Basin SH6 Sanitary Sewer Study

Village of Shorewood

August 2000

Introduction

This report outlines the hydrologic and hydraulic analysis of the Basin SH6 in the Village of Shorewood. Our work consisted of creating a computer model of the sewer system, conducting a hydrologic and hydraulic analysis, and developing improvement alternatives to prevent and eliminate sanitary sewer backups in the service area.

System Description

Service Area and Land Use

Basin SH6 refers to an area bound by Oakland Avenue to the east, Wilson Drive to the west, Olive Street to the south and Glendale Avenue to the north. The total service area of the system is approximately 150 acres. Surface drainage in Basin SH6 is accomplished through a storm sewer system, with an outfall to the Milwaukee River.

The majority of the 867 residential units in Basin SH6 are single family dwellings, with the remainder consisting of duplexes. The Lake Bluff Middle School is the only institutional facility in the area. The school has 555 students and approximately 45 faculty and staff on the premises. Oakland Avenue, north of Kensington Boulevard is a commercial area where 13 businesses are part of the basin.

Existing Sewer Network and Performance

The sewer network in the area is part of a larger system encompassing sanitary sewers in Basin WB3 in the Village of Whitefish Bay. The main collector sewer in this system is an east-west line located along Glendale Avenue in Shorewood and Courtland Place in Whitefish Bay. At each intersecting street, north-south lines connect to this collector, which itself connects to the MMSD MIS in the vicinity of the intersection of Wilson Drive and Diversey Boulevard. The sewer system is schematically represented in Figure 1.

Flow from the entire Basin SH6 is collected along Glendale Avenue between Oakland Avenue to the east and Woodruff Avenue to the west. Flow is then conveyed north along Marlborough Drive and then proceeds west along Courtland Place all the way to the MIS.

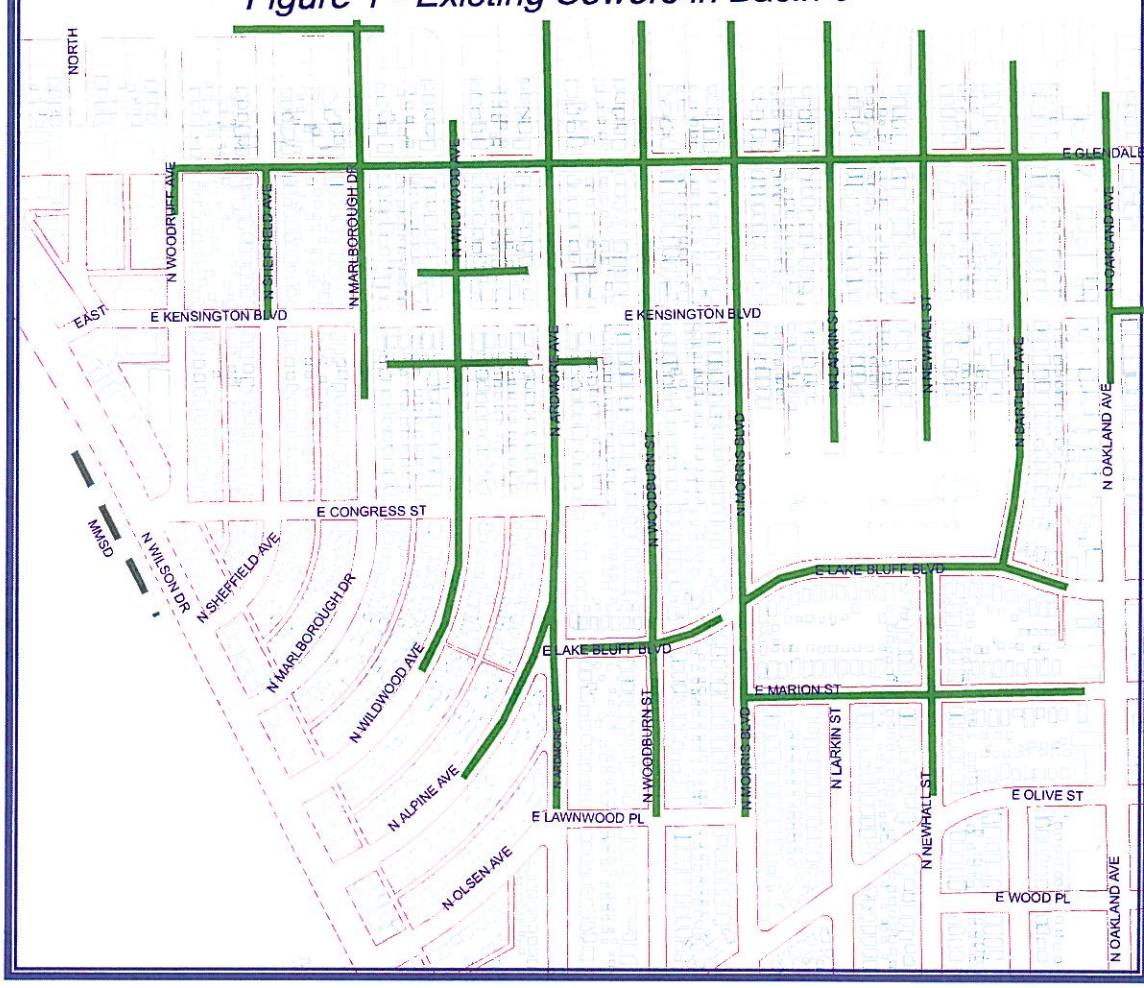


Figure 1 - Existing Sewers in Basin 6

The existing system is prone to wet weather surcharging that frequently causes sewer backups in residential basements. The backup risk areas are rather well defined, consisting mainly of the eastern two thirds of Basin WB3 in Whitefish Bay and an eight block area bound by Glendale Avenue, Morris Boulevard, Congress Street, and Marlborough Drive in Basin SH6. Other isolated pockets of backup occurrences also exist, but are not directly related to systemic problems affecting the WB3/SH6 area. Figure 2 shows the reported sewer backup locations during the summer of 1999.

It is clear that the wet weather surcharging problem is rooted in chronic inflow and infiltration (I/I), and that the ultimate protection against basement backups lies in the total elimination of clear water from the sewer system. However, the recent 2010 MMSD facilities Plan Update has identified a peak factor of 7.6 for Basin SH6, and 8.5 for Basin WB3. Though not ideal, these peak factors are well within acceptable limits, especially in the North Shore, where peak factors of 15, 20, or even 35 are not uncommon.

Specifically in Shorewood, a peak factor of 7.6 places Basin SH6 at the bottom of the I/I reduction priority list. In our opinion, with such low peak factors, further reduction of I/I in this basin would be tantamount to seeking the complete elimination of I/I, which is an unreasonable design objective. Based upon this argument, we are proposing a capacity and conveyance solution to the surcharging problems in Basin SH6.

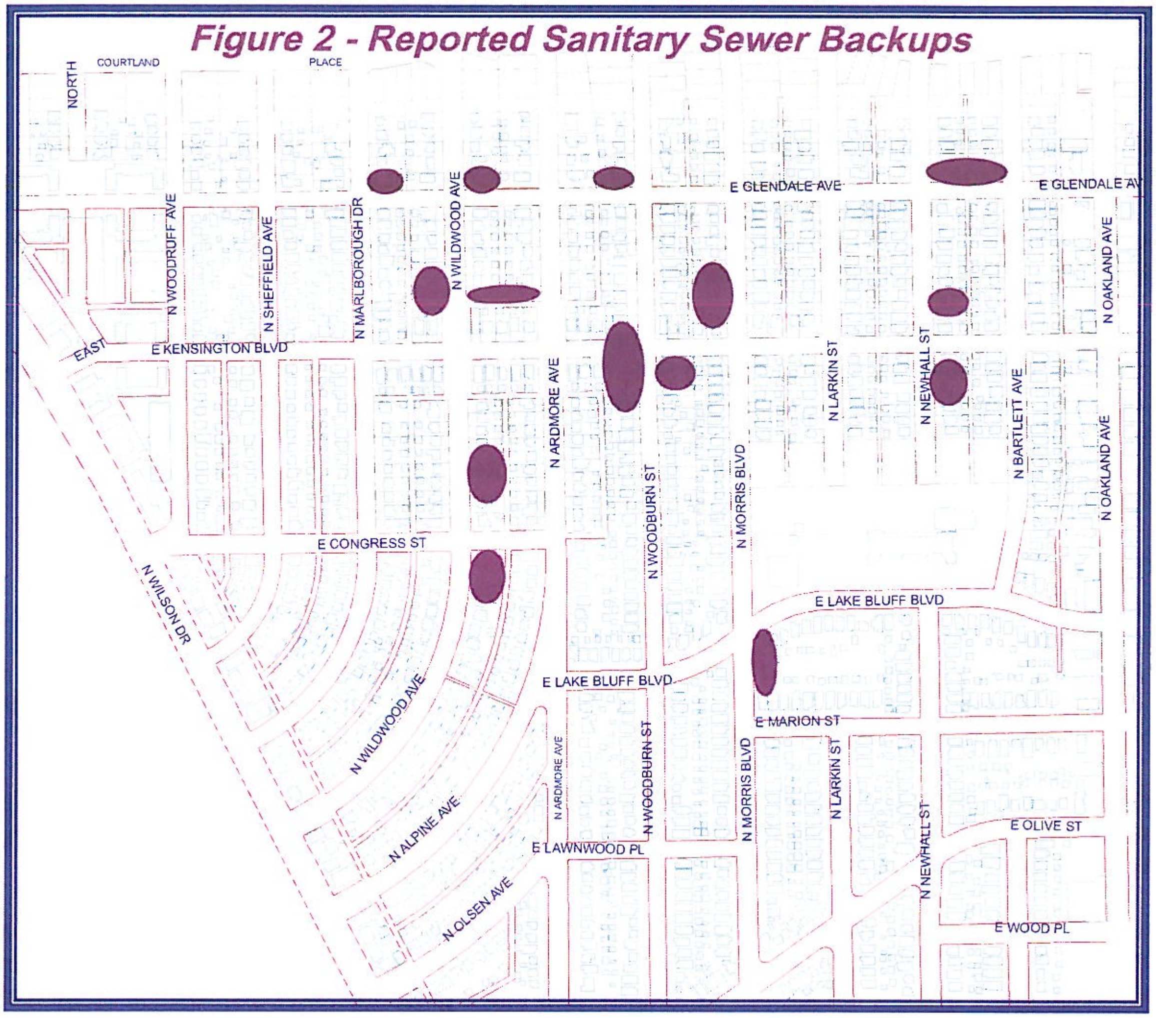


Figure 2 - Reported Sanitary Sewer Backups

System Analysis

The main work effort in this phase involved the modeling of the sewer network, the selection of the design flows, the determination of design performance criteria, and the calibration of the model using sewer flows measured during 1999.

Recent rainfalls have exposed the system's weaknesses and several occurrences of sewer backups have prompted the officials in both Villages to act towards a solution to this recurring problem. In the case of Whitefish Bay, the severity of the surcharging problem appears to have led the community to seek a relief sewer that would discharge the wet weather flows into the Milwaukee River. This approach aims to reduce surcharging of the Courtland Place and Glendale Avenue collector sewers, thereby reducing backup risks in the connecting sewers. Extensive modeling and calibration by Earth Tech, Inc. has demonstrated the benefits of this scheme.

The Earth Tech model included all sewer lines in the Village of Whitefish Bay, as well as the sewer along Glendale Avenue in Shorewood. The model was calibrated at nine flow meter locations for both dry and wet weather flows and in our opinion, represented an accurate description of the system in place. At the conclusion of an alternatives analysis by Earth Tech, relief sewers and a Milwaukee River overflow were presented to Whitefish Bay and Shorewood as a potential solution to backup problems in basins WB3 and SH6. However, further analysis revealed that the benefits of the proposed solution did not extend into the problem areas in Shorewood, and that several additional relief sewers would have to be added to the original proposal for it to perform as originally devised.

Concerned about the increasing construction cost estimates and probable lengthy implementation timeline, the Village of Shorewood proceeded with the development of solutions that were less costly, more effective, and without wet weather overflows to the river. The Village also sought a solution that would complement the project pursued by Whitefish Bay, even though the two Villages would be taking independent actions within their boundaries.

To satisfy these design goals, we have taken the Whitefish Bay sewer model created by Earth Tech and enhanced it by adding the sewers of Basin SH6, thereby creating a complete description of the existing sanitary sewers in the area. We chose to continue using the entire Whitefish Bay system model because the proposed relief sewer there would eventually establish a hydraulic connection between all basins, including SH6. Despite longer computation times, we wanted to ensure that our analysis of SH6 fully integrated with the proposed Whitefish Bay relief system, including the Milwaukee River overflow.

Model Calibration

Earth Tech's original model was calibrated using the records obtained from nine flow monitoring locations. Both wet weather flow and hydraulic performance were optimized so that the predicted surcharge locations closely matched known backup locations in Whitefish Bay. However, when the same calibration data was used with the SH6 sewers in the model, we were not able to obtain a reasonable prediction of surcharging in Shorewood.

This meant that the original model could not be used to develop solutions for Basin SH6. To address this situation, we re-calibrated the input parameters based on known surcharge and backup locations, without compromising the model's existing predictive ability for the Whitefish Bay portion of the system.

Three of the more severe rainfalls that occurred in 1999 were used to calibrate the model's predictive capability. This work included the comparison of analysis results to the reported sewer backup locations. The rains in question occurred on June 12 (3.13 inches in 6 hours), June 28 (1.9 inches in 30 minutes), and July 21 (3.16 inches in 3 hours).

From a hydraulic standpoint, the July 21, 1999 event represents the most severe rainfall. In our analysis, the computer model successfully predicted backups at several blocks that actually experienced them. We also confirmed that the model still satisfied the flow monitoring observations to a reasonable degree. We therefore concluded that the model could be used to predict the benefits of sewer improvements that will be implemented in the future.

Calculation of Wet Weather Flows

The 1% probability rainfall event was adopted as the standard design level for the calculation of wet weather flows in Whitefish Bay, where the severity and frequency of sewer backups have dictated such a high design expectancy. Since one of our goals was to design a system that worked in tandem with Whitefish Bay's, we chose the same criterion in our analysis of the Basin SH6 sewer system.

Given the recurrence interval, the total depth of the rain is governed by the rainfall duration. After evaluating rainfall durations of 0.5, 1, and 2 hours, we have determined that the critical rainfall duration for this particular system is 1 hour. In other words, compared to the other durations, the 1-hour rain resulted in the highest wet weather flow in the system.

For a given duration, the rainfall distribution describes how the intensity of rain varies through the duration of the rain. Once the critical rainfall duration is determined, we used four different rainfall distributions to further define the most critical flow condition in the system. In the case of the southeast sewer system, we found that, during a 60 minute rain, if the peak rain intensity occurs between the 1st and 15th minutes (i.e., 1st quartile), we obtained the highest flows in the system. The design rainfall is thus determined to be the 100 year, 1 hour, 1st quartile rainfall, with a cumulative rainfall depth of 2.65 inches during this period.

Selection of System Performance Criteria

The hydraulic models used in this analysis provide a time series of the hydraulic grade line in the entire system. It is therefore possible to calculate the expected surcharging at any location in the system and we chose this information to represent hydraulic performance.

In order to determine the acceptable amount of surcharging in the system, we examined the two-foot contour interval topographic maps, compared estimated basement floor elevations to the elevation of the sewer system, and calculated the maximum hydraulic grade line elevation allowable in each sewer line. The difference between the manhole rim elevation and the maximum allowable hydraulic grade line elevation gave us the target freeboard in each manhole of the model.

As a result of this work, we confirmed that the area with the highest number of basement backups (i.e., eight blocks bound by Glendale Avenue, Morris Boulevard, Congress Street, and Marlborough Drive) was also the least tolerant to surcharging and needed the largest freeboard.

In general, we tried to achieve the largest freeboard throughout the system. In particular, we decided that the minimum freeboard in the high risk area should be eight feet. In most other areas, we found that a minimum freeboard of seven feet would be sufficient to keep sewage out of basements during the design wet weather flows. Note that these freeboard limits are only enforced in the Basin SH6 portion of the hydraulic model. Whitefish Bay has chosen a uniform freeboard of six feet as the design criteria.

□ Recommended Improvements

The proposed solution to backup problems consists of a gravity sewer in Kensington between Wildwood and Oakland. This new sewer would intercept flow from the south and convey it to a lift station at the intersection of Wildwood and Kensington. Additionally, to further relieve the sanitary sewer in Glendale Avenue, a new sewer would be constructed from Glendale Avenue to the lift station at Wildwood and Kensington. This line would be parallel to the existing sewer in Wildwood. Sewage collected at the lift station would be pumped to the intersection of Wildwood and Congress where it would be discharged into a proposed gravity sewer along Congress. This line would connect the force main to the MMSD MIS at the intersection of Wilson and Congress. The estimated cost of this project is $700,000, including the lift station. Figure 3 shows the proposed alignment of the sewer extension.

Dry Weather Performance of Proposed Sewers

The dry weather flow characteristics of the combined SH6/WB3 system were originally monitored as part of the Village of Whitefish Bay Sanitary Sewer Evaluation Study. With the flow meter located at the intersection of Courtland and Hollywood, the sewershed consists of a total of 1,196 residential units, Lake Bluff Middle School (555 students, 45 faculty and/or staff), and 13 retail businesses. According to the monitoring results, the average daily base flow is estimated at 250,000 gal/day, and the peak daily flow is 450,000 gal/day, indicating a peak flow factor of 1.8. The flow metering data is available from the Village of Whitefish Bay, and their consultants, Earth Tech, Inc.

In order to interpolate dry weather base flows anywhere within Basin SH6/WB3, we used typical unit values for wastewater generation and established close agreement with measured data. The typical values are available in literature, e.g., "Wastewater Engineering – Treatment Disposal, Reuse, 3rd Ed.," Tchobanoglous, G., Burton, F. L., McGraw-Hill Publishers, 1991. We can therefore be fairly confident in the unit wastewater flow rates shown in Table 1.

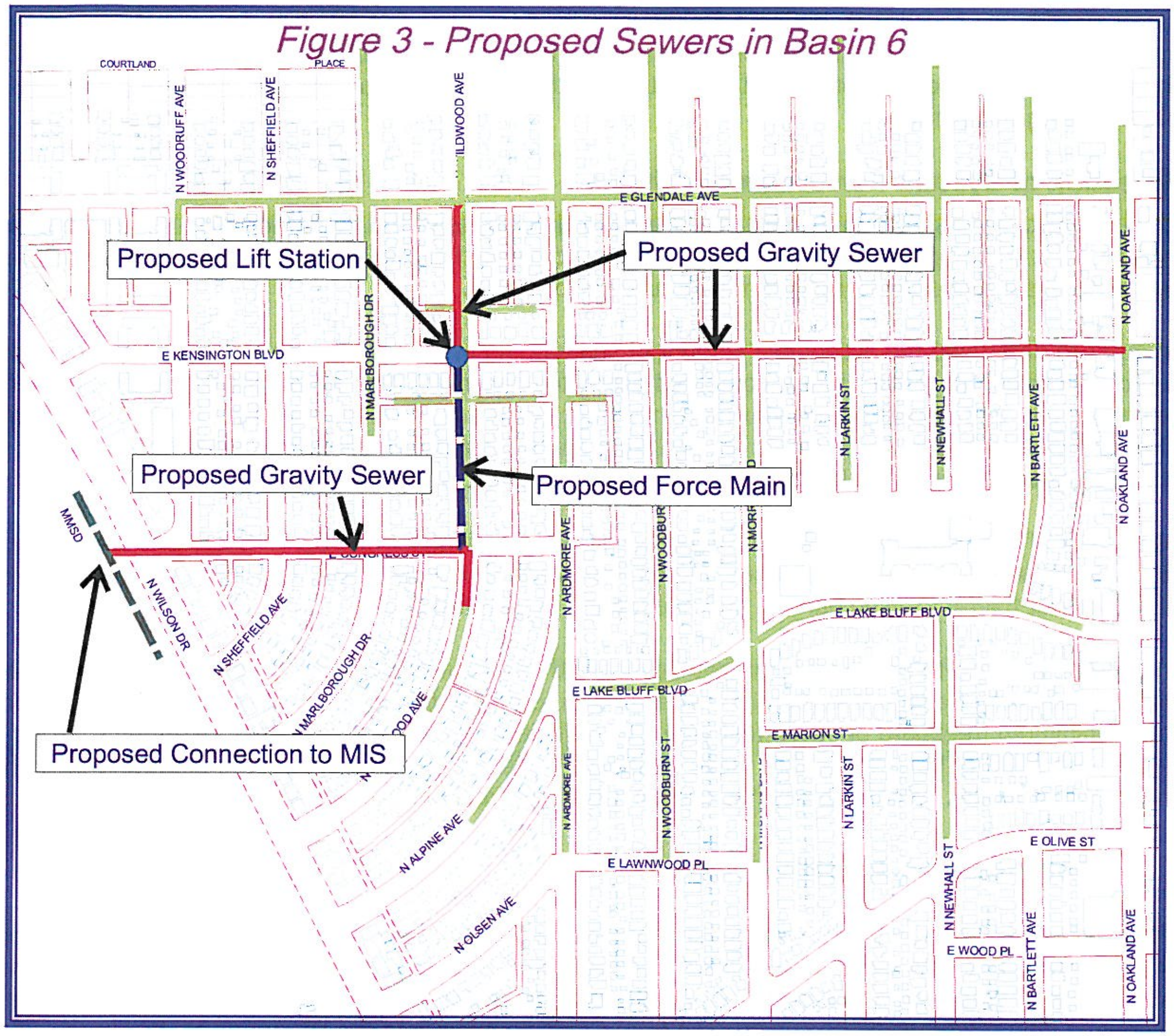


Table 1 – Dry Weather Wastewater Flow Rate in Basin SH6/WB3 - Existing

Source	Wastewater flow (gallon/day/Unit)	Unit	Number of Units	Wastewater Flow (gallon/day)
Residential	68 (MMSD Facilities Plan)	Persons	3,588 (1,196 residences @ 3 persons/residence)	244,000
School	15 (Metcalf & Eddy, Inc.)	Students and faculty	600	9,000
Retail Businesses	10 (Metcalf & Eddy, Inc.)	Employees	26 (13 businesses @ 2 employees/business)	260
			Average Daily Flow	**253,260**

During dry weather, the net effect of the proposed system would be to split Basin SH6 into two zones. The portion of Basin SH6 east of Wildwood, and the portion of Basin WB3 east of Ardmore would be discharged into the MIS at Congress and Wilson. The portion of Basin SH6 west of Wildwood and the portion of Basin WB3 west of Ardmore would still discharge to the MIS at Diversey and Wilson. In other words, the combined SH6/WB3 wastewater flow would be split as shown in Tables 2 and 3.

Table 2 – Dry Weather Wastewater Flow to Diversey and Wilson - Proposed

Source	Wastewater flow (gallon/day/Unit)	Unit	Number of Units	Wastewater Flow (gallon/day)
Residential	68 (MMSD Facilities Plan)	Persons	747 (249 residences @ 3 persons/residence)	50,800
			Average Daily Flow	**50,800**

Table 3 – Dry Weather Wastewater Flow to Congress and Wilson - Proposed

Source	Wastewater flow (gallon/day/Unit)	Unit	Number of Units	Wastewater Flow (gallon/day)
Residential	68 (MMSD Facilities Plan)	Persons	2,841 (947 residences @ 3 persons/residence)	194,000
School	15 (Metcalf & Eddy, Inc.)	Students and faculty	600	9,000
Retail Businesses	10 (Metcalf & Eddy, Inc.)	Employees	26 (13 businesses @ 2 employees/business)	260
			Average Daily Flow	**203,260**

During dry weather, the proposed system would completely replace a portion of the existing system. This means that approximately 80% of the wastewater would be removed from the MIS at Diversey and Wilson, and re-routed to the MIS at Congress and Wilson.

Wet Weather Performance of Proposed Sewers

As described earlier, the wet weather performance of the sewer system results in sewer backups in residential basements during design wet flow conditions. Our calculations show that, during design wet weather flow, the mean discharge from Basin SH6/WB3 to the MIS at Diversey and Wilson is 1.5 cubic feet per second (cfs), with a peak discharge of 7.7 cfs. We estimate that a total volume of 80,000 cubic feet would be delivered to the MIS during the design wet weather flow. Table 4 summarizes calculated existing wet weather conditions and the corresponding daily flow rates per unit source.

Table 4 – Wet Weather Flow Rate in Basin SH6/WB3 - Existing

Source	Wet Weather flow (gallon/day/Unit)	Unit	Number of Units	Wet Weather Flow (gallon/day)
Residential	262 (Design Value)	Persons	3,588 (1,196 residences @ 3 persons/residence)	942,200
School	45 (Design Value)	Students and faculty	600	27,000
Retail Businesses	30 (Design Value)	Employees	26 (13 businesses @ 2 employees/business)	800
			Average Daily Wet Weather Flow	**970,000**

With the proposed project in place, the mean discharge from Basin SH6/WB3 to the MIS at Diversey and Wilson would be reduced to 0.5 cfs, with a peak discharge of 4.6 cfs. The total volume discharged to the MIS would also be reduced to 25,000 cubic feet.

The mean discharge rate from Basin SH6 into the MIS at Congress and Wilson would be 0.9 cfs, with a peak of 5.4 cfs. The total volume discharged to the MIS at this point would be approximately 50,000 cubic feet.

Note that the comparison of total flows in existing and proposed conditions differs by 5,000 cubic feet, which is reasonable, given the fact that the two systems are hydraulically very different, and that the analysis involves a total of 1.5 million cubic feet flowing through 1, 075 conduits with four separate outfalls. It is also reasonable that the proposed system, with much lower hydraulic grade line elevations, results in lower flow rates, and since the computation period is the same in both runs, lower flow rates translate into lower total volumes. Nevertheless, the purpose of this comparison is to show that the proposed system does not increase the total flow into the MIS during wet weather design flow. Instead, the proposed sewers split the wet weather flow between two discharge locations, with the existing connection maintaining a third of the flow, and the new connection discharging the remaining two thirds.

Tables 5 and 6 summarize calculated wet weather conditions and the corresponding daily flow rates per unit source under proposed conditions.

Table 5 – Wet Weather Flow to Diversey and Wilson - Proposed

Source	Wet Weather flow (gallon/day/Unit)	Unit	Number of Units	Wet Weather Flow (gallon/day)
Residential	432 (Design Value)	Persons	747 (249 residences @ 3 persons/residence)	323,000
			Average Daily Flow	**323,000**

Table 6 – Wet Weather Flow to Congress and Wilson - Proposed

Source	Wet Weather flow (gallon/day/Unit)	Unit	Number of Units	Wet Weather Flow (gallon/day)
Residential	194 (Design Value)	Persons	2,841 (947 residences @ 3 persons/residence)	553,200
School	45 (Design Value)	Students and faculty	600	27,000
Retail Businesses	30 (Design Value)	Employees	26 (13 businesses @ 2 employees/business)	800
			Average Daily Flow	**581,000**

☐ Conclusion

1. The proposed sewer extension addresses wet weather surcharging problems in Basin SH6 in the Village of Shorewood. Currently, all dry and wet weather flows from this basin are routed to the MIS at the intersection of Diversey and Wilson.

2. The proposed sewer extension re-routes 100% of dry weather and 66% of wet weather flows to the MIS at Congress and Wilson. Detailed hydraulic analysis indicates that the total volume to be delivered to the MIS remains constant. Based on extensive modeling and calibration, the dry and wet weather flows in the existing system and the proposed sewer extension are summarized as follows:

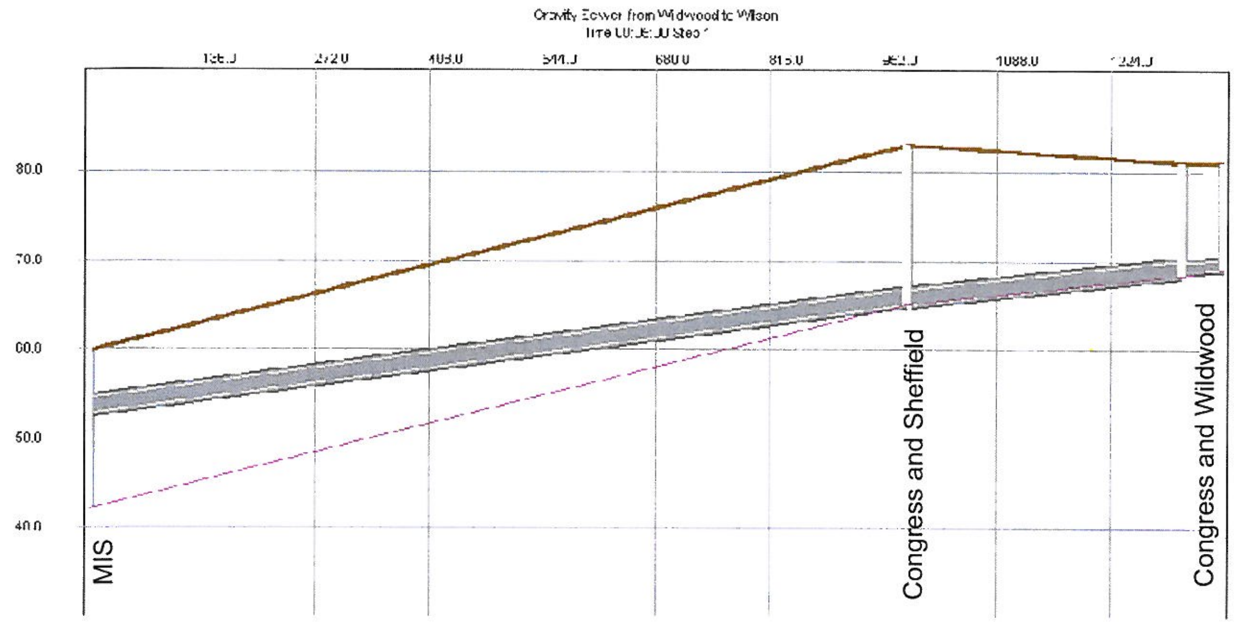
Average Daily Flow (gallon/day)	Existing		Proposed	
	Diversey-Wilson	**Congress-Wilson**	**Diversey-Wilson**	**Congress-Wilson**
Dry Weather	253,260	0	50,800	203,260
Wet Weather	970,000	0	323,000	581,000

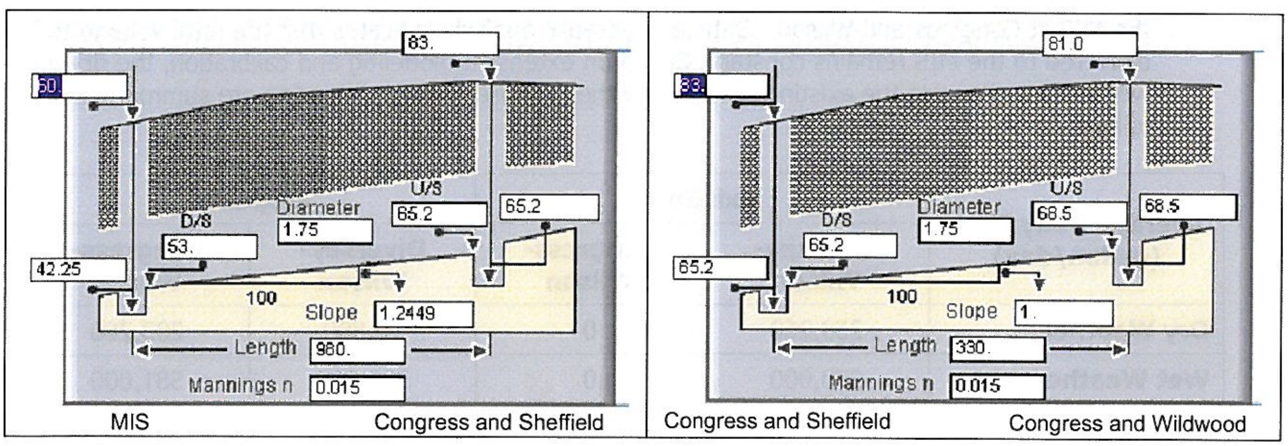
3. The proposed sewer extension does not require a wet weather overflow.

4. The proposed sewer extension reduces system-wide surcharging and provides protection from basement backups during the design wet weather flow, which is the 1% probability, 1-hour duration rainfall (i.e., 2.65 inches) with a 1st quartile Huff distribution. The inflow and infiltration resulting from such an event are derived from flow monitoring data collected by Earth Tech, Inc. for the Village of Whitefish Bay Sanitary Sewer Evaluation Study.

5. The proposed sewer extension will work in concert with any future sewer relief project that may be undertaken by the Village of Whitefish Bay (Basin WB3). However, the discharge calculations presented herein assume that such a project is not implemented.

6. Existing sewers that serve 26 homes on Wildwood, south of Congress will be connected to the proposed gravity sewer connection to the MIS. The calculated peak wet weather flow from this sewer line is 0.67 cfs. No other sewer or lateral connections are proposed for this segment. The proposed sewer profile between the MIS and the Wildwood sewer is shown below.





7. The proposed lift station is rated at a peak capacity of 5 cfs, which will be the maximum flow in the proposed force main. The lift station will control the rate of flow into the proposed MIS connection at Congress and Wilson.

8. The proposed sewer extension will change the boundary between Basin SH6 and WB3. The existing and proposed basin boundaries are shown in Figures 4 and 5 respectively.

Figure 4 - Existing Basin SH6/WB3

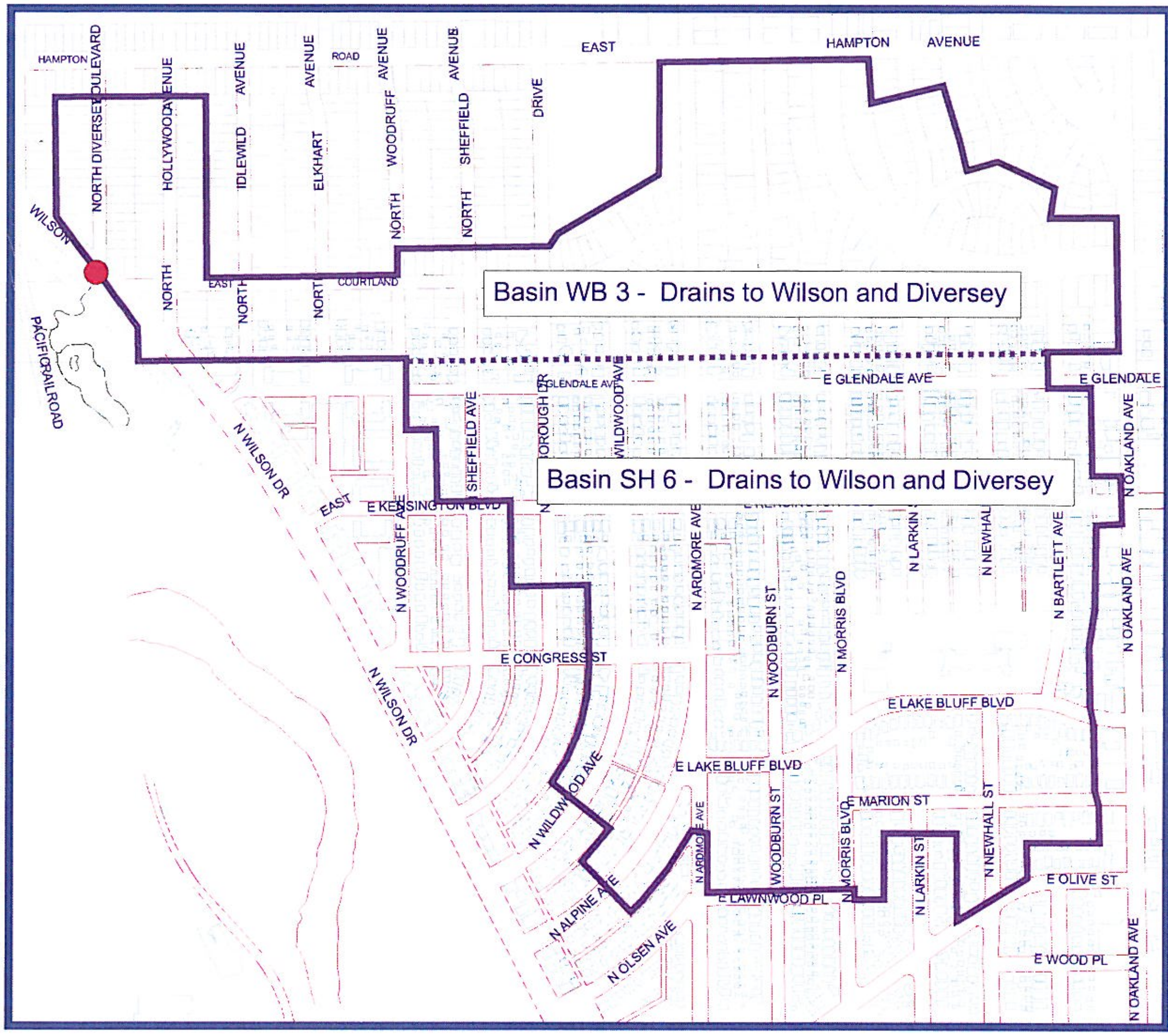
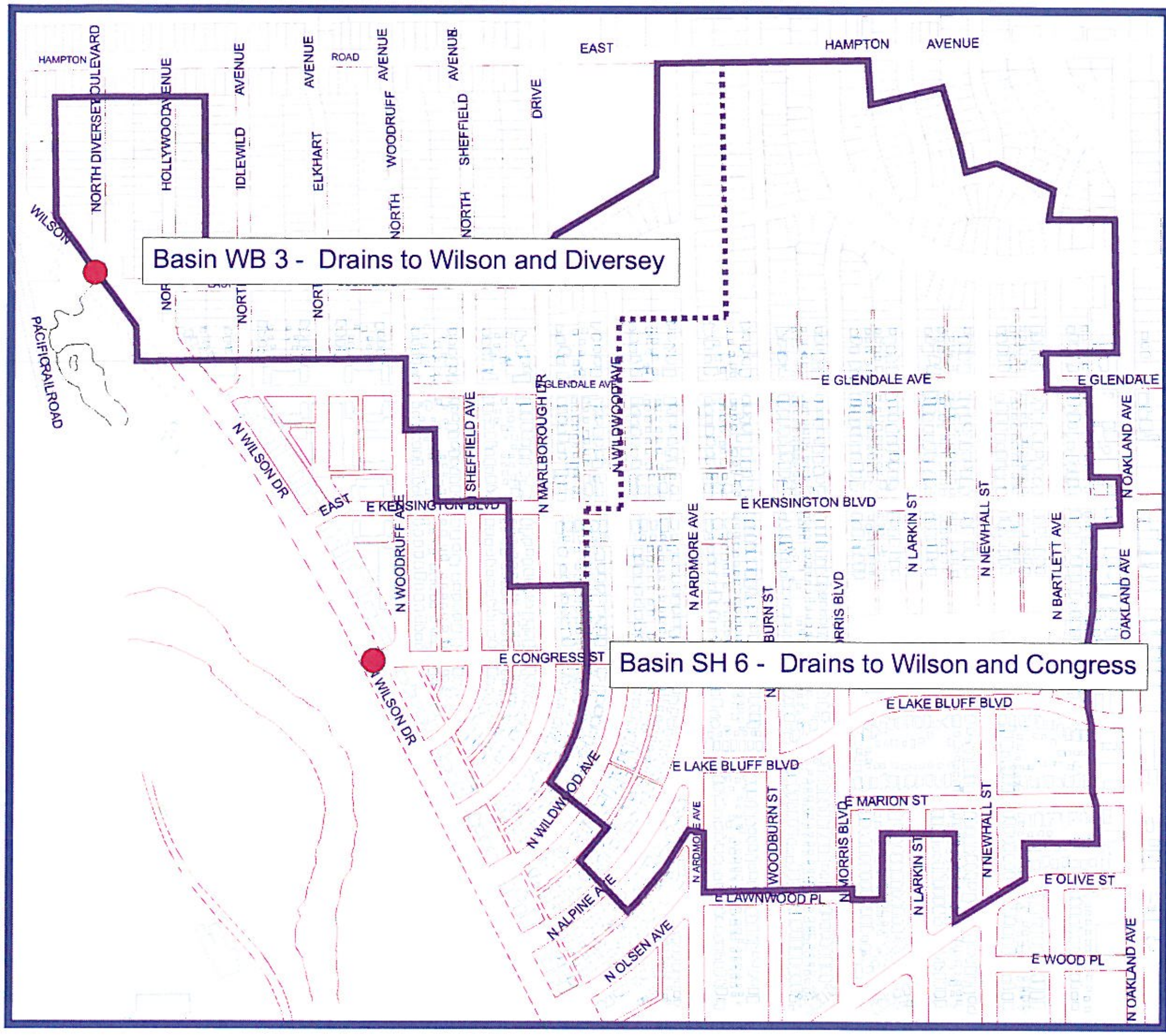


Figure 5 - Proposed Basin SH6/WB3



October 16, 2000

Mr. Edward Madere
Village Manager
Village of Shorewood
3930 North Murray Avenue
Shorewood, WI 53211

Re: Basin SH6 Sanitary Sewer Improvements
Effect of I/I Reduction on Backup Prevention
File No. 880-00-104

Dear Ed,

In the light of a cost estimate prepared by Mr. James Lynch of the Village of Shorewood, we have revised the sump pump installation cost down from $6,500 per foundation to $2,500. With a total of 640 buildings, this means that the total cost of sump pump installation in Basin SH6 is estimated at $1.28 million.

As per our meeting on Friday, October 13, 2000, we investigated whether selected portion of the Basin could be targeted for sump pump installation. After careful review of calculations, we found that our hydraulic model of the Basin will not allow us to simulate sump pump installation to such a detail.

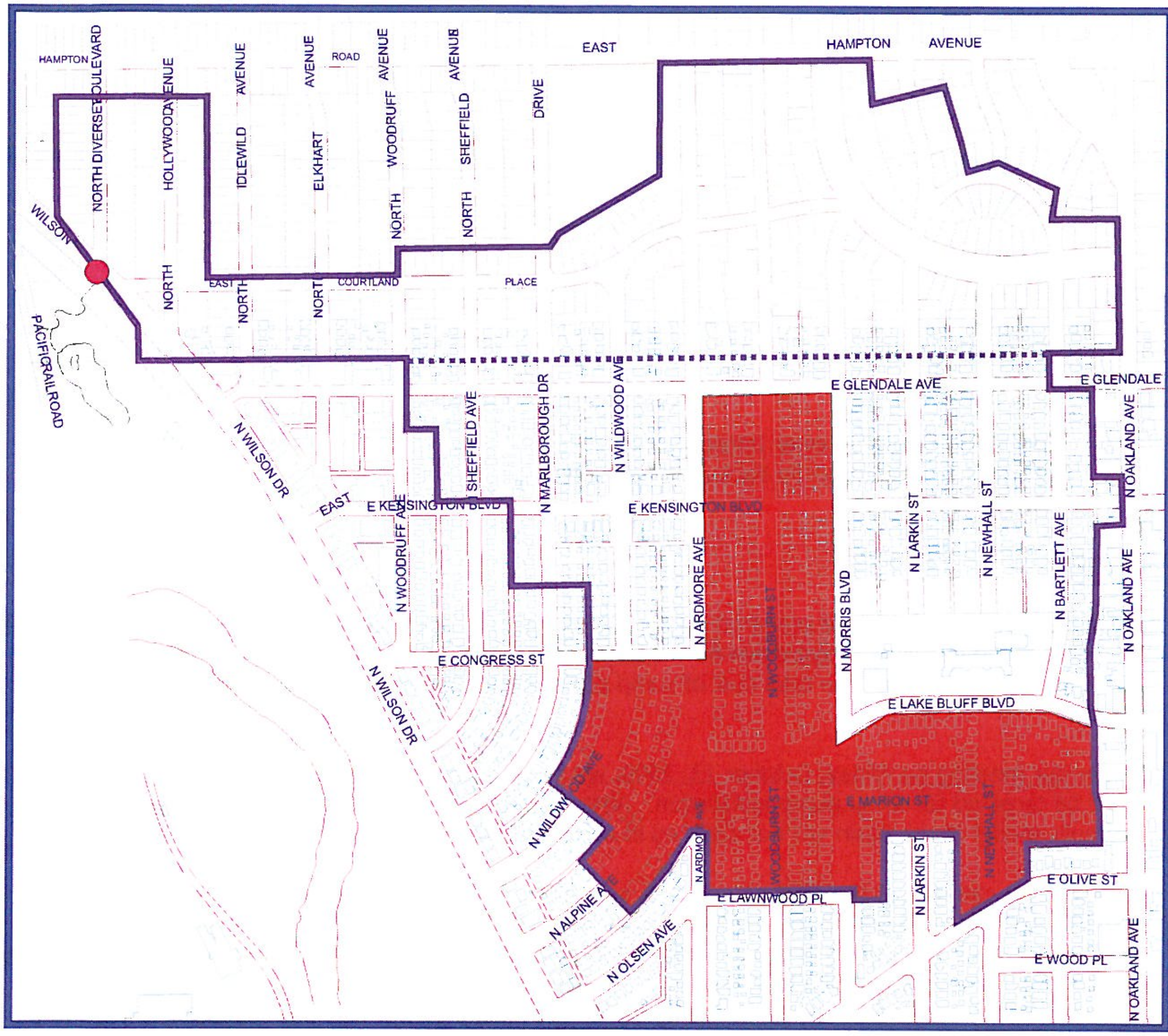
However, we can look at the existing numbers in a different way. We know that we need to remove 20,000 cubic feet (150,000 gallons) of water from the system. If this number is distributed among all foundations, each foundation needs to remove 235 gallons per hour. We also know that an actual sump pump would remove about 500 to 700 gallons per hour. If we consider that 500 gallons per hour as a reasonable and conservative performance figure for each sump pump, only 300 foundations need to be included in the sump pump program.

The following figures show possible groupings of 300 foundations in Basin 6. In general, we recommend that sump pump installations begin in the southern portion of the basin and proceed towards Glendale Avenue. However, please note that, in our opinion, removing the required amount of clear water from the system is more important that where the removal occurs.

Should you have any comments or questions regarding the issues discussed in this letter, please call us at 262-241-6950.

Very Truly Yours,
Bonestroo, Rosene, Anderlik and Associates, Inc.

Mustafa Z. Emir, Ph.D.
Project Manager



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NORTH HOLLYWOOD AVENUE
NORTH IDLEWILD AVENUE
NORTH ELKHART AVENUE
NORTH WOODRUFF AVENUE
NORTH SHEFFIELD AVENUE
DRIVE
WILSON
PACIFIC RAILROAD
EAST COURTLAND PLACE
E GLENDALE AVE
N WILSON DR
SHEFFIELD AVE
N MARLBOROUGH DR
N WILDWOOD AVE
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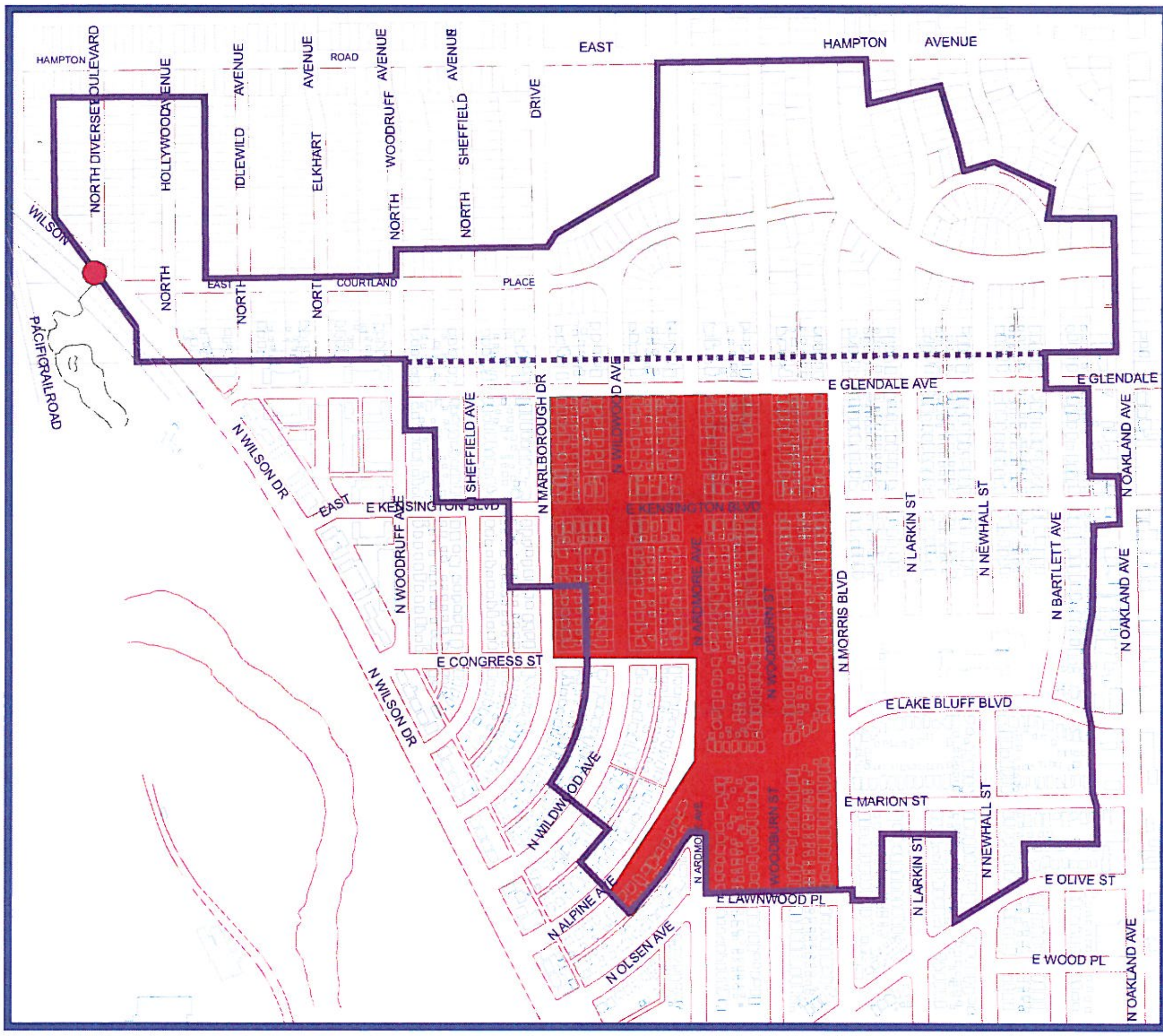

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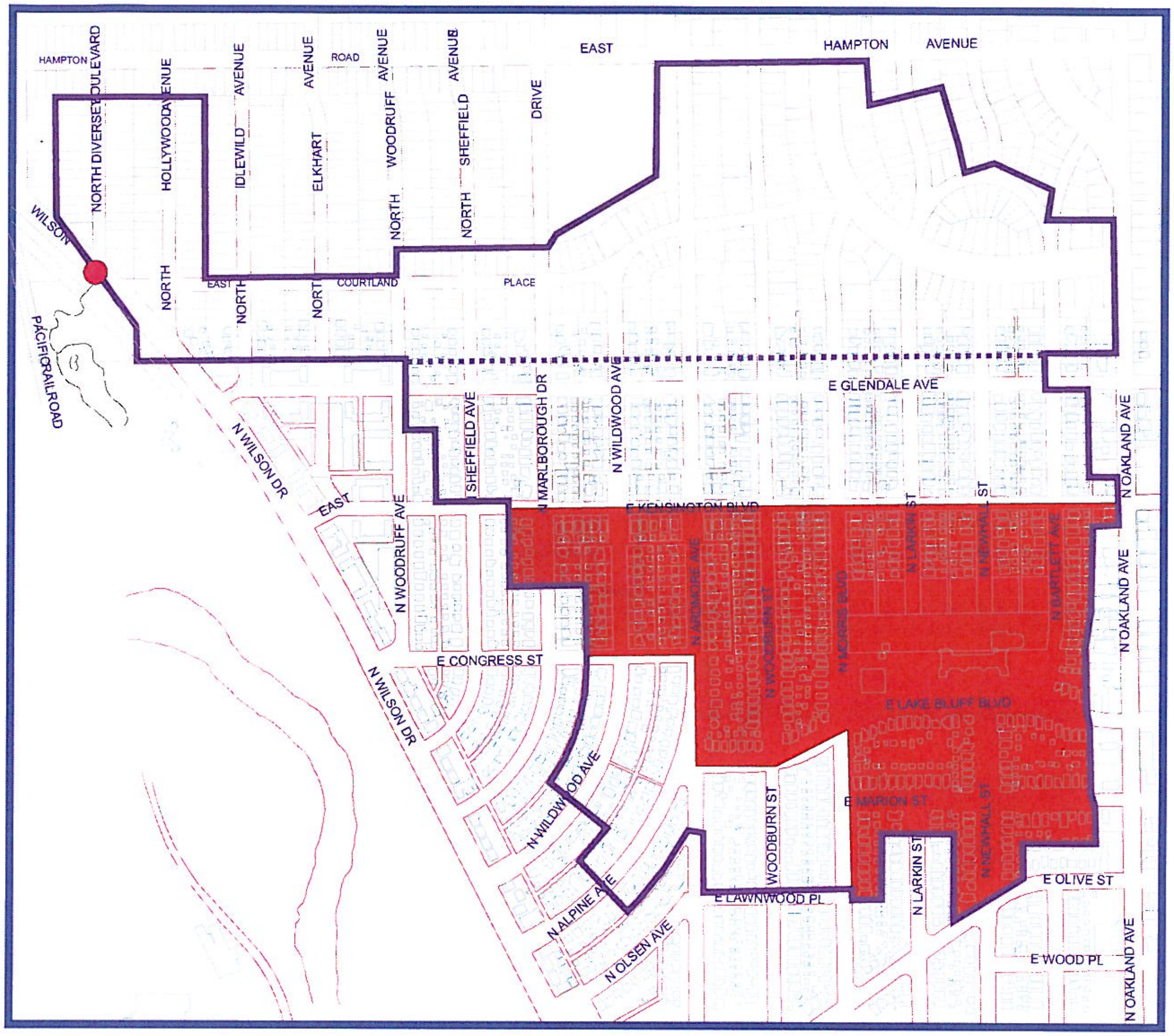

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Southeast Area
Combined Sewer Study

Village of Shorewood

April 2000

Introduction

This report outlines the hydrologic and hydraulic analysis of the Southeast Shorewood combined sewers. Our work consisted of creating a computer model of the sewer system, a hydrologic and hydraulic analysis, and the development of sewer improvement alternatives to prevent and eliminate sanitary sewer backups in the service area.

System Modeling

Service Area

The southeast sewer is an extensive network of combined sewers generally draining the portion of the Village east of Oakland Avenue and north of Edgewood Avenue. The total service area of the system is 666 acres, with 504 acres in Shorewood and the remaining 162 acres in the City of Milwaukee.

The northern portion of the service area in Shorewood is served by a storm sewer system, with two outfalls to Lake Michigan. The storm system collects street runoff, while the combined sewers receive runoff from down spouts and foundation drains in this area. We estimate that the storm sewer system handles about 50 percent of the runoff in this 188 acre partially separated portion of the Village. Everywhere else, the combined sewers handle all the runoff.

Land Cover

The southeast sewer service area is characterized by residential land uses with about 40 percent impervious land cover in Shorewood and 50 percent impervious land cover in Milwaukee. Within Milwaukee, the University of Wisconsin-Milwaukee Campus is characterized by higher levels of imperviousness at about 75 percent, accounting for any future building activity that may take place there.

Comparisons with Previous Work

We have confirmed that the acreage and the impervious land cover ratios are in agreement with previous modeling efforts by the City of Milwaukee. It should be noted that the City's analysis did not include the partially separated area in Shorewood, so we would expect that Milwaukee's analysis would yield generally higher flows in the sewer system. In fact, at the Edgewood –

Maryland intersection, the peak flow computed in the present analysis is 10 percent lower than the flow computed by Milwaukee. We attribute this discrepancy to the higher level of detail applied to the present analysis.

It should be noted that the present analysis does not agree well with the previous work conducted by Rust Environmental and Infrastructure, Inc. (Rust E&I). Although no design report outlining methodologies and analysis summaries were available, we were able to deduce the design flows from computer modeling output files. Overall, we have found the design flows proposed by Rust E&I were much lower than those identified here, as well as by the City of Milwaukee. For example, at the Edgewood – Maryland intersection, the peak flow computed in the present analysis is 2.3 times higher than the flow computed by Rust E&I.

Sewer Network
The network description is based on the Village sewer maps and plans, Rust E&I modeling files, as well as system plans obtained from the City of Milwaukee. The 1998 Bottleneck Project improvements are included, so that the resulting sewer network model represents a detailed description of the existing conditions.

System Outfall
The outfall of the southeast sewer consists of three separate and complementary facilities.

1. The dry weather outflow is directed to a 39-inch diameter Municipal Interceptor Sewer (MIS) that is under the jurisdiction of the Milwaukee Metropolitan Sewerage District (MMSD).

2. The wet weather outflow is directed to the Deep Tunnel System through a 72-inch diameter pipe that is under the jurisdiction of MMSD. This pipe is connected to drop shaft NS-4.

3. When the Deep Tunnel is full and the gates are closed, the wet weather flow is discharged to the Milwaukee River through a 72-inch diameter pipe that connects NS-4 to the river.

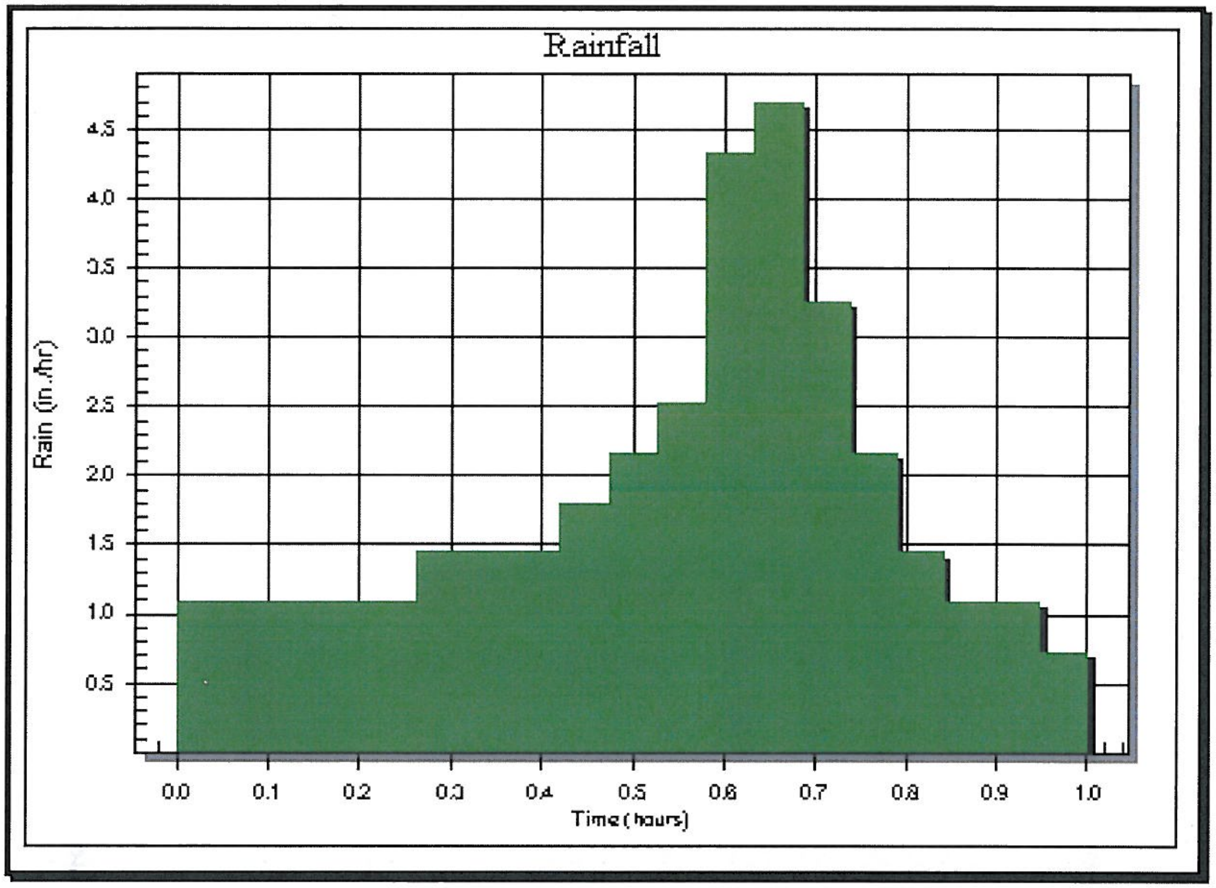
☐ Hydrologic and Hydraulic Analysis

The main work effort in this phase involved the selection of the design rainfall event and the calibration of the model using actual rainfalls experienced in 1999. The calibrated model, along with the design rainfall, forms the base line to which all improvement alternatives are compared.

Selection of Design Rainfall
The 10 percent probability rainfall event is adopted as the standard design level for the southeast sewer system. In other words, this rainfall has a 10 percent chance of being equaled or exceeded during any 365 day period. The recurrence interval of such an event is 10 years. Given the recurrence interval, the total depth of the rain is governed by the rainfall duration. After evaluating rainfall durations of 0.5, 1, 2, and 6 hours, we have determined that the critical rainfall duration for this particular system is 1 hour. In other words, compared to the other durations, the 1 hour rain results in the highest flow rates in the system.

For a given duration, the rainfall distribution describes how the intensity of rain varies through the duration of the rain. Once the critical rainfall duration is determined, we used four different rainfall distributions to further define the most critical flow condition in the system. In the case of the southeast sewer system, we found that, during a 60 minute rain, if the peak rain intensity occurs between the 30th and 45th minutes (i.e., 3rd quartile), we obtained the highest flows in the system.

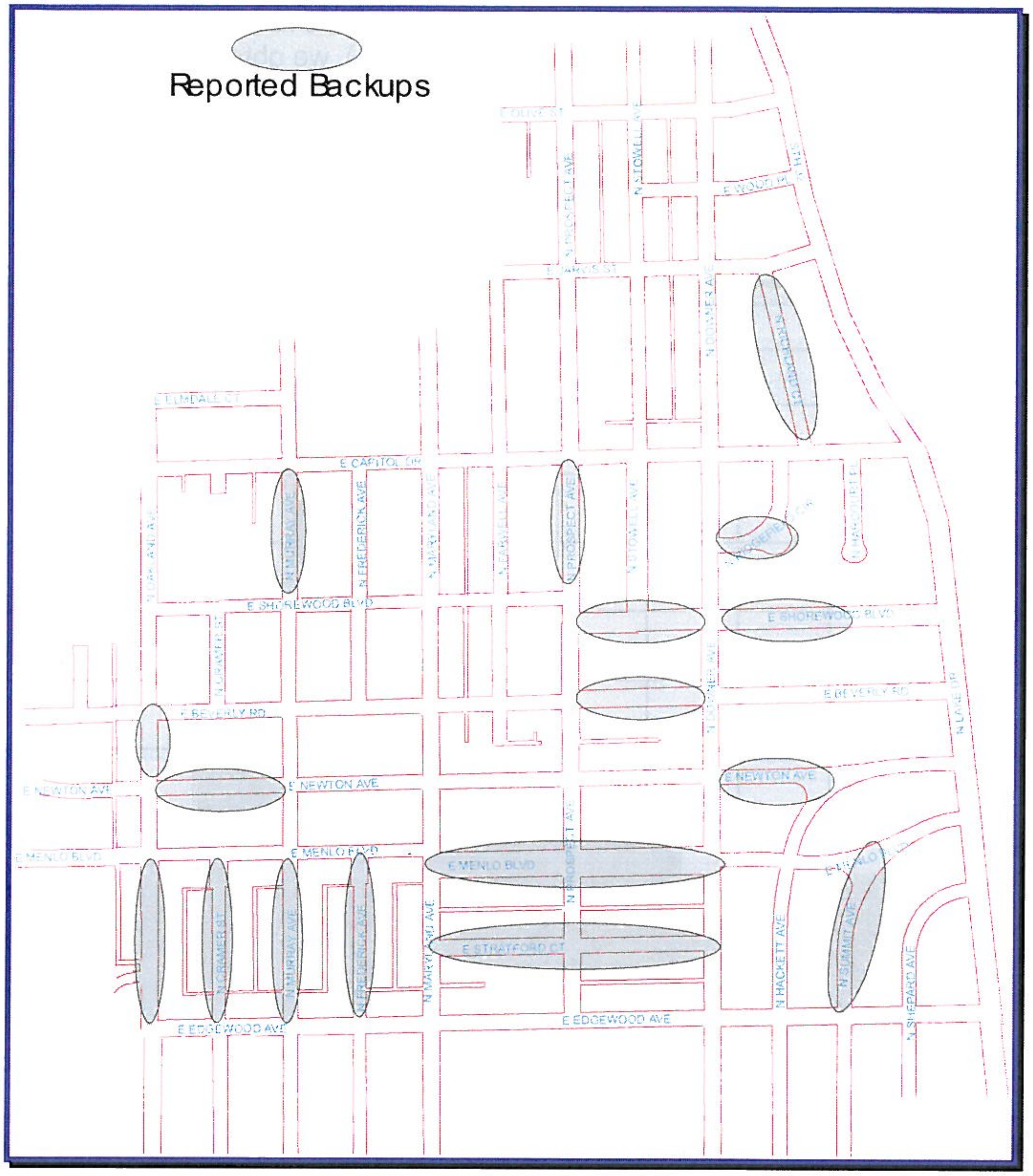
The design rainfall is thus determined to be the 10 year, 1 hour, 3rd quartile rainfall, with a total rainfall depth of 1.9 inches during this period. The following graph depicts the temporal distribution of the design rainfall.



Model Calibration
Three of the more severe rainfalls that occurred in 1999 were used to calibrate the model's predictive capabilities. This work included the comparison of analysis results to the reported sewer backup locations. The rains in question occurred on June 12 (3.13 inches in 6 hours), June 28 (1.9 inches in 30 minutes), and July 21 (3.16 inches in 3 hours).

From a hydraulic stand point, the July 21, 1999 event represents the most severe rainfall. In our analysis, the computer model successfully predicted backups at several blocks that actually experienced them. The model can therefore be used to predict the benefits of sewer improvements that will be implemented in the future.

Based on reported backups throughout the year, we have developed the following map showing the general location of problem sewer line segments in the southeast sewer service area:



□ Southeast Sewer Improvement Alternatives

The hydraulic analysis of the system indicates that the sanitary sewer backup problems occurring in the southeast area have three distinct causes:

- Lack of hydraulic capacity in the Edgewood sewer is the cause of sewer backups in the southern portion of the service area. Our analysis reveals that the entire Edgewood sewer from Maryland to the Milwaukee River is below capacity. The portion of the Edgewood sewer that was included in the 1998 Bottleneck Project is part of this capacity problem.

- Lack of capacity in the Prospect and Shorewood Boulevard sewers is the cause of sewer backups in the northeast portion of the service area. Specifically, the 1998 Bottleneck Project needs to be extended further north to replace existing pipes in Shorewood Boulevard and Prospect Avenue.

- Flat pipe slopes in the 48-inch line in Murray Avenue between Shorewood Boulevard and Newton Avenue cause the reported backups in this area.

Edgewood Corridor Alternatives
In our opinion, the Edgewood Avenue sewer between Maryland Avenue and the Milwaukee River lacks adequate capacity to handle the design rainfall without causing sewer backups. Our analysis shows that neither the 1998 Bottleneck Project improvements, nor the rest of the system downstream of the Bottleneck Project, provide the system with adequate capacity. This problem is exacerbated by the addition of Milwaukee flows into the Shorewood system at the intersection of Maryland and Edgewood.

Previous work indicated several alternative solutions to the backup and capacity problems in the Edgewood corridor. In the present study, we are concentrating on two of these solutions:

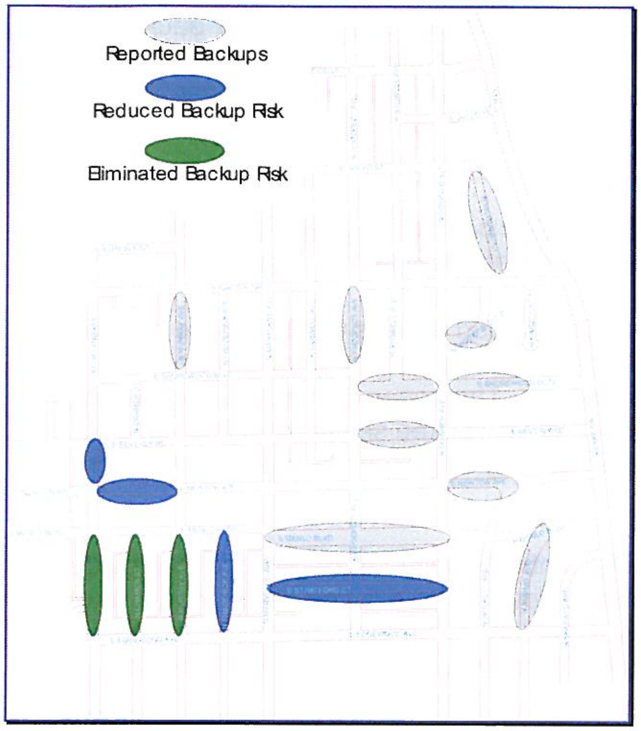
1. Complete separation of the Milwaukee and Shorewood sewers would reduce the flow in the newly improved Shorewood system and would bring the Bottleneck Project acceptably close to the required design capacities. The separation would involve the rebuilding of approximately 1,350 feet of 66-inch Milwaukee sewer from Maryland to Oakland. In addition, the MMSD would need to relay the 72-inch sewer to a 96-inch size.

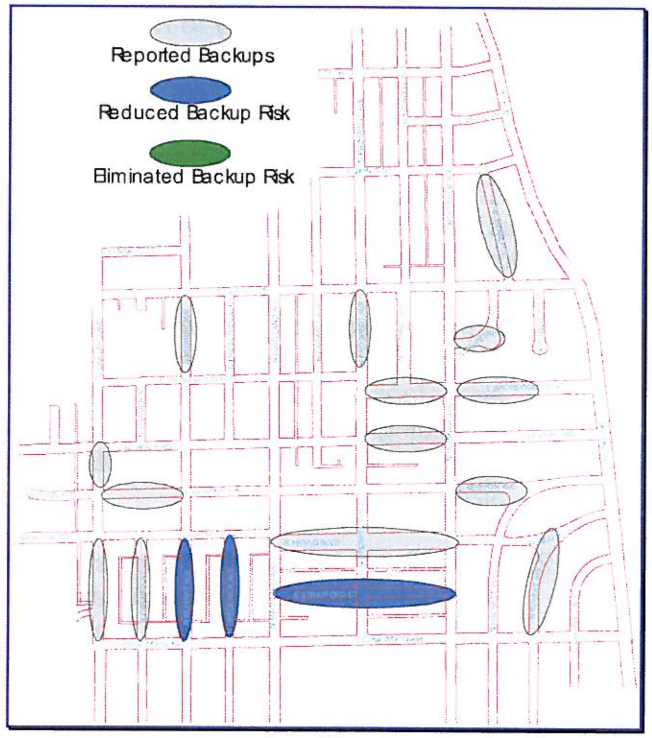
2. The Village would relay the existing 78-inch combined sewer in Edgewood to provide an adequate outlet for Milwaukee and Shorewood flows. The existing sewer would have to be relayed from Maryland to Oakland (approximately 1,350 feet) as an 84-inch sewer. In addition, the MMSD would need to relay the 72-inch sewer to 84 and 96-inch sizes.

Since both solution alternatives involve the replacement of the MMSD outfall, this component was evaluated separately. It is reasonable to assume that the MMSD outfall may be upgraded before the rest of the improvements are implemented.

Based on the design flows, MMSD's 72-inch diameter Milwaukee River outfall poses a capacity restriction that directly affects the Edgewood sewer between Maryland and Oakland. Through our modeling, we are able to demonstrate that replacing this 72-inch pipe with a 96-inch diameter pipe would provide immediate and measurable benefits to the residents of Cramer, Murray, Frederic, and Maryland, just north of Edgewood. This is shown on the following figure. **Without the MMSD Outfall improvements, the Edgewood sewer improvements do not provide an appreciable benefit to the residents of the area. The following figure shows that the benefits of either pipe up-sizing or sewer separation are very limited, both in magnitude and geographical extent.**

Benefits of the MMSD Outfall Improvements only	Benefits of Edgewood Avenue improvements without the MMSD Outfall Improvements





On the other hand, coupled with the MMSD outfall upgrade, both the separation and Edgewood relay options provide important, measurable, and real benefits to the residents affected by sewer backups. Both options will eliminate backups along the Edgewood Corridor - from Oakland to Maryland- including Cramer, Murray, Frederic, and Maryland, just north of Edgewood Avenue. Both options also eliminate backups along Stratford Court.

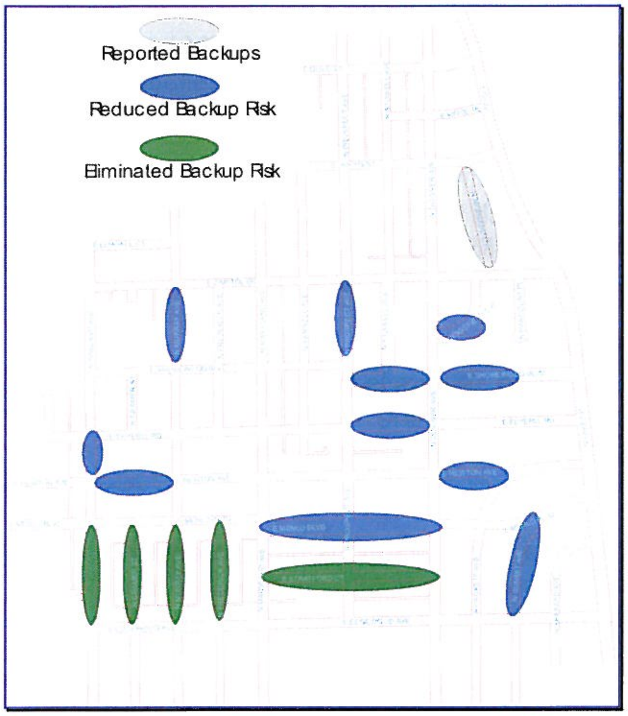
As we move further upstream in the system, the performance of the options will start to differ slightly. While Option 1 will reduce backup potential along Menlo, Newton and Beverly, we find that Option 2 will actually eliminate backups in these areas.

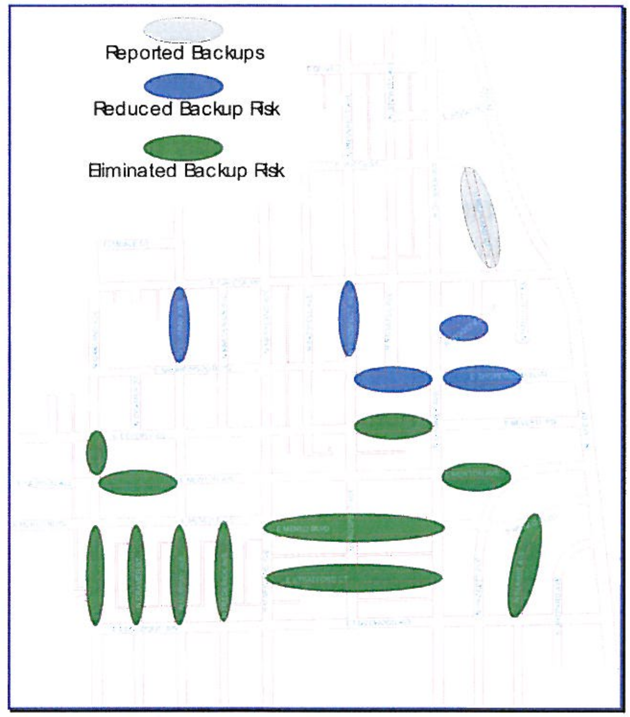
Further north, both options will reduce surcharging at Shorewood Boulevard, Ridgefield Court, and Richland Court. However, we do not anticipate these surcharge reductions to be sufficient enough to provide actual protection from sewer backups under design conditions. Problems in these areas are specifically addressed with capacity improvements at the Prospect and Shorewood sewer upgrades.

In summary, we conclude that both options provide a high level of surcharge reduction in the southeast sewer system. However, we find that Option 2 results in a much larger area of actual backup risk elimination compared to Option 1. Our findings are depicted in the following figures.

Summary of Edgewood Corridor Improvement Alternatives

Benefits of separating Milwaukee and Shorewood Flows and the MMSD Outfall Improvements	Benefits of Village of Shorewood Sewer Relay and the MMSD Outfall Improvements





Cost Estimates for Edgewood Corridor Improvements

Edgewood Option 1 - $ 1.1 Million

Separation would be accomplished with a connection to the existing 66-inch Milwaukee pipe -which serves areas east of Maryland and south of Edgewood- to a newly constructed sewer from Maryland to Oakland.

Preliminary engineering indicates that the relay would consist of removing 360 feet of 30-inch, 638 feet of 36-inch, and 352 feet of 60-inch pipe, to be replaced with 100 feet of 66-inch and 1,370 feet of 72-inch pipe.

Edgewood Option 2 - $ 1.25 Million

Under this option, no work on the Milwaukee sewers will be necessary. The Shorewood sewers will be upsized to accept the flows from both communities, with pipe sizes large enough to convey the wet weather design flows to the NS-4 drop shaft and to the MMSD outfall.

Preliminary engineering indicates that the Shorewood sewer relay would be accomplished by removing 1,360 feet of 78-inch pipe and installing 700 feet of 84-inch pipe and 660 feet of 96-inch pipe.

MMSD Outfall Upgrade - $ 1.25 Million

As described earlier, both options require that the MMSD outfall to the river be upgraded to provide more capacity to the southeast sewer system. This upgrade is even more important because system-wide improvements now under consideration will bring more flow to the MMSD sewer. It is therefore imperative that the outfall capacity matches the newly created capacity throughout the system

Preliminary engineering indicates the MMSD Outfall upgrades would be accomplished by the removal of 1,100 feet of 72-inch pipe and installation of 1,100 feet of 96-inch pipe. The cost estimate does not include any diversion structures that may need to be reconstructed by the MMSD.

In spite of the higher cost, Option 2 is the preferred approach because of the significant benefits it brings to the residents of Shorewood. In our opinion, the MMSD outfall upgrade must be performed regardless of which option the Village and the City of Milwaukee ultimately adopt.

Shorewood Boulevard Alternatives and Cost Estimates

Lack of capacity in the Prospect and Shorewood Boulevard sewers is the cause of sewer backups in the northeast portion of the service area. Specifically, the 1998 Bottleneck Project needs to be extended further north to replace existing pipes in Shorewood Boulevard and Prospect Avenue.

We have identified two alternate routes to serve this area. Both solutions provide equal benefits, and when coupled with Edgewood Option 2, result in complete coverage of the southeast sewer service area against backups risks during the design rainfall.

While Options 1 and 3 involve the construction of larger pipes, they also represent a natural extension of the 1998 Bottleneck Project. Option 2, consists of smaller pipes, but requires the removal of a portion of the 1998 Bottleneck Project to accommodate higher flows on Newton.

Shorewood Boulevard Option 1 - $ 875,000

This alternative consists of relaying older sewer lines in Shorewood Boulevard between Downer and Prospect, and in Prospect Avenue between Shorewood Boulevard and Menlo. In effect, this project would begin at the upstream end of the 1998 Bottleneck Project, extending it to the north and east until all backup locations are served.

The existing 700 feet of 54-inch and 650 feet of 60-inch pipe would be replaced by 700 feet of 60-inch pipe and 1,100 feet of 66-inch pipe.

Shorewood Boulevard Option 2 - $ 600,000

This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Newton and Prospect. The new line would flow south on Downer and west on Newton. The portion of the 1998 Bottleneck Project on Newton would have to be removed and replaced with larger pipes to accommodate increased flows from the north.

The project would consist of approximately 650 feet of new 42-inch pipe on Downer, and the replacement of 700 feet of 27-inch pipe by 700 feet of 42-inch pipe.

Shorewood Boulevard Option 3 - $ 680,000

This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Menlo and Prospect. The new line would flow south on Downer and west on Menlo.

The project would consist of approximately 1,100 feet of new 42-inch pipe on Downer, and 700 feet of 42-inch pipe on Menlo.

Ease of construction and lower cost would indicate Shorewood Boulevard Option 2 as the preferred alternative. However, this Option would have the unfortunate implications of removing newly installed sewers in Newton Avenue. Because of this, Option 3 may be the most feasible solution to this problem.

We have also evaluated the impact of performing the Shorewood Boulevard improvements as a stand-alone project. We anticipate this work could be undertaken in short order, even before the design and construction of the outfall upgrades by the MMSD. Our analysis confirms that the Downer – Menlo sewer project would achieve a significant reduction in surcharging in pipes upstream of Beverly. In other words, the benefits of this project are not dependent on the work proposed in Edgewood Avenue, nor the MMSD outfall.

Murray Avenue Alternatives and Cost Estimates

Flat pipe slopes in the 48-inch line in Murray Avenue between Shorewood Boulevard and Newton cause the reported backups along Murray Avenue. Currently, the Murray Avenue sewer between Capitol Drive and Edgewood Avenue consists of 48-inch pipe. Our analysis shows that only the portion of this line between Shorewood Boulevard and Newton Avenue contributes to the backup problems.

We propose to keep the existing sewers and install relief sewers parallel to the existing lines in order to reduce the surcharging between Shorewood Boulevard and Newton Avenue. However, we have also looked into the removal and replacement of the existing sewer pipes to increase capacity through steeper slopes. We do not envision using larger pipes because we would like to limit the relay to the segment between Shorewood and Newton. Using larger pipes would mean that the downstream segment between Newton and Edgewood would remain as is. Therefore, we would end up with larger pipes discharging into smaller ones. Regardless of the slope changes that may account for equal capacities, unless there is a very compelling reason to do this, we do not consider running larger pipes into smaller ones as proper engineering practice.

Murray Avenue Option 1 - $ 300,000

This alternative consists of the construction of 850 feet of new 24-inch sewer line parallel to the existing sewer in Murray from Shorewood Boulevard to Newton. This sewer would be connected to the existing line at Murray and Shorewood Boulevard, Beverly, and Newton intersections.

Murray Avenue Option 2 - $ 550,000

This alternative consists of removing and replacing the existing sewer in Murray from Shorewood Boulevard to Menlo. The existing 400 feet of 42-inch pipe and 830 feet of 48-inch pipe would be removed and replaced by 1,230 feet of 48-inch pipe at a steeper slope. The only advantage of this option is that it would allow the Village to have a single sewer line in Murray Avenue.

Despite potential constructibility and conflict concerns, the lower cost of a parallel sewer makes Murray Avenue Option 1 the preferred alternative.

We have evaluated the impact of performing the Murray Avenue improvements as a stand-alone project. We anticipate this work could be undertaken in short order, even before the design and construction of the outfall upgrades by the MMSD. Our analysis confirms that the Murray Avenue parallel sewer project would achieve a significant reduction in surcharging in pipes upstream of Newton. In other words, the benefits of this project are not dependent on the work proposed in Edgewood Avenue, nor the MMSD outfall.

☐ Recommended Improvement Projects

Based on our preliminary analysis, the solution to the backup problems in the southeast sewer service area consists of the following recommended improvement projects. The total estimated cost of improvements is $ 3.48 million.

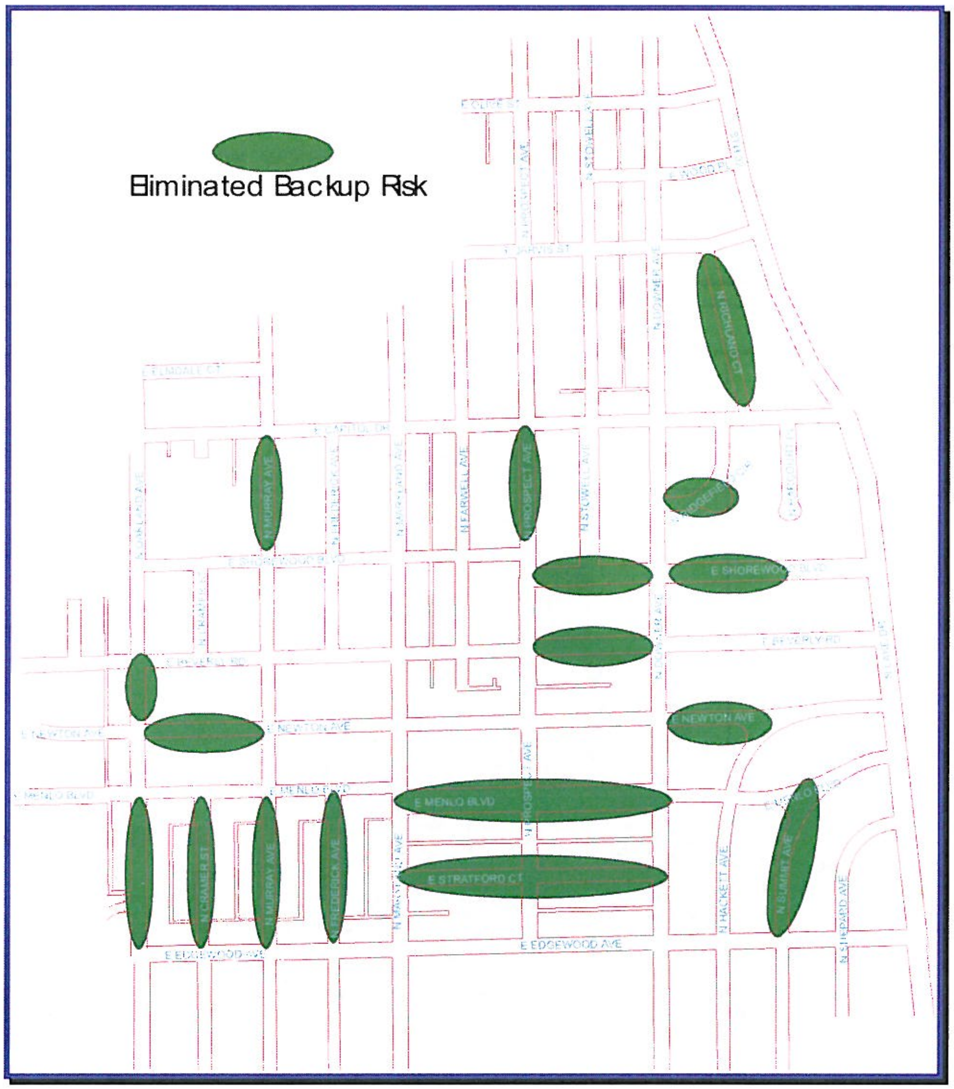
1. **MMSD Outfall Upgrade - $ 1.25 Million**
   The MMSD outfall to the river must be upgraded to provide increased capacity to the southeast sewer system. This upgrade is even more important because system-wide improvements that are being recommended will bring more flow to the MMSD sewer. The cost estimate does not include any diversion structures that may need to be reconstructed by the MMSD.

2. **Edgewood Option 2 - $ 1.25 Million**
   Under this option, no work on the Milwaukee sewers will be necessary. The Shorewood sewers will be upsized to accept the flows from both communities, and would be constructed large enough to convey the wet weather design flows to the NS-4 drop shaft and to the MMSD outfall.

3. **Shorewood Boulevard Option 3 - $ 680,000**
   This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Menlo and Prospect. The new line would flow south on Downer and west on Menlo Boulevard.

4. **Murray Avenue Option 1 - $ 300,000**
   This alternative consists of the construction of 850 feet of new 24-inch sewer line parallel to the existing sewer in Murray from Shorewood Boulevard to Newton.

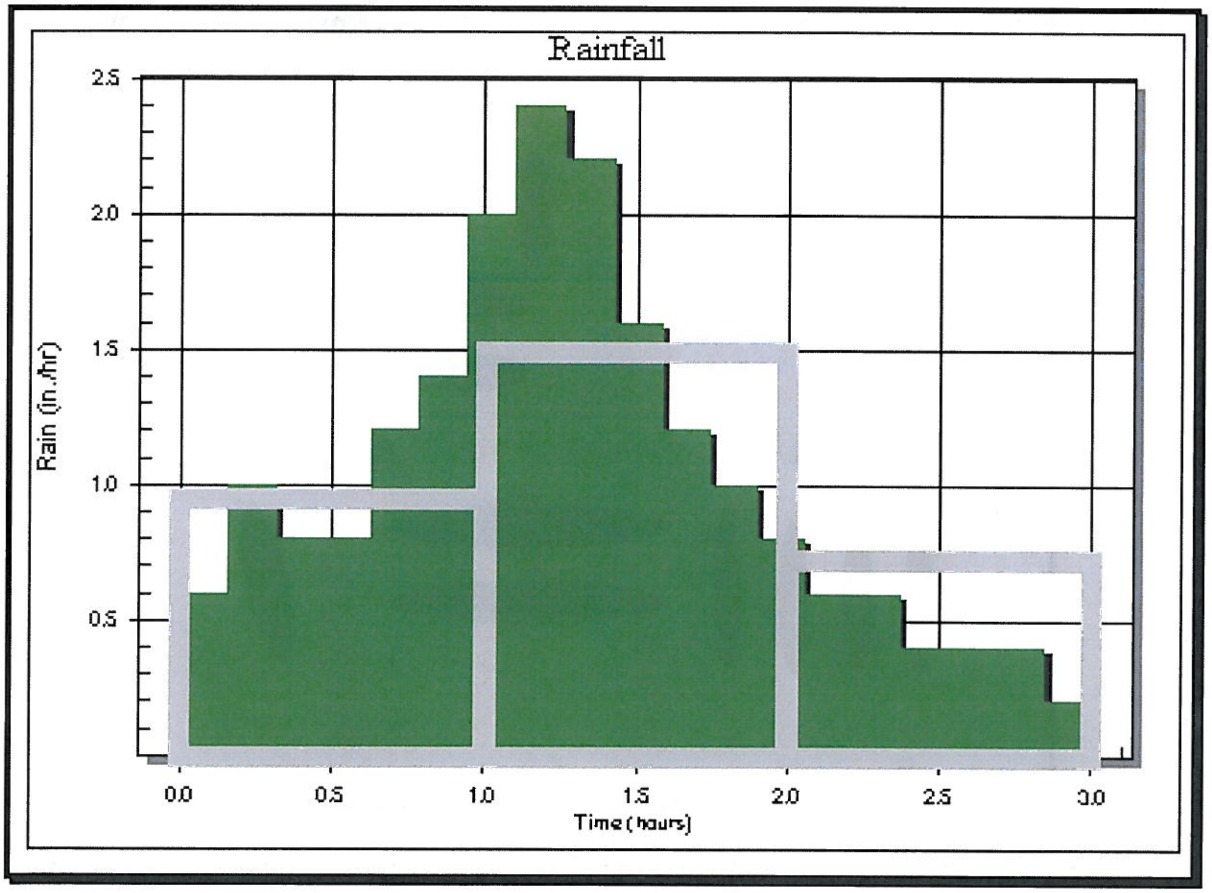
System performance for the 10 year rainfall after relay of Village sewer in Edgewood, MMSD Outfall upgrades along with sewer construction on Downer, Menlo, and Murray Avenues



Real Life Impact of Improvements

So far, we have concentrated on performance improvements based on a theoretical design rainfall that was accepted as representative of an acceptable level of protection from sewer backups. This rainfall was described in detail in the preceding sections of this report.

In order to provide an understanding of how the performance improvements would have affected residents during recent heavy storms, we have generated estimates of system performance during the July 21, 1999 rainfall, consisting of 3.39 inches in a 6 hour period, including 3.16 inches within a 3 hour period. We have approximated this most intense three hour period of rain as a 2nd quartile distribution as shown below, with the actual hourly rainfall shown in gray for comparison.

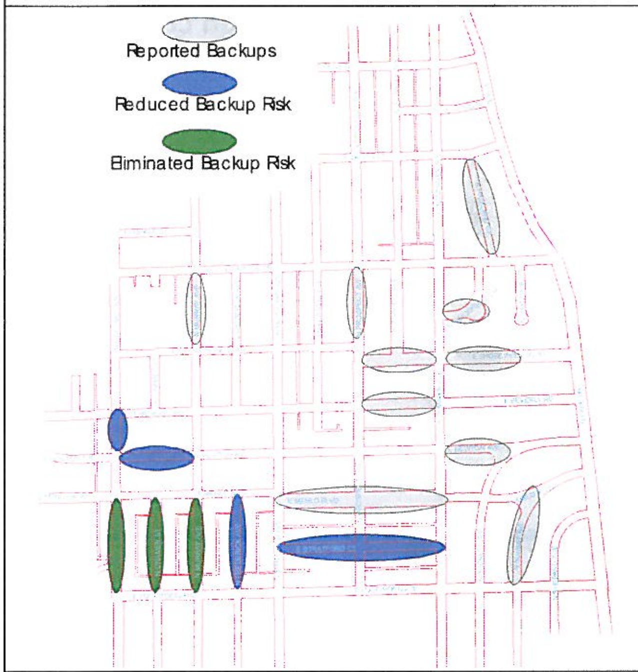
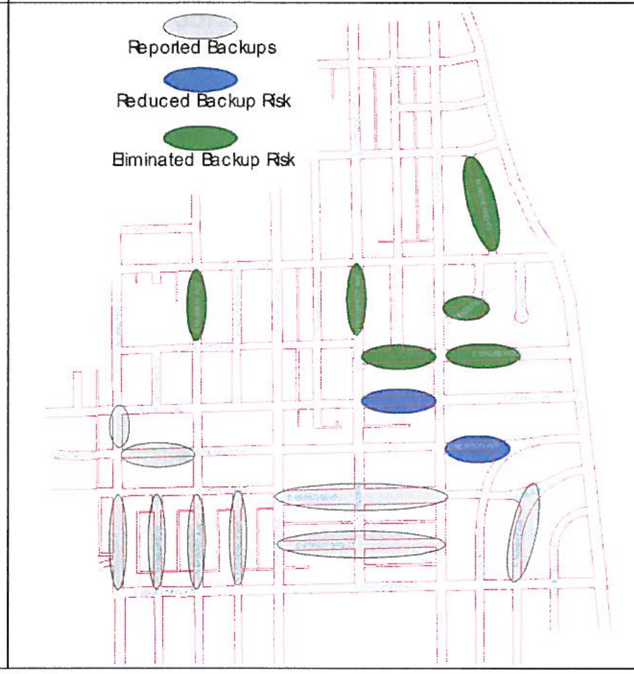
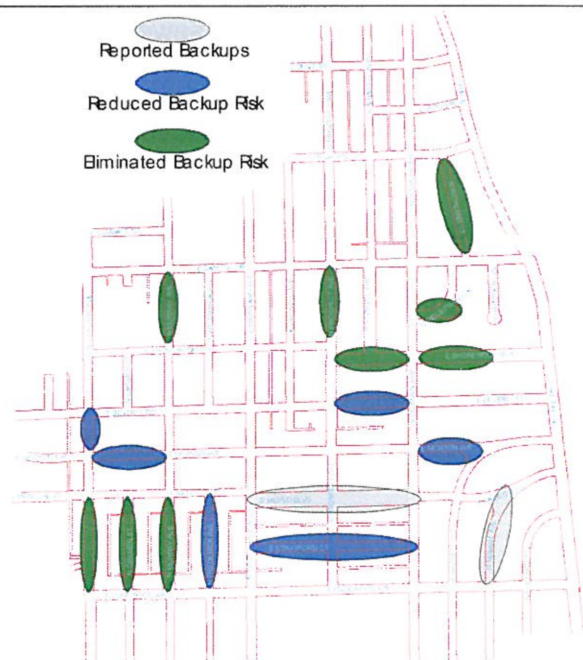


Based on the rainfall intensities shown here, the July 21, 1999 rainfall is less severe than the design storm used in this study. This means that the benefits shown for the design storm will be valid for the July 21, 1999 rainfall analysis.

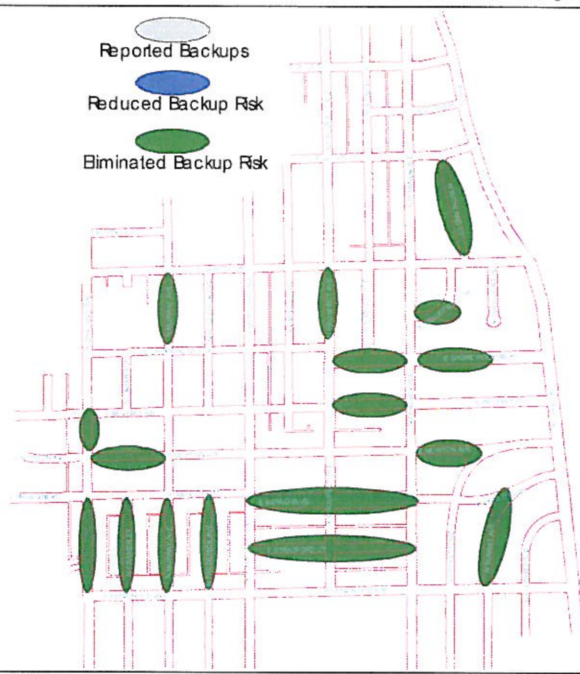
Implementation Strategies

In order to develop an implementation strategy, we are presenting each component independently. That way, we can follow the progress of the solution and examine different timelines. To this end, we have developed two scenarios to describe the possible sequence of the improvements.

Scenario 1

<table>
<tr><th colspan="2">STEP 1</th></tr>
<tr><th>MMSD undertakes Outfall Upgrades</th><th>The Village undertakes Murray, Downer, Menlo Sewer Improvements</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">STEP 2</th></tr>
<tr><th colspan="2">MMSD Outfall Upgrades and Murray, Downer, Menlo Sewer Improvements complete; no action on Edgewood sewers.</th></tr>
<tr><td colspan="2">
</td></tr>
</table>

Scenario 1(cont.)

STEP 3
Edgewood sewer relay is implemented; **southeast sewer service area performance meets the 10 year design criteria.**


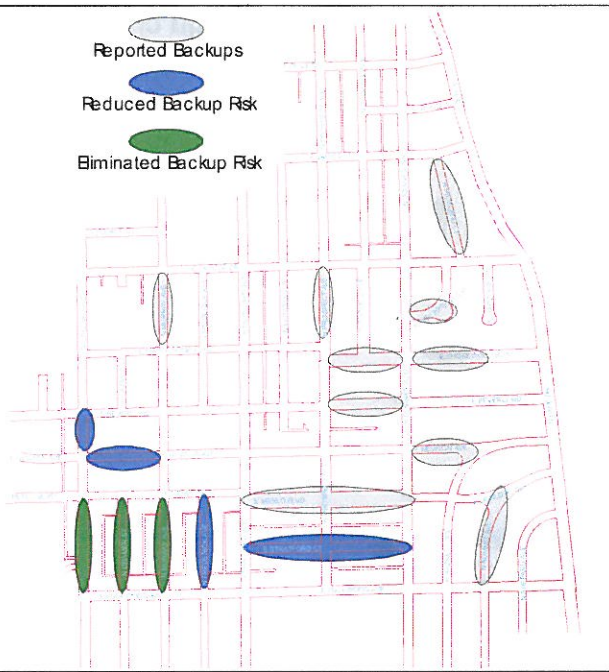
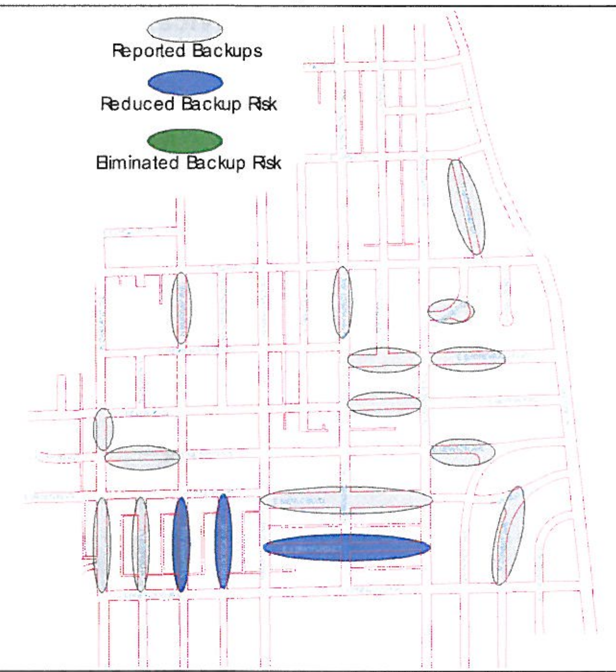
Scenario 1 assumes that negotiations with the City of Milwaukee will take longer than expected, thereby delaying a final agreement on the Edgewood sewer relay project. However, under this scenario, the Village may choose to undertake those projects that can proceed independent of the MMSD or the City of Milwaukee. This affords a limited level of backup prevention for Village residents; however, it allows work to begin while negotiations with the other stakeholders take place.

Should the MMSD take quick action on the outfall upgrade, Scenario 1 also allows the Village to quickly expand the benefit area as shown in Step 2. Since the Edgewood sewer relay is effective only when the MMSD upgrades are in place, Step 3 indicates this work will be the last component of Scenario 1.

In the event that the duration of negotiations with the City of Milwaukee is not the limiting factor, and if the MMSD acts within the desired time frame, the Edgewood sewer relay project may be pursued concurrently with the MMSD outfall upgrades. This process is described in Scenario 2.

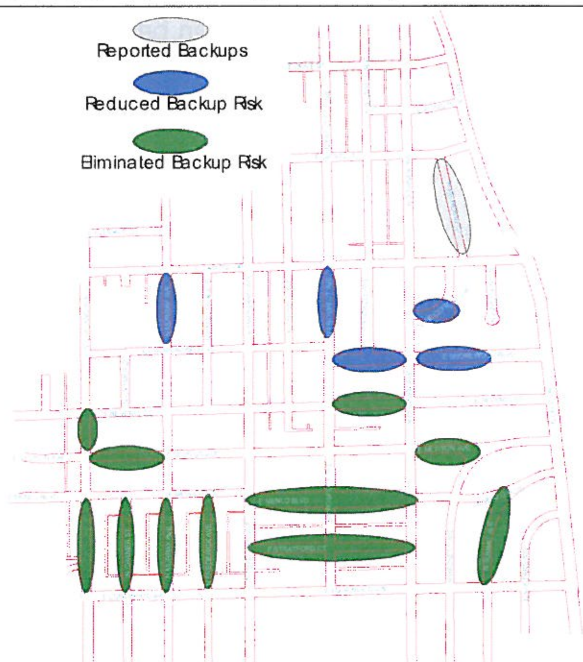
Scenario 2

STEP 1

MMSD undertakes Outfall Upgrades	The Village undertakes the Edgewood Sewer Improvements
	

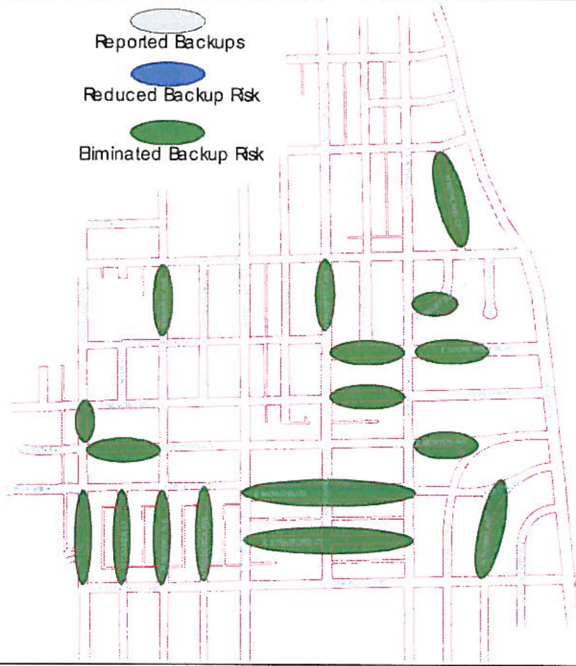
STEP 2

MMSD Outfall Upgrades and the Edgewood sewer upgrades complete; no action on Murray, Downer, Menlo Sewers.



Scenario 2(cont.)

STEP 3
Murray, Downer, Menlo Sewer Improvements implemented; southeast sewer service area performance meets the 10 year design criteria.



Scenario 2 is rather optimistic in that it assumes both the MMSD and the City of Milwaukee will cooperate with the Village in a timely fashion. If this can be achieved, the entire process will be expedited and most, if not all, project components can take place concurrently.

Southeast Shorewood and MIS Combined Sewer Study

Village of Shorewood

March 2001

Revised June 15, 2001 as per comments by Jeff Polenske P.E., City of Milwaukee

☐ Introduction

This report outlines the hydrologic and hydraulic performance of the Southeast Shorewood combined sewers. Our work consisted of creating a computer model of the sewer system, a hydrologic and hydraulic analysis, and the development of sewer improvement alternatives to reduce the risk of sewer backups in the service area.

☐ System Modeling

Service Area
The southeast sewer is an extensive network of combined sewers generally draining the portion of the Village east of Oakland Avenue and north of Edgewood Avenue. The total service area of the system is 666 acres, with 504 acres in Shorewood and the remaining 162 acres in the City of Milwaukee.

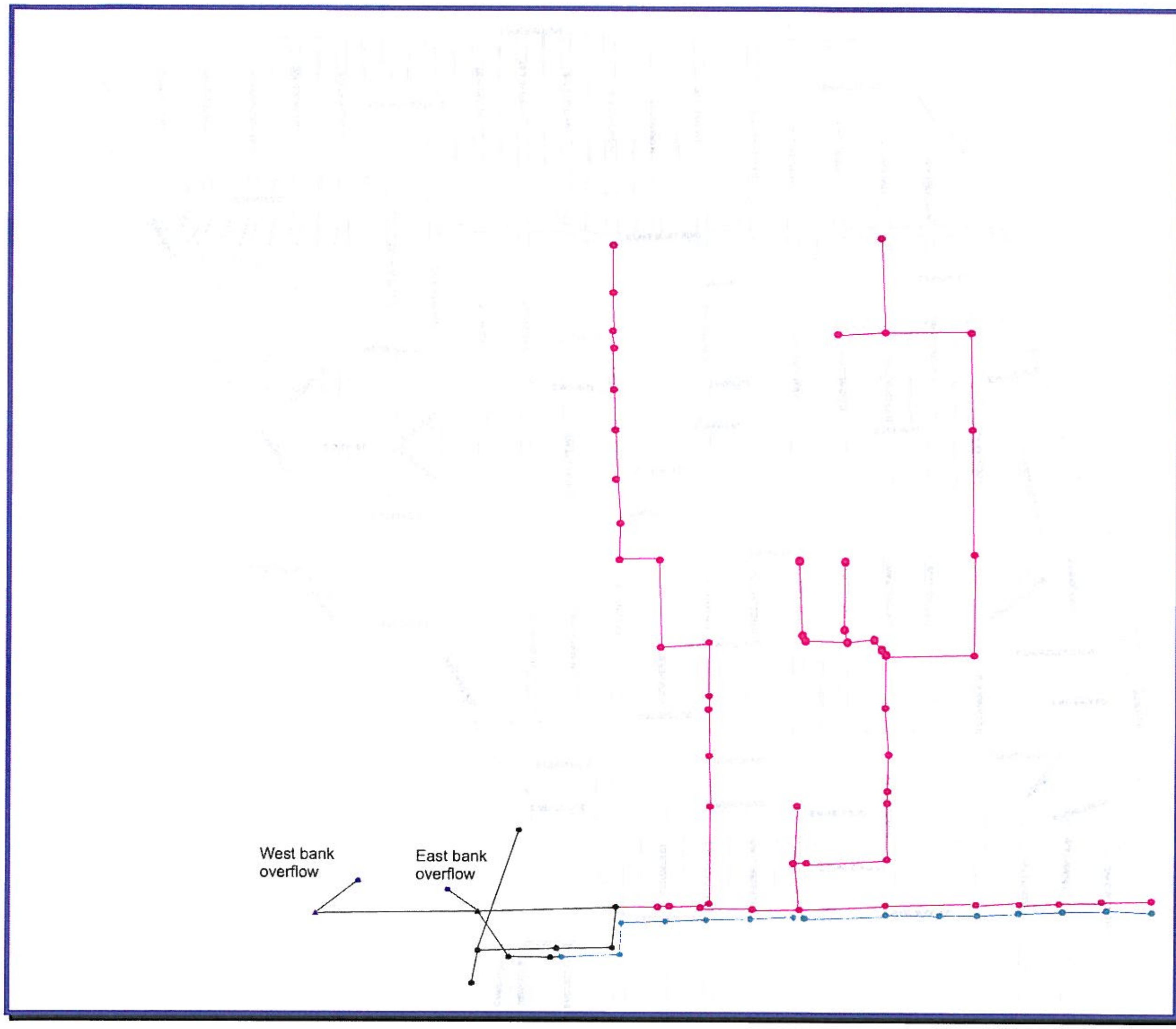
The northern portion of the service area in Shorewood is served by a storm sewer system, with two outfalls to Lake Michigan. The storm system collects street runoff, while the combined sewers receive runoff from down spouts and foundation drains in this area. We estimate that the storm sewer system handles about 50 percent of the runoff in this 188 acre partially separated portion of the Village. Everywhere else, the combined sewers handle all the runoff.

Land Cover
The southeast sewer service area is characterized by residential land uses with about 40 percent impervious land cover in Shorewood and 50 percent impervious land cover in Milwaukee. Within Milwaukee, higher levels of imperviousness characterize the University of Wisconsin-Milwaukee Campus at about 75 percent, accounting for any future building activity that may take place there. The level of imperviousness described herein and used in the hydrologic analysis is consistent with previous engineering analyses of this system by the City of Milwaukee, Infrastructure Services Division.

Sewer Network
The network description is based on the Village sewer maps and plans, Rust E&I modeling output files, as well as system plans obtained from the City of Milwaukee and the Milwaukee Metropolitan Sewerage District (MMSD). The 1998 Bottleneck Project improvements are included, so that the resulting sewer network model represents a detailed description of the existing conditions.

The system model includes Village of Shorewood sewers, City of Milwaukee sewers, MMSD MIS, MMSD west bank and east bank overflows, NS-4 Deep Tunnel drop shaft, and the MMSD West Bank Connector sewer. Tributary drainage areas to both Shorewood and Milwaukee sewers were determined from existing maps and system plans obtained from these municipalities. A 200-scale drainage area map is included with this report.

The sewer pipe segments that are specifically included in the model are shown in the following figure where Shorewood sewers are red, Milwaukee sewers green, and MMSD sewers are black.



System Behavior

The outfall of the southeast sewer consists of four separate and complementary facilities.

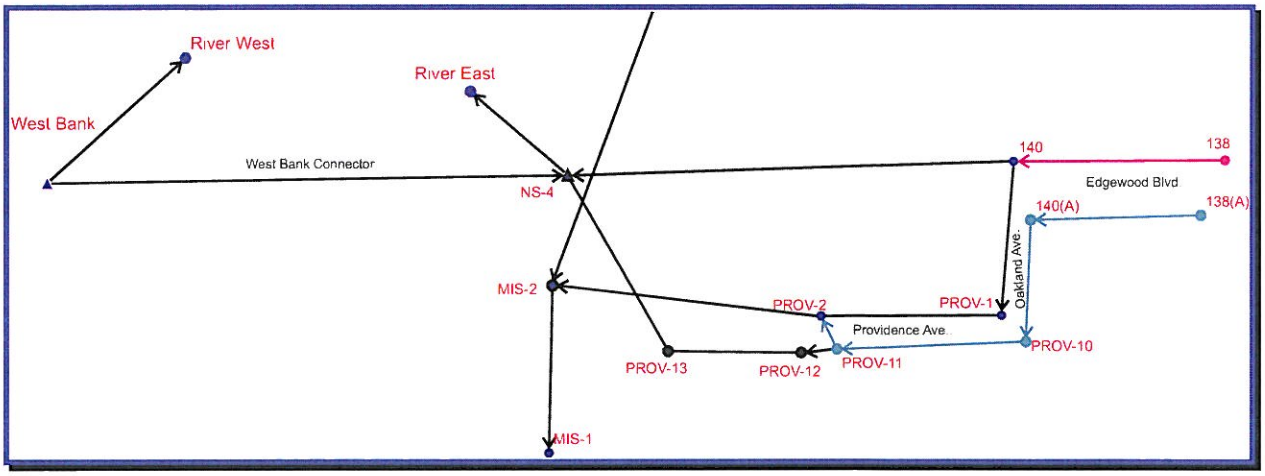
1. The dry weather outflow is directed to a 39-inch diameter Municipal Interceptor Sewer (MIS) that is under the jurisdiction of MMSD.

2. The wet weather outflow is directed to the Deep Tunnel System through a 72-inch diameter pipe that is under the jurisdiction of MMSD. This pipe is connected to drop shaft NS-4.

3. When the Deep Tunnel is full and the gates are closed, the wet weather flow can back up across the Milwaukee River through the West Bank Connector, where on overflow to the river exists. When the West Bank Connector is sufficiently overloaded, the west bank overflow may become operational.

4. During overflow conditions at the west bank, if the hydraulic grade continues to rise in NS-4, another overflow (this one on the east bank, down slope from NS-4) is activated.

These four conditions are further explained below. The following figure depicts the configuration of the Shorewood, Milwaukee, and MMSD sewers between Oakland Avenue and the Milwaukee River. Once again, Shorewood sewers are red, Milwaukee sewers green, and MMSD sewers are black.



The key hydraulic features of the sewer system shown above are the following:

<u>DRY WEATHER FLOW:</u>

- The Shorewood sewer on Edgewood drains most of the southeast portion of Shorewood and portions of Milwaukee east of Maryland Avenue, including the UWM Campus. This is shown in red between nodes 138 and 140 in the above figure, where node 140 corresponds to the intersection of Edgewood and Oakland.

- The sewer connects to the MIS at Node 140, where the dry weather flow is carried by the 39-inch special section MIS depicted by the black links between nodes 140, PROV-1, PROV-2, MIS-2. Note that the nodes with the "PROV" prefix are located on Providence Avenue. During dry weather, there is no flow in the link representing the 72-inch Combined Sewer Overflow (CSO) between Node 140 and NS-4.

- The 39-inch special section MIS connects to the 54-inch diameter MIS at Node MIS-2.

- The Milwaukee sewer on Edgewood drains portions of the City between Oakland Avenue and Maryland Avenue. This segment is shown in green between Node 140(A) and PROV-10 in the above figure. Additional drainage from Milwaukee is collected by local sewers and conveyed to Node PROV-11.

- Dry weather flow from the portion of the City of Milwaukee west of Maryland Avenue, south of Edgewood Avenue, and east of the Milwaukee River is directed to the 39-inch special section MIS through a 12-inch diameter pipe represented as a link between Nodes PROV-11 and PROV-2. This connection is located at the intersection of Providence and Bartlett.

- Under existing conditions, the 39-inch special section MIS provides dry weather flow service to both Milwaukee and Shorewood combined sewer systems included in the present study. The drainage area in question is included with this report as a 200-scale map.

WET WETAHER FLOW

- Wet weather flows from Shorewood sewers on Edgewood that exceed the hydraulic capacity of the 39-inch special section MIS are diverted to NS-4 through a 72-inch diameter CSO sewer depicted in black between Nodes 140 and NS-4 in the above figure.

- Wet weather flows from Milwaukee sewers on Edgewood and Providence that exceed the hydraulic capacity of the 39-inch special section MIS are also diverted to NS-4 through the 60-inch diameter CSO sewer shown as the black links between nodes PROV-11, PROV-12, PROV-13, and NS-4.

- Wet weather flows are also directed to NS-4 from the west side of the Milwaukee River through the 66-inch diameter West Bank Collector sewer.

- Under normal wet weather operating conditions, flow from the two CSO and the Collector sewer is introduced into the Deep Tunnel at NS-4.

EXTREME WET WEATHER FLOW

- If Deep Tunnel gates are closed, wet weather flow will accumulate in NS-4 until the hydraulic grade elevation causes a flow reversal in the West Bend Connector sewer and potential overflow may occur on the west side of the Milwaukee River.

- Further hydraulic grade elevation increases in NS-4 would cause an overflow on the east side of the river as well.

□ Hydrologic and Hydraulic Analysis

The main work effort in this phase involved the selection of the design rainfall event and the calibration of the model using actual rainfalls experienced in 1999. The calibrated model, along with the design rainfall, forms the base line to which all improvement alternatives are compared.

Selection of Design Rainfall

The 10 percent probability rainfall event is adopted as the standard design level for the southeast sewer system. In other words, this rainfall has a 10 percent chance of being equaled or exceeded during any 365-day period. The recurrence interval of such an event is 10 years.

Given the recurrence interval, the total depth of the rain is governed by the rainfall duration. After evaluating rainfall durations of 0.5, 1, 2, and 6 hours, we have determined that the critical rainfall duration for this particular system is 1 hour. In other words, compared to the other durations, the 1 hour rain results in the highest flow rates in the system.

For a given duration, the rainfall distribution describes how the intensity of rain varies through the duration of the rain. Once the critical rainfall duration is determined, we used four different rainfall distributions to further define the most critical flow condition in the system. In the case of the southeast sewer system, we found that, during a 60-minute rain, if the peak rain intensity occurs between the 30th and 45th minutes (i.e., 3^{rd} quartile), we obtained the highest flows in the system. Thus, the design rainfall is thus determined to be the 10 year, 1 hour, 3^{rd} quartile rainfall, with a total rainfall depth of 1.9 inches during this period.

Model Calibration

Three of the more severe rainfalls that occurred in 1999 were used to calibrate the model's predictive capabilities. This work included the comparison of analysis results to the reported sewer backup locations. The rains in question occurred on June 12 (3.13 inches in 6 hours), June 28 (1.9 inches in 30 minutes), and July 21 (3.16 inches in 3 hours).

From a hydraulic standpoint, the July 21, 1999 event represents the most severe rainfall. In our analysis, the computer model successfully predicted backups in several sewer segments and we found a strong correlation between the predicted hydraulic grade line elevations and those observed during the rainfall event through basement backups.

Comparisons with Previous Work
In addition to simulating actual sewer backups, we compared our modeling efforts to those previously conducted for this area. Doing so, we found that the present analysis does not agree well with the previous work conducted by Rust Environmental and Infrastructure, Inc. (Rust E&I), now doing business under the name Earth Tech. Although no design reports outlining methodologies or analysis summaries were available from Rust E&I, we were able to deduce their design flows from computer modeling output files they provided to Shorewood. Overall, we have found the design flows proposed by Rust E&I were much lower than those identified here, as well as by the City of Milwaukee. For example, at the Edgewood – Maryland intersection, the peak flow computed in the present analysis is 2.3 times higher than the flow computed by Rust E&I.

However, we did confirm that the acreage and the impervious land cover ratios are in agreement with previous calculations by the City of Milwaukee. We noted that the City's analysis did not consider the existence of a partially separated area in Shorewood, so we would expect that Milwaukee's analysis would yield generally higher flows in the sewer system. Our computations confirmed this expectation: at the Edgewood – Maryland intersection, the peak flow computed in the present analysis is only about 10 percent lower than the flow computed by the City of Milwaukee.

Finding agreement with the City's previous work, and after conducting a rigorous review of our own analysis, we confirmed that our model was sufficiently accurate in describing the hydrologic and hydraulic conditions of the study area.

Performance of the Existing System
The hydraulic analysis of the existing system indicates that the sanitary sewer backup problems occurring in the southeast Shorewood area have three distinct causes:

1. Our analysis suggests that the combined capacity of the 39-inch special section MIS and the 72-inch diameter MIS that are supposed to receive wet and extreme wet weather flows from the Shorewood's Edgewood sewer do not have adequate capacity.

2. We also find that the MIS capacity inadequacy is limited to the portion of the MIS between Oakland Avenue and NS-4. The existence of the west bank overflow means that the 72-inch diameter overflow on the east bank is not a capacity restrictor on Edgewood sewers.

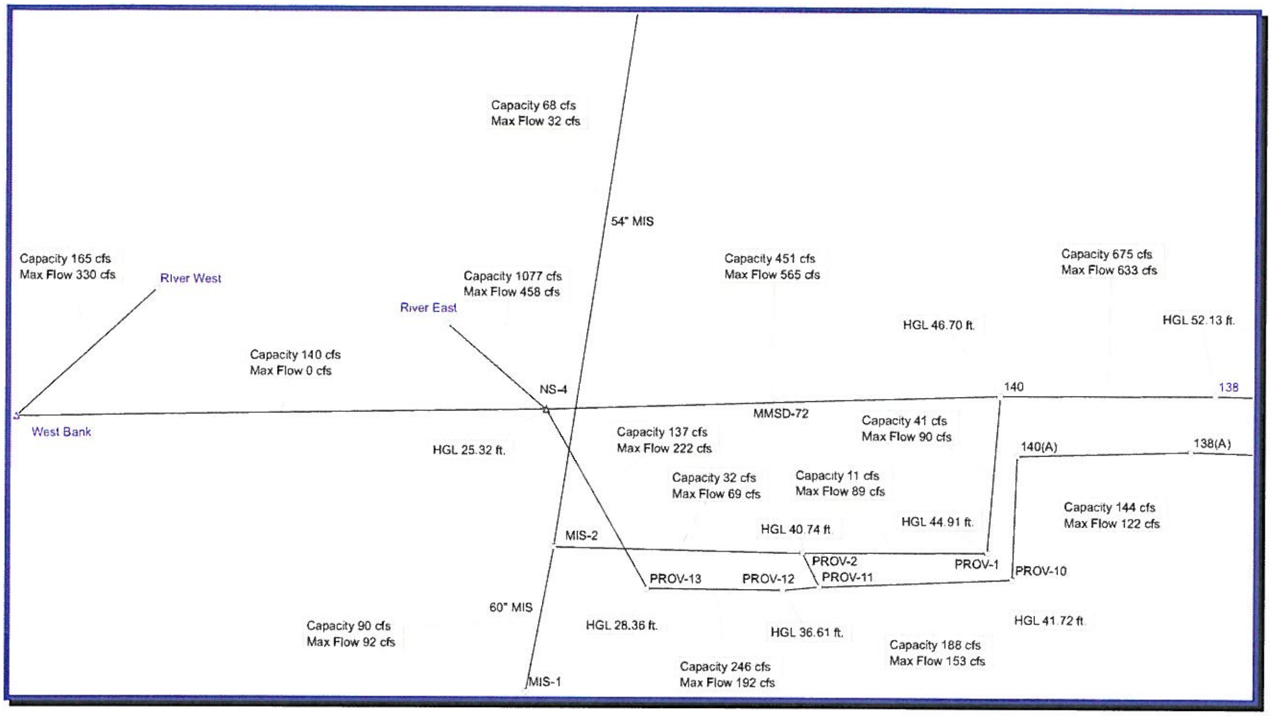
3. Upstream of the MIS, the lack of hydraulic capacity in the Edgewood sewer is the cause of sewer backups in the southern portion of the service area. Our analysis reveals that the entire Edgewood sewer from Maryland to the MIS is below capacity. The portion of the Edgewood sewer that was included in the 1998 Bottleneck Project is part of this capacity problem.

4. Lack of capacity in the Prospect and Shorewood Boulevard sewers is the cause of sewer backups in the northeast portion of the service area. Specifically, the 1998 Bottleneck Project needs to be extended further north to replace existing pipes in Shorewood Boulevard and Prospect Avenue.

5. Flat pipe slopes in the 48-inch line in Murray Avenue between Shorewood Boulevard and Newton Avenue cause the reported backups in this area.

Modeled Operation of the Existing CSO Sewers

As previously discussed, the extreme wet weather capacity of the existing CSO sewers between Oakland Avenue and NS-4 drop shaft structure was found to be inadequate. This conclusion is based on the analysis of the existing system using the 10-year, 1-hour rainfall over the drainage area. The computed flows as compared to the full flow capacities and calculated hydraulic grade lines at nodes are shown in the following figure.



The peak flows values do not fully describe the extreme wet weather operation of the CSO. To further describe this condition, we have included flow hydrographs for selected pipes as an attachment to this report. When hydrographs are examined, they clearly show that as the NS-4 hydraulic grade line builds rises, the flow of the West Bank Connector is reversed, and overflow occurs on the west bank. Next, as the Milwaukee sewers overload the 39-inch special section MIS at Node PROV-2, flow is reversed and redirected to NS-4 through the 60-inch CSO.

More importantly for the Shorewood sewers on Edgewood however, we note that the hydraulic head condition at Node 140 (i.e., intersection of Oakland and Edgewood) does not allow the full pipe capacity of the Edgewood sewer to be mobilized. This finding shows that, even a considerable capacity increase in the Shorewood sewers would not be sufficient to provide the necessary sewer capacity to the system as a whole.

The hydraulic grade lines that correspond to the flows presented in the figure are presented next. These peak values provide a clear picture of the operation of the CSO, Collector, MIS and local sewers that connect to it. Please note that the hydraulic grade elevation of 46.7 ft. at Node 140, corresponding to nearly 14.5 feet of surcharging in the manhole at Oakland and Edgewood.

☐ CSO Improvement Alternatives

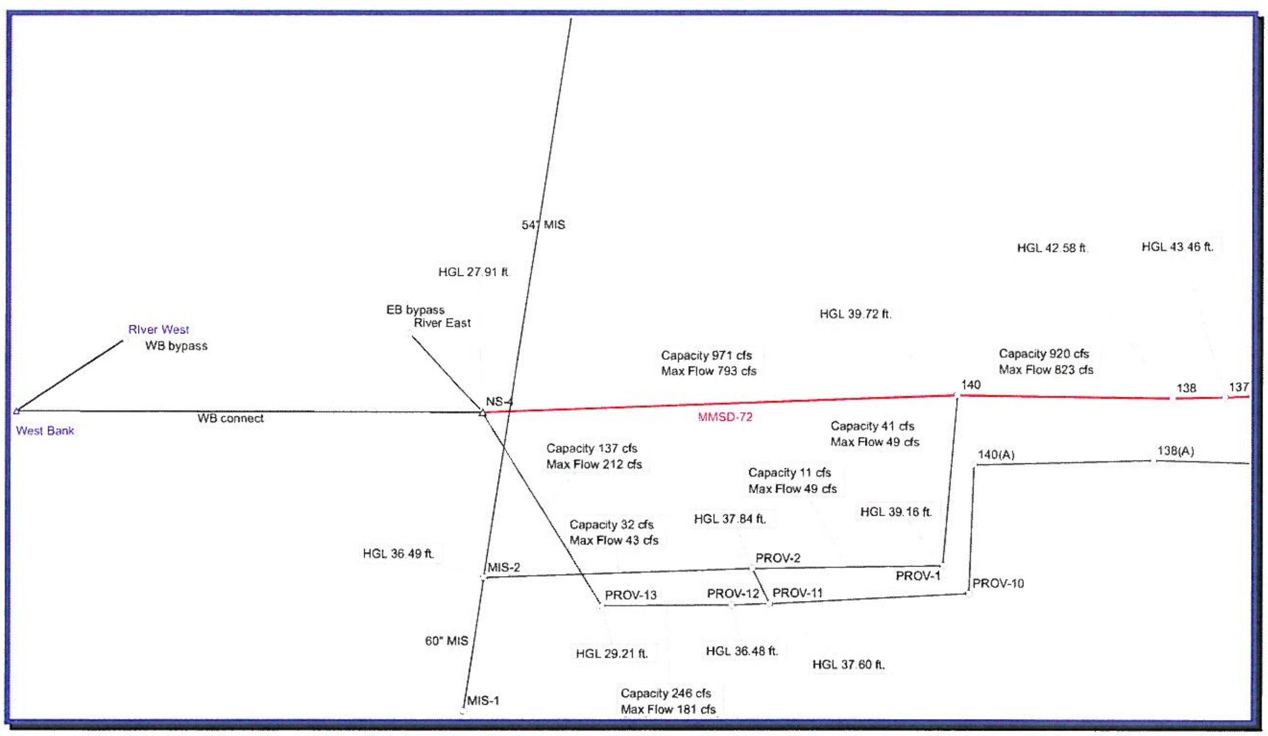
Based on design flows, either or both of the CSO pipes between Oakland and NS-4 represent a capacity restriction that directly affects Shorewood sewers on Edgewood upstream of Oakland. Through our modeling, we are able to demonstrate that any improvement that would result in a 7-foot reduction of hydraulic head at Node 140 (Oakland-Edgewood) would provide immediate and measurable benefits to the residents of Cramer, Murray, Frederic, and Maryland, just north of Edgewood.

In this study, we consider three improvement options. Though the final selection of MMSD's course of action is outside the scope of the present work, we are nevertheless able to provide design guidelines that the selected option must meet; namely, the proposed capacity and hydraulic characteristics of the improvements must be such that the hydraulic grade line at Oakland and Edgewood is **below elevation 40.0**, and that the CSO conveyance capacity at the same location must be a **minimum of 825 cfs**.

Upgrade Option 1 – Replace the 72-inch CSO between Oakland and NS-4

The replacement of this 900 ft. 72-inch diameter pipe with a 96-inch diameter pipe provides both the hydraulic head and capacity needs described above. Because the west bank overflow occurs first, the east bank overflow is not a capacity restriction on the overall system and need not be improved.

The following figure shows the maximum flows and hydraulic grade lines for Option 1. The pipes shown in red indicate those segments that are to be improved. Note that Option 1 reduces the hydraulic grade line at Oakland-Edgewood to 39.79 ft, and allows the full mobilization of the hydraulic capacity of Shorewood Edgewood sewer improvements.

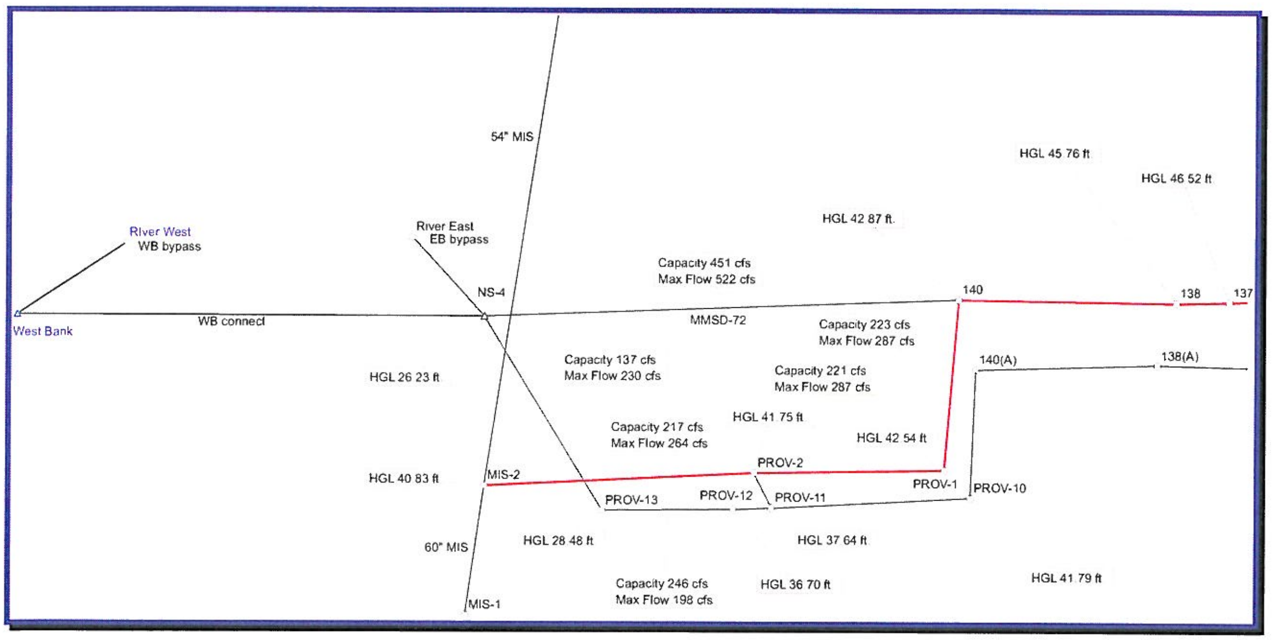


Upgrade Option 2 – Replace the 39-inch MIS between Oakland-Edgewood and the East Bank MIS

The replacement of the 980 ft segment of the 39-inch special section MIS with an 84-inch diameter pipe that maintains the existing grades at Oakland-Edgewood and the East Bank Interceptor provides approximately half the required reduction in surcharge elevations at Oakland–Edgewood (i.e., hydraulic grade line elevation reduced from 46.7 to 42.9 ft.). We note that further increase in pipe diameter does not result in significant additional surcharge elevation reduction at Oakland-Edgewood.

For Shorewood's Edgewood sewers, this option translates into the addition of an average of 3 feet of surcharging throughout the Edgewood sewer, from Oakland, all the way to Lake Drive. While 3 ft. of additional surcharge is not critical between Oakland and Murray Avenues, between Murray and Lake Drive, this additional surcharge becomes a crucial performance deficiency.

In the following figure, pipes shown in red indicate those segments that are to be improved.



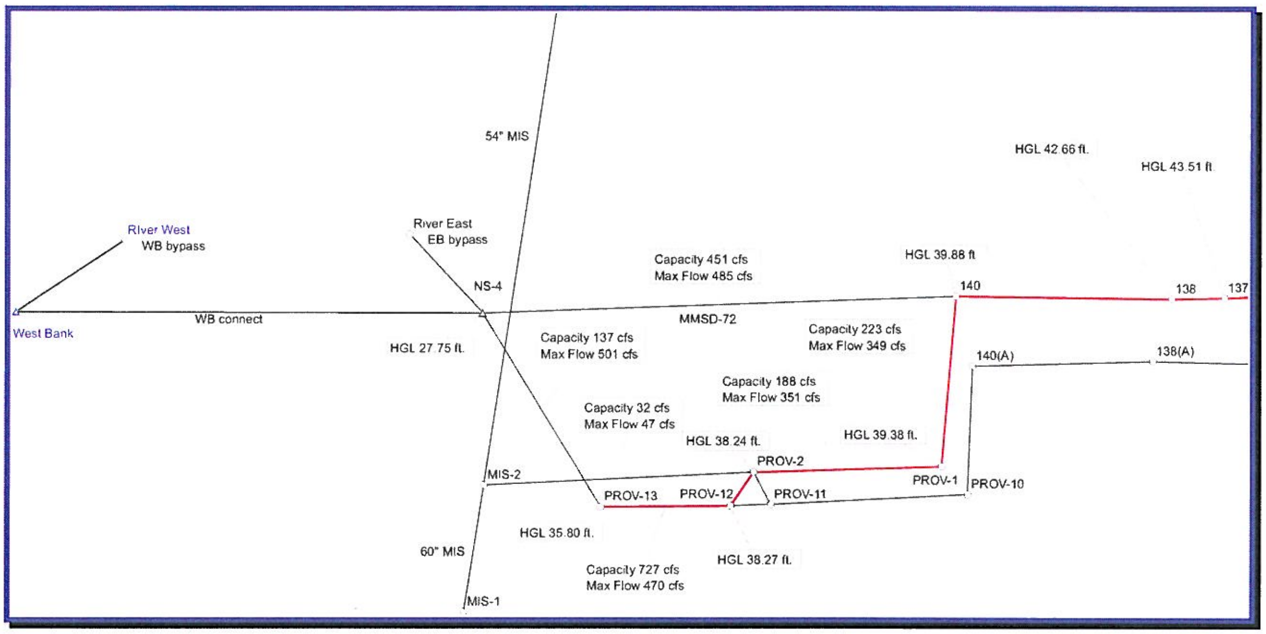
Upgrade Option 3 – Replace the 39-inch MIS between Oakland-Edgewood and Providence-Bartlett, Replace the 60-inch CSO between Providence-Bartlett and NS-4

This option consists of the replacement of 470 feet of 39-inch special section MIS with an 84-inch diameter pipe between Oakland-Edgewood and Providence-Bartlett. This portion of construction would have to follow the existing grades between these two extremities. At the intersection of Providence and Bartlett, a new diversion structure would be constructed so that the dry weather flow can still be conveyed to the East Bank MIS through the existing segment of the 39-inch special section MIS. In our analysis we assumed a weir height of 1.45 ft. to differentiate between dry and wet weather flows (i.e., anything exceeding this elevation within the MIS is deemed to be wet weather flow).

In wet and extreme wet weather, the new diversion structure would divert the flow into a new 450 ft. 84-inch diameter pipe that would be constructed as a replacement for the existing 60-inch diameter MIS on Providence Avenue between Bartlett and Cambridge Avenue. From a purely hydraulic standpoint, the segment of 60-inch pipe between the intersection of Providence-Cambridge and NS-4 need not improved.

Our assessment of Option 3 indicates that the desired surcharge reduction and the accompanying capacity increase would be realized. The resulting benefits are similar to Option 1.

Once again, in the following figure, pipes shown in red indicate those segments that are to be improved.



□ Recommendations for MIS/CSO Improvements

While the present study concentrates largely on the impact of the MIS and CSO systems downstream of Shorewood's Edgewood sewers, we are nevertheless able to identify hydraulic head and capacity improvements that are needed for Shorewood's design objectives to be met. Namely, the hydraulic grade line elevation at the intersection of Oakland Avenue and Edgewood Avenue needs to be 40.0 or less, while the hydraulic capacity of the MMSD systems downstream of this point needs to be 825 cfs or more.

Our calculations show that there are at least two distinct alternatives achieving the design objectives: Options 1 and 3. Since the final selection of an improvement alternative is outside the scope of this study, we recommend that Options 1 and 3 be further examined in the context of a feasibility study that addresses ease of construction, cost, and impact on other MIS facility operations. However, it should be noted that Option 3 would cause the introduction of wet weather flows into the MIS, a practice that is specifically avoided by MMSD.

☐ Shorewood Southeast Sewer Improvement Alternatives

Edgewood Corridor Alternatives

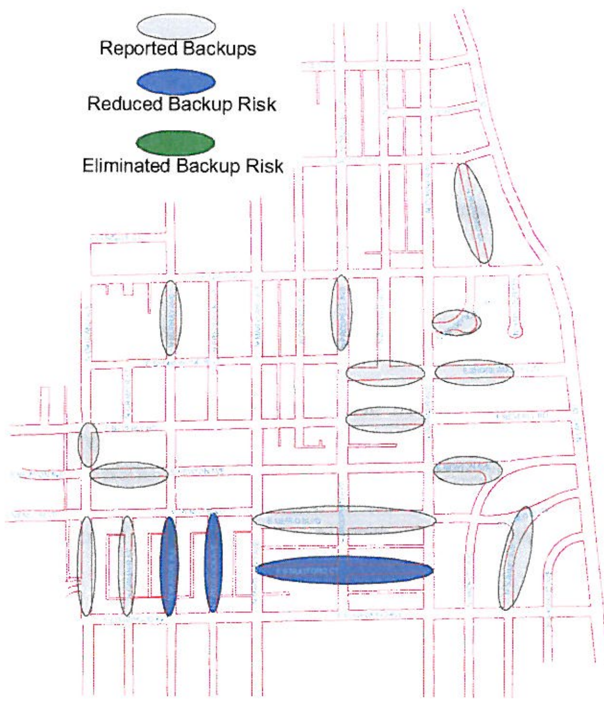
In our opinion, the Edgewood Avenue sewer between Maryland Avenue and the Milwaukee River lacks adequate capacity to handle the design rainfall without causing sewer backups. Our analysis shows that neither the 1998 Bottleneck Project improvements, nor the rest of the system downstream of the Bottleneck Project, provide the system with adequate capacity. This problem is exacerbated by the addition of Milwaukee flows into the Shorewood system at the intersection of Maryland and Edgewood.

Previous work indicated several alternative solutions to the backup and capacity problems in the Edgewood corridor. In the present study, we are concentrating on two of these solutions:

1. Complete separation of the Milwaukee and Shorewood sewers would reduce the flow in the newly improved Shorewood system and would bring the Bottleneck Project acceptably close to the required design capacities. The separation would involve the rebuilding of approximately 1,350 feet of 66-inch Milwaukee sewer from Maryland to Oakland. In addition, MIS improvements as discussed above would be needed.

2. The Village would relay the existing 78-inch combined sewer in Edgewood to provide an adequate outlet for Milwaukee and Shorewood flows. The existing sewer would have to be relayed from Maryland to Oakland (approximately 1,350 feet) as an 84-inch sewer. Again, MIS improvements as discussed above would be needed.

Without the MMSD Outfall improvements, neither improvement option provides an appreciable benefit to the residents of the area as shown in the figure to the right. The benefits of pipe upgrades or sewer separation are very limited, both in magnitude and geographical extent.



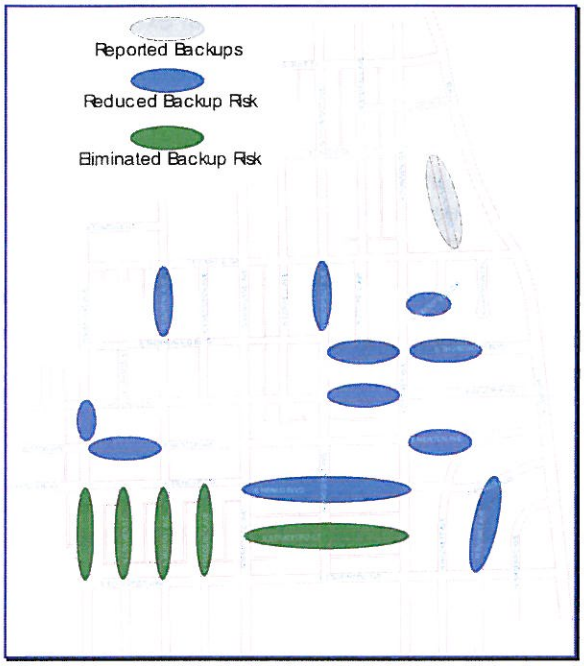
On the other hand, coupled with the MIS upgrades, both options provide important, measurable, and real benefits to the residents affected by sewer backups. Both options will eliminate backups along the Edgewood Corridor - from Oakland to Maryland- including Cramer, Murray, Frederic, and Maryland, just north of Edgewood Avenue. Both options also eliminate backups along Stratford Court.

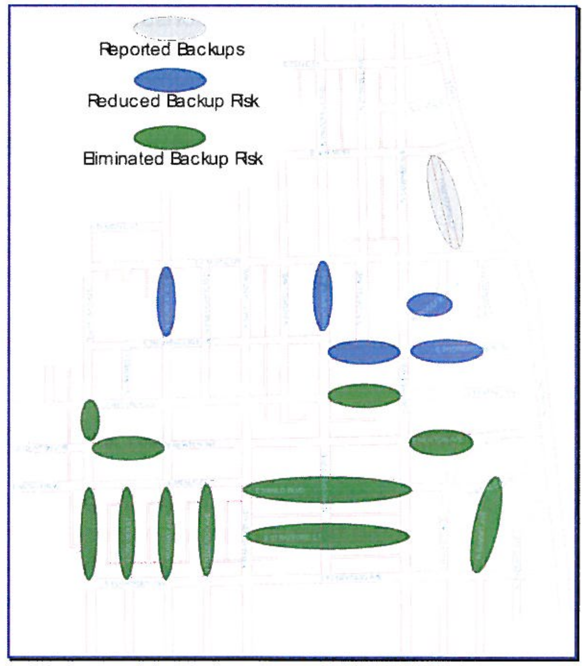
As we move further upstream in the system, the performance of the options will start to differ slightly. While Option 1 reduces backup potential along Menlo, Newton and Beverly, we find that Option 2 eliminates backups in these areas.

Further north, both options will reduce surcharging at Shorewood Boulevard, Ridgefield Court, and Richland Court. However, we do not anticipate these reductions to be significant enough to provide actual protection from backups under design conditions. Problems in these areas are specifically addressed with capacity improvements at the Prospect and Shorewood Boulevard sewer upgrades.

In summary, we conclude that both options provide a high level of surcharge reduction in the southeast sewer system. However, we find that Option 2 results in a much larger area of actual backup risk elimination compared to Option 1. Our findings are depicted in the following figures.

OPTION 1 - Benefits of separating Milwaukee and Shorewood Flows and the MIS Improvements	OPTION 2 - Benefits of Village of Shorewood Sewer Relay and the MIS Improvements





Cost Estimates for Edgewood Corridor Improvements

Edgewood Option 1 - $ 1.1 Million

Separation would be accomplished with a connection to the existing 66-inch Milwaukee pipe -which serves areas east of Maryland and south of Edgewood- to a newly constructed sewer from Maryland to Oakland.

Preliminary engineering indicates that the relay would consist of removing 360 feet of 30-inch, 638 feet of 36-inch, and 352 feet of 60-inch pipe, to be replaced with 100 feet of 66-inch and 1,370 feet of 72-inch pipe.

Edgewood Option 2 - $ 1.25 Million

Under this option, no work on the Milwaukee sewers will be necessary. The Shorewood sewers will be upsized to accept the flows from both communities; with pipe sizes large enough to convey the wet weather design flows to the NS-4 drop shaft and to the MMSD outfall.

Preliminary engineering indicates that the Shorewood sewer relay would consist of removing 1,360 feet of 78-inch pipe and installing 700 feet of 84-inch pipe and 660 feet of 96-inch pipe.

In spite of the higher cost, Option 2 is the preferred approach because of the significant benefits it brings to the residents of Shorewood.

Shorewood Boulevard Alternatives and Cost Estimates

Lack of capacity in the Prospect and Shorewood Boulevard sewers is the cause of sewer backups in the northeast portion of the service area. Specifically, the 1998 Bottleneck Project needs to be extended further north to replace existing pipes in Shorewood Boulevard and Prospect Avenue.

We have identified two alternate routes to serve this area. Both solutions provide equal benefits, and when coupled with Edgewood Option 2, result in complete coverage of the southeast sewer service area against backups risks during the design rainfall.

While Options 1 and 3 involve the construction of larger pipes, they also represent a natural extension of the 1998 Bottleneck Project. Option 2, consists of smaller pipes, but requires the removal of a portion of the 1998 Bottleneck Project to accommodate higher flows on Newton.

Shorewood Boulevard Option 1 - $ 875,000

This alternative consists of relaying older sewer lines in Shorewood Boulevard between Downer and Prospect, and in Prospect Avenue between Shorewood Boulevard and Menlo. In effect, this project would begin at the upstream end of the 1998 Bottleneck Project, extending it to the north and east until all backup locations are served.

The existing 700 feet of 54-inch and 650 feet of 60-inch pipe would be replaced by 700 feet of 60-inch pipe and 1,100 feet of 66-inch pipe.

Shorewood Boulevard Option 2 - $ 600,000

This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Newton and Prospect. The new line would flow south on Downer and west on Newton. The portion of the 1998 Bottleneck Project on Newton would have to be removed and replaced with larger pipes to accommodate increased flows from the north.

The project would consist of approximately 650 feet of new 42-inch pipe on Downer, and the replacement of 700 feet of 27-inch pipe by 700 feet of 42-inch pipe.

Shorewood Boulevard Option 3 - $ 680,000

This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Menlo and Prospect. The new line would flow south on Downer and west on Menlo.

The project would consist of approximately 1,100 feet of new 42-inch pipe on Downer, and 700 feet of 42-inch pipe on Menlo.

Ease of construction and lower cost would indicate Shorewood Boulevard Option 2 as the preferred alternative. However, this Option would have the unfortunate implications of removing newly installed sewers in Newton Avenue. Because of this, Option 3 may be the most feasible solution to this problem.

We have also evaluated the impact of performing the Shorewood Boulevard improvements as a stand-alone project. We anticipate this work could be undertaken in short order, even before the design and construction of the outfall upgrades by the MMSD. Our analysis confirms that Option 2 (i.e., the Downer – Menlo sewer) would achieve a significant reduction in surcharging in pipes upstream of Beverly. In other words, the benefits of this project are not dependent on the work proposed in Edgewood Avenue, nor the MMSD outfall.

Murray Avenue Alternatives and Cost Estimates

Flat pipe slopes in the 48-inch line in Murray Avenue between Shorewood Boulevard and Newton cause the reported backups along Murray Avenue. Currently, the Murray Avenue sewer between Capitol Drive and Edgewood Avenue consists of 48-inch pipe. Our analysis shows that only the portion of this line between Shorewood Boulevard and Newton Avenue contributes to the backup problems.

We propose to keep the existing sewers and install relief sewers parallel to the existing lines in order to reduce the surcharging between Shorewood Boulevard and Newton Avenue. However, we have also looked into the removal and replacement of the existing sewer pipes to increase capacity through steeper slopes. We do not envision using larger pipes because we would like to limit the relay to the segment between Shorewood and Newton. Using larger pipes would mean that the downstream segment between Newton and Edgewood would remain as is. Therefore, we would end up with larger pipes discharging into smaller ones. Regardless of the slope changes that may account for equal capacities, unless there is a very compelling reason to do this, we do not consider running larger pipes into smaller ones as proper engineering practice.

Murray Avenue Option 1 - $ 300,000
This alternative consists of the construction of 850 feet of new 24-inch sewer line parallel to the existing sewer in Murray from Shorewood Boulevard to Newton. This sewer would be connected to the existing line at Murray and Shorewood Boulevard, Beverly, and Newton intersections.

Murray Avenue Option 2 - $ 550,000
This alternative consists of removing and replacing the existing sewer in Murray from Shorewood Boulevard to Menlo. The existing 400 feet of 42-inch pipe and 830 feet of 48-inch pipe would be removed and replaced by 1,230 feet of 48-inch pipe at a steeper slope. The only advantage of this option is that it would allow the Village to have a single sewer line in Murray Avenue.

Despite potential constructibility and conflict concerns, the lower cost of a parallel sewer makes Murray Avenue Option 1 the preferred alternative.

We have evaluated the impact of performing the Murray Avenue improvements as a stand-alone project. We anticipate this work could be undertaken in short order, even before the design and construction of the outfall upgrades by the MMSD. Our analysis confirms that the Murray Avenue parallel sewer project would achieve a significant reduction in surcharging in pipes upstream of Newton. In other words, the benefits of this project are not dependent on the work proposed in Edgewood Avenue, nor the MMSD outfall.

☐ Recommendations for Shorewood Southeast Sewer Improvements

Based on our preliminary analysis, the solution to the backup problems in the southeast sewer service area consists of the following recommended improvement projects.

1. **Edgewood Option 2 - $ 1.25 Million**
   Under this option, no work on the Milwaukee sewers will be necessary. The Shorewood sewers will be upsized to accept the flows from both communities, and would be constructed large enough to convey the wet weather design flows to the NS-4 drop shaft and to the MMSD outfall.

2. **Shorewood Boulevard Option 3 - $ 680,000**
   This alternative consists of constructing a relief sewer from the intersection of Downer and Shorewood Boulevard to the intersection of Menlo and Prospect. The new line would flow south on Downer and west on Menlo Boulevard.

3. **Murray Avenue Option 1 - $ 300,000**
   This alternative consists of the construction of 850 feet of new 24-inch sewer line parallel to the existing sewer in Murray from Shorewood Boulevard to Newton.

Southeast Shorewood and MIS Combined Sewer Study

Village of Shorewood

November 2001

Introduction

This report outlines the hydrologic and hydraulic performance of the Southeast Shorewood combined sewers. Our work consisted of creating a computer model of the sewer system, a hydrologic and hydraulic analysis, and the development of sewer improvement alternatives to reduce the risk of sewer backups in the service area.

System Modeling

Service Area
The southeast sewer is an extensive network of combined sewers generally draining the portion of the Village east of Oakland Avenue and north of Edgewood Avenue. The total service area of the system is 666 acres, with 504 acres in Shorewood and the remaining 162 acres in the City of Milwaukee.

Edgewood Sewer Service Area Model
The southeast sewer is an extensive network of combined sewers generally draining the portion of the Village east of Oakland Avenue and north of Edgewood Avenue, as well as portions of the City of Milwaukee between Maryland Avenue and Lake Drive, north of Hartford Avenue. The present study includes runoff from total a 110-acre portion of Milwaukee that is discharged into the Edgewood sewers at the intersection of Edgewood and Maryland avenues, while the drainage area assigned to Shorewood in both analyses is 501 acres.

The drainage area to be assigned to the portion of the watershed in Milwaukee was found to be 110 acres. This fact is supported by the sewer system atlas of the City of Milwaukee (File 279), which clearly shows that (a) the entire University of Wisconsin-Milwaukee (UWM) Campus, (b) most of the area bound by Downer-Edgewood-Lake-Hartford, (c) approximately one half of the area bound by Downer-Hartford-Marietta-Kenwood, and (d) about a quarter of the area bound by Maryland-Hartford-Downer-Kenwood ultimately drain to the Edgewood sewer system. Furthermore, the sanitary sewer system plan (File 172-80, January 10, 1985) obtained from the City of Milwaukee shows all connections from the UWM Campus to the Edgewood sewer, including 27-inch and 10-inch storm sewers, and a 12-inch combined sewer connection from UWM. In addition, UWM has design drawings pertaining to the 27-inch storm sewer connection to Edgewood sewer.

Partially Separated Service Area Model
The northern portion of the service area in Shorewood is served by a storm sewer system, with two outfalls to Lake Michigan. Almost all street inlets in this area are connected to the storm sewers and it is reasonable to assume that all street runoff is discharged to the Lake, while the combined sewers only receive runoff from downspouts and foundation drains in this area.

Both the present work and Rust's previous analysis use equivalent methods to account for the existence of the storm sewers. In our analysis, we assume that roofs constitute approximately 12 percent of the total area and that all runoff from the roofs are collected by the sanitary sewer system. Rust's analysis assumes that roof constitute between 10 and 15 percent of the total area and that 85 percent of the runoff from the roofs are discharged into the sanitary sewer system.

Land Cover

The southeast sewer service area is characterized by residential land uses with an average of 40 percent impervious land cover in Shorewood and 50 percent impervious land cover in Milwaukee. These values were obtained by measurements performed on digital maps that show building footprints, streets, sidewalks, driveways, and garage footprints.

Within Milwaukee, higher levels of imperviousness characterize the UWM Campus at about 75 percent, accounting for any future building activity that may take place there. The level of imperviousness described herein and used in the hydrologic analysis is consistent with previous engineering analyses of this system by the City of Milwaukee, Infrastructure Services Division.

Sewer Network Model

The network description used for this report is based on the Village sewer maps and plans, system plans obtained from the City of Milwaukee and the Milwaukee Metropolitan Sewerage District (MMSD). The system model includes Village of Shorewood sewers, City of Milwaukee sewers, MMSD Municipal Interceptor Sewer (MIS), East Bank Combined Sewer Overflow (CSO), and the NS-4 Deep Tunnel drop shaft. The 1998 Bottleneck Project improvements are included, so that the resulting sewer network model represents a detailed description of the existing conditions.

Our sewer network model includes most if not all significant individual pipe segments (or hydraulically equivalent pipe segments) previously modeled by Rust. As such, the two models are equivalent mathematical descriptions of the pipe network that serves the area. Furthermore, parameters such as pipe diameter, invert elevations, diameters, and lengths are identical between the two models. The following features are included:

1. Representation of the Bottleneck Project improvements,
2. Representation of the Providence MMSD MIS that handles dry weather flows from the Edgewood sewer,
3. Representation of the East Bank MIS that governs the hydraulic performance of the Providence MIS,
4. Representation of the NS-4 drop shaft and the East Bank CSO,
5. Representation of Milwaukee sewers in the Oakland-Providence area that interact with flows in the Edgewood sewer.

With these features in place, the XP-SWMM model created for this report presents a detailed description of the sewer network in place. Most importantly, the model contains the Bottleneck Project improvements and thereby allows the Village to assess the effectiveness of the project for the first time since it was first conceptualized. In addition, the hydraulic performance of Shorewood, Milwaukee, and MMSD sewer system components are specifically included in the analysis.

☐ Hydrologic and Hydraulic Analysis

System Evaluation Criteria

Both this and Rust's work seek to identify those sewer segments that are most prone to causing sewer backups in basements that occur when the pressure in the sewer system reaches the elevation of the basement floor elevation.

The topography and building types in Shorewood in general, and the Southeast Sewer Service Area in particular, are such that hydraulic grade line elevations that do not rise above a point approximately 7 feet below the ground surface are not likely to intersect basement floor elevations. This assumption was initially used by Rust and also formed the basis of performance evaluation criteria in the present work. All pipes with pressure levels more than 7 feet below ground are considered adequate, any with less than 7 feet are considered to pose a backup risk for the buildings along it. This criterion will henceforth be referred to as the "7 ft. freeboard" rule.

Selection of Design Rainfall

The 10 percent probability rainfall event is adopted as the standard design level for the southeast sewer system. In other words, this rainfall has a 10 percent chance of being equaled or exceeded during any 365-day period. The recurrence interval of such an event is 10 years.
Given the recurrence interval, the total depth of the rain is governed by the rainfall duration. After evaluating rainfall durations of 0.5, 1, 2, and 6 hours, we have determined that the critical rainfall duration for this particular system is 1 hour. In other words, compared to the other durations, the 1 hour rain results in the highest flow rates in the system.

For a given duration, the rainfall distribution describes how the intensity of rain varies through the duration of the rain. Once the critical rainfall duration is determined, we used four different rainfall distributions to further define the most critical flow condition in the system. In the case of the southeast sewer system, we found that, during a 60-minute rain, if the peak rain intensity occurs between the 30th and 45th minutes (i.e., 3rd quartile), we obtained the highest flows in the system. Thus, the design rainfall is thus determined to be the 10 year, 1 hour, 3rd quartile rainfall, with a total rainfall depth of 1.9 inches during this period.

System Performance

Our analysis indicates that the sewer backup problems that continue to occur in the service area have two causes:

1. The combined capacity of the 39-inch special section MIS that receives dry weather flows and the 72-inch diameter CSO that receives wet and extreme wet weather flows from the Southeast Area sewer do not have adequate capacity.

2. Upstream of the MIS and the CSO, the lack of hydraulic capacity in the Edgewood sewer is the cause of sewer backups in the southern portion of the service area. Our analysis reveals that the entire Edgewood sewer from Maryland to Oakland is below capacity. The portion of the Edgewood sewer that was included in the 1998 Bottleneck Project is part of this capacity problem.

This means that the most effective and economical way to increase the level of service of the Bottleneck Project is to address one or both of these causes. For example, the simple upgrade of the CSO would have immediately removed backup risks on Cramer Street, Murray Avenue, and Frederick Avenue on the first blocks north of Edgewood Avenue. In addition, if the Bottleneck project had been extended another 650 feet to Oakland Avenue, it would have provided backup relief to almost 90 percent of the at-risk homes.

In our opinion, the entire length of sewer between Maryland Avenue and the Milwaukee River lacks adequate capacity to handle the design rainfall without causing sewer backups. Our analysis shows that neither the 1998 Bottleneck Project improvements, nor the upgrade of the system downstream of the Bottleneck Project provide adequate capacity. This problem is exacerbated by the addition of Milwaukee flows into the Shorewood system at the intersection of Maryland and Edgewood.

Without the MMSD CSO improvements, the benefits of pipe upgrades on Edgewood will be very limited, both in magnitude and geographical extent. On the other hand, coupled with the CSO upgrades, the reconstruction of the Edgewood sewer from Maryland to Oakland will provide important, measurable, and real benefits to the residents affected by sewer backups. This will eliminate backups along the Edgewood Corridor - from Oakland to Maryland- including Cramer, Murray, Frederick, and Maryland, just north of Edgewood Avenue, and along Stratford Court.

Based on design flows, the CSO between Oakland and NS-4 represents a capacity restriction that directly affects Shorewood sewers on Edgewood upstream of Oakland. Through our modeling, we are able to demonstrate that any improvement that would result in a 7-foot reduction of hydraulic head at Node 140 (Oakland-Edgewood) would provide immediate and measurable benefits to the residents of Cramer, Murray, Frederic, and Maryland, just north of Edgewood.

Though the final selection of MMSD's course of action is outside the scope of the present work, we are nevertheless able to provide design guidelines that the solution must meet; namely, the proposed capacity and hydraulic characteristics of the improvements must be such that the hydraulic grade line at Oakland and Edgewood is **below elevation 40.0**, and that the CSO conveyance capacity at the same location must be a **minimum of 825 cfs**. The replacement of this 900 ft. 72-inch diameter pipe with a 96-inch diameter pipe provides both the hydraulic head and capacity needs as described above.

Final Report

Wet Weather Flow Volume and Peak Management Project

MMSD Contract: M03011P01
BRAA File: 801-03-237

Combined Sewer Service Area of the Village of Shorewood and portions of the City of Milwaukee

April 27, 2004

Presented to:

Milwaukee Metropolitan Sewerage District
260 West Seeboth Street
Milwaukee, WI 53204

By:

Bonestroo, Rosene, Anderlik & Associates, Inc.
12075 N. Corporate Pkwy, Suite 200
Mequon, WI 53092

Project Manager and Contact Person:

Mustafa Emir, PhD, PE
memir@bonestroo.com
(262) 643-9004

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Executive Summary

❑ Project Purpose

The purpose of the project is to provide basement backup protection for the combined sewer service area of the Village of Shorewood since no basement backups have recently been observed in the portions of the study area in the City of Milwaukee.

While structural solutions that provide adequate pipe capacity to achieve this purpose have already been identified, the Project seeks an alternative approach that is aimed at managing wet weather capacities, runoff volumes, and flow peaks in order to arrive at a more cost effective and comprehensive solution package that coincides with Milwaukee Metropolitan Sewerage District's (MMSD) interest in volume and peak management improvements throughout its service area.

The Project also recognizes that the wet weather volume and flow management practices implemented through this project will become valuable education, demonstration, and evaluation opportunities for MMSD as similar efforts in portions of the rest of the combined sewer service area are implemented.

In summary, the three main purposes of the proposed project are:

- Provide demonstration, evaluation, and education opportunities for management practices.
- Evaluate the effect of management techniques on reducing basement backup risks in the combined service area of Shorewood.
- Evaluate the effect of management techniques on volume and peak flows discharging to the MMSD systems.

❑ Wet Weather Flow Management Plan Development

While surcharge reduction through capacity improvements may address Shorewood's problems, it can also mean that the peak flow rates delivered to the MMSD systems may have to increase to keep up with the improved efficiency of the local system. This in turn could affect MMSD's system capacity management approach during wet weather conditions.

The current project proposes an approach that combines the concepts of volume and peak management and focus on two main sources of runoff: (a) rooftops and (b) ground. For each runoff source, the study will consider volume control (i.e., permanent removal of runoff from the combined sewer) and peak flow rate control (i.e., safe temporary storage of runoff).

❑ Evaluation of Runoff Management Measures

The study includes the evaluation of the following flow management measures:

- Downspout Disconnection in the Shorewood Storm Sewer Service Area
- Downspout Disconnection in the Shorewood Combined Sewer Service Area
- On-Lot Flow Management in the Shorewood Combined Sewer Service Area
- Inlet Flow Regulators and Street Storage in the Shorewood Combined Sewer Service Area
- Separated Storm Sewer Service for UWM and Columbia-St. Mary's Hospital
- Storm Sewer Service Area Expansion in Shorewood

The effectiveness and the expected benefits of most of the measures discussed here have been estimated through the use of a sophisticated hydraulic model that was developed for the system. The proposed project includes an evaluation program to be implemented after the improvements are in place so that the results or the estimates generated by the computer models can be verified.

Because the project is so closely related to MMSD's runoff control and management efforts, it is important that the results of the evaluation be shared in the community. This is especially relevant because it is reasonable to expect that Shorewood's runoff management and reduction program will be coordinated with MMSD's Strategic Plan for Stormwater Reduction.

This means that the findings of the Shorewood project will be extremely valuable in developing a MMSD-wide approach to runoff reduction. Ultimately, these results will be included in the development of recommendations for the MMSD 2020 Facilities Planning project. Specifically, the Shorewood Wet Weather Project will provide the following information that will be useful to the 2020 Facilities Plan:

1. How to achieve widespread implementation of downspout disconnections and on-lot practices such as rain gardens and rain barrels.
2. Performance and effectiveness of on-lot practices and street inlet restrictors to prevent surcharging of the combined sewer system and basement backups.
3. Water quality benefits of using on-lot practices.
4. Capital and maintenance costs associated with stormwater reduction and storage impacts.

❑ Conclusions

The following conclusions are based on the computer modeling of the combined and storm sewer systems. In general, the hydrologic and hydraulic characteristics described in this section are valid for a range of rainfall events, up to and including the 10-year rainfall.

1. Runoff management can achieve project goals.
2. Flow management can reduce basement backup risks for design rainfall events. Therefore, the approach is a viable alternative to pipe improvements.
3. Not every downspout needs disconnecting; a limited number of disconnections will also result in measurable benefits.
4. While on-lot measures can reduce runoff volumes in the entire study area, we find that they should be primarily used to improve water quality in the storm sewer service area.
5. Limited storm sewer extension is shown to yield important benefits. The system should be extended to expand the storm sewer service area and reduce the flows in the combined sewers.
6. Some inlets in the storm sewer service area have been found to be connected to combined sewers. These should be rerouted to storm sewers.
7. Flow management measures are expected to provide modest benefits in peak flow reduction from Milwaukee.
8. Flow management measures are expected to provide minimal benefits in volume reduction from Milwaukee.

❑ Recommendations

We recommend that the following action items be scheduled, budgeted, and implemented in the sequence presented herein, recognizing that some of these actions are long term efforts while others lend themselves to relatively quick implementation. Each of the recommended actions contributes to the final solution, and we expect that increasing implementation levels will be directly correlated to increasing performance (i.e., protection and flow reduction) levels.

1. Catch Basin Rerouting
2. Storm Sewer Construction
3. Downspout Disconnection in Storm Sewer Service Area
4. On-Lot Flow Management as a BMP in Shorewood Storm Sewer Area
5. Inlet Flow Regulators in the Shorewood Combined Sewer Area
6. Runoff Reduction at UWM and Columbia / St. Mary's

Introduction

❑ Background

The total service area of the system in question is 715 acres, with 512 acres in Shorewood and the remaining 203 acres in the City of Milwaukee. The service area is characterized by residential land uses with about 40 percent impervious land cover in Shorewood and 50 percent impervious land cover in the residential areas of Milwaukee. These values were obtained by measurements performed on digital maps that show building footprints, streets, sidewalks, driveways, and garage footprints. Within Milwaukee, higher levels of imperviousness characterize the University of Wisconsin-Milwaukee Campus with 50 acres at about 75 percent. The watershed land cover and municipality distribution is summarized below.

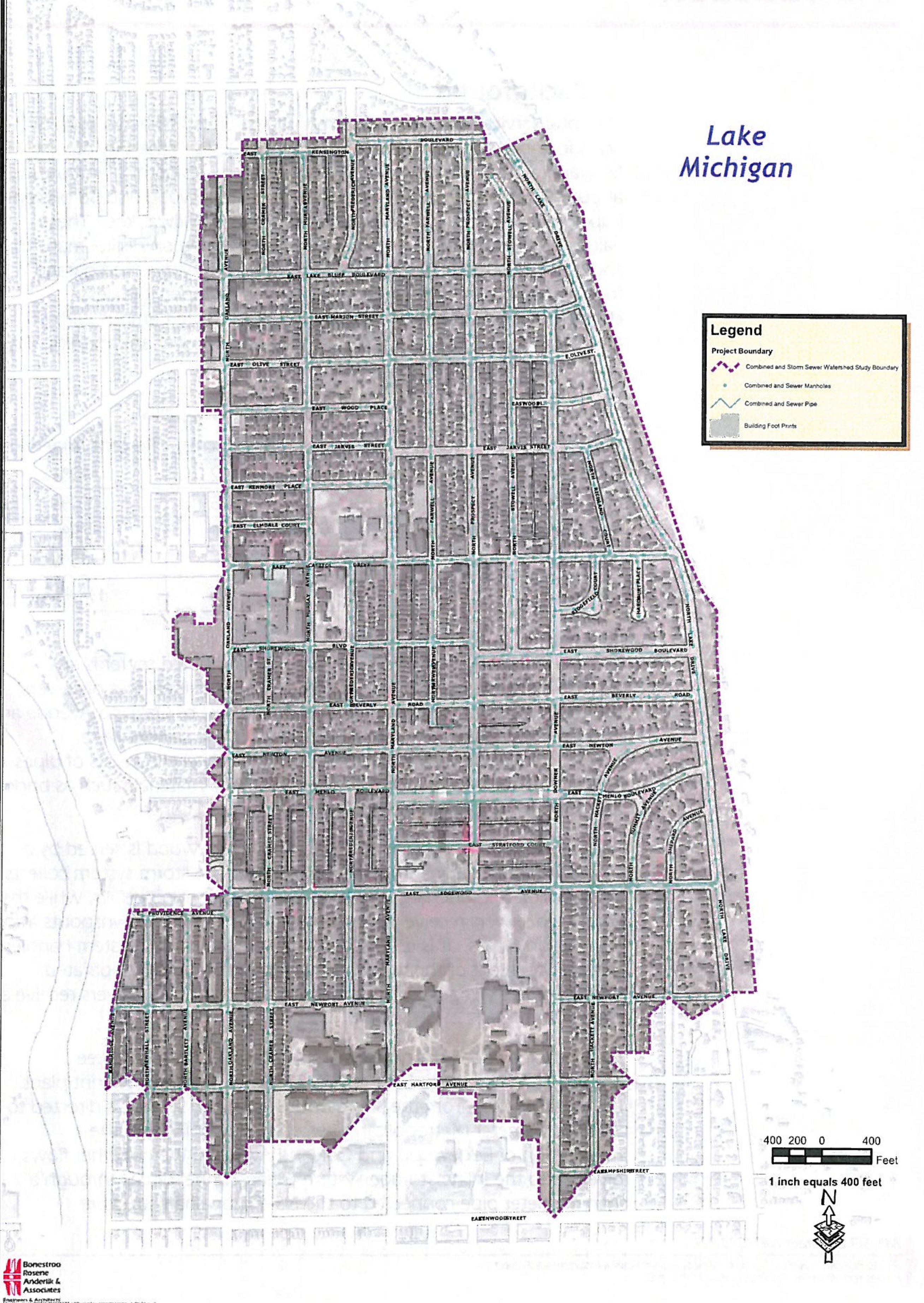
Watershed land cover by municipality		
	Area (acres)	Percent Impervious
Shorewood - residential	512	40%
Milwaukee – residential	125	50%
Milwaukee – UWM Campus	63	75%
Milwaukee – Columbia Hospital	15	75%
TOTAL	**715**	**+/- 45%**

The southeast Shorewood and Milwaukee combined sewer is an extensive gravity network (approximately 96,000 lineal feet of sewers) generally draining the portion of the Village east of Oakland Avenue and north of Edgewood Avenue. The majority of the sewers were constructed in the early part of the 20th century and consists of pipes ranging from 12 to 78 inches in diameter. Pipe materials such as brick and vitrified clay are found along with reinforced concrete.

The northern portion of the service area in Shorewood is served by a dual combined sewer - storm sewer system. The storm system collects street runoff and discharges to Lake Michigan at two outfalls, while the combined sewers receive wastewater and flows from downspouts and foundation drains. It is estimated that the storm sewer system handles about 50 percent of the runoff in this 188-acre, partially separated, portion of the Village. Everywhere else, the combined sewers receive all runoff.

All combined and sanitary flows are received at the Milwaukee Metropolitan Sewerage District (MMSD) Jones Island treatment plant. Dry weather flow from the Shorewood combined sewers is directed to a 39-inch diameter Metropolitan Interceptor Sewer (MIS) at the intersection of Edgewood and Oakland Avenues. Wet weather flows are diverted to the Inline Storage System (Deep Tunnel or ISS) through a 72-inch diameter pipe connected to the NS-4 drop shaft structure.

Combined and Storm Sewer Study Area



Problem Statement

The combined sewer system in Shorewood has historically been prone to surcharging during high intensity, short duration rainfall events. Hydraulic analyses have shown that one of the causes of surcharging is the existence of local bottlenecks. Other potential contributors to surcharging are hydraulic conditions at the MIS or the combined sewer overflow (CSO) to the drop shaft at NS-4.

In order to remedy the local bottleneck problem, the Village of Shorewood commissioned a hydrologic and hydraulic study of the combined sewers in 1996 and following the recommendations of their consultant, implemented pipe capacity improvements in a portion of the system. The construction project was completed in 1998.

However, a number of high intensity, short duration rainfall events since 1998 have shown that the problem had not been addressed to the Village's satisfaction. Consequently, Shorewood commissioned further hydraulic studies that showed that providing an adequate level of service to the Shorewood combined sewer service area meant that (i) additional pipe improvements in Shorewood would be needed, and (ii) the 72-inch CSO would also have to be upsized.

Meanwhile, MMSD's consultants who undertook similar hydraulic studies concluded that pipe size improvements would not result in an acceptable reduction in basement backup risk in Shorewood. This study stressed the importance of hydraulic junction losses (as determined from computer analyses) and recommended field measurements to determine these losses for further use in the models. In addition, the report recommended the consideration and evaluation of flow regulators and roof downspout disconnection.

In the interest of quickly and effectively addressing the problem at hand, the Village designed a comprehensive wet weather flow management study that would provide the expected level of basement backup protection in Shorewood. At the same time, the Village also realized that its efforts could be made to align with MMSD's capacity management and system operation goals.

Project Purpose

The purpose of the project is to provide basement backup protection for the combined sewer service area of the Village of Shorewood since no basement backups have recently been observed in the portions of the study area in the City of Milwaukee.

While structural solutions that provide adequate pipe capacity to achieve this purpose have already been identified, the Project seeks an alternative approach that is aimed at managing wet weather capacities, runoff volumes, and flow peaks in order to arrive at a more cost effective and comprehensive solution package that coincides with MMSD's interest in volume and peak management improvements throughout its service area.

The Project also recognizes that the wet weather volume and flow management practices implemented through this project will become valuable education, demonstration, and evaluation opportunities for MMSD as similar efforts in portions of the rest of the combined sewer service area are implemented.

In summary, the three main purposes of the proposed project are:

- Provide demonstration, evaluation, and education opportunities for management practices.
- Evaluate the effect of management techniques on reducing basement backup risks in the combined service area of Shorewood.
- Evaluate the effect of management techniques on volume and peak flows discharging to the MMSD systems.

Wet Weather Flow Management Plan Development

While surcharge reduction through capacity improvements may address Shorewood's problems, it can also mean that the peak flow rates delivered to the MMSD systems may have to increase to keep up with the improved efficiency of the local system. This in turn could affect MMSD's system capacity management approach during wet weather conditions.

The current project proposes an approach that combines the concepts of volume and peak management and focus on two main sources of runoff: (a) rooftops and (b) ground. For each runoff source, the study will consider volume control (i.e., permanent removal of runoff from the combined sewer) and peak flow rate control (i.e., safe temporary storage of runoff).

Rooftop Runoff Management

Even in the portions of the area where storm sewers exist, it is believed that all roof downspouts are connected to the combined sewer system. Since the total roof area in Shorewood is approximately 12 to 15 percent of the total, the rooftop runoff constitutes a sizeable portion of the total wet weather flow that must be handled by the combined system.

Rooftop Runoff Volume Reduction	Rooftop Runoff Peak Reduction
In the northern third of the study area where storm sewer service is available, downspout disconnection will amount to a net runoff volume reduction from the combined system. Even with some of the rain barrel – rain garden solutions, a limited amount of runoff volume reduction is possible. The proposed project will evaluate potential roof runoff reduction options and the expected hydraulic benefits on the system under design flow conditions.	If the disconnected downspouts cannot be discharged into storm sewers, there is still a possibility to reduce peak runoff rates by routing the downspouts through landscaped areas that act as temporary storage or infiltration areas on each property. Larger rain gardens can also be sited in public property, in parks, and in boulevards. Rain barrels may also help in controlling rooftop runoff peaks by storing smaller quantities of roof runoff for an extended period.

In addition to simple methods such as downspout disconnection, the proposed project will also evaluate the feasibility of other, more advanced options like rain barrels, rain gardens, green roofs, and roof restrictors.

Ground Runoff Management

It is reasonable to expect that the most cost effective approach to reducing volumes and peaks in the combined sewers would be through the management of ground runoff because we estimate that up to 85 percent of the wet weather flow in the sewers originates from streets, yards, parking lots, driveways, lawns, etc.

Ground Runoff Volume Reduction	Ground Runoff Peak Reduction
The reduction of ground runoff flowing in the combined sewers involves the extension of existing storm sewers or the construction of new storm sewers. The runoff removed from the combined sewers must be evaluated for nonpoint source pollution and adverse effects must be mitigated through Best Management Practices. The project will investigate the capacity of the existing storm sewers, storm sewer alternatives without resorting to complete separation of combined sewers.	The idea of temporarily storing runoff in designated portions of the streets can be an effective peak flow rate control method in combined sewer service areas. In order to accomplish this, two components will be required. First, the catch basin flows must be regulated such that the resulting flow in the combined sewers is reduced to target levels. Second, designated surface storage areas must be created by street grade modifications.

The evaluation of the number and placement of the catch basin flow regulators or restrictors is an important component of the project. The project therefore includes a surface drainage analysis component that identifies grade modification along selected streets to provide the required surface storage volume. It is also possible that storage locations other than streets may be feasible in the Village, including potential above ground or underground storage areas.

❑ Evaluation of Runoff Management Measures

The effectiveness and the expected benefits of most of the measures discussed here have been estimated through the use of a sophisticated hydraulic model that was developed for the system. The proposed project includes an evaluation program to be implemented after the improvements are in place so that the results or the estimates generated by the computer models can be verified.

Because the project is so closely related to MMSD's runoff control and management efforts, it is important that the results of the evaluation be shared in the community. This is especially relevant because it is reasonable to expect that Shorewood's runoff management and reduction program will be coordinated with MMSD's Strategic Plan for Stormwater Reduction in 2004 and 2005. This means that the findings of the Shorewood project will be extremely valuable in developing a MMSD-wide approach to runoff reduction. Ultimately, these results will be included in the development of recommendations for the MMSD 2020 Facilities Planning project.

Hydrology: Rainfall Depth

The design rainfall depth and distribution selected for the present study were published by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in Technical Report No. 40, "Rainfall Frequency in the Southeastern Wisconsin Region" (TR-40) in April 2000. The rainfall information in this study represents the most up to date and modern review and statistical interpretation of available rainfall records in southeastern Wisconsin.

The following table shows the design rainfall duration and recurrence intervals used in the study. Rainfall depths for the 2, 5, 10, 25, and 100 year recurrence intervals are adopted directly from TR-40. Depths for 3, 6, and 12 month recurrence intervals have been calculated using the 2 year depths and the factors from Tables 3 and 4, "Rainfall Frequency Atlas of the Midwest", Floyd A. Huff and James R. Angel, Illinois State Water Survey Bulletin 71, 1992.

	Rainfall Duration and Recurrence Interval							
Storm Duration	**3 month**	**6 month**	**12 month**	**2 year**	**5 year**	**10 year**	**25 year**	**100 year**
15 minute	0.37	0.46	0.58	0.83	0.98	1.07	1.21	1.41
30 minute	0.50	0.64	0.79	1.07	1.29	1.45	1.68	2.02
60 minute	0.64	0.81	1.00	1.31	1.60	1.84	2.20	2.82
120 minute	0.79	1.00	1.24	1.54	1.93	2.23	2.73	3.64
180 minute	0.87	1.10	1.36	1.68	2.07	2.40	2.93	3.89
360 minute	1.02	1.29	1.60	1.95	2.40	2.79	3.44	4.70
	Derived from 2 year SEWRPC TR-40 and Huff coefficients			Depths as published in SEWRPC TR-40				

We note that there are three other commonly used sources of design rainfall depths available that provide data for Southeastern Wisconsin. These are the following:

- **"Rainfall Frequency Atlas of the United States-Technical Paper 40" (TP-40), David Hershfield, May 1961.**

  TP-40 provides design rainfall depths for the two-, five-, 10-, 25-, 50- and 100-year recurrence interval events for durations of one-half hour, one, two, three, six, 12, and 24 hours. These depths are provided in 48 separate isopluvial contour (contours of equal rainfall depth) maps of the United States. The maps were developed by analysis of the highest quality rainfall records available in the late 1950s. Rainfall quantiles were obtained by fitting the records to the Extreme Value Type 1 (EV1), or Gumbel, distribution. Many of the Gumbel fits were completed in the development of NWS HYDRO 25 documents in 1955. Apparently, considerable smoothing was employed in drawing the TP-40 contour maps. The isopluves (lines of equal rainfall depth) on each map are smooth and sweeping indicating a consistent trend of decreasing rainfall depth with increasing distance from humidity sources such as the Gulf of Mexico. The TP-40 estimate for the 100-year 24-hour rainfall in the southeastern Wisconsin region is approximately 5.5 inches.

In recent years, the dated TP-40 has become less used nationally, although it contains important procedures and findings. These include the widespread use of the Gumbel distribution to fit rainfall, the relationships between "calendar" hour rainfall and peak hour rainfall, and the published selection of durations and recurrence intervals, which have since become a standard.

- **"Rainfall Frequency Atlas of the Midwest", Floyd A. Huff and James R. Angel, Illinois State Water Survey Bulletin 71, 1992.**

  Illinois State Water Survey (ISWS) Bulletin 71 presents the results of an analysis of 275 gauge records in nine Midwestern states including Wisconsin. The computed rainfall depths are presented in two formats: as tables providing rainfall quantiles for each of 76 climatic regions (nine of which are in Wisconsin), and as isopluvial maps. There is an extraordinary difference between the Bulletin 71 maps and the TP-40 maps. The TP-40 maps intend to illustrate the logical variation of rainfall, while the Bulletin 71 maps meticulously document the variations in the result obtained from the analyses of 275 rainfall records. The difference can mislead users who are familiar with TP-40. The highs and lows of the Bulletin 71 maps usually indicate the locations of anomalous gauge records, rather than real regional trends.

  The Bulletin 71 results are based on a computational procedure that is unknown outside Huff's own publications. The method relies on fitting a curve to a plot of the logarithm of the estimated recurrence interval versus the logarithm of extreme rainfall. Daily records are primarily used in the method. Short duration storms were derived according to ratios obtained from a few hourly records and studies previously conducted by Huff in Illinois. Only three gauge records used in the Bulletin 71 analysis are located in the southeastern Wisconsin area.

- **"Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District", published by SEWRPC in CAPR No. 152, December 1990.**

  Early comprehensive estimates of rainfall frequency were conducted around 1955 for the HYDRO-25 study by the U.S. Weather Bureau using Milwaukee rainfall recorded from 1903 through 1951. The HYDRO-25 results were incorporated into the isopluvial maps published as TP-40. In 1969, SEWRPC conducted an independent analysis of rainfall frequency

(SEWRPC, 1973). Like TP-40, the estimates were based on fits to the Extreme Value Type 1 (EV1), or Gumbel distribution. The Milwaukee rainfall gauge, now located at General Mitchell Field, was the only long record available. The SEWRPC analysis extended the period of record used for NWS HYDRO-25 and TP-40 by 15 years, considering rainfalls from 1903 through 1966. The additional 15 years of data had little impact on the estimated 100-year 24-hour rainfall yielding an estimate of 5.71 inches.

Shortly after the storm of August 6, 1986, SEWRPC reevaluated the rainfall series that had now grown to 84 years (from 1903 through 1986). Once again, the estimates were derived by fitting to the Gumbel distribution. This analysis resulted in an estimated 100-year 24-hour rainfall of about 5.5 inches (SEWRPC, 1990). This design depth, along with the other data, has generally served as the design standard in southeastern Wisconsin for the past 10 years.

❑ Hydrology: Rainfall Duration

The 10 percent probability (i.e., 10 year recurrence interval) rainfall event is adopted as the standard design level for the southeast sewer system in Shorewood. This level of performance was established early in the design solution alternative development process in the Village dating back to 1995.

Given the recurrence interval, the total depth of the rain is governed by the rainfall duration. After evaluating rainfall durations of 0.5, 1, 2, and 6 hours, we have determined that the critical rainfall duration for this particular system varies between 1 and 2 hours. The following table identifies the critical rainfall durations for each recurrence interval included in the present analysis.

Critical rainfall durations		
Recurrence Interval	Rainfall Duration (hr)	Rainfall Depth (in)
3 month	2	0.79
6 month	2	1.00
12 months	2	1.24
2 year	1	1.31
5 year	1	1.60
10 year	1	1.84
25 year	1	2.20
100 year	2	3.64

❑ Hydrology: Temporal Distribution of Rainfall

For a given duration, the rainfall distribution describes how the intensity of rain varies through the duration of the rain. In all cases, the temporal distribution of rainfall is the 90th percentile distribution, which

- Is most appropriate to be used in conjunction with the SEWRPC 2000 rainfall depth data,
- Is based on recorded rainfalls in Wisconsin,
- Produces flood flows that agree well with those computed based on analysis of long term USGS stream gauge records or long term continuous simulation of stream flow for relatively large watersheds,
- Produces flood flows that are similar to other design storm methods commonly applied in southeastern Wisconsin for intermediate and small sized watersheds,
- Provides conservative design values for peak flow without producing overly conservative volume values.

❑ Hydrology: Watershed Properties

The study area was determined through an exhaustive review of available documents obtained from the Village of Shorewood, City of Milwaukee, and MMSD.

The present study includes all of the combined sewer service area in the Village of Shorewood and additional areas within the City of Milwaukee. In Shorewood, the study area is roughly bound by Lake Michigan to the east, Edgewood Avenue to the south, Oakland Avenue to the west, and Kensington Boulevard to the north.

In Milwaukee, the study area is approximately bound by Summit Avenue to the west, Hartford Avenue to the south, Cambridge Avenue to the west, and Edgewood Avenue to the north. Portions of the University of Wisconsin – Milwaukee campus, as well as the Columbia/St. Mary's Hospital complex are located within this general area.

The sewer system atlas of the City of Milwaukee (File 279), shows that (a) the entire University of Wisconsin-Milwaukee (UWM) Campus, (b) most of the area bound by Downer-Edgewood-Lake-Hartford, (c) approximately one half of the area bound by Downer-Hartford-Marietta-Kenwood, and (d) about a quarter of the area bound by Maryland-Hartford-Downer-Kenwood ultimately drain to the Edgewood sewer system.

The study area is characterized by residential land uses with an average of 40 percent impervious land cover in Shorewood and 50 percent impervious land cover in Milwaukee. These values were obtained by measurements performed on digital maps that show building footprints, streets, sidewalks, driveways, and garage footprints. The level of imperviousness described herein and used in the hydrologic analysis is consistent with previous engineering analyses of this system by the City of Milwaukee, Infrastructure Services Division.

Watershed Imperviousness by Municipality		
	Area (acres)	Percent Impervious
Shorewood - residential	512	40%
Milwaukee – residential	125	50%
Milwaukee – UWM Campus	63	75%
Milwaukee – Columbia Hospital	15	75%
TOTAL	**715**	**+/- 45%**

Approximately 180 acres in the northern portion of the study area in Shorewood is served by a storm sewer system that has two outfalls to Lake Michigan. Almost all street inlets in this area drain to the storm sewers and this flow is discharged to Lake Michigan. Less than 20 catch basins have been identified as being connected to the combined sewers in the storm sewer service area.

In our analysis, we assume that roofs constitute approximately 12 percent of the total area and that all runoff from the roofs are collected by the combined sewer system through downspouts.

❑ Hydraulics: Conveyance System Definition

The network description used for this study is based on the Village of Shorewood sewer maps and plans, GIS system maps, as-built plans, system plans obtained from the City of Milwaukee and the Milwaukee Metropolitan Sewerage District (MMSD). The system model includes Village of Shorewood sewers, City of Milwaukee sewers, MMSD Municipal Interceptor Sewer (MIS), East Bank Combined Sewer Overflow (CSO), and the NS-4 Deep Tunnel drop shaft. The 1998 Shorewood Bottleneck Project improvements are included, so that the resulting sewer network model represents a detailed description of the existing conditions. The following features are included:

- Representation of the Bottleneck Project improvements,
- Representation of Milwaukee sewers in the Oakland-Providence area that interact with flows in the Edgewood sewer.
- Representation of the Providence Avenue MIS that handles dry weather flows from the Edgewood sewer,
- Representation of the East Bank MIS that governs the hydraulic performance of the Providence MIS,
- Representation of the NS-4 drop shaft and the East Bank CSO,

With these features in place, the XP-SWMM model created for this report presents a detailed description of the sewer network in place. Most importantly, the model contains the Bottleneck Project improvements and thereby allows the Village to assess the effectiveness of the project for the first time since it was first conceptualized. In addition, the hydraulic performance of Shorewood, Milwaukee, and MMSD sewer system components are specifically included in the analysis.

The overall behavior of the local systems in Shorewood and Milwaukee are closely linked to the operations and performance of the receiving structures and facilities. The following is a QUALITATIVE description of the hydraulic system behavior:

- Dry weather outflow discharges to a 39-inch diameter MIS at the Intercepting Structure IS73 located at the intersection of Edgewood and Oakland Avenues. This is where the local system connects to the MIS (MS0505 through Providence Avenue sewer and Intercepting Structure IS73) and the ISS (NS-4 through P5948 and IS73).

- Wet weather outflow in excess of the design flow of the 39-inch MIS diverts to the ISS through a 72-inch diameter CSO connected to drop shaft NS-4. Should the ISS gates at NS-4 be closed, the 72-inch CSO may overflow to the Milwaukee River and continue to provide the subject local system a free outfall throughout the duration of the runoff event.

The hydraulic analysis used in this study uses the computer program XP-SWMM, an advanced modeling tool that can simulate underground and surface conveyance facilities with equal ease and accuracy. The software is also particularly well suited to unsteady state modeling of flows and hydraulic heads throughout complex hydraulic systems. In general terms, the hydraulic system consists of the following three components:

- Combined sewer network
- Storm sewer network
- Street (gutter flow) conveyance

The computer model created for this project includes approximately 95,000 lineal feet of combined sewer pipes in Shorewood, about 100,000 feet of street conveyance, and approximately 15,000 feet of storm sewer pipes.

The hydraulic model includes street flows as part of the overall movement of runoff in the study area. This feature is important because of the need to quantify the volume of runoff that will be handled on the surface once the inlet flows are regulated. The streets are modeled as open channels to represent gutter flow and street ponding. Overall, approximately 100,000 lineal feet of street flow and/or storage are modeled.

This component of the model describes how the runoff that cannot enter the catch basin will travel to the next catch basin, and so on, until it starts ponding in depressions. In other words, this analysis describes the consequences of reduced surface drainage and identifies those areas that are likely to be inundated during storms.

While most of the main pipes are already included in our models, none of the streets or other topographical characteristics have ever been modeled before. With this new project, the entire study area is identified, defined, and added to the computer models, including existing depressions, street elevations, slopes, etc.

The portion of the study area in Milwaukee consists of two separate sub-areas roughly divided by the UWM Campus. In general, the UWM campus and the residential areas east of the campus drain to the intersection of Edgewood and Maryland Avenues. The residential areas to the west of the campus drain to the intersection of Edgewood and Oakland Avenues.

- Approximately 11,500 feet of combined sewers serve the needs of the UWM Campus and the residential areas bound by Maryland Avenue, Edgewood Avenue, Lake Drive and Hampshire Street.
- Approximately 13,000 feet of combined sewers serve the area bound by Maryland Avenue, Edgewood Avenue, Oakland Avenue, and Hartford Avenue.

This component of the analysis includes the addition of the Milwaukee combined sewers into the model using the information provided by the City of Milwaukee and other materials available to MMSD and/or the Village of Shorewood.

❑ Hydraulics: Conveyance System Evaluation Criteria

Conventional steady state hydraulic capacity evaluations generally consider full flow capacities of hydraulic conduits, and compare this value to the calculated peak runoff rates to determine conduit design adequacy. However, in an extensive pipe network such as the one under consideration, the evaluation of system component adequacy will depend on the overall hydraulic pressures developed within the entire system as a result of the design runoff conditions.

The evaluation of improvement alternatives will be exactly tailored to match the project purposes as previously defined.

Evaluation Criteria for Local Systems

The measure of the impact of flow management practices on local systems is the calculated risk of basement backup during the design rainfall. In order to identify current basement backup risks and evaluate risk reduction strategies, we calculate the hydraulic head at each conveyance node (i.e., manhole) and compare this elevation to the ground surface elevation.

The topography and building types in the analysis area are such that if the hydraulic grade line elevations do not reach a level approximately 6 feet below the street elevation (as represented by the manhole rim elevation), then it is likely that basement flooding will not occur.

Consequently, all pipes with pressure levels more than 6 feet below street grade are considered adequate, any with less than 6 feet are considered to pose a backup risk for the buildings along it. This criterion will henceforth be referred to as the "6 ft. freeboard" rule.

Evaluation Criteria for MMSD Systems

All MMSD impacts are calculated across a range of design rainfalls, and the results are included as a project deliverable for further analysis and evaluation.

In order to quantify the impact of adopted flow management measures on MMSD operated systems, we have selected the total runoff volume, average flow rate, and peak flow rate at Intercepting Structure IS73 located at the intersection of Edgewood and Oakland Avenues. In general QUALITATIVE terms, the peak and average flow rates and the total runoff volume is expected to have the following behavior in response to runoff management practices in the study area.

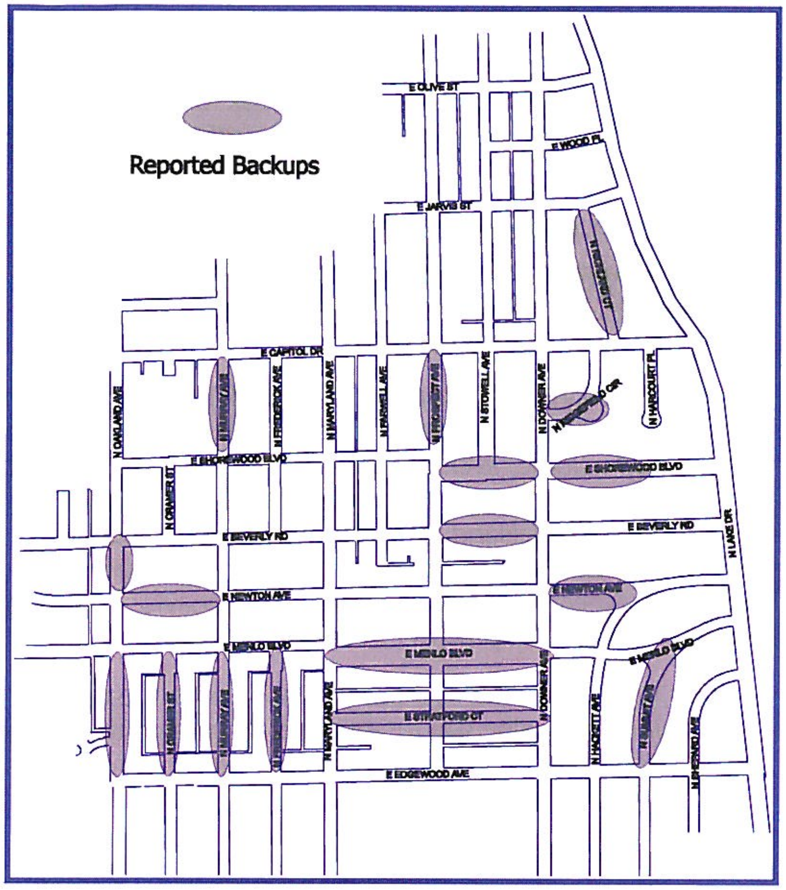
- With increasing hydraulic capacity, as in the case of increased pipe size for example, the peak and average flow rates at IS73 would be expected to increase, while the total volume of runoff would remain relatively unchanged.
- In general, as the network pressures drop, the average and peak flow rates would be expected to drop, while the total volume would remain relatively unchanged.
- Where sewer separation occurs, or whenever runoff is removed from the combined sewer system, peak and average flows, as well as total runoff volumes would be expected to drop.

❑ Hydraulics: Behavior of the Existing System

Three of the more severe rainfalls that occurred in 1999 were used to calibrate the model's predictive capabilities. This work included the comparison of analysis results to the reported sewer backup locations. The rains in question occurred on June 12 (3.13 inches in 6 hours), June 28 (1.9 inches in 30 minutes), and July 21 (3.16 inches in 3 hours).

Basement backup complaints were collected by the Village of Shorewood Department of Public Works and summarized on a map similar to the one shown on the following page. In each block, a number of residences were affected; therefore, the total number of people affected by basement backups in 1999 was considerable.

In contrast, no basement backups were reported in the Milwaukee portion of the study area, a fact that indicates that adequate hydraulic capacity is available.



From a hydraulic stand point, the July 21, 1999 event represents the most severe rainfall. Therefore, our computer model successfully predicted backups at several blocks that actually experienced them.

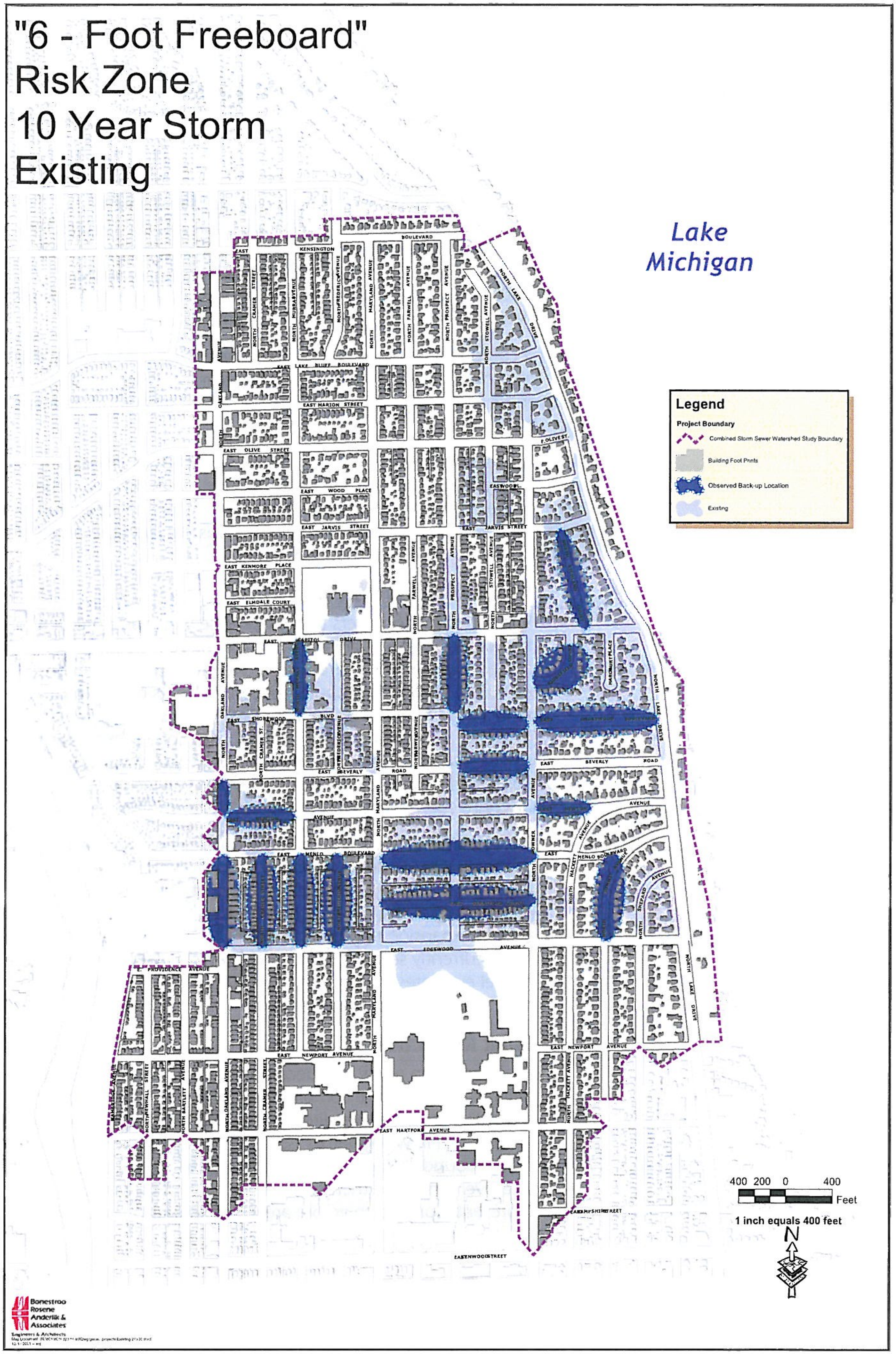
The hydraulic simulations are presented as regions with high backup risk as determined by the "6-foot freeboard rule" described earlier. The high backup risk regions under existing conditions correlate closely with the observed and reported locations of basement backups.

Our analysis indicates that the sewer backup problems that occur in the Shorewood combined service area have the following causes:

- According to some studies, the combined capacity of the 39-inch special section MIS that handles dry weather flow and the 72-inch diameter CSO that handles wet and extreme wet weather flows from the southeastern portion of the Shorewood study area does not contribute to the sewer backup problems while other studies indicate the opposite. However, it is not the intent of the present study to evaluate the existing conditions at this location of the system.
- Upstream of the MIS and the CSO, the lack of hydraulic capacity in the Edgewood sewer is the cause of sewer backups in the southern portion of the Shorewood combined service area. Our analysis reveals that the entire Edgewood sewer from Maryland to Oakland is below capacity.
- Lack of capacity in the Prospect and Shorewood Boulevard sewers is the cause of sewer backups in the northeast portion of the Shorewood combined service area.
- Flat pipe slopes in the 48-inch line in Murray Avenue between Shorewood Boulevard and Newton Avenue cause the reported backups in this area.

The following map of the existing backup risks clearly shows that the hydrologic and hydraulic analysis is a reasonably accurate representation of the combined sewer service levels in the study area. Based on this conclusion, we can further conclude that the model can be used to evaluate the effectiveness of flow management measures and provide a reasonably accurate indication of the performance of improvement alternatives.

"6 - Foot Freeboard" Risk Zone 10 Year Storm Existing



Volume and Peak Reduction Measures

A major objective of the present study is the quantification of the expected performance benefits of various flow management components for runoff control. Most runoff controls can be directly modeled to provide reliable simulation results for evaluation. These include street storage, catch basin flow regulators, downspout disconnection, expanded storm sewer service, surface or underground storage facilities, and pipe capacity improvements.

Both the computer simulations and the recommended implementation items will provide qualitative and quantitative information on the effectiveness and applicability of the management techniques in this and other similar areas.

The evaluation of benefits that may be achieved by these measures was performed by MMSD and other consultants for use in this and other similar studies currently underway. Consequently, we have worked with MMSD and other consultants to obtain a consistent measure of benefits for on-lot practices to be used in our models.

Volume Reduction Measures

Volume reduction refers to the decrease in the amount of runoff handled by the combined sewer system. Volume reduction in the subject combined sewer service area is realistic and can be evaluated through computer modeling. In its purest form, volume control involves partial or complete separation and therefore will include either the expansion of the existing storm sewer system, or the construction of new storm sewers. Volume control that addresses roof top drainage will include downspout disconnection in addition to expanded storm sewer service.

Using the pipe and street hydraulic models, we have evaluated the feasibility of partial separation in the combined service area with and without downspout disconnection. This model will allow the evaluation of any excess capacity and the potential for system expansion to pick up additional street or roof runoff from areas currently served by combined sewers. In addition, the model evaluates the effect of downspout disconnection in the northern portion of the watershed.

Peak Reduction Measures

Peak reduction refers to a decrease in peak flow rates of runoff being handled by the combined sewer system. Several peak reduction measures are directly modeled in the computer model. Catch basin flow regulators, street storage, off line surface, underground storage, and combined sewer pipe capacity improvements lend themselves to reliable mathematical representation and therefore are included in this evaluation.

The computer simulations provide a range of benefits with increasing levels of implementation complexity. We have evaluated the optimum combination of volume and peak control measures from all runoff sources to arrive at a comprehensive and cost effective solution to the problem.

A total of nineteen alternative scenarios, consisting of different combinations of runoff control measures, were developed and analyzed. In addition, we have the existing (i.e., baseline) conditions as described in the previous section of this report. The hydrologic component of the analysis uses the SEWRPC TR-40 rainfall depths and the associated 90th percentile distributions for the 0.25, 0.5, 1, 2, 5, 10, 25, and 100 year events for each of the scenarios.

❑ Downspout Disconnection in the Shorewood Combined Sewer - Storm Sewer Service Area

HIGH effectiveness in volume and peak reduction

LOW to MEDIUM implementation cost

May require construction of a collection system

The northern portion of the service area in Shorewood is served by a dual combined sewer - storm sewer system. Within this area, this measure aims to reduce the peak flow rate and the volume of runoff entering the combined sewers by redirecting roof runoff from the combined system into the storm system. Downspout disconnection in the Shorewood combined sewer – storm sewer service area was found to be very effective and should be included in the flow management strategy in this study area.

In order to examine the effect of disconnection rates on overall flow reduction, we evaluated two disconnection rates: the disconnection of 50 percent of the roof downspouts was considered to be reasonable since some downspouts may not have free flow paths to the streets or lawns (i.e. the rear of the homes). There are 840 homes in the area served by storm sewers. In the context of this study, a 50 percent rate of disconnection success either refers to completely disconnecting the downspouts of 420 homes, or disconnecting half of the downspouts from all 840 homes.

We also analyzed 100 percent removal of roof runoff from the combined system in order to provide an upper boundary for the level of volume and peak reduction that can be expected from downspout disconnection.

We assumed that participation and effectiveness will be directly proportional. This assumption of direct relationship between flow reduction and participation rate has also been adopted by the Ad HOC modeling team in various evaluations of runoff reduction techniques.

Downspouts draining toward the streets would be disconnected at the ground level or underground at the property line. Drainage would be maintained with either overland flow, assisted by pipes or troughs, or by underground pipes or drain tiles that outlet at the street or are conveyed by a collection system to the storm sewer. The collection system would be placed in the boulevard behind the curb and discharge into the nearest storm sewer catch basin.

The modeling of this measure was performed by transferring 50 or 100 percent of the roof runoff from combined sewers to storm sewers.

Downspout disconnection, in its simplest form can be achieved with very little expense. Typically, the cost for each downspout will range from $150 to $250. However, for maximum public acceptance of the idea, it may be preferable to install a downspout collection system that will route the downspout flow into the storm sewers.

The downspout disconnection in the storm sewer service area is an important component of wet weather flow management. Implemented at the rate of 50 percent, and during the 10 year rainfall, we estimate that the freeboard in the combined sewer network will INCREASE by 20 percent and the total runoff volume carried by the local system to the MMSD structure IS73 will DECREASE by 10 percent. Freeboard increase and runoff volume decrease amounts in the local system have been found to vary according to the rainfall amount. Generally, both the freeboard increase and the volume decrease are inversely proportional to the rainfall amount.

We would expect that the reduction in the flow delivered to IS73 by the Shorewood combined system will have continued downstream benefits; the numerical evaluation and quantification of these benefits is the topic of the response to Ad HOC request 17, the results of which will be presented to the MMSD by the Ad HOC modeling consultant.

Downspout disconnection in the combined sewer - storm sewer area has two very important challenges to overcome: increased nonpoint source pollution and increased inflow/infiltration (I/I) potential.

By definition, the more widespread downspout disconnection is, the more runoff will be discharged into Lake Michigan because more impervious surface will be added to the watershed. The increase in the amount of water in the streets will also mean that the pollutant wash-off potential of each rainfall will increase. In the absence of best management practices, this means that the average annual nonpoint source pollutant loading to Lake Michigan will increase as downspouts are disconnected in the storm sewer service area.

The challenge of increased nonpoint source pollution is met by implementing treatment, filtration or infiltration practices to reduce pollutants discharged to Lake Michigan. To this end, the project proposes the use of on-lot stormwater quality practices, without which significant increases in nonpoint source pollution may result.

While the runoff from the disconnected downspouts is eventually collected by storm sewers, more runoff at the ground surface means increased potential for I/I into the combined sewer system. While this is not as important as the I/I problem in separated sewers, any water that finds its way back into the combined sewers from the surface will decrease the benefits of downspout disconnection.

Potential I/I risks of downspout disconnection include:

- Infiltration through the sewer lateral due to ground saturation in front yards receiving downspout discharge,
- Infiltration through the sewer lateral due to ground saturation in yards equipped with infiltration practices such as rain gardens,
- Inflow through foundation drains connected to the sanitary laterals due to higher ground saturation around buildings,
- Inflow through leaking of storm sewers into the sanitary sewer laterals wherever the latter crosses under the former.

The challenge of increased I/I risk is met by placing infiltration devices as far away from the sanitary laterals as feasible, by extending the disconnected downspouts at least 5 feet from the basement wall, and installing collection systems that convey the runoff to the nearest storm sewer wherever feasible.

Downspout Disconnection in the Shorewood Combined Sewer Service Area

NO volume reduction

LOW to MEDIUM peak reduction depending on other complimentary measures like inlet restriction, on-lot practices.

LOW implementation cost

This measure consists of expanding downspout disconnection measures to the southern portion of the Village served exclusively by combined sewers. While this measure does not remove the runoff from the combined system, it allows us to put the runoff upstream of potential management practices instead of introducing into the combined sewer pipe immediately at the start of the rain. We note however that, after it is disconnected, all or some of the downspout flow still needs to travel to the nearest combined sewer catch basin.

Downspout disconnection in this area allows us to increase the performance and effectiveness of inlet flow regulators by subjecting more of the runoff to restriction and regulation. It also allows us to infiltrate more of the flow by either directing the downspouts to lawns or, better yet, rain gardens or rain barrels. From a hydrologic stand point, combined area downspout disconnection means that the roof runoff which is normally generated by the 100 percent impervious roof surface can now be directed to either a PERVIOUS surface (i.e., lawn, rain garden), or an on-lot storage device, i.e., rain barrel. These practices are further explored in the next section of the report.

In sharp contrast to the storm sewer area, the downspout disconnection in the combined sewer area needs to be coordinated with on-lot practices and inlet restrictors. The effectiveness of downspout disconnection in the Shorewood combined sewer service area can be dramatically increased through the use of on-lot practices to infiltrate and further slow the runoff down. Similarly, the use of inlet flow regulators in this area can result in a substantial increase in benefit to downspout disconnection.

We selected an implementation rate of 50 percent as a benchmark point for the area. We assumed that participation and effectiveness will be directly proportional. This assumption of direct relationship between flow reduction and participation rate has also been adopted by the Ad HOC modeling team in various evaluations of runoff reduction techniques.

There are 1,350 homes in the area served by combined sewers. In the context of this study, a 50 percent rate of disconnection success refers to completely disconnecting the downspouts of 675 homes, or disconnecting half of the downspouts from all 1,350 homes.

Downspout disconnection in the combined sewer area does not increase the average annual nonpoint source pollution to the area waters because the combined system continues to receive all runoff in the area.

In contrast to the storm sewer area, the increase in I/I due to downspout disconnection in the combined sewer area is not likely to negate the effectiveness of the measure because in the combined area, the disconnection aims to RETARD the flow into the combined sewer, not to REMOVE it.

On-Lot Flow Management in the Shorewood Storm Sewer and Combined Sewer Service Area

On-lot peak and volume control practices are evaluated for implementation in both the storm sewer and combined sewer service areas of the village. In the storm sewer service area, on-lot measures are intended as a runoff volume reduction technique to help with water quality improvements. In the combined sewer service area, on-lot measures are intended to complement the benefits obtained from downspout disconnection and inlet restriction.

Moderate volume and peak reduction

Requires downspout disconnection

LOW implementation cost

Private property installation may be challenging

Contributes to WATER QUALITY by reducing runoff volume

In this study, rain barrels and rain gardens are the primary means of achieving the desired on-site volume and peak control. Other possible methods include green roofs, roof storage, and green parking lots.

Peak flow and volume reduction benefits provided by rain barrels, rain gardens, and the accompanying downspout disconnection were all analyzed by MMSD's consultants and provided to the project team for inclusion in hydrologic and hydraulic modeling. The benefits appear to be quite important, and result in measurable reduction in peak flows and volumes reaching the combined sewers.

It should be noted that MMSD consultants evaluated these on-lot measures by using a generalized sample residential block in the City of Milwaukee. Minor changes in impervious/pervious area ratios and varying soil conditions may mean that the expected benefits may be different in the project area. Nevertheless, it is clear that on-lot measures do result in a net reduction of runoff volumes and peak flow rates under most conditions.

According to the Ad HOC modeling team's recent work on this topic, at a typical residential property, rain barrels can result in approximately 5 percent reduction in total volume and 10 percent reduction in peak flow rates during the 10-year rainfall. For small storms (i.e., common rains) rain barrels are much more effective, and volume reduction rates of 15 percent can be expected during rainfalls of less than an inch.

Rain gardens are even more effective because they tend to have a larger storage volume and can take advantage of natural infiltration. Compared to a patch of conventional lawn, a rain garden allows about 30 percent more water to soak into the ground. By reducing the amount of water that enters the local storm drain systems, rain gardens can also reduce the chances of local flooding, and reduce bank and shoreline damage where storm drains empty into streams and lakes.

A rain garden is an infiltration device in which stormwater runoff is the main water supply for the plantings. The garden is planted at the end of a downspout or at a low area where water collects, like a drainage swale. The plants used in the garden are selected based on site-specific growing conditions, such as the amount of sunlight available and the underlying soil conditions. During typical rains, the gardens infiltrate most of the runoff generated from the area and use it to sustain the plantings. As such, pollutants are removed as well.

According to the latest studies by the Ad HOC modeling team, a typical rain garden at a typical residential lot can result in a 25 percent reduction in total volume and 22 percent reduction in peak flow rates during the 10-year rainfall. For small (i.e., common rains) rain gardens are found to achieve volume reduction rates of 38 percent can be expected during rainfalls of less than an inch.

It is important to note that the volume and peak reduction rates are assumed to be linearly related to installation rates. In other words, if we manage to install on-lot practices at a quarter of the properties, we can expect to achieve about a fourth of the volume and peak reductions identified above.

On-lot practices such as rain gardens can increase I/I potential and in the storm sewer area, this may reduce the efficiency and effectiveness of downspout disconnection efforts.

By definition, a rain garden is an infiltration and evapo-transpiration facility. Because of this, we must assume that ground saturation in the vicinity of the garden will increase and that we must ensure proper horizontal and vertical separation between the garden and combined sewers and sanitary laterals.

Potential I/I risks of rain gardens include:

- Infiltration through the sewer lateral due to ground saturation in the vicinity of the garden,
- Inflow through foundation drains connected to the sanitary laterals due to higher ground saturation in the vicinity of the garden,

The challenge of increased I/I risk is met by placing rain gardens as far away from the sanitary laterals as feasible.

❑ Inlet Flow Regulators and Street Storage in the Shorewood Combined Sewer Service Area

No volume reduction

Significant peak reduction

Minimal cost for inlet flow regulators

MEDIUM to HIGH cost for storage components

In recent years, inlet restrictors or flow regulators have been used in several municipalities to control combined sewer wet weather flows when the addition of hydraulic capacity is economically unfeasible. In the Milwaukee area, such devices have only been used on a trial basis, e.g., by Shorewood, while Illinois municipalities like Chicago, Wilmette, Skokie, and Evansville, have used these devices as part of a flow management system to solve recurring sewer backup problems.

The flow rate reduction is achieved through the use of low-flow grates or through inlet restrictors that limit the maximum flow introduced into the system at each catch basin or inlet location. This means that there is always an upper limit to the flow within the system regardless of the rainfall amount. In effect, the flow regulators, when placed judiciously, limit the hydraulic grade elevations in the system and always protect basements from backups by transferring the standing water to the streets or other storage areas. An obvious requirement for this approach is adequate gutter and street storage capacity in the affected areas of the Village.

There are about 302 catch basins in the Shorewood combined sewer service area. These catch basins are found in 130 "clusters" or groups, so it is likely that a flow restrictor is not warranted at each and every one of the catch basins because several are inter-connected upstream of the combined sewer connection.

In the computer model, the flow regulators were represented at each catch basin. Each catch basin is assigned a capacity of 0.15 cubic feet per second (cfs). Runoff that exceeds this capacity flows on to the next available inlet location using the street as a conduit. Obviously, if the street grades so dictate, localized ponding (street flooding) will occur. The computer model is able to simulate this behavior.

The installation of flow regulators will mean that a handful of streets will experience temporary flooding due to increased surface flows. We recommend that these street segments be clearly identified and publicized. At the location of the expected street flooding we recommend that regulators NOT be installed.

In addition to surface storage in low lying areas, we also evaluated the construction on underground in-line storage facilities consisting of large diameter pipes placed as warranted by the hydraulics of the combined system. The in-line storage will be obtained through the construction of oversized pipes paralleling existing pipes.

A potential underground storage facility can be located on Downer Avenue between Beverly Road and Edgewood Avenue. This unit is likely to be 1,250 feet long and consists of a 78 inch diameter pipe that will provide 1 acre-foot of storage. Due to its limited service area and high cost of construction (estimated $0.9 million) the in-line storage option was not pursued and is not recommended at this time.

❑ Separated Storm Sewer Service for UWM and Columbia-St. Mary's Hospital

Highly impervious institutional land uses have high benefit potential

Existing records indicate separate drainage and sewerage systems

Water Quality impacts must be mitigated

Successful separation means volume AND peak reduction

Our preliminary research and investigation reveals that UWM and the Hospital have separated drainage and sewerage systems that both discharge to municipal combined sewers. This means that the removal of runoff originating from these institutions from the combined sewers may be feasible.

In order to establish a benefit of separating storm sewers at UWM and the Hospital, we evaluated the hydraulic impacts of removing all or a portion of the clear water from the combined sewer system. Due in part to the high percentage of imperviousness at these two locations, storm sewer separation is expected to have a relatively important reduction in combined sewer flows.

It should be noted that the specific manner in which runoff will be separated, conveyed, treated, and discharged to Lake Michigan or Milwaukee River is outside the scope of the present study. Instead, we concentrate on evaluating the potential benefits of such a separation to determine if further engineering effort is warranted on this subject.

Our hydraulic evaluation of storm runoff separation from the University and the Hospital grounds assume that 50 percent of the runoff can be expected to be effectively removed from the combined sewer system.

This relatively modest implementation level is intended to reflect the potential limitations and constraints that may arise when the separation is contemplated.

The challenges of storm sewer separation at the university or the hospital grounds are numerous, including local topography, elevations of existing storm sewers, and availability of direct flow routes to the Milwaukee River or Lake Michigan. In addition, storm sewer separation means increased pollutant loading to the receiving water bodies. Any runoff management approach that diverts flow from the combined sewers will need to address water quality concerns and ensure that appropriate BMPs be implemented to treat the runoff.

❑ Storm Sewer Service Area Improvements in Shorewood

The northern third of the Village has two storm sewer networks that serve surface drainage needs by conveying street runoff to Lake Michigan at two outlets. This measure consists of two distinct initiatives working together to expand and consolidate the storm sewer service area:

Water Quality Impacts

The expansion of the storm sewer service area means that additional untreated runoff is added to existing storm sewer discharges.

We recommend that nonpoint source pollution loading estimates be included in the evaluation of all new storm sewer extension projects.

1. Consolidation of the storm service area by assessing catch basin connections to confirm that no catch basins remain connected to combined sewers.

   The Village catch basin atlas provides reliable information regarding the location of catch basins, but does not clearly indicate which pipe network the catch basins are connected to. To remedy this uncertainty, Village of Shorewood Department of Public Works personnel field has already inspected all catch basins in the storm sewer service area. The investigation revealed that catch basins at 10 locations are connected to the combined sewer system.

   These 10 locations represent small pockets where storm sewer service is not available and that street runoff is handled by combined sewers. It appears that these pockets are connected to the combined sewers because there are no storm pipes available nearby. However, with very limited storm sewer construction on five streets, 9 of the 10 pockets can be eliminated:

   - Approximately 400 ft. of 12 inch diameter pipe on Cramer Street, between Lake Bluff and Kensington,
   - Approximately 375 ft of 12 inch pipe on Lake Bluff, from Cramer to Oakland Avenue
   - Approximately 600 ft. of 12 inch diameter pipe on Prospect Avenue, between Lake Bluff and Kensington,
   - Approximately 450 ft of 12 inch pipe on Lake Drive, north of Lake Bluff,

- Approximately 750 ft of 12 inch pipe on Lake Drive, between Marion Street and Wood Place,
- Approximately 350 ft. of 12 inch pipe on Wood Place, between Stowell Avenue and Downer Avenue.

The catch basin at the cul-de-sac at the north end of Stowell Avenue will remain connected to the combined sewer because it has a very small drainage area and there are no existing storm sewer pipes that would serve this catch basin.

2. Analysis and assessment of potential expansion of storm sewer service to blocks or streets where topography allows gravity pipe construction.

   We identified 5 locations at the north end of the combined service area where the existing combined sewer inlets can be connected to existing storm sewers.

   The hydraulic analysis indicates that these existing storm sewers on Stowell, Downer, Richfield Court, between Capitol Drive and Jarvis Street will have the required capacity to handle the additional inlets. The estimated need for storm sewer construction is relatively minor:

   - Approximately 350 feet of 12 inch diameter pipe, and 2 catch basins on North Downer Avenue,
   - Approximately 375 feet of 12 inch diameter pipe, and 2 catch basins on North Stowell Avenue,
   - Approximately 380 feet of 12 inch diameter pipe, 400 feet of 15 inch pipe, and 6 catch basins on North Lake Drive,
   - 2 catch basins and catch basin leads on Richland Court

   The benefits of these storm sewer extensions are significant: by this small initiative, the storm sewer service coverage is increased by about 15 acres, and significant volume and peak flow reduction can be observed in combined sewers.

   In all rainfall analyses, the fairly minimal storm sewer installation provides measurable and significant benefits in controlling basement backups in the Richfield Court area.

While the additional storm sewers in the area will reduce combined sewer flows, the main challenge created by this approach is the net increase in runoff discharged into Lake Michigan, which means a net increase in nonpoint source pollution loading.

The challenge of increased nonpoint source pollution should be met by implementing source control or end-of-pipe treatment practices to reduce pollutants discharged to Lake Michigan.

Flow Management Alternatives

The wet weather flow management alternatives considered in this study consist of different combinations of the volume and peak control measures as described in the previous section of this report.

The benefits we can expect from the measures are simulated using computer models, which allow us to combine different approaches into different groupings of volume and peak control measures.

The metrics selected for alternative effectiveness evaluation reflect the study's three main priorities and objectives:

The freeboard metric is measured as the arithmetic average across the entire combined sewer network.

Individual backup risk areas are shown on freeboard maps.

The volume metric is a direct measure of the amount of runoff that can be expected at MMSD systems.

The peak flow rate metric is an indirect measure of the severity of the runoff event.

- Basement backup risk is described and measured by the hydraulic grade line elevation with respect to the first floor elevation. The measure of this risk is the "6 foot freeboard" concept described earlier. Freeboard is calculated at each network node and plotted as a hydraulic grade elevation contour across the study area. Under existing conditions, the "6 foot freeboard" contour shows the basement backup risk area. As flow management measures are implemented, the size of the risk area shrinks, indicating reduced basement backup risks.
- Peak flow reduction benefits are described and measured by the instantaneous peak flow rate at the manhole where the local systems connect to the MIS, i.e., IS73 and IS74. The peak flow rate is a good indication of the amount of runoff MMSD systems are required to handle during the height of the rainfall and can have a large impact on the hydraulic grade lines everywhere in the network.
- Volume reduction benefits are described and measured by the computed total volume of runoff at the manhole where the local Shorewood system connects to the MIS, i.e., IS73. The volume is computed through the duration of the runoff event, with sufficient time allowed for the entire runoff hydrograph to move through the node. Any volume reduction computed at this node represents a decrease in the amount of runoff that must be managed and handled by MMSD systems.

At this stage, our focus is on whether the flow management techniques can be an alternative to pipe upgrades that deliver the basement backup and volume reduction benefits we are seeking. The cost of implementation will be brought into the overall flow management approach after we identify which alternatives are selected for implementation.

The overall demonstration value of the project consists therefore of two essential elements: first, we establish methods and means to predict the expected performance of management alternatives; second, we conduct a large scale field implementation program to verify and quantify the simulated benefits.

Using the three metrics presented here we have evaluated fifteen combinations of the six management measures described in the previous section. Our objective was to identify the optimum combination of measures that provide the desired outcomes while providing maximum flexibility in implementation, economic feasibility, and a reasonable expectation of fruition. The table on the following page lists the components of each management alternative.

We began our alternatives evaluation by assessing the impacts of individual impacts on the three metrics. Though it likely that no single measure will be implemented by itself, it is important to identify the strengths of each measure so that more intelligent and feasible combinations can be put together. Of course, to be truly effective, downspout disconnection in the combined area is most reasonably implemented in conjunction with one other measure such as either inlet restriction or on-lot practices. Therefore, Measures 2 and 3 or 2 and 4 should be considered as package deals in this context.

The implementation rates used for downspout disconnection and on-lot practices are 0, 50 and 100 percent. Based on the assumption that runoff reduction is directly proportional to the number of instances of implementation, our intention is to establish a relationship between properties included and runoff reduced.

The following alternatives represent single measures:

- Alternative 1 represents the effectiveness of downspout disconnection with 50 percent implementation rate in the storm sewer area.
- Alternative 9 represents the effectiveness of downspout disconnection with 100 percent implementation rate in the storm sewer area.
- Alternative 2 represents the effectiveness of inlet flow regulators in the combined sewer area.
- Alternative 4 represents the effectiveness of downspout disconnection in the combined sewer area along with inlet regulators.
- Alternative 6 represents the effectiveness of downspout disconnection in the combined sewer area along with on-lot practices.

	Management Measures to be Implemented in Shorewood				
	Downspout disconnection in storm sewer area	Downspout disconnection in combined sewer area	Rain Barrels/ Gardens	Inlet flow regulators	Shorewood Storm sewer
Alt 1	50% removal				
Alt 1a	50% removal				y
Alt 1b	100% removal				y
Alt 2				y	
Alt 3	50% removal			y	
Alt 3a	50% removal			y	y
Alt 3b	100% removal			y	y
Alt 4		50% removal		y	
Alt 5	50% removal	50% removal		y	
Alt 5a	50% removal	50% removal		y	y
Alt 5b	100% removal	50% removal		y	y
Alt 6		50% removal	50% of properties		
Alt 7		50% removal	50% of properties	y	
Alt 8	50% removal	50% removal	50% of properties	y	
Alt 9	100% removal				

Note that Alternatives 11 through 14 describe flow management initiatives to be undertaken in the City of Milwaukee, including storm separation on the University and Hospital grounds. These alternatives are considered separately from the Shorewood initiatives because the flow reduction initiatives in Milwaukee residential areas, storm disconnection at the University, or the Hospital have been found to yield very little for the Edgewood sewer system and therefore should not be evaluated at IS73. Instead, we identified two locations where residential and institutional management activities can be evaluated:

- Princeton Avenue MIS and CSO, where flow management at the Hospital and residential areas west of Maryland and south of Edgewood Avenue.
- Junction chamber connecting Milwaukee and Shorewood combined sewers at the intersection of Edgewood and Maryland Avenues, where flow management at the University grounds and Milwaukee residential areas east of Maryland and south of Edgewood Avenues.

	Management Measures to be Implemented in Milwaukee			
	Downspout disconnection in combined sewer area	Rain Barrels/ Gardens	Storm sewer Separation at UWM	Storm sewer Separation at the Hospital
Alt 11			50% removal	50% removal
Alt 12			50% removal	
Alt 13				50% removal
Alt 14	50% removal	50% of properties		

❑ Basement Backup Risk Reduction Alternatives

Basement backup risk is measured by the computed hydraulic grade line during the 10-year rainfall event. As a measure of the overall hydraulic pressure in the system, we consider the average "freeboard" (ground elevation minus hydraulic grade line elevation) throughout the system, including Shorewood and Milwaukee combined sewers. While the backup risks (i.e., low freeboard elevations) are localized, the average value is found to represent the overall distribution of hydraulic pressures quite adequately for system evaluation purposes.

The following table lists the freeboard increasing benefits of each alternative in descending order as indicated by the relative increase in freeboard compared to existing conditions during the 10-year rainfall. The last column shows the normalized benefit by comparing the performance of each alternative to the MOST EFFECTIVE one. Using this normalized benefit concept, we can reach some important fundamental conclusions that frame project performance expectations and set realistic implementation goals.

Flow management activities in Milwaukee (i.e., Alternatives 11 through 14) have been found to be ineffective in increasing system-wide freeboard (1 percent or less increase) and therefore are not included in the summary of the computer modeling.

SYSTEM-WIDE FREEBOARD INCREASE AS AN INDICATOR OF BASEMENT BACKUP RISK REDUCTION				
	Average Freeboard (ft)	Freeboard Increase (ft)	Freeboard Increase	Normalized Freeboard Increase
Existing	7.49	0.00	0%	0%
Alt 6	8.03	0.54	7%	13%
Alt 1	8.53	1.04	14%	25%
Alt 1a	8.96	1.47	20%	35%
Alt 2	9.14	1.65	22%	40%
Alt 4	9.48	1.99	27%	48%
Alt 9	9.62	2.13	28%	51%
Alt 7	9.68	2.19	29%	53%
Alt 3	10.03	2.54	34%	61%
Alt 1b	10.26	2.77	37%	67%
Alt 5	10.28	2.79	37%	67%
Alt 8	10.43	2.94	39%	71%
Alt 3a	10.44	2.95	39%	71%
Alt 5a	10.62	3.13	42%	75%
Alt 3b	11.50	4.01	54%	96%
Alt 5b	11.66	4.17	56%	100%

The benefits of wet weather flow management on basement backup reduction are summarized as follows:

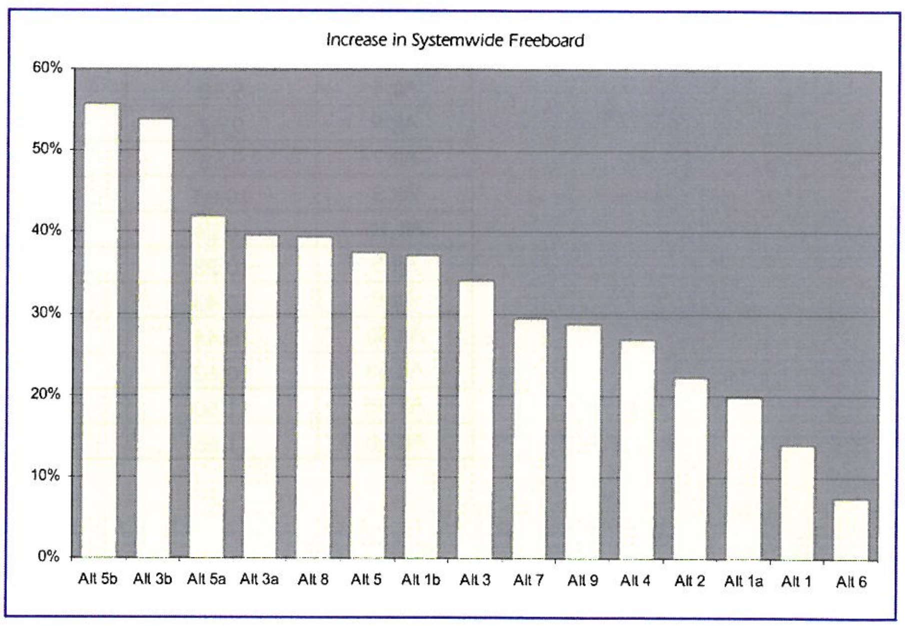
1. Among all measures considered, Alternatives 5b and 3b offer the highest level of freeboard increase, i.e., the highest level of basement backup risk reduction. With these alternatives in place, the average system-wide freeboard can be increased by about 50 percent during the 10-year rain.

2. Both 5b and 3b prescribe 100 percent removal of downspouts in the storm sewer area, the use of inlet flow regulators in the combined sewer area, limited storm sewer construction north of Capitol Drive. In addition, Alternative 5b includes 50 percent downspout disconnection in the combined area while 3b does not.

3. Alternatives 5a, 3a, 8, 5, and 1b bring similar benefits, all within about 10 percent of each other. These measures offer about 75 percent of the benefits offered by Alternatives 5b and 3b. With these alternatives in place, the average system-wide freeboard can be increased by about 40 percent during the 10-year rain.

4. When the average freeboard increase is about 35 percent or more, the performance of the system is similar to building large pipes throughout the Village and in the MMSD portions of the system. We therefore select the 56 percent freeboard increase as the maximum achievable in the context of this study.

5. The remaining management measures are found to bring freeboard increases of less than 35 percent, and therefore not considered to satisfy the basement backup risk reduction goals of the study. These alternatives are 3, 7, 9, 4, 2, 1a, 1, and 6.



Based on the foregoing evaluation, the following alternatives are considered to offer reasonable solutions for basement backup reduction in Shorewood:

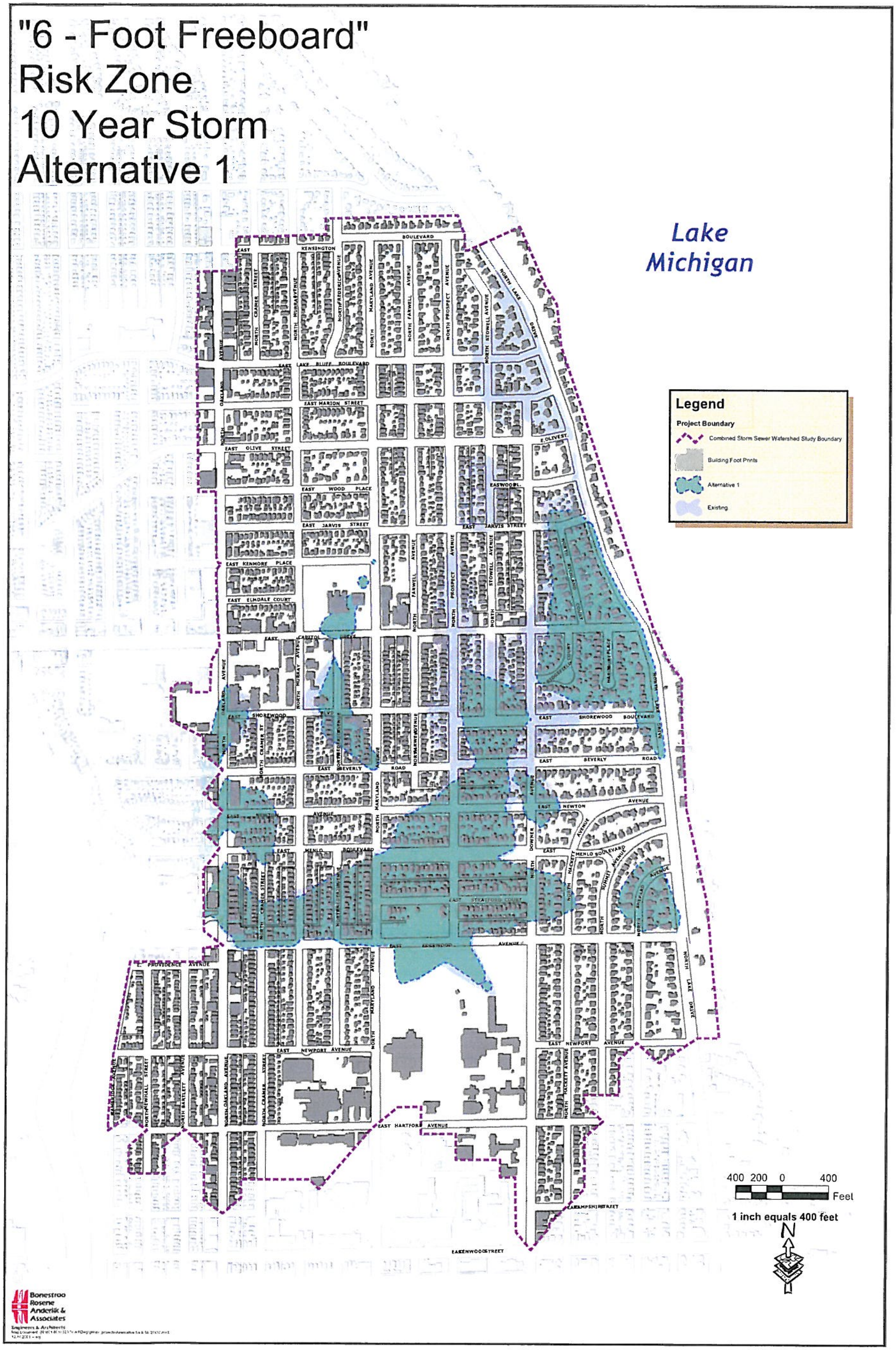
Basement Backup Risk Reduction Measures to be Implemented in Shorewood				
Downspout disconnection in storm sewer area	Downspout disconnection in combined sewer area	Rain Barrels/ Gardens	Inlet flow regulators	Shorewood Storm sewer
55% Increase in Freeboard				
100% success rate	Up to 50% success rate	n/a	installed in the combined area	constructed
40 to 35% Increase in Freeboard				
50% success rate	Up to 50% success rate	Implemented in up to 50% of properties	installed in the combined area	constructed

While the average freeboard increase is highest with Alternatives 5b and 3b, the actual decrease in basement backup risk improves only by a negligible amount compared to Alternatives 5a and 3a. In other words, once about 50 percent of downspouts are disconnection in the storm sewer service area, any additional disconnections will bring no appreciable additional reduction in basement backup risk area.

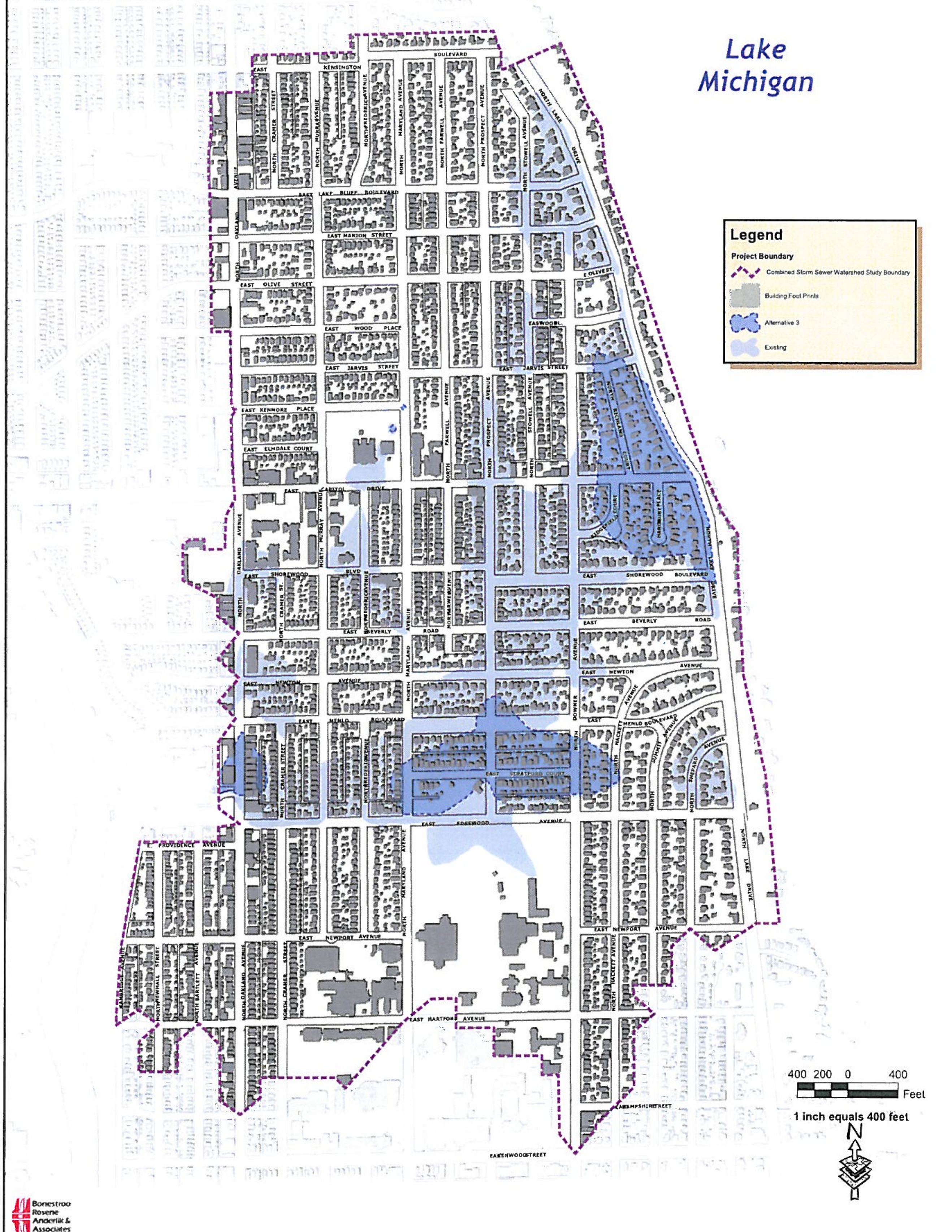
This is clearly shown on the following maps of the hydraulic analysis results for Alternatives 5a, 5b, 3a, 3b, 1a, and 1b where the difference in the size of the 6 foot freeboard is found to be negligible.

We therefore conclude that the 50 percent implementation rate for downspout disconnection in the storm sewer area is a minimum target and increasing this rate over 50 percent does not yield linearly increasing benefits as far as the basement backup risks are concerned.

"6 - Foot Freeboard" Risk Zone 10 Year Storm Alternative 1



"6 - Foot Freeboard"
Risk Zone
10 Year Storm
Alternative 3



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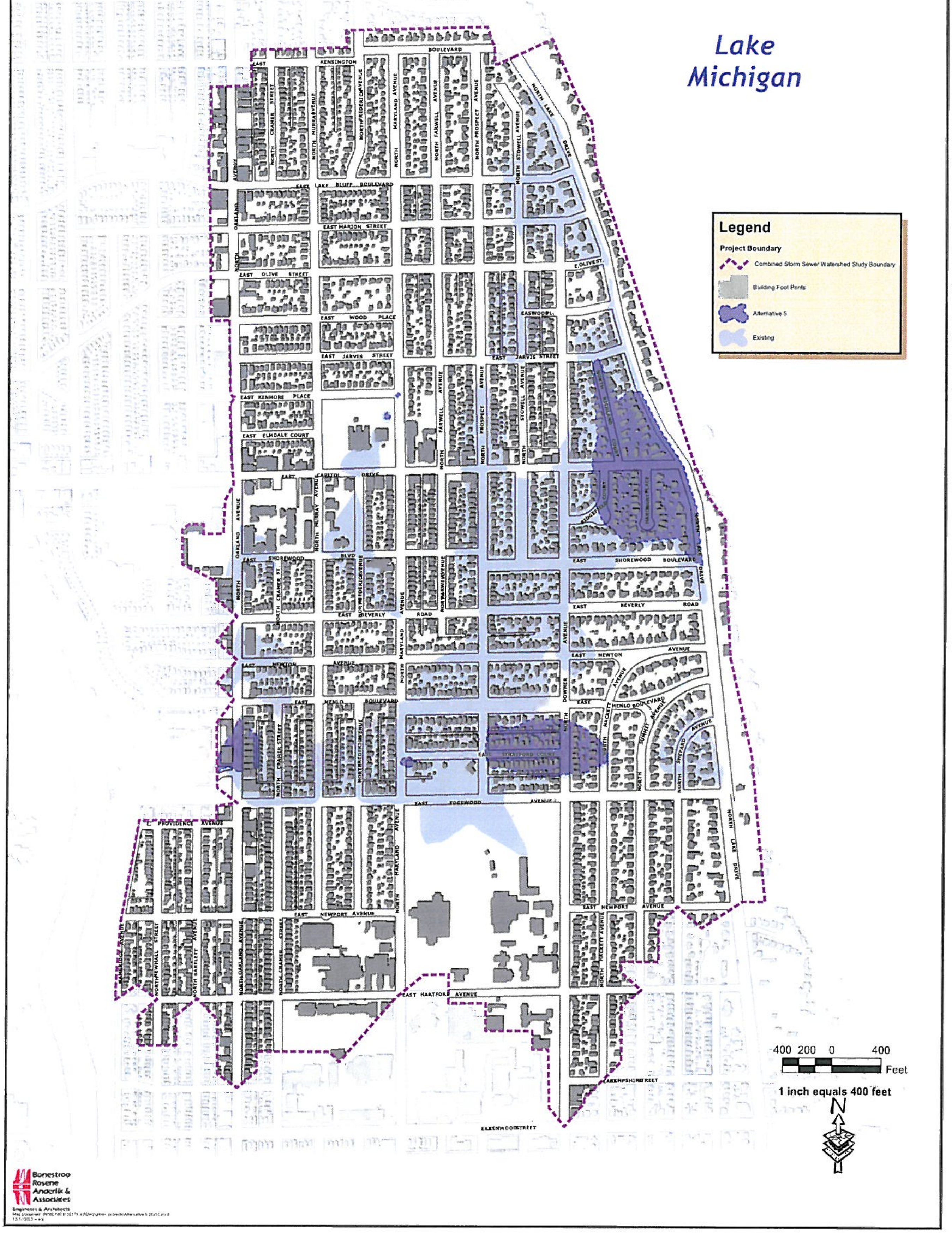
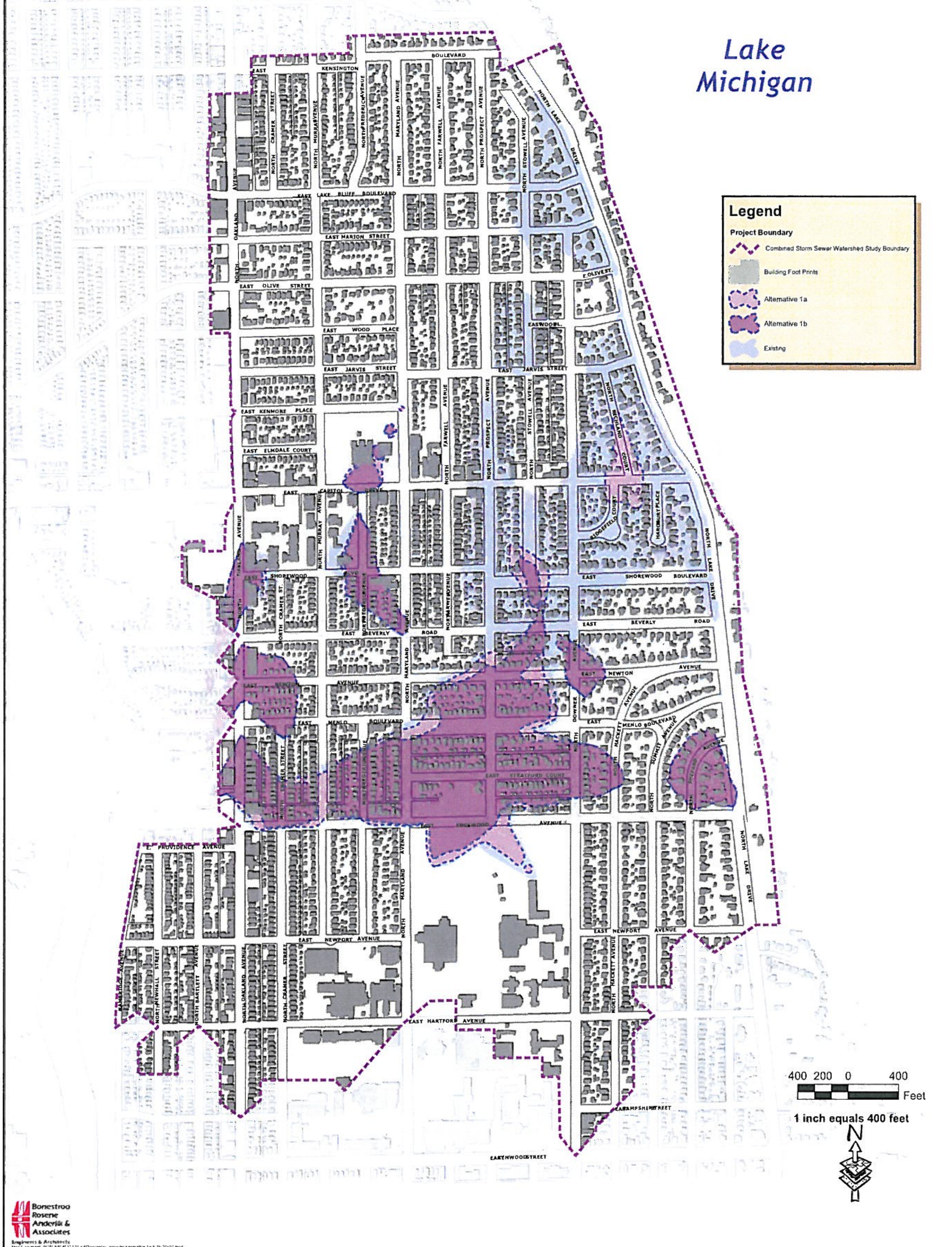
Engineers & Architects

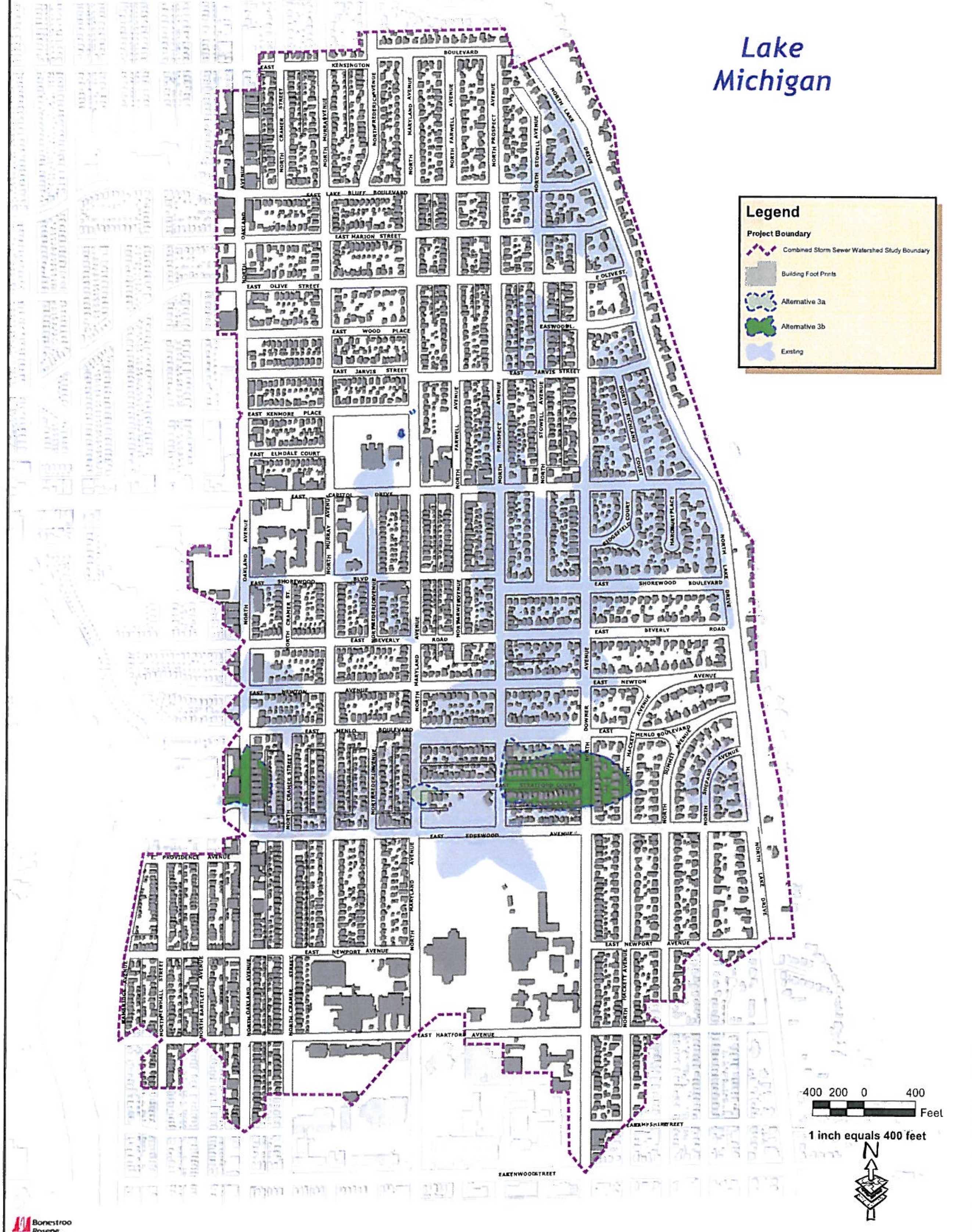
"6 - Foot Freeboard" Risk Zone 10 Year Storm Alternative 5



"6 - Foot Freeboard"
Risk Zone
10 Year Storm
Alternative 1a & 1b

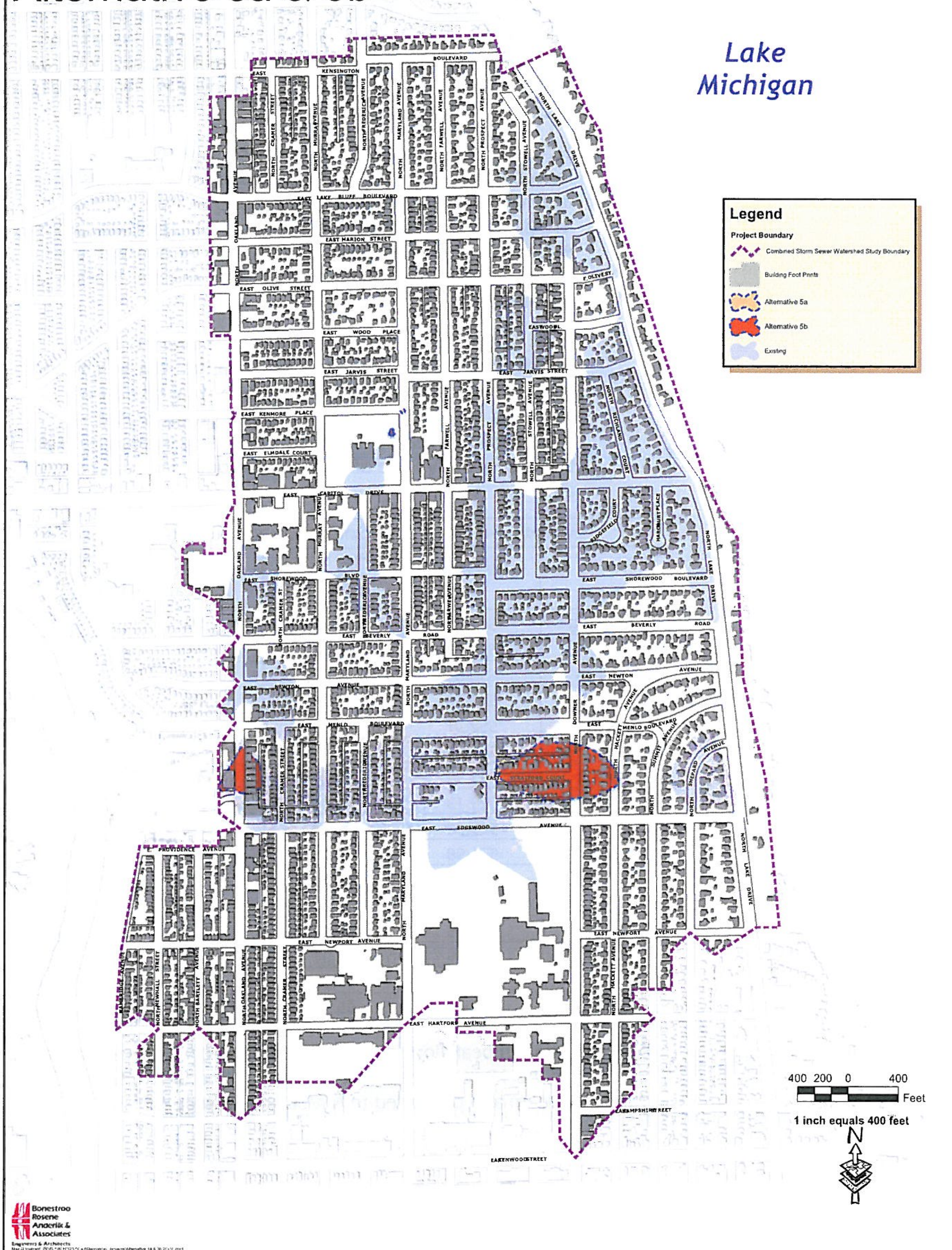


"6 - Foot Freeboard" Risk Zone 10 Year Storm Alternative 3a & 3b



Bonestroo Rosene Anderlik & Associates
Engineers & Architects

"6 - Foot Freeboard" Risk Zone 10 Year Storm Alternative 5a & 5b



❑ Peak Flow Reduction Alternatives

Peak flow reduction benefits due to flow management in Shorewood and Milwaukee will be evaluated at three different locations in the system:

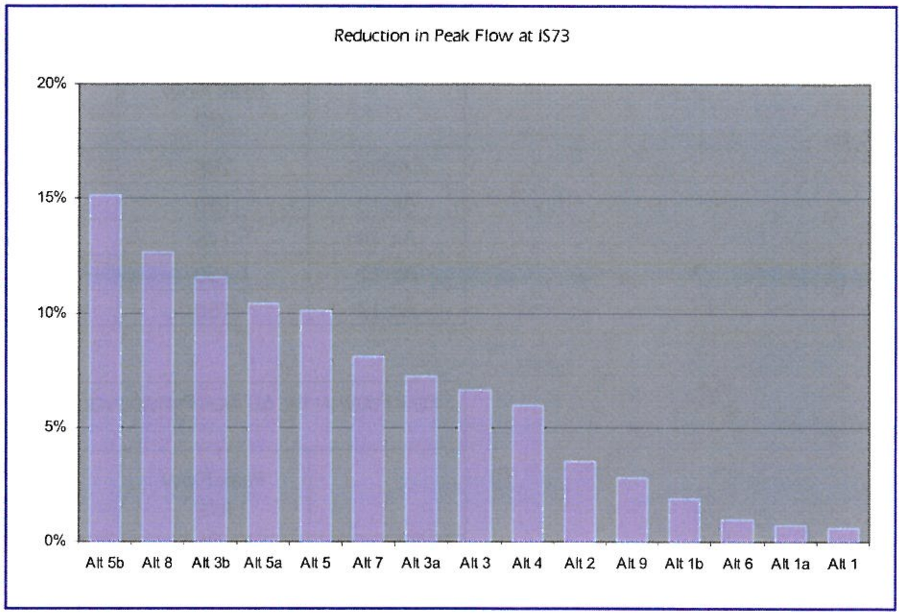
1. Peak flow at the junction manhole located at the intersection of Oakland and Edgewood Avenues measures the benefits of alternatives implemented in Shorewood. At this manhole, wet weather flows are split between the Providence Avenue MIS and the 72 inch diameter CSO.

2. Peak flow at the junction manhole at the intersection of Providence and Bartlett Avenues measures the benefits of alternatives implemented in Milwaukee, in areas west of Maryland, including the Columbia-St. Mary's Hospital grounds. At this manhole, wet weather flows are split between the Providence Avenue MIS and the 60 inch diameter Providence Avenue CSO.

3. Peak flow at the junction manhole at the intersection of Maryland and Edgewood Avenues measures the benefits of alternatives implemented in Milwaukee, in areas east of Maryland, including the UWM Campus grounds. At this manhole, wet weather flows from Milwaukee are joined with flows from the Village of Shorewood combined sewer service area.

PEAK FLOW IN THE 72 INCH CSO DOWNSTREAM OF IS73 DURING THE 10-YEAR RAINFALL				
	Peak Flow (cfs)	Peak Flow Decrease (cfs)	Peak Flow Decrease	Normalized Peak Flow Decrease
Existing	562.76	0.00	0%	0%
Alt 1	559.51	3.25	1%	4%
Alt 1a	558.65	4.11	1%	5%
Alt 6	557.17	5.59	1%	7%
Alt 1b	552.31	10.45	2%	12%
Alt 9	547.09	15.67	3%	18%
Alt 2	542.99	19.77	4%	23%
Alt 4	529.13	33.63	6%	39%
Alt 3	525.50	37.26	7%	44%
Alt 3a	521.98	40.78	7%	48%
Alt 7	517.10	45.66	8%	54%
Alt 5	505.95	56.81	10%	67%
Alt 5a	504.35	58.41	10%	68%
Alt 3b	497.75	65.01	12%	76%
Alt 8	491.50	71.26	13%	84%
Alt 5b	477.44	85.32	15%	100%

The reduction in peak flows discharged to the MIS at IS73 for rainfalls other than the 10 year event have been evaluated by the Ad HOC Modeling team and presented to MMSD under Request 17.



As the above graph shows, Alternative 5b is the most effective peak flow reduction method analyzed here. However, we should note that the peaks are only reduced by 15 percent over existing rates, so the peak control properties of the flow management alternatives do not appear to be as significant as freeboard control properties. Nevertheless, we select those alternatives that yield a greater than 10 percent reduction in peak flow rates as acceptable measures to control peak rates to a reasonable level. Accordingly, the following approach is considered to offer a reasonable solution for peak flow rate reduction at IS73:

Management Measures to be Implemented in Shorewood to Reduce Peak Flow Rates at IS73				
Downspout disconnection in storm sewer area	Downspout disconnection in combined sewer area	Rain Barrels/ Gardens	Inlet flow regulators	Shorewood Storm sewer
15 to 10% Decrease in 10-year peak flow rate				
50 to 100% success rate	Up to 50% success rate	Implemented in up to 50% of properties	installed in the combined area	constructed

Peak Flow Reduction in Milwaukee

Peak flow reductions due to measures implemented in Milwaukee are presented in the following tables and graphs. In general, we find that the opportunities presented by the university and hospital grounds are much more effective and promising than the measures that can be implemented in the residential areas of the Milwaukee combined sewer service area. The peak reduction in Milwaukee is measured at two locations as summarized in the following tables.

Peak Flow from Milwaukee at the Junction Chamber at Edgewood and Maryland During the 10-Year Rainfall				
	Peak Flow (cfs)	Peak Flow Decrease (cfs)	Peak Flow Decrease	Normalized Peak Flow Decrease
Existing	205	0	0%	0%
Alt 13	190	0	0%	0%
Alt 14	176	14	7%	33%
Alt 11	150	40	21%	100%
Alt 12	150	40	21%	100%

Peak Flow in the 60 inch Providence Avenue CSO Downstream of IS74 During the 10-Year Rainfall				
	Peak Flow (cfs)	Peak Flow Decrease (cfs)	Peak Flow Decrease	Normalized Peak Flow Decrease
Existing	190	0	0%	0%
Alt 12	197	8	4%	33%
Alt 13	194	11	5%	46%
Alt 14	190	15	7%	63%
Alt 11	181	24	12%	100%

Our computations show that, at the junction chamber at Edgewood and Maryland, the most important peak flow reduction benefits are provided by Alternative 11 (the separation of 50 percent of the runoff from within the UWM Campus and the Hospital grounds) and Alternative 12 (the separation of 50 percent of the runoff from within the Hospital grounds only).

A closer look indicates that the flow reduction calculated at Edgewood-Maryland is entirely due to the separation of 50 percent of the runoff from within the UWM Campus grounds. This reduction amounts to about 50 cfs, not an unimportant amount, but certainly not sizeable enough to have any realistic impact on hydraulic grade lines (i.e., basement backup risks) in any other location than the immediate vicinity of Edgewood and Maryland Avenues.

We also find that Alternative 14, with downspout disconnection and on-lot measures in 50 percent of residential properties yields limited peak flow reduction at Edgewood and Maryland. In fact, our models show that separating 50 percent of the runoff at the university campus would achieve three times the benefit derived from disconnecting downspout and installing on-lot practices at half of the residences.

> We conclude that the storm sewer separation at the university grounds should be a definite goal of any flow management activity in the portion of the study area east of Maryland Avenue.

At the Providence Avenue CSO, important peak flow reductions are realized with Alternative 11 (separation of 50 percent of the runoff from within the UWM Campus and the Hospital grounds). Interestingly, if we concentrate exclusively on the Providence Avenue CSO, the downspout disconnection and on-lot measures appear to be an acceptable approach to peak flow reduction.

Considering the entire Milwaukee combined sewer service area, Alternative 11 must be the recommended approach to realize a significant reduction in peak flows during the 10-year rainfall.

❑ Volume Reduction Alternatives

The estimated runoff generated from within the study area under existing conditions and during the 10-year rainfall event is 2.9 million cubic feet or 21.7 million gallons. To contextualize this amount for the entirety of MMSD system operations is the topic of a parallel study by the Ad HOC Modeling Team. Preliminary results by that team indicate that the runoff reduction techniques have modest volume reduction benefits under a variety of rainfall conditions. The findings are summarized in the memorandum addressing Request 17.

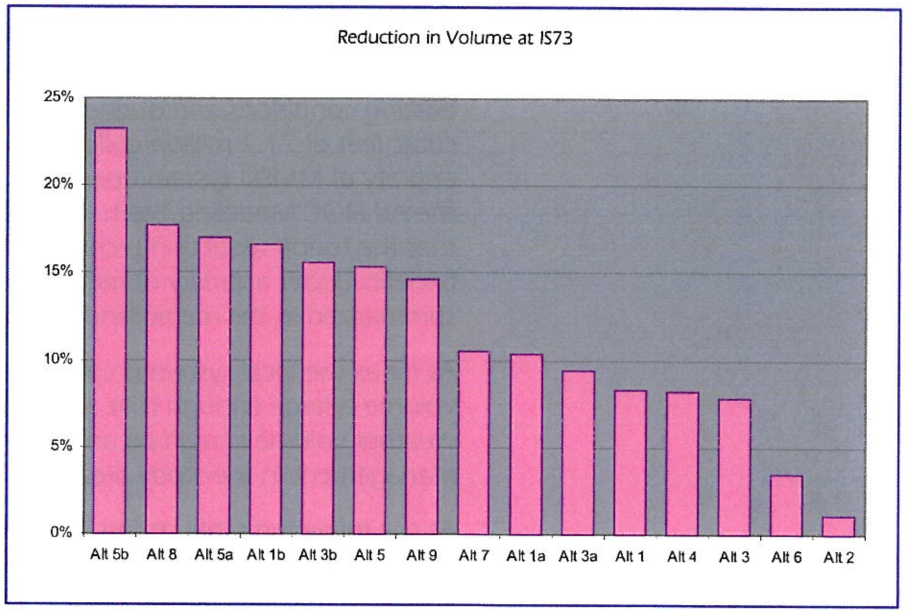
As far as the local system is concerned, we can state that the runoff volume is large enough that any potential reduction in total wet weather volume should be an important component of flow management in the study area.

As the following table shows, a number of different measures will yield volume reductions of 15 to 23 percent. In absolute terms, this means volume reductions between 3.1 and 5 million gallons during a 10-year rainfall.

Total Volume Decrease at IS73 During the 10-Year Rainfall				
	Total Volume (cu ft)	Volume Decrease (cu ft)	Volume Decrease	Normalized Volume Decrease
Existing	2,900,000	0	0%	0%
Alt 2	2,869,000	31,000	1%	5%
Alt 6	2,800,000	100,000	3%	15%
Alt 3	2,674,000	227,000	8%	34%
Alt 4	2,661,000	240,000	8%	35%
Alt 1	2,660,000	241,000	8%	36%
Alt 3a	2,627,000	274,000	9%	41%
Alt 1a	2,599,000	302,000	10%	45%
Alt 7	2,594,000	306,000	11%	45%
Alt 9	2,475,000	425,000	14%	63%
Alt 5	2,454,000	447,000	15%	66%
Alt 3b	2,447,000	453,000	16%	67%
Alt 1b	2,418,000	483,000	17%	72%
Alt 5a	2,406,000	494,000	17%	73%
Alt 8	2,386,000	514,000	18%	76%
Alt 5b	2,226,000	675,000	23%	100%

1. Alternative 5b once again provides the highest level of management success by removing 23 percent of the runoff delivered to MMSD systems.

2. Alternatives 8, 5a, 1b, 3b, 5, and 9 offer similar benefits to each other, removing between 15 and 18 percent of the volume from the system and providing about 75 percent of the benefit yielded by the leading choice, Alternative 5b.



Based on our modeling, the following approach is considered to offer a reasonable amount of total runoff volume reduction at IS73:

Management Measures to be Implemented in Shorewood to Reduce Total Runoff Volume at IS73				
Downspout disconnection in storm sewer area	Downspout disconnection in combined sewer area	Rain Barrels/ Gardens	Inlet flow regulators	Shorewood Storm sewer
23% Decrease in 10-year total runoff volume				
100% success rate	Up to 50% success rate	n/a	installed in the combined area	constructed
15 to 10% Decrease in 10-year total runoff volume				
50 to 100% success rate	Up to 50% success rate	Implemented in up to 50% of properties	installed in the combined area	constructed

Volume Reduction in Milwaukee

We have found that the volume reductions that can be achieved through Alternatives 11, 12, 13, and 14 in the City of Milwaukee are negligible and we do not expect that the measures proposed in this study will have a calculable impact on the volume of runoff collected at the two locations under consideration.

The hydraulic conditions of the Maryland-Edgewood junction chamber are thought to be more dependent on the flows from Shorewood than Milwaukee. This portion of the system is hydraulically limited, and therefore is slow to respond to hydrological variations.

❑ Preferred Management Alternatives

The previous three sections presented the flow management alternatives from each of the three perspectives identified for the study. This section offers an evaluation of management alternatives when all three perspectives are considered simultaneously.

To this end, the normalized benefit of each metric as presented in the previous sections is summed up to develop an overall score. This sum is then used to rank the alternatives by overall impact: note that the order of alternatives by overall rank is not the same as the order given by individual metrics.

The "Top 10" ranking presented in the following table confirms the effectiveness of measures included in Alternatives 5b, 3b, 8, 5a, 5, and 3a. These packages have ranked in the top for each of the metrics analyzed in this study, and therefore the measures included in them are selected as the recommended flow management practices to be implemented in the study area. In the next section of this report, the estimated design and implementation costs of the recommended practices are summarized.

Benefit Ranking				
Alternative	Overall Benefit Ranking	Freeboard Increase Ranking	Peak Reduction Ranking	Volume Reduction Ranking
5b	1	1	1	1
3b	2	2	3	5
8	3	4	2	2
5a	4	3	4	3
5	5	6	5	6
3a	6	5	7	10
7	7	9	6	8
1b	8	7	12	4
3	9	8	8	13
9	10	10	11	7

In addition, we found that Alternative 11 in Milwaukee results in calculable peak flow reduction benefits at IS74. Therefore, we include the partial separation of storm sewers in the university and hospital grounds to the overall management program in the area.

Conclusions and Recommendations

❑ Conclusions

The following conclusions are based on the computer modeling of the combined and storm sewer systems. In general, the hydrologic and hydraulic characteristics described in this section are valid for a range of rainfall events, up to and including the 10-year rainfall.

1. **Runoff management can achieve project goals**

   The extensive hydraulic analysis and consideration of different combinations of several flow management measures, the study categorically concludes that the implementation of runoff management in the area will provide hydraulic benefits that will reduce basement backup risks, reduce the volume of runoff, and reduce the peak flow rates at IS73 and IS74.

2. **Flow management can reduce basement backup risks for design rain**

   Under optimal implementation levels, the hydraulic benefits of runoff management are found to equal or exceed those that can be obtained through pipe capacity improvements. One of the main reasons for this is that the physical constraints on the pipe system limit the maximum hydraulic capacity that can reasonably achieved.

3. **Not every downspout needs disconnecting**

   If a 50 percent level of downspout disconnection is achieved in the storm sewer service area, we found that any additional disconnection will bring no significant reduction in basement backup risk.

   However, this also means that the kind of basement reduction benefit targeted in this study requires that approximately a 50 percent implementation rate be achieved.

4. **On-lot management measures in the storm sewer area can reduce pollution by reducing total runoff volume**

   On-lot measures like rain barrels and rain gardens, when combined with downspout disconnections, have been found to reduce runoff peaks and volumes computed at IS73 and IS74. In this study, we find that downspout disconnections and on-lot measures in the storm sewer area result in more significant benefits than the same approach in the combined sewer area.

   While downspout disconnection in the storm sewer area greatly reduces the flows in the combined system, rain gardens and barrels reduce flows discharged to the streets and storm sewers. Since less flow means less nonpoint source pollution transport, we can conclude that the use of rain barrels and rain gardens within the storm sewer service area will help reduce the pollutants discharged to Lake Michigan.

Therefore, while on-lot measures can reduce runoff volumes in the entire study area, we find that they should be primarily used to improve water quality in the storm sewer service area.

5. **Storm sewers should be extended to provide additional service**

   In all rainfall analyses, the relatively minimal storm sewer installation provides measurable and significant benefits in controlling basement backups in the Richfield Court area. The hydraulic analysis indicates that storm sewers should be installed on Stowell, Downer, Richfield Court, between Capitol Drive and Jarvis Street. We also note that a short storm sewer pipe segment should be constructed on North Lake Drive just south of Capitol Avenue.

   The benefits of these storm sewer extensions are important: by this small initiative, the storm sewer service coverage is increased by about 15 acres, and significant volume and peak flow reduction can be observed in combined sewers.

6. **Inlets in the storm sewer service area still connected to combined sewers**

   Field investigations have revealed that 18 catch basins at 9 separate locations within the storm sewer service area in Shorewood are connected to the combined sewer system.

   Minor construction at these 9 locations will disconnect catch basin leads from the combined sewers and connect them to the nearest storm sewer manhole. This simple action will achieve complete separation and total removal of street runoff from combined sewers.

7. **Modest benefits in peak flow reduction from Milwaukee**

   It was found that the storm sewer separation opportunities at the university and hospital grounds will be effective and promising. Our computations show that, at the junction chamber at Edgewood and Maryland is entirely due to the separation of 50 percent of the runoff from within the UWM Campus grounds.

   It was also determined that separating 50 percent of the runoff at the university campus would achieve three times the benefit derived from disconnecting downspout and installing on-lot practices at 50 percent of the residences.

   Therefore, we conclude that the storm sewer separation at the university grounds should be a definite goal of any flow management activity in the portion of the study area east of Maryland Avenue.

   As far as the Providence Avenue CSO is concerned however, the downspout disconnection and on-lot measures appear to be an acceptable approach to peak flow reduction.

   The computer models were not able to identify any tangible benefits in Shorewood systems due to peak flow reduction measures in Milwaukee.

8. **Minimal benefits in volume reduction from Milwaukee**

The volume reduction that can be achieved through wet weather flow management in the City of Milwaukee is found to be negligible and we would not expect that the measures proposed in this study will have a calculable impact on the volume of runoff conveyed to MMSD systems.

The computer models were not able to identify any tangible benefits in Shorewood systems due to volume reduction measures in Milwaukee.

❑ Plan of Action

Based on the numerical evaluation of alternatives, and conclusions reached in this section, we have developed a course of action that will meet the project goals by:

- Reducing basement backup risks in the combined service area of Shorewood,
- Reducing total design runoff volume and peak flows discharging to the MMSD systems,

We therefore recommend that the following six action items be scheduled, budgeted, and implemented in the sequence presented herein, recognizing that some of these actions are long term efforts while others lend themselves to relatively quick implementation. Each of the recommended actions contributes to the final solution, and we expect that increasing implementation levels will be directly correlated to increasing performance (i.e., protection and flow reduction) levels.

The implementation of the Shorewood project as recommended herein will be a valuable demonstration and verification process in developing a MMSD-wide approach to runoff reduction. Ultimately, these results will be relevant to the development of the MMSD 2020 Facilities Planning project. Specifically, the Shorewood Wet Weather Project will provide the following information that will be useful to the 2020 Facilities Plan:

1. How to achieve widespread implementation of downspout disconnections and on-lot practices such as rain gardens and rain barrels.
2. Performance and effectiveness of on-lot practices and street inlet restrictors to prevent surcharging of the combined sewer system and basement backups.
3. Water quality benefits of using on-lot practices.
4. Capital and maintenance costs associated with stormwater reduction and storage impacts.

❑ Recommended Action 1: Catch Basin Rerouting

The Village of Shorewood Department of Public Works personnel have identified 18 catch basins at 9 separate locations within the storm sewer service area that are connected to the combined sewer system.

We recommend that minor construction be undertaken at these 9 locations to disconnect the catch basin leads from the combined sewers and connect them to the nearest storm sewer manhole. This action will achieve the near total removal of street runoff from combined sewers, thereby reducing the total volume of runoff in the combined sewers.

More importantly, the catch basin re-routing initiative recommended here offers the opportunity to evaluate a very important consequence of local separation of storm sewers: increased nonpoint source pollution discharge.

Catch Basin Rerouting Implementation Summary	
Next Step(s)	Pollutant Load Assessment (SLAMM) as a refinement of Shorewood's existing models Survey, design and construction of catch basin leads at identified locations
Action Timeline	Design of CB re-routing – Summer 2004 Construction – Summer 2004
Implementation Agent	Pollutant Load Assessment – MMSD Design & Construction CB re-routing - Village of Shorewood
Water Quality Impacts	Recommended Action 4 is designed to address adverse water quality impacts of catch basin rerouting by providing runoff treatment within the storm sewer area.
Capital Cost Estimate	Design - $8,000 (Village of Shorewood) Construction - $40,000 (Village of Shorewood)
Annual Operation and Maintenance Cost Estimate	Cleaning and maintenance operations for the storm sewer catch basins will be included in the Village-wide program already in-place. The additional cost in labor and materials due to these 18 newly connected catch basins is expected to be insignificant compared to the total number of storm sewer catch basins (189) included in the annual maintenance cycle.
Public Involvement and Education	Public information as necessary and customary for Village construction projects. Most basic approach consists of a letter to be sent to residents to inform them on the project purpose, schedule, and any disruptions it may cause in the project area.
Evaluation & Monitoring	I/I monitoring to identify potential transference between storm and combined sewers. Inclusion of the new catch basins in the Shorewood catch basin cleaning and dry weather monitoring program as part of the NR 216 permit requirements.

Catch basin rerouting means that a small amount of runoff that was previously treated at the sewage treatment plant will now be discharged into Lake Michigan untreated, thereby causing an increase in the amount of nonpoint pollutants reaching Lake Michigan.

By itself, the water quality impact of catch basin re-routing is expected to be relatively minor. However, combined with other recommended activities, the cumulative water quality impact may end up being significant.

In order to quantify any adverse pollution impacts, we recommend that a pollutant loading assessment using SLAMM be performed in order to guide the selection of BMPs to be implemented to counteract the increase in pollutant loads to Lake Michigan. BMPs to be considered should include source controls, on-lot practices, end-of-pipe measures, or combinations thereof.

The Village has already performed SLAMM analysis for this particular area; however, the Village's existing SLAMM models assume that all of the runoff in this area is discharged into Lake Michigan. We recommend this additional SLAMM model to determine the difference between existing conditions and proposed separation.

Instead of countering the impacts of individual action items, we recommend that water quality mitigation activities target the overall package of flow management initiatives. BMPs to be considered should include source controls, on-lot practices, end-of-pipe measures, or combinations thereof.

❑ Recommended Action 2: Storm Sewer Construction

The immediate and positive benefit brought by a relatively small amount of storm sewer construction has been demonstrated in hydrologic and hydraulic models where the hydraulic performance was clearly found to be superior to alternatives where storm sewer construction was not included.

Similar to the demonstration value of catch basin re-routing, the constructions of storm sewers to expand the separated area will offer the opportunity to evaluate the very important issue of increased nonpoint source pollution discharge.

Storm sewer construction means that runoff from 15 additional acres of urbanized area will now be discharged into Lake Michigan untreated, thereby increasing the total annual pollutant load into Lake Michigan from the Village of Shorewood. The size of the additional watershed warrants the detailed study and quantification of the pollutant loading through computer modeling.

The incremental increase in runoff and associated nonpoint source pollution may be significant enough to justify the installation of BMPs. BMPs to be considered should include source controls, on-lot practices, end-of-pipe measures, or combinations thereof. BMPs should target the entire storm sewer service area rather than the 15 or so acres that will be added to the watershed as a result of the storm sewer extension project.

We recommend that a SLAMM analysis be performed to quantify the pollution loading impacts of storm sewer construction. The Village already has SLAMM models that cover the storm sewer area, so the recommended models would provide pollution assessments for the area added by the project.

The hydraulic benefits of these storm sewer extensions are significant: by this small initiative, the storm sewer service coverage will be increased by approximately 15 acres, and significant volume and peak flow reduction can be observed in combined sewers. We therefore recommend the construction of storm sewers as follows:

- Approximately 350 feet of 12 inch diameter pipe, and 2 catch basins on North Downer Avenue,
- Approximately 375 feet of 12 inch diameter pipe, and 2 catch basins on North Stowell Avenue,
- Approximately 380 feet of 12 inch diameter pipe, 400 feet of 15 inch pipe, and 6 catch basins on North Lake Drive,
- Construction of 2 new catch basins on Richland Court.

The cost of storms sewer extension is estimated at $95,000, including design, survey, construction administration, inspection, and contingency costs.

Storm Sewer Construction Implementation Summary	
Next Step(s)	Pollutant Load Assessment (SLAMM) as an addition to Shorewood's existing models Survey, design, and construction of storm sewer.
Action Timeline	Pollutant Load Assessment – Spring 2004 Storm Sewer Design – Summer 2004 Storm Sewer Construction – Summer 2004
Implementation Agent	Pollutant Load Assessment – MMSD Storm Sewer Design & Construction - Village of Shorewood
Water Quality Impacts	Recommended Action 4 is designed to address adverse water quality impacts of storm sewer construction by providing runoff treatment within the storm sewer area.
Capital Cost Estimate	Pollutant Load Assessment - $7,500 (MMSD) Storm Sewer Design - $15,000 (Village of Shorewood) Storm Sewer and catch basin Construction - $75,000 (Village of Shorewood)
Annual Operation and Maintenance Cost Estimate	Operation and maintenance for the new storm sewer pipes will be included in the Village-wide pipe maintenance program already in-place. The additional cost in labor and materials due to the new pipe segments is expected to be insignificant compared to the total system maintenance expenditures.
Public Involvement and Education	Public information as necessary and customary for Village construction projects. Most basic approach consists of a letter to be sent to residents to inform them on the project purpose, schedule, and any disruptions it may cause in the project area.
Evaluation & Monitoring	I/I monitoring to identify potential transference between storm and combined sewers. Inclusion of the storm sewers in the Shorewood catch basin cleaning and dry weather monitoring program as part of the NR 216 permit requirements.

❑ Recommended Action 3: Downspout Disconnection in Storm Sewer Service Area

Despite the storm sewer system serving the area, most roof downspouts are still connected to the combined sewers through sanitary laterals. Therefore, we would expect a considerable reduction in wet weather flows if all or part of roof runoff is removed from the combined sewer pipes. The recommended minimum implementation level is a 50 percent removal of roof runoff from combined sewers, resulting in the following benefits:

- The calculated 10-year freeboard in the combined sewer network will INCREASE by 20 percent,

- The total calculated 10-year runoff volume discharged to the MMSD systems from this area will DECREASE by 10 percent.

We therefore recommend that downspouts at the street side of the house be disconnected at nearly every one of the 840 structures in the storm sewer service area, thereby achieving approximately 50 percent of the roof runoff to be diverted to the storm sewer system.

The cost of downspout disconnection is estimated at $350,000, including design, survey, construction administration, inspection, and contingency costs. The zone in which we recommend downspout disconnection is shown on the map of Recommended Flow Management Actions.

We recognize that successful diversion of downspout at the back of the houses will be challenging. Therefore, we are reluctant to expect the effective disconnection of ALL downspouts at a given property.

The downspout disconnection program can be greatly enhanced by the installation of a specialized collection system to collect and convey downspout flows into the storm sewer catch basins. The system is likely to consist of a shallow flexible pipe system (4 or 6 inch diameter corrugated PVC pipe) placed along the boulevard, the terrace, or right behind the curb. Similar small diameter flexible conduits would be installed between the house and the collection pipe near the street.

While this approach will surely increase the acceptance and practicality of the project, our preliminary estimates indicate that the required quantity of collection pipe is so large as to render this idea economically impractical. Based on the location of existing catch basins and storm sewer pipes, a collection system that serves each house would mean the installation of up to 50,000 lineal feet of flexible drain pipe.

Because of the large quantities of pipe required, the downspout collection system is determined to be both too disruptive and expensive to install. Therefore, we do not recommend this component to be included in the downspout disconnection program in the storm sewer service area.

Unlike previous attempts to downspout disconnection at various communities in the metropolitan area, the recommended program clearly targets runoff reduction to large enough scale to produce the intended amount of reduction in basement backup risk.

One of the crucial components of a downspout disconnection strategy will be the on-site assessment of how the disconnection can best be performed at each building in the service area. The field assessment sets the stage for (a) face to face contact with area residents, (b) early home-owner involvement, (c) and finally, a successful disconnection program that includes a specific approach to individual properties.

Therefore, the demonstration value of this recommendation is to determine how MMSD and Shorewood can compel a large proportion of the residents to follow through with downspout disconnection. The lessons learned and strategies developed in this project will make a big difference in the rest of the metropolitan area where disconnection may be an option.

Downspout Disconnection in Storm Sewer Service Area Implementation Summary	
Next Step(s)	Pollutant Load Assessment (SLAMM analysis) House to house field visit to (1) identify disconnection opportunities, (2) downspout discharge location identification, and (3) evaluation of connection possibilities to storm sewers.
Action Timeline	Pollutant Load Assessment – Spring 2004 Field Assessment in Summer 2004 Downspout disconnection in 2005 through 2006
Implementation Agent	Pollutant Load Assessment – MMSD & Village of Shorewood Field Assessment – MMSD & Village of Shorewood Downspout Disconnection - MMSD & Village of Shorewood
Water Quality Impacts	Recommended Action 4 is designed to address adverse water quality impacts of downspout disconnection by providing runoff treatment within the storm sewer area.
Capital Cost Estimate	Pollutant Load Assessment - $7,500 (MMSD) Field Study - $35,000 (MMSD & Village of Shorewood) Disconnection implementation - $200,000 (MMSD & Village of Shorewood)
Annual Operation and Maintenance Cost Estimate	none
Public Involvement and Education	Getting 100% participation at the 840 structures will likely be close to impossible without it being required by law. Even if it is required by law, it will still be difficult to get 100% participation, but it is feasible. If a change in local ordinance is pursued, an intense public outreach and education program must precede the discussions. • Target neighborhood and block watch meetings • Involve the local school(s) • Address why program is needed and what benefits will result • Speak to community and business organizations to educate their members • Create a series of flyer and handouts to be distributed to impacted homeowners • Create inserts for the local newspaper and City newsletter • Partner with the local news media After the ordinance is approved, an implementation program must commence. • Conduct an intensive door-to-door campaign • Create a "community event" to generate interest and enthusiasm for the program • Involve local groups such as the boy scouts or the Milwaukee Community Service Corp to train them and use their labor to help implement • Feature stories of blocks that have completed the effort • Offer contests or awards for completion
Evaluation & Monitoring	none

Downspout disconnection in the storm sewer service area will add untreated runoff to the total discharge to Lake Michigan. Though the nonpoint source pollutant contribution from residential roofs may be somewhat limited, a calculable increase in total annual pollutant loads is to be expected. At a minimum, a SLAMM computer model of the roof runoff should be performed so that the water quality impact of various levels of roof disconnection can be evaluated.

We recommend that a water quality analysis be performed to establish the relationship between nonpoint pollution and the number of disconnected downspouts. This relationship can then be used to determine at what level of downspout disconnection success will warrant the installation of BMPs in the system.

❑ Recommended Action 4: On-Lot Flow Management as a BMP in Shorewood Storm Sewer Area

We have determined that all activities in Recommended Actions 1 through 3 involve an increase to the amount of runoff in the system, which means that the amount of nonpoint source pollution being discharged to Lake Michigan will also increase. There will be two new sources of additional runoff to be added into the system:

> The implementation of on-lot practices in the study area will greatly benefit from the support of grass roots community involvement.
>
> We recommend exploring potential partnerships with organizations such as Milwaukee Community Service Corps or the Urban Ecology Center.
>
> Partnering with grass roots organizations will play a crucial role in implementation and monitoring of recommended practices.

- Catch basin re-routing and storm sewer extension will add surface runoff consisting of lawns, sidewalks, driveways, and streets. We expect that the total area added to the storm system is about 45 acres, bringing the area from about 190 acres to about 235 acres.
- Downspout disconnection at the targeted rate of 50 percent means that 15 to 20 acres of roof surface will be added to the storm sewer watershed.

In order to mitigate the increase of nonpoint source pollutants that may be directed to Lake Michigan as a result of the recommendations outlined in this report, we recommend the implementation of water quality BMPs in the Shorewood storm sewer service area. The increase in nonpoint source pollution can be prevented in several ways:

- End-of-pipe BMPs like detention, retention, or bio-treatment facilities, which, in our opinion, are not feasible in this situation because both storm sewer outlets serving Shorewood are located at the water's edge in Lake Michigan and therefore offer no opportunity to place a detention or bio-treatment facility. Just upstream of the shore, the steep bluffs of Lake Michigan prevent the installation of structural water quality measures.
- Inlet filters and similar structural devices, when used properly, can offer a high level of water quality protection and pollutant removal, but these devices are most effective when used in small drainage areas. To be effective on a watershed scale, a number of these catch basin filter type structures would need to be installed. Typically, a large filter unit can handle a 20 to 30 acre urban watershed for an approximate cost of approximately $65,000 each. In a 235 acre watershed, we would therefore estimate that a minimum of 8 of these units would be needed for an estimated installation cost of $0.52 million, not including survey, engineering, design, construction contract administration, inspection, and contingencies. Based on this cost assessment, we have found the initiative financially

prohibitive due to the high unit cost of available catch basin and inlet filter devices.

- Source area controls like street sweeping do provide water quality benefits and but these practices are already in place. While an incremental increase in pollutant removal may be obtained through increased sweeping frequency, this incremental pollutant removal will not compensate for the addition in annual pollutant loads due to proposed Recommended Actions 1 through 3.
- On-lot management measures like rain barrels and rain gardens can provide sediment and nutrient reduction benefits if implemented on a widespread area. Volume controls such as collecting rooftop runoff in rain barrels or rain gardens help reduce runoff from residential areas.

Increases in stormwater runoff rates and volume have been shown to have a detrimental effect on water quality and aquatic habitat. While many measures exist to reduce peak flow rates, there are not many practical ways to reduce runoff volumes unless soil conditions permit. With the predominantly clay soils present throughout the Milwaukee area, there is not much chance to reduce runoff volume through infiltration unless it is in small areas like rain gardens.

The implementation of the rain barrel – rain gardens in the area can also benefit from a partnership similar to the one recently proposed by the Milwaukee Community Service Corps or the Urban Ecology Center in response to the Stormwater BMPs Partnership request for proposals by MMSD. Both of the projects outlined in these proposals have relevance to this issue, and therefore, we recommend that Action Item 4 include a partnership initiative with community organizations like the Milwaukee Community Service Corps or the Urban Ecology Center. These partnerships will also play an important role in the evaluation and monitoring of installed management practices.

We also note that the public education and involvement will play an exceedingly high role in the success of this component of the management plan. A coordinated, intensive, and coherent message must be developed and delivered effectively.

As a result, we recommend the implementation of on-lot practices as an area –wide source control measure that addresses the pollutants generally found in roof runoff. In residential areas, roof runoff is thought to be relatively clean compared to industrial roofs, however, the additional runoff introduced to the ground surface after downspout disconnection may wash off pollutants to the storm sewer system and thereby cause an increased potential for nonpoint pollution transport. By catching and holding this relatively important new source of runoff and pollution, we anticipate that the rain gardens and rain barrels will provide on-lot treatment before discharge into the municipal systems.

On-Lot Flow Management as a BMP in the Shorewood Storm Sewer Area Implementation Summary	
Next Step(s)	Coordination with Grass Roots Organizations Public Education and Involvement development BMP design BMP implementation/construction
Action Timeline	Coordination with Grass Roots Organizations – Spring/Summer 2004 BMP design – Summer/Fall 2004 Public Education & Involvement Program - 2004 BMP implementation/construction – 2004 through 2005
Implementation Agent	MMSD & Village of Shorewood, and Grass roots community partners
Water Quality Impacts	Nonpoint pollutant reduction through: • bio-filtration and infiltration in rain gardens • reduction of total runoff volume through rain barrels
Capital Cost Estimate	BMP design and implementation assistance - $75,000 (MMSD) BMP implementation/construction - $200,000 (MMSD & Village of Shorewood) • $175 per rain barrel including labor, materials, incidentals • $3,500 per rain garden including labor, materials, incidentals
Annual Operation and Maintenance Cost Estimate	The maintenance and operation of these practices would be the responsibility of the property owner and no further public cost be incurred for this installation.
Public Involvement and Education	Coordinate with grass roots organizations like the Urban Ecology Center. Coordinate with community groups like the Milwaukee Community Service Corps. Education program to include information on Water quality, Water quantity, Basement back-ups, "How to" program, Maintenance. Target neighborhood and block meetings. Offer incentives to property owners. Seek sponsorship and support from local businesses.
Evaluation & Monitoring	We recommend that continuous monitoring opportunities be initiated through relationships with educational and environmental organizations. Partnerships with grass roots organizations like the Citizen Science Project of the Urban Ecology Center can enable monitoring and evaluation programs through college level research projects. The cost of the evaluation and monitoring for this action is included in the budget cost estimate provided herein.

❑ Recommended Action 5: Inlet Flow Regulators in the Shorewood Combined Sewer Area

In recent years, the use of inlet restrictors or flow regulators have been used to control combined sewer wet weather flows when the addition of hydraulic capacity is economically unfeasible. In the Milwaukee area, such devices have only been used on a trial basis, while Illinois municipalities like Chicago, Wilmette, Skokie, and Evansville have used these devices as part of a flow management system to solve recurring sewer backup problems.

The flow rate reduction is achieved through the use of through inlet restrictors that limit the maximum flow introduced into the system at each catch basin or inlet location. The two kinds of regulators most commonly used for this purpose are the vortex and elbow regulators. The former typically has a maximum capacity of 0.15 to 0.25 cfs, while the latter can be expected to limit flows to about 0.5 cfs. Vortex regulators achieve a relatively constant maximum flow, while the discharge through the elbow regulators is somewhat dependent on the submergence of the device in the catch basin. Regardless of the type, the existence of the devices means that there is always an upper limit to the flow within the system regardless of the rainfall amount.

Since the flow regulators were found to be an effective way to control peak flows in the combined sewers, we recommend their use and installation in the selected portions of the combined sewer service area in Shorewood. The area in which we recommend flow regulators in catch basins is shown on the map of Recommended Flow Management Actions.

Inlet Flow Regulators and Designated Street Storage in the Shorewood Combined Sewer Area Implementation Summary	
Next Step(s)	Field investigation to establish and confirm catch basin lead connectivity to determine exact number of flow regulators needed. Design of street profiles for storage enhancement.
Action Timeline	Field Study of Catch Basins – Spring 2004 Installation of Regulators – Summer 2004 Design of street profiles – Summer 2004 Street reconstruction – Summer/Fall 2004
Implementation Agent	Village of Shorewood
Water Quality Impacts	none
Capital Cost Estimate	Installation of Regulators – $50,000(Village of Shorewood) Design of street profiles - $15,000(Village of Shorewood) Construction of streets - $100,000(Village of Shorewood)
Annual Operation and Maintenance Cost Estimate	Regularly scheduled inspection and cleaning of catch basin flow regulators coordinated with Village's catch basin cleaning program as outlined in the NR 216 Permit.
Public Involvement and Education	Education program to address: • need for the project • safety concerns (adults, children) by partnering with police department or schools • public safety issues – police, fire, ambulance • impacts to homes • impacts to vehicles • accessibility to school buses • information for realtors • information targeted for municipal employees who will be the front line government workers interacting with the impacted homeowners (DPW, engineering, building inspection, appraisal, fire and police) • how to drive in streets with flooding/excess water • anticipated frequency of events • realtors and home inspectors education program Public information meetings/open house meetings should be held to allow the public to talk to experts; public hearings should be held to allow the public an opportunity to have their opinions heard by their local officials. Install street signs to offer information on what to do in case of rain.
Evaluation & Monitoring	Scheduled inspection of regulators, cleaning and unplugging orifices. Field verification of increased street flooding, volume estimates, photos, videos.

The use of flow regulators to a scale recommended here has not been attempted in the Milwaukee area. Therefore, the benefits of this approach and its impact on conveyance systems have not been fully explored. With this project, we attempt to complement the hydraulic modeling data with field implementation so we can increase the value of the project as a demonstration and evaluation tool of flow management strategies throughout the metropolitan area.

The installation of flow regulators will mean that a handful of streets will experience temporary flooding due to increased surface flows. We recommend that these street segments be clearly identified and publicized. At the location of the expected street flooding we recommend that regulators NOT be installed. These areas of designated street storage are shown on the map of Recommended Flow Management Actions.

There are two locations where we anticipate street profile modifications to increase storage capacity through street profile modifications for storage purposes:

1. Prospect Avenue, between Menlo Boulevard and Stratford Court
2. Shepard Avenue, north of Edgewood Boulevard

This is accomplished by the construction of a flat low-rise "berm" across the street such that water can be impounded on the upstream side. The "berm" is no more than 6 inches high, and spread over 40 feet, so it is virtually imperceptible to the motorists. In addition, the top elevation is such that the impoundment is no higher than the adjacent sidewalks. This also means that no extensive or expensive street construction is necessary.

❑ Recommended Action 6: Runoff Reduction at UWM and Columbia / St. Mary's

> The "Zero Discharge" study includes a comprehensive stormwater monitoring program at campus facilities.
>
> Similar programs may be feasible at the hospital grounds as well.

Our preliminary research and investigation reveals that UWM and the Hospital have separated drainage and sewerage systems that are only combined when they reach the municipal combined sewers. This means that the removal of runoff originating from these institutions from the combined sewers can be effective and beneficial.

While simple in concept, the successful diversion of runoff from combined sewers into newly constructed storm sewers will be a challenging proposition. Local topography, elevations of existing storm sewers, and availability of direct flow routes to the Milwaukee River or Lake Michigan all pose potential setbacks to sewer separation initiatives. We nevertheless note that the specific manner in which runoff will be separated, conveyed, treated, and discharged to Lake Michigan or Milwaukee River is outside the scope of this study.

Furthermore, runoff reduction may be an alternative to storm sewer separation as described and proposed in a project prepared by the UWM School of Graduate Studies in response to a MMSD Request for Proposals for the 2004 Stormwater BMPs Partnership, where a "zero discharge zone" was proposed at the UWM campus grounds. The proposed project consists of a planning process resulting in a comprehensive plan and several projects implementing various BMPs at the university grounds. It isn't inconceivable to implement a similar approach at the newly developing hospital campus and achieve similar benefits.

Bringing the Campus grounds into the present project strategy is important because the value of such zero discharge attempts in the service area should be fully explored and evaluated. In this case, we have computer simulation of expected benefits, along with project management and implementation resources from the University community. In other words, this action item has both technical demonstration values as well as setting an example of inter-agency and inter-jurisdictional collaboration.

We have evaluated the hydraulic impacts of removing all or a portion of the clear water from the combined sewer system, regardless of how this is done. Our hydraulic evaluation of storm runoff separation from the University and the Hospital grounds assumed that 50 percent of the runoff can be expected to be effectively removed from the combined sewer system. At this implementation level, we found considerable benefits in 10-year peak flow and total runoff volume reductions at IS74.

Separated Storm Sewer Service for UWM and Columbia-St. Mary's Hospital Implementation Summary	
Next Step(s)	Develop the UWM "Zero-Discharge Zone" proposal and initiative. Investigate feasibility of implementing low or zero discharge methods in Columbia / St. Mary's new campus. Investigate BMP installation needs at UWM and Columbia / St. Mary's grounds to compensate for storm sewer separation.
Action Timeline	2004 through 2005
Implementation Agent	Comprehensive plan and BMP implementation – MMSD
Water Quality Impacts	Storm sewer separation without runoff reduction will require BMPs. Low or zero discharge will not have a negative water quality impact.
Capital Cost Estimate	UWM and Hospital grounds comprehensive planning - $60,000 (MMSD)
Annual Operation and Maintenance Cost Estimate	The maintenance and operation of practices would be the responsibility of UWM.
Public Involvement and Education	The UWM "zero discharge zone" initiative will have an education component consisting of hosting the UW Green Campus Symposium. The initiative also includes an interdisciplinary course on information design that will develop signage system and a web site for stormwater issues on campus.
Evaluation & Monitoring	We recommend that a monitoring program similar to the one proposed by UWM be implemented as part of this action item. The program consists of a system of flow measuring devices fitted into the existing storm sewers serving the pervious and impervious areas. The program also includes an overall evaluation of quantity and quality of runoff before and after the implementation of BMPs and other management practices in the campus. The cost of the evaluation and monitoring for this action is included in the budget cost estimate provided herein.

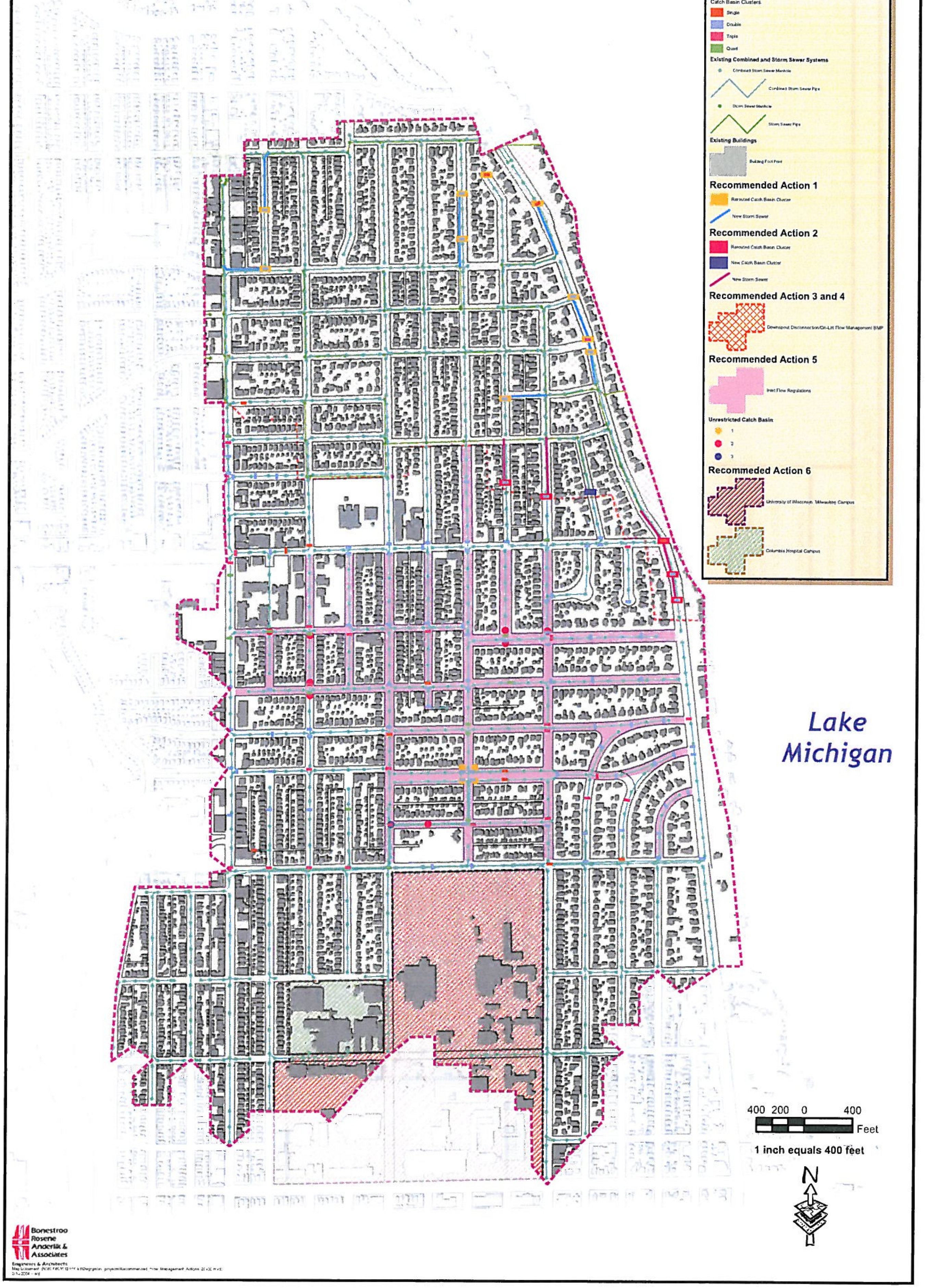
Implementation Plan

Recommended Management Actions 1 through 4				
	ACTION ITEM 1 Catch Basin Rerouting	ACTION ITEM 2 Storm Sewer Construction	ACTION ITEM 3 Downspout Disconnection in Storm Sewer Service	ACTION ITEM 4 BMP Implementation in the Shorewood Storm Sewer Area
Next Step(s)	Pollutant Load Assessment (SLAMM) as a refinement of Shorewood's existing models Survey, design and construction of catch basin leads at identified locations	Pollutant Load Assessment (SLAMM) as an addition to Shorewood's existing models Survey, design, and construction of storm sewer.	Pollutant Load Assessment (SLAMM analysis) House to house field visit to (1) identify disconnection opportunities, (2) downspout discharge location identification, and (3) evaluation of connection possibilities to storm sewers.	Coordination with Grass Roots Organizations Public Education and Involvement development BMP design BMP implementation/construction
Action Timeline	Design of CB re-routing – Summer 2004 Construction – Summer 2004	Pollutant Load Assessment – Spring 2004 Storm Sewer Design – Summer 2004 Storm Sewer Construction – Summer 2004	Pollutant Load Assessment – Spring 2004 Field Study in Summer 2004 Downspout disconnection in 2005 through 2006	Coordination with Grass Roots Organizations – Spring/Summer 2004 BMP design – Summer/Fall 2004 Public Education & Involvement Program - 2004 BMP implementation/construction – 2004 through 2005
Implementation Agent	Pollutant Load Assessment – MMSD Design & Construction CB re-routing - Village of Shorewood	Pollutant Load Assessment – MMSD Storm Sewer Design & Construction - Village of Shorewood	Pollutant Load Assessment – MMSD & Village of Shorewood Field Study – MMSD & Village of Shorewood Downspout Disconnection – MMSD & Village of Shorewood	MMSD, Village of Shorewood, and Grass roots community partners
Water Quality Impacts	Recommended Action 4 is designed to address adverse water quality impacts of catch basin rerouting by providing runoff treatment within the storm sewer area.	Recommended Action 4 is designed to address adverse water quality impacts of storm sewer construction by providing runoff treatment within the storm sewer area.	Recommended Action 4 is designed to address adverse water quality impacts of downspout disconnection by providing runoff treatment within the storm sewer area	Nonpoint pollutant reduction through: bio-filtration and infiltration in rain gardens reduction of total runoff volume through rain barrels
Capital Cost Estimate	Design - \$8,000 (Village of Shorewood) Construction - \$40,000 (Village of Shorewood)	Pollutant Load Assessment - \$7,500 (MMSD) Storm Sewer Design - \$15,000 (Village of Shorewood) Storm Sewer and catch basin Construction - \$75,000 (Village of Shorewood)	Pollutant Load Assessment - \$7,500 (MMSD) Field Study - \$35,000 (MMSD & Village of Shorewood) Disconnection implementation - \$200,000 (MMSD & Village of Shorewood)	BMP design and implementation assistance - \$75,000 (MMSD) BMP implementation/construction - \$200,000 (MMSD & Village of Shorewood)
Annual Operation and Maintenance Cost Estimate	Cleaning and maintenance operations for the storm sewer catch basins will be included in the Village-wide program already in-place. The additional cost in labor and materials due to these 18 newly connected catch basins is expected to be insignificant compared to the total number of storm sewer catch basins (189) included in the annual maintenance cycle.	Operation and maintenance for the new storm sewer pipes will be included in the Village-wide pipe maintenance program already in-place. The additional cost in labor and materials due to the new pipe segments is expected to be insignificant compared to the total system maintenance expenditures.	none	The maintenance and operation of these practices would be the responsibility of the property owner and no further public cost be incurred for this installation.
Public Involvement and Education	Public information as necessary and customary for Village construction projects. Most basic approach consists of a letter to be sent to residents to inform them on the project purpose, schedule, and any disruptions it may cause in the project area.	Public information as necessary and customary for Village construction projects. Most basic approach consists of a letter to be sent to residents to inform them on the project purpose, schedule, and any disruptions it may cause in the project area.	Target neighborhood and block watch meetings Involve the local school(s) Address why program is needed and what benefits will result Speak to community and business organizations to educate their members Create a series of flyer and handouts to be distributed to impacted homeowners Create inserts for the local newspaper and City newsletter Partner with the local news media Conduct an intensive door-to-door campaign Create a "community event" to generate interest and enthusiasm for the program Involve local groups such as the boy scouts or the Milwaukee Community Service Corp to train them and use their labor to help implement Feature stories of blocks that have completed the effort Offer contests or awards for completion	Coordinate with grass roots organizations like the Urban Ecology Center. Coordinate with community groups like the Milwaukee Community Service Corps. Education program to include information on Water quality, Water quantity, Basement back-ups, "How to" program, Maintenance. Target neighborhood and block meetings. Offer incentives to property owners. Seek sponsorship and support from local businesses.
Evaluation & Monitoring	I/I monitoring to identify potential transference between storm and combined sewers. Inclusion of the new catch basins in the Shorewood catch basin cleaning and dry weather monitoring program as part of the NR 216 permit requirements.	I/I monitoring to identify potential transference between storm and combined sewers. Inclusion of the storm sewers in the Shorewood catch basin cleaning and dry weather monitoring program as part of the NR 216 permit requirements.	none	We recommend that continuous monitoring opportunities be initiated through relationships with educational and environmental organizations. Partnerships with grass roots organizations like the Citizen Science Project of the Urban Ecology Center can enable monitoring and evaluation programs through college level research projects. The cost of the evaluation and monitoring for this action is included in the budget cost estimate provided herein.

Recommended Management Actions 5 and 6

	ACTION ITEM 5 Inlet Flow Regulators and Designated Street Storage in the Shorewood Combined Sewer Area	ACTION ITEM 6 Separated Storm Sewer Service for UWM and Columbia-St. Mary's Hospital	
Next Step(s)	Field investigation to establish and confirm catch basin lead connectivity to determine exact number of flow regulators needed. Design of street profiles for storage enhancement.	Develop the UWM "Zero-Discharge Zone" proposal and initiative. Investigate feasibility of implementing low or zero discharge methods in Columbia / St. Mary's new campus. Investigate BMP installation needs at UWM and Columbia / St. Mary's grounds to compensate for storm sewer separation.	
Action Timeline	Field Study of Catch Basins – Spring 2004 Installation of Regulators – Summer 2004 Design of street profiles – Summer 2004 Street reconstruction – Summer/Fall 2004	2004 through 2005	
Implementation Agent	Village of Shorewood	Comprehensive plan and BMP implementation – MMSD	
Water Quality Impacts	none	Storm sewer separation without runoff reduction will require BMPs. Low or zero discharge will not have a negative water quality impact.	
Capital Cost Estimate	Installation of Regulators – $50,000(Village of Shorewood) Design of street profiles - $15,000(Village of Shorewood) Construction of streets - $100,000(Village of Shorewood)	UWM and Hospital grounds comprehensive planning - $60,000 (MMSD)	
Annual Operation and Maintenance Cost Estimate	Regularly scheduled inspection and cleaning of catch basin flow regulators coordinated with Village's catch basin cleaning program as outlined in the NR 216 Permit.	The maintenance and operation of practices would be the responsibility of UWM.	
Public Involvement and Education	Education program to address: need for the project, safety concerns (adults, children) by partnering with police department or schools, public safety issues – police, fire, ambulance, impacts to homes, impacts to vehicles, accessibility to school buses, information for realtors, information targeted for municipal employees who will be the front line government workers interacting with the impacted homeowners (DPW, engineering, building inspection, appraisal, fire and police) ,how to drive in streets with flooding/excess water, anticipated frequency of events, realtors and home inspectors education program. Public information meetings/open house meetings should be held to allow the public to talk to experts; public hearings should be held to allow the public an opportunity to have their opinions heard by their local officials. Install street signs to offer information on what to do in case of rain.	The UWM "zero discharge zone" initiative will have an education component consisting of hosting the UW Green Campus Symposium. The initiative also includes an interdisciplinary course on information design that will develop signage system and a web site for stormwater issues on campus.	
Evaluation & Monitoring	Scheduled inspection of regulators, cleaning and unplugging orifices. Field verification of increased street flooding, volume estimates, photos, videos.	We recommend that a monitoring program similar to the one proposed by UWM be implemented as part of this action item. The program consists of a system of flow measuring devices fitted into the existing storm sewers serving the pervious and impervious areas. The program also includes an overall evaluation of quantity and quality of runoff before and after the implementation of BMPs and other management practices in the campus. The cost of the evaluation and monitoring for this action is included in the budget cost estimate provided herein.	

Recommended Flow Management Actions



Implementation Plan Cost Summary

	2004		2005		2006	
	Shorewood	**MMSD**	**Shorewood**	**MMSD**	**Shorewood**	**MMSD**
Catch basin rerouting design in storm sewer area	$8,000					
Catch basin rerouting construction in storm sewer area	$40,000					
Storm sewer design in storm sewer area	$15,000					
Storm sewer Construction in storm sewer area	$75,000					
Installation of catch basin flow regulators	$50,000					
Design of street profiles for storage	$15,000					
Construction of street profiles for storage			$100,000			
Storm Sewer Area Downspout Disconnection Feasibility Study	$17,500	$17,500				
Storm Sewer Area Downspout Disconnection implementation				$100,000	$100,000	
Pollutant Load Assessment		$15,000				
BMP design and implementation assistance		$40,000		$35,000		
BMP implementation, construction , monitoring and evaluation (50% cost share)			$100,000	$100,000		
UWM and Hospital grounds comprehensive planning, implementation, construction , monitoring and evaluation		$30,000		$30,000		
TOTAL IMPLEMENTATION COST	**$220,500.00**	**$102,500.00**	**$200,000.00**	**$265,000.00**	**$100,000.00**	**$0.00**

Public Education and Involvement Plan for Downspout Disconnection

Getting 100% participation at the 840 structures will likely be close to impossible without it being required by law. Even if it is required by law, it will still be difficult to get 100% participation, but it is feasible. If a change in local ordinance is pursued, an intense public outreach and education program must precede the discussions.

- Target neighborhood and block watch meetings
- Involve the local school(s)
- Address why program is needed and what benefits will result
- Speak to community and business organizations to educate their members
- Create a series of flyer and handouts to be distributed to impacted homeowners
- Create inserts for the local newspaper and City newsletter
- Partner with the local news media

After the ordinance is approved, an implementation program must commence.

- Conduct an intensive door-to-door campaign
- Create a "community event" to generate interest and enthusiasm for the program
- Involve local groups such as the boy scouts or the Milwaukee Community Service Corps to train them and use their labor to help implement
- Feature stories of blocks that have completed the effort
- Offer contests or awards for completion

❑ Public Education and Involvement Plan for On-Lot Flow Management Practices

- Education program to include information on:
    - Water quality
    - Water quantity
    - Basement back-ups
    - "How to" program
    - Maintenance information
- Target neighborhood and block meetings
- Offer incentives and programs similar to implementation in Recommended Action 3
- Seek sponsorship from local businesses

❑ Public Education and Involvement Plan for Inlet Flow Regulators

- Education program to address:
    - need for the project
    - safety concerns (adults, children) by partnering with police department or schools
    - public safety issues – police, fire, ambulance
    - impacts to homes
    - impacts to vehicles
    - accessibility to school buses
    - information for realtors
    - information targeted for municipal employees who will be the front line government workers interacting with the impacted homeowners (DPW, engineering, building inspection, appraisal, fire and police)
    - how to drive in streets with flooding/excess water
    - anticipated frequency of events
    - realtors and home inspectors education program
- Public information meetings/open house meetings should be held to allow the public to talk to experts; public hearings should be held to allow the public an opportunity to have their opinions heard by their local officials.
- Install street signs to offer information on what to do in case of rain.

July 31, 2000

Ms. Nancy U. Schultz, P.E.
Project Manager
MMSD
260 West Seeboth Street
Milwaukee, WI 53204-1446

RE: Proposed Improvements to MIS between
Oakland Avenue, NS-4, and Milwaukee River
Our file 880-99-101

Dear Nancy,

In order to further along your review of the proposed improvements at the above referenced location, we are sending you a copy of the design study report for the southeastern portion of the Village of Shorewood. The area in question is served by combined sewers that discharge into the Milwaukee Metropolitan Sewerage District system at two locations. Low flows are diverted into the 39 inch diameter MIS at Oakland Avenue, while higher flows continue to the NS-4 drop shaft structure. When the gates are closed at NS-4, the overflow is discharged into the Milwaukee River.

The Village of Shorewood is seeking to alleviate frequent sewer backups in the southeast area by undertaking capacity improvements throughout the sewer system. One of the components of this approach is to obtain additional hydraulic capacity at the MIS segment between Oakland Avenue and the Milwaukee River.

As you will see, increasing the capacity of the 72-inch diameter MIS from Oakland Avenue to the Milwaukee River is an integral and crucial part of the proposed solution. The current full flow capacity of this segment is 451 cfs, while the required capacity is 795 cfs. This means that the current 72-inch diameter conduit should be upgraded to an 84 or 96-inch diameter conduit. The existing and proposed profiles are schematically depicted in the following pages.

Information regarding the hydrologic analysis, comparisons to existing computations by the City of Milwaukee Department of Public Works Infrastructure Services Division, and the computed benefits of the proposed improvements are described in the enclosed report.

Please contact me at 262-241-6950 if you have any questions or comments regarding this matter.

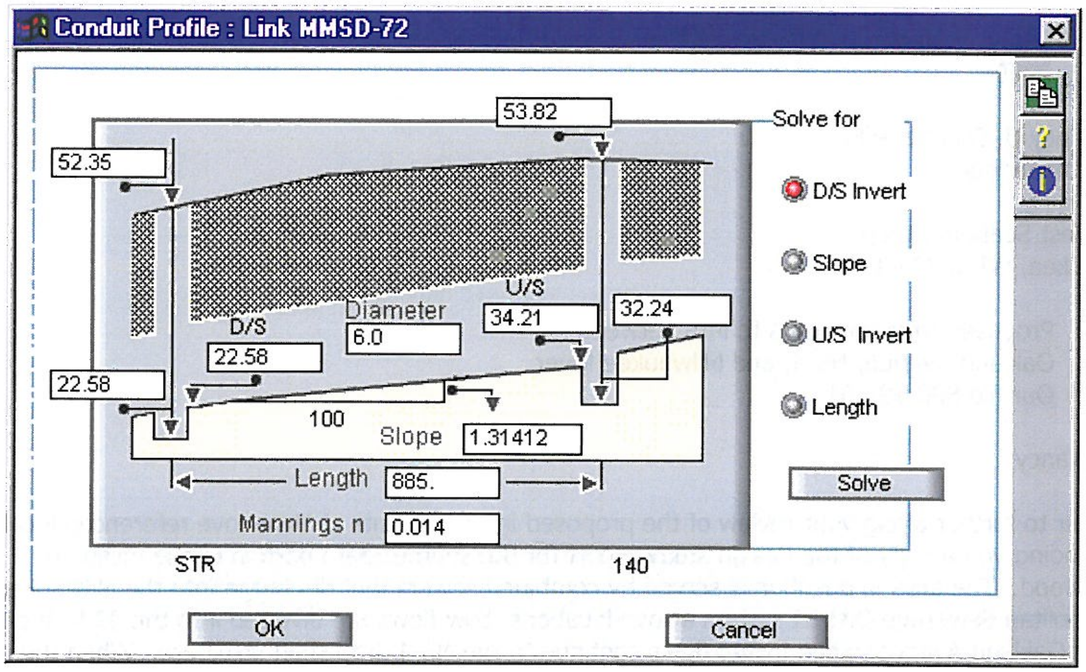
Sincerely,

Bonestroo, Rosene, Anderlik and Associates, Inc.

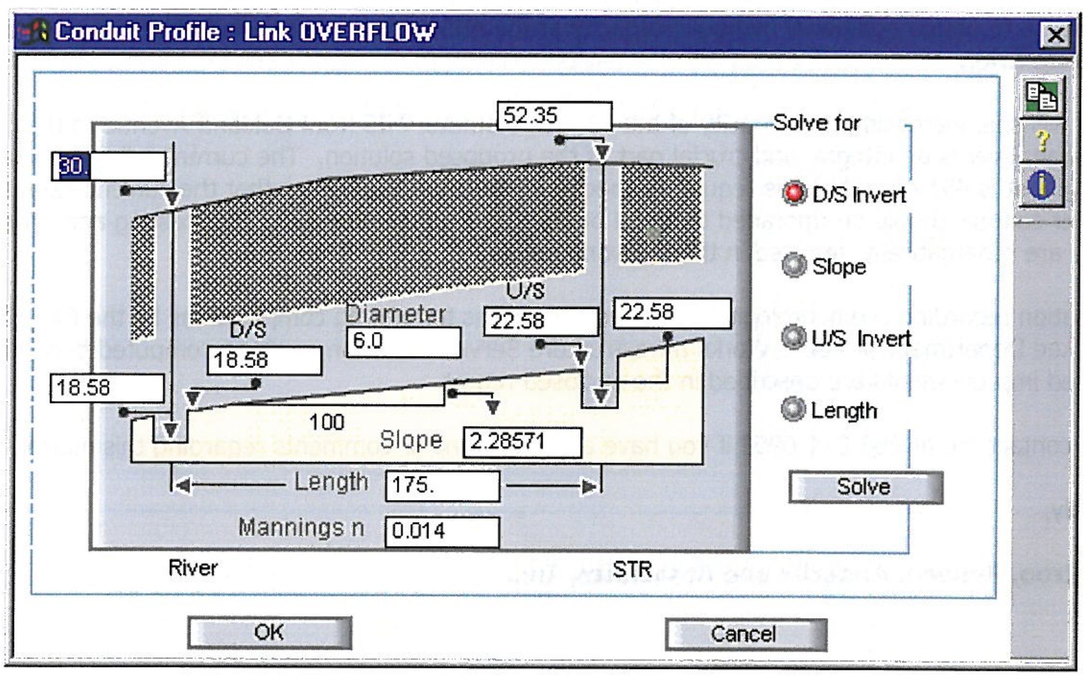
Mustafa Z. Emir, Ph.D.
Project Manager

Existing MMSD MIS

Oakland Avenue to NS-4

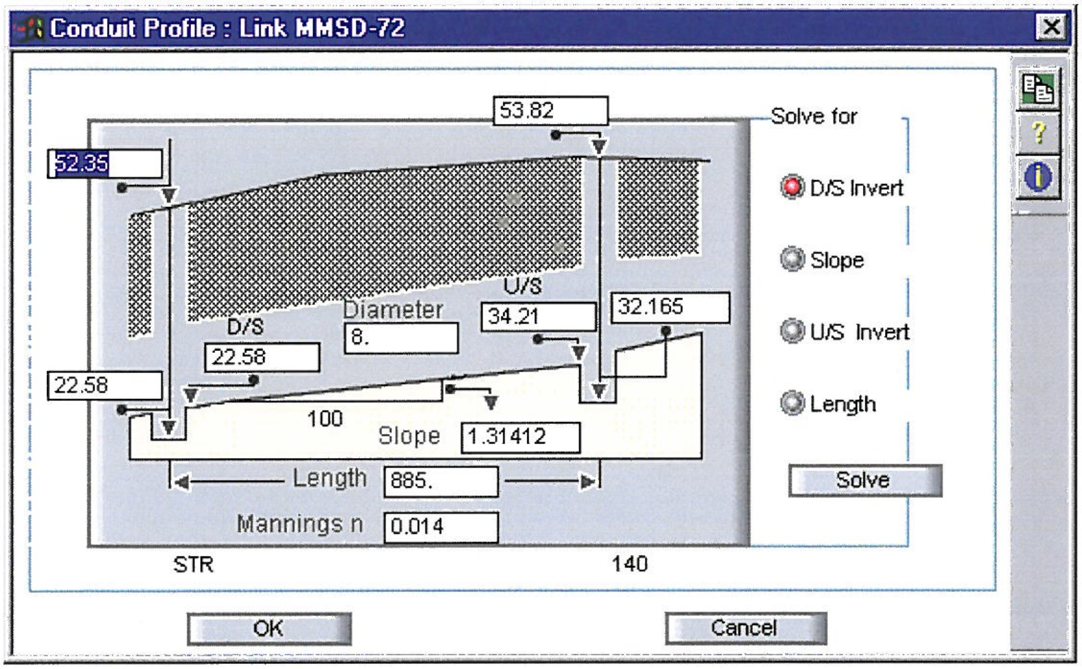


NS-4 to Milwaukee River

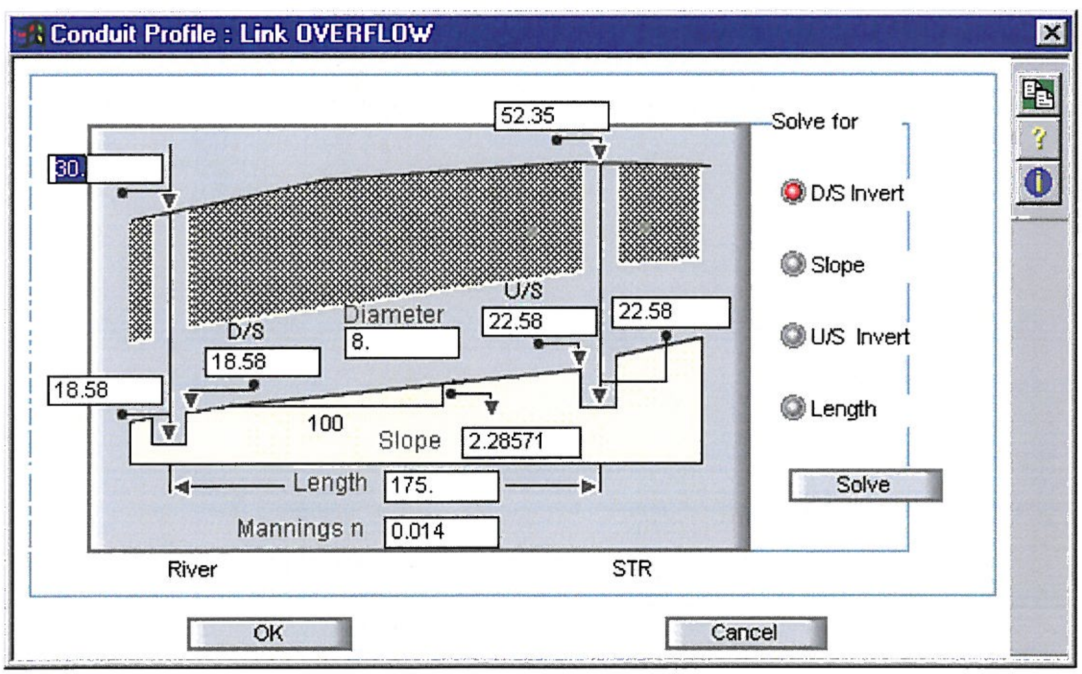


Proposed Upgrades to MMSD MIS

Oakland Avenue to NS-4



NS-4 to Milwaukee River



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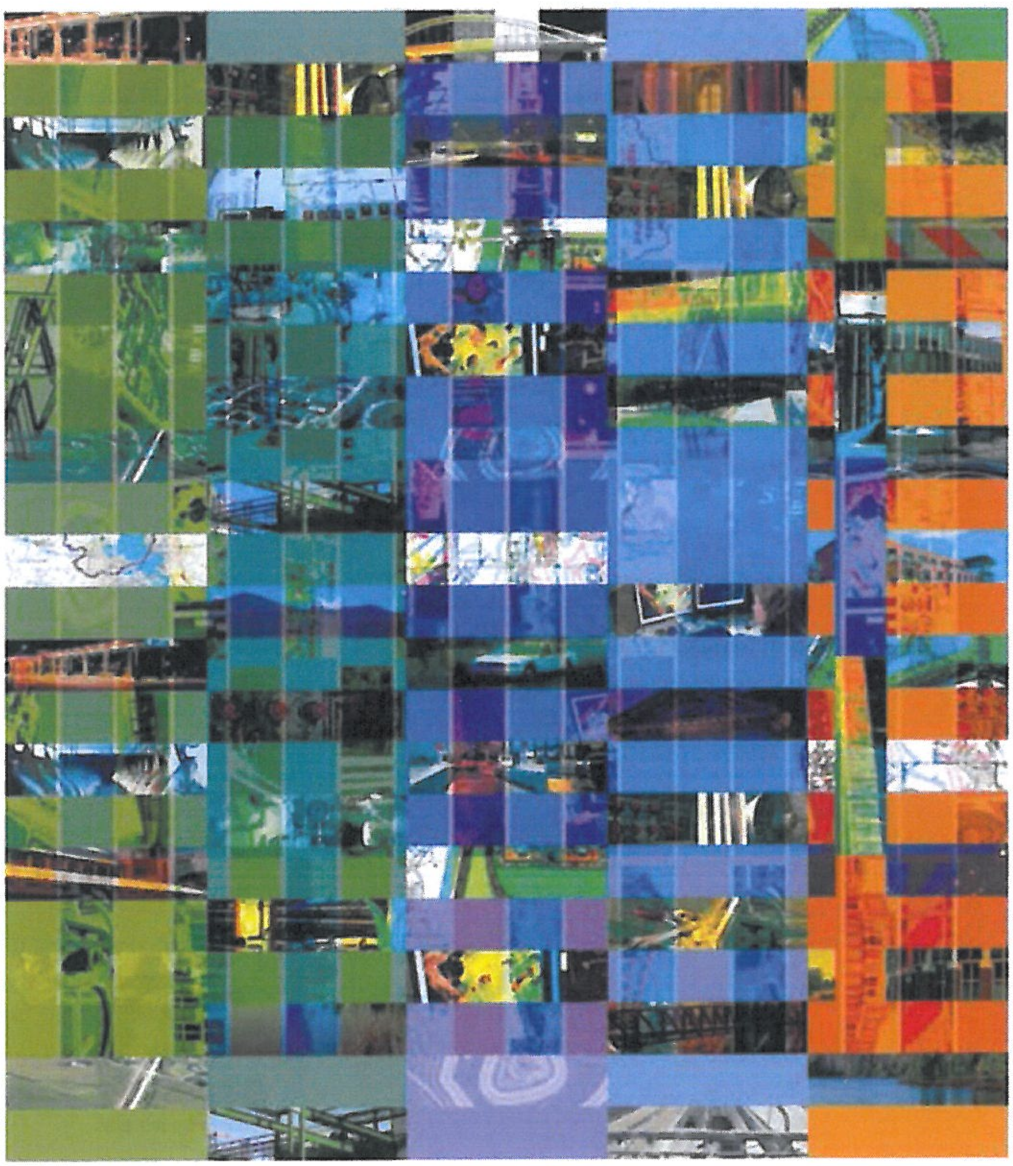
Basin SH5001 Sanitary Sewer Study



Report

Village of

Shorewood, WI

October 2011

STRAND
ASSOCIATES

Report for

Village of Shorewood, Wisconsin

Basin SH5001 Sanitary Sewer Study

WISCONSIN
ANDREW L.
CRAVEN
E-30069
Madison,
WI
PROFESSIONAL ENGINEER

10/5/11

Prepared by:

STRAND ASSOCIATES, INC.®
910 West Wingra Drive
Madison, WI 53715
www.strand.com

October 2011

STRAND
ASSOCIATES®

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SECTION 1
INTRODUCTION

1.01 INTRODUCTION

This report summarizes the methods and results of a sanitary sewer study completed by Strand Associates, Inc.® for Basin SH5001. Basin SH5001 is a fully developed urban watershed prone to wet weather sanitary sewer capacity issues, such as basement backups and street flooding. In addition, Milwaukee Metropolitan Sewerage District (MMSD) has identified Basin SH5001 (located within MMSD metershed MS0522) as a "broken" sewershed. A broken sewershed has had metered sanitary sewer flows that have exceeded the allowable discharge limit of 22,000 gallons per acre per day (gpad) established by MMSD for Basin SH5001. MMSD rules require communities with broken sewersheds to develop and implement a peak hourly flow rate reduction program. The program requires the following items.

1. Investigate sources of infiltration and inflow (I/I) on both public and private property.
2. Reduce I/I sources/flow, implement local storage, or take other action to reduce peak hourly flow rates.
3. Consider reducing private sources of I/I along with public sources.
4. Achieve the maximum allowable peak hourly flow rate within the shortest reasonable time.

The intent of the study is to address both pipe capacity and I/I issues and thereby provide a comprehensive set of recommendations to minimize future sanitary sewer basement backups and reduce peak hourly flow rates.

A. Background

Basin SH5001 refers to an area approximately bound by Capital Drive on the south, Oakland Avenue to the east, Olive Street to the north, and Wilson Drive to the west. The service area of the system is approximately 96 acres. Surface drainage is accomplished through a storm sewer system with an outfall to the Milwaukee River. Figure 1.01-1 shows the basin boundary along with the sanitary sewer system.

Basin SH5001 has approximately 736 equivalent single-family units (ESFU) primarily consisting of a mix of single-family dwellings and duplexes. The basin also has apartments and commercial properties.

The main interceptor sewer in the system is an east-west sewer located along Olive Avenue. At each intersecting street, north-south lines connect to this interceptor, which itself connects to the MMSD metropolitan interceptor sewer (MIS) west of Wilson Drive in Estabrook Park. Flow is metered in the interceptor prior to discharge in the MIS by a permanent flow meter located upstream of the MIS connection (MH 10022).

Flow metering results from the permanent flow meter are used to evaluate flows in the system and to calculate "peaking factors" for the basin for various wet weather events. The peaking factor is the ratio of maximum peak flow to the average daily flow in a sewer. In general, the higher the peaking factor, the higher the amount of nonsewage wet weather flow found in sewers. Based on historical flow metering data, peaking factors over 20 are not uncommon in Basin SH5001. Historical data used by MMSD in the 2020 Facilities Plan (Appendix 5D) shows that simulated flows in Basin SH5001 produce peak I/I rates per unit area of 32,000 gpad. As noted earlier, the maximum allowable I/I for Basin SH5001 is 22,000 gpad, indicating Basin SH5001 exceeds allowable limits.

B. Problem Definition

Basin SH5001 problems include basement backups and wet weather flows exceeding discharge limits set by MMSD. The existing sewer system is prone to wet weather surcharging that contributed to basement backups in residential basements. The backup risk areas are generally located along North Newhall Street and North Larkin Street with other isolated areas spread throughout the basin.

Starting in the 1990s, the Village began investigating the causes of basement backups and identified several key components to the underlying problem, which are summarized as follows:

1. Infiltration

Infiltration is usually slow leakage into the sewers during dry or wet weather conditions through cracks or other defects in the pipes. In general, the wetter the ground and the higher groundwater level, the more infiltration is observed. By itself, infiltration can be an important source of unwanted flow in the system. Infiltration adds to the flow in the sewers, and when the flow exceeds the capacity of the sewers, surcharging can occur.

Surcharging is defined as the condition of the sewer when the sewer is full and begins to flow under pressure. The surcharging pressures can rise to the basement levels and cause backups.

Preventing infiltration is an integral part of sewer system capacity management.

The Village has undertaken several initiatives to reduce infiltration in Basin SH5001.

a. Preventing Groundwater Leaks Into Sanitary Sewer Manholes: In 1997, a manhole inspection program identified those structures in need of repair and rehabilitation. In 2009 the Village inspected all manholes in Basin SH5001. Recommendations for rehabilitation based on the 2009 inspections are included in this study.

b. Preventing Storm Sewers from Leaking Into Sanitary Sewers: Field investigations have shown that several stretches of storm sewers were leaking into the sanitary sewers. In response, the Village lined storm sewers in 1999 and 2003 along North Newhall Street, North Bartlett Avenue, and East Kenmore Place as shown on Figure 1.01-2.

c. Preventing Groundwater Leakage Into Private Laterals: In 2007, the Village established a pilot program to investigate the effectiveness of lining private laterals to reduce groundwater infiltration. Sixteen laterals were lined along North Woodburn Street from property numbers 4100 to 4141 as shown in Figure 1.01-3. Additional discussion regarding the lining program can be found in the 2010 Northwest Sewer Study, Basin SH5006.

d. Preventing Leakage Into Sanitary Sewer Main: In 2005, the Village used televising equipment to assess the condition of the majority of the Village-owned sanitary sewers within Basin SH5001. The sewers that were televised are shown in Figure 1.01-4.

In 2007 Shorewood began lining sanitary sewer in Basin SH5001 to help reduce I/I into the Village-owned sanitary sewer mains. Lining was completed on North Woodburn Street in 2007 and North Morris Boulevard in 2008/2009 as shown in Figure 1.01-3.

2. Wet Weather Inflow

Wet weather inflow is a direct response to rainfall and can be observed in sewers shortly after the start of rainfall. Inflow adds to the flow in the sewers, and when the flow exceeds the capacity of the sewers, surcharging can occur. Inflow sources include, but are not limited to, downspout, sump pump, foundation drain, and storm sewer direct connections to the sanitary sewer. The Village has completed smoke testing and disconnected foundation drains in portions of Basin SH5001 in an effort to identify and reduce inflow into the sanitary sewer system.

a. Preventing Inflow from Downspout Connections and other Direct Connections: in 2009 the Village conducted smoke testing along North Larkin Street, North Newhall Street, North Bartlett Avenue, and East Kenmore Place in Basin SH5001 as shown in Figure 1.01-5. The smoke testing identified eight connected downspouts, one storm sewer and two catch basins with smoke, three unsealed drain pipes where the downspout now drains to the yard, and smoke emanating from cracks around two manholes.

b. Preventing Inflow from Foundation Drain Connections: As discussed in the 2010 Northwest Sewer Study for Basin SH5006 the Village undertook a pilot program that subsidized residents who agreed to have their foundation drains disconnected from the sewers in Basin SH5006. This was accomplished by installing sump pumps at these properties. Continuous monitoring of these sump pumps revealed that the amount of groundwater collected at the sumps was less than anticipated and that foundation drain disconnections would not be effective in large scale.

3. Hydraulic Deficiencies of Village Sewers

A sewer study of Basin SH5001 was recently completed by Strand Associates as a part of the report titled Village of Shorewood *Comprehensive Facility Plan for Sanitary Sewer, Combined Sewer, and Storm Sewer Improvements* (October 2011). Hydraulic deficiencies of the Village sewers in Basin SH5001 were identified and improvements were recommended. Specifically, the sewers along North Newhall Street and East Olive Street were identified as areas requiring additional conveyance capacity.

BASIN SH5001 - SANITARY SEWER AND BASIN BOUNDARY
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 1.01-1
3646.001

Path: S:\MAD\3600--3699\3646\001\Data\GIS\Figures\Figure 1.01-1 Sanitary Sewer Lined 11x17.mxd

BASIN SH5001 - SANITARY SEWER PREVIOUSLY TELEVISED
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 1.01-4
3646.001

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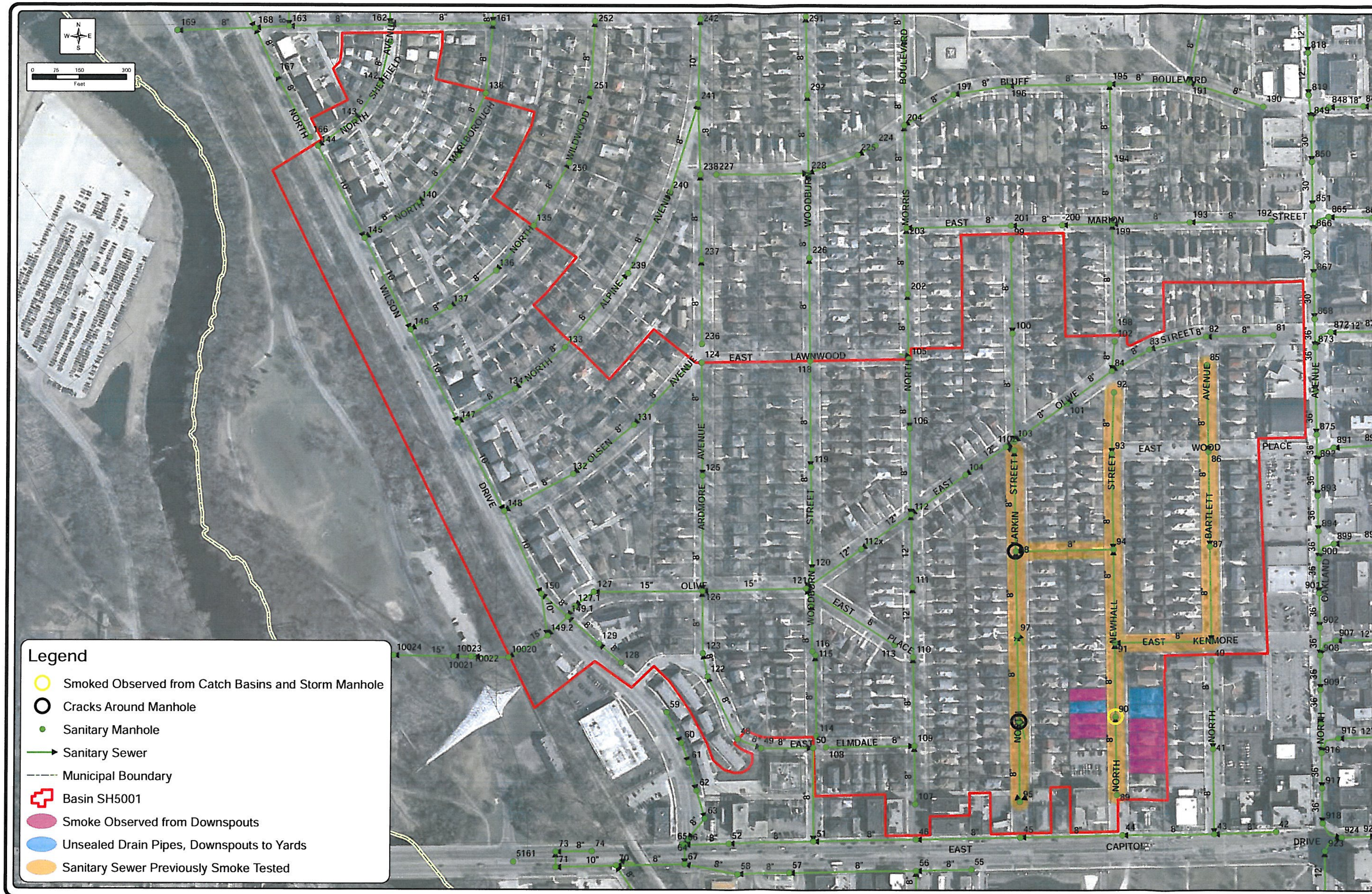


BASIN SH5001 - SANITARY SEWER PREVIOUSLY SMOKE TESTED
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 1.01-5
3646.001

Path: S:\MAD\3600--3699\3646\001\Data\GIS\Figures\Figure 1.01-5 Smoke Tested 11x17.mxd

SECTION 2
INFILTRATION AND INFLOW INVESTIGATION

2.01 INTRODUCTION

As part of this study, the sanitary sewer capacity of Basin SH5001 was evaluated using flow data obtained from five Isco 2150 flow monitors located in such a way to divide the study area into five subbasins. Figure 2.01-1 is a map of Basin SH5001 showing the five subbasins and flow meter locations. The first digit in the flow meter reference number "1" corresponds with the basin number "1." The last three digits represent the manhole the flow meter was installed in based on the Village's manhole numbering system. Table 2.01-1 lists the five flow meters installed during this study period and the subbasins tributary to the meters.

Flow Meter	Tributary Subbasins	Approximate Locations	Dates Installed
SH 1098	S1A	North Larkin Street and Easement	May 21, 2011–Currently Installed
SH 1104	S1A + S1B	East Olive Street between North Morris Boulevard and North Larkin Street	March 11, 2011–Currently Installed
SH 1148	S1D	North Wilson Drive and North Olsen Avenue	March 11, 2011–Currently Installed
SH 1149	S1A + S1B + S1C	North Wilson Drive and East Olive Street	March 11, 2011–Currently Installed
CK 0522	S1A + S1B + S1C + S1D + S1E	Estabrook Park South Parking Lot	May 2, 2007–Currently Installed

Table 2.01-1 Flow Meters and Associated Tributary Subbasins

In addition to the five meters installed during this study period, two additional portable meters were installed prior to the study as shown in Table 2.01-2.

Flow Meter	Tributary Subbasins	Approximate Locations	Dates Installed
SH 0121	S1A+S1B and Portions of S1C	East Olive Street and North Woodburn Street	March 31, 2008–March 16, 2009
SH 1098	S1A	North Larkin Street and Easement	March 26, 2009–Nov. 20, 2009

Table 2.01-2 Flow Meters Installed Prior to Study

The flow metering data provides metered sewerage flow, velocity, and depth in 5-minute intervals. The data is used to evaluate dry weather and wet weather flow rates. The data is used in conjunction with a computer model to predict the system's response to various rainfall events.

Rain gauge data was also obtained from permanent rain gauge locations maintained by MMSD. Figure 2.01-2 shows various rain gauge locations. For this study we have assumed rain gauge WS1202 to represent the rainfall events that occur over Basin SH5001. Rainfall data from other gauge locations was obtained for comparison but is not presented. Rain gauge WS1225 was installed in June 2011 in the Shorewood Department of Public Works Yard. Since the gauge was not installed for the full duration of the study, rainfall data was used for comparison purposes only and is not presented.

Rain gauge data is used to evaluate the intensity and duration of various rainfall events. The rainfall events are compared to the flow metering results to analyze the response of the sanitary sewer system to various rainfall events. Table 2.01-3 lists historic rainfall and flow metering data along with data from three events metered as a part of this study. Peak instantaneous flows are the maximum metered flow. Flow metering data is obtained every five minutes. Peak hourly flow is the maximum metered flow over a one hour period. Peak hourly GPAD is the peak hourly flow divided by the area of the subbasin in acres. Note the June 21, 2011, event had the highest metered flow during the study period and is similar in magnitude to the April 26, 2009 event. The June 21, 2011, is smaller in magnitude than the historic events of July 2010, June 2008, and June 2009. Additional detail regarding the three events metered as a part of this study is provided later in this report.

Date	Instanteous Peak Flow (mgd)	Peak Hourly Flow (mgd)	24-hr Rainfall (in)	1-hr Rainfall (in)	Peak Hourly GPAD
6/7/2008	5.9	4.6	5.6	1.9	47,600
4/26/2009	2.9	2.6	1.5	0.4	27,200
6/19/2009	3.6	3.0	2.9	2.0	31,300
7/15/2010	6.5	4.7	3.8	1.9	48,700
7/22/2010	8.0	7.5	7.7	5.0	77,600
4/26/2011	1.7	1.6	1.7	0.4	16,500
6/21/2011	2.9	2.4	2.6	1.6	24,900
7/27/2011	1.0	0.7	2.8	0.6	7,000

Table 2.01-3 Historic Flow Metering (Meter CK0522) and Rain Gauge Data (WS-1202)

2.02 INFILTRATION AND INFLOW INVESTIGATION

When comparing I/I in various subbasins, the number of laterals, pipe diameters, and pipe lengths are considered. Pipe diameter and length are generally combined to calculate the quantity of inch-diameter pipe miles for a subbasin. The result is a single number per subbasin, describing the relative length and size of pipes found in that subbasin that can be compared with flow metering data. The higher the amount of sewer pipe (both in terms of length and size/diameter), the greater potential for I/I. The connection information of each basin is presented in Table 2.02-1. Refer to Figure 2.01-1 for the location of the flow metering basins.

Subbasin ID	Area (acres)	Sewer Pipe (in-mile)	Equivalent Single Family Units (ESFU)	Service Laterals
S1A	16.5	4.2	163	136
S1B	18.4	4.7	117	61
S1C	32.1	10.4	237	173
S1D	21.0	5.5	159	72
S1E	8.5	3.4	60	23
Totals	96.4	28.3	736	465

Table 2.02-1 Basin SH5001 Area and Connection Data

A. Dry Weather Flow

Metered dry weather flow rates were evaluated during four dry weather periods consisting of three consecutive days of dry weather. The following dry weather periods were evaluated:

1. March 15, 2011 to March 17, 2011
2. May 8, 2011 to May 10, 2011
3. July 2, 2011 to July 4, 2011
4. July 8, 2011 to July 10, 2011

The dry weather flow rates were variable between various periods of dry weather, and it was found that an average of the four periods of dry weather yielded meaningful results for Subbasins S1A, S1B, S1C, and S1D. Meaningful results were not obtained for Subbasin S1E as the flow metered from CK0522, the meter measuring all flow from the entire basin, was less than the flow measured in upstream meters. Some of the variability in results may be attributed to the shallow flow depths observed in the metering manholes, specifically, the manhole with flow meter CK0522. Shallow flow depths can create inaccuracies in flow metering measurements.

Water use records are sometimes used as an estimate of dry weather wastewater flow rates. Table 2.02-2 contains a summary of water use records for the study area from February 15 to May 15, 2011, broken down by tributary basin. In order to check the validity of these water use records, the flow per ESFU was calculated. For Basin SH5001, this was determined to be approximately 150 gallons/ESFU. This is within accepted industry standards for residential neighborhoods. A previous evaluation of Basin SH5006, also located in the Village of Shorewood, determined that the flow per ESFU was approximately 175 gallons/ESFU. Therefore, it was determined that the water use records provided could be used as a reliable estimate of dry weather wastewater flow rates.

Table 2.02-2 presents a comparison of the measured daily water usage and the metered residential sewer flows. The difference between these two values provides an estimate of dry weather infiltration in the study area. The results indicate the presence of dry weather infiltration in three of the five subbasins.

Subbasin ID	Measured Daily Water Usage (gal/day)	Metered Daily Residential Sewer Flow (gal/day)	Computed Daily Dry Weather Infiltration (gal/day)	Dry Weather Infiltration as a Percent of Daily Sewer Flow
S1A	22,000	55,500	33,500	137%
S1B	19,700	46,000	26,300	150%
S1C	35,400	155,600	120,200	338%
S1D	20,100	14,100	0	0%
S1E	8,400	Inconclusive		
Totals	105,600	271,200	180,000	

Table 2.02-2 Dry Weather Infiltration in Subbasins

Subbasins S1A and S1B are located on the east end of basin SH5001 in areas that have been known to experience wet weather problems. Subbasin S1C is in the middle of basin SH5001 and has some known wet weather problems, although not as extensive as subbasins S1A and S1B. Subbasins S1D and S1E have not experienced extensive wet weather problems and do not appear to have significant dry weather infiltration. Based on the flow metering results, dry weather infiltration is occurring in subbasins S1A, S1B, and S1C. As noted earlier, dry weather flow metering data was variable (one reason being the low flow depths observed in manholes) and that the data listed in Table 2.02-2 should be used as a trending tool versus quantifying actual volumes of dry weather infiltration. The flow metering results will be used in conjunction with the televising and smoke testing findings to develop rehabilitation and investigation recommendations that will be discussed in Section 3.

B. Wet Weather Flow

Approximately 14 rainfall events were evaluated during the 7 months of flow monitoring. As shown in Figure 2.02-1, the three largest storm events occurred on April 26, 2011 (0.38 inches in 1 hour, 1.71 inches in 24 hours), June 21, 2011 (1.61 inches in 1 hour), and July 27, 2011 (0.62 inches in 1 hour, 2.77 inches in 24 hours). The flows recorded from these three events were used for the wet weather analysis.

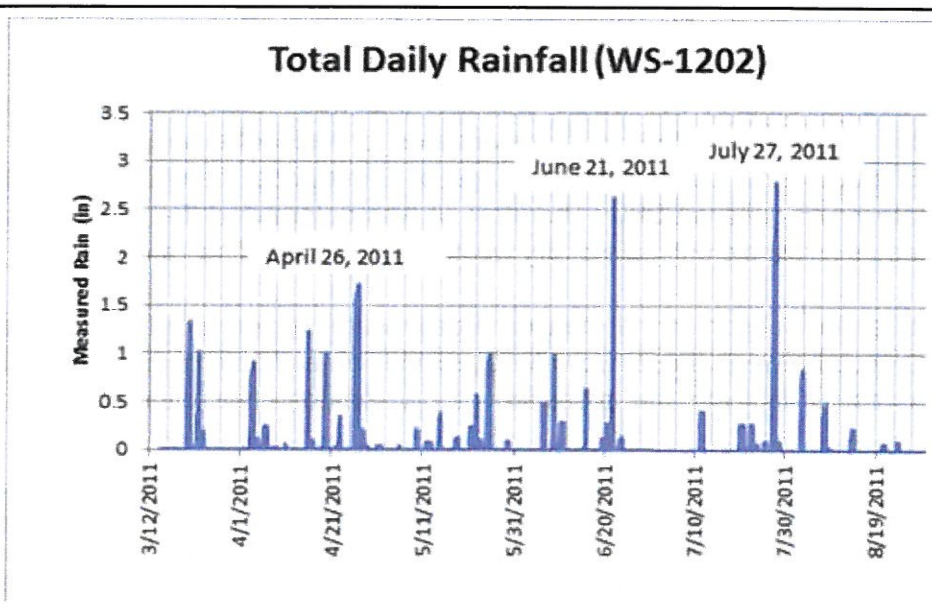
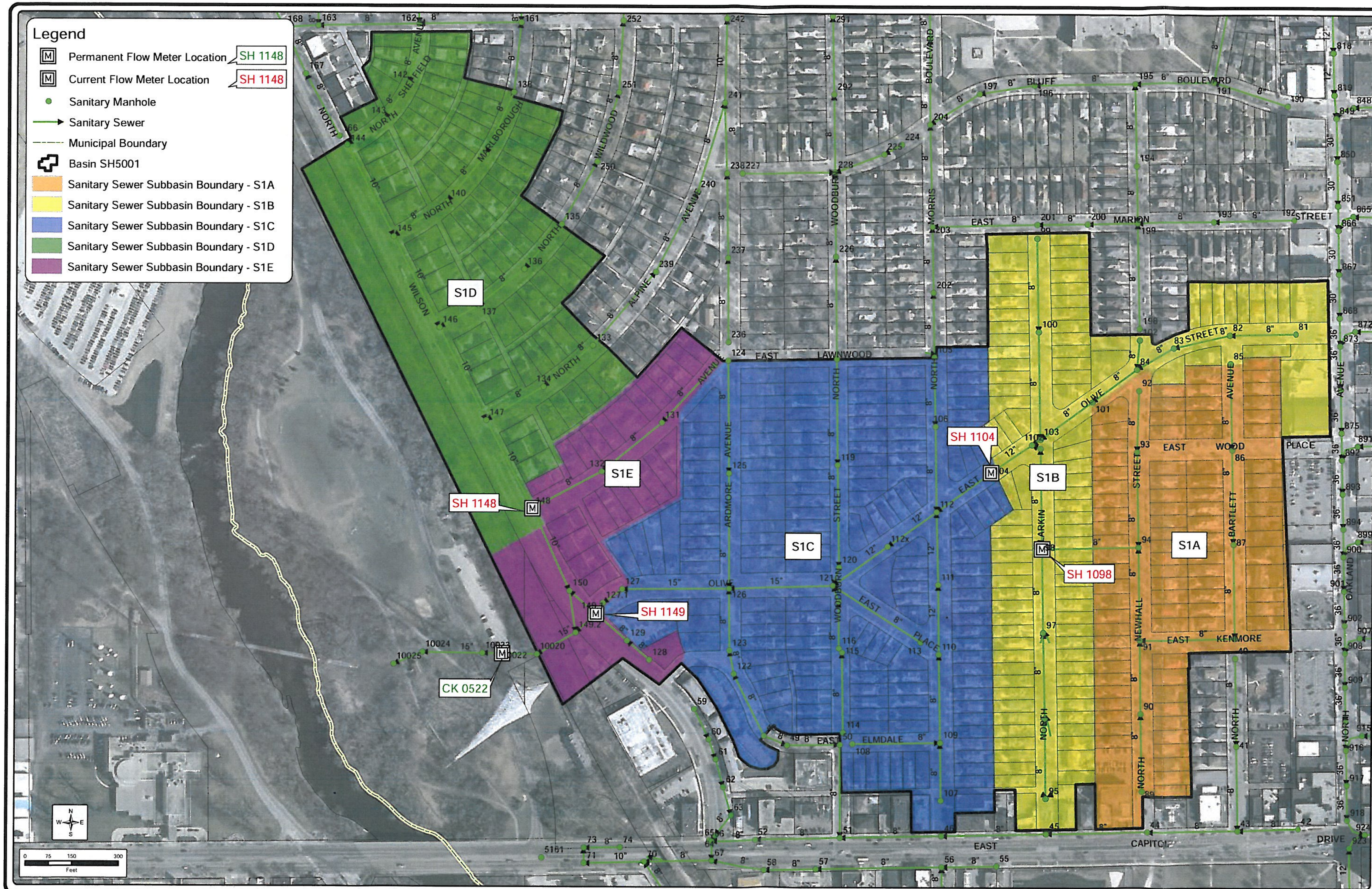


Figure 2.02-1 Total Daily Rainfall (WS-1202)

Figure 2.02-2 is a plot of the metered flow at the permanent metering site CK0522 that metered flow from the entire basin. The largest flow occurred on June 21, 2011. The flow meters at the other temporary metering sites show similar responses to the rainfall events, i.e., peak flow on June 21, 2011, and higher flows on April 26, 2011, and July 27, 2011, in response to rainfall events. This graph also shows numerous wet weather responses in March and April. This would be expected because of higher soil moisture conditions associated with spring weather.



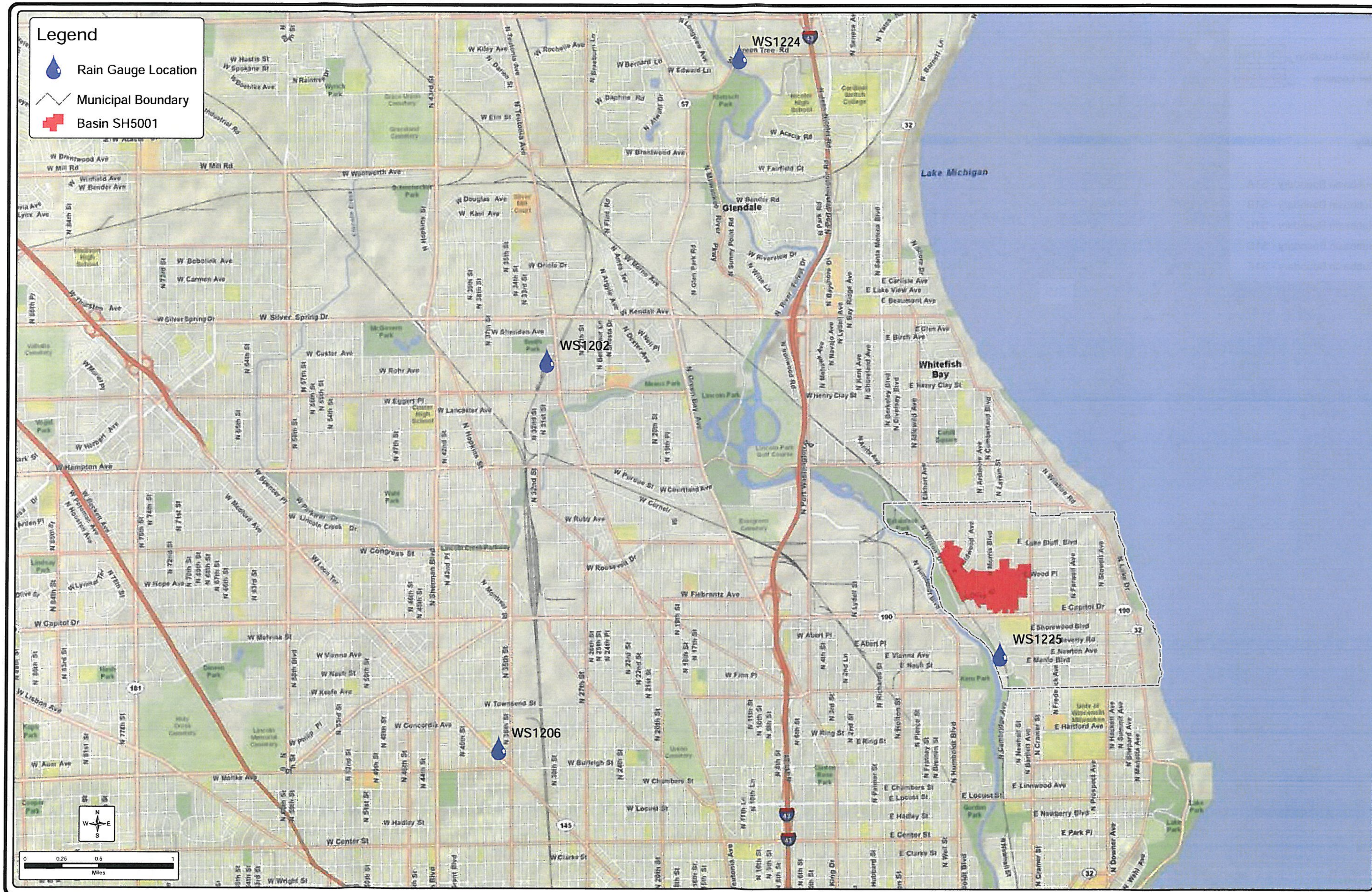
Path: S:\MAD\3600--3699\3646\001\Data\GIS\Figures\Figure 2.01-1 Sub Basins 11x17.mxd

BASIN SH5001 - SANITARY SEWER SUBBASINS AND FLOW METER LOCATIONS
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 2.01-1
3646.001



BASIN SH5001 - MMSD RAIN GAUGE LOCATIONS
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 2.01-2
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BASIN SH5001 - RECOMMENDED SEWER UPGRADES
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 2.02-7
3646.001

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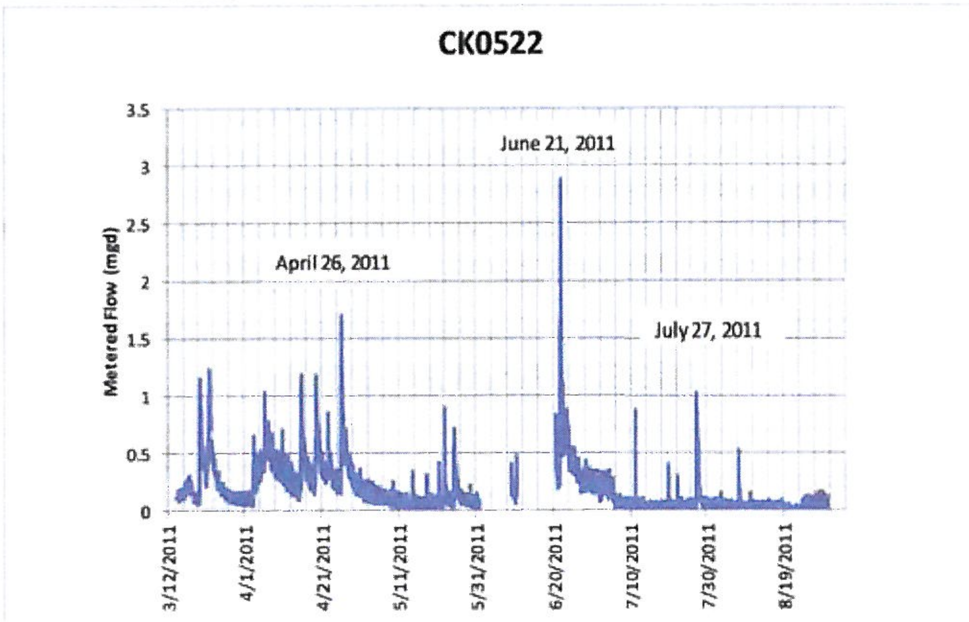

Figure 2.02-2 Metered Flow at CK0522–Entire Study Period

These events along with other smaller events show a distinctive peak in flows generally within the first hour after the start of the rainfall event. This peak can be largely attributed to inflow sources. As the ground becomes saturated because of rainfall, the water finds its way into the cracks of the pipes and infiltrates the system. Infiltration into the system generally occurs after inflow sources are contributing to sewer flows.

Figure 2.02-3 is a plot of rainfall and metered flow for CK0522 for the April 26, 2011 event. The April 26 rainfall occurred over an approximately seven-hour period and caused an I/I event of about 32 hours, which means that flow measurement did not return to near dry weather conditions for 32 hours after the beginning of the rain. In general, the first quarter of the event saw a large peak, indicating inflow sources were active, followed by a gradually diminishing flow for the next 24 hours, which is largely attributed to slower leakage and infiltration into the pipes through cracks and joints in the pipes. The flow meters at the other temporary metering sites show similar responses to the rainfall events, i.e., a quick steady increase in flow followed by a more gradual reduction in flow.

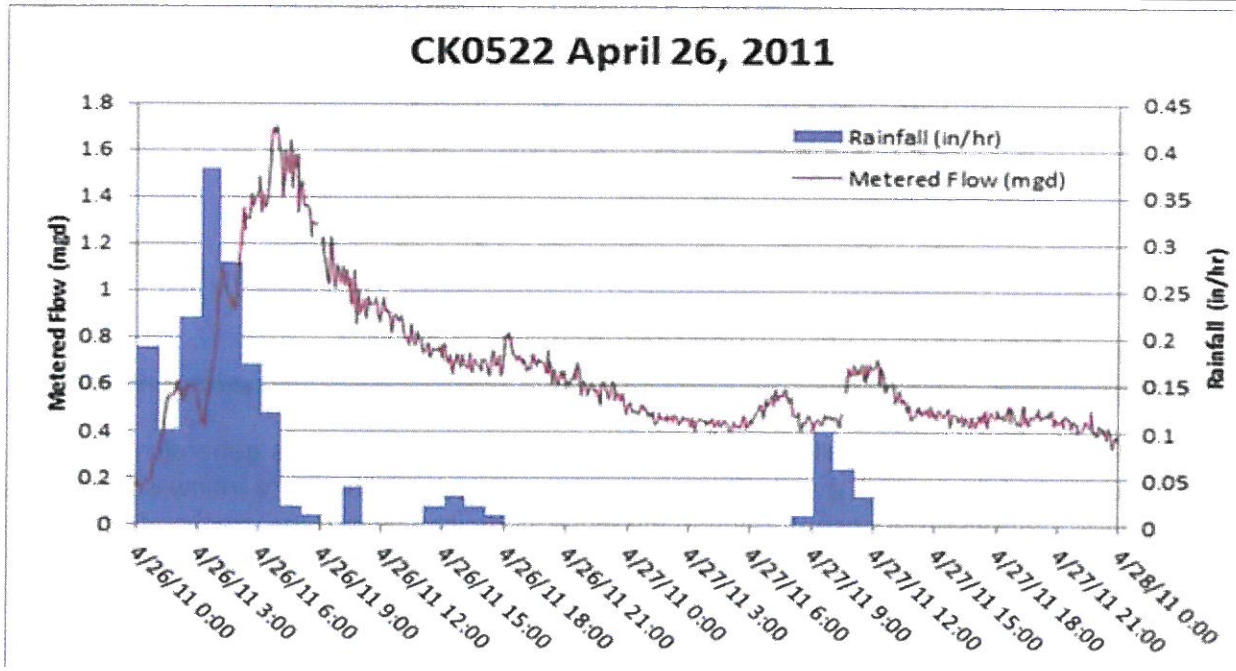

Figure 2.02-3 Rainfall and Metered Flow at CK0522 for April 26, 2011

Figure 2.02-4 is a plot of rainfall and metered flow for CK0522 for the June 21, 2011 event. The June 21 rainfall occurred over an approximately three-hour period and caused an I/I event of about 15 hours. Sewage flows increased within ten minutes of rainfall being measured and were indicative of inflow into the system. The flow diminished quickly following the peak as rain stopped for about an hour. Flow then increased sharply in response to additional rainfall and decreased quickly after the rainfall stopped. Following the last rainfall, flow dropped sharply and then gradually diminished over the remaining ten hours as infiltration diminished. The flow meters at the other temporary metering sites showed similar responses to the rainfall events, i.e., a sharp increase in flow followed by a more gradual reduction in flow.

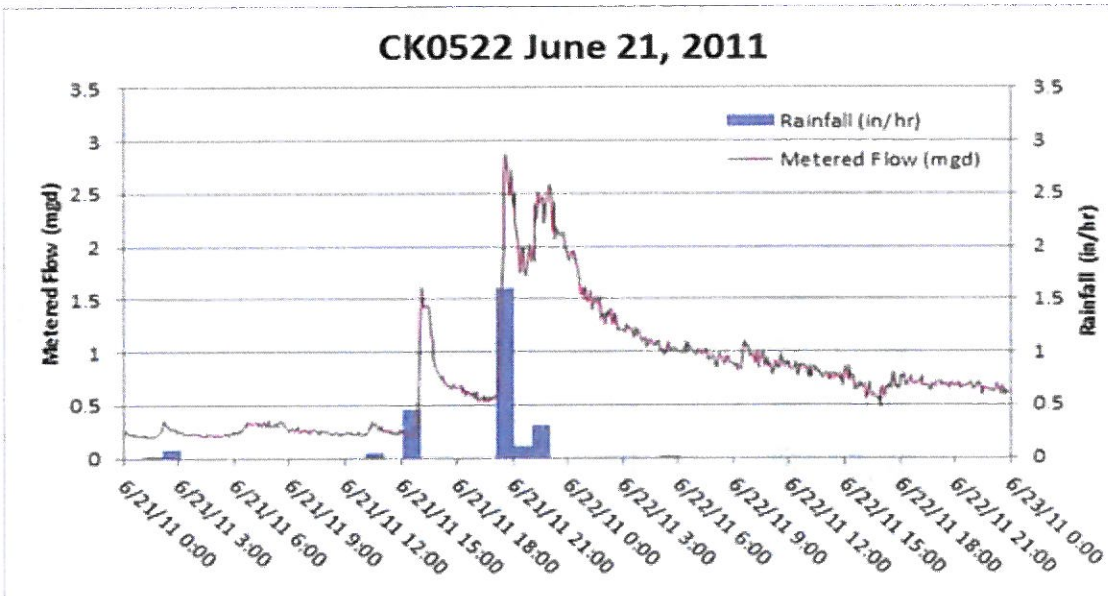

Figure 2.02-4 Metered Flow at CK0522 for June 21, 2011

Figure 2.02-5 is a plot of rainfall and metered flow for CK0522 for the July 27, 2011 event. The July 27 rainfall occurred over an approximately 16-hour period and caused an I/I event of about 18 hours. The July 27 rainfall had four distinct events. Flow increased sharply within the first half-hour of the rainfall beginning for each event, indicative of inflow into the system. Flow decreased quickly after the rainfall event stopped indicating inflow contributed to the majority of the increase in flow. Ground conditions for the July 27 events were likely much drier than they were for the June 21 and April 26 events based on rainfall totals preceding the events. The flow meters at the other temporary metering sites show similar responses to the rainfall events, i.e., a sharp increase in flow followed by a sharp decrease in flow.

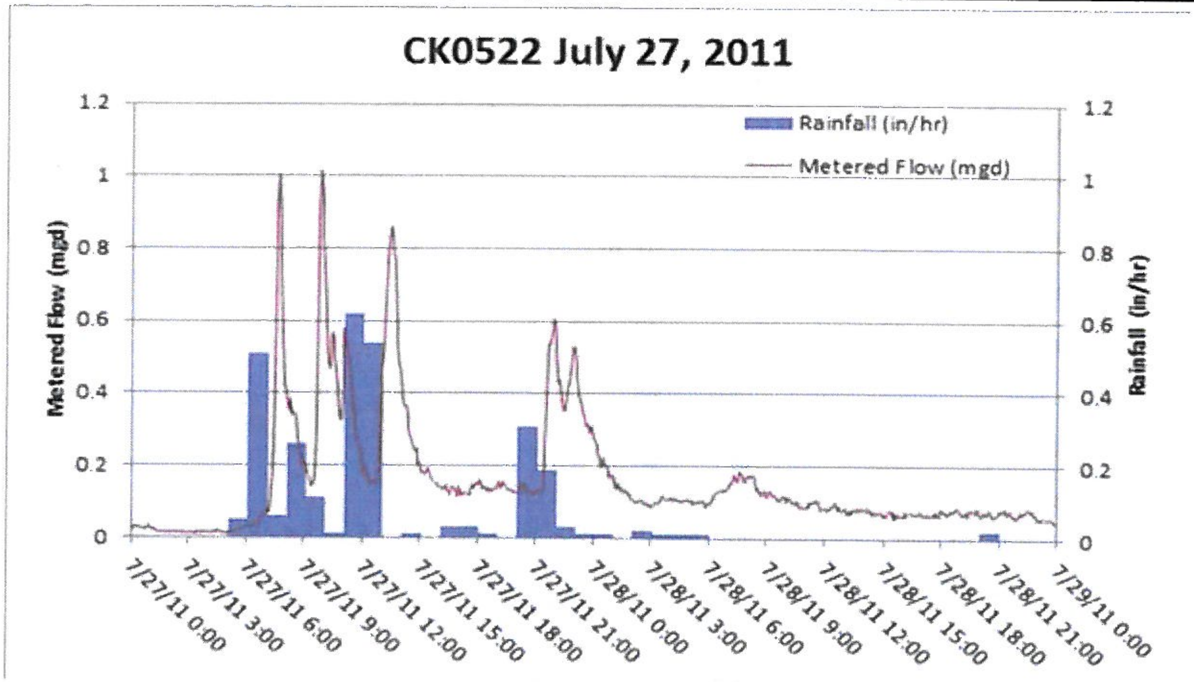

Figure 2.02-5 Metered Flow at CK0522 for July 27, 2011

Figure 2.02-6 is a plot of rainfall intensity versus metered peak hourly flow for CK0522 for the 14 rainfall events evaluated. A linear regression line has been added to the plot and shows that the data has a linear relationship. A linear relationship indicates a direct link between rainfall and peak flow rates, which is indicative of inflow into the system. This is also supported by the rapid increase in flows after the rain events begin and the rapid decrease in flows after the event ends. Note that the response of a sewer system to various rainfall events is dependent on numerous conditions such as soil type, soil moisture, and groundwater level. However, for an inflow-dominated system, the response to the system is affected less by antecedent soil conditions.

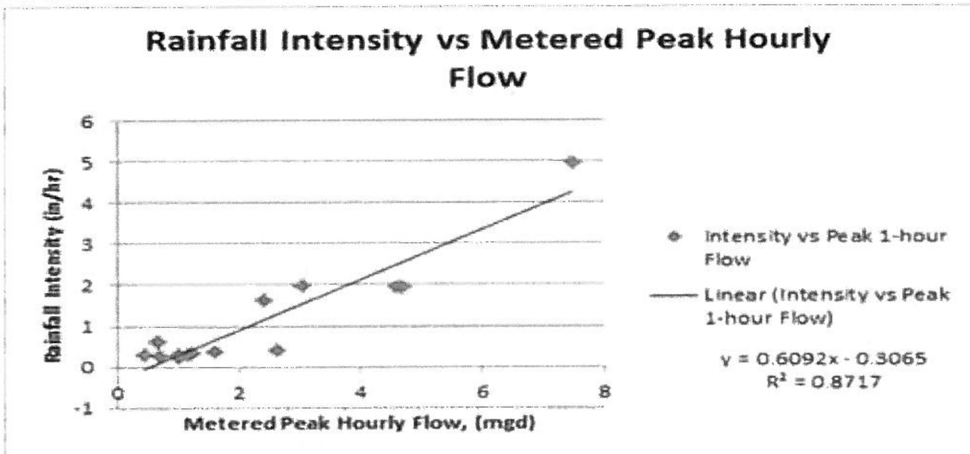

Figure 2.02-6 Rainfall Intensity vs. Metered Peak Hourly Flow

The June 21, 2011, event had the largest metered peak hourly and instantaneous flow and was analyzed in additional detail. To determine the peak hourly and instantaneous flows tributary to each subbasin, a mass balance calculation was completed as follows:

Flow meter SH1098 metered subbasin S1A
Flow meter SH1104 metered the combined flow from subbasins S1A+S1B
Flow meter SH1149 metered the combined flow from subbasins S1A+S1B+S1C

Flow in Subbasin S1B = SH1104 - SH1098
Flow in Subbasin S1C = SH1149 - SH1104

In order to understand the wet weather performance of the subbasins, peak instantaneous and peak hourly flow rates were evaluated. Table 2.02-3 presents a summary of the peak instantaneous flows that were calculated for each subbasin within the study area. Also presented in Table 2.02-3 are the percentages of sewer (in terms of inch diameter miles) that are contained in each basin. A comparison of the percentage of flow in each subbasin and the percentage of pipe provides an indication of the severity of I/I in each subbasin. For example, subbasin S1A contains approximately 15 percent of the pipe, but contributes 23 percent of the peak instantaneous flow. The flow metering results in Table 2.02-3 also indicate significant amounts of inflow to all subbasins.

Subbasin ID	Peak Instantaneous Wet Weather Flow (gal/day)[1]	% of Flow of Basin SH5001	% Pipe Diameter Miles (in-dia-miles)
S1A	940,000	23%	15%
S1B	710,000	18%	17%
S1C	1,080,000	27%	37%
S1D	490,000	12%	19%
S1E	800,000	20%	12%
Totals	4,020,000[2]		

[1]For each subbasin during rainfall event
[2]Sum of all subbasins. This does not represent the peak instantatneous metered flow from the study as measured at CK0522.

Table 2.02-3 Peak Instantaneous Flow Data for the June 21, 2011 Rainfall

Table 2.02-4 presents a summary of peak hourly flows that were calculated for each subbasin within the study area. Also presented in Table 2.02-4 are the tributary areas for each subbasin. These two values were used to calculate the gpad value for each subbasin. This allows comparison of each subbasin to the MMSD standard of 22,000 gpad. The values also allow a comparison between subbasins, which assists in determining priorities for future investigation and rehabilitation activities.

The peak hourly flow for the entire basin, as metered at site CK0522, was approximately 2.4 mgd (2,400,000 gpd). Basin SH5001 has a total area of approximately 96 acres. Therefore, for the June 21, 2011 rainfall event, the basin contributed approximately 25,000 gpad, which is above the MMSD threshold value.

Subbasin ID	Peak Hourly Wet Weather Flow (gal/day)	Area (acres)	Wet Weather Flow (gal/ac/day) GPAD
S1A	850,000	16.5	51,500
S1B	660,000	18.4	35,900
S1C	370,000	31.6	11,700
S1D	420,000	21.0	20,000
S1E	490,000	8.5	57,600

Table 2.02-4 Peak Hourly Flow Data for the June 21, 2011 Rainfall

As mentioned in Section 1, hydraulic deficiencies have been identified in Basin SH5001. These deficiencies were identified assuming a uniform distribution of sewerage input into an XPSWMM computer model. Based on flow metering results, the sewage input into the system is not uniform.

The peak instantaneous flows shown in Table 2.02-3 for subbasins S1A and S1D, along with the total metered flow from CK0522 were used to update and calibrate the XPSWMM computer to better reflect the metered sewage flow distribution into the system. The updated and calibrated XPSWMM computer model was used to assess the performance of Basin SH5001 during the design storm event of 2 inches/hour. The recommended capacity upgrades are shown in Figure 2.02-7 and include increases in sewer piping size along North Newhall Street and East Olive Street.

2.03 SEWER AND MANHOLE CONDITION ANALYSIS

As mentioned in Section 1, the Village has completed numerous investigations and rehabilitation efforts for the sanitary sewer collection system and stormwater conveyance system. The results of the investigations and rehabilitation efforts have been reviewed, and additional investigations and rehabilitation work is recommended as follows.

A. Sewer Investigation and Rehabilitation

Various methods are available to investigate and rehabilitate sanitary sewers. Investigative methods recommended include dye water flooding of storm sewers, smoke testing, and sanitary sewer televising. The method recommended to rehabilitate sewer mains is sanitary sewer lining.

In areas where laterals were observed to be cracked or have root penetration, dye water flooding of the storm sewer is recommended. Smoke testing of sanitary sewers is recommended for the entire basin to help identify potential sources of I/I, particularly inflow. In subbasin S1A, the sanitary sewer has been smoked tested and some inflow sources have been identified. Subbasin S1A does have a significant number of downspout connections that drain below grade. Smoke testing of the storm sewer would help confirm downspouts are not connected to the sanitary sewer system through foundation drains. The findings of the sewer investigation work and recommendations for collection system rehabilitation are discussed in Section 3. The need for sanitary sewer lining was determined based on review of sanitary sewer televising information. In pipes that were observed to have leaks, root penetration, or structural deficiencies, such as cracks and holes, sanitary sewer lining is recommended.

B. Manhole Rehabilitation

Manhole rehabilitation recommendations were determined based on manhole inspection reports provided by the Village. If defects were identified in at least two sections of the manhole a cementitious liner and cast-in-place (CIP) chimney liner is recommended. If defects were only found in the chimney, a CIP chimney liner is recommended. If the manhole frame was offset or a gap noted, it is recommended to rebuild the top of the manhole. If leaks or minor defects were observed in one section of the manhole, minor grouting is recommended. Also, note the cover gasket is missing on a substantial number of manhole covers, and reinstallation is recommended.

SECTION 3
CONCLUSIONS AND RECOMMENDATIONS

3.01 SUMMARY OF FINDINGS AND RECOMMENDATIONS

Flow metering results indicate dry weather infiltration is observed in the majority of the basin, particularly in subbasins S1A, S1B, and S1C. Flow metering results also indicate significant amounts of inflow into all parts of the basin.

Table 3.01-1 provides a summary of recommended sewer investigation and work such as sanitary sewer mainline lining, smoke testing, dye water flooding, televising, and rehabilitation of manholes. Based on the findings of additional investigations, the need for storm sewer and lateral lining, and other rehabilitation will be determined.

The Village has performed many repairs to the sewers in Basin SH5001; however significant amounts of I/I remain in the system. Removing additional I/I from the sewer system will provide a higher level of basement backup protection for residents and reduce peak hourly flows to address discharge limits set by MMSD. As mentioned previously, Basin SH5001 is above allowable discharge limits set by MMSD.

A summary of findings is shown in Table 3.01-1. Recommended investigative and rehabilitation efforts are also shown in Figures 3.01-1 through 3.01-6. The following is a list of the figures and figure title.

1. Figure 3.01-1 Sanitary Sewer Recommended for Lining
2. Figure 3.01-2 Sanitary Sewer Manhole Rehabilitation Recommendations
3. Figure 3.01-3 Sanitary Sewer Recommended for Smoke Testing
4. Figure 3.01-4 Existing Storm Sewer Recommended for Smoke Testing
5. Figure 3.01-5 Dye Water Flooding Recommended
6. Figure 3.01-6 Sanitary Sewer Recommended for Televising

A summary of recommended sewer investigation and rehabilitation is shown in Table 3.01-2. Further investigation efforts include mainly smoke testing and dye water flooding. Capital improvements consist of sanitary sewer lining and manhole rehabilitation.

3.02 PROPOSED FOUR-YEAR SCHEDULE FOR REHABILITATION

The recommended plan is a four-year plan that addresses currently known deficiencies and provides investigations and engineering design to address anticipated future discoveries of deficiencies. Future discoveries will be implemented into a revised plan based on the investigations conducted in 2012. All investigative work is scheduled for 2012. Table 3.02-1 (2012) and Table 3.02-2 (2013, 2014, and 2015) list the recommended capital improvements and investigative work. Capital improvements work in 2012 focuses on subbasin S1A, which has history of basement backups. Capital improvements work in 2013 focuses on subbasin S1B and S1C. Capital improvements work is scheduled for 2014 and 2015 for subbasins S1D and S1E.

TABLE 3.01-1 SUMMARY OF FINDINGS

Subbasin	Wet Weather Flow	Predominant Source of Wet Weather Flow	Dry Weather Flow	Sewer Rehabilitation Focus
S1A	Very High	Inflow	Moderate	• TV on Bartlett and Newhall shows need for sanitary sewer lining • Sanitary sewers have been smoke tested • Smoke testing of storm sewers recommended • Storm sewers in basin have been lined • Dyed water flood testing not recommended with lined storm sewer • TV sewer in easement, MH 94 to MH 98
S1B	Very High	Inflow	Moderate	• • TV on Larkin shows need for sanitary sewer lining • Smoke testing of sanitary sewers recommended • Dyed water flood testing needed • Storm sewer and lateral lining to be considered based on results of above investigations completed
S1C	Moderate	Infiltration/Inflow	High	• TV on Woodburn, Kenmore, Ardmore, and Elmdale shows need for sanitary sewer lining • Smoke testing of sanitary sewers recommended • Dyed water flood testing needed • Sewers on Morris have been lined • Storm sewer and lateral lining to be considered based on results of above investigations completed
S1D	High	Inflow	Low	• TV on Wilson, Marlborough, Wildwood, and Alpine shows need for sanitary sewer lining • Smoke testing of sanitary sewers recommended • Dyed water flood testing needed • Storm sewer and lateral lining to be considered based on results of above investigations completed
S1E	Moderate	Inflow	Low	• TV on Olsen and Wilson shows need for sanitary sewer lining • Smoke testing of sanitary sewers recommended • Dyed water flood testing needed • Storm sewer and lateral lining to be considered based on results of above investigations completed • TV sewers at Wilson and Olive intersection and sewers west of Wilson in parkway

TABLE 3.01-2 RECOMMENDED SEWER INVESTIGATION AND REHABILITATION WORK

Subbasin	Recommended Investigation	Recommended Capital Improvements
S1A	880 ft of smoke testing of storm sewer on Bartlett	580 ft of lining on Bartlett
	310 ft of smoke testing of storm sewer on Kenmore	490 ft of lining on Newhall
	1,600 ft of smoke testing of storm sewer on Newhall	
	310 ft of televising from MH-94 to MH-98	
S1B	640 ft of smoke testing of sanitary sewer on Larkin	1,130 ft of lining on Larkin
	540 ft of smoke testing of sanitary sewer on Olive	10 manholes to be rehabilitated
	90 ft of smoke testing of sanitary sewer on Newhall	
	970 ft of dyed water flooding on Larkin	
S1C	1,520 ft of smoke testing of sanitary sewer on Morris	670 ft of lining on Woodburn
	340 ft of smoke testing of sanitary sewer on Kenmore	340 ft of lining on Kenmore
	1,200 ft of smoke testing of sanitary sewer on Woodburn	420 ft of lining on Elmdale
	500 ft of smoke testing of sanitary sewer on Elmdale	360 ft of lining on Ardmore
	730 ft of smoke testing of sanitary sewer on Ardmore	12 manholes to be rehabilitated
	960 ft of dyed water flooding on Morris	
	670 ft of dyed water flooding on Woodburn	
	200 ft of dyed water flooding on Elmdale	
	730 ft of dyed water flooding on Ardmore	
S1D	420 ft of smoke testing of sanitary sewer on Alpine	400 ft of lining on Marlbourgh
	520 ft of smoke testing of sanitary sewer on Wildwood	140 ft of lining on Wildwood
	620 ft of smoke testing of sanitary sewer on Marlborough	420 ft of lining on Alpine
	420 ft of smoke testing of sanitary sewer on Sheffield	980 ft of lining on Wilson
	1,310 ft of smoke testing of sanitary sewer on Wilson	12 manholes to be rehabilitated
	210 ft of dyed water flooding on Alpine	
	220 ft of dyed water flooding on Marlborough	
	140 ft of dyed water flooding on Sheffield	
S1E	1,040 ft of smoke testing of sanitary sewer on Olsen	250 ft of lining on Olsen
	700 ft of smoke testing of sanitary sewer on Wilson	290 ft of lining on Wilson
	120 ft of smoke testing of sanitary sewer on Parkway	150 ft of lining on Sheffield
	250 ft of dyed water flooding on Olsen	6 manholes to be rehabilitated
	380 ft of dyed water flooding on Wildwood	
	820 ft of televising as shown on Figure 3.01-6	
	Summary of Recommended Investigations	**Summary of Recommended Capital Improvements**
Totals	**2,790 ft of smoke testing of storm sewer**	**6,620 ft of sewer lining**
	10,960 ft of smoke testing of sanitary sewer	**40 manholes to be rehabilitated**
	4,730 ft of dyed water flooding	
	1,130 ft of additional televising	
Opinion of Probable Costs	**$11,000 Smoke Testing/Report**	**$ 300,000 Capital Improvements**
	$50,000 Dyed Water Flood Testing/Televising/Report	**$30,000 Engineering/Admin**
	$25,000 Engineering and Reporting	**$45,000 Contingency**
	$86,000 Total	**$ 375,000 Total**

TABLE 3.02-1 RECOMMENDED SEWER INVESTIGATIONS AND REHABILITATION WORK FOR 2012

Year	Recommended Investigations	Recommended Capital Improvement	Opinion of Probable Cost
2012	880 ft of smoke testing of storm sewer on Bartlett 310 ft of smoke testing of storm sewer on Kenmore 1,600 ft of smoke testing of storm sewer on Newhall 640 ft of smoke testing of sanitary sewer on Larkin 540 ft of smoke testing of sanitary sewer on Olive 90 ft of smoke testing of sanitary sewer on Newhall 1,520 ft of smoke testing of sanitary sewer on Morris 340 ft of smoke testing of sanitary sewer on Kenmore 1,200 ft of smoke testing of sanitary sewer on Woodburn 500 ft of smoke testing of sanitary sewer on Elmdale 730 ft of smoke testing of sanitary sewer on Ardmore 420 ft of smoke testing of sanitary sewer on Alpine 520 ft of smoke testing of sanitary sewer on Wildwood 620 ft of smoke testing of sanitary sewer on Marlborough 420 ft of smoke testing of sanitary sewer on Sheffield 1,310 ft of smoke testing of sanitary sewer on Wilson 1,040 ft of smoke testing of sanitary sewer on Olsen 700 ft of smoke testing of sanitary sewer on Wilson 120 ft of smoke testing of sanitary sewer on Parkway 970 ft of dyed water flooding on Larkin 960 ft of dyed water flooding on Morris 670 ft of dyed water flooding on Woodburn 200 ft of dyed water flooding on Elmdale 730 ft of dyed water flooding on Ardmore 210 ft of dyed water flooding on Alpine 220 ft of dyed water flooding on Marlborough 380 ft of dyed water flooding on Wildwood 140 ft of dyed water flooding on Sheffield 250 ft of dyed water flooding on Olsen 310 ft of televising from MH-94 to MH-98 820 ft of televising as shown on Figure 3.01-6	580 ft of lining on Bartlett 490 ft of lining on Newhall	$126,000

TABLE 3.02-2 RECOMMENDED SEWER INVESTIGATIONS AND REHABILITATION WORK FOR 2013, 2014, AND 2015

Year	Recommended Investigations	Recommended Capital Improvement	Opinion of Probable Cost
2013	None	10 manholes to be rehabilitated in sub-basin S1B 1,130 ft of lining on Larkin 670 ft of lining on Woodburn 340 ft of lining on Kenmore	$114,000
2014	None	420 ft of lining on Elmdale 360 ft of lining on Ardmore 400 ft of lining on Marlbourgh 140 ft of lining on Wildwood 420 ft of lining on Alpine 12 manholes to be rehabilitated in sub-basin S1C tbd ft of storm sewer lining	$111,000
2015	None	980 ft of lining on Wilson 250 ft of lining on Olsen 290 ft of lining on Wilson 150 ft of lining on Sheffield 18 manholes to be rehabilitated in sub-basins S1D and S1E tbd ft of storm sewer lining	$109,000

BASIN SH5001 - SANITARY SEWER RECOMMENDED FOR LINING
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 3.01-1
3646.001

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BASIN SH5001 - SANITARY SEWER MANHOLE REHABILITATION RECOMMENDATIONS

BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 3.01-2
3646.001

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BASIN SH5001 - SANITARY SEWER RECOMMENDED FOR SMOKE TESTING
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 3.01-3
3646.001

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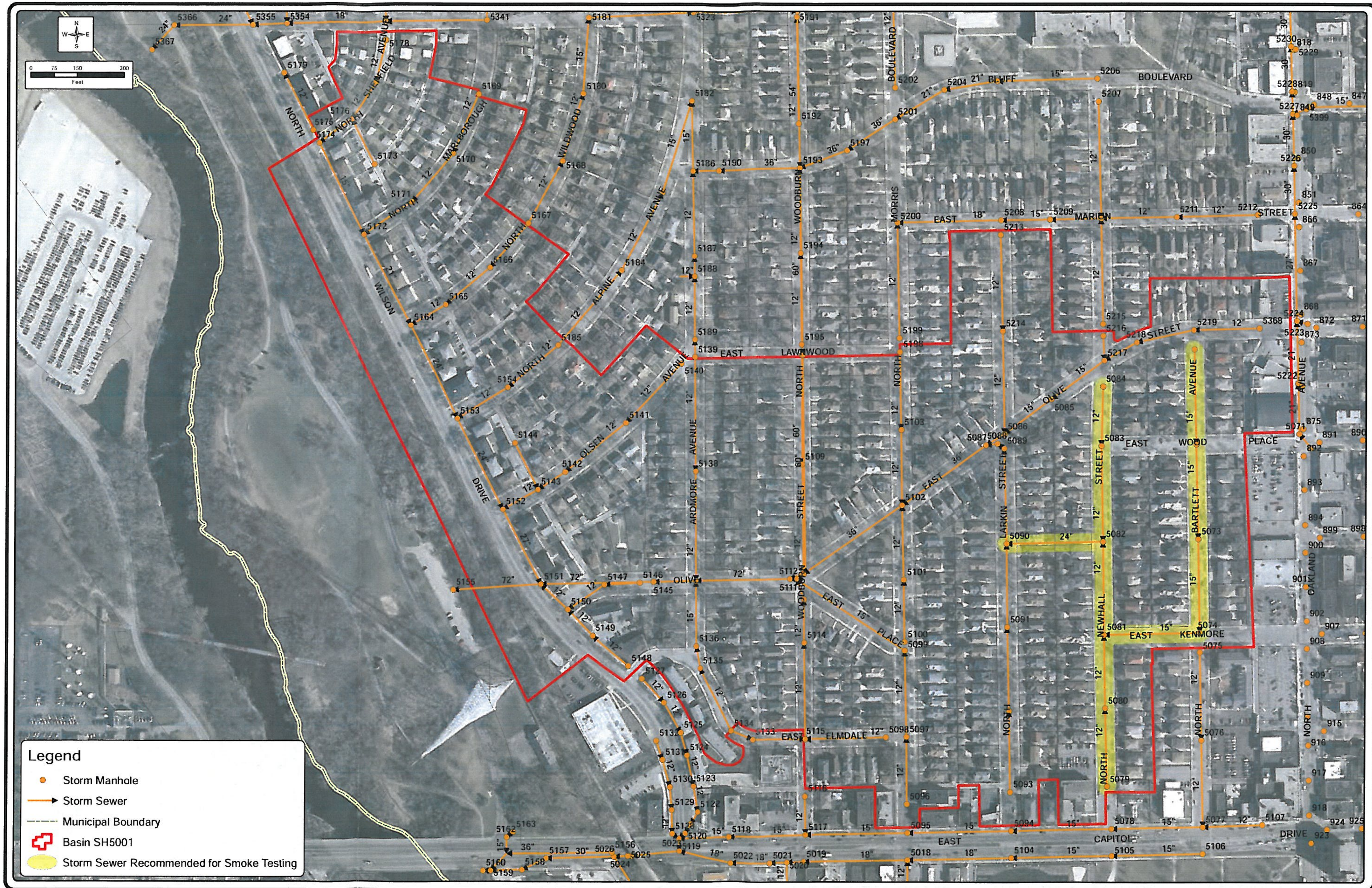

BASIN SH5001 - EXISTING STORM SEWER RECOMMENDED FOR SMOKE TESTING

BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 3.01-4
3646.001

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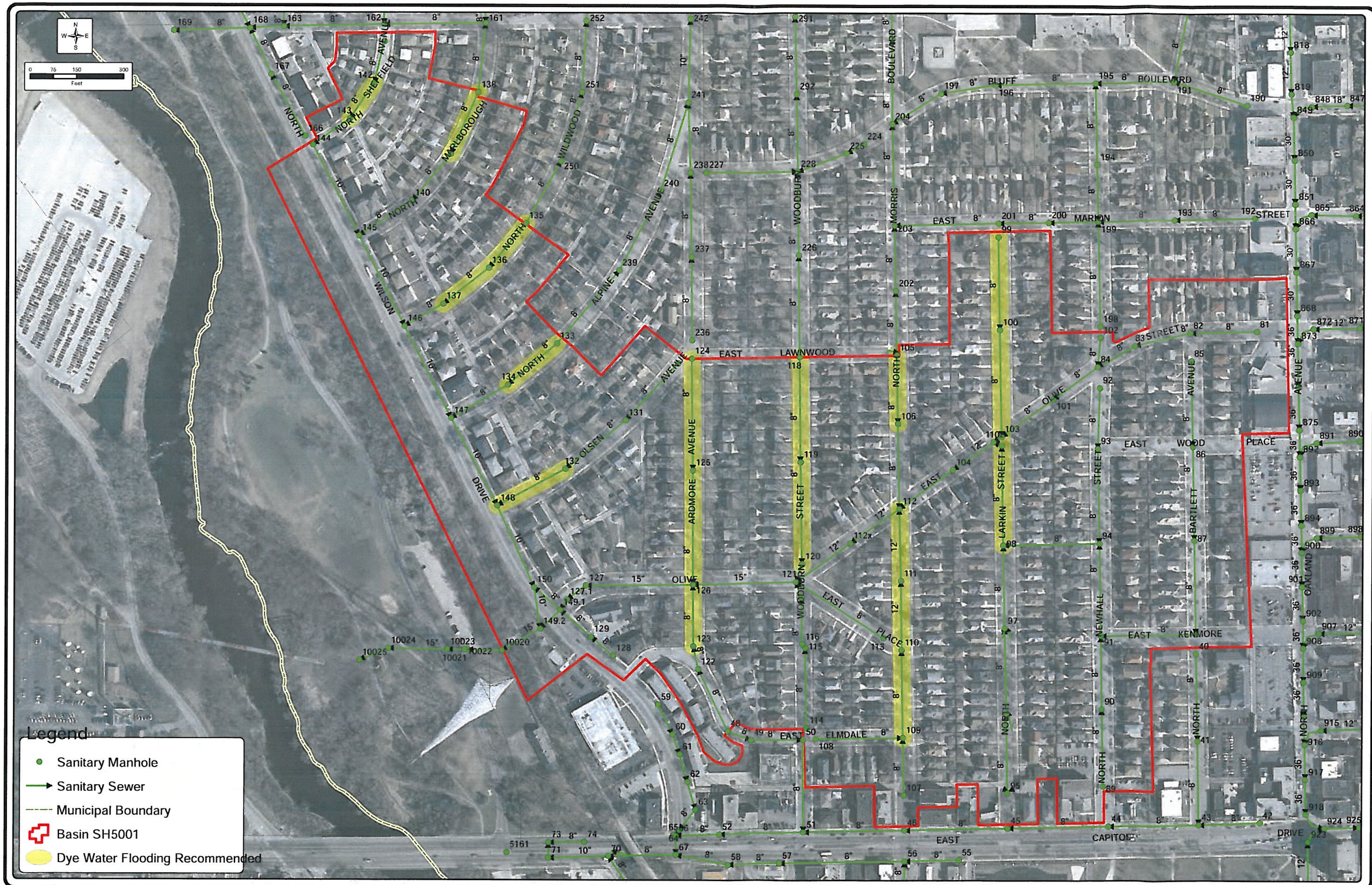

BASIN SH5001 - DYE WATER FLOODING RECOMMENDED
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 3.01-5
3646.001

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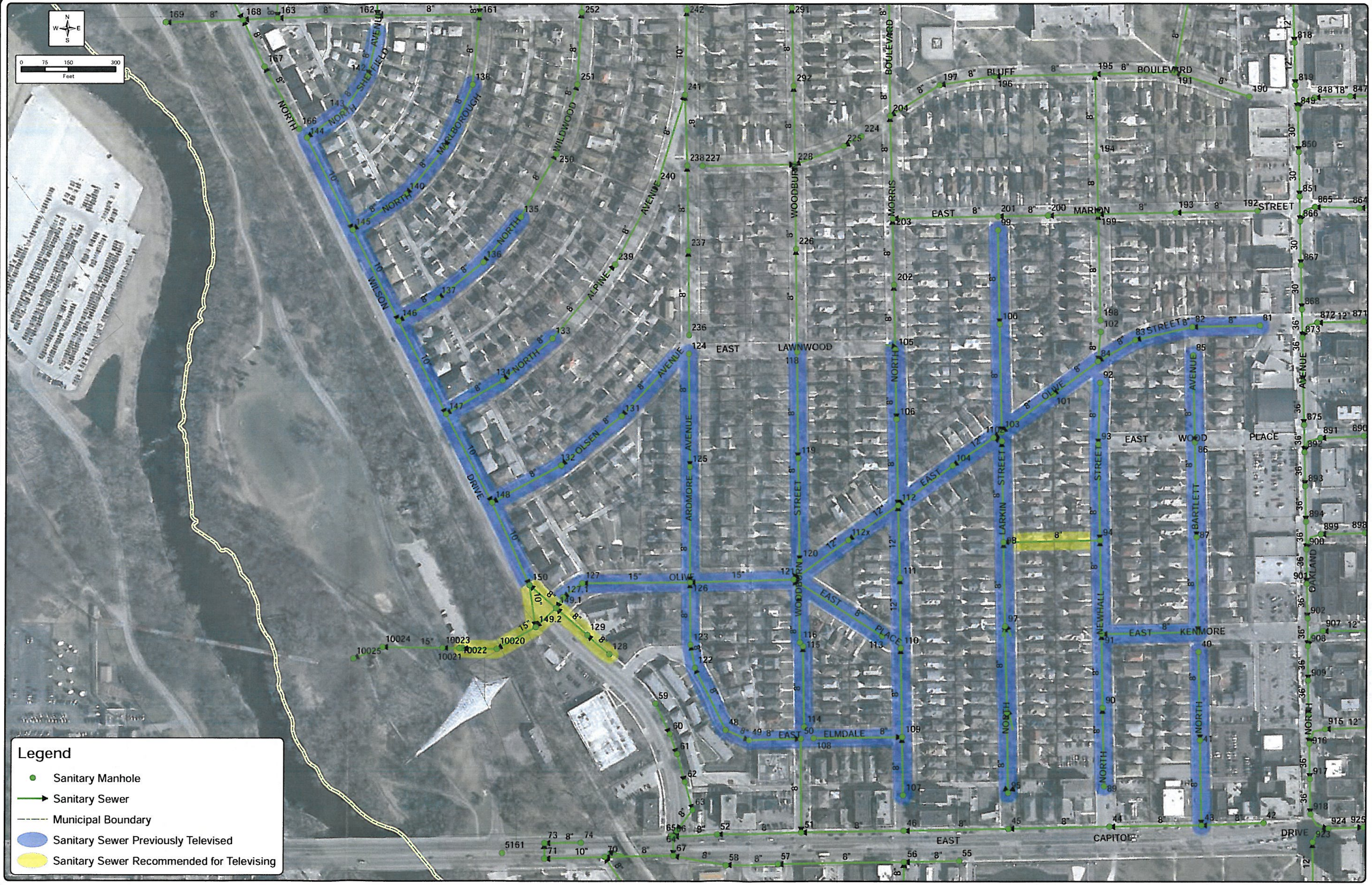

BASIN SH5001 - SANITARY SEWER RECOMMENDED FOR TELEVISING
BASIN SH5001 I/I STUDY

VILLAGE OF SHOREWOOD
MILWAUKEE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.
ENGINEERS

FIGURE 3.01-6
3646.001

Path: S:\MAD\3600--3699\3646\001\Data\GIS\Figures\Figure 3.01-6 Sanitary Sewer RecommendedTelevised 11x17.mxd