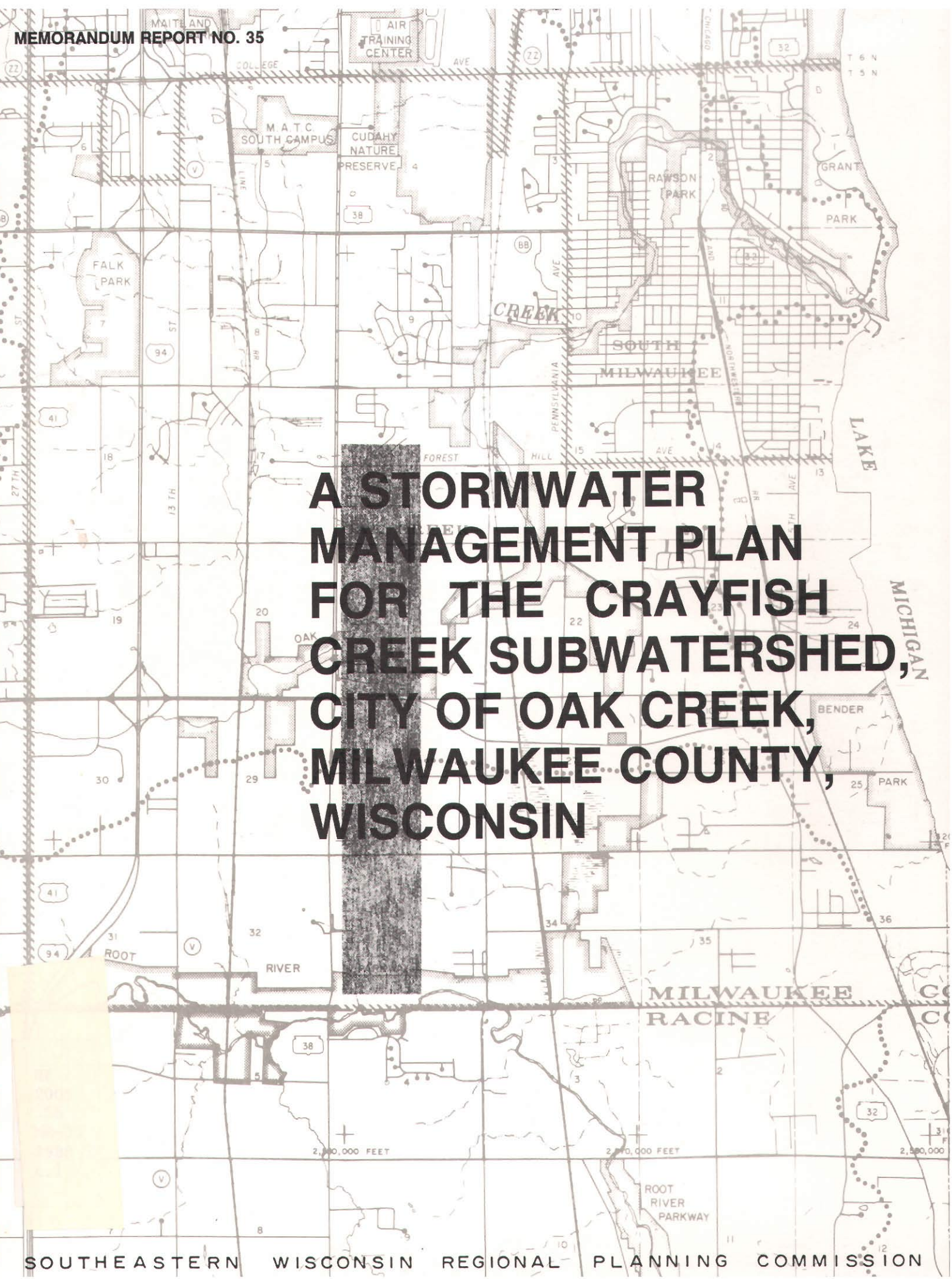
MEMORANDUM REPORT NO. 35

# A STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED, CITY OF OAK CREEK, MILWAUKEE COUNTY, WISCONSIN

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Special acknowledgement is due Mr. Curtis R. Hulterstrum, SEWRPC Principal Water Resource Engineer, and Mr. Roger A. Baumann, former SEWRPC Principal Water Resource Engineer, for their efforts in the conduct of this study and in the preparation of this report.

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MEMORANDUM REPORT NUMBER 35

# A STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED

## CITY OF OAK CREEK MILWAUKEE COUNTY, WISCONSIN

Prepared by the

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

June 1988

Inside Region $5.00
Outside Region $10.00

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# SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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June 6, 1988

Mayor, Common Council, and
City Plan Commission
c/o City Engineer
City of Oak Creek
8640 S. Howell Avenue
Oak Creek, Wisconsin 53154

Ladies and Gentlemen:

In 1985, the City of Oak Creek requested the Southeastern Wisconsin Regional Planning Commission to assist the City in the preparation of a stormwater management plan for the Crayfish Creek subwatershed in the southern part of the City. The Regional Planning Commission, working in cooperation with the City's engineering staff and the City's Root River Drainage Task Force, has now completed the technical work required, and is pleased to herewith transmit a recommended stormwater management plan for consideration by the City Plan Commission and the City Common Council.

The Crayfish Creek subwatershed includes about one square mile of land in the Town of Caledonia, Racine County, and, upon adoption of the plan by the City, a copy of the plan should be forwarded to the Town of Caledonia, to Racine County, and to certain other units and agencies of government to help ensure intergovernmental coordination in plan implementation. The Root River Drainage Task Force held three intergovernmental meetings to discuss the plan recommendations with the representatives of the agencies that will be involved in implementation of the plan, including representatives of the Town of Caledonia, Racine County, the Wisconsin Department of Natural Resources, the Milwaukee County Department of Parks, Recreation and Culture, and the Milwaukee Metropolitan Sewerage District.

The stormwater management plan presented herein is consistent with regional as well as local land use development, water quality management, and flood control objectives, and is intended to serve as a guide to public officials in the making of sound decisions over time concerning the development of stormwater management facilities in the Crayfish Creek subwatershed.

The Regional Planning Commission is particularly appreciative of the contributions of the members of the Task Force over so many months to the preparation of the plan. The Commission staff stands ready to assist the City in securing the adoption of the plan and in promoting its implementation over time.

Sincerely,

Kurt W. Bauer
Executive Director

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# Chapter I

## INTRODUCTION AND BACKGROUND

The focus of this report is the Crayfish Creek drainage area, a subwatershed of the Root River watershed located in the southern portion of the City of Oak Creek and the northern portion of the Town of Caledonia.

Certain residential and agricultural lands within the Crayfish Creek subwatershed experience periodic flooding and related stormwater drainage problems. These drainage problems may be expected to be exacerbated by the further development of the remaining open lands within the subwatershed not planned for park and open space uses. The frequency of occurrence and relative severity of this flooding and the associated drainage problems caused the City of Oak Creek to request the Regional Planning Commission to evaluate alternative means by which the flooding could be alleviated, and drainage improved. This report sets forth the findings of that evaluation, and recommends a stormwater management system plan for the subwatershed.

More specifically, this report:

1. Describes the stormwater drainage system and the flooding and stormwater drainage problems of the Crayfish Creek subwatershed, and identifies the causes of these problems;

2. Describes existing and proposed future land use conditions, and assesses the impact of those conditions on existing and future stormwater management problems in the subwatershed;

3. Presents alternative stormwater management system plans designed to abate the stormwater management problems in the subwatershed;

4. Provides a comparative evaluation of the technical, economic, and environmental features of the alternative plans;

5. Recommends a stormwater management system plan for the Crayfish Creek subwatershed consisting of various structural and nonstructural measures; and

6. Identifies the responsibilities of, and actions required by, the various governmental units and agencies concerned to carry out the recommended plan.

This report was prepared by the staff of the Southeastern Wisconsin Regional Planning Commission in cooperation with the staff of the City of Oak Creek in response to a letter request from the City dated January 16, 1985. The recommended stormwater management plan for Crayfish Creek, as presented herein, is properly set within the context of the broader flood control and water quality management recommendations of the adopted comprehensive plan for the Root River watershed;[1] the stormwater management-related water quality recommendations of the adopted nonpoint source water pollution control plan for the Root River watershed;[2] and the adopted, areawide, water quality management plan.[3]

### DISTINCTION BETWEEN STORMWATER DRAINAGE AND FLOOD CONTROL

Both stormwater drainage and flood control deal with the problems of disposal of unwanted water, and the distinction between the two issues is not always clear-cut. For the purposes of this report, flood control is defined as the prevention of damage from the overflow of natural streams and watercourses—that is, from waters moving

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[1] *See SEWRPC Planning Report No. 9, A Comprehensive Plan for the Root River Watershed, July 1966.*

[2] *See SEWRPC Community Assistance Planning Report No. 37, A Nonpoint Source Water Pollution Control Plan for the Root River Watershed, March 1980.*

[3] *See SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings; Volume Two, Alternative Plans; and Volume Three, Recommended Plan.*

out of and away from natural stream channels. Drainage is defined as the prevention of damage from excess stormwater on the land surface before such water has entered stream channels—that is, from waters moving toward natural stream channels. Because of the topographic conditions within the subwatershed, the two problems are interrelated. Accordingly, this report, which focuses primarily on the need for and means of providing improved drainage in the subwatershed, also considers flood control as necessary to avoid the intensification of existing, or the creation of new, flood damage problems along the natural streams and watercourses of the subwatershed. In addition, flood control is considered because the flood stages on the Root River do impact directly on the drainage system of the Crayfish Creek subwatershed. During major floods along the Root River, flood waters may extend up into the Crayfish Creek subwatershed as far as E. Elm Road for a duration of up to 12 days.

## BASIC CONCEPTS INVOLVED

The basic concepts underlying urban stormwater management are undergoing revision. The older concepts sought to eliminate excess surface water during and after a rainfall as quickly as possible through the provision of an efficient drainage system, a system usually consisting of enclosed conduits, although sometimes consisting of improved open channels. The problems created by application of this traditional conveyance approach to urban stormwater drainage were more or less acceptable when urban development was compact and confined to relatively small areas. These problems have become increasingly more serious, aggravating, and unacceptable as the pattern of urban development has changed, and as urban land uses have diffused over even larger areas of regions such as southeastern Wisconsin.

The newer concepts consider, in addition to improved conveyance, the retention or detention of stormwater, even at some localized inconvenience, thus reducing both the total and the peak rate of runoff and protecting against increased downstream flooding. The newer concepts also look to controlling the quality as well as the quantity of stormwater runoff.

Stormwater runoff systems are generally designed to fulfill four basic objectives: 1) to prevent significant damage from relatively rare but reasonably foreseeable major storm events; 2) to provide an acceptable degree of rapid stormwater drainage, allowing convenient access to and egress from the various land uses of an urban area following more frequent, minor runoff events; 3) to avoid undue hazards to public safety and health; and 4) to mitigate the effects of nonpoint sources of pollution. Thus, the total stormwater runoff system for an area may be conceived of as consisting of a major element operating relatively infrequently, and a minor element operating frequently. The minor system usually consists of storm sewers and other engineered drainage facilities, and the major system usually consists of the street rights-of-way and interconnected major drainageways and natural watercourses.

Both of these elements of the system can, under certain conditions, utilize stormwater retention or detention, as well as improved conveyance, as a design solution. The benefits of stormwater storage are that it can reduce the high kinetic energy of surface runoff, reduce peak discharges, provide multiple-use opportunities for recreational and aesthetic purposes, provide groundwater recharge, trap some pollutants, and reduce the adverse impacts of the remaining pollutants by controlled release.

The recommended stormwater management plan for Crayfish Creek, as set forth herein, incorporates compatible multiple-use concepts and recognizes the constraints imposed by other community needs, such as parks and open space, and transportation. Drainage requirements under existing and plan year 2010 land use conditions are evaluated. Both flood control and drainage problems are addressed as necessary.

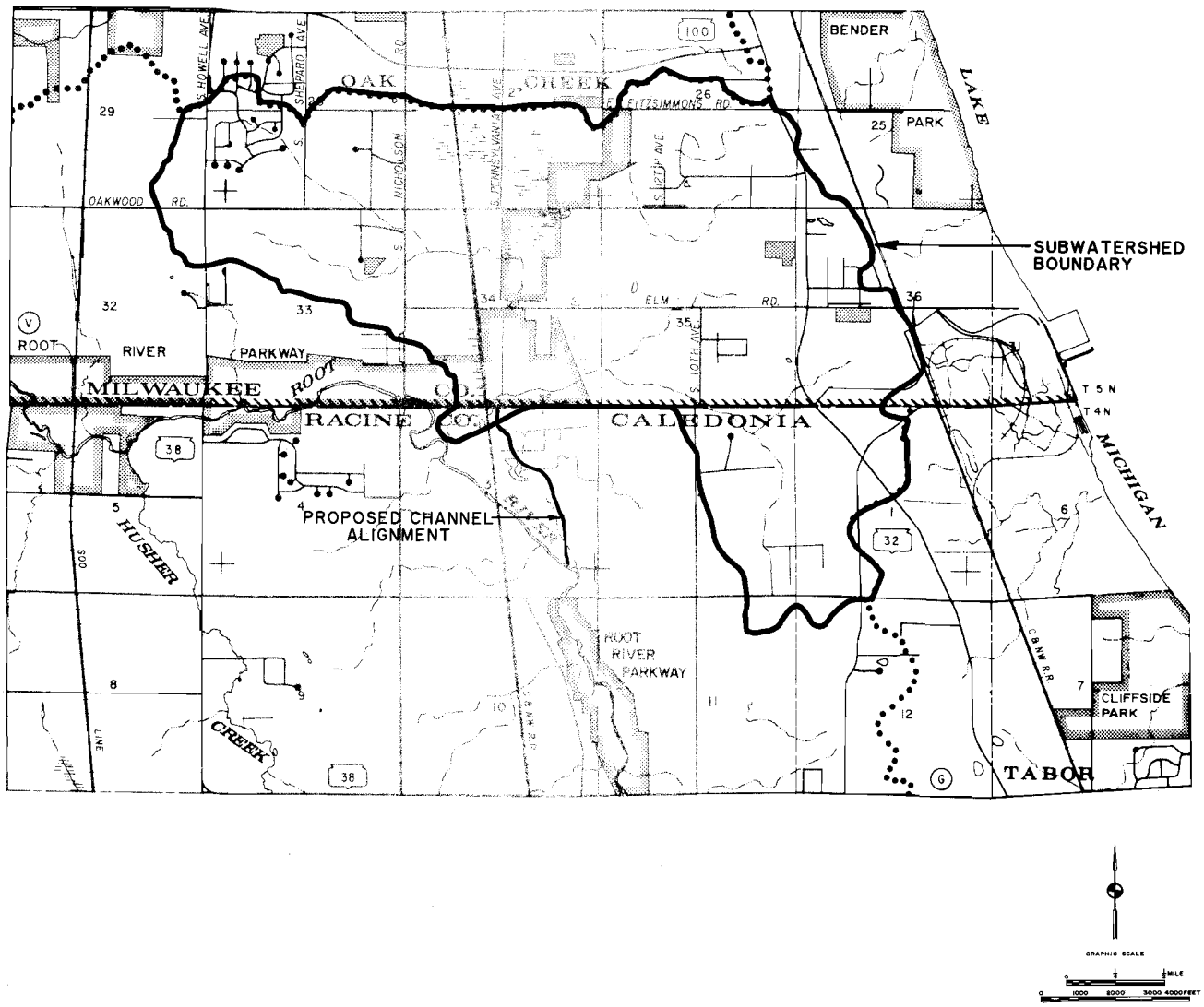
## REVIEW OF PREVIOUS STUDIES

The first step in the preparation of the stormwater management plan for the Crayfish Creek subwatershed was a review of the findings and recommendations of previous stormwater drainage studies for the area. These studies are documented in various letter reports and staff memoranda on file in the City Hall. The studies reviewed are listed below, and their salient findings and recommendations summarized.

A Drainage Study of Alternative Open Channel and Detention Basin Plans for the Crayfish Creek Drainage Area South of County Line Road, April 1982. Prepared by J. C. Zimmerman Engineering Corporation, Greenfield, Wisconsin.

**Map 1**

**LOCATION OF PROPOSED CHANNEL SET FORTH IN J. C. ZIMMERMAN ENGINEERING CORPORATION REPORT, 1982**




*Source: J. C. Zimmerman Engineering Corporation and SEWRPC.*

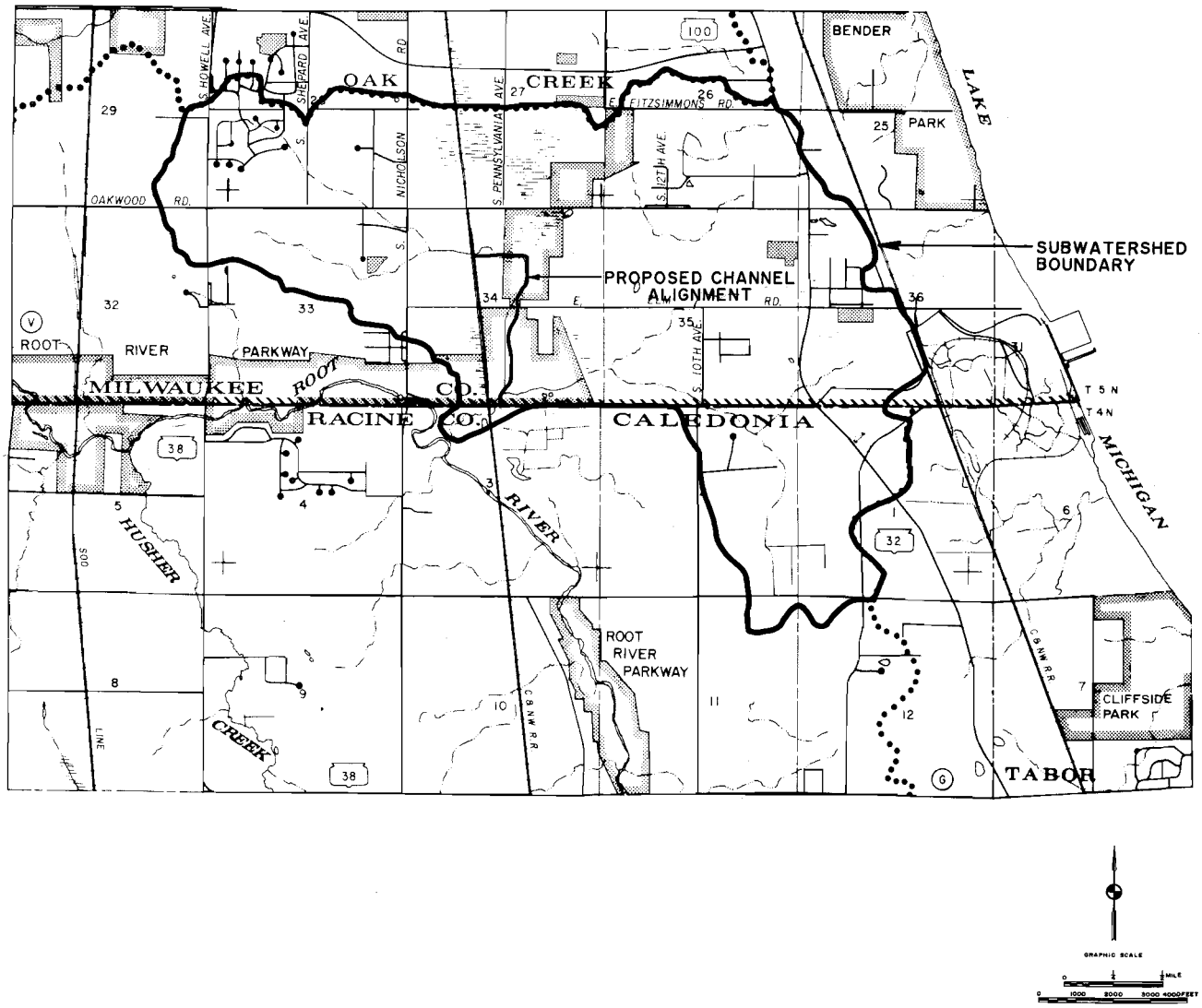
In 1982, the City retained the firm of Zimmerman Engineering Corporation to evaluate alternative alignments for the construction of a major drainage channel at a new location beginning at E. County Line Road and extending south to the Root River in the Town of Caledonia, Racine County, as shown on Map 1. This plan considered alternatives but favored the construction of a new grass-lined channel with a bottom width of 20 feet, one on four side slopes, and a maximum depth of five feet, south of County Line Road. In addition, the improvement of an existing pond near the Root River was envisioned, with the new channel discharging into the pond ahead of the Root River as a water quality improvement mechanism.

Preliminary Open Channel Design for a Proposed Channel from E. Elm Road to E. County Line Road, August 1982. Prepared by Graef-Anhalt-Schloemer & Associates, Inc., Milwaukee, Wisconsin.

In 1982, the City also retained the firm of Graef-Anhalt-Schloemer & Associates, Inc., to prepare

**Map 2**

**LOCATION OF PROPOSED CHANNEL SET FORTH IN GRAEF-ANHALT-SCHLOEMER & ASSOCIATES, INC., REPORT, 1982**




*Source: Graef-Anhalt-Schloemer & Associates, Inc., and SEWRPC.*

preliminary designs for channel modification along 5,700 lineal feet of the existing channel of Crayfish Creek, beginning about 0.3 mile east of Nicholson Road and extending easterly and then southerly to E. County Line Road, as shown on Map 2. The proposed channel modification consisted of the construction of a grass-lined channel with a bottom width of up to 18 to 26 feet, one on four side slopes, and a maximum depth of five feet. This channel would be located along the general alignment of the existing creek.

Letter Report Evaluating the Environmental Impacts of the Proposed Relocation and Channelization of Crayfish Creek, July 8, 1983. Prepared by the Southeastern Wisconsin Regional Planning Commission.

In March 1983, the City asked the Regional Planning Commission to evaluate the environmental impacts of the channel improvements proposed in the reports by the firms of J. C. Zimmerman Engineering Corporation and Graef-Anhalt-Schloemer & Associates, Inc., including the effectiveness of the channel improvements in abating the flooding and drainage problems. In response to this report, the Commission staff submitted a letter report to the City in July 1983 which indicated that the environmental impacts of the proposed project would, overall, not be significant. The hydrologic and hydraulic analyses, however, indicated that the flow regime of the Root River was a major determinant of the rate at which lands in the Crayfish Creek subwatershed generally, and along Crayfish Creek specifically, drain.

Consequently, it was concluded that while the proposed channelization might improve local drainage during minor runoff events when the stages of the Root River do not increase significantly, it would have limited effect during major runoff events when the Root River rises to bankfull or higher stage. The Commission staff recommended that the City consider additional alternatives which may be more effective than the proposed project.

During the summer of 1984, the City of Oak Creek formed a Drainage Task Force composed of local officials and citizens, the membership of which is listed on the inside front cover of this report. The purpose of the Drainage Task Force was to consider the flooding and drainage problems of the Crayfish Creek subwatershed and alternative means of mitigating those problems. At a meeting of the Drainage Task Force held on July 27, 1984, alternative means of alleviating flooding problems in the subwatershed were discussed. In addition, the Task Force discussed the need for a comprehensive stormwater management planning effort to include the formulation and evaluation of alternatives, and the development of a recommended plan for improved stormwater drainage, improved water quality, and the alleviation of seasonal flooding. The stormwater management planning effort was to clearly document the basis for the recommended plan. The Task Force work effort lead to a request by the City on January 16, 1985, that the Regional Planning Commission undertake the preparation of a stormwater system management plan for the Crayfish Creek subwatershed.

## SUMMARY

The City of Oak Creek has asked the Regional Planning Commission to evaluate alternative means of abating the drainage and flooding problems within the Crayfish Creek drainage area, a subwatershed of the Root River watershed.

This report presents the results of the evaluation, along with a recommended stormwater management plan for the subwatershed. The plan seeks to promote the development of an effective stormwater system for the study area through the year 2010, a system that will minimize damages attendant to poor drainage as well as to flooding. More specifically, this report describes the existing stormwater drainage system and stormwater drainage and flooding problems of the Crayfish Creek subwatershed; describes existing and proposed future land use conditions in the subwatershed; identifies related stormwater management requirements; provides a set of stormwater management objectives and supporting principles and standards to guide the development of an effective stormwater management system for the subwatershed; presents alternative stormwater management system plans and compares the technical, economic, and environmental features of these plans; recommends a stormwater management plan for the Crayfish Creek subwatershed basin; and sets forth a plan implementation program.

The plan considers both stormwater drainage and flood control problems, addressing the latter, however, to the extent necessary to avoid the intensification of existing or the creation of new flood control problems along the natural streams and watercourses which must receive the discharge from the proposed urban stormwater management facilities. The relationships within the subwatershed between flooding and drainage are also considered, since during major floods along the Root River, the backwater effects extend up into the Crayfish Creek subwatershed as far as Elm Road.

The recommended stormwater management plan presented herein also recognizes that the basic concepts underlying urban stormwater management are undergoing revision. The older concepts sought to eliminate excess surface water during and after a rainfall as quickly as possible through the provision of an efficient drainage system, a system consisting primarily of enclosed conduits and improved open channels for improved conveyance. The newer concepts, in addition to improved conveyance, look to the retention or detention of stormwater, even at some localized inconvenience, thus reducing both the total volume and the peak rate of runoff, and providing protection against increased downstream flooding. The newer concepts also look to controlling the quality as well as the quantity of runoff.

The plan presented herein regards the stormwater runoff system of the subwatershed as consisting of a major element operating infrequently and a minor element operating frequently, with both of these elements potentially incorporating the storage of excess runoff. Drainage requirements are evaluated under both existing and planned land use conditions, and flood control, also, is addressed as necessary.

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## Chapter II

## INVENTORY AND ANALYSIS

### INTRODUCTION

Accurate information on certain pertinent natural and man-made features of the study area is essential to sound stormwater management planning. Accordingly, the first operational step in the stormwater management planning process is the collation and collection of definitive information on the key hydrologic and hydraulic characteristics of the stormwater management planning area, on the existing stormwater drainage system of that area, and on the erosion and sedimentation characteristics of that area. The resulting information is essential to the planning process, because alternative stormwater management plans cannot be formulated and evaluated without an in-depth knowledge of the pertinent conditions in the planning area. This is particularly true for stormwater management planning, which must address the complex interaction of natural meteorologic events, key hydrologic and hydraulic characteristics of the planning area, and certain man-made physical systems.

Accordingly, this chapter presents pertinent data on the location, configuration, and capacity of the stormwater drainage system of the Crayfish Creek subwatershed, on the magnitude of stormwater flows to be accommodated by that system, and on the hydrologic phenomena governing the magnitude and frequency of those flows. Also presented are data on actual historic flood events and on existing drainage problems. The data pertinent to stormwater management planning are presented in this chapter under the headings land use, climate, soils, environmentally sensitive areas, stormwater drainage systems, and stormwater management problems. Because water quality impacts are becoming increasingly of concern in stormwater management, this chapter also presents data on water quality conditions in the Crayfish Creek subwatershed, and discusses those sources of pollution related to stormwater management.

### LAND USE

The type, density, and spatial distribution of land uses are important determinants of the quantity and quality of stormwater runoff. The amount of impervious area, the type of stormwater drainage system, the level and characteristics of human activity, and the type and amount of water pollutant deposition all vary with land use. Pertinent data on the existing land use pattern in the Crayfish Creek subwatershed are presented in Table 1, and that pattern is shown on Map 3.

The study area encompasses an area of about 3,701 acres, or 5.78 square miles. As indicated in Table 1, in 1980 urban land uses accounted for about 897 acres, or about 24 percent of the total study area. Of these developed urban land uses, residential uses occupied 776 acres, or 87 percent, and the remaining urban land uses—governmental and institutional, commercial, industrial, transportation and utilities, and recreational—together occupied 121 acres, or the remaining 13 percent. In 1980, rural land uses still accounted for 2,804 acres, or 76 percent of the total study area.

Agricultural lands occupied 1,992 acres, or 71 percent of the rural area. Other rural land uses, including wetlands, woodlands, and open water, occupied 812 acres, or 22 percent of the study area, and 29 percent of the rural area.

As of 1980, the portion of the Crayfish Creek subwatershed within the City of Oak Creek encompassed approximately 3,065 acres, or 83 percent of the study area. Urban land uses accounted for 762 acres, or 21 percent, of the study area within the City, with the dominant urban land use being residential, covering 667 acres, or 22 percent, of the study area within the City, but 88 percent of the developed area of the City. Rural land uses still accounted for 2,303 acres, or 75 percent, of the study area within the City, with the dominant use being agriculture, which occupied 1,592 acres, or 69 percent, of the rural land area within the City.

### CLIMATE AND HYDROLOGY

Air temperatures and the type, intensity, and duration of precipitation events affect the extent of areas subject to inundation and the type and magnitude of stormwater problems that

Table 1

EXISTING LAND USE CONDITIONS IN THE CRAYFISH CREEK SUBWATERSHED STUDY AREA: 1980

| Land Use Category | City of Oak Creek | | Town of Caledonia | | Total | |
|---|---|---|---|---|---|---|
| | Acres | Percent of Total | Acres | Percent of Total | Acres | Percent of Total |
| Urban | | | | | | |
| Residential | 667 | 88 | 109 | 81 | 776 | 87 |
| Commercial | 4 | --[a] | 0 | 0 | 4 | --[a] |
| Industrial | 12 | 2 | 1 | 1 | 13 | 2 |
| Governmental and Institutional | 29 | 4 | 0 | 0 | 29 | 3 |
| Recreational | 50 | 6 | 25 | 18 | 75 | 8 |
| Subtotal | 762 | 100 | 135 | 100 | 897 | 100 |
| Rural | | | | | | |
| Agricultural | 1,592 | 69 | 400 | 80 | 1,992 | 71 |
| Woodlands, Wetlands, and Other Open Lands | 711 | 31 | 101 | 20 | 812 | 29 |
| Subtotal | 2,303 | 100 | 501 | 100 | 2,804 | 100 |
| Total | 3,065 | -- | 636 | -- | 3,701 | -- |

[a]*Contains less than 0.5 percent.*

*Source: SEWRPC.*

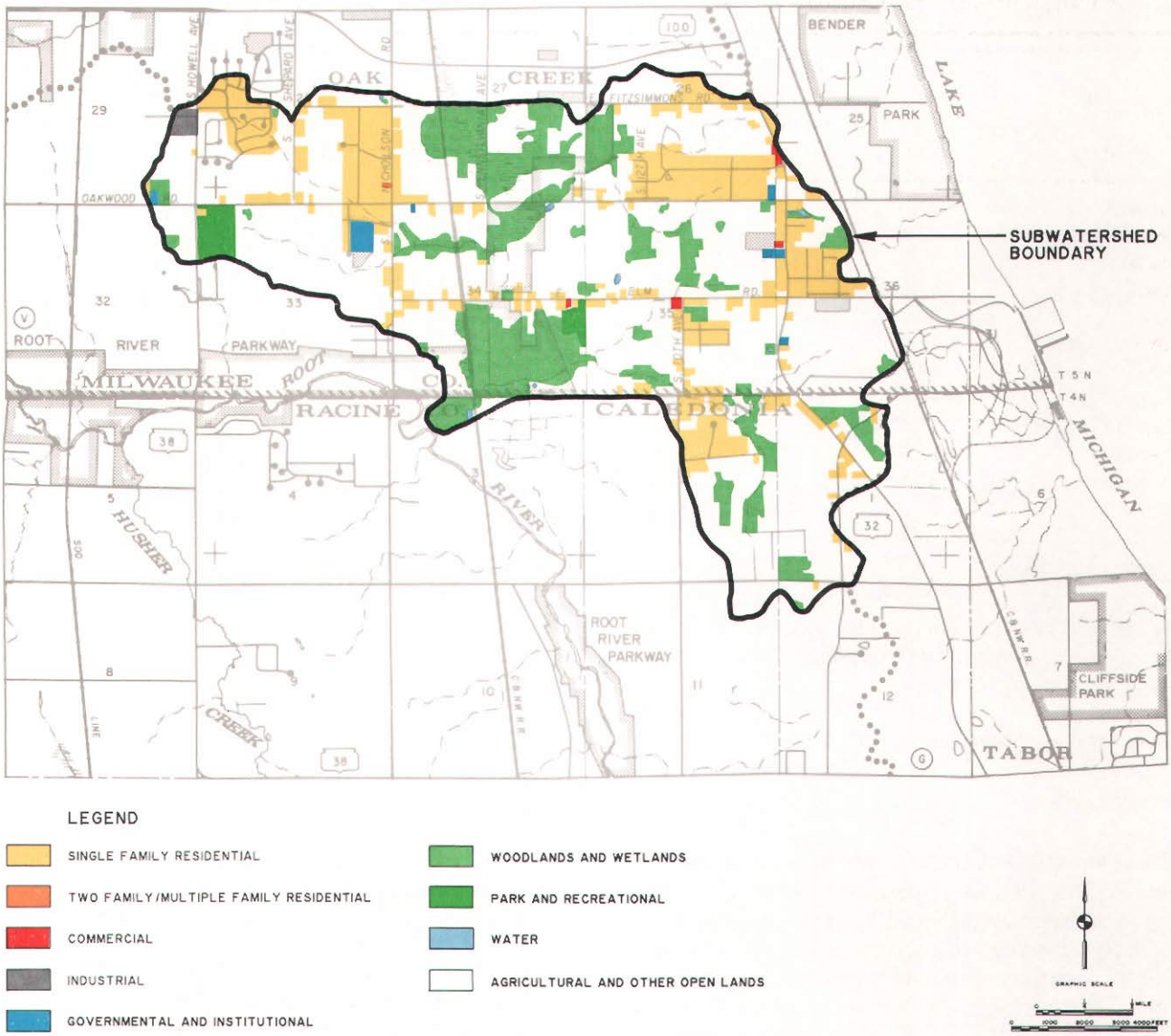
occur throughout the study area. The study area has a continental-type climate characterized primarily by a continuous progression of markedly different seasons and a wide range in monthly temperatures. The study area lies in the path of both low-pressure storm centers moving generally from the west and southwest, and high-pressure fair weather centers moving generally from the northwest. The confluence of these air masses results in frequent weather changes, particularly during spring and winter. These temporal weather changes consist of marked variations in temperature, precipitation, relative humidity, wind speed and direction, and cloud cover. The meteorologic events influence the rate and amount of stormwater runoff, the severity of storm drainage problems, and the required capacities of stormwater conveyance and storage facilities. Meteorologic data are available from the National Weather Service station at General Mitchell Field, located near the Crayfish Creek subwatershed.

Temperature and Season Considerations

Air temperatures, which exhibit a wide monthly range, are relevant to stormwater management planning and determine whether precipitation occurs as rainfall or snowfall, whether the ground is frozen and therefore essentially impervious, and the rate of snowmelt and attendant runoff. Table 2 presents average monthly air temperature variations at the Milwaukee National Weather Service station for the 30-year period from 1951 through 1980. Summer temperatures, as measured by the monthly means for June, July, and August, averaged 65°F to 70°F. Winter temperatures, as measured by the monthly means for December, January, and February, averaged 19°F to 25°F. For the period 1871 through 1970 at Milwaukee, the maximum recorded temperature was 105°F in July 1934, and the lowest recorded temperature was 25°F in January 1875. The growing season, which is defined as the number of days between the last 32°F temperature reading in spring and the first in fall, averages about 180 days for the

Map 3

EXISTING LAND USE IN THE CRAYFISH CREEK SUBWATERSHED AREA




*Source: SEWRPC.*

study area. The last frost in spring normally occurs near the end of April, whereas the first freeze in fall usually occurs during the latter half of October. Streams and lakes begin to freeze over in late November, and ice breakup usually occurs in late March or early April. Ice jams at bridges in spring can be a major cause of localized flooding. Such occurrences can be severe when combined with spring rainfall periods.

Precipitation

Precipitation within the study area takes the form of rain, sleet, hail, and snow, and ranges from gentle showers of trace quantities to brief, but intense and potentially destructive thunderstorms or major rainfall-snowmelt events causing property damage, inundation of poorly drained areas, stream flooding, street and basement flooding, and severe soil erosion and sedimentation. Average monthly and annual total precipitation and snowfall data from the Milwaukee National Weather Service station at General Mitchell Field for the period 1951 through 1980 are presented in Table 3. The average annual precipitation in the Crayfish Creek subwatershed is 30.94 inches, expressed as water equivalent; the average

Table 2

AVERAGE MONTHLY AIR TEMPERATURE AT MILWAUKEE: 1951 THROUGH 1980

| Month | Average Daily Maximum (°F) | Average Daily Minimum (°F) | Mean[a] (°F) |
|---|---|---|---|
| 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 |
| Annual | 54.6 | 37.6 | 46.1 |

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

*Source: National Weather Service and SEWRPC.*

Table 3

AVERAGE MONTHLY PRECIPITATION AND SNOW AND SLEET AT MILWAUKEE: 1951 THROUGH 1980

| Month | Average Total Precipitation (inches) | Average Snow and Sleet (inches) |
|---|---|---|
| January | 1.64 | 13.5 |
| February | 1.33 | 10.5 |
| March | 2.58 | 10.1 |
| April | 3.37 | 2.1 |
| 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 | 0.2 |
| November | 1.98 | 3.4 |
| December | 2.03 | 11.4 |
| Year | 30.94 | 51.2 |

*Source: National Weather Service and SEWRPC.*

annual snowfall and sleet measured as snow and sleet is 51.2 inches. Assuming that 10 inches of measured snowfall and sleet is equivalent to one inch of water, the average annual snowfall of 51.2 inches is equivalent to 5.12 inches of water. Therefore, only about 17 percent of the average annual precipitation occurs as snowfall and sleet. Average monthly precipitation for the Crayfish Creek subwatershed ranges from 1.33 inches in February to 3.59 inches in June. The principal snowfall months are December, January, February, and March, during which 89 percent of the average annual snowfall may be expected to occur.

An important consideration in stormwater drainage is the seasonal nature of precipitation patterns and the occurrence of major storms in the spring when ground is either frozen or saturated. These periods generally result in the most significant stormwater drainage problems in the study area. During the period 1940 through 1980, most floods occurred in the Root River watershed during late winter or early spring. During that period, approximately 60 percent of the yearly peak flows occurred in March or April.

Based on a period of record from 1870 through 1980 at General Mitchell Field, the minimum annual precipitation was 18.69 inches reported in 1901, and the maximum annual precipitation was 50.36 inches reported in 1876. The maximum monthly precipitation was 10.03 inches recorded in June 1917, and the maximum 24-hour precipitation was 5.76 inches also recorded in June 1917. Based on a period of record from 1940 through 1980, the maximum and minimum annual snowfall amounts were 90.8 inches in 1951-1952, and 12.1 inches in 1967-1968.

Stormwater drainage system design must also consider the characteristics of rainfall events for periods of time substantially shorter than 24 hours. The characteristics of rainfall events over these shorter peak precipitation periods are discussed in the section on hydrology.

Snow Cover and Frost Depth

The likelihood of snow cover and the depth of snow on the ground are important factors that influence the planning, design, construction, and maintenance of stormwater management facilities. Snow cover in the Crayfish Creek subwatershed is most likely to occur during the months of December, January, and February, during which at least a 0.4 probability exists of having one inch or more of snow cover, as measured at the Milwaukee weather station. The amount of snow cover influences the severity of spring snowmelt-rainfall flood events, which usually occur during March.

The depth and duration of ground frost, or frozen ground, influences hydrologic processes, particularly the proportion of rainfall or snowmelt that will run off the land directly into storm sewerage systems and surface watercourses. The amount of snow cover is an important determinant of frost depth. Since the thermal conductivity of snow cover is less than one-fifth that of moist soil, heat loss from the soil to the colder atmosphere is greatly inhibited by the insulating snow cover. Frozen ground is likely to exist throughout the study area for approximately four months each winter season, extending from late November through March, with frost penetration to a depth ranging from six inches to more than four feet occurring in January, February, and the first half of March.

Hydrology

Rainfall intensity-duration-frequency relationships are an important element in stormwater management data analysis and system design. Such relationships facilitate determination of the average rainfall intensity—normally expressed in inches per hour—expected to be reached or exceeded for a particular duration at a given recurrence interval. Under its comprehensive water resources planning program, the Southeastern Wisconsin Regional Planning Commission has developed a set of rainfall intensity-duration-frequency relationships using both a graphic procedure and a mathematical curve fitting method executed by a digital computer program. The data, based upon annual series analysis of 64 years of record collected by the National Weather Service observation station in Milwaukee from 1903 through 1966, were published in graphic and tabular form in SEWRPC Technical Record, Vol. 3, No. 5, March 1973. These data were updated in 1987 by adding the data from 1967 through 1986 to the period of record. The resultant rainfall intensity-duration-frequency curves thus developed are not significantly different from the curves prepared in 1973.

The intensity-duration-frequency equations in Table 4 are appropriate for determining the magnitude of, and are directly applicable to urban stormwater management system analyses and design.

The volume of rainfall and stormwater associated with a given storm is also useful in assessing the adequacy of stormwater drainage systems. The determination of annual maximum precipitation event volumes was based on about 37 years of hourly precipitation data—for the period January 1, 1940 through October 31, 1976—as recorded at the Milwaukee National Weather Service station currently located at General Mitchell Field. These data had been obtained, verified, and placed in a computer file under the Commission water resources planning program.

A "discrete" precipitation event may be defined as a continuous or uninterrupted period of rainfall. The available historic records report precipitation on an hourly basis; therefore, in accordance with the above definition, a precipitation event would be defined as the period preceded by and followed by at least one hour during which no precipitation was recorded. The minimum length of the antecedent and subsequent dry period used to define a precipitation event must be tailored to the intended use of the resulting data on rainfall volumes.

Because of the apparent importance of the minimum length antecedent and subsequent dry period used to define precipitation events, the 37-year precipitation record was analyzed using a range of dry periods. Specifically, the number, time of occurrence, and depth of precipitation events during that period were determined using minimum antecedent and subsequent dry periods of 1, 2, 3, 6, 12, and 24 hours.

Table 5 presents selected information about the precipitation events identified for each of the six minimum lengths of antecedent and subsequent dry periods, including the number of events in the 37-year period, the average number of events per

Table 4

PARTIAL SERIES POINT RAINFALL
INTENSITY-DURATION-FREQUENCY EQUATIONS FOR MILWAUKEE, WISCONSIN

| Recurrence Interval (years) | Duration of Five Minutes or More But Less than 60 Minutes[b] | Duration of 60 Minutes or More Through 24 Hours[b] |
|---|---|---|
| 2 | $i = \frac{85.1}{14.8 = t}$ | $i = 26.9\ t^{-0.771}$ |
| 5 | $i = \frac{118.9}{16.7 + t}$ | $i = 36.4\ t^{-0.771}$ |
| 10 | $i = \frac{143.0}{17.8 + t}$ | $i = 43.3\ t^{-0.773}$ |
| 25 | $i = \frac{172.0}{18.7 + t}$ | $i = 51.0\ t^{-0.772}$ |
| 50 | $i = \frac{193.4}{19.2 + t}$ | $i = 56.8\ t^{-0.771}$ |
| 100 | $i = \frac{214.4}{19.4 + t}$ | $i = 63.0\ t^{0.773}$ |

[a] *The equations are based on Milwaukee rainfall data for the 84-year period from 1903 to 1986. These equations are applicable, within 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.*

year, the depth of the largest and smallest events, and the depth of the median event. As would be expected, the total number of events in the 37-year period and the average number of events per year decreases as the minimum length of the antecedent and subsequent dry period increases. For example, using a minimum antecedent and subsequent dry period of one hour, 6,719 precipitation events occurred during a 37-year period for an average of 182 per year, with the largest event having a depth of 3.42 inches. When the minimum antecedent and subsequent dry period is increased to 24 hours, the number of precipitation events in the 37-year period decreases 58 percent to 2,842, or an average of 77 events per year, and the magnitude of the largest event increases by 81 percent to 6.20 inches.

Figure 1 permits determination of a precipita-

Table 5

SELECTED INFORMATION ABOUT PRECIPITATION EVENTS AS DEFINED USING MINIMUM ANTECEDENT AND SUBSEQUENT DRY PERIODS OF 1, 2, 3, 6, 12, AND 24 HOURS[a]

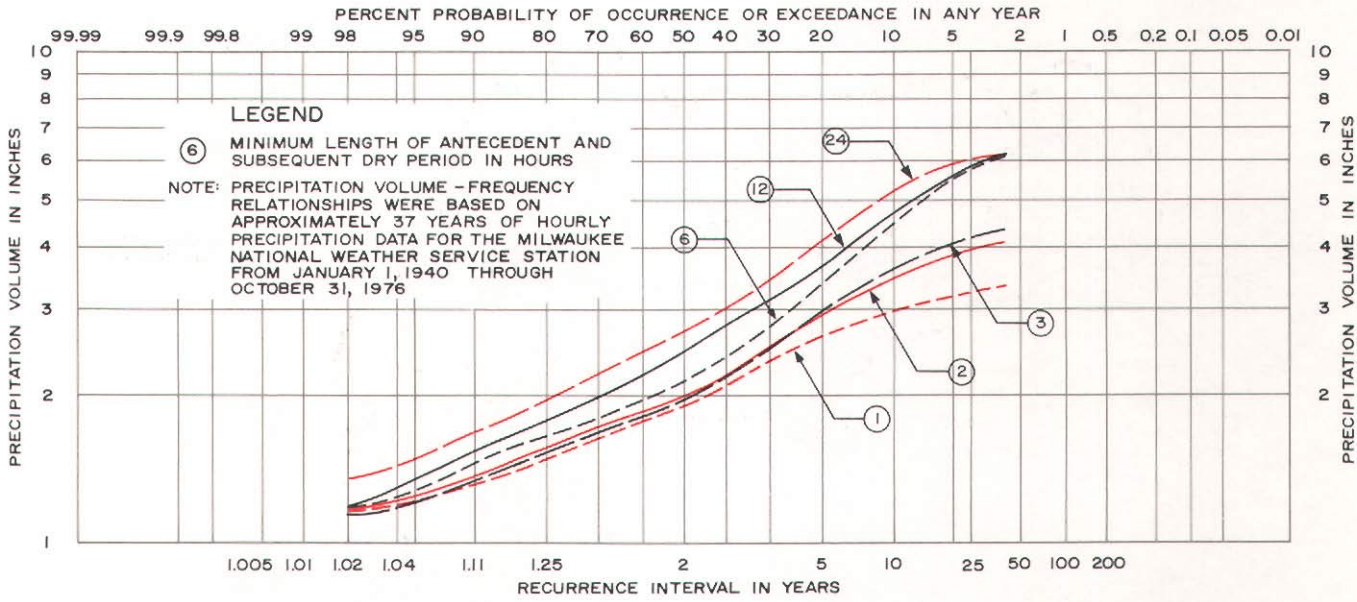
| Minimum Antecedent and Subsequent Dry Period (hours) | Number of Precipitation Events | | Smallest Event (inches) | Largest Event (inches) | Median Event (inches) |
|---|---|---|---|---|---|
| | In 37-Year Period | Average per Year | | | |
| 1 | 6,719 | 182 | 0.01 | 3.42 | 0.04 |
| 2 | 5,577 | 151 | 0.01 | 4.16 | 0.06 |
| 3 | 5,008 | 136 | 0.01 | 4.31 | 0.07 |
| 6 | 4,147 | 113 | 0.01 | 6.05 | 0.10 |
| 12 | 3,458 | 94 | 0.01 | 6.20 | 0.14 |
| 24 | 2,842 | 77 | 0.01 | 6.20 | 0.19 |

[a] *Based on approximately 37 years of hourly precipitation data for the Milwaukee National Weather Service station from January 1, 1940 through October 31, 1976.*

*Source: National Weather Service and SEWRPC.*

Figure 1

PRECIPITATION VOLUME-FREQUENCY RELATIONSHIPS




*Source: SEWRPC.*

recurrence interval and a specified minimum length antecedent and subsequent dry period. That design precipitation volume can then be converted to a design stormwater runoff volume.

## SOILS

Soil properties are an important factor influencing the rate and amount of stormwater runoff from land surfaces. The type of soil is also an important consideration in the evaluation of shallow groundwater aquifer recharge and stormwater storage. Also, the soil characteristics and the slope and vegetative cover of the land surface affect the degree of soil erosion that occurs during runoff events.

In order to assess the significance of the diverse soils found in southeastern Wisconsin, the Southeastern Wisconsin Regional Planning Commission, in 1963, negotiated a cooperative agreement with the U. S. Soil Conservation Service under which detailed operational soil surveys were completed for the entire Planning Region. The results of the soil surveys have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil surveys have resulted in the mapping of soils within the Region in great detail. At the same time, the surveys have provided data on the physical, chemical, and biological properties of the soils, and more importantly, have provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes, and underlying stormwater management purposes. Detailed soils maps of the study area are available for use in stormwater management planning.

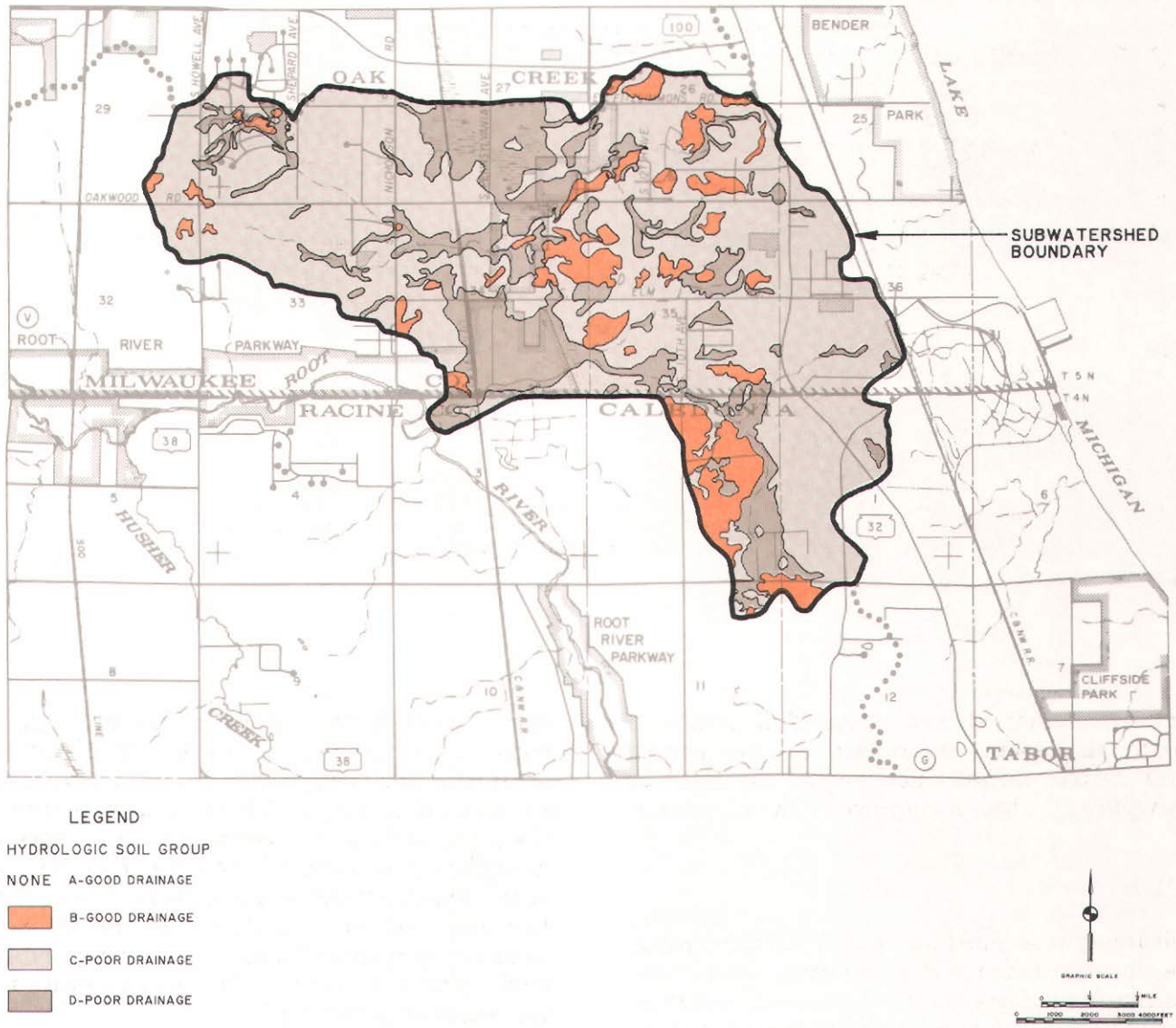
With respect to watershed hydrology, the most significant soil interpretation for stormwater management is the categorization of soils into hydrologic soil groups A, B, C, and D. In terms of runoff characteristics, these four groups are defined as follows:

- Hydrologic Soil Group A: Very little runoff because of high infiltration capacity, high permeability, and good drainage.

- Hydrologic Soil Group B: Moderate amounts of runoff because of moderate infiltration capacity, moderate permeability, and good drainage.

Map 4

HYDROLOGIC SOIL GROUPS WITHIN THE CRAYFISH CREEK SUBWATERSHED




*Source: SEWRPC.*

- Hydrologic Soil Group C: Large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage.

- Hydrologic Soil Group D: Very large amounts of runoff because of very low infiltration capacity, low permeability, and poor drainage.

The spatial distribution of the four hydrologic soil groups within the study area is shown on Map 4. Hydrologic soil group A does not occur in the study area; hydrologic soil groups B, C, and D cover 12 percent, 64 percent, and 24 percent, respectively, of the study area.

## WATER QUALITY

Neither the Regional Planning Commission nor the Wisconsin Department of Natural Resources has collected any water quality samples from Crayfish Creek. Commission water quality simulation studies, however, indicate that the water quality of Crayfish Creek, and of the main stem of the Root River into which it flows, probably do not meet adopted water use objectives and supporting water quality standards. The water use objectives include the maintenance of a warmwater fishery and associated aquatic life and full recreational use. The achievement of these objectives will require the implementation

of urban and rural nonpoint source pollution abatement practices. Implementation of such practices in the Root River watershed is being carried out under the Wisconsin Fund Priority Watersheds Program. The need for nonpoint source pollution abatement measures in the watershed, as well as the estimated costs and effectiveness of such measures, is documented in SEWRPC Community Assistance Planning Report No. 37, A Nonpoint Source Water Pollution Control Plan for the Root River Watershed. The study area is located in a portion of the Root River watershed designated as a high-priority area for County Land Conservation Committee technical assistance under the Priority Watersheds Program. This designation is based upon an assessment of the magnitude of the existing and probable future nonpoint source pollutant loadings to the surface waters. It must be noted that the 300 acres of wetlands located along the existing and proposed channels of the subwatershed perform an important role in maintaining, and eventually improving, the water quality of Crayfish Creek, and thereby serve to reduce pollutant loadings to the Root River from this tributary. The mean annual flow from the tributary area is estimated to be four cubic feet per second (cfs), and the mean annual flow of the Root River at the confluence with the tributary concerned is estimated to be 120 cfs.

## STORMWATER DRAINAGE SYSTEM

The existing stormwater drainage system serving the study area is influenced by the topography of the land surface, the natural watercourse pattern of the subwatershed, and any engineered drainage systems.

### Topography

The topography, or relative elevation of the land surface, of the study area is one of the most important considerations in the planning and design of a stormwater management system. The topography of the land surface defines drainage areas, influences the rate and magnitude of surface water runoff and soil erosion, and determines the uses to which the land can be put, and therefore the stormwater management needs. For analytical purposes, the Crayfish Creek subwatershed was divided into five hydrologic units as shown on Map 5.

The elevation of the study area ranges from a low of about 657 feet above National Geodetic Vertical Datum (NGVD) in the northwest one-quarter of Section 3, Township 4 North, Range 22 East, in the Town of Caledonia, to a high of about 735 feet above NGVD in the northeast one-quarter of Section 32, Township 5 North, Range 22 East, in the City of Oak Creek. Land surface slopes for small drainage areas within the subwatershed range from a low of about 0.01 percent for a drainage area located in the northwest one-quarter of Section 35, Township 5 North, Range 22 East, to a high of about 6.7 percent for a drainage area located in the southwest one-quarter of Section 26, Township 5 North, Range 22 East. The watershed may be described as being very flat in the central portion with very little slope from north to south, while the eastern and western portions rise up from the valley.

### Streams, Drainage Channels, and Ponds

The intermittent and perennial streams in the study area serve as the major drainage outlets for the storm sewers and drainage ditches. As such, they are important components of the drainage system which must be considered in order to plan a stormwater management system. All known intermittent and perennial streams and ponds in the study area are shown on Map 5.

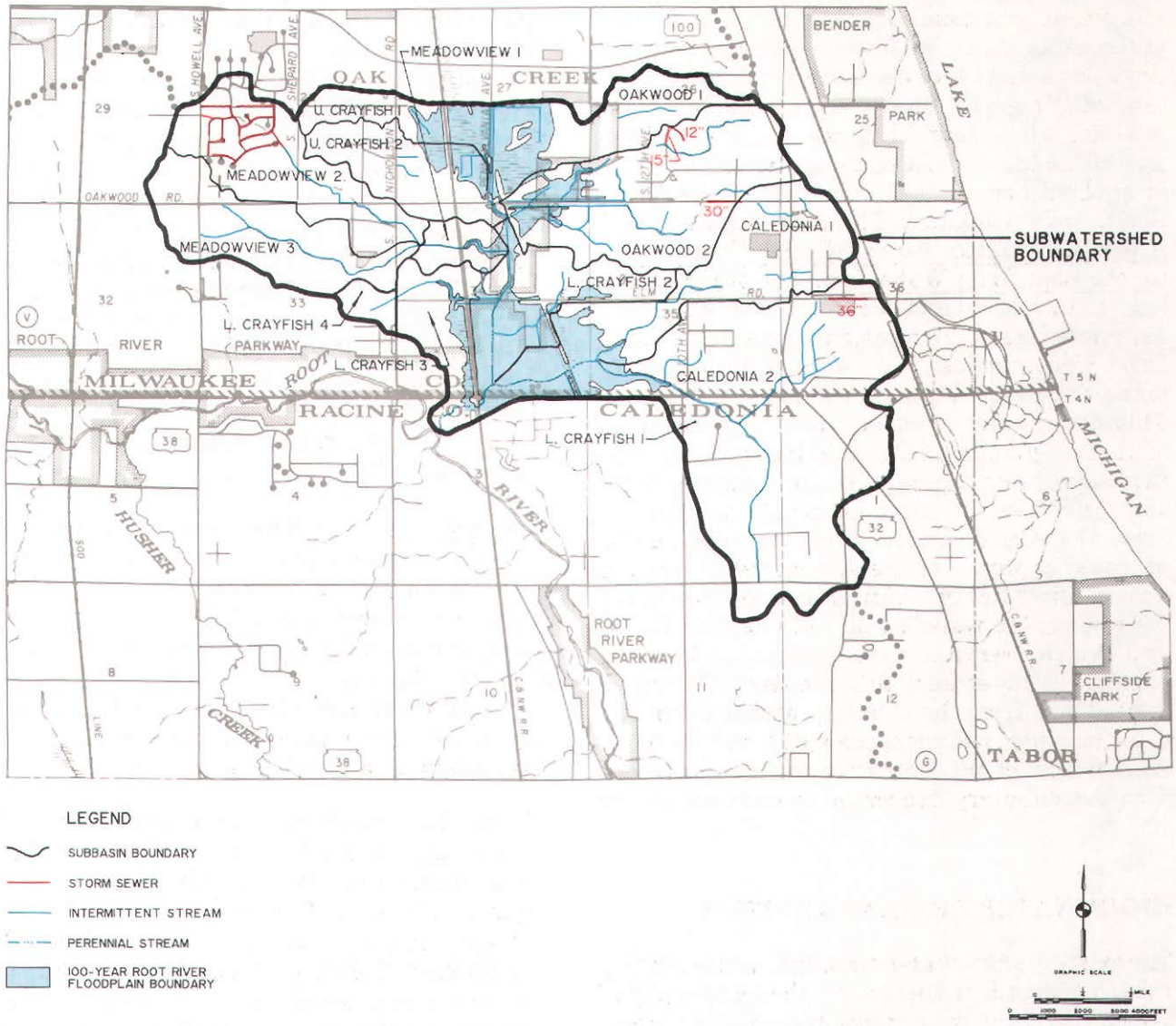
Peak flood discharges and stages have been calculated for the Root River. These discharges and stages were initially developed by the Regional Planning Commission in 1966 as part of the comprehensive plan for the Root River watershed. These data were subsequently updated by the Commission and incorporated into the flood insurance study for the Federal Emergency Management Agency. The Oak Creek peak flood discharges and stages have been calculated as part of the watershed study recently completed by the Regional Planning Commission.

### Engineered Drainage System

The location, configuration, and tributary areas of the existing stormwater drainage system serving the Crayfish Creek subwatershed are shown on Map 5. The existing storm sewer system within the subwatershed consists of approximately 12,350 lineal feet of sewer, ranging in size from 12 inch diameter to 66 inch diameter. There are also 900 lineal feet of low-flow drain pipe and 950 lineal feet of ditch enclosure pipe. Most of the sewers and drains are constructed of reinforced concrete pipe. There are no major stormwater pumping facilities in the storm sewer system.

Map 5

INTERMITTENT AND PERENNIAL STREAMS AND ENGINEERED STORMWATER DRAINAGE SYSTEMS IN THE CRAYFISH CREEK SUBWATERSHED: 1985




*Source: SEWRPC.*

The majority of the storm sewers in the subwatershed are located in the Shepard Hills Subdivision area between Fitzsimmons Road and Oakwood Road and between Howell Avenue and Shepard Avenue in the City of Oak Creek. A minor amount of storm sewer is located in the New Heights Subdivision between Hillview Avenue and 11th Avenue. In addition to the storm sewer, a low-flow drain is located in Oakwood Road between 7th Avenue and 9th Avenue extended, which provides positive drainage for a road ditch through a slight rise in surrounding grade. A ditch enclosure is located on Elm Road between Barton Road extended and 4th Avenue. In addition to these storm sewers, there are numerous culverts and roadside ditches serving the area.

The storm sewer systems are maintained by the public works departments of the City of Oak Creek and the Town of Caledonia. Maintenance activities include sewer, culvert, and channel cleaning; storm inlet cleaning; and minor repair work on sewers, manholes, and inlets.

## SPECIAL ENVIRONMENTALLY SENSITIVE AREAS

### Wetlands

Wetlands are natural areas in which the groundwater table lies near, at, or above the surface of the ground which support certain types of vegetation common in a wet environment. Wetlands are

usually covered by organic soils, silts, and marl deposits. Wetlands support valuable ecological habitats, enhance water quality conditions by trapping pollutants, and stabilize streamflows by storing peak discharges and releasing water during low-flow conditions. Wetlands also have important recreational, educational, and aesthetic values.

A sound stormwater management plan should utilize the stormwater storage capacity of the natural wetlands, incorporating this storage into the drainage system. Thus, wetland preservation should be an integral part of a stormwater management plan.

The location, type, and extent of wetlands in the study area are shown on Map 6. As shown on Map 6, in 1980 there were approximately 510 acres of wetlands in the study area, comprising about 14 percent of that area. Most of the wetlands in the study area are dominated by emergent and submergent vegetation. These vegetation types are generally considered to be the most effective for storing surface water runoff and for trapping pollutants.

Primary 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, and which therefore should be preserved and protected. Such areas, defined as primary environmental corridors, 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.

A sound stormwater management plan should recognize the importance of primary environmental corridors. Thus, the preservation of primary environmental corridors should be an integral part of a stormwater management plan.

The location, type and extent of primary environmental corridors in the Crayfish Creek subwatershed are shown on Map 7. These corridors contain most of the remaining high-value 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 7, about 480 acres, or 13 percent, of the total watershed area are encompassed within the primary environmental corridors. The environmental corridors encompass 390 acres, or 76 percent, of the approximately 510 acres of wetlands remaining in the subwatershed.

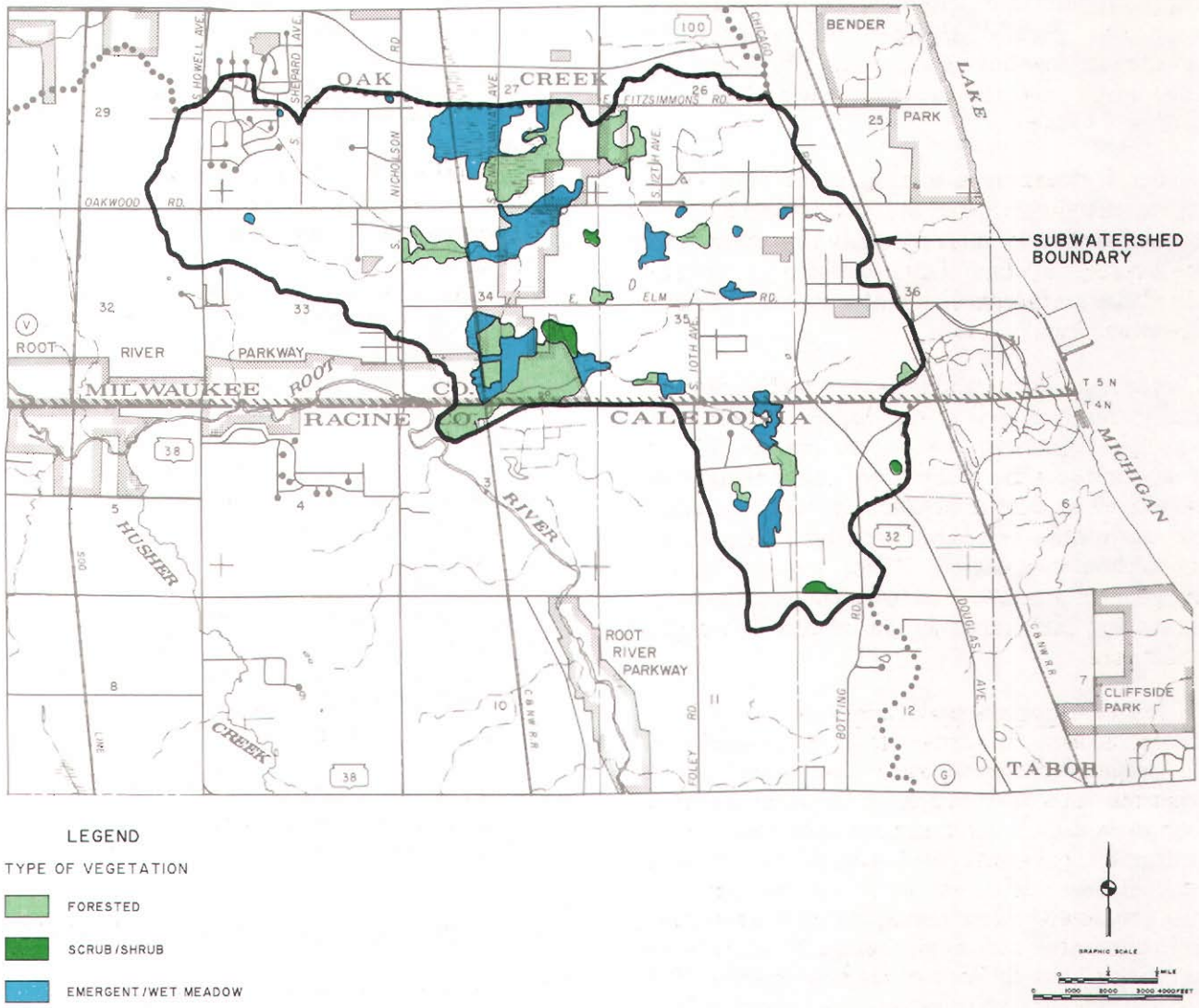
## STORMWATER MANAGEMENT PROBLEMS

Stormwater problems consist of stormwater drainage and flood control problems. Drainage problems may be defined as the impact from the accumulation of excess stormwater on the land surface before such water has entered stream channels. These problems are caused by the inability of stormwater runoff to reach the stream channels in a timely manner. Flood control problems may be defined as the impact from the overflow of natural stream channels and watercourses. Such problems are caused by streamflow exceeding the bank full capacity and moving away from the stream channels to inundate adjacent floodlands.

Within the study area, the stormwater management problems consist of both drainage and flood control problems. The watershed divide lies generally between Fitzsimmons Road extended and Oakwood Road, but because of the flat

Map 6

WETLANDS IN THE CRAYFISH CREEK SUBWATERSHED: 1985




LEGEND

TYPE OF VEGETATION

- FORESTED
- SCRUB/SHRUB
- EMERGENT/WET MEADOW

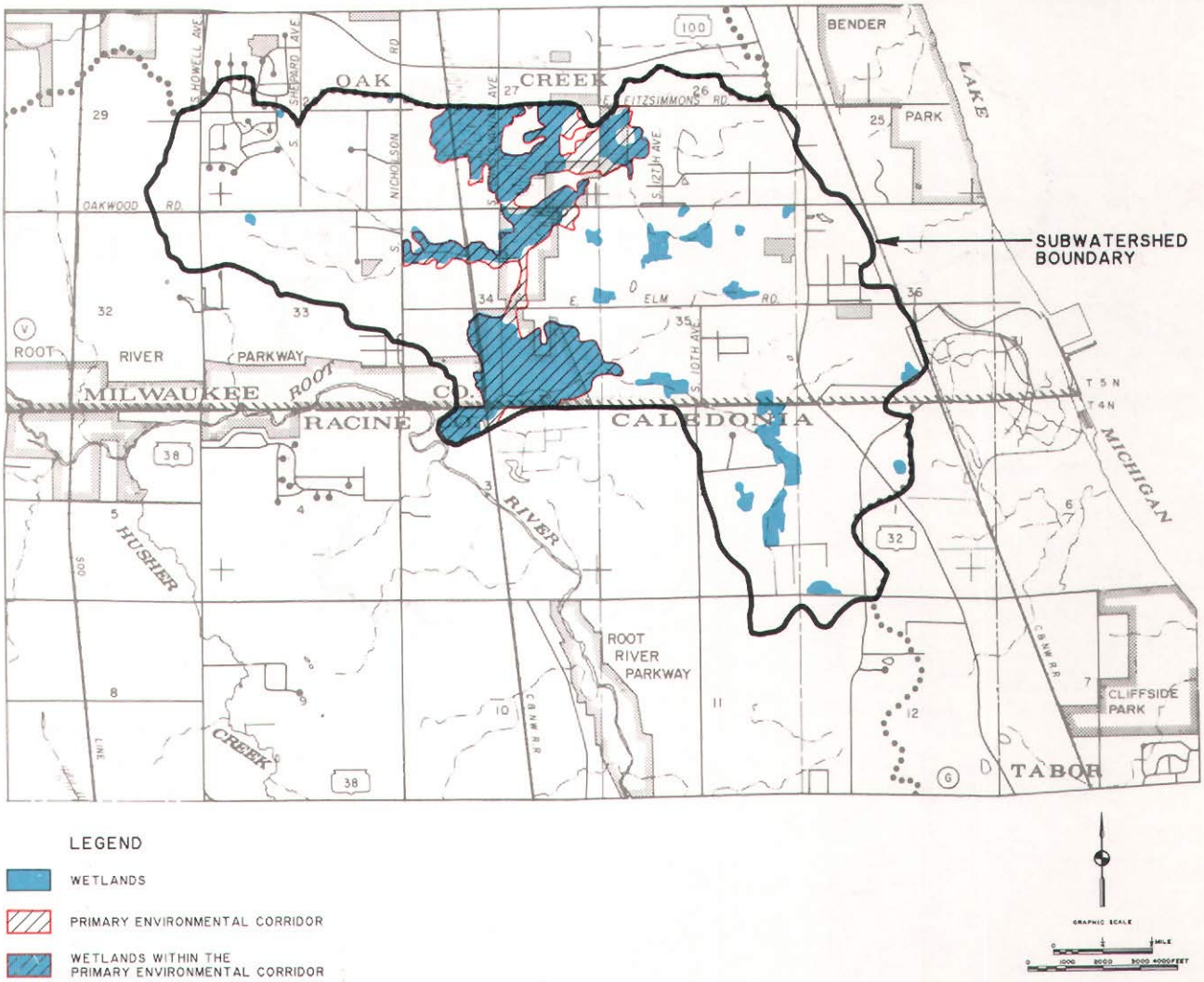
*Source: SEWRPC.*

topography is ill-defined. In fact, roadside ditch and culvert inverts near the divide are subject to flooding and backwater from both the main Oak Creek channel and the main Root River channel by as small a flood event as a two-year recurrence interval event on either stream. In addition, lands in the vicinity of the drainage divide are subject to flooding from channel backwaters of both streams during a five-year recurrence interval flood event. After allowance is made for the flow gradients needed to drain the Crayfish Creek subwatershed into the network of channels draining to the Root River, flooding is substantially more frequent than stated above. This is borne out by the history of drainage complaints from citizens regarding this area indicating a flooding frequency of several times per year. The drainage problems are aggravated by the existence of drainage ditches with insufficient slopes and conveyance capacities which provide inadequate outlets for local storm drainage facilities.

The presence of wet or poorly drained soils in the area also contributes to the drainage problems. These poorly drained areas can only be developed with the aid of costly special measures such as under-drainage systems and artificial fill. Sanitary sewers located in these areas will be susceptible to high rates of groundwater infiltration. Stormwater which may accumulate in these areas during and following storm events may pose health hazards and hamper transportation

Map 7

PRIMARY ENVIRONMENTAL CORRIDORS AND
WETLANDS IN THE CRAYFISH CREEK SUBWATERSHED: 1985




*Source: SEWRPC.*

by inundating streets, flooding basements, and serving as breeding sites for mosquitoes. These areas therefore need to be carefully considered, and, where appropriate, incorporated into the stormwater management plan in order to minimize problems. The location and extent of poorly drained areas are shown on Map 4. Areas covered by hydrologic soil groups C and D, which together cover about 88 percent of the study area, can be considered to have poor natural drainage.

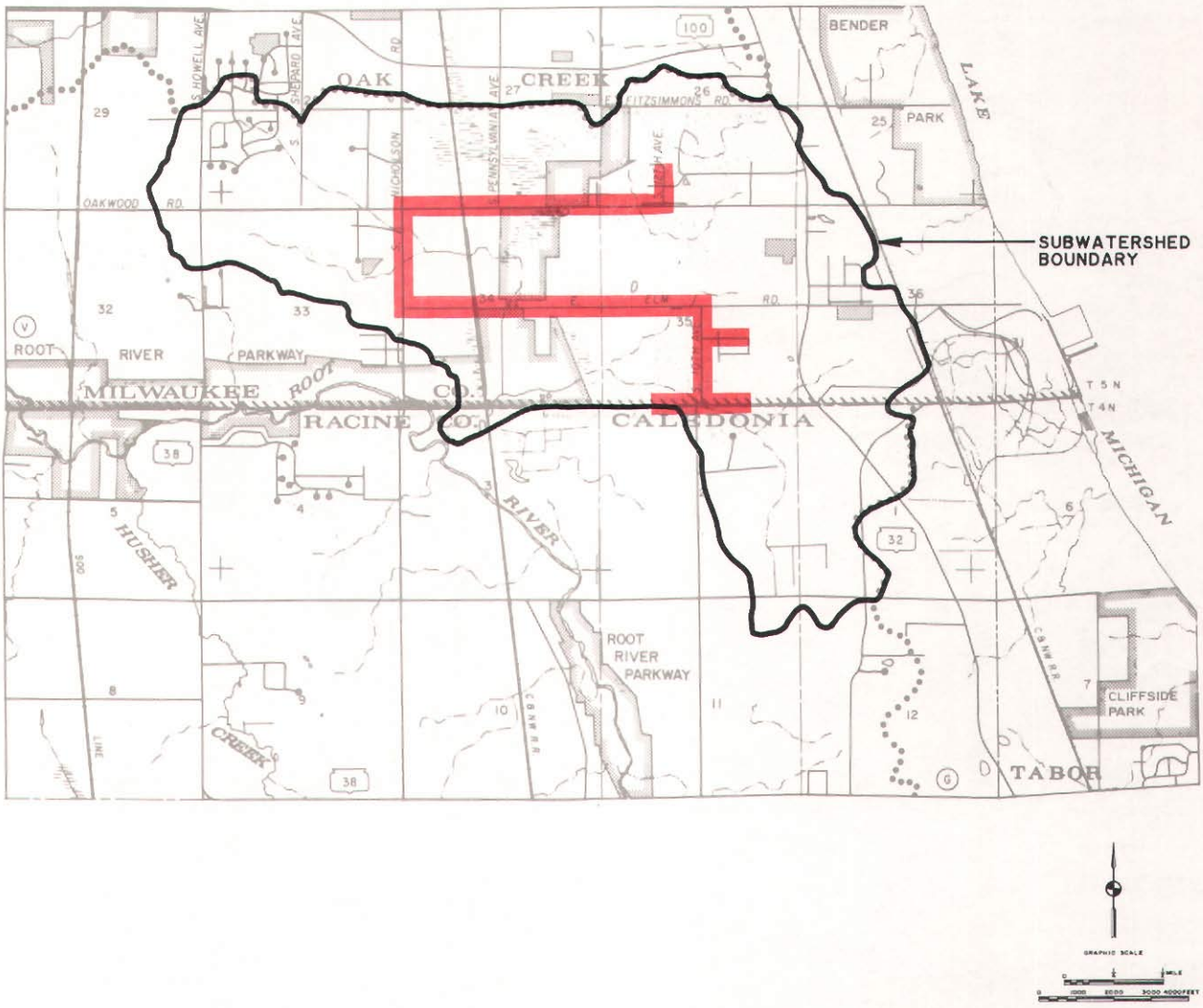
The area of flood inundation and substantial citizen complaints regarding drainage within the subwatershed is generally defined as from Nicholson Road to 10th Avenue and from Oakwood Road to County Line Road. More particularly, the focus of the problem areas may to be described as follows: Nicholson Road between Elm Road and Oakwood Road; Oakwood Road at 12th Avenue; 10th Avenue at Becker Road; County Line Road at 10th Avenue; and Elm Road between Nicholson Road and 10th Avenue, as shown on Map 8. These areas are regarded by city staff as flooding several times per year.

## SUMMARY

An accurate inventory of certain hydrologic-hydraulic characteristics of the study area and related natural and man-made features is an essential step in the stormwater management planning

Map 8

AREAS OF SUBSTANTIAL CITIZEN COMPLAINTS REGARDING DRAINAGE AND FLOODING IN THE CRAYFISH CREEK SUBWATERSHED




*Source: City of Oak Creek and SEWRPC.*

process. Data on the existing stormwater drainage system and on existing drainage and flooding problems have accordingly been presented in this chapter. Also presented are data on land use, climate, soils, hydrology, and water quality.

Land use characteristics, including impervious area, the type of storm drainage system, the level and characteristics of human activity, and the type and amount of pollutants deposited on the land surface, greatly influence the quantity and quality of stormwater runoff. In 1980, urban land uses covered about 24 percent of the study area, with residential land uses comprising the singularly largest category of urban land use. Within the study area, agricultural land use still accounted for 71 percent of the rural land uses, with other rural uses consisting of woodlands, wetlands, and other open lands.

Climatological factors affecting stormwater management include air temperature and the type and amount of precipitation. The relationship between rainfall intensity, duration, and frequency is an important element in stormwater management analysis and system design. Intensity, duration, and frequency relationship equations, based on 84 years of record at Milwaukee, are presented

in this chapter. This information permits peak flow rates from stormwater drainage systems to be estimated.

Soil properties influence the rate and amount of runoff from land surfaces. Only about 12 percent of the study area is covered by soils that generate moderate amounts of runoff, while 88 percent of the area is covered by soils that have relatively poor drainage characteristics and that may be expected to generate high amounts of runoff.

The water quality impacts of stormwater management are of increasing concern. High surface runoff and erosion can result in high pollutant concentrations in surface waters, which reduce the suitability of the waters for recreational uses and limit the ability of the water to support desired forms of fish and other aquatic life.

The preservation of wetlands and primary environmental corridors is an important element of stormwater management. Wetlands and primary environmental corridors cover 14 and 13 percent, respectively, of the study area.

The intermittent and perennial streams in the subwatershed serve as the major drainage outlets for the storm sewers and drainage ditches. There are approximately 12,350 lineal feet of storm sewer in the study area, ranging in size from 12 inches in diameter to 66 inches in diameter, with most of it located in the Shepherd Hills Subdivision.

Stormwater problems within the study area consist of both stormwater drainage and flood control problems. Flat topography, inadequate conveyance capacity, and the presence of wet or poorly drained soils are factors contributing to the stormwater problems. The area of substantial flood inundation and citizen complaints is generally bounded by Nicholson Road to 10th Avenue and Oakwood Road to County Line Road. Flooding problems in this area occur several times per year.

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# Chapter III

# ANTICIPATED GROWTH AND CHANGE

## INTRODUCTION

The Crayfish Creek subwatershed stormwater management plan is intended to identify the stormwater management needs of the Crayfish Creek subwatershed over the foreseeable future, and to propose the best means of meeting those needs. Land use in the study area markedly influences stormwater runoff processes. The conversion of land from rural to urban use, and the associated increase in impervious area, will tend to increase both the rate and volume of stormwater runoff for a given rainfall event, and decrease the time of runoff. Unless special stormwater management measures are taken, the typical net effect of urbanization is to produce an increase in both the peak rates of stormwater runoff and the total volume of runoff. Stormwater runoff from urban lands also carries different types and increased amounts of pollutants than does runoff from rural lands. Not only does land use—and probable changes in such use over time—affect stormwater runoff processes, and therefore loadings to the stormwater management system, but it must serve to support the existing land use development in the subwatershed and to promote desirable development in the future. Therefore, consideration of both the existing and probable future land use pattern is necessary for the sound development of alternative stormwater management plans, and for the selection of a recommended plan. Accordingly, this chapter presents information on the anticipated type, density, and spatial distribution of land uses in the Crayfish Creek subwatershed and on the impact of the anticipated changes in land use on the stormwater management needs of the subwatershed.

## LAND USE

Approximately 3,065 acres, or about 83 percent, of the Crayfish Creek subwatershed lies in the City of Oak Creek, Milwaukee County. The remaining 636 acres, or about 17 percent, lies in the Town of Caledonia, Racine County. The firm of Harland Bartholomew & Associates, Inc., recently completed a land use plan for the City of Oak Creek. This plan, which is documented in a report entitled, Comprehensive Plan 85, City of Oak Creek, Wisconsin was used in determining a probable future land use pattern for that portion of the Crayfish Creek subwatershed lying within the City of Oak Creek. The plan was adopted by the City Plan Commission in July 1985, and by the Common Council on August 20, 1985. Racine County adopted a land use plan for that part of the subwatershed lying within the Town of Caledonia. This plan was adopted by the Racine County Board on March 29, 1982. That plan is documented in SEWRPC Community Assistance Planning Report No. 46, A Farmland Preservation Plan for Racine County, Wisconsin, August 1981, and was used in determining a probable future land use pattern for that portion of the Crayfish Creek subwatershed lying within the Town of Caledonia.

The entire stormwater management study area—that is, all of the Crayfish Creek subwatershed—encompasses an area of about 3,701 acres. The existing 1980 and design year 2000 areas associated with each of the various land uses within the subwatershed are set forth in Table 6. The plan year 2000 land use pattern within the subwatershed is shown on Map 9. As indicated in the table, about 1,777 acres of rural land, or about 48 percent of the subwatershed, may be expected to be converted from rural to urban use over the approximately 20-year plan design period. This conversion would increase the amount of land in urban use within the subwatershed by about 200 percent. Of the total area to be converted, about 1,446 acres, or about 81 percent, would be converted to residential use; about 88 acres, or about 5 percent, to recreational use; and about 243 acres, or about 14 percent, to industrial use.

As indicated in Table 6, under year 2000 land use conditions, urban land uses would account for about 2,674 acres, or 72 percent, of the subwatershed. Of these developed urban lands, residential uses would occupy about 2,185 acres, or about 82 percent, and the remaining urban land uses—industrial, commercial, governmental and institutional, and recreational—together would occupy about 489 acres, or the remaining 18 percent. Under design year 2000 conditions, rural land uses would still account for about 1,027 acres, or 28 percent, of the subwatershed. Agricultural

## Table 6

## EXISTING AND PROBABLE LAND USE IN THE CRAYFISH CREEK SUBWATERSHED AREA: 1980 AND 2000

| Land Use Category | City of Oak Creek | | | | | | Town of Caledonia | | | | | | Total Subwatershed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Existing 1980 | | Planned Increment | | Total 2000 | | Existing 1980 | | Planned Increment | | Total 2000 | | Existing 1980 | | Planned Increment | | Total 2000 | |
| | Acres | Percent of Major Category | Acres | Percent Change | Acres | Percent of Major Category | Acres | Percent of Major Category | Acres | Percent Change | Acres | Percent of Major Category | Acres | Percent of Major Category | Acres | Percent Change | Acres | Percent of Major Category |
| Urban | | | | | | | | | | | | | | | | | | |
| Residential | 667 | 88 | 1,446 | 217 | 2,113 | 84 | 72 | 53 | 0 | 0 | 72 | 50 | 739 | 83 | 1,446 | 196 | 2,185 | 82 |
| Commercial | 4 | --[a] | 0 | 0 | 4 | --[a] | 0 | 0 | 0 | 0 | 0 | 0 | 4 | --[a] | 0[b] | 0[b] | 4[b] | --[a] |
| Industrial | 12 | 2 | 242 | 2,017 | 254 | 10 | 1 | --[a] | 1 | 0 | 2 | 1 | 13 | 2 | 243 | 1,869 | 256 | 10 |
| Governmental and Institutional | 29 | 4 | 0 | 0 | 29 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 3 | 0 | 0 | 29 | 1 |
| Recreational | 50 | 6 | 80 | 160 | 130 | 5 | 62 | 47 | 8 | 16 | 70 | 49 | 112 | 12 | 88 | 79 | 200 | 7 |
| Subtotal | 762 | 100 | 1,768 | 232 | 2,530 | 100 | 135 | 100 | 9 | 7 | 144 | 100 | 897 | 100 | 1,777 | 198 | 2,674 | 100 |
| Rural | | | | | | | | | | | | | | | | | | |
| Agricultural | 1,592 | 69 | -1,592 | -100 | 0 | 0 | 400 | 80 | 43 | 11 | 443 | 90 | 1,992 | 71 | -1,549 | -78 | 443 | 43 |
| Woodlands and Other Open Lands | 711 | 31 | -176 | -25 | 535 | 100 | 101 | 20 | -52 | -51 | 49 | 10 | 812 | 29 | -228 | -28 | 584 | 57 |
| Subtotal | 2,303 | 100 | -1,768 | -77 | 535 | 100 | 501 | 100 | -9 | -40 | 492 | 100 | 2,804 | 100 | -1,777 | -63 | 1,027 | 100 |
| Total | 3,065 | -- | 0 | -- | 3,065 | -- | 636 | -- | -- | -- | 636 | -- | 3,701[c] | -- | -- | -- | 3,701 | -- |

[a] *Contains less than 0.5 percent.*

[b] *No new major commercial development is planned. As land is developed for residential use, however, it is anticipated that some neighborhood commercial areas will also be developed as needed.*

[c] *This table does not include the extra 425 acres in Racine County that will become part of the Crayfish Creek subwatershed upon construction of the new Crayfish Creek channel.*

*Source: SEWRPC.*

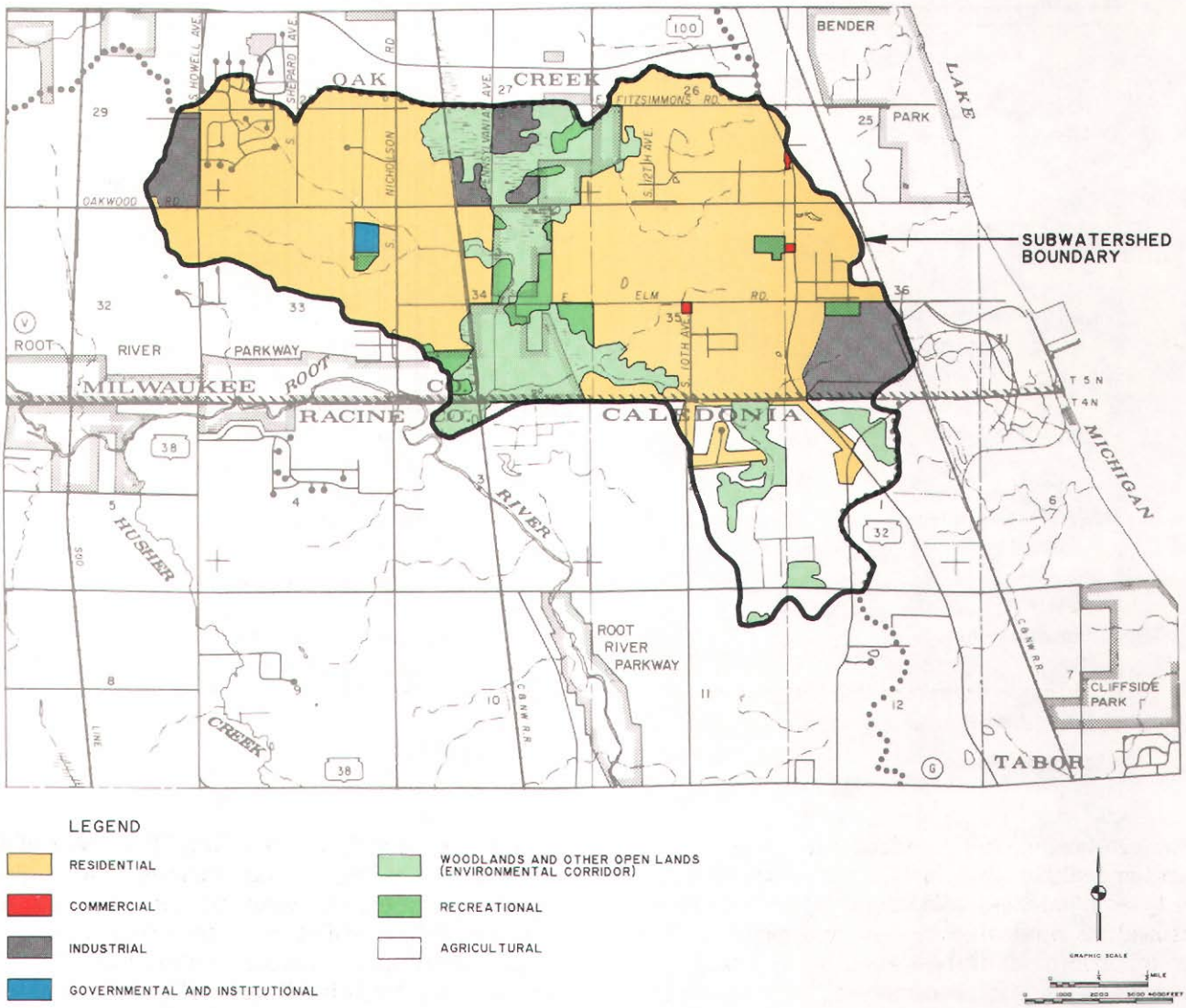
lands would occupy about 443 acres of that total, or about 12 percent. Other rural land uses, including woodlands and other open lands, wetlands, and open waters, would occupy about 584 acres, or about 16 percent.

The existing 1980 and design year 2000 areas associated with each of the various land uses within the city portion of the subwatershed are set forth in Table 6. The year 2000 land use pattern is shown on Map 9. As indicated in the table, about 1,768 acres of rural land, or about 58 percent of the total area of the City within the subwatershed, may be expected to be converted from rural to urban use over the approximately 20-year plan design period. This conversion would increase the amount of land in urban use within the city portion of the subwatershed by about 230 percent. Of the total area to be converted, about 1,446 acres, or 82 percent, would be converted to residential use; about 242 acres, or 14 percent, to industrial use; and about 80 acres, or 4 percent, to recreational use. No new major commercial development is planned. As land is developed for residential use, however, it is anticipated that some neighborhood commercial areas will also be developed as needed. Thus, as indicated in Table 6, under design year 2000 conditions, urban land uses would account for about 2,530 acres, or 83 percent of the total area of the city portion of the subwatershed. Of these developed urban lands, residential uses would occupy about 2,113 acres, or about 84 percent, and the remaining urban land uses—commercial, industrial, governmental and institutional, and recreational—together would occupy 417 acres, or the remaining 16 percent. Under year 2000 conditions, rural land uses would account for about 535 acres, or about 17 percent of the total area of the city portion of the subwatershed.

The existing 1980 and design year 2000 areas associated with each of the various land uses within the Town of Caledonia portion of the subwatershed are also set forth in Table 6. The year 2000 land use pattern is shown on Map 9. As indicated in the table, only about nine acres of rural land, or less than 2 percent of the total area of the Town within the subwatershed, may be expected to be converted from rural to urban uses over the approximately 20-year plan design period. This conversion would increase the amount of land in urban use within the town portion of the subwatershed by about 7 percent. Thus, as indicated in Table 6, under design year 2000 conditions, urban land uses would account for about 144 acres, or 23 percent, of the total area of the town portion of the subwatershed. Of these developed urban lands, residential uses would occupy about 72 acres, or about 50 percent,

Map 9

PLANNED LAND USE PATTERN WITHIN THE CRAYFISH CREEK SUBWATERSHED: 2000




*Source: Harland, Bartholomew, and Associates, Inc., City of Oak Creek, and SEWRPC.*

and the remaining urban land uses—industrial and recreational—together would occupy 72 acres, or the remaining 50 percent. Under year 2000 conditions, rural land uses would account for about 492 acres, or 77 percent, of the total area of the town portion of the subwatershed.

## IMPACT OF CHANGED LAND USE ON STUDY AREA STORMWATER MANAGEMENT SYSTEMS

As already noted, the conversion of 1,777 acres of rural land within the subwatershed to urban uses would result in about 2,674 acres, or about 72 percent of the study area, being devoted to urban land use by the design year 2000. This compares to the 897 acres, or 24 percent of the study area, in urban land use under existing 1980 conditions, and, as already noted, indicates an increase of approximately 200 percent in the amount of land in urban use. This change in land use may be expected to have a significant impact upon the quality, amount, and rate of stormwater runoff.

The combined land use and cover of an area is probably the single characteristic which best indicates the influence of urban development on the hydrologic processes. In an area like southeastern Wisconsin, both land use and land

Table 7

RANGE OF SURFACE IMPERVIOUSNESS FOR LAND USE AND LAND COVER CONDITIONS

| Description | Range of Percent Imperviousness | Typical Corresponding Land Use/Cover Combinations |
|---|---|---|
| Rural | 0 - 8 | Agricultural lands, woodlands, wetlands, and unused lands |
| Low Imperviousness | 9 - 20 | Low-density residential with supporting urban uses and associated land cover |
| Low to Medium Imperviousness | 21 - 33 | Low- to medium-density residential with supporting urban uses and associated land cover |
| Medium Imperviousness | 34 - 45 | Medium-density residential with supporting urban uses and associated land cover |
| High Imperviousness | 46 - 65 | High-density residential with supporting urban uses and associated land cover |
| Very High Imperviousness | 66 - 100 | Commercial and industrial and associated land cover |

*Source: SEWRPC.*

cover are largely the result of human activities. Land cover differs from land use in that it describes the types of surfaces—for example, roofed, paved, grassed, or wooded—whereas land use describes the function or activity served by the land—for example, residential, commercial, or recreational. The combination of land use and cover is an important determinant of the stormwater runoff characteristics of an area, and, as such, is used in the quantification of loadings on, and in the design of, stormwater management systems. Table 7 lists the imperviousness ranges defined for various land use and land cover conditions.

The percent of impervious surface in a given area is an important factor in determining both the amount and rate at which stormwater runoff is generated. Industrial and commercial areas may have more than 65 percent of the total area in impervious surface, while residential areas may have from 10 to 65 percent of the total area in impervious surface, depending upon the density or intensity of the development. Rural areas generally have less than 10 percent of the total area in impervious surface. The impact of the planned changes in land use on the volume and rate of stormwater runoff from each of the drainage subbasins established for this study is set forth in Chapter IV, which presents the results of the stormwater drainage system hydrologic-hydraulic simulation modeling work.

An important related consideration is the increased urban area within the city portion of the subwatershed which must be provided with urban stormwater drainage facilities. As shown in Table 6, new stormwater drainage systems will be needed to serve about 1,446 acres of new residential land, and about 243 acres of new industrial lands. While the planning in this study considered the facilities needed to serve these new urban land uses, the planning effort focused on the rehabilitation needed to properly maintain and, as necessary, improve and extend the existing stormwater management system serving the 897 acres of already developed lands within the Crayfish Creek subwatershed.

## SUMMARY

The existing and probable future land use patterns of a stormwater management study area directly influence stormwater management needs. Thus, consideration of both existing and probable future land use conditions is necessary for the sound development of alternative stormwater management plans, and for the selection of a recommended plan. Accordingly, this chapter presents information on the type, extent, and distribution of land uses anticipated in the City of Oak Creek and in the study area in the plan design year 2000.

Urban land uses in the City of Oak Creek portion of the Crayfish Creek subwatershed may be expected to increase from 762 acres in 1980 to about 2,530 acres by the year 2000, an increase of about 230 percent. Thus, urban land uses may be expected to occupy about 83 percent of the city portion of the subwatershed by the plan design year 2000, as opposed to about 25 percent in 1980. The residential land use category is expected to experience the largest absolute increase—about 1,446 acres—to a plan design year total of about 2,185 acres. Within the subwatershed as a whole, urban land uses are expected to increase from a total of about 897 acres in 1980 to about 2,674 acres in the year 2000, an increase of about 200 percent. Thus, urban land uses are expected to occupy about 72 percent of the subwatershed by the design year 2000, as opposed to about 24 percent in 1980.

This change in land use may be expected to significantly impact the amount, rate, and quality of stormwater runoff. Increased rates of runoff result from the higher proportion of impervious areas—such as streets, parking lots, and rooftops. Impervious surfaces generally cover from 30 to more than 65 percent of urban areas, as compared to less than 10 percent of rural areas. In addition, the development of the types of stormwater drainage systems typically constructed to serve urban areas may be expected to convey this runoff to the receiving watercourse more rapidly. Thus, the urbanization of an area may be expected to significantly increase flood flows and stages in downstream areas.

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## Chapter IV

## STORMWATER MANAGEMENT OBJECTIVES AND DESIGN CRITERIA

### INTRODUCTION

Planning may be defined as a rational process for formulating and meeting objectives. Consequently, the formulation of objectives is an essential task which must be undertaken before plans can be prepared. Accordingly, this chapter sets forth a set of stormwater management objectives and supporting standards for use in the design and evaluation of alternative stormwater management system plans for the Crayfish Creek subwatershed, and in the selection of a recommended plan from among those alternatives.

In addition, this chapter sets forth certain engineering design criteria and describes certain analytical procedures that were used in the preparation and evaluation of the alternative stormwater management system plans. These criteria and procedures include the engineering techniques used to design the alternative plan elements, to test the physical feasibility of those elements, and to make necessary economic comparisons between the alternative plan elements. The description of these criteria and procedures is intended to document the degree of detail and level of sophistication employed in the preparation of the recommended stormwater management plan, and thereby provide a better understanding of the plan and of the need for refinements of some aspects of that plan prior to and during implementation.

### STORMWATER MANAGEMENT OBJECTIVES

The following five stormwater management objectives were formulated to guide the design, test, and evaluation of alternative stormwater management plans for the Crayfish Creek subwatershed stormwater management planning area and to select a recommended plan from among the alternatives considered:

1. The development of a stormwater management system that reduces the exposure of people to drainage-related inconvenience and to health and safety hazards, and that reduces the exposure of real and personal property to damage through inadequate stormwater drainage and inundation.

2. The development of a stormwater management system that will effectively serve existing and proposed future land uses.

3. The development of a stormwater management system that will minimize soil erosion, sedimentation, and attendant water pollution.

4. The development of a stormwater management system that will be flexible and readily adaptable to changing needs.

5. The development of a stormwater management system that will efficiently and effectively meet all of the other stated objectives at the lowest practicable cost.

### ENGINEERING DESIGN CRITERIA AND ANALYTIC PROCEDURES

#### Introduction

Certain engineering criteria and procedures were used in the design of alternative stormwater management plan elements, and in the making of the economic evaluations. While most of these criteria and procedures are widely accepted and firmly based in current engineering practice, it is, nevertheless, believed useful to briefly document them here. The criteria and procedures provide the means for quantitatively sizing and analyzing the performance of both the minor and major components of the total stormwater management system components specifically considered in this stormwater management plan. In addition, these criteria and procedures can serve as a basis for the more detailed design of stormwater management system components. These criteria and procedures thus constitute a reference for use in facility design, and as such are intended to be applied uniformly and consistently in all phases of the implementation of the stormwater management plan.

Stormwater quality management measures include stormwater storage and other nonpoint

source pollution abatement measures. Stormwater storage measures remove pollutants in stormwater runoff by sedimentation, biological uptake, and chemical reaction. Other nonpoint source pollution abatement measures protect water quality by reducing the rate and volume of storm runoff which transports pollutants to a receiving stream, and by controlling pollutants at their source before transport by runoff. This stormwater management plan primarily addresses those pollution abatement measures—such as storage facilities—that can provide both water quality improvement and a reduction in the rate and amount of stormwater runoff.

Two distinct drainage systems were considered in the development of a stormwater management plan for the Crayfish Creek subwatershed: the minor system and the major system. The minor stormwater drainage system is intended to minimize the inconveniences attendant to inundation from more frequent storms, generally up to the 10-year recurrence interval storm event. The minor drainage system consists of sideyard and backyard drainage swales, street curbs and gutters, roadside swales and grass filter strips, storm sewers and appurtenances, stormwater infiltration systems, and some storage facilities. It is composed of the engineered paths provided for the stormwater runoff to reach the receiving streams and watercourses during these more frequent storm events.

The major stormwater drainage system is designed for the management of stormwater runoff during major storm events—that is, generally, for storms exceeding the 10-year recurrence interval up to the 100-year recurrence interval—when the capacity of the minor system is exceeded. The major stormwater drainage system consists of the entire street cross-section and interconnected drainage swales, watercourses, and stormwater storage facilities. Portions of the streets, therefore, serve as components of both the minor and major stormwater drainage systems. When providing transport of overland runoff to the piped storm sewer system, the streets function as a part of the minor drainage system; when utilized to transport overflow from surcharged pipe storm sewers and culverts and overflowing roadside swales, the streets function as a part of the major drainage system. Major drainage system components must be carefully studied to identify areas subject to inundation during major storm events.

Stormwater Flow Rate and Volume

The quantification of the stormwater flow rates and volumes under both existing and probable future land use conditions allows sound, rational decisions to be made concerning stormwater management. Such quantification aids in determining the type, location, and configuration of stormwater management facilities and is essential to sizing facilities such as storm sewers, open channels, culverts and bridges, and storage and pumping facilities. The techniques used to quantify stormwater flow rate and volume in both the minor and major drainage systems have been briefly described above. These techniques provide the basic quantitative data needed to locate, configure, and size drainage facilities, and are needed to determine surface water flow rates, velocities, and volumes at the inlet and outlet points of each catchment area, and to determine the hydrologic and hydraulic characteristics of the catchment areas.

To ensure that the stormwater system is able to facilitate the control of the stormwater runoff in a cost-effective manner, storm events of specified recurrence intervals must be selected as a basis for the design and evaluation of both the minor and major drainage systems. The selection of these design storm events should be dictated by careful consideration of the frequency of inundation which can be accepted versus the cost of protection. This involves value judgments which should be made by the responsible local officials involved and applied consistently in both the public and private sectors.

The average frequency of the rainfall occurrence used for design determines the degree of protection afforded by the stormwater management system. This protection should be consistent with the damage prevented. In practice, however, the calculation of benefit-cost ratios is not deemed warranted for ordinary urban drainage facilities, and the selection of a design storm recurrence interval is made on the basis of engineering judgment and experience with stormwater management facilities in similar areas.

In this respect, it should be noted that the cost of storm sewers and other drainage facilities is not directly proportional to either the design storm frequency or the flow rates. A 10-year recurrence interval storm produces approximately 16.5 percent greater rainfall intensities and 26 percent greater runoff intensities than a five-year recurrence interval storm. This higher runoff rate

requires sewer pipe diameters to be on the order of 10 percent larger. However, drainage systems are limited to commercially available pipe sizes which, in the most frequently used range of 15 to 66 inch diameter, have incremental diameter increases of 10 to 20 percent, corresponding incremental capacity increases of 27 to 58 percent, and corresponding average in-place cost increases of 12 to 24 percent. However, the incremental cost increases on a systemwide basis may be expected to be about 12 percent, because only portions of any given system will require modified sizes.

Another consideration in evaluating alternative design recurrence intervals for drainage facilities is the risk of exceedance of capacity. Table 8 indicates that a five-year recurrence interval event, which is expected to occur on the average of 20 times in 100 years, has a 50 percent chance of being exceeded in about 3.5 years. In contrast, a 10-year recurrence interval event, which is expected to occur on the average of 10 times in 100 years, has a 50 percent chance of being exceeded in about seven years.

The major local concerns in the Crayfish Creek subwatershed are associated with those storm events, and the corresponding inconveniences, that occur more often than once per year. Thus, consideration was given in this planning effort to designing facilities to resolve problems that occur on a frequent basis as well as to designing facilities for less frequent storms such as five- or 10-year recurrence interval events.

Based upon consideration of the costs and risks involved, a 10-year recurrence interval storm event was selected for use in the design of the minor elements of the alternative stormwater management plans for the Crayfish Creek subwatershed, including the design of most conveyance and storage facilities. This recurrence interval is widely used to size storm drainage facilities within the Southeastern Wisconsin Region. However, consideration was also given in the recommended plan to staging, or modifying, the recommended facilities in such a manner as to reduce the costs and to better meet the objectives by using a more frequent design storm.

A 100-year recurrence interval storm event was selected for use in delineating areas of potential inundation along the stormwater management system, and to size the major elements of the system. This recurrence interval—which is also used by the Regional Planning Commission in its flood control planning efforts, and by federal and state agencies for floodland regulation—was selected because the 100-year recurrence interval event approximates, with respect to the amount of land area inundated, the largest known flood levels that have actually occurred in the Region, thereby providing a conservatively safe level of protection against property damage and hazards to human health and safety from surcharge of the major, as opposed to the minor, stormwater management system.

Rainfall data, including rainfall intensity-duration-frequency relationships, were available from the files of the Regional Planning Commission as input to various methods used to compute stormwater runoff rates and volumes. These data are described in Chapter II. Data on the hydrologic and hydraulic characteristics of the study area were also available from the files of the Commission, including data on soils; topography; the drainage patterns of the natural streams and watercourses, of the waterway openings of related bridges and culverts, and of related flood hazard areas; wetlands; and areas with flood problems. Topographic maps prepared by the City to Regional Planning Commission specifications at a scale of 1 inch equals 100 feet, with two-foot contour intervals, and Commission ratioed and rectified aerial photographs at a scale of 1 inch equals 400 feet were used in the analyses. Storm drainage system maps, construction plans, as-built plans, and other pertinent information were also obtained from the files of the City and of a number of other governmental agencies having jurisdiction in the study area. These materials were evaluated and included in the body of resource materials drawn upon in the analytic and design phases of the work.

The data noted above were utilized to estimate hydraulic loadings—stormwater runoff rates and volumes—under existing and planned future land use conditions, and under existing and proposed stormwater management system configurations in the study area using three techniques. The first technique is one developed specifically for estimating the magnitude and frequency of floods on waterways in urban areas of Wisconsin. The method was developed by the U. S. Geological Survey in a cooperative project involving that agency, the Milwaukee Metropolitan Sewerage District, and the Southeastern Wisconsin Regional Planning Commission. The report describing the method is entitled Water Resources Inves-

Table 8

THEORETICAL DISTRIBUTION OF RETURN PERIOD FOR CALCULATION OF RISK OF DESIGN RECURRENCE INTERVAL BEING EXCEEDED

| Average Recurrence Interval Tr, Years | Probability That Interval Between Events Will Not Be Exceeded in Period of N Years | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| 10 | 29.957 yr | 23.026 yr | 13.863 yr | 6.931 yr | 2.877 yr | 1.054 yr | 0.513 yr |
| 5 | 14.979 | 11.513 | 6.931 | 3.466 | 1.438 | 0.575 | 0.256 |
| 2 | 5.991 | 4.605 | 2.773 | 1.386 | 0.575 | 0.211 | 0.103 |
| 1 | 2.996 | 2.303 | 1.386 | 0.693 | 0.288 | 0.105 | 0.051 |
| 0.5 | 1.498 | 1.151 | 0.693 | 0.347 | 0.144 | 0.053 | 0.026 |
| 0.25 | 0.749 | 0.576 | 0.347 | 0.173 | 0.072 | 0.026 | 0.013 |

Based on:

$$Pn = e^{-N/Tr}$$

$$N = Tr \times LOG_e \frac{1}{Pn}$$

$$Tr = \frac{N}{LOG_e \frac{1}{Pn}}$$

Where:

Pn = Probability of nonoccurrence
N = Number of years of interest
Tr = Recurrence interval, years

PEAK MONTH (JULY) PROBABILITY/ANNUAL PROBABILITY FOR ONE-HOUR DURATION RAINFALL EVENT

| Recurrence Interval, Years | 1 | 2 | 5 | 10 | 25 | 50 |
|---|---|---|---|---|---|---|
| Ratio | 0.251 | 0.268 | 0.295 | 0.360 | 0.425 | 0.700 |

Source: SEWRPC.

tigation Report 86, Estimating the Magnitude and Frequency of Floods for Wisconsin Urban Streams, 1986. The method uses equations developed by multiple-regression analyses to compute flood magnitudes and frequencies. The significant characteristics considered in the equations are recurrence interval, drainage area, and percent imperviousness (based upon land use).

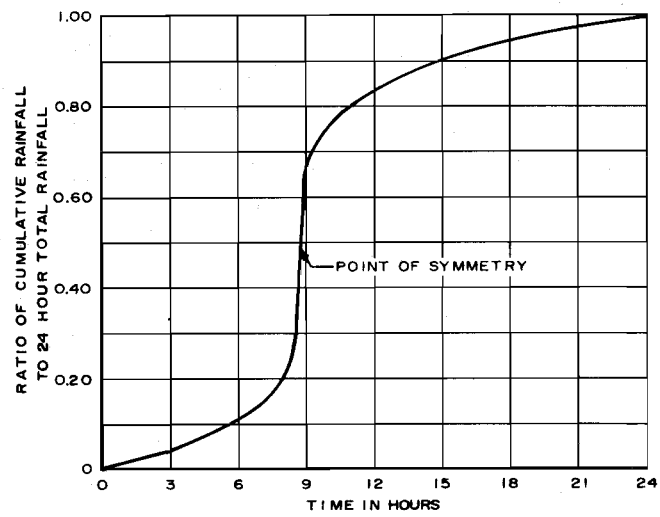
The second technique used was the U. S. Soil Conservation Service TR 55 method. This technique uses general empirical relationships between features that affect runoff and peak rates of discharge in small watersheds to compute flood magnitudes and frequencies. These features include recurrence interval, drainage area, watershed slope, percent ponds and swamp, land use and percent impervious area, vegetative cover, rainfall depth, hydrologic soil group, and maximum watershed hydraulic length.

The third technique used was a mathematical simulation model known as the runoff hydrograph and routing model (HYDROUT). This model uses the continuous rainfall pattern for the selected recurrence interval design storms based on results of the intensity-duration-frequency analyses. Such analyses have been performed by the Regional Planning Commission on Milwaukee

area meteorological data.[1] The rainfall function used for both the 10- and 100-year recurrence interval storms is shown in Figure 2 and is generated as an internal input in the model. In the application of this method, the study area is divided into catchment areas, and a runoff hydrograph is produced for each area. The hydrograph is a product of the rainfall pattern, the U. S. Soil Conservation Service runoff curve number used in the conversion of rainfall to runoff, and a dimensionless index hydrograph. These hydrographs are combined and hydrologically routed downstream from one critical location in the system to the next to provide system hydraulic loadings in the form of peak flow rates and total flow volumes. The reservoir routing mode allows for the routing of the flow through a reservoir based on the storage and outflow characteristics of the reservoir. The output hydrograph produced in this mode can then be combined with additional hydrographs as it is routed downstream via conveyance facilities or through additional reservoirs. This simulation model allows the effects of multiple, sequential reservoir storage facilities on downstream peak flow rates to be evaluated.

Figure 2

CUMULATIVE RAINFALL UNITGRAPH




*Source: SEWRPC.*

Stormwater Management System Component Sizing

The system component sizing was determined using commonly used formulas and design criteria, including graphic design charts. These techniques generally utilize Manning's formula, the cross-sectional areas, and slopes to determine the hydraulic capacity, and are described in more detail in the following sections.

Criteria and Assumptions Relating to Street Cross-Sections, Related Site Grading, Inlets, and Parallel Roadside Culverts

An important secondary function of all streets and highways is the collection and conveyance of stormwater runoff. The planning of stormwater drainage systems should therefore be done simultaneously with the planning of the location, configuration, and gradients of the street system. At the systems planning level, recommendations concerning the approximate centerline elevations and gradients of existing and proposed streets are provided. Pertinent aspects of the details of the curbs and gutters, roadside swales, and street crowns are assumed based upon typical cross-sections, and must be further addressed in subsequent project development engineering.

The location and size of inlets and culverts, as a part of the minor stormwater drainage system, are dictated by the allowable stormwater spread and depth of flow in streets and attendant interference with the safe movement of pedestrian and vehicular traffic. The commonly used street cross-section in the City of Oak Creek has uniform pavement cross slopes of 0.02 foot per foot, and is drained with roadside swales and culverts. Grading beyond the right-of-way is at a slope of one foot vertical on five feet horizontal.

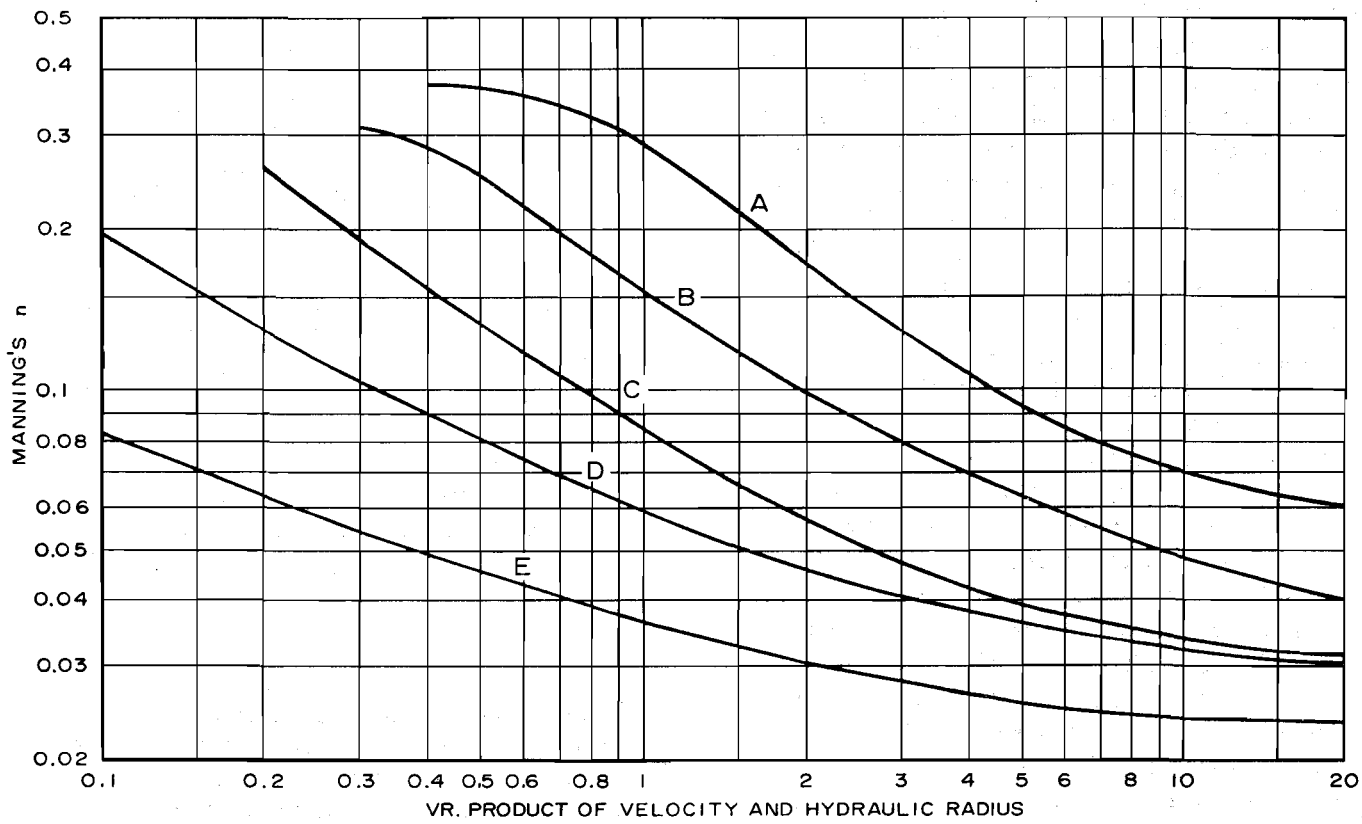
Two assumptions concerning site grading, and one assumption concerning culverts and inlets, were made for the systems planning. It was assumed that all new urban development and redevelopment would be designed to facilitate good drainage, with slopes away from all sides of buildings of at least one-quarter inch per foot to provide positive gravity drainage to streets or to interior drainage swales. It was assumed that interior drainage swales along side or back lot lines or site boundaries would have a minimum gradient of 0.01 foot per foot, and would provide positive gravity drainage to streets.

With regard to inlets and parallel roadside culverts, it was assumed that these system com-

[1] *See SEWRPC Technical Record, Vol. 3, No. 5, March 1973.*

Figure 3

MANNING'S "n" FOR VEGETAL-LINED CHANNELS FOR VARIOUS RETARDANCE LEVELS




*Source: U. S. Soil Conservation Service.*

ponents would be designed to provide sufficient capacity to intake all flow in the tributary gutters or swales from storms up to and including the 10-year recurrence interval event. In the systems planning, critical locations were selected at which to check the specified overland and swale flow depths.

Criteria and Assumptions Relating to Roadside Swales and Grass Filter Strips

At the systems planning level, only recommendations relating to the general configuration, size, depth, slope, and type of roadside swales and grass filter strips are provided. More detailed engineering at the project development level will be needed to determine the precise depth, location, and horizontal and vertical alignment of the swales and strips, and the best response to constraints posed by structures and utilities.

In the systems planning, the Manning equation was used together with the cross-sectional area of flow to determine the required hydraulic capacity of swales. A Manning's "n" value corresponding to retardance level "C" in Figure 3 was assumed for well-constructed, properly maintained, frequently mowed (one- to two-month mowing cycle), grass-lined roadside drainage swales commonly found in rural areas. The retardance level for other vegetation is classified in Tables 9 and 10.

The following assumption and criteria relating to grass-lined storm drainage swales and channels in and along street rights-of-way were used in the development of the stormwater management plan:

1. Swales were assumed generally to be located in public street rights-of-way and to follow the street alignments and gradients.

Table 9

GUIDE TO SELECTION OF VEGETAL RETARDANCE

| Stand | Average Length of Vegetation | Degree of Retardance | Stand | Average Length of Vegetation | Degree of Retardance |
|---|---|---|---|---|---|
| Good | Longer than 30 inches | A | Fair | Longer than 30 inches | B |
| | 11 to 24 inches | B | | 11 to 24 inches | C |
| | 6 to 10 inches | C | | 6 to 10 inches | D |
| | 2 to 6 inches | D | | 2 to 6 inches | D |
| | Less than 2 inches | E | | Less than 2 inches | E |

Source: U.S. Soil Conservation Service.

Table 10

CLASSIFICATION OF VEGETAL COVERS AS TO DEGREE OF RETARDANCE

| Retardance | Cover | Condition |
|---|---|---|
| A | Weeping lovegrass | Excellent stand, tall (average 30 inches) |
| | Yellow bluestem Ischaemum | Excellent stand, tall (average 36 inches) |
| B | Kudzu | Very dense growth, uncut |
| | Bermuda grass | Good stand, tall (average 12 inches) |
| | Native grass mixture (little bluestem, blue grama, and other long and short mid-west grasses) | Good stand, unmowed |
| | Weeping lovegrass | Good stand, tall (average 24 inches) |
| | Lespedeza sericea (19 inches) | Good stand, not woody, tall |
| | Alfalfa | Good stand, uncut (average 11 inches) |
| | Weeping lovegrass | Good stand, mowed (average 13 inches) |
| | Kudzu | Dense growth, uncut |
| | Blue grama | Good stand, uncut (average 13 inches) |
| C | Crabgrass | Fair stand, uncut (10 to 48 inches) |
| | Bermuda grass | Good stand, mowed (average 6 inches) |
| | Common lespedeza | Good stand, uncut (average 11 inches) |
| | Grass-legume mixture--summer (orchard grass, redtop, Italian ryegrass, and common lespedeza) | Good stand, uncut (6 to 8 inches) |
| | Centipedegrass | Very dense cover (average 6 inches) |
| | Kentucky bluegrass | Good stand, headed (6 to 12 inches) |
| D | Bermuda grass | Good stand, cut to 2.5-inch height |
| | Common lespedeza | Excellent stand, uncut (average 4.5 inches) |
| | Buffalograss | Good stand, uncut (3 to 6 inches) |
| | Grass-legume mixture--fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza) | Good stand, uncut (4 to 5 inches) |
| | Lespedeza sericea | After cutting to 2-inch height. Very good stand before cutting |
| E | Bermuda grass | Good stand, cut to 1.5-inch height |
| | Bermuda grass | Burned stubble |

NOTE: Covers classified have been tested in experimental channels. Covers were green and generally uniform.

Source: U.S. Soil Conservation Service.

2. All swales should be designed to accommodate the peak runoff expected from a minor—that is, a 10-year recurrence interval—storm when flowing full with no freeboard.

3. All swales should be designed to provide a maximum flow velocity of five feet per second when accommodating the design storm.

4. The minimum depth of swales below street shoulder should be one and one-half feet, while the maximum depth should not exceed three feet.

These criteria were intended to provide a sufficient level of stormwater filtration and sedimentation within the grass. The criteria included calculations using data on intensity and total amount of rainfall, the extent and characteristics of the tributary drainage area, soil percolation rates, land surface slope, and the type and condition of the vegetation.

Criteria and Assumptions Relating to Cross Culverts

Cross culverts, which are a common feature of open drainage systems, are used to convey stormwater under a street, highway, railroad, or embankment. At the systems planning level, recommendations concerning the location and size of cross culverts are provided. More detailed engineering at the project development stage will be needed to determine the precise depth, location, and horizontal and vertical alignment of the culverts; the type of material to be used; and the best response to constraints posed by structures and utilities.

In the systems planning, the Manning equation was used to determine flow rates and headlosses of culverts. The hydraulic capacity of any culvert is affected by its cross-sectional area, shape, entrance geometry, length, slope, and construction material, and the depth of ponding at the inlet and outlet, details which must all be addressed at the project development level. In planning the system, required culvert sizes were determined by evaluating multiple constraints and selecting an appropriate size that best met all requirements. Inlet control nomographs relating culvert headwater depth to flow rates for specific-type culvert entrances, and culvert headloss nomographs for annular corrugated metal pipes flowing full were used in the study. These nomographs are available from the Federal Highway Administration (FHA). Culvert capacity charts which relate culvert headwater depth, flow rates, pipe lengths, and pipe gradients for annular corrugated metal pipes are also available from the FHA. Similar design information is readily available in the literature for elliptical, or box sections for other entrance conditions and for other materials such as precast concrete, corrugated aluminum, and structural plate corrugated metal.

As shown in Figure 4, Manning's "n" values were assumed for properly installed and maintained corrugated metal pipe and pipe arch culverts. A Manning's "n" value of 0.012 was assumed for well-constructed, precast, concrete pipe culverts flowing full. Where analyses indicated that pipes would flow less than full at design loading, the hydraulic elements graph for concrete pipes set forth in American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 37, Design and Construction of Sanitary and Storm Sewers, was used to determine the critical characteristics required for solution of Manning's equation, or those characteristics were computed directly in the simulation model. For corrugated steel and structural pipe arches, the hydraulic elements graph available in industry publications was used. Hydraulic conditions for major system components under major storm event conditions were evaluated on a case-by-case basis.

The following criteria and assumptions were used in the development of culvert sizes for the stormwater management system plan:

1. The culvert location should provide a direct exit, avoiding an abrupt change in direction at the outlet end and, preferably, at the inlet end.

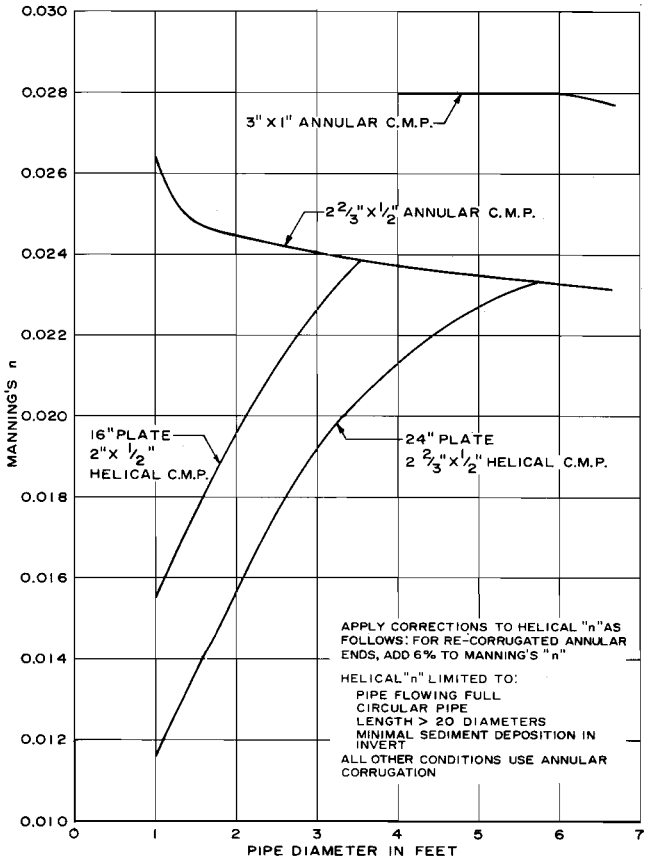
2. The minimum culvert size should be 12 inches in diameter.

3. The culverts should be laid on a uniform gradient.

4. Culverts were assumed to be circular or pipe arches, constructed of corrugated metal pipe with either a commercially available apron endwall or a headwall inlet.

Figure 4

MANNING'S "n" VERSUS DIAMETER FOR CORRUGATED METAL PIPE CULVERTS FLOWING FULL




*Source: Federal Highway Administration and SEWRPC.*

5. Culverts were assumed to have an unsubmerged outlet during a minor—that is, a 10-year recurrence interval—storm event.

Criteria and Assumptions Relating to Open Drainage Channels

At the systems planning level, recommendations relating only to the general location, cross-section bottom width, bottom elevation, side slopes, area, gradient, and type of open drainage channels are provided. More detailed engineering at the project development level will be needed to determine the precise location and horizontal and vertical alignment of the channels, the need for and type of channel lining, and the best response to constraints posed by structures, other utilities, and street layout.

Open drainage channels in and along exclusive rights-of-way are a necessary and appropriate component of the total stormwater drainage system of the City and environs. In certain areas, such channels may serve as part of the minor drainage system—for example, in parks and cemeteries, in some some commercial and industrial areas, and in some low-density residential areas. Such channels inevitably form part of the major stormwater drainage system as well. In some areas of the stormwater management study area, open drainage channels together with roadside swales may serve as the sole component of the engineered stormwater drainage system.

In the systems planning, the Manning's equation was used together with the cross-sectional area of flow to determine the hydraulic capacity of open channels. A Manning's "n" value of 0.035 was assumed for all turf-lined channels, and a value of 0.015 for all concrete-lined channels. Composite channels with grass slopes and a concrete cunette or bottom pavement were analyzed by summation of flows in each vertical segment using the appropriate Manning's "n" value. Receiving natural stream channels were analyzed using the U. S. Army Corps of Engineers' HEC-2 step backwater simulation model. Depths and velocities of open channel flow for various channel cross-sections were computed directly in the simulation model.

Channel rating charts were developed from this information, and a sample chart is shown in Figure 5.

The following criteria relating to the details of the open drainage channels were used in the development of the stormwater management plan:

1. All open drainage channels should be designed to accommodate the peak runoff from a major—that is, a 100-year recurrence interval—storm when flowing full with no freeboard.

2. Turf-lined side slopes should not exceed one vertical on two and one-half horizontal, and where practical should be one vertical on four horizontal.

3. The minimum gradient of all turf-lined open channels should be 0.010 foot per foot.

4. All concrete-lined and composite-lined channels should be designed to provide a maximum flow velocity of five feet per second when accommodating the peak runoff from a minor—that is, a 10-year recurrence interval—storm.

## Criteria and Assumptions Relating to Storm Sewers

At the systems planning level, only recommendations relating to the general configuration, size, invert elevation, slope, and type of storm sewer facilities are provided. More detailed engineering at the project development level will be needed to determine the precise invert elevation, location, and horizontal and vertical alignment of the sewer, the type of material to be used for the sewer, and the best response to constraints posed by structures and other utilities.

In the systems planning, Manning's equation was used together with the cross-sectional area of flow to determine the hydraulic capacity of sewers. Values for the Manning's roughness coefficient "n" vary with the type and conditions of the sewer, the depth of flow in the sewer, and the diameter of the sewer. A Manning's "n" value of 0.012 was assumed typical of well-constructed, precast, concrete pipe sewer lines. Sewer capacities and flow velocities were calculated directly in the simulation model.

Where the analyses indicated the sewers would flow less than full at design loading, the hydraulic elements graph set forth in American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 37 was used to determine the critical characteristics, or those characteristics were computed directly in the simulation model.

The following assumption and criteria relating storm sewers were used in the development of the stormwater management plan:

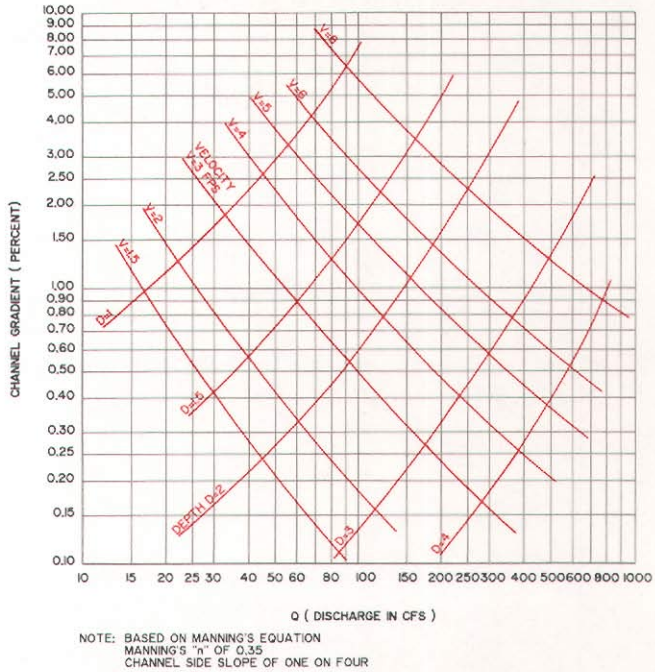
1. Storm sewers were assumed generally to be located in public street rights-of-way and to follow the street alignments and gradients.

2. All storm sewers should be designed to accommodate the peak runoff expected from a minor—that is, a 10-year recurrence interval—storm when flowing full.

3. The minimum pipe size should be 12 inches in diameter.

**Figure 5**

**CHANNEL RATING CHART FOR 7.5-FOOT-WIDE BOTTOM OPEN CHANNEL**




*Source: SEWRPC.*

4. The minimum desirable velocity during the design storm event should be 2.5 feet per second.

5. At all junctions and changes in pipe size, the 0.8 depth-diameter point of the pipes should be aligned.

6. At all changes in horizontal direction of 30 or more, a drop should be provided to compensate for associated energy losses. The drop shall equal:

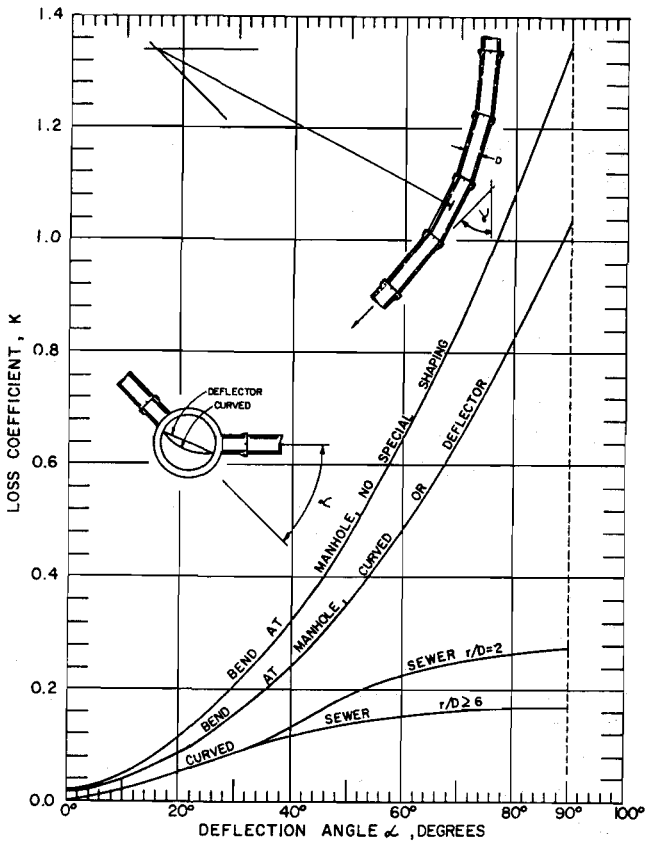
$$K \times \frac{V^2}{2g},$$

where K is determined from Figure 6.

7. The radius of the centerline of a bend should be at least one and one-half times the diameter of the sewer. Additional drop

Figure 6

SEWER BEND LOSS COEFFICIENT




*Source: Denver Regional Council of Governments, Urban Storm Drainage.*

should be provided to the pipe to compensate for associated energy losses. The drop shall equal:

$$K \times \frac{V^2}{2g},$$

where K is determined from Figure 6.

8. The minimum depth of cover over the top of the sewer should be three feet.

Criteria and Assumptions for Stormwater Storage and Infiltration Facilities

Natural storage of stormwater is provided during overland flow in surface depressions, vegetated areas, and pervious soils. Natural storage can be enhanced by preserving open areas, woodlands, wetlands, ponds, and areas with large infiltration capacities. These attributes can usually be incorporated into a stormwater management system at less cost than would be required for the incorporation of artificial storage facilities. Artificial storage facilities include constructed onsite swales, roadside swales, temporary storage facilities on parking lots and other open areas, and retention and detention basins.

At the systems planning level, recommendations concerning only the location, type, approximate size, and capacity of storage and infiltration facilities and outlet flow constraints are provided. More detailed engineering at the project development level will be needed to precisely locate, configure, and size storage and infiltration facilities, and to specify such details as the inlet and outlet control facilities.

In planning the system, required storage volumes were calculated using the HYDROUT simulation model, and were checked using the U. S. Soil Conservation Service Curve Runoff Number method. The following criteria relating to storage facilities were used in the development of the stormwater management system plan:

1. Storage facilities should be sized to accommodate a minor storm event. This criterion does not apply to storage facilities designed as components of the downstream floodland management system, which should be sized to accommodate a major storm event.

2. Storage facilities should be considered to achieve reductions in peak runoff rates to eliminate identified site-specific problems.

3. Storage provided through the use of dry detention basins simplifies maintenance. Accordingly, wet pond retention basins should be used only on a site-specific basis when warranted for recreational, aesthetic, water quality, or water supply considerations.

4. Where practical, the length of the storage facility, as measured from the inlet to the outlet, should be at least twice the width. Storage facilities should, where possible, be wedge-shaped, with the apex, or narrow end, containing the inlet, and have side slopes not exceeding one on three.

5. Storage depths on parking lots, truck stopping areas, and similar open spaces should not exceed six inches during the design storm event.

The design criteria for the stormwater storage facilities were intended to allow sufficient detention or retention for settling and biological removal of pollutants within the facilities. The type, size, and design of stormwater storage facilities were determined by the intensity and total amount of rainfall, the extent and characteristics of the tributary drainage area, soil and topographic characteristics, desired facility outflow discharge rates, and pollutant loading characteristics.

Stormwater Pumping

The purpose of stormwater pumping is to remove stormwater from low-lying areas that cannot be effectively drained by gravity. Stormwater pumping stations are also commonly associated with stormwater storage facilities that have limited land surface available and are restricted to deep storage. Pumping should not be a component of the stormwater management plan when another alternative providing gravity drainage is practical.

At the systems planning level, only recommendations concerning the location, type, and capacity of the pumping facility are provided. More detailed engineering at the project development level will be needed to determine the type of pumps, type of drives and motor requirements, type of electrical controls, and size and configuration of intake facilities.

The following criteria and assumption relating to stormwater pumping facilities were used in the development of the stormwater management system plan:

1. Pumping stations should be designed with sufficient capacity to handle the estimated flows from a minor—that is, a 10-year recurrence interval—storm event with one pump out of service.

2. The pumping station should be designed with a gravity overflow to the major drainage system.

3. For systems planning purposes, it was assumed that the pumps would be high-capacity, low-head centrifugal pumps with constant speed motors designed for intermittent service.

Construction Erosion Control Measures

The measures previously discussed are intended to help control water pollution from developed urban areas. During the construction phase of a new urban land use development, however, large amounts of pollutants can be generated. Adequate water quality protection will require that the pollutant loadings generated by construction also be controlled.

Total mitigation of pollutant loadings during construction activities is not practical. Therefore, the acceptable level of risk of significant pollution occurring should be determined for areas temporarily susceptible to erosion such as construction sites, taking into account the expected duration of vulnerability to excessive erosion, time of year of vulnerability, fraction of site vulnerable, erodibility of onsite soils, cost of construction and maintenance of control measures, and cost of damage and restoration if capacities are exceeded. The risk recurrence interval-probability of nonexceedance is shown in Figure 7, and can be calculated from values provided in Table 8. The selection of an appropriate risk involves value judgments which should be made by the responsible local officials involved and applied consistently in both the public and private sectors. Selection of an acceptable risk level should be based on engineering judgment and on the performance of erosion and sediment control facilities in similar circumstances.

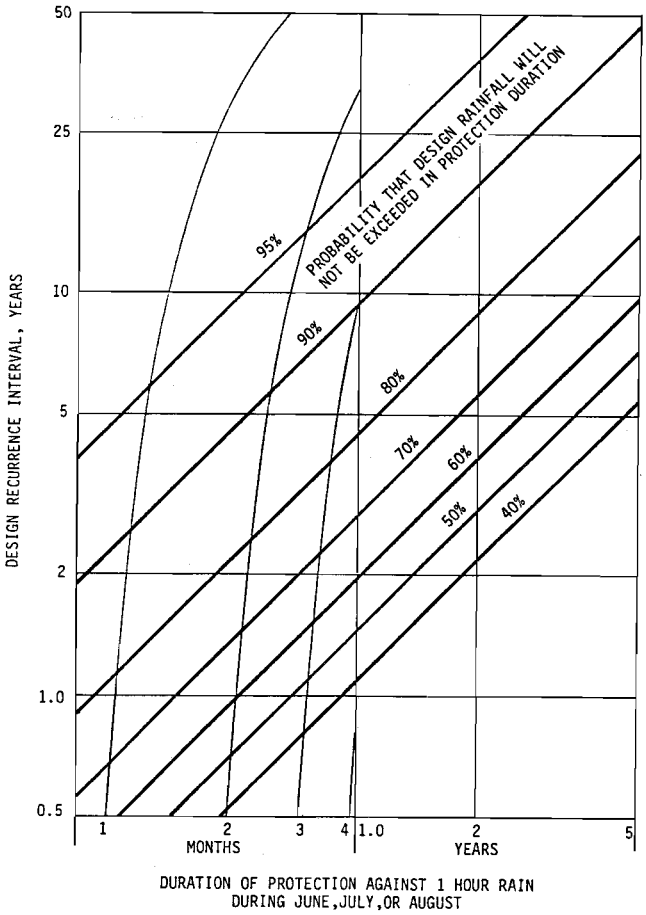
The following criteria were used in the development of this stormwater management plan:

1. Where large amounts of settleable sand and silt-sized solids are generated, a combination of onsite source controls and sedimentation basins should be applied. Where pollutant contributions consist primarily of small clay-sized particles that resist settling or dissolved pollutants, such as nitrates, onsite source controls should be emphasized.

2. Temporary erosion control and sedimentation measures, such as those that should be applied at construction sites during summer construction, should be designed to provide adequate protection for a no more than 33

Figure 7

CALCULATED RISK DIAGRAM




*Source: SEWRPC.*

percent risk level (which has a 67 percent probability of not being exceeded)—that is, on the average there is one chance in three that the facility capacity will be exceeded during its life. These recurrence intervals are based upon a partial series rainfall analysis as opposed to an annual series analysis. The following recurrence interval storms should be considered for use in the design of structural construction site erosion control measures:

Construction Period Including June, July, or August

| Duration of Construction During Summer | Design Recurrence Interval Storm Event | One Hour Design Storm Depth (inches) |
|---|---|---|
| 1 Month | 0.6 year | 0.84 |
| 2 Months | 1.3 years | 1.12 |
| 3 Months | 2.0 years | 1.28 |
| 4 Months-1 Year | 2.5 years | 1.37 |

For final design, the design storm for erosion control measures should be selected taking into account project-specific factors such as location, soils, and adjacent natural resources.

3. Vegetative cover should be restored as soon as possible on land disturbed for construction activity, agricultural production, and industrial uses.

## ECONOMIC EVALUATION DATA

It is customary to evaluate plans for water resource development projects on the basis of benefits and costs. This is particularly appropriate if the prospective development represents opportunities for investments to provide economic return to the public and if a comparison of alternative investments is desirable. In the case of stormwater management systems, however, it is assumed that such systems must be provided to fulfill a fundamental need of the community, and consequently, they do not compete with alternatives of investment in other economic sectors. Accordingly, it is assumed that the least costly alternative system that meets the stormwater management objectives set forth in this chapter will be the most desirable alternative economically.

The economic evaluations conducted under this stormwater management planning program include the estimation of capital and annual operation and maintenance costs. Capital costs include construction contract costs plus engineering, inspection, and contract administration costs. Unit costs for storm sewers, culverts, manholes, inlets, open channels, surface storage basins, and pumping stations are presented in Table 11. Costs for infiltration facilities vary substantially and were calculated on a site-specific basis.

The unit costs presented in Table 11 were used in the economic evaluation of alternative systems plans, and are not intended to be used for project estimating purposes. Actual costs will vary from these estimates, reflecting site-specific conditions, local availability and supply, and labor costs. Any necessary land and acquisition costs were estimated for the economic evaluations utilizing the latest available state equalized assessed valuations.

Table 11

UNIT COSTS FOR SELECTED STORMWATER MANAGEMENT COMPONENTS

| Component | Description | Unit Cost |
|---|---|---|
| Corrugated Metal Culverts | 12-inch diameter | $ 16 per lineal foot |
| | 15-inch diameter | 18 per lineal foot |
| | 18-inch diameter | 20 per lineal foot |
| | 24-inch diameter | 28 per lineal foot |
| | 30-inch diameter | 36 per lineal foot |
| | 36-inch diameter | 50 per lineal foot |
| | 42-inch diameter | 60 per lineal foot |
| | 48-inch diameter | 70 per lineal foot |
| | 60-inch diameter | 110 per lineal foot |
| Reinforced Concrete Storm Sewers--Four- to Seven-foot Cover | 12-inch diameter | $ 30 per lineal foot |
| | 15-inch diameter | 32 per lineal foot |
| | 18-inch diameter | 36 per lineal foot |
| | 24-inch diameter | 44 per lineal foot |
| | 30-inch diameter | 60 per lineal foot |
| | 36-inch diameter | 70 per lineal foot |
| | 42-inch diameter | 90 per lineal foot |
| | 48-inch diameter | 100 per lineal foot |
| | 60-inch diameter | 150 per lineal foot |
| | 72-inch diameter | 200 per lineal foot |
| | 84-inch diameter | 270 per lineal foot |
| Manholes Five to Eight Feet Deep | For 12- to 30-inch pipe | $ 850 each |
| | 36-inch diameter | 1,050 each |
| | 48-inch diameter | 1,400 each |
| | 60-inch diameter | 1,800 each |
| | 72-inch diameter | 2,500 each |
| | 84-inch diameter | 3,400 each |
| Street Inlets | Standard inlet | $ 600 each |
| | Inlet bowl | 500 each |
| Open Channels | Grass-lined: | |
| | 7.5 feet bottom x 6 feet deep | $ 36 per lineal foot |
| | 9 feet bottom x 7 feet deep | 50 per lineal foot |
| | 21 feet bottom x 8 feet deep | 75 per lineal foot |
| | Composite-lined: | |
| | 15 feet bottom x 6 feet deep | 120 per lineal foot |
| | 20 feet bottom x 7 feet deep | 170 per lineal foot |
| | 32 feet bottom x 8 feet deep | 240 per lineal foot |
| Surface Storage Basins | Storage volume: | |
| | 10 acre-feet | $ 140,000 each |
| | 25 acre-feet | 300,000 each |
| | 50 acre-feet | 550,000 each |
| | 100 acre-feet | 860,000 each |
| | 250 acre-feet | 2,400,000 each |
| Pumping Stations | 1 cubic foot per second | $ 50,000 each |
| | 20 cubic feet per second | 240,000 each |
| | 50 cubic feet per second | 390,000 each |
| | 100 cubic feet per second | 570,000 each |
| | 500 cubic feet per second | 1,350,000 each |
| Maintenance | Storm sewer maintenance | $1,000 per mile per year |
| | Open channel maintenance | 2,000 per mile per year |

Source: City of Oak Creek Engineering Department; and SEWRPC, 1985.

## SUMMARY

The process of formulating objectives for stormwater management is an essential part of the planning process. To reflect the basic needs and values of the community, it is necessary that these objectives be prepared within the context of, and be fully consistent with, proposed land use conditions and broad community development objectives.

The following five stormwater management objectives were established to guide the design and evaluation of alternative stormwater management plans:

1. The development of a stormwater management system that reduces the exposure of people to drainage-related inconvenience and to health and safety hazards, and that reduces the exposure of real and personal property to damage through inadequate stormwater drainage and inundation.

2. The development of a stormwater management system that will effectively serve existing and proposed future land uses.

3. The development of a stormwater management system that will minimize soil erosion, sedimentation, and attendant water pollution.

4. The development of a stormwater management system that will be flexible and readily adaptable to changing needs.

5. The development of a stormwater management system that will efficiently and effectively meet all of the other stated objectives at the lowest practicable cost.

In addition to presenting and discussing the objectives established for the Crayfish Creek subwatershed stormwater management plan, this chapter has presented the engineering design criteria and analytic procedures that were used to design and size the alternative plan elements and which will serve as a basis for the more detailed design of stormwater management system components. Criteria and procedures were developed for determining stormwater flow rate and volume and for designing street cross-sections, swales and grass-lined strips, culverts, storm sewer inlets, storm sewers, open channels, storage and infiltration facilities, pumping facilities, and construction erosion control measures. Criteria were also presented for developing and evaluating economic data for the system components.

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# Chapter V

# EVALUATION OF ALTERNATIVE FUTURE STORMWATER MANAGEMENT SYSTEMS

## INTRODUCTION

This chapter describes and evaluates alternative stormwater management plans designed to serve the Crayfish Creek subwatershed through the design year 2000. A description of the existing stormwater drainage system of the study area, and of the drainage and flooding problems in the area, is presented in Chapter II. As indicated in Chapter IV, a 10-year recurrence interval storm event was used to evaluate and design the minor system components of the alternative stormwater management plans, consisting of drainage swales, roadside swales, open channels, storm sewers, storage facilities, and related appurtenances. However, consideration was also given to the ability of an alternative to be staged, or modified, to resolve drainage problems that occur from more frequent storm events.

Following a description of certain pertinent characteristics of the subbasins identified for alternative system plan design and analysis, this chapter describes and evaluates alternative conceptual approaches to stormwater management which could be applied in the planning area to mitigate existing stormwater management problems and accommodate runoff from existing and planned development to the design year 2000. This chapter also describes and evaluates 17 specific alternative stormwater management system plans for the planning area.

## STUDY AREA SUBBASIN DESCRIPTION

The total planning area was divided into five subbasins for analytical purposes, as shown on Map 3 of Chapter II. Of the total of five subbasins, four were located totally within the City of Oak Creek, while the remaining subbasin included portions of both the City of Oak Creek and the Town of Caledonia. The pertinent characteristics of each subbasin are described in Table 12. Data are provided on subbasin size, soil type, percent impervious land surface, and the peak stormwater runoff rates expected to be generated from the subbasin under both existing and planned land use conditions.

## DESCRIPTION AND EVALUATION OF ALTERNATIVE STORMWATER MANAGEMENT APPROACHES

### Introduction

As indicated in Chapter III of this report, the amount of land in urban use within the study area may be expected to approximately triple between 1980 and the year 2000. This urbanization may be expected to produce an increase in the peak rate of stormwater runoff and in the volume of runoff for a given storm event, thereby exacerbating the drainage and flooding problems in the study area. Stormwater runoff from urban land also contains different types—and, in some cases, increased amounts—of pollutants compared to stormwater runoff from rural land. Accordingly, further urbanization may be expected to place increased demands on the existing stormwater management system, requiring additional engineered drainage facilities to accommodate the increased loadings. These facilities should be designed to minimize the occurrence of stormwater management problems and the associated disruption of the urban environment.

To accommodate these increased loadings and to abate existing and potential stormwater management problems, several alternative approaches to stormwater management in the area were considered. These approaches were first evaluated on a conceptual basis, considering their technical feasibility, applicability, and advantages and disadvantages. Elements of the most feasible approaches were then incorporated into 17 system level alternative stormwater management plans for the Crayfish Creek subwatershed area as described later in this chapter.

Alternative approaches to stormwater management that were considered for application in the Crayfish Creek subwatershed included conveyance, centralized detention, decentralized onsite detention, centralized retention, decentralized onsite retention, and nonstructural measures. Pertinent characteristics of each of the alternative approaches are set forth in Table 13. Based upon consideration of these characteristics, the

## Table 12

## CHARACTERISTICS OF ALTERNATIVE STORMWATER MANAGEMENT APPROACHES

| Characteristics | Conveyance | Centralized Detention | Decentralized Onsite Detention | Centralized Retention | Decentralized Onsite Retention | Nonstructural |
|---|---|---|---|---|---|---|
| Function | Rapid collection and conveyance of stormwater from the area so as to minimize disruptive and possibly damaging surface ponding in streets and low-lying areas; possible inundation of residential and other sites and structures; wet basements; failing foundations of pavements and structures; and excessive inflow and infiltration of clear water into sanitary sewers | Provide for the temporary storage of stormwater runoff in the service area for subsequent slow release to downstream channels or storm sewers, thus reducing the required size and cost of any constructed downstream conveyance facilities | Provide for the temporary storage of stormwater runoff at small sites located close to the source of generation of the runoff to be controlled | Provide for the storage of stormwater runoff for subsequent evaporation and infiltration to groundwater, thus removing the area runoff from the surface drainage system and reducing the required size and cost of downstream conveyance facilities | Same as centralized retention | Reduce damages from excessive stormwater runoff and flooding, rather than controlling the runoff rates or flood levels |
| Components Principal | Improved open drainage channels, storm sewers and pumping facilities | Surface or subsurface detention facilities—including basins (dry) and ponds (wet)—with outlets to storm sewers or engineered drainage channels or to natural surface water drainageways | Parking lot storage facilities<br>Rooftop storage facilities<br>Relatively small detention ponds and basins | Surface retention facilities, consisting of evaporation ponds and infiltration facilities, with outlets to surface water drainageways only when the design storm is exceeded | Relatively small evaporation ponds<br>Small surface and subsurface infiltration systems | Floodproofing and elevation of structures<br>Relocation of structures<br>Land use regulations<br>Open space and floodland preservation |
| Secondary | Stormwater inlets<br>Culverts<br>Outfalls<br>Manholes | Open drainage channels<br>Stormwater inlets<br>Storm sewers<br>Culverts<br>Pumping facilities<br>Outfalls<br>Manholes<br>Inlet and outlet works and/or pumping facilities | Same as centralized detention | Same as centralized detention | Same as centralized detention | Can be used with other stormwater management facilities |
| Applicability | Suitable for installation in both existing and newly developing urban areas | Most suitable for incorporation in newly developing urban areas if suitable surface or subsurface sites are available | Same as centralized detention | Same as centralized detention | Same as centralized detention | Suitable for implementation in existing and newly developing urban areas |
| Downstream Impact Quantity | May increase—relative to predevelopment conditions—downstream discharges, stages, and areas of inundation | May be designed to cause no significant increases, relative to predevelopment conditions, in downstream discharges, stages, and areas of inundation | Same as centralized detention | Same as centralized detention | Same as onsite detention | Preservation of open space lands may maintain higher levels of natural storage and infiltration than if these lands were developed |
| Quality | Transmits suspended solids and other pollutants to downstream areas | Detention ponds provide for removal by natural settling processes of sediment and other suspended material, thus reducing the pollutant loading on receiving waters; and provide for physical-chemical treatment such as disinfection, coagulation-flocculation, and swirl concentration. Detention basins normally provide minimal water quality control | Onsite detention ponds provide some pollutant removal, but usually less than centralized detention. No opportunity for physical-chemical treatment as with centralized facilities.<br>Onsite detention basins and other facilities that drain between storm events provide minimal water quality control | Provides removal of suspended and settleable pollutants, but dissolved pollutants may percolate to the water table without significant reduction | Same as centralized retention | Minimal impact |
| Multipurpose Capability | The modification of channels can limit fish and aquatic life habitat | Quantity control<br>Quality control if ponds are included | Quantity control<br>Quality control if ponds are included | Quantity control<br>Quality control<br>Recreation benefits | Same as centralized retention | Park and open space areas |

## Table 12 (continued)

| Characteristics | Conveyance | Centralized Detention | Decentralized Onsite Detention | Centralized Retention | Decentralized Onsite Retention | Nonstructural |
|---|---|---|---|---|---|---|
| Multipurpose Capability (continued) | | Can provide park and open space areas<br>Pond may have poor water quality, which could have negative impact on fish and aquatic life | | Aesthetic benefits<br>Groundwater recharge<br>Wildlife habitat<br>Can result in poor water quality conditions in impoundment and have negative impact on fish and aquatic life | | |
| Operation and Maintenance Requirements | Periodic cleaning and repair of stormwater inlets, channels, and storm sewers required<br>Maintenance of open channel lining material required<br>Substantial maintenance required for pumping stations | Pumping and/or inlet-outlet control operation and maintenance required<br>Insect and odor control may be required<br>Periodic sediment removal, cleaning, *and maintenance* of facility lining required<br>Dam maintenance may be required | Same as centralized detention except that maintenance of onsite facilities required at a larger number of sites | Operation and maintenance required<br>Sediment removal required<br>Insect and odor control may be required<br>Weed and algae control and water pollution control may be required<br>Bank maintenance required | Same as centralized retention except that maintenance of onsite facilities required at a larger number of sites | Minimal |
| Impact on Sanitary Sewer System | Decrease clearwater inflow and infiltration | Runoff volumes in excess of available storage volume and runoff rates in excess of the capacity of receiving storm sewers and channels may be accompanied by inundation of streets and excessive inflow and infiltration of clear water<br>May increase groundwater levels and resulting infiltration | Same as centralized detention | Percolation waters may result in excessive infiltration of clear water into sanitary sewers | Same as centralized retention | Minimal |
| Hazards | Minimal public health and safety hazards associated with storm sewers<br>High velocities in improved open channels may pose a safety hazard to children | Minimal hazard associated with subsurface storage, but surface storage may pose a health and safety hazard | Ponded water in parking lots, small detention facilities, and swales may pose a health and safety hazard, particularly to children | Ponded water may pose a health and safety hazard, particularly to children | Ponded water may pose a health and safety hazard, particularly to children | Minimal |
| Hydrologic-Hydraulic Analysis | Requires determination only of the peak rate of flow associated with a specified recurrence interval storm *event using relatively simple* and widely accepted techniques | Requires determination of both a peak rate and a volume of inflow associated with a specified recurrence interval storm event of allowable outflow; and of storage. More complex technique must be used to simulate flows and volumes | Same as centralized detention | Same as centralized detention | Same as centralized detention | Requires delineation of areas affected by flooding and poor stormwater drainage. A more complex technique such as the Hydrologic Engineering Center (HEC-2) model must be used to determine flood stages under various recurrence interval storm events |
| Ability to Meet Stormwater Management Objectives | All objectives can be met, except that water quality standards may be violated in receiving waters unless combined with nonpoint source pollution control measures | This alternative would not satisfy the objectives by itself but must be combined with the conveyance approach to abate existing flooding and drainage problems. If detention basins are utilized, water use objectives may be violated in receiving waters unless combined with nonpoint source pollution control measures. If detention ponds are utilized, water use objectives can be met | Same as centralized detention | Same as centralized detention | Same as centralized detention | This alternative approach would not satisfy the recommended objectives by itself, and must be combined with other alternative approaches |

*Source: SEWRPC.*

Table 13

SELECTED CHARACTERISTICS OF SUBBASINS IN THE CRAYFISH CREEK SUBWATERSHED

| Subbasin | Area (acres) | Predominant Hydrologic Soil Type[a] | Existing 1980 Conditions | | | | Year 2000 Conditions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Percent Impervious | Peak Flows (cfs) | | | Percent Impervious | Peak Flows (cfs) | | |
| | | | | 2-Year | 10-Year | 100-Year | | 2-Year | 10-Year | 100-Year |
| Upper Crayfish | 457 | C | 11 | 50 | 60 | 90 | 30 | 120 | 125 | 195 |
| Oakwood | 757 | C | 11 | 70 | 85 | 125 | 33 | 160 | 175 | 270 |
| Meadowview | 688 | C | 13 | 90 | 110 | 115 | 40 | 210 | 215 | 225 |
| Caledonia | 1,362 | C | 10 | 110 | 125 | 190 | 25 | 220 | 240 | 400 |
| Lower Crayfish | 437 | C | 8 | 250[b] | 290[b] | 385[b] | 29 | 510[b] | 535[b] | 815[b] |

[a] *See Chapter II for a description of the four generalized hydrologic soil types and of the stormwater drainage characteristics of each type. Type C soils generally have low infiltration capacity, low permeability, and poor drainage characteristics.*

[b] *The estimated flow rates were developed based upon the entire tributary area of 3,701 acres, since the first four subbasins are tributary to the Lower Crayfish subbasin.*

*Source: SEWRPC.*

general feasibility and applicability of each approach to the Crayfish Creek subwatershed were determined.

Conveyance

The conveyance approach would utilize storm sewers and vegetation-lined, concrete-lined, or composite—vegetation- and concrete-lined—channels and related appurtenances to provide for the collection and relatively rapid conveyance of stormwater runoff to receiving streams. The major advantages of this type of approach are the minimization of onsite inconvenience because the stormwater is rapidly collected and conveyed downstream; and ready applicability to both existing and newly developing urban areas. Properly designed, constructed, and maintained storm sewers and channels present no hazard to the public health and safety, and the hydraulic design procedures, as well as the construction techniques, are relatively simple, well developed, and commonly used.

The disadvantages of the conveyance approach include: Downstream peak flows and stages and areas of inundation may be increased; pollutants are not removed from the runoff; and habitat for fish and other desirable forms of aquatic life may be reduced.

Application of the conveyance approach within the Crayfish Creek subwatershed would represent a continuation of the existing practices within the City of Oak Creek. Hence, this approach would likely be understood and accepted by local public officials and citizens alike. Technically, the existing stormwater management problems of the subwatershed, as well as probable future problems, could be abated using the conveyance approach. However, the conveyance approach may have impacts of concern to downstream communities.

Given the advantages of the conveyance approach, this alternative was considered feasible and applicable and was utilized in the development of alternative stormwater management system plans for the Crayfish Creek subwatershed.

Centralized Detention

A centralized detention approach would utilize major detention facilities to provide for the temporary storage of stormwater runoff for subsequent slow release to downstream channels or storm sewers. The centralized detention facilities would be located at one or more strategic sites to maximize benefits. The centralized detention facilities may be basins, which normally drain between storm events, or ponds, which retain a permanent pool of

water. The centralized detention facilities can be supplemented by improved conveyance facilities as necessary.

The major advantages of a centralized detention approach are that it limits the effects of urban development on downstream discharges, stages, and areas of inundation; it removes sediment and other particulate pollutants if detention ponds are utilized; it may reduce the size and cost of downstream conveyance facilities; and the facilities can provide recreation and open space benefits.

The disadvantages of a centralized detention approach are that relatively large, flat, open areas are needed as sites; the operation and maintenance requirements may be substantial; the detention lag may cause peak outflows to coincide with the peak flows from the total watershed, thus causing an increase in downstream peak flow rates and flood levels; for a permanent pool facility, the ponded water may be perceived as a public health and safety hazard; odor problems and insect nuisances may be produced; and the hydraulic design techniques and analytic procedures are more involved than those for conventional open channel drainage systems. Opposition to ponds or dry basins in urban areas by some citizens for aesthetic or health and safety reasons may make this approach impractical in some areas. While readily applicable as an integral part of large-scale urban development proposals, the approach is more difficult to apply to areas of existing urban development.

Within the Crayfish Creek subwatershed, centralized detention facilities alone would have only a minimal impact on the existing and potential flooding and stormwater runoff problems. Centralized detention would be useful only in the upper reaches of the subwatershed to reduce downstream conveyance needs or in conjunction with pumping facilities so that the sizes of the pumping facilities could be reduced; or where storage is needed while the outlet from the study area is restricted or closed by downstream flooding. Thus, detention storage in this particular subwatershed would be used only in conjunction with conveyance facilities. While detention basins would have limited use in reducing flooding and drainage problems in this subwatershed, such basins can be used for removal of nonpoint source pollutants. Because of its potential benefits when used in combination with other alternative approaches, the centralized detention approach was considered feasible and applicable, and was utilized in the development of alternative stormwater management plans for the Crayfish Creek subwatershed.

Decentralized Onsite Detention

Like centralized detention, decentralized onsite detention provides for the temporary storage of stormwater runoff, but the storage sites are located close to, or at, the source of runoff generation. Hence, these detention sites tend to be much smaller than centralized detention facilities. Decentralized onsite detention measures include small basins and ponds, parking lot storage, swales, and large channels with gentle slopes. To a certain extent, decentralized onsite detention is included in all alternative approaches to stormwater management in the Crayfish Creek subwatershed, since the land use plan for the subwatershed recommends the preservation of the remaining floodlands, wetlands, and other natural open areas comprising the primary environmental corridor lands within the subwatershed, all of which effectively serve as detention areas. The decentralized onsite detention systems, like centralized detention systems, can be supplemented by improved conveyance facilities.

Generally, the advantages of the decentralized onsite detention approach are similar to those of the centralized detention approach. However, decentralized onsite detention facilities may be less suitable than centralized detention facilities for multipurpose uses such as recreation and open space, but more suitable for uses such as parking or yard space in commercial and industrial areas.

A major disadvantage of the decentralized onsite detention approach is that the existing drainage problems could not, as a practical matter, be abated by this approach. Other disadvantages are that maintenance requirements may be substantial; the ponded water may cause local inconvenience and represent a health and safety hazard; odor problems and insect nuisances may be produced; hydraulic design techniques are more involved than for conveyance systems; and the capital costs may be high if not offset by smaller downstream conveyance systems. There may be citizen opposition to ponded water in urban areas, although the smaller sites and greater availability of potential sites may make this approach more acceptable than the centralized approach. While the onsite detention approach may be applicable as an integral part of large-scale urban development proposals, the concept is

difficult to effectively implement with small-scale, piecemeal development proposals and in areas of existing urban development.

The decentralized onsite detention approach could not be used to effectively abate the existing flooding and drainage problems in the study area, because the study area is currently poorly drained and has no system outlet capacity during prolonged periods of flooding on the Root River. Detaining additional stormwater on the land surface would not help to abate these problems. This approach was, however, considered applicable as a means of preventing future development from exacerbating the existing problems. Thus this approach was considered only as a means of limiting the sizing of the plan components to those needed to resolve problems under existing land use conditions. Decentralized onsite detention facilities were therefore considered as an alternative for reducing stormwater runoff from areas of future development.

Centralized Retention

A centralized retention approach would utilize major retention facilities and provide for the storage of stormwater runoff for subsequent evaporation and/or infiltration. The centralized retention facilities would be located at one or more strategic sites to maximize benefits. The retention facilities may be either a pond with an outlet that discharges only when the design storm is exceeded, or an infiltration system. This approach can also be supplemented by improved conveyance facilities.

The major advantages of the centralized retention approach are that it limits the effects of urban development on downstream peak discharges, stages, and areas of inundation; sediment and other particulate pollutants are removed; the size and resultant cost of downstream conveyance facilities may be reduced and the need for reconstruction sometimes avoided; the facilities can provide multipurpose open space areas; and the facilities can provide groundwater recharge.

The disadvantages of the centralized retention approach are that relatively large, flat, open areas are needed as sites; less permeable soils require large facilities; maintenance requirements are substantial; and for a permanent pool facility, the water quality of the pool may be poor. The effects on groundwater levels may create problems such as wet basements, costly operation of sump pumps, and excessive infiltration of clear water into sanitary sewers. Because of the large site requirements, this approach is generally suitable only in newly developing urban areas. Any permanently ponded water may present a health and safety hazard, and the hydraulic design and construction techniques are more involved than for conveyance systems.

Centralized retention facilities are not a feasible alternative for abating the stormwater management problems in the study area. The poorly drained soils limit the development of infiltration facilities, and evaporation ponds would need to be excessively large. Accordingly, centralized retention facilities were not considered an applicable alternative in the development of alternative stormwater management plans for the Crayfish Creek subwatershed.

Decentralized Onsite Retention

Like centralized retention, decentralized onsite retention provides for the temporary storage and subsequent infiltration and/or evaporation of stormwater runoff, but the storage sites are located close to, or at, the source of runoff generation. Hence, these sites can be made much smaller than centralized retention facilities.

The advantages of the decentralized onsite retention approach are similar to those of the centralized retention approach. Onsite retention facilities, however, do have smaller unit site requirements. Onsite facilities may be less suitable than centralized retention facilities for multipurpose uses such as recreation and open space, but more suitable for uses such as parking or yard space in residential areas.

Major disadvantages of the decentralized onsite retention approach are that the existing poor drainage problems would not be resolved, and the poorly drained soils are unsuitable for onsite infiltration facilities. Other disadvantages of the decentralized onsite retention approach are that maintenance requirements may be substantial; less permeable soils require larger facilities; the ponded water may cause local inconvenience and represent a health and safety hazard; odor problems and insect nuisances may be produced; hydraulic design techniques are more involved than for conveyance systems; and the costs may be high if not offset by smaller downstream conveyance systems. The decentralized onsite retention facilities could increase groundwater levels, which could create severe problems such as wet basements, costly operation of sump pumps,

and excessive infiltration of clear water into sanitary sewers. While the decentralized onsite retention approach may be applicable as an integral part of some large-scale urban development proposals, the concept is more difficult to effectively and dependably implement with small-scale, piecemeal development proposals and in areas of existing urban development.

Because of the general lack of soils conducive to infiltration in the area, the potential for odor and insect problems, and the potential adverse effects on groundwater levels, decentralized onsite retention facilities were not considered a viable alternative, and were not utilized in the development of alternative plans for the Crayfish Creek subwatershed.

Nonstructural Measures

The nonstructural approach to stormwater management primarily involves reducing damages from unusually high stormwater runoff and inundation rather than controlling the runoff rates or inundation levels themselves. Nonstructural measures include structure floodproofing, relocation of structures, land use regulations, and open space and floodland preservation.

The advantages of the nonstructural approach are that the measures are suitable for use in existing as well as newly developing urban areas; the measures are highly flexible and adaptable to different situations; the cost of nonstructural measures is generally low; the measures can often be used to create needed park and open space; and there are few hazards associated with nonstructural measures. The disadvantages of the nonstructural approach are that downstream water quantity and quality is generally not controlled; most stormwater problems are not abated; and condemnation of private property may be necessary.

Although the nonstructural approach was not directly utilized in the design of alternative stormwater management plans for the Crayfish Creek subwatershed, the approach was, in fact, indirectly incorporated into each alternative plan. The planned land use conditions, as described in Chapter III, provide for the protection of the existing primary environmental corridors, which contain the majority of the floodplain and wetland areas in the Crayfish Creek subwatershed, thereby minimizing stormwater damages and enhancing the natural water quantity and quality benefits of the floodplain and wetland areas.

## ALTERNATIVE STORMWATER MANAGEMENT PLANS

Utilizing the alternative stormwater management approaches described above, 17 alternative stormwater management system plans were developed for the Crayfish Creek subwatershed.

Alternative Stormwater Management System Plans

The alternative approaches to stormwater management considered for application in the Crayfish Creek subwatershed were conveyance and detention in various combinations. In addition, retention and nonstructural measures were incorporated into all of the plan alternatives in that the recommended land use pattern for the study area included the maintenance in essentially natural, open uses of the primary environmental corridor lands along Crayfish Creek, including substantial wetland and floodplain areas, as shown on Map 7 in Chapter III. Pertinent characteristics of the 17 alternatives are set forth in Table 14, and are shown on Maps 10 through 26. A brief description of each alternative is provided.

All alternatives require an internal system of storm sewers and open channels to provide a collection capability. These localized collection facilities are shown as part of the recommended plan in Chapter VI, and the cost of these facilities is included in the total cost of the recommended plan. Certain alternatives involve modification of this basic internal open channel collection system. This is true of those alternatives under which the proposed outlet location of the subwatershed is other than at its present location at S. Pennsylvania Avenue extended and E. County Line Road. The alternative outlet locations considered included S. Pennsylvania Avenue and E. Fitzsimmons Road extended to convey the stormwaters northerly to the Oak Creek watershed, and E. Elm Road and the Chicago & North Western Railway former lakeshore passenger line to convey the stormwater directly to Lake Michigan. The collection channels were assumed under each of the alternatives to be turf-lined, with side slopes of 1 on 4.

Because of the complexity of the existing flooding and drainage problems, alternative plans have been developed that would mitigate these

Table 14

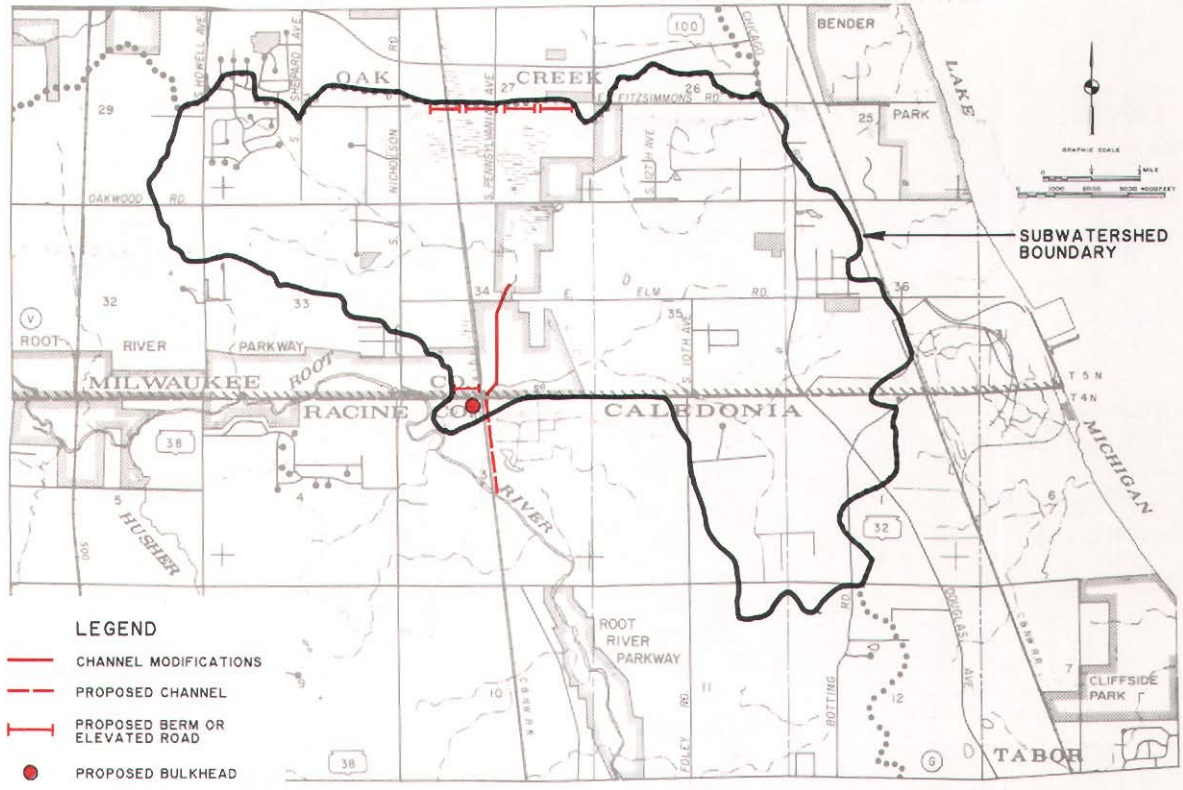
PERTINENT CHARACTERISTICS OF THE ALTERNATIVE STORMWATER MANAGEMENT SYSTEM PLANS CONSIDERED

| Alternative No. | Cost Rank | Collection Channel | Conveyance Channel | Backwater Gates | Pump | Storage | Force Main | Capital Cost | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 2-Year Recurrence Interval Design Storm | 10-Year Recurrence Interval Design Storm |
| 1 | 1 | X | X | | | | | $ 800,000 | $ 900,000 |
| 2 | 4 | X | X | | | | | 1,400,000 | 1,600,000 |
| 3 | 14 | X | X | | | | | 7,900,000 | 8,900,000 |
| 4 | 15 | X | X | | | | | 7,900,000 | 8,900,000 |
| 5 | 16 | X | X | | | | | 9,500,000 | 11,000,000 |
| 6 | 17 | X | X | | | | | 9,500,000 | 11,000,000 |
| 7 | 2 | X | X | X | | | | 1,100,000 | 1,300,000 |
| 8 | 5 | X | X | X | | | | 1,700,000 | 1,900,000 |
| 9 | 6 | X | | | X | | X | 2,300,000 | 2,800,000 |
| 10 | 9 | X | X | | X | | X | 3,200,000 | 3,800,000 |
| 11 | 13 | X | X | | X | | X | 4,800,000 | 5,700,000 |
| 12 | 10 | X | X | X | | X | | 2,600,000 | 4,200,000 |
| 13 | 12 | X | X | X | | X | | 3,600,000 | 5,400,000 |
| 14 | 7 | X | | | X | X | X | 2,300,000 | 3,100,000 |
| 15 | 8 | X | | | X | X | X | 2,800,000 | 3,500,000 |
| 16 | 11 | X | X | | X | X | X | 4,200,000 | 4,900,000 |
| 17 | 3 | X | X | X | | | | 1,200,000 | 1,400,000 |

*Source: SEWRPC.*

Map 10

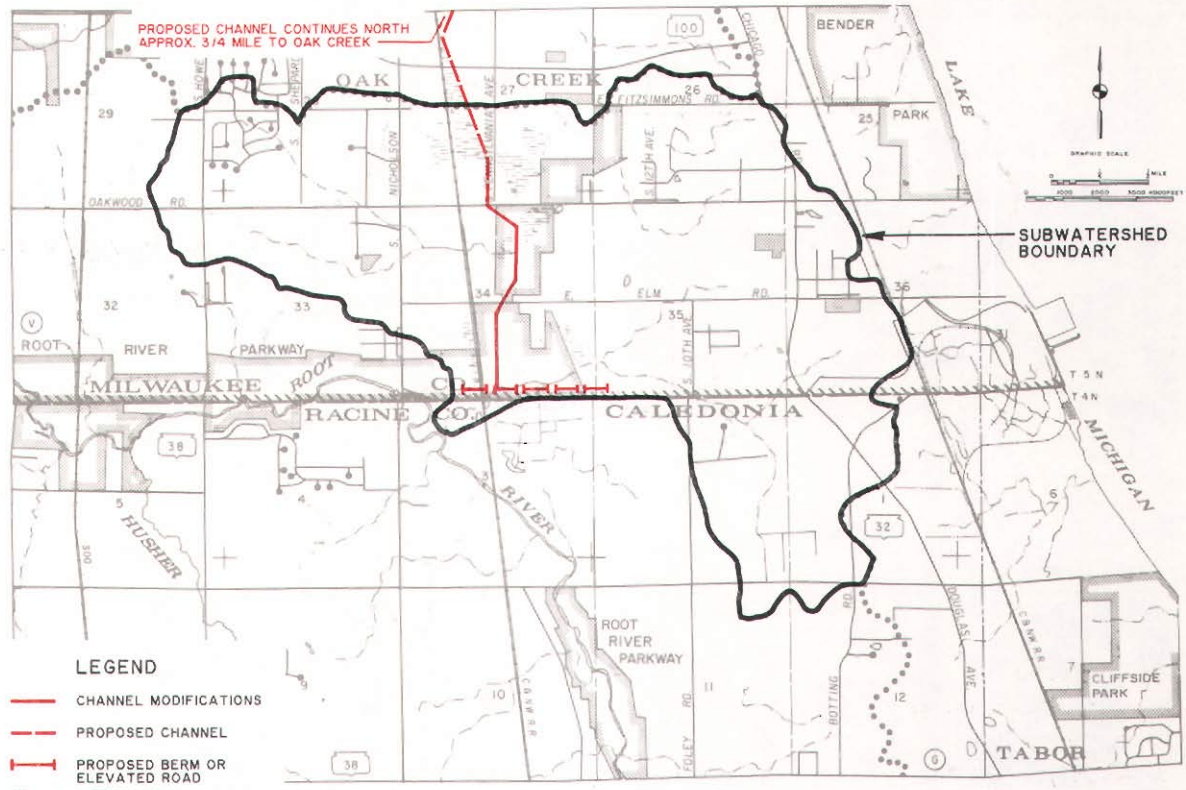
## ALTERNATIVE 1: CONVEYANCE TO ROOT RIVER VIA ROUTE A




*Source: SEWRPC.*

Map 11

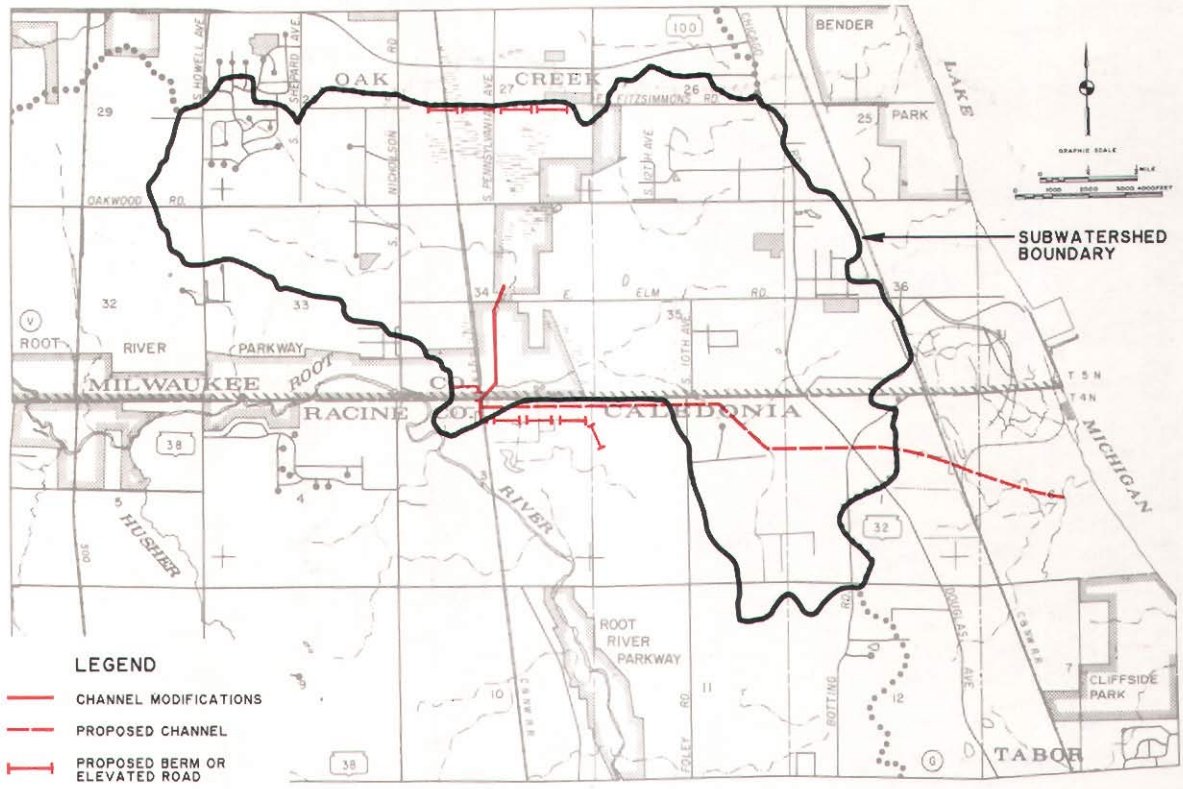
## ALTERNATIVE 2: DIVERSION CONVEYANCE TO OAK CREEK




*Source: SEWRPC.*

Map 12

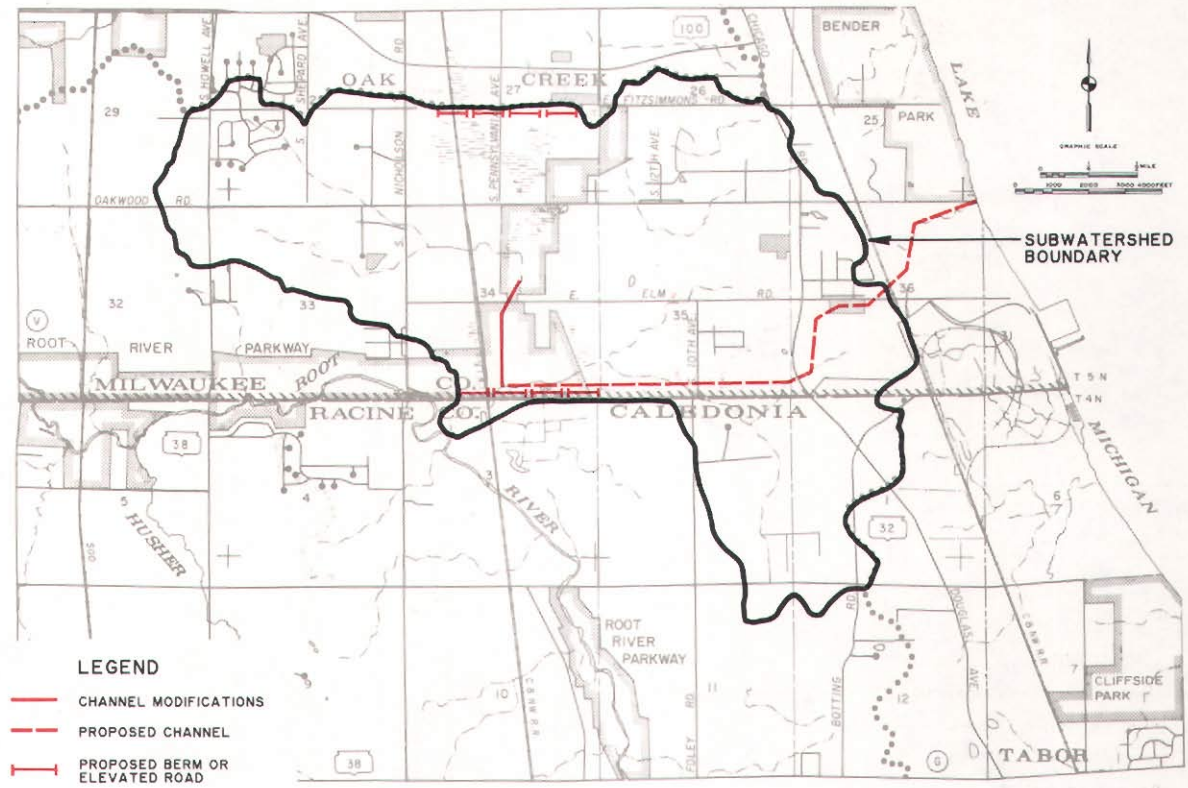
## ALTERNATIVE 3: DIVERSION CONVEYANCE TO LAKE MICHIGAN–A




*Source: SEWRPC.*

Map 13

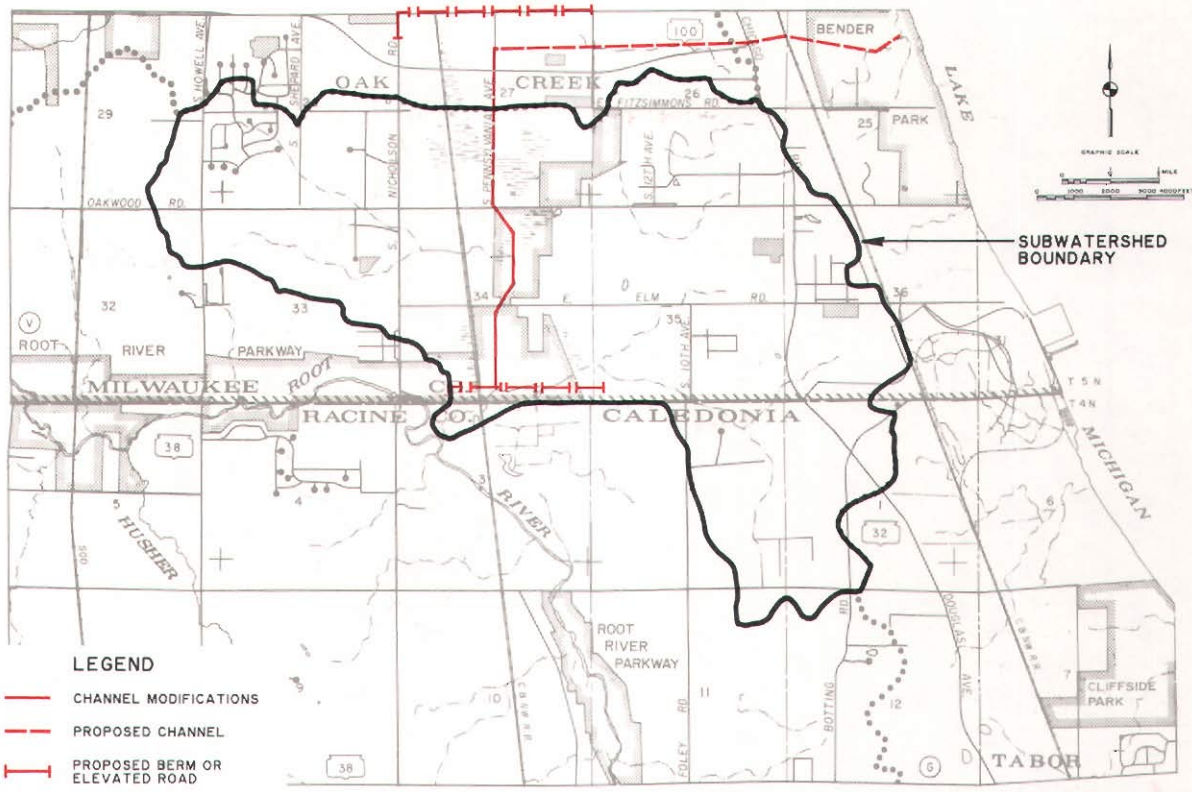
## ALTERNATIVE 4: DIVERSION CONVEYANCE TO LAKE MICHIGAN–B




*Source: SEWRPC.*

Map 14

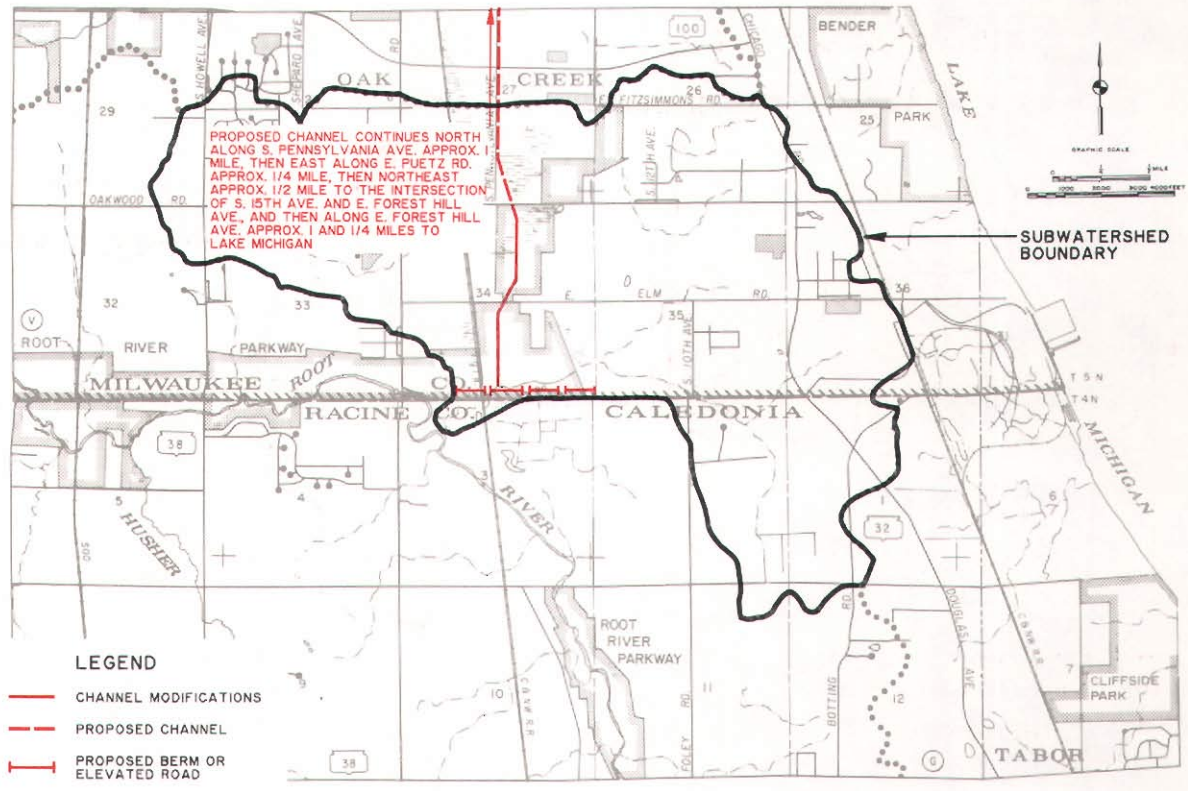
## ALTERNATIVE 5: DIVERSION CONVEYANCE TO LAKE MICHIGAN–C




*Source: SEWRPC.*

Map 15

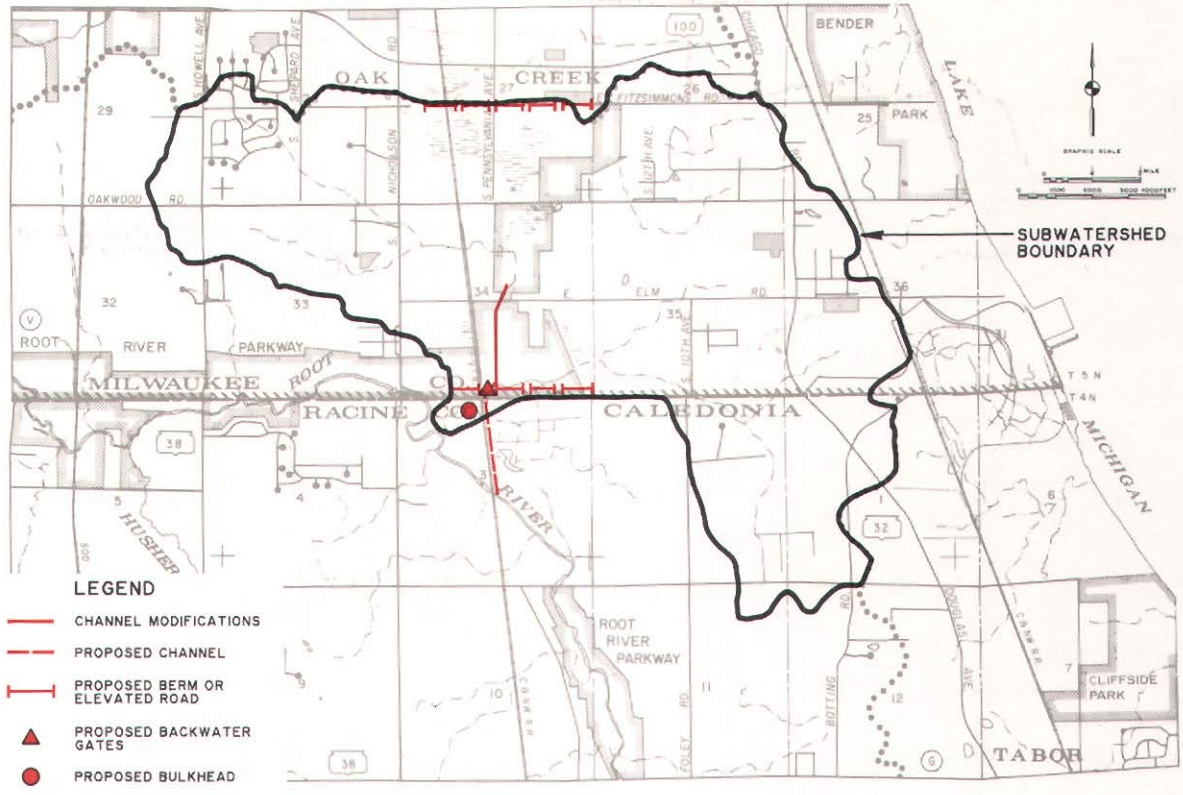
## ALTERNATIVE 6: DIVERSION CONVEYANCE TO LAKE MICHIGAN–D




*Source: SEWRPC.*

Map 16

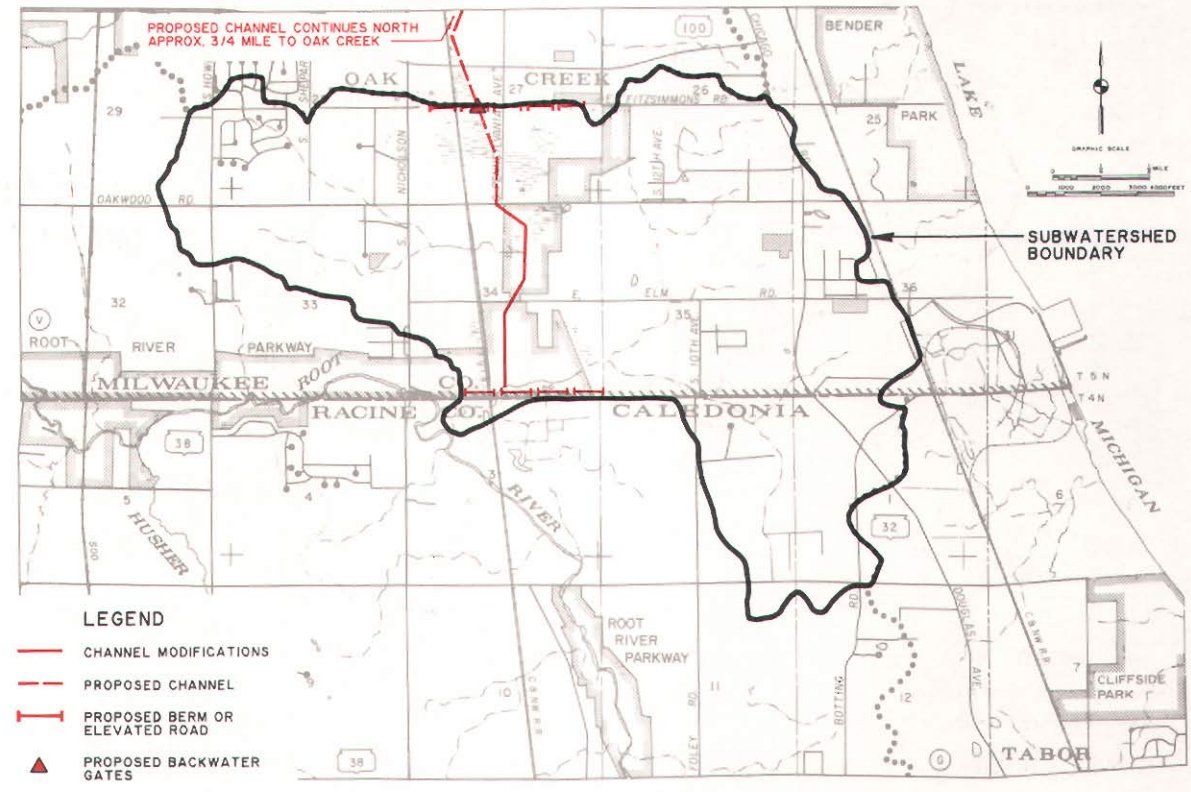
## ALTERNATIVE 7: CONVEYANCE TO ROOT RIVER VIA ROUTE A WITH BACKWATER GATES




*Source: SEWRPC.*

Map 17

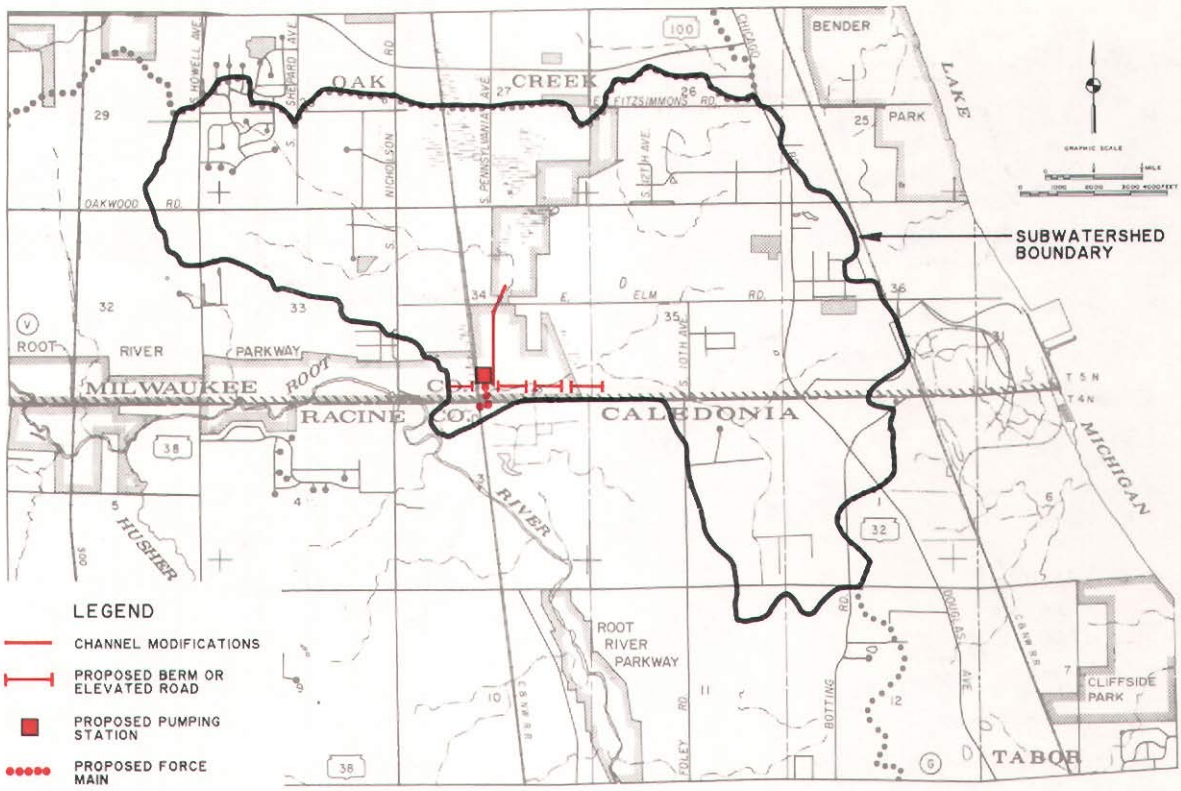
## ALTERNATIVE 8: DIVERSION CONVEYANCE TO OAK CREEK




*Source: SEWRPC.*

Map 18

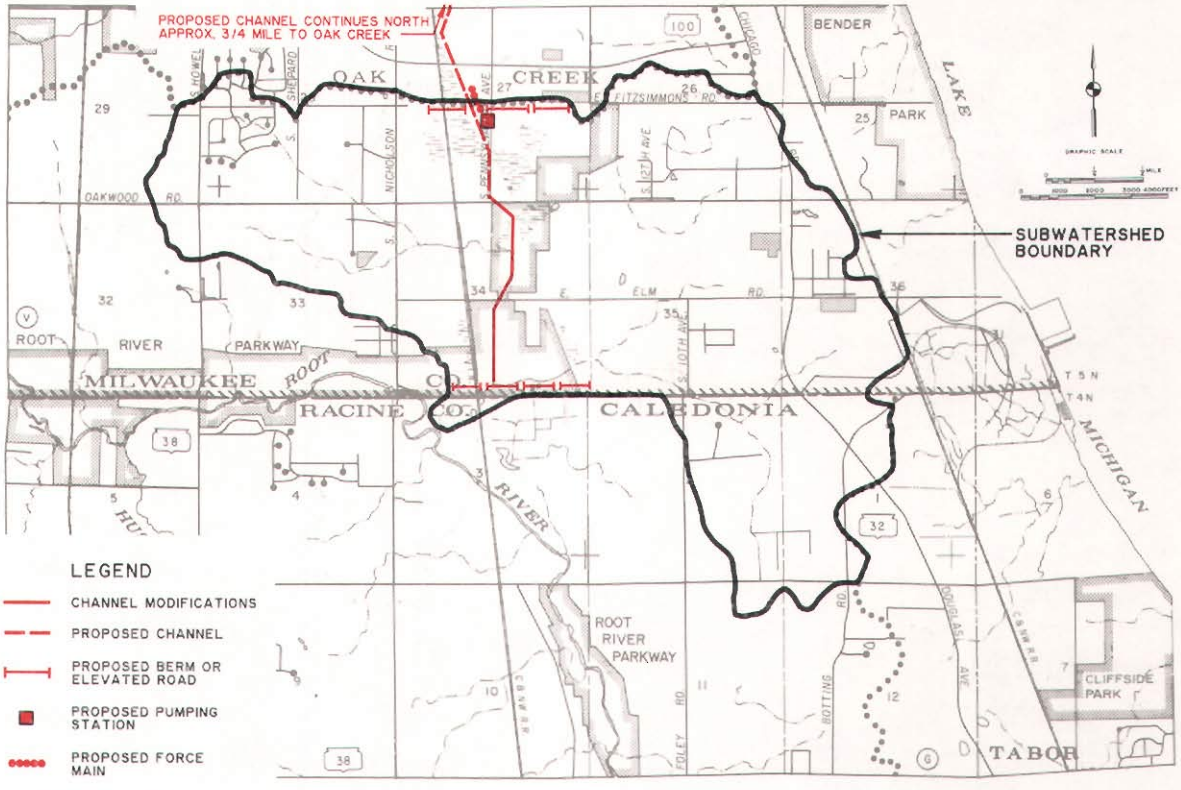
## ALTERNATIVE 9: PUMPING TO ROOT RIVER




*Source: SEWRPC.*

Map 19

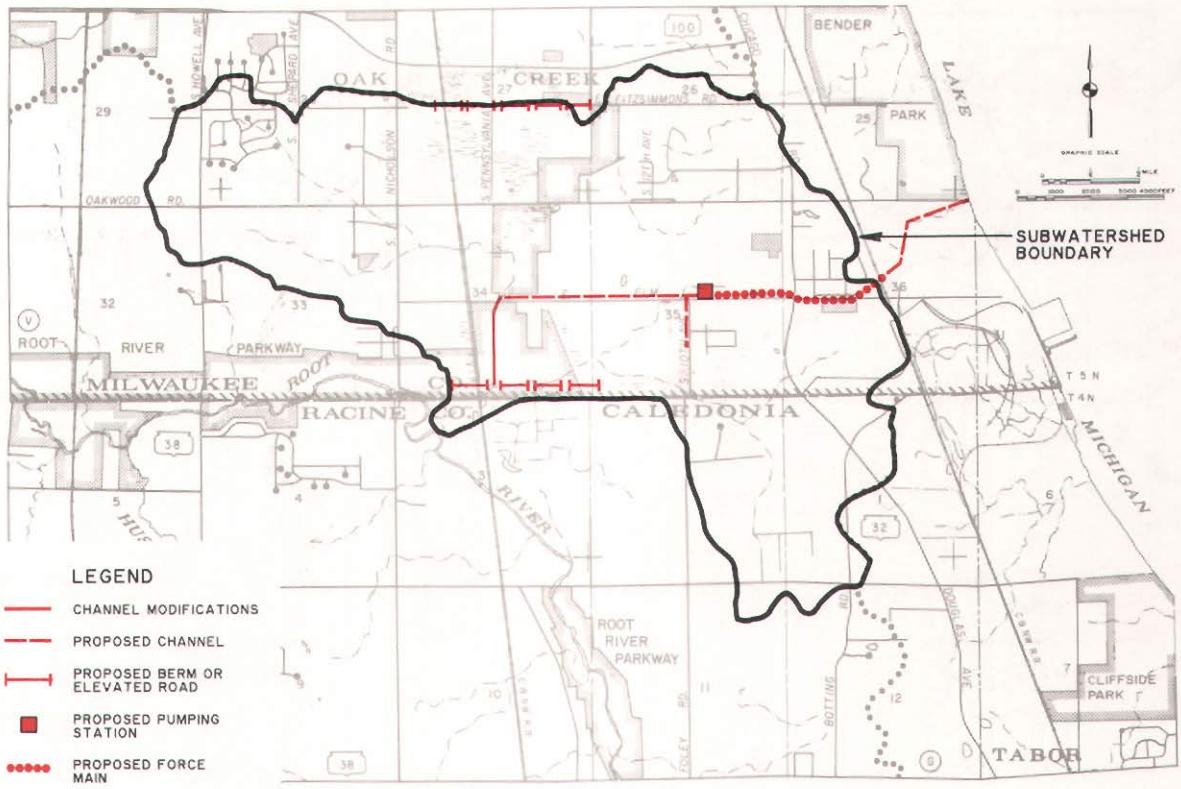
## ALTERNATIVE 10: PUMPING TO OAK CREEK




*Source: SEWRPC.*

Map 20

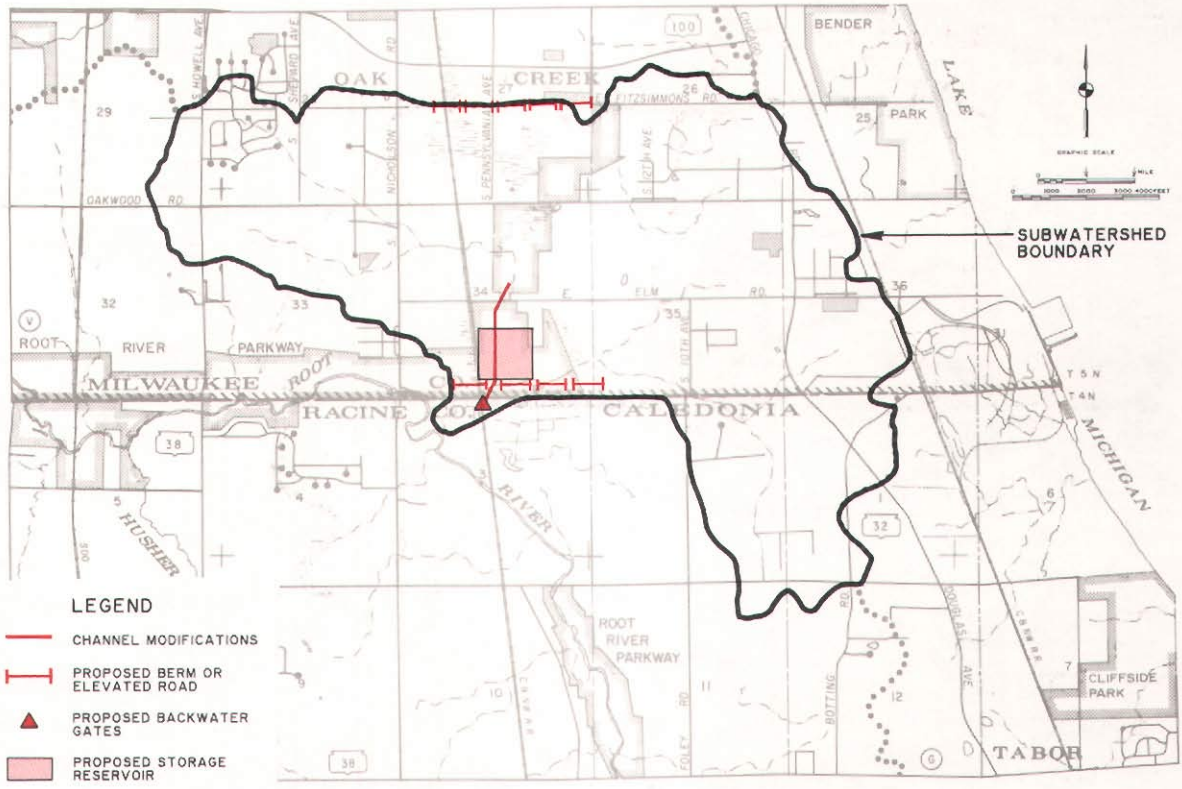
## ALTERNATIVE 11: DIVERSION PUMPING TO LAKE MICHIGAN




*Source: SEWRPC.*

Map 21

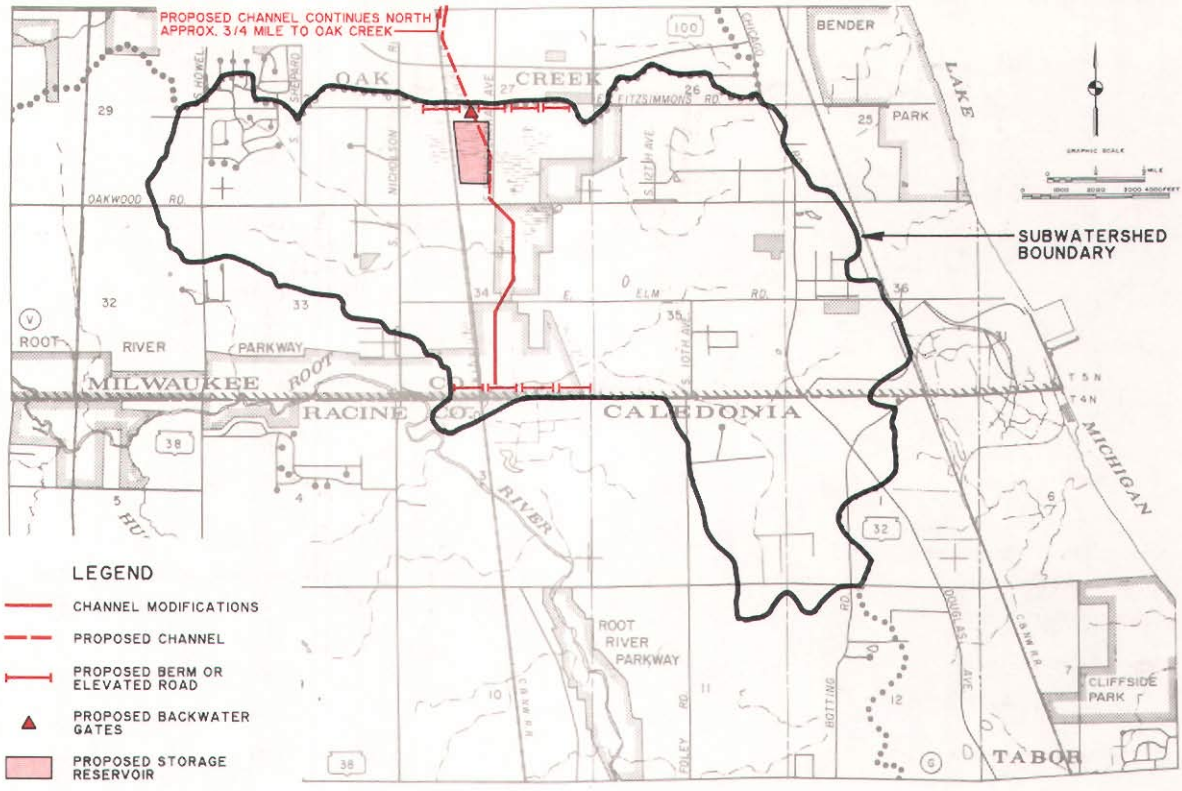
## ALTERNATIVE 12: STORAGE AND CONVEYANCE TO ROOT RIVER VIA ROUTE A




*Source: SEWRPC.*

Map 22

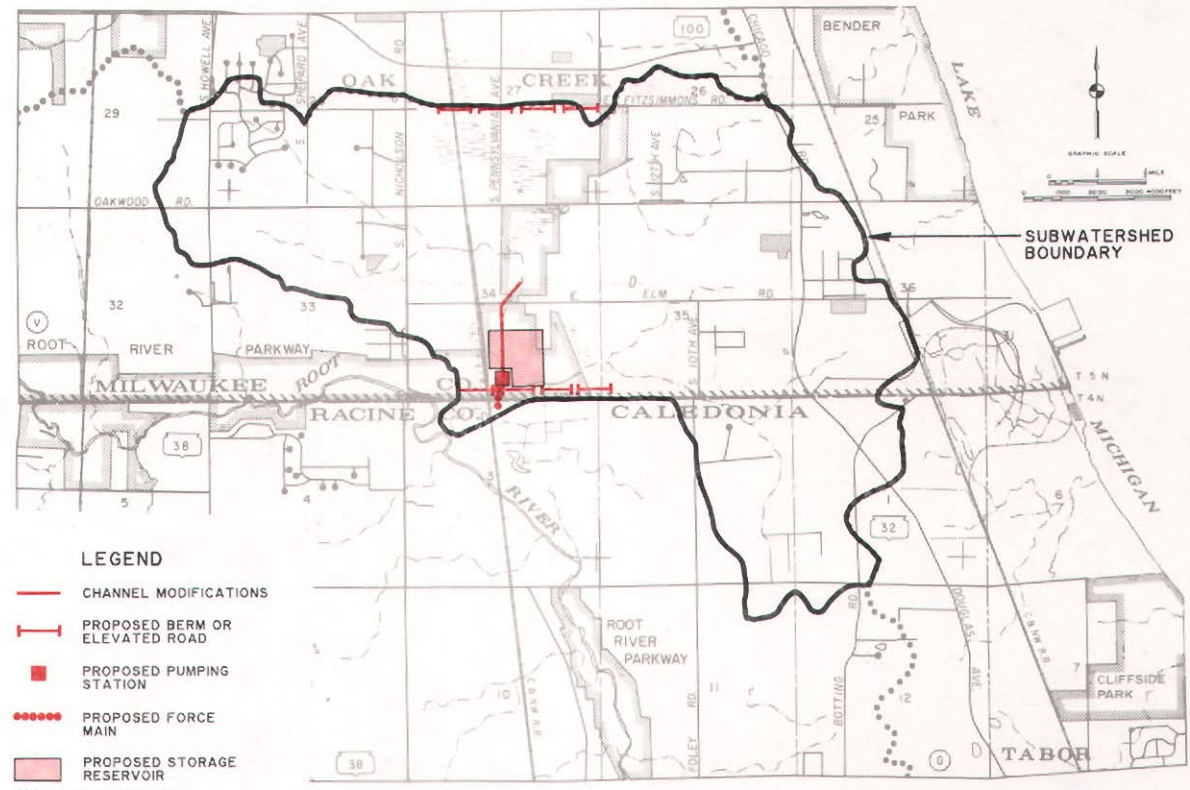
## ALTERNATIVE 13: STORAGE AND DIVERSION BY CONVEYANCE TO OAK CREEK




*Source: SEWRPC*

Map 23

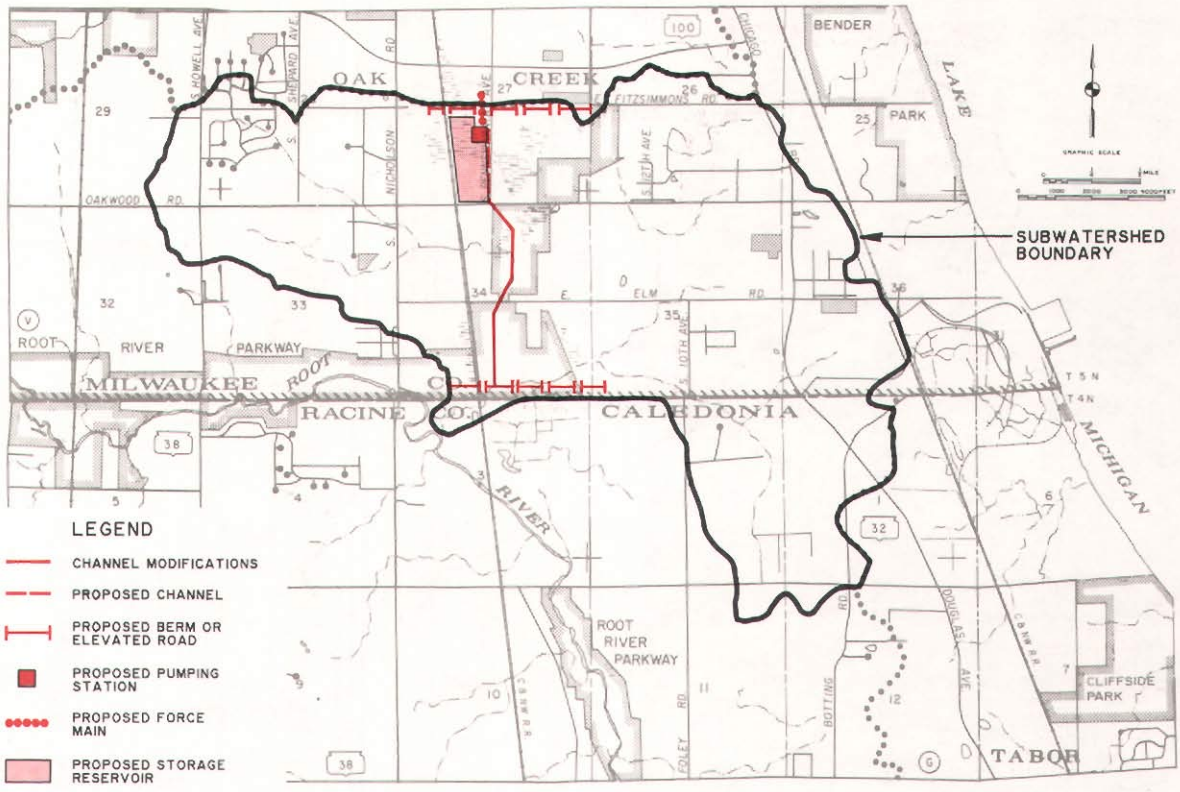
## ALTERNATIVE 14: STORAGE AND PUMPING TO ROOT RIVER




*Source: SEWRPC.*

Map 24

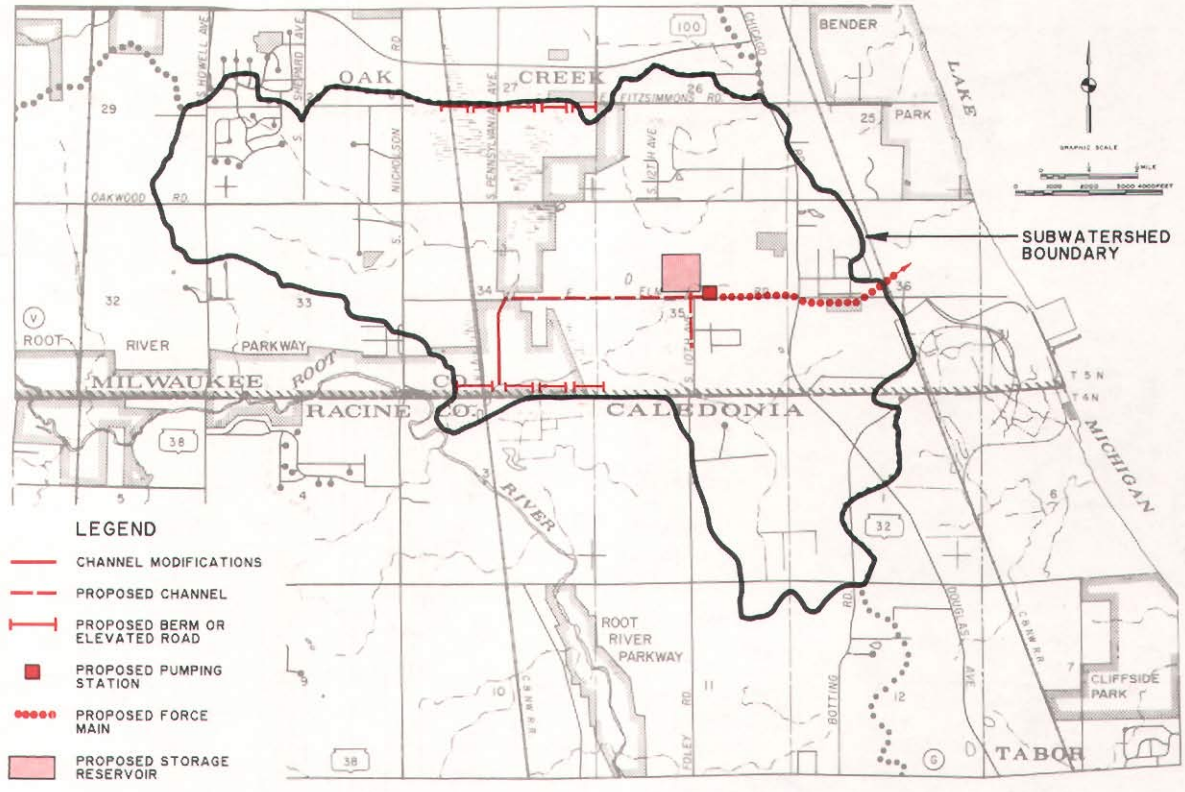
## ALTERNATIVE 15: STORAGE AND DIVERSION PUMPING TO OAK CREEK




*Source: SEWRPC.*

Map 25

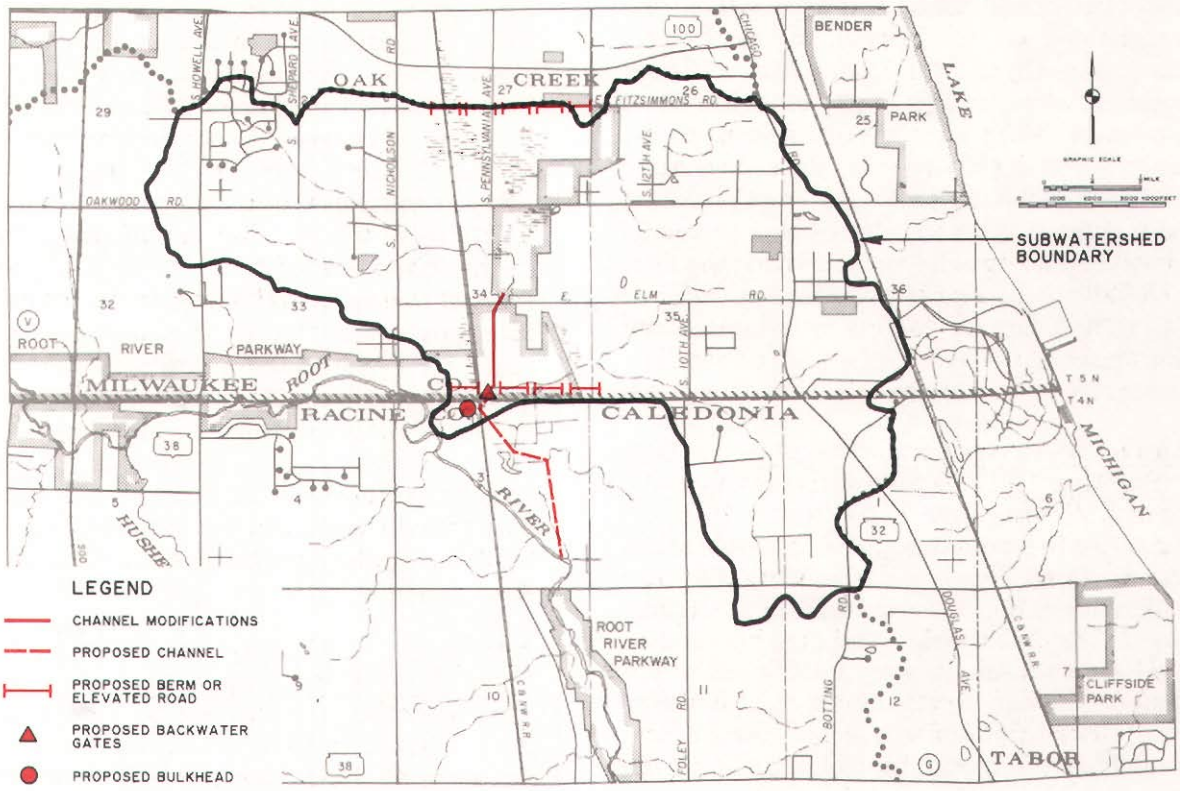
## ALTERNATIVE 16: STORAGE AND PUMPING TO LAKE MICHIGAN




*Source: SEWRPC.*

Map 26

ALTERNATIVE 17: CONVEYANCE TO ROOT RIVER VIA ROUTE D




*Source: SEWRPC.*

problems to varying degrees. In the alternative evaluation, the alternatives were placed in one of three categories based on the degree to which they serve to mitigate flooding and drainage problems.

The first category of mitigation applies to alternatives with improved internal drainage systems within the Crayfish Creek subwatershed, but with no provisions to eliminate backed-up floodwaters from the Root River and Oak Creek into the subwatershed. These alternatives were categorized as providing a limited degree of abatement of the flooding and drainage problems.

The second category of mitigation applies to alternative plans that provide for an improved internal drainage system within the Crayfish Creek subwatershed, and include provisions to seal off the backed-up floodwaters from the Root River and Oak Creek. Under this category of alternatives, the outlets from the watershed would be closed during flooding periods on the Root River and Oak Creek, and thus some flooding and drainage problems would remain. These alternatives were considered to provide a significant degree of abatement of the flooding and drainage problems.

Finally, the third category of mitigation applies to those alternatives with improved internal drainage systems within the Crayfish Creek subwatershed, provisions to seal off the backed-up floodwaters from the Root River and Oak Creek, and an adequate outlet from the subwatershed at all times. These alternatives were categorized as providing a high degree of abatement of the flooding and drainage problems.

Alternative 1—Conveyance to Root River via Route A (See Map 10): This alternative involves the construction of a drainage channel from the Root River adjacent to and along the east side of the Chicago & North Western Railway right-of-way in the Town of Caledonia northerly to County Line Road. The culverts beneath the Chicago & North Western tracks through which Crayfish Creek presently drains would be bulkheaded to divert the flow to the Root River via the new channel. A berm would also be constructed along about 500 feet of E. County Line Road west from the Chicago & North Western tracks. Crayfish Creek would be deepened and widened from where it enters the new channel just south of E. County Line Road northerly to E. Elm Road in the City of Oak Creek. Also, a berm along E. Fitzsimmons Road extended would be installed between S.

15th Avenue and just west of the Chicago & North Western tracks under this alternative. The backwater flood elevations from the Root River would be lowered by about 1.0 foot during a 10-year recurrence interval storm event as a result of the new outlet being located downstream of the present outlet to the Root River. This alternative would abate the flooding and drainage problems only to a limited degree in that those problems caused by the backup of floodwaters from the Root River would not be sufficiently abated. Similar but preferable alternatives were investigated and described under Alternatives 7 and 17. Therefore, this alternative was not considered further.

Alternative 2—Diversion Conveyance to Oak Creek (See Map 11): This alternative involves the raising of E. County Line Road from S. 15th Avenue extended to a point about 500 feet west of the Chicago & North Western Railway right-of-way and bulkheading the culverts beneath E. County Line Road. Crayfish Creek would then be widened and graded to reverse its flow northward to the abandoned Chicago North Shore & Milwaukee Electric Railway right-of-way. From there a new diversion channel would be constructed to the north, outletting to Oak Creek south of Puetz Road. Under this alternative, the backwater flood elevations from Oak Creek would extend into the study area. Under existing land use conditions, these elevations are about two feet lower than those of the Root River at the outlet location provided under Alternative 1. However, under planned land use conditions in the Oak Creek watershed, the flood elevation at the Oak Creek outlet would be about the same as at the Root River outlet. The duration of backwater flooding would, however, be reduced. This alternative would reduce the flooding and drainage problems within the study area only to a limited degree in that those problems caused by the backed-up floodwaters from Oak Creek would not be abated. Therefore, this alternative was not considered further.

Alternatives 3 through 6—Diversion Conveyance to Lake Michigan (See Maps 12, 13, 14, and 15): Each of these alternatives involves conveying stormwater runoff by gravity flow from the Crayfish Creek subwatershed directly to Lake Michigan. Four different conveyance routes were considered, and each alternative involved either the raising of E. County Line Road from S. 15th Avenue extended to a point about 500 feet west of the Chicago & North Western Railway right-of-way and bulkheading cross culverts under E. County Line Road, or the construction of a berm parallel to and just south of County Line Road between S. 15th Avenue extended and a point about 500 feet west of the Chicago & North Western right-of-way. Also, under Alternatives 3 and 4, a berm along E. Fitzsimmons Road extended would be installed between S. 15th Avenue and just west of the Chicago & North Western tracks under this alternative. While each of these alternatives would solve the flooding and drainage problems in the subwatershed to a high degree, the capital costs of these alternatives were the highest of the alternatives considered. Because of these high costs, only Alternative 4 was considered further. The cost of Alternative 4 was found to be similar to that of Alternative 3, and lower than the costs of Alternatives 5 and 6. In addition, the diversion facilities required would be located entirely in the City of Oak Creek, and would thus be more readily implementable than the diversion facilities under Alternative 3.

Alternative 7—Conveyance to Root River via Route A, with Backwater Gates (See Map 16): This alternative is similar to Alternative 1 in that it would involve the construction of a new drainage channel from the Root River adjacent to and along the east side of the Chicago & North Western Railway right-of-way in the Town of Caledonia northerly to E. County Line Road and the existing Crayfish Creek channel. The culvert beneath the Chicago & North Western right-of-way through which Crayfish Creek drains would be bulkheaded to divert the flow to the Root River via the new channel. As in Alternative 1, Crayfish Creek would be widened and deepened from where it would enter the new channel south of E. County Line Road to E. Elm Road in the City of Oak Creek. Also, a berm along E. Fitzsimmons Road extended would be installed between S. 15th Avenue and just west of the Chicago & North Western right-of-way under this alternative. Further, E. County Line Road would be raised from S. 15th Avenue extended to a point about 450 feet west of the Chicago & North Western right-of-way. Finally, six backwater gates would be installed on the multiple culverts carrying Crayfish Creek under E. County Line Road. Under this alternative, the flooding and drainage problems of the subwatershed would be abated to a significant degree, although not fully eliminated since the outlet of Crayfish Creek would be closed for extended periods when the Root River flood stages were high. This would, however, constitute a substantial improvement over existing conditions, since in most cases the peak flows in Crayfish Creek would be discharged

prior to the Root River flood stages being reached. Therefore, this alternative was considered further.

Alternative 8—Diversion Conveyance to Oak Creek (See Map 17): This alternative is the same as Alternative 2 with two additions: A berm would be constructed at E. Fitzsimmons Road extended from S. 15th Avenue to just west of the Chicago & North Western Railway right-of-way, and six backwater gates would be installed on the multiple culverts beneath the proposed berm located south of E. Fitzsimmons Road extended carrying stormwater runoff to the Oak Creek channel. Under this alternative, the flooding and drainage problems would be abated to a significant degree, although not fully eliminated since the new outlet from the subwatershed would be closed for extended periods when the Oak Creek flood stages were high. Since the peak flows and stages in the Oak Creek watershed and in the Crayfish Creek subwatershed occur at similar times, the impacts of this diversion on Oak Creek flood flows and stages would be a major concern and an impediment to implementation. In addition, the costs of this alternative are higher than those of Alternative 7. Therefore, this alternative was not considered further.

Alternative 9—Pumping to Root River (See Map 18): This alternative is the same as Alternative 1 except that the stormwater runoff would be pumped to the Root River. A stormwater pumping station would be constructed north of E. County Line Road and east of the Chicago & North Western Railway right-of-way. A force main would be installed under E. County Line Road from the pumping station and would discharge into the existing Crayfish Creek channel. Crayfish Creek would be deepened and widened from the pumping station northerly to E. Elm Road. This alternative would reduce the drainage and flooding problems in the study area to a high degree. Moreover, the cost of this alternative is less than that of a similar alternative which would provide for discharge to Oak Creek. Thus, this alternative was considered further.

Alternative 10—Pumping to Oak Creek (See Map 19): This alternative is similar to Alternative 2 with three additions. First, a berm would be constructed along E. Fitzsimmons Road extended from S. 15th Avenue to just west of the Chicago & North Western Railway right-of-way. Second, a stormwater pumping station would be installed at E. Fitzsimmons Road extended west of S. Pennsylvania Avenue. Third, a force main would be installed under the E. Fitzsimmons Road berm from the pumping station to the new channel. This alternative would reduce the drainage and flooding problems in the subwatershed to a high degree. However, the cost of this alternative is greater than the cost of a similar alternative—Alternative 9—and the downstream impacts on Oak Creek could be more severe. Thus, this alternative was not considered further.

Alternative 11—Diversion Pumping to Lake Michigan (See Map 20): Under this alternative, a berm would be constructed along E. Fitzsimmons Road extended from S. 15th Avenue to just west of the Chicago & North Western Railway right-of-way. East County Line Road would be raised from S. 15th Avenue extended to the Chicago & North Western right-of-way. Crayfish Creek would be widened and the flow reversed from E. County Line Road northerly to E. Elm Road. A new drainage channel would be constructed along the north side of E. Elm Road draining from Crayfish Creek to S. 10th Avenue. A pumping station would be constructed there, and a force main laid from the pumping station easterly along E. Elm Road to the Chicago & North Western right-of-way. An existing drainage channel would be enlarged to transport stormwater from the force main to Lake Michigan. This reconstructed channel would run in a northeasterly direction, from the force main outfall east of the Chicago & North Western right-of-way to Lake Michigan. This alternative would reduce the flooding and drainage problems in the subwatershed to a high degree, and there would be limited impacts on downstream flooding. Therefore, this alternative was considered further.

Alternative 12—Storage and Conveyance to Root River via Route A (See Map 21): This alternative would involve the construction of a berm along E. Fitzsimmons Road extended from S. 15th Avenue to just west of the Chicago & North Western Railway right-of-way, and the raising of E. County Line Road between S. 15th Avenue extended and the Chicago & North Western right-of-way. In addition, Crayfish Creek would be widened and deepened from E. Elm Road to just south of E. County Line Road in the Town of Caledonia. Six backwater gates would be installed on the multiple culverts carrying Crayfish Creek under E. County Line Road at this point. A detention basin would be constructed north of E. County Line Road adjacent to the Chicago & North Western right-of-way. The basin could

include a pond with a permanent pool to provide removal of pollutants in the stormwater. Under this alternative, the flooding and drainage problems in the subwatershed would be abated to a significant degree, although not fully eliminated since the outlet of Crayfish Creek would be closed for extended periods when the Root River flood stages were high. This would, however, constitute a substantial improvement over existing conditions, since in most cases the peak flows in Crayfish Creek would be discharged prior to the Root River flood stages being reached. The detention basin would provide storage to mitigate downstream impacts. The cost of this alternative is less than that of a similar alternative providing for discharge to Oak Creek, and the downstream impacts would be attenuated. Therefore, this alternative was considered further.

Alternative 13—Storage and Diversion by Conveyance to Oak Creek (See Map 22): This alternative is the same as Alternative 8 with one addition: A detention basin would be constructed south of E. Fitzsimmons Road between S. Pennsylvania Avenue and the Chicago & North Western Railway right-of-way. The detention basin could include a pond with a permanent pool to provide removal of pollutants in the stormwater. Stormwater runoff from the Crayfish Creek subwatershed would drain by gravity northerly to the Oak Creek channel. This alternative plan would abate the flooding and drainage problems in the subwatershed to a significant degree, but would not fully eliminate those problems, since the backwater gate at the outlet would be closed during high flood stages on Oak Creek. Downstream impacts would be attenuated by the detention basin. This alternative is more costly than a similar alternative providing an outlet to the Root River—Alternative 12. Thus, this alternative was not considered further.

Alternative 14—Storage and Pumping to Root River (See Map 23): This alternative involves constructing a berm along E. Fitzsimmons Road extended between S. 15th Avenue and just west of the Chicago & North Western Railway right-of-way, and the raising of E. County Line Road from S. 15th Avenue extended to the Chicago & North Western right-of-way. A pumping station would be constructed north of E. County Line Road and east of the Chicago & North Western right-of-way, and a force main installed under E. County Line Road from the proposed pumping station to the existing Crayfish Creek channel. Crayfish Creek would be widened and deepened from the proposed pumping station northward to E. Elm Road. A detention basin would be constructed adjacent to the proposed pumping station. The basin could include a pond with a permanent pool to provide removal of pollutants in the stormwater. This alternative would abate the flooding and drainage problems of the watershed to a high degree. The cost of this alternative would be somewhat lower than the cost of any other pumping alternative. Thus, this alternative was considered further.

Alternative 15—Storage and Diversion Pumping to Oak Creek (See Map 24): This alternative is similar to Alternative 10 with two exceptions. First, a detention basin would be constructed between S. Pennsylvania Road extended, the Chicago & North Western Railway right-of-way, E. Oakwood Road, and E. Fitzsimmons Road. The basin could include a pond with a permanent pool to provide removal of pollutants in the stormwater. Also, under this alternative, stormwater runoff would be discharged from the force main north of E. Fitzsimmons Road at S. Pennsylvania Road into the existing drainage ditch, no diversion channel being needed. The stormwater runoff would then flow northerly into Oak Creek. This alternative would abate the flooding and drainage problems of the subwatershed to a high degree. Since the peak flows from the Crayfish Creek subwatershed and the Oak Creek watershed have similar times of concentration, the impacts on Oak Creek would be a major concern and an impediment to implementation. The cost of this alternative would be higher than the cost of Alternative 14, which would provide stormwater storage and an outlet to the Root River. Therefore, this alternative was not considered further.

Alternative 16—Storage and Pumping to Lake Michigan (See Map 25): This alternative is similar to Alternative 11 with two exceptions. First, under this alternative, a detention basin would be constructed north of the intersection of E. Elm Road and S. 10th Avenue. The basin could include a pond with a permanent pool to provide removal of pollutants in the stormwater. Second, under this alternative, the force main from the proposed pumping station would discharge into the existing watercourse north of E. Elm Road east of the Chicago & North Western Railway right-of-way and then direct flow to Lake Michigan. This alternative would abate the flooding and drainage problems of the subwatershed to a high degree and downstream impacts would be minimal. The cost of this alternative, however, would be higher

than that of any of the other storage alternatives considered. Therefore, this alternative was not considered further.

Alternative 17—Conveyance to Root River via Route D (See Map 26): This alternative is similar to Alternative 7 with the following exception: The outlet channel from E. County Line Road south would follow the route of the channel proposed under Alternative D of the City of Oak Creek drainage study, dated November 1981, prepared by Zimmerman Engineering Corporation, as shown on Map 26. Accordingly, stormwater runoff from the subwatershed would enter the Root River approximately one-quarter mile upstream of the 7-Mile Road bridge, the channel skirting the east side of the existing landfill site. Under this alternative, the flooding and drainage problems of the subwatershed would be abated to a significant degree, although not eliminated since the outlet of Crayfish Creek would be closed for extended periods when the Root River flood stages were high. This would, however, be a substantial improvement over existing conditions, since in most cases the peak flows in Crayfish Creek would be discharged prior to the Root River flood stages being reached. This alternative would allow for the use of an existing pond located south of County Line Road for nonpoint source pollution abatement purposes. The cost of this alternative is relatively low. Therefore, this alternative was considered further.

## EVALUATION OF ALTERNATIVE STORMWATER MANAGEMENT PLANS

The preceding section described the 17 alternative stormwater management system plans considered for the Crayfish Creek subwatershed area. Based upon a general evaluation of these alternatives, seven were identified for further consideration. Additional information was developed for each of these seven alternatives to provide a basis for a comparative evaluation. The seven alternatives would resolve the identified flooding and drainage problems of the subwatershed to varying degrees. In addition to the degree of flooding and drainage problem mitigation, the principal criteria considered in the comparative evaluation were cost, water quality protection, development restriction, operation and maintenance requirements, impact on downstream flows, and public acceptance. The findings of the comparative evaluation of the alternatives are summarized in Table 15. Table 16 compares the capital costs, the additional annual operation and maintenance costs, and the 50-year present worth of each alternative.

Alternatives 4, 7, and 17 would involve conveyance to the Root River or Lake Michigan without any required pumping or storage of stormwater. All three of these alternatives would provide little pollution abatement, would have low operation and maintenance costs, would have little impact on downstream flows, and with the exception of Alternative 4, may be expected to have a high degree of public acceptance. Alternative 4, which would involve diversion to Lake Michigan, would have a relatively high cost, would severely restrict development of some areas of the subwatershed, and may be expected to have a low degree of public acceptance. Alternative 4 would, however, abate the flooding and drainage problems in the subwatershed to a high degree, since the outlet elevation at Lake Michigan would allow adequate drainage in the subwatershed, and the effects of the backwater from the flooding of the Root River would be eliminated. Alternative 7, which would involve conveyance to the Root River, would have a relatively low cost and would not significantly restrict development in the subwatershed. This alternative would abate the flooding and drainage problems to a significant degree, although less so than Alternative 4, or than any alternative utilizing pumping, since the outlet to the Root River would be closed under flooding conditions, and stormwater generated in the Crayfish Creek subwatershed would be stored within the subwatershed. Flows from the Crayfish Creek subwatershed will normally peak prior to flows on the Root River, thus requiring storage only during periods following the peak flows. This alternative would provide an outlet elevation that is about 1.0 foot lower than under existing conditions. Alternative 17, which would also involve conveyance to the Root River but along a different route than under Alternative 7, would have a relatively low cost, and would not significantly restrict development within the subwatershed. This alternative would abate flooding and drainage problems to the same degree as would Alternative 7.

Alternative 9 would involve pumping to the Root River and Alternative 11 would involve diversion pumping to Lake Michigan. Neither alternative would provide for the storage of stormwater. Both of these alternatives would provide little pollution abatement, would have moderate operation and maintenance requirements, and would have

## Table 15

## SUMMARY COMPARISON OF ALTERNATIVE STORMWATER MANAGEMENT SYSTEM PLANS

| Alternative Plan | Abatement of Drainage and Flooding Problems | Water Quality | 50-Year 6 Percent Equivalent Average Annual Cost | Development Restrictions | Operation and Maintenance Requirements | Impact on Downstream Flows | Public Acceptance |
|---|---|---|---|---|---|---|---|
| 4—Diversion Conveyance to Lake Michigan | Flooding and drainage problems would be abated to a high degree | Increased pollutant loadings would be discharged directly to Lake Michigan, while pollutant loadings to the Root River would decrease. Some pollutant removal would be provided by the grass-lined open conveyance channel | $507,000 for 2-year; $571,000 for 10-year | High | Low | Low | Low |
| 7—Conveyance to the Root River via Route A | Flooding and drainage problems would be abated to a significant degree Outlet from the subwatershed would be closed during Root River flooding | Pollutant loadings would continue to be discharged to the Root River. Some pollutant removal would be provided by the grass-lined open conveyance channel | $74,000 for 2-year; $86,000 for 10-year | Low | Low | Low | Moderate |
| 9—Pumping to the Root River | Flooding and drainage problems would be abated to a high degree | Pollutant loadings would continue to be discharged to the Root River. Some pollutant removal would be provided by the grass-lined open conveyance channel | $156,000 for 2-year; $188,000 for 10-year | Low | Moderate | Low | High |
| 11—Diversion Pumping to Lake Michigan | Flooding and drainage problems would be abated to a high degree | Increased pollutant loadings would be discharged directly to Lake Michigan, while pollutant loadings to the Root River would decrease. Some pollutant removal would be provided by the grass-lined open conveyance channel | $317,000 for 2-year; $375,000 for 10-year | Moderate | Moderate | Low | Low |
| 12—Storage and Conveyance to the Root River | Flooding and drainage problems would be abated to a significant degree Outlet from the subwatershed would be closed during Root River flooding | Pollutant loadings would continue to be discharged to the Root River. Some pollutant removal would be provided by the grass-lined open conveyance channel. If a detention pond is utilized, substantial pollutant removal would be achieved | $195,000 for 2-year; $316,000 for 10-year | Low | Moderate | Low | Moderate |
| 14—Storage and Pumping to the Root River | Flooding and drainage problems would be abated to a high degree | Pollutant loadings would continue to be discharged to the Root River. Some pollutant removal would be provided by the grass-lined open conveyance channel. If a detention pond is utilized, substantial pollutant removal would be achieved | $171,000 for 2-year; $242,000 for 10-year | Low | Moderate | Low | Moderate |
| 17—Conveyance to the Root River via Route D | Flooding and drainage problems would be abated to a significant degree Outlet from the subwatershed would be closed during Root River flooding | Pollutant loadings would continue to be discharged to the Root River. Some pollutant removal would be provided by the grass-lined open conveyance channel. Potential exists for use of existing pond located south of County Line Road for pollutant removal | $79,000 for 2-year; $92,000 for 10-year | Moderate | Low | Low | Moderate |

*Source: SEWRPC.*

Table 16

ECONOMIC ANALYSIS OF ALTERNATIVE STORMWATER MANAGEMENT SYSTEM PLANS

| Alternative No. | Initial Capital Cost (millions) | | Annual Operation and Maintenance Cost | | 50 Year-6 Percent Present Worth Cost (millions) | | 50 Year-6 Percent Equivalent Average Annual Cost | |
|---|---|---|---|---|---|---|---|---|
| | 2-Year | 10-Year | 2-Year | 10-Year | 2-Year | 10-Year | 2-Year | 10-Year |
| 4 | $7.9 | $8.9 | $ 6,000 | $ 6,000 | $8.00 | $9.00 | $507,000 | $571,000 |
| 7 | 1.1 | 1.3 | 4,000 | 4,000 | 1.16 | 1.36 | 74,000 | 86,000 |
| 9 | 2.3 | 2.8 | 10,000 | 11,000 | 2.46 | 2.97 | 156,000 | 188,000 |
| 11 | 4.8 | 5.7 | 13,000 | 14,000 | 5.00 | 5.92 | 317,000 | 375,000 |
| 12 | 2.6 | 4.2 | 30,000 | 50,000 | 3.07 | 4.99 | 195,000 | 316,000 |
| 14 | 2.3 | 3.1 | 25,000 | 45,000 | 2.69 | 3.81 | 171,000 | 242,000 |
| 17 | 1.2 | 1.4 | 3,000 | 3,000 | 1.25 | 1.45 | 79,000 | 92,000 |

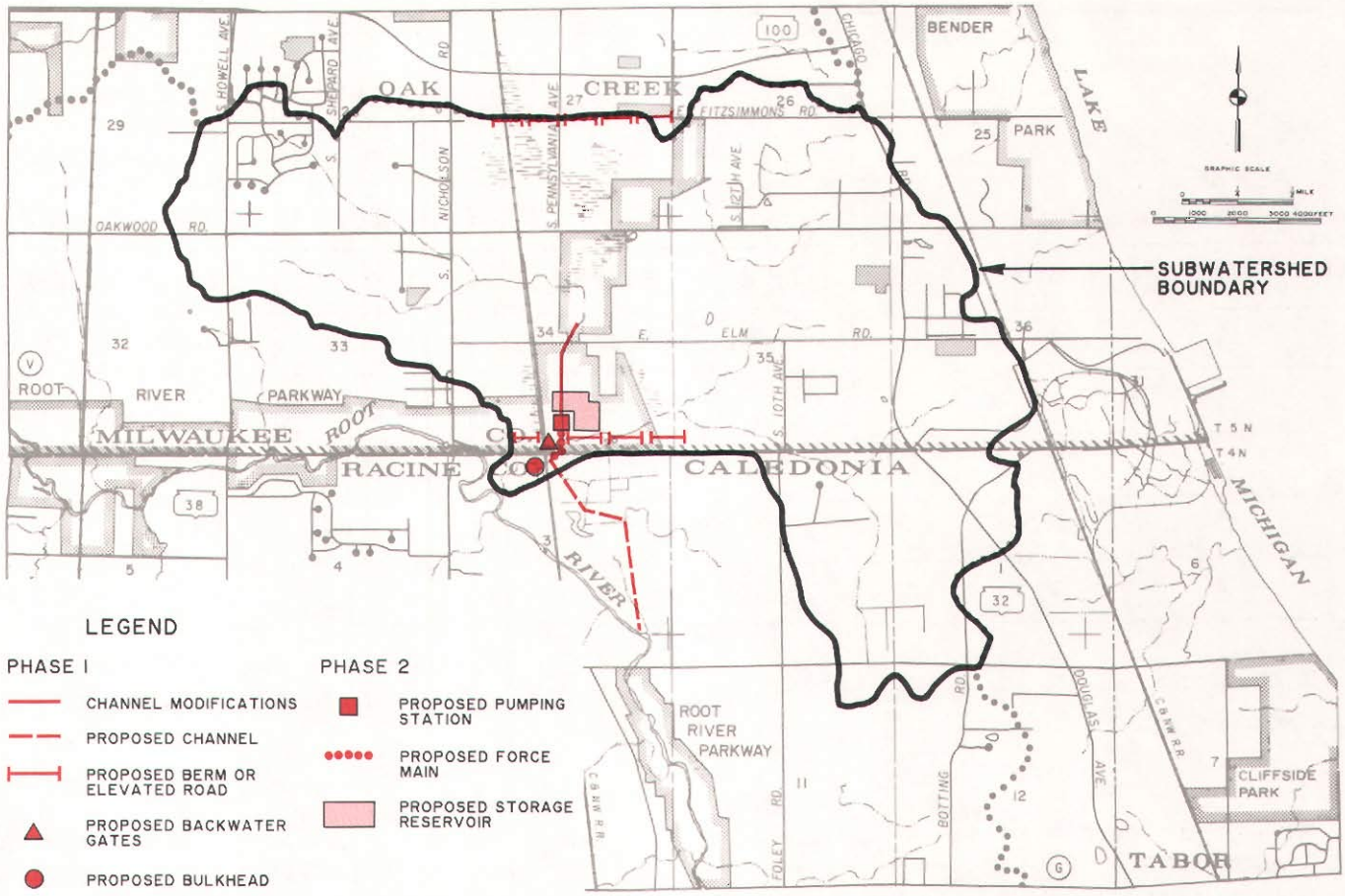
*Source: SEWRPC.*

little impact on downstream flows. Alternative 9 would have a relatively moderate cost, would not significantly restrict development within the subwatershed, and would have a high degree of public acceptance. This alternative would abate the flooding and drainage problems in the subwatershed to a high degree, since the pumping station would provide an adequate outlet, thereby eliminating the backwater effects of flooding on the Root River. Alternative 11 would have a relatively high cost, would entail moderate restrictions on development in the subwatershed, and would have a low degree of public acceptance. The alternative would abate the flooding and drainage problems to a high degree, since the pumping station would provide an adequate outlet, thereby eliminating the backwater effects of flooding on the Root River.

Alternative 12 would involve storage and conveyance to the Root River, and Alternative 14 would involve storage and pumping of stormwater to the Root River. Under both of these alternatives, a relatively high level of pollutant removal could be achieved if detention ponds were utilized in the storage facilities. If detention basins with no ponds were utilized, however, little water quality protection would be provided. These two alternatives would have relatively moderate costs, little impact on downstream flows, high operation and maintenance requirements, and a moderate degree of public acceptance. Also, these alternatives would place only slight restrictions on development within the subwatershed. Alternative 12 would abate the flooding and drainage problems to a significant degree, although less than would Alternative 4 or than any alternative utilizing pumping, since the outlet to the Root River would be closed under flooding conditions and stormwater generated in the Crayfish Creek subwatershed would be stored within the subwatershed. This alternative provides for a new storage facility and thus represents an improvement over Alternative 7, which would rely on the existing storage system. As already noted, flows from the Crayfish Creek subwatershed will normally peak prior to flows on the Root River, thus permitting discharge of the peak flows from Crayfish Creek and requiring storage only during periods following the peak. This alternative would also provide an outlet elevation that is about 1.0 foot lower than under

Map 27

COMPONENTS OF THE PRELIMINARY RECOMMENDED PLAN




*Source: SEWRPC.*

existing conditions. Alternative 14 would abate the flooding and drainage problems to a high degree, since the pumping station would provide an adequate outlet, thereby eliminating the backwater effects of flooding on the Root River.

## SELECTION OF PREFERRED ALTERNATIVES

The comparative evaluation of the alternative stormwater management plans considered indicated that a combination of the components from Alternatives 14 and 17 should be considered in the synthesis of a recommended plan—incorporating in that plan the best features of each of these two alternatives. Such a combined plan should provide beneficial water quantity and quality control at the least cost, be implementable, and fully satisfy the stormwater management objectives formulated under the study. The recommended combination of the preferred alternatives is shown on Map 27.

The comparative evaluation of the seven alternative stormwater management plans for the Crayfish Creek subwatershed indicated that the capital cost of the plans may be expected to range from $1.1 million to $7.9 million for a two-year recurrence interval design storm, and from $1.3 million to $8.9 million for a 10-year recurrence interval design storm. The alternatives having the lowest equivalent annual cost, by far, are Alternatives 7 and 17, having equivalent annual costs of $74,000 and $79,000, respectively, for a two-year recurrence interval design storm, and of $86,000 and $92,000, respectively, for a 10-year recurrence interval design storm. Both of these alternatives would involve conveyance

to the Root River. Of the two alternatives, Alternative 17 contains the preferred route for the conveyance channel because the route discharges at a lower elevation on the Root River; the route avoids construction along the edge of an existing abandoned landfill; and the route provides for potential pollutant removal through detention in an existing pond located south of County Line Road. The flooding and drainage problems in the subwatershed, however, would not be fully resolved by the construction of the facilities proposed in Alternative 17 since the outlet from the subwatershed would be closed when the Root River is at flood stage. Thus, it is recommended that components of Alternative 14 be incorporated into the recommended plan in order to obtain a higher degree of flooding and drainage problem mitigation. The costs of Alternatives 12 and 14 are similar. However, Alternative 14 would include a pumping station and would provide for storage, which could be designed to meet the dual purpose of drainage and nonpoint source pollutant abatement. The pumping system would continue to discharge water from Crayfish Creek to the Root River even when the outlet of Crayfish Creek is closed, thereby preventing the occurrence of flooding problems when the elevation of the Root River is high.

This preferred alternative, which incorporates elements of both Alternative 14 and Alternative 17, was further refined to properly integrate the components and minimize costs, to ensure a high degree of drainage improvement and flood control, and to provide a high level of water quality protection.

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# Chapter VI

# RECOMMENDED STORMWATER MANAGEMENT PLAN

## INTRODUCTION

In Chapter V of this report, 17 alternative stormwater management plans were discussed and evaluated for the Crayfish Creek subwatershed. The alternatives considered focused on the discharge location and major system plan elements for the main drainageway serving the area. The 17 alternative plans included conveyance, detention, and backwater prevention facilities, or a combination of such facilities. In addition, retention and nonstructural measures were incorporated into all of the plan alternatives in that the recommended land use pattern for the study area included maintenance in essentially natural, open uses of the primary environmental corridor lands and wetland areas along Crayfish Creek.

A combination of components from two of the 17 alternative plans was selected for refinement and detailing as the recommended system plan for the study area as a whole. The comparative evaluation of these plans, as presented in Chapter V, was focused primarily on the cost of the stormwater management system components, and on the ability of the plans to resolve existing and future stormwater drainage problems. The impact of the alternative plans on the peak flow rates and quality of the downstream receiving watercourses was also considered in the comparative evaluation. The evaluation of the alternatives indicated that Alternative 17, combined with the potential for stormwater detention and possible future pumping proposed under Alternative 14, installed in two phases, would best serve the Crayfish Creek subwatershed. That alternative plan would provide for the discharge of stormwater to the Root River at a location about 0.9 mile downstream of the present location, the provision of backwater facilities to prevent flood flows on the Root River and Oak Creek from backing up into Crayfish Creek, and the provision of stormwater detention facilities for both flood-flow reduction and water quality management purposes. The plan could readily accommodate the addition of a stormwater pumping station at the outlet should operational experience indicate a higher level of protection is needed later in the plan period.

This chapter presents the recommended stormwater management system plan for the study area. The recommended system components are described in some detail, including the approximate locations, lengths, and sizes of required storm sewers and culverts; the approximate locations, lengths, sizes, and slopes of required open channels; and the approximate locations, site areas, sizes, storage capacities, water depths, and outlet capacities of required detention facilities.

The design of the recommended plan was based upon careful consideration of many factors, with primary emphasis upon the degree to which the recommended stormwater management objectives and supporting standards for Crayfish Creek are satisfied. Most important among the considerations were cost, environmental impacts, and the ability of the system components to accommodate flows resulting from the design storm events without exacerbating downstream drainage and flooding problems.

## ADDITIONAL ALTERNATIVE EVALUATIONS

Following selection of the recommended plan, two additional alternative evaluations were conducted in order to refine the plan recommendations for certain components. The first evaluation considered the need to deepen and widen the main channel of Crayfish Creek from County Line Road north to Oakwood Road. The second evaluation considered the need to construct stormwater pumping and storage facilities just north of County Line Road in order to provide for adequate drainage during periods when the Root River flows and stages were high, thus causing the closure of the proposed backwater gates on culverts under E. County Line Road to prevent floodwaters on the Root River from entering Crayfish Creek north of County Line Road.

### Consideration of the Need to Deepen and Widen Crayfish Creek North of E. County Line Road

The need to provide for stream channelization north of E. County Line Road along the main channel of Crayfish Creek was considered. This evaluation considered several factors, including the cost of the improvements, the ability to

provide drainage to the developed and developing areas of the watershed, and the environmental impacts of construction. Two alternatives were considered. The first alternative would provide for the construction of 2,700 feet of new grass-lined channel with a bottom width of 15 feet, one on four side slopes, and a maximum depth of five feet beginning about 0.3 mile east of Nicholson Road and extending thence easterly and southerly to E. Elm Road; and about 2,800 lineal feet of new grass-lined channel with a bottom width ranging from 18 to 26 feet, one on four side slopes, and a maximum depth of four feet extending from E. Elm Road southerly to E. County Line Road, all as shown on Map 28. The capital cost of this alternative is estimated to be $200,000, with no significant increase in annual operation and maintenance costs.

Under the second alternative, the channel of Crayfish Creek would be maintained in its existing condition with only minor cleaning and debrushing, and minimal channel regrading to eliminate the negative slope conditions in certain reaches. The capital cost of this alternative plan is estimated to be $15,000, with no significant increase in annual operation and maintenance costs.

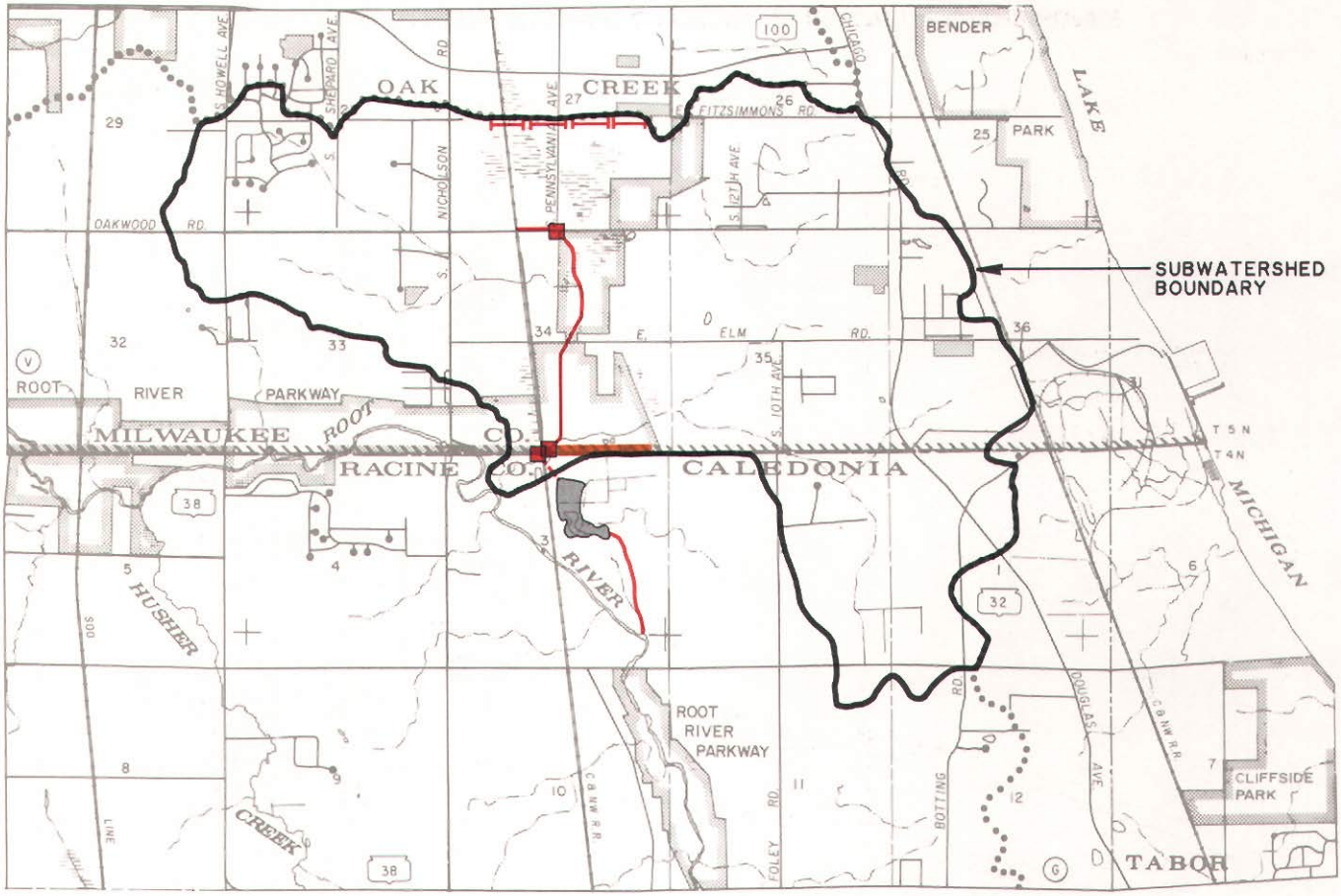
Under the first alternative, which provides for major channel modifications, the hydraulic gradient along the main stem of Crayfish Creek would be lowered by about 0.5 foot under a 10-year recurrence interval storm event, and by about 1.0 foot under a 100-year recurrence interval storm event, compared to conditions without modifications to this portion of the channel. The flood stage and streambed profiles for both the first and second alternatives are shown in Figure 8. The flood stage and streambed profiles for existing channel conditions and under the second alternative channel conditions are shown in Figure 9. Under the first or major channelization alternative, there would be a slight improvement in the ability to adequately drain the areas adjacent to the channel that are proposed to be developed. However, analyses made during the design of the improvements indicated that it would be possible, under the second or minor channelization alternative, to effectively drain nearly all of the adjacent lands proposed for development in the land use plan set forth in Chapter III. This land use and concomitant drainage system development would require the filling of development sites within the area shown on Map 29 if it is envisioned that the area will develop using urban street cross-sections with curbs and gutters and storm sewer. This area has relatively flat gradients available for construction of local storm sewers and/or channels. Thus, the filling and development of the area with relatively large lots and rural street cross-sections with roadside ditches for drainage would be required. In some cases, the current city policy of requiring a minimum of four feet of cover over all storm sewers may not be fully met. However, in over 85 percent of the area recommended for development, adequate storm sewer or conveyance channel gradients could be provided with careful design, and a minimum cover of at least three feet could be obtained.

An important consideration in the provision of drainage is the capability of the major channels to convey stormwater runoff from the subwatershed following a local storm event and/or a flood event on the Root River. As part of the hydrologic and hydraulic analyses conducted under this study, estimates were made of the time required to drain the flood-prone areas of the subwatershed, assuming that the flood stages on the Root River had receded to a level allowing such drainage to occur freely. The analyses indicated that the proposed channel considered under the first alternative would indeed result in a somewhat more rapid rate of drainage of lands located adjacent to Crayfish Creek. The analyses indicated that about four hours is required to drain the entire area of impact through the existing channel, assuming no restrictions such as might be caused by sediment deposits in the channel or blocked culverts. The same area could be drained in about two hours through the channel if the channel were deepened and widened as envisioned under the first alternative.

With regard to environmental impacts, under the first alternative, which proposes major channelization, dissolved oxygen concentrations in Crayfish Creek may be reduced by one to two milligrams per liter (mg/l), and water temperatures may increase by three to five degrees Fahrenheit during low-flow, warm-weather conditions as a result of the channelization. In addition, the wetland complex along Crayfish Creek may be less effective in acting as a filter system to remove pollutant materials. These changes in water quality, together with likely increases in suspended sediment and nutrient concentrations, may be expected to make the attainment of the adopted water use objectives and support-

Map 28

LOCATION OF MAJOR CHANNEL IMPROVEMENTS UNDER MAJOR CHANNELIZATION ALTERNATIVE




LEGEND

- MAJOR CHANNEL IMPROVEMENTS CONSIDERED UNDER ALTERNATIVE PLAN IA
- PROPOSED BERM
- PROPOSED CULVERT MODIFICATION
- PROPOSED SEDIMENTATION POND

OTHER IMPROVEMENTS TO BE INCLUDED IN THE RECOMMENDED PLAN

- PROPOSED NEW CHANNEL
- PROPOSED ELEVATED ROAD

*Source: SEWRPC.*

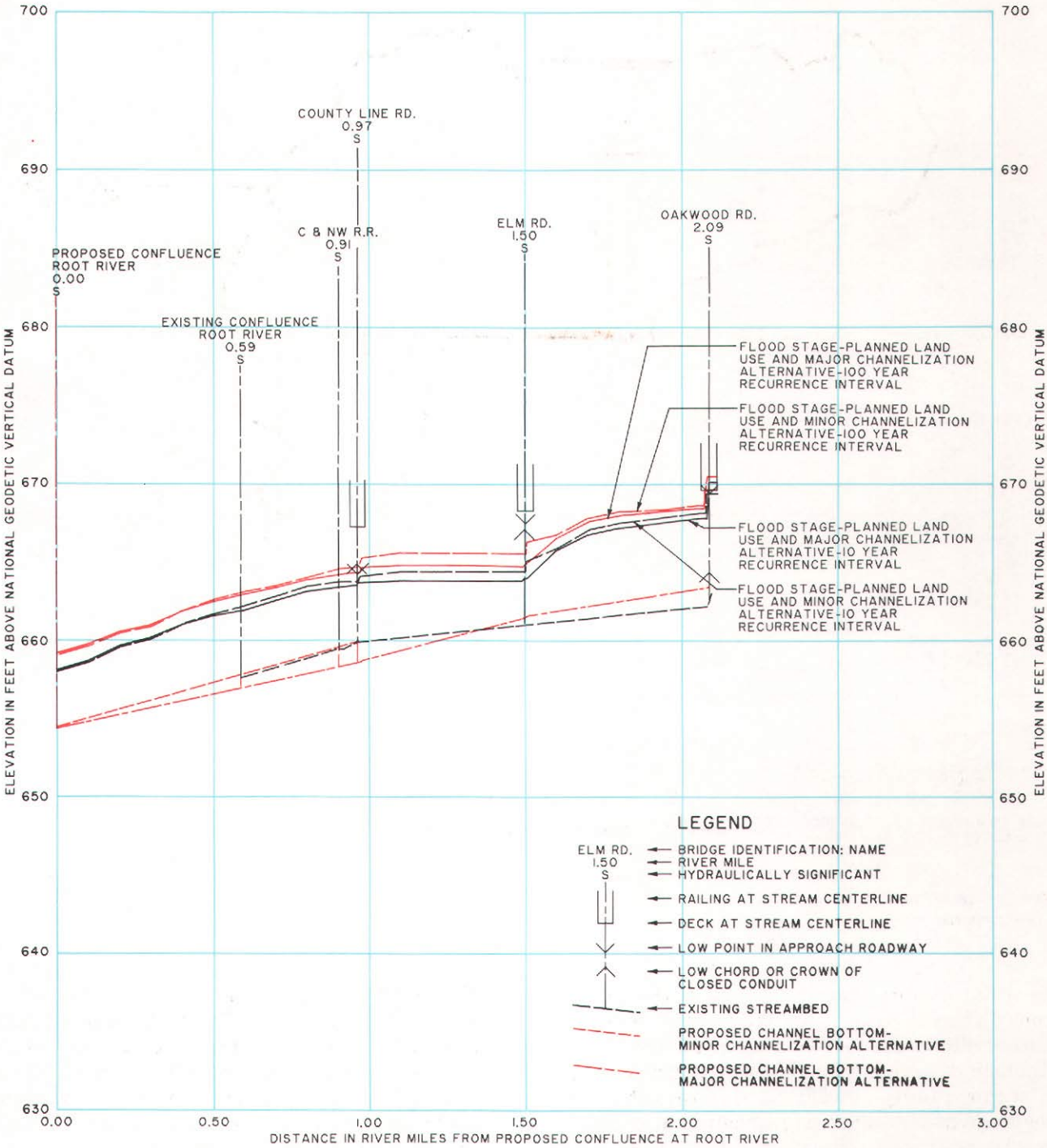
ing water quality standards for Crayfish Creek more difficult. Also, a higher level of nonpoint source pollutant reduction may be required in the tributary drainage area. These negative impacts on water quality conditions in Crayfish Creek would not be expected to significantly affect water quality conditions in the Root River itself owing to the relatively small streamflows involved relative to flows in the Root River. The mean annual flow from the tributary area is estimated to be 4 cubic feet per second (cfs), while the mean annual flow of the Root River, at the confluence with the tributary concerned, is estimated to be 120 cfs.

With regard to the impacts of the excavation of materials on wetlands during channel construction under the first alternative, it was assumed that the materials excavated would be disposed of on upland areas or spread on nearby agricultural lands outside adjacent wetlands, thus minimizing any disturbance of the wetland areas.

Regarding primary environmental corridor impacts, there are approximately 300 acres of wetland within the primary environmental corridor and along the existing and proposed channels. A detailed inventory of the wetland types was

Figure 8

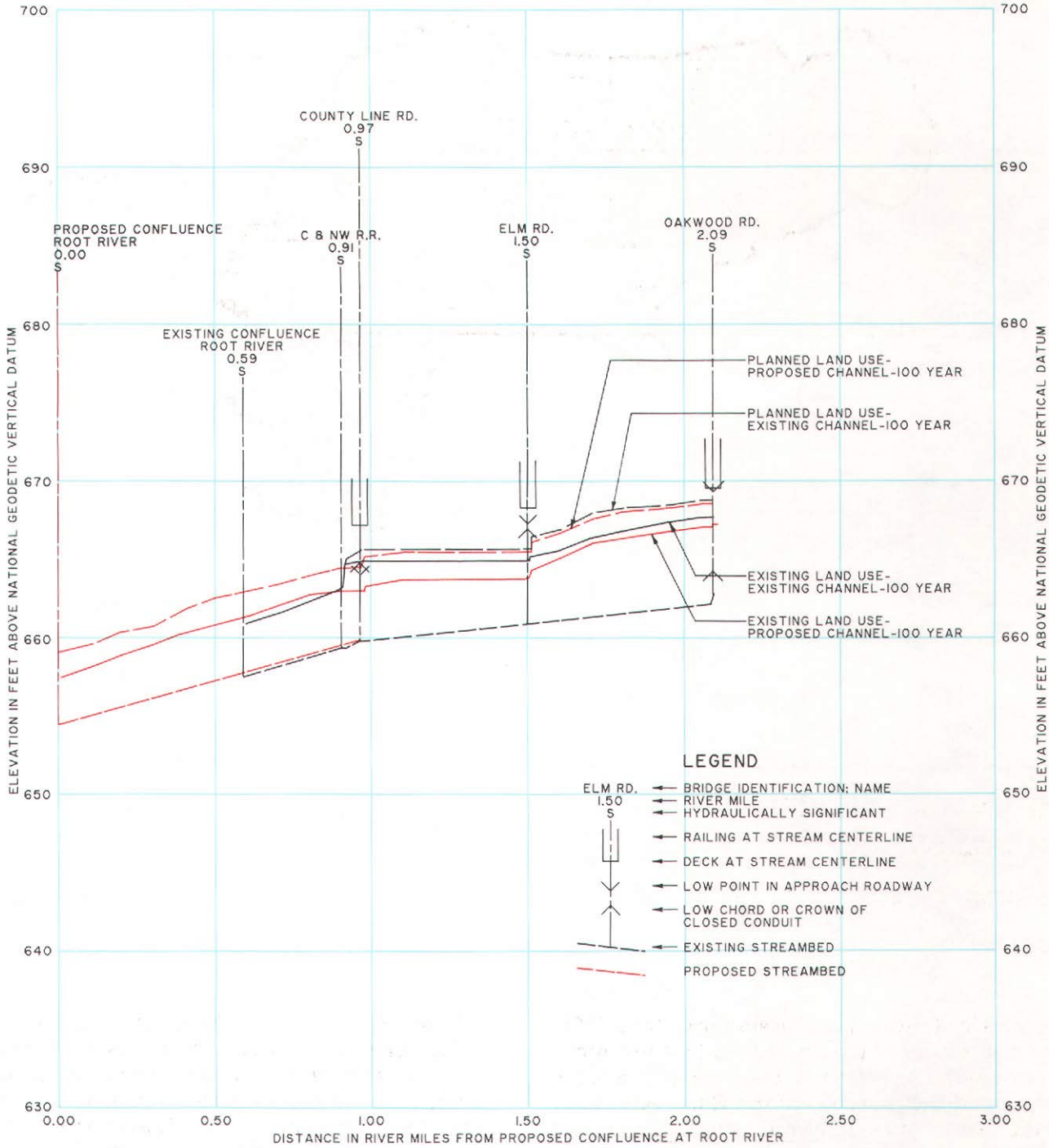
## FLOOD STAGE AND STREAMBED PROFILE FOR CRAYFISH CREEK UNDER MAJOR CHANNELIZATION AND MINOR CHANNELIZATION ALTERNATIVES




*Source: SEWRPC.*

Figure 9

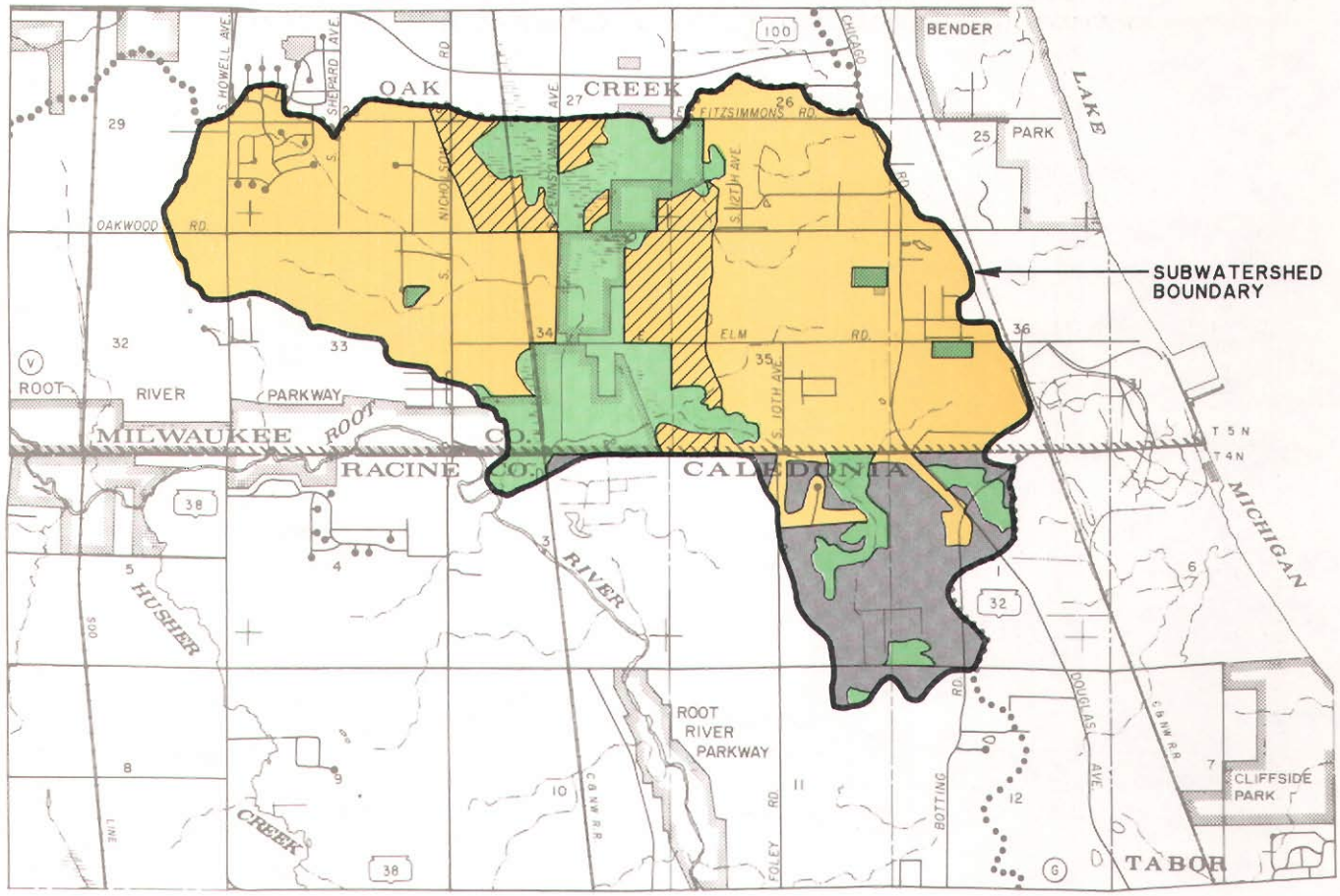
## FLOOD STAGE AND STREAMBED PROFILE FOR CRAYFISH CREEK UNDER EXISTING CHANNEL CONDITIONS AND MINOR CHANNELIZATION ALTERNATIVE




*Source: SEWRPC.*

Map 29

AREAS THAT MAY NEED TO BE FILLED TO BE DEVELOPED IN CRAYFISH CREEK SUBWATERSHED




LEGEND

- AREAS PLANNED TO BE DEVELOPED
- AREAS PLANNED TO BE DEVELOPED BUT WHICH MAY NEED TO BE FILLED
- WOODLANDS, RECREATIONAL AREAS, OR OTHER OPEN LANDS NOT PLANNED TO BE DEVELOPED
- AGRICULTURAL LANDS NOT PLANNED TO BE DEVELOPED

GRAPHIC SCALE

*Source: SEWRPC.*

prepared by the Commission staff in October 1979, and a summary of the findings of that inventory is provided in Appendix A. Field inspection of the area noted the presence of the European strain of tall manna grass (Glyceria spectabilis) in the subject wetland complex. Although this grass has been recorded at only one other station in Wisconsin, it is very aggressive and could become an aquatic nuisance should the channelization result in its spreading beyond its present location. The aesthetic and wildlife habitat values of the primary environmental corridor within and immediately adjacent to the channel may be expected to be somewhat diminished as a result of the proposed channelization project. The corridor, however, may be expected to remain a functional corridor, continuing to meet the criteria for classification as a primary environmental corridor.

The wildlife habitat values in the area in which the channelization project would be constructed under the first alternative would be altered somewhat as a result of the construction. Aquatic vegetation and substrates necessary to support fish and other

aquatic life and insects would be reduced. The ecological complexity of the area within and immediately adjacent to the proposed channel would be changed from the present diverse condition to a more monotype grass-lined channel. Thus, the diversity and relative abundance of the total community, including both game and nongame species, could be expected to be somewhat less desirable if the channel were to be constructed as considered under the first alternative.

In view of the foregoing, it is recommended that the main channel located north of County Line Road not be significantly modified. The channel should be properly maintained with minor debrushing and culvert cleaning, and with minor regrading when sediment deposits create negative channel bottom gradients.

Consideration of the Need to Provide Storage and Pumping Facilities at County Line Road

Two alternatives were considered to accommodate the stormwater drainage during periods when the Root River flows and stages exceed those levels which would allow a free outlet from the subject drainage area. This evaluation considered several factors, including the cost of the improvements, the ability to provide drainage to the developed and developing areas of the watershed, and the environmental impacts of the construction. Under the first alternative, consideration was given to the need to provide additional stormwater storage facilities north of County Line Road and the need to provide stormwater pumping facilities to facilitate adequate outlet conditions at the lower end of the watershed. Under this alternative, either 250 acre-feet of engineered storage capacity would be constructed adjacent to Crayfish Creek just north of County Line Road, or a pumping station would be installed at this location with a capacity of about 500 cubic feet per second. A combination of storage and pumping capacity could also be provided. These facilities would be designed to accommodate a two-year recurrence interval storm event rather than a 10-year or 100-year recurrence interval event, since the two-year event over the Crayfish Creek subwatershed would be an extremely rare event in combination with a major flood event on the Root River itself. The times of concentration for the Root River watershed and the Crayfish Creek subwatershed are discussed in a later section of this report. The capital cost of this alternative is estimated to be $1 million, with an average annual operation and maintenance cost of about $20,000 assuming a cost-effective combination of storage and pumping.

Under the second alternative, the storage available in the existing wetland complex was evaluated to determine if the capacity would be adequate. The evaluation indicated that the wetland complex could provide about 350 acre-feet of storage above elevation 662.6 feet National Geodetic Vertical Datum (82.0 feet local datum), the elevation at which the water levels in the wetland may be expected to recede when the Root River is within its banks at the downstream outlet location. This storage volume would be adequate to accommodate the runoff volume from a two-year storm event—about 250 acre-feet—over the subwatershed. Most of the stormwater generated in the Crayfish Creek subwatershed would be conveyed to the Root River prior to the need to seal off the outlets from the drainage area. Thus, only the residual rainfall on the Crayfish Creek subwatershed would have to be stored in the existing wetland areas, provided those areas are left in their natural condition as recommended in the land use plan set forth in Chapter III.

There would be no additional capital or operation and maintenance cost associated with the continued use of this wetland complex for storage of stormwater.

With regard to environmental impacts, under the first alternative about 50 acres of the wetland complex would be disturbed during construction. It is expected that these impacts would be minimal over the long term if proper construction techniques were used and proper mitigative actions taken. With regard to the impacts of excavated material, it was assumed that all such materials would be disposed of on upland areas or spread on nearby agricultural lands outside the wetlands, thus minimizing any undesirable impacts on the wetland areas.

The use of pumping facilities would result in the consumption of energy and require more maintenance than a gravity flow alternative.

The use of storage facilities may have positive environmental impacts by providing low-flow augmentation for Crayfish Creek and the Root River. In addition, the storage system could provide some water quality benefits through sedimentation. However, water quality benefits would also be

provided by the wetland complex and by the detention pond incorporated into the plan on the channel reach downstream of County Line Road.

Based upon consideration of the foregoing, it is recommended that initially no additional engineered stormwater storage or pumping facilities be provided in the Crayfish Creek subwatershed at County Line Road. Should experience indicate that the backup of floodwaters from the Root River creates problems more frequently than acceptable, the recommended plan, as described in the subsequent sections of this chapter, could be modified to readily accommodate a small pumping station at the lower end of the subwatershed just north of County Line Road.

## PLAN RECOMMENDATIONS

The system components recommended for inclusion in the stormwater management plan for the Crayfish Creek subwatershed are set forth in Tables 17 and 18, along with the associated costs. The recommended plan is summarized in graphic form on Map 30 and on a one inch equals 1,000 feet scale system plan map, located in the pocket attached to the inside back cover of this report.

The minor stormwater management system for the subwatershed would include conveyance and storage, and infiltration and retention components designed to ultimately contain flows for storm events up to and including the 10-year recurrence interval storm under future land use conditions. The conveyance components include open channels and storm sewers. The storage component includes a single detention basin, a single detention pond with associated facility inlets and outlets, and the maintenance of the large primary environmental corridor/wetland complex along Crayfish Creek and its tributary drainageways. The infiltration and retention components include the use of natural or turf-lined channels and the maintenance in its natural state of the large primary environmental corridor and wetland complex along Crayfish Creek and its tributary drainageways.

The major stormwater management system for the subwatershed would include conveyance components designed to accommodate flows up to and including the 100-year recurrence interval event. Conveyance components include major open channel drainageways and receiving watercourses. In addition, the major system includes the detention, retention, and infiltration components provided by the maintenance in an essentially natural state of the primary environmental corridor/wetland complex located along Crayfish Creek and its tributaries.

### Discussion of the Recommended Phase I Stormwater Management System

The Phase I stormwater management system consists of improvements to the drainage capability of the main stem of Crayfish Creek to accommodate increased stormwater runoff from existing and anticipated development. A brief summary of the recommended Phase I stormwater management plan components by hydrologic unit is provided below. The area included and the location and extent of the hydrologic units are shown on Map 28. There are no Phase I components for the Oakwood, Caledonia, or Meadowview hydrologic units.

Upper Crayfish Hydrologic Unit: To accommodate anticipated runoff conditions, the existing 36-inch corrugated metal culvert pipe (CMCP) at the E. Oakwood Road crossing of Crayfish Creek would be replaced with a 48-inch CMCP, and the existing channel in the vicinity of Oakwood Road would be regraded to ensure drainage to the south, thus correcting the current problem of accumulated stormwater at the intersection of E. Oakwood Road and Pennsylvania Avenue draining north to the Oak Creek watershed. In addition, a berm would be constructed along Fitzsimmons Road extended from the Chicago & North Western Railway tracks to S. 15th Avenue. This would prevent floodwaters from the adjacent Oak Creek watershed from entering the Crayfish Creek subwatershed as discussed in Chapter V of this report.

Lower Crayfish Hydrologic Unit: To accommodate anticipated runoff, a new channel would be constructed from the study area boundary between E. County Line Road and the Chicago & North Western Railway tracks to the southeast to an existing reservoir, and from the reservoir to the Root River approximately 850 feet north of Seven Mile Road. The new channel would be turf-lined and have a bottom width of 25 feet, with one on four side slopes and an average depth of about five feet. In addition to the proposed new channel, E. County Line Road would be raised from just west of the Chicago & North Western tracks to S. 15th Avenue extended. Alternatively, a berm could be constructed adjacent to the road. Also, four 72-inch-diameter corrugated metal culvert pipes would be installed under E. County Line Road equipped with backwater gates to prevent floodwaters

Table 17

## SELECTED CHARACTERISTICS AND COSTS OF THE RECOMMENDED STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED–PHASE I

| Hydrologic Unit | Project Component Description | Estimated Cost | |
|---|---|---|---|
| | | Capital | Annual Operation and Maintenance[a] |
| Upper Crayfish | 1. Replacement of the existing 36-inch corrugated metal pipe (CMP) culvert at Oakwood Road crossing of Crayfish Creek with a 48-inch CMP culvert | $ 4,000 | $ 0 |
| | 2. Construction of a berm parallel to and 50 feet south of Fitzsimmons Road extended from 250 feet west of the Chicago & North Western Railway tracks 3,500 feet to the east, to S. 15th Avenue extended | 60,000 | 1,000 |
| | 3. Regrading of existing channel in the vicinity of Oakwood Road | 10,000 | 0 |
| | Engineering and Contingencies | $ 10,000 | $ 0 |
| | Subtotal | $ 84,000 | $ 1,000 |
| Lower Crayfish | 1. Reconstruction of 2,500 feet of E. County Line Road east of the Chicago & North Western Railway tracks or a berm adjacent to the road | $ 80,000 | $ 0 |
| | 2. Replacement of the existing 5' x 17' concrete box culvert at the County Line Road crossing of Crayfish Creek with four 72-inch CMP culverts | 40,000 | 0 |
| | 3. Installation of four backwater gates on County Line Road culverts | 75,000 | 8,000 |
| | 4. Bulkheading of the four 48-inch CMP culverts at Chicago & North Western Railway crossing of Crayfish Creek | 3,000 | 0 |
| | 5. Construction of 700 lineal feet of new open channel from County Line Road to the existing retention pond located 700 feet south of E. County Line Road and adjacent to the Chicago & North Western Railway, and 2,110 feet of new channel from that retention pond to the Root River 850 feet north of Seven Mile Road | 90,000 | 1,000 |
| | 6. Inlet and outlet refinements to the existing pond located downstream of County Line Road | 3,000 | 0 |
| | Engineering and Contingencies | $ 25,000 | $ 0 |
| | Subtotal | $316,000 | $ 9,000 |
| | Total | $397,000 | $10,000 |

[a]*Costs were noted to be zero when the project proposed replacement of a component with a component that has similar operation and maintenance.*

*Source: SEWRPC.*

Table 18

## SELECTED CHARACTERISTICS OF THE RECOMMENDED STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED—PHASE II

| Hydrologic Unit | Project and Component Description | Estimated Cost | |
|---|---|---|---|
| | | Capital | Annual Operation and Maintenance[a] |
| Oakwood | Subbasin No. 1 Improvements | | |
| | 1. 1,800 feet of 48-inch-diameter reinforced concrete pipe (RCP) along Fitzsimmons Road from 10th Avenue extended to the west | $ 180,000 | $ 0 |
| | 2. 1,200 feet of 24-inch-diameter RCP along Fitzsimmons Road from S. 10th Avenue extended to the east | 50,000 | 0 |
| | Subbasin No. 2 Improvements | | |
| | 1. 900 feet of 18-inch-diameter RCP along Oakwood Road from Chicago Road to the east | 30,000 | 0 |
| | 2. 1,300 feet of 36-inch-diameter RCP along Oakwood Road from Chicago Road to the west to the proposed channel | 90,000 | 0 |
| | 3. 4,700 feet of channel modifications from the existing 30-inch-diameter RCP outfall to the west | 30,000 | 0 |
| | 4. 1,100 feet of new open channel from the proposed 36-inch-diameter outfall to the subbasin divide | 60,000 | 200 |
| | Engineering and Contingencies | $ 40,000 | $ 0 |
| | Subtotal | $ 480,000 | $ 200 |
| Caledonia | Subbasin No. 1 Improvements | | |
| | 1. 2,800 feet of 36-inch-diameter RCP along E. Elm Road from the section line between Sections 35 and 36 to just west of S. 10th Avenue | $ 200,000 | $ 0 |
| | 2. 3,900 feet of channel modifications from the proposed new open channel south of Oakwood Road to the southwest to the primary environmental corridor boundary | 40,000 | 0 |
| | Subbasin No. 2 Improvements | | |
| | 1. 3,200 feet of 60-inch-diameter RCP from E. Elm Road at S. 4th Avenue to the south to E. County Line Road and then west to just west of the section line between Sections 35 and 36 | 480,000 | 0 |
| | 2. 3,500 feet of channel modifications from E. County Line Road just west of the section line between Sections 35 and 36 to the southwest into Caledonia, and then to the northwest across E. County Line Road up to the primary environmental corridor boundary in the southwest quarter of Section 35 | 30,000 | 0 |
| | 3. 1,300 feet of channel modifications from S. Elaine Road at East Schmitz Drive to the southwest to the primary environmental corridor boundary | 20,000 | 0 |
| | Engineering and Contingencies | $ 80,000 | $ 0 |
| | Subtotal | $ 850,000 | $ 0 |
| Meadowview | Subbasin No. 1 Improvements | | |
| | 1. 2,000 feet of channel modifications from the Milwaukee County Parkland boundary in the northwest quarter of Section 34 to the west to the confluence with Subbasin No. 2 and Subbasin No. 3 channels, respectively | $ 0[b] | $ 0 |
| | Subbasin No. 2 Improvements | | |
| | 1. 900 feet of channel modifications from the confluence with the Subbasin No. 3 channel to the northwest to Nicholson Road | 0[b] | 0 |
| | 2. 1,700 feet of 48-inch-diameter RCP along the north side of Oakwood Road from McGraw Drive to Nicholson Road and then south along Nicholson Road to the existing channel | 170,000 | 0 |

## Table 18 (continued)

| Hydrologic Unit | Project and Component Description | Estimated Cost | |
|---|---|---|---|
| | | Capital | Annual Operation and Maintenance[a] |
| Meadowview (continued) | 3. 800 feet of of 24-inch-diameter RCP from the proposed detention basin to the southeast to E. Oakwood Road and then along Oakwood Road to the existing channel just west of McGraw Drive | $ 40,000 | $ 0 |
| | 4. 16.5 acre-foot detention facility north of Oakwood Road just east of Shepard Avenue | 210,000 | 10,000 |
| | 5. 300 feet of 63-inch by 98-inch horizontal elliptical RCP from Shepard Avenue to the proposed detention facility | 60,000 | 0 |
| | 6. 1,200 feet of channel modifications from Shepard Avenue just west of the proposed detention facility to the northwest to Oak Lane | 10,000 | 0 |
| | Subbasin No. 3 Improvements | | |
| | 1. 4,500 feet of channel modifications from the confluence with the Subbasin No. 2 channel to the west to just west of Shepard Avenue extended | 50,000 | 0 |
| | 2. 3,700 feet of 48-inch-diameter RCP along Shepard Avenue extended from the Subbasin No. 3 channel to the north up to Oakwood Road and then west along Oakwood Road to Howell Avenue | 370,000 | 0 |
| | 3. 1,200 feet of 36-inch-diameter RCP along Oakwood Road from Howell Avenue to the west | 80,000 | 0 |
| | Engineering and Contingencies | $ 100,000 | $ 0 |
| | Subtotal | $1,090,000 | $10,000 |
| Upper Crayfish | Subbasin No. 1 Improvements | | |
| | 1. 1,100 feet of new open channel along Fitzsimmons Road extended from Nicholson Road to the east | $ 20,000 | $ 400 |
| | 2. 900 feet of 42-inch-diameter RCP along Fitzsimmons Road from McGraw Drive to Nicholson Road | 80,000 | 0 |
| | 3. 1,500 feet of 36-inch-diameter RCP along Fitzsimmons Road from McGraw Drive to the west | 110,000 | 0 |
| | Subbasin No. 2 Improvements | | |
| | 1. 2,100 feet of 36-inch-diameter RCP along Oakwood Road from Pennsylvania Avenue to Nicholson Road | 150,000 | 0 |
| | 2. 900 feet of channel modifications from Nicholson Road at Oak Lane to the east | 0[b] | 0 |
| | 3. 900 feet of 36-inch-diameter RCP along Oak Lane from Nicholson Road to McGraw Drive | 60,000 | 0 |
| | Engineering and Contingencies | $ 40,000 | $ 0 |
| | Subtotal | $ 460,000 | $ 400 |
| Lower Crayfish | Subbasin No. 1 Improvements | | |
| | 1. None | $ -- | $ -- |
| | Subbasin No. 2 Improvements | | |
| | 1. 1,200 feet of 48-inch-diameter RCP along Elm Road in the northwest quarter of Section 35 | 120,000 | 0 |
| | 2. 1,700 feet of channel modifications along Elm Road from the proposed 48-inch-diameter RCP to the west | 10,000 | 0 |

Table 18 (continued)

| Hydrologic Unit | Project and Component Description | Estimated Cost | |
|---|---|---|---|
| | | Capital | Annual Operation and Maintenance[a] |
| Lower Crayfish (continued) | Subbasin No. 3 Improvements | | |
| | 1. 1,000 feet of 72-inch-diameter RCP along E. Elm Road from the Crayfish Creek channel to the west to just west of the Chicago & North Western Railway tracks | $ 200,000 | $ 0 |
| | 2. 1,000 feet of 54-inch-diameter RCP along E. Elm Road from the Chicago & North Western Railway tracks to the west to just east of Nicholson Road | 130,000 | 0 |
| | Subbasin No. 4 Improvements | | |
| | 1. 2,400 feet of 36-inch-diameter RCP along Nicholson Road from Elm Road to the Root River | 170,000 | 0 |
| | Engineering and Contingencies | $ 130,000 | $ 0 |
| | Subtotal | $ 760,000 | $ 0 |
| | Total | $3,640,000[c] | $10,600[c] |

[a] *Costs were noted to be zero when the project proposed replacement of a component with a component that has a similar operation and maintenance cost.*

[b] *This section of channel has been modified and therefore was not included in the recommended plan cost estimate.*

[c] *The addition of four sedimentation basins as described in a subsequent section of the report would add $200,000 to the capital cost and $8,000 to the operation and maintenance costs.*

*Source: SEWRPC.*

from the Root River from entering the Crayfish Creek subwatershed north of County Line Road. One of these culverts should be set at a lower elevation than the others to accommodate fish migration during low-flow conditions. The details of this culvert system should be reviewed and approved by the Wisconsin Department of Natural Resources fish management personnel. It is envisioned that backwater gates would be manually operated by city personnel based upon flood level observations on the Root River main stem. Automated operation of the gates could be provided, however. In addition to these improvements, the four existing 48-inch-diameter culverts under the Chicago & North Western Railway line would be bulkheaded or removed. The recommended plan could readily accommodate the addition of a pumping station at the outlet, should operational experience indicate a higher level of protection is needed later in the plan period.

## Discussion of the Recommended Phase II Stormwater Management System

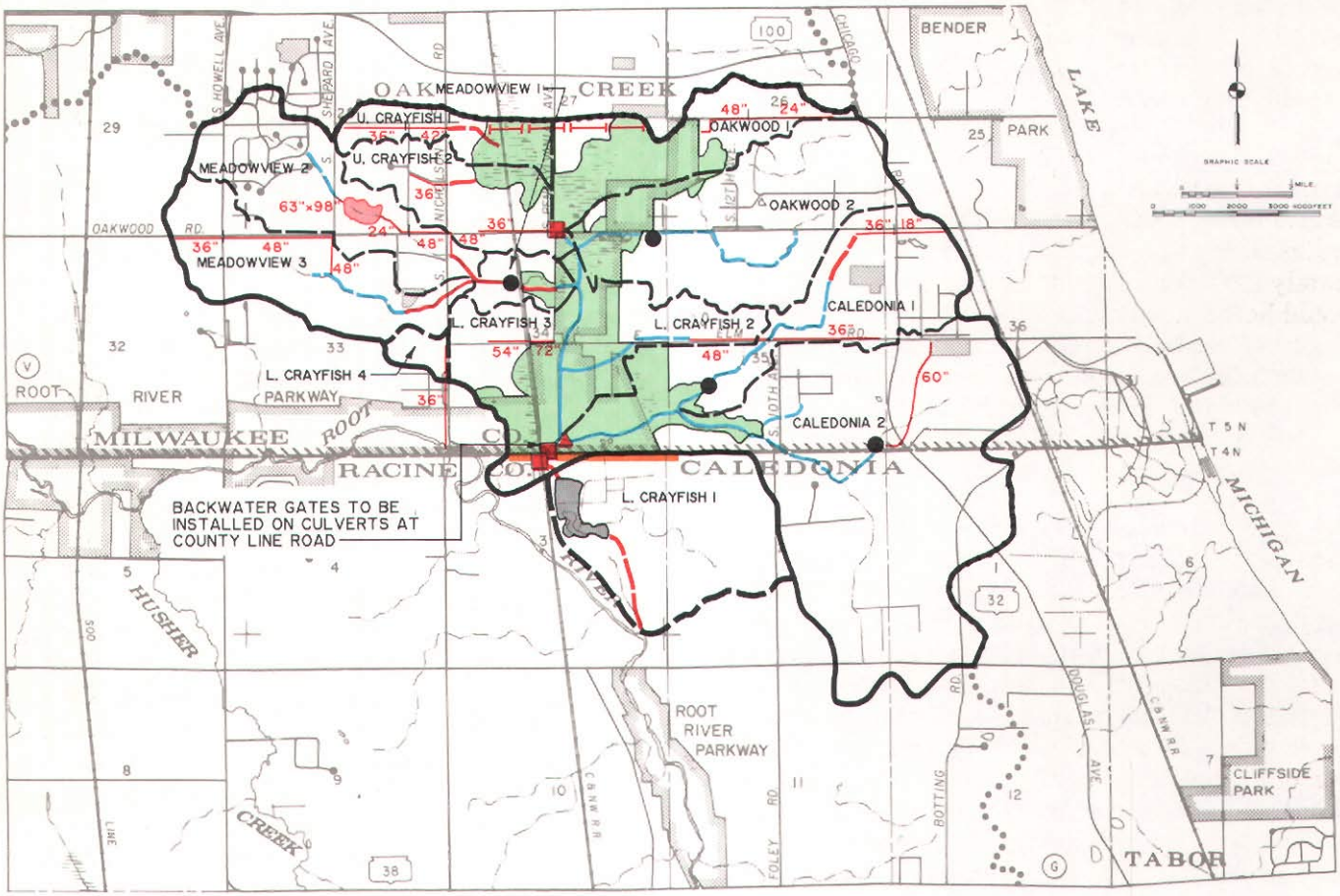
The Phase II stormwater management system consists of drainage improvements to accommodate runoff from both existing and proposed development areas. A brief summary of the recommended Phase II stormwater management plan components by hydrologic unit subbasin is provided below.

Upper Crayfish Subbasin 1: The Phase II stormwater management plan components for Upper Crayfish Subbasin 1 consist of approximately 2,400 lineal feet of storm sewer ranging in size from 36 inches in diameter to 42 inches in diameter, and approximately 1,100 feet of new open channel. Approximately 1,500 lineal feet of 36-inch-diameter storm sewer would be installed along Fitzsimmons Road from McGraw Drive to the west. Approximately 900 lineal feet of 42-inch-diameter storm sewer would be installed along Fitzsimmons Road from McGraw Drive to Nicholson Road. Approximately 1,100 feet of new turf-lined open channel with a five-foot-wide bottom and side slopes of one on four would be provided along Fitzsimmons Road extended from the proposed 42-inch-diameter sewer outfall at Nicholson Road to the east.

Upper Crayfish Subbasin 2: The Phase II stormwater management plan components for Upper Crayfish Subbasin 2 consist of 3,000 feet

Map 30

## RECOMMENDED PLAN FOR THE CRAYFISH CREEK SUBWATERSHED




LEGEND

- EXISTING SUBWATERSHED BOUNDARY
- PROPOSED REVISED SUBWATERSHED BOUNDARY
- PRIMARY ENVIRONMENTAL CORRIDOR
- SUBBASIN BOUNDARY
- OAKWOOD 1 — SUBBASIN INDENTIFICATION- HYDROLOGIC UNIT AND SUBBASIN NUMBER
- PROPOSED ELEVATED ROAD OR BERM
- PROPOSED BERM
- PROPOSED CULVERT MODIFICATION
- EXISTING CHANNEL TO BE RETAINED
- EXISTING CHANNEL TO BE MODIFIED
- CHANNEL MODIFICATION COMPLETED
- PROPOSED NEW CHANNEL
- 48" — PROPOSED STORM SEWER AND DIAMETER
- PROPOSED DETENTION BASIN
- PROPOSED SEDIMENTATION POND
- LOCATION OF SEDIMENTATION BASINS TO BE CONSIDERED AS AN ALTERNATIVE TO THE SEDIMENTATION POND SOUTH OF COUNTY LINE ROAD PENDING RESOLUTION OF TOXIC MATERIALS CONTAMINATION PROBLEMS IN THE VICINITY OF THE SOUTH POND.
- POTENTIAL FUTURE STORMWATER PUMPING STATION TO BE ADDED SHOULD EXPERIENCE INDICATE THAT A GREATER PROTECTION LEVEL IS NEEDED

NOTE: CONSTRUCTION OF PROPOSED CHANNEL SOUTH OF COUNTY LINE ROAD TO BE DEFERRED OR WILL REQUIRE REALIGNMENT DUE TO GROUND AND SURFACE WATER CONTAMINATION FROM A LANDFILL IN THAT VICINITY. DETAILS TO BE CONSIDERED IN FINAL DESIGN IN CONJUNCTION WITH THE LANDFILL CLEANUP PROGRAM.

THE MINOR STORMWATER DRAINAGE SYSTEM INCLUDING STORM SEWERS AND LOCAL CHANNELS ARE EXPECTED TO BE CONSTRUCTED OVER THE PLAN PERIOD AS DEVELOPMENT DICTATES A NEED AND ARE EXPECTED TO BE PARTIALLY FUNDED BY THE PRIVATE SECTOR.

*Source: SEWRPC.*

of 36-inch storm sewer and 900 feet of channel modifications. The modified channel would run from the proposed 36-inch-diameter outfall at Nicholson Road and Oak Lane to the east. Approximately 900 feet of 36-inch-diameter storm sewer would be installed in Oak Lane from McGraw Drive to Nicholson Road. Approximately 2,100 feet of 36-inch-diameter storm sewer would be installed in Oakwood Road from Crayfish Creek at Pennsylvania Avenue to the

**west. The costs of modifying the channel are not included in the recommended plan cost estimate since the proposed channel modifications have actually been completed. The modified channel is turf-lined and has a base width of five feet and side slopes of one on four.**

Oakwood Subbasin 1: The Phase II stormwater management plan components for Oakwood Subbasin 1 consist of 3,100 feet of storm sewer ranging in size from 24 to 42 inches in diameter. Approximately 1,300 feet of 24-inch-diameter storm sewer would be installed along Fitzsimmons Road from S. 10th Avenue extended to the east. Approximately 1,800 feet of 48-inch-diameter storm sewer would be installed along Fitzsimmons Road from S. 10th Avenue extended to the west and then south, discharging to an open channel.

Oakwood Subbasin 2: The Phase II stormwater management plan components for Oakwood Subbasin 2 consist of 2,200 lineal feet of storm sewer ranging in size from 18 to 36 inches in diameter, approximately 4,700 feet of channel modifications, and approximately 1,100 feet of new open channel. Approximately 900 feet of 18-inch-diameter storm sewer would be installed along Oakwood Road from Chicago Road to the east. Approximately 1,300 feet of 36-inch-diameter storm sewer would be installed along Oakwood Road from Chicago Road to the west, discharging into the proposed new open channel. The approximately 4,700 feet of proposed channel modifications would begin at Oakwood Road just east of 10th Avenue extended, follow the existing channel south, west, and then north back to Oakwood Road, and then follow Oakwood Road to the primary environmental corridor boundary. The modified channel is to be turf-lined and have a bottom width of 10 feet, side slopes of one on four, and an average depth of about four feet.

The proposed open channel would begin at Oakwood Road at the proposed 36-inch-diameter storm sewer outfall and extend southwesterly to the subbasin divide. The new open channel is to be turf-lined and have a bottom width of 10 feet, side slopes of one on four, and an average depth of about four feet.

Meadowview Subbasin 1: The Phase II stormwater management plan components for Meadowview Subbasin 1 consist of approximately 2,000 feet of channel modifications from the Milwaukee County Parkland boundary in the northeast quarter of Section 34 to the west, to the confluence with the Meadowview Subbasin 2 and Meadowview Subbasin 3 channels. The costs of modifying the channel are not included in the recommended plan cost estimate since the proposed channel modifications have recently been completed. The modified channel is turf-lined and has a base width of 18 feet and side slopes of one on four.

Meadowview Subbasin 2: The Phase II stormwater management plan components for Meadowview Subbasin 2 consist of channel modifications, storm sewer, and a detention basin. The proposed detention basin would be located north of Oakwood Road just east of Shepard Avenue, and would have a storage volume of approximately 16.5 acre-feet and a 15-inch-diameter outlet pipe. About 3,000 feet of storm sewer ranging in size from 24 inches in diameter to 63 inch by 98 inch horizontal elliptical is proposed to be installed. Approximately 1,700 feet of 48-inch-diameter storm sewer would be installed along Nicholson Road from the modified channel to Oakwood Road, and then along the north side of Oakwood Road to McGraw Drive. Approximately 1,000 feet of 24-inch-diameter storm sewer would be installed from McGraw Drive to the northwest to the 15-inch-diameter outlet from the proposed detention facility. Approximately 300 lineal feet of 63-inch by 98-inch horizontal elliptical storm sewer would be installed in the existing channel from Shepard Avenue to the proposed detention facility. Approximately 1,200 feet of channel modifications are proposed from Oak Lane to the inlet of the proposed 63-inch by 98-inch storm sewer at Shepard Avenue. The modified channel is to be turf-lined and have a bottom width of 10 feet and one on four side slopes. Approximately 900 feet of channel modifications are proposed from the confluence with the Meadowview Subbasin 1 channel to Nicholson Road. The modified channel would be turf-lined and have a bottom width of eight feet and side slopes of one on four. Since this section of channel has been modified, the cost is not included in the recommended plan cost estimate.

Meadowview Subbasin 3: The Phase II stormwater management plan components for Meadowview Subbasin 3 consist of approximately 4,900 feet of new storm sewer ranging in size from 36 to 48 inches in diameter, and approximately 4,300 feet of channel modifications. Approximately 1,200 feet of 36-inch-diameter storm sewer would be installed along Oakwood Road from Howell Avenue to the west. Approximately 3,700 feet of

48-inch-diameter storm sewer would be installed along Oakwood Road from Howell Avenue to Shepard Avenue, and then to the south along Shepard Avenue extended to the existing channel. The approximately 4,300 feet of channel modifications are proposed from 500 feet west of the proposed 48 inch-diameter storm sewer outfall at Shepard Avenue extended to the confluence with the Meadowview Subbasin 1 channel.

Caledonia Subbasin 1: The Phase II stormwater management plan components for Caledonia Subbasin 1 consist of new storm sewer and channel modifications. Approximately 2,800 feet of 36-inch-diameter storm sewer is proposed to be installed along E. Elm Road from the section line between Sections 35 and 36 to the existing channel just west of S. 10th Avenue extended, and discharged into the modified channel. Approximately 4,500 feet of proposed channel modifications would begin in the northeast one-quarter of U. S. Public Survey Section 35, starting at the proposed new open channel, following the existing channel to the southwest across Elm Road, and continuing to the primary environmental corridor boundary in the southwest one-quarter of U. S. Public Survey Section 35. The modified channel would be turf-lined and have a bottom width of 15 feet and side slopes of one on four.

Caledonia Subbasin 2: The Phase II stormwater management plan components for Caledonia Subbasin 2 consist of new storm sewer and channel modifications. Approximately 2,000 feet of 60-inch-diameter storm sewer would be installed from E. Elm Road at S. 4th Avenue to the south to E. County Line Road, and then west along E. County Line Road to just west of the section line between U. S. Public Land Survey system Sections 35 and 36, where it would discharge into the existing channel. Approximately 3,500 feet of proposed channel modifications would start at E. County Line Road at the proposed 60-inch-diameter storm sewer outfall, following the existing channel into Caledonia and then back across E. County Line Road into Oak Creek to the primary environmental corridor boundary west of S. 10th Avenue. The modified channel would be turf-lined and have a bottom width of five feet and side slopes of one on four. Approximately 1,300 feet of channel modifications would start at S. Elaine Road at E. Schmitz Drive, following the existing channel to the south and west to the primary environmental corridor boundary. The modified channel would be turf-lined and have a bottom width of five feet and side slopes of one on four.

Lower Crayfish Subbasin 1: There are no improvements proposed for Lower Crayfish Subbasin 1 under Phase II of the stormwater management plan.

Lower Crayfish Subbasin 2: The Phase II stormwater management plan components for Lower Crayfish Subbasin 2 consist of new storm sewer and channel modifications. Approximately 1,200 feet of 48-inch-diameter storm sewer would be installed along E. Elm Road in the northwest one-quarter of Section 35. The approximately 1,700 feet of channel modifications would begin at the proposed 48-inch-diameter sewer outfall and follow the existing channel along E. Elm Road. The modified channel would be turf-lined and have a bottom width of five feet and side slopes of one on four.

Lower Crayfish Subbasin 3: The Phase II stormwater management plan components for Lower Crayfish Subbasin 3 consist of 2,500 feet of storm sewer ranging in size from 54 to 72 inches in diameter. Approximately 900 feet of 72-inch-diameter storm sewer would be installed along E. Elm Road from the Crayfish Creek channel to the west to just beyond the Chicago & North Western Railway tracks. Approximately 1,600 feet of 54-inch-diameter storm sewer would be installed along E. Elm Road from the Chicago & North Western tracks to the west to Nicholson Road.

Lower Crayfish Subbasin 4: The Phase II stormwater management plan components for Lower Crayfish Subbasin 4 consist of 2,400 feet of 36-inch-diameter storm sewer along Nicholson Road from E. Elm Road to the Root River.

Nonpoint Source Pollution Abatement

Some of the recommended stormwater management system components would provide substantial reductions in nonpoint source pollutant loadings. Construction site erosion control measures are also recommended. The recommended detention pond and turf-lined open channels, and the storage and filtration in the primary environmental corridor/wetland complex, may be expected to remove a substantial portion of the pollutant loadings discharging to these facilities. All of the study area would drain to the primary environmental corridor/wetland complex and the recommended detention pond. On an annual

basis, the storage in the primary environmental corridor/wetland complex, the pond, and the infiltration and filtration in the turf-lined open channels may be expected to remove about 90 percent of the total solids, about 80 percent of the lead, and nearly 60 percent of the total phosphorus carried by the runoff discharged from the tributary drainage area.

Under the recommended stormwater management plan, about 1,200 acres, or about 60 percent, of the anticipated urban area of the Crayfish Creek subwatershed in the City of Oak Creek would drain to the turf-lined open channels tributary to the main stem of Crayfish Creek. These channels would allow stormwater to infiltrate the soil and remove associated pollutants by filtration and settling. The channels would be the most effective in removing pollutants during smaller storm events and the least effective during larger storm events.

It is recommended that erosion associated with construction and development activities be controlled through the implementation of a construction erosion control ordinance. Upon request, the Commission staff would assist the City in drafting such an ordinance. The ordinance would provide a definition of land disturbance activities subject to control, set forth standards and criteria for erosion control, describe permit application and administration procedures, identify enforcement and appeal procedures, and define pertinent terms used in the ordinance.

Auxiliary Plan Recommendations

The foregoing recommendations primarily address stormwater drainage system improvements. To provide a comprehensive stormwater management plan, however, these drainage system recommendations must be supplemented by plan elements relating to natural resource and open space protection, and by provision for the proper maintenance of the stormwater drainage system over time.

Natural Resource and Open Space Preservation: A land use plan should be adopted by the City for the Crayfish Creek subwatershed that provides for the preservation of the primary environmental corridors, including associated floodlands and wetlands, in essentially natural, open uses. The protection of floodlands and wetlands from intrusion by urban land uses has important implications for stormwater management since these lands can provide needed capacity for the storage of stormwater runoff. As presented in Table 6 in Chapter III, the land use pattern used in the drainage system plan design and evaluation envisions the preservation of about 535 acres of wetlands, woodlands, and other open lands, or about 17 percent of the City of Oak Creek portion of the Crayfish Creek subwatershed.

Maintenance of Stormwater Management Facilities: The effectiveness of the stormwater conveyance and detention facilities, once developed, can be maintained only if proper operation, repair, and maintenance procedures are carefully followed. Important maintenance activities include the periodic inspection and repair of culverts; clearing of culvert obstructions; maintenance of open channel vegetative lining; clearing of debris and sediment from open channels; maintenance of detention facility inlets and outlets; maintenance of detention basin vegetative cover; and periodic removal of sediment accumulated in detention basins. These activities are recommended to be carried out on a continuing basis to maximize the effectiveness of the stormwater management facilities and measures, and to protect the capital investment in the facilities. It should be noted that, in Milwaukee County, some sections of channel are located on county parklands and may involve maintenance activities for the County. In addition, for the reaches of Crayfish Creek determined to be under the jurisdiction of the Milwaukee Metropolitan Sewerage District, the District would assume responsibility for maintaining the flood-carrying capacity of the channel once the area is within the District limits. Cost estimates of the recommended maintenance activities are included in the total plan costs.

Stormwater Management System Costs

The capital and operation and maintenance costs of the recommended stormwater management plan are presented by hydrologic unit and component in Tables 17 and 18. Table 17 presents those costs required for implementation of the Phase I drainage system components, and Table 18, the costs required for implementation of the Phase II components.

The capital cost of the recommended stormwater management plan is estimated to be $4.0 million, of which about $0.4 million, or 10 percent, is required for Phase I drainage system costs, and $3.6 million, or 90 percent, is required for Phase II costs. The annual operation and maintenance costs of the recommended stormwater manage-

ment plan are estimated to be $20,600. These costs are based upon full development of the urban service area, and do not include the cost of the minimum-diameter collector sewers and road culverts that may be required to drain collector and land access roadways, the alignments of which have not as yet been determined. Also not included in the recommended plan costs are the costs of roadway sections in newly developing areas that have been designated to function as a component of the drainage system.

## IMPACTS OF RECOMMENDED STORMWATER MANAGEMENT PLAN

### Hydraulic Impacts

The primary impact of the recommended stormwater management plan would be that storm flows from a 10-year recurrence interval storm event or smaller would be safely and efficiently conveyed to the main stem of Crayfish Creek with only minimal inconvenience to residents of the subwatershed. Also, storm flows and flood stages from a 10-year to a 100-year recurrence interval storm event would not significantly increase along the main stem of and major tributaries to Crayfish Creek, and in some instances would be effectively reduced as a result of the stormwater management plan recommendations.

The recommended stormwater management plan components would not have a significant impact on the Root River flood flows and stages because of the significant difference in the times of concentration, and because of the relatively small amount of storage in the Crayfish Creek subwatershed compared to the storage available in the upstream and adjacent reaches of the Root River.

Figure 10 shows the rainfall distribution over time of a typical mean annual storm event and the resulting flood hydrograph for the Root River at the confluence of Crayfish Creek as developed by the Commission. As shown in Figure 10, the peak flood discharge on the Root River at the confluence of Crayfish Creek occurs about three days after the peak rainfall intensity for this particular storm event. This lag time between the peak rainfall intensity and the peak flood discharge is estimated to be less than 12 hours on Crayfish Creek at its confluence with the Root River for a similar storm event. Therefore, flood discharges from Crayfish Creek have no impact on flood discharges of the Root River.

This phenomenon was observed when a rainfall of about two inches occurred in the study area over a period of about two hours on June 27, 1986. Field observation made about 12 hours after the storm indicated that the Crayfish Creek floodwaters had receded several hours earlier, while the Root River floodwaters at the mouth of Crayfish Creek were observed to be in the process of rising. Observation of the Root River at this same location three days later indicated that the Root River floodwaters had begun to recede within the previous 12 hours, thus resulting in a lag time of about three days.

As noted above, the recommended stormwater management plan calls for the installation of backwater gates on the culvert at the E. County Line Road crossing of Crayfish Creek to prevent the floodwaters of the Root River from backing up into the Crayfish Creek subwatershed. This would, however, reduce the amount of floodplain storage available along the Root River. Therefore, an analysis was conducted of the impact of this loss in storage on downstream flood flows and stages on the Root River.

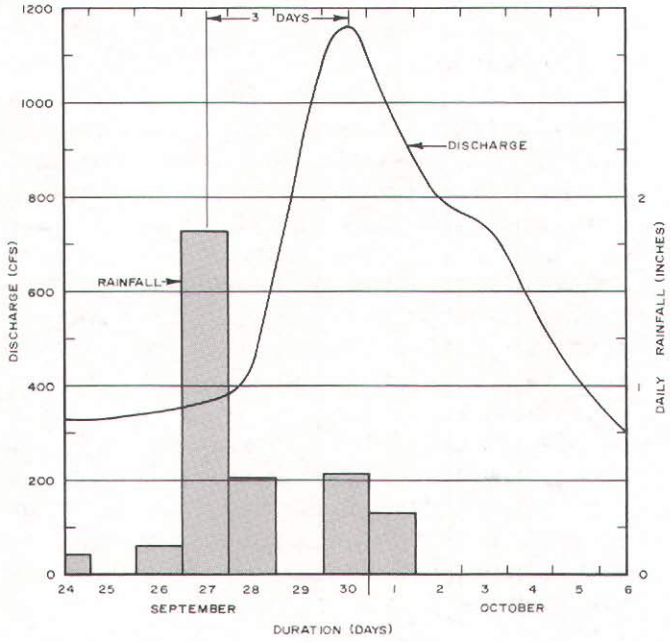
Figure 11 shows the 100-year recurrence interval flood hydrograph for the Root River at the confluence of Crayfish Creek as developed by the Commission. This hydrograph represents a volume of runoff of about 41,500 acre-feet. The water surface elevation on the Root River at the confluence of Crayfish Creek, which corresponds to a peak flood discharge of 4,100 cfs, is 666 feet NGVD. At this flood elevation, the Root River would occupy about 460 acre-feet of storage in the Crayfish Creek subwatershed north of E. County Line Road. Loss of this storage would result in an increase in the hydrograph runoff volume of about 1 percent. This increase would be even less if the entire amount of floodplain storage in this area during the 100-year flood event was considered. Therefore, installation of the backwater gates should have no significant impact on downstream flood flows and stages of the Root River.

### Water Quality Improvement

The recommended plan would provide water quality benefits in that it would result in the detention of some stormwater runoff, with subsequent settling of particulate pollutants within the detention facilities. As noted earlier, the nonpoint source pollutant removal efficiencies of stormwater management systems are estimated to range from 60 to 90 percent. The attendant reductions in such pollutants as biochemical

Figure 10

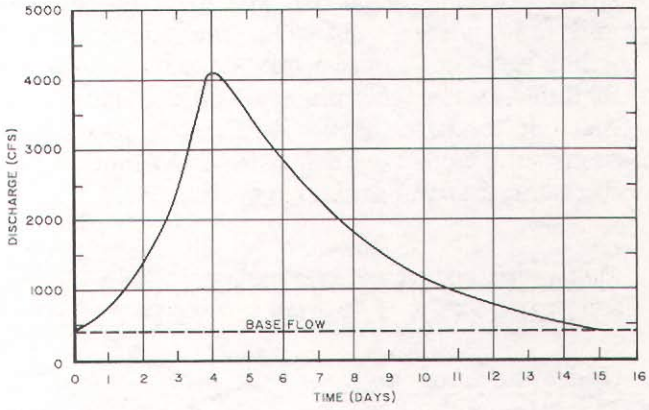
TYPICAL MEAN ANNUAL FLOOD EVENT FOR THE ROOT RIVER AT THE CONFLUENCE OF CRAYFISH CREEK: SEPTEMBER-OCTOBER 1945




*Source: SEWRPC.*

Figure 11

100-YEAR RECURRENCE INTERVAL FLOOD HYDROGRAPH FOR THE ROOT RIVER AT THE CONFLUENCE OF CRAYFISH CREEK




*Source: SEWRPC.*

oxygen-demanding organic materials, nutrients, and toxic metals such as lead are consistent with, and serve to advance, the regional water quality management plan prepared and adopted by the Regional Planning Commission, and will help in achieving the recommended water quality standards in the stream system.

## REFINEMENTS TO THE RECOMMENDED STORMWATER MANAGEMENT PLAN FOR CRAYFISH CREEK BASED UPON INTERAGENCY MEETINGS HELD TO REVIEW THE PRELIMINARY PLAN

A meeting of the Root River Drainage Task Force was held on November 12, 1987, to review the recommended stormwater management plan for the Crayfish Creek subwatershed with representatives of the Town of Caledonia; the Milwaukee County Department of Parks, Recreation, and Culture; the Racine County Parks Department; and the Wisconsin Department of Natural Resources. During that meeting four issues were raised which required additional staff work:

1. The recent finding that the Hunts/Caledonia Corporation landfill site located about one-quarter mile south of County Line Road in U. S. Public Land Survey Sections 27 and 33, Township 5 North, Range 22 East, City of Oak Creek, was contaminated with toxic materials.

2. The desirability of providing sedimentation control facilities ahead of the major environmental corridor/wetland complex which Crayfish Creek traverses in U. S. Public Land Survey Sections 27 and 33, Township 5 North, Range 22 East, City of Oak Creek.

3. The potential downstream impacts of removing Crayfish Creek floodland areas from areas inundated by backwaters of the Root River.

4. The adequacy of the planned drainage channel system serving the Caledonia 2 subbasin.

Each of these four issues was investigated by the SEWRPC staff. The findings of these investigations are herein reported, together with recommended changes to the stormwater management plan.

Concern Over the Potential Toxic Materials Associated with the Hunts/ Caledonia Corporation Landfill Site

It has recently become known through the Racine County Parks Department and the Wisconsin Department of Natural Resources that the landfill site known as the Hunts/Caledonia Corporation disposal site, located in U. S. Public Land Survey Sections 27 and 33, Township 5 North, Range 22 East, about one-quarter mile south of County Line Road and just east of the Chicago & North Western Railway, contains toxic materials. The site has been placed on the State's Superfund site list and investigations have been initiated into the extent of the problem and the means by which the problem can be resolved. Work is presently in the investigation stages, with no details regarding the extent of the problem and the solutions yet available. It is believed, however, that the pond located just to the north of the landfill site may be contaminated.

As indicated on Map 30, under the stormwater management plan as originally proposed, about 700 feet of new channel would be constructed from County Line Road to the existing pond and about 2,100 feet of new channel from the pond to the Root River at a location about 850 feet north of Seven Mile Road. The pond was intended to serve as one component of the nonpoint source pollution abatement plan element recommendations. The pond would not have any significant hydrologic/hydraulic function. In view of the potential contamination of the pond, it would not be desirable to connect the proposed channel to the pond and to the Root River as originally proposed since this could result in the flushing of pollutants from the pond into the River. It was concluded at the November 12 meeting by the parties involved that over time a solution to the toxic and hazardous material problem at this site would have to be found and implemented. Thus, should at some future time the toxic pollution problem concerned be resolved, this could serve as a component of the stormwater management plan as originally conceived. However, the time period entailed is now unknown, but may be expected to be at least five years. Furthermore, the means by which the problem will be resolved is now unknown. Conceivably, solutions which might be considered could eliminate the pond by filling. In view of this, it appears that while the eventual routing of the drainage system through the pond still appears to be desirable, that option may not exist for some period of time and could be foreclosed as a result of the findings of the ongoing investigation at the pond site.

Because this pond served as an important water quality control component of the original plan, other options should be considered on a short-term basis to perform this function. Such options are discussed below. In addition, at the time of plan implementation, it is recommended that an alternative alignment for the channel south of County Line Road be explored as part of the detailed design, taking into account findings of the landfill site investigations available at that time.

The Potential for Providing Sedimentation Controls Ahead of the Major Wetland Complex Through Which Crayfish Creek Flows

During the November 12 meeting, it was pointed out by the Wisconsin Department of Natural Resources' staff that the use of the existing pond located south of County Line Road as a sedimentation basin would provide improved quality for waters entering the Root River. However, because of its location, the pond would not reduce pollutant loadings to Crayfish Creek itself and the large adjacent corridor/wetland complex. It was indicated that a preferable solution in terms of water quality in the wetland area and Crayfish Creek would be to provide sedimentation basins ahead of the corridor/wetland complex.

A review of the stormwater management system plan arrangement indicates that to fully provide sedimentation facilities ahead of the environmental corridor/wetland complex for the entire subwatershed, about 10 basins would need to be installed to serve areas ranging from 120 acres to 600 acres in area. A review of the various sizes of the basins indicates that the 10 basins would have to range from 0.5 acre to 2.1 acres—and from 2.0 to 8.0 acre-feet—in size and would have a total cost of nearly $400,000. In addition, an annual operation and maintenance cost of about $15,000 would be incurred. This cost can be compared with the capital cost of less than $10,000 and an annual operation and maintenance cost of less than $1,000 to utilize the existing pond located south of County Line Road. Sedimentation basins located upstream of the environmental

corridor/wetland complex concerned would offer water quality protection to all of Crayfish Creek, the environmental corridor/wetland complex, and the Root River, while the basin south of County Line Road would offer protection only to the Root River. However, the costs of construction and operation of these basins would be substantial, entailing an increase of over 10 percent in the cost of the entire stormwater management plan. The basins could, however, be built as the development takes place, and thus the construction of some of the basins could be deferred to a time beyond the planning period, or even indefinitely.

An alternative upstream sedimentation basin option would provide for the construction of only four sedimentation basins at locations receiving drainage from subbasins within the Crayfish Creek subwatershed. These four basins would be located at the outlets of the Caledonia 1, Caledonia 2, Oakwood 2, and Meadowview 1 subbasins. This alternative would reduce the cost of the sedimentation basin alternative to about $200,000, while controlling runoff from about 1,800 acres, or just over 56 percent, of the Crayfish Creek subwatershed, excluding the wetlands. These basins could also be constructed as development proceeded in the subwatershed. While this alternative would entail a substantial increase in the cost of the plan, it would allow the improvements to proceed in accordance with development needs without regard for the landfill cleanup action in Caledonia. Should the landfill remedial actions in Caledonia be accomplished in a timely manner, the use of the existing pond south of County Line Road could then be reconsidered, if all of the upstream basins had not been constructed at that time.

It is possible that partial funding for the sedimentation basins could be obtained through the Wisconsin Department of Natural Resources Priority Watersheds Program, thus reducing the local capital costs to perhaps 30 to 40 percent of the total cost, or to $60,000 to $80,000. It is accordingly recommended that the stormwater management plan for the Crayfish Creek subwatershed as originally proposed be modified to include, as an option, the construction of four sedimentation basins in the upstream areas if development takes place in the subbasins tributary to those basins prior to the time that remedial action cleanup efforts are completed for the pond located south of County Line Road. The approximate locations of these ponds are shown on the recommended plan map—Map 30. The recommended sizes of the basins are set forth in Table 19.

Table 19

**SELECTED CHARACTERISTICS OF SEDIMENTATION BASINS FOR THE CRAYFISH CREEK SUBWATERSHED**

| Subbasin Location | Approximate Drainage Area | Approximate Capacity (acre-feet) | Pond Area (acres) |
|---|---|---|---|
| Caledonia 1 . . . . . | 240 | 2.1 | 1.0 |
| Caledonia 2 . . . . . | 220 | 2.0 | 1.0 |
| Meadowview 1. . . . . | 710 | 6.3 | 2.5 |
| Oakwood 2 . . . . . | 590 | 5.4 | 2.0 |

*Source: SEWRPC.*

Potential for Downstream Impacts as a Result Removing the Crayfish Creek Subwatershed from the Areas Inundated by the Root River

The representative of the Town of Caledonia attending the November 12 meeting suggested that the removal of the floodlands in the Crayfish Creek subwatershed from the backwater area of the Root River could result in increased flood flows and stages along downstream reaches of the Root River. The recommended stormwater management plan does include the installation of backwater gates on the culverts under the E. County Line Road crossing of Crayfish Creek to prevent Root River floodwaters from backing up into the Crayfish Creek subwatershed. This would result in a reduction in available floodplain storage within the larger Root River watershed under some conditions. However, the stormwater from the Crayfish Creek subwatershed will be stored. That stormwater will, in effect, partially offset the loss of storage available for backwater from the Root River. Analyses conducted as part of this study indicated that the loss of storage resulting from the recommended improvements would be less than 1 percent of the peak flood runoff volume of the Root River north of E. County Line Road. It was therefore concluded that there should be no significant changes in the downstream flood flows and stages on the Root River. Furthermore, the floodplain immediately downstream of the area is included in parkway and open space lands.

The analysis that was conducted was done in the absence of a complete reapplication of the hydrologic/hydraulic simulation model for the Root River watershed. As of December 1, 1987, the Southeastern Wisconsin Regional Planning Commission was in the process of conducting

a new hydrologic/hydraulic investigation of the entire Root River system as part of a drainage and flood control system planning effort for the Milwaukee Metropolitan Sewerage District. That investigation will include new simulation model applications in both Milwaukee and Racine Counties. It will quantitatively determine the effects of the proposed improvements for the Crayfish Creek subwatershed, as well as other improvements for the larger Root River watershed, on Root River flood flows and stages. This more detailed evaluation is expected to be completed by June 1988, and thus will be available prior to the initiation of any plan implementation actions. In view of the concerns raised by the Town of Caledonia representative, it is recommended that the Milwaukee Metropolitan Sewerage District system plan include a discussion on this issue in order to confirm the initial findings on the effects of the Crayfish Creek stormwater management plan recommendations on downstream flood flows and stages. Should that modeling analysis indicate that downstream problems could occur, then a reevaluation of the Crayfish Creek plan would be required.

The Adequacy of the Existing and Planned Channel System Serving the Caledonia 2 Subbasin

The Town of Caledonia representative at the November 12 meeting noted that some drainage system improvements are being considered within the Caledonia 2 subbasin. He also noted that a 60-inch storm sewer is proposed to be constructed in Oak Creek to County Line Road and then east to an existing drainageway leading from the Town of Caledonia, and that ultimately most of that tributary area within the City of Oak Creek is proposed to be developed. In view of these considerations, the town representative expressed concern as to whether the drainageway beginning at a point about 500 feet north of County Line Road and extending easterly to Crayfish Creek would be adequate.

In response to this concern, the Commission staff reviewed the drainage system that services the Caledonia 2 subbasin. Drainage improvements are proposed along about 3,500 feet of this channel. The improvements would provide for a channel with a bottom width of five feet, a depth of about four feet, and side slopes of one on four. The average deepening would be about one foot. The channel would be improved from the eastern crossing of County Line Road to the location where it enters the limits of the primary environmental corridor, at which location the channel would be tapered to match the existing section. At this location, the channel slope becomes about 0.14 percent, compared to about 0.03 percent along most of the upstream improvements. Within the primary environmental corridor lands, the flood hazard area would extend beyond the channel limits but would not extend beyond the limits of the primary environmental corridor. The floodplain becomes relatively broad in this area, and substantial increases in flows are not accompanied by substantially increased stages. No major improvements are recommended in this area.

The Commission staff has reviewed the drainage improvements proposed to be constructed in the Town of Caledonia. The results of that review are documented in the Commission's letter of April 5, 1988, to the County Planning and Development Director, a copy of which is included in Appendix B. The analyses conducted indicate that the improvements proposed in this report will provide an adequate outlet for the drainage ditch in Caledonia, with no significant increase in stages due to the planned channel improvements.

## SUMMARY

Based on the best alternative for each of five hydrologic units, a recommended stormwater management system plan was developed for the Crayfish Creek subwatershed which includes conveyance system and storage components. The minor system components are designed for a 10-year recurrence interval storm event peak flow with one exception, that being the detention pond located just south of County Line Road, which was left at its existing size. Because of the pond's function as a water quality improvement component, the pond effectiveness is calculated using a broad range of design storms. The major system components are designed for a 100-year recurrence interval storm event peak flow. The improvements considered design storms on both the Crayfish Creek subwatershed and the Root River at its confluence with Crayfish Creek.

The recommended drainage system components consist of two storage facilities; 26,710 lineal feet of new or improved open channels; 29,900 lineal feet of storm sewers; the installation of backwater gates to prevent the backup of Root River flood flows into the study area; the preservation and maintenance of the large environmental

corridor/wetland complex located within the subwatershed; and the continued use of the Crayfish Creek main channel in its present condition north of County Line Road. The plan could readily accommodate the addition of a pumping station at the outlet should operational experience indicate a higher level of protection is needed later in the plan period. Because of problems encountered with groundwater and surface water contamination in the vicinity of an abandoned landfill in the area south of County Line Road, an alternative channel alignment should be considered in that area as part of the detailed design which would take into account ongoing site remedial action investigations. In addition, it is recommended that consideration be given to constructing four sedimentation basins in the tributary drainage areas as part of the stormwater management facilities, since use of the downstream basin may be precluded at this time. The total capital cost of the recommended plan is about $4.2 million, and the average annual operation and maintenance cost is about $29,000.

The plan recommends the most cost-effective means of resolving existing and probable future drainage and flooding problems in the subwatershed, thereby reducing the public costs attributable to improperly functioning drainage facilities. Implementation of the recommended plan would provide protection against substantial inconvenience to residents during minor storm events, and against major property damage or a significant hazard to human health and safety during major storm events. It would support the continued sound land use development and redevelopment of the subwatershed, enhancing the quality of life within the Crayfish Creek subwatershed in the City of Oak Creek.

# Chapter VII

# PLAN IMPLEMENTATION

## INTRODUCTION

The recommended stormwater management plan described in Chapter VI is designed to attain, to the maximum extent practicable, the stormwater management objectives and standards set forth in Chapter IV of this report. In a practical sense, however, the plan is not complete until the steps required to implement it—that is, to convert the plan into action policies and programs—have been specified. Following formal adoption of this plan by the City of Oak Creek, realization of the plan will require a long-term commitment to the objectives of the plan and a high degree of coordination and cooperation among city officials and staff, Town of Caledonia officials and staff, land developers, and concerned citizens in undertaking the substantial investments and series of actions needed to provide both existing and future urban development in the Crayfish Creek subwatershed with an efficient and effective stormwater management system. The plan should be used as a guide for the development of the stormwater management system in the subwatershed.

The first section of this chapter describes the relation of land use development to the effectiveness of the planned stormwater management measures. The second section discusses the importance of more detailed engineering to implementation of the plan. The third section sets forth the actions required to implement the plan. A preliminary implementation schedule and information relating to financing is set forth in the fourth section. The fifth section discusses the need for periodic reevaluation and updating of the plan itself.

## RELATION TO LAND USE DEVELOPMENT

Fundamental to implementation of a sound stormwater management plan is coordination with land use development. A design year 2000 land use pattern for the stormwater management area was described in Chapter III of this report. To a large extent, the effectiveness of the recommended stormwater management measures will depend upon the degree to which land use development and stormwater management system development are coordinated and related.

Implementation of the stormwater management plan will assure that the Crayfish Creek subwatershed will be served by a stormwater drainage system that is both economical and effective; that has the capacity to accommodate stormwater runoff from not only existing development but planned development; and that will not exacerbate existing, or create new, downstream flooding problems. The plan also provides an estimate of the capital investment required to meet the stormwater management needs, allowing the public officials concerned to fairly allocate capital cost requirements, as well as to consider the operation and maintenance costs to be allocated to the City of Oak Creek.

Importantly, the stormwater management plan identifies those areas of the drainage basin which should be preserved in essentially natural, open uses. Such preservation will provide economies in stormwater management—maximizing the use of natural stormwater conveyance and storage, and permitting such conveyance and storage to be incorporated into the stormwater management plan and system. If the preservation of these open areas is compromised, stormwater management problems, such as localized flooding, poor drainage, and water pollution, may be expected to result.

## RELATION OF DETAILED ENGINEERING DESIGN TO SYSTEM PLANNING

The systems level stormwater management plan presented in this report is intended to serve as a guide to the design and construction of stormwater management facilities in the Crayfish Creek subwatershed. The detailed engineering phase of stormwater management facility development begins where the systems planning phase ends. The detailed engineering phase should examine in greater depth and detail the variations in the technical, economic, and environmental features of the recommended solutions to problems identified in the systems plan in order to determine the best means of carrying out the plan. The resulting facility development plans should be fully consistent with the stormwater collection, conveyance,

and storage facility recommendations presented in Chapter VI of this report.

Chapter IV of this report presented the engineering design criteria and analytic procedures used in the preparation and evaluation of the alternative stormwater management system plans. These criteria and procedures, firmly based in good engineering practice, provided the means for quantitatively sizing and analyzing the performance of the stormwater drainage system components. These criteria and procedures should also serve as a basis for the more detailed design of stormwater management system components in the implementation of the recommended plan. It is important that such criteria and procedures be applied uniformly and consistently in all phases of implementation if the resulting system is to perform as envisioned in the plan. It is recognized that over time new design techniques may be developed and become available for use in the design of stormwater management system components. Such techniques should, however, be carefully reviewed before adoption for consistency with the criteria and procedures set forth in the plan.

## PLAN IMPLEMENTATION

Implementation of the plan will require primarily the cooperative actions of two units of government: the City of Oak Creek and the Milwaukee Metropolitan Sewerage District. Other units of government and agencies involved in plan implementation include Racine County, Milwaukee County, the Town of Caledonia, the Wisconsin Department of Natural Resources, and possibly the U. S. Army Corps of Engineers. The plan implementation recommendations in this chapter are based upon existing programs and enabling legislation.

The Milwaukee Metropolitan Sewerage District is recommended to be the lead agency in the construction and maintenance of the Phase I stormwater management improvements, while the City of Oak Creek is recommended to be the lead agency in the construction of the Phase II improvements. This division of responsibility has been made in light of the policy plan[1] recently adopted by the District which identifies those streams and watercourses for which the District will assume jurisdiction with regard to drainage and flood control. That plan indicates that the District will assume jurisdiction over the perennial reaches of the main stem of Crayfish Creek and the tributary extending northeasterly from the main stem at County Line Road. The remaining stream and channel reaches where improvements have been recommended are to remain under the jurisdiction of the local unit of government—the City of Oak Creek. The completion of the stormwater drainage and flood control policy plan by the District was followed by the preparation in 1987 of a stormwater drainage and flood control system plan identifying specific projects for stream reaches under the District's jurisdiction and the priority system for implementation.

It should be noted that no improvements will be made by the District within areas not included in the District boundaries. As of September 1987, the Crayfish Creek channel was not included within the District boundaries. Under the District's policy plan, the Phase I improvements can be carried out by the District only if Crayfish Creek is within the District limits. Thus, the City may wish to request that the District limits be modified to include the portion of Crayfish Creek within the City.[2]

### Plan Adoption

An important first step in plan implementation is the formal adoption of the recommended stormwater management plan, as documented herein, by the City Plan Commission of the City of Oak Creek, by the Common Council of the City of Oak Creek, and by the Milwaukee Metropolitan Sewerage District.

Upon such adoption, the stormwater management plan becomes the official guide to the making of stormwater management decisions in the Crayfish Creek subwatershed by city and District officials. Such formal adoption serves to signify agreement with and official support of the recommendations contained in the plan, and enables

[1] *See SEWRPC Community Assistance Planning Report No. 130, A Stormwater Drainage and Flood Control Policy Plan for the Milwaukee Metropolitan Sewerage District, March 1986.*

[2] *During the first half of 1988 the City did petition the District to include the Crayfish Creek subwatershed in the District boundaries. The District approved the request, and after proceeding with the required legal steps have added the area to the District.*

the city and District staffs to begin integrating the plan recommendations into the ongoing public works development planning and programming processes of the City and the District, and into the zoning and subdivision plat review processes of the City.

Implementation Procedures

With regard to stormwater management facilities, there are a a number of legal and administrative tools available to assist the City in plan implementation. These tools include development proposal review; capital improvements programming; maintenance programming; and coordination with stormwater management programs in adjacent communities.

In reviewing land subdivision plats, the City Plan Commission should determine the compatibility of the proposed plats with the land use assumptions set forth in the stormwater management plan. Any proposed departures from those assumptions should be carefully considered in light of the stormwater management needs of the proposed development and the impacts on upstream and downstream areas. It should be noted that future development in the Town of Caledonia portion of the study area will have an impact on stormwater management needs in the Crayfish Creek subwatershed. It will therefore be important to attempt to achieve agreement between the Town of Caledonia and the City on the plan, and on plan implementation actions involving land use as well as stormwater management facility development.

Capital improvements programming can be an important tool for implementing the recommended stormwater management plan. Typically, a capital improvements program is a five-year program for the timing and financing of capital improvement projects. Such a program is based upon the projected financial capability of the community, and is formulated from a detailed analysis of municipal revenues, debt service obligations, financing procedures, and external funding potentials. Once formulated, the program should be reevaluated, refined, and extended on an annual basis. The City has a well-developed procedure for capital improvement financing, and it is recommended that the stormwater management plan components be incorporated into the program.

A common stormwater management problem facing municipalities is a lack of a continuing maintenance program for stormwater facilities, including periodic inspection and routine preventive maintenance. This problem is caused by the absence of an assured, continuous source of funding, and incomplete records to justify budgeting for this funding. Stormwater facility maintenance can be ignored for a limited period of time, and many officials and citizens alike incorrectly perceive that certain components, such as open channels or sewers, are self-maintaining, or that no hazards will result if such facilities become defective. A sound, preventive maintenance program is, however, essential to the proper operation of a stormwater management system, particularly for a system that includes various types of components such as storm sewers, roadside swales, culverts, open channels, backwater gates, and onsite and centralized detention facilities that are interrelated and interconnected. The City does have a maintenance program for drainage facilities. It is therefore recommended that the public works program of the City continue to provide for the maintenance, as well as construction, of the stormwater management facilities—including periodic inspection of conveyance and detention facilities; timely repair of facilities; cleaning of storm sewers, open channels, and detention facility inlets and outlets; maintenance of open channel and detention facility lining materials; and periodic removal of accumulated sediment from conveyance, detention, and sediment control facilities.

The Milwaukee Metropolitan Sewerage District would be responsible for maintaining the hydraulic capacity of the channel from Elm Road downstream to the confluence with the Root River, including periodic inspection and cleaning of the backwater gates. Routine housekeeping maintenance in this reach would be the responsibility of Milwaukee County and the City of Oak Creek.

With regard to the stormwater management facilities proposed to be under the jurisdiction of the District, the initial step in implementation is to have the needed facilities incorporated into the District's stormwater drainage and flood control system plan. Incorporation of the recommended improvements into that plan will provide a project priority in the District capital improvement program to complement the system plan.

It will be also be necessary for the City and the District to coordinate specific stormwater management facility development with the Town of Caledonia and Racine County. Channel im-

provements are recommended for a portion of the unnamed Crayfish Creek tributary originating in Oak Creek in the southeast quarter of Section 36, and flowing southward under E. County Line Road into Caledonia and then northward back under E. County Line Road into Oak Creek. In addition, a new channel is recommended to be constructed for Crayfish Creek between County Line Road and the Root River in Racine County.

## PLAN SCHEDULE OF IMPLEMENTATION AND FINANCING

Upon adoption of the recommended stormwater management plan by the City Plan Commission, the Common Council of the City of Oak Creek, and the District, implementation of the plan will require that the system development costs be allocated equitably between the public sector and the private sector, that the means of financing the plan components be identified, and that a schedule of capital and operation and maintenance costs be prepared. Public sector costs would primarily be borne by the City of Oak Creek and the Milwaukee Metropolitan Sewerage District, although state or county funds could be used to construct and maintain certain stormwater drainage systems associated with state or county trunk highways. Private sector costs would, in most cases, be borne by land developers, and these costs would generally be passed on to individual building site purchasers.

Total plan implementation costs would include land acquisition, construction, operation and maintenance, facility replacement, and administrative costs. The plan costs presented herein include only the construction, or capital, costs, operation and maintenance costs, administrative costs, and land acquisition costs for the detention basin located north of E. Oakwood Road and east of S. Shepard Avenue. Costs of land for rights-of-way are not specifically included. However, these costs may not be significant since most of the recommended stormwater management facilities can be placed in public street rights-of-way.

### Deferral of Improvements

Many of the recommended plan components are located in the lower reaches of the watershed where existing development is sparse. In those areas, the City may wish to stage implementation of the recommended plan components as development occurs and the improvements become necessary.

### Public Sector and Private Sector Costs

In order to develop a plan implementation schedule, it must be determined whether each component will be funded by the public sector or the private sector. In general, capital costs were assumed to be borne by the public sector if the components were designed to serve public property, or if the general public—not simply the owners of the new development—would benefit from the component. Capital costs were assumed to be borne by the private sector if the primary benefit of the component would accrue to the new development. The following criteria were applied to allocate capital costs to the public sector and private sector:

1. The improvement of existing drainage system components in order to resolve stormwater problems for more than a single property or an isolated area, and of components designed to serve public property, was assumed to be funded by the public sector.

2. Components, or portions of components, designed to serve new, private urban land use development, or to solve an isolated problem relating to a single property, were assumed to be funded by the private sector.

3. Components intended to serve new, private urban land use development which must be oversized to provide capacity for additional upstream urban development were assumed to be funded by both the public sector and the private sector. The portion of the total capital cost allocated to each sector was based upon the percentage of the total component service area covered by the specific new urban development. The private sector was assumed to finance the costs of serving the new urban development; the public sector was assumed to finance the costs of the oversizing required to serve the additional urban development upstream.

All operation and maintenance costs for conveyance facilities—storm sewers and open channels—were assumed to be financed by the public sector, regardless of whether public sector or private sector funds were used to construct the facilities. It was assumed that all conveyance facilities constructed with private sector funds would be dedicated to the City following construction. Public sector and private sector expenditures

Table 20

ASSIGNMENT OF PUBLIC SECTOR AND PRIVATE SECTOR COSTS FOR SYSTEM COMPONENTS OF THE RECOMMENDED STORMWATER MANAGEMENT PLAN–PHASE I

| Hydrologic Unit Designation | Component Designation | Public Sector[a] | | Private Sector | | Total[a] | |
|---|---|---|---|---|---|---|---|
| | | Capital | Annual Operation and Maintenance | Capital | Annual Operation and Maintenance | Capital | Annual Operation and Maintenance |
| Upper Crayfish | 1 | $ 4,000 | $ -- | -- | -- | $ 4,000 | $ -- |
| | 2 | 60,000 | 1,000 | -- | -- | 60,000 | 1,000 |
| | 3 | 10,000 | -- | -- | -- | 10,000 | -- |
| | E & C | 10,000 | -- | -- | -- | 10,000 | -- |
| Lower Crayfish | 1 | $ 80,000 | $ -- | -- | -- | $ 80,000 | $ -- |
| | 2 | 40,000 | -- | -- | -- | 40,000 | -- |
| | 3 | 75,000 | 8,000 | -- | -- | 75,000 | 8,000 |
| | 4 | 3,000 | -- | -- | -- | 3,000 | -- |
| | 5 | 90,000 | 1,000 | -- | -- | 90,000 | 1,000 |
| | E & C | 25,000 | -- | -- | -- | 25,000 | -- |
| Total | | $397,000 | $10,000 | -- | -- | $397,000 | $10,000 |

NOTE: E & C denotes engineering and contingencies.

[a] *All costs on this table for the Phase I improvements are for facilities on stream reaches under the jurisdiction of the Milwaukee Metropolitan Sewerage District.*

*Source: SEWRPC.*

required for plan implementation are listed in Tables 20 and 21. Those tables also indicate the public costs that would be entailed in the construction and operation and maintenance of facilities under the jurisdiction of the District, as well as of the City of Oak Creek.

Public Sector Financing

As previously noted, funding may be available through the District for the construction of the Phase I projects that are located on stream reaches under District jurisdiction. The remaining projects with costs allocated to the public sector will have to be funded by the City of Oak Creek.

Several means of financing stormwater management components are available to local governmental agencies that are not available to the private sector. However, although these means offer flexibility, certain constraints and limitations are imposed on these financing methods by State law and, especially, by the approvals required of the electorate. Therefore, successful public financing of the recommended plan will require careful study of the costs and available revenues, and a timely approach to securing public support and approval.

State grants are available to finance stormwater management measures when those facilities have water quality benefits. The City may therefore be able to obtain some financial assistance from the Wisconsin Fund Nonpoint Source Pollution Abatement Program administered by the Wisconsin Department of Natural Resources for the construction of the detention basin recommended to be provided at Shepard Avenue and Oakwood Road, since that basin would provide water quality benefits. In addition, the construction of the

Table 21

## ASSIGNMENT OF PUBLIC SECTOR AND PRIVATE SECTOR COSTS FOR SYSTEM COMPONENTS OF THE RECOMMENDED STORMWATER MANAGEMENT PLAN—PHASE II

| Hydrologic Unit Designation | Component Designation | Public Sector[a] | | Private Sector | | Total | |
|---|---|---|---|---|---|---|---|
| | | Capital | Annual Operation and Maintenance | Capital | Annual Operation and Maintenance | Capital | Annual Operation and Maintenance |
| Oakwood | 1-1 | $ 101,000 | $ -- | $ 79,000 | -- | $ 180,000 | $ -- |
| | 1-2 | -- | -- | 50,000 | -- | 50,000 | -- |
| | 2-1 | -- | -- | 30,000 | -- | 30,000 | -- |
| | 2-2 | 70,000 | -- | 20,000 | -- | 90,000 | -- |
| | 2-3 | 20,000 | -- | 10,000 | -- | 30,000 | -- |
| | 2-4 | 40,000 | 200 | 20,000 | -- | 60,000 | 200 |
| | Sedimentation Basin | 70,000 | 2,700 | -- | -- | 70,000 | 2,700 |
| | E & C | 40,000 | -- | -- | -- | 40,000 | -- |
| Caledonia | 1-1 | $ 160,000 | $ -- | $ 40,000 | -- | $ 200,000 | $ -- |
| | 1-2 | 20,000 | -- | 20,000 | -- | 40,000 | -- |
| | 2-1 | 339,000 | -- | 141,000 | -- | 480,000 | -- |
| | 2-2 | 15,000 | -- | 15,000 | -- | 30,000 | -- |
| | 2-3 | 10,000 | -- | 10,000 | -- | 20,000 | -- |
| | Sedimentation Basin | 25,000 | 1,000 | -- | -- | 25,000 | 1,000 |
| | E & C | 60,000 | -- | -- | -- | 60,000 | -- |
| Meadowview | 1-1 | $ -- | S -- | $ -- | -- | $ --[b] | $ -- |
| | 2-1 | -- | -- | -- | -- | --[b] | -- |
| | 2-2 | 95,000 | -- | 75,000 | -- | 170,000 | -- |
| | 2-3 | -- | -- | 40,000 | -- | 40,000 | -- |
| | 2-4 | 210,000 | 10,000 | -- | -- | 210,000 | 10,000 |
| | 2-5 | 47,000 | -- | 13,000 | -- | 60,000 | -- |
| | 2-6 | 5,000 | -- | 5,000 | -- | 10,000 | -- |
| | 3-1 | 25,000 | -- | 25,000 | -- | 50,000 | -- |
| | 3-2 | 207,000 | -- | 163,000 | -- | 370,000 | -- |
| | 3-3 | 27,000 | -- | 53,000 | -- | 80,000 | -- |
| | Sedimentation Basin | 80,000 | 3,300 | -- | -- | 80,000 | 3,300 |
| | E & C | 100,000 | -- | -- | -- | 100,000 | -- |
| Upper Crayfish | 1-1 | $ 10,000 | $ 400 | $ 10,000 | -- | $ 20,000 | $ 400 |
| | 1-2 | 40,000 | -- | 40,000 | -- | 80,000 | -- |
| | 1-3 | 44,000 | -- | 66,000 | -- | 110,000 | -- |
| | 2-1 | 110,000 | -- | 40,000 | -- | 150,000 | -- |
| | 2-2 | -- | -- | -- | -- | --[b] | -- |
| | 2-3 | 20,000 | -- | 40,000 | -- | 60,000 | -- |
| | E & C | 40,000 | -- | -- | -- | 40,000 | -- |
| Lower Crayfish | 2-1 | $ 67,000 | $ -- | $ 53,000 | -- | $ 120,000 | $ -- |
| | 2-2 | 5,000 | -- | 5,000 | -- | 10,000 | -- |
| | 3-1 | 156,000 | -- | 44,000 | -- | 200,000 | -- |
| | 3-2 | 80,000 | -- | 50,000 | -- | 130,000 | -- |
| | 4-1 | 64,000 | -- | 106,000 | -- | 170,000 | -- |
| | Sedimentation Basin | 25,000 | 1,000 | -- | -- | 25,000 | 1,000 |
| | E & C | 130,000 | -- | -- | -- | 130,000 | -- |
| Total | | $2,557,000 | $18,600 | $1,263,000 | -- | $3,820,000 | $18,600 |

NOTE: E & C denotes engineering and contingencies.

[a] *All costs on this table are for improvements on stream reaches not considered under the jurisdiction of the Milwaukee Metropolitan Sewerage District.*

[b] *Since these components have been completed, their costs are not included in the cost estimate.*

*Source: SEWRPC.*

four sedimentation basins would likely be eligible for Wisconsin Fund assistance since their sole purpose is to provide water quality benefits.

The operation and maintenance costs attendant to implementation of the plan should be funded out of the city general fund as part of the ongoing public works program. The expected increase in operation and maintenance costs of $20,600 per year upon full plan implementation may be expected to be phased in as new facilities are constructed.

Private Sector Financing

For new urban developments that encompass recommended stormwater management components, provision of the recommended facilities by the developer would ordinarily be a condition of plat approval by the City. Thus, the costs, while initially borne by the developer, would be ultimately borne by the land parcel purchasers.

Regulatory Considerations

Implementation of some of the drainage improvements recommended in this system plan may require the prior approval of certain regulatory agencies other than the City, including the Wisconsin Department of Natural Resources, the U. S. Army Corps of Engineers, Milwaukee County, Racine County, and the Town of Caledonia. In addition, District approvals may be needed for certain facilities, including those constructed on streams not considered under its jurisdiction for flood control and drainage improvements. The regulatory process involved is complex and has been the subject of dispute between the staffs of at least two of the regulatory agencies concerned. Accordingly, the City should seek legal counsel prior to proceeding with any drainage improvements that involve the construction or improvement of artificial waterways connecting to navigable waters; the alteration or enclosure of navigable watercourses; the removal of material from the beds of navigable watercourses; or the filling of wetlands.

The federal regulatory authority relates to the filling of wetlands and is granted under Section 404 of the Federal Water Pollution Control Act of 1972, as amended. The administering agency is the U. S. Army Corps of Engineers.

The state regulatory authority relates to the construction or improvement of artificial waterways connecting to, or located within, a prescribed distance of a navigable waterway; the alteration of navigable waterways; the placement of deposits or structures in the bed of navigable waterways or the enclosure of navigable waterways; and the removal of material from navigable waters. The authority is contained in Sections 30.12, 30.19, 30.195, 30.196, and 30.20 of the Wisconsin Statutes. The administering agency is the Wisconsin Department of Natural Resources. Some of the authority granted to that Department under these sections of the Statutes may not apply to Milwaukee County, as it has a population of more than 500,000. Under Section 66.894 of the Wisconsin Statutes, the Milwaukee Metropolitan Sewerage District has authority to improve watercourses within the District, such improvement including the deepening, widening, or otherwise changing of watercourses, including navigable watercourses, where such change is deemed necessary to carry off surface or drainage waters. This District authority has been disputed in some instances by the staff of the Wisconsin Department of Natural Resources. Under the cited regulatory authority, the District has promulgated rules requiring municipalities to obtain the prior approval of the District for the construction of certain types of drainage improvements. Accordingly, because the City of Oak Creek lies within Milwaukee County and within the Milwaukee Metropolitan Sewerage District, certain drainage improvements within the City may be subject to approval by the Milwaukee Metropolitan Sewerage District. Finally, since some of the improvements proposed to be constructed lie in the Town of Caledonia in Racine County and on land owned by Racine County, it will be important to coordinate implementation efforts with those governing bodies in order to assure that all parties involved are in agreement on the improvements.

## PLAN REEVALUATION AND UPDATING

The recommended stormwater management components, as well as the forecasts and assumptions used as a basis for plan development, should be reevaluated at 10-year intervals in light of changes in actual city development. The plan components, as well as the need for certain facilities and the location, size, and capacity of facilities, should be revised as necessary to reflect changing development patterns and stormwater management needs. In addition, in the initial plan development it was necessary to limit the analysis and recommendations to major conveyance and detention facilities, since the layout of collector and land access streets had

not been determined. A major effort in plan updating should be directed toward developing recommendations and updating inventories for these smaller-size conveyance elements both in the City and in upstream areas as development plans are prepared, and incorporating this information into the master stormwater management plan.

## SUMMARY

This chapter has presented recommendations for implementing the stormwater management plan for the Crayfish Creek subwatershed. That plan is intended to be used as a guide to both land use and stormwater management system development within the drainage basin. The importance of relating land use development to the stormwater management plan, and the essential role of detailed engineering design activities in implementing the plan, cannot be overemphasized.

An important implementation consideration is the jurisdictional responsibility for the stream reaches in the subwatershed. The Milwaukee Metropolitan Sewerage District recently completed a policy plan which indicates that the District will assume jurisdiction for drainage and flood control improvements on the main stem of Crayfish Creek and on a tributary extending northeasterly from Crayfish Creek at County Line Road. Thus, the implementation of the recommended plan should be a cooperative effort of the District and the City.

The initial step in plan implementation is formal adoption of the plan by the City Plan Commission, the Common Council, and Milwaukee Metropolitan Sewerage District. The actions recommended in the plan should then be integrated into the city public works program and the District system plan to initiate construction of the recommended facilities, as well as to ensure reliable and stable operation and maintenance of both the existing and new facilities. In order to implement the plan, the City should adjust its zoning to the plan; should review subdivision plats to determine conformance between proposed land uses and the recommended plan; and should incorporate public expenditures for stormwater management into a sound overall capital improvements program for the City.

Phase I of the recommended plan should be implemented first, with Phase II being implemented only as further development occurs. About $2.95 million, or about 70 percent of the total capital cost of $4.22 million required to implement the plan, is recommended to be borne by the public sector. Of this cost, $393,000, or 13 percent, would be expended on stream reaches under the jurisdiction of the District. The remaining $2,557,000, or 87 percent, would be expended on facilities under city jurisdiction. The remaining $1.26 million, or about 30 percent of the capital cost, would be financed by the private sector, primarily land developers and land parcel purchasers. All of the approximately $28,600 increase in annual operation and maintenance costs over the implementation period would be financed by the public sector, with about $10,000, or 49 percent, being expended for facilities on stream reaches under the jurisdiction of the District; and $10,600, or 35 percent, on stream reaches under the jurisdiction of the City.

The recommended stormwater management plan provides the City of Oak Creek with important guidelines for coordinating land use development and stormwater drainage and control system development. The stormwater management plan should assist city officials in guiding the physical development of the Crayfish Creek subwatershed. In this respect, implementation of the plan will contribute toward enhancing the overall quality of the environment within the study area, and thereby contribute toward making the City of Oak Creek a safer, more attractive, and more healthful, as well as more efficient and economical, place in which to live and work.

## Chapter VIII

# SUMMARY OF STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED

Stormwater drainage, or, as it has been more recently called, stormwater management, consists of the collection, temporary storage, transport, and disposal of excess stormwater. Stormwater management is one of the most important requirements of sound urban development, being essential to the provision of an attractive, efficient, safe, and healthful urban environment. Inadequate stormwater management can be costly and disruptive, can create health and safety hazards, and can have adverse effects on the overall quality of the environment. Sound stormwater management planning involves the art of urban engineering, the sciences of hydrology and hydraulics, and economic and environmental impact assessment, and takes into account public perceptions of, and attitudes toward, stormwater drainage problems.

Those portions of the Crayfish Creek subwatershed lying within the City of Oak Creek are expected to experience substantial urban development over the next two decades. In the absence of adequate planning and engineering, this development may be expected to exacerbate existing, and create new, stormwater management problems. Therefore, the City of Oak Creek requested the Regional Planning Commission to assist the City in the preparation of a long-range stormwater management system plan for the Crayfish Creek subwatershed. The plan is intended to facilitate the development of an effective stormwater management system for the subwatershed that will minimize the damages attendant to poor drainage, as well as the costs of stormwater management facilities. The recommended plan for the Crayfish Creek subwatershed focuses on stormwater management, but also considers flood control since stormwater management and flood control are directly interrelated because of the topographic conditions of the subwatershed.

The plan recognizes that the basic concepts underlying urban stormwater management are undergoing revision. The new concepts are aimed at controlling the quality, as well as the quantity, of runoff, and seek to manage stormwater as a resource rather than to treat it as a nuisance. These new concepts envision the stormwater management system of an urban area as consisting of two elements: a minor element to manage the runoff from the smaller, more frequent rainfall events; and a major element to manage the runoff from the larger, less frequent rainfall and snowmelt events. The former element is intended to avoid the nuisances attendant to minor ponding of stormwater runoff in yards and streets, and consists of curbs and gutters, or road ditches, and storm sewer inlets and sewers. The latter element is intended to avoid the much more serious flooding of basements and first floors of buildings, and consists of the full cross-section of the public streets and highways, with runoff discharging to either engineered or natural streams and watercourses. In order to minimize costs and pollution, the major system is designed, insofar as practicable, to utilize storage as well as conveyance. As part of the planning process, criteria and procedures were developed for use by the City in estimating stormwater flows and for designing street cross-sections, storm sewer inlets, storm sewers, open drainage channels, storage facilities, pumping facilities, culverts, and water quality management measures.

## PLANNING AREA

The planning area consists of the incorporated area of the City of Oak Creek within the Crayfish Creek subwatershed, together with those portions of the Town of Caledonia tributary to Crayfish Creek. The planning area is drained by Crayfish Creek, and by the Caledonia, Meadowview, and Oakwood Branches of Crayfish Creek. The study area is about 3,701 acres, or about 5.8 square miles, in areal extent, of which about 83 percent lies within the corporate limits of the City. The boundaries of the planning area, together with the drainage basin boundaries, are shown on Map 3 in Chapter II.

## INVENTORY AND ANALYSIS

Data were collated and collected on the existing land use, climate, soils, natural and man-made stormwater drainage systems, drainage and

flooding problems, and erosion and sedimentation control problems of the planning area. Urban land uses in 1980 occupied about 24 percent of the total planning area, with residential uses making up the largest urban land use category. Agricultural land use accounted for about 54 percent of the planning area, with other open uses, including woodlands, wetlands, and surface water, constituting about 22 percent of the planning area.

Because the relationships between rainfall intensity, duration, and frequency are important considerations in stormwater management planning, the Regional Planning Commission has developed a set of rainfall intensity-duration-frequency relationships for use in estimating peak rates of runoff in southeastern Wisconsin, including the Oak Creek area, together with data for use in estimating the volume of rainfall and stormwater runoff associated with a given frequency and duration storm event.

Soil properties are an important factor influencing the rate and amount of stormwater runoff from land surfaces. Accordingly, the soils of the area were categorized into four hydrologic soil groups, and the location and extent of the areas covered by each group mapped and quantified. Over 85 percent of the area of the subwatershed is covered by soils considered to have low infiltration capacity, low permeability, and poor drainage characteristics. These soil conditions place severe limitations on the available stormwater management system components, such as infiltration systems.

The intermittent and perennial streams in the subwatershed serve as the major drainage outlets for the drainage ditches and storm sewers. There are approximately 12,400 lineal feet of storm sewer in the study area, ranging in size from 12 inches in diameter to 66 inches in diameter.

## ANTICIPATED GROWTH

The stormwater drainage plan was intended to identify the stormwater management needs of the Crayfish Creek subwatershed through the year 2000. Accordingly, information was collected on the anticipated type, density, and spatial distribution of land uses in the planning area, and on the impact of anticipated changes in land use on the stormwater management needs of the area. About 1,777 acres of land, or an additional 48 percent of the planning area, may be expected to be converted from rural to urban land uses over the next two decades, resulting in about 72 percent of the total planning area being in urban land uses by the plan design year.

## DESIGN CRITERIA AND OBJECTIVES

Early in the planning process, stormwater management design criteria, as well as objectives, were established and agreed upon. The plan was developed considering two basic objectives: 1) to prevent significant monetary damage from any reasonably foreseeable major storm event—defined as a 100-year recurrence interval event; and 2) to provide convenient access to the various land uses of the urban area following minor, more frequent rainfall events—defined as events up to and including the 10-year recurrence interval event. The plan was thus designed to consider both major—operating infrequently—and minor—operating frequently—stormwater management facilities.

The minor stormwater drainage system is intended to minimize the inconveniences attendant to inundation from more frequent storms and consists of sideyard and backyard drainage swales, street curbs and gutters, roadside swales, storm sewers, and some stormwater storage facilities. It is composed of the engineered paths provided for stormwater runoff to reach the receiving streams and watercourses during the more frequent, minor storm events.

The major stormwater drainage system is designed for conveyance and/or storage of stormwater runoff during major storm events when the capacity of the minor system is exceeded. The major stormwater drainage system consists of the entire street cross-section and interconnected drainage swales, watercourses, and stormwater storage facilities. Portions of the streets, therefore, serve as components of both the minor and major stormwater drainage systems.

## ALTERNATIVE PLANS

Prior to designing and evaluating alternative stormwater management plans, the existing stormwater drainage system was evaluated. The

hydraulic capacities of the major components of the existing system were determined and compared to estimated design flows. Those system components that were found to be unable to accommodate the runoff expected from the design storms under either existing or future land use conditions, or both, were thus identified, and the deficiencies of these components were then addressed in the design of alternative stormwater management plans. Problem components were identified under both existing and design year development conditions.

Alternative approaches to stormwater management that were considered for application in the Crayfish Creek subwatershed included conveyance, centralized detention, decentralized onsite detention, centralized retention, decentralized onsite retention, and nonstructural measures. Using various combinations of these approaches, 17 alternative stormwater management system plans were considered for the Crayfish Creek subwatershed. Of the 17 alternative plans, seven were identified for further consideration. The capital cost of the seven selected alternatives ranged from $1.36 to $9.0 million for a 10-year design. Evaluation of the alternatives indicated that Alternative 17, as described in Chapters V and VI, with refinements and installed in two phases, would best serve the Crayfish Creek subwatershed.

## RECOMMENDED PLAN

The recommended stormwater management system plan provides for the discharge of stormwater to the Root River at a location about 0.9 mile downstream of the present location, the provision of backwater facilities to prevent flood flows on the Root River and Oak Creek from backing up into Crayfish Creek, and the provision of stormwater detention facilities for both flood-flow reduction and water quality management purposes. The minor system components are designed for a 10-year recurrence interval storm event, and the major system components are designed for a 100-year recurrence interval storm event. The recommended drainage system components consist of two storage facilities, 26,710 lineal feet of new or improved open channels, 29,900 lineal feet of storm sewers, the installation of backwater gates, the preservation and maintenance of the existing environmental corridor/wetland complex, and the continued use of the Crayfish Creek main channel generally in its present condition north of County Line Road, with, however, limited debrushing and regrading in areas where a positive slope to the outlet does not exist. The plan could readily accommodate the addition of a pumping station at the outlet should operational experience indicate a higher level of protection is needed later in the plan period. Because of the recently discovered groundwater and surface water contamination caused by an abandoned landfill in the vicinity of the planned channel south of County Line Road, the channel route will need to be reconsidered as part of the detailed design. This evaluation would be done using the findings of ongoing remedial plans for the landfill cleanup. The existing contamination problems will delay the implementation of actions associated with the use of the existing pond south of County Line Road as a sedimentation pond. Thus, in order to provide for improved water quality conditions, it is recommended that four sedimentation basins be constructed in the City in areas upstream of the large wetland complex along Crayfish Creek.

## WATER QUALITY IMPROVEMENT

The recommended plan may be expected to have water quality benefits as a result of the detention of stormwater runoff owing to the settling of particulate pollutants such as biochemical oxygen-demanding organic materials, nutrients, and toxic metals, including lead. Thus, the inclusion of detention facilities in the recommended stormwater management plan is consistent with, and serves to advance implementation of, the regional water quality management plan prepared and adopted by the Regional Planning Commission, and will help in achieving adopted water use objectives and supporting water quality standards in the stream system. In addition, implementation of the City's erosion control program would further assist in improving water quality conditions.

## PLAN IMPLEMENTATION

Implementation of the plan will require primarily the cooperative actions of two units of government: the City of Oak Creek and the Milwaukee Metropolitan Sewerage District. Other units of government and agencies involved in plan implementation include Racine County, the Town of Caledonia, the Wisconsin

Department of Natural Resources, and possibly the U. S. Army Corps of Engineers. The plan implementation recommendations in this chapter are based upon existing programs and enabling legislation.

The Milwaukee Metropolitan Sewerage District should be the lead agency in the construction of recommended Phase I stormwater management improvements, while the City of Oak Creek should be the lead agency in the construction of the Phase II improvements. This division of responsibility is recommended in light of a stormwater management and flood control policy plan recently adopted by the District which identifies those streams and watercourses for which the District will assume jurisdiction for drainage and flood control. That plan indicates that the District will assume jurisdiction over the perennial reaches of the main stem of Crayfish Creek and of the tributary extending northeasterly from the main stem at County Line Road. Under the District's policy plan, the Phase I improvements can be carried out by the District only if Crayfish Creek is within the District limits. Thus, the City may wish to request that the District limits be modified to include the portion of Crayfish Creek within the City. The remaining stream reaches for which improvements are recommended are to remain under the jurisdiction of the local unit of government—the City of Oak Creek. The completion of the stormwater drainage and flood control policy plan by the District was followed by the preparation in 1988 of a stormwater drainage and flood control system plan identifying specific projects for stream reaches under the District's jurisdiction and the priority for implementation.

Costs

The capital and annual operation and maintenance costs of the minor and major system components of the recommended plan are set forth in Table 22. The total capital cost of the recommended improvements is approximately $4.2 million, with a total annual increase in operation and maintenance costs of about $28,600.

In addition to the capital cost, the Phase I improvements are estimated to have an operation and maintenance cost of about $10,000 per year, and the Phase II improvements of about $18,600 per year. All of the operating and maintenance costs are assumed to be public sector costs. It should be noted that the minor system improvements, including storm sewers and local channels, are assumed to be constructed over the plan period as development dictates.

The Milwaukee Metropolitan Sewerage District would be responsible for all of the public sector Phase I improvements. The City of Oak Creek would be responsible for all of the public sector Phase II improvements.

## IMPACTS OF RECOMMENDED STORMWATER MANAGEMENT PLAN

Under the recommended stormwater management plan, stormwater runoff from a 10-year recurrence interval storm event or smaller would be safely and efficiently stored and conveyed by the minor drainage system to major natural drainage channels with minimal inconvenience to residents. Storm flows from larger events up to and including the 100-year recurrence interval event would be transported by the major drainage system without substantial property damage or danger to human health or safety. Following or during a major storm event, the backwater gates at E. County Line Road would be closed to prevent Root River floodwaters from backing up into the Crayfish Creek channel. In some localized areas, ponding and flooding may occur during a major storm event. However, because there is sufficient storage in the existing wetland/environmental corridor complex, the expected ponding and flooding should not cause major property damage, nor should it endanger human health or safety. Careful consideration was given in the plan to the impacts of the recommended plan downstream of the city limits, and the analyses indicated that implementation of the plan would not exacerbate downstream problems.

## PUBLIC REACTION TO THE RECOMMENDED PLAN AND SUBSEQUENT ACTION OF THE CRAYFISH CREEK SUBWATERSHED COMMITTEE

Introduction

The recommended stormwater management plan for the Crayfish Creek subwatershed was the subject of a public informational meeting and hearing held on June 15, 1988. The hearing was conducted by the City of Oak Creek Root

Table 22

CRAYFISH CREEK SUBWATERSHED STORMWATER MANAGEMENT PLAN COST SUMMARY

| System | Total Capital Cost | | Capital Cost per Acre | |
|---|---|---|---|---|
| | Public Sector | Private Sector | Public Sector | Private Sector |
| Phase I | $ 397,000 | $ 0 | $107 | $ 0 |
| Phase II | 2,557,000 | 1,263,000 | 691 | 341 |
| Total | $2,954,000 | $1,263,000 | $798 | $341 |

NOTE: Costs are expressed in 1985 dollars.

*Source: SEWRPC.*

River Drainage Task Force, with the Chairman of the Task Force presiding. The purpose of the hearing was to present the findings and preliminary recommendations of the stormwater management study for review and comment by public officials and interested citizens. The hearing was announced by a communication from the City to all property owners within the subwatershed. A copy of this communication is provided in Appendix C. A summary of the proposed plan was made available to all interested parties prior to and at the hearing. A copy of this summary is also provided in Appendix C. The public hearing was well attended, with 60 public officials and citizens present. Minutes of the hearing were published by the City.

Those commenting at the hearing generally expressed concerns about certain aspects of the plan. Several citizens suggested alternative means of resolving the drainage and flooding problems of the subwatershed, including diversion, channel cleaning, reducing sediment loadings, and removal of the Horlick Dam on the main stem of the Root River in the City of Racine. Concerns were expressed that the improvements proposed, while beneficial, would not fully resolve the problems existing in the subwatershed. Other citizens questioned the details of how plan implementation would be carried out and by what agencies. Yet other citizens commented on the perceived causes of the identified problems. Several citizens also identified site-specific flooding, drainage, and surface- and groundwater quality problems within and adjacent to the subwatershed, asking that these be resolved. Finally, support for the proposed plan was indicated by some of the elected officials and Root River Drainage Task Force members present.

The following paragraphs summarize the comments received at the hearing and the staff and Task Force response to those comments.

Alternative Means of Resolving the Drainage and Flood Control Problems in the Crayfish Creek Subwatershed

The most significant concerns and issues raised at the hearing were related to alternative means of resolving the identified drainage and flood control problems of the Crayfish Creek subwatershed. Five people suggested that diversion of flood flows from Crayfish Creek or from the Root River directly to Lake Michigan would provide a better solution than the proposed plan. Also, five people suggested that the removal of sediment and of trees, brush, and debris from the Root River channel downstream of the confluence with Crayfish Creek would solve the problems concerned. Three people suggested that sediment loadings generated from within the Crayfish Creek subwatershed should be reduced, with particular emphasis on construction erosion control in the urbanizing areas.

With regard to the suggestion that flood flows should be diverted directly to Lake Michigan, it was noted that five such diversion alternatives from Crayfish Creek to Lake Michigan had been evaluated, with the findings of the evaluations documented in the planning report. Those alternatives had a capital cost ranging from $5.7 million to $11.0 million for the major system

components. Furthermore, it was noted that earlier studies of the Regional Planning Commission had evaluated alternatives providing for diversion from the Root River itself to Lake Michigan.[1] In 1988 dollars, the construction costs of the diversion alternatives set forth in these earlier studies for the Root River itself vary from $8.0 to $12.0 million. The costs of these diversion alternatives were all found to be excessive considering the cost of the improvements recommended in the proposed plan, which total about $400,000.

Nevertheless, because of the concerns raised at the hearing, another review was made of the diversion alternatives. Based upon a reevaluation of those alternatives, it appears that several factors, as indicated below, make it impractical to implement a diversion alternative to resolve problems within the Crayfish Creek subwatershed.

1. The relatively high cost of such improvements would place a large burden on taxpayers from within the Crayfish Creek subwatershed and the City of Oak Creek. The capital costs of providing for an outlet from the subwatershed would approximate $3,500 per acre of planned urban land within the watershed. In addition, approximately $1,600 per acre of urban land within the watershed would be required for major connecting storm sewers and channels. Local minor system drainage improvements would also be required. Clearly, the costs of diversion would be higher than could be borne by the local property tax base.

2. Review of the drainage and flooding problems within the watershed indicates that these problems are related primarily to crop damages, residential yard flooding, indirect flooding of basements, and lack of ability to develop land owing to poor drainage. Very little damage occurs as a result of direct structure flooding. Because of these conditions, the quantifiable benefits of the construction of a major diversion project will be limited, and the corresponding benefit-cost ratio would be less than 0.1. Typically, a major drainage improvement and flood control project is eligible for funding by a federal agency such as the Corps of Engineers only if it has a benefit-cost ratio exceeding 1.0. Thus, federal funding for the project is unlikely. No state funding programs are available. Funding by the Milwaukee Metropolitan Sewerage District would be available only for the most cost-effective alternative; such funding would therefore not be available for the implementation of diversion alternatives.

3. Finally, diversion would entail serious legal problems which would make the feasibility of implementation uncertain in any case.

In conclusion, reconsideration of the alternative providing for diversion from the Crayfish Creek subwatershed or Root River indicates this alternative is not practical and that other alternatives will have to be applied to resolve the problems in the Crayfish Creek subwatershed. Thus, the preliminary recommended plan should remain unchanged in this regard.

Another alternative which was suggested by citizens at the public hearing was the cleaning and clearing of the Root River channel in order to improve the hydraulic efficiency of that system and thus lower the stages on the Root River and the concomitant impact on the Crayfish Creek subwatershed. Review of the channel cross-sections and hydraulic grade line of the Root River main stem downstream of the confluence with Crayfish Creek indicates that minor channel clearing and sediment removal would have very limited impact on flood stages on the main channel. The cross-sectional area of the floodplain of the Root River in the vicinity of Crayfish Creek under a 10-year recurrence interval flood event varies from 2,000 to 4,000 square feet. Removal of two feet of accumulated sediment in the main channel may be expected to increase that cross-sectional area by about 40 square feet, or by about 1 percent. Similarly, removal of trees and brush along the channel would have little impact on the conveyance capacity of the broad floodplain of the Root River during high-flow periods. Such changes may be expected to reduce the flood stage on the Root River by less than 0.1 foot. Significant reductions in flood stages on the Root River could be achieved only through major channelization, which would deepen and widen the

[1] *SEWRPC Planning Report No. 9, A Comprehensive Plan for the Root River Watershed, September 1966.*

channel for a considerable distance downstream of the confluence with Crayfish Creek. The costs of such channelization would be of the same order of magnitude as those for the diversion of flood waters, with similar implications for implementation. Furthermore, the construction of such improvements would require a permit from the Wisconsin Department of Natural Resources. The permit process would require an evaluation of the environmental impacts of the channelization, as well as of the benefits and costs concerned. It is doubtful that a permit for major channelization could be obtained in light of the required analysis, and of the policy of the Department to discourage major stream channelization projects. Accordingly, the staff and Task Force concluded that the plan should not be modified to provide for major channel improvements on the Root River.

Another alternative raised at the hearing was the removal of the Horlick Dam located on the Root River in the City of Racine about 11 miles downstream of the confluence with Crayfish Creek. Review of the flood stage profile for the Root River indicates that the reduction in stage resulting from the removal of the dam—about 10 feet at the dam—would extend only about six miles upstream of the dam site and would not reduce the flood stages on the Root River in the vicinity of the confluence with Crayfish Creek. Flood stages at the dam have an approximate elevation of 635 feet above National Geodetic Vertical Datum (NGVD), while flood stages at the confluence with Crayfish Creek have an approximate elevation of 664 feet above NGVD.

One other alternative was suggested at the hearing by three persons, including a representative of the Wisconsin Department of Natural Resources. This alternative proposed limiting the sediment discharge to Crayfish Creek using onsite measures, including construction erosion control. The Department representative indicated that alternatives providing for the reduction of stormwater discharge rates and volumes as well as pollutant loadings using onsite measures should be considered. Such measures would require developers to include provisions for stormwater infiltration or storage in development proposals.

In response, the staff and Task Force noted that the proposed plan did indeed include specific recommendations for the incorporation of construction erosion control measures to limit sediment discharge to Crayfish Creek and the Root River. With regard to the use of onsite stormwater retention and detention facilities, it was noted that the report specifically considered but rejected inclusion of this approach as a primary component of the recommended plan. This conclusion was reached in part because of the difficulty of implementing onsite detention and infiltration as part of the small-scale, piecemeal development proposals that may be expected to occur within the subwatershed given the existing land ownership pattern; in part because the drainage and flooding problems of the Crayfish Creek subwatershed are directly related to flood stages on the Root River, which cause the backup of floodwaters into the Crayfish Creek subwatershed; and in part because nearly all of the soils in the subwatershed are poorly drained and exhibit high groundwater levels. Thus, onsite infiltration and storage may be expected to be ineffective in abating the problems of the Crayfish Creek subwatershed. The plan was accordingly designed to provide for adequate flood control and nonpoint source abatement using a more centralized approach to detention.

Concern for Maintenance Requirements Along the Major Channels Within and Downstream of the Subwatershed

Four people at the hearing expressed concern over the lack of routine maintenance along the drainageways serving the Crayfish Creek subwatershed. They indicated that many of these channels traverse county-owned property and that it appeared that the required debrushing and cleaning was not being done. They concluded that this lack of maintenance was impeding the proper drainage of the subwatershed. In this respect, it was noted by the staff and Task Force that proper maintenance of the main channel of Crayfish Creek would be the responsibility of the City, the County, and the Milwaukee Metropolitan Sewerage District. Based upon a recently developed drainage and flood control policy plan, the Milwaukee Metropolitan Sewerage District was to assume responsibility for the proper maintenance of a portion of Crayfish Creek. Thus, improvements in the maintenance of at least the major channel of the subwatershed should be forthcoming. Maintenance of the minor channels would continue to be the responsibility of the County, the City, and the individual property owners. It was recommended

by the Task Force that upon completion and adoption of this plan, discussions be held between the agencies involved in maintenance activities to clarify each agency's responsibilities.

Landfill, Groundwater, and Surface Water Contamination in the Town of Caledonia

One citizen expressed concern about the apparent contamination by hazardous and toxic materials at the Hunt's landfill site in the Town of Caledonia. He indicated that cleanup of that area was necessary regardless of the impact of the area on the drainage improvements, and it was his recommendation that such cleanup be pursued as rapidly as possible. In response to this comment, the staff and Task Force indicated that the planning report does recognize this problem at the landfill and includes a specific recommendation that cleanup work be undertaken to resolve the potential surface- and groundwater pollution problems regardless of whether or not the area is to be traversed by a new channel constructed to drain the Crayfish Creek subwatershed.

Potential Maintenance and Aesthetic Problems of the Recommended Sedimentation Basins and the Life Expectancy of the Recommended Improvements

Two citizens suggested that there were potential maintenance, aesthetic, safety, and nuisance problems associated with the recommended detention and sedimentation ponds. They also questioned the life expectancy of those facilities. In response, the staff and Task Force noted that most of the detention and sedimentation basins are proposed to be located in the lower reaches of the subwatershed adjacent to a wetland complex which Crayfish Creek traverses. Thus, the basins would be expected to be relatively remote from urban land development. The Task Force noted that if properly designed and maintained, the basins should not constitute nuisances. Rather, it was pointed out that these facilities could become a positive feature of a development. It was noted that there were basins such as those proposed located elsewhere in the City and that significant problems of the type cited had not been reported. Furthermore, it was noted that the proposed basins were to be designed and constructed to have useful lives of at least 50 years. It was noted that proper maintenance would be required, including periodic removal of accumulated sediment. In this regard, the maintenance could be minimized if the construction erosion control measures recommended in the plan were implemented.

General Support for the Plan

There was support expressed at the hearing for the plan recommendations as providing a reasonable, cost-effective solution to the problems of the subwatershed. Such support came from elected officials, the Wisconsin Department of Natural Resources staff, and the members of the Root River Drainage Task Force who were in attendance. It was generally noted that while other alternatives might serve to more directly and efficiently resolve the problems, those alternatives were impractical due to cost, timing of implementation, and regulatory constraints.

Site-Specific Individual Problems

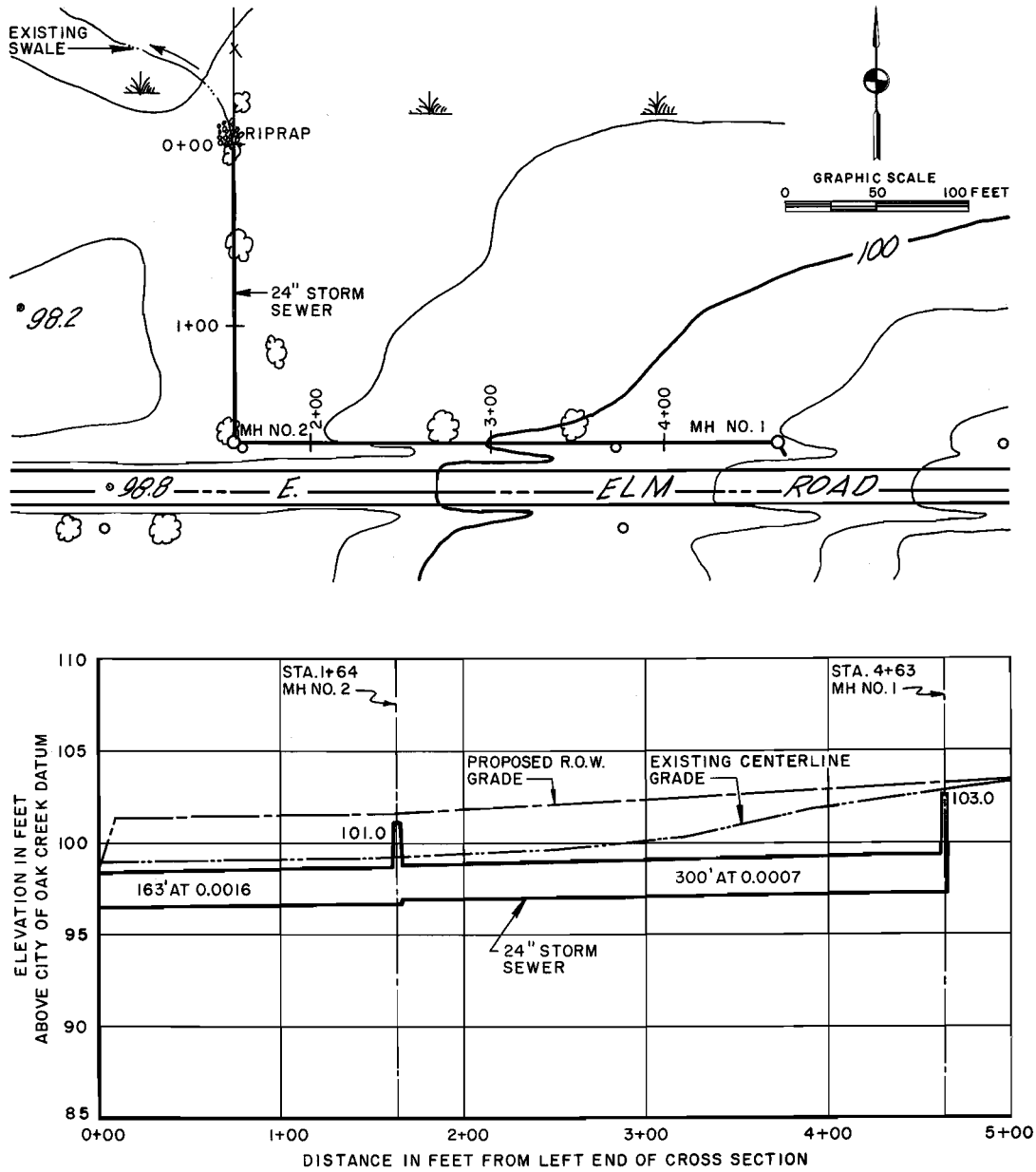
Five persons testifying at the hearing cited certain site-specific problems dealing with drainage, flooding, surface water quality, and groundwater quality. The staff and Task Force responses to these concerns are presented below.

1. One resident noted that a culvert located approximately 1,600 feet south of Elm Road had been partially filled with sediment as a result of a subdivision construction project located to the north of that culvert in the vicinity of S. 10th Avenue and E. Elm Road. He indicated that a sediment buildup of about 18 inches existed in the culvert which caused standing water in the drainageway tributary to the culvert, and provided a breeding place for mosquitoes. Review of the problem indicated that the situation could be readily remedied by the City. It should be noted that implementation of the construction erosion control practices recommended in the plan should minimize the recurrence of such problems within the City.

2. A problem was cited by a resident with regard to the construction of a storm sewer on E. Elm Road about 1,000 feet east of S. 10th Avenue. The resident asked why the storm sewer in that area had been constructed "above the road elevation," and why the storm sewer discharged into an open area located behind the houses. Review of the situation indicated that the storm sewer was not constructed above the roadway elevation, as alleged, but was

Figure 12

**PLAN AND PROFILE OF EXISTING STORM SEWER IN E. ELM ROAD EAST OF S. 10TH AVENUE**




*Source: City of Oak Creek Engineering Department.*

below the existing roadway grade, as shown on the profile in Figure 12. Further, it was found that the roadway grade was to be raised in the future and that the sewer design was based upon future street grades. The storm sewer was designed to discharge to an open drainageway which provided a positive outlet for the piped system. That drainageway is recommended to be maintained in the same location and improved in the Crayfish Creek stormwater management plan.

3. Another citizen indicated that a drainage ditch located adjacent to his property at the intersection of County Line Road and S. 10th Avenue was experiencing problems resulting from the restoration work asso-

ciated with the construction of a sanitary sewer in 10th Avenue and in County Line Road. The restoration work impeded flow in the drainage ditch. Review indicated that the situation could be readily remedied by the City through routine maintenance.

4. A resident of the Town of Caledonia indicated that two ponds in the City of Oak Creek located across from his home at 7933 E. County Line Road were contaminated, the contamination resulting from malfunctioning onsite sewage disposal systems in the area located to the east, and from agricultural runoff from south of County Line Road. The resident further indicated that private wells in the vicinity were unusable as a result of the contamination. A review of this situation indicated that the area in question was now served by public sanitary sewers; thus, this potential source of pollution has been abated. The problem of contamination from agricultural runoff should be addressed through the institution of good soil and water conservation practices under the auspices of the County. In addition, the ponds could be checked by the City to determine if a health hazard exists.

5. Another homeowner indicated that a problem existed on her property located in the 1200 block of E. Oakwood Road. She indicated that the drainageway located along Oakwood Road south of her home was inadequate, and suggested that the channel be realigned so that Oakwood Road crosses it before it reaches her property, thus eliminating the yard flooding problem on her property. A review of the situation indicated that at one time the drainage channel concerned, which currently is located along Oakwood Road south of the property concerned, was located through the property, as shown on Map 31—a copy of a portion of a large-scale topographic map prepared in 1961. The drainageway was realigned in about 1974 to parallel the north side of E. Oakwood Road on the south edge of the property, as shown on Map 32. This drainageway alignment was done by the developers of the Sheppard Hills Subdivision as part of the drainage improvement requirements for that subdivision. The proposed stormwater management plan proposes the construction of a detention basin upstream of this location to reduce the flow rates at the location where the problem occurs. Furthermore, a portion of the flow will be conveyed by storm sewer from the detention basin under McGraw Drive, which will serve to further reduce the cited problem. These improvements should eliminate the problem on the property concerned resulting from the main drainage system. Additionally, a review of the topography of the property concerned indicates that there is no positive course for local drainage through the property. It is therefore recommended that the homeowner consider constructing a drainage swale to convey local drainage from the property.

Concluding Remarks

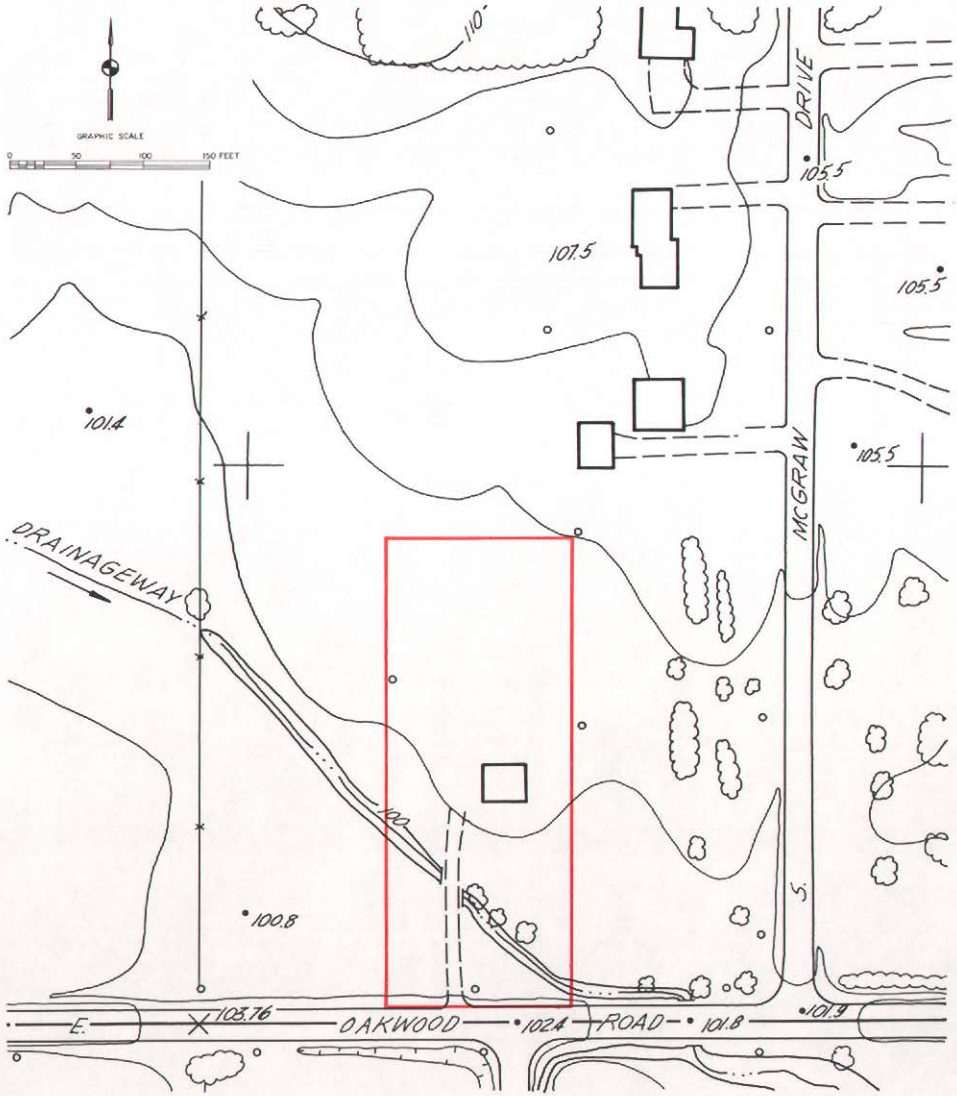
Based upon the testimony submitted at the public informational meeting, it was concluded that no significant changes to the preliminary Crayfish Creek stormwater management plan would be necessary, and that the plan as proposed and presented at the public hearing should be adopted. Opportunity for plan refinement will be available as design of the recommended facilities proceeds.

## CONCLUSION

Implementation of the recommended stormwater management plan would provide protection against substantial inconvenience to residents during minor storm events, and against major property damage or a significant hazard to human health and safety during major storm events. It would support the continued sound land use development of the portion of the City within the Crayfish Creek subwatershed, enhancing the quality of life within the City.

**Map 31**

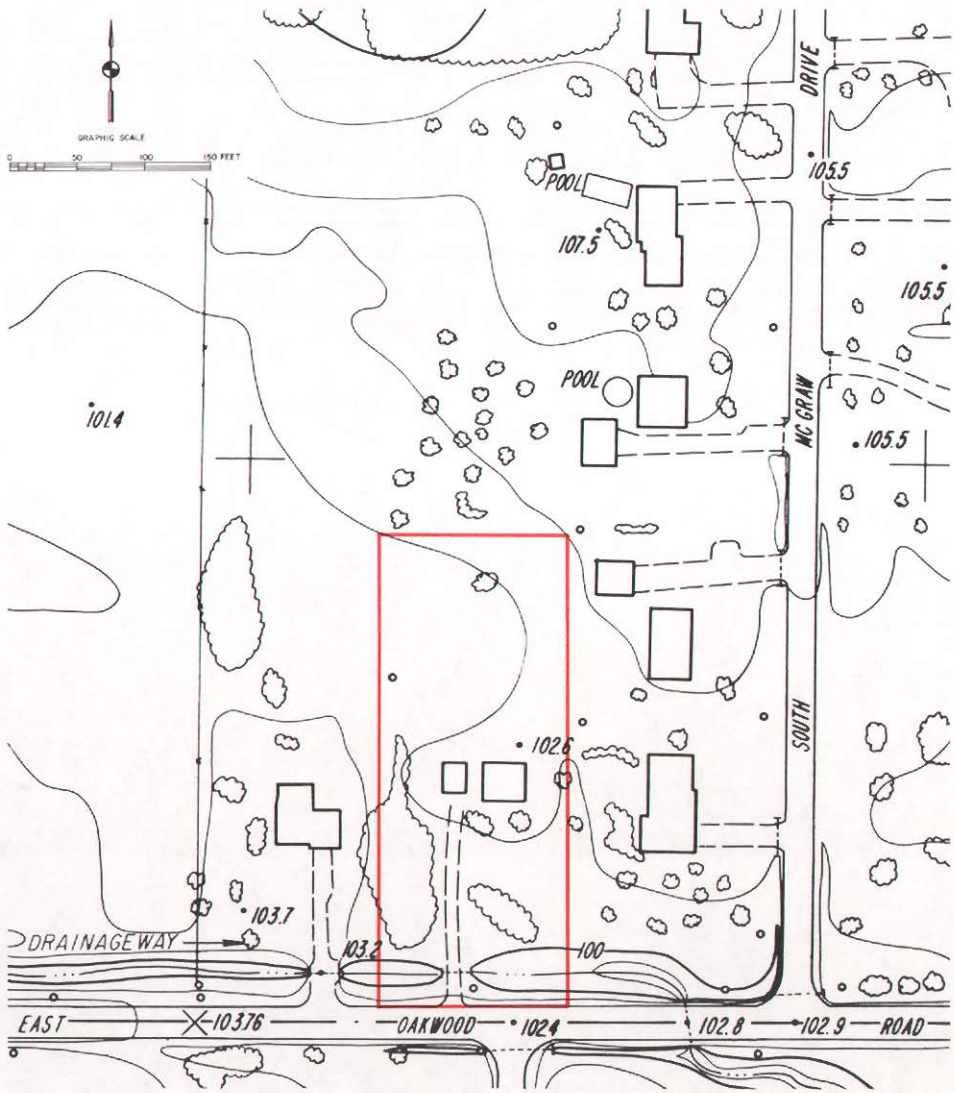
**PORTION OF LARGE-SCALE TOPOGRAPHIC MAP SHOWING THE LOCATION OF A LAND PARCEL AND DRAINAGEWAY ALONG E. OAKWOOD ROAD: 1961**




Source: SEWRPC.

**Map 32**

**PORTION OF LARGE-SCALE TOPOGRAPHIC MAP SHOWING THE LOCATION OF A LAND PARCEL AND RELOCATED DRAINAGEWAY ALONG E. OAKWOOD ROAD: 1977**




Source: SEWRPC.

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# APPENDICES

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Appendix A

## INVENTORY OF PLANT COMMUNITY TYPES AND QUALITY PRESENT IN THE LARGE WETLAND COMPLEX OF THE CRAYFISH CREEK SUBWATERSHED

COPY


SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

916 NO. EAST AVENUE • P.O. BOX 769 • WAUKESHA, WISCONSIN 53187 • TELEPHONE (414) 547-6721

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WASHINGTON
WAUKESHA


Mr. Udo L. Wilharm, P. E.
Acting City Engineer
City of Oak Creek
8640 S. Howell Avenue
Oak Creek, Wisconsin 53154

October 2, 1979

Attention: Mr. Robert Doren

Dear Mr. Wilharm:

In response to your August 24, 1979 letter request, the Commission staff has completed a field investigation of the 140-acre wetland area located in Section 34, Town 5 North, Range 22 East, in the City of Oak Creek to determine the plant community types and quality and the wildlife habitat values present in the wetland. The findings of that investigation, which was conducted by Mr. Donald M. Reed, Senior Biologist on the Commission staff, on September 5, 1979, are hereby provided for your consideration:

1. Plant communities identified during the evaluation include shallow marsh; fresh (wet) meadow; shrub carr; and southern wet and wet-mesic hardwood forest.

2. The entire wetland complex has been disturbed by water-level changes resulting from ditching, encroachment of croplands, and clear cutting of the lowland hardwoods as indicated by the dominance of alien, or non-native grasses--Reed-canary grass (Phalaris arundinacea) and Tall manna grass (Glyceria spectabilis)--and the presence of second growth hardwoods.

3. No rare, endangered, or threatened native plant species were observed. However, the Eurasian species of Tall manna grass (Glyceria spectabilis) has only been recorded from one other station in Wisconsin. This grass appears to be very aggressive as it dominates the shallow marsh areas and could present an aquatic nuisance problem in the future.

4. The overall plant community quality rating ranges from a D+ quality in the shallow marsh and fresh (wet) meadow to a C+ in the southern wet to wet-mesic hardwoods.

   The plant community quality ratings are based on the diversity of native plant species present, the expected plant community structure and integrity, and the extent of significant disturbance due to human activities. A definition of the specific plant community quality ratings is enclosed for your information.

5. The wetland area contains medium value pheasant wildlife habitat as identified in the Commission's inventories. A 1975 aerial photograph showing the wetland area and the areal extent of the wildlife habitat area concerned is enclosed for your information.

   Wildlife habitat areas were initially inventoried throughout the entire Southeastern Wisconsin Region in 1963 and this initial inventory was updated in 1970 for the Commission by the Wisconsin Department of Natural Resources, Bureau of Research. High value wildlife habitat areas contain a good diversity of wildlife, are adequate in size to meet all of the habitat requirements for the species concerned, and are generally located in proximity to other wildlife habitat areas. Medium value wildlife habitat areas generally lack one of the three aforementioned criteria for a high value wildlife habitat. Low value wildlife habitat areas are remnant in nature in that they generally lack two or more of the three aforementioned criteria for a high value wildlife habitat, but may nevertheless be important if located in close proximity to other medium and/or high value wildlife habitat areas, if they provide corridors linking higher value habitat areas, or if they provide the only available range in an area. The major factors considered in assigning value ratings to wildlife habitat areas are diversity, territorial requirements, vegetative composition and structure, proximity to other wildlife habitat areas, and disturbance.

   The wildlife habitat areas are further classified by the Commission as deer, pheasant, waterfowl, muskrat-mink, song bird, squirrel, or mixed habitat. These designations are applied to help characterize a particular wildlife habitat area as meeting the particular requirements of the indicated species. This classification does not imply that the named species is the most important or dominant species in that particular habitat. For example, an area designated as a deer habitat may also provide squirrel and song bird habitat as well.

6. The Commission, as part of its land use plan for southeastern Wisconsin, has adopted a set of land use development objectives, principles, and standards which specifically relate to wetlands which states "All wetland areas 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." The Commission's land use development objectives, principles, and standards are set forth in Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin--2000, Volume Two, "Alternative and Recommended Plans," May 1978.

We trust the foregoing comments will be helpful to you. Should you have any questions concerning this matter, please do not hesitate to call.

Sincerely,

Kurt W. Bauer
Executive Director

KWB/mja
Enclosures

Appendix B

RESULTS OF REVIEW OF DRAINAGE IMPROVEMENTS
PROPOSED TO BE CONSTRUCTED IN THE TOWN OF CALEDONIA


SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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WAUKESHA


Mr. Arnold L. Clement
Planning and Development Director
Racine County Office of Planning
and Zoning
14200 Washington Avenue
Racine, Wisconsin 53177

April 15, 1988

Re: SEWRPC No. CA 303-41

Dear Mr. Clement:

Pursuant to your letter request of February 23, 1988, the Commission staff has completed an analysis of a proposed channel maintenance project for an approximately 6,600-foot stream reach between E. County Line Road and Seven Mile Road consisting of 1,700 feet of the Caledonia Branch of Crayfish Creek and 4,900 feet of a tributary; the entire stream reach being located in U.S. Public Land Survey Section 2, Township 4 North, Range 22 East, Town of Caledonia. The drainage area tributary to the Caledonia Branch of Crayfish Creek at its confluence with Crayfish Creek is approximately 2.1 square miles. The proposed project will provide for tree, brush, and accumulated silt removal along the channel. Spoils are proposed to be disposed of by spreading at shallow depths--0.5 foot or less--on adjacent lands. The analysis was conducted to determine the downstream impact on flood flows and stages of the proposed channel cleanout project, the limits of which are shown on the attached map.

The Commission staff utilized the method set forth in the U.S. Soil Conservation Service Technical Release No. 55, Urban Hydrology for Small Watersheds, to develop 100-year recurrence interval and mean annual peak flood discharges for Caledonia Branch. Flood discharges were developed for both existing and proposed channel conditions and for both existing and planned land use conditions and are set forth in the attached table.

Application of the U.S. Army Corps of Engineers HEC-2 backwater simulation model developed for the Caledonia Branch of Crayfish Creek by the Commission staff indicated that the proposed channel maintenance project may be expected to result in an increase in 100-year recurrence interval flood stages of up to 0.16 foot on the Caledonia Branch under existing land use conditions and of up to 0.09 foot under planned land use conditions, as shown in the attached table. It can be noted that in some of the reaches the increase in stages are greater under existing land use conditions with lower peak flow rates than under planned land use conditions. This results from the fact that the bridge at the abandoned railroad in the lower reaches of the tributary is overtopped under planned land use condition flows assuming both existing and planned channel conditions, but not under existing land use conditions. When the bridge is overtopped, increases in flows result in relatively small

increases in stages when compared to the stage increases associated with flow rate increases when the flow is confined to the bridge opening. It should be noted that the increase in flood flows and stages are the result of the removal of vegetative matter and accumulated sediment. The flood flows and stages would not exceed the flood flows and stages expected assuming the channel as it was last improved. The proposed channel maintenance project would have a negligible impact on the average channel flow velocities downstream of E. County Line Road under 100-year recurrence interval flood conditions. This velocity is about 2.2 feet per second (fps) under existing land use and channel conditions; about 2.0 fps under planned land use and existing channel conditions; and about 2.0 fps under planned land use and planned channel conditions.

In addition, it was determined that the proposed channel maintenance project would result in an increase in mean annual flood stages of up to about 0.47 foot under existing land use conditions, and 0.85 foot under planned land use conditions along the Caledonia Branch. The proposed channel maintenance project would also have a negligible impact on the average channel velocities downstream of E. County Line Road under mean annual flood conditions. This velocity is about 2.2 fps under existing land use and channel conditions; about 1.9 fps under planned land use and existing channel conditions; and about 1.9 fps under planned land use and planned channel conditions. However, as noted above, the flood flows, stages, and velocities resulting from the project would not exceed the flows, stages, and velocities expected assuming the channel conditions as it was last improved.

It should be noted that under the City of Oak Creek stormwater management planning program for the Crayfish Creek subwatershed, it is recommended that the 2,300-foot reach of the Caledonia Branch between a point about 600 feet downstream of S. 10th Avenue and the confluence with its tributary be improved. The improved channel would be turf-lined and have a bottom width of five feet and side slopes of one on four, and represents a somewhat larger channel conveyance area than that proposed under the channel maintenance project. That project would carry the improvements down to the reach of the Caledonia Branch where the slope becomes about 0.14 percent compared to the slope of 0.03 percent in the reach proposed for the maintenance work, thus providing a suitable outlet for the subject channel. Consideration should be given to bringing the channel to its proposed ultimate cross section under the maintenance project, thus eliminating a later, in part duplicative, effort.

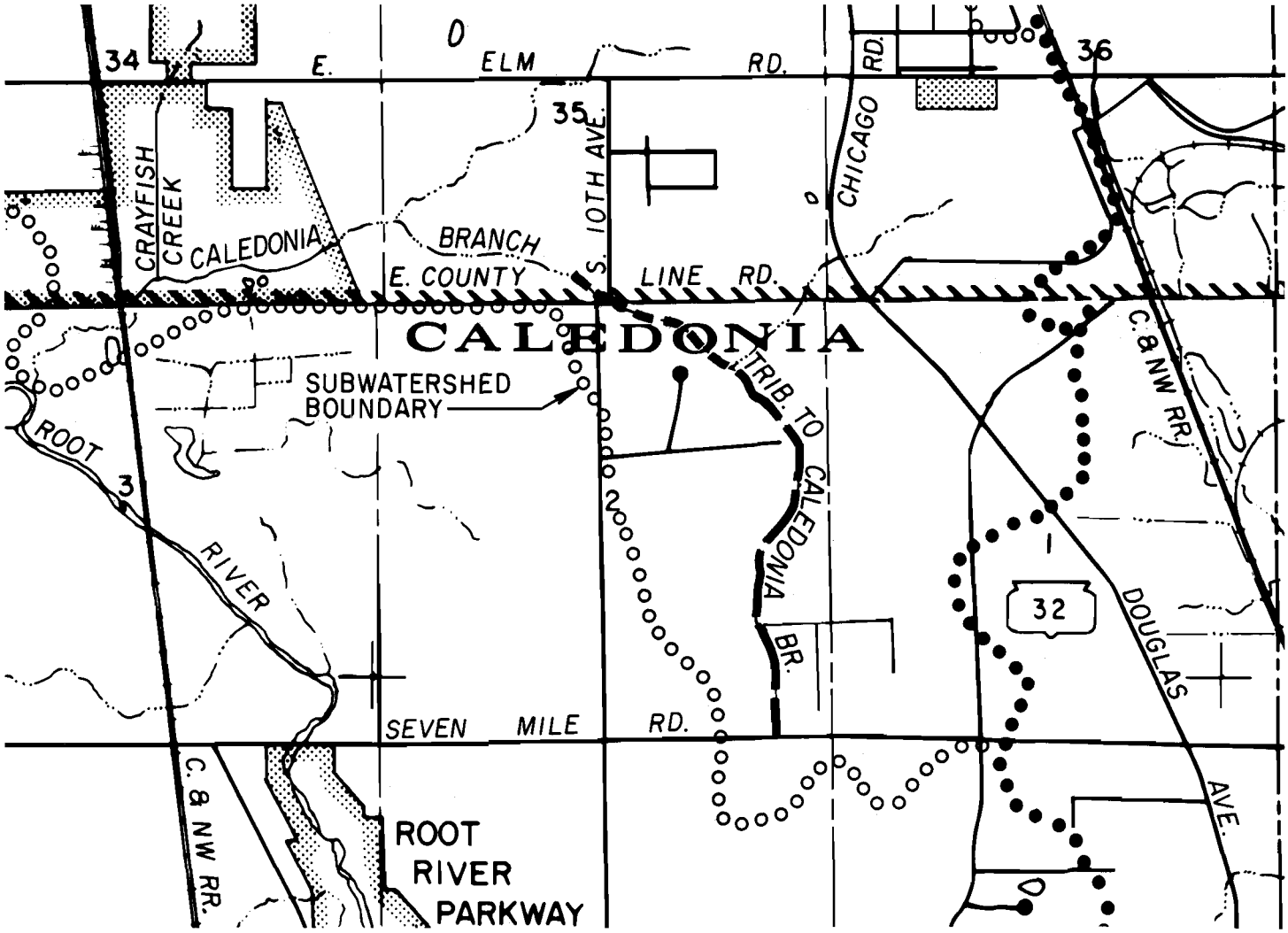
We trust this information will be helpful to you. Should you have any questions, or require any further assistance in this matter, please do not hesitate to call.

Sincerely,

Kurt W. Bauer
Executive Director

KWB/ib
Enclosure

**LOCATION OF PROPOSED CHANNEL MAINTENANCE PROJECT ALONG A PORTION OF CALEDONIA BRANCH AND TRIBUTARY**




LEGEND

RECOMMENDED CHANNEL IMPROVEMENT UNDER SEWRPC CRAYFISH CREEK STORMWATER MANAGEMENT PLAN

PROPOSED CHANNEL MAINTENANCE

1" = 2000'

## Table 1

## PEAK FLOOD DISCHARGES AND ELEVATIONS FOR THE CALEDONIA BRANCH

| River Mile[c] | Peak Flood Discharge[a] | | | | | | | | Peak Flood Elevations[b] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Existing Land Use | | | | Planned Land Use | | | | Existing Land Use | | | | Planned Land Use | | | |
| | Existing Channel | | Proposed Channel | | Existing Channel | | Proposed Channel | | Existing Channel | | Proposed Channel | | Existing Channel | | Proposed Channel | |
| | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year | 2-Year | 100-Year |
| Abandoned Railroad | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 0.45 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 664.13 | 665.35 | 664.60 | 665.51 | 665.80 | 667.20 | 666.65 | 667.20 |
| 0.56 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 665.16 | 665.60 | 665.30 | 665.71 | 665.87 | 667.22 | 666.68 | 667.23 |
| 0.60 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 665.38 | 665.71 | 665.52 | 665.80 | 665.89 | 667.22 | 666.69 | 667.23 |
| 0.64 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 666.01 | 666.10 | 666.08 | 666.11 | 666.04 | 667.23 | 666.70 | 667.24 |
| 0.75 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 668.49 | 668.72 | 668.63 | 668.75 | 668.60 | 668.37 | 668.31 | 668.39 |
| 0.86 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 669.16 | 669.40 | 669.31 | 669.42 | 669.27 | 669.64 | 669.51 | 669.69 |
| 0.93 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 669.25 | 669.50 | 669.40 | 669.52 | 669.37 | 669.73 | 669.59 | 669.78 |
| 1.03 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 669.28 | 669.56 | 669.45 | 669.59 | 669.41 | 669.79 | 669.63 | 669.84 |
| 1.10 | 100 | 170 | 140 | 180 | 130 | 230 | 180 | 250 | 671.06 | 671.50 | 671.33 | 671.54 | 671.27 | 671.75 | 671.51 | 671.83 |
| S. 10th Avenue | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1.11 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 671.42 | 672.20 | 671.86 | 672.32 | 671.74 | 672.79 | 672.31 | 672.83 |
| E. County Line Road | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1.13 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 671.47 | 672.28 | 671.94 | 672.41 | 671.80 | 672.95 | 672.40 | 673.04 |
| 1.18 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 671.76 | 672.68 | 672.18 | 672.69 | 672.14 | 673.36 | 672.68 | 673.36 |
| 1.24 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 672.17 | 673.12 | 672.38 | 672.89 | 672.58 | 673.70 | 672.89 | 673.52 |
| 1.31 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 672.37 | 673.32 | 672.52 | 673.05 | 672.78 | 673.87 | 673.05 | 673.69 |
| 1.40 | 70 | 125 | 100 | 135 | 90 | 170 | 135 | 185 | 672.48 | 673.37 | 672.60 | 673.11 | 672.86 | 673.90 | 673.11 | 673.73 |
| Tributary to Caledonia Branch | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

[a] *Discharge in cubic feet per second (cfs).*

[b] *Elevations in feet National Geodetic Vertical Datum (NGVD).*

[c] *Distance in river miles measured from the confluence with Crayfish Creek.*

## Appendix C

## ANNOUNCEMENT OF PUBLIC INFORMATIONAL MEETING AND HEARING, AND SUMMARY OF PROPOSED PLAN

City of Oak Creek

8640 SOUTH HOWELL AVENUE · P.O. BOX 27 · OAK CREEK, WISCONSIN 53154-0027

UDO L. WILHARM
CITY ENGINEER

May 31, 1988

Dear Property Owner:

SUBJECT: Storm Water Management Plan
for the Crayfish Creek Subwatershed

The Root River Drainage Task Force Committee of the City of Oak Creek is hosting an informal Public Informational Meeting on June 15, 1988, in the City Hall Common Council Chambers starting at 7:00 p.m. The purpose of this meeting will be the presentation of a summary report of the Storm Management Plan for the Crayfish Creek Subwatershed as prepared by the Southeastern Wisconsin Regional Planning Commission. The Task Force has worked with the Commission on this plan since its inception.

The Crayfish Creek Subwatershed is located in the southeastern part of the City, encompassing about 5.8 square miles including approximately 1 square mile in the Town of Caledonia.

A limited number of copies of the summary report will be available on or about June 8, 1988, at the Engineering Department counter. Additional copies will be ready for handout at the meeting.

Very truly yours

Udo L. Wilharm

Udo L. Wilharm, P.E.
City Engineer

ULW:cmm
cc: Task Force Committee
Mayor Bastian
Common Council
DNR
SEWRPC
MMSD
Milwaukee County
Racine County
Town of Caledonia

# STORMWATER MANAGEMENT PLAN FOR THE CRAYFISH CREEK SUBWATERSHED SET FOR PUBLIC INFORMATIONAL MEETING

## OVERVIEW

Stormwater management is one of the most important requirements of urban development, being essential to the provision of an attractive, efficient, safe, and healthful urban environment. Proper stormwater management not only focuses on the collection, temporary storage, transport, and disposal of excess stormwater, but also considers the water quality impacts of nonpoint sources of pollution.

In considering stormwater management options, it is important to note the distinction between stormwater drainage and flood control. Both stormwater drainage and flood control deal with the problems of disposal of unwanted water, and the distinction between the two issues is not always clear-cut. Flood control is generally defined as the prevention of damage from the overflow of natural streams and watercourses; that is, from waters moving out of and away from natural stream channels. Drainage is defined as the prevention of damage from excess stormwater on the land surface before such water has entered stream channels; that is, from waters moving toward natural stream channels. The two problems are interrelated, particularly in the Crayfish Creek subwatershed.

It is anticipated that those portions of the Crayfish Creek subwatershed lying within the City of Oak Creek will experience substantial urban development over the next two decades. In the absence of adequate planning and engineering, this development may be expected to intensify existing, and create new, stormwater management problems. Therefore, the City of Oak Creek requested the Regional Planning Commission to assist the City in the preparation of a long-range stormwater management system plan for the Crayfish Creek subwatershed. The plan is intended to facilitate the development of an effective stormwater management system for the subwatershed that will minimize the damages attendant to poor drainage, as well as minimize the costs of providing stormwater management facilities. The recommended plan for the Crayfish Creek subwatershed focuses on stormwater management, but also considers flood control, since stormwater management and flood control are interrelated because of the topographic conditions of the subwatershed.

## PLANNING AREA

As shown on Map 1, the planning area consists of all that part of the City of Oak Creek draining to Crayfish Creek, together with those portions of the Town of Caledonia draining to Crayfish Creek. The watercourses concerned are Crayfish Creek, and the Caledonia, Meadowview, and Oakwood Branches of Crayfish Creek. The planning area encompasses an area of about 3,700 acres, or about 5.8 square miles, or which about 83 percent lies within the City of Oak Creek.

## INVENTORY AND ANALYSIS

Data were collated and collected on the existing land use, climate, soils, natural and man-made stormwater drainage system, drainage and flooding problems, and erosion and sedimentation problems in the planning area. Urban land uses in 1980 occupied about 24 percent of the total planning area, with residential uses making up the largest urban land use category. Agricultural land use accounted for about 54 percent of the planning area, with other open uses, including woodlands, wetlands, and surface water, constituting about 22 percent of the planning area.

Soil properties are an important factor influencing the rate and amount of stormwater runoff from land surfaces. Accordingly, the soils of the area were categorized into four hydrologic soil groups, and the location and extent of the areas covered by each group mapped and quantified. Over 85 percent of the area of the watershed is covered by soils considered to have low infiltration capacity, low

permeability, and poor drainage characteristics. These soil conditions place severe limitations on the available stormwater management system components, such as infiltration systems.

## ANTICIPATED GROWTH

The stormwater drainage plan was intended to identify the stormwater management needs of the Crayfish Creek subwatershed through the year 2000. Accordingly, information was collected on the anticipated type, density, and spatial distribution of land uses in the planning area, and on the impact of anticipated changes in land use on the stormwater management needs of the planning area. About 1,780 acres of land, or an additional 48 percent of the planning area, may be expected to be converted from rural to urban land uses over the next two to three decades, resulting in about 72 percent of the total planning area being in urban land uses by the plan design year.

## DESIGN CRITERIA AND OBJECTIVES

Early in the planning process, stormwater management design criteria, as well as objectives, were established and agreed upon. The plan was developed considering two basic objectives: 1) to prevent significant monetary damage from any reasonably foreseeable major storm event—defined as a 100-year recurrence interval event; and 2) to provide convenient access to the various land uses of the urban area following minor, more frequent rainfall events—defined as events up to and including the 10-year recurrence interval event. The plan was thus designed to consider both major—operating infrequently—and minor—operating frequently—stormwater management facilities.

## ALTERNATIVE PLANS

Alternative approaches to stormwater management that were considered for application in the Crayfish Creek subwatershed included conveyance, centralized detention, decentralized onsite detention, centralized retention, decentralized onsite retention, and nonstructural measures. Using various combinations of these approaches, 17 alternative stormwater management system plans were initially conceptualized for the Crayfish Creek subwatershed area. Of these 17 plans, seven were found to warrant further, more detailed consideration. The capital cost of these seven alternatives ranged from $1.36 to $9.0 million. The seven alternatives were evaluated based upon cost, environmental impacts, and feasibility of implementation, with the best alternative being selected for further refinement as described below.

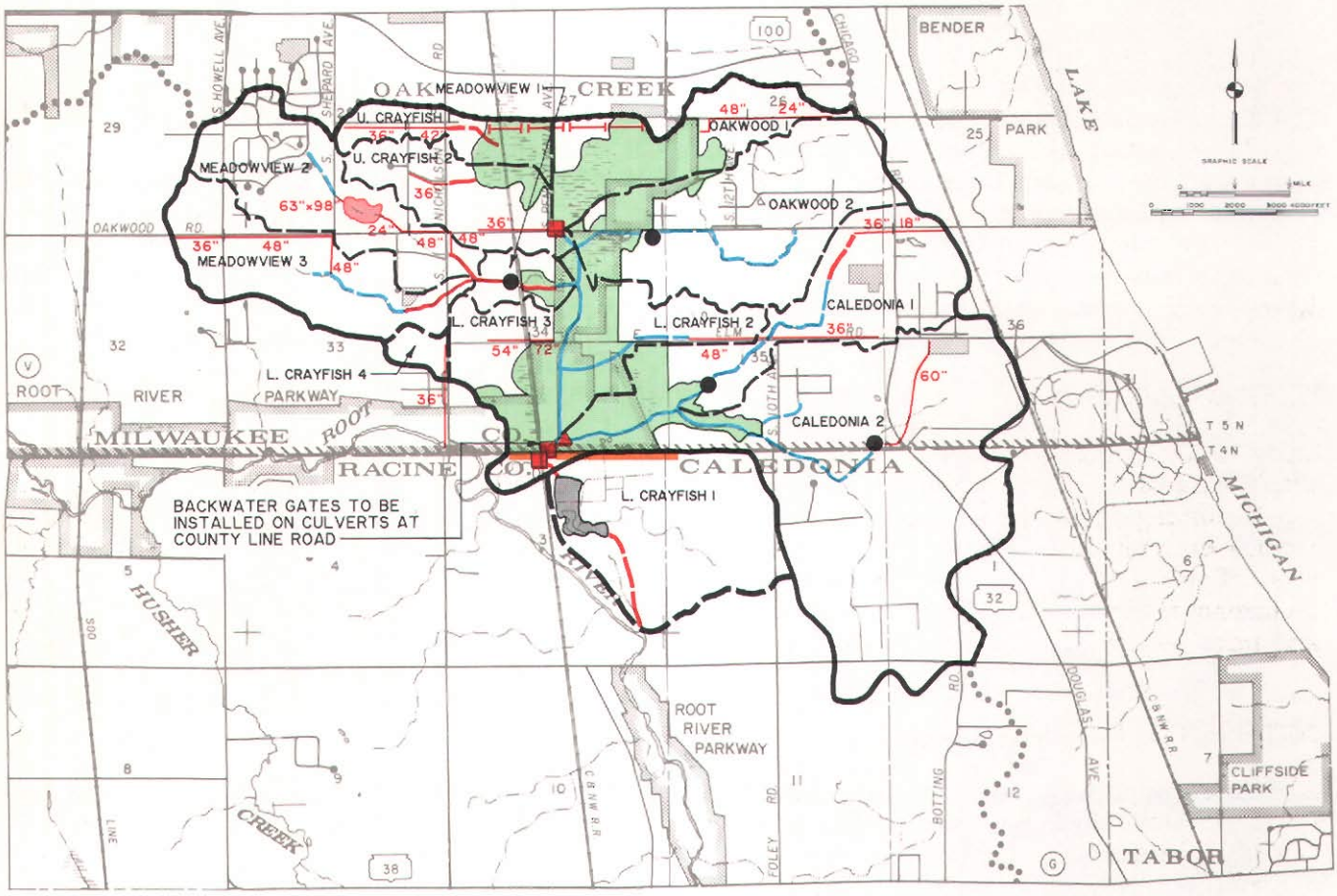
## RECOMMENDED PLAN

The recommended stormwater management system plan, as shown on Map 1, provides for the discharge of stormwater to the Root River at a location about 0.9 mile downstream of the present location; the provision of backwater control facilities to prevent flood flows on the Root River and Oak Creek from backing up into Crayfish Creek; and the provision of stormwater detention facilities for both flood-flow reduction and water quality management purposes. The minor system components are designed for a 10-year recurrence interval storm event, while the major system components are designed for a 100-year recurrence interval storm event. The recommended drainage system components consist of two storage facilities; 26,710 lineal feet of new or improved open channels; 29,900 lineal feet of storm sewers; the installation of backwater gates; the preservation and maintenance of the existing environmental corridor/wetland complex in the subwatershed; and the continued use of the existing Crayfish Creek main channel in its present condition north of County Line Road.

Late in 1987, the Hunts/Caledonia Corporation disposal site, located about one-quarter mile south of County Line Road and just east of the Chicago & North Western Railway, was found to contain toxic materials. The site was accordingly placed on the state "Super Fund" site list, and investigations

Map 1

## RECOMMENDED PLAN FOR THE CRAYFISH CREEK SUBWATERSHED




LEGEND

- EXISTING SUBWATERSHED BOUNDARY
- PROPOSED REVISED SUBWATERSHED BOUNDARY
- PRIMARY ENVIRONMENTAL CORRIDOR
- SUBBASIN BOUNDARY
- OAKWOOD 1 — SUBBASIN INDENTIFICATION-HYDROLOGIC UNIT AND SUBBASIN NUMBER
- PROPOSED ELEVATED ROAD OR BERM
- PROPOSED BERM
- PROPOSED CULVERT MODIFICATION
- EXISTING CHANNEL TO BE RETAINED
- EXISTING CHANNEL TO BE MODIFIED
- CHANNEL MODIFICATION COMPLETED
- PROPOSED NEW CHANNEL
- 48" — PROPOSED STORM SEWER AND DIAMETER
- PROPOSED DETENTION BASIN
- PROPOSED SEDIMENTATION POND
- LOCATION OF SEDIMENTATION BASINS TO BE CONSIDERED AS AN ALTERNATIVE TO THE SEDIMENTATION POND SOUTH OF COUNTY LINE ROAD PENDING RESOLUTION OF TOXIC MATERIALS CONTAMINATION PROBLEMS IN THE VICINITY OF THE SOUTH POND.
- POTENTIAL FUTURE STORMWATER PUMPING STATION TO BE ADDED SHOULD EXPERIENCE INDICATE THAT A GREATER PROTECTION LEVEL IS NEEDED

NOTE: CONSTRUCTION OF PROPOSED CHANNEL SOUTH OF COUNTY LINE ROAD TO BE DEFERRED OR WILL REQUIRE REALIGNMENT DUE TO GROUND AND SURFACE WATER CONTAMINATION FROM A LANDFILL IN THAT VICINITY. DETAILS TO BE CONSIDERED IN FINAL DESIGN IN CONJUNCTION WITH THE LANDFILL CLEANUP PROGRAM.

THE MINOR STORMWATER DRAINAGE SYSTEM INCLUDING STORM SEWERS AND LOCAL CHANNELS ARE EXPECTED TO BE CONSTRUCTED OVER THE PLAN PERIOD AS DEVELOPMENT DICTATES A NEED AND ARE EXPECTED TO BE PARTIALLY FUNDED BY THE PRIVATE SECTOR.

*Source: SEWRPC.*

initiated into the extent of the problem and the means by which the problem can be solved. As of early 1988, work was still in the investigation stages, and no details regarding the extend of the problem and solutions were available. It is believed, however, that the pond located just to the north of the landfill site may be contaminated with toxic materials.

As can be seen on Map 1, under the stormwater management plan as initially proposed, about 700 feet of new channel would have been constructed from County Line Road to the existing pond, as well as about 2,100 feet of new channel from the pond to the Root River at a location about 850 feet north of Seven Mile Road. The pond was intended to serve as a component of the nonpoint source pollution abatement recommendations of the plan. The relocation of the proposed outlet would have provided approximately 1.5 feet of additional fall, compared to the existing outlet on the Root River, and thus would have helped to improve drainage within the Crayfish Creek subwatershed. In view of the potential contamination of the pond, it would not be desirable to connect the proposed channel to the Root River through the pond as originally proposed, since this could result in the flushing of pollutants from the pond into the river. However, at such time as the toxic pollution problem is resolved, the plan components could be fully implemented as shown on Map 1. In the interim, it is recommended that the existing outlet from the Crayfish Creek drainage area be maintained and that other options be considered for abating nonpoint source pollution within the watershed. Specifically, it is recommended that consideration be given to providing four sedimentation basins upstream of the large wetland complex through which Crayfish Creek flows. These basins would be installed only as development takes place and as drainage improvements need to be installed. In addition, it is recommended that at the time the detailed design for the major improvements proceeds, analyses of alternative channel routes be conducted for the channel south of County Line Road with the analyses taking into account the results of ongoing landfill remedial action investigations.

## WATER QUALITY IMPROVEMENT

The recommended plan may be expected to have water quality benefits as a result of the detention of stormwater runoff owing to the settling of particulate pollutants such as biochemical oxygen-demanding organic materials, nutrients, and toxic metals, including lead. Furthermore, the maintenance of the large wetland complex along Cryafish Creek in its natural state with no major channelization will provide positive water quality impacts. Thus, the inclusion of detention facilities in the recommended stormwater management plan is consistent with, and will serve to advance implementation of, the regional water quality management plan, and will help to achieve adopted water use objectives and supporting water quality standards. Adoption by the City of a construction erosion control ordinance would further assist in abating nonpoint source pollution.

## PLAN IMPLEMENTATION

Implementation of the plan will require the cooperative actions of primarily two units of government: the City of Oak Creek and the Milwaukee Metropolitan Sewerage District. Other units of government and agencies involved in plan implementation include Racine County, the Town of Caledonia, the Wisconsin Department of Natural Resources, and possibly the U. S. Army Corps of Engineers. The plan implementation recommendations are based upon existing programs and enabling legislation.

The Milwaukee Metropolitan Sewerage District should be the lead agency in the construction of recommended stormwater management improvements along the perennial reaches of the main stem of Crayfish Creek, and of the tributary extending northeasterly from the main stem at County Line Road. Improvements along the remaining stream reaches are proposed to be carried out by the City of Oak Creek.

This division of responsibility is recommended in light of a stormwater management and flood control policy plan recently adopted by the District which identifies those streams and watercourses for which the District will assume jurisdiction for drainage and flood control. Under the District's policy plan, the

Table 1

CRAYFISH CREEK SUBWATERSHED STORMWATER MANAGEMENT PLAN COST SUMMARY

| System | Total Capital Cost | | Capital Cost per Acre | |
|---|---|---|---|---|
| | Public Sector | Private Sector | Public Sector | Private Sector |
| Milwaukee Metropolitan Sewerage District | $ 397,000 | $ 0 | $107 | $ 0 |
| City of Oak Creek | 2,557,000[a] | 1,263,000 | 691 | 341 |
| Total | $2,954,000 | $1,263,000 | $798 | $341 |

[a]*Of this cost, about $140,000 may be available from the Wisconsin Fund Nonpoint Source Program for construction of the four sedimentation basins.*

*Source: SEWRPC.*

needed improvements can be carried out by the District only if Crayfish Creek is within the District limits. Thus, the City has requested that the District limits be expanded to include the portion of Crayfish Creek within the City. That request was subsequently approved by the District.

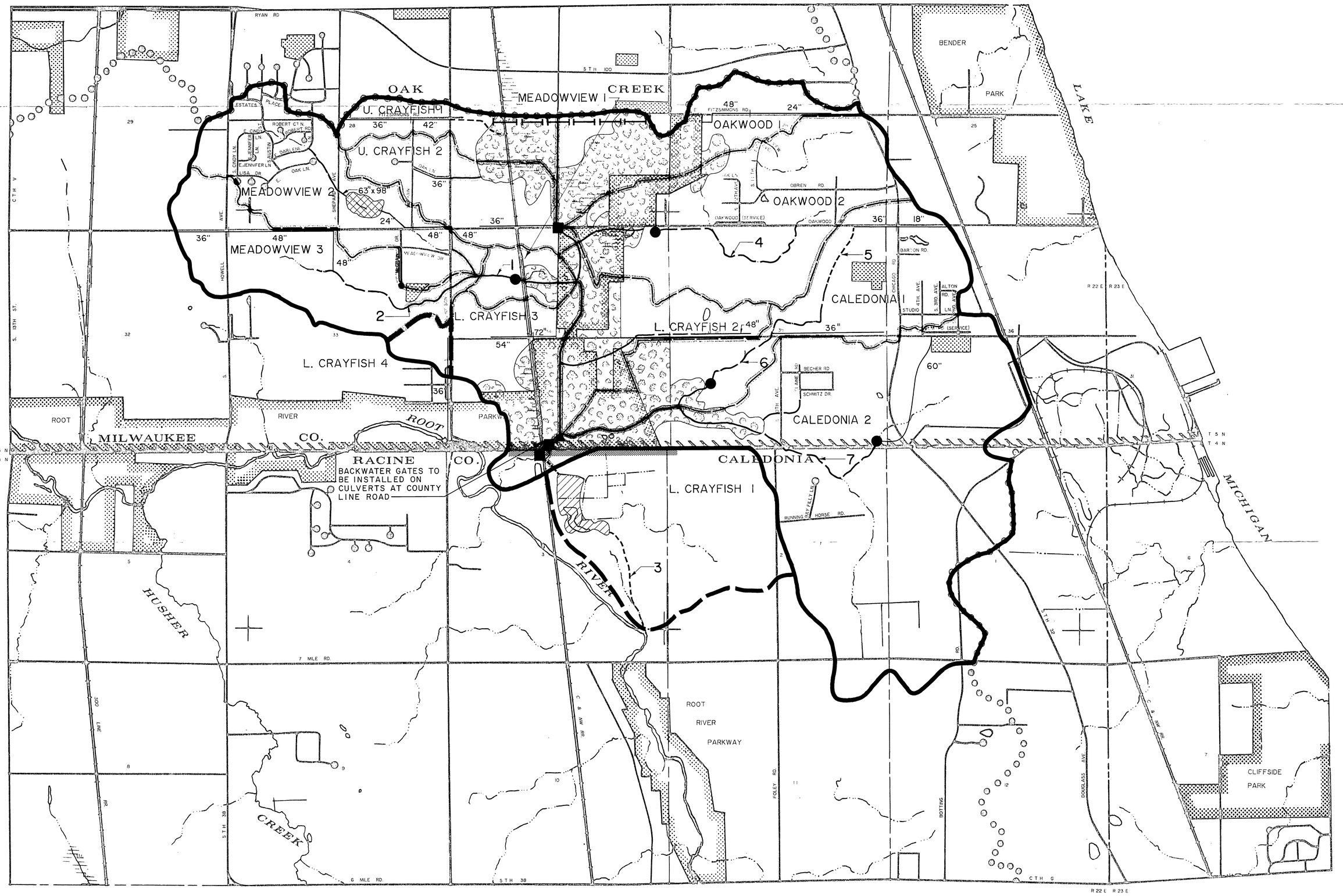
Costs

The capital and annual operation and maintenance costs of the stormwater management system components of the recommended plan are set forth in Table 1. The total capital cost of the recommended drainage and flood control improvements is estimated to be $4.2 million, with an attendant annual operation and maintenance cost of about $28,600. It should be noted that most of the costs to be incurred by the City of Oak Creek and the private sector are expected to be incurred over approximately 20 years as development occurs.

## IMPACTS OF RECOMMENDED STORMWATER MANAGEMENT PLAN

Under the recommended stormwater management system plan, runoff from up to and including a 10-year recurrence interval storm would be safely and efficiently stored and conveyed to major natural drainage channels with minimal inconvenience to residents. Runoff from larger events, up to and including the 100-year recurrence interval event, would be transported by the major drainage system without substantial property damage or danger to human health or safety. During a major storm event, the backwater gates at E. County Line Road would be closed to prevent Root River floodwaters from backing up into the Crayfish Creek channel. Some ponding may occur in localized areas during a major storm event. However, because there is sufficient storage in the existing wetland/environmental corridor complex, the expected ponding and flooding should not cause significant property damage, nor endanger human health or safety. Careful consideration was given in the plan to the impacts of the recommended plan downstream of the city limits. The quantitative analyses clearly indicated that implementation of the plan would not significantly increase downstream peak flood flows or stages.

Implementation of the recommended stormwater management plan would provide protection against substantial inconvenience to residents during minor storm events, and protection against major property damage or a significant hazard to human health and safety during major storm events. Such implementation would support the continued sound land use development in that portion of the City within the Crayfish Creek subwatershed.




## LEGEND

- EXISTING SUBWATERSHED BOUNDARY
- PROPOSED REVISED SUBWATERSHED BOUNDARY
- PRIMARY ENVIRONMENTAL CORRIDOR
- SUBBASIN BOUNDARY
- OAKWOOD I — SUBBASIN IDENTIFICATION- HYDROLOGIC UNIT AND SUBBASIN NUMBER
- PROPOSED ELEVATED ROAD OR BERM
- PROPOSED BERM
- PROPOSED CULVERT MODIFICATION
- EXISTING CHANNEL TO BE RETAINED
- EXISTING CHANNEL TO BE MODIFIED
- CHANNEL MODIFICATION COMPLETED
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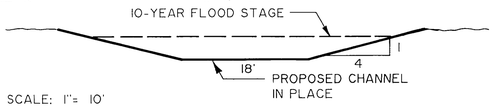
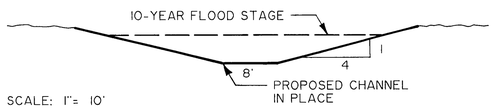
- POTENTIAL FUTURE STORMWATER PUMPING STATION TO BE ADDED SHOULD EXPERIENCE INDICATE THAT A GREATER PROTECTION LEVEL IS NEEDED.
- 3 — CROSS-SECTION IDENTIFICATION NUMBER

### 1
TYPICAL CROSS-SECTION OF CHANNEL UPSTREAM OF THE C & N W RAILROAD IN MEADOWVIEW I SUBBASIN



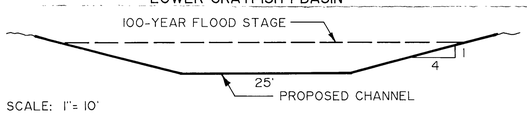

SCALE: 1"= 10'

### 2
TYPICAL CROSS-SECTION OF CHANNEL UPSTREAM OF S. NICHOLSON ROAD IN MEADOWVIEW 3 SUBBASIN



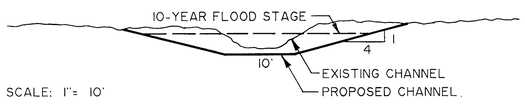

SCALE: 1"= 10'

### 3
TYPICAL CROSS-SECTION OF CHANNEL BETWEEN PROPOSED SEDIMENTATION BASIN AND THE ROOT RIVER IN LOWER CRAYFISH I BASIN



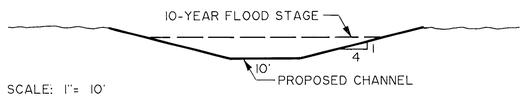

SCALE: 1"= 10'

### 4
TYPICAL CROSS-SECTION OF CHANNEL IN OAKWOOD 2 SUBBASIN TRIBUTARY TO CRAYFISH CREEK



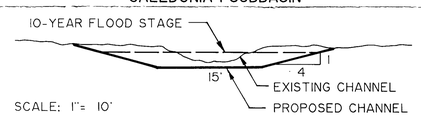

SCALE: 1"= 10'

### 5
TYPICAL CROSS-SECTION OF CHANNEL IN OAKWOOD 2 SUBBASIN TRIBUTARY TO CALEDONIA I SUBBASIN



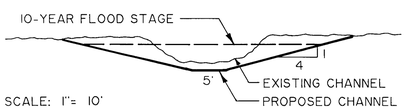

SCALE: 1"= 10'

### 6
TYPICAL CROSS-SECTION OF CHANNEL DOWNSTREAM OF E. ELM ROAD IN CALEDONIA I SUBBASIN




SCALE: 1"= 10'

### 7
TYPICAL CROSS-SECTION OF CHANNEL UPSTREAM OF E. COUNTY LINE ROAD IN CALEDONIA 2 SUBBASIN




SCALE: 1"= 10'

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

NOTE: CONSTRUCTION OF PROPOSED CHANNEL SOUTH OF COUNTY LINE ROAD TO BE DEFERRED OR WILL REQUIRE REALIGNMENT DUE TO GROUND AND SURFACE WATER CONTAMINATION FROM A LANDFILL IN THAT VICINITY. DETAILS TO BE CONSIDERED IN FINAL DESIGN IN CONJUNCTION WITH THE LANDFILL CLEANUP PROGRAM.

# MAP 30

## RECOMMENDED PLAN FOR THE CRAYFISH CREEK SUBWATERSHED

NORTH — SCALE: 1" = 1000'

1000 0 1000 2000 3000

SCALE IN FEET

| | |
|---|---|
| BASE MAP DESIGN: K.W. BAUER | |
| DRAWN BY: B.L. NOWAK | DATE: JUNE 20, 1988 |
| CHECKED BY: L.H. KREBLIN | DATE: JUNE 21, 1988 |
| APPROVED BY: | DATE: |
| DATE OF LAST REVISION: | |