Chapter 2

Background

In this chapter:

Municipal sewer systems are an extensive and valuable part of the nation's infrastructure. In 2000, 16,202 wastewater treatment facilities and 21,264 sewer systems (both CSS and SSS) were in operation in the United States. These systems serve about 208 million people in the United States, as reported in EPA's *Clean Watersheds Needs Survey 2000 Report to Congress* (EPA 2003b). EPA estimates that publicly-owned sewer systems account for about 724,000 miles of sewer pipe and approximately 500,000 miles of privately-owned pipes deliver wastewater into these systems.

Much of the nation's wastewater infrastructure is aging. Components of some sewer systems date back over 100 years, as evidenced by wood and brick sewers still in operation in some cities. A survey of 42 wastewater utilities indicated the age of sewer system components ranged from new to 117 years, with an average age of 33 years (ASCE 1999). Over time, municipalities have used a wide variety of materials, design and installation practices, and maintenance and repair procedures, which has led to considerable variability in the current condition of sewer infrastructure.

This chapter provides a brief history of sewer systems and wastewater treatment in the United States, using context provided by the Clean Water Act. Additional information on federal and state efforts related to the control of CSOs and SSOs is presented in Chapter 7.

2.1 What is the History of Sewer Systems in the United States?

In the pre-sewer era, human waste was dumped into privy vaults and cesspools, and storm water ran into the streets or into surface drains. Population increases during the 1800s, particularly in urban areas, created the need for more effective sanitary systems. Between 1840 and 1880, the percentage of Americans living in urban areas rose from 11 percent to 28 percent (Burian et al 1999). This rapid urbanization resulted in increased quantities of wastewater that overwhelmed privy vaults and cesspool systems. Consequently, municipalities began installing sewer systems to protect public health and to address aesthetic and flooding concerns (Melosi 2000). Little precedent existed for the construction of underground sewer systems, however, and engineers were reluctant to experiment with expensive capital works (Tarr 1996). In 1858, the first comprehensive sewer system was designed for the city of Chicago (Burian et al. 1999). Extensive construction of municipal sewer systems did not start until the 1880s.

In the United States, municipalities installed sewer systems using two predominant design options:

- *Combined sewer systems* – domestic, commercial, and industrial wastewater, and storm water runoff are collected and conveyed in a single pipe system, as shown in Figure 2.1; or
- *Separate sanitary sewer and storm sewer systems* – domestic, commercial, and industrial wastewater, and storm water runoff are collected and conveyed using two separate systems of pipe, as shown in Figure 2.2.

Combined sewer systems were less expensive for municipalities that needed both sanitary and storm sewers, while SSSs were less expensive

Figure 2.1

Typical Combined Sewer System

Combined sewer systems are designed to discharge directly to surface waterbodies such as rivers, estuaries, and coastal waters during wet weather, when total flows exceed the capacity of the CSS or treatment plant.

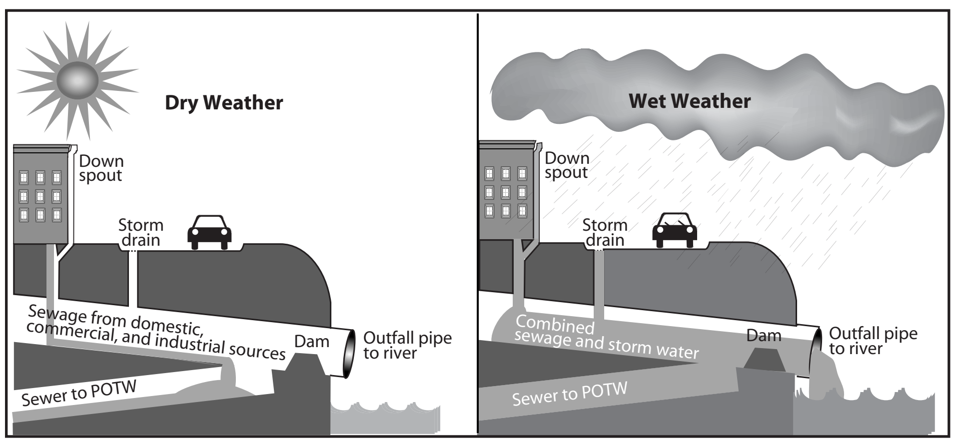
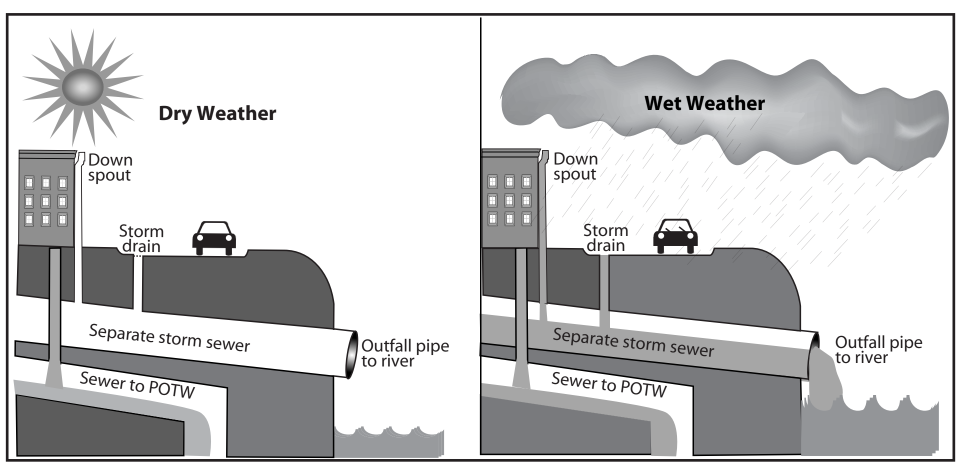


Figure 2.2

Typical Separate Sanitary and Storm Sewer Systems

Sanitary sewer systems are designed to collect and convey wastewater mixed with limited amounts of infiltration and inflow to a treatment plant. A separate storm sewer system is used in many areas to collect and convey storm water runoff directly to surface waterbodies.



for municipalities that needed only a wastewater collection system. Sanitary sewers were sized to convey domestic, commercial, and industrial wastewater, and limited amounts of infiltrated groundwater and storm water inflow. Unlike CSSs, they were not intended to collect large amounts of runoff from wet weather events. In general, large cities tended to construct CSSs, given the flood control advantages offered by such systems. By the end of the 19th century, most of the large urban areas with sewer systems had CSSs. Smaller communities generally pursued construction of separate sanitary and storm sewers (Melosi 2000).

At the time, sanitary engineers thought that both CSSs and SSSs provided roughly equivalent health protection, as neither design included wastewater treatment (Tarr 1996). This view was supported by an 1881 report to the National Board of Health that recommended that design choice be based on local conditions and financial considerations (Hering 1977).

Construction of sewer systems greatly improved local sanitary conditions and in many cases reduced illness. The direct discharge of untreated wastewater to local receiving waters, however, adversely impacted downstream communities. During the 1880s and 1890s, the rate of typhoid deaths rose in cities with drinking water intakes downstream of untreated wastewater discharges. Bacterial analysis confirmed the link between sewage pollution in rivers and epidemics of certain diseases (Tarr 1996). Large outbreaks of cholera, which claimed thousands of lives, were also linked to sewage-contaminated water supplies (Snow 1936). As a result, views on the safety of discharging untreated wastewater directly to receiving waters began to shift toward the end of the 19th century.

As the need to provide wastewater treatment was recognized, the major design difference between CSSs and SSSs became apparent. Although combined sewers offered an efficient means of collecting and conveying storm water and wastewater, they made treatment more difficult due to the large variation in flows between dry and wet weather conditions. Sanitary sewer systems simplified and lowered the cost of wastewater treatment, due to significantly smaller volumes of wet weather flows (Burian et al. 1999). Nonetheless, municipalities with CSSs often continued to utilize and expand the areas served by such systems (Tarr 1996).

Centralized municipal wastewater treatment was still in its infancy in the late 1800s (Burian et al. 1999). In 1892, only 27 municipalities treated their wastewater; of these, 26 had SSSs.

2.1.1 Combined Sewers and CSOs

CSOs are primarily caused by wet weather events (e.g., rainfall or snowmelt), when the combined volume of wastewater and storm water entering the system exceeds the capacity of the CSS or treatment plant. When this occurs, combined systems overflow directly to a receiving water. Overflow frequency and duration varies both from system to system and

Privy vaults and a water pump are located side by side in this Pittsburgh neighborhood, circa 1909.

Photo: Paul Underwood Kellog

from outfall to outfall within a single CSS. Some CSO outfalls discharge infrequently, while others activate every time it rains. When constructed, CSSs were typically sized to carry three to five times the average dry weather flow. Thus, there is usually considerable conveyance capacity within a CSS during dry weather. Discharges from a CSS during dry weather, referred to as dry weather overflows, are infrequent and are prohibited under the NPDES program.

State and local authorities generally have not allowed the construction of new CSSs since the first half of the 20th century. As shown in Figure 2.3, most of the communities served by CSSs are located in the Northeast and Great Lakes regions, while relatively few are located in the Midwest, Southeast, and Pacific Northwest. Currently, 828 NPDES permits authorize discharges from 9,348 CSO outfalls in 32 states (including the District of Columbia).

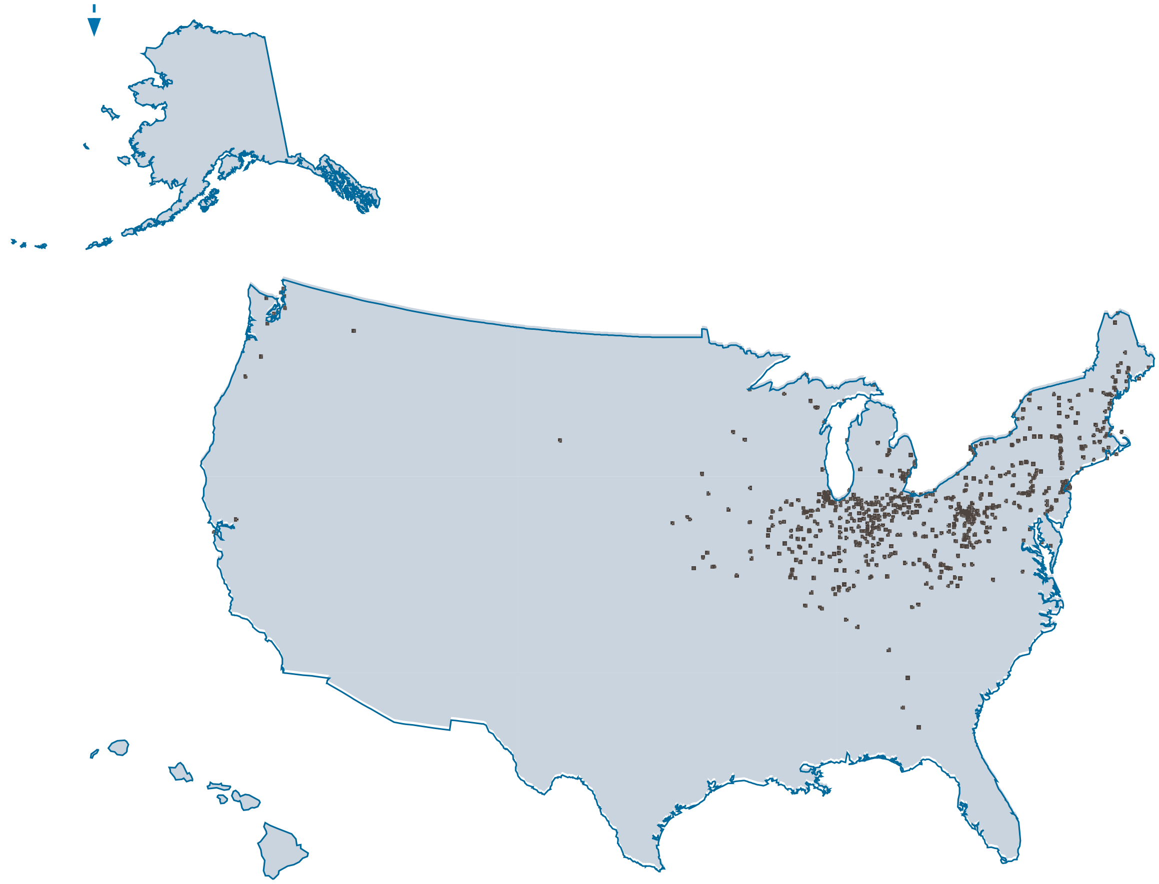
2.1.2 Sanitary Sewers and SSOs

SSOs include unauthorized discharges from SSSs that reach waters of the United States, as well as overflows out of manholes and onto city streets, sidewalks, and other terrestrial locations. A limited number of municipalities have SSO discharges

Figure 2.3

National Distribution of Communities Served by CSSs

CSSs are found throughout the United States, but are most heavily concentrated in the Northeast and Great Lakes regions.



from fixed points within the sewer system, similar to CSO outfalls.

SSOs, including those that do not reach waters of the Unites States, may be indicative of improper operation and maintenance of the sewer system. Causes of SSOs include, but are not limited to:

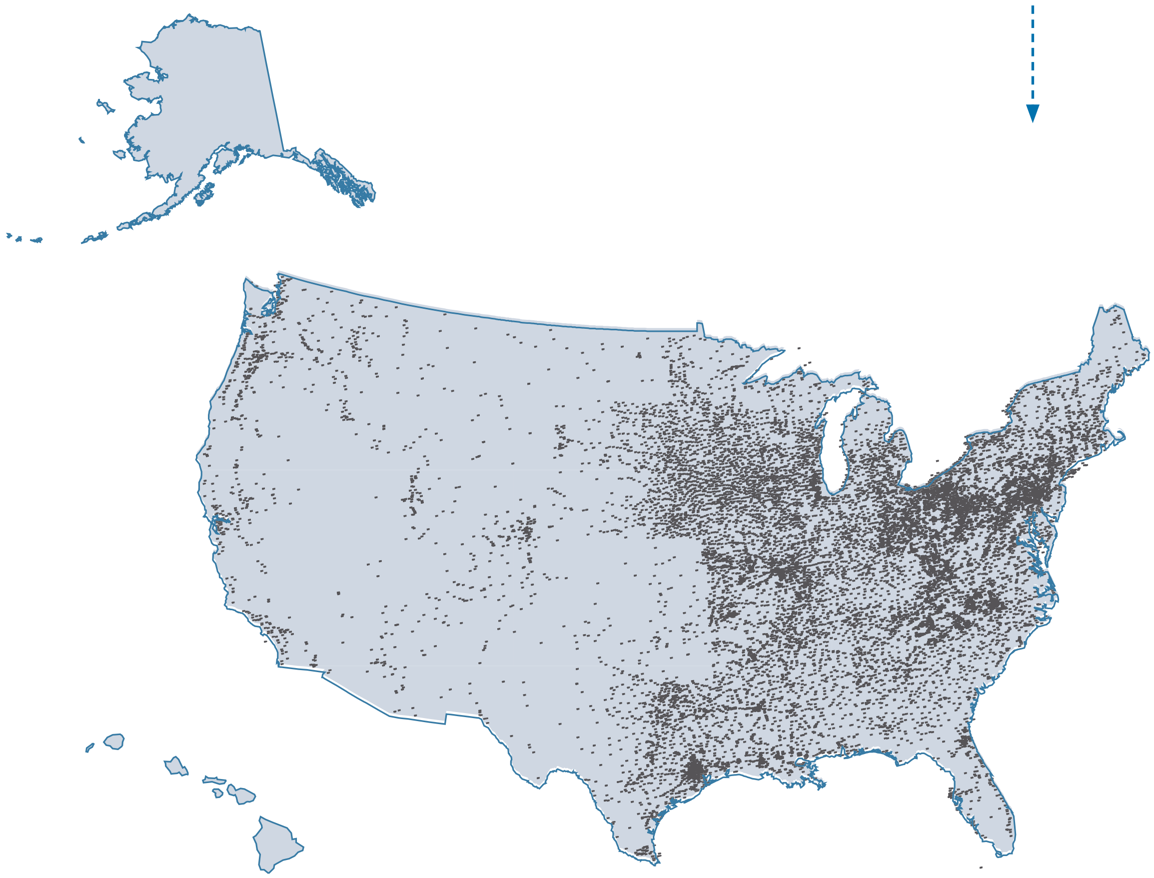
- Blockages
- Structural, mechanical, or electrical failures
- Collapsed or broken sewer pipes
- Insufficient conveyance capacity
- Vandalism

In addition, high levels of infiltration and inflow (I/I) during wet weather can cause SSOs. Many SSSs that were designed according to industry standards experience wet weather SSOs because levels of I/I may exceed levels originally expected; removal of I/I has proven more difficult and costly than anticipated; or the capacity of the system has become inadequate due to an increase in service population without corresponding system upgrades. SSSs are located across the country, as presented in Figure 2.4. EPA believes that all SSSs have the potential to have occasional SSOs.

Figure 2.4

National Distribution of Communities Served by SSSs

SSSs are located in all 50 states, but are concentrated in the eastern half of the United States and on the west coast. SSSs are shown for approximately 75 percent of systems, where locational data (latitude/longitude) were available from EPA's Permit Compliance System.



2.2 What is the History of Federal Water Pollution Control Programs?

The desire for a federal water pollution control program increased steadily through the first half of the 20th century. Congress and the public became more aware of the environmental and human health impacts resulting from direct discharges of untreated wastewater to local receiving waters. Recognizing the national interest in abating water pollution for the benefit of water supply and water resources, the 80th Congress stated:

> *"The pollution of our water resources by domestic and industrial wastes has become an increasingly serious problem for the rapid growth of our cities and industries. . . Polluted waters menace the public health through the contamination of water and food supplies, destroy fish and game life, and rob us of other benefits of our natural resources." (Senate Report No. 462 of the 80th Congress, 1948)*

San Francisco's CSO Oceanside Water Pollution Control Plant treats an average of 17 million gallons per day (mgd) during dry weather and has 65 mgd of peak flow capacity.

Photo: San Francisco Public Utilities Commission

In 1948, Congress passed the Federal Water Pollution Control Act (FWPCA), P.L. 80-845, creating a legislative basis for water pollution control in the United States. The original FWPCA was amended many times (in 1956, 1961, 1965, 1966, 1970, 1972, 1977, 1981, and 1987). Notably, the 1972 Amendments (P.L. 92-500), commonly known as the Clean Water Act, restructured the authority for water pollution control and consolidated that authority in the Administrator of the EPA. The Clean Water Act provided a framework for:

- Prohibition of point source discharges except as authorized by a permit;
- Establishment of the National Pollutant Discharge Elimination System (NPDES), a regulatory program that requires "point source" dischargers, such as municipal wastewater collection and treatment plant operators, to obtain a permit and meet applicable regulations issued under the Clean Water Act;
- Development of technology-based effluent limits, based on the pollutant reduction capacity of demonstrable treatment technologies, to be met by NPDES permit holders; and
- Water quality standards and water quality-based effluent limitations, where technology-based limits are inadequate to meet state water quality standards.

As a result of investment in wastewater treatment, the United States has realized major improvements in environmental quality and human health. Widespread epidemics of typhoid fever and cholera that killed thousands of people in the 19th century and early 20th century were brought under control and have remained under control due to disinfection of drinking water supplies and advances in wastewater treatment.

2.2.1 Secondary Treatment

Many of the first wastewater treatment facilities were designed to simply separate solids and floating debris from wastewater prior to discharge; this process is often referred to as primary treatment (Rowland and Heid 1976). This modest level of treatment, however, was unable to offset increased pollutant loads associated with rapidly growing urban populations and associated increases in the volume of wastewater generated. An additional level of treatment was needed to protect the quality of the nation's waters.

The 1972 Clean Water Act provided the first statutory requirement for achievement of effluent limits based on secondary treatment by POTWs. Specifically, Section 301 of the Clean Water Act required POTWs to meet limits based on secondary treatment by July 1, 1977. EPA developed limits based on secondary treatment to include maximum allowable concentrations of key parameters as well as percent removal requirements. Limits based on secondary treatment include maximum acceptable concentrations for biochemical oxygen demand measured over five days (BOD_5), total suspended solids (TSS), and pH. Percent removal requirements for BOD_5 and TSS were also included. Adjustments to percent removal requirements are available, on a case-by-case basis, for POTWs with less-concentrated influent that may prevent compliance with the standard requirements (EPA 2000a).

2.2.2 Construction Grants

In addition to establishing effluent limits for POTWs, the FWPCA and its amendments brought about substantial investment in wastewater treatment between the 1940s and the present. The 1956 Amendments (P.L. 84-660) established the Construction Grants Program for the construction of wastewater treatment facilities and provided $150 million in funding for the program. Additional construction grant funding was authorized with the 1961, 1965, and 1966 amendments. With passage of the Clean Water Act in 1972, funding for the Construction Grants Program dramatically increased. EPA's Construction Grants Program distributed $100.7 billion (2002 dollars) to communities between 1970 and 1995 (EPA 2000a). The 1987 amendments to the Clean Water Act transformed the financial assistance from a grant program to a loan program. The Construction Grants Program was phased out by 1991 and replaced by the State Revolving Fund (SRF) program.

Federal funding provided a strong impetus for constructing and upgrading wastewater infrastructure. The level of treatment provided at POTWs improved substantially over the last 50 years (EPA 2000a):

- 30 percent of POTWs (3,529 of 11,784) provided secondary treatment in 1950.
- 72 percent of POTWs (10,052 of 14,051) provided secondary treatment in 1968.
- 99 percent of 16,024 POTWs provided secondary or greater treatment, or were "no-discharge facilities," in 1996.

High levels of compliance with secondary treatment requirements resulted in notable decreases in pollutant loadings from POTWs, even as the service population increased. As an example, the amount of BOD_5 discharged from POTWs declined by about 23 percent between 1968 and 1996, despite a 35 percent increase in influent loadings to POTWs during the same period (EPA 2000a).

2.2.3 Pretreatment

In the mid-1980s, more than one-third of all toxic pollutants entering the nation's waters were discharged from POTWs (EPA 1986a). POTWs are not typically designed to remove toxic pollutants, and in some cases constituents in industrial wastewater can actually interfere with the removal of conventional pollutants such as BOD_5 and TSS. To address the discharge of toxic pollutants, EPA, pursuant to Clean Water Act Section 307, established the National Pretreatment Program. The National Pretreatment Program requires that industrial and commercial dischargers treat or control toxic pollutants in their wastewater prior to discharge to a municipal sewer system.

Some municipalities promote storm drain stenciling as a storm water pollution prevention measure.

Photo: EPA

The General Pretreatment Regulations require all large POTWs (i.e., those designed to treat flows of more than 5 million gallons per day (mgd)) and smaller POTWs with significant industrial users to establish local pretreatment programs. These local programs implement national pretreatment standards and requirements in addition to any more stringent local requirements necessary to protect site-specific conditions. More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users. The National Pretreatment Program has made great strides in reducing the discharge of toxic pollutants to sewer systems and to waters of the United States (EPA 1999a).

2.2.4 Wet Weather

Initial implementation of the Clean Water Act during the 1970s and 1980s focused on discharges from traditional point sources of pollution, such as POTWs and industrial facilities. Beginning in the late 1980s, attention shifted to wet weather sources of pollution. Under the NPDES program, four program areas address wet weather discharges: CSOs, SSOs, storm water, and concentrated animal feeding operations (CAFOs).

Storm Water

EPA published Phase I of the NPDES Storm Water Program in 1990 (55 FR 47990). Phase I applies to large dischargers; that is, those associated with industrial activities, municipal separate storm sewer systems serving 100,000 people or more, and construction projects disturbing more than five acres of land. In 1999, EPA published the Phase II Final Rule, which requires NPDES permit coverage for storm water discharges from smaller sources, including cities and towns in urban areas with separate storm sewer systems serving fewer than 100,000 people, and smaller construction projects that disturb less than five acres (64 FR 68722).

CAFOs

CAFOs are point sources, as defined by Clean Water Act Section 502(14). On February 12, 2003, EPA published the Concentrated Animal Feeding Operations Rule to ensure that manure and wastewater from CAFOs are properly managed to protect the environment and public health (68 FR 7175).

2.2.5 Watershed-Based Permitting

On December 17, 2003, EPA published the Watershed-Based NPDES Permitting Implementation Guidance (EPA 2003c). Watershed-based permitting under the NPDES program emphasizes addressing all stressors (including CSOs and SSOs) within a watershed, rather than individual pollutant sources on a discharge-by-discharge basis. The watershed-based permitting approach is supported by EPA as a cost-effective mechanism for improving water quality and meeting watershed goals. The approach builds on watershed policy and guidance developed during the 1990s: EPA's Watershed Strategy, Watershed Framework, and Clean Water Action Plan (EPA 1994b, 1996a, EPA and USDA 1998). In addition, the approach fulfills commitments articulated in recent initiatives such as EPA's Trading Policy and Watershed-Based Permitting Policy Statement (EPA 2003d, 2003e).

Watershed-based permitting can encompass a variety of activities ranging from synchronizing NPDES permits within a basin to developing water quality-based effluent limits using a multiple discharger modeling analysis. Within a broader watershed management system, the watershed-based permitting approach is a tool that can assist with implementation activities such as monitoring, reporting, and assessment.

2.3 What is the Federal Framework for CSO Control?

CSOs are point source discharges and are subject to NPDES permit requirements. CSOs are not subject to limits based on secondary treatment requirements otherwise applicable to POTWs. Permits for CSOs must include technology-based effluent limits, based on the application of best available technology economically achievable (BAT) for toxic and non-conventional pollutants and best conventional pollutant control technology (BCT) for conventional pollutants. Additionally, like all NPDES permits, permits authorizing discharges from CSO outfalls must include more stringent water quality-based requirements, when necessary, to meet water quality standards. The development of the federal framework to address CSOs is described in detail below.

2.3.1 CSO Case Law

In 1980, the U.S. Court of Appeals for the D.C. Circuit accepted EPA's interpretation of the Clean Water Act that discharges at CSO outfalls are not discharges from POTWs and thus are not subject to the limits based on secondary treatment standards otherwise applicable to POTWs (*Montgomery Environmental Coalition vs. Costle*, 46 F2d 568 (D.C. Cir. 1980)). Following this decision, EPA and states renewed their focus on permit requirements for CSO discharges under the NPDES program.

The sewer utility serving Louisville, Kentucky, has restructured its organization to coordinate CSO control needs with other water quality improvement programs as part of an effort to move toward watershed-based permitting.

Photo: Louisville-Jefferson County Metropolitan Sewer District

2.3.2 The National CSO Control Strategy and the MAG

In 1989, EPA issued the National CSO Control Strategy (54 FR 37371). The National CSO Control Strategy encouraged states to develop statewide permitting strategies to ensure all CSOs were subject to an NPDES permit and recommended six minimum measures for CSO control; additional controls could be required as necessary. As EPA, states, and municipalities worked to implement the National CSO Control Strategy in the early 1990s, the impacts of CSOs (discussed in Chapters 5 and 6 of this report) continued to receive national attention. Environmental interest groups pushed for further action, while municipal organizations, concerned that the National CSO Control Strategy did not provide sufficient clarity, sought a consistent national approach to CSO control. In response to these concerns, EPA formed a Management Advisory Group (MAG) in 1992. The MAG included representatives from states, municipalities, industry associations, and environmental interest groups.

A CSO outfall in Wilmington, Delaware.

Photo: Wilmington Department of Public Works

2.3.3 The CSO Control Policy

EPA published the CSO Control Policy on April 19, 1994 (59 FR 18688). The purpose of the CSO Control Policy was twofold: 1) to elaborate on EPA's 1989 National CSO Control Strategy; and 2) to expedite compliance with Clean Water Act requirements. The policy sought to minimize adverse impacts from CSOs on water quality, aquatic biota, and human health (EPA 1994a).

EPA's CSO Control Policy assigns primary responsibility for its implementation and enforcement to NPDES authorities and water quality standards authorities. This policy also established objectives for CSO communities: 1) to implement the nine minimum controls (NMC) and submit documentation on NMC implementation; and 2) to develop and implement a long-term control plan (LTCP). Implementation status of the NMC and LTCPs is presented in Chapter 7. More information on the CSO Control Policy is provided in EPA's *Report to Congress–Implementation and Enforcement of the Combined Sewer Overflow Control Policy* (EPA 2001a).

2.4 What is the Federal Framework for SSO Control?

SSOs that reach waters of the United States are point source discharges and, like other point source discharges from municipal SSSs, are prohibited unless authorized by an NPDES permit. Moreover, SSOs, including those that do not reach waters of the United States, may be indicative of improper operation and maintenance of the sewer system, and thus may violate NPDES permit conditions. In the 1989 National CSO Control Strategy, EPA explained that:

"sanitary sewer systems must adhere to the strict design and operational standards established to protect the integrity of the sanitary sewer system and wastewater treatment facilities."

In 1994, a number of municipalities asked EPA to establish an SSO Federal Advisory Committee (FAC) of key stakeholders to make recommendations on how the NPDES program should address SSOs. The municipalities indicated a desire for greater national clarity, consistency in NPDES requirements applicable to SSOs, and a workable regulatory framework. Five general stakeholder groups were represented in the SSO FAC: sanitary sewer system operators, SSO-related health professionals, state regulatory agencies, technical professionals, and environmental and citizen groups.

In 1995, EPA chartered an Urban Wet Weather Flows FAC with stakeholder representation to address cross-cutting issues associated with wet weather discharges (i.e., CSOs, SSOs, and storm water). The Urban Wet Weather Flows FAC formed its SSO Subcommittee by reconvening the SSO FAC established in 1994. The SSO Subcommittee was tasked with developing a framework for addressing SSOs and their impacts through regulatory and non-regulatory actions.

Between 1995 and 1999, the SSO Subcommittee held 12 meetings and developed a number of documents, including a series of issue papers and a draft comprehensive guidance document. In January 2001, EPA prepared a notice of proposed rulemaking related to SSOs, which was withdrawn for review before it was published in the Federal Register. EPA is considering various options for moving forward.

2.5 What is the Wet Weather Water Quality Act?

In December 2000, as part of the Consolidated Appropriations Act for Fiscal Year 2001 (P.L. 106-554), Congress amended the Clean Water Act by adding Section 402(q). This amendment is commonly referred to as the Wet Weather Water Quality Act of 2000. Section 402(q) requires that each permit, order, or decree issued pursuant to the Clean Water Act after the date of enactment for a discharge from a municipal combined sewer system shall conform to the CSO Control Policy. It authorized a $1.5-billion grant program for controlling CSOs and SSOs. Section 402(q) also required EPA to issue guidance to facilitate the conduct of water quality and designated use reviews for CSO receiving waters. EPA issued this guidance on August 2, 2001 (EPA 2001b).