Chapter 8

Technologies Used to Reduce the Impacts of CSOs and SSOs

Since the enactment of the Clean Water Act in 1972, federal, state, and local governments have made substantial investments in the construction, operation, and maintenance of wastewater collection and treatment systems. Municipalities employ a wide variety of technologies and operating practices to maintain existing infrastructure, minimize the introduction of unnecessary waste and flow into the sewer system, increase capture and treatment of wet weather flows reaching the sewer system, and minimize the impact of any subsequent discharges on the environment and human health. For the purposes of this Report to Congress, technologies used to control CSOs and SSOs are grouped into five broad categories:

- Operation and maintenance practices
- Collection system controls
- Storage facilities
- Treatment technologies
- Low-impact development techniques

Most technologies and operating practices are designed to reduce, not eliminate, the discharge of pollutants and attendant impacts because it is generally not feasible to eliminate all discharges.

This chapter provides an overview of technologies used to control CSOs and SSOs. In addition, the chapter also discusses:

- Factors that can influence the effectiveness of specific technology applications;
- Combinations of technologies that have proven more effective than application of individual technologies; and
- Emerging technologies that show promise in controlling CSOs and SSOs.

A complete set of detailed technology descriptions is contained in Appendix L of this report.

In this chapter:

8.1 What Technologies are Commonly Used to Control CSOs and SSOs?

Municipalities have used numerous technologies and operational practices to reduce the volume, frequency, and impacts of CSO and SSO events. The performance and cost-effectiveness of these technologies is often related to a number of site-specific factors. Technologies deemed highly effective in one location may prove inappropriate in another. Specific factors that may influence the selection of a given technology include:

- Current condition of the sewer system;
- Characteristics of wet weather flows (e.g., peak flow rate, flow volume, concentration of key pollutants, frequency and duration of wet weather events);
- Hydraulic and pollutant loading to a particular facility;
- Climate, including seasonal variations in temperature and rainfall patterns;
- Implementation requirements (e.g., land or space constraints, surrounding neighborhood, noise, disruption, etc.); and
- Maintenance requirements.

This section describes 23 of the technologies and operational practices most commonly used to control CSOs and SSOs, including considerations for determining the applicability of different controls for individual locations. More detailed information on each technology, including cost and performance considerations, is presented in the technology descriptions provided in Appendix L of this report.

8.1.1 Operation and Maintenance Practices

Over time, CSSs and SSSs can deteriorate structurally or become clogged by FOG and other obstructions introduced into the sewer system. Left uncorrected, these conditions can result in dry weather CSOs and SSOs. Further, these conditions often are exacerbated during wet weather when the capacity of sewer systems and treatment facilities can be severely taxed.

The objective of O&M practices is to ensure the efficient and effective collection and treatment of wastewater and to minimize the volume and frequency of CSO and SSO discharges. For purposes of this report, O&M practices include activities designed to ensure that sewer systems function as designed and strategies that rely on public education and participation. The specific O&M practices considered for this report are summarized in Table 8.1 and include:

- Inspecting and testing of the sewer system to track condition and identify potential problems;
- Cleaning or flushing deposits of sludge, sediment, debris, and FOG from the sewer system;
- Working with customers to reduce pollutant loads delivered to the sewer system; and

- Establishing procedures for notifying the public in the event of a CSO or SSO.

Sewer Inspection and Testing

Sewer inspection is used to determine the condition of sewer lines and identify potential problems. Common sewer system inspection techniques can be grouped into two categories: manual and remote. Manual inspection techniques, such as visual inspection and lamping, are simple and typically limited to the first few feet of pipe upstream and downstream of each accessible manhole. Remote inspection techniques, such as closed-circuit television and sonar, use units that are either self-propelled or pulled through the sewer line to capture information on sewer condition.

In general, sewer testing techniques are used to identify leaks that allow unwanted infiltration into the sewer system and to determine the location of direct connections of storm water sources to the sewer system (e.g., roof leaders, area drains, basement sump pumps). Sewer testing techniques fall into three categories:

- Air testing
- Hydrostatic testing
- Smoke testing

Air testing and hydrostatic testing identify cracks and other defects in the sewer system that might allow storm water or groundwater to infiltrate. Smoke testing is used to identify connections that allow direct storm water inflow to the sewer system.

Sewer Cleaning

Sewer cleaning and flushing techniques remove blockages caused by solids, FOG, and root intrusion. Sewer cleaning techniques are particularly important because blockages are the leading cause of SSO events (see Section 4.7). Cleaning techniques fall into three categories:

- Hydraulic
- Mechanical
- Chemical

Hydraulic cleaning techniques employ the cleansing action of high velocity water. Cleansing velocities are achieved by allowing water pressure to build in a sewer line or by using a pump to produce water pressure. In general, hydraulic cleaning techniques tend to be simpler and more cost-effective in removing deposited solids when compared to other sewer cleaning techniques (CSU 2001). Alternatively, mechanical cleaning methods rely on a scraping, cutting, pulling, or pushing action to remove obstructions from sewer lines. Mechanical techniques

Table 8.1

Summary of Operation and Maintenance Practices

The objective of O&M practices is to ensure that sewer systems function as designed and convey the maximum amount of flow practicable to a treatment facility.

Technology	Type of System	Pollutants/Problems Addressed
Sewer inspection and testing	CSS, SSS	I/I
Sewer cleaning	CSS, SSS	BOD_5, TSS, nutrients, toxics, pathogens, floatables, FOG
Pollution prevention	CSS, SSS	Nutrients, toxics, FOG
Water quality monitoring and public notification	CSS, SSS	BOD_5, TSS, nutrients, toxics, pathogens

are typically used in areas where the volume, size, weight, or type of debris limits the effectiveness of hydraulic techniques. Chemicals can be used to control roots, grease, odors, concrete corrosion, rodents, and insects (CSU 2001). Chemicals can be helpful aids for cleaning and maintaining sewers, though chemical applications often are localized or coupled with a hydraulic or mechanical technique.

Pollution Prevention

Pollution prevention is defined as any practice that reduces the amount of pollutants, hazardous substances, or contaminants entering the waste stream, which in turn would mean fewer pollutants in potential CSO or SSO discharges (EPA 2002b). Pollution prevention practices most often take the form of simple, individual actions that reduce the pollutants generated by a particular process. Therefore, pollution prevention programs must be implemented with broad participation to realize a discernible reduction in pollutant loads discharged to sewer systems. Public education is a key component of most pollution prevention activities. Education programs are most successful when tailored to a specific audience (i.e., residential, institutional, or commercial).

Pollution prevention activities usually focus on best management practices for both commercial/industrial facilities and residential customers to reduce pollutant loads discharged to sewer systems. Pollutants of concern include FOG, household hazardous wastes, fertilizers, pesticides, and herbicides. In particular, the effective management of FOG has recently received attention as an important technique for controlling SSOs.

As reported in Chapter 4, FOG is the leading cause of blockages in the United States, and blockages account for nearly half of all SSO discharges. The best way to prevent blockages due to FOG is to keep FOG out of the sewer system. Many municipalities have adopted regulations controlling the introduction of FOG into the sewer system. Education programs are important in making residents and owners of institutional and commercial establishments, especially restaurants, aware of their role in managing FOG. Grease trap design and maintenance is a vital part of any

Sewer Cleaning: Sioux Falls, SD

The SSS for the City of Sioux Falls, South Dakota, consists of 578 miles of pipes ranging in size from six to 66 inches in diameter. The sewer system is divided into 20 drainage basins, and the maintenance program provides that the entire system is cleaned once every three years. Maintenance records are stored in a database that generates work orders by date and drainage basin. Sanitary sewer maintenance includes high pressure jetting, vacuuming to remove loosened debris, and mechanical and chemical root control. Closed circuit television (CCTV) is used to identify trouble spots. This results in more frequent cleaning than the scheduled three-year interval requires in problem areas. In 2001, 372 miles of sewer (64 percent of the sewer system) were televised and cleaned. The cost for these activities was approximately $236 per inch-diameter mile of pipe. Assuming an average pipe diameter of ten inches, inspection and cleaning costs about $0.45 per linear foot.

education program for commercial and institutional customers.

Water Quality Monitoring and Public Notification

Water quality monitoring and public notification practices are important in minimizing potential human health impacts that can result from exposure to pathogens and other pollutants in CSO and SSO discharges. Water quality monitoring is used routinely to verify the suitability of a particular waterbody for fishing, swimming, or as a drinking water source; and to identify whether a specific CSO or SSO event has impaired water quality. Public notification programs are intended to communicate water quality monitoring results, general information regarding the occurrence of CSO and SSO events, and municipal efforts to control discharges. Public notification program activities include posting temporary or permanent signs where CSOs and SSOs occur, coordinating with civic and environmental organizations, and distributing fact sheets to the public and the media. Monitoring and public notification programs should be a high priority at beaches or recreational areas, whether directly or indirectly affected by CSOs and SSOs, due to the increased risk of human contact with pollutants and pathogens (EPA 2002i).

When developing a monitoring and public notification program, the lag time that often occurs between collecting water samples and providing the public with results is important to consider. This lag is due to the time required (from 24 to 72 hours) to test for the presence of bacterial indicators of contamination. During this time, pathogen levels, weather, and water conditions, and related environmental or human health risks may change. This means that decisions regarding beach and recreational water postings, closings, and re-openings using bacterial indicators often reflect conditions as they were one to three days earlier (EPA 2002i). Further, contaminants may no longer be present once test results are available, and safe beaches may be closed needlessly. As described in Chapter 6, some communities and beaches have procedures to close beaches proactively when a CSO-producing rainfall event has occurred.

8.1.2 Collection System Controls

Collection system controls are designed to maximize the capacity of the sewer system to transport or store domestic, commercial, and industrial wastewater. This is accomplished by adjusting hydraulic control points to maximize available sewer system capacity and by implementing programs and practices to minimize the volume of I/I that enters the sewer system. The specific collection system controls considered for this report are summarized in Table 8.2, and include:

- Maximizing flow to the treatment plant;
- Installing a network of flow monitors to better understand and manage the response of the sewer system to wet weather events;
- Identifying and eliminating direct connections of storm water to the sewer system (inflow);
- Separating combined sewer systems into storm and sanitary systems; and

This CSO notification sign is posted along Brandywine Creek in Wilmington, Delaware, as part of a public notification program. It warns swimmers of the presence of a CSO outfall and advises that raw sewage and bacteria may be present after a storm.

Photo: City of Wilmington Department of Public Works

- Rehabilitating sewer system components.

Collection system controls are designed to maintain the structural integrity of CSSs and SSSs, and to maximize available capacity for transporting wastewater to a treatment plant. Some municipalities have found combining various rehabilitation techniques with inflow reduction activities to be a cost-effective and successful means of controlling SSOs. Other municipalities have found that implementing one or more of these collection system controls in conjunction with storage facilities or treatment a cost-effective CSO control.

Maximizing Flow

EPA encourages plants serving CSSs and SSSs to minimize CSOs and SSOs during wet weather events by using existing infrastructure to maximize flow to the treatment plant (EPA 1994a; NYSDEC 1997). Maximizing flow to the treatment plant often involves simple and low-cost measures, including:

- Capacity evaluations of the sewer system and pumping stations to determine the maximum amount of flow that can be transported (Sherrill et al. 1997).
- Sewer investigations to identify bottlenecks or constrictions that limit flow in specific areas and prevent downstream treatment capacity from being fully utilized.
- Targeted O&M activities to address structural deterioration, obstructions due to FOG and sediment buildup and excessive I/I.

The benefits of maximizing wet weather flows to the existing treatment plant depend on the ability of the plant to accept and provide treatment to increased flows. The consequences of mismanaging extreme flows at the treatment plant include flooding the treatment plant and washing out biological treatment processes, which can result in reduced treatment capacity and efficiency at the plant for extended periods of time. Likewise, changes in sewer system operation without a careful analysis of transport capacity can result in increased building backups or street flooding.

Table 8.2

Summary of Collection System Controls

Collection system controls are designed to maximize the use of existing sewers to collect and convey wastewater to a treatment facility.

Technology	Type of System	Pollutants/Problems Controlled
Maximizing flow to the treatment plant	CSS, SSS	BOD_5, TSS, nutrients, toxics, pathogens, floatables
Monitoring and real-time control	CSS, SSS	Peak wet weather flow rate
Inflow reduction	CSS, SSS	I/I, peak wet weather flow rate
Sewer separation	CSS	I/I, peak wet weather flow rate
Sewer rehabilitation	CSS, SSS	I/I, peak wet weather flow rate
Service lateral rehabilitation	CSS, SSS	I/I, peak wet weather flow rate
Manhole rehabilitation	SSS	I/I, peak wet weather flow rate

Monitoring and Real-Time Control

Basic flow monitoring is an important component of O&M programs in most systems. Effective monitoring programs enable evaluations of diurnal and day-to-day flow patterns as well as I/I in a sewer system. Moreover, monitoring is extremely valuable in establishing maintenance schedules, developing hydraulic models, planning related to capital improvements, and ensuring regulatory compliance.

Enhanced monitoring programs in SSSs and real-time control systems in CSSs use more complex flow monitoring networks to optimize sewer system performance. In SSSs, enhanced monitoring information can be used to identify blockages or capacity-constrained areas of the sewer system where wet weather SSOs are likely to occur. In CSSs, integration of real-time flow, regulator, pump, and storage information can be used to maximize use of storage capabilities and to maximize flow to the treatment plant.

Inflow Reduction

Inflow is the entry of extraneous storm water into a sewer system from sources other than infiltration, such as basement drains, roof leaders, manholes, and storm drains. Inflow reduction refers to the identification and elimination of these sources to reduce the amount of storm water that enters CSSs and SSSs. By reducing the volume of storm water entering the sewer system, more conveyance, storage, and treatment capacity is available for sanitary flows during wet weather. This, in turn, aids in reducing the frequency, volume, and duration of wet weather CSO and SSO events. Common inflow reduction techniques include the disconnection of roof leaders, redirection of area and foundation drains and basement sump pumps, and elimination of cross-connections between separate sanitary and storm water systems (EPA 1999f).

Inflow reduction techniques can be an efficient way to improve sewer system performance, especially when the diverted storm water can be conveniently directed either to surface waters or to open land for infiltration or detention (EPA 1999f). For SSSs, inflow reduction techniques usually target specific areas with chronic SSOs. For CSSs, these techniques are applied more broadly to minimize the size of structural controls.

Sewer Separation

Sewer separation is the practice of separating the single-pipe CSS into separate systems for sanitary and storm water flows. Full separation can be applied on a system-wide basis to eliminate the CSS. This approach is most practical for communities with small areas served by combined sewers. Separation of select areas within a CSS is widely used by large and small CSO communities as an element of a broader LTCP.

Sewer separation can be highly effective in controlling the discharge of untreated wastewater. Under ideal circumstances, full separation can eliminate CSO discharges. A survey of readily available information in NPDES files indicates that sewer separation is the most widely used CSO control, accounting for half of CSO control measures found in LTCP

The Milwaukee Metropolitan Sewer District uses real-time data to monitor the flow in its sewer system tunnels and pipes.

Photo: Milwaukee Metropolitan Sewer District

Monitoring and Real-Time Control: Seattle, WA

Seattle was one of the first U.S. communities to implement and operate an advanced real-time control system to control CSO discharges. Seattle's system, called Computer Augmented Treatment and Disposal (CATAD), began operating in 1971. In the late 1980s, treatment plant computer hardware was upgraded, remote telemetry units at regulators and pump stations were replaced by programmable logic controllers, and graphical displays used by operators were improved. Based on the success of the CATAD technology, Seattle implemented a new, predictive real-time control system that went on-line in early 1992. Rainfall prediction capabilities that utilize rain gage data and a runoff model were added. A global optimization program was introduced that computed optimal flow and corresponding gate position for each regulator within the CSS. A distributed network allows control decisions to be implemented without operator intervention. The computer program uses real-time operation and system performance data to predict or forecast conditions through the system and directs control elements to utilize in-line storage during periods of high flow.

The direct connection of roof leaders (shown above) and other inflow sources can limit sewer system capacity for conveying sanitary wastewater during wet weather.

Photo: Milwaukee Metropolitan Sewer District

documentation (EPA 2001a). This suggests that many CSO communities identify portions of their CSS in which separation is a cost-effective CSO control. Under these circumstances, separation is often implemented in conjunction with other public works projects, including road work and redevelopment. Sewer separation on its own, however, does not always lead to an overall reduction in pollution or the attainment of water quality standards. Storm water discharges from the newly created separate storm sewer system can contain substantial pollutant loads that may cause or contribute to water quality problems. Implementation of storm water controls may be necessary following sewer separation in order to achieve the pollutant load reductions necessary for attainment of water quality standards.

In practice, there are three distinct approaches to sewer separation:

- Full separation wherein new sanitary sewer lines are constructed with the existing CSS becoming a storm sewer system. This is probably the most widely used form of separation.
- Full separation wherein an entirely new storm sewer system is constructed with the existing CSS remaining as a sanitary sewer system. This form of separation is not often used because the capacity of the existing CSS was designed to accommodate storm water runoff, which is more than what is required to accommodate sanitary flows.
- Partial separation wherein a new storm sewer system is constructed for street drainage, but roof leaders and basement sump pumps remain connected to the existing CSS.

Sewer Rehabilitation/Replacement

The structural integrity of many sewer system components deteriorates with use and age. This gradual breakdown allows more groundwater and storm water to infiltrate into the sewer system. This increases the hydraulic load and, in turn, reduces the system's ability to convey all flows to the treatment plant. During wet weather events, excessive infiltration can cause or contribute to CSOs and SSOs. Sewer rehabilitation/replacement restores and maintains the structural integrity of the sewer system, in part by reducing or mitigating the effects of infiltration. Common sewer rehabilitation and replacement techniques include:

- Removal and replacement of defective lines;
- Trenchless technologies that use the existing sewer to support a new pipe or line;
- Shotcrete, wherein a mixture of cement, sand, and water is applied to sewer walls; and
- Grouting and epoxy injections to seal leaks and cracks.

Inspecting and evaluating current sewer condition is necessary before a sewer rehabilitation technique is chosen, as the condition of the sewer may favor specific techniques. Removing and replacing defective lines is the most commonly used rehabilitation technique when the sewer line is structurally deficient (CSU 2001). Complete replacement is often the most effective rehabilitation method in areas where increased conveyance capacity is needed (WEF 1999a).

Trenchless technologies are especially well-suited to urban areas where the traffic disruption associated with large-scale excavation projects can be a significant obstacle to a project (WEF 1999a). In addition, many sewers are located near other underground utilities in urban areas, which can complicate traditional dig-and-replace methods; trenchless technologies avoid underground utilities by using the existing sewer to support a new pipe or line. Trenchless technologies include sliplining, cured-in-place pipe (CIPP), modified cross-section liners, and pipe bursting.

Shotcrete, a non-invasive rehabilitation method, is often used to rehabilitate sewers with major structural problems. Shotcrete, however, can be used only in pipe with a diameter of at least 36 inches (CSU 2001).

Grouting and epoxy injections are most appropriate when the sewer is structurally stable but experiencing infiltration.

Service Lateral Rehabilitation

Private building service laterals are the pipes that convey wastewater from individual buildings, including houses, to the municipal sewer system. Recent studies indicate that a significant component of the infiltration in any sewer system is the result of service lateral defects that contribute varying quantities of I/I (WEF 1999b). During wet weather events, excessive I/I can cause or contribute to CSOs and SSOs. In general, service lateral rehabilitation techniques are similar to those used for larger diameter sewers and include:

- Removing and replacing defective service laterals;
- Applying trenchless technologies that use the existing service lateral to support a new pipe or liner; and
- Using grouting and epoxy injections to seal leaks and cracks.

Assigning responsibility for the repair or replacement of service laterals is often cited as the biggest obstacle to correcting known defects. Notably, several studies highlighted significant problems in gaining access to private property until the municipality assumed full financial responsibility for the repair or replacement costs (Paulson et al. 1984; Curtis and Krustsch 1995).

Manhole Rehabilitation

Manholes must be maintained and kept in working condition. Structurally defective manholes can be a significant source of I/I that otherwise would not enter an SSS. Damage to manhole covers and rims often occurs during road work, and it can allow storm water runoff from roads and sidewalks to flow directly into the sewer system. Further, cracks and openings in the sidewalls and base of the manhole can allow groundwater and storm water to infiltrate into the sewer system. Manhole rehabilitation can reduce I/I, restore the structural integrity of the manhole, and preserve SSS capacity for transporting wastewater. Common manhole rehabilitation methods include (ASCE 1997):

- Sealing pick holes in the manhole cover and installing gaskets between the manhole cover and frame to eliminate storm water inflow;
- Implementing spot repairs with chemical grout or fast-drying cement to patch defects in manhole sidewalls or bases;
- Coating systems to rebuild structural integrity and protect concrete, steel, and masonry manhole structures against deterioration;

Service Lateral Rehabilitation: Montgomery, AL

In Alabama, the Montgomery Water Works and Sanitary Sewer Board (MWWSSB) evaluated nearly 2.2 million linear feet of its sewer system, identifying 3,394 defects. Eighty-five percent of these defects were in service laterals; 97 percent of lateral defects identified have been repaired.

Lateral repairs necessary within the city street right-of-way are made by MWWSSB with consent and release of liability from the property owner. MWWSSB replaces missing clean-out covers for a minimal cost with written permission from the property owner. The property owners are responsible for the cost of all lateral repair and replacement on their property.

Property owners initially received a 60-day notice of lateral repair requirements. Another 10-day notice was sent if the property failed to respond to the initial notice. Finally, if the property owner failed to respond to either notice, water service to the property was shut off. Sixty-five percent of property owners responded after receiving the initial notice. The remaining property owners corrected their defects under threat of having their water service discontinued.

In selected areas where service lateral rehabilitation has been completed, the I/I was reduced by an average of 42 percent. It is estimated that the annual I/I volume in the MWWSSB service area has been reduced by 36 million gallons. The cost of establishing the I/I program was approximately $150,000. MWWSSB spends $207,000 annually to operate the program.

- Reconstructing manholes in cases of substantial structural degradation; and
- Placing inserts and liners in deteriorated manholes.

Inspection of the manhole components is a necessary first step in selecting an appropriate rehabilitation technique. Spot repairs of manhole components are most appropriate for addressing minor defects, and chemical grouts are commonly used for rehabilitating structurally sound manholes made of brick. Coating systems are applicable for manholes with brick structures that show little or no evidence of movement or subsidence and at sites not conducive to excavation or major reconstruction. Structural linings are applicable for standard manhole dimensions (48- to 72-inch inner diameter) where substantial structural degradation has occurred. Structural linings tend to be more expensive than other rehabilitation techniques.

8.1.3 Storage Facilities

Many sewer systems experience increased flow during wet weather. In systems that are unable to transport or provide full treatment for wet weather flows, storage facilities are often used to reduce the volume, frequency, and duration of CSO and SSO events. Storage facilities fill during wet weather and are drained or pumped to the wastewater treatment plant once conveyance and treatment capacity have been restored following the wet weather event. Specific types of storage facilities considered for this report are summarized in Table 8.3.

Storage facilities have seen wide application as a CSO control because of the large and frequent volumes of combined sewage requiring control; however, a number of communities have also found storage facilities, especially flow equalization basins, to be an effective wet weather SSO control.

In-line Storage

In-line or in-system storage is the term used to describe storage of wet weather flows within the sewer system. Taking advantage of storage within the sewer system has broad application and can often reduce the frequency and volume of CSOs and SSOs without large capital investments. Maximization of storage in the sewer system is also one of the NMC required of all CSO communities. The amount of storage potentially available in the sewer system largely depends on the size or capacity of the pipes that will be used for storage and on the suitability of sites for installing regulating devices.

Damaged manholes, such as the broken cover shown above, can be a significant source of storm water I/I into an SSS.

Photo: Limno-Tech, Inc.

Table 8.3

Summary of Storage Facilities

Storage facilities have seen wide application in attenuating peak wet weather flows in both CSS and SSS.

Technology	Type of System	Pollutants/Problems Addressed
In-line storage	CSS, SSS	Peak wet weather flow rate, BOD_5, TSS, nutrients, toxics, pathogens, floatables
Off-line storage	CSS, SSS	Peak wet weather flow rate, BOD_5, TSS, nutrients, toxics, pathogens, floatables
On-site storage and flow equalization basins	CSS, SSS	Peak wet weather flow rate, BOD_5, TSS, nutrients, toxics, pathogens, floatables

In-line storage techniques include the use of flow regulators, in-line tanks or basins, and parallel relief sewers. Flow regulators optimize in-line storage by damming or limiting flow in specific areas of the sewer system. Storage tanks and basins constructed in-line are typically governed by flow regulators. Dry weather flows pass directly through in-line storage tanks or basins, and flow regulators limit flow exiting the facility during wet weather periods. In-line capacity can also be created by installing relief sewers parallel to existing sewers or by replacing older sewers with larger diameter pipes. Again, flow regulators are used to optimize storage within these facilities.

Areas where the sewer slope is relatively flat typically offer the best opportunities for in-line storage. One factor that limits the applicability of in-line storage is the possibility that this approach can increase basement backups and street flooding (EPA 1999g). Use of in-line storage may also slow flow, allowing sediment and other debris to settle in the sewer. If allowed to accumulate, sediment and debris can reduce available storage and conveyance capacity. Therefore, an important design consideration for in-line storage is to ensure that minimum flow velocities are provided to flush and transport solids to the wastewater treatment plant.

Off-line Storage

Off-line storage is the term used to describe facilities that store wet weather flows in near-surface storage facilities, such as tanks and basins or deep tunnels located adjacent to the sewer system. Off-line storage facilities have broad applicability and can be adapted to many different site-specific conditions by changing the basin size (volume), layout, proximity to the ground surface, inlet or outlet type, and disinfection mechanism. For these reasons, off-line storage facilities are one of the most commonly implemented CSO controls (EPA 2001a). The use of off-line storage tends to be more expensive than in-line storage; it is usually considered in areas where in-line storage is insufficient or unavailable.

A typical near-surface storage facility is a closed concrete structure built at or near grade alongside a major interceptor. Deep tunnel storage facilities are used where large storage volumes are required and opportunities for near-surface storage are unavailable. As their name implies, deep tunnels are typically located 100 to 400 feet below ground. Tunnel diameters range from 10 to 50 feet, and many are several miles in length.

During dry weather, untreated wastewater is routed around, not through, off-line storage facilities. In contrast, during wet weather, flows are diverted from the sewer system to the off-line storage facilities by gravity drainage or with pumps. The wastewater is detained in the storage facility and returned to the sewer system once downstream conveyance and treatment capacity become available. Overflows can occur if the capacity of off-line storage structures is exceeded. Some treatment is provided through settling; however, the primary function of such facilities is storage and the attenuation of peak wet weather flows.

In-line Storage: Philadelphia, PA

As part of Philadelphia's effort to control CSOs, the City Water Department plans to install three inflatable dams in large diameter sewers that have available in-line storage. The dams will range from 11 to 15 feet high and will be automatically controlled for both dry and wet weather conditions. The three dams will enable 16.3 MG of flow that might otherwise discharge to local receiving waters to be stored in existing sewers per storm event, reducing CSO volumes by 650 MG per year.

The first inflatable dam, located in the city's main relief sewer, will be operational by the end of 2004. The associated civil work projects including sewer rehabilitation have been completed for this project. When operational, the dam will have the ability to store up to 4 MG of combined sewage, and it is expected to reduce the number of CSO discharges to the Schuylkill River from 32 per year to four per year. Another inflatable dam will be installed in Rock Run during the summer of 2005. The total cost for the installation of the dams and sewer rehabilitation is approximately $4.8 million, or $0.29 per gallon of storage.

On-site Storage

On-site storage, which is storage developed at the wastewater treatment facility, is often an effective control for managing wet weather flows in systems where sewer system conveyance capacity exceeds that of the treatment plant. On-site storage can play an important role in improving treatment plant operations by providing operators with the ability to manage and store excess flows. The costs associated with the development of on-site storage are, on average, considerably lower than the construction costs for typical near surface off-line storage facilities built outside the bounds of the treatment plant. Much of the cost savings derive from siting storage facilities on land already owned by the utility. It should be noted, however, that sewer system conveyance capacity may limit the amount of wet weather flow that can be brought to an on-site storage facility, and expanding conveyance capacity can be extremely expensive.

The two most common forms of on-site storage are flow equalization basins (FEBs) and converted abandoned treatment facilities. FEBs are used to attenuate peak wet weather flows and to improve wet weather treatment plant operations (Metcalf and Eddy 2003). Abandoned treatment facilities can function in a manner similar to FEBs in attenuating peak wet weather flows. Abandoned facilities that have been successfully converted for storage include old clarifiers, treatment or polishing lagoons, and abandoned pretreatment facilities at industrial sites near the treatment plant.

8.1.4 Treatment Technologies

In many systems, wet weather flows can exceed the existing conveyance and treatment capacity. The development of wet weather treatment systems presents a viable alternative to storing excess flows. Treatment technologies are end-of-pipe controls, used to provide physical, biological, or chemical treatment to excess wet weather flows immediately prior to discharge from a CSS or SSS. Specific treatment technologies can address different pollutants, such as settleable solids, floatables, and pathogens.

On-site Storage: Oakland, ME

The sewer system in Oakland, Maine, consists mainly of combined sewers. The city has been implementing CSO controls since 1997. These efforts include separating a portion of the CSS and targeted inflow reduction activities. As a result, Oakland has been able to eliminate both of its CSO outfalls and transport all wet weather flows to its wastewater treatment plant. Although the city had sufficient sewer system capacity to transport these wet weather flows, it did not have facilities capable of treating the peak wet weather flow. The city was able to use an FEB installed at a nearby textile mill that is no longer operating. The FEB was built in 1990 by the textile mill as part of their pretreatment program and had not been used since the plant closed. Oakland is able to store 0.2 MG of excess wet weather flows in the FEB, and release it back to the wastewater plant for treatment as capacity becomes available. The FEB is mainly used to control excess wet weather flow during spring snowmelts. Bringing the FEB back into operation cost approximately $27,610, or $0.14 per gallon of storage.

For the purposes of this Report to Congress, treatment technologies are assumed to operate intermittently, with dry weather flows from the CSS or SSS handled by the existing wastewater treatment plant. Treatment technologies considered here include strategies for developing wet weather treatment capacity at remote locations in the sewer system and for enhancing the performance of the existing treatment facility when flows exceed the rated capacity of the plant. Specific technologies and operational practices are summarized in Table 8.4 and include:

- Constructing supplemental treatment facilities for treating excess wet weather flows;
- Modifying the POTW to better accommodate high flows;
- Disinfecting excess wet weather flows;
- Using vortex separators to provide partial treatment for excess wet weather flows; and
- Constructing facilities to remove floatables from CSO discharges.

In general, treatment technologies have not been as widely applied as other CSO and SSO controls, partly due to cost and the difficulty of remote control. Also, the requirements for permitting treated discharges from off-site SSO facilities during wet weather are somewhat unclear.

Supplemental Treatment

As the name implies, supplemental treatment technologies are intended to supplement existing wastewater treatment capacity during periods of wet weather. Example applications include installing a small scale treatment facility in a capacity-constrained area of the sewer system, or adding a parallel treatment process at the existing treatment plant to be operated only during wet weather. Selection of a supplemental treatment technology is determined by the level of treatment required and the characteristics of the wet weather flow. Technologies commonly considered as potential supplemental treatment processes for excess wet weather flows include:

- Ballasted flocculation or sedimentation using a fine-grained

Table 8.4

Summary of Treatment Technologies

Based on life-cycle cost evaluations, treatment technologies may be an effective technique for handling excess wet weather flows.

Technology	Type of System	Pollutants/Problems Controlled
Supplemental treatment	CSS, SSS	Peak wet weather flow rate, BOD_5, TSS, pathogens
Plant modifications	CSS, SSS	Peak wet weather flow rate, BOD_5, TSS
Disinfection	CSS, SSS	Pathogens
Vortex separators	CSS	TSS, floatables
Floatables controls	CSS	Floatables

sand, or ballast, and a coagulant to accelerate settling of solids from wastewater;

- Chemical flocculation using metal salts and polymers to accelerate settling of solids from wastewater;
- Deep bed filtration with coarse sand to filter wastewater; and
- Microscreens.

Supplemental treatment technologies must have quick start-up times after extended periods of no flow (or low flow) conditions, accommodate sudden increases in flow at unplanned times, and provide adequate treatment despite significant variation in flow rates and influent pollutant concentrations.

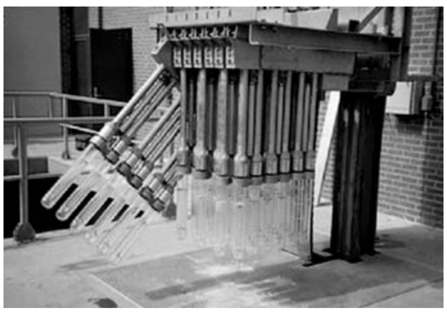
Plant Modifications

Simple modifications to existing wastewater treatment facilities can increase their ability to handle wet weather flows. Modifications can involve changes to the physical configuration of various treatment processes and the operation of specific plant processes during wet weather. Most modifications require the active involvement of the treatment plant operator to ensure effective implementation. Example modifications that maximize the treatment of wet weather flows include:

- Ensuring the even distribution of flow among treatment units;

Supplemental Treatment: Tacoma, WA

The Central Treatment Plant (CTP) for the City of Tacoma, Washington, receives flow from an SSS serving a population of 208,000. The CTP has a peak biological treatment capacity of 78 mgd. The sewer system, however, can deliver up to 110 mgd to the CTP. Tacoma plans to install a ballasted flocculation process at the CTP, in parallel with the existing processes, to handle wet weather flows in excess of the peak biological treatment capacity. The ballasted flocculation process will cost approximately $12.4 million. All related peak wet weather flow facilities upgrades are estimated at $50.7 million. In comparison, expanding the existing activated sludge processes would cost an estimated $130 million; this estimate does not include the cost for additional primary clarification capacity. When the ballasted flocculation process is brought on-line for wet weather treatment, effluent from the process will be separately disinfected and blended with disinfected biologically treated effluent prior to discharge. The blended effluent is expected to meet permit limits. The ballasted flocculation process is expected to operate a maximum of 5.5 days in a row, 8 days in a month, and 21 days per year (Parametrix 2001).



Ultraviolet light is used to disinfect wet weather flows as part of the Columbus, Georgia, Water Works CSO Technology Testing Program.

Photo: Columbus Water Works

- Installing baffles to protect clarifiers from hydraulic surges (NYSDEC 2001);
- Using metal salts and polymers to increase suspended solids removal;
- Switching the mode of delivering flow from the primary to the secondary treatment units;
- Switching from "series" operation of unit processes during dry weather flows to "parallel" operation during wet weather flows; and

Performance evaluations are conducted to determine whether additional capacity can be obtained from existing facilities. While plant modifications are generally more cost effective than new construction, some modifications that improve wet weather performance may result in increased concentrations of pollutants in treatment plant effluent during dry weather. For example, if not properly designed, a clarifier modified for wet weather flows may have inadequate settling characteristics during dry weather (Metcalf and Eddy 2003). Further, modifications that require operator attention before and after a wet weather event may interrupt regular dry weather operations and potentially compromise the quality of treated wastewater during dry weather.

Disinfection

Disinfection of wastewater is necessary for public health protection when the public may come into contact with wastewater discharges. Wastewater treatment plants typically include a disinfection process designed specifically to inactivate bacteria, viruses, and other pathogens in the treated wastewater. The application of disinfection to CSO and SSO discharges has been limited.

Achieving adequate disinfection of excess wet weather flows can be difficult. High flow rates can result in reduced exposure of wastewater to the disinfecting agent and possibly reduced effectiveness of the disinfection process. Among conventional disinfection processes, chlorine disinfection has been used most often to successfully disinfect wet weather flows. Effects of this method, however, include toxic residual chlorine and chlorine disinfection by-products that limit the utility of chlorination for disinfection in some areas. Experience with ultraviolet (UV) light and other alternatives has increased considerably in recent years and may be practical for wet weather flow receiving a minimum of primary treatment.

Vortex Separators

Vortex separators (swirl concentrators) are designed to concentrate and remove suspended solids and floatables from wastewater or storm water. Applications of vortex separators, for the most part, have been limited to CSSs. Vortex separators use centripetal force, inertia, and gravity to divide combined sewage into a smaller volume of concentrated sewage, solids, and floatables; and a large volume of more dilute sewage and surface runoff. Typically, the concentrated sewage and debris are conveyed to the treatment plant, and the dilute mix is discharged to a receiving water. This discharge may or may not receive disinfection.

Vortex separators provide a modest level of treatment for a modest cost. They are useful in controlling suspended solids and floatables and in reducing pollutants associated with solids such as metals bound to sediments. Vortex separators have limited ability to reduce dissolved pollutant or bacteria concentrations unless, in the latter case, disinfection is applied in conjunction with vortex separation (Brashear et al. 2002). When used in combination with other CSO controls, the placement of vortex separators is very important. Because they are designed to remove suspended solids and floatables, vortex separators should not be placed downstream of other facilities that perform the same function, such as sedimentation basins or grit chambers. (Moffa 1997).

Floatables Controls

Floatables controls are principally applied in CSSs and are designed to mitigate aesthetic impacts of CSO discharges by minimizing the amount of litter and other debris entrained in the CSO. Floatables controls are widely used to control solids and floatables in urban storm water discharges from separate storm sewer systems. Improvements in water quality from floatables controls may be secondary. The CSO Control Policy recognized the importance of controlling solid and floatable material by including it under the NMC (EPA 1994a). Floatables controls can be grouped into three categories:

- Source controls that work to prevent solids and floatables from entering the CSS.
- Collection system controls that keep solids and floatables in the sewer system, so they can be collected and removed at strategic locations or transported to the wastewater treatment plant.
- End-of-pipe controls, such as containment booms and skimmer boats, capture solids and floatables as they are discharged from the sewer system. End-of-pipe controls can create temporary unsightly conditions near CSO outfalls and may be undesirable in areas with waterfront development.

Ensuring the efficient and effective operation of all types of floatables controls requires proper maintenance. The optimal period between maintenance activities ranges from a few weeks to semi-annually, depending on the technology employed.

8.1.5 Low-Impact Development Techniques

Low-impact development (LID) techniques seek to control the timing and volume of storm water discharges from impervious surfaces (e.g., building roofs and parking lots) to the sewer system as well as the volume of wastewater generated by residential, commercial, and industrial customers. Controlling the timing and volume of storm water discharges can be an important component of a program to control CSOs. Reducing the volume of wastewater generated within the service area frees capacity within both CSSs and SSSs for transport of additional flows during wet weather. Specific LID techniques considered for this report are summarized in Table 8.5.

Table 8.5

Summary of Low-Impact Development Techniques

Low-impact development techniques are most useful in attenuating peak wet weather flow rates associated with urban and suburban storm water runoff.

Technology	Type of System	Pollutants/Problems Controlled
Porous pavement	CSS	Peak wet weather flow rate
Green roofs	CSS	Peak wet weather flow rate
Bioretention	CSS	Peak wet weather flow rate
Water conservation	CSS, SSS	Peak wet weather flow rate

While the concept of using LID to control storm water runoff is familiar, the application of LID techniques for CSO control has been limited (University of Maryland 2002). It is unlikely that LID techniques alone are sufficient to fully control CSOs, yet they have shown promise as part of larger programs in reducing the size of structural controls (e.g. storage). The use of LID as an SSS control is limited to situations in which LID might contribute to inflow control. LID has great potential as a storm water control for the separate storm sewer system that complements an SSS.

Porous Pavement

Porous pavement is an infiltration system in which storm water runoff enters the ground through a permeable layer of pavement or other stabilized permeable surface (EPA 1999h). The use of porous pavement reduces or eliminates impervious surfaces, thus reducing the volume of storm water runoff and peak discharge volume generated by a site. Reducing the amount of stormwater that enters the CSS increases conveyance and storage capacity. This in turn leads to reductions in the volume and frequency of CSOs.

Porous pavement is used as an alternative to conventional impervious pavement, under certain conditions. The success of porous pavement applications depends on design criteria including site conditions, construction materials, and installation methods. Typically, porous pavement is most suitable for areas with sufficient soil permeability and low traffic volume. Common applications include parking lots, residential driveways, street parking lanes, recreational trails, golf cart and pedestrian paths, shoulders of airport runways, and emergency vehicle and fire access lanes. This technology is not recommended for areas that generate highly contaminated runoff such as commercial nurseries, auto salvage yards, fueling stations, marinas, outdoor loading and unloading facilities, and vehicle washing facilities, as contaminants could infiltrate into groundwater (SMRC 2002).

Green Roofs

Green roofs use rooftop vegetation and underlying soil to intercept storm water, delay runoff peaks, and reduce runoff discharge rates and volume. Their use can lead to reductions in the volume or occurrence of CSOs. Green roofs are becoming an important tool in areas with dense development where the use of other space-intensive storm water management practices, such as detention ponds and large infiltration systems, is impractical.

There are two basic types of green roofs: intensive and extensive. Intensive green roofs, also known as conventional roof gardens, are landscaped environments developed for aesthetic and recreational uses that require high levels of management. Extensive green roofs, or eco-roofs, make use of a continuous, thin layer of growing medium that sustains low-maintenance vegetation tolerant of local climatic conditions.

Intensive and extensive green roofs have been successfully installed in cities across the United States, both as part of new building design and retrofitted to existing buildings (e.g., Chicago, IL; Philadelphia, PA; Portland, OR). Green roofs can be designed for commercial buildings, multi-family homes, industrial structures, and single-family homes and garages. Factors that must be considered before installing a green roof include the load-bearing capacity of the roof deck, the moisture and root penetration resistance of the roof membrane, roof slope and shape, hydraulics, and wind shear.

Bioretention

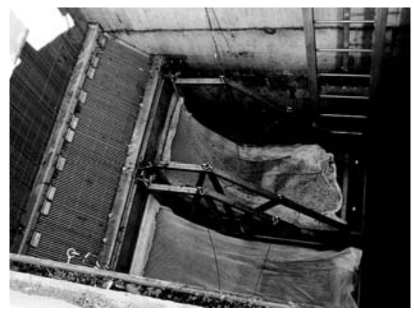
Bioretention is a soil and plant-based storm water management practice used to filter and infiltrate runoff from impervious areas such as streets, parking lots, and rooftops. Bioretention systems are essentially plant-based filters designed to mimic the infiltrative properties of naturally vegetated areas, reducing runoff rates and volumes. Their use can lead to reductions in CSO and SSO volume and frequency. The complexity of bioretention systems depends on the volume of runoff to be controlled, available land area, desired level of treatment, and available funding. Bioretention systems can be used as a stand-alone practice (off-line) or connected to a separate storm sewer system (on-line).

Bioretention systems can be implemented in new development or be retrofitted into developed areas. Bioretention systems are easier to incorporate in new developments, due to fewer constraints regarding siting and sizing. They can be applied in heavily urbanized areas, including commercial, residential, and industrial developments. For example, bioretention can be used as a storm water management technique in median strips, parking lots with or without curbs, traffic islands, sidewalks, and other impervious areas (EPA 1999i).

The effectiveness of bioretention systems depends on infiltration capacity and treatment capability. Systems must be sized to match expected runoff. Runoff volumes in excess of the system's capacity must be handled in such a way as to avoid erosion and destabilization of the site. Typical maintenance activities for bioretention systems include re-mulching void areas; treating, removing, and replacing dead or diseased vegetation; watering plants until they are established; inspecting and repairing soil, as needed; and removing litter and debris.

Water Conservation

Water conservation is the efficient use of water in a manner that extends water supplies, conserves energy, and reduces water and wastewater



In-system netting can provide floatables control at strategic locations in the sewer system.

Photo: New Jersey Department of Environmental Protection treatment costs. Reducing water use can decrease the total volume of domestic sewage conveyed by a sewer system, which can increase conveyance and treatment capacity during periods of wet weather and potentially reduce the volume and frequency of CSOs and SSOs. Numerous indoor and outdoor practices reduce water consumption, including (GBS 2002):

- High efficiency fixtures and appliances such as low-flow toilets, urinals, showerheads, and faucets, and water-efficient washing machines and dishwashers.
- Water recycling and reuse of wastewater from sinks, kitchens, tubs, washing machines, and dishwashers for landscaping, flushing toilets, and other non-potable purposes.
- Waterless technologies such as composting toilets and waterless urinals.
- Rain harvesting, in which roof runoff is collected, stored, and used primarily for landscaping.

Bioretention systems can reduce the amount of storm water runoff generated by impervious surfaces, such as parking lots, that enters a CSS during wet weather.

Photo: Prince George's County, MD

In most instances, money saved from reduced water and sewer bills offsets installation costs over time. Among high efficiency fixtures and appliances, low-flow showerheads and faucet aerators are almost always cost-effective to install due to their relatively low cost and minimal labor requirements. Low-flow toilets also have widespread application, particularly in commercial and institutional settings, because the economic offset period can be relatively short. The cost effectiveness of the other water conservation technologies mentioned depends on site-specific considerations.

8.2 How Do CSO and SSO Controls Differ?

Although many of the technologies considered in this report have proven useful in controlling overflows from both CSSs and SSSs, EPA found that applications of certain technologies were more common to a particular type of system. This section highlights technologies with particular application in either CSSs or SSSs.

8.2.1 Common CSO Control Measures

Implementation of the NMC was expected to be one of the first steps taken by CSO communities in response to the CSO Control Policy. In general, the NMC are controls that reduce CSOs and their impacts on the environment and human health, but do not require significant engineering studies or major construction, and are implemented in a relatively short period (e.g., within a few years). Most activities completed as part of implementing the NMC are considered O&M practices or collection system controls. The most common NMC activities include (EPA 2001a):

- Sewer cleaning
- Pollution prevention
- Inflow reduction

In developing and implementing a CSO LTCP, municipalities are expected to consider more significant structural

Water Conservation: Houston, TX

Low-flow plumbing fixtures were installed in a 60-unit low income multi-family housing complex in Houston, Texas. The average number of occupants per unit was 4.4. Devices installed in each unit included low-flow toilets (1.6 gallons per flush), low-flow aerators on faucets (2.2 gallon per minute) and new water meters. Faucet leaks were repaired, and tenants were educated on conservation techniques. The project resulted in a reduction in average monthly water consumption for the complex from 1.3 MG pre-installation to 367,000 gallons post-installation. Average monthly water bills for the complex decreased from $8,644 to $1,810, resulting in savings of approximately $6,834 each month. Due to the success of the project, Houston retrofitted four other low income housing developments with low-flow plumbing fixtures.

controls. Specifically, municipalities are asked to evaluate the applicability of more comprehensive collection system controls, storage facilities, and treatment technologies.

Sewer separation is the CSO control most widely implemented as part of an LTCP (EPA 2001a). Complete or limited sewer separation has been implemented or planned by the majority of CSO communities for which CSO controls were documented in the NPDES authority files that EPA reviewed as part of data collection to support its 2001 *Report to Congress–Implementation and Enforcement of the CSO Control Policy*. Other common CSO control measures identified in LTCPs include:

- Off-line storage facilities
- Plant modifications
- Sewer rehabilitation
- Disinfection facilities

8.2.2 Common SSO Control Measures

There is no national standard equivalent to the LTCP for communities with SSSs that are working to control SSOs, so it is difficult to determine the prevalence of specific controls. Based on interviews EPA conducted to support the development of this report, it appears that communities with recurrent dry weather SSOs tend to rely on O&M activities, while communities with wet weather SSOs rely more heavily on collection system controls (e.g., inflow reduction, rehabilitation).

8.3 What Technology Combinations are Effective?

Most communities evaluate and use a wide variety of technologies for their CSO and SSO programs. Some technologies have proven to be advantageous when applied together. This section describes several examples of beneficial technology pairings; this list should not be construed as an exhaustive list of technology combinations.

8.3.1 Inflow Reduction or Low-Impact Development Coupled with Structural Controls

Inflow reduction and LID techniques reduce the quantity of storm water runoff that enters a sewer system. Since these controls can reduce both the peak flow rate and volume of storm water delivered to a sewer system, the size of more capital-intensive downstream control measures, such as storage facilities or treatment technologies, can be reduced, or, in some cases, eliminated completely.

8.3.2 Disinfection Coupled with Solids Removal

A number of the pollutants present in wastewater can interfere with disinfection processes and reduce their efficacy. High concentrations of BOD_5, ammonia, and iron can reduce the effectiveness of disinfection. These substances can consume or otherwise prevent the disinfectant from reaching microbial pathogens. Solids in wastewater can also interfere physically with the disinfection process. Pathogens can be "shielded" by larger solids that surround and insulate microbial pathogens from the disinfectant (Hoff and Akin 1986). Physical interference can be significant for both chlorine and UV disinfection.

In general, solids removal enhances disinfection by removing interfering substances and by physically removing the pathogens themselves. The performance of disinfection facilities to treat CSO and SSO discharges can be improved through the use of technologies that provide solids control. Technologies with demonstrated abilities to remove solids include off-line storage facilities, vortex separators, and supplemental treatment facilities.

8.3.3 Sewer Rehabilitation Coupled with Sewer Cleaning

Sewer rehabilitation is undertaken to restore the structural integrity of sewers and reduce infiltration. The presence of debris and roots within sewer systems can limit the effectiveness of sewer rehabilitation efforts, particularly where Shortcrete or trenchless technologies are employed. Therefore, it is essential that sewer cleaning techniques are employed prior to any scheduled sewer rehabilitation efforts.

8.3.4 Real-Time Control Coupled with In-line or Off-line Storage Facilities

Real-time control technology is used to maximize storage within the collection system and maximize flow to the POTW, thereby reducing the volume and frequency of untreated discharges. Real-time control systems use monitoring data, operating rules, and customized software to operate system components (e.g., weirs, gates, dams, valves, and pumps) in a dynamic manner to optimize storage and treatment. Real-time control is most often applicable in CSSs, as these systems tend to have substantial in-line storage in large diameter pipes designed to transport excess wet weather flows. CSSs may also have off-line storage facilities (e.g., tunnels and basins), which can be incorporated into a real-time control strategy. The dynamic operation possible under real-time control tends to require less storage than would be required for similar performance without real-time control.

8.4 What New Technologies for CSO and SSO Control are Emerging?

This section describes two different broad types of measures that have potential for widespread implementation in controlling the impacts of CSOs or SSOs. These controls are viewed as "emerging" for the following reasons: techniques are evolving and warrant further study; and, in general, applications to date have been limited to larger municipalities, although the technologies appear to have value for use in smaller systems. Again, this should not be construed to be an exhaustive list.

8.4.1 Optimization of Sewer System Maintenance

Sewer system maintenance is critical to providing safe and efficient service. Optimizing sewer system maintenance involves allocating labor, equipment, and materials to maximize system performance, so that the system can efficiently collect and transport wastewater to the treatment plant. Determining how much maintenance is enough is rarely straightforward, however. Currently, there is no standard approach for determining the optimal frequency of various maintenance procedures except through experience and professional judgement (ASCE 1999). Several EPA regions and states, as well as professional organizations, have initiated efforts to develop such an approach. These include Region 4's MOM Program (Section 7.3.1) and the toolkit of effective O&M practices recently published by WERF (WERF 2003a).

8.4.2 Information Management

Effective sewer system management largely depends on the availability of accurate, easily accessible data. Manual, paper-based data systems are used to some degree in all sewer systems (Arbour and Kerri 1998). Many utilities have been and continue to be operated and managed in an effective manner without the assistance of computer-based systems. The use of a computer system, however, can improve data storage and processing. Previously, the considerable expense of such systems limited their applicability to larger sewer systems. As the costs of computers and customized software have decreased, however, these systems are now available to most utilities (CSU 2002). An information management system can be designed to meet multiple needs, including:

- Simplifying maintenance planning and scheduling;
- Tracking workforce productivity;
- Developing accurate unit costs for specific maintenance activities;

- Measuring the impact of resource allocation to various maintenance activities; and
- Developing and tracking sewer system performance measures.

A number of vendors have designed software packages specifically to assist utility staff in sewer system management. The software is typically a tailored database program that provides a means for efficient data organization, storage, and analysis. Most software packages include basic tools for sorting and filtering maintenance data; many also offer report generation capabilities. Other software packages contain basic tools as well as more advanced decision support systems. Most packages offer the ability to link to other external data systems such as a GIS or computer models.