Mayor's Independent MMSD Audit Committee

Final Report

Presented to Mayor Tom Barrett

October 1st, 2004

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The Honorable Tom Barrett
Mayor of the City of Milwaukee
City Hall, Room 201
200 East Wells Street
Milwaukee, WI 53202

Regarding: Final Recommendations and Performance Review of the Milwaukee Metropolitan Sewerage District (MMSD) Conducted by the Mayor's MMSD Audit Committee

Dear Mayor Barrett:

On behalf of the Mayor's MMSD Audit Committee, we are proud to present to you the following *Final Recommendations and Performance Review of MMSD*. While running for Mayor of Milwaukee, you announced as part of The Barrett First 100 Days Action Plan that you would initiate an independent audit of MMSD.

At your directive, the Committee has conducted all of its proceedings in public and has heard extensive testimony from a variety of outstanding individuals and organizations. The Committee would like to thank the many scientists, local public officials, environmentalists, fishing organizations, national wastewater treatment experts, and staff members from the Wisconsin Department of Natural Resources (DNR) and the Southeastern Regional Planning Commission (SEWRPC) who appeared before the Committee. Their expertise, base of knowledge, commitment to clean water and unique perspectives were invaluable in producing this audit of MMSD's practices and performance.

This review has been conducted over the past three months with the assistance of nationally respected leaders in the wastewater industry including Dick Sandaas, a consultant with extensive history in the wastewater treatment industry, and Andy Lukas and staff from Brown and Caldwell. The *Final Recommendations and Performance Review of MMSD* contains new scientific information developed specifically for purposes of this audit. The review also consisted of document reviews as well as extensive discussions and testimony from MMSD executives and staff. United Water Services staff also provided input.

Clean water is a regional challenge that will take a coordinated regional response. The Committee hopes that its audit will benefit MMSD, the 28 municipalities it serves, and all those dedicated to improving water quality and moving the region forward.

On behalf of the entire Committee, we would like to thank you for the honor and privilege of serving on the Mayor's MMSD Audit Committee.

Sincerely,

Mayor's MMSD Audit Committee:

Don Theiler, Committee Chair
Division Director
King County Wastewater Treatment
Division

Tony Earl
Former Governor of Wisconsin

Theresa M. Estness
Mayor of Wauwatosa

Nancy Frank
UW-Milwaukee, School of Architecture &
Urban Planning

Ashanti Hamilton, Milwaukee Alderman

Wally Morics, City of Milwaukee Comptroller

RoseMary Oliveira, Citizen

1. Executive Summary

In June of 2004, Mayor Tom Barrett of the City of Milwaukee formed the MMSD Audit Committee to explore the causes of the large volume of sewer overflows in May 2004. The review was to evaluate the adequacy of the sewer system and its management during this period as well as other periods of wet weather. In addition, the Mayor requested that the Audit Committee answer several questions in this regard and make recommendations for improvements. The Audit Committee conducted five day-long meetings, during which it accumulated extensive information leading to its recommendations. The Audit Committee received input from expert panels, MMSD staff presentations, and consultant presentations. This provided a wide spectrum of information covering policy, environmental, regulatory, technical, and operational matters.

The issues reviewed by the Audit Committee were complex. However, certain facts are clear to the committee as a result of its deliberations. First and foremost, there is too much storm water getting into the system during major storm events. This excess water is overwhelming the MMSD sewer system and causing an unacceptable level of overflows.

Two of the Committee's recommendations address excessive wet-weather flows into the MMSD system. The first calls for MMSD and the 28 contributing communities to reduce excessive infiltration and inflow in the separate sewer area. This could be accomplished by eliminating illegal connections, developing a cost effective infiltration and inflow (I/I) reduction program, and establishing maximum I/I levels. The second calls for development of a program to reduce excess flows into the combined sewered area, which would include partial sewer separation.

The Committee recommends that MMSD follow through on overflow reduction project implementation, minimize blending, and build treatment systems at combined sewer overflow points to minimize environmental damage. The Committee also recommends that the municipalities in the MMSD service area create a system to share the cost of I/I reduction as well the cost of treating storm water and non-point source pollution.

Complete separation of the existing combined system is not recommended at this time for a combination of reasons: the cost is prohibitive; the disruption of the downtown area would be enormous; and the impact on water quality would be negative because of the loss of the stormwater treatment, which currently occurs.

Finally, the Committee sensed a willingness on the part of regional leaders to work together on the solutions to this problem. The successful implementation of these recommendations is reliant upon regional leadership and cooperation. Assigning MMSD with sole responsibility for solutions to regional issues will not work. The committee is encouraged by the efforts of the MMSD Executive Director, Kevin Shafer, who is working regionally to improve communications and understanding of the issues. Local suburban officials who appeared before the Audit Committee testified that Mr. Shafer has been "extremely good" at sharing information and involving communities in developing regional solutions. The regional summit hosted by MMSD on September 23 of this year is an example of these efforts.

2. Recommendations

Wastewater collection systems in the Milwaukee area and the Milwaukee Metropolitan Sewer District (MMSD) have recently been overwhelmed – notably in May 2004 - by the amount of stormwater entering the system. Stormwater enters the system from both the combined sewer area and the separate sewer area. The result has been overflows and backups of untreated sewage into the area rivers, lakes, streams, and basements. MMSD has clear and specific responsibilities in this regard, including: 1) Elimination of sewer backups into homes caused by the public sewer system, 2), Elimination of Sanitary Sewer Overflows (SSOs) from the separate sewer system, and 3) Minimization and reduction of Combined Sewer Overflow (CSO) impacts. The Audit Committee recommendations are directed primarily at addressing these three areas of concern.

2.1. Reduce wet weather flow into the sewer system.

Activities must address infiltration and inflow (I/I) reduction in the separate sewer service area, and combined sewer runoff reduction in the combined sewer service area. Wet weather flows into the system have reached a level which is causing separate system overflows which must be eliminated. Flow reductions cannot occur unless both the combined sewer area and the separated sewer area undertake programs to reduce flows to an acceptable level.

a. All MMSD communities have ordinances making stormwater connections to the separate sewer illegal. MMSD must ensure that all communities enforce these ordinances.
b. MMSD should develop a continual I/I management program that provides for the cost effective reduction of I/I in existing service areas and significantly limits I/I from future development. The program must be:
    - enforceable,
    - rapidly implementable,
    - measurable,
    - fundable, and
    - supported by the communities.

    The program must include comprehensive and consistent I/I investigations in all communities to identify sources of the I/I, and the costs and benefits of controlling these sources. The program should identify I/I sources and implement activities designed to reduce I/I from identified illegal connections and from other sources which would be cost effective to control.

    The program should include a set of actions to insure that future I/I does not increase above an accepted rate. Examples are:

- Requiring the identification of possible I/I from residences and commercial establishments at time of sale;
- Developing ongoing programs to replace or repair defective or failing sanitary and storm sewers when streets, alleys, and highways are repaired;
- Providing backflow preventors in areas experiencing basement backups; and
- Testing laterals for soundness following the reconstruction of buildings.

c. MMSD should undertake a program with Milwaukee County and the cities of Milwaukee and Shorewood to analyze runoff reduction opportunities in the combined sewer area including downspout disconnection, rain barrels, rain gardens, rooftop storage and flow restrictors, catch basin storage and other techniques. These techniques should be implemented where it is determined to be reasonable and will not create other problems, such as localized flooding and building foundation problems.

d. MMSD should establish maximum acceptable I/I levels from future development.

2.2. Additional actions to reduce the impact of or eliminate overflows

a. MMSD should follow through on project commitments made in the Stipulation Agreement with WDNR.

b. MMSD should prioritize projects that will accelerate reduction of existing overflows and eliminate sewer backups into homes. MMSD should also look for opportunities to accelerate these projects. Among them, Port Washington Road and Wisconsin Avenue Relief Sewer projects provide overflow reduction and both might be accelerated, with a change in contracting policy. MMSD must, at the same time, be mindful of other organizational constraints that may limit the ability to deliver projects at an accelerated rate.

c. Using the results of the high rate treatment pilot project, MMSD should implement this type of treatment technology at appropriate CSO points to reduce impacts of untreated overflows in the combined system.

d. MMSD must make every attempt to reduce the need for blending by reducing system wet weather flows or adding treatment capacity. As a part of the blending reduction effort, MMSD should also explore the feasibility and desirability of fast flow treatment of the flows diverted around the secondary treatment process.

e. MMSD, the cities of Milwaukee and Shorewood, and Milwaukee County should look at opportunities to reduce flows to the combined sewer area by partially separating portions of the combined sewer where the first flush pollutants could still be captured in the MMSD system. Examples of where this approach is already being pursued are the Marquette Interchange and Canal Street Reconstruction Projects. Complete separation of the existing combined system is not recommended at this time for a combination of reasons: the cost is prohibitive; the disruption of the downtown area would be enormous; and the impact on water quality would be negative because of the loss of the stormwater treatment, which currently occurs.

2.3. Financing

a. If determined to be cost-effective, MMSD should provide funding or incentives for private property owners who rehabilitate their private laterals.
b. MMSD should establish a program which creates financial incentives to control and reduce excess flows within each community's sewer system. This program could involve a surcharge for excess flows above a predetermined base flow within each community's system. The charge should reflect the cost of transporting and treating excess flows from that community including the maintenance of the overall system. Such a rate program should be designed to reward communities which control and reduce excess flows in their systems. Consideration should be given to putting at least a portion of the rates from such a charge into a fund to assist communities to control and reduce excess flows into the MMSD and local sewer systems.

2.4. Enforcement

a. Enact programs that ensure illegal contributions to sanitary system are eliminated.
b. WDNR should be aggressive and equitable in SSO enforcement actions throughout the state. Communities in Wisconsin which have experienced SSOs should be required to eliminate them.

2.5. *Non-Point Source and Stormwater Pollution/ Beach Closures*

Water quality problems, such as beach closures, are not caused by MMSD overflows alone. Eliminating all MMSD overflows would not prevent most beach closings. Pollution from non-point sources and pollution from municipal and county stormwater collection systems must be addressed in order to achieve the water quality levels desired by the public. There is a vacuum in assigned responsibility for and leadership in addressing non-point source and stormwater pollution.

a. MMSD should aggressively continue its efforts to assist the region in dealing with these issues.
b. All communities contribute to the water quality impacts because they generate non-point source and stormwater pollution. The Intergovernmental Cooperation Council (ICC) and MMSD contract communities should take the lead in developing a system of cost sharing for treating stormwater in the region. By virtue of the deep tunnel, all MMSD customers currently pay for treating a substantial volume of stormwater generated in the combined sewer areas of Milwaukee and Shorewood. The cost-sharing system would need to recognize this reality and include equitable ways to fund stormwater treatment in the separate sewer areas.
c. MMSD should contribute, within the limits of their authority and responsibility, to solutions that reduce non-point source and stormwater pollution to tributary lakes and rivers, for example, improving stormwater management on parking lots that discharge without treatment into receiving waters near beaches.
d. Other entities such as Milwaukee County should take actions that would have an immediate, cost-effective benefit on water quality near beaches. Such actions would include beach raking and local stormwater control on and near the beaches.

2.6. *Public Communications*

Public communication is needed to clarify the causes and potential solutions for regional water quality problems. It is important for everyone to understand that there is no single villain causing our water quality problems, just as there is no single cure.

a. Other organizations, working with MMSD, should communicate with the public on the respective roles and responsibilities of MMSD and other governmental entities in protecting and improving regional water quality.

b. Research public expectations on water quality and sewer overflows to assist in establishing specific water quality goals for the region taking into account public willingness to pay for the solutions.
c. Communicate with public on five key things:
    i. Nature of the regional water quality problem.
    ii. SSO and CSO goals and their impacts on water quality.
    iii. Nature of I/I and strategies for controlling I/I.
    iv. Nature of non-point source and stormwater pollution and strategies for achieving control goals.
    v. Respective responsibilities for achieving water quality goals.

2.7. United Water Services (UWS) Oversight

The Audit Committee focused its attention on the May 2004 overflows and did not identify UWS as a significant contributor to them. However, the Audit Committee has identified a number of concerns going forward.

a. To ensure that an adequate number of skilled technical staff will be available in the future to operate this highly complex system, MMSD should require any subsequent contractor to provide a Succession Plan for key human resources.
b. MMSD should follow-up on 2003 UWS Performance Evaluation recommendations related to maintenance schedules on non-critical assets.
c. On future operating contracts, MMSD should include contract incentives pertaining to overflow prevention that were recommended in the 2003 Performance Evaluation.
d. MMSD should ensure the Technical Environment Committee is fulfilling its charge of overseeing the performance of UWS in meeting its responsibilities. This should include active participation of its members, regular meetings and, at a minimum, quarterly reports to the MMSD Commission.

2.8. Regional Watershed Approach to Solutions

a. Develop and implement a mechanism for meaningful and effective suburban input to implement the recommendations in this report in an atmosphere of cooperation so that all members of the sewered community feel included in decision-making.
b. The region must develop and implement mechanisms to address all sources of pollution and also determine what the specific water quality goals are for the area. Without this information the communities

responsible for the sewer system cannot determine how to design and maintain their individual systems.

c. The WDNR should become more active in fulfilling its responsibilities and be provided with the resources to assist the region in establishing specific goals and implementation solutions.

3. Discussion of Panel Questions Regarding May 2004 Performance

Mayor Barrett commissioned the Audit Committee to answer several pressing questions regarding the environmental situation and causes surrounding the overflows in May 2004. The Mayor and his cabinet created seven categories of questions for the Audit Committee to focus on, and they are discussed as follows.

3.1. Relating to United Water Service (UWS) Performance

What impact has privatization of Milwaukee Metropolitan Sewerage District's (MMSD's) operations had on overflows?

There is no clearly identifiable impact of privatization on the major overflows which occurred in May 2004. The tunnel operating decisions are made jointly between UWS and MMSD during larger storm events. Otherwise, UWS has full authority to make operational decisions. Some isolated overflows events appear to be due to operational errors during the period UWS has been operating the system.

Weather information used by UWS and MMSD management during the May storm events for making decisions on tunnel operation, included radar and satellite imaging; current storm intensity, duration, and probability; recorded rainfall amounts for preceding events; and forecasted rainfall amounts. Resources include National Oceanic and Atmospheric Administration (NOAA) forecasts, weather-related internet websites, the Great Lakes Weather Service, and MMSD rain gages. The historic reliability of weather forecasting resources is not known at this time.

The 2003 UWS Performance Evaluation reviewed whether UWS cost-savings measures could be contributing to overflows. That review did not find that this was the case. Further, tunnel operating data would indicate that the tunnel was performing in a similar manner while MMSD was solely responsible. The review did express some concerns for reduced staffing levels, including experienced staff, and the potential for performance impacts in the future.

How has UWS performed against their contract?

UWS's performance has generally been satisfactory.

There are no contract incentives/disincentives linked to overflow prevention, as contrasted with the treatment plant operations which have incentives/disincentives. UWS has responded in a positive fashion to the incentives for treatment in their current contract. UWS follows standard operating procedures and collaborates with MMSD management while operating the system.

Is UWS making errors that are causing or contributing to the overflows?
A limited number of minor overflows might have been prevented if UWS had better technology provided to experienced operators. Also, during the first May 2004 storm, basement backups occurred, and a review is underway regarding UWS operation of overflow gates during that period.

Is UWS trying to save money at the expense of our environment?
Nothing is currently evident to suggest that UWS is making decisions that harm the environment. However, issues identified in the 2003 Performance Evaluation, such as staffing levels (reduced by one-third and lack of succession planning), and deferred maintenance of non-critical equipment, will have an impact on system performance if not addressed. The effects of cost pressures on UWS from sky-rocketing utility costs should be monitored for any future impact on their performance.

The 2003 Performance Evaluation showed the system performance since the tunnel has gone "on line" is not significantly different since UWS came under contract. Some operational protocols for the tunnel have changed as operating experience has been built, but these changes had the input of both MMSD and UWS staff and management.

The effluent quality at treatment plants has historically exceeded contract requirements, which are significantly lower than the WPDES permit for effluent. For this, UWS has received performance bonuses as provided in their contract. The following outlines the bonus, penalty, contract and permit limits for wastewater effluent.

Table 1. UWS Contract Incentives for Treatment Plant Effluent

Constituent	Bonus Limit (Less than)	Penalty Threshold (Greater than)	Contract Limit (Greater than)	Permit Limit (Greater than)
BOD	9 mg/L[2]	13 mg/L[2]	15 mg/L[1]	30 mg/L[1]
TSS	8 mg/L[2]	13 mg/L[2]	15 mg/L[1]	30 mg/L[1]
Total phosphorus	None	None	1 mg/L at South Shore 0.5 mg/L at Jones Island[1]	1.0 mg/L[1]
Fecal Coliform	None	None	100 units/100 mL[2]	400 units/100 ml[3]

[1]Monthly average
[2]Annual average
[3]Monthly geometric mean

There are no incentives/penalties in the contract for CSO's, SSO's, or other operational performance.

3.2. Relating to Deep Tunnel

What exactly was the deep tunnel supposed to accomplish for us?
The deep tunnel was initially designed to capture all overflows from the separate system for the largest storm of concern that was analyzed for the Water Pollution Abatement Program (WPAP). The period of record analyzed was from 1940 to 1978. Engineers

then determined that a storm in June 1940 produced the largest amount of separate sewer flow that would require storage. Subsequently this storm was termed "the Storm of Record." The tunnel sizing was based on the estimated flows from the June 1940 Storm of Record assuming 12.8 percent reduction in local sewer system I/I.

Since this type of storm is rare (once in 40 years), engineers also determined that smaller storms occurring much more frequently would not use much of the tunnel volume. MMSD determined that using the excess tunnel capacity in smaller events to capture potential CSO would allow it to meet its water pollution abatement goals at significant cost savings over other alternatives. The result was a dual purpose tunnel: preventing SSOs and reducing the number of CSOs. When the decision was made to use the tunnel for dual purposes, the overall volume of the tunnel was increased to the present size. MMSD's challenge is to operate the tunnel in a manner that maximizes CSO controls while at the same time not jeopardizing its ability to prevent SSOs. The Appendix provides further information regarding tunnel design and performance history.

Unfortunately, as MMSD communicated the plans and expected performance for the tunnel, the public came away with a perception that no overflows of any kind would occur after the tunnel was operational. However, newspaper accounts from the Milwaukee Sentinel in September 1993, shortly after the tunnel became operational, clearly make a distinction between expected control performance for CSO (1.4 per year after the tunnel is operational) and SSO (elimination).

What are the standards the deep tunnel is required to meet?

The design standards for the deep tunnel are no separate sewer overflows (SSOs) and an annual average of 1.4 combined sewer overflows (CSOs). The permit standards for the MMSD wastewater system are zero SSOs and up to 6 CSOs annually. An explanation of tunnel permit and design standards is provided in Appendix B. It is important to note that during the original planning (WPAP), engineers recognized that there would be events of significant CSO volumes. Public attention from the May 2004 events has been focused on the magnitude of the overflow volume; however, it would be more appropriate to consider the significance of the SSO events which are not allowed by permit.

Is the deep tunnel meeting these expectations and standards?

The deep tunnel falls short of public expectations for a very expensive project. It does, however, appear to be performing close to the technical objectives established during the design. To answer this question properly, it must be broken into two categories: CSO and SSO. The ability to meet CSO control objectives is largely determined by the weather, and more specifically how many large storm events occur during a given year. MMSD records indicate that the annual average for the 10 year operational history of the tunnel (1994 through 2003) is approximately 2.4 CSOs per year, which is higher than the estimated 1.4 per year. This includes a yearly high of 6 and a low of zero (shown in Figure 1). From this perspective, the tunnel has allowed MMSD to meet the permit conditions for CSO and control overflows to close to the design expectations. It is important to note that the tunnel was not sized to contain total CSO volumes during heavy rains. In fact, during the original planning (WPAP), engineers estimated that there would be events of significant CSO volume (greater than 1 billion gallons).

As for SSO events, there are two primary causes: 1) tunnel-related, and 2) pipeline bottlenecks in the system. This discussion deals with tunnel-related SSOs. Even with the changes in tunnel operation protocols that improved the capture of SSOs after 1999, SSOs have occurred. This means the zero SSO permit requirement has not been met. The remaining question is whether this is because the tunnel was originally sized with insufficient capacity or if flows from the separate sewer area are greater than what was anticipated at the time of the WPAP. Further discussion of this question is provided below.

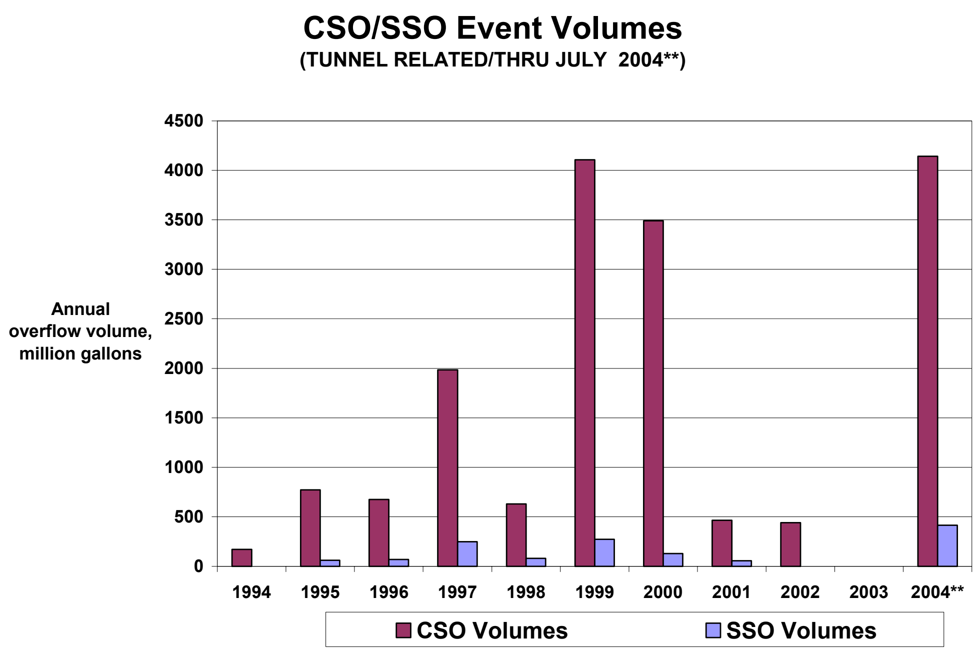


Figure 1. Tunnel-Related CSO and SSO Volumes Reported by MMSD Since 1994

If not, what are the reasons?

Excess I/I appears to be a key factor. MMSD has the authority to order I/I remediation in local systems but has not exercised it. Their current approach is to use 2020 Facility planning for dealing with I/I. The DNR is seeking legal remedies against 28 communities for excessive flows.

During the May 2004 storms, about 13 percent (equal to 7.6 billion gallons) of the rain that fell on the MMSD separate sewer service area flowed into the sewer system. This is a significant amount. Even so, it is within the range experienced in the past five years (1999 through 2003). Over that five-year period, the amount of rain flowing into the separate sewer system ranged from 7 percent to 15 percent, with an average of 9 percent. This shows the May 2004 storms were not exceptional in terms of the percentage of stormwater entering the MMSD separate sewer system; however, the volumes were extraordinary. Appendix D provides further information on these calculations.

A comparison of these I/I percentages to the Seattle, Washington area separate system shows that the MMSD system has much more I/I. An analysis of a portion of the Seattle system showed the following:

- 1 to 2 percent I/I rate for a 1 year storm event.
- 2 to 4 percent for a 20 year storm event

A broader estimate for the entire separate system in Seattle indicated the I/I is in the range of 6 to 7 percent for the 20 year storm. All of these amounts characterizing the Seattle system show significantly less I/I than in the MMSD system.

What is just as telling is the comparison of separate sewer flow to combined sewer flow that enters the MMSD system. Over the past 5 years, the separate sewer system generated, on average, 64 percent of the wet weather flow. For comparison, during May 2004 storms, 66 percent of the wet weather flow originated in the separate sewer area. This means that the majority of total sewer flow during storm events originates in the separate sewer system.

Another reason is the difficulty in predicting the amount of tunnel volume to reserve for flow from the separate sewer area. This is particularly challenging in extended rainy periods such as May 2004. A post-event analysis performed for this audit indicated that if the entire tunnel had been reserved for SSO capture, the tunnel would not have filled completely. This action would have increased CSO volumes by approximately 800 million gallons. MMSD has several projects addressing this operating constraint, including contracting with a provider of long-range precipitation forecasts.

A Monday Morning Quarterback could criticize the MMSD for not reserving all of the capacity for the separate sewer flows; however, if this had occurred, as pointed out above the increase in overflow volume would have been approximately 400 million gallons. Also, if the rainfall had ended earlier, the tunnel would not have been fully utilized. In that event, the MMSD would have certainly been rebuked for not using the tunnel to reduce combined sewer overflows.

3.3. Relating to Other Communities with Combined Sewers

How does Milwaukee's situation compare to other similar sized communities with similar climate? What efforts have these communities made to reduce CSO's?

The communities of Minneapolis, as well as St. Paul and South St. Paul, Minnesota, separated their combined sewers in the 1970s through the 1990s. Despite sewer separation, Minneapolis still experiences overflows in larger storm events, with the most active overflows spilling four times per year or more. A primary cause of this continued overflow activity is incomplete separation on private property that was deemed too expensive to tackle at the time. Minneapolis has recently initiated a downspout disconnection program that will require all homeowners to eventually disconnect from the system.

Chicago's system, operated by MWRDGC, includes approximately 400 square miles of combined sewer area. Chicago's most recent permit authorizes CSOs, but requires the system be able to convey and treat up to 10 times dry weather flows without a CSO occurring. This is consistent with Illinois state standards for CSO, which also requires CSOs to be treated in order to prevent sludge deposits, floating debris, and solids, and to prevent depression of dissolved oxygen levels below the applicable water quality standard. MWRDGC has no direct overflows to Lake Michigan, but in large flood events CSOs to the Chicago Sanitary and Ship Canal can discharge to the lake. The last such event was in 2002. The MMSD system performs at a higher standard than the 10 times dry weather flow standard, but would not meet the CSO treatment standard. Appendix F provides further discussion of the differing regulatory approaches to CSO and SSO discharges in the Great Lakes states.

The City of Detroit has a combined sewer area of 500 to 550 square miles, roughly 20 times the size of Milwaukee's. Detroit has implemented a $1 Billion program for downspout disconnection to reduce combined sewer flows, CSO treatment to reduce overflow impacts, and containment of stormwater in the combined sewer area to reduce the need to overflow. A sewer separation study indicated that separation was not a viable option due to the cost and the negative impact of polluted stormwater runoff on water quality if it were removed from the sewer system. Detroit plans on constructing a deep tunnel which would be designed for 1 overflow per year and 200 MG of storage for the CSO. They are also investigating I/I concurrently to quantify if it is a cost effective solution.

What has been their operational experience under similar rainfall conditions?
The City of Detroit generally experiences the same weather patterns as Milwaukee, and has historically experienced up to 50 overflows per year for the combined sewer area. Based on our understanding of the Detroit system plan, overflows will occur more frequently in Detroit than Milwaukee, but most of these overflows will receive treatment.

The State of Michigan requires treatment to consist of screening and disinfection at a minimum.

Chicago continues to implement its Tunnel and Reservoir Plan (TARP); however, overflows still occur. Records obtained from MWRDGC indicate that CSOs occurred at major discharge locations on 20 dates in 2004 thus far. MWRDGC has 145 permitted CSO discharge points. For comparison, MMSD has 117 permitted CSO outfalls.

3.4. Relating to Existing Plans at MMSD

What projects are currently developed and can/should they be accelerated?
There are a number of projects currently being undertaken by MMSD and included in the Stipulation Agreement with the Wisconsin Department of Natural Resources. Current projects that will provide additional storage are:

- Northwest Side Relief Sewer (88 MG – complete in 2005);
- Port Washington Road Relief Sewer (up to 30 MG – complete in 2008);
- West Wisconsin Avenue Relief Sewer (25 MG – complete in 2009).

The Harbor Siphons project will also add capacity from the combined sewer system into the Jones Island Wastewater Treatment Plant. This capacity will allow MMSD to delay the discharge of combined sewer flows into the deep tunnel, thus preserving storage for separate sewer flows.

Acceleration opportunities are being sought by MMSD staff for Port Washington Road and West Wisconsin Avenue. It should be noted that MMSD organizational constraints can impede these project acceleration efforts. For example, MMSD's $1.2 Billion Capital Improvement Program over the next six years exceeds the MMSD's capacity to do the work. A recent American Society of Civil Engineers (ASCE) peer review confirmed these project delivery constraints.

Current MMSD Commission policy requires a second Request for Proposals process to obtain final design services for both Port Washington Road and West Wisconsin Avenue projects. Changing this policy to allow amending the current preliminary engineering contracts to provide for final design services could save approximately six months for each project.

How would these projects have affected the May storm events if they had been in place at that time?
Based on an analysis of system operating data, it appears that these planned projects would have allowed MMSD and UWS to prevent tunnel-related SSOs during the May storm.

During the May storm period, MMSD was only able to use two of the three deep tunnel pumps due to an emergency construction project. The project was initiated to avoid a catastrophic failure of the pumping system. If full pump capacity had been available during that event, one of the tunnel-related SSOs would have been avoided. The SSOs on May 23-24 would still have occurred, but would have been substantially less. There would have been virtually no reduction in the CSO volume reported, which at a reported 4.1 billion gallons is the largest portion of the May overflows.

What additional projects would have had a substantial positive effect on the May 2004 overflows?

Based on the analysis for this Audit, it appears that additional pumping out of the tunnel, beyond what is currently designed into the system, would have allowed MMSD to greatly reduce SSOs in May. This additional pumping would take advantage of treatment plant capacity that was available at certain times during the May storms. Some SSOs would still have occurred with this additional pumping, but CSO volumes would not have been reduced. Had additional storage and pumping both been implemented before the May 2004 events, tunnel-full SSOs could have been avoided, but CSO volumes probably would have been reduced only slightly.

MMSD has provided WDNR with a list of the SSO locations during the May storms and projects that will provide local relief for SSOs. Of the sixteen reported SSO locations, five are associated with either the Port Washington or Wisconsin Avenue Relief Sewer projects. Another three would be addressed by other projects already underway. Three more locations overflowed due to the tunnel being full and could potentially be addressed with more storage. There are no planned projects for the five remaining SSO locations, and further analysis will be required to address them.

3.5. Relating to Sewer Separation

Is sewer separation a viable option?

Full separation is not a viable option for the following reasons:

- Untreated discharge of the stormwater resulting from separation would increase the level of pollution currently being experienced
- Disruption to the combined sewer area would be extensive during the extended construction period required for full separation.
- Cost of separation would be very great and not cost-effective when compared to the benefits.

Partial separation projects should be pursued where feasible when considering cost, disruption, and environmental impacts. Wherever partial separation is pursued, the first flush of stormwater pollutants should be delivered to a treatment system. The Appendix provides further details concerning the potential impacts of sewer separation.

What would full separation cost?
Estimates for full separation range from $2.1 – $2.7 billion (not including private property costs) in studies conducted for MMSD in 2000 and 2002. These costs did not include separation costs for private property owners' sewer improvements. In some instances these costs could be substantial and should not be overlooked when considering the full cost of sewer separation. The 2020 Facilities Plan team is performing a very thorough evaluation of separation costs and effectiveness that will include input from local construction experts.

What would be the impact on water quality and flooding?
Without proper stormwater treatment, sewer separation will cause a net increase in pollutants to area rivers and the lake. Untreated stormwater discharges would have a negative impact on water quality. The flooding impact of separation is unknown, but any further evaluations of separation should include the costs required to provide the same or better level of flood protection residents currently experience.

How does sewer separation compare to other options?
Sewer separation has not been shown as a cost effective option in many studies, especially when the cost of stormwater treatment is taken into account. Partial separation and CSO treatment should be pursued instead of full separation where shown to be viable and where it would provide significant environmental benefit.

3.6. Relating to Eliminating Overflows

Is achieving zero overflows from the entire collection system a realistic and desirable goal?
It is a realistic and necessary goal for SSOs. A reasonable goal for CSOs is to reduce them and limit their impact. Tactics could include reducing runoff to combined sewers and treating CSOs. During this Audit, the Committee received considerable scientific input indicating that CSOs are not the major contributors to beach closures and other water quality problems. If proven to be correct with further study, it would be difficult to justify the cost to achieve zero CSOs. It is quite likely that significant water quality problems will remain even if overflows were eliminated.

3.7. Relating to MMSD Management of System

How did MMSD management perform during these wet weather events?
The joint decision making process between MMSD and UWS during tunnel events seems appropriate and effective. There is a strong commitment within MMSD to achieve optimum system operation. Since the tunnel became operational in 1994, MMSD and UWS have learned how to better operate the system to reduce and in some cases avoid overflows. The key decision in this operation relates to interpreting weather forecasts to anticipate when to close off combined sewer flows to the tunnel. While this decision is hampered by the availability of reliable long term rainfall forecasts, decision-makers appear to be doing a reasonable job of managing the system.

Were there actions which MMSD should have taken which could have improved the outcome of the wet weather events and reduced overflows?

For this Audit, an analysis of system operational data was performed for the May 2004 events to determine the significance of those storms and the impact of reduced tunnel pumping on overflows. This analysis, based on recent 2020 Facilities Planning modeling, concluded that May 2004 was approximately a 10-year event from the perspective of tunnel volume required to control SSOs. MMSD has performed a separate analysis of rainfall data across the service area and determined that this 19-day window of storms had a 32-year return period.

As for the impact of reduced tunnel pumping, it was determined that the first tunnel-full SSO could have been avoided and the second greatly reduced if the full pumping capacity had been available. Pump availability would have had virtually no impact on CSO volumes, which is the largest portion of the reported overflow volume.

The Committee learned about an overflow incident at Marshall Street at the Milwaukee River on August 3, 2004. This facility, along with a number of others, has instrumentation and configuration characteristics which need remediation. There has been a lack of urgency within the MMSD organization to resolve such issues.

Strong long-term action to limit new I/I and reduce historical I/I in the separate sewer system should have been taken by MMSD in the past. If such strong action had been taken, the separate sewer overflows would have been reduced and perhaps eliminated altogether.

Appendix A:
Glossary of Acronyms and Technical Terms

Glossary of Acronyms and Technical Terms

Term	**Meaning**
AMSA	Association of Metropolitan Sewer Agencies. AMSA represents the interests of the country's wastewater treatment agencies by maintaining a key role in the development of environmental legislation, and works closely with federal regulatory agencies in the implementation of environmental programs.
BG	Billion gallons
BMP	Best Management Practices. BMPs are developed techniques and designs that reduce the impact of stormwater, water and non-point source runoff discharges on the rivers and lakes.
BOD	Biochemical Oxygen Demand. BOD represents the demand for oxygen in a sample of water needed to biodegrade any present pollution. It is used as a gauge of the effectiveness of wastewater treatment plants.
CCTV	Closed Circuit Television. CCTV is used to evaluate the condition of buried sewer pipe and laterals.
CMAR	Compliance Maintenance Annual Reporting. CMAR is intended to assist small wastewater plant operators in preparing an annual report that is designed to indicate trouble areas within the wastewater treatment facility and to promote action before these problems become severe.
CMOM	Capacity Management Operation and Maintenance. CMOM is a program based upon best practices for wastewater collection resulting in maximized conveyance and treatment of wastewater, and minimization of dry and wet weather sanitary sewer overflows.
CSO	Combined Sewer Overflow. Locations where combined sewage discharges from a combined sewer, either after some treatment or no treatment.
CWA	Clean Water Act. Passed in 1972, the Act established the basic structure for regulating discharges of pollutants into the waters of the United States, and gave the EPA authority to implement pollution control programs such as setting wastewater standards for industry. It made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. The Act also funded the construction of sewage treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by nonpoint source pollution.

DNR	Wisconsin Department of Natural Resources
EPA	Environmental Protection Agency
First Flush	The first flush is the initial stormwater runoff from and urbanized area that is highly polluted with the oils, grease, dirt, etc. on the impervious surfaces. It has higher pollutant levels after a dry weather period, than after consecutive rain events.
HRT	High Rate Treatment. HRT was discussed at the August 9, 2004 meeting of the Audit Committee. The meeting minutes explain the use and process of a HRT system. In general, HRT allows for treating wastewater with smaller less expensive facilities.
ICC	Intergovernmental Cooperation Council of Milwaukee County.
I/I	Inflow and Infiltration. I/I are terms used to describe the ways that groundwater and stormwater enter the sanitary sewer system. Inflow is water that enters into the sewer system through improper connections, such as downspouts and groundwater sump pumps. Infiltration is groundwater that enters the sewer system through leaks in pipes or manholes. All of this water is called "clear water" to distinguish it from sanitary sewage.
ISS	Inline Storage System. The ISS is also referred to as the Deep Tunnel. It is used for storing excess wastewater until it can be conveyed to a wastewater treatment plant.
JIWWTP	Jones Island Wastewater Treatment Plant
MG	Million gallons
MGD	Million gallons per day
MIS	Metropolitan Interceptor Sewer. The MIS system is owned by MMSD and conveys local community sewage contributions to the wastewater treatment plants.
MMSD	Milwaukee Metropolitan Sewerage District
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
NOAA	National Oceanic and Atmospheric Administration.

NPDES	National Pollutant Discharge Elimination System. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States.
NPS	Non-Point Source Pollution. NPS pollution is caused by rainfall or snowmelt moving over and through the ground, picking up and carrying away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.
Partial Separation	For this document, partial separation is considered the separation of the combined sewer system into a sanitary sewer system and a storm sewer system in locations that are feasible and cost effective.
SEWRPC	Southeast Wisconsin Regional Planning Commission. SEWRPC provides water quality planning services for the Southeastern Wisconsin Region.
SSWWTP	South Shore Wastewater Treatment Plant
SOP	Standard Operating Procedure. An SOP is a predetermined procedure for operating something or for dealing with a given situation.
SSO	Separate Sewer Overflow
TEC	Technical Environment Committee. The TEC was created by MMSD to oversee UWS on certain issues during the contract period.
TSS	Total Suspended Solids. TSS are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.
UWS	United Water Services
WPAP	Milwaukee Water Pollution Abatement Program. The WPAP was created to reduce the frequency of untreated sewage discharged into Lake Michigan during periods of heavy precipitation. This $2.3 billion program, the largest public works project in the State's history, included upgrading sewage treatment plants; improving and replacing sewer lines; constructing several deep tunnels to store sewage during peak periods; and constructing a new facility for the production of Milorganite, a fertilizer made from heat-dried sludge.

Appendix B:
Deep Tunnel Design Criteria and Historical Performance

MEMORANDUM

October 1, 2004 26157-002

TO: MEMBERS OF THE MAYOR'S AUDIT COMMITTEE

FROM: BROWN AND CALDWELL

SUBJECT: DEEP TUNNEL SIZING CRITERIA AND HISTORICAL PERFORMANCE

The Mayor's Audit Committee is interested in the facts concerning the following:

- Sizing criteria for the Inline Storage System (ISS) aka, the Deep Tunnel,
- Performance of the ISS during its operational history
- Comparison of May 2004 conditions to the tunnel sizing criteria

This memorandum attempts to answer questions concerning these interests to our best abilities given time and budget constraints. Some of the information and analysis presented in this memorandum should be viewed as an initial evaluation and could be improved upon with more detailed work.

SIZING CRITERIA FOR THE DEEP TUNNEL

The ISS or Deep Tunnel is a dual-purpose facility that stores wastewater from both separate sewer area (SSA) and combined sewer area (CSA). The ISS concept evolved during planning for relief of the Metropolitan Interceptor Sewer System (MIS) and control of combined sewer overflows (CSOs) during the Milwaukee Water Pollution Abatement Program. The evolution of the ISS started with a need to provide major relief interceptors, 12 feet in diameter, paralleling the Milwaukee and Menomonee Rivers. These relief interceptors were needed to convey peak flows from the SSA. It was concluded that the most cost-effective approach for building interceptors of this size was to construct them in hard rock about 300 feet below grade. Having reached this conclusion, it was determined that further benefit could be provided by "over-sizing" these relief tunnels to provide storage to shave peak flows to be discharged to the District wastewater treatment plants, thus reducing the required capacities of the plants and eliminating the need for sewer separation in the combined sewer area.

A significant amount of analysis was performed to determine the appropriate sizing of the ISS. In general, hydrologic models are used to develop typical runoff patterns in the MMSD service area. A portion of the surface runoff and groundwater generated by rain and snowmelt was known to flow into the MMSD system through defects in the sewer system and stormwater inlets in the CSA. The models were constructed to mimic the behavior of the actual system. A calibration and verification process was used by the modelers to confirm a good correlation between rain and snow melt events and system flows. Once models were appropriately constructed, it was possible to simulate other storm conditions with the models to compare their effect on the system and also evaluate changes to the system, such as storage tunnels, and how this would affect system overflow conditions.

Using these models, engineers determined that flow conditions resulting from a rainy period in June 1940 would produce the largest separate sewage storage volume during the 40-year period of record (1940 through 1979). This rainy period included a storm that delivered 4.3 inches in a little more than a day. Analysis of this event indicated that about 660 acre-feet (or 220 million gallons) of storage in the ISS would be needed to contain SSOs from the separate system. During simulation of this event, the model of the tunnel reserved most of the tunnel for separate system flows and very little combined sewer flows into the tunnel. Due to the importance of this event on the sizing of the ISS, it was labeled "the Storm of Record."

As planning progressed in parallel to address CSOs, it was recognized that the storage tunnels for separate sewage storage would only be used a few times each year and the full tunnel volume would be needed for separate sewage very infrequently. It was reasoned that the tunnel system could also be used to store combined sewage to reduce CSOs, if a means could be provided to accommodate these dual objectives. Because combined sewer flows are generated much more quickly than separate sewer flows, successful implementation of the dual-purpose concept required a means to limit the amount of tunnel volume used for combined sewage so that volume would be available to store separate sewage.

To evaluate the proper size for this dual-purpose facility, MMSD used computer models that were configured to prevent SSOs and to minimize the occurrence of CSOs. After this analysis, the tunnel was sized for 1,150 ac-ft (or 375 million gallons). The actual constructed tunnel volume is 1,243 ac-ft or 405 million gallons. Table 1 summarizes the anticipated storage needed and estimated CSOs resulting from the largest flow events analyzed from the historical record. These results reflect an assumed I/I reduction of 12.6 percent in the separate sewer area.

Table 1. Summary of Simulated Storage Events During WPAP (Ranked by CSO Volume Amounts)

Approximate Event Date	Event Duration, hours	Maximum Tunnel Storage During Event, MG	Storage for Separate Sewer Flow, MG	Storage for Combined Sewer Flow, MG	Simulated SSO Volume, MG	Simulated CSO Volume, MG
03/29/1960	114	315.5	149.3	166.2	0.0	1,423
06/21/1940	128	277.9	223.3	54.5	0.0	1,419
09/07/1941	59	58.1	50.9	7.2	0.0	1,292
07/17/1959	69	173.2	68.6	104.5	0.0	842
07/31/1953	74	153.1	17.6	135.5	0.0	769
08/02/1960	78	244.3	53.6	190.7	0.0	762
07/17/1964	68	178.4	39.6	138.8	0.0	731
04/20/1973	103	317.0	79.4	237.6	0.0	595
04/24/1976	123	333.1	114.6	218.5	0.0	584
05/12/1978	113	302.7	86.1	216.6	0.0	561
07/19/1950	102	268.8	99.6	169.2	0.0	553
07/16/1977	110	259.5	29.8	229.8	0.0	552
06/13/1950	74	288.0	46.5	241.5	0.0	504
06/25/1969	169	368.4	8.2	360.2	0.0	478
09/11/1978	112	298.1	8.1	289.9	0.0	403
07/17/1952	86	253.6	23.9	229.7	0.0	395
09/12/1961	98	262.3	6.9	255.4	0.0	328
06/23/1968	164	312.6	52.4	260.2	0.0	325
06/02/1954	98	290.9	59.3	231.6	0.0	301
07/06/1954	89	290.6	13.5	277.1	0.0	280

Tunnel Operations Description

Having the ISS serve as a dual-purpose facility led to the development of a prediction algorithm for the volume reserved for separate sewage inflow (VRSSI). The purpose of the prediction algorithm was to forecast the volume of separate sewage that would need to be stored for a wet weather event so that combined sewage flow to the ISS could be stopped to reserve an appropriate tunnel volume for separate sewage.

The algorithm for volume reserved for separate sewage is a function of the following parameters:

- Previous 7-day precipitation
- Decrease in snow depth over last 2 days
- Precipitation predicted in next 24 hours
- Precipitation predicted in next 48 hours

In the early years of operating the post-WPAP sewer system, MMSD discovered there were difficulties in predicting the appropriate VRSSI and controlling flows to achieve that operating objective. Because of difficulties in controlling flow to the ISS to reserve sufficient volume for separate sewage and to avoid overfilling the ISS, the District revised the algorithm to always reserve a minimum amount. The minimum amount has stood at several values over recent years, but now is at 150 MG.

If too little volume is reserved, the tunnel will fill with too much combined sewage and an SSO may occur. If too much volume is reserved, there may be unused ISS volume during an event that could have been used to reduce CSOs. Improving the accuracy of the prediction algorithm will help to optimize the use of the ISS for storage of both separate and combined sewage flows. MMSD is continuously attempting to improve its approach to managing the ISS. The most recent effort by MMSD to improve prediction of VRSSI is the real-time control (RTC) strategies improvement project.

ISS PERFORMANCE HISTORY

The ISS became operational in 1994. Since then, a total of 24 tunnel-related CSOs and 14 tunnel-related SSOs were reported by MMSD. While the average annual number of CSOs has been higher than estimated (2.11 versus 1.4), the system has not caused more than the discharge permit maximum number of CSOs in a given year (6). The WPAP modeling predicted an annual maximum number of events, based on the historical record, of 4 in one year. The number of CSOs in a given year is strongly correlated to the rain patterns for that year. The 2003 UWS Performance Evaluation concluded that the occurrence of CSO events closely coincides with rain events that produce a daily total of 1.5 inches or more.

The number of tunnel-related SSOs is strongly correlated to the selection of an initial reserved volume for separate sewer flow (VRSSI). Since changing to a VRSSI of 150 to 200 MG, the SSOs have reduced. Table 2 summarizes the tunnel operating performance since 1994.

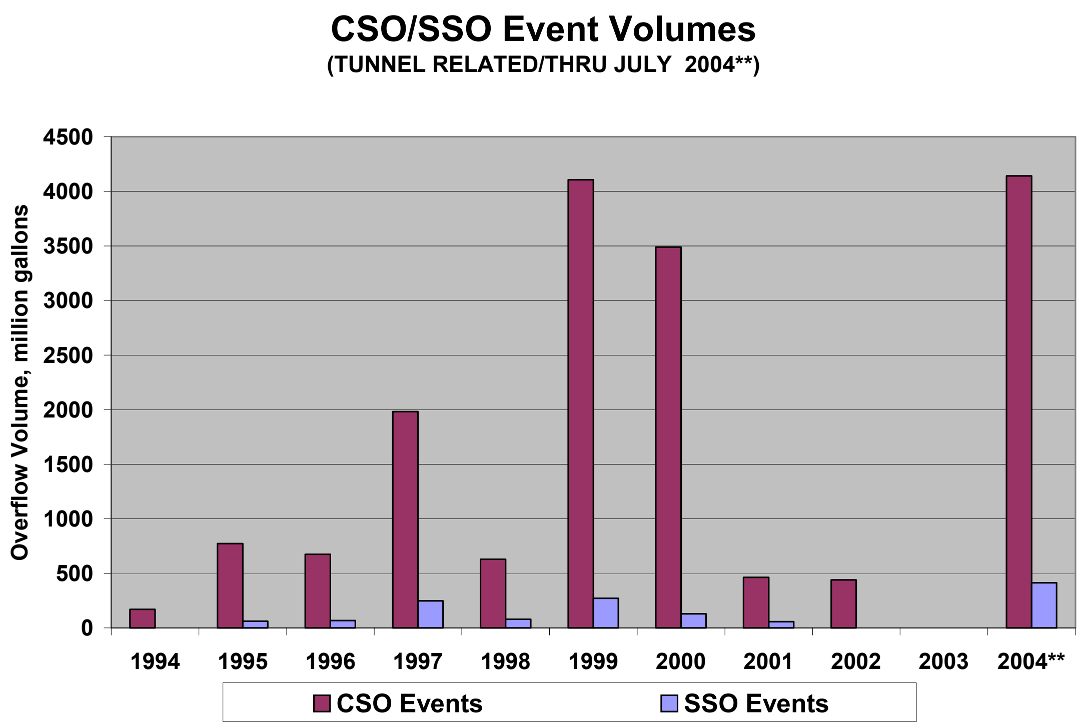
Table 2. Summary of ISS-Related Overflows

	OVERFLOWS RESULTING FROM TUNNEL GATE CLOSING			
YEAR	Number of Reported CSO's[1]	Volume (MG)	Number of Reported SSO's	Volume (MG)
1994	1	171	0	0
1995	1	773	1	62
1996	1	675	1	68
1997	2	1,983	2	248
1998	2	629	2	80
1999	6	4,106	4	272
2000	5	3,490	2	130
2001	3	464	1	56
2002	2	440	0	0
2003	0	0	0	0
2004[5]	1	4,141	1	415
TOTAL	24	16,872	14	1,331

Notes: Source is from MMSD Contract Compliance Office records.
[1]WPDES permit allows up to six CSO events per year.
[2]On 9/3/1999 Tunnel Reserve Capacity changed from 40 MG to 150 MG (confirm with susan anthony)
[3]On 10/12/99 Tunnel Reserve Capacity changed from 150 MG to 200 MG
[4]On 5/8/2003 Tunnel Reserve Capacity changed from 200 MG to 150 MG
[5]2004 information is preliminary.

Figure 1 presents reported overflow results for the MMSD system based on tunnel-full conditions. Pipeline bottlenecks in the system cause additional overflows during wet weather and these overflow numbers are not included in this figure.

Figure 1



COMPARING MAY 2004 TO TUNNEL SIZING CRITERIA

We determined that the best basis of comparing the May 2004 event to other storms in the historical record was to use the estimated amount of separate sewer flow sent to the tunnel during the event. Rainfall is not a good estimator, as rainfall statistics ignore the back-to-back nature of the storms that tend to have the greatest demand on a storage system such as the deep tunnel.

This comparison is based on recently modeling performed by the 2020 Facilities Plan team. The modeling approach follows a long-standing practice for evaluating storage requirements during rain and snowmelt events. Hydrologic models are used to develop typical runoff patterns in the MMSD service area. A portion of the surface runoff and groundwater related to storms is linked to flow in the MMSD system. A calibration and verification process is used by the modelers to confirm a good correlation between rain and snow melt events and system flows. Once models are appropriately constructed, it is possible to simulate other storm conditions with the models to compare their effect on the system. This model development process is being followed by the 2020 Facilities Plan team, and the results were interpreted in order to compare May 2004 to other rainy periods occurring since 1940.

More specifically, the 2020 modeling is performing long-term simulations of system flows and tunnel utilization using a model called MACRO 2004. The MACRO 2004 model is a macro-scale model that represents the MMSD service area as four large sewered areas. Flow is accumulated in each area and routed to either treatment or storage facilities depending on designated facility capacities. When facility capacities are reached, the resulting overflows to receiving waters are computed. The MACRO program was custom-made for the District and simulates system operations given a set of sewer flow inputs generated by an external hydrologic model called HSPF.

To provide proper context for the May 2004 event, the modeling team ran MACRO 2004 with a flow time series from January 1, 1940, through May 30, 2004. The model produces a large number of outputs, but the most important for comparing one event to another is the wet weather flow volume generated in the separate sewer area that could be either captured by the tunnel or become an SSO. Our summary refers to this number as "Separate Sewer Flow to the ISS."

Table 2 summarizes this output for the twenty largest events in the simulation period. All events were simulated with identical system assumptions for storage, plant capacity, and tunnel pumpout rates. The only difference is that the May 2004 events were simulated using rainfall measured at a temporary rain gauge for the Port Washington Road Relief Tunnel Predesign Project. Based on a review of rain data for May 2004, this gauge provided a good representative record of conditions experienced across the service area. All other historical events were simulated with the Mitchell Airport rainfall time series.

The 2020 Facilities Plan modeling team has determined that there were significant challenges in calibrating the model to flow events that are driven by snowmelt. The main reason for this challenge is that since the tunnel has become operational in 1994, there have been no major snowmelt-driven events to which the models could be calibrated. Considering this and the fact that the May 2004 events were rainfall-driven, our comparison to June 1940 is based on a statistical return period using only the rainfall-driven event data set. Based on these results, the June 1940 event would rank third overall. The May 2004 event would rank 5th for the rainfall events, and would represent the largest flow event since the tunnel became operational.

Using statistical techniques common to flow analysis, the May 2004 event was assigned a return period of approximately 11 years when considering only rainfall-driven events. If snowmelt events are included in these rankings, May 2004 would have a return period of just over 5 years. As these are not exact figures, it would be appropriate to characterize the May 2004 return period as approximately 10 years. It would also be reliable to state that May 2004 conditions were not as demanding on the system as the June 1940 Storm of Record.

Table 2. Approximate Return Period of Significant Events Simulated with MACRO

Approximate storm date	Separate Sewer Flow to the ISS, acre-feet	Event Rank	Approximate Return Period, years	Type of event, “Snow and rain-driven” or “Rain-driven”	Approximate Return Period of Rain-Driven Events, years
April 1960	3,669	1	65.0	Snow and rain	-
March 1979	3,536	2	32.5	Snow and rain	-
March 1962	2,439	3	21.7	Snow and rain	-
September 1941	1,953	4	16.3	Rain	65.0
April 1983	1,932	5	13.0	Rain	32.5
February 1985	1,854	6	10.8	Snow and rain	-
June 1940	1,827	7	9.3	Rain	21.7
May 1990	1,596	8	8.1	Rain	16.3
April 1993	1,473	9	7.2	Rain	13.0
May 2004	**1,418**	**10**	**6.5**	**Rain**	**10.8**
April 1976	1,387	11	5.9	Rain	9.3
July 1950	1,341	12	5.4	Rain	8.1
June 1954	1,185	13	5.0	Rain	7.2
May 2000	1,133	14	4.6	Rain	6.5
February 1994	1,117	15	4.3	Snow and rain	-
May 1978	1,108	16	4.1	Rain	5.9
June 1968	1,105	17	3.8	Rain	5.4
March 1976	1,072	18	3.6	Snow and rain	-
May 1948	1,052	19	3.4	Rain	5.0
April 1999	1,048	20	3.3	Rain	4.6

Return period is calculated with the following = Years of Analysis / Event Rank

CONCLUSIONS

Based on the tunnel operating data, it appears that the tunnel as constructed and designed is achieving the CSO control objective of the WPAP. Tunnel-full SSOs do occur, but they are not frequent and depend upon an appropriate initial volume reserved for separate sewer flow (VRSSI).

Current system evaluations under the 2020 Facilities Plan are considering additional events that occurred since 1980 and therefore were not represented in tunnel sizing analysis done during the WPAP. Those “new” events that occurred since the tunnel was operational in 1994 add insight into long-term system performance.

The 2020 Facilities Plan effort is also performing an updated characterization of wet weather flows throughout the service area. It is important to note that this effort represents both a reflection of current conditions and an improved approach to evaluating wet weather flows in the separate sewer area. This will result in more accurate evaluations of system capacity needs.

Appendix C:
Analysis of May 2004 Tunnel Operations

MEMORANDUM

October 1, 2004 26157-002

TO: MEMBERS OF THE MAYOR'S AUDIT COMMITTEE

FROM: BROWN AND CALDWELL

SUBJECT: ANALYSIS OF INLINE STORAGE SYSTEM UTILIZATION DURING MAY 2004 STORM EVENTS

Several questions posed by the Audit Committee pertained to the performance of the Inline Storage System (ISS) or "Deep Tunnel" during the May 2004 storm events. In particular, we have been asked the following questions, which are answered in this memorandum:

1. Would the overflows have been prevented if all tunnel pumps were available in May 2004?

2. Would additional pumping capacity, beyond what is currently constructed, have prevented the overflows in May 2004?

3. Would the additional storage projects in planning, design, and construction phases allowed MMSD to prevent the May 2004 overflows?

In order to evaluate these questions, we requested hourly recorded data from MMSD for tunnel pumping, tunnel level, tunnel inflows, treatment plant influent flows, Sanitary Sewer Overflows (SSOs), and Combined Sewer Overflows (CSO). We received all but the CSO time series, so our analysis is confined to whether SSOs could have been eliminated as a result of these scenarios as opposed to eliminating CSOs. The seven specific scenarios evaluated are described in detail in the remainder of this memorandum. First, we present our approach and base assumptions for the analysis.

Base Assumptions

To perform these analyses, we needed to make certain important assumptions. We have attempted to qualify the extent to which any of these assumptions had an affect on the results.

1. Based on a volumetric balance analysis of tunnel inflows, tunnel volumes, and tunnel pumpout, we determined that, in aggregate through May 2004, tunnel inflows measured some 17 percent low. An accurate time series of tunnel inflows is critical to determine tunnel performance after an event, but not so important during the actual event. In order to perform a more accurate analysis, we reconstructed a theoretical inflow time series based on the amount of volume change in the tunnel over an hour compared to what was recorded pumped out over that hour. We further dissected this theoretical inflow time

series into a separate sewer inflow time series and a combined sewer inflow time series. The split between separate and combined was based on the measured values during that hour since at certain times of the events the gate closures prevented combined flow from entering the tunnel.

2. Two of the analyses considered whether the tunnel would have been sufficient to prevent SSOs if the entire tunnel were reserved for only separate sewer inflows during the month. This required us to develop distinct inflow time series for the separate and combined systems based on the theoretical tunnel inflow and measured flows from these two systems into the tunnel.

3. SSO data were provided by MMSD as start of event, end of event, total duration of event, location, and total amount of overflow. In order to perform the analysis, we needed to develop an hourly time series of SSO from the available data. To do this, we assumed a constant amount of SSO over the time period in which SSOs were active and attributed to tunnel conditions.

4. The ISS is pumped out by three large pumps. One pump is dedicated to discharge to Jones Island WWTP, one is dedicated to South Shore WWTP, and the third can discharge to either. To simplify the analysis of scenarios that considered design pumpout rates, we assumed that two pumps would go to Jones Island and the third would go to South Shore. MMSD provided measured pump rates for the three pumps individually. During the actual May 2004 conditions, only one pump each could discharge to the plants. The impact of this pumping restriction could be evaluated with this approach.

5. The ability to pump out of the tunnel is impacted by treatment plant capacity. This restriction is particularly important when attempting to determine the benefits of increased pumping capacity from the tunnel. For this analysis, we assumed peak treatment plant capacities of 300 MGD at both Jones Island and South Shore WWTP. MMSD's NPDES permit also allows up to 60 MGD of additional capacity at Jones Island WWTP when flows receive primary treatment but are diverted around secondary treatment and then blended with secondary effluent prior to disinfection. Plant hydraulics actually accommodate a diversion rate of 90 million gallons. Due to the complexity of this balance between rate and volume in a given day, blended flow at Jones Island was not factored into the analysis. Although blending did occur during actual May 2004 storm conditions, this practice would have been reflected in the actual pumping rates and plant flows used in our analysis.

6. The amount of tunnel volume plays a critical role in this analysis as it does in the actual operation of the system. For current conditions, 405 MG of tunnel volume were used. For expanded tunnel volume scenarios, a total of 548 MG of tunnel volume were used, which reflects additional storage to be provided by the Northwest Side Relief Tunnel (88 MG), the West Wisconsin Avenue Relief Tunnel (25 MG) and the Port Washington Road Relief Tunnel (30 MGD). Each of these projects are either under construction or in preliminary design phase of implementation. While these projects are not likely to be

true extensions of the deep tunnel, the analysis assumes that they effectively function as such.

7. Some of the scenarios evaluated in this analysis reflect changed conditions that potentially could have affected how MMSD and UWS operated the system during May 2004; however, factoring in how these changes would have affected the outcome of SSO occurrence and volume is nearly impossible. The real implication of this assumption is that our analysis used what we believe to be the actual flows diverted to the tunnel during the event and did not attempt to divert additional combined sewer flows into the tunnel to determine the potential CSO reduction that would have resulted. A discussion of these results attempts to indicate what impact the scenario would have had on system operating decisions, but at no point did we attempt to determine an outcome with changed operations.

8. Another important definition for "Storm of Record" is necessary for reviewing this memorandum. During the Water Pollution Abatement Program (WPAP) modeling analysis, flow conditions associated with a rainfall period in June 1940 produced the largest simulated separate sewage storage volume during the 40-year period of record (1940 through 1979). This led to sizing the tunnel for 660 acre-feet of separate sewage storage in the ISS to contain SSOs from the separated system. During the simulation of this storm, it was assumed that almost the entire tunnel would be reserved for separate system flows and would allow a small amount of combined sewer flows into the tunnel. Due to the importance of this event on the sizing of the ISS, it was labeled "the Storm of Record." This term is used later in this memo.

9. The evaluation of tunnel performance is keyed to the ability of the scenario to prevent tunnel-full-related SSOs. This means that with the tunnel full, no additional flow from the separate sewer area could enter the tunnel and would then overflow. This does not mean that the tunnel is actually overflowing. From an operational perspective, it means that gates allowing separate sewer flow to enter the tunnel are closed, producing a tunnel-full-related SSO.

Analysis Approach
The approach for determining tunnel performance during this specific set of events took the following steps:

1. With a starting volume from the previous hour, determine a new tunnel volume for the hour based on flow into the tunnel.

2. Determine the appropriate amount of volume to be pumped from the tunnel during the hour. Depending upon the scenario, this volume could be the actual recorded or a theoretical value that reflects actual pumping design capacity or a maximum available capacity at the two treatment plants. Even under actual pumping design capacity rates, the capacity of the plants can restrict the pumping amounts.

3. Determine the tunnel volume after subtracting what is determined to be pumped from the tunnel during the hour.

4. Compare the remaining tunnel volume required to the actual tunnel storage capacity. If the volume required is greater than the storage capacity, determine the volume of SSO. The SSO volume is the difference between volume required and available capacity. After this comparison, set the tunnel volume for the next hour's calculations (either the estimated tunnel volume or the tunnel capacity).

Analysis Results
Seven specific scenarios were analyzed according to these assumptions and approach. Each is discussed in turn below. Again, no attempt is being made to analyze CSO reductions in this analysis; however, the ability of the system to control CSOs in such an event is discussed in the conclusions section of this memorandum. Table 1 summarizes the results of these analyses.

Actual Conditions
This scenario indicates the reliability of the assumptions and analysis approach for evaluating further scenarios. Under this scenario, tunnel pumping is kept to what was actually recorded in the system. Two key comparisons indicate the reliability of the approach. First, a comparison of total SSO estimated to what was reported by MMSD. This shows very good agreement of 419 MG estimated to 415 MG reported. This scenario would have resulted in the same amount of CSO volume as reported (4.1 billion gallons). The second comparison is of actual tunnel volume change over time compared to the estimated tunnel volume change. Figure 1 provides this comparison in graphical form. The "Potential Tunnel Inflows" line represents actual tunnel inflows and tunnel-full-related SSOs for each hour. Overall there is very good agreement between the estimated actual tunnel conditions and what was measured by MMSD.

Reserve Tunnel for Separate Flow Only
Under this scenario, we analyze tunnel storage volume with two key assumptions. First, we restrict the pumping to the rates that were actually utilized during the May 2004 events – reflecting the fact that only two pumps were available at that time. The second assumption relates to the approach for sizing the tunnel during the WPAP, in that the storage was sized for controlling separate sewer overflows during the June 1940 Storm of Record. If MMSD and UWS had perfect prediction of precipitation during May 2004, they may have elected to have only allowed flows from the separate sewer area into the tunnel. Our analysis indicates that this would have eliminated the tunnel-full-related SSO of 419 MG; however, it would have increased CSO by nearly 900 MG. This is the amount of combined flow estimated to be sent into the tunnel and pumped out to the treatment plants during May 2004. Figure 2 presents a compared time history of estimated and actual tunnel volumes under this scenario. Under this scenario, approximately 60 MG of non-tunnel-related SSO would still have resulted due to system capacity restrictions.

Reserve Tunnel for Separate Flow Only and Designed Pumpout
This scenario considers the reduction in tunnel-full-related SSO if the designed tunnel pumpout capacity were available and only separate sewer flows were allowed into the tunnel. Not

surprisingly, this analysis also indicates that tunnel-full-related SSOs would have been prevented. Figure 3 presents a compared time history of estimated and actual tunnel volumes under this scenario.

With this scenario, the tunnel would have filled to a maximum volume of 313 MG under this scenario, the tunnel would have been under-utilized and could have taken additional flow from the combined area. This effect was not estimated, however, so the resulting CSO under this scenario increases by 900 MG. For comparison, the WPAP analysis predicted needing 221 MG to store separate sewer flow during the June 1940 Storm of Record. The WPAP figure represents 1980 I/I conditions with planned reductions and Year 2005 population and land use.

Actual Inflow and Designed Pumpout
This scenario evaluates tunnel operations as if all tunnel pumps were available during the May events. A comparison to actual tunnel volumes is shown in Figure 4. This scenario indicates that tunnel-related SSO would not have been eliminated, but volumes would have been substantially decreased to 119 MG. Most importantly, this evaluation indicates that will all pumps available, the system would have been able to empty the tunnel after the first major fill event by May 18, prior to the second fill event starting on May 21.

Actual Inflow and Maximum Pumpout
At times, the amount of tunnel pumpout is restricted by the design capacity of the pumping system itself, and not by the available capacity at the WWTPs. Figure 5 shows the results of an analysis in which the tunnel pumpout is governed by available WWTP capacity. This condition would have allowed the system to avoid the first tunnel-related SSO and reduce overall SSO volume to 8 MG. Maximum pumping rates required to achieve this performance is estimated at 322 MGD. Achieving this rate would likely require additional conveyance capacity for flows to South Shore WWTP.

Actual Inflow, Design Pumpout, and Extra Storage
For this scenario, the impact of additional storage projects (described previously) is evaluated assuming all could have been utilized to their full capacity. The analysis factored in an additional 143 MG of storage from the three projects, raising the total to 548 MG, and current design pumpout rates. Figure 6 shows that this scenario would have resulted in no tunnel-related SSO, and a maximum storage level at 523 MG.

Actual Inflow, Maximum Pumpout, and Extra Storage
This final scenario combines the maximum pumpout assumption with the extra storage from the planned projects. Figure 7 shows the results, which also indicate zero tunnel-related SSO.

Actual Inflow, Actual Pumpout, and Extra Storage
The final scenario evaluated whether tunnel-full-related SSOs could have been eliminated even with restricted pumping if the extra storage projects had been in place. This evaluation, shown in Figure 8, indicates an SSO of 276 MG.

Table 1. Summary of Tunnel Utilization Scenarios Analyzed

Scenario	Tunnel Storage Assumed MG	Maximum Pumpout Rate Assumed MGD	Estimated Tunnel-Full-Related SSO MG	Estimated Tunnel-Full-Related CSO MG	Storage Required to Prevent Tunnel-Full SSO MG
Actual Conditions (Figure 1)	405	80	419	4100	824
Reserve Tunnel for Separate Flow Only and Actual Pumpout (Figure 2)	405	80	0	4897	391
Reserve Tunnel for Separate Flow Only and Designed Pumpout (Figure 3)	405	120	0	4897	313
Actual Inflow and Designed Pumpout (Figure 4)	405	120	119	4100	523
Actual Inflow and Maximum Pumpout (Figure 5)	405	322	8	4100	409
Actual Inflow, Design Pumpout, and Extra Storage (Figure 6)	548	120	0	4100	523
Actual Inflow, Maximum Pumpout, and Extra Storage (Figure 7)	548	322	0	4100	409
Actual Inflow, Actual Pumpout, and Extra Storage (Figure 8)	548	120	276	4100	824

Conclusions
These analyses were performed to evaluate three specific questions. Answers are provided as appropriate.

1. *Would the overflows have been prevented if all tunnel pumps were available in May 2004?*

   The scenario shown on Figure 4 shows that tunnel-full-related SSO volumes would have been substantially reduced under this condition, but not eliminated. As controlling SSOs are a higher operational priority for MMSD and UWS, this would imply that CSO volumes and events would not have been reduced.

2. *Would additional pumping capacity, beyond what is currently constructed, have prevented the overflows in May 2004?*

   The scenario presented in Figure 5 shows indicates that this condition would have nearly eliminated tunnel-full-related SSO events and volumes. Again, this additional capacity would not have prevented all such SSOs, so CSO events and volumes would not have been reduced. Increasing tunnel pumping capacity would also require some degree of additional pipe capacity to convey flows to the South Shore WWTP.

3. *Would the additional storage projects in planning, design, and construction phases allowed MMSD to prevent the May 2004 overflows?*

   The most appropriate answer to this question comes from the scenario presented in Figure 6, which shows that tunnel-full-related SSO events and volumes would have been prevented if designed pump capacity were available. It is also possible that CSO volumes could have been slightly reduced, but it was not possible to factor this into the analysis. It is unlikely that CSO volumes reported (4.1 BG) would have been substantially reduced. This conclusion assumes that all of these remote storage facilities could have functioned as extensions of the deep tunnel during the event.

Figure 1. Estimated Actual Tunnel Performance with Recorded Pumping and Flow Into Tunnel As Measured (Reported Tunnel-Related SSO Was 415 MG)

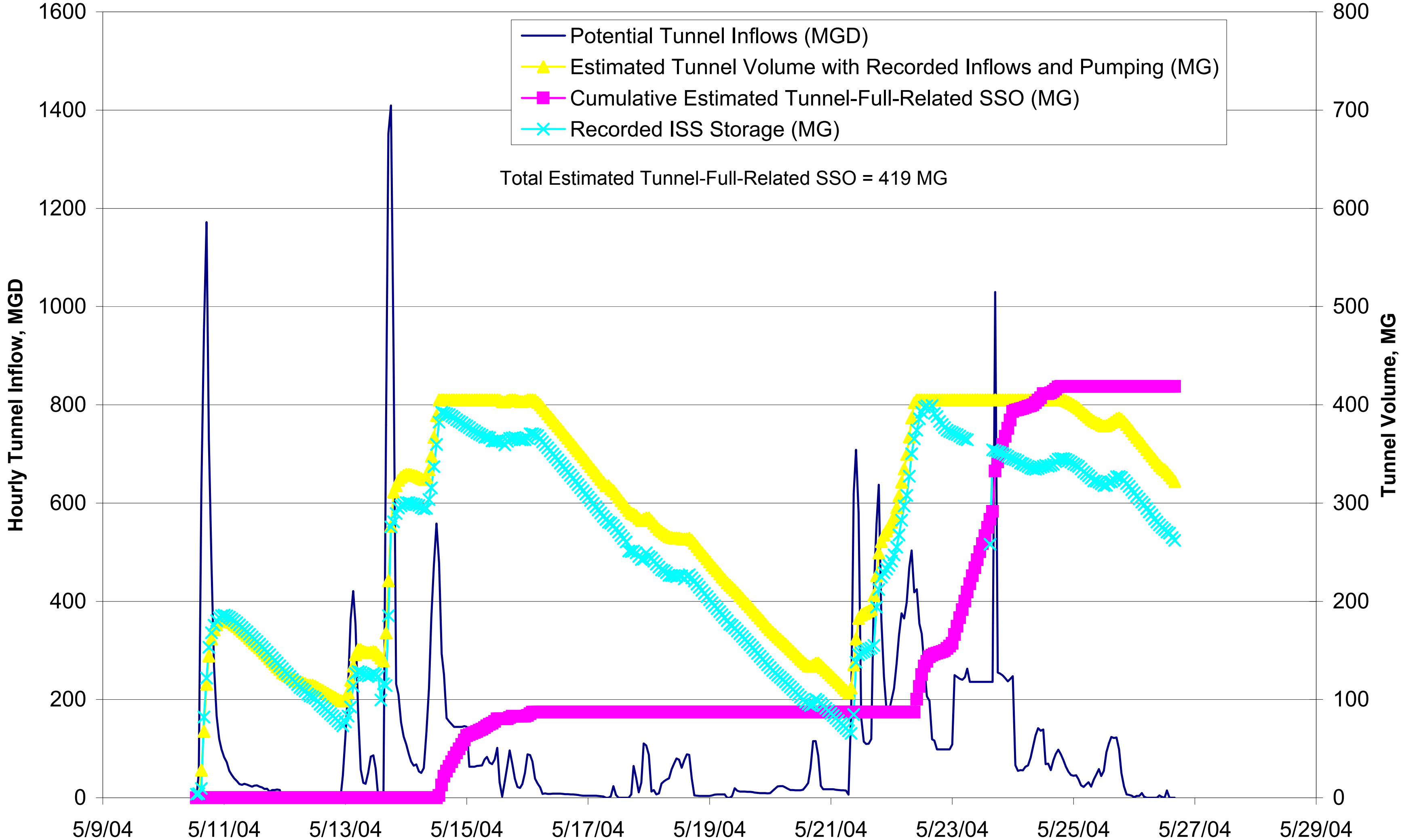


Figure 2. Estimated Tunnel Performance with Recorded Amount of Pumping Assuming No Combined Sewer Flow Into Tunnel

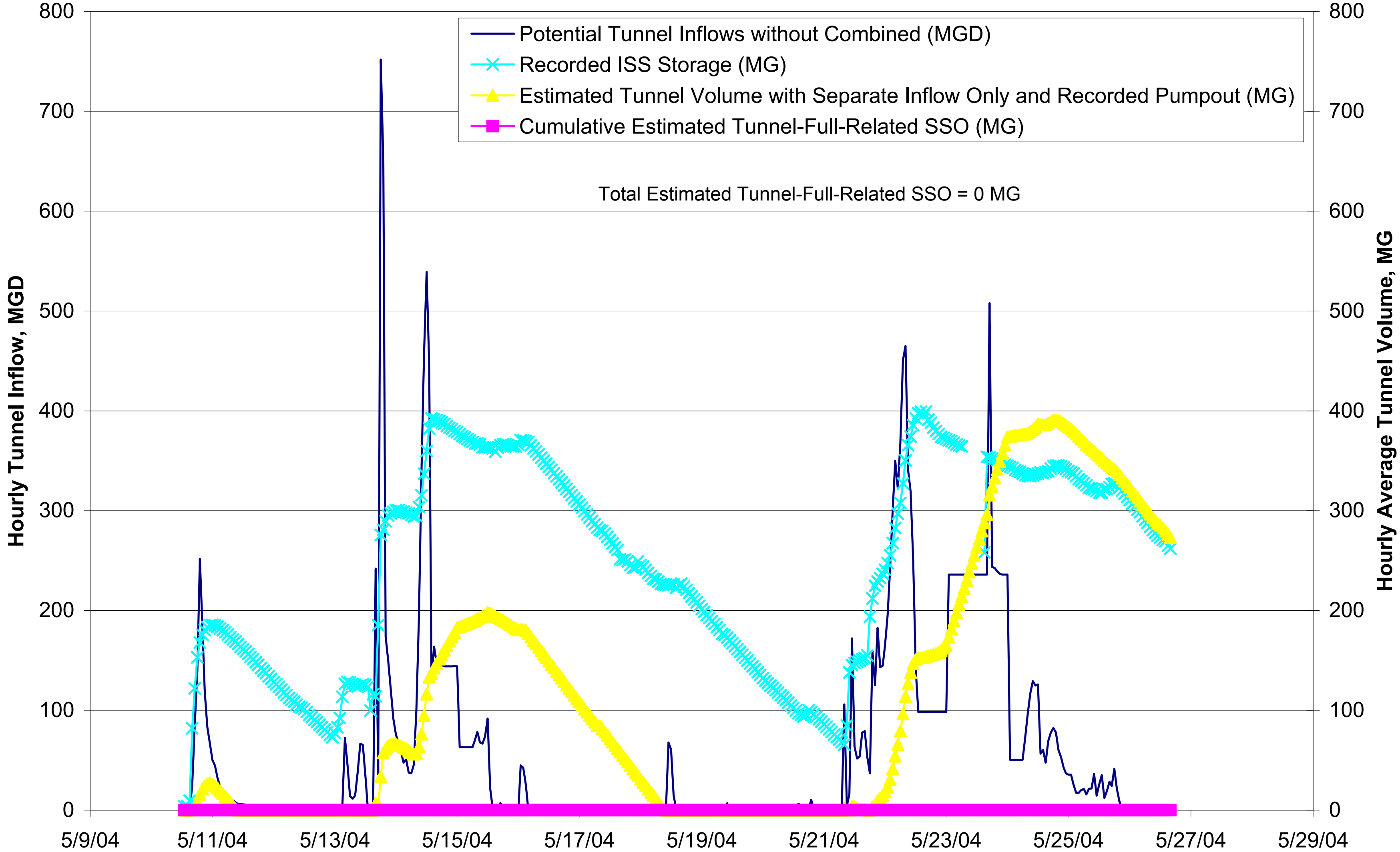


Figure 3. Estimated Tunnel Performance with Design Pumpout (Based on Pump and Plant Capacity) Assuming No Combined Sewer Flow Into Tunnel

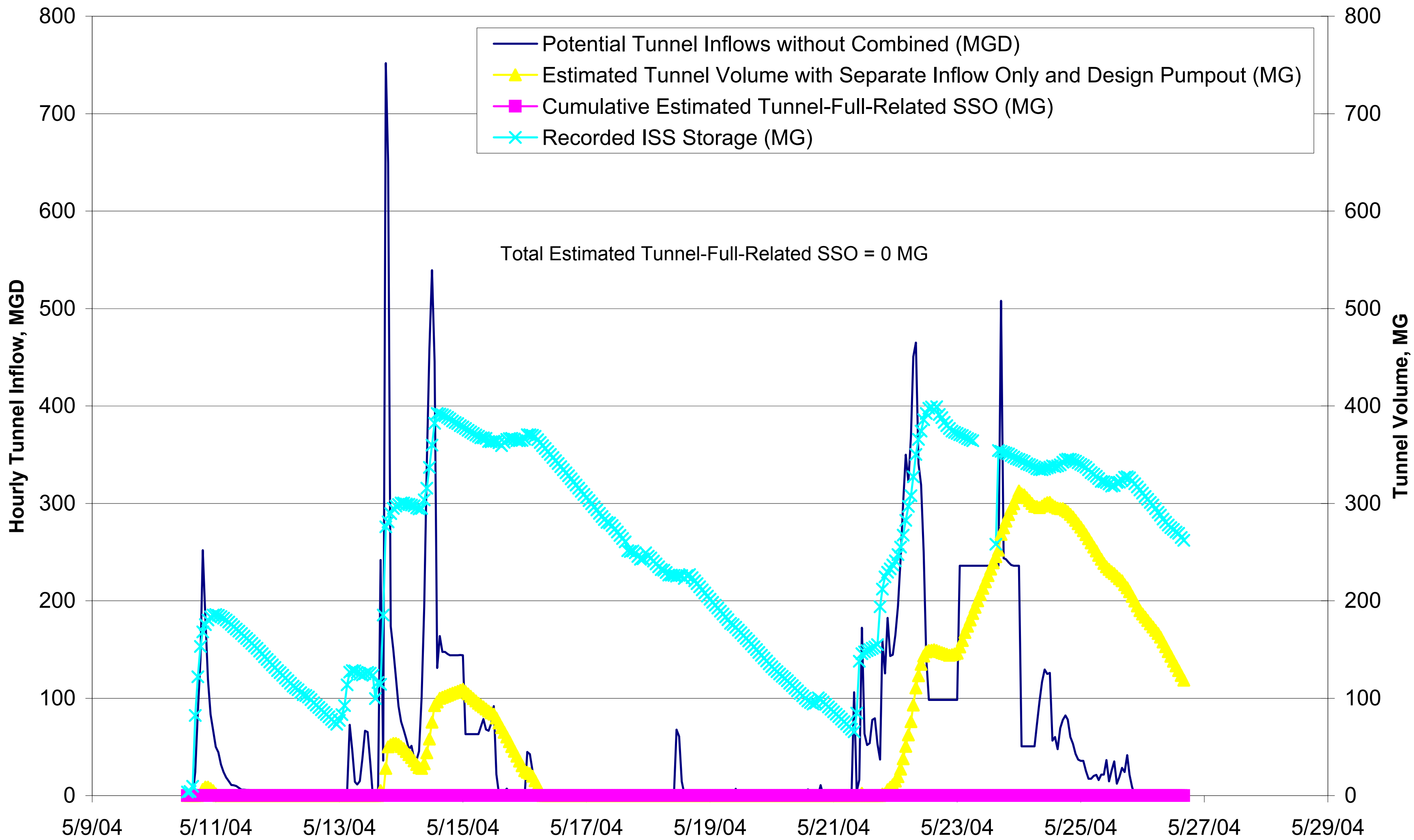


Figure 4. Estimated Tunnel Performance with Design Pumpout (Based on Pump and Plant Capacity) Assuming Flow Into Tunnel As Measured

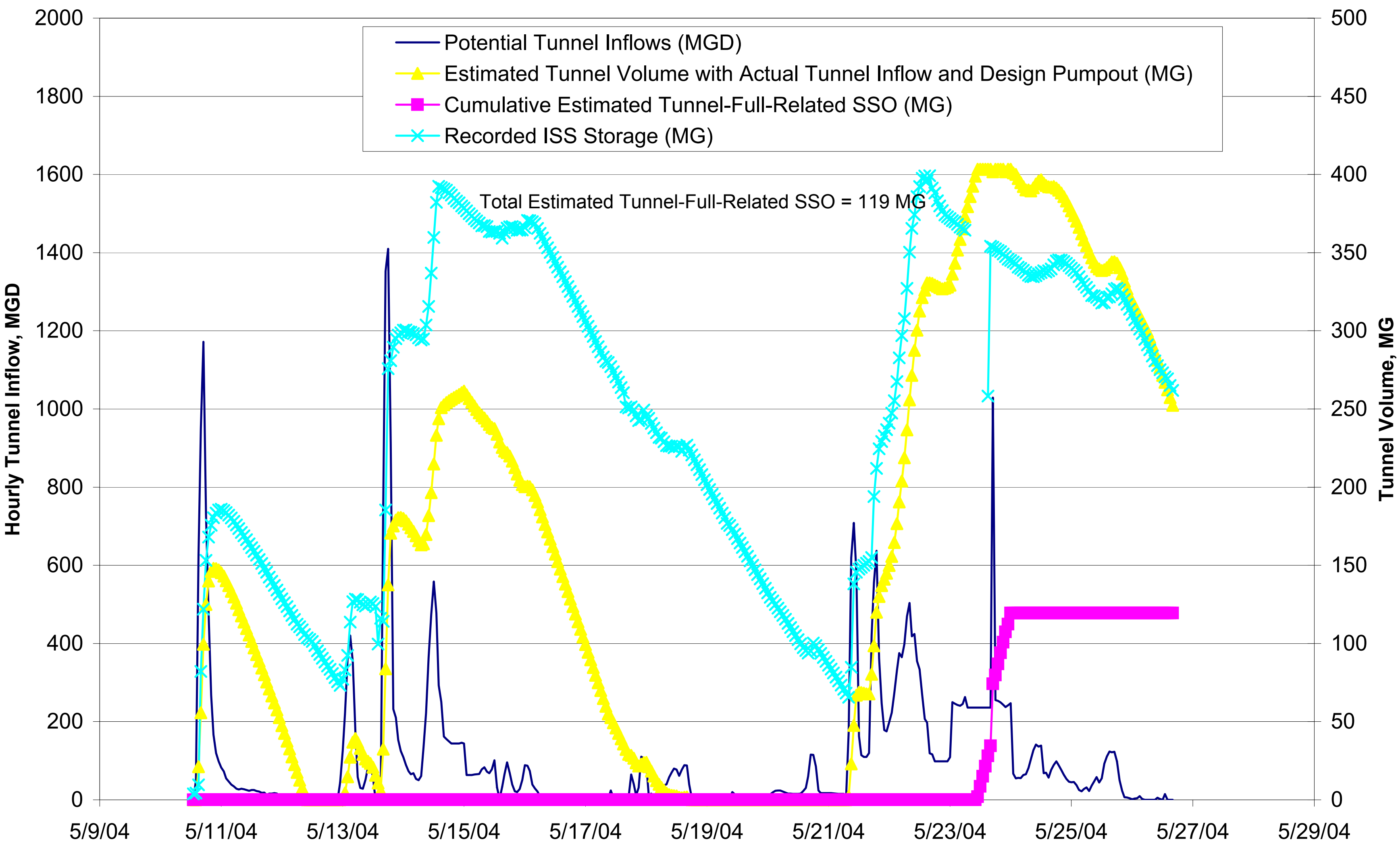


Figure 5. Estimated Tunnel Performance with Maximized Tunnel Pumpout (Based on Plant Capacity Only) Assuming Flow Into Tunnel As Measured

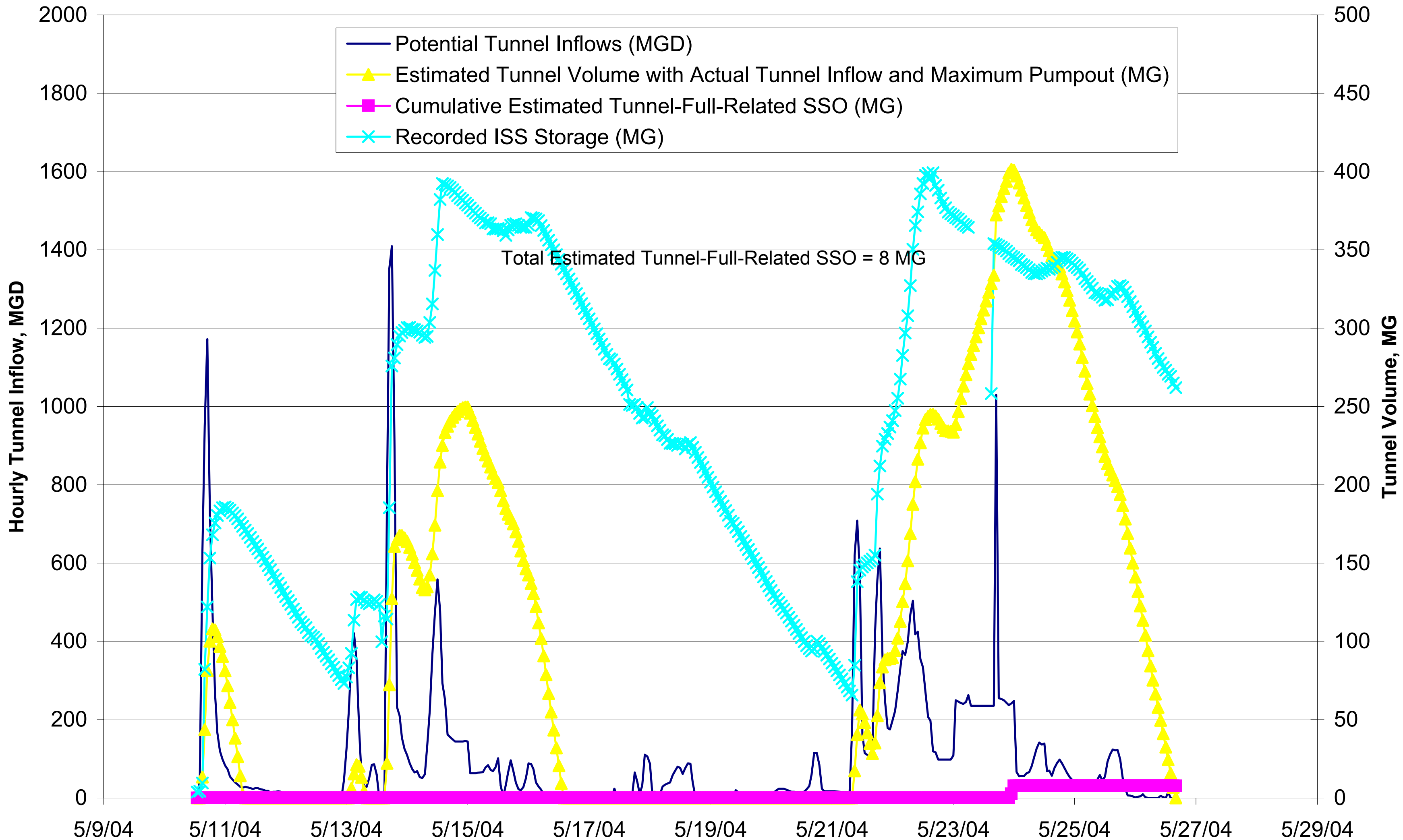


Figure 6. Estimated Tunnel Performance with Design Pumpout (Based on Pump and Plant Capacity) Assuming Flow Into Tunnel As Measured

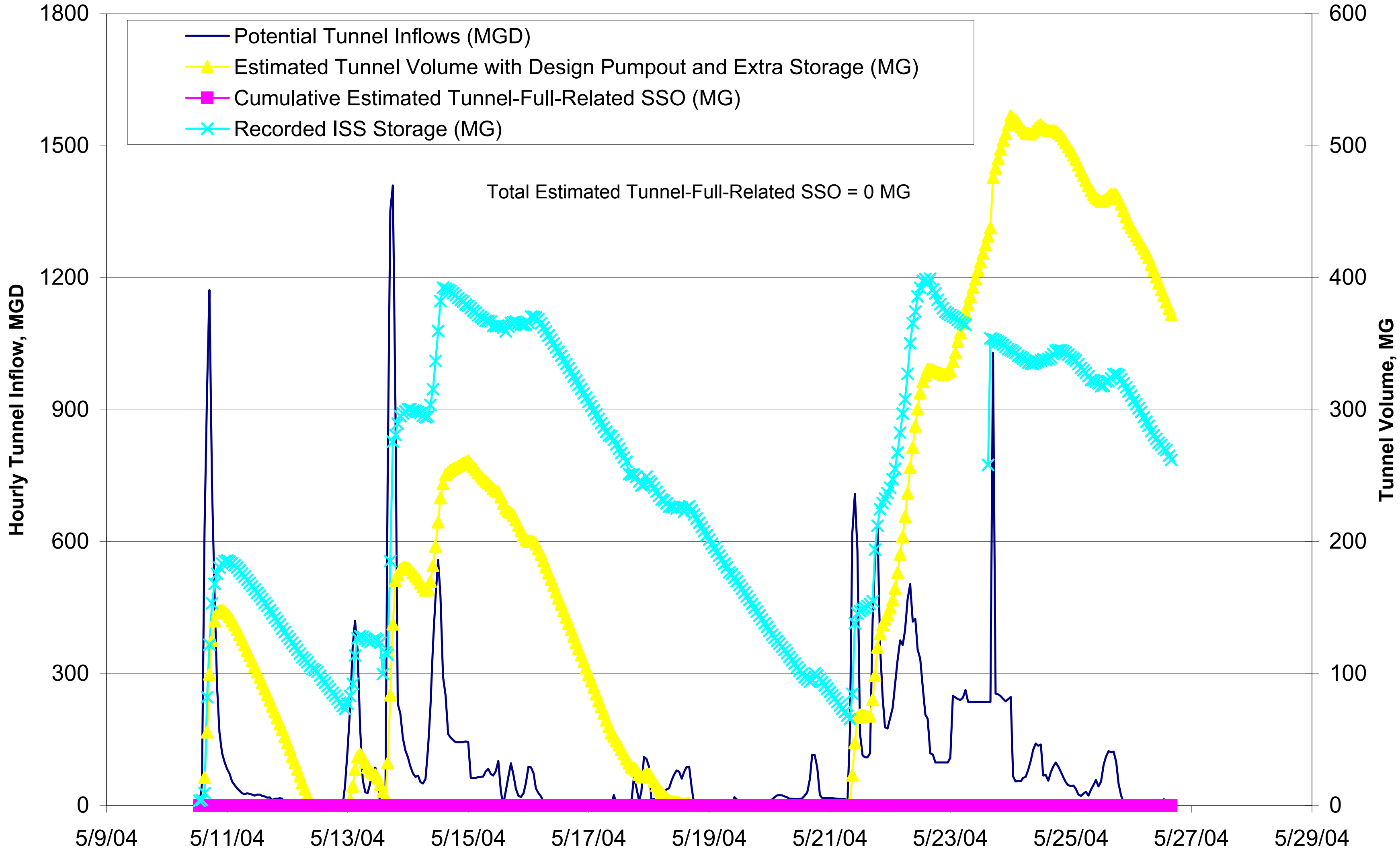


Figure 7. Estimated Tunnel Performance with Maximized Tunnel Pumpout (Based on Plant Capacity Only) and Additional Storage Assuming Flow Into Tunnel As Measured

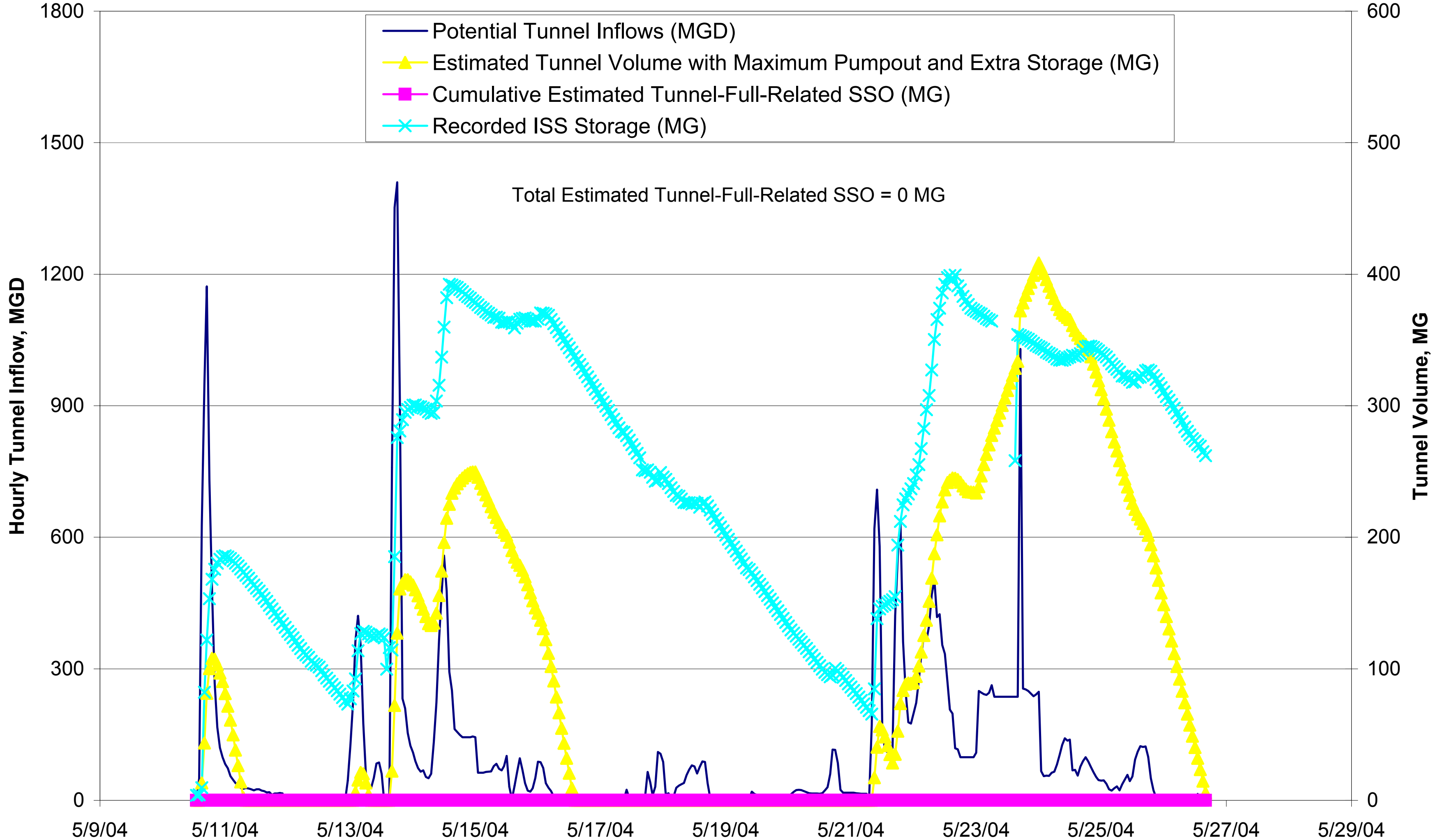
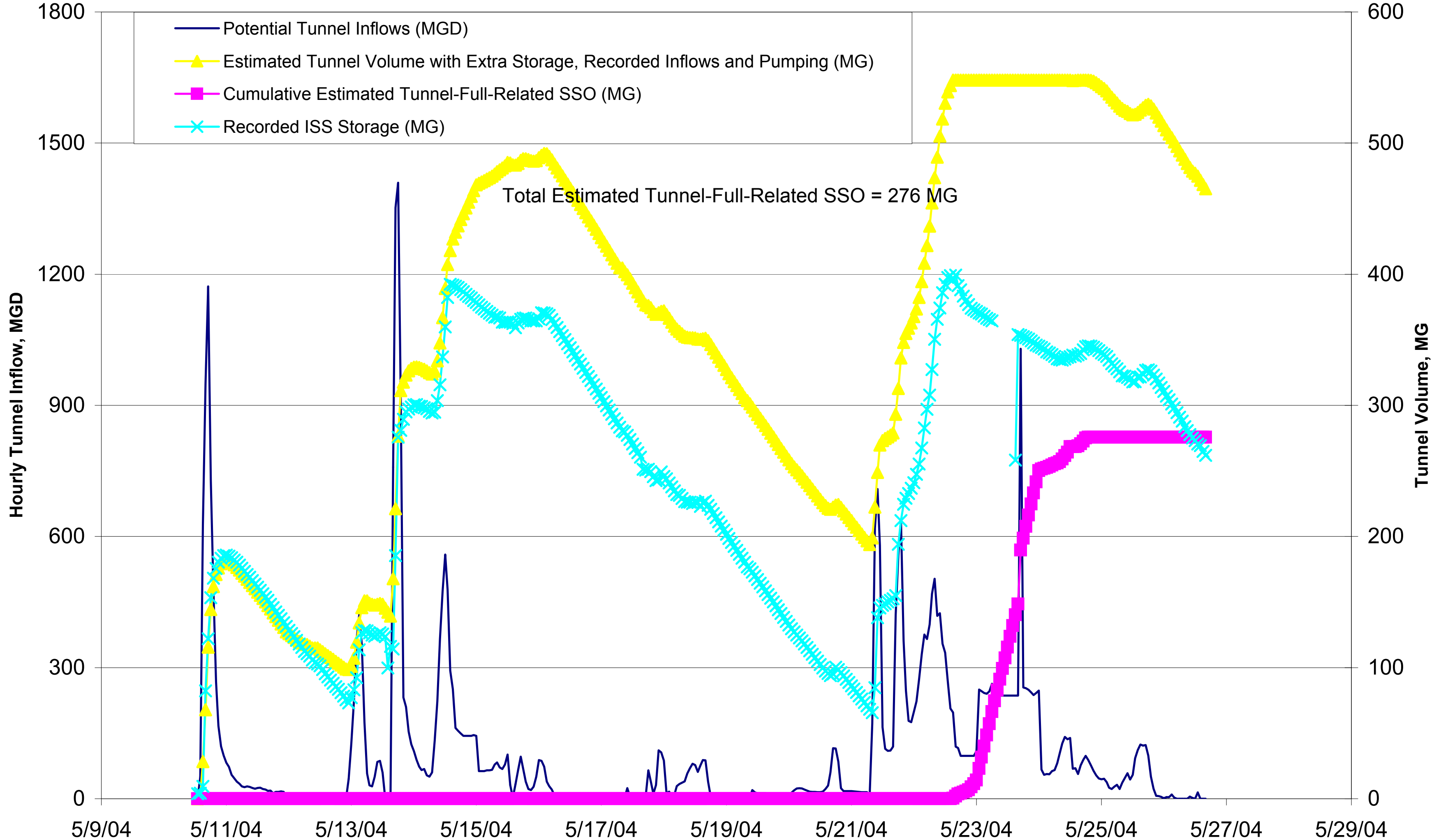


Figure 8. Estimated Tunnel Performance with Actual Tunnel Pumpout and Additional Storage Assuming Flow Into Tunnel As Measured



Appendix D:
Analysis of Service Area Flow Conditions During Rain Events

MEMORANDUM

October 1, 2004 26157-002

TO: MEMBERS OF THE MAYOR'S AUDIT COMMITTEE

FROM: BROWN AND CALDWELL

SUBJECT: ANALYSIS OF SERVICE AREA FLOW CONDITIONS DURING RAIN EVENTS

The purpose of this memorandum is to provide an analysis of flow conditions within the Milwaukee Metropolitan Sewerage District (MMSD) sewer system during rain events. Two specific analyses are provided. First, an analysis was performed for conditions during the May 2004 rainfall events which produced a reported 4.6 billion gallons of sewer overflows. Second, an analysis of average annual conditions was performed and compared to the May 2004 results. The results are expressed in terms of rainfall converted to sewer flows and percent of wet weather flow generated in the separate sewer area.

MMSD System Overview

MMSD is a state-chartered, governmental agency providing wastewater services for 28 municipalities within a 420-square-mile service area, located within 5 counties, with a population of about 1 million. A 2,200-mile system of collector sewers, a 310-mile system of intercepting and main sewers, and a 19-mile long Inline Storage System (ISS or "deep tunnel") convey wastewater to two MMSD-owned wastewater treatment plants (WWTPs). The two WWTPs collect and treat more than 200 million gallons of wastewater on an average day which discharge effluent to Lake Michigan. According to its operating permit MMSD maintains flow meters that measure flow entering both wastewater treatment plants. Figure 1 shows the major MMSD facilities and the extent of the service area.

The MMSD service area is comprised of both separated sewer and combined sewer areas. The combined sewer area is approximately 25 square miles and is situated in the cities of Milwaukee and Shorewood. The ISS provides 405 million gallons of storage for wet weather flows generated in the separate and combined sewer areas. A pump station with a capacity of 120 million gallons per day (MGD) dewaters the ISS into either of the two WWTPs.

Under sufficient rainfall conditions, combined sewer flows are allowed to discharge into the ISS. According to a pre-defined operating strategy, MMSD and its contracted operator United Water may decide to close off gates which allow combined sewer flow into the deep tunnel – an action which causes a combined sewer overflow (CSO). If the tunnel is near full, another operational decision may be made which closes another set of flow control gates that allow flow from separate sewer area into the tunnel – an action which produces a tunnel-full-related sanitary sewer overflow (SSO). MMSD reports the occurrence of CSOs and SSOs to the permitted regulatory authority, the Wisconsin Department of Natural Resources (WDNR), and in doing so reports the date and time of the discharge, the location, the duration, and the estimated volume.

May 2004 Rainfall Conditions
Southeastern Wisconsin received a significant amount of rainfall during the month of May 2004. Although estimates by the National Weather Service indicated a monthly total of 8.18 inches at the official weather station at General Mitchell International Airport, there were reports of significantly more rainfall elsewhere. In order to obtain a better estimate of rainfall that would reflect conditions across the MMSD service area, we obtained dense rainfall data estimates based on radar data. The company OneRain, Inc., was hired to derive rainfall estimates at five minute intervals for May 2004 at a density of 1 kilometer by 1 kilometer. The spatial extent of this data included the entire 420 square mile service area of MMSD, which resulted in establishing over 2,200 “virtual” rain gauges.

The NEXRAD radar data were analyzed and corrected according to measured rainfall at City of Milwaukee and MMSD rain gauges. This is a very important step in deriving radar-derived rainfall estimates. Figure 2 shows a color-coded map of radar-derived rainfall totals for May 2004. For the study area, the monthly total maximum, average, and minimum amounts were 12.8, 9.0, and 5.7 inches, respectively. OneRain also derived an estimated average monthly rainfall for the separate sewer area at 8.75 inches, and an average monthly rainfall for the combined sewer area at 9.5 inches. These figures indicate that the combined sewer area received more rainfall than the service area on average.

Flow Measurement in the MMSD System
MMSD maintains a large number of flow measurement devices throughout its system; however, the most accurate and useful data for the analysis presented here are those data that represent outflows from the system. Using these data, we are able to calculate what amount of rainfall was converted into system flows. The key measurements are:

- Flow into the Jones Island WWTP
- Flow into the South Shore WWTP
- Estimated CSO discharge
- Estimated SSO discharge

System Capture Calculations
Based on the rainfall estimates and system flow measurements, we were able to derive several key results pertaining to the May 2004 rain events. Figure 3 shows the data used and the results of the calculations. Figure 4 is a companion illustration that shows conceptually how the mass balance analysis was performed. The actual period analyzed was from May 1, 2004 to June 6, 2004. This period represents the start of the rainy period to the end of the rainy period. Additional rainfall occurred on June 7 and the days following. By June 6, the flows at the two WWTPs had returned near dry weather conditions (207 MGD).

Figure 3. Results of Mass Balance Analysis for May 2004 Conditions

Mass Balance Analysis for May 1 through June 6, 2004

Combined Sewer Service Area	=	25	square miles
Separate Sewer Service Area	=	395	square miles
Rainfall on the Combined Area	=	9.5	inches
Rainfall on the Separate Area	=	8.75	inches
Combined Area Rainfall Volume	=	4.1	billion gallons
Separate Area Rainfall Volume	=	60.1	billion gallons
Separate Sewer Overflow Volume	=	0.42	billion gallons
Combined Sewer Overflow Volume	=	4.10	billion gallons
WWTP Volume	=	12.78	billion gallons
Dry Weather Flow (wastewater) Volume	=	5.55	billion gallons
Excess flow through WWTPs	=	7.23	billion gallons
Excess system flow	=	11.75	BG (WWTP excess + SSO + CSO)
SSA Flow Volume Delivered	=	7.62	BG (Excess system flow - Combined Area Rain Volume)
SSA Rainfall Capture	=	13%	
Percent of excess flow generated in separate area	=	65%	
Percent of excess flow that overflowed (SSO+CSO)	=	38%	

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The analysis indicates that of the rain that fell on the separate sewer area, approximately 13 percent was converted into flow in the system. Further, of the excess flow in the system during this time period, some 65 percent was generated in the separate sewer area. Of the total 11.75 BG of excess flow entering the system, approximately 38 percent overflowed as CSO or SSO.

Another similar analysis was performed on annual totals of wastewater flow and rainfall going back to the first year of tunnel operation – 1994. These results, provided in Figure 5, show a range for separate sewer system rainfall capture from 7 percent to 15 percent, which indicates the May 2004 number of 13 percent is a reasonable estimate. As for percent of wet weather coming from the separate sewer area, the annual average ranges from 59 percent to 75 percent, which also indicates the May 2004 number is a reasonable estimate. Figure 6 presents the systemwide annual percent of wet weather flow estimates.

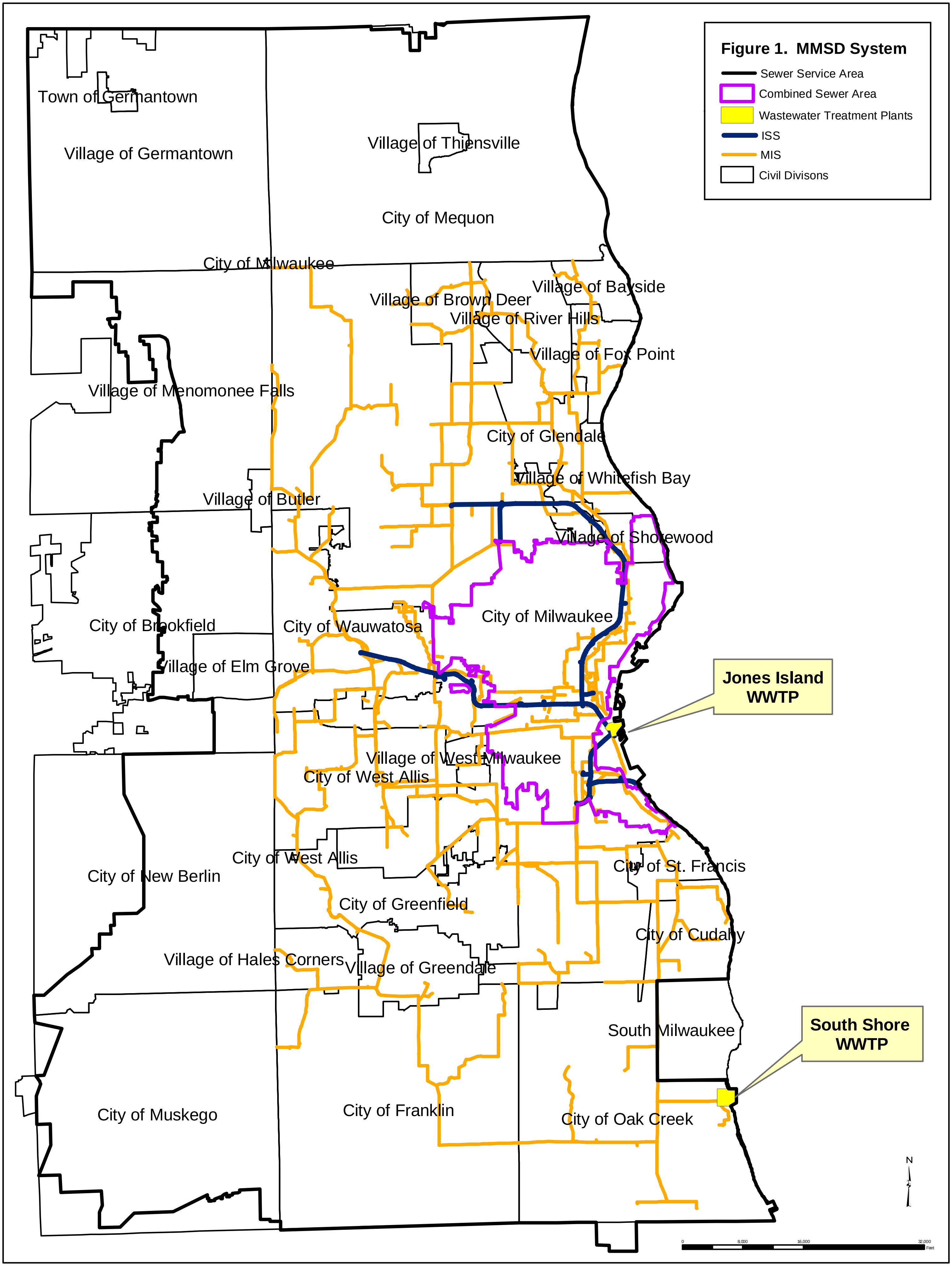


Figure 1. MMSD System
Sewer Service Area
Combined Sewer Area
Wastewater Treatment Plants
ISS
MIS
Civil Divisons
Town of Germantown
Village of Germantown
Village of Thiensville
City of Mequon
City of Milwaukee
Village of Brown Deer
Village of Bayside
Village of River Hills
Village of Fox Point
Village of Menomonee Falls
City of Glendale
Village of Whitefish Bay
Village of Butler
Village of Shorewood
City of Milwaukee
City of Brookfield
City of Wauwatosa
Village of Elm Grove
Jones Island WWTP
Village of West Milwaukee
City of West Allis
City of West Allis
City of New Berlin
City of St. Francis
City of Greenfield
City of Cudahy
Village of Hales Corners
Village of Greendale
South Milwaukee
South Shore WWTP
City of Muskego
City of Franklin
City of Oak Creek
N
0
8,000
16,000
32,000
Feet

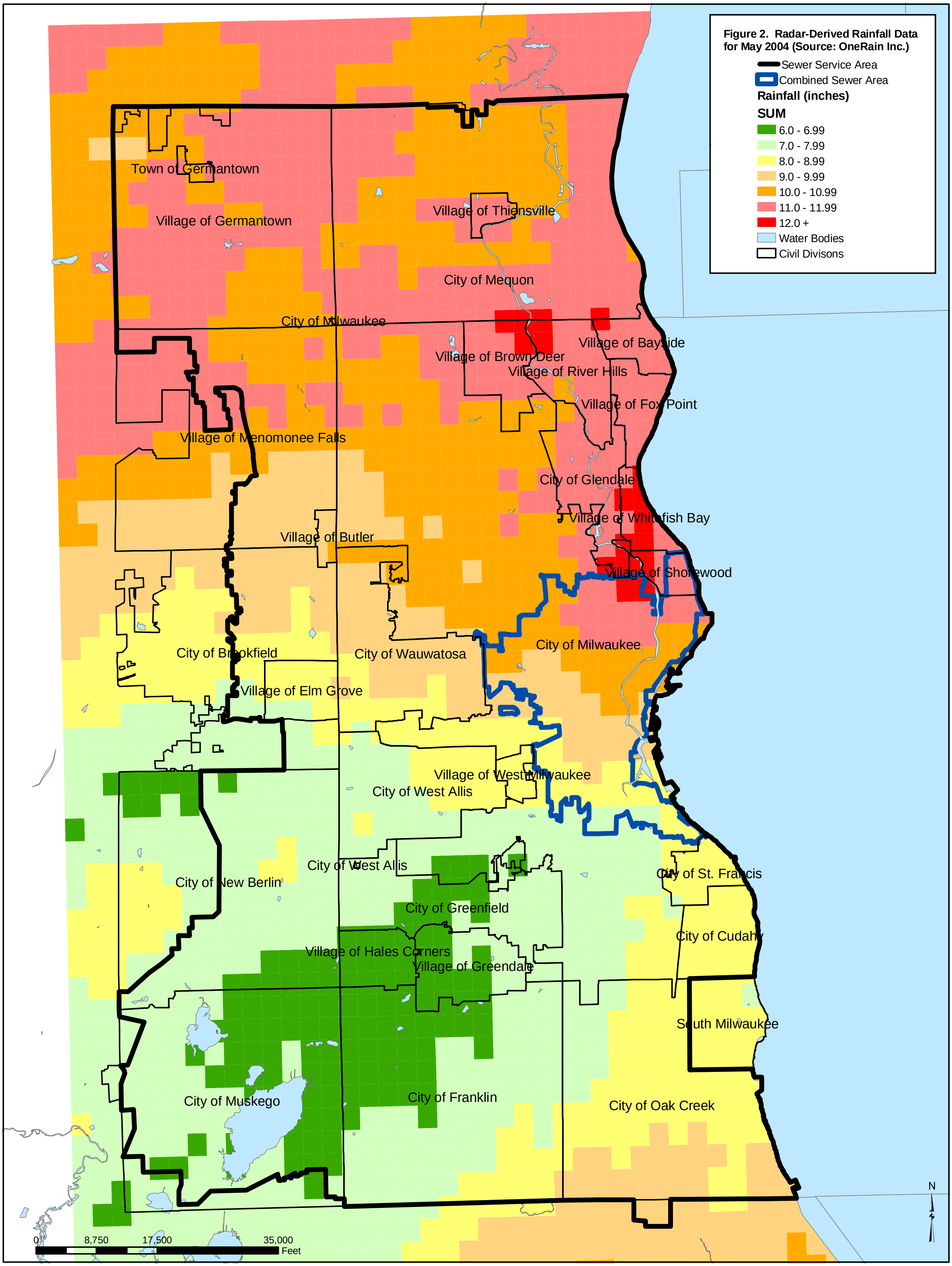
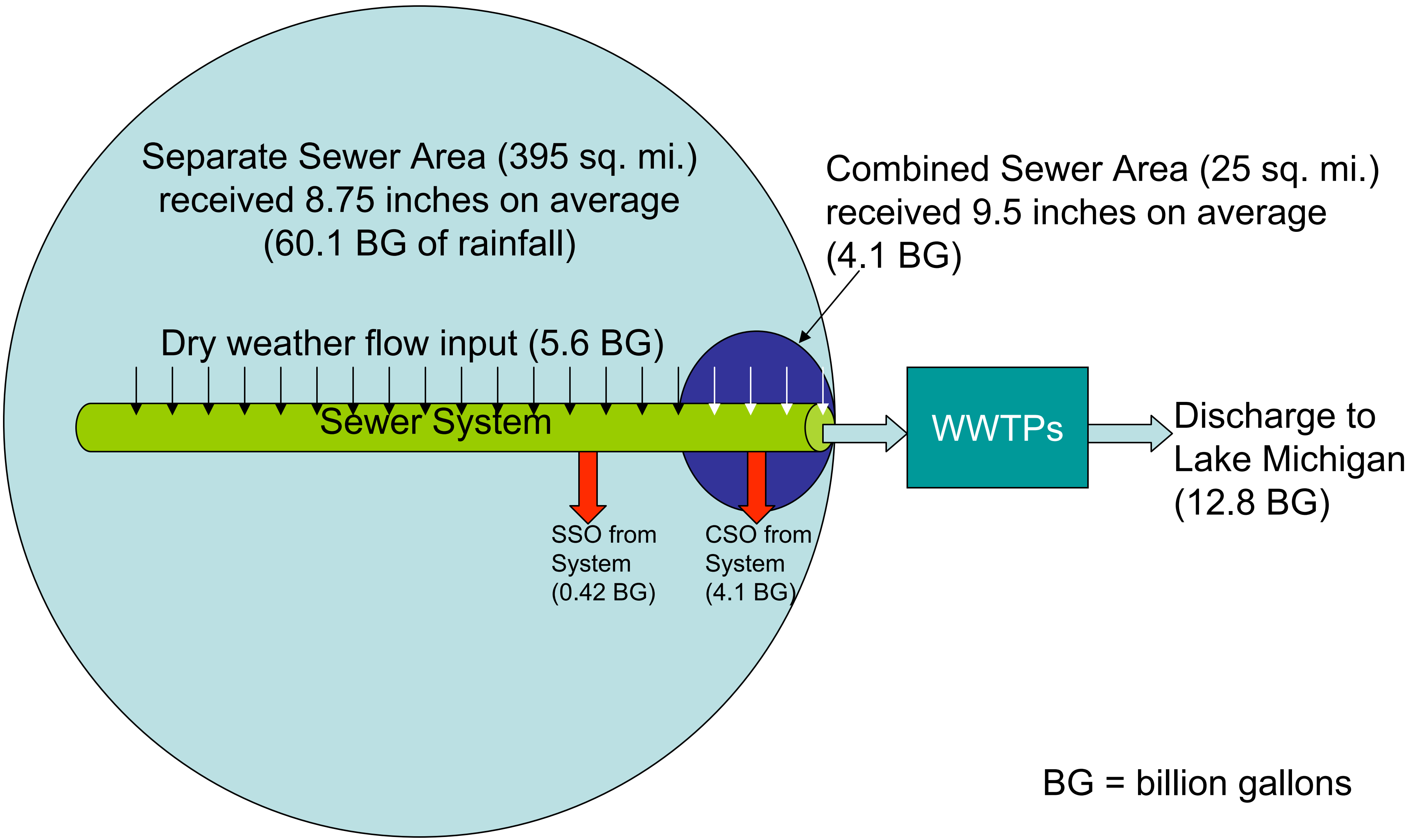


Figure 2. Radar-Derived Rainfall Data for May 2004 (Source: OneRain Inc.)
Sewer Service Area
Combined Sewer Area
Rainfall (inches)
SUM
6.0 - 6.99
7.0 - 7.99
8.0 - 8.99
9.0 - 9.99
10.0 - 10.99
11.0 - 11.99
12.0 +
Water Bodies
Civil Divisons
Town of Germantown
Village of Germantown
Village of Thiensville
City of Mequon
City of Milwaukee
Village of Bayside
Village of Brown Deer
Village of River Hills
Village of Fox Point
Village of Menomonee Falls
City of Glendale
Village of Whitefish Bay
Village of Butler
Village of Shorewood
City of Brookfield
City of Wauwatosa
City of Milwaukee
Village of Elm Grove
Village of West Milwaukee
City of West Allis
City of West Allis
City of New Berlin
City of St. Francis
City of Greenfield
City of Cudahy
Village of Hales Corners
Village of Greendale
South Milwaukee
City of Muskego
City of Franklin
City of Oak Creek
0
8,750
17,500
35,000
Feet
N

Figure 4.

Simplified System Schematic Depicting Calculation Inputs for Mass Balance Analysis



BG = billion gallons

Figure 5.

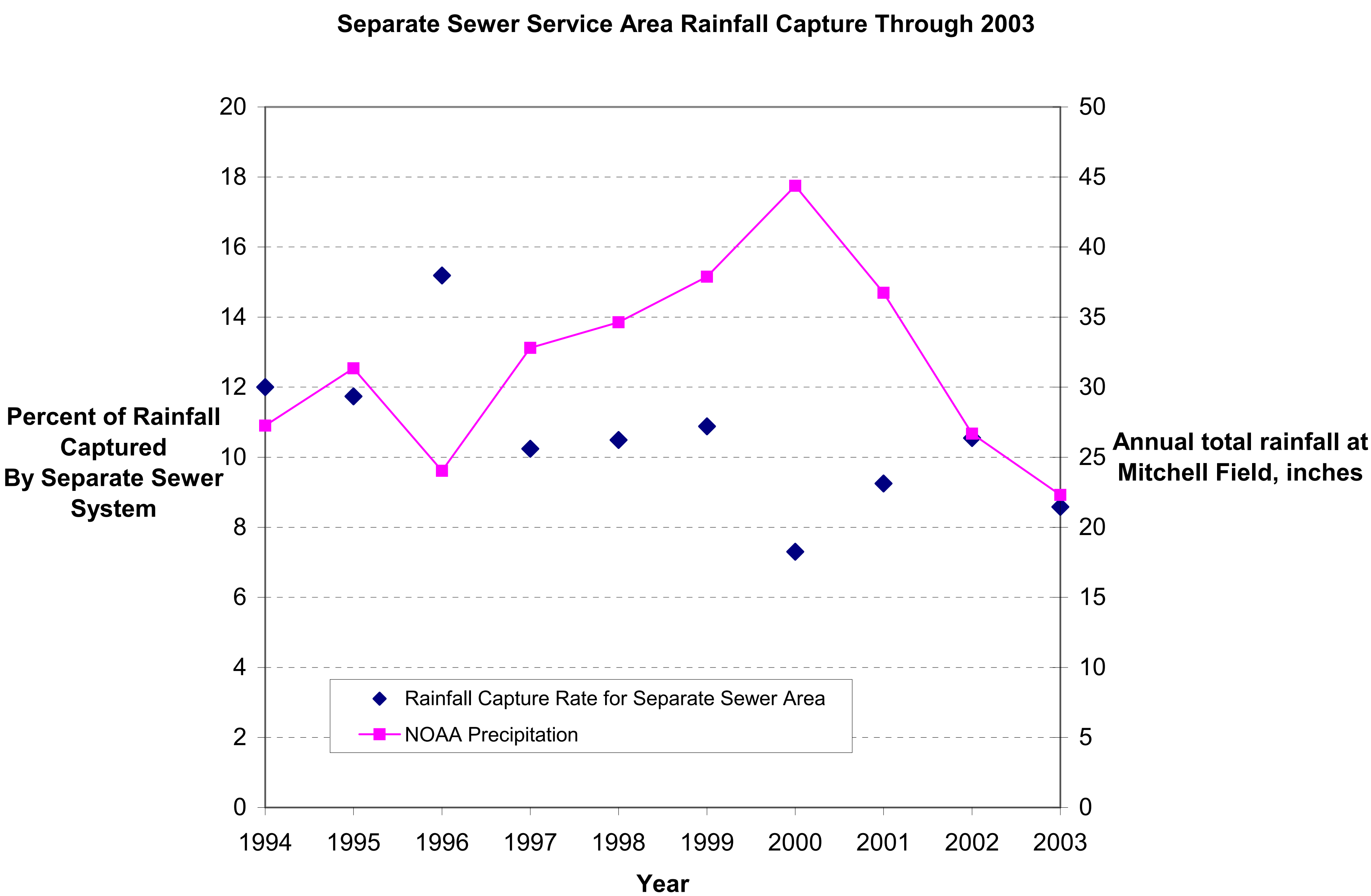
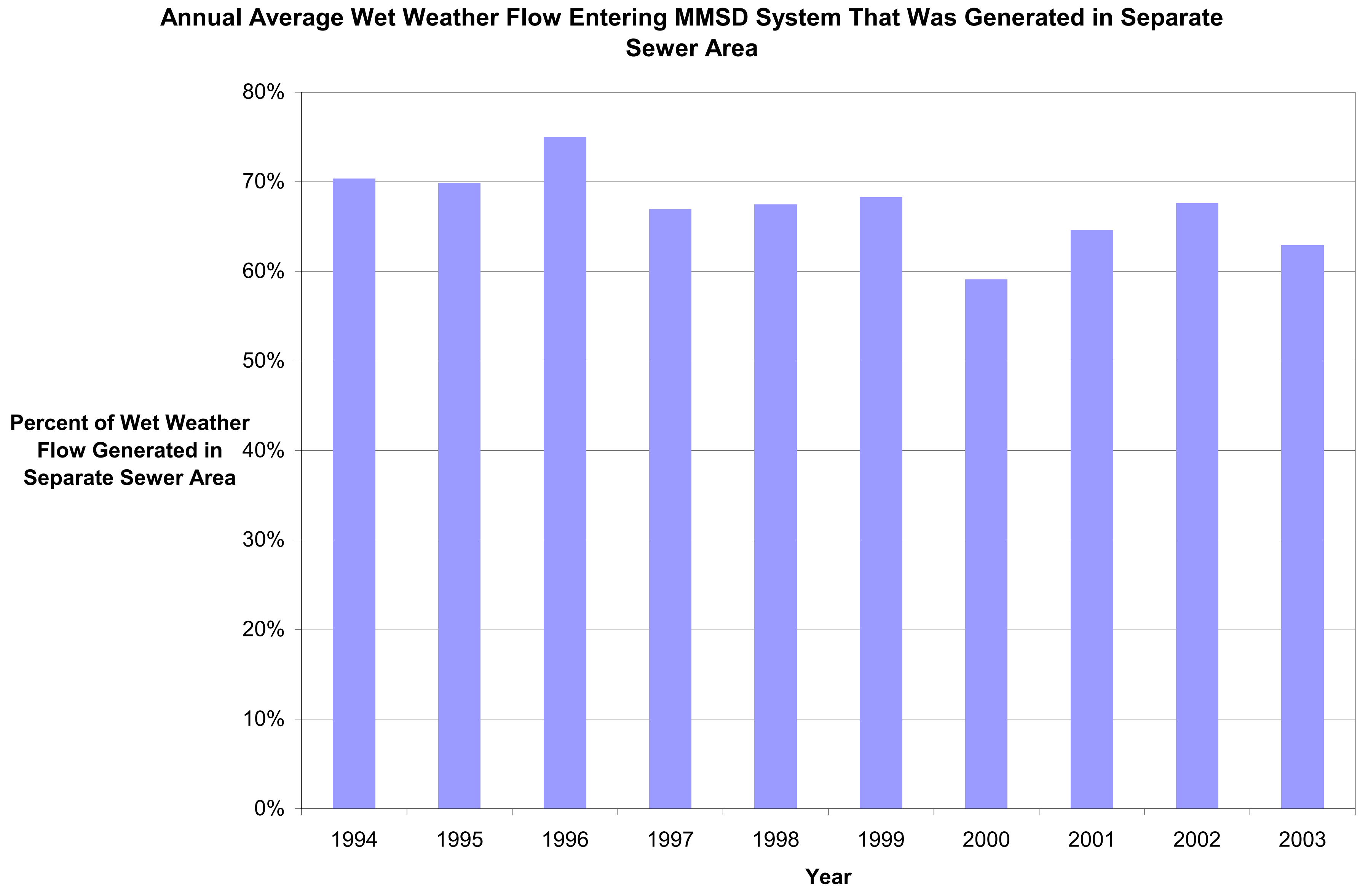

Separate Sewer Service Area Rainfall Capture Through 2003
Percent of Rainfall Captured By Separate Sewer System
Annual total rainfall at Mitchell Field, inches
Year
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
40
45
50
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Rainfall Capture Rate for Separate Sewer Area
NOAA Precipitation

Figure 6.


Annual Average Wet Weather Flow Entering MMSD System That Was Generated in Separate Sewer Area
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Wet Weather Flow Generated in Separate Sewer Area
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Year

Appendix E:
Analysis of Sewer Separation

MEMORANDUM

October 1, 2004 26157-004

TO: MEMBERS OF THE MAYOR'S AUDIT COMMITTEE

FROM: BROWN AND CALDWELL

SUBJECT: ANALYSIS OF POLLUTANT LOADING CHANGES RESULTING FROM SEWER SEPARATION WITHIN MMSD SYSTEM

Introduction

The Milwaukee Metropolitan Sewerage District (MMSD) collects sewage from approximately 420 square miles, of which 24 square miles contain combined sewers. These combined sewers convey both stormwater and wastewater during storm events. This extra volume requiring conveyance during peak wet weather events can lead to combined sewer overflows (CSOs).

The theory proposed is that if there were no combined sewers, the collection system would not suffer from overflows which are directly tied to storm events. While it is true that separation would significantly reduce the volume conveyed in the sewers, the separated stormwater would not receive the level of treatment provided by the District's two wastewater treatment plants (WWTPs). In order to better understand the potential environmental impacts of sewer separation, the combined sewer service area (CSSA) was reviewed to estimate the average volume of stormwater conveyed in the combined sewer.

Analysis Approach and Results

Using MACRO, the model developed to evaluate long-term tunnel performance for the MMSD, the annual average total volume conveyed in the CSSA was calculated using data from the period 1997 through 2002. Backing out the total wastewater volume from residential, commercial and industrial sources leaves the volume due to stormwater. Figure 1 presents the estimated average annual volumes of stormwater and total wastewater generated in the combined sewer areas. Additionally the annual average CSO volume is presented.

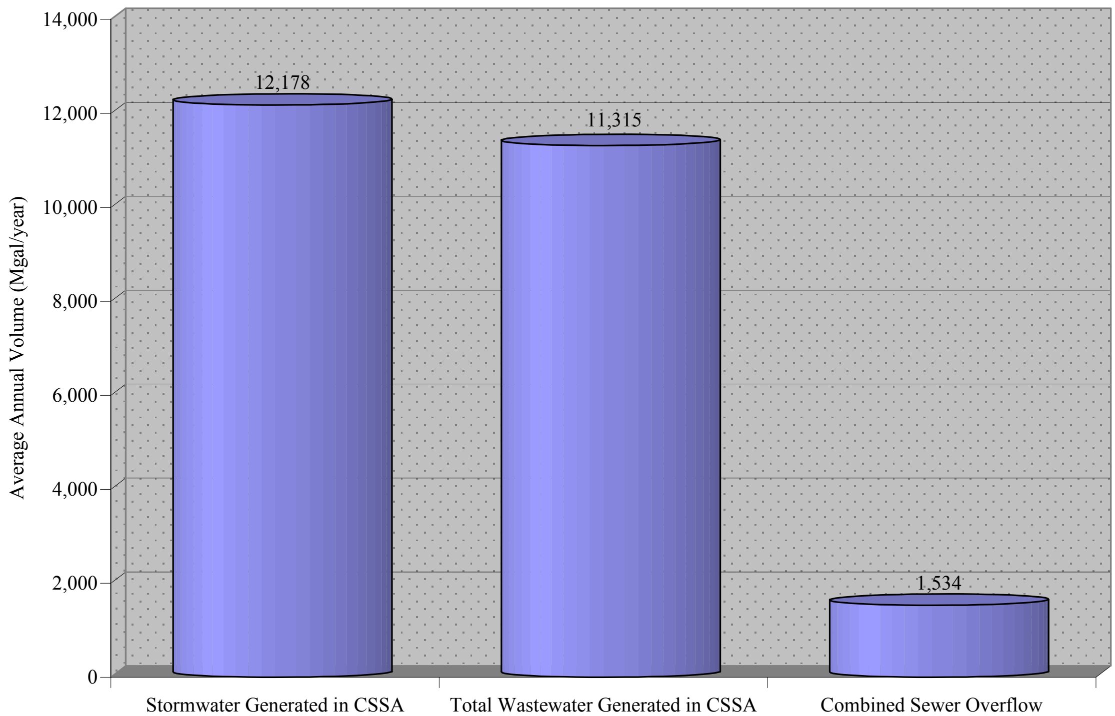


Figure 1. Estimated Average Annual Volumes

The average annual stormwater volume for the period of review is within ten percent of the total wastewater volume generated in the CSSA. Currently, of the approximately 23.5 billion gallons generated in the combined sewer area annually, only 1.5 billion gallons or roughly six percent becomes combined sewer overflow. This figure translates to an average annual capture rate of 94 percent for flows generated in the CSSA. MMSD's NPDES permit specifies a flow capture performance standard of 85 percent on an annual average basis.

While volumes are an important aspect of CSOs, this analysis is more concerned with the mass of pollutants released to the environment through overflows as compared to the estimated mass released via stormwater after separation.

While no direct sampling of stormwater was conducted specifically for this evaluation, prior area stormwater sampling and national stormwater characteristics databases were consulted to develop the stormwater contaminant concentrations. The values are presented in Table 1.

Table 1. Characteristics of Stormwater Runoff and Combined Sewer Overflow

	National Urban Runoff Program Stormwater	Triad Report for Stormwater	Triad Report for Combined Sewer Overflow
Total suspended solids, mg/L	67	216	89
Biochemical oxygen demand, mg/L	17	14	16
Total phosphorus, mg/L	0.32	0.43	0.56
Total nitrogen, mg/L	1.08	0.78	8.5
Heavy metals, mg/L	0.295	---	---

Using these values as mean event concentrations, coupled with the volumes previously developed, we estimated the annual mass loadings to the environment due to the stormwater from the CSSA. Figures 2 through 6 present pollutant loadings to the environment in terms of total suspended solids (TSS), biochemical oxygen demand (BOD), total phosphorus, total nitrogen, and heavy metals as the sum of zinc, copper, and lead. The loadings associated with the stormwater generated in the CSSA were then processed through a municipal wastewater treatment plant (conventional activated sludge treatment) and a state-of-the-art stormwater treatment device (Arkal pressurized filtration system) to determine the environmental releases due to the treated stormwater. Treatment system performance was assumed to be that typical of activated sludge for the municipal wastewater treatment plant and that reported by EPA Environmental Technology Verification Program for the Arkal device. The loadings released during the CSO events were not adjusted to reflect any treatment.

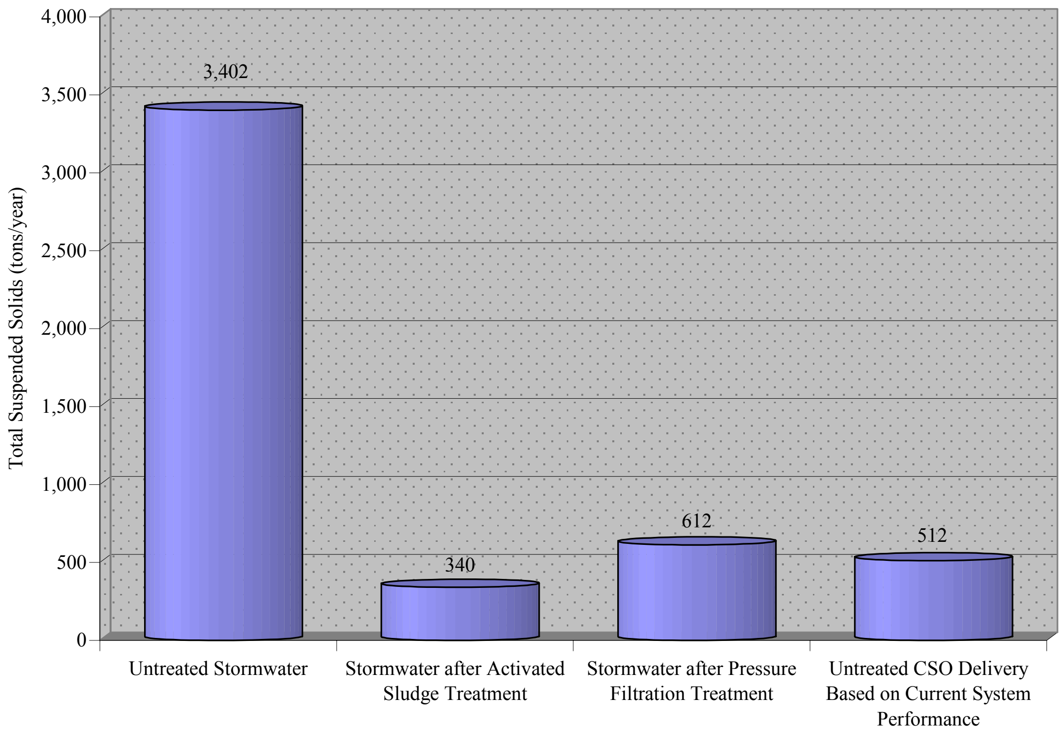


Figure 2. Estimated Annual Average Total Suspended Solids Loadings

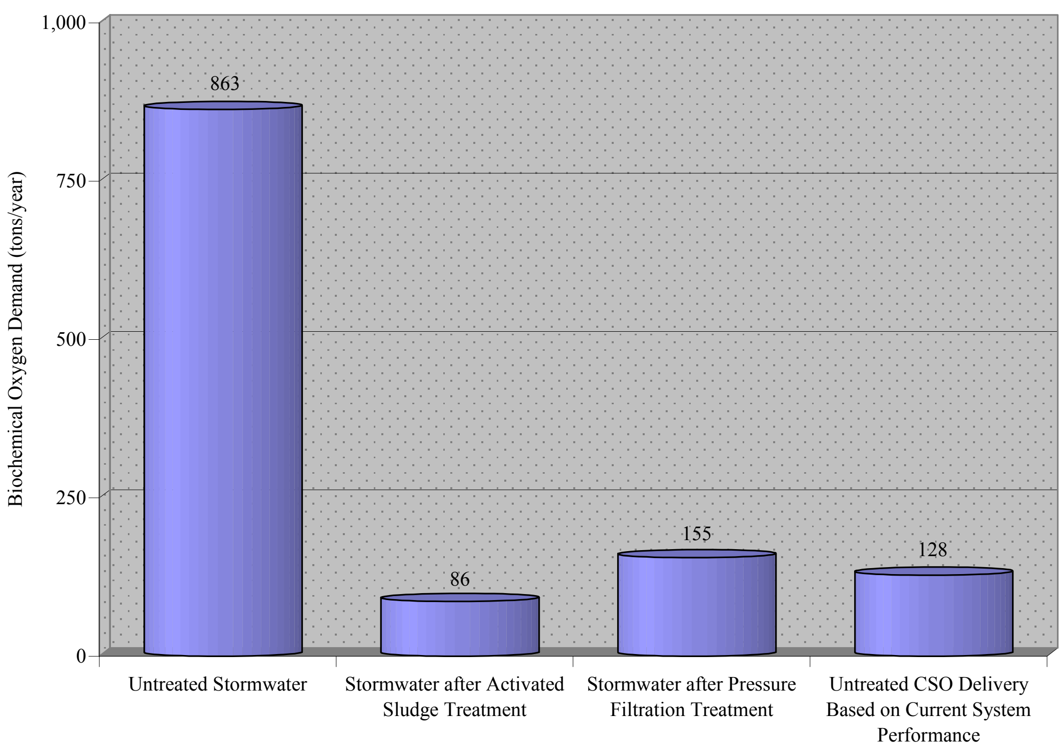


Figure 3. Estimated Annual Average Biochemical Oxygen Demand Loadings

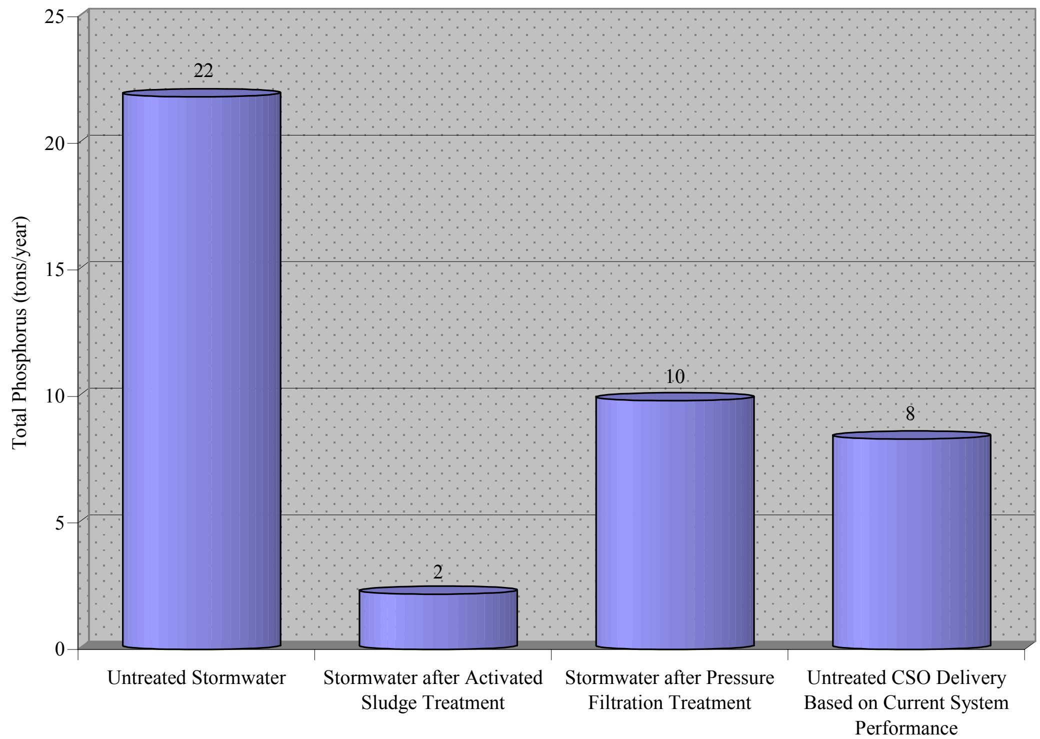


Figure 4. Estimated Annual Average Total Phosphorus Loadings

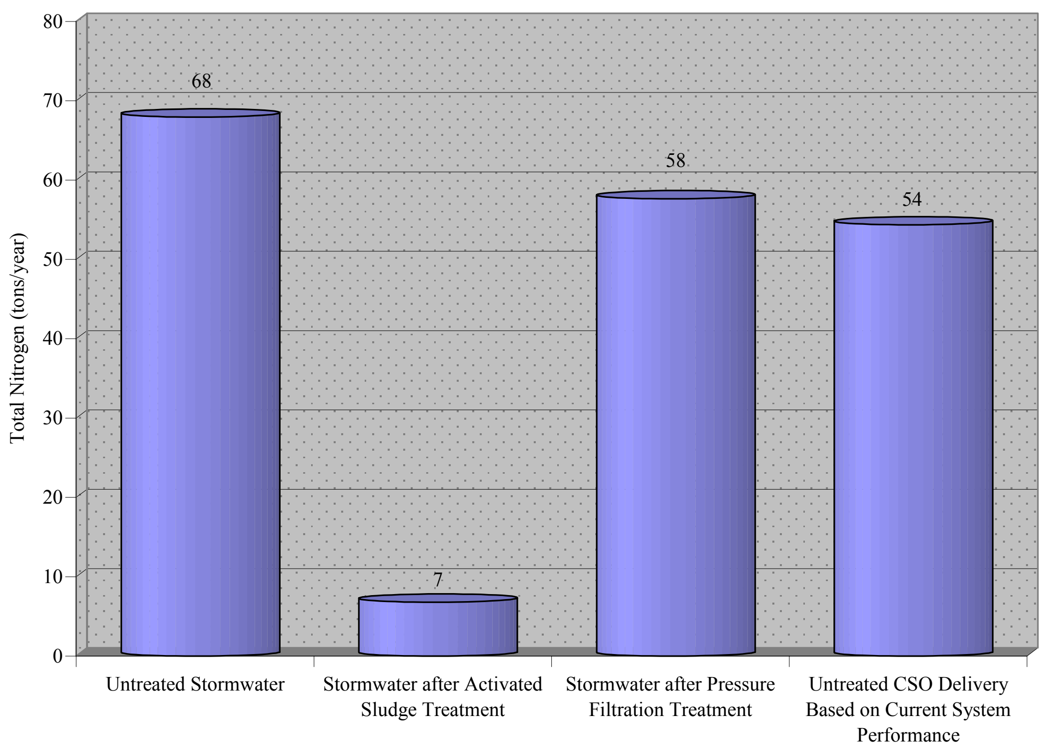


Figure 5. Estimated Annual Average Total Nitrogen Loadings

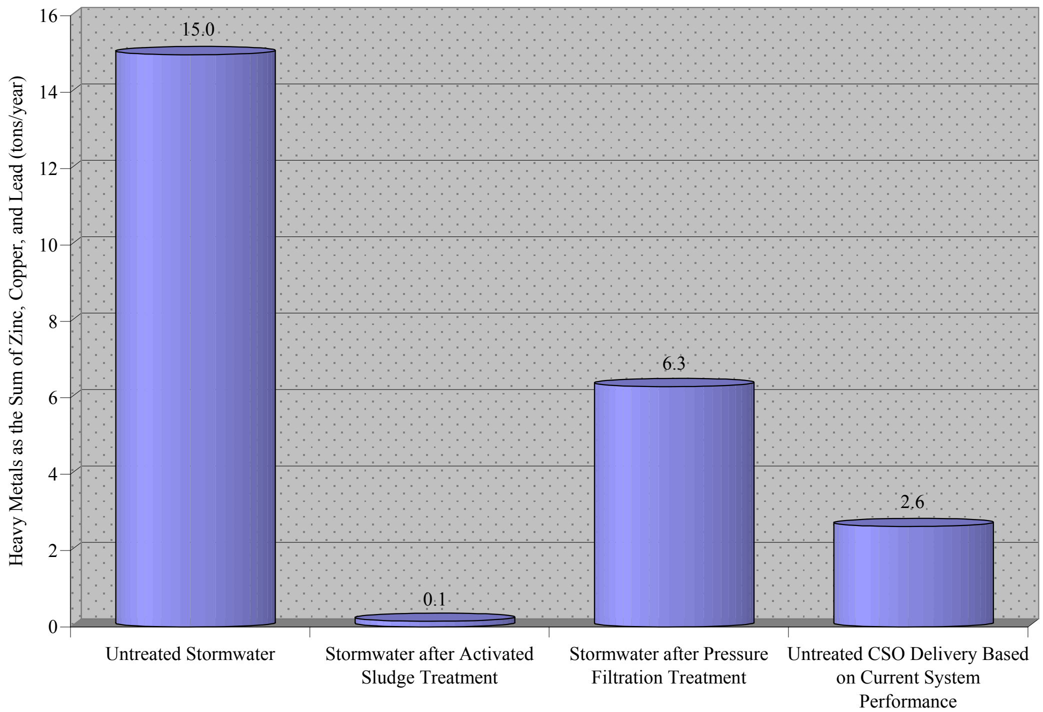


Figure 6. Estimated Annual Average Heavy Metal Loadings

Conclusion

As presented in the series of figures above, direct release of the stormwater collected in the combined service area to the environment will increase the local pollutant loadings significantly. Therefore if separation of the combined sewers were to be undertaken, stormwater pollution controls would need to be implemented to minimize the impact on the environment. Due to the nature of stormwater flows, it is difficult to design a system as effective as activated sludge in controlling pollutants. Even a system considered advanced for the treatment of stormwater cannot perform as well as the activated sludge process. While separation of the combined sewers may reduce the frequency and volume of sewer overflows, total mass loadings of pollutants will most likely be increased without effective stormwater treatment.

This analysis did not include an analysis of further pollutant reductions if CSO were treated. It is most likely that these processes would, at a minimum, include floatables capture and disinfection. Such processes would have minimal impact on the pollutants evaluated in this analysis. Disinfection in particular, would result in lower amounts of fecal coliform discharged during CSO events, but evaluating the benefits of this practice is complicated and beyond the scope of this analysis.

Appendix F:
Summary of Regulatory Approaches to Overflows in Great Lakes State

MEMORANDUM

October 1, 2004 26157-004

TO: MEMBERS OF THE MAYOR'S AUDIT COMMITTEE

FROM: BROWN AND CALDWELL

SUBJECT: CSO AND SSO REGULATORY APPROACHES FOR THE GREAT LAKES REGION

The purpose of this memorandum is to summarize the different regulatory approaches toward Combined Sewer Overflows (CSO) and Sanitary Sewer Overflows (SSO) in Great Lakes states. In contacting the various regulatory agencies in the Great Lakes region, the regulatory approach regarding combined sewer overflows has been somewhat varied depending on the state. However, in the case of separate sewer overflows, there has been a certain degree of consistency among the states.

The Milwaukee Metropolitan Sewerage District's (MMSD) NPDES Permit requires that MMSD meet either of two performance standards set by the Wisconsin Department of Natural Resources. According to the permit, the MMSD may not have more than 6 overflow discharge events per year or the capture and delivery to either of the two treatment plants, Jones Island or South Shore, must be no less than 85 percent by volume of the combined sewage collected in the combined sewer system.

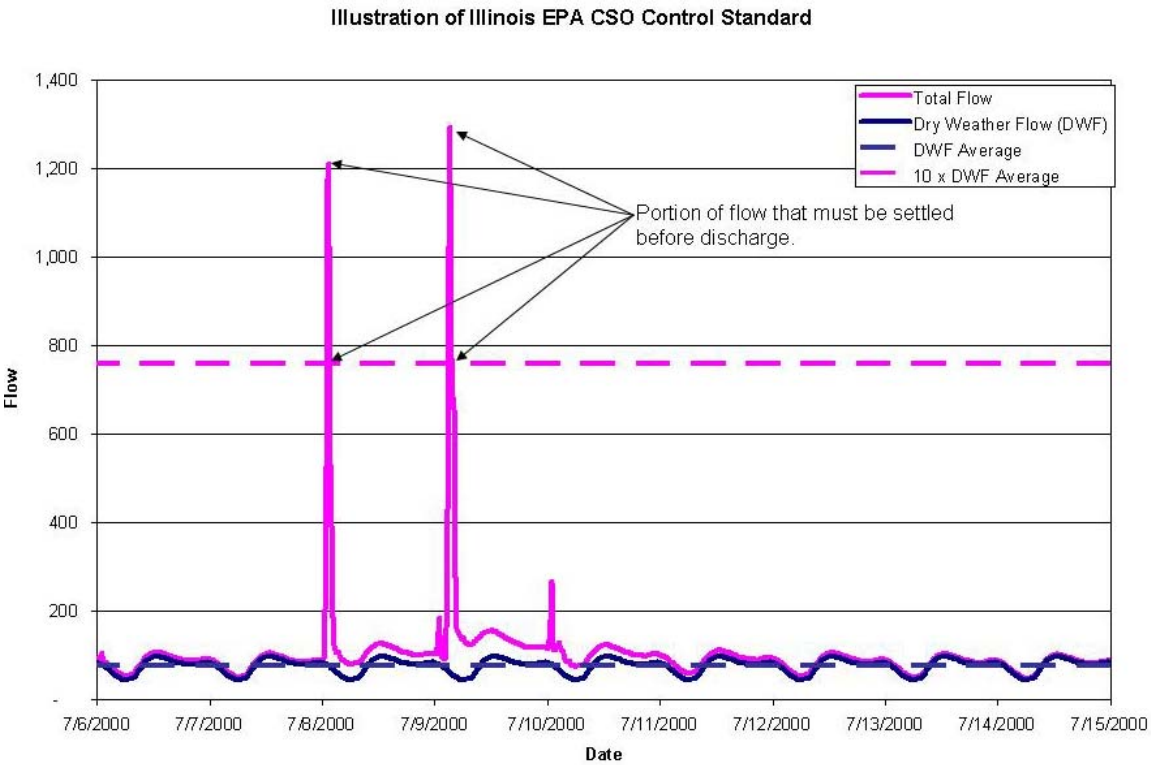
Illinois CSO

In Illinois, the Illinois Environmental Protection Agency (IEPA) does not have a stated overflow frequency within their policy, however in most cases if the number of overflows goes beyond 4 per year, the IEPA will step in and require some action to be taken. If an overflow occurs more often, then the municipality will be required to do more studies on the effects of the overflows and more reporting, among other things. If regulators believe that an overflow should not have occurred, if there are no controls in place to prevent overflows, or if the CSO has a severe environmental impact, then enforcement actions will be taken. However, in these situations the CSOs are evaluated on a case-by-case basis.

Although, according to the interviewed regulatory staff, the goal of the IEPA is to eliminate CSOs altogether, there is a six page overflow condition in the NPDES permits. Also within the permit are treated overflows, which are called out individually as outfalls. In order for overflows to be considered treated, the system must capture the first flush, or 10 times the average dry weather flow which is measured on a flow rate basis, and provide settling for that flow. This concept is illustrated in Figure 1. If there is primary treatment and disinfection, there are no limits to the frequency of overflows.

While there are no dual standards for wet weather and dry weather overflows, there are separate water quality standards that must be met if a CSO were to discharge into Lake Michigan. However, there are presently no CSOs that go directly into the Lake. At present all CSOs from the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) go into the Illinois River basin as a result of historical events that prompted this change in the late 1800s. It is possible for flows to back up into Lake Michigan, but only in extreme cases such as a 50-year storm event. Additional information may be found in Title 35 of the Illinois Administrative Code, Subtitle C, Chapter 1, Subpart C.

Figure 1



Michigan CSO

The Michigan Department of Environmental Quality (MDEQ) CSO policy is similar to that of the IEPA in that there is no stated overflow frequency. The frequency varies from year to year depending on the amount of rain. As is the case in Illinois, MDEQ staff stated a regulatory goal to eliminate CSOs and there is a program in place for every community that has a combined sewer system. The programs vary by community. The MDEQ handles treated and untreated overflows differently. Treated discharges are permitted and require a Discharge Monitoring Report (DMR) which includes water quality sampling as well as other requirements stipulated in the permit. Untreated discharges are listed in the permit; however these discharges do not require a DMR or water quality sampling. However, untreated discharges do require the flow volume, rainfall data, and outfall location to be reported.

In addition to this, the CSO policy seeks to control overflows either by sewer separation or by treating the discharge. There are two different definitions for treating the discharge. The first is the presumptive adequate treatment definition, which includes retention for transportation and treatment at a waste water treatment plant (WWTP) for flows during storms up to a 1-year/1-hour event. The 1-year/1-hour event is the equivalent of 1-inch in 1-hour. It also includes primary treatment of flows during storms up to a 10-year/1-hour event, where primary treatment consists of 30 minutes of detention time or equivalent for settling, skimming, and disinfection. The 10-year/1-hour event is the equivalent of 1.8 inches in 1-hour. Finally, the presumptive adequate treatment definition includes treatment of flows during storms greater than the 10-year/1-hour event to the extent possible.

The second definition for treating the discharge is the demonstrative adequate treatment definition. Demonstrative adequate treatment provides the opportunity for the discharger to build facilities to their own criteria while demonstrating that the level of control and treatment achieved is equivalent to, or that the alternative provided is adequate to achieve the water quality standards set forth by the MDEQ. However, the demonstrative adequate treatment is handled on a case-by-case basis. Additional information may be found in the MDEQ Sanitary Sewer Overflow Policy Statement and the Michigan Combined Sewer Overflow Control Program Manual. It is our understanding that the City of Detroit is implementing a Long Term Control Plan (LTCP) based on a demonstrative approach.

Ohio CSO

The state of Ohio differs slightly from Illinois and Michigan, but only in certain areas. There is a stated overflow frequency in the Long Term Control Plan for each CSO community that is consistent with the National Control Policy's goal of four overflows per year. Unlike the IEPA and the MDEQ, the Ohio EPA considers any untreated overflow from the system as one overflow event. If primary clarification and disinfection occur prior to discharge, then it is not considered an overflow event. If the discharger is considering end-of-pipe treatment options to avoid overflows, the EPA encourages them to thoroughly explore other alternatives first. If the discharge goes directly into Lake Erie, it is given much closer scrutiny because the lake is considered a sensitive area, with designated bathing beaches, etc., and the focus here is to eliminate all overflows to Lake Erie, provided that it is technically and financially feasible. On the other hand, if the discharge goes to a river tributary to Lake Erie, then it is not as closely scrutinized because the tributary is not necessarily a sensitive area. Currently, there are no specific provisions for wet weather overflows in the state policy. The state policy mirrors the National CSO Policy and since 2000 has incorporated its requirements and it associated guidance documents. Additional information may be found in the State of Ohio Combined Sewer Overflow Strategy, as well as the EPA's National CSO Policy.

Minnesota CSO

In contrast, the state of Minnesota has no stated overflow frequency and does not handle treated and untreated overflows differently. The Minnesota Pollution Control Agency (MPCA) handles CSOs on a case-by-case basis and the language is specific to the permit. From a permitted location, a CSO is considered one event even if it spans multiple days. The MPCA also does not have any specific standards or limits of overflow frequency regarding the Great Lakes and does not usually assign limits to permitted bypass points. It should be noted that Minnesota has no CSO communities whose discharges are tributary to the Great Lakes Basin. Unlike some of the other Great Lakes states, Minnesota does have different regulatory approaches to wet and dry weather overflows; however, they are handled on a case-by-case basis.

Indiana CSO

The Indiana Department of Environmental Management's (IDEM) CSO guidance document does not specify an overflow frequency, nor do they have separate standards for wet and dry weather overflows. Since the waters in the state of Indiana are all designated as full-body recreational contact use as well as for the support of a well balanced aquatic community, CSOs cannot affect water quality of surrounding waters. More specific information can be found in the CSO Long-Term Control Plan Use Attainability Analysis Guidance document.

Pennsylvania CSO

For the most part, the Pennsylvania Department of Environmental Protection follows EPA's presumptive approach to CSOs which allows 4 to 6 overflows per year. However, if there is at least 85% capture of wet weather flow and primary treatment, the discharge is not necessarily considered an overflow. If there is no primary treatment, it would be considered an untreated overflow. Otherwise, CSOs are evaluated on a case by case basis. While there are no statewide policies specific to CSOs that are tributary to the Great Lakes, there is a possibility that the City of Erie, which may discharge directly into Lake Erie, may handle these overflows in a different way. Also, the state of Pennsylvania has no separate wet weather standards at this time. Additional information may be found in the Pennsylvania Combined Sewer Overflow Policy.

New York CSO

The state of New York's Department of Environmental Conservation (NY DEC) utilizes the Long Term Control Plan guidance which allows the permittee to choose either the presumptive or demonstrative approach, which in turn determines how the NPDES permit is written. If the CSO outfall does not negatively affect water quality, then there is no limit on the frequency of overflows. If there is minimum primary treatment, the discharge is not considered an overflow. Depending on water quality standards, overflows are handled differently if they are tributary to the Great Lakes. There are not, however, different standards for wet weather overflows. More information can be found in the New York CSO Control Strategy, the CSO Best Management Practices for the state of New York, and the New York Long Term Control Plan guidance documents.

SSO Regulations

Unlike the various approaches to CSOs, the approach to SSOs from a regulatory standpoint has been fairly consistent throughout the various states, with only a few variations. In general, SSOs are strictly prohibited in all of the Great Lakes states and need to be eliminated or immediately corrected should they occur. In Illinois, SSOs are strictly prohibited except for emergency bypasses at treatment plants. Since they are expressly prohibited, by the EPA as well as the states, there is no stated frequency for overflows. In Ohio, Indiana, Minnesota, and Pennsylvania, there are no specific policies regarding the enforcement of SSOs. In some cases, the Ohio EPA has entered into Consent Orders with some communities in order to correct the SSO problem. In Pennsylvania, Administrative Orders to correct the problem are issued when an SSO occurs. Generally, the federal regulations regarding SSOs are followed fairly closely and overflows are dealt with on a case by case basis.

In the states of Michigan and Illinois, an enforcement policy regarding SSOs does exist. The MDEQ Surface Water Quality Division: Strategy for the Regulatory Control and Correction of Illegal Overflow from Separate Sanitary Sewer Systems in Michigan states that all SSOs must be eliminated or treated to Federal secondary treatment standards. If there is a Corrective Action Plan implemented with design criteria equivalent to the 25-year/24-hour storm event (3.9 inches in 24 hr), then enforcement discretion is considered. Additional information can be found in the aforementioned Strategy for Regulatory Control. In the state of Illinois, all guidelines and documents regarding enforcement of SSOs are internal IEPA documents unavailable to the public; however, IEPA staff does maintain that state standards are as strict as the federal regulations. The IEPA also evaluates SSOs on an individual basis.

The state of New York defines SSOs by location and each of these definitions has a permit strategy and compliance strategy associated with it. Type I SSOs are defined as permanent emergency overflow structures which are designed and intended only for emergency discharges. These are typically located at or immediately upstream of a pump station or plant headworks. These outfalls are required to be listed in the SPDES permit and discharge is prohibited except in an emergency. Each discharge from a permitted outfall is evaluated against emergency discharge criteria and events that do not meet these criteria are considered prohibited discharge violations and are then addressed by the NY DEC. An emergency discharge is defined as one that was “unavoidable to prevent loss of life, personal injury, public health hazard, environmental degradation or severe property damage” and there were no viable alternatives to the discharge. [Ref. 6 NYCRR Part 750-2 (b)(2)]

Type II SSOs are defined as Overflow Retention Facilities (ORF) and were designed, approved, and constructed under an SSO abatement program. ORFs capture and return most sewer system surges to the POTW for treatment. ORFs are also required to be listed in the permit and the specific effluent limits and reporting requirements are listed as well. These types of discharges, when they occur, are reported in a DMR or other monthly operation report, depending upon permit specifications. Type III SSOs are locations which require abatement and do not fall into the Type I or Type II category. These locations are not included the SPDES permit; however, the permit may contain system wide requirements and any abatement schedules that previously exist in the permit are moved to consent orders. Since Type III SSOs are illegal discharges that require abatement, the NY DEC's response may be informal or formal enforcement, or a combination of the two.

Although the states tend to follow the EPA regulations regarding SSOs quite closely, there is some dissention among the states regarding the issue of affirmative defense. The Ohio EPA, for example, does not uphold that EPA proposed position even though they do employ suggested programs such CMOM. On the other hand, the MPCA agrees with the EPA's proposed affirmative defense position if there are extenuating circumstances and if proof, such as rainfall logs, of these circumstances can be provided. The IEPA does not hold with the affirmative defense proposal; however the IEPA does issue a violation notice and then may or may not take action depending upon the response.

Conclusions

This memorandum summarizes CSO and SSO regulatory approaches of the Great Lakes States. Statements are based on available documents and interviews with regulatory staff. There are several important points to make with regard to a number of these regulatory approaches.

First of all, it was never the intent of the federal Policy to eliminate CSOs but rather to eliminate the pollution from CSOs. Some attorneys have mistakenly interpreted this to mean that the only solution is separation. In our opinion, this is incorrect. Furthermore, when studies evaluate the cost of separation and resulting stormwater problems, there tends to be a change in attitude toward the benefits of combined sewers. The correct interpretation is consistent with the language of some State Policies, e.g. Ohio, Pennsylvania and by implication, Illinois (no limit to frequency if treated to a primary level), that if CSOs are "treated", then it is not a CSO.

Many states permit CSOs to be treated to presumptive criteria as in Michigan and Pennsylvania. However, ultimately communities are and will be required to meet the demonstration approach per federal Policy; in that Policy, communities are only "presumed" to meet Water Quality Standards if they meet one of the three criteria but, in fact, citizen suits can still result until there is Water Quality Compliance. Per the EPA Guidance of July 2001, compliance is subject to public and state acceptance of modification of conventional water quality standards via appropriate steps including possibly a Use Attainability Analysis (UAA). Therefore, states that determine treatment on a case by case basis are most closely following the EPA Guidance.

Based on any of the CSO performance standards used by these states, with the exception of those that require CSO treatment, MMSD's current system would be in compliance. The system has met the 85 percent capture standard and the 10 to 1 standard.

Appendix G:
MMSD Audit Committee Activities

Appdendix G

Mayor Barrett's MMSD Audit Committee Meeting Agendas

(All meetings were held at the Port of Milwaukee unless otherwise noted)

Friday, June 11, 2004
16th Street Community Health Center

1) Introductions and Purpose of Meeting – Patrick Curley, Mayor Barrett's Chief of Staff
2) Overview of MMSD System – Kevin Shafer, MMSD Executive Director
3) Brief Overview of United Water Services Audit – Don Theiler, Chairman
4) Current Status of MMSD Scope and Questions to be Addressed by the Committee – Don Theiler, Chairman
5) Housekeeping Issues - Don Theiler, Chairman
6) Comments from the Mayor of Milwaukee – The Honorable Mayor Tom Barrett

Monday, June 28, 2004

1) Local Elected Officials Panel Discussion
    - Alderman Joe Davis, Milwaukee
    - Mayor Christine Nuernberg, Mequon
    - Village President Kathleen Pritchard, Whitefish Bay
    - Village President Jim Ryan, Hales Corners
    - Mayor Ted Wysocki, New Berlin

2) Organizational Discussion
3) Regional & Regulatory Agencies Panel Discussion
    - Todd Ambs, DNR
    - Rick Prosise, DNR
    - Chuck Burney, DNR
    - James Fratrick, DNR
    - Phil Evenson, SEWRPC
    - Bob Biebel, SEWRPC

Friday, July 16, 2004

1) Environmental & Sporting Organizations Panel Discussion
    - George Meyer, Wisconsin Wildlife Federation
    - Lynn Broaddus, Friends of Milwaukee's Rivers
    - Chuck Plotz, Wisconsin Council of Sport Fishing Organizations
    - Jodie Habush, Midwest Environmental Advocates
    - Dale Olen, Sierra Club
    - Dale Bryson, Lake Michigan Federation

2) Review of SSO incidents with Representatives from MMSD and United Water Services
3) Discussion of Organizational Issues & Audit Report
4) Scientist Panel Discussion
    Val Klump, UWM Great Lakes WATER Institute
    Sandra McLellan, UWM Great Lakes WATER Institute
    Roger Bannerman, DNR, Non-point Monitoring Specialist
    Mark Schwartz, UWM, Geography Department Chair and Professor
    John Eise, NOAA, Science and Operations Officer
    Brian Hahn, NOAA, Hydrologist
    Dr. Paul Roebber, UWM - Professor of Meteorology

5) Comments from the Mayor of Milwaukee – The Honorable Mayor Tom Barrett
6) Discussion of Preliminary Responses to Audit Questions

Monday, August 9, 2004
Wauwatosa City Hall

1) Panel Discussion of Rogue River Project
2) Presentation on Fast Flow Treatment, John Poppe, City of Bremerton Wastewater Manager

Tuesday, August 10, 2004

1) Presentation on May 2004 Storm Event, Kevin Shafer, MMSD Executive Director
2) August 3rd CSO at Marshall Street, Mike Martin, MMSD Technical Services Director
3) Audit Report Drafting Session
4) Overview of Miami-Dade Water & Sewer Authority I&I Program, Rodney Lovett
5) Audit Report Drafting Session
6) Discussion of MMSD's Legal Authority Regarding I&I Reduction, Mike McCabe, MMSD Legal Counsel
7) UWS Audit Presentation, Don Theiler, Chairman
8) Audit Report Drafting Session

Friday, August 27, 2004

1) MMSD Presentation on Water Quality Data for May 2004 Storm Event - Kevin Shafer, MMSD Executive Director
2) Legal aspects of basement backups - Chris Jaekels
3) Discussion of Audit Committee Questions and Recommendations
4) Report on August 25th Legislative Hearing on MMSD – Steve Jacquart, MMSD Intergovernmental Coordinator
5) Discussion of Audit Committee Questions and Recommendations

Thursday, October 30, 2004

1) Discussion of Audit Committee Questions and Recommendations
2) Discussion of Public Policy Forum Presentation, Don Theiler, Chairman

Appendix H:
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