sustain

a journal of environmental and sustainability issues

Issue 35
Fall/Winter 2017

The
Kentucky Institute
for the Environment
and Sustainable
Development

sustain

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The Kentucky Institute for the Environment and Sustainable Development (KIESD) was created in July 1992 within the Office of the Vice President for Research, University of Louisville.

The Institute provides a forum to conduct interdisciplinary research, applied scholarly analysis, public service and educational outreach on environmental and sustainable development issues at the local, state, national and international levels.

KIESD is comprised of eight thematic program centers: Environmental Education, Environmental Science, Land Use and Environmental Responsibility, Sustainable Urban Neighborhoods, Pollution Prevention, Environmental and Occupational Health Sciences, Environmental Policy and Management, and Environmental Engineering.

Sustain is published semi-annually by the Kentucky Institute for the Environment and Sustainable Development, University of Louisville, 203 Patterson Hall, Louisville, Kentucky 40292.

louisville.edu/KIESD/sustain-magazine

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This Publication is printed on recycled paper.

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Consent Decree:
A wet weather storage basin that will be used for temporary combined sewer overflow (CSO) control during rain events is under construction at Logan Street and Breckenridge Street in Louisville, Kentucky.

MSD-Louisville, Kentucky

Keeping Sewage out of America's Water: Clean Water Act Enforcement using Consent Decrees

Loren Denton, Chief
Municipal Enforcement Branch,
Water Enforcement Division,
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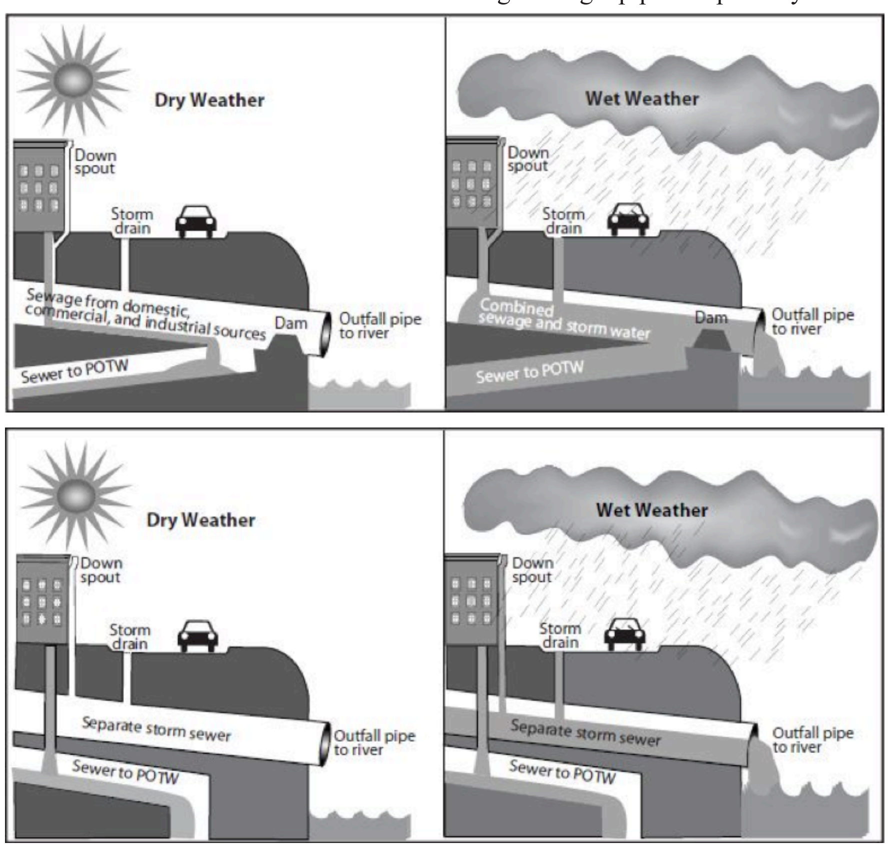
A sewage spill caused partial closure of Wikiki Beach in Honolulu, Hawaii.
Source: EPA (https://www.epa.gov/enforcement/water-enforcement)

When Congress passed the Clean Water Act (CWA) in 1972, it set the lofty goal of eliminating all discharges of pollutants into navigable waters by 1985. In the interim, the Act aimed to achieve a water quality that protects fish, shellfish, and other wildlife and provides for recreation in and on the water. Great strides to meet this goal have been made by requiring wastewater treatment plants to meet secondary treatment standards, which reduces harmful organic substances as well as toxic pollutants and heavy metals, and other water quality based requirements, which can remove pathogens, nutrients and other pollutants. The Agency has also administered grants and low interest loan programs to help fund municipal efforts to meet federal treatment and water quality standards. However, more than 30 years after Congress set these goals, in 2004 the EPA reported back to Congress that cities were still discharging over 850 billion gallons of untreated sewage, via sewage overflows, into national waters. The Agency also estimates that approximately 40% of rivers and lakes cannot support the fishing or recreational uses for which they were dedicated. To remedy untreated or partially treated wastewater discharges and their harmful impact on receiving water and aquatic life, the EPA has assessed most large municipal sewer systems and initiated enforcement actions where appropriate. However, to accomplish Congress's objective of achieving water quality to protect human health and the environment, there is progress left to be made. Judicial Consent Decrees have become an important tool to move our nation towards cleaner, safer water in compliance with the CWA, using creative and effective strategies that work for each community.

The Problem

Municipalities predominantly utilize two types of public sewer systems: combined sewer systems (CSSs) and sanitary sewer systems (SSSs). Combined sewer systems are designed to convey domestic, commercial, and industrial wastewater along with stormwater runoff through a single pipe to a publicly-owned



Diagrams of Sanitary Sewer Systems and Combined Sewer Systems during dry and wet weather.
Source: EPA 2004 Report to Congress: Impacts and Control of CSOs and SSOs

Urban Storm Water Pollutant Concentrations

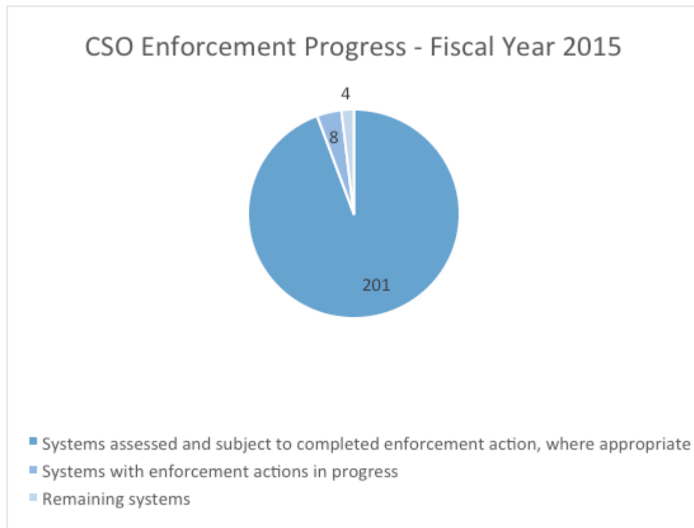
Municipal Sources	Median Fecal Coliform (colonies/100 mL)	Median Biochemical Oxygen Demand (mg/L)	Median Total Suspended Solids (mg/L)	Median Lead (μg/L)	Median Cadmium (μg/L)
Treated wastewater	<200	30	30	.6	.04
Urban storm water	5,081	8.6	58	16	1
Wet weather SSOs	500,000	42	91	—	—
CSOs	215,000	43	127	48	2

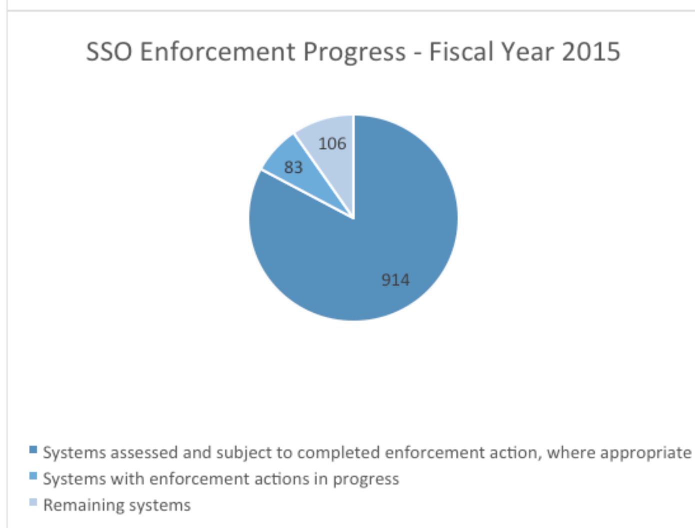
Median concentration of several pollutants released during CSO and SSO events. Source: EPA 2004 Report to Congress: Impacts and Control of CSOs and SSOs

treatment center. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems. Alternatively, SSSs are designed to convey domestic, commercial, and industrial wastewater, while the stormwater runoff is instead collected separately by a municipal storm sewer system. A combined sewer overflow (CSO) or sanitary sewer overflow (SSO) usually occurs when excess stormwater or a blockage causes the volume of wastewater to exceed the capacity of the system, resulting in a release of wastewater prior to the wastewater being treated.

CSOs and SSOs are harmful because they introduce microbial pathogens, oxygen depleting substances, floatable solids, and toxic materials into the water or at other unintended locations. These discharges elevate the pollutant levels in the water, making them unsafe for recreation or fishing. But more importantly, CSOs and SSOs can have significant impacts on human and environmental health. In addition to the pathogens (bacteria, viruses, cryptosporidium, giardia, etc.) which are discharged into the water when sewers overflow, untreated sewage can contain metals which if ingested can bioaccumulate in the human brain, liver, fat, and kidneys, causing a host of detrimental health effects. Sewer overflows can contaminate groundwater and drinking water supplies, and affect ecosystem health by contaminating or killing fish and shellfish. Finally, raw or partially treated sewage may flow out of manholes onto streets, sidewalks and yards; it can also back up from the municipal system through pipes into businesses and homes. Tackling this environmental and human health risk is a top priority for EPA.

To mitigate these harmful effects, the CWA prohibits all discharges into national waters, including wastewater overflows, which are not authorized by a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits, which are generally issued by an authorized state agency, limit the frequency, volume, and pollutant concentration of discharges. Permit limitations are based on technology-based standards and where necessary to avoid exceedances of State water quality standards and requirements. In 1994, EPA issued the CSO Control Policy. The CWA was later amended to require that each permit, enforcement order and Consent Decree must conform with the 1994 CSO Policy. Under the Policy, cities with combined sewer systems that discharge untreated wastewater are required to create a long-term control plan to ultimately result in compliance with the CWA. However, sewer overflows in many cities continue to pose risks to human health and the environment because they fail to adequately develop and implement a long-term control plan and/or violate other terms of their CSO permit.



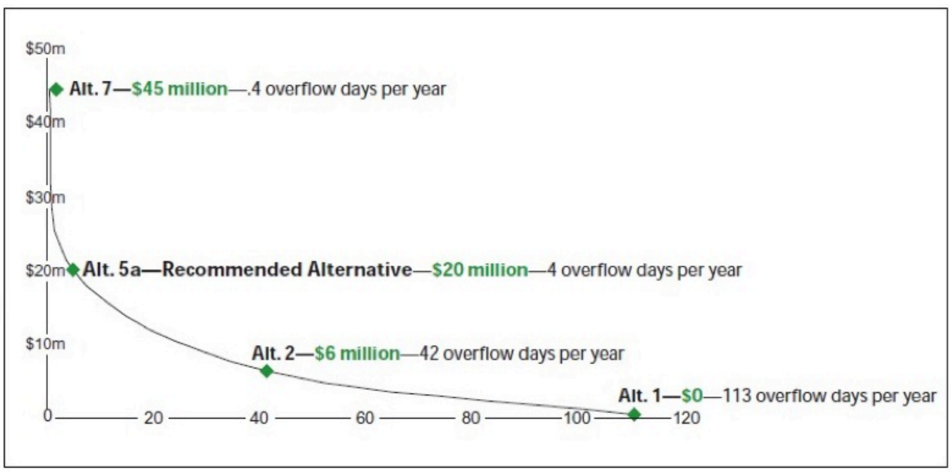


Number of combined and sanitary sewer systems by their enforcement status at the end of fiscal year 2015. Source: EPA 2004 Report to Congress: Impacts and Control of CSOs and SSOs

An Enforcement Solution

EPA is tasked with reducing or eliminating these harmful wastewater discharges. EPA generally works with the community to find a solution to the violations that both addresses the environmental and public health risk, and meets the needs and finances of the local community. Consent Decrees (CDs) are the most common and preferable resolutions of enforcement cases because the parties can avoid undue delay and expense, while still creating a judicially enforceable agreement. The principal benefits of a Consent Decree are that:

- the dispute is put to rest through a negotiation process that leads to an approach that is acceptable to all parties in the agreement;
- the resources are spent solving the problem rather than litigating;
- it allows flexibility and adaptive strategies that recognize the unique situation in each community;
- it allows for the agreement to be amended if the situation on the ground changes.



An example of a cost-benefit analysis in which the most expensive option yielded marginal benefits in comparison to the more affordable recommended alternative. Source: EPA Report to Congress: Implementation and Enforcement of the Combined Sewer Overflow Control Policy

To achieve a CD resolution in CSO enforcement actions, the EPA negotiates an agreement that is both technologically and financially achievable. The EPA considers at length the city's unique circumstances, including its financial capability, distribution of sensitive populations, and its other CWA legal obligations. The Agency also encourages entities to develop a range of sewer overflow control alternatives and determine if there is a more cost effective approach to achieving the pollution reduction. Cost efficiency is an important consideration in determining which wastewater overflow control options are appropriate, and the EPA is cognizant that completely eliminating overflows can be financially impractical.

After conducting this holistic analysis, the EPA negotiates with the city to create a timeline for the city to complete certain CSO control projects. Most agreements provide cities years, sometimes even decades, to remedy their CWA violations, which reduces the financial strain on the city and its citizens. In addition, the public and interested third parties not involved in the resolution of the dispute are afforded the opportunity to comment on the proposed CD. The Department of Justice files the written comments and the government's response with the court, which are considered by the judge when entering the final judgment. These procedures ensure the final CD adequately addresses the interests of the city and the interests of affected third parties.

The EPA first used a Consent Decree to eliminate CSOs from the city of Lynn, Massachusetts, in 1978. As of March 30, 2016, the EPA has entered into over a hundred Consent Decrees with municipalities in order to bring the cities' CSSs and SSSs into compliance. The estimated cost of bringing municipal sewer system's addressed into compliance has ranged from $5.4 million to $4.7 billion, and the time given to remedy violations has varied from 2 to 31 years. This variation in cost and duration of the city's legal obligations can be accounted for by the nature of the non-compliance in a given case and the EPA's documented dedication to considering the city's financial capability and other public health priorities.

Financial Capability

The 1994 CSO Control Policy provides that the permittee's financial capability be considered when creating enforceable schedules to implement long-term control plans. Guidance on assessing a community's financial capability is provided in the 1997 CSO Guidance for Financial Capability Assessment and Schedule Development, which describes how cities are to conduct detailed evaluations of their current financial conditions when creating Long Term Control Plans. In order to assess a city's financial capability, the city is to first consider the financial impact of CSO controls and wastewater treatment on individual households by looking at how much the CSO control measures will cost in comparison to residents' household incomes. Next the city's financial capability to pay for CSO controls is considered by weighing metrics such as the city's current burden of debt, unemployment, and its tax revenues. The city may also submit any additional documentation that would create a more accurate and complete picture of its financial capability. The Agency works with the City to examine the totality of the circumstances to set the appropriate schedule for implementing the pollution reduction measures. Moody's Investors Service, a well-known rating agency, published a report in 2014 that lead them to conclude that "[s]ewer utilities under Consent Decree often remain highly rated…" Moody's went on to suggest that the "primary reason many utilities maintain strong ratings even under Consent Decree is that the EPA considers utilities' ability to fund upgrades required by a settlement." Finally, Moody's notes that "Consent Decrees stimulate better capital planning and ensure ongoing infrastructure upkeep that might not have otherwise occurred."

The Agency has recently reiterated its dedication to flexibility in order to accommodate municipalities' unique financial challenges. The 2014 Financial Capability Assessment Framework clarifies the flexibility available when considering costs and the best approach for solving the violations. This Framework makes clear that all municipal CWA obligations (wastewater and stormwater) may be considered when determining what sewer overflow control measures should be implemented and on what schedule, instead of only considering the costs of sewer overflow control projects. The guidance also enumerates examples of additional financial considerations that may provide a more nuanced understanding of the municipality's financial circumstances. These considerations include metrics such as the percentage of residents that rent, historical population trends, and stochastic stressors that may result from natural disasters and unpredictable capital market conditions. By considering more nuanced financial factors along with the cost of all CWA-related obligations, the Agency can create a more complete picture of the water utility costs and make sure the agreement takes account of those factors in working with the City to design clean water solutions that make sense.

Integrated Planning

The EPA's Integrated Planning Framework (Integrated Municipal Stormwater and Wastewater Planning Approach Framework) represents the Agency's understanding that it must work cooperatively with states and communities to achieve CWA objectives. This Framework, developed with Mayors and other local government officials, encourages cities to work with NPDES authorities and EPA regional authorities to coordinate a community's distinct CWA obligations to best prioritize investments and risks to human health. Importantly, the integrated planning approach is voluntary, providing communities with the opportunity, but not the obligation, to develop and propose the plan. Municipalities that choose to develop an integrated plan identify relative priorities for projects and describe how the priorities reflect the importance of human health and water quality, as well as the municipality's own financial capability. This plan can then inform the development of implementation schedules in enforceable documents, like CDs.

Integrated planning also presents a unique opportunity to incorporate innovative technologies, like green infrastructure (GI), that present sustainable and affordable solutions to sewer overflows. GI differs from traditional stormwater management because it does not focus on the use of conventional piped drainage systems. Instead, GI mimics nature by using soil and vegetation to capture and absorb stormwater runoff. Managing stormwater runoff with GI can be as simple as planting vegetation alongside roads or parking lots to increase water retention and to naturally filter stormwater. Other common methods of GI include distributing rain barrels that collect water conveyed by gutters into a storage container and planting gardens on the roofs of buildings.

The EPA has provided a source of funding for municipalities lacking the financial resources to implement GI technology. The Clean Water State Revolving Fund (CWSRF) provides loan assistance to manage stormwater for both permitted and non-permitted entities. Loans are provided with low interest rate—an average of 30% below market rate—and sometimes as low as 0%. In addition, the CWSRF can cover up to 100% of a project's costs and provides for flexible repayment options. Utilization of integrated planning, including the use of GI, has been successfully implemented by many municipalities.

Financial Capability

Some of the factors that the EPA considers when determining a city's financial capability are listed below:

- Current and projected operation and maintenance expenses
- Number of households in service area and median household income
- Income distribution, poverty rates, as well as income and population trends
- Unemployment data and trends
- Projected, current, and historical sewer and stormwater fees
- Financial impacts of all Clean Water Act obligations
- Percent of households who own versus rent
- Data and trends on late payments, disconnections, and service terminations
- City bond ratings and circumstances that may affect the bond rating
- City debt as a percent of full market property value
- City tax revenue collection rate as a percent of full market property value
- City grant and loan availability
- Extraordinary stressors, such as natural disasters and bankruptcy

Source: Created by the author from information in the 2014 Financial Capability Assessment Framework

Vegetated swales planted along roadways can absorb stormwater to help prevent sewer overflows. Source: EPA, Nancy Arazan (https://www.epa.gov/sites/production/files/2015-11/documents/sw_ms4_compendium.pdf)

District of Columbia

The District of Columbia (DC) and DC Water initially entered into a Consent Decree with the EPA in 2005, which required the municipality to construct several large storage tunnels to manage CSOs. Ten years later, the EPA worked with DC Water to amend the agreement to allow DC Water to incorporate green infrastructure into its control measures at two locations. After extensive planning, DC officials determined that technologies like green roofs, porous pavement, and rain gardens would provide greater benefits than traditional “gray” infrastructure. In addition to eliminating or reducing the need for expensive tunnel construction, DC officials found that the GI measures would also create local jobs, increase property values, and mitigate extreme temperatures during the summer. By planning and proposing an integrated plan to incorporate green technology, DC Water officials were able to come to an agreement with the EPA that increased environmental and economic benefits.

Seattle, Washington

The EPA entered into Consent Decrees with the City of Seattle and King County in 2013 to eliminate more than 95% of each entity’s CSO discharges by the end of 2030, at an estimated combined cost of approximately $1.5 billion. However, the CDs provided the county and city with the opportunity to propose water quality improvement projects through an Integrated Planning Proposal. In addition, the CD allowed the county and city to substitute green infrastructure projects for traditional piped drainage and water treatment systems at several locations.

Planting gardens on rooftops is another type of green infrastructure that can reduce the impact of wet weather events on sewer overflows. Source: EPA, Nancy Arazan (https://www.epa.gov/sites/production/files/2015-11/documents/sw_ms4_compendium.pdf)

As a result, Seattle has been able to amend its long-term control plan to make CSO control projects in a low income community the highest priority because of environmental justice concerns. King County has also begun implementing green infrastructure initiatives to control CSOs in Puget Sound, including bioretention swales along public roads, and is partnering with Seattle Public Utilities to offer rebates to certain residents who install rain gardens and cisterns on their property.

Climate Change

Climate change will continue to increase the intensity of storms, which may pose an additional challenge for municipalities moving forward. Current climate change models predict rainfall to become more variable and in some places storm events more severe and more common. Implementing green infrastructure helps create climate change resiliency by managing flooding, reducing urban heat islands, and lowering energy demands for buildings and municipal water treatment centers. As described above, cities can take advantage of the EPA’s Clean Water State Revolving Fund to finance infrastructure improvements to plan for the anticipated effects of climate change.

Transparency and Accountability

In 2015, the Agency made enormous strides towards transparency by promulgating the National Pollutant Discharge Elimination System (NPDES) Electronic Reporting Rule. This

Washington, D.C., was required to place a CSO indicator light at several CSO outfalls along the Potomac River as part of their CD. Source: EPA (https://www.epa.gov/sites/production/files/2015-06/documents/npdesnextgencomplcompendium.pdf)

rule requires permitted entities and state and federal regulators to electronically report data required by the NPDES permit program instead of filing written reports. This approach will not only ease the reporting burden borne by states, but will make inspection and enforcement history, pollutant monitoring results, and other data publically accessible through the EPA's website. In addition, the CSO Control Policy provides that CSO permits are to ensure that the public receives adequate notification of CSO occurrences and impacts.

CDs have furthered EPA's goal of increasing transparency and public awareness of sewer overflows. For example, CDs with Shreveport and St. Louis require reports submitted to the EPA to also be posted on the web for access by the general public. Some CDs have also heightened notification requirements by requiring that signs be posted at outfalls or indicator lights flash when a CSO event has occurred. Future technological advances will continue to aid EPA transparency and notification requirements in CDs and otherwise.

Conclusion

In conclusion, CDs have become a powerful tool to achieve CWA compliance with greater efficiency. Eliminating unauthorized, untreated sewer overflows discharging into national waters is challenging, but the effort EPA and cities put into it is worth it, and pays off in environmental and health benefits to communities across the country. In light of Congress's objective to eliminate all unauthorized discharges into waters of the United States, the Agency has made great strides to remedy sewer overflows by working with states and cities to fund infrastructure improvements and find workable solutions. EPA's enforcement office has worked to make the promise of the law a reality for communities across the country, and has had success in finding cost effective and flexible solutions in settlement agreements CDs have proven to be an efficient tool to reduce wastewater discharges, find affordable solutions that respond to the individual needs of each community, and sometimes even save money and create local jobs and green spaces at the same time.

Loren Denton currently leads EPA's Municipal Enforcement Branch of the Water Enforcement Division in Washington, DC. Over his 19-year tenure with EPA, Mr. Denton has served in various capacities with EPA's Office of Enforcement and Compliance Assurance and EPA Region 5. Since 2006, Mr. Denton has served within the Water Enforcement Division, where he has overseen Clean Water Act settlements with many municipalities involving primarily combined sewer and sanitary sewer overflows. Prior to 2006, Mr. Denton was one of EPA's national experts on coal-fired power plants while serving as an Environmental Engineer in the Air Enforcement Division in DC and the Air and Radiation Division in Chicago. Mr. Denton holds an MS in Environmental Engineering from the University of Colorado; in his free time, he is working towards a PhD in Engineering Management & Systems Engineering from George Washington University.

Mr. Denton would like to express gratitude to Ms. Krista Alford Hekking, a law student at the University of Virginia, for her substantial contributions to the research and writing of this article. Ms. Hekking worked as a Law Clerk in EPA's Water Enforcement Division during the summer of 2016.

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Louisville and Jefferson County MSD
Amended Consent Decree – A Mid-Point Review

Angela Akridge
MSD Chief Engineer

Introduction – Consent Decree Redefines Priorities

MSD provides a wide variety of services that are among the most vital components of the community's backbone - wastewater collection and treatment, stormwater management, and reliable flood protection. This means the agency has numerous high-value priorities that compete for resources. From 1985 to 2003, MSD spent close to $1 billion on improvements to the wastewater collection and treatment system. The focus during this time was to provide safe, reliable sewer service by eliminating failing treatment facilities and septic tanks that were jeopardizing public health and safety on a daily basis. MSD built over 1,000 miles of new sewer interceptor and collector sewers that eliminated more than 300 poor performing package treatment plants that had outlived their useful operation. These package plants were small treatment systems privately built some 60 years ago as part of the post-WWII building boom, and subsequently owned and operated by MSD. The new collector sewers also allowed the elimination of over 40,000 failing septic tanks on private property by providing properties access to the sanitary sewer system.

While MSD was focused on these high priority public health and safety issues, a program for managing intermittent wet weather sewer overflows was also underway. This program invested nearly $134 million, as a part of the larger $1 billion investment, to study the system behavior, and subsequently design and construct several important sewer overflow abatement facilities. However, the investment made to tackle sewer overflows was not deemed sufficient to meet water quality goals within timeframes established by the federal and state regulators.

In 2003, MSD received a notice of alleged Clean Water Act violations from the US Environmental Protection Agency (EPA) and the Kentucky Department for Environmental Protection (KDEP). This resulted in a negotiated settlement between these parties in 2005. This settlement, most commonly referred to as the Consent Decree, outlined the compliance program and schedules for achieving specific objectives including the development and implementation of discharge abatement plans. With the filing of the enforcement action, sewer overflows became the critical priority, and MSD shifted resources and investment agency-wide to tackle this massive federally-mandated undertaking.

In response to the Consent Decree, MSD developed the Integrated Overflow Abatement Plan (IOAP), a long-term plan to control combined sewer overflows (CSOs) and eliminate sanitary sewer overflows (SSOs) and other unauthorized discharges in MSD's sewer system. This plan was submitted in 2008 and approved by EPA and KDEP in 2009. It included definition of $850 million in capital improvements, associated incremental operating costs, and a high level financial plan that included cash flow projections, projected borrowing schedules and projected rate increases through the year 2024.

Concurrently with the final stages of the IOAP completion, the regulatory agencies (EPA and KDEP) initiated a second enforcement action related to Water Quality Treatment Center (WQTC) performance, record keeping and reporting. This resulted in an amendment to the Consent Decree that was approved in 2009. The IOAP, also approved in 2009, fully addressed the amendment. This Amended Consent Decree is the legal document that MSD is currently required to comply with through the completion date in 2024, and beyond.

Adaptive Management Implications

Recognizing the 19-year long-term nature of the IOAP, MSD negotiated a Consent Decree with the regulators that committed to an adaptive management process based on demonstrating compliance. Under the adaptive management process, system performance assumptions are continually validated and mid-course corrections are made as more is learned about the performance of projects and the related response of the sewer system. The benefit of this approach to the community is an assurance that the significant investment being made to comply with the Consent Decree will be based on continual updates about the system, rather than static assumptions made during the early years of the program. MSD and the regulators understood from the outset that changes developed due to the adaptive management process can result in fluctuations of both increasing and decreasing scope and cost refinements in the years leading to final completion, meaning the cost status of the overall program at any given time is subject to change in subsequent years as adjustments are made.

In 2011, MSD had the opportunity to evaluate four more years of flow monitoring data and to perform a planned recalibration of the hydraulic models used to develop, evaluate, and design overflow abatement projects. As a result of this recalibration, MSD found opportunities to revise the proposed suite of projects, providing increased levels of overflow abatement faster, and for approximately the same cost. In 2012, an IOAP Modification was submitted to account for project changes in technology, size, and schedule, and the resultant benefits of making those changes. MSD developed a programmatic justification for this 2012 IOAP Modification using the same benefit/cost methodology as the 2009 approved plan. The modifications, approved by EPA and KDEP in May 2014, will achieve a higher overall benefit to the community through earlier overflow reduction, increased use of green infrastructure and acknowledgement of public input.

2015 Basin Balancing and Cost Implications

As part of the adaptive management approach outlined in the IOAP, MSD has been expanding the monitoring network throughout its sewer system. Data from this monitoring network is used to recalibrate the hydrologic and hydraulic models that assist in sizing overflow abatement projects, and to further refine individual project approaches and sizes based on an improved understanding of the sewer system operation and the relationship of certain overflows to one another. This process to-date has led to two negotiations with regulators that "balanced" the system model based on actual data and allowed MSD to more accurately size storage basins and other IOAP projects.

In 2015, this approach was applied when new monitoring data and improved modeling results indicated that the size of the proposed Southwestern Parkway Storage Basin should be increased, resulting in a reevaluation of the design level of control for this basin. Using the same approach approved by EPA and KDEP for setting level of control in the original IOAP, this evaluation indicated that the Southwestern Parkway Storage Basin should be designed for eight overflows per year in the ”typical year,” rather than zero, as originally determined. Preliminary discussions with the regulators indicated that the resulting increase in the average annual overflow volume would not be approved. MSD was challenged to find an approach to adjusting basin sizing to minimize costs while avoiding any increase in the approved level of residual sewer overflows. MSD confronted this challenge head-on, and in August, 2015 submitted a programmatic justification for optimizing the size of five hydraulically connected basins, including the Southwestern Parkway Storage Basin. MSD demonstrated through this justification that the combined optimized suite of five proposed modifications resulted in a net reduction in the residual annual average overflow volume at the lowest additional cost to MSD’s customers. Additionally, the optimization of basin sizes resulted in an overall benefit to the community by reducing residual overflow levels at discharge locations upstream of Waterfront Park, thereby reducing the potential for public contact with sewer overflows following rain events. EPA and KDEP acknowledged MSD’s successful efforts, and accepted the submittal.

As previously stated, the adaptive management approach has positive impacts that are beneficial to the environment and cost-justified by using consistent IOAP benefit/cost methodology, however the approach can have programmatic cost impacts. The adaptive management process to-date has lowered the cost of some projects and increased the cost of other projects. The 2015 basin balancing adaptation contributed to escalating IOAP programmatic costs by approximately $33 million. Adaptive management evaluations will continue through all planning, design and construction activities until the IOAP is complete. It is likely that continued adjustments (either up or down) will be required prior to program completion.

IOAP Implementation Benefits

Benefits of the IOAP implementation to-date are evidenced across the entire community. The IOAP prioritized projects in a way that dealt first with some of the most serious public health and safety issues impacting Louisville neighborhoods, while at the same time balancing cash flows over the 19-year program, and providing time to perform the analysis and monitoring necessary to fully characterize combined sewer system behavior during wet weather. This resulted in a phased approach allowing MSD to concentrate on one particular suite of projects at a time, achieving significant overflow reduction with each subsequent phase. The four phases have been loosely defined as follows:

- Phase 1 – Major SSO Eliminations
- Phase 2 –WQTC Eliminations
- Phase 3 – CSO Abatement
- Phase 4 – Remainder of SSO Eliminations

The IOAP specifically identified long-range benefits of the program to the community. The suite of projects selected for CSO abatement will result in approximately 98 percent capture and treatment of wet weather combined sewage during an average year. This benefit represents an 89 percent reduction in CSO volume compared to 2008 conditions. It is worth noting that MSD’s 98 percent capture and treatment result will not only meet but will exceed EPA’s own presumptive approach for compliance which sets the bar at 85 percent in the Clean Water Act CSO Control Policy. Remaining CSO loads will no longer cause fecal coliform water quality standards violations in the Ohio River.

The suite of projects selected for SSO control will result in the elimination of capacity-related SSOs up to the site-specific level of protection. The SSO projects are anticipated to eliminate an average of 145 SSO events per year (290 million gallons {MG} of overflow volume), based on 2005–2007 data normalized for rainfall. In terms of water quality, SSO projects will eliminate 100 tons of five-day biochemical oxygen demand (BOD5) and approximately 200 tons of suspended solids annually.

Along with delivering water quality improvements from sewer overflow control, MSD participates in other community water quality improvement efforts. Sewer overflow control is essential to improving water quality, but sewer overflow control alone is not sufficient to meet water quality standards. In light of this challenge, MSD continues to leverage its role in supporting broader water quality improvement efforts in the community. The IOAP is just one of the key elements of MSD's participation.

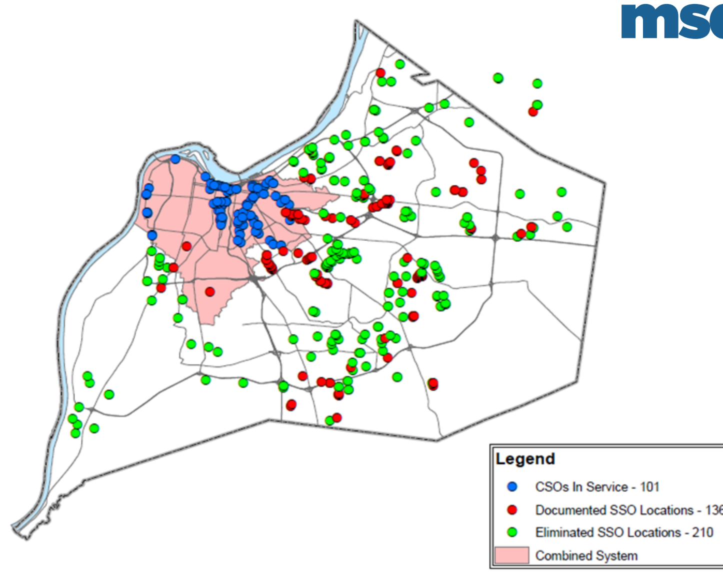

Figure 1 - Service Area Map Indicating SSO/CSO Locations and Eliminations

Community Investment Benefits to Date

Under the Consent Decree, MSD refocused on sewer overflows and vigorously pursued overflow abatement and elimination across the county. MSD has eliminated the last 15 small package plants and routed all wastewater to five modern, well-operated regional water quality treatment centers. MSD added over 100 MGD of wet weather treatment capacity at the Derek R. Guthrie WQTC, and has another 50 MGD of wet weather treatment capacity under construction at the Bells Lane Wet Weather Treatment Facility near the Morris Forman WQTC. MSD has added over 100 million gallons of wet weather flow equalization capacity, with over 44 million gallons of additional capacity already under construction. Forty-six miles of sewer has been rehabilitated or replaced, including large parts of the "temporary facilities" still in service in the Camp Taylor area. These facilities are deemed temporary because when they were constructed in 1917 the intent was they would only be used during the time that area served as a WWI US Army training facility. While some of the 100-year old pipes at these facilities were able to be repaired and rehabilitated, much of the old pipe has been, and is continuing to be, completely replaced.

While the Consent Decree program is only midway through completion, the results to date have been impressive. Of the 346 SSOs documented in 2005, over 200 have been eliminated as defined per the IOAP and as shown by the green dots on the map in Figure 1.

Some of the SSOs eliminated include numerous locations of pumped overflows in the residential areas of Beechwood Village, Hikes Point, and Highgate Springs. In these neighborhoods, developer-constructed sewers from the 1960's allowed significant infiltration and inflow into the pipes during wet weather, forcing MSD to pump untreated wastewater directly from the collection system to nearby waterways to prevent widespread basement backups. These pumped overflow locations have all been eliminated per the IOAP. Downstream water quality after rainstorms has also significantly improved, as illustrated by the graph in Figure 2.

In the combined sewer system, MSD's overflow abatement efforts predated the Consent Decree enforcement action. Since 2001, CSO discharges have been reduced by over 50 percent as shown by the graph in Figure 3.

MSD has implemented a post-construction compliance monitoring program to proactively assess the performance of IOAP projects as they are completed. This will ensure that the desired levels of control will be achieved for the entire system when the IOAP construction is complete. Monitoring results to date have demonstrated that the constructed projects will, in fact, achieve the desired performance objectives.

New Connections due to System Capacity Assurance Program

In response to the Consent Decree, MSD faced the potential for a complete moratorium on new sewer connections. This would have effectively shut down economic growth and development in the entire county. To avoid this, MSD was able to negotiate an approach to offset new connections with documented reductions in wet weather infiltration and inflow, developing a credit program to track flow reductions and new connections.

Credits are gained when projects are completed that increase system capacity and credits are used when new connections to the system are made. The number of credits that are gained depends upon the type and size of the project. Currently there is a positive credit balance in all basins. Proposing this program limited the connection moratorium to the Jeffersontown area; however, that moratorium was lifted when the treatment facility was eliminated in 2015.

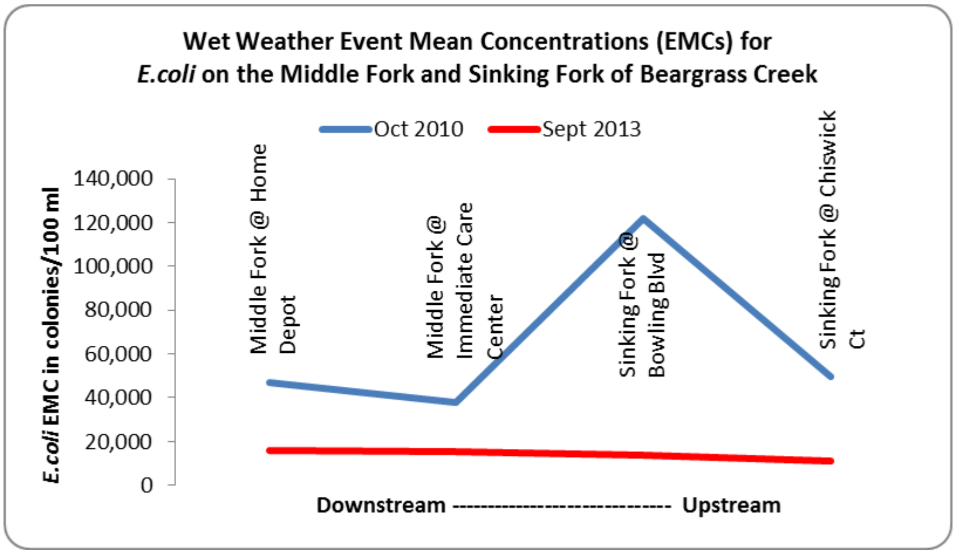

Figure 2 - Water Quality Snapshot in two segments of Beargrass Creek

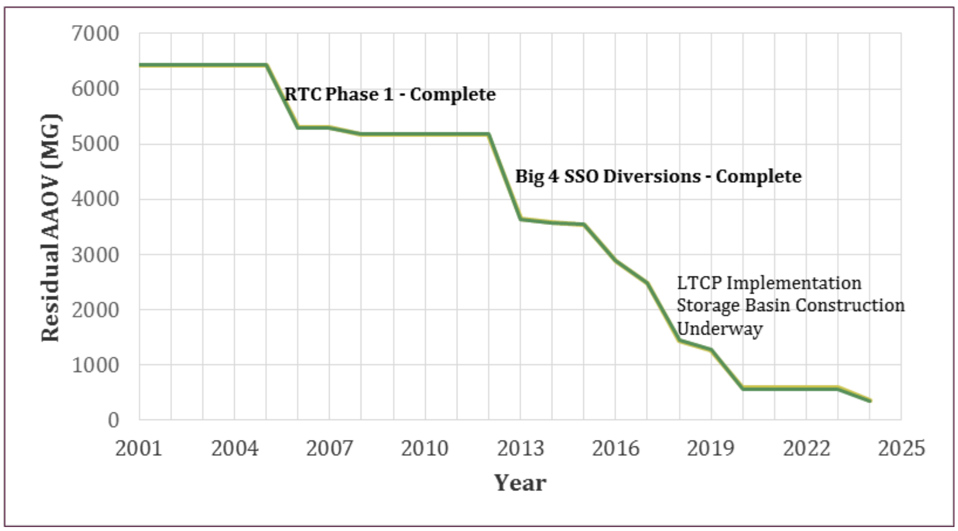

Figure 3 - Residual Average Annual Overflow Volume 2001-2024

Maintaining this program allows the development community to continue building in the MSD service area, a critical factor in continued prosperity for citizens and businesses alike.

Green Infrastructure

Removing stormwater from the sanitary sewer system is a cost effective way to reduce sewer overflows, while also providing enhancements to the community. While the IOAP is made up of mostly 'gray' infrastructure, such as storage basins and interceptors, modeling in some areas supported strategic integration between 'gray' and 'green' elements. In considering the broader contribution to quality of life that was possible through the significant investment being made in the Consent Decree program, MSD collaborated with the Wet Weather Team Stakeholder Group in petitioning the EPA to allow a portion of the integrated wet weather IOAP and Consent Decree response be performed with green infrastructure. The IOAP was initially proposed as a "gray" plan with financial commitments to implement green infrastructure controls only for "right-sizing" solutions. The Wet Weather Team stakeholders encouraged MSD to look beyond that and explore the use of green infrastructure to reduce the volume and frequency of CSOs. In response, and to demonstrate MSD's commitment to leveraging community investments above ground as well as below, MSD initiated a more robust green infrastructure program, which integrates green project and program elements with traditional gray solutions. As a result, $47 million of the $850 million Consent Decree has been identified for use to implement green infrastructure. MSD has completed 19 green demonstration projects at a cost of approximately $3 million as part of our commitment to implementing and testing the effectiveness of a variety of green management practice types. The suite of green infrastructure technologies considered were green alleys, green streets, green parking, rain gardens/biofiltration, infiltration trenches and green roofs.

Community Benefits of Green Infrastructure

- Achieve multiple objectives and benefits beyond reduction of sewer overflows
- Improve air and water quality
- Increase green space and wildlife habitat
- Reduce heat island effect in the urban core
- Reduce overflow volume and frequency
- Beautify community

The current Green Infrastructure initiatives include streetscapes, reforestation and stipends (incentives for private development of green infrastructure). During the 2012 IOAP Modification, the CSO 130 and CSO 190 projects converted gray infrastructure to green infrastructure at a lower cost to the community. In addition to overflow control, the green elements provided enhancements to the landscape and reduction of urban heat island impacts by removal of impervious surfaces.

National Recognition for MSD's Green Infrastructure Program

MSD was an early adopter of strategic green infrastructure as a wet weather management tool. Regulatory agencies, as well as industry organizations, were interested in MSD's efforts and followed them closely as the projects were built. Recognition of the environmental and community benefits garnered includes:

- Inaugural EPA Region 4 Rain Catcher Award for the CSO 130 Green Infrastructure Project
- KY/TN Water Environment Association Outstanding Watershed Management Award for the Central Louisville Green Infrastructure Partnership
- YouthBuild Louisville Public Partner Award
- Water Environment Federation Silver Level Certification-Program Management for large MS4 communities
- Water Environment Federation Silver Level Certification-Innovation for large MS4 communities
- National Association of Clean Water Agencies (NACWA) Award for Environmental Achievement – CSO 130 Green Infrastructure Project

Job Creation

The Department of Commerce estimates that each job created in the local water and wastewater industry creates 3.68 jobs in the national economy and each public dollar spent yields $2.62 dollars in economic output in other industries. The Value of Water Coalition estimates that 16 jobs are created for every $1 million spent. The economic impact in Louisville is $3.4 billion and 2,310 jobs over 10 years. It is clear the $850 million infrastructure investment mandated by the Consent Decree will have a significant and positive impact on the Louisville area. Figure 4 and Figure 5.

MSD has a history of working to connect with minority-owned and woman-owned businesses in the Louisville community. As one of the community's economic engines, MSD supports more than 2,300 jobs annually. During the course of the last five years, MSD has continued this effort to identify new opportunities that help grow these businesses as we work together, building sustainable relationships and an exceptional supply base that benefits customers and communities where we live and work. For fiscal year 2016, MSD awarded $40 million in contracts to minority- and women owned firms.

Conclusion

When MSD first faced allegations of Clean Water Act violations due to sewer overflows, the intervention of USEPA was perceived as a negative action by the community. The requirements of the program were, in reality, no more than accelerating the pace and establishment of enforceable performance requirements for system improvements MSD was already working on. Midway through the Consent Decree response implementation, the community is already seeing the benefits of cleaner waterways, reduced exposure to the health risks of untreated overflows, and jobs creation that has a significant multipler effect as the projects ripple through the design and construction support supply chain.

MSD remains committed to satisfying the terms of the Consent Decree on the established timeline, with completion of the last set of projects scheduled for December, 2024.

Angela Akridge was appointed Louisville MSD's Chief Engineer by Mayor Greg Fischer on May 1, 2015. Ms. Akridge, a native of Louisville and a graduate of the University of Louisville's J. B. Speed School of Engineering, is the first woman to hold this position since MSD's creation by state statute in 1946.

She began working for MSD as an engineering intern, and upon completion of her civil engineering bachelor's and master's degrees, she joined MSD as a full-time employee. Ms. Akridge has served in engineering and management positions throughout her 24+ years at MSD. In that time, she was named National Young Engineer of the Year in 2006 and has served as president of both the Louisville and State chapters of the Kentucky Society of Professional Engineers.

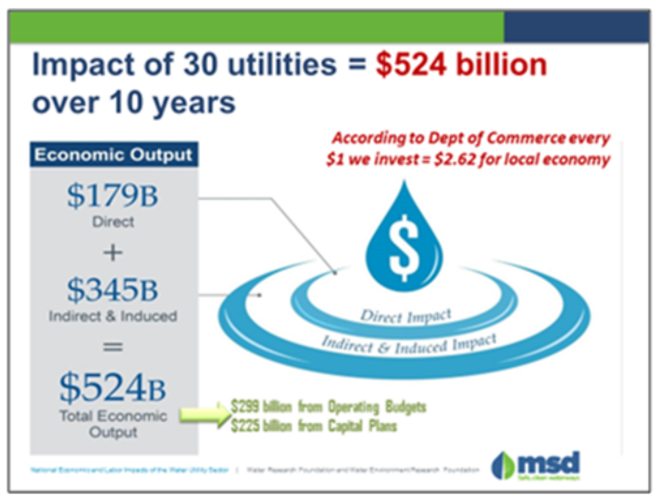

Figure 4 - National Economic and Labor Impacts of the Water Utility Sector, WERF Study

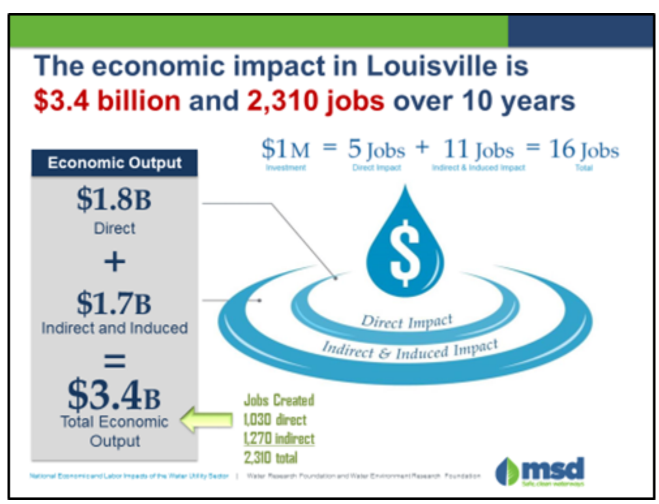

Figure 5 – Economic Impact of Utility Operations at Louisville MSD on Louisville/Jefferson County

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Water Research Foundation (WRF) & Water Environment Research Foundation (WERF) (2014.)

National economic and labor impacts of the water utility sector.

Environmental Justice in the Metropolitan St. Louis Sewer District's Consent Decree

Brian Hoelscher, P.E
Executive Director & CEO

The Metropolitan St. Louis Sewer District (MSD) is a municipal corporation that was created on February 9, 1954, when voters – per a provision of the Missouri State Constitution – in the City of St. Louis (Missouri) and parts of St. Louis County approved the formation of an independent government agency tasked with the collection, treatment, and disposal of sewage on a metropolitan-wide basis. MSD began operations in January 1956 in an area roughly composed of the City of St. Louis and the portion of St. Louis County located east of today's Interstate 270. MSD took over all publicly-owned wastewater and stormwater drainage facilities within its jurisdiction and began the construction of an extensive system of collection and interceptor sewers and regional treatment facilities. Most of the remainder of St. Louis County was folded into MSD through a voter approved annexation in 1977. Today, MSD's service area covers all of the City of St. Louis and approximately 90% of St. Louis County – approximately 525 square miles, with a population of just under 1.3 million. Service area boundaries are the Missouri River to the north; the Mississippi River to the east; the Meramec River to the south; and Highway 109 to the west. (Figure 1.)

MSD owns and operates seven wastewater treatment plants that treat over 325 million gallons of wastewater per day; 278 pump stations; over 3,000 miles of stormwater sewers; over 4,700 miles of sanitary sewers; and over 1,800 miles of combined sewers. The sewers maintained by MSD range in age from less than a year old to over 160 years old, and are serviced out of three regional maintenance facilities. The agency's fiscal year 2017 budget (July 1st, 2016 through June 30th, 2017) totals $673.9 million, which entails $196.6 million for operations and maintenance; $378.5 million for capital projects; and $98.8 million for debt service. For fiscal year 2017, MSD's authorized work force is 1,018.

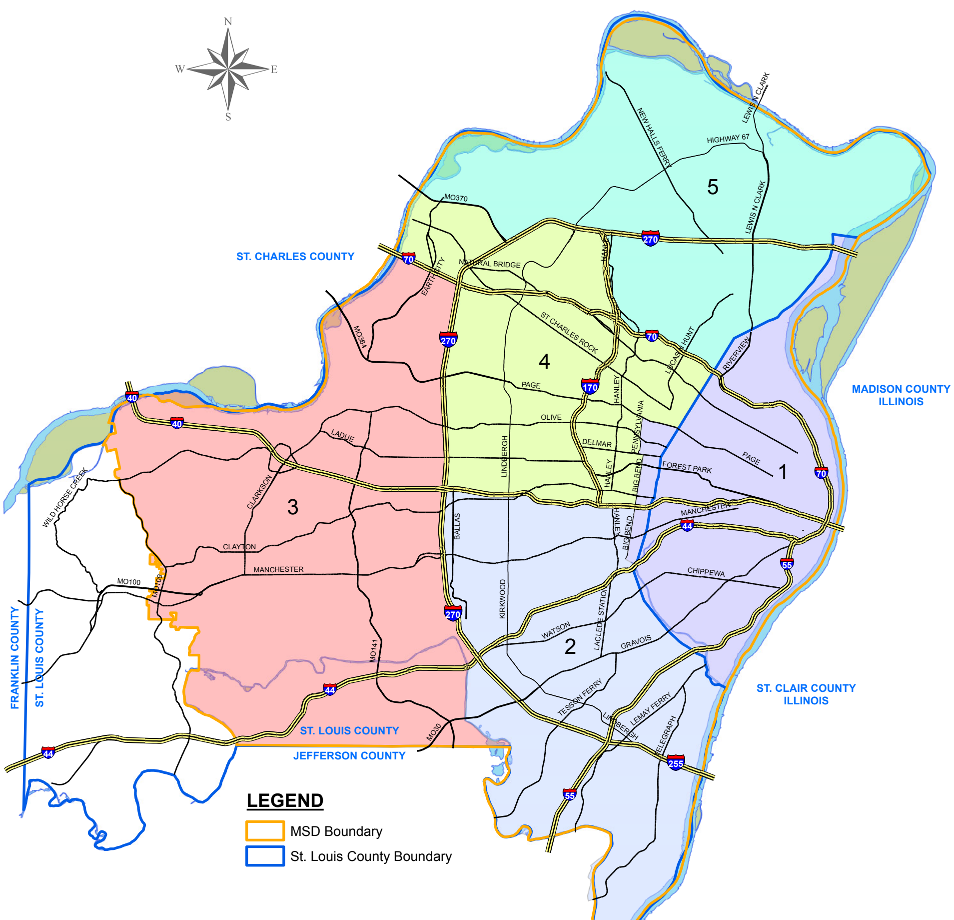

Figure 1: Map of MSD Service Area

Over the years, MSD has taken over 79 separate public and private sewer systems. As such, the environmental issues facing MSD are equally spread out amongst our entire service area. Ergo, MSD is just as likely to have a sanitary sewer overflow located in the backyard of a home in a high income neighborhood, as to have one exist anywhere else in its service area.

In April 2012, a $4.7 billion, 23-year Consent Decree with the United States Environmental Protection Agency and the Missouri Coalition for the Environment was entered with the United States Federal Court. The Consent Decree established a timeline and agreed to projects and activities to address outstanding issues – mainly sewer overflows – in MSD's separate sanitary and combined sewer systems. While the cost and term of the Consent Decree is significant, it is the continuation of work MSD had been performing for many years and planned on continuing. For example, between 1992 and 2012, MSD had spent approximately $2.7 billion to eliminate over 380 sewer overflows. What the Consent Decree represents for MSD is an agreed to regulatory compliant schedule for continuing this work.

As overflows are spread throughout MSD's service area, it was not possible to identify a particular area or areas that would be appropriate for environmental justice remediation efforts. However, our Consent Decree does contain three specific programs which do honor the spirit of environmental justice efforts.

The first program is called the Cityshed Mitigation Program (Figure 2). Portions of the approximately 80 square mile area served by MSD's combined sewer system regularly experience a significant amount of overland flooding and basement backups. In these areas, sewer issues could almost be termed chronic. The problem is rooted when development first occurred in these areas – in many cases the late 19th century and early 20th century – the combined sewer systems were not adequately sized to handle many moderate to severe rainstorms. Thus, the goal of the Cityshed Program is to alleviate the effects of wet weather surcharging and overland flooding of the combined sewer system. Per the Consent Decree, MSD will spend $230 million in combined sewer area sub-watersheds. Activities include relief sewers, control and detention of wet weather flows, and, in some cases, sewer separation.

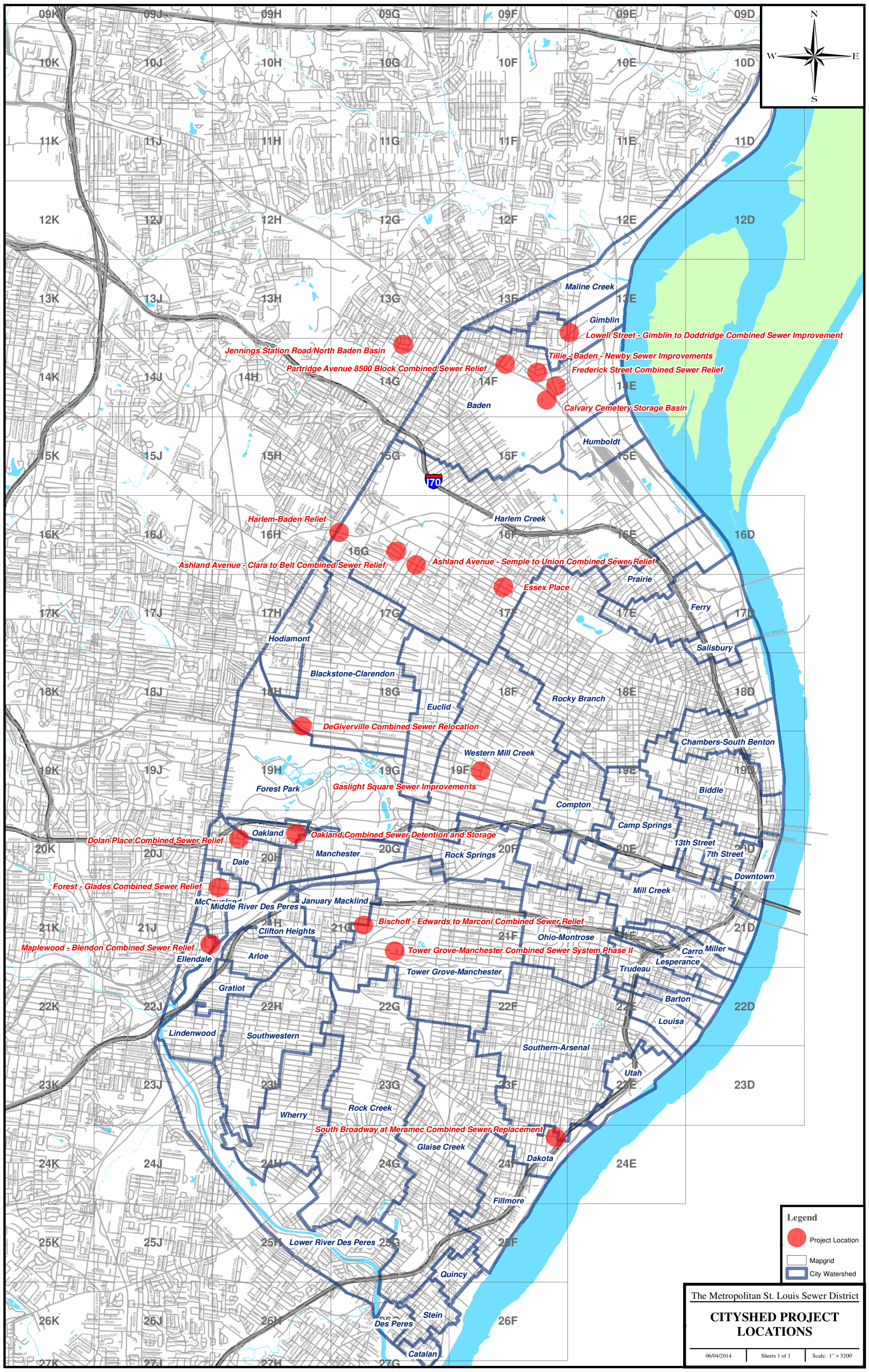

Figure 2. The Cityshed Project.

Old North Rain Garden

In some areas that fall under the Cityshed Program, recurring system surcharges are nearly impossible to prevent. In these areas, homes may have been built in low-lying areas or along original sewers that were once creek beds or even small lakes. Past efforts to "engineer" our way out of the problem resulted in limited success. Therefore, it was determined that offering voluntary buyouts to homeowners in specific locations – and removing them completely from these low-lying areas – was the best solution. Over the life of the Cityshed program, it is estimated over 200 individual property owners will be offered buyouts. The buyouts are modeled after Federal buyout programs and offer full relocation support for homeowners and/or their renters.

To date, approximately 190 homeowners have been bought out or offered buyouts. Once the homes are demolished, MSD will either use the property for a project – most likely a basin of some sort – or seek to find a community partner wishing to repurpose the land. In repurposing the land, MSD does require, in perpetuity, that the property not be developed on again.

The second program employed by MSD that echoes environmental justice is our Rainscaping Program, with rainscaping being what is commonly known in the wastewater industry as green infrastructure. Our definition of rainscaping

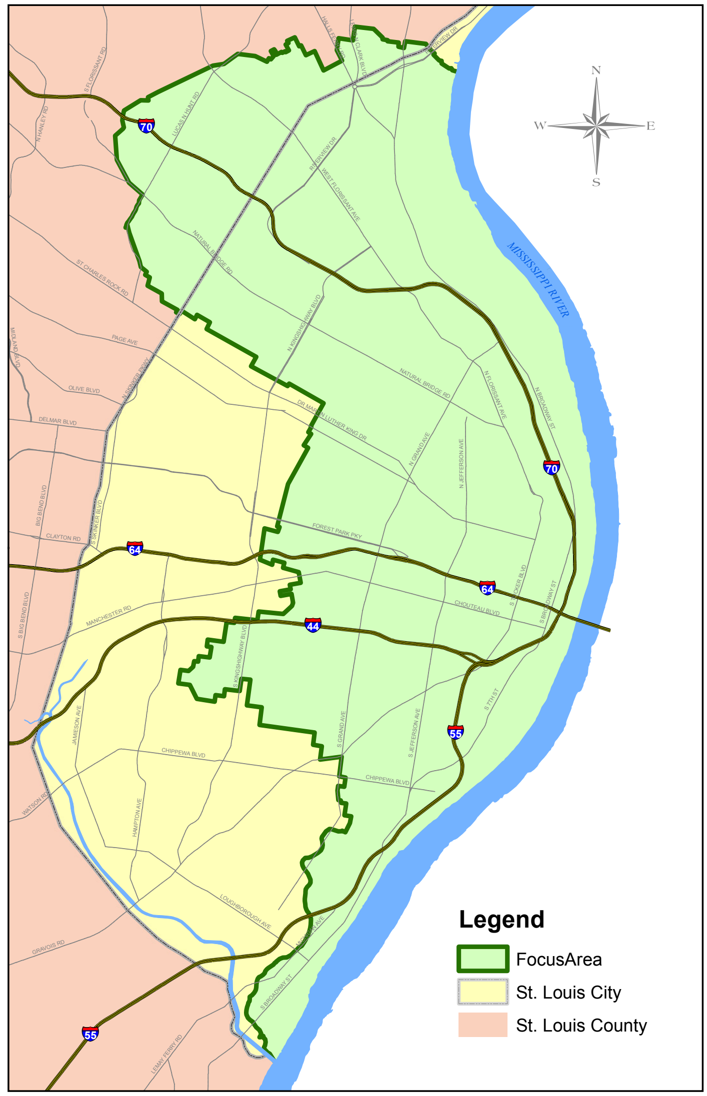

Figure 3. Rainscaping Focus Area.

is any combination of plantings, water features, catch basins, permeable pavements, and other activities that manage stormwater as close as possible to where it falls, rather than moving it someplace else (i.e., the sewer system). Below ground level, improved soils store and filter stormwater, allowing the surrounding area to slowly absorb it over time. Above ground level, native plants, basins, and water features create public green spaces that also help store water. Used effectively, rainscaping can reclaim stormwater naturally, reduce sewer overflows, and minimize basement backups.

While the Cityshed Program is spread throughout MSD's combined service area, the Rainscaping Program is focused on a concentrated section of our combined service area; specifically, the portion of the combined sewer system within the Bissell Pointe watershed. The Bissell Pointe watershed generally covers the eastern and northern portions of the City of St. Louis, extending into parts of St. Louis County (Figure 3). Through grant programs, cost sharing with developers, and direct spending, MSD is installing rainscaping features throughout the focus area. Over the life of the Consent Decree, this investment will total $100 million – which is a significant cost savings when compared to the conservative $1 billion estimate for a stormwater storage tunnel that might have otherwise been required under the Federal Clean Water Act.

The reason the Rainscaping Program echoes of environmental justice is that the area where this investment is occurring is a prime example of what happened to many older urban areas when suburban flight took place in the mid to late 1900s. A large percentage of the area's population is minority and low-income. From a built environment standpoint, the area is marked by pockets of dilapidated or abandoned housing and tracts of sparsely developed land.

MSD's hope, and the approach we have taken, is that the Rainscaping Program must be about more than Consent Decree compliance. Rather, it must be about finding and developing value adds that benefit the neighborhoods in which the Rainscaping Program is being implemented. For example, by partnering with progressive developers, we might be able to effect a more sustainable and healthier built environment for residents. Or, by partnering with non-profits that are dedicated to eliminating "food deserts" within urban areas, we might be able to bring healthier and more nutritious foods to underserved populations. While we are still in the early stages of the Rainscaping Program, it certainly holds more promise than if we had simply built a several mile long stormwater storage tunnel 150 feet below ground.

The third program that alludes to environmental justice is an Alternative Supplemental Environmental Project (SEP) Program, required by the Consent Decree. The SEP calls for MSD to spend at least $1.6 million on connecting low-income residents that have septic systems to the public sewer system.

Inadequate or failing septic systems present both public health and environmental risks that can be avoided by connecting to the public sewer system. However, many homeowners do not want to connect to the public sewer system due the upfront capital costs that are required. This financial obstacle is particularly acute for low income residents. In MSD's service area, it is estimated that 8,000 to 10,000 homes are still on septic systems.

The SEP Program includes the construction of sewer laterals and public sewers and the removal of septic tanks for homeowners whose annual income does not exceed the greater of $50,000 or 150% of MSD's Customer Assistance Program. The SEP Program includes the installation of sewer service lines (i.e., a lateral line that connects a home's plumbing to the public sewer system); repair or replacement of sewer service lines; construction of a public sewer line, if needed, to reach the homes of participating property owners; and removal of septic tanks once connecting to the public sewer is complete.

The SEP Program is voluntary and is available to residents of owner-occupied, single family homes that are on properties not connected to a public sewer; or for those who are connected to a public sewer and have a defective private lateral.

The 2016 Poverty Guidelines

Persons in family	Annual Income	Annual Income @ 200%	Annual Income @ 250%
1	$11,880	$23,760	$29,700
2	$16,020	$32,040	$40,050
3	$20,160	$40,320	$50,400
4	$24,300	$48,600	$60,750
5	$28,440	$56,880	$71,100
6	$32,580	$65,160	$81,450
7	$36,730	$73,460	$91,825
8	$40,890	$81,780	$102,225
For each additional person, add	$4,160	$8,320	$10,400

While the Consent Decree is a significant undertaking for MSD – and one that will dictate MSD's strategic activities for a generation – is it a challenge worth fully embracing? As we often say at MSD, if at the end of 23-years and spending $4.7 billion, all we did was achieve compliance with the Consent Decree, it would be a regulatory success, but a community failure. Spending of this size and duration offers a once-in-a-lifetime opportunity for a community. Accordingly, we must find ways for this spending to be about more than just sewers. Rather, it must also be about improving our community and improving the quality of life for those we serve. The three programs described above are but three "tools" we use to achieve this vision.

Brian Hoelscher is the Executive Director and Chief Executive Officer of the Metropolitan St. Louis Sewer District (MSD). He is ultimately responsible for all operational, financial, regulatory, leadership responsibilities at MSD, including implementation of a $4.7 billion, 23-year agreement with the Environmental Protection Agency and the Missouri Coalition for the Environment. Brian began his career with MSD in May 1995 as Manager of Construction. He has since held positions as Assistant Director of Engineering for Construction Management and Director of Engineering. Brian was named Executive Director/CEO in March 2013.

Brian holds a Bachelor of Science in Civil Engineering from Washington University in St. Louis. He is a licensed professional engineer in Missouri and Illinois. Brian is a member of the American Society of Civil Engineers, the Water Environment Federation, the Missouri Water Environment Association, and the Engineers Club of St. Louis, the latter of which he is a former director.

Leveraging Consent Decrees to Strengthen Neighborhoods

Susan E. Ashbrook
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The City of Columbus, Ohio has an approved integrated plan to address its wet weather Consent Decrees. This article will describe how the City pursued its integrated plan.

Background

The City of Columbus, Ohio owns and operates water, sewer and storm utilities that serve the City's 800,000 residents. In addition, the City provides water and sewer services to over 20 suburbs, for a total customer base of approximately 1.1 million.

The City's sanitary sewer system consists of almost 5,000 miles of sanitary sewers and two wastewater treatment plants. A small portion of the sewer system is a combined system, where the sanitary waste and the stormwater are directed into the same pipe, which is routed to the treatment plants. The combined area is located in some of the oldest parts of the City, specifically downtown and north to The Ohio State University. The rest of the City is served by separate sanitary sewers, with a separate storm sewer system. Over 90% of the City is served with the separate sanitary system. The sanitary sewers are routed to the treatment plants, while the storm sewers discharge rain water directly into creeks and rivers, without treatment.

The City's sanitary sewer system works extremely well most of the time. The treatment plants consistently meet all permit requirements. During heavy rain events, however, the sewer system can overflow. There are two types of sewer overflows.

The first are known as combined sewer overflows or CSOs. As noted, combined sewers were designed to carry both sanitary waste and rain water. During most rain events, the combined system transports all the rain and waste water to the treatment plants. The system is designed to overflow during certain large rain events.

The second type of overflows are sanitary sewer overflows or SSOs. The separate sanitary system is not designed to handle large amounts of rain fall; rain should be routed to storm sewers. Unfortunately, during heavy rain events, rain water can find its way into the sanitary sewer system. This mostly occurs in older neighborhoods. Rain water can get into the sanitary system through cracks in sewer pipes, both the public owned pipes and the privately owned pipe that goes from a house to the public sewer, known as a lateral. In addition, in older homes, the foundation drain around the home is often tied directly into the sanitary sewer, which also allows rain water into the system. This is known as "inflow and infiltration" or I/I. As the sanitary sewer system is not designed to handle large amounts of rain water, during these events the sewer may overflow into creeks or rivers. The sewers may also back up into basements, known as "water in basements" or WIBs.

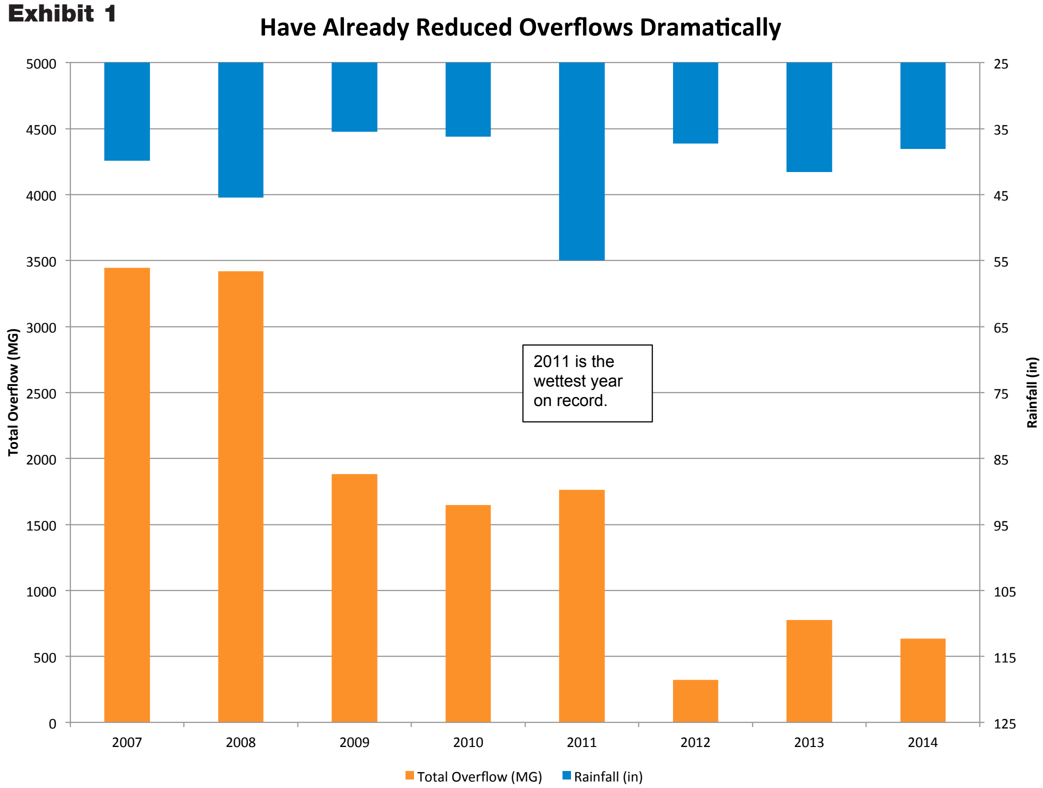
In 2002, the City and the State entered into a Consent Decree that requires the City to eliminate SSOs and WIBs. In 2004, the City and State entered a second Consent Decree to control CSOs. The CSO Consent Decree required the City to make a significant reduction in CSOs by 2010, and to have final controls in place by 2025.

In 2005, Columbus submitted a plan to Ohio EPA to address the requirements of both Consent Decrees. This plan, known as the Wet Weather Management Plan, included a number of features. First, to meet the interim date of reducing CSOs by 2010, the Wet Weather Management Plan called for increasing the capacity of both treatment plants by 50%. In addition, it called for a large five mile long CSO tunnel that will serve the downtown area.

The City successfully increased the capacity of the treatment plants in time to meet the 2010 deadline. This has led to a dramatic decrease in overflows (Exhibit 1). As shown on this exhibit, 2011 was a record wet year, and yet overflows were down significantly. The CSO tunnel is now nearing completion. The plant work and the new tunnel, which together cost approximately $1 billion, will largely complete the City's CSO obligations.

The rest of the City's 2005 Wet Weather Management Plan focused on SSOs and WIBs, and proposed two SSO tunnels as the primary solution. As noted above, the vast majority of the City is served by a separate sanitary system, so the tunnels needed to be much longer - approximately 14 miles each – or more than five times longer than the CSO tunnel. The SSO tunnels, which would

Exhibit 1



have cost approximately $2.5 billion, would only have activated during really heavy rain events that cause SSOs – maybe 4 or 5 times per year. And because the SSO volumes are a fraction of the CSO volumes, the value of the tunnels in terms of dollars per gallon of overflow removed, was not nearly as favorable as the CSO tunnel.

Another drawback to the SSO tunnel approach is that it would do little to improve water quality. The tunnels would remove relatively small amounts of raw sewage from the rivers, which is an improvement. However, the tunnels would do nothing to improve discharges from the City's storm sewers. In central Ohio, stormwater discharges have a more significant impact on water quality, as compared to sewer overflows.

Integrated Planning

On June 5, 2012, USEPA issued a memo entitled: Integrated Municipal Stormwater and Wastewater Planning Approach Framework. This memo was the result of several years of conversations between municipalities and USEPA regarding allowing municipalities more flexibility in Clean Water Act compliance. In particular, the memo states that one of its overarching principles is to "allow a municipality to balance CWA requirements in a manner that addresses the most pressing public health and environmental protection issues first." In addition, it recognized the importance of using green infrastructure.

In light of the Integrated Planning Memo and in light of its increasing concerns about the cost/benefit of the SSOs tunnels, in the summer of 2012 the City approached Ohio EPA and asked for permission to delay the first SSO tunnel, which was scheduled to start construction in 2014, while the City explored Integrated Planning. Ohio EPA and the City agreed that Columbus would submit an Integrated Plan on Sept. 15, 2015.

The central idea the City wanted to explore with integrated planning was whether the sewer overflows could be eliminated by going after the source of the problem: rain water (I/I) getting into sanitary sewers where is does not belong. Building big tunnels to transport the I/I entering the sanitary sewers is treating the symptom, not the cause.

The City has been studying I/I for decades. As a result of these studies, the City knows a great deal about where and how the I/I is occurring. The majority of the I/I is entering the system from older residential neighborhoods. In particular, homes built before the early 1960s, before sump pumps were required, often have foundation drains that allow rain water to go into the sanitary sewers. These same homes also tend to have clay laterals, which deteriorate over time, again allowing rain water in.

The City's approach to I/I removal thus focused on individual homes. It has three main components. These are depicted on Exhibit 2 and described below.

Lining of sewers including City owned mainline sewers and the private laterals connecting homes to the City sewer. Lining is a process that allows a sewer line or lateral to become rehabilitated and to function as a new plastic pipe.

Redirecting of rooftop water away from homes and into the right of way. This protects foundation drainage around the house from the roof water. The City's analysis determined that roof water should be directed at least seven feet from the home.

A voluntary sump pump installation program to further protect the foundation drain. A sump pump can intercept an existing foundation drain and move all of that rain water to the street.

The bulk of developing the integrated plan was spent determining how much I/I could be removed using these three strategies. The City used existing research and its own I/I studies to make reasonable assumptions about how much I/I could be

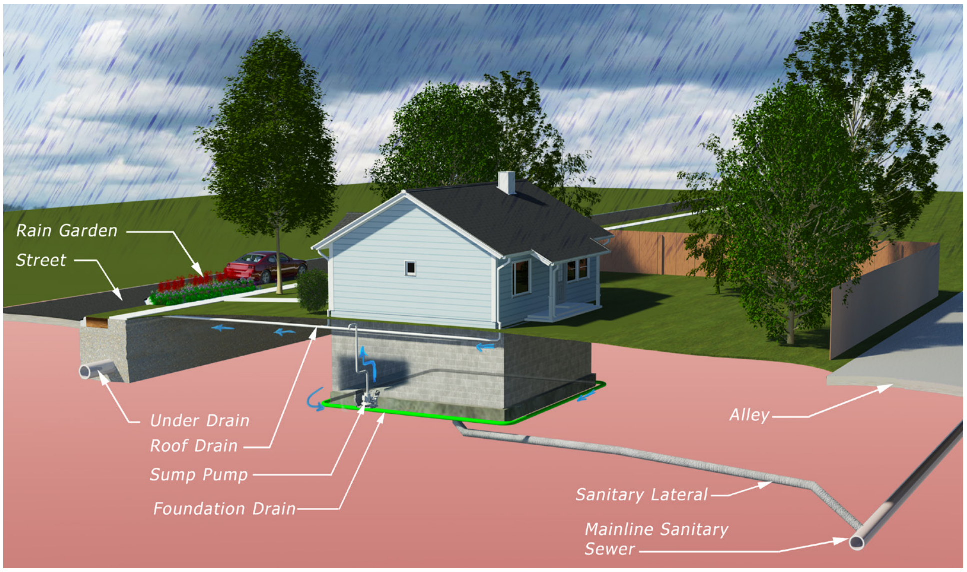


Exhibit 2

removed per house and also how many houses could reasonably be expected to participate. The City used a computer model of its sewer system and twenty years of rain records to run various scenarios. As a result, the City identified approximately 18,000 acres of the City which needed to have the I/I removal technologies applied to the homes in order to eliminate SSOs. See Exhibit 3.

In addition to the I/I removal, the City also wanted to include in its plan a component that directly addressed stormwater. The City was concerned that removing rain water from the sanitary sewer and routing it to the streets might make local flooding worse. In addition, the City wanted to achieve a substantial water quality improvement. To meet these goals, the City is including a robust green infrastructure component in its plan. The green infrastructure will be built on City owned property, such as right-of-ways, parks and vacant lots. Exhibit 4 is a new park with substantial green infrastructure completed as part of this effort. The green infrastructure will be designed to meet a "*do no harm*" standard with regard to flooding, and a 20% removal rate for total suspended solids, a common pollutant of concern in stormwater.

Blueprint Columbus: Clean Streams. Strong Neighborhoods.

Unlike "*out of sight, out of mind"* tunnels, the integrated planning approach contemplated by the City will impact local neighborhoods much more directly. This will be especially true as

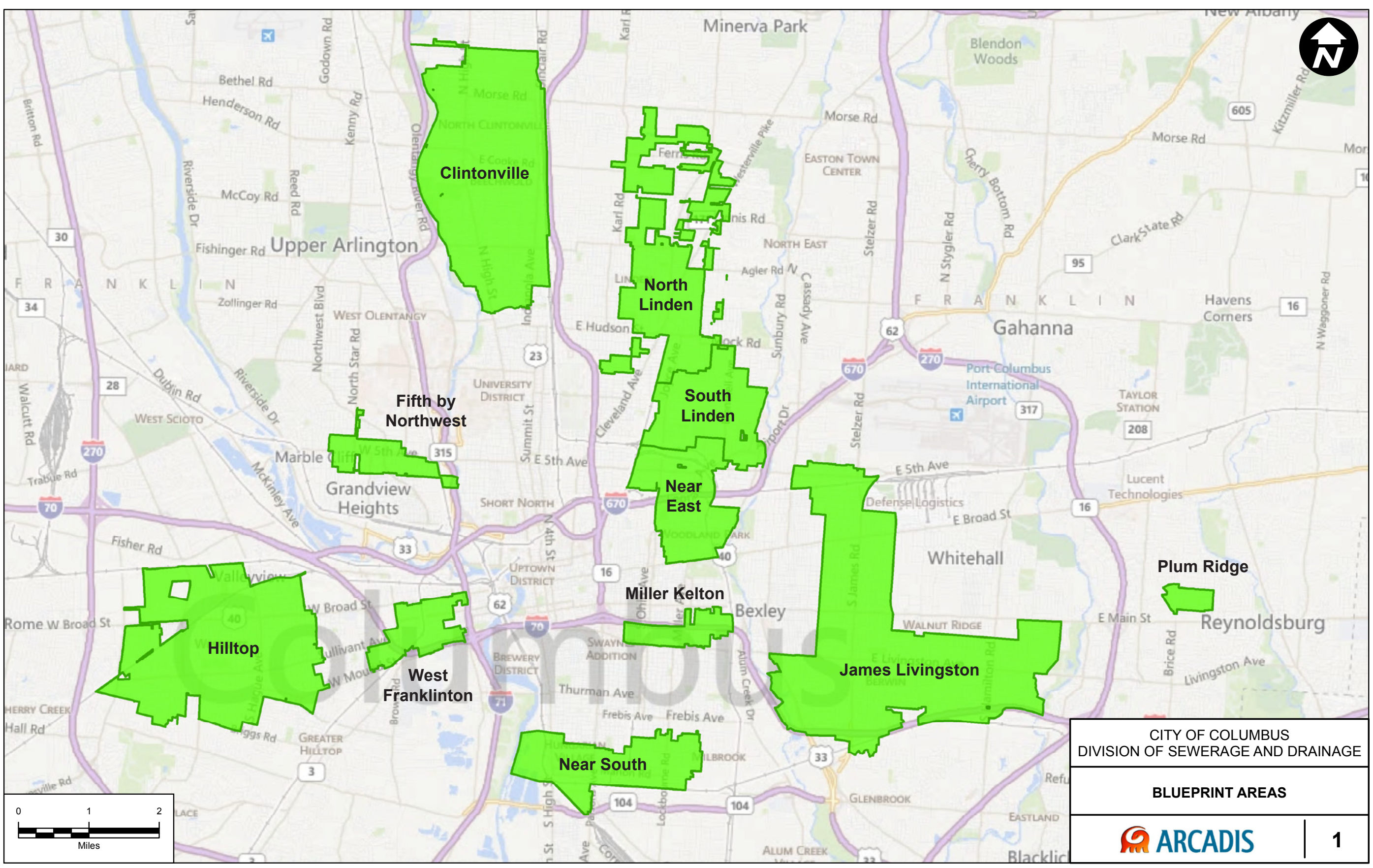


Exhibit 3

Exhibit 4

the City pursues elimination of private I/I, which would involve doing work on private homes in certain neighborhoods. As such, the City determined that as part of developing its integrated plan, it needed an effective outreach and education effort. An education effort was also required by the Integrated Planning Memo. The U.S. EPA Integrated Municipal Stormwater and Wastewater Planning Approach Framework Element 3 states that while developing an integrated plan, municipalities should provide the opportunity for meaningful input from relevant community stakeholders.

The City branded its new program "Blueprint Columbus: Clean Streams. Strong Neighborhoods." Columbus believes this tag line helps convey that this is more than just a sewer project. Exhibit 5.

One challenge in designing a robust community engagement was determining how to make sure all populations are included. Columbus is a large and diverse City. Gaining resident and small business perspectives about this new approach came with some challenges. The outreach team developed primary filters for the selection of four representative neighborhoods to focus its outreach efforts in, such as locations where residents are more likely to be affected by Blueprint Columbus in the near term and areas where one-third of the housing stock was built before 1960. The team then used secondary selection criteria to assess the actual size of the clusters, the percentage of owner-occupied housing and the percentage of neighborhood businesses. In the last stage of the selection process, the project team maintained a balance of underrepresented demographics to ensure the appropriate mix of race, education levels and home values.

The engagement strategy featured a variety of educational tools and engagement methods designed to have mass appeal while also targeting hard-to-reach populations. The strategies included: creation of a video; distribution of baseline and reinforcement educational materials; neighborhood educational events; focus groups; and residential polling on the Blueprint and traditional WWMP approaches to reduce SSOs in Columbus. See Exhibit 6.

The engagement process produced a rich portrait of stakeholder views regarding sewer overflows and the Blueprint Columbus approach. Generally, residents found the proposed Blueprint solutions interesting and thought-provoking, and they were pleasantly surprised that the City took the time to inform them and ask for their input. Polled residents responded overwhelmingly positive or neutral to Blueprint Columbus. This finding remained consistent across the four representative neighborhoods, as well as the city at large. Over seventy percent

BLUE PRINT COLUMBUS

Clean streams.
Strong neighborhoods.

Exhibit 5

Exhibit 6

Exhibit 7

Blueprint Also Works Better

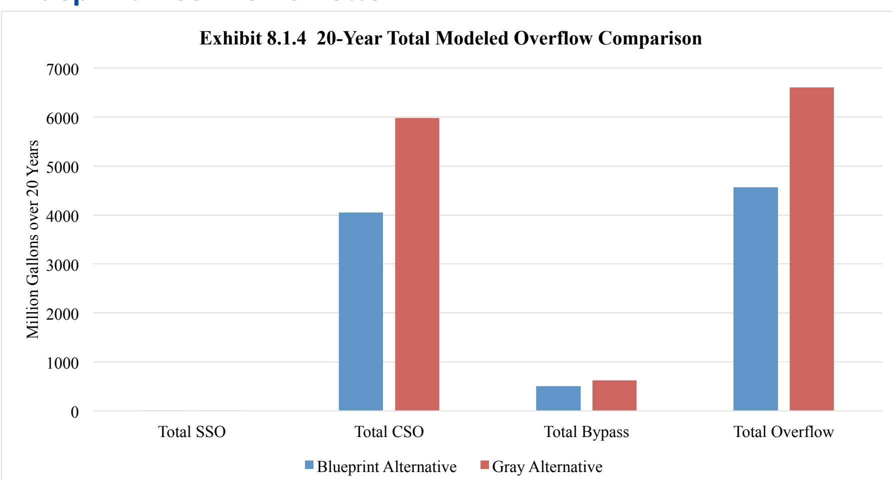


Exhibit 8

of all survey participants support the Blueprint Columbus approach; less than three percent did not support the plan. Of the four components of Blueprint, green infrastructure by far ranked as the most appealing. Respondents saw it as neighborhood beautification. Respondents were also pleased to learn that their laterals would be repaired at no direct cost to them.

In addition to the community engagement, the City also established a Community Advisory Panel (CAP) to advise the City of Columbus on the development of its Integrated Plan. Representatives from Columbus' diverse neighborhoods, the business community, environmental interests, construction and homebuilding firms, academia, other governmental agencies, senior citizen advocacy groups and ratepayers served on the CAP. See Exhibit 7. CAP met eight times and had two field trips.

The CAP was educated on the existing sewer system, wet weather issues, affordability analyses, anticipated workforce and economic development impacts, and proposed work schedules and implementation plans. The CAP provided feedback to the City on the various approaches and solutions. Members shared concerns and raised questions that helped the City to clarify its messaging and to be more effective in its communications. CAP voted overwhelmingly to support the City's integrated planning approach.

Final Plan Submitted and Approved

The City submitted its 2015 Wet Weather Management Plan Update and Integrated Plan to Ohio EPA on September 15, 2015. This plan, known as the Blueprint Report, included two full plans. First, the City updated the 2005 WWMP, which was basically an update of the two SSO tunnels. In addition, the City submitted a "blue" alternative, which focused on I/I removal and green infrastructure. It turned out that the Blue alternative was actually more effective in reducing overflows. See Exhibit 8.

The Mayor's submittal letter to Ohio EPA highlighted some of the advantages to the Blueprint alternative:

It is faster and cheaper. The 2005 WWMP included a 40 year schedule, meaning that the improvements would not be completed until 2045. If the City were to proceed with implementing the 2005 WWMP, it will have to spend $2.5 billion over the next thirty years. Instead, the City is proposing to implement Blueprint Columbus, which will cost $1.8 billion over 20 years and achieve the same or even better results.

It is greener. Blueprint Columbus will be significantly better for the environment than the original plan because of the green infrastructure contained in the improvements. In fact, as previously noted, the City has already dramatically reduced CSO overflows. Both the WWMP and Blueprint will eliminate the remaining overflows, but Blueprint will also improve stormwater discharges, resulting in better water quality.

It is more affordable. Even with the accelerated schedule, the City will be able to manage rate increases. Unlike the 2005 WWMP, the Blueprint plan should not create any double digit rate increases.

It is better for our neighborhoods and our local economy. Blueprint will create neighborhood amenities. For instance, in the Clintonville pilot area, the City is proposing to build a porous pavement street, which will include a sidewalk. In the Barthman-Parsons pilot area, the City is building a park, rain gardens and a porous pavement basketball court. Blueprint will also create more jobs and have a greater impact on our local economy.

It is what our community wants. The City has done significant public outreach as part of this planning effort. While many residents are concerned about rates, once it is explained that there is no "*do-nothing*" alternative, the community is overwhelming in support of Blueprint. As the Dispatch opined, "If the city of Columbus has to spend $2.5 billion to stop stormwater from overwhelming sanitary-sewer lines, getting the job done by turning roadside strips, vacant lots and patches of park into grassy rain gardens is far more appealing than building 28 miles of underground tunnels that would sit empty all but a few days per year." Columbus Dispatch Editorial, March 19, 2014.

See cover letter of Blueprint Report at www.Columbus.gov/blueprint

On December 1,2015, Ohio EPA approved the City's Blueprint Report recommended approach. The City is currently implementing Blueprint Columbus.

Ms. Ashbrook has been an environmental attorney and advocate for over 25 years. Currently, Ms. Ashbrook oversees the City's Department of Public Utilities' sustainability and regulatory compliance program. The Department provides water and sewer services to over one million residents of Central Ohio. The Department also has a Division of Power that is responsible for providing power to numerous customers and maintaining street lights. Ms. Ashbrook is currently involved in various projects, including Blueprint Columbus, GreenSpot, and the Department's certified EMS program.

METROPOLITAN SEWER DISTRICT of greater CINCINNATI

Necessity is the Mother of Invention: MSD of Greater Cincinnati's Use of Technological Innovation to Lower Costs for Customers

Jack Rennekamp
Deb Leonard
Gina Marsh

"A crow perishing with thirst saw a pitcher, and hoping to find water, flew to it with delight. When he reached it, he discovered to his grief that it contained so little water that he could not possibly get at it. He tried everything he could think of to reach the water, but all his efforts were in vain. At last he collected as many stones as he could carry and dropped them one by one with his beak into the pitcher, until he brought the water within his reach and thus saved his life."[1] Moral of the story? Necessity is the mother of invention.

Like the crow in this Aesop fable, the Metropolitan Sewer District of Greater Cincinnati (MSD) was pressed to find a solution to a knotty issue: how to make a $3.2 billion Consent Decree to reduce combined sewer overflows (CSOs) more affordable to its customers in an urban area with high rates of poverty.

As a Midwestern utility serving more than 200,000 households and commercial users, MSD turned to a technological innovation as practical as adding pebbles to a pitcher of water: using the existing collection and treatment system to reduce CSOs instead of building expensive new infrastructure.

Historical Background

Like other "legacy city"[2] sewer utilities across the United States, MSD negotiated a settlement agreement (Consent Decree) with the U.S. EPA, Ohio EPA, and ORSANCO[3] to reduce combined sewer overflows (CSOs) and eliminate sanitary sewer overflows (SSOs) by making wet-weather capacity improvements to its sewage collection and treatment system. This unfunded federal mandate was put into effect in 2002 and 2004. During a typical year, about 11 billion gallons discharge from more than 200 CSO outfalls along local rivers and streams in Cincinnati and Hamilton County. One of these waterways is the Mill Creek, an industrialized and channelized urban waterway running through the central City that was once critical to the city's and county's early residential and commercial development. In 1997, it was designated by American Rivers as the "most endangered urban river in North America."[1]

MSD's $3.2 billion Consent Decree is structured to eliminate specified SSOs, to reduce the volume of CSO discharges, and to adjust the utility's ability to treat wet weather flows in the system, approximately 40% of which is a combined system. Improvement in water quality is an optimal by-product of this effort. MSD's Phase 1 series of Consent Decree projects are designed to provide sufficient volumetric capacity where needed, to provide variable stormwater source control to reduce the CSOs when and where possible, and to improve the ability to treat wet weather flows that reach the end-points of the system. These end-points are comprised of three river-based wastewater treatment facilities that were initially constructed between 1953-1961 during one of the first phases of sewage treatment in the middle Ohio River Valley. Phase 2 of the Consent Decree will be developed in 2017 and implemented after 2018.

The MSD Consent Decree enforces criteria for getting to "clean," with the specifics outlined by a U.S. District Court-approved wet weather improvement plan (WWIP). Re-inventing and re-invigorating Hamilton County's 188-year-old sewer system to comply with modern pollution control requirements is not only technically challenging – as most sewer assets are complex networks of buried pipes – but fiscally exasperating as well. The improvements delivered as a result of MSD's Consent

Decree WWIP are publicly financed expenditures, paid for by sewerage services costs (rates), that create questions of equity for all rate-payers.[2] The Cincinnati Standard Metropolitan Statistical Area has a 14% rate of urban poverty among its residents (30% within the center city of Cincinnati), including crisis levels of childhood poverty in its center city. Consent Decree costs have spawned a need to innovate technologically.

The Innovation

Sewers and wastewater management and the civil engineering behind its processes are nothing new in a historical context. So, use of the term "innovation" in this industry is rather odd for what is basically a 2,000+ year old technology. After all, there are only so many ways that humans can transport and treat their waste products in an urban setting in ways that have not been used before throughout history: pits and channels, chemical and biological treatment, membrane filtration, aeration, flocculation, and incineration, UV disinfection, interceptor sewers, flow monitors, combined sewer overflow controls, SCADA monitoring and controls and deep-tunnel storage. The historical goal of sewage control in American cities is to find the "ultimate sink" (or way to deal with urban wastes), the perfect confluence of technology and ability to modify and control the environment to suit human ends and protect human health.[3] But what if the innovation is not in new devices, but a combination of existing technologies in ways that have not yet been used? What if the outcome, the "invention," is to make the sewer system more useful and able to respond to rapid changes in flow through its pipes without taking away human control and accountability?

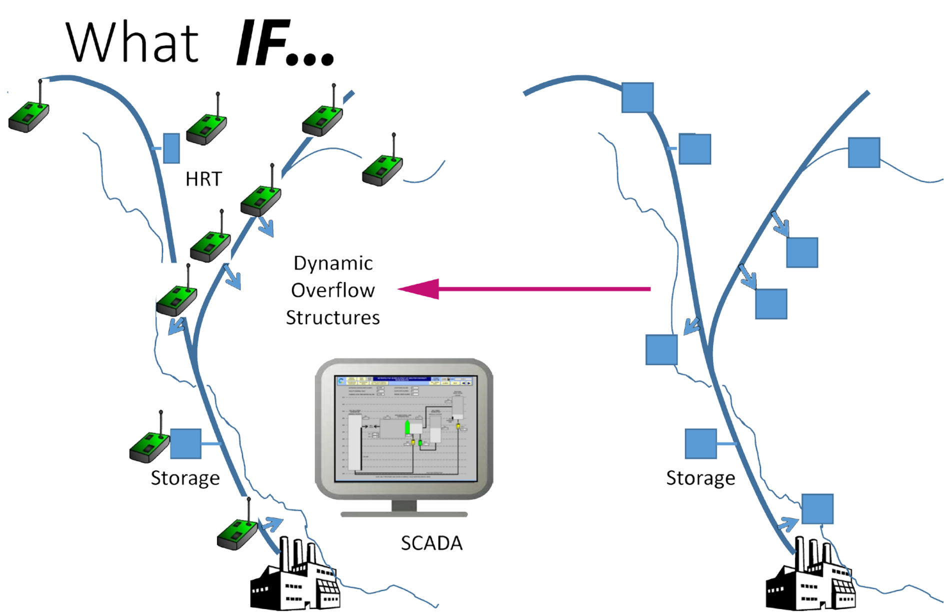
To that end, MSD is developing a smart sewer system that uses existing infrastructure combined with "real-time" controls, including sensors, gates and a computer-controlled monitoring system (Wet Weather SCADA). These "real time controls" are a paradigm shift in wastewater management: instead of only building bigger pipes, deeper storage tunnels, or new treatment plants, the utility can use, store, or divert excess flows to existing sewer lines, storage tanks or treatment facilities that have available capacity, thus reducing CSOs into local streams and rivers. South Bend, Ind. recently invested in a similar technology, which is projected to reduce its Consent Decree spending by 27%. MSD's new system is anticipated to save tens of millions of dollars in capital investments in Consent Decree projects.

How it Works

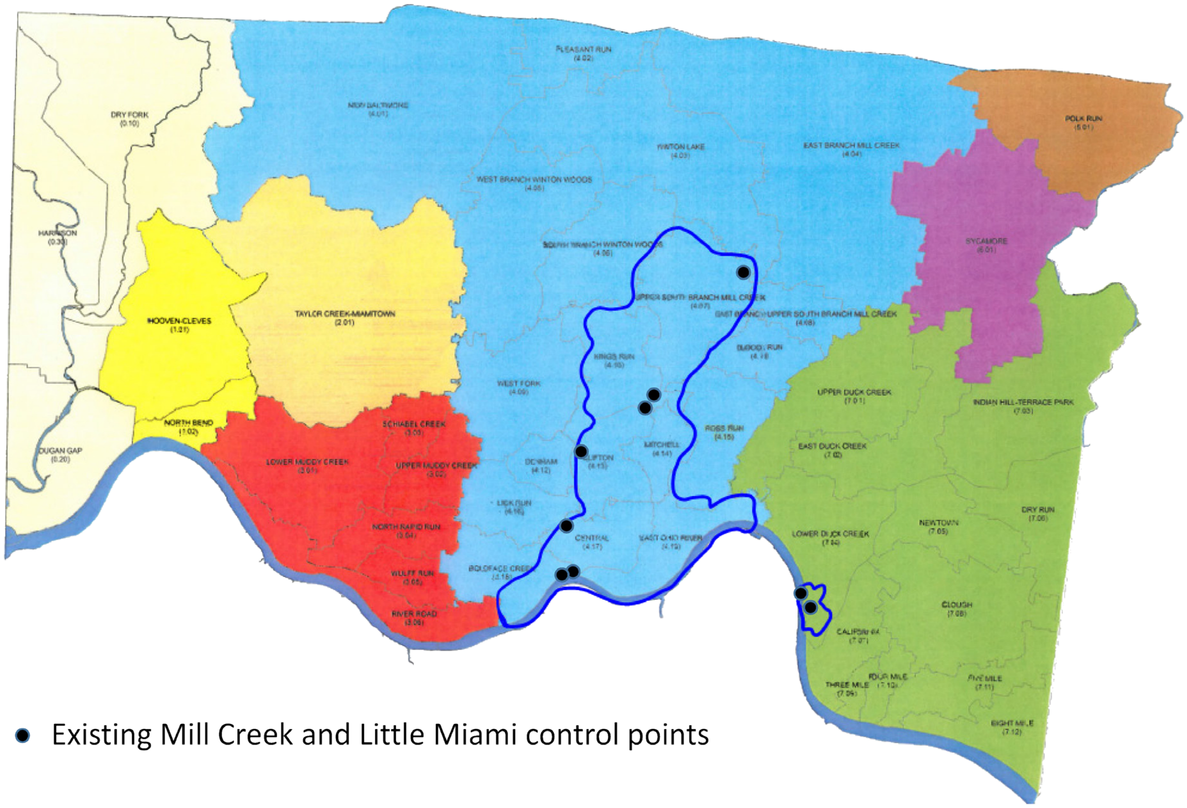
MSD sought to identify new ways to maximize capacity, repurpose existing sewer pipe, and develop a robust and dedicated SCADA control system to better effect the control of CSOs than traditional methods of static weirs and dams, and more costly measures like deep tunnels. MSD began by asking such questions as: "What if we could use all available capacity in our pipes before overflows occurred?" and "What if we could use an unused storage tank to reduce overflows many miles away?" MSD recognized that its best opportunity in managing a "dumb" system was to make it "smart:" to innovate by turning upside-down the traditional uses of sewer infrastructure and re-thinking the best use of its existing infrastructure. What if over 100 miles of interceptor and large diameter trunk sewers and several wet weather facilities, linked to a modern remote command and control SCADA system, could maximize the conveyance and treatment capabilities of this extensive infrastructure during rain events? Rather than manage system problems during wet weather, what if the paradigm was shifted, leveraging technology to operate the MSD collection system as an extension of the receiving treatment plant? Dynamic adaptability and flexibility would augment – and maybe even supplant – a static sewer system that was continually expanded over the last 100 years.

If a sewer collection system was to become "smart" and innovatively operated like a treatment plant, MSD would need to possess real-time command and controls to monitor, evaluate, and operate/control sewage flows throughout its pipe network. MSD created such a system through advanced, reliable, and low-cost cellular-based remote monitoring technology, installing over 140 sensors to "see" what's happening in the system. MSD also gave the new system a "brain" consisting of a new SCADA-based system platform on which it is building the visualization and analytic tools, similar to what is used to monitor and control treatment plant processes.

In early 2015, the District deployed its new Wet Weather SCADA system covering Mill Creek, its largest service basin. MSD is now able to guide wet weather control based on flow predictions and real time data, detect some instances of

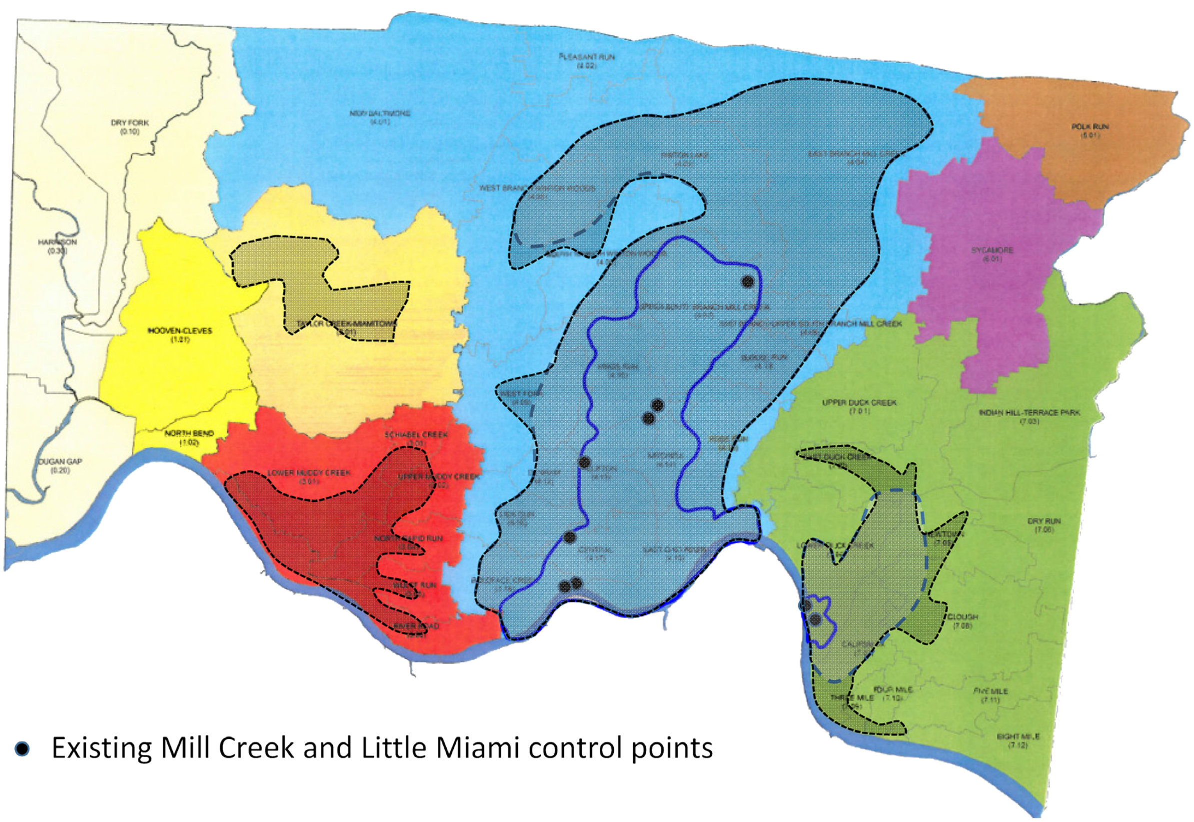


Wet Weather SCADA System Coverage June 2015



• Existing Mill Creek and Little Miami control points

Wet Weather SCADA System Coverage June 2016



• Existing Mill Creek and Little Miami control points river intrusion, and provide advanced alerts to operations and maintenance staff. This connectivity leveraged tying the existing wet weather control facilities developed under the Consent Decree into the new Wet Weather SCADA system.

This transformational technology provided real-time observation of the District's wastewater system over a large geographic area. Within the first several weeks, it was used to manage storage tank dewatering at a wet weather facility, avoiding 1.4 MG in overflow at a location nearly 11 miles away. It was also relied on to isolate large volumes of river intrusion during a period of Ohio River flooding, allowing the MSD treatment plant operators to direct the more concentrated wastewater to the plant for treatment. By limiting the intake from areas with higher river intrusion, the water temperature intake at the receiving plant also rebounded, resulting in more effective BOD treatment.

Added to this matrix of smart system command and control is an opportunity to dynamically maximize and re-purpose the MSD wastewater collection and treatment system to serve new ends: to develop an interactive – rather than reactive – system that will enable its static components to change the physical status at various points in the system, the ability to make a change in the physical system that modifies the hydraulic conditions, and thereby stores, conveys or treats more sewer flows.

Summary

Like Aesop's crow, MSD was faced with what seemed like an insurmountable problem and invented or innovated its way to a new, more affordable solution.

MSD's identification of technological innovation to manage wastewater evolved through a need to comply with its federal Consent Decree with scarce local resources. Its use of real-time controls allowed MSD to maximize its capital assets, both those that were required under the Consent Decree and those that were part of an existing system, creating a next level evolution of the traditional sewer system designed to collect wastewater through gravity and treat sanitary flows at a system endpoint. It allowed for on-going development of an adaptive sewer system that, while nearly 200 years old, is still able to serve the needs of its customers, grow to allow changing development to succeed, and be able to help in controlling costs of Consent Decree improvements. And, it recognized the reality that "legacy city" sewerage utilities can and must still protect the public health and the environment in an era when the sunk costs of the existing system must continue to be of value in order for it to fulfill its duty.

The authors of the article are City of Cincinnati employees working at the Metropolitan Sewer District of Greater Cincinnati. The Sewer District is a State of Ohio county sewer district, that is based upon a collaborative arrangement between 43 Greater Cincinnati municipalities, townships, villages, and the County of Hamilton, and is situated in the southwest corner of the state. It is managed by the City of Cincinnati's Department of Sewers under a 50-year agreement with Hamilton County, executed in 1968.

Jack Rennekamp is the Sewer District's Assistant Superintendent for Legislation Services and its historian. He specializes in the history of 20th century American politics and law, culture, and urban systems, and taught American History at the University of Cincinnati prior to joining the City of Cincinnati.

Deb Leonard is part of the Sewer District's communications and community engagement group, managing print and social media. She previously worked for Environmental Quality Management, Inc. as their Communications and Community Engagement Manager and has Accreditation in Public Relations (APR) with the Public Relations Society of America.

Gina Marsh is the Sewer District's Director of Government and Public Affairs. She previously served as its General Counsel, and as an Assistant City Solicitor for the City of Cincinnati Department of Law. As of press time, Ms. Marsh has left City of Cincinnati employment and is currently executive director of a Cincinnati non-profit human services collaborative.

References

1 Aesop's Fables, "The Crow and the Pitcher," http://www.aesopfables.com/cgi/aesop1.cgi?1&TheCrowandthePitcher&&crowpitc2.ram

2 As defined by the International City/County Management Association, "legacy cities" are "former industrial powerhouses and urban economic hubs rich with history and culture dotted throughout the Northeast to the Great Lakes regions that experienced dramatic decline through the 1980s." See http://icma.org/en/icma/knowledge_network/blogs/blogpost/1436/New_Strategies_for_Revitalizing_American_Legacy_Cities. Also see A. Mallach and L. Brachman, Regenerating America's Legacy Cities, 2013, Cambridge: Lincoln Institute of Land Policy. Approximately 772 urban communities across the U.S. contain "legacy" sewers infrastructure, mainly located in the Northeast, Great Lakes regions, and Pacific Northwest.

3 Ohio River Valley Water Sanitation Commission. Chartered by the 74th U.S. Congress in 1936 and ratified in 1948, ORSANCO was a mid-20th century multi-state effort at water pollution control, and a forerunner to U.S. environmental protection efforts that led to the U.S. Environmental Protection Agency in 1970. ORSANCO, First Annual Report, 1948-1949, 1949, Cincinnati.

The Indianapolis Combined Sewer Overflow Challenge

Excerpted from Citizens Energy Group Website
Jamie Dillard, Director, Wastewater Operations, Citizens Energy Group

Deep Rock Tunnel Connector

The Problem

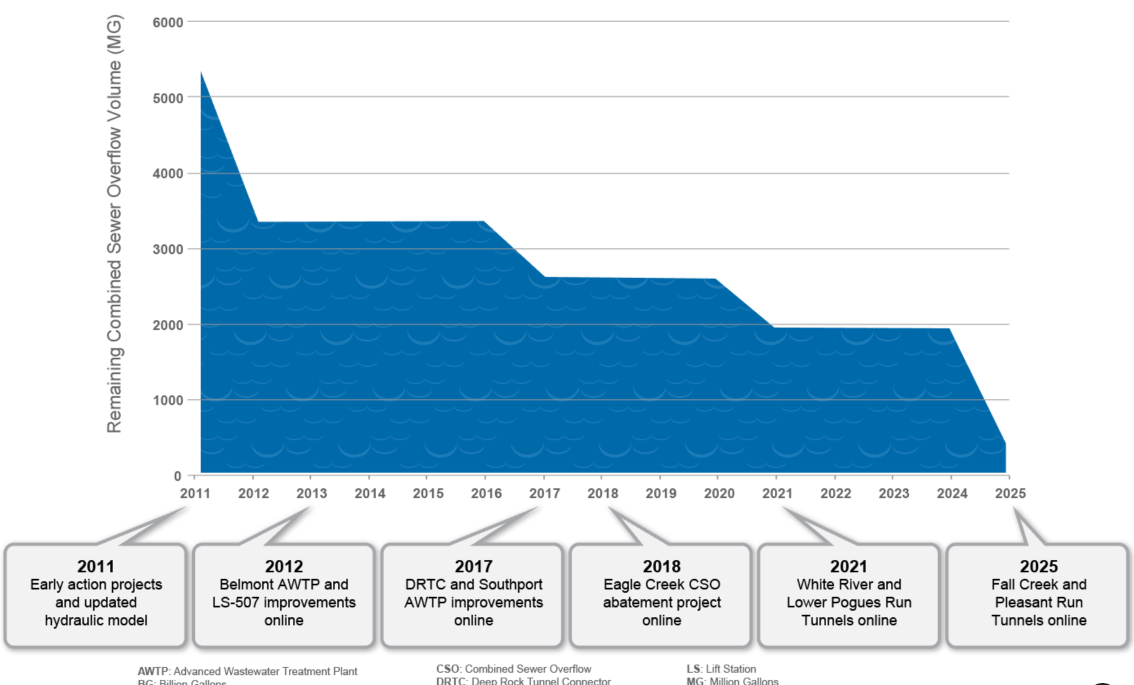
More than 100 years ago, Indianapolis built its first sewer system to carry storm water away from streets, homes and businesses. When indoor plumbing came along, sewage lines from homes and businesses were hooked to these same sewers, combining storm water and sewage in one pipe and sending it directly to our rivers and streams. These "combined sewers" were state of the art at a time when many communities did not yet have sewers of any type.

As sanitation engineering techniques improved and the city grew, the city built wastewater treatment plants to treat the sewage. Since Indianapolis was an unusually large city adjacent to a relatively small river, some of the early development of secondary treatment processes was done at the Indianapolis sanitary treatment plant. During periods of normal rainfall, the combined sewer systems function properly by conveying both storm water and sewage to wastewater treatment facilities. However, during periods of heavy rainfall, the combined system will allow raw sewage to overflow, called Combined Sewer Overflows (CSOs), into our streams and rivers causing a potential threat to public health. In the central part of Indianapolis within the combined sewer system, even a light rain storm can allow raw sewage to overflow and pollute Indianapolis waterways. Unfortunately, without the ability for the sewers to overflow, raw sewage would instead back up into people's basements and onto streets.

In newer neighborhoods today, we build separate sewers for storm water and sewage. However, combined sewers remain in many of the city's older neighborhoods. Raw sewage overflows are a major cause of wet-weather pollution in portions of White River, Fall Creek, Eagle Creek, Pleasant Run, Bean Creek, Pogues Run, Lick Creek and State Ditch in the Indianapolis community.

Under the U.S. Environmental Protection Agency (EPA) Clean Water Act, Indianapolis and other combined sewer communities must develop plans to reduce these overflows to protect human health and the environment. Ignoring these problems makes it more difficult to attract new businesses, jobs

Expected Average Annual CSO Volume Discharged to Waterways
Based on Current Consent Decree Schedule



and residents to our world-class city. To address CSOs, Citizens is implementing a $1.6 billion Long Term Control Plan that is required to be completed by 2025 under a Consent Decree with the EPA and the Indiana Department of Environmental Management (IDEM).

The table below indicates the volume of water discharged annually from the Combined Sewer System in Indianapolis. As we complete the Long Term Control the volumes discharged will decrease to a small fraction of the current volumes.

The Solution

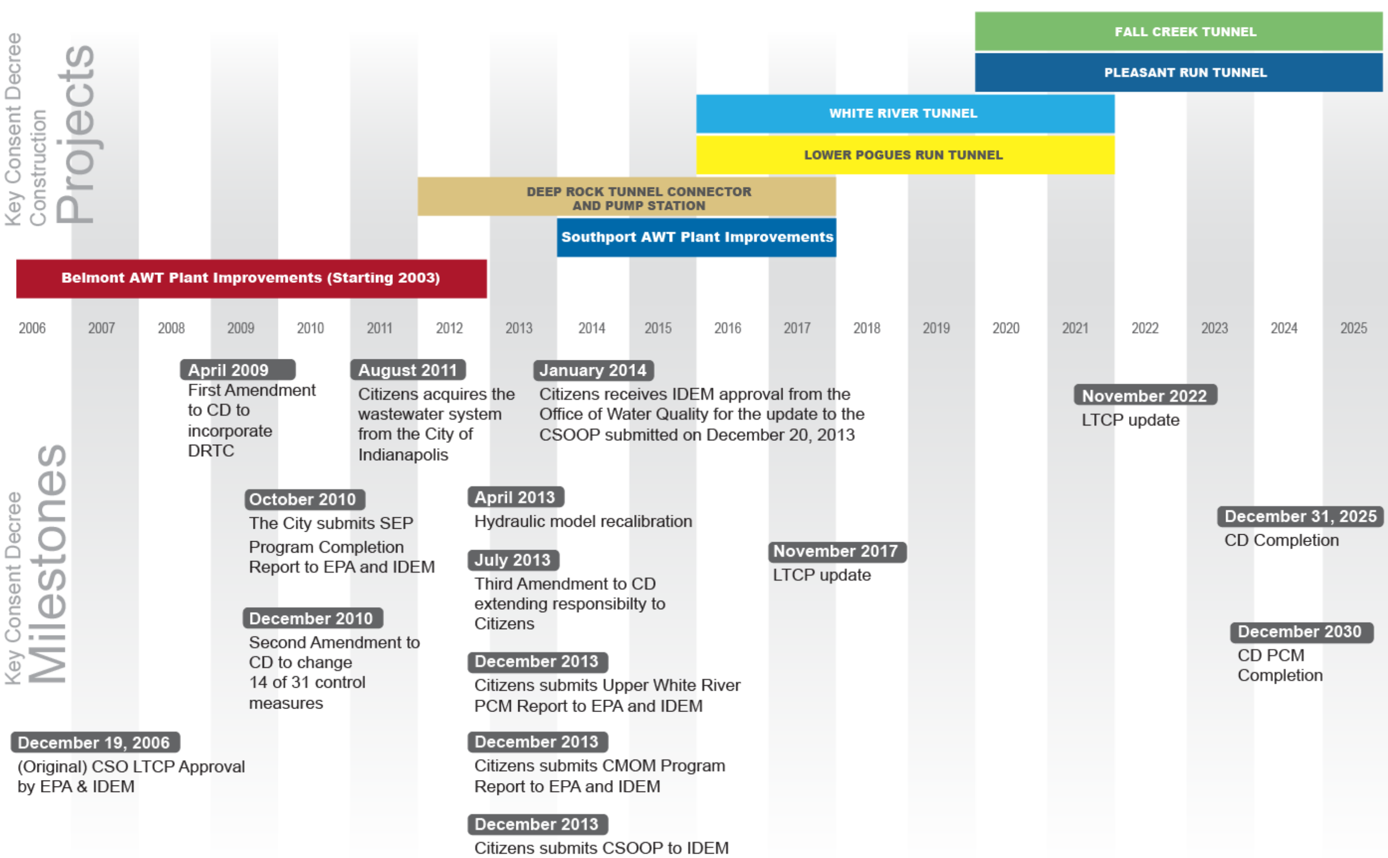
At more than 200-feet below ground, the DigIndy Tunnel System will store more than 250 million gallons of sewage during and after wet weather events, and then slowly release the sewage to the Southport Advanced Wastewater Treatment Plant, when capacity at the plant becomes available. When the project is complete, sewage overflows into Indiana waterways will be significantly reduced, and water quality will be improved.

The tunnel system will be built in bedrock 250 feet below the surface using a piece of specialized equipment called a tunnel boring machine. After the machine bores the tunnel, a tunnel lining will be installed. The lining will help keep groundwater out and keep sewage in the tunnel. By using deep tunnel technology, disturbances to neighborhoods along the project route will be reduced.

The Deep Rock Tunnel Connector serves as the first phase of the Dig Indy Tunnel System. Improvements to the first phase resulted in modifications to later project phases and revealed the potential for significant cost savings. The Deep Rock Tunnel will extend about 8 miles from the Southport Sewage Treatment Plant in southern Marion County to the 1700 block of West Street in downtown Indianapolis. The finished diameter of the tunnel will be approximately 19 feet, resembling a subway tunnel in appearance.

The Fall Creek and White River Tunnels will extend 7 to 10 miles, beginning near the Indiana State Fairgrounds on the north, running parallel to Fall Creek and White River, and ending

Timeline of Key Consent Decree Dates



CD: Consent Decree
Citizens: CWA Authority Doing Business as Citizens Energy Group
CMOM: Capacity, Management, Operations and Maintenance Plan
CSO: Combined Sewer Overflow
CSOOP: CSO Operational Plan
DRTC: Deep Rock Tunnel Connector
EPA: U.S. Environmental Protection Agency
IDEM: Indiana Department of Environmental Management
LTCP: Long-Term Control Plan
PCM: Post-Construction Monitoring
SEP: Supplemental Environmental Projects
The City: City of Indianapolis Department of Public Works

near White River Parkway East Drive and West Street on the south side of Indianapolis. The exact route of the tunnel will be determined during design of the project and will continue to be refined to ensure long-term environmental and economic benefits. The finished length of the entire tunnel system will be approximately 27 miles.

Also included in the Long Term Control Plan were significant expansions of both the wastewater treatment plants in Indianapolis. In 2012, the Belmont Advanced Wastewater Treatment Plant was expanded from a 150 MGD (million gallons per day) capacity to a 300 MGD treatment capacity. This expansion removed approximately 2,000,000 gallons annually of combined sewer overflows from the Indianapolis waterways.

In 2016/2017, the Southport Advanced Wastewater Treatment Plant will be expanded from a 150 MGD capacity to a 250 MGD capacity facility. This expansion will allow the plant to handle up to 90 MGD of discharge from the Deep Rock Tunnel facility without impacting the normal sanitary volumes treated at the facility.

In 2017, the first section of the Deep Rock Tunnel system will begin collecting and storing combined sewers overflow volumes. The Deep Rock Tunnel Pump Station will pump the stored volumes into the Southport Advanced Wastewater Treatment Plant for treatment.

The Indianapolis Long Term Control Plan is currently ahead of schedule. Upon full implementation, the CSO Control Measures are expected to result in:

- At least 95 percent capture and up to four (4) CSO events on the White River, Pleasant Run, Pogues Run and Eagle Creek in a typical year
- 97 percent capture and up to two CSO events on Fall Creek in a typical year

The timeline below indicates the key dates involved in the Indianapolis Long Term Control Plan.

The Benefits

Citizens' water and wastewater (sewer) investments will have enormous benefits for the quality of life and the economy of Central Indiana.

- **Public Health** - Virtually eliminating combined sewer overflows and steadily reducing the number of failing septic tanks over the next decade in Marion County will remove dangerous bacteria like E-coli from rivers, streams and neighborhood ditches.
- **Recreation** - As the White River, Fall Creek and other streams become clean again, people will be able to safely enjoy recreational activities such as canoeing, fishing and swimming.
- **Good Paying Jobs** - A newly released study by Black and Veatch projects Citizens water and wastewater investments will create or support 100,000 good paying jobs in the U.S. over the next 12 years, including 58,000 jobs here in Indiana. Citizens engages both local and diverse vendors and has defined goals for engaging minority, women and veteran-owned businesses.
- **Economic and Neighborhood Redevelopment** - Cleaner waterways will produce significant economic development and neighborhood revitalization across Central Indiana.

Strategies for Success

With the help of current and future vendors, designers and contractors, we are evaluating the sequencing, design and the capacity of the Indianapolis tunnel system. By employing a tactic known as value engineering, we are constantly looking for ways to reduce costs and maximize savings. As we continue to stay ahead of schedule in the Sanitary Sewer Discharge (SSD) and CSO Programs, Citizens will remove up to an additional four (4) billion gallons of CSO by 2025. Through ongoing collaborations with peer cities, such as Louisville, St. Louis, Cincinnati, and Columbus, OH, we are learning and developing best management practices.

Sustainability

Citizens' commitment to sustainability includes a focus on environment, business and community - known as the EBCs. We employ our EBCs by maximizing the efficiency of our operations, sustaining our business with financial and strategic planning, and our community with conservation incentives and public outreach.

Additionally, we will evaluate cost-effective sustainability programs for our capital projects, including the use of green infrastructure. As an effort to engage our community and support careers in science, technology, engineering and math (STEM), we have ongoing partnerships with Indiana colleges and universities to conduct guest lectures, seminars and tours to our construction sites for students seeking careers in the field of construction.

Citizens Energy Group is looking forward to the completion of the Long Term Control Plan and the positive benefits that it will bring to the community. The biggest challenge we face is the affordability of the solution and minimizing the cost impact of these improvements on customer rates in general and more specifically on our low-income customers.

Quantifying Water Quantity and Quality Benefits of a Permeable Pavement Stormwater Control Measure.

Sam Abdollahian, Engineering Specialist,
Vision Engineering, LLC
Hamidreza Kesemi, Research Associate,
Center for Infrastructure Research, University of Louisville
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Introduction

As a result of the impermeable surfaces in urbanized areas, during storm events a wide range of pollutants maybe be conveyed directly into the receiving waters and thus degrade water quality (Gan et al. 2008). Sediments, nutrients, pathogens (bacteria and viruses), heavy metals, deicing salts, oil and grease are some of the nonpoint source pollutants which are common in stormwater runoff and could be a danger to the quality of receiving waters (Schueler, 2003).

In recent years, the use of Green Infrastructure (GI) Stormwater Control Measures (SCMs) such as permeable pavements, bio-swales, and planter boxes to mitigate stormwater runoff by utilities has grown. While these SCM are proven effective at capturing and mitigate stormwater runoff before entering conveyance system they also potentially may mitigate water quality issues associated with stormwater runoff (Winer, 2000). Previous research indicate that GI SCM's can potentially reduce pollutant loadings from phosphorus, nitrogen, suspended solids and pathogenic bacteria (Brattebo and Booth, 2003; Hunt et al., 2008; Kaseva, 2004; Legret and Colandini, 1999). Thus, understanding both the water quantity and quality benefits of the GI SCMs is an important component to reducing the pollution within our surface waters.

This study conduct an initial assessment of the hydrological performance and pollutant removal efficiency of a permeable pavement system with an underlying infiltration trench. Previous research studies have found permeable pavements effective at mitigating surface runoff and effective mechanism for pollutant removal (Brattebo and Booth, 2003; Legret and Colandini, 1999; Fassman and Blackbourn, 2010). To quantify the hydrological performance of the GI SCM, the study examined embedded piezometers remotely monitored collected water levels changes inside this system correlated with rainfall data. The study compared a finite

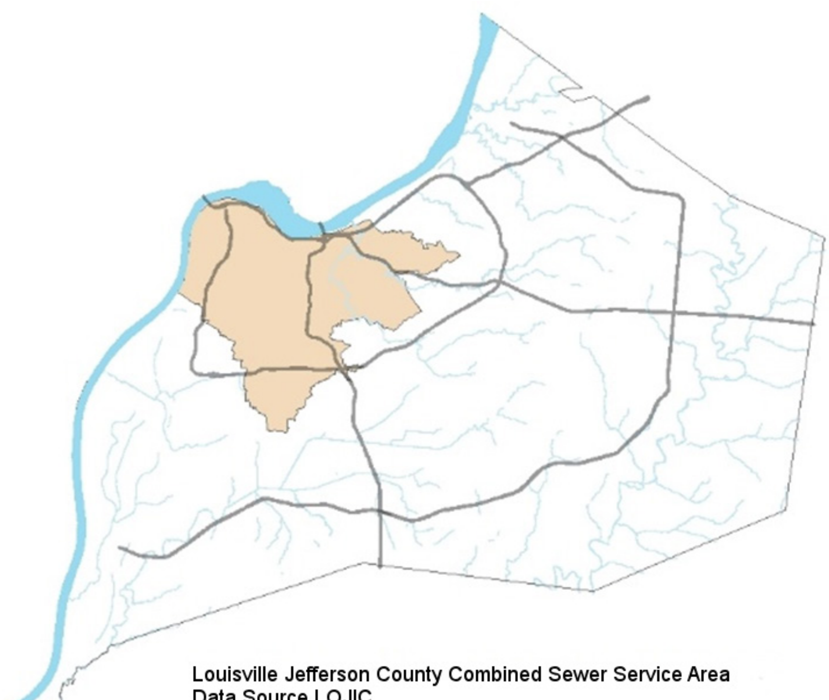

Figure 1: The CSS area encompasses 10% (43 sq. miles) of MSD's total service area.

number of grab samples of surface stormwater runoff and captured stormwater obtained from the bottom of the infiltration trench. The study measured the total suspended solids (TSS) and nutrients concentration of nitrate, nitrite, ammonia and TP, and Escherichia coli (E. coli) of samples collected from 11 rainfall events.

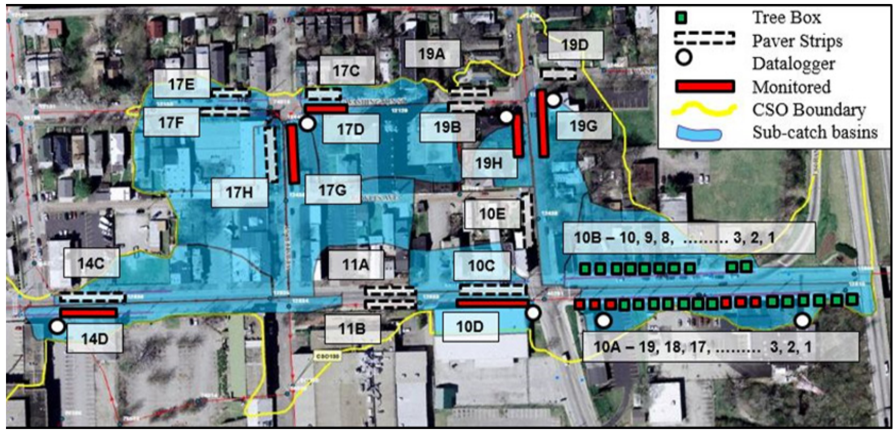

Figure 2: Study area

Background

During the early 1800s, Louisville constructed their first sewers system. Originally, these systems were designed to drain stormwater runoff to a river or stream. As indoor plumbing became commonplace, the city augmented the existing sewers to collect wastewater along with the rainfall, known as Combined Sewer Systems (CSSs). Today these systems continue serve communities inside the Watterson Expressway ("Louisville's Sewer Overflows", 2012).

During wet weather events, the stormwater runoff can exceed system capacity resulting in Combined Sewer Overflows (CSO). These CSO events can cause exceedances of water quality standards and may pose a threat to public health and safety.

To address these concerns, the Louisville Jefferson County Metropolitan Sewer District (MSD) is pursuing an aggressive sewer overflow abatement program under a federal consent decree by the Environmental Protection Agency (EPA) and Kentucky Department for Environmental Protection (KDEP). The MSD is examining both traditional gray solution as well as innovative green stormwater management solutions to mitigate the volume of frequency of these events.

In support the green infrastructure component, the MSD formed a coalition with U.S. EPA's Office of Research and Development (ORD), AECOM Corporation, and the Center for Infrastructure Research (CIR) at the University of Louisville. The CIR research team, under the direction of Dr. Thomas Rockaway, faculty member from the Department of Civil and Environmental Engineering, is working to quantify the potential quantity and quality benefits of green infrastructure utilizing field data.

Study Area

In 2011, MSD began installation of a series green infrastructure SCM's to mitigate the volume and frequency of CSO event of a small urbanized sewer basin, see figure 3. Over the course of three years MSD installed a total of 14 permeable paver strips and 29 tree boxes in the public right of way. To quantify the long-term hydrological performances of the systems, select SCM's were embedded with electronic sensors as well as lysimeters and monitoring well for assessing potential water quality benefits of select SCM's, see figure 2. This research presents a synopsis of the hydrological performance and preliminary assessment of the potential water quality benefits of a permeable pavement SCM's, referred to as 17G.

The permeable pavement system 17G utilized a permeable articulating concrete blocks/mats (PACB/M) produced that does not require aggregated filled joints. The construction specifications for 17G are provided in figure 3. The trench had a variable depth, with a maximum of 3.9 meters (12.75 ft.). The sub-drainage area for this SCM was approximately 0.43 hectare, resulting in a larger than normal drainage ratio of 27 to 1.

Methodology

To quantify the hydrologic performance of 17G, the study used a variety of electronic sensors and datasets. Four piezometers, installed at the bottom of the trench, monitored the water levels in 1-minute intervals. The rainfall data, used to estimate stormwater runoff, was derived from Next-Generation Radar (Nexrad) for 1-km2 pixels, recorded at 5-minute intervals.

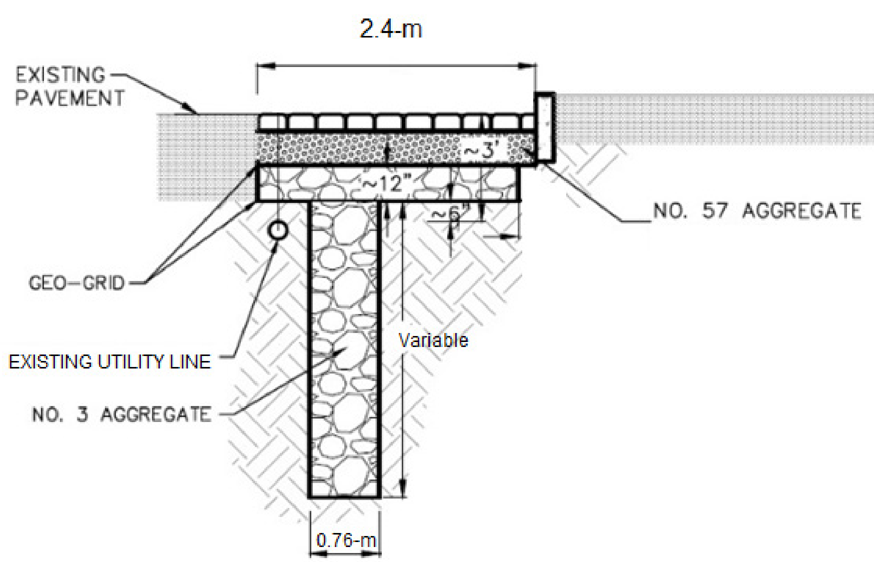

Figure 3: Cross-Section of the Permeable Pavement System 17G
(image source MSD)

Figure 4: Surface infiltration test apparatus

In addition to the electronic monitoring, manual surface infiltration tests were conducted before and after pavement surface cleaning operations (maintenance treatment) to evaluate the restoration in infiltration rates of the permeable surface, see figure 4. The tests followed a modified version of ASTM C1701 as introduced by EPA, which employs a neoprene gasket to provide the sealing between the cylinder and the preamble pavement surface (Borst 2010).

To quantify the water quality performance of the 17G, the study collected time-weighted composite samples and compared pollutant concentration levels at inflow and outflow points. Three individual grab samples of equal volume (250 ml) from the street runoff at equal time increments (10 minutes) were collected during the first 1.27 cm (0.5 inch) of rainfall events and then a single composite sample was prepared by mixing the grab samples. The runoff from the first half inch of precipitation, also referred to as 'first flush', represents a small portion of a storm's total discharge, but a large percentage of the total contaminant loading (Prince Georges County 1999).

To quantify the pollutant removal efficiency of the 17G, the research team samples extracted from the bottom of the trench through the 1-inch diameter monitoring by using a mechanical bladder pump. Following the previously established time-weighted composite sampling procedure, a single time-weighted composite sample from the stormwater runoff captured by the 17G.

Both the inflow and outflow samples were analyzed for E. coli analysis and the nutrients. All samples were tested for TSS [EPA 160.2], E. coli [EPA 1604], Nitrate-Nitrite (NO3+2-N) [Hach, TNT835 and TNT839 Equivalent to EPA 353.2], Ammonia (NH3-N) [Hach TNT831, Equivalent to EPA 350.1] and Total Phosphorus (TP) [Hach TNT843, Equivalent to EPA 365.3]. Additional field measurements conducted onsite following the sampling included pH, temperature, conductivity, Total Dissolved Solids (TDS) and conductivity.

Results and Discussion

Analysis of the water level changes inside 17G showed that over time the volume captured by the system decreased as compared to the months following installation of the GI. The maintenance treatment on June 19 2014, restored infiltration capacity, see Figure 5. An arithmetic mean of the measured water levels from the four piezometers is used for simplicity. The observed changes in infiltration performance is attributed to surface clogging caused by debris, fine sediments, and organic matter washed onto the surface with each rainfall event. As the clogging covers the surface of the permeable pavement, the infiltration capacity of the system decreases. Initial results from field surface infiltration measurements also indicated that measured infiltration rates were significantly restored on tested locations following the maintenance treatment, see Table 1.

To evaluate the changes in hydrological performance of 17G, measured water levels were used to calculate the captured stormwater runoff volume by considering the system's internal dimensions, porosity for the storage layer stones, and the intra-event exfiltration process. To correct for intra-event exfiltration, the recession rates (varying with different water levels) were estimated for the first two months following the installation of the 17G. By assuming constant recession rates, the measured water levels during rainfall events were corrected by adding up the water level escalation and recession rates. The corrected water level rise was used to estimate the total captured volume.

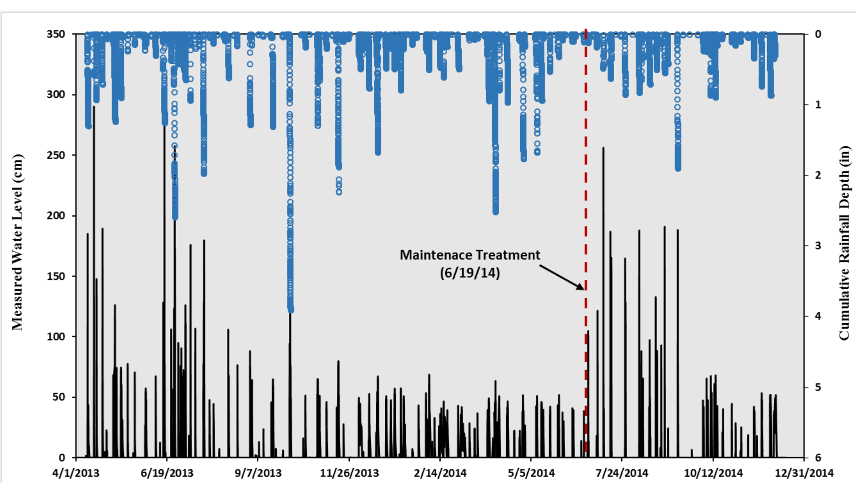

Figure 5: Average Measured Water Levels in GI 17G and the Cumulative Rainfall Depth per Each Rainfall Event

Following construction of the GI, it fully captured the stormwater runoff from the upgradient areas until the clogging covered a large portion of its surface. Since visual inspections during initial rainfalls didn't indicate any runoff bypass into the

Table 1: Measured Pre and Post-Maintenance Infiltration Rates

Distance from Upgradient Edge (m)	Distance from Curbside (m)	Infiltration Rates (cm/hr)	
		Pre-Maintenance	Post-Maintenance
6.1	0.15	-	3,230.4
12.2	0.15	11.5	3,545.6
16.8	0.15	91.8	4,153.4

Table 2: In-situ water quality measurements.

Pollutant	Number of Samples	Mean Concentration		Decrease %	*p*-Value
		Runoff	Captured		
E. coli (CFU/100ml)	11	**3420**	**1345**	**60.68**	**0.02**
TSS (mg/L)	11	**298.2**	**168.5**	**43.49**	**0.001**
Nitrate (mg/L)	11	0.694	0.691	0.41	0.985
Nitrite (mg/L)	11	0.056	0.044	21.4	0.275
Ammonia (mg/L)	11	0.21	0.124	41.33	0.098
Total Phosphorus (mg/L)	11	**0.323**	**0.167**	**48.34**	**0.004**

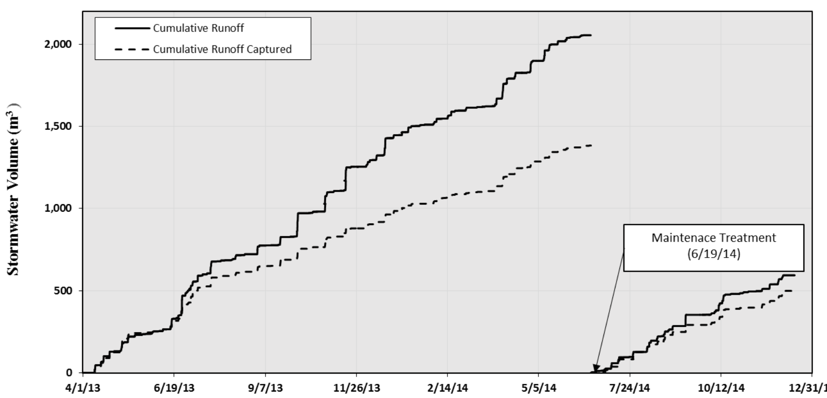

Figure 6 - Cumulative Surface Runoff and Volume Captured by GI 17G

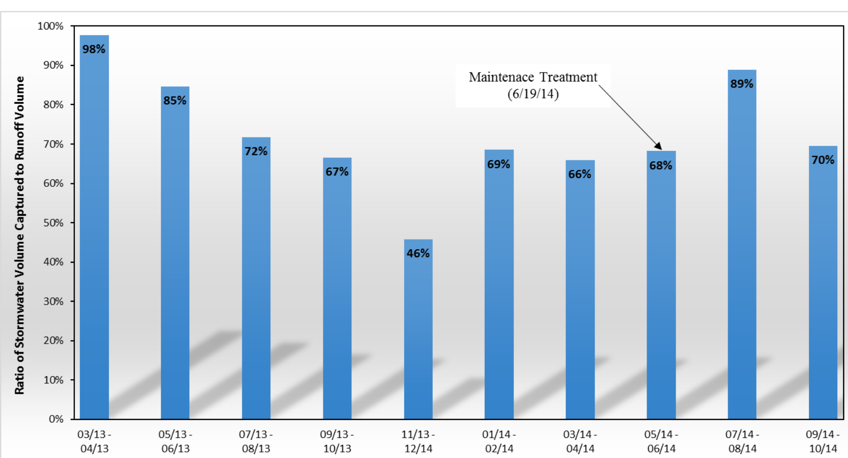

Figure 7 - Bi-Monthly Ratio of Stormwater Volume Captured to total Runoff

sewer system, it was assumed that runoff volume captured was equal to total runoff.

The effective drainage area for 17G was determined to be equal to 0.142 hectare (0.35 acre), with a drainage ratio of 27 to 1. Initial analysis of the cumulative stormwater runoff and captured volumes for 17G indicated the system captured most of the runoff stormwater volume until the end of June 2013. At this time the permeable pavement surface became clogged and the ratio of the captured stormwater runoff decreased. The comparison of the cumulative runoff and captured volumes were reset following the maintenance treatment and that the ratio of the captured stormwater volume to runoff volume was restored to 100% for a short period, see Figure 6.

To investigate changes in infiltration capacity the research team calculated the ratio of stormwater runoff captured to total runoff for every two months following the construction of the permeable pavements, see Figure 8. Initial results indicate that the minimum infiltration performance ratio occurred when the permeable pavement surface become clogged at the end of the fall season with its heavy organic debris. The average of infiltration performance for the period of September 2013 to April 2014, is equal to approximately 62%. Suggesting that even a clogged permeable pavement surface can still maintain a portion of their initial infiltration capacities.

While previous studies have investigated the ability of these GI practices in removing various pollutants from the stormwater runoff, there is very limited data available on their bacterial contamination removal efficiency. The research team examined the pollutant removal efficiencies of green infrastructure SCM, 17G, by comparing runoff and captured water pollutant concentrations. Initial observations indicate the captured volume had a lower concentration of TSS and E. coli as compared to the runoff samples, see Figures 8 and 9. The mean value of TSS and E. coli concentrations in the captured volume were found to be 61% and 43% lower compared to the runoff concentrations. According to paired t-tests,

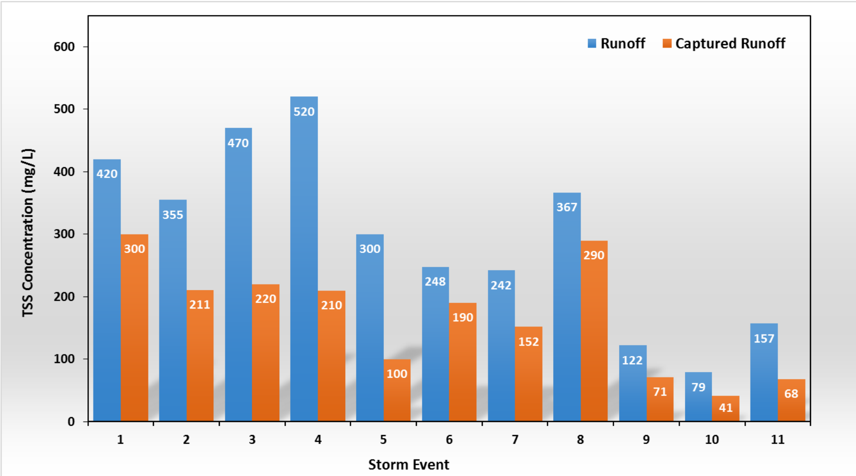

Figure 8 : Concentration of TSS from Runoff and Captured Samples per Rainfall Event

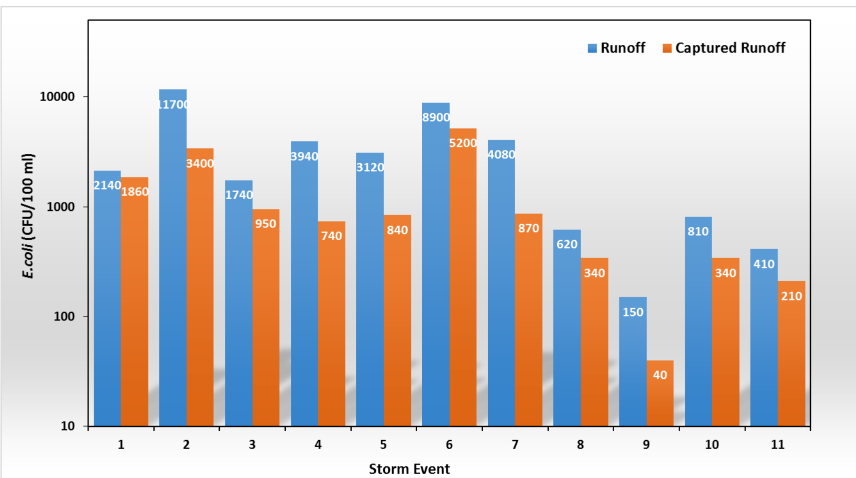

Figure 9 : Concentration of E. coli from Runoff and Captured Samples per Rainfall Event. The vertical axis is plotted on logarithmic scale.

the difference between the runoff and captured volume were significant (p-values< 0.05) for these two parameters.

Reductions of nutrients were not statistically significant, except for TP, which had a p-value of 0.004 and a 48% decrease. The average measured concentration of the other pollutants examined, NO3, NO2, and NH3, showed no significant differences between the runoff and captured samples.

The study also collected field measurement of pH, temperature, and Specific Conductivity (SC) values of the runoff and captured samples, see table 2. There was no significant difference was observed between runoff and captured volumes for any of these parameters.

Conclusions

This study examined the hydrological performance and potential water quality benefits of a permeable pavement SCM. Analysis of the water quantity data indicate that 17G efficiently captured stormwater runoff. Overtime clogging along the infiltration surface attributed to decreased efficiencies. Although the surface clogging limits the infiltration performance, the 17G still maintains 60% of its initial infiltration capacity. The minimum infiltration capacity observed for 17G was 46%, which was observed during the late fall season (November and December). Over the course of the water quantity data collection component of this effort (March 2013 – December 14), it was estimated that 2,684 (m3) of stormwater runoff flowed across GI 17G, of which 1,883 (m3) was captured. Surface maintenance treatments restored the infiltration capacity.

The preliminary water quality analyses indicated a significant difference for E. coli and TSS concentrations between the stormwater runoff and captured volume samples. The differences of nitrogen oxides (NO2, and NO3) and ammonia (NH3), as well as field measurement (pH, SC, and temperature), between runoff and captured volume samples were observed to be partial and insignificant.

The preliminary results indicate that permeable pavement systems can potentially provide secondary benefits beyond stormwater volume reduction by serving as effective pollutant removal mechanism. It is recommended that further study be conducted using a more robust analysis to confirm the water quantity and quality benefits of permeable paver systems and the impacts of maintenance activities on these benefits.

Acknowledgments

The authors would like to thank Mr. Michael Borst, Dr. Robert Brown from the U.S.EPA ORD as well as Pars Environmental Inc., AECOM, and the Louisville MSD management and staff for their support and guidance with this research effort.

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Dr. Hamidreza Kazemi is a research associate working for the Center for Infrastructure Research at UofL's Department of Civil & Environmental Engineering. He has earned his Ph.D. in Civil and Environmental Engineering at UofL and has a background in Geotechnical Engineering. Dr. Kazemi has extensive experience

in evaluating the hydrological and quality performance of Green Infrastructure Stormwater Control Measures. His research interests include stormwater, water, and wastewater management.

Mr. Josh Rivard a Research Coordinator for the Center for Infrastructure Research at the University of Louisville, has over10 years of experience addressing water infrastructure issues. He has worked on water infrastructure related grants for the international and national organizations, and has participated as speaker at many national conferences. Mr. Rivard holds a Bachelor of Science degree in Environmental Science from Morehead State University and a Master of Urban Planning (MUP) from University of Louisville.

Dr. Thomas D. Rockaway, Ph.D., P.E., is an Associate Professor in the Civil and Environmental Engineering Department, and Director for the Center for Infrastructure Research at the University of Louisville. His research work has focused on identifying methods to extend the life and improve the performance of urban infrastructure. Much of his worked has included water and wastewater initiatives and incorporating green concepts into existing systems. He has doctorate from the Georgia Institute of Technology, a Masters and Bachelors degree in Civil Engineering from Purdue University, and a Bachelor of Arts degree from DePauw University.

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The removal efficiency statistics for permeable pavements and infiltration trenches presented in the National Pollutant Removal Performance Database (Winer, 2000) indicate a relatively high removal efficiency for total suspended solids (TSS), and total phosphorus (TP), however the nitrogen oxides (NOx) removal was reported close to zero.

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