

# **A New Era in Flood Management**

## **A Recent History of Flood Management Policies, Programs, and Projects in the Milwaukee Metropolitan Sewerage Districts Planning Area (1997-2017)**

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### **Introduction**

This document characterizes the series of events and challenges that led to the evolution of groundbreaking flood management policies, programs, and projects for the Milwaukee Metropolitan Sewerage District over a 20-year history from 1997 through 2017. It highlights the transformation in traditional rational and engineering practices that guided the public safety and environmentally balanced approach to flood management projects.

### **Background**

The Milwaukee Metropolitan Sewerage District (MMSD) is authorized under Wisconsin State Statutes to manage and maintain watercourses within Milwaukee County. This permissive authority was given to MMSD so that drainage could be maintained and improved to prevent adverse impacts to MMSD's wastewater collection system and infrastructure that could be seriously affected by overbank flooding. In the 1950's, 1960's, and 1970's, MMSD implemented numerous flood control and streambank stabilization projects for watercourses within Milwaukee County.

The projects completed up through the 1970's predominantly focused on storm/flood water conveyance capacity. Flooding streams, creeks, and rivers at the time were viewed both as serious nuisances and/or as storm/flood water conveyance conduits that must be controlled. Rarely were the waterways seen as valuable environmental resources and community assets worth protecting. During this time, MMSD's flood management program consisted primarily of straightening, deepening, and widening the various streams, creeks, and rivers within its jurisdictional area. These channel modifications were deemed as necessary to rapidly convey additional storm and floodwater downstream. These watercourse alterations consisted most often of concrete-lined channels, configured as open channels with trapezoidal cross-sections, having both the low flow channel and side slopes constructed from concrete to reduce friction, prevent erosion, and reduce the need for frequent maintenance.

These were the most commonly utilized flood control techniques for the day, and many streams, creeks, and rivers in the Milwaukee region received these types of alterations. By the 1980's, about 17 miles of concrete-lined watercourse channels existed in Milwaukee County. These methods, however, gave little regard to aquatic organisms and habitat; therefore, serious environmental consequences from this type of flood control were seen throughout the Milwaukee metropolitan region. Loss of habitat and stream morphology and structure resulted in declines in fish numbers and diversity and loss of other organisms that serve as their food sources. Additionally, surrounding communities' land use and development was not well regulated during this time. This resulted in increasingly larger percentages of the watersheds within Milwaukee County to consist of highly impervious, harden surfaces. What ensued from

this growth was the generation of higher volumes of stormwater runoff conveyed to the adjacent waterways. Not surprisingly, the increases in stormwater runoff created greater flood flow volumes and elevations, so much so that they exceeded the hydraulic capacities of the rivers and streams and the concrete-lined flood channels alike. The effectiveness of flood control efforts that were made by MMSD in the 1950's, 1960's, and 1970's was dramatically reduced or severely compromised by the 1980's.

In 1986, MMSD adopted a policy plan for flood management within MMSD's planning boundaries. The plan, entitled "*Stormwater Drainage & Flood Control Policy Plan for Milwaukee Metropolitan Sewerage District - Southeastern Wisconsin Regional Planning Commission's (SEWRPC) Community Assistance Planning Report #130*" identified perennial and selected intermittent streams where MMSD has regulatory authority. The policy plan also recommended that MMSD act as the primary management agency for the construction and maintenance of needed drainage and flood management work. In June 1987, MMSD adopted the "*Stormwater Drainage & Flood Control Policy Plan*". MMSD's policy considers the owner of the land adjacent to and under the streambed when determining its ultimate maintenance responsibility. A year after adopting the policy plan, only 16 of 29 communities served by MMSD adopted the recommended *Stormwater Drainage & Flood Management Policy Plan*, primarily because of disputes surrounding how projects were to be funded or cost-shared.

In December 1990, the companion plan to the policy plan called "*Stormwater Drainage & Flood Control System Plan for Milwaukee Metropolitan Sewerage District - SEWRPC Community Assistance Planning Report #152*" was completed. The "*Flood Control System Plan*" identified the type, general location, and horizontal and vertical alignments of needed drainage and flood control facilities. This includes the approximate elevation, size, grade, and capacity of channels and appurtenant bridge waterway openings, major storm sewers, detention basins, and retention basins, pumping stations, and other appurtenances of area wide significance and such data on flood stages under existing and planned conditions as may be required for MMSD to issue safe and reliable flood protection elevations. The system plan also identifies the costs and benefits of the recommended improvements and identifies an order of priority and schedule for project construction over time, constituting, in effect, a capital improvements program for area wide drainage and flood control works within MMSD's service area. Like the policy plan before it, the "*Flood Control System Plan*" was not widely accepted by the various affected municipalities, environmental groups, governmental agencies (Wisconsin Department of Natural Resources (WDNR) and Milwaukee County Parks), citizens, and other stakeholders due to a lack of a common vision, conflicting values, and competing interest.

### **New Era in Flood Management**

Clearly, the philosophy of flood control and accompanying engineering practices needed to evolve into something better, not only having public safety foremost in mind, but also having long lasting environmental and quality of life benefits connected with projects. This prompted MMSD in 1996 to invest in environmentally responsible systemwide watershed planning program. The program goals were to solve current flooding problems while putting policies and programs in place to prevent future problems. This new program's philosophy was a shifted from the old paradigm of flood "control" to flood "management". The shift in philosophy recognized

that severe weather, extreme rainfalls, and resulting floods could only truly be managed to the extent possible and not controlled. The systemwide watershed planning program also provided an opportunity to reverse some adverse flood relief techniques utilized in the past. It was recognized that urban channels could be rehabilitated with proper planning to accommodate both flood flows and provide an environmental stream corridor that incorporates meandering channels with pools and riffle sections as habitat enhancements and have aesthetic, stable, and native species vegetated banks. All these features collectively provide an attractive community/neighborhood asset that can also stimulate economic benefits and increase surrounding property values.

### **Lincoln Creek Flood Management Plan:**

Lincoln Creek was the first of watercourses to have this new holistic approach to flood management applied. Lincoln Creek had a long history of flooding problems with over 1,600 properties in the regulatory 100-year floodplain with most being single family residences. In August 1994, the Lincoln Creek Preliminary Feasibility Study was completed to address these flooding issues. This study examined the possibility a fully integrated water resources management plan for the Lincoln Creek watershed. The plan incorporated flood management and stormwater management, water quality improvement, and aquatic and terrestrial habitat restoration. The results of the feasibility study left several serious concerns and issues that required resolution. Of primary concern was the use of many dry and wet detention basins located on Milwaukee County parkland. Because of these and other deficiencies, no resolution and consensus could be reached; therefore, the plan was never accepted nor implemented.

Another planning effort was made to resolve the Lincoln Creek impasse and conflicts. In November 1996, the "*Lincoln Creek Environmental Restoration and Flood Management Plan*" was successfully completed and was broadly accepted by all interested parties and stakeholders. This plan replaced the previous 1993-1994 attempt for a comprehensive flood management plan for Lincoln Creek. The environmental restoration and flood management plan aimed to protect properties and to restore, stabilize, and enhance Lincoln Creek. The goals and objectives developed for the Lincoln Creek watershed were not solely aimed at solving flooding problems, but included improvements to the existing environmental integrity of the watershed. This included a creek corridor that would be aesthetically attractive to area residents, property protection from flood damages from the 100-year flood, retention of existing homes along the creek, preservation of historical landmarks, efforts to minimize safety and security concerns, efforts to improve water quality, repair, and stabilization of eroding stream banks and additional or enhanced habitat for fish and other aquatic life. The plan included floodwater detention, deepening and widening the creek for flood conveyance, creating a wetland for water quality improvement and floodwater detention, restoring eroding and concrete creek banks with native vegetation, and improving stream bed substrate. The final recommendations from this plan formed the basis of the Lincoln Creek flood protection and environmental restoration program that followed.

In June 1999, the first Lincoln Creek flood management construction project began at the Havenwoods State Forest Environmental Education Center. An 11-acre wetland detention area was constructed to reduce both downstream flooding and pollutant loadings during major

storms. In its normal state, the 90-acre-foot detention area was to serve as a naturally functioning wetland with educational features integrated into the park that included interpretive nature trails along raised boardwalks. This first construction project on Lincoln Creek created the momentum, determination, and public enthusiasm to continue with the full project. After nearly five years and a \$117 million investment, the Lincoln Creek Flood Management construction was completed in September 2003. The project protected 2,025 structures (homes and business) from the 100-year flood.

### **Watercourse System Plan-Phase I:**

While *the Lincoln Creek Environmental Restoration and Flood Management Plan* was underway the MMSD Watercourse System Plan - Phase 1 was started in March 1997. This Watercourse System Plan was intended to update the SEWRPC Community Assistance Planning Report #152, building on the successes of the *Lincoln Creek Environmental Restoration and Flood Management Plan*. The Watercourse Management System Plan was to refine statistical definition of rainfall event recurrence and associated flood flows and stages for six watersheds in the MMSD service area (the Milwaukee River, Menomonee River, Kinnickinnic River, Root River, Oak Creek, and the Lake Michigan Drainage tributaries). It updated 100-year floodplain limits within respective watersheds to reflect current and future land use conditions within the various watercourse segments. The land adjacent to watercourses had previously been evaluated and mapped to identify 100-year floodplain limits (i.e., land which has a one percent probability of being flooded in a year). Floodplains have been defined for each community by the Federal Emergency Management Administration (FEMA) and evaluation of floodplain limits was a part of watershed plans prepared from the 1960's through the early 1980's by SEWRPC. Floodplain mapping initiated in the 1970's was updated in Watercourse System Plan to reflect changes in the watershed runoff characteristics, topographic modifications, or actual flood experiences. The plan identified over 3,800 structures within the 100-year floodplain of the six watersheds. Many of these structures were not built in an original floodplain, but became inundated with floodwaters caused by nearby and upstream development. The Watercourse Management System Plan also incorporated local community stormwater management programs into the planning process and identified projects, such as modifying channel configuration or structures and providing detention or retention facilities or other flood management measures.

The Watercourse Management System Plan was completed in August 2000 and incorporated within its recommendations measures that were consistent with objectives for aquatic habitat improvements and revised recreational objectives for the watercourse. The recommendations and plans for each watershed were to reflect the flood management preferences of local communities and citizens and determined costs and benefits of potential flood management measures. The ultimate focus of the Watercourse System Plan was to develop solutions to overbank flooding that threatens public safety and causes property damage, but the plan also advanced and built upon the lessons learned from Lincoln Creek project which demonstrated that urban channels could be rehabilitated with proper engineering. This inspired further interest in restoration of aquatic habitat for streams not previously considered to have the potential to support a diversity of biota. Additionally, the potential of improved water quality also produced interest in modification of stream channels to create a more natural aesthetic

focus for watercourse channels within parkways areas providing recreation to the citizens of Milwaukee County.

### **Watercourse Policy Plan**

Some of the many varied solutions identified by Watercourse Management System Plan to reduce flooding problems in the six watersheds included: providing storage, adjacent floodplain lowering, building levees or earthen berms, bridge removal or adjustments, property buyouts, and floodproofing. Just as important as these engineered structural flood reduction techniques were the nonstructural policies and programs also designed to reduce the risks of future flooding. MMSD's Watercourse Management System Plan also added four key protective policies and programs to further ensure that the structural and engineered flood management solutions and projects would remain highly functional and protective far into the future. The first of these was the development of a regionally uniform Watercourse Policy Plan. This policy plan was developed over the course of two years (1997-1999) using the framework of the original 1986 policy plan and with the input and feedback of many diverse stakeholders that included elected officials, community environmental advocates, citizens groups, individuals, municipal engineers, SEWRPC, and WDNR. On April 26, 1999, the MMSD Commission adopted a *Watercourse Policy* through Resolution 99-048-4(02) (MMSD, 1999). This policy document defines the following for the MMSD's jurisdictional watercourses: (1) MMSD jurisdictional areas, (2) purposes eligible for MMSD funding, (3) maintenance responsibilities and prescribed actions, and (4) project prioritization.

### **Chapter 13: Surface Water and Stormwater rules**

The second of these policies and programs was the implementation of a stormwater runoff management rules for all 28 municipalities in the MMSD service area. The rule, "*Discharge Regulations and Enforcement Procedures, Chapter 13: Surface Water and Stormwater*" was implemented on January 1, 2002. This rule was designed to ensure that flood risks do not increase due to future development or redevelopment in MMSD's service area. The rule provides that local governments must design stormwater conveyance systems, including outfalls, so they do not reduce the level of protection that an MMSD flood abatement project provides or increase flooding problems downstream. The adoption of this rule reflects a region-wide effort to manage future flooding and was the first time a proactive regional approach has been taken to reduce the risk of flooding in southeastern Wisconsin. These rules set uniform runoff standards for each community based upon the amount of impervious surface for both new and redevelopment. By establishing uniform volume limits on the amount to runoff for development, no community would have a competitive advantage over the other in terms of future growth. The stormwater rule applies to development or redevelopment that involves an increase to impervious surfaces of one-half (0.5) acre or more. These safeguards would protect the investments made in structural flood management projects by curtailing future flooding incidents by not allowing growth and land use to outpace and/or exceed the design capacity and functionality of the new flood management projects.

### **Watercourse Maintenance Program Plan:**

The third protective measure that was put in place was the “*Watercourse Maintenance Program Plan and Manual*”. This manual was completed by the MMSD in December 2001 and was developed to provide overall watercourse maintenance guidelines for natural waterways and watercourse improvement projects within MMSD’s jurisdictional boundaries. The maintenance plan included inspection schedules, annual preventive maintenance activities, annual vegetation management and maintenance, and development of plans for repairs and maintenance likely to be required after flood events. The Watercourse Maintenance Plan also provided guidelines and schedules for preventive maintenance tasks that will help MMSD avoid costly corrective maintenance. The Watercourse Maintenance Plan provided consistent practices on MMSD jurisdictional watercourse which led to more efficient coordination through a custom application database that tracks inspection locations, routine and event-based inspection dates, work orders, and associated costs. It establishes a system-wide inspection and maintenance standard operating procedures (SOP’s) which promote safe and environmentally secure watercourses within MMSD’s jurisdictional limits.

### **Greenseams® Conservation Program:**

The fourth protective measure put in place is known as the “*Greenseams® Program*”. The Greenseams® Program is designed to preserve natural ponding areas and undeveloped floodplain areas through property acquisition to help reduce the risk of future flooding. Under the plan, MMSD hired the Conservation Fund, a national nonprofit conservation organization that works with local community groups, property owners, municipalities, and others to acquire easements on properties that have been identified as critical to protect against future flooding in the Milwaukee River, Menomonee River, Oak Creek, and Root River watersheds. This program buys undeveloped land in locations throughout various watersheds to keep them from future development and restores developed floodplains to their natural functionality thereby encouraging land use compatible with flooding. These areas could be natural area or under agricultural cultivation, in which case drain tiles are hydraulically disconnected from adjacent waterways. All areas have a common denominator; they contain what are known as hydric soils. Hydric soils act as large natural sponges to retain water onsite. These areas can hold and retain large volumes of water, which curbs downstream flooding. The Greenseams® Program supports activities to research, identify, acquire, maintain, preserve, and defend natural flood storage on lands within MMSD’s planning area and is complimentary to the Chapter 13 stormwater rules.

### **Significant Rainfall Events and Flooding**

Virtually all serious flood events result from heavy rainfalls which occur over a period of one day or less. Flooding can also result because of many consecutive days of more of moderate rainfall volumes. These distinct types of flooding events were represented multiple times in the 20-year history from 1997 through 2017. The relationship between rainfall volume, intensity, duration, and damages is not well documented because of the great temporal and geographic variability of rainfall and other factors that influence runoff rates and volumes. Between 1962 and 1982, the Milwaukee area experienced an extended period with few major storm events. This period was relatively dry with annual rainfall exceeding 35 inches only four times in 21 years. No 24-hour period exceeded 3.11 inches of rain at official recording stations between 1960 and

1985; however, since the mid-1980's, heavy rainfalls have been more frequent, demonstrating the temporal variability of rainfall amounts. Severe floods occurred in 1986, twice in 1997, in 1998, 2004, 2008, and twice in 2010, causing hundreds of millions of dollars in damage and even loss of life. Seven rain events that exceeded the 1% probability occurrence in the 13 years between 1997 and 2010.

The storms of note in the MMSD service area are described below:

**August 6, 1986** - This extremely intense thunderstorm produced the single day record rainfall of 6.84 inches at the Mitchell Field recording station. The storm included a five-inch volume in a two-hour period, which caused widespread flooding in the Mitchell Field area and closed the airport. Severe damage occurred along the Kinnickinnic River between South 6th Street and South 16th Street.

**June 20-21, 1997** - The June 1997 event was unusually large in its geographic distribution with at least four inches of rain across Milwaukee County. Most of the county received more than six inches, and more than nine inches of rain were recorded in the Village of Brown Deer. Mitchell Field, which is partially in the Kinnickinnic River watershed, recorded one of the lowest totals in the County, only 4.12 inches. Sewer backup flooding was reported in the Kinnickinnic River watershed, but no damage resulting from overbank flooding was reported.

**July 2, 1997** – Though not nearly as severe as the storm two weeks earlier, the July 2 storm released as much as four inches on the area still recovering from the June 20 flood. Fortunately, this storm produced little additional property damage.

**August 6, 1998** - This storm dropped over six inches of rain in eastern Waukesha County and northwest Milwaukee County. For the second time in 15 months, there was significant property damage due to overbank flooding along the Menomonee River, Root River, and Lincoln Creek.

**May 6-25, 2004** - Extreme amounts of rainfall with an average of 8.9 inches fell over MMSD service area during a 19-day period, which resulted in widespread regional flooding, sewer overflows, and sewer backups. The long duration of this storm was unprecedented in its length and extent, which required extensive analysis by SEWRPC to classify the storm's recurrence interval. The rainfall event ultimately was much greater than one percent probability storm.

**June 7-11, 2008** – Heavy rain fell over several days leading to severe statewide, regional, and local flooding. There was extensive flood damage, sewer overflows, and sewer backups in the Milwaukee region and MMSD service area, where approximately between nine and 11 inches of rain occurred in 96 hours. The Interstate Highway system was closed in multiple locations for a period of days and, in some cases, several weeks. The rainfall event was greater than the one percent probability storm in many areas, including the entire MMSD service area.

**July 10, 2010** - Extreme amounts of rainfall on July 10, which resulted in local flooding, extensive flood damage, overflows, and sewer backups.

**July 22-23, 2010** - Extreme amounts of rainfall resulted in regional and local flooding, extensive flood damage, overflows, and sewer backups. Rainfall exceeded five inches in two hours and 7.5 inches in 12 hours. The event was greater than 0.5% probability storm in some areas of MMSD's service area.

### **June 20-21, 1997 Rain Event and Flooding leads to Regional Cooperation**

While the MMSD Watercourse System Plan - Phase 1 was underway, a devastating rain event of nearly 10 inches struck the region on June 20-21, 1997. The widespread severity of the rain event led to enormous flood damages and economic losses (tens of millions of dollars). This single event acted as a regional catalyst for cooperation and support of the updated Watercourse System Plan - Phase 1. Although the first attempt in 1990 at a Stormwater Drainage and Flood Control System Plan was not generally accepted by the various stakeholders due to a lack of common vision and goals, this Watercourse System Plan had the concurrence and support of the local communities, affected citizens, elected officials, governmental agencies, and other effected stakeholders, such as the Milwaukee County Parks Department. Each of the six watersheds flood management plans' overarching goals were to restore free flowing streams and rivers, to establish green space along more aesthetically pleasing waterway channels, and to do so without diminishing the ability to manage large flood flow events. The Watercourse System Plan also recognized the interests and requirements of regulatory agencies, such as WDNR and federal permit requirements of the U.S. Army Corps of Engineers (USACE). The open, transparent planning process of the Watercourse System Plan - Phase 1 provided many opportunities for input by all stakeholders necessary to develop a recommended plan that was protective, functional, fundable, and implementable. For these reasons, the Watercourse System Plan was successful, but it is debatable how quickly and how willing the cooperation would have been without the flood of June 20-21, 1997.

### **Early-Out Flood Management Plans, and Projects**

The June 20 and 21, 1997, storm event prompted MMSD to develop numerous early-out watercourse plans and projects. These were plans and/or projects that would be implemented before the full Watercourse System Plan could be completed, but met an urgent and immediate hardship. These projects were integral components of the full Watercourse System plan's recommendations; therefore, they were considered necessary and beneficial to commence regardless of the full plan's final recommendations.

Six of these plans/projects are mentioned here for illustration purposes. The June 20 and 21, 1997, storm dropped a total of 9.79 inches of rain in Brown Deer over a 26-hour period. This event caused \$14 million in flood damage to about 100 structures along Beaver Creek, Southbranch Creek, and the local drainage system tributary to these creeks. An early-out Watercourse Management Plan was developed for Southbranch and Beaver Creek and was completed in November 1998. The plan was multifaceted, including floodplain lowering, acquisition and removal of properties/homes, conveyance (deepening and widening a portion of the channel), and detention. The plan's recommendations included installing three detention basins (64-acre-feet), replacing one culvert with an open channel, enlarging three box culverts, and adding an additional eight-foot-diameter circular pipe in a road crossing. Actual flood

management construction on Southbranch Creek began in June 1999 and went through various phases of advanced planning and engineering with construction concluding in September 2003.

Simultaneously, MMSD completed the early-out Watercourse Management Plan for Indian Creek in May 1998 for the Villages of Bayside, Fox Point, and River Hills. The recommendations included construction of three detention facilities (91.2-acre-feet), replacement of six stream crossings, removal of one stream crossing, widening channel from Port Washington Road to Manor Lane, providing flap gates on culverts beneath railroad, and construction of a diversion culvert. Indian Creek, Southbranch Creek, and Beaver Creek are all within the larger Milwaukee River watershed. Actual flood management construction on Indian Creek began in June 1999 and went through various phases of advanced planning and construction, concluding in April 2009.

The Ryan Road Flood Management and Stormwater Control project was also an early-out project for the Oak Creek watershed. The Ryan Road underpass at the Oak Creek crossing had ongoing and frequent flooding problems due to the low nature storm sewers and drainage issues during heavy rains. This drainage/flooding problem occurs because of the minimal difference in elevation between Ryan Road and the creek bottom (approximately three to four feet). Alternatives were developed, and a cost sharing agreement was established among the City of Oak Creek, MMSD, and Wisconsin Department of Transportation to remedy the problem, which included a stormwater pump station, new storm sewer inlets, and improved drainage. The Ryan Road project began in February 2000 and concluded in June 2001.

In December 1997, MMSD started the early-out project of sediment removal from the concrete-lined Menomonee River channel in Milwaukee's Valley Park neighborhood located between I-94 and Bluemound Road that resulted from the June 1997 flood. Sediments and gravel deposits accumulated and filled the bottom of the concrete low flow channel. The neighborhood was worried that the Menomonee River's flow carrying capacity was being compromised or restricted. Similarly, in February 1999, MMSD started an early-out project along the Hart Park area in Wauwatosa to remove woody debris from the Menomonee River. Very large and multiple tangles of woody debris formed on gravel bars within the main channel of the Menomonee River in the Hart Park area. Again, the citizens of the area were very concerned of the debris tangle causing flow obstructions and worsening flooding. Both these early out projects were undertaken to ease the apprehensions of the local citizens and elected officials. All necessary permitting was acquired quickly and the sediment and woody debris removal was completed in February 1998 and May 1999 respectively.

The final early-out project discussed here was the Valley Park Project. Valley Park is a neighborhood located in the City of Milwaukee along the eastside Menomonee River between Mount Vernon Avenue and Bluemound Road. This project was a key element in the overall Flood Management plan for the Menomonee River. The project began in September 2000 and consisted of a seven-foot-high, 800-foot-long levee with a five-foot-high flood wall. Along the base of the levee and flood wall a 1,200-foot-long walking path was installed as a neighborhood amenity. Eighteen properties/homes were acquired to accommodate the project, and there was an expansion and enhancement of an existing Milwaukee County Park. Below ground, all throughout the Valley Park neighborhood, the storm sewer system was upgraded and enlarged.

The storm sewers eventually drained to a one-million-gallon underground stormwater detention tank constructed under the public park with a surface pump station built to aid interior drainage due to the surrounding topography. A neighborhood revitalization plan was developed with the assistance of a professional urban planner and vigorous input from the residents. The Valley Park project was completed in December 2002.

### **Watercourse System Plan Recommendations by Watershed:**

The Watercourse Management System Plan was completed in August 2000 for six watersheds (the Milwaukee River, Menomonee River, Kinnickinnic River, Root River, Oak Creek, and the Lake Michigan Drainage tributaries). Specific plans were developed for each respective watershed; although, consistent to all were the common objectives that allowed for aquatic habitat and water quality improvements, enhanced aesthetics, improved recreational opportunities, and public safety for individual watercourses. The recommendations for flood management measures for each watershed reflected the preferences of the local communities and their citizens. The initial watercourse planning effort was typically followed up with three explicit phases before construction began: (1) Advance Planning – this was performed for each watershed to further develop concepts and particular details of the plan; (2) Preliminary Engineering – this was done to distill recommended alternatives further by refining flood flow and stage characteristics and other calculations; and (3) Final Design - this confirmed the design and engineering specifications of the final recommended alternatives. Below is a brief description of the initial flood management measures accepted and approved for each watercourse.

The Oak Creek Watercourse plan was completed in August 2000. Recommendations for Oak Creek included:

- Upper Oak Creek Mainstem: Floodproof three industrial structures and acquire one residential structure.
- Lower Oak Creek Mainstem: Floodproof one industrial structure and acquire six residential structures.
- Upper North Branch Oak Creek: Floodproof five commercial/industrial structures and acquire one residential structure.
- Lower North Branch Oak Creek: Floodproof one apartment building and acquire one residential structure.
- Mitchell Field Drainage Ditch: Floodproof three governmental structures.
- Ryan Road Flood Management and Stormwater Control.

In May 2003, Oak Creek Weir Removal began on two weirs on Upper North Branch (one Upper Drop Weir at 6th Street and one Lower Drop Weir north of Rawson Avenue along 6th Street) and one on Upper Oak Creek mainstem south of the Ryan Road crossing. Removal of sheet pile drop structures would restore Oak Creek's potential to support aquatic resources. The concrete or sheet pile drop structures were originally placed in the Oak Creek as part of previous drainage or channel modification projects where stream beds were lowered to improve drainage or conveyance or provide grade control or velocity reduction. The removal of these drop structures would improve aquatic conditions while still ensuring needed conveyance and stable channel conditions are maintained.

The Root River Watercourse plan was completed in August 2000. Recommendations for the Root River included:

- East Branch of Root River: Floodproof or buyout of 11 structures.
- Lower North Branch of Root River: Floodproofing or buyout of 1 residential structure and 1 commercial structure.
- Whitnall Park Creek: Floodproofing or buyout of 11 structures and overflow conduit.
- Upper North Branch of Root River and Hale Creek West Allis: Floodproofing or buyout of 12 structures on North Branch of Root River and Hale Creek combined with a storm sewer diversion for Hale Creek.

The Root River Geomorphic and Sediment Transport Planning Study was completed in September 2007 and was conducted: (1) to obtain a baseline analysis of existing channel stability conditions within the North Branch of the Root River and its principal tributaries, and (2) using hydrologic, hydraulic and sediment transport tools to predict the impacts of any future proposed flood management work on the vertical and lateral stability of the stream channels within the MMSD jurisdictional reaches. Results of the study indicate that the North Branch and its principal tributaries are generally vertically and laterally stable and that they are somewhat insensitive to hydrologic changes in the watershed.

The Menomonee River Watercourse plan was completed in August 2000. Recommendations for the Menomonee River included:

- 750 feet of five-foot-high floodwall and 750 feet of seven-foot-high levee in Valley Park and, as previously mentioned, 6,500 feet of five-foot- to seven-foot-high levee in Hart Park in Wauwatosa.;
- One foot to two feet of floodplain lowering in Hart Park.
- 800-acre feet of storage at Milwaukee County Grounds.
- Removal of access bridge at Hawley Road.
- Forty-two residential property acquisitions, seven to 18 nonresidential acquisitions, and 12-23 floodproofing of structures.
- Grantosa Creek: construct 30-acre feet of detention storage at Timmerman Field.
- Honey Creek: floodproofing or acquisition of six structures.
- Nor-x-way Channel: Acquire one residential structure.
- Little Menomonee River: floodproofing or acquiring three residential structures and one industrial structure.
- Underwood Creek: concrete removal for stream restoration.

In September 2000, the MMSD Commission authorized Menomonee River Flood Management Advanced Planning and Design. This project recommended additional improvement to the Menomonee River Flood Management Plan. Recommendations included: levee/floodwall system in Western Milwaukee; levee/floodwall system near Concordia Avenue along the Menomonee River; levee/floodwall system along Grantosa Creek Parkway just upstream of confluence with Menomonee River; additional isolated property acquisitions; and channel stability recommendation for highly eroded reaches of Underwood and Grantosa Creeks. In February 2001, recommendations for Lower Wauwatosa and Western Milwaukee were

completed in a preliminary engineering report. This report evaluated the Hart Park Floodplain Design Project, which included a levee/floodwall system, internal gravity drainage system, and stormwater pump station. It also evaluated plans for property acquisitions, soil erosion, sediment control, traffic control, and operations and maintenance.

The Kinnickinnic River Watercourse plan completed in August 2000. The Recommendation for the Kinnickinnic included a Kinnickinnic River mainstem that recommended further analysis to verify potential for damages and structural improvements in reach between 6th and 16th Streets. This recommendation evolved into the Kinnickinnic River Channel Rehabilitation Project of 2009-2017, which extended from South 6th Street to South 27th Street. This project's goals were to identify an alternative for channel rehabilitation within the project boundaries, maximize the environmental and ecological potential, support the neighborhood/community and its economic development initiatives, and ultimately provide long-term community value with improvements to the quality of life. The initial plan also recommended cooperative USACE streambank stabilization projects at multiple locations. Wilson Park Creek was recommended for further analysis to verify potential for damages and structural improvement. Lyons Park Creek was recommended for further analysis to evaluate floodproof/acquisition of two structures and conveyance alternatives in advanced planning. Villa Mann Creek and Villa Mann Creek Tributary were recommended for further analysis to evaluate floodproof/acquisition of five structures and one conveyance alternative. 43rd Street Ditch was recommended for further analysis to evaluate floodproofing one industrial structure.

The Milwaukee River tributaries and Fish Creek Watercourse plan was completed in August 2000. Recommendations for the Milwaukee River tributaries were included in the Lincoln Creek, Indian Creek, Southbranch Creek, and Beaver Creek flood management plans previously mentioned. Fish Creek recommendations included completing a geomorphic study, which was performed to develop a geomorphic, hydrologic, and hydraulic analysis database to support planning and engineering that went into Fish Creek Watercourse Flood Management Plan - Advanced Planning Analysis, Design Services & Engineering Services. This project included an analysis of dam repair and removal alternatives for the Fish Creek Dam. The geomorphic study concluded that the dam does not have a significant effect on water surface elevations or stream flows during design storm events.

### **20 Years of Flood Management Success in the Milwaukee Metropolitan Region**

The MMSD flood management efforts and achievements over the past 20 years have been monumental. Originally, 3,833 properties/structures were identified in the 100-year floodplain in the Watercourse System plan (1997-2000). As the various components and projects from the Watercourse System plan were implemented over the last 20 years, the number of properties in the 100-year floodplain has greatly diminished. Many of these properties/structures were physically removed from the 100-year floodplain through purchase/acquisition and then demolition; however, the majority were merely protected as the spatial and lateral expanse of the 100-year floodplain was drawn inward toward the various watercourse channels due to the multifarious flood management measures employed, such as floodplain lowering, detention, floodwalls, levees, improved channel capacity and enlarged bridge passages with low and high bypass channels. As of July 2017, over 2,550 properties/structures are no longer considered to be in 100-year floodplain, which represents a

67.1% removal and/or protection from flood risk. Additionally, over three miles of concrete channel has been removed (from the total of nearly 17 miles) and replaced with more natural meandering channels with pools and riffle sections as habitat enhancements and aesthetic, stable, and native vegetated banks have been established.

Overall, the Watercourse System Management Plan met its intended objectives to: (1) refine statistical definition of rainfall event recurrence and associated stream flow, (2) update 100-year floodplain limits to reflect future (2035) land use conditions within the various stream segments, (3) incorporate local community stormwater management programs into planning process, (4) identify projects such as modifying channel configuration, floodplain lowering, engineering structures, such as levees and floodwalls, providing detention or retention facilities, and/or other preventive flood management measures, (5) determine costs and benefits of potential flood management measures, (6) identify flood management measures that are consistent with balanced, holistic objectives for aquatic habitat improvements and recreational opportunities for the streams for which flood management measures are desired, and (7) develop plans that reflect the preferences of local communities, governmental agencies, environmental groups and interested parties.

It is both challenging and problematic to predict what the future will bring in terms of changing weather patterns, rainfall amounts, and flooding potential, but the MMSD flood management program continues to plan for the future by developing adaptive management strategies and building resiliency and capacity into all its flood management projects, while maintaining community compliance with strict enforcement of MMSD's stormwater runoff rules and promoting proactive programs that also reduce runoff, such as the Freshcoast-740 Green Infrastructure program and the Greenseams® Program.

The enormous flood management efforts of the past 20 years with a total cost estimated at over \$400 million are evident wherever one looks in the MMSD 400-square-mile service area: improved watercourse floodway corridors, protected neighborhoods, preserved uplands, uniform development runoff controls, fish passage enhancements, economic development, increased property values and aesthetically pleasing watercourses with recreational opportunities. While these flood management features abound throughout the region, they are designed in harmony with the surrounding landscape that makes them ironically as inconspicuous as they are noticeable. It is truly amazing the amount of flood protection afforded to the populace of the region in the last 20 years, yet flood management projects and construction continues, as there is always more to alleviate, resolve, and accomplish.