2	2.7	2.7	900	714.9	714.7	0.2	2.9	2.9
435	W. Rawson Avenue/ CTH BB	3.51	1S	50	Yes	560	714.8	714.5	0.3	- -	- -	820	715.9	715.2	0.7	- -	- -	900	716.3	715.4	0.9	- -	- -
436	S. 6th Street	3.86	1S	10	Yes	560	717.0	716.5	0.5	- -	- -	820	718.1	717.4	0.7	- -	- -	900	718.5	717.7	0.8	- -	- -
437	Spillway	3.90	2S	- -	- -	560	717.1	717.0	0.1	- -	- -	820	718.1	718.1	0.0	- -	- -	900	718.5	718.5	0.0	- -	- -
438	Spillway	4.20	2S	- -	- -	560	724.6	724.4	0.1	- -	- -	820	725.0	724.9	0.1	- -	- -	900	725.3	725.2	0.1	- -	- -
439	Private Bridge	4.35	1S	- -	- -	150	725.6	725.0	0.5	0.6	- -	220	725.8	725.5	0.3	0.9	- -	240	726.0	725.8	0.2	1.1	- -
440	Private Bridge	4.59	1S	- -	- -	150	730.3	729.4	0.9	- -	- -	220	731.3	729.9	1.4	- -	- -	240	731.5	730.1	1.4	- -	- -
441	Private Bridge	4.62	1S	- -	- -	150	730.6	730.3	0.3	- -	- -	220	731.7	731.3	0.4	- -	- -	240	732.0	731.5	0.5	- -	- -
442	Private Bridge	4.67	1S	- -	- -	150	731.2	730.8	0.4	- -	- -	220	732.3	731.8	0.5	- -	- -	240	732.6	732.1	0.5	- -	- -
443	Private Bridge	4.74	1S	- -	- -	150	731.3	731.3	0.0	- -	- -	220	732.4	732.4	0.0	- -	- -	240	732.7	732.7	0.0	- -	- -
444	Chicago, Milwaukee, St. Paul & Pacific Railroad	4.75	1S	100	Yes	120	732.4	731.3	1.1	- -	- -	200	735.4	732.4	3.0	- -	- -	220	736.3	732.7	3.6	- -	- -
445	W. College Avenue/ CTH ZZ	4.91	1S	50	Yes	145	732.4[h]	732.4[h]	0.0	- -	- -	250	735.4[h]	735.4[h]	0.0	- -	- -	280	736.3[h]	736.3[h]	0.0	- -	- -
450	Private Bridge	4.94	1S	- -	- -	190	732.4[h]	732.4[h]	0.0	- -	- -	350	735.4[h]	735.4[h]	0.0	2.3	0.9	390	736.3[h]	736.3[h]	0.0	3.2	1.8
455	S. 13th Street	5.21	1S	50	Yes[i]	190	732.4	732.4[h]	0.0	- -	- -	350	735.4[h]	735.4[h]	0.0	0.4	- -	390	736.3[h]	736.3[h]	0.0	1.3	- -
460	W. Ramsey Avenue and IH 94 Box Culvert	5.65	1S	100	Yes	250	735.3	734.2	1.1	- -	- -	370	736.6	735.4[h]	1.2	- -	- -	410	737.0	736.3[h]	0.7	- -	- -
462	IH 94 Exit Ramp	5.85	1S	- -	- -	250	739.2	736.7	2.5	- -	- -	370	740.4	737.4	3.0	- -	- -	410	740.8	737.7	3.1	- -	- -

[a]*Measured in miles above confluence with Oak Creek.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g]*There is a drop of about 4.0 feet in the streambed at the downstream side of the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge.*

[h]*The flood stage indicated represents the water surface elevation due to the backwater from the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge at River Mile 4.75.*

[i]*The approach road is overtopped due to backwater from the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge. It is not due to an inadequate hydraulic capacity of the culverts at S. 13th Street.*

Source: SEWRPC.

Table E-6

HYDROLOGIC-HYDRAULIC SUMMARY—MITCHELL FIELD DRAINAGE DITCH: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
500	Chicago & North Western Railway	0.14	1S	100	Yes	580	661.1[g]	661.1[g]	0.0	--	--	900	662.2	662.0[g]	0.2	--	--	1,050	662.7	662.4[g]	0.3	--	--
505	E. Rawson Avenue/ CTH BB	0.80	1S	50	Yes	560	665.3	665.0	0.3	--	--	830	666.5	665.6	0.9	--	--	950	667.0	665.8	1.2	--	--
510	E. College Avenue/ CTH ZZ	1.83	1S	50	No	450	672.6	672.1	0.5	--	--	560	673.8	672.9	0.9	0.4	--	620	674.0	673.1	0.9	0.6	0.2
515	Private Bridge	2.15	1S	--	--	450	674.3	673.7	0.6	3.5	1.5	560	675.0	674.5	0.5	4.2	2.2	620	675.3	674.8	0.5	4.5	2.5
520	Airport Runway Culvert	2.60	1S	--	--	305	680.1	674.9	5.2	0.3	--	310	680.3	675.4	4.9	0.5	--	315	680.5	675.7	4.8	0.7	--
525	Private Bridge	2.74	1S	--	--	640	680.1[h]	680.1[h]	0.0	3.4	1.5	1,010	680.3[h]	680.3[h]	0.0	3.6	1.7	1,180	680.5[h]	680.5[h]	0.0	3.8	1.9
530	Pedestrian Bridge	2.80	1S	--	--	640	680.1[h]	680.1[h]	0.0	1.1	--	1,010	681.5	680.3[h]	1.2	2.5	0.9	1,180	681.9	680.5[h]	1.4	2.9	1.3
535	Private Bridge	3.10	1S	--	--	640	687.1	684.9	2.2	2.2	2.0	1,010	687.6	685.7	1.9	2.7	2.5	1,180	687.8	686.0	1.8	2.9	2.7
540	S. Howell Avenue/ STH 38	3.31	1S	50	Yes	640	692.0	689.8	2.2	--	--	1,010	693.8	690.5	3.3	--	--	1,180	694.6	690.7	3.9	--	--

[a]Measured in miles above confluence with Oak Creek.

[b]Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c]A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d]The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e]City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.

[f]Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

[g]The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the Mitchell Field Drainage Ditch.

[h]The flood stage indicated represents the water surface elevation due to the backwater from the airport runway culvert.

Source: SEWRPC.

Table E-7

HYDROLOGIC-HYDRAULIC SUMMARY—SOUTHLAND CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
600	S. 13th Street/CTH V	0.47	1S	50	Yes	180	702.4	702.0	0.4	--	--	370	704.6	703.1	1.5	--	--	450	705.5	703.4	2.1	--	--
605	IH 94	0.88	1S	100	Yes	110	705.0	703.8	1.2	--	--	220	706.5	705.3	1.2	--	--	270	707.2	705.9	1.3	--	--
610 & 615	Culvert Between S. 20th Street and S. 21st Street[g]	1.23	1S	10	Yes	110	724.3	718.1	6.1	--	--	220	725.3	718.9	6.4	--	--	270	726.2	719.2	7.0	--	--
620	S. 26th Street	1.57	1S	10	No	110	729.8	728.7	1.1	0.3	0.1	220	730.3	729.4	0.9	0.8	0.6	270	730.4	729.6	0.8	0.9	0.7
625	W. Grays Lane	1.69	1S	10	No	110	732.5	730.1	2.4	0.9	--	220	732.9	730.6	2.3	1.3	--	270	733.0	730.8	2.2	1.4	--
630	Parking Lot Culvert	1.70	1S	--	--	110	735.6	732.5	3.1	0.7	0.7	220	736.0	732.9	3.1	1.1	1.1	270	736.1	733.0	3.1	1.2	1.2
635	Parking Lot Culvert	1.72	1S	--	--	110	735.6	735.6	0.0	2.4	2.4	220	736.0	736.0	0.0	2.8	2.8	270	736.1	736.1	0.0	2.9	2.9
640	S. 27th Street/STH 41	1.77	1S	50	No	100	736.4	735.6	0.8	--	--	180	737.2	736.0	1.2	0.4	0.4	230	737.5	736.1	1.4	0.7	0.7

[a]Measured in miles above confluence with the North Branch of Oak Creek.

[b]Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c]A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d]The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e]City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.

[f]Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

[g]The Southland Creek channel was enclosed in a culvert between S. 20th Street and a point 290 feet upstream of S. 21st Street in the fall of 1984. This culvert is reflected in the flood stages listed in this table and on the profiles in Appendix G.

Source: SEWRPC.

Table E-8

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO SOUTHLAND CREEK: YEAR 2000 PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
700	IH 94	0.19	1S	100	Yes	80	705.2	703.3[g]	1.9	- -	- -	150	705.8	705.0[g]	0.8	- -	- -	180	706.0	705.8[g]	0.2	- -	- -
705	W. Puetz Road	0.73	1S	50	No	70	725.0	723.9	1.1	0.3	0.3	140	725.3	724.6	0.7	0.6	0.6	180	725.4	724.8	0.6	0.7	0.7

[a] *Measured in miles above confluence with Southland Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The flood stage indicated represents the water surface elevation of Southland Creek at the confluence with the tributary to Southland Creek.*

Source: SEWRPC.

Appendix F

HYDROLOGIC-HYDRAULIC SUMMARY FOR STRUCTURES ON OAK CREEK AND SELECTED MAJOR TRIBUTARIES: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Table F-1

HYDROLOGIC-HYDRAULIC SUMMARY—LOWER OAK CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
100	Pedestrian Bridge	0.14	1I	--	--	1,910	--	--	--	--	--	2,540	--	--	--	--	--	2,810	--	--	--	--	--
105	1st Oak Creek Parkway Bridge	0.35	1S	10	Yes	1,910	587.7	586.6	1.1	--	--	2,540	589.3	587.6	1.7	--	--	2,810	589.9	588.0	1.9	--	--
110	2nd Oak Creek Parkway Bridge	0.88	1S	10	Yes	1,910	601.3	599.6	1.7	--	--	2,540	602.9	600.4	2.5	--	--	2,810	603.9	600.7	3.2	--	--
115	Mill Road	0.94	1S	50	Yes	1,910	604.0	603.3	0.7	--	--	2,540	605.3	603.9	1.4	--	--	2,810	605.7	604.4	1.3	--	--
120	Oak Creek Parkway Dam	0.95	2S	--	--	1,910	617.6	604.0	13.6	--	--	2,540	618.3	605.3	13.0	--	--	2,810	618.5	605.7	12.8	--	--
125	3rd Oak Creek Parkway Bridge	1.18	1S	10	Yes	1,910	617.9	617.6	0.3	--	--	2,540	618.9	618.3	0.6	--	--	2,810	619.2	618.5	0.7	--	--
130	4th Oak Creek Parkway Bridge	1.32	1S	10	Yes	1,910	620.3	618.6	1.7	--	--	2,540	622.0	619.3	2.7	--	--	2,810	622.7	619.5	3.2	--	--
135	Chicago Avenue/STH 32	1.61	1S	50	Yes	1,890	626.1	623.5	2.6	--	--	2,510	627.5	624.5	3.0	--	--	2,770	628.0	624.9	3.1	--	--
140	5th Oak Creek Parkway Bridge	2.14	1S	10	Yes	1,890	633.1	632.5	0.6	--	--	2,510	634.2	633.5	0.7	--	--	2,770	634.7	633.9	0.8	--	--
145	Pedestrian Bridge	2.24	1I	--	--	1,890	--	--	--	--	--	2,510	--	--	--	--	--	2,770	--	--	--	--	--
150	Chicago & North Western Railway	2.35	1S	100	Yes	1,890	638.3	637.4	0.9	--	--	2,510	639.6	638.5	1.1	--	--	2,770	640.0	638.9	1.1	--	--
155	15th Avenue	2.84	1S	50	Yes	1,840	642.7	641.6	1.1	--	--	2,440	644.0	642.4	1.6	--	--	2,700	644.6	642.7	1.9	--	--
160	Pedestrian Bridge	3.18	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
165	Pine Street	3.37	1S	10	Yes	1,840	647.6	647.0	0.6	--	--	2,440	648.6	648.0	0.6	--	--	2,700	448.9	648.3	0.6	--	--
170 & 175	E. Rawson and 16th Avenues[g]	3.65	1S	50	Yes	1,840	650.4	649.7	0.7	--	--	2,440	652.3	650.7	1.6	--	--	2,700	653.1	651.1	2.0	--	--
180	15th Avenue	3.76	1S	50	Yes	1,840	650.8	650.6	0.2	--	--	2,440	653.0	652.5	0.5	--	--	2,700	654.0	653.3	0.7	1.0	--
185	Pedestrian Bridge	3.89	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
190	Milwaukee Avenue	4.01	1S	50	Yes	1,840	651.4	651.2	0.2	--	--	2,440	653.6	653.2	0.4	--	--	2,700	654.8	654.2	0.6	0.3	--
195	15th Avenue	4.06	1S	50	Yes	1,840	651.6	651.4	0.2	--	--	2,440	653.7	653.6	0.1	--	--	2,700	655.2	654.8	0.4	1.0	--
200	Pedestrian Bridge	4.18	1I	--	--	1,840	--	--	--	--	--	2,440	--	--	--	--	--	2,700	--	--	--	--	--
205	S. Pennsylvania Avenue[h]	4.71	1S	50	Yes	1,840	653.8	652.7	1.1	--	--	2,440	654.7	654.6	0.1	--	--	2,700	655.9	655.8	0.1	--	--

[a] *Measured in miles above mouth at Lake Michigan.*

[b] *Structure codes are as follows: 1–bridge or culvert; 2–dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of South Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.97 feet. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The bridges at E. Rawson and 16th Avenues were replaced in fall 1985 with a single structure. The new bridge is reflected in the flood stages listed in this table and on the profiles in Appendix G.*

[h] *There is a drop of about 4.0 feet in the streambed at the downstream side of the S. Pennsylvania Avenue bridge.*

Source: SEWRPC.

Table F-2

HYDROLOGIC-HYDRAULIC SUMMARY—MIDDLE OAK CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
210	Chicago & North Western Railway	5.25	1S	100	Yes	1,500	661.4	661.1	0.3	- -	- -	2,030	662.5	662.1	0.4	- -	- -	2,270	662.9	662.4	0.5	- -	- -
215	E. Drexel Avenue	5.56	1S	50	Yes	1,500	662.1	662.0	0.1	- -	- -	2,030	663.6	663.0	0.6	- -	- -	2,270	664.1	663.4	0.7	- -	- -
220	Chicago & North Western Railway	6.06	1S	100	Yes	1,500	663.3	663.0	0.3	- -	- -	2,030	664.6	664.2	0.4	- -	- -	2,270	665.8	664.8	1.0	- -	- -
225	E. Forest Hill Avenue	6.25	1S	10	No	1,500	663.5	663.4	0.1	1.8	0.7	2,030	664.8	664.8	0.0	3.1	2.0	2,270	665.9	665.9	0.0	4.2	3.1
230	E. Puetz Road	6.88	1S	50	No	1,500	664.3	663.9	0.4	- -	- -	2,030	665.6	665.0	0.6	0.6	- -	2,270	666.2	666.0	0.2	1.2	- -
235	Chicago & North Western Railway	7.34	1S	100	Yes	2,080	665.5	665.0	0.5	- -	- -	2,870	666.6	665.8	0.8	- -	- -	3,220	667.2	666.4	0.8	- -	- -
240	S. Nicholson Road	7.44	1S	50	No	2,080	666.7	666.0	0.7	1.5	- -	2,870	667.6	667.0	0.6	2.4	- -	3,220	668.0	667.6	0.4	2.8	- -
250	S. Shepard Avenue	8.41	1S	10	No	2,080	671.0	670.4	0.6	0.4	- -	2,870	671.6	670.9	0.7	1.0	- -	3,220	671.8	671.1	0.7	1.2	- -
255	S. Howell Avenue/ Northbound STH 38	9.22	1S	50	Yes	2,080	677.6	677.2	0.4	- -	- -	2,870	678.5	677.9	0.6	- -	- -	3,220	678.9	678.2	0.7	0.2	- -
256	S. Howell Avenue/ Southbound STH 38	9.24	1S	50	Yes	2,080	677.6	677.6	0.0	- -	- -	2,870	678.7	678.5	0.2	- -	- -	3,220	679.2	678.9	0.3	0.5	- -

[a] *Measured in miles above mouth at Lake Michigan.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table F-3

HYDROLOGIC-HYDRAULIC SUMMARY—UPPER OAK CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
260	W. Ryan Road/STH 100	10.06	1S	50	No	1,030	682.0	680.9	1.1	3.6	--	1,620	684.5	682.2	2.3	5.9	0.3	1,830	685.0	682.7	2.3	6.4	0.8
261	Spillway	10.12	2S	--	--	1,030	682.0	682.0	0.0	--	--	1,620	684.5	684.5	0.0	--	--	1,830	685.0	685.0	0.0	--	--
265	Chicago, Milwaukee, St. Paul & Pacific Railroad	10.24	1S	100	Yes	1,030	682.1	682.1	0.0	--	--	1,620	684.8	684.5	0.3	--	--	1,830	685.4	685.0	0.4	--	--
270	Private Bridge	10.25	1S	--	--	1,030	684.8	682.1	2.7	3.0	3.0	1,620	685.9	684.8	1.1	4.1	4.1	1,830	686.4	685.4	1.0	4.6	4.6
275	Private Bridge	10.46	1S	--	--	1,030	687.6	687.1	0.5	--	--	1,620	689.2	688.0	1.2	--	--	1,830	689.8	688.3	1.5	--	--
280	Private Bridge	10.60	1I	--	--	1,030	--	--	--	--	--	1,620	--	--	--	--	--	1,830	--	--	--	--	--
285	S. 13th Street/CTH V	10.69	1S	50	Yes	1,030	689.3	688.9	0.4	--	--	1,620	691.5	690.1	1.4	--	--	1,830	692.1	690.7	1.4	0.3	0.3
286	Pedestrian Bridge	10.72	1I	--	--	1,030	--	--	--	--	--	1,620	--	--	--	--	--	1,830	--	--	--	--	--
290	IH 94 Northbound	10.97	1S	100	Yes	690	690.0	690.0	0.0	--	--	1,140	691.9	691.9	0.0	--	--	1,330	692.4	692.4	0.0	--	--
295	IH 94 Southbound	10.99	1S	100	Yes	690	690.0	690.0	0.0	--	--	1,140	692.0	691.9	0.1	--	--	1,330	692.4	692.4	0.0	--	--
300	S. 20th Street	11.24	1S	10	No	690	692.3	690.1	2.2	0.3	0.3	1,140	693.1	692.0	1.1	1.1	1.1	1,330	693.3	692.5	0.8	1.3	1.3
305	S. 27th Street/STH 41	11.70	1S	50	Yes	400	693.6	692.8	0.8	--	--	700	695.4	693.8	1.6	--	--	840	695.6	694.0	1.6	--	--
310	S. 31st Street	11.97	1S	10	Yes	200	697.8	697.8	0.0	--	--	390	699.2	698.5	0.7	--	--	490	699.9	698.7	1.2	0.3	--
312	Private Bridge	12.23	1S	--	--	200	702.8	702.2	0.6	--	--	390	704.1	702.7	1.4	0.1	0.1	490	704.8	702.8	2.0	0.8	0.8
315	W. Ryan Road/STH 100	12.52	1S	50	Yes	200	711.9	709.4	2.5	--	--	390	714.9	710.3	4.6	--	--	490	717.6	710.5	7.1	--	--
316	Concrete Drop Sill	12.69	2S	--	--	200	713.8	713.8	0.0	--	--	390	715.3	715.3	0.0	--	--	490	717.6	717.6	0.0	--	--
317	Concrete Drop Sill	12.90	2S	--	--	200	719.0	719.0	0.0	--	--	390	720.6	720.6	0.0	--	--	490	721.1	721.1	0.0	--	--
318	Concrete Drop Sill	13.07	2S	--	--	100	724.0	724.0	0.0	--	--	170	725.5	725.5	0.0	--	--	210	726.0	726.0	0.0	--	--
320	W. Southland Drive	13.18	1S	10	Yes	100	731.7	730.6	1.1	--	--	170	732.5	731.0	1.5	--	--	210	733.0	731.2	1.8	--	--
325	W. Woodward Drive	13.31	1S	10	Yes	50	733.8	733.6	0.2	--	--	90	734.4	734.0	0.4	--	--	110	734.6	734.2	0.4	--	--
330	W. Glenwood Drive	13.58	1S	10	Yes	10	743.4	741.8	1.6	--	--	30	744.6	742.0	2.6	--	--	40	744.8	742.1	2.7	0.2	0.2
331	Private Drive	13.60	1S	--	--	10	745.0	743.4	1.6	--	--	30	745.8	744.6	1.2	0.3	0.3	40	745.8	744.8	1.0	0.3	0.3
332	Private Drive	13.62	1S	--	--	10	745.7	745.0	0.7	--	--	30	746.4	745.8	0.6	0.3	0.3	40	746.5	745.8	0.7	0.4	0.4
333	W. Maple Crest Drive	13.64	1S	10	Yes	10	746.0	745.7	0.3	--	--	30	746.8	746.4	0.4	--	--	40	746.8	746.5	0.3	--	--
335	Reservoir Outlet	13.65	1S	--	--	10	747.3	746.0	1.3	--	--	30	747.8	746.8	1.0	--	--	40	747.9	746.8	1.1	--	--
340	Private Bridge	13.76	1S	--	--	20	748.6	747.3	1.3	--	--	50	748.6	747.8	1.6	--	--	60	748.6	747.9	0.7	--	--
345	W. Puetz Road	13.79	1S	50	No	20	750.9	748.8	2.1	--	--	50	752.6	749.0	3.0	0.1	0.1	60	752.6	749.0	3.6	0.1	0.1

[a]*Measured in miles above mouth at Lake Michigan.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek and City of Franklin Vertical Datums = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

Source: SEWRPC.

Table F-4

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO UPPER OAK CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
800	Private Drive	0.02	1S	--	--	20	735.6	733.8[g]	1.8	--	--	50	735.9	734.4	1.5	--	--	60	736.0	734.6	1.4	--	--
803	Private Drive	0.04	1S	--	--	20	736.1	735.6	0.5	--	--	50	736.3	735.9	0.4	--	--	60	736.4	736.0	0.4	--	--
805	Private Drive	0.05	1S	--	--	20	736.6	736.1	0.5	--	--	50	737.0	736.3	0.7	--	--	60	737.1	736.0	1.1	0.1	0.1
810	W. Glenwood Drive	0.21	1S	10	Yes	20	742.6	740.8	1.8	--	--	50	743.7	741.1	2.6	--	--	60	744.2	741.2	3.0	0.1	0.1
815	Private Drive	0.27	1S	--	--	20	745.0	742.7	2.3	--	--	50	745.0	743.8	1.2	--	--	60	745.0	744.2	0.8	--	--
817	Private Drive	0.28	1S	--	--	20	745.2	745.0	0.2	--	--	50	745.4	745.0	0.4	--	--	60	745.5	745.0	0.5	--	--
820	W. Maple Crest Drive	0.30	1S	10	No	20	746.4	745.2	1.2	0.1	0.1	50	746.4	745.4	1.0	0.1	0.1	60	746.4	745.5	0.9	0.1	0.1
825	W. Puetz Road	0.55	1S	50	Yes	3	753.8	753.0	0.8	--	--	8	754.1	753.4	0.7	--	--	10	754.3	763.5	0.8	--	--

[a]*Measured in miles above confluence with Oak Creek.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Franklin Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g]*The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the tributary to Upper Oak Creek.*

Source: SEWRPC.

Table F-5

HYDROLOGIC-HYDRAULIC SUMMARY—NORTH BRANCH OAK CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
400	Chicago, Milwaukee, St. Paul & Pacific Railroad[g]	0.10	1S	100	Yes	1,210	685.3	682.7	2.6	- -	- -	2,000	687.8	684.0	3.8	- -	- -	2,320	689.3	684.4	4.9	- -	- -
402	Private Bridge	0.21	1S	- -	- -	1,210	687.2	686.4	0.8	2.4	0.6	2,000	688.7	688.6	0.1	3.9	2.1	2,320	689.9	689.8	0.1	5.1	3.3
403	Private Bridge	0.34	1I	- -	- -	1,210	- -	- -	- -	- -	- -	2,000	- -	- -	- -	- -	- -	2,320	- -	- -	- -	- -	- -
405	W. Puetz Road	0.92	1S	50	No	1,130	696.4	695.4	1.0	- -	- -	1,750	698.6	696.6	2.0	0.8	0.7	1,940	699.0	696.9	2.1	1.2	1.1
407	Private Bridge	1.71	1S	- -	- -	1,130	703.9	703.8	0.1	2.8	2.8	1,750	704.9	704.8	0.1	3.8	3.8	1,940	705.1	705.0	0.1	4.0	4.0
410	W. Wildwood Drive	2.00	1S	10	No	940	704.8	704.8	0.0	1.2	1.2	1,190	705.8	705.7	0.1	2.2	2.2	1,260	706.0	706.0	0.0	2.4	2.4
415	W. Drexel Avenue	2.21	1S	50	Yes	940	705.6	705.0	0.6	- -	- -	1,190	707.0	705.9	1.1	- -	- -	1,260	707.3	706.2	1.1	- -	- -
420	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.25	1S	100	Yes	890	709.4	705.6	3.8	- -	- -	1,130	710.9	706.9	4.0	- -	- -	1,190	711.4	707.3	4.1	- -	- -
425	S. 6th Street	2.41	1S	10	No	890	710.0	709.4	0.6	1.5	1.4	1,130	711.0	711.0	0.0	2.5	2.4	1,190	711.5	711.5	0.0	3.0	2.9
430	W. Marquette Avenue	3.04	1S	10	No	560	714.0	713.8	0.2	2.0	2.0	820	714.7	714.5	0.2	2.7	2.7	900	714.9	714.7	0.2	2.9	2.9
435	W. Rawson Avenue/ CTH BB	3.51	1S	50	Yes	560	714.8	714.5	0.3	- -	- -	820	715.9	715.2	0.7	- -	- -	900	716.3	715.4	0.9	- -	- -
436	S. 6th Street	3.86	1S	10	Yes	560	717.0	716.5	0.5	- -	- -	820	718.1	717.4	0.7	- -	- -	900	718.5	717.7	0.8	- -	- -
437	Spillway	3.90	2S	- -	- -	560	717.1	717.0	0.1	- -	- -	820	718.1	718.1	0.0	- -	- -	900	718.5	718.5	0.0	- -	- -
438	Spillway	4.20	2S	- -	- -	560	724.5	724.4	0.1	- -	- -	820	725.0	724.9	0.1	- -	- -	900	725.3	725.2	0.1	- -	- -
439	Private Bridge	4.35	1S	- -	- -	150	725.4	725.0	0.4	0.5	- -	220	725.7	725.5	0.2	0.8	- -	240	725.9	725.8	0.1	1.0	- -
440	Private Bridge	4.59	1S	- -	- -	150	727.6	727.3	0.3	- -	- -	220	728.6	728.2	0.4	- -	- -	240	728.8	728.4	0.4	- -	- -
441	Private Bridge	4.62	1S	- -	- -	150	727.8	727.6	0.2	- -	- -	220	728.9	728.6	0.3	- -	- -	240	729.2	728.8	0.4	- -	- -
442	Private Bridge	4.67	1S	- -	- -	150	728.4	728.1	0.3	- -	- -	220	729.4	729.2	0.2	- -	- -	240	729.7	729.4	0.3	- -	- -
443	Private Bridge	4.74	1S	- -	- -	150	728.7	728.6	0.1	- -	- -	220	729.7	729.7	0.0	- -	- -	240	730.0	730.0	0.0	- -	- -
444	Chicago, Milwaukee, St. Paul & Pacific Railroad	4.75	1S	100	Yes	120	729.8	728.7	1.1	- -	- -	200	732.7	729.7	3.0	- -	- -	220	733.5	730.0	3.5	- -	- -
445	W. College Avenue/ CTH ZZ	4.91	1S	50	Yes	145	729.8	729.8	0.0	- -	- -	250	732.7	732.7	0.0	- -	- -	280	733.5	733.5	0.0	- -	- -
450	Private Bridge	4.94	1S	- -	- -	145	729.8	729.8	0.0	- -	- -	250	732.7	732.7	0.0	- -	- -	280	733.5	733.5	0.0	- -	- -
455	S. 13th Street	5.21	1S	50	Yes	190	731.8	730.0	1.8	- -	- -	350	732.9	732.7	0.2	- -	- -	390	733.5	733.5	0.0	- -	- -
460	W. Ramsey Avenue and IH 94 Box Culvert	5.65	1S	100	Yes	250	735.3	734.2	1.1	- -	- -	370	736.6	735.0	1.6	- -	- -	410	737.0	735.1	1.9	- -	- -
462	IH 94 Exit Ramp	5.85	1S	- -	- -	250	739.2	736.7	2.5	- -	- -	370	740.4	737.4	3.0	- -	- -	410	740.8	737.7	3.1	- -	- -

[a] *Measured in miles above confluence with Oak Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *There is a drop of about 4.0 feet in the streambed at the downstream side of the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge.*

Source: SEWRPC.

Table F-6

HYDROLOGIC-HYDRAULIC SUMMARY—MITCHELL FIELD DRAINAGE DITCH: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
500	Chicago & North Western Railway	0.14	1S	100	Yes	580	661.1[g]	661.1[g]	0.0	--	--	900	662.2	662.0[g]	0.2	--	--	1,050	662.7	662.4[g]	0.3	--	--
505	E. Rawson Avenue/ CTH BB	0.80	1S	50	Yes	560	665.3	665.0	0.3	--	--	830	666.5	665.6	0.9	--	--	950	667.0	665.8	1.2	--	--
510	E. College Avenue/ CTH ZZ	1.83	1S	50	No	450	672.6	672.1	0.5	--	--	560	673.8	672.9	0.9	0.4	--	620	674.0	673.1	0.9	0.6	0.2
515	Private Bridge	2.15	1S	--	--	450	674.3	673.7	0.6	3.5	1.5	560	675.0	674.5	0.5	4.2	2.2	620	675.3	674.8	0.5	4.5	2.5
520	Airport Runway Culvert	2.60	1S	--	--	305	680.1	674.9	5.2	0.3	--	310	680.3	675.4	4.9	0.5	--	315	680.5	675.7	4.8	0.7	--
525	Private Bridge	2.74	1S	--	--	640	680.1[h]	680.1[h]	0.0	3.4	1.5	1,010	680.3[h]	680.3[h]	0.0	3.6	1.7	1,180	680.5[h]	680.5[h]	0.0	3.8	1.9
530	Pedestrian Bridge	2.80	1S	--	--	640	680.1[h]	680.1[h]	0.0	1.1	--	1,010	681.5	680.3[h]	1.2	2.5	0.9	1,180	681.9	680.5[h]	1.4	2.9	1.3
535	Private Bridge	3.10	1S	--	--	640	687.1	684.9	2.2	2.2	2.0	1,010	687.6	685.7	1.9	2.7	2.5	1,180	687.8	686.0	1.8	2.9	2.7
540	S. Howell Avenue/ STH 38	3.31	1S	50	Yes	640	692.0	689.8	2.2	--	--	1,010	693.8	690.5	3.3	--	--	1,180	694.6	690.7	3.9	--	--

[a] *Measured in miles above confluence with Oak Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60. City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The flood stage indicated represents the water surface elevation of Oak Creek at the confluence with the Mitchell Field Drainage Ditch.*

[h] *The flood stage indicated represents the water surface elevation due to the backwater from the airport runway culvert.*

Source: SEWRPC.

Table F-7

HYDROLOGIC-HYDRAULIC SUMMARY—SOUTHLAND CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
600	S. 13th Street/CTH V	0.47	1S	50	Yes	180	702.4	702.0	0.4	--	--	370	704.6	703.1	1.5	--	--	450	705.5	703.4	2.1	--	--
605	IH 94	0.88	1S	100	Yes	110	705.0	703.8	1.2	--	--	220	706.5	705.3	1.2	--	--	270	707.2	705.9	1.3	--	--
610 & 615	Culvert Between S. 20th Street and S. 21st Street[g]	1.23	1S	10	Yes	110	724.3	718.1	6.1	--	--	220	725.3	718.9	6.4	--	--	270	726.2	719.2	7.0	--	--
620	S. 26th Street	1.57	1S	10	No	110	729.8	728.7	1.1	0.3	0.1	220	730.3	729.4	0.9	0.8	0.6	270	730.4	729.6	0.8	0.9	0.7
625	W. Grays Lane	1.69	1S	10	No	110	732.5	730.1	2.4	0.9	--	220	732.9	730.6	2.3	1.3	--	270	733.0	730.8	2.2	1.4	--
630	Parking Lot Culvert	1.70	1S	--	--	110	735.6	732.5	3.1	0.7	0.7	220	736.0	732.9	3.1	1.1	1.1	270	736.1	733.0	3.1	1.2	1.2
635	Parking Lot Culvert	1.72	1S	--	--	110	735.6	735.6	0.0	2.4	2.4	220	736.0	736.0	0.0	2.8	2.8	270	736.1	736.1	0.0	2.9	2.9
640	S. 27th Street/STH 41	1.77	1S	50	No	100	736.4	735.6	0.8	--	--	180	737.2	736.0	1.2	0.4	0.4	230	737.5	736.1	1.4	0.7	0.7

[a] *Measured in miles above confluence with the North Branch of Oak Creek.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c] *A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e] *City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f] *Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g] *The Southland Creek channel was enclosed in a culvert between S. 20th Street and a point 290 feet upstream of S. 21st Street in the fall of 1984. This culvert is reflected in the flood stages listed in this table and on the profiles in Appendix G.*

Source: SEWRPC.

Table F-8

HYDROLOGIC-HYDRAULIC SUMMARY—TRIBUTARY TO SOUTHLAND CREEK: YEAR 2000 PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

Structure Identification and Selected Characteristics						10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
700	IH 94	0.19	1S	100	Yes	80	705.2	703.3[g]	1.9	--	--	150	705.8	705.0[g]	0.8	--	--	180	706.0	705.8[g]	0.2	--	--
705	W. Puetz Road	0.73	1S	50	No	70	725.0	723.9	1.1	0.3	0.3	140	725.3	724.6	0.7	0.6	0.6	180	725.4	724.8	0.6	0.7	0.7

[a]*Measured in miles above confluence with Southland Creek.*

[b]*Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

[c]*A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d]*The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.*

[e]*City of Oak Creek Vertical Datum = National Geodetic Vertical Datum - 580.56 feet.*

[f]*Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.*

[g]*The flood stage indicated represents the water surface elevation of Southland Creek at the confluence with the tributary to Southland Creek.*

Source: SEWRPC.

Appendix G

FLOOD STAGE AND STREAMBED PROFILES AND AERIAL PHOTOGRAPHS SHOWING AREAS SUBJECT TO FLOODING

Map G-1

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG OAK CREEK (RIVER MILE 0.00 TO 4.00)

LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS THAT WOULD BE ELIMINATED UNDER PLANNED CHANNEL CONDITIONS

NOTE: DUE TO MAP SCALE LIMITATIONS, THE DIFFERENCE BETWEEN THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS, AND THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS, MAY NOT APPEAR ON THIS MAP. WHERE NO DIFFERENCE APPEARS REFERENCE SHOULD BE MADE TO THE FLOOD STAGE PROFILE SHOWN BELOW

GRAPHIC SCALE

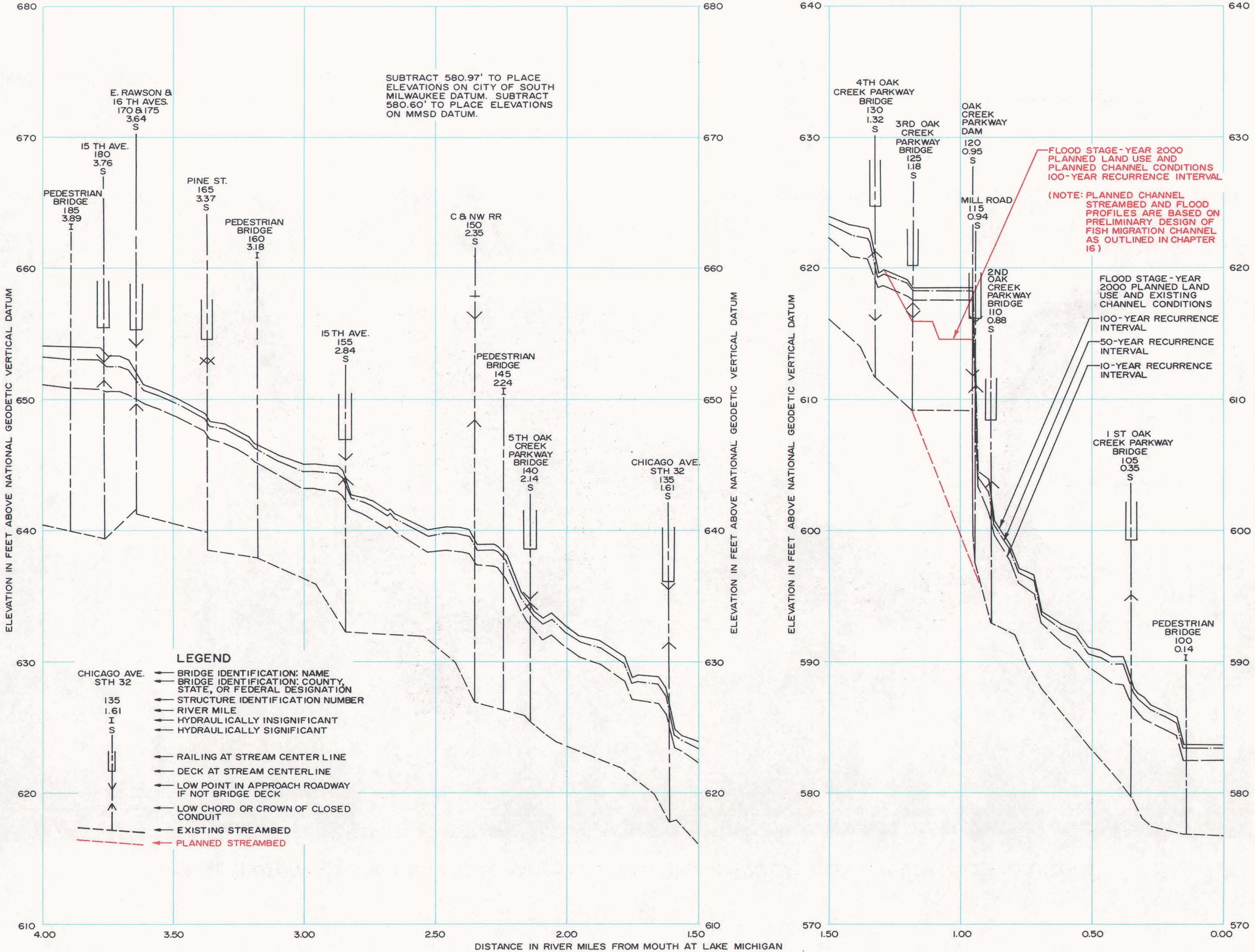
0 1/2 1 MILE

Source: SEWRPC.

DATE OF PHOTOGRAPHY: APRIL 1986

Figure G-1

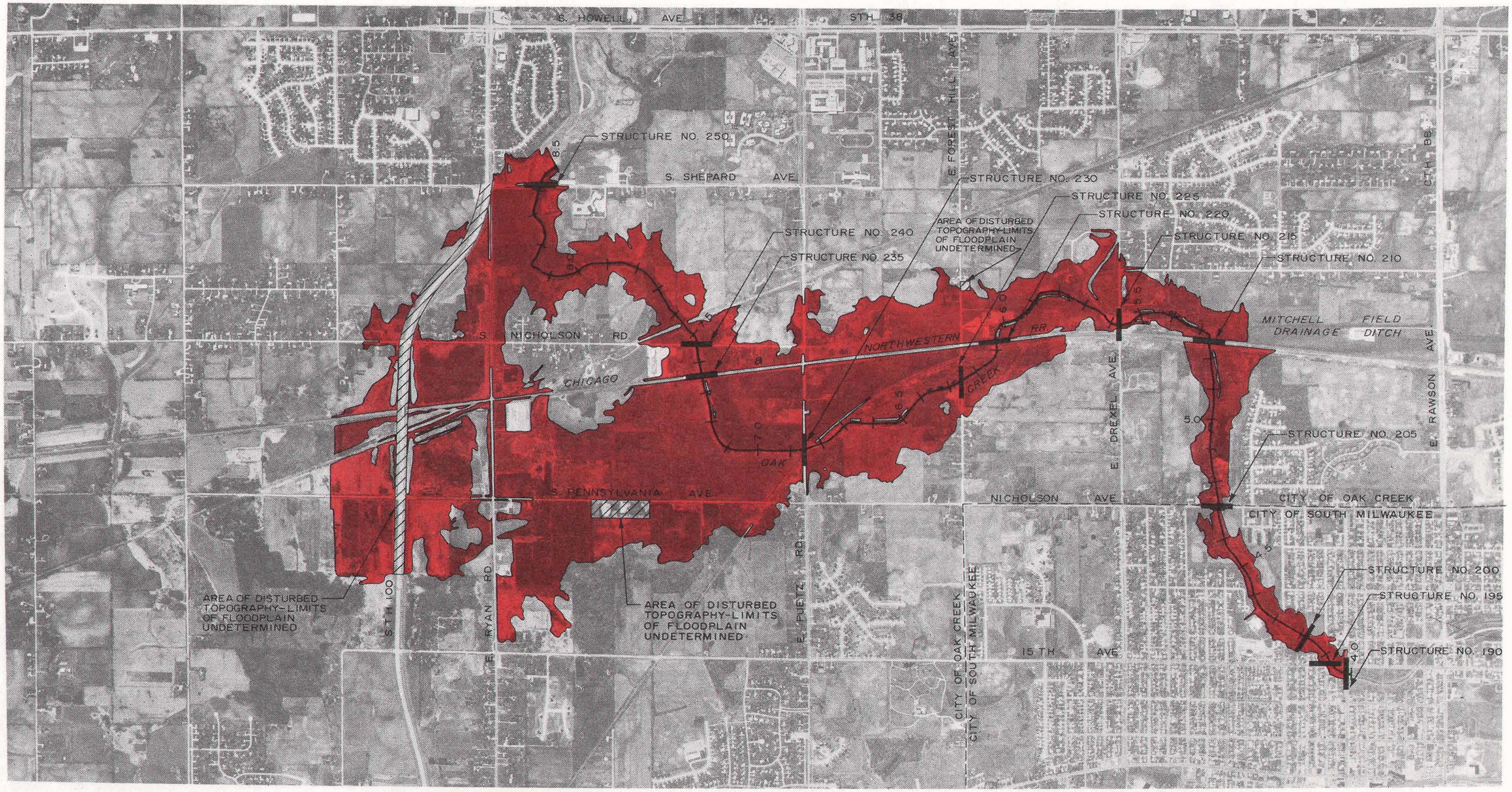
FLOOD STAGE AND STREAMBED PROFILE FOR OAK CREEK (RIVER MILE 0.00 TO 4.00)



Source: SEWRPC.

Map G-2

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG OAK CREEK (RIVER MILE 4.00 TO 8.50)



LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

GRAPHIC SCALE

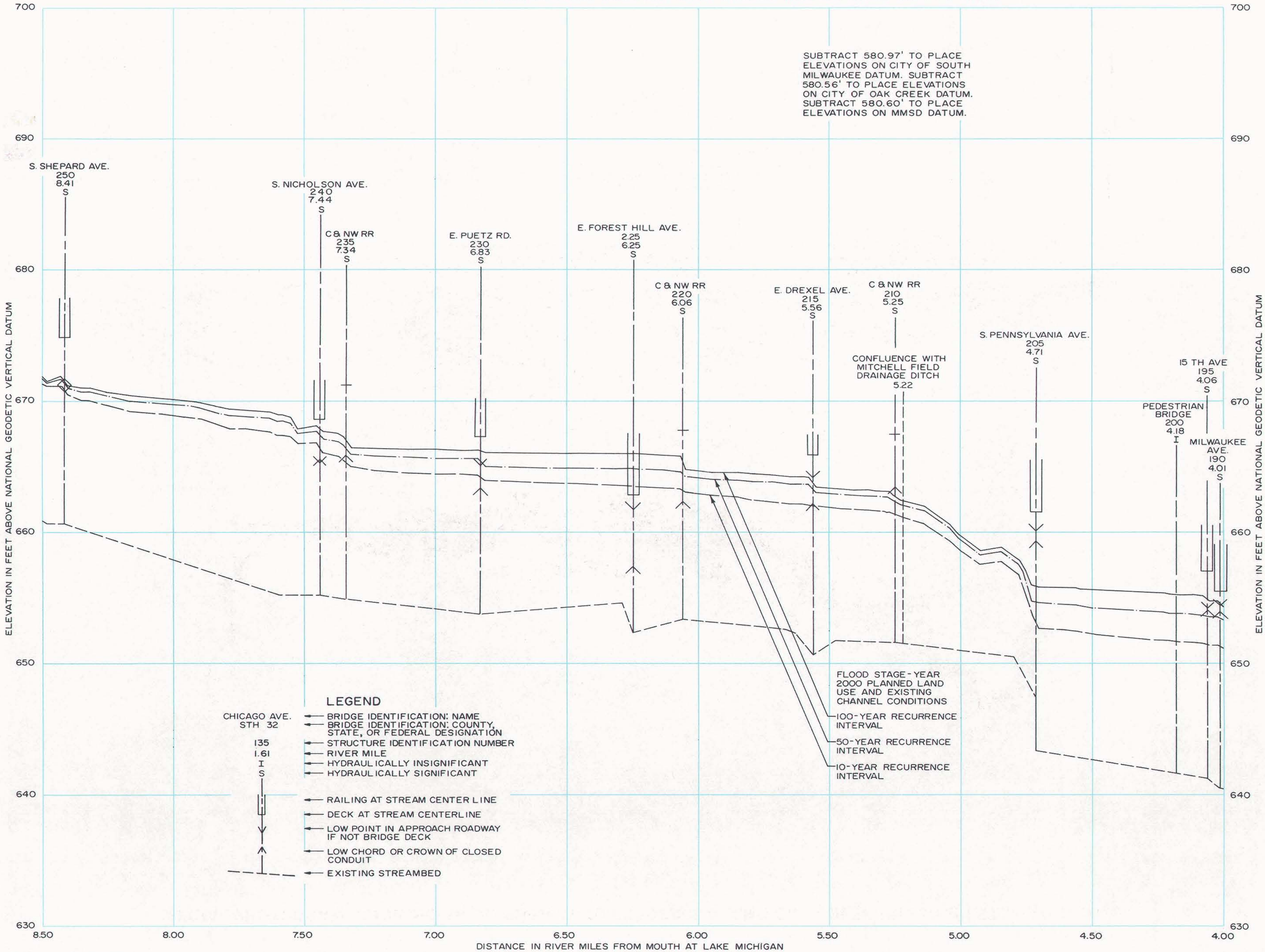
0 1/2 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-2

FLOOD STAGE AND STREAMBED PROFILE FOR OAK CREEK (RIVER MILE 4.00 TO 8.50)



Source: SEWRPC.

Map G-3

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG OAK CREEK (RIVER MILE 8.50 TO 13.00)

LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVERMILE STATIONING

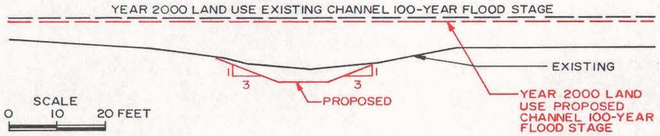
100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

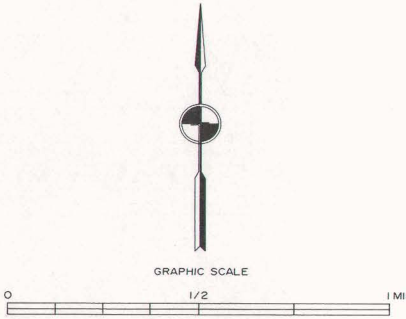
100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS THAT WOULD BE ELIMINATED UNDER PLANNED CHANNEL CONDITIONS

NOTE: DUE TO MAP SCALE LIMITATIONS, THE DIFFERENCE BETWEEN THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS, AND THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS, MAY NOT APPEAR ON THIS MAP. WHERE NO DIFFERENCE APPEARS REFERENCE SHOULD BE MADE TO THE FLOOD STAGE PROFILE SHOWN BELOW

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG OAK CREEK

FROM RM 10.3 TO RM 11.7 (S. 27TH. ST.)



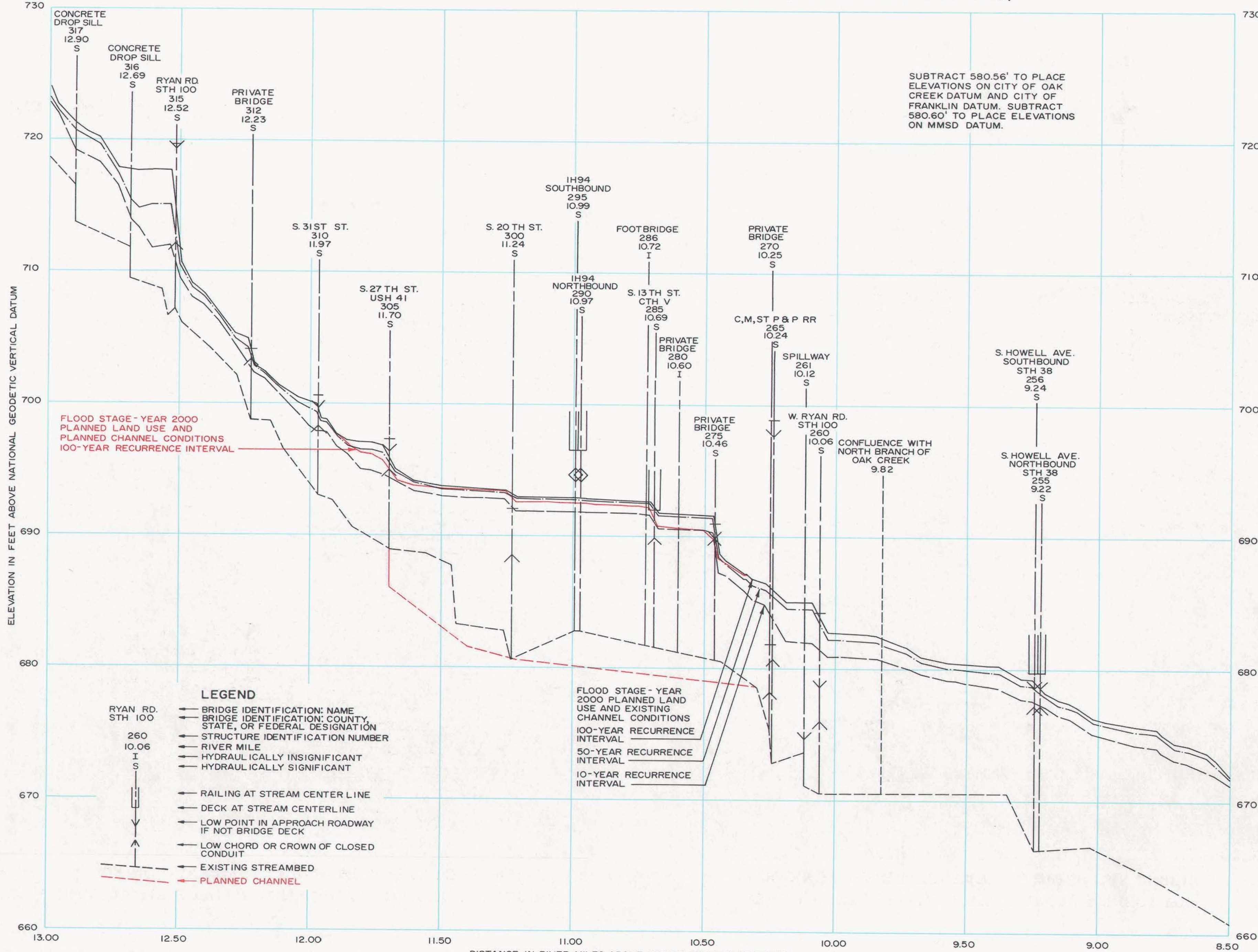


DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-3

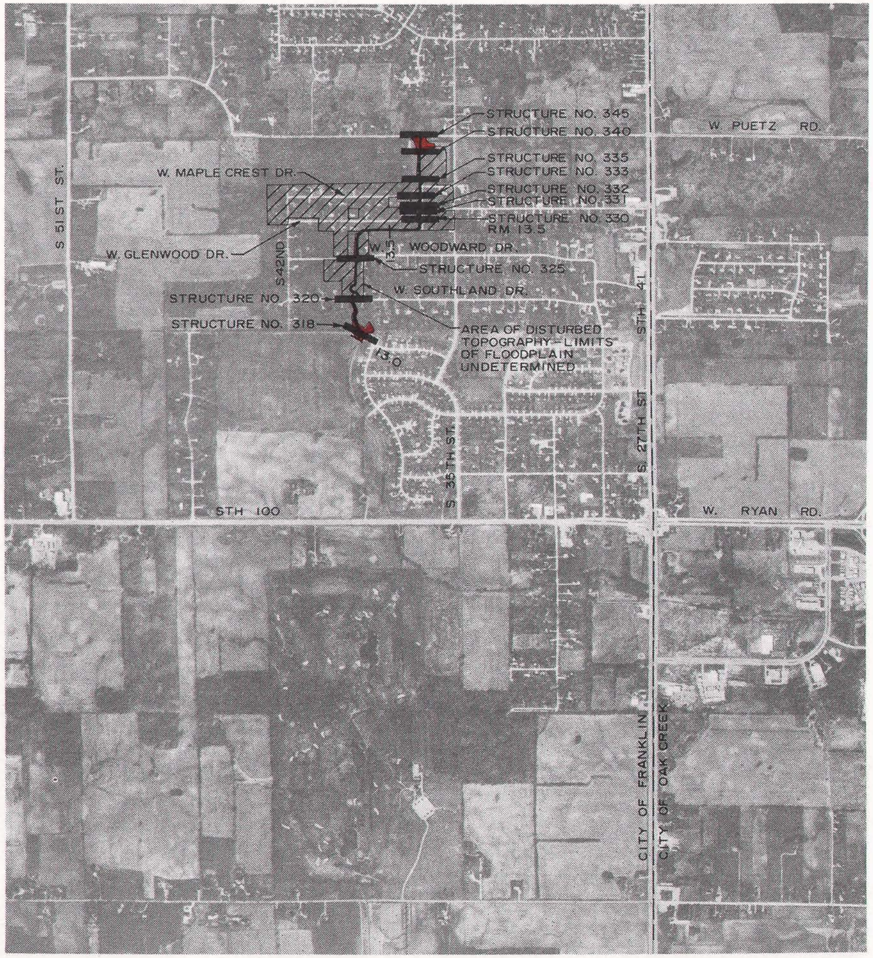
FLOOD STAGE AND STREAMBED PROFILE FOR OAK CREEK (RIVER MILE 8.50 TO 13.00)



Source: SEWRPC.

Map G-4

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG OAK CREEK (RIVER MILE 13.00 TO 13.79)



LEGEND

13.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

GRAPHIC SCALE

0 — 1/2 — 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Map G-5

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG TRIBUTARY TO UPPER OAK CREEK

LEGEND

1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

GRAPHIC SCALE

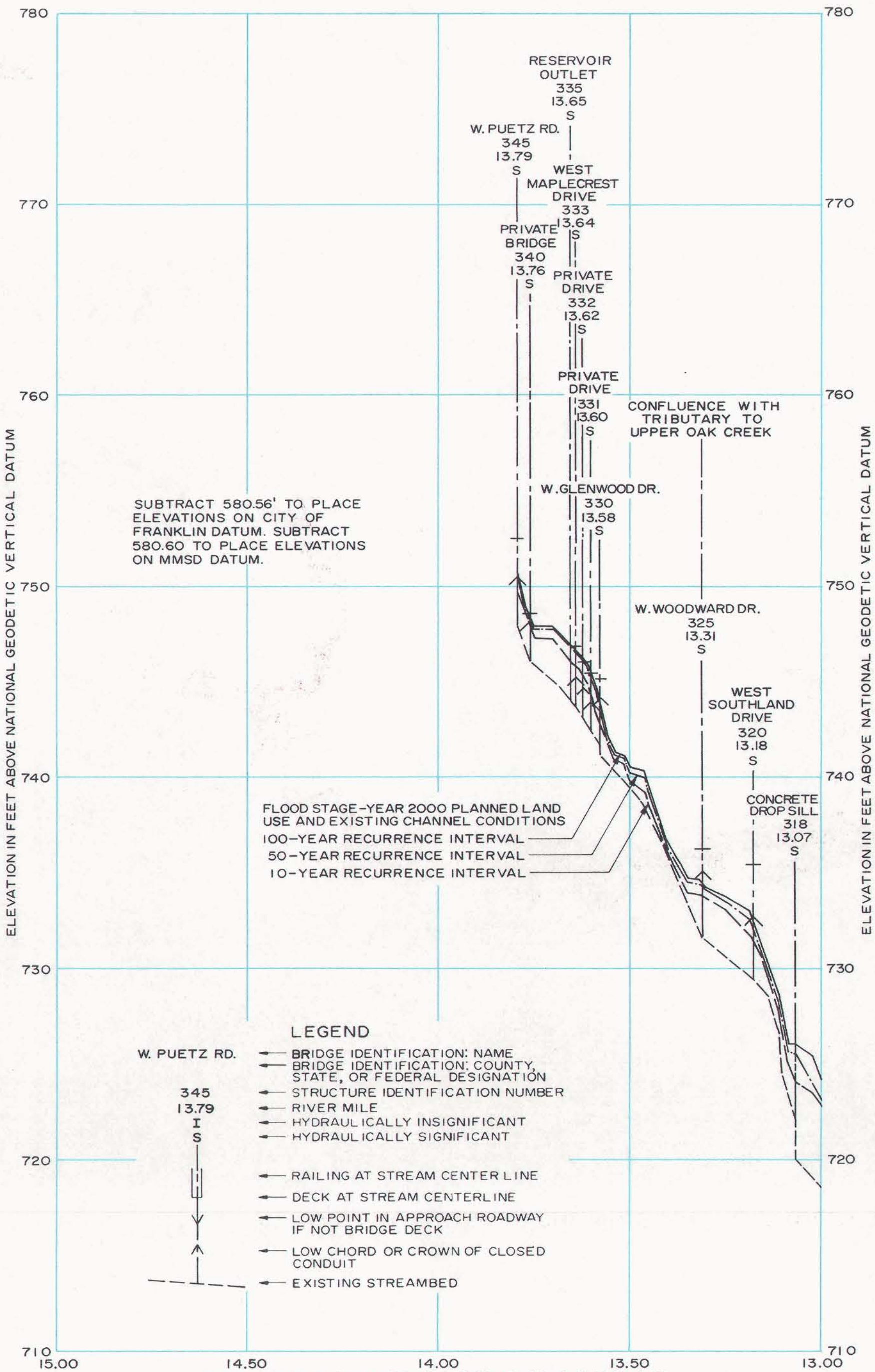
0 — 1/2 — 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-4

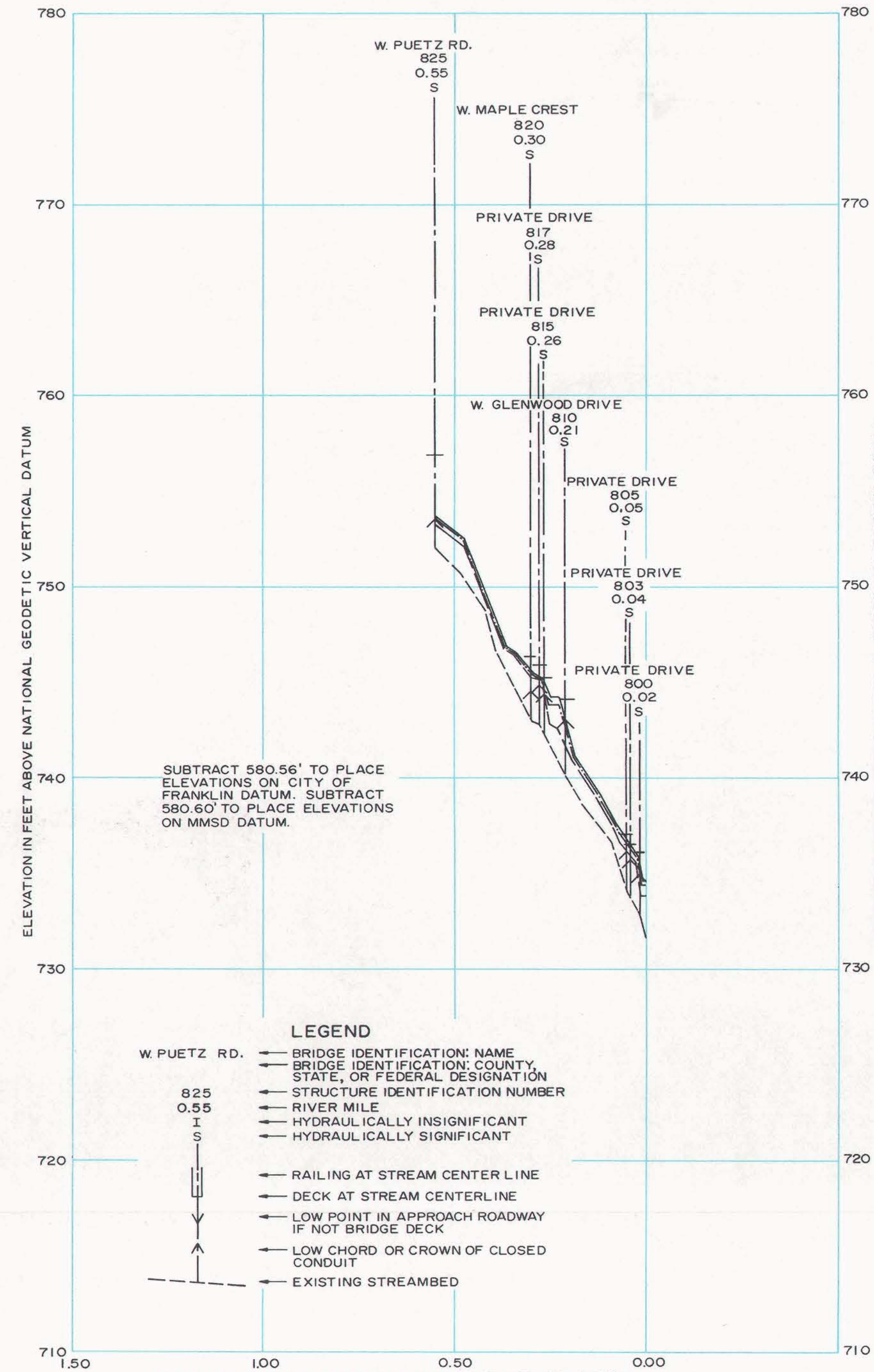
FLOOD STAGE AND STREAMBED PROFILE FOR OAK CREEK (RIVER MILE 13.00 TO 13.79)



Source: SEWRPC

Figure G-5

FLOOD STAGE AND STREAMBED PROFILE FOR TRIBUTARY TO UPPER OAK CREEK



Source: SEWRPC

Map G-6

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG MITCHELL FIELD DRAINAGE DITCH

LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

GRAPHIC SCALE

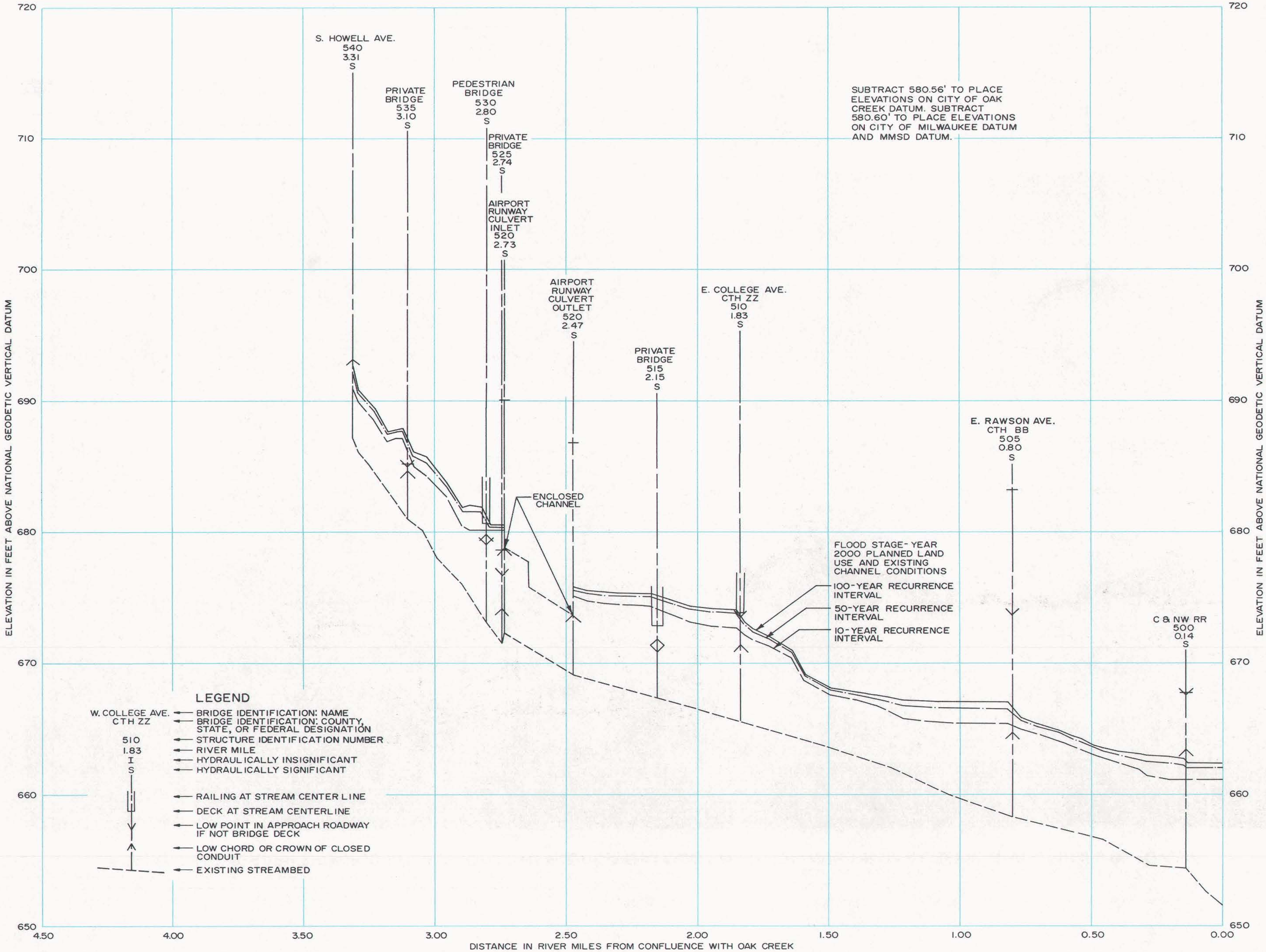
0 1/2 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-6

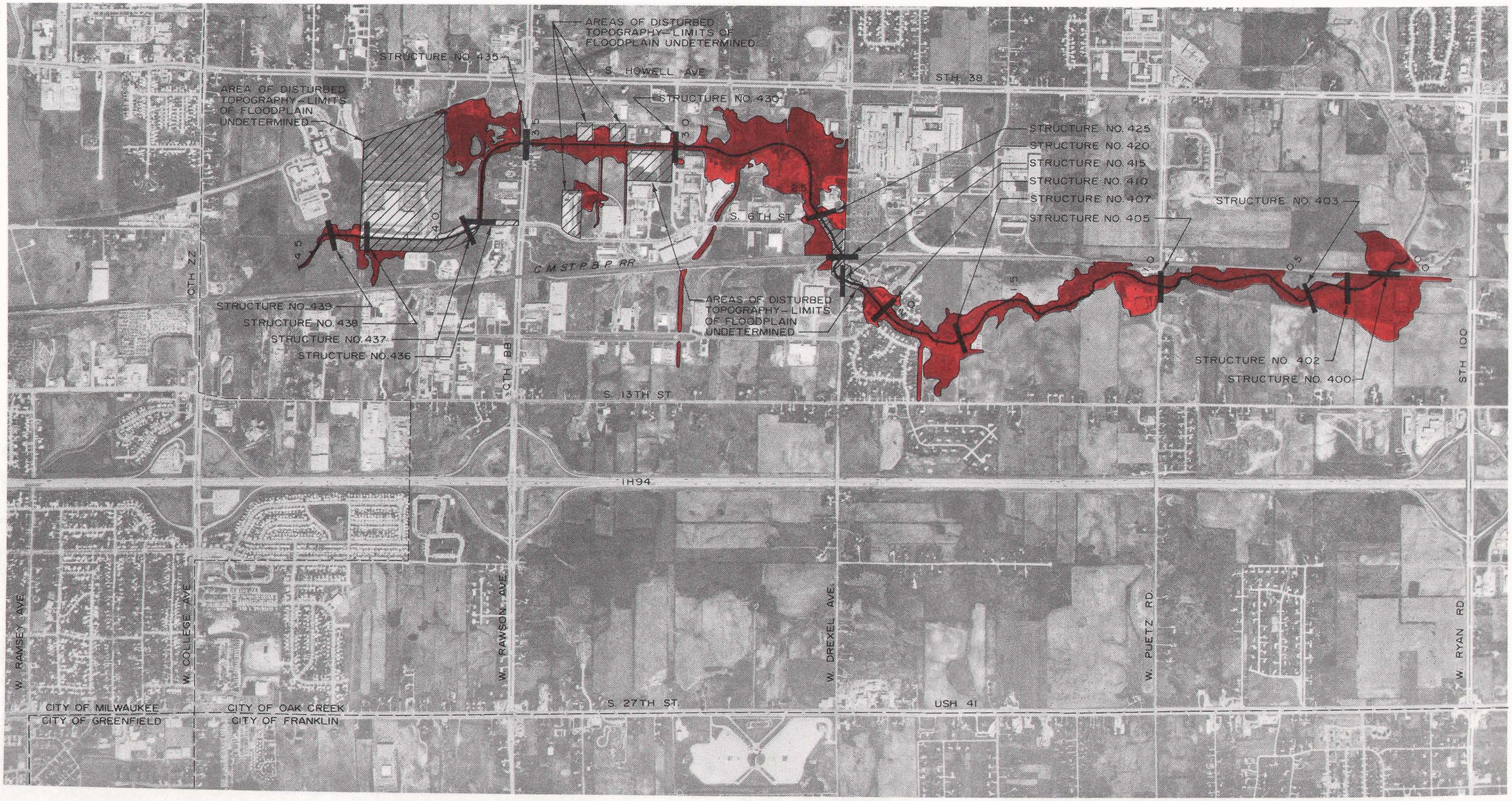
FLOOD STAGE AND STREAMBED PROFILE FOR MITCHELL FIELD DRAINAGE DITCH



Source: SEWRPC.

Map G-7

AERIAL PHOTOGRAPH SHOWING AREA SUBJECT TO FLOODING ALONG NORTH BRANCH OF OAK CREEK (RIVER MILE 0.00 TO 4.50)

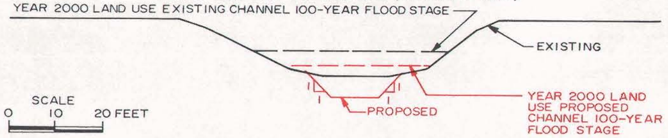


LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS-- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK FROM RM 4.2 TO RM 5.21 (S. 13TH ST.)



GRAPHIC SCALE

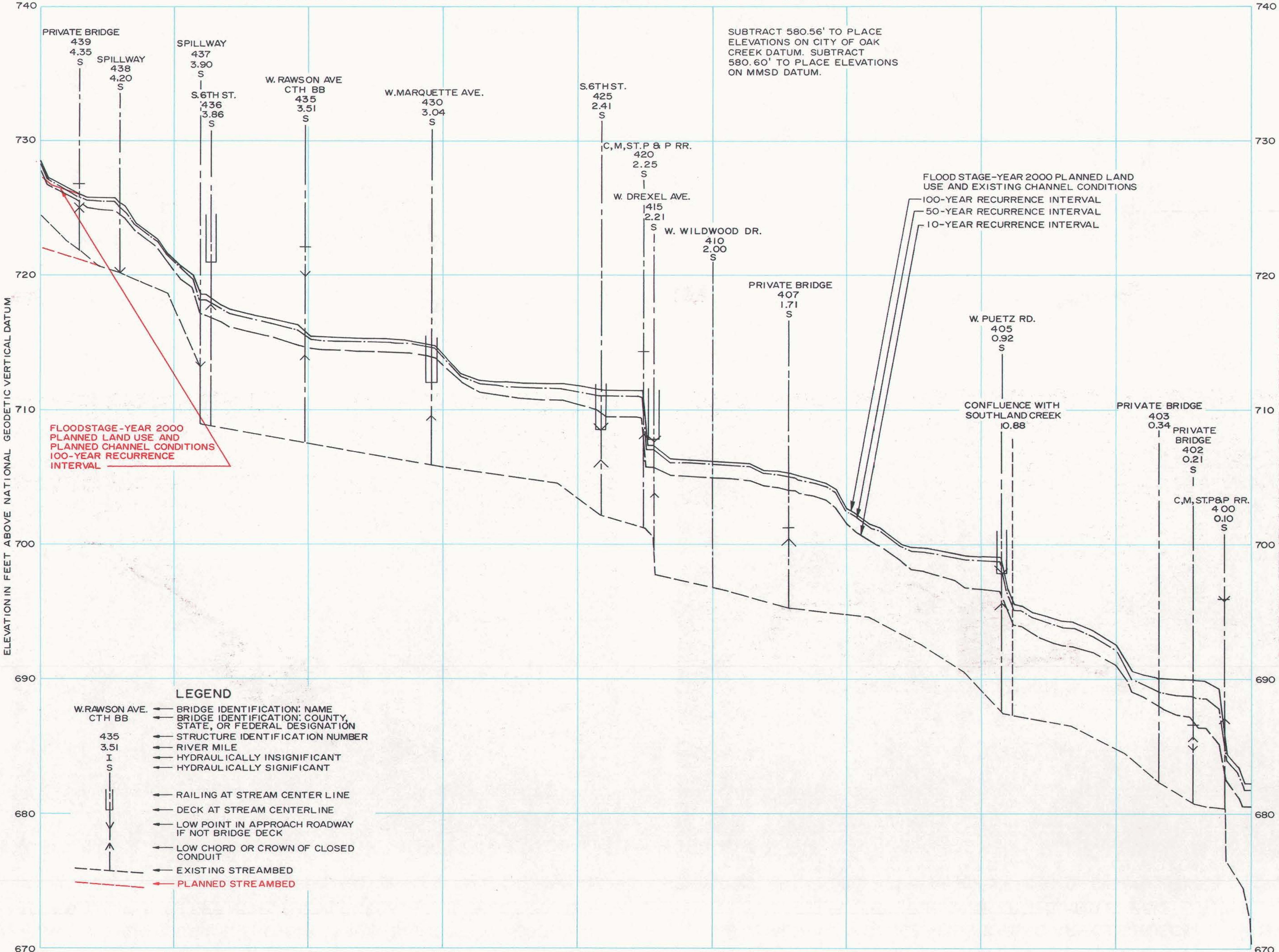
0 1/2 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-7

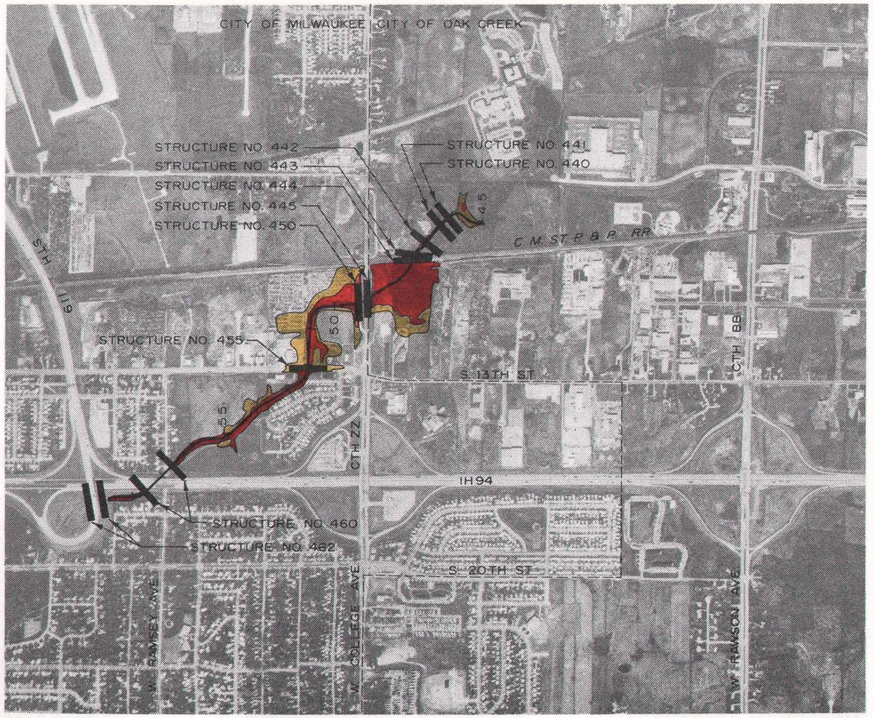
FLOOD STAGE AND STREAMBED PROFILE FOR NORTH BRANCH OF OAK CREEK (RIVER MILE 0.00 TO 4.50)



Source: SEWRPC.

Map G-8

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE NORTH BRANCH OF OAK CREEK (RIVER MILE 4.50 TO 5.85)



LEGEND

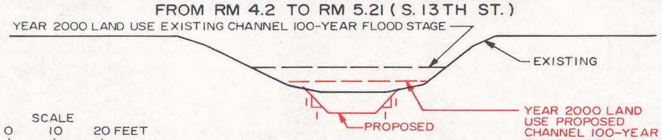
APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

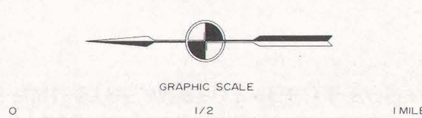
100-YEAR RECURRENCE INTERVAL FLOODLANDS--PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

100-YEAR RECURRENCE INTERVAL FLOODLANDS--PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS THAT WOULD BE ELIMINATED UNDER PLANNED CHANNEL CONDITIONS

NOTE: DUE TO MAP SCALE LIMITATIONS, THE DIFFERENCE BETWEEN THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS, AND THE 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS, MAY NOT APPEAR ON THIS MAP. WHERE NO DIFFERENCE APPEARS REFERENCE SHOULD BE MADE TO THE FLOOD STAGE PROFILE SHOWN BELOW.

TYPICAL CROSS-SECTION OF THE EXISTING AND PROPOSED CHANNEL ALONG THE NORTH BRANCH OF OAK CREEK FROM RM 4.2 TO RM 5.21 (S. 13TH ST.)



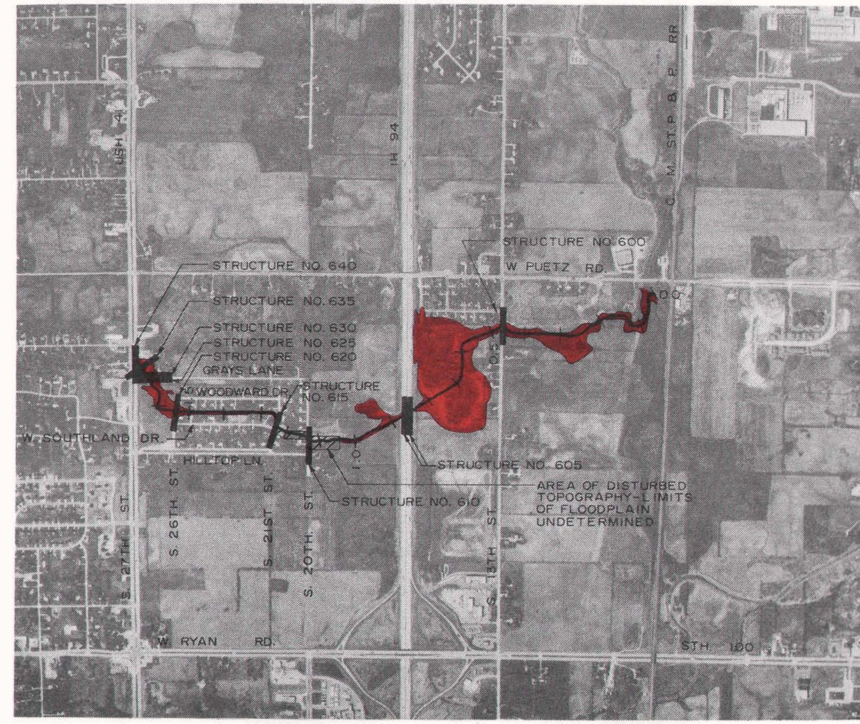


DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Map G-9

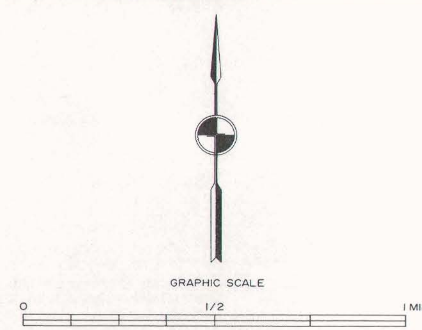
AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG SOUTHLAND CREEK



LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODLANDS--PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS

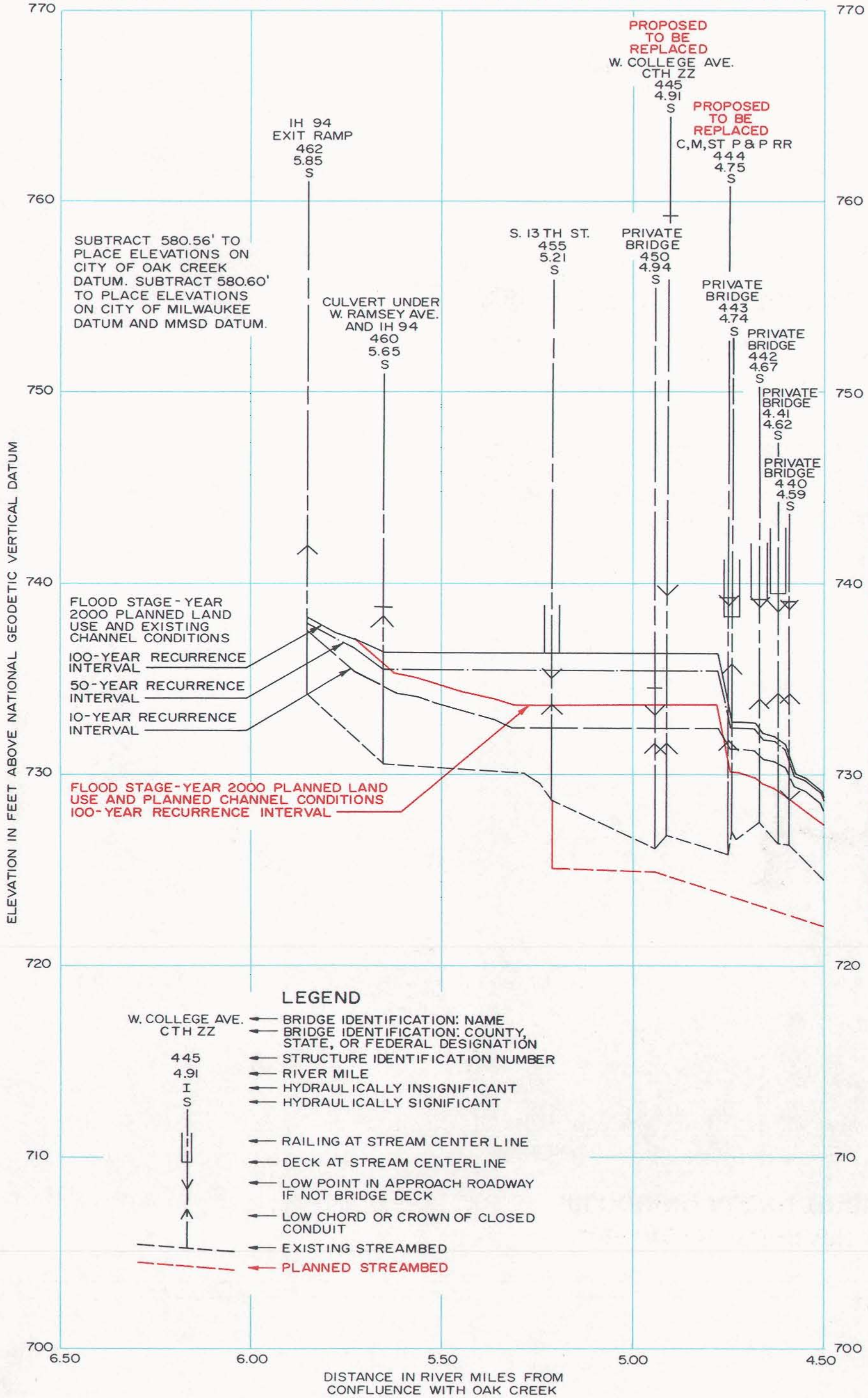


DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure G-8

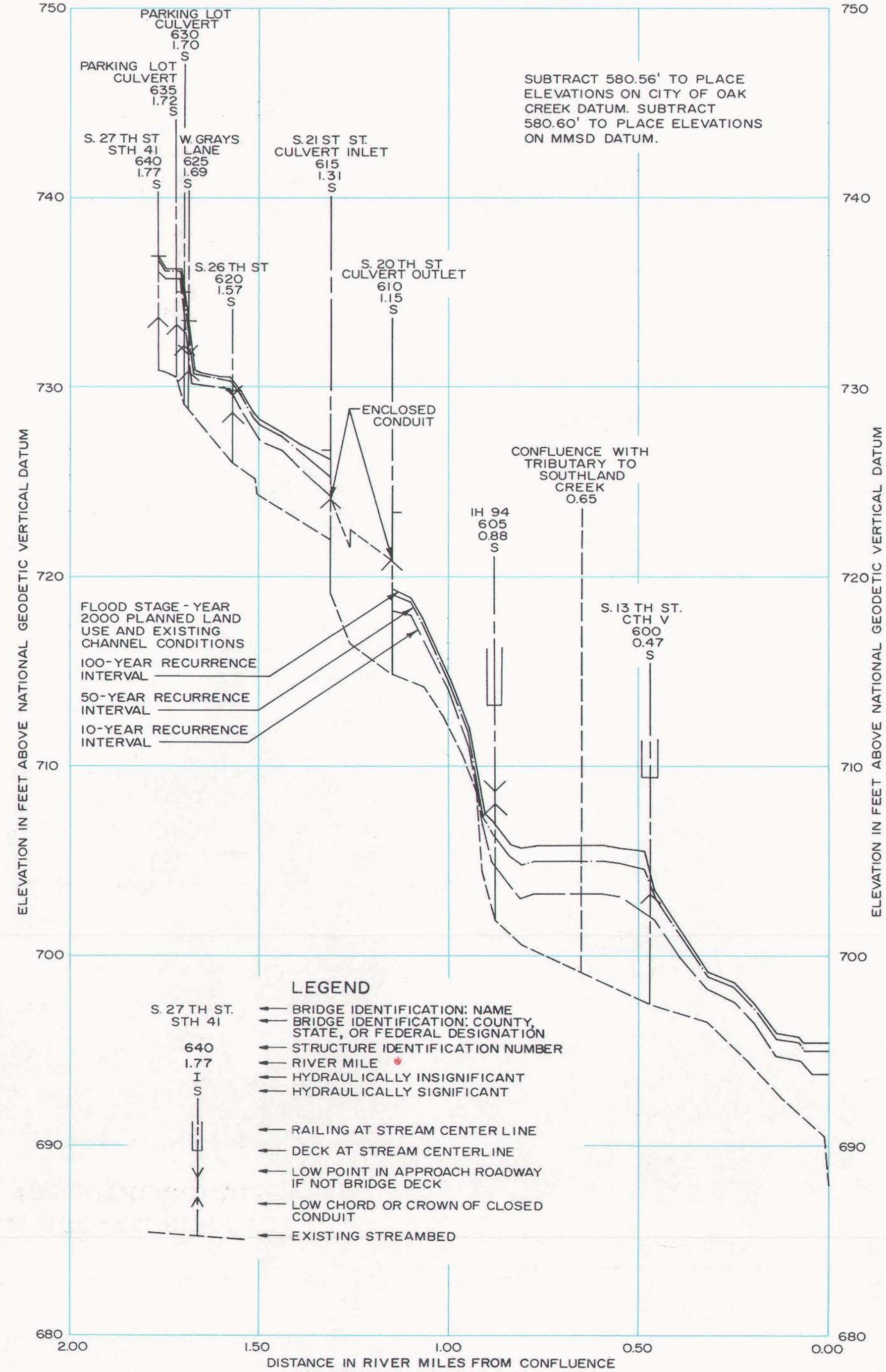
FLOOD STAGE AND STREAMBED PROFILE FOR THE NORTH BRANCH OF OAK CREEK (RIVER MILE 4.50 TO 5.85)



Source: SEWRPC.

Figure G-9

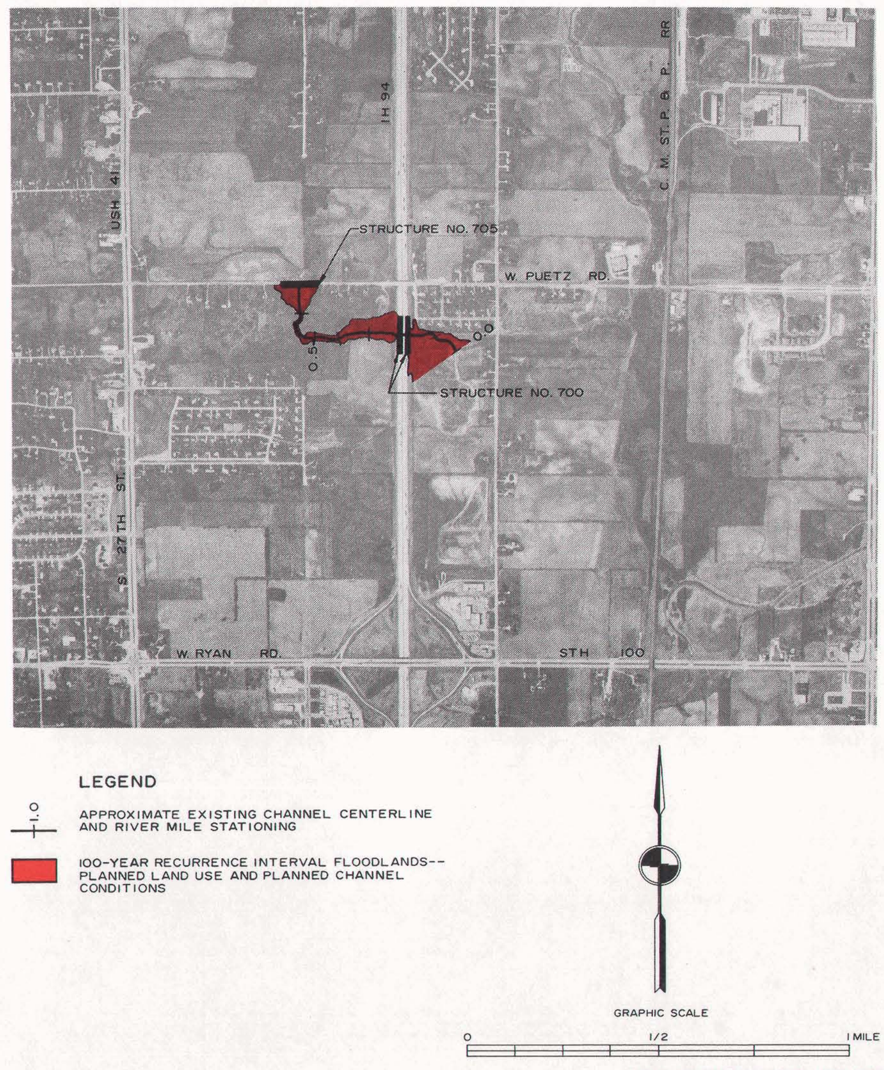
FLOOD STAGE AND STREAMBED PROFILE FOR SOUTHLAND CREEK



Source: SEWRPC.

Map G-10

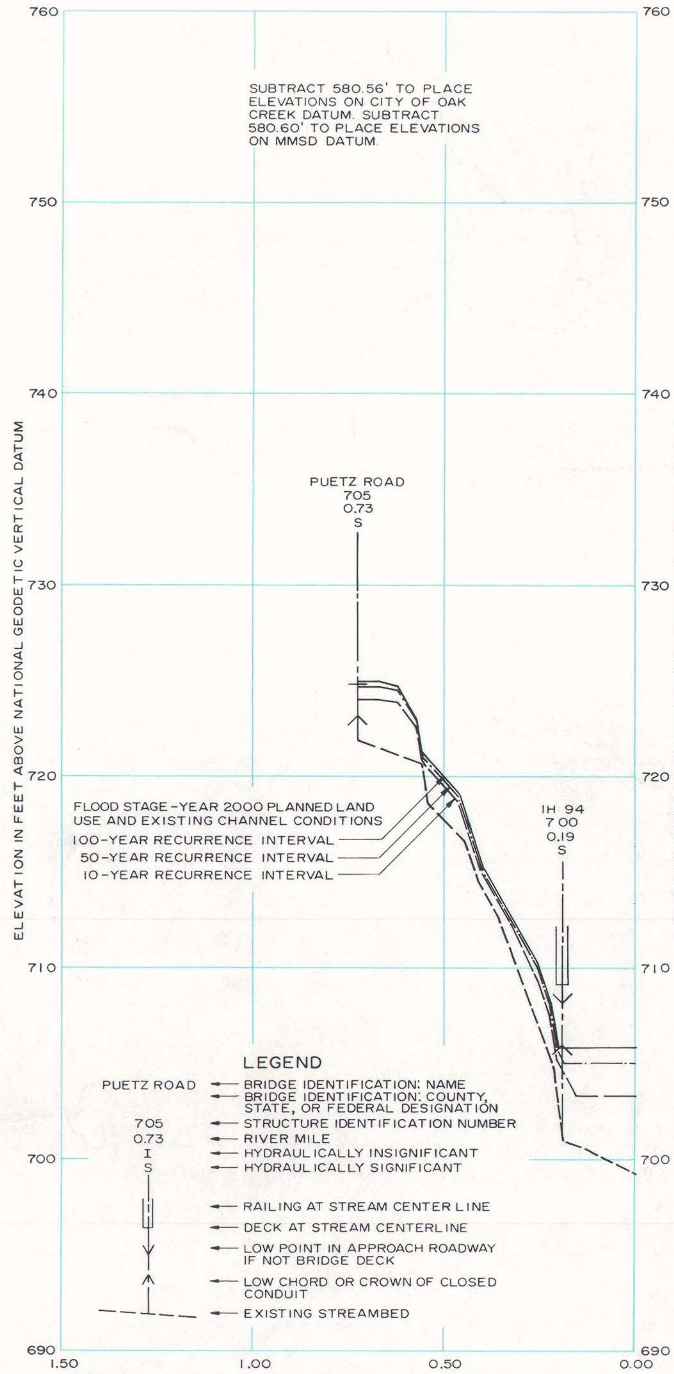
AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG TRIBUTARY TO SOUTHLAND CREEK



Source: SEWRPC.

Figure G-10

FLOOD STAGE AND STREAMBED PROFILE FOR TRIBUTARY TO SOUTHLAND CREEK



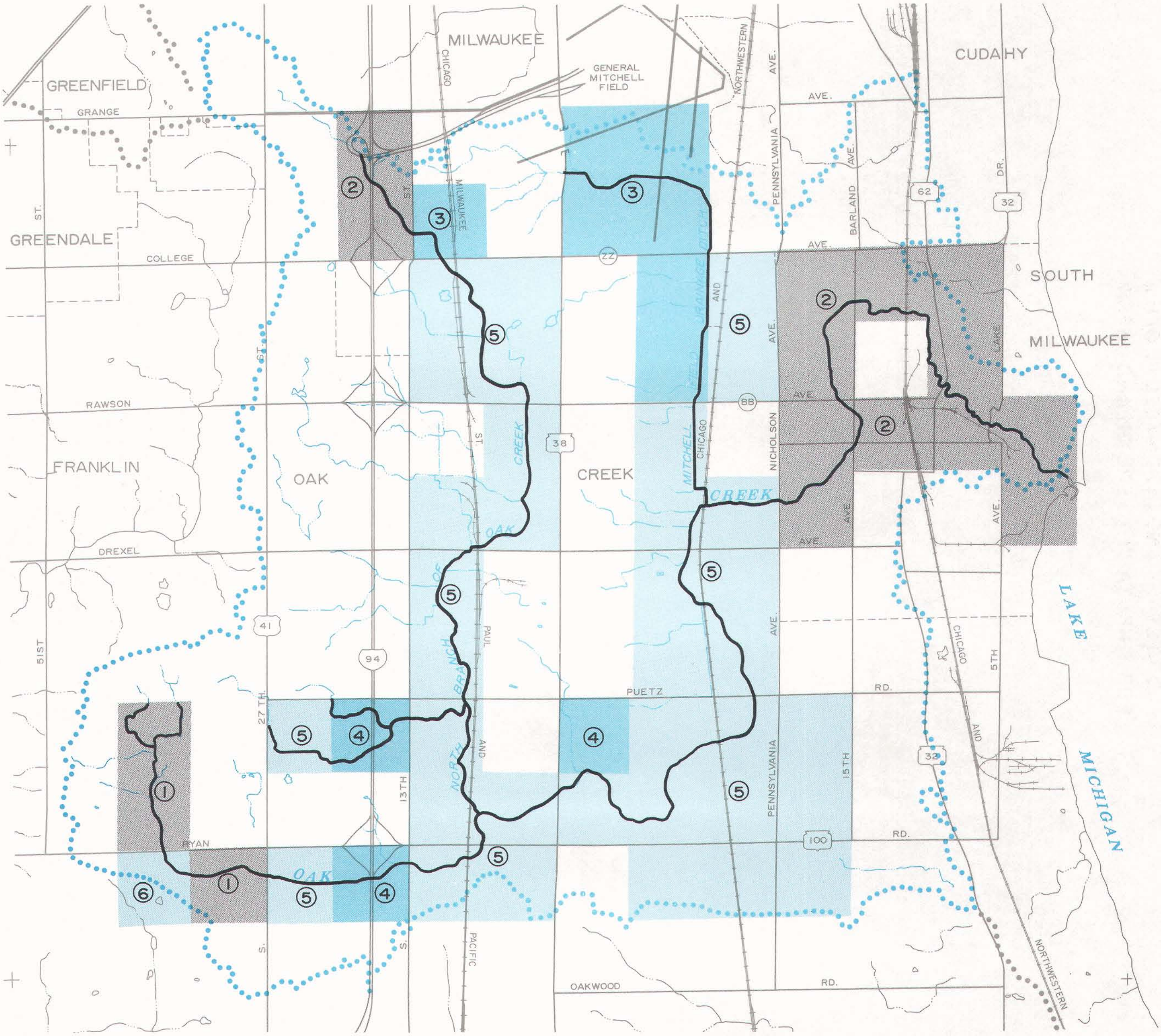
Source: SEWRPC.

Appendix H

LARGE-SCALE TOPOGRAPHIC MAPPING IN FLOOD HAZARD AREAS OF THE OAK CREEK WATERSHED

Map H-1

INDEX TO LARGE-SCALE TOPOGRAPHIC MAPPING IN FLOOD HAZARD AREAS IN THE OAK CREEK WATERSHED: 1986



LEGEND

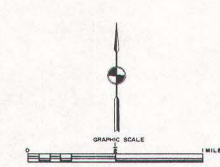
PORTION OF STREAM SYSTEM FOR WHICH FLOOD STAGE PROFILES WERE DEVELOPED

② IDENTIFICATION NUMBER OF TOPOGRAPHIC MAPS (SEE TABLE H-1)

NOTE: 1. THIS MAP IS LIMITED TO THAT PORTION OF THE WATERSHED STREAM SYSTEM FOR WHICH FLOOD STAGE PROFILES HAVE BEEN DEVELOPED

2. TOPOGRAPHIC MAPPING IS AVAILABLE BY U.S. PUBLIC LAND SURVEY QUARTER-SECTION

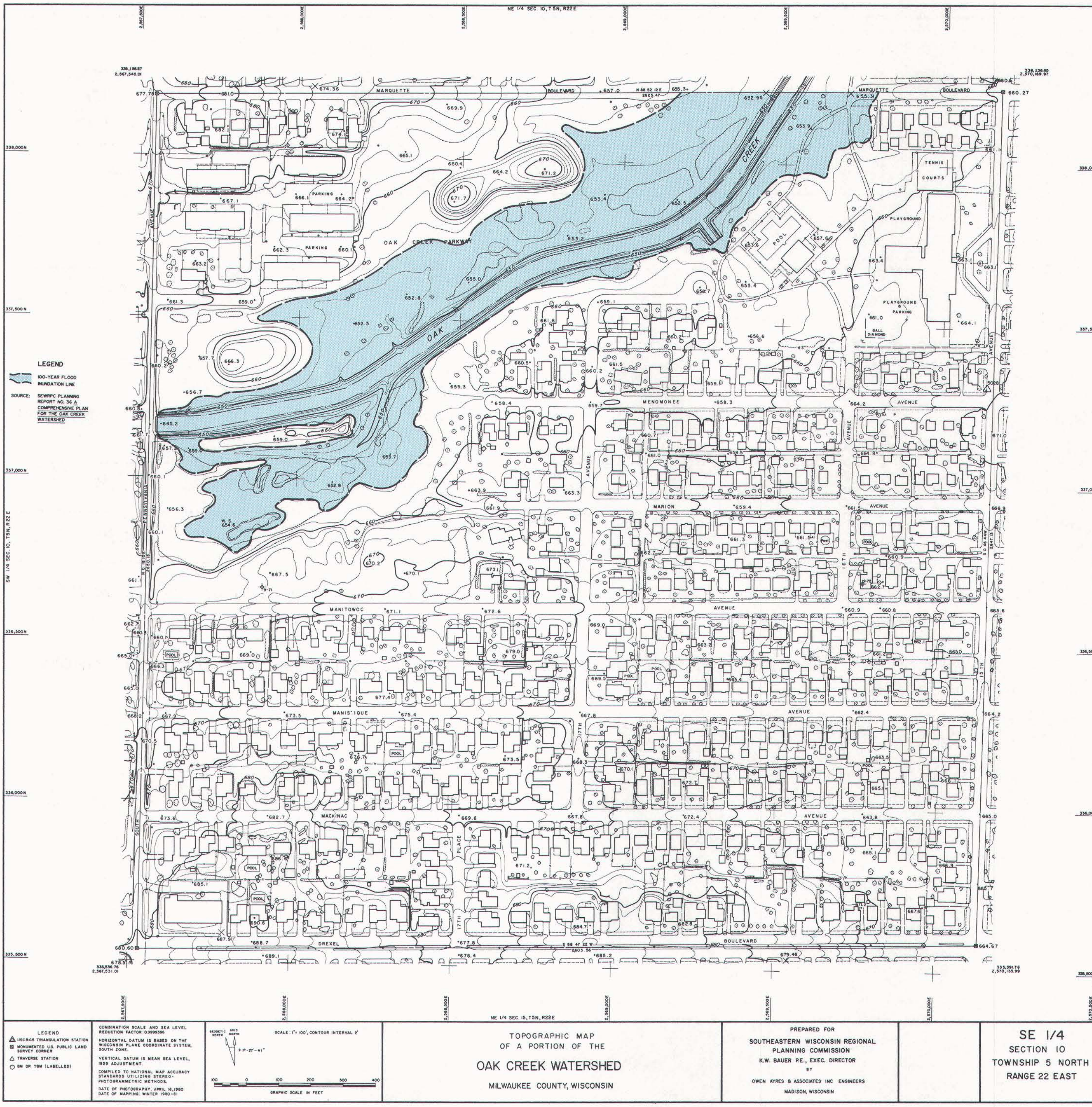
3. SMALL-SCALE (1" = 1/2 MILE) FLOOD HAZARD AERIAL PHOTOGRAPHS AND CORRESPONDING FLOOD STAGE AND STREAMBED PROFILES ARE PRESENTED IN APPENDIX G OF THIS REPORT



Source: SEWRPC.

Map H-2

TYPICAL FLOOD HAZARD MAP OF A PORTION OF THE OAK CREEK WATERSHED



Source: SEWRPC.

Table H-1

SELECTED INFORMATION PERTAINING TO LARGE-SCALE TOPOGRAPHIC MAPPING IN FLOOD HAZARD AREAS IN THE OAK CREEK WATERSHED[a]

Identification Number on Map H-1	City, Village, or Town	Agency or Community from Which Large-Scale Topographic Mapping Can be Obtained	Date of Photography Used for Map Preparation
1	City of Franklin	City of Franklin	1963
2	Cities of Milwaukee and South Milwaukee	SEWRPC	1980
3	Cities of Milwaukee and Oak Creek	Milwaukee County Airport Department	1980
4	City of Oak Creek	State of Wisconsin, Department of Transportation, Division of Highways	1970
5	City of Oak Creek	City of Oak Creek	1961[b]
6	City of Franklin	SEWRPC	1983

[a] *All topographic maps used as a basis for flood hazard mapping are available at a horizontal scale of 1 inch equals 100 feet with a vertical contour interval of two feet.*

[b] *All of these maps were updated between 1976 and 1978 except for the northwest one-quarter of Section 19, Township 5 North, Range 22 East.*

Source: SEWRPC.

Appendix I

MODEL RESOLUTION FOR ADOPTION OF THE COMPREHENSIVE PLAN FOR THE OAK CREEK 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 Metropolitan Sewerage District and the City of South Milwaukee in November 1982 requested the development of a comprehensive plan by the Southeastern Wisconsin Regional Planning Commission for the Oak Creek 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 open space reservation, to generally promote the orderly and economical development of the Oak Creek watershed; and

WHEREAS, such plan has been completed and the Southeastern Wisconsin Regional Planning Commission did on the 8th day of September 1986 approve a resolution adopting the comprehensive plan for the Oak Creek 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; structure floodproofing; 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; fishery development; and navigation improvements at the Oak Creek mouth, and is, therefore, a desirable and workable water control and water-related community facility plan for the 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. 36, A Comprehensive Plan for the Oak Creek Watershed, published in August 1986; and

WHEREAS, the Commission has transmitted certified copies of its resolution adopting such comprehensive plan for the Oak Creek watershed, together with the aforementioned SEWRPC Planning Report No. 36, 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 Oak Creek watershed prepared by the Commission is a valuable guide to the development of not only the watershed but 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 Oak Creek watershed previously adopted by the Commission as set forth in SEWRPC Planning Report No. 36 as a guide for watershed and community development.

BE IT FURTHER HEREBY RESOLVED that the__________clerk transmit a certified copy of this resolution to the Southeastern Wisconsin Regional Planning Commission.

____
(President, Mayor, or Chairman of the Local Governing Body)

ATTESTATION:

____
(Clerk of Local Governing Body)