Chapter 4

Characterization of CSOs and SSOs

Consistent with the congressional directive, this chapter provides a comprehensive description of CSOs and SSOs with respect to the location of discharges, the frequency and volume of discharges, and the constituents discharged. Similarities and differences in the character of CSO and SSO discharges are noted where they occur. Comparisons of CSOs and SSOs to other sources of pollution have been made where appropriate. The CSO and SSO characterization information provided in this chapter is important for assessing the environmental and human health impacts of CSOs and SSOs.

For purposes of this Report to Congress, the terms "wet weather" and "dry weather" are used to distinguish sewer overflows that are rainfall- or snowmelt-induced from those that are not caused by rainfall or snowmelt. The discussion of CSOs in this report is limited to wet weather CSOs. That is, those CSOs that are rainfall- or snowmelt-induced and occur at permitted CSO outfalls. Dry weather CSO discharges are prohibited under the NPDES program.

SSOs can be induced by rainfall or snowmelt when excess I/I causes the conveyance capacity of the SSS to be exceeded. SSOs also occur as a result of other, non-wet weather causes such as blockages, line breaks, vandalism, mechanical failures, and power failure. The terms "wet weather SSOs" and "dry weather SSOs" are used in this report to differentiate these two general types of SSOs because these events have different characteristics and respond to different control strategies. The discussion of SSOs in this report, including national estimates of volume and frequency, does not account for wet weather or dry weather discharges occurring after the headworks of the treatment plant, regardless of the level of treatment, or backups into buildings caused by problems in the publicly-owned portion of the SSS.

In this chapter:

4.1 What Pollutants are in CSOs and SSOs?

The principal pollutants present in CSO and SSO discharges include:

- Microbial pathogens
- Oxygen depleting substances (measured as BOD_5)
- TSS
- Toxics
- Nutrients
- Floatables

The pollutants in CSOs and SSOs come from a variety of sources. Domestic wastewater contains microbial pathogens, BOD_5, TSS, and nutrients. Wastewater from industrial facilities, commercial establishments, and institutions can contribute additional pollutants such as fats, oils, and grease (FOG), and toxic substances including metals and synthetic organic compounds. Fungi do not have a major presence in wastewater (WERF 2003b). Storm water can also contribute pollutants to CSSs and, in some instances, SSSs. The concentration of pollutants in storm water is generally more dilute than in wastewater, but can contain significant amounts of microbial pathogens, BOD_5, TSS, toxics (notably metals and pesticides), nutrients, and floatables. Pollutant concentrations in CSOs and SSOs vary substantially, not only from community to community and event to event, but also within a given event.

Descriptions of the pollutants in CSOs and SSOs are provided in the following subsections and include comparisons of concentration data for discharges from different municipal sources. The comparisons include, where available, median pollutant concentrations and ranges of concentrations found in treated wastewater, untreated wastewater, CSOs, wet weather SSOs, dry weather SSOs, and urban storm water. The origin and relative availability of data on pollutant concentrations in discharges were not consistent for the different municipal sources. In general, adequate data were available to characterize treated and untreated wastewater, CSOs, and urban storm water. Monitoring data to characterize actual wet and dry weather SSO discharges, however, were less readily available.

EPA compiled a limited dataset on pollutant concentrations in wet weather SSOs as part of municipal interviews conducted for this Report to Congress. EPA also identified a study conducted by the Wisconsin Department of Natural Resources that quantified the concentration of various constituents in wet weather SSOs from a number of federal and locally-sponsored studies (WDNR 2001). The findings of the WDNR study support the data EPA collected on wet weather SSOs for this Report to Congress. For the purposes of this report, EPA assumed that dry weather SSOs would have the same characteristics and pollutant concentrations as untreated wastewater.

The descriptions of pollutants in CSOs and SSOs include an overview of the types of impacts typically associated with these pollutants. The presence of pollutants in a CSO or SSO discharge in and of itself is not indicative of environmental or human health impacts. The occurrence of actual impacts depends on the concentration of the pollutant present, the volume and duration of the CSO or SSO event, the location of the discharge, the condition of the receiving water at the time of the discharge, and, in the case of human health, exposure. More detailed discussions of environmental and human health impacts of CSOs and SSOs are presented in Chapters 5 and 6, respectively.

4.1.1 Microbial Pathogens

Microbial pathogens are microorganisms that can cause disease in aquatic biota and illness or even death in humans. The three major categories of microbial pathogens present in CSOs and SSOs are bacteria, viruses, and parasites. These microbial pathogens are, for the most part, easily transported by water. A brief discussion of these pathogens, including the concentrations present in various municipal discharges, is presented below. A more detailed discussion of pathogens is presented in Chapter 6 of this report.

Bacteria

The two broad categories of bacteria associated with wastewater are indicator bacteria and pathogenic bacteria. Indicator bacteria are widely used as a surrogate for microbial pathogens in wastewater and water quality assessments. Indicator bacteria suggest the presence of disease-causing organisms, but generally are not pathogenic themselves. The principal indicator bacteria used to assess water quality are fecal coliform, *E. coli,* and enterococcus. All three are found in the intestines and feces of warm-blooded animals.

Fecal coliform concentrations from municipal sources are presented in Table 4.1. As shown, concentrations of fecal coliform found in CSOs and wet weather SSOs are generally less than the concentrations found in untreated wastewater and dry weather SSOs, and greater than the concentrations reported for urban storm water.

Pathogenic bacteria are capable of causing disease. Examples of pathogenic bacteria associated with untreated wastewater, CSOs, and SSOs

Table 4.1

Fecal Coliform Concentrations in Municipal Discharges

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with fecal material of humans or other warm-blooded animals.

Municipal Sources	Fecal Coliform (colonies/100 ml)		
	Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs	--	1,000,000[a] - 1,000,000,000[d]	--
Wet weather SSOs[a]	--	--	500,000
CSOs[b]	603	3 - 40,000,000	215,000
Urban storm water[c]	1,707	1 -5,230,000	5,081
Treated wastewater	--	--	<200[e]

[a] WDNR 2001
[b] Data collected as part of municipal interviews
[c] Pitt et al. 2003
[d] NRC 1996
[e] Limit for disinfected wastewater

include *Campylobacter*, *Salmonella*, *Shigella*, *Vibrio cholerae*, and *Yersina*.

Viruses

More than 120 enteric (intestinal) viruses may be found in sewage (NAS 1993). Concentrations of viruses reported in wastewater vary greatly and depend on the presence and amount of infection in the population served by a sewer system, season of the year, and the methods used for enumerating the virus counts. Examples of viruses associated with untreated wastewater, CSOs, and SSOs include poliovirus, infectious hepatitis virus, and coxsackie virus.

Parasites

The common parasites of human health concern in untreated wastewater are parasitic protozoa and helminths (NAS 1993). Parasitic protozoa include *Giardia*, *Cryptosporidium*, and *Entamoeba*. *Giardia* is the most common protozoan infection in the United States (NAS 1993). *Giardia* has been detected in treated and untreated wastewater at levels of 0.0002 to 0.011 cysts per L and 2 to 200,000 cysts per L, respectively (Payment and Franco 1993; Yates 1994; NAS 1998; Rose et al. 2001b). *Cryptosporidium* has also been detected in treated and untreated wastewater at concentrations of 0.0002 to 0.042 oocysts per L and less than 0.3 to 13,700 oocysts per L, respectively (Payment and Franco 1993; NAS 1998; Rose et al. 2001a; McCurin and Clancy 2004).

Several recent studies have specifically investigated the presence of *Cryptosporidium* and *Giardia* in CSOs. *Giardia* concentrations ranging from 2 to 225 cysts per L were measured in samples collected during two overflow events at each of the six CSO outfalls (EPA 2003f). A study conducted in Pittsburgh also found *Cryptosporidium* (0 to 30 oocysts per L) and *Giardia* (37.5 to 1,140 cysts per L) in CSOs (States et al. 1997). Given that both CSOs and SSOs include untreated wastewater, this suggests that CSOs and SSOs are also likely to contain significant concentrations of *Giardia*, and possibly *Cryptosporidium*.

Helminths include roundworms, hookworms, tapeworms, and whipworms. These organisms are endemic in areas lacking inadequate access to hygiene facilities, including toilets. Their transmission is generally associated with untreated sewage and sewage sludge. However, there is very little documentation of waterborne transmission of helminths (NAS 1993).

4.1.2 BOD_5

BOD_5 is widely used as a measure of the amount of oxygen-demanding organic matter in water or wastewater. The organic matter in sewage is a mix of human excreta, kitchen waste, industrial waste, and other substances discharged into sewer systems. When significant amounts of BOD_5 are discharged to a waterbody, the dissolved oxygen can be depleted. This occurs principally through the decay of organic matter and the uptake of oxygen by bacteria. The depletion of dissolved oxygen in waterbodies can be harmful or fatal to aquatic life. Low levels of dissolved oxygen are responsible for many of the fish

Municipal Sources	BOD_5 (mg/l) Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs[a]	--	88 - 451	--
Wet weather SSOs[b]	22	6 - 413	42
CSOs[b]	501	3.9 - 696	43
Urban storm water[c]	3,110	0.4 - 370	8.6
Treated wastewater[d]	--	--	30

[a] AMSA 2003a. 85 facilities reported annual average BOD_5 concentration data; each facility based its value on an unspecified amount of monitoring
[b] Data collected as part of municipal interviews
[c] Pitt et al. 2003
[d] Typical limit for wastewater receiving secondary treatment

Table 4.2

BOD_5 Concentrations in Municipal Discharges

The consequences of high BOD_5 concentrations are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

kills reported and tracked by resource agencies. BOD_5 concentrations from municipal sources are presented in Table 4.2. As shown, the median concentrations of BOD_5 in CSOs and wet weather SSOs are typically five times greater than concentrations found in urban stormwater. Median BOD_5 concentrations in CSOs and wet weather SSOs are typically 1.3 to 1.4 times greater than concentrations found in treated wastewater.

4.1.3 TSS

TSS is a measure of the small particles of solid pollutants that float on the surface of, or are suspended in, water or wastewater. TSS in wastewater includes a wide variety of material, such as decaying plant and animal matter, industrial wastes, and silt. High concentrations of TSS can cause problems for stream health and aquatic life. TSS can clog fish gills, reduce growth rates, decrease resistance to disease, and impair reproduction and larval development. The deposition of solids can damage habitat by filling spaces between rocks that provide shelter to aquatic organisms. TSS can accumulate in the immediate area of CSO and recurrent SSO discharges, creating turbid conditions that smother the eggs of fish and aquatic insects. TSS concentrations from municipal sources are presented in Table 4.3. As shown, the median concentration of TSS in CSOs and wet weather SSOs is

Municipal Sources	TSS (mg/l) Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs[a]	--	118 - 487	--
Wet weather SSOs[b]	27	10 - 348	91
CSOs[b]	995	1 - 4,420	127
Urban storm water[c]	3,396	0.5 - 4,800	58
Treated wastewater[d]	--	--	30

[a] AMSA 2003a. 121 facilities reported annual average TSS concentration data; each facility based its value on an unspecified amount of monitoring
[b] Data collected as part of municipal interviews
[c] Pitt et al. 2003
[d] Typical limit for wastewater receiving secondary treatment

Table 4.3

TSS Concentrations in Municipal Discharges

Over the long-term, the deposition of solids in the immediate area of CSO and SSO discharges can damage aquatic life habitat.

higher than concentrations in urban storm water.

4.1.4 Toxics

Toxics are chemicals or chemical mixtures that, under certain circumstances of exposure, present an environmental or human health risk. Toxics include metals, hydrocarbons, and synthetic organic chemicals. Concentrations of toxics in wastewater can be a concern in industrialized areas or where monitoring data indicate potential toxicity (Moffa 1997). Storm water contributions to CSOs in urbanized areas can also contain significant concentrations of hydrocarbons and metals. Metals concentrations from municipal sources are presented in Tables 4.4 and 4.5.

In general, environmental problems related to toxicity fall into two categories: chronic or long-term exposure to toxics causing reduced growth and reproduction, and acute

Table 4.4

Cadmium and Copper Concentrations in Municipal Discharges

For many municipalities, the largest source of copper in wastewater is corrosion of copper pipes (PARWQCP 1999). Other sources include industrial discharges, copper-based root killers, and cooling water discharges.

Municipal Sources	Cadmium (μg/l)			Copper (μg/l)		
	Number of Samples	Range	Median	Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs[a]	---	0.1 - 101	--	--	1.8 - 322	--
Wet weather SSOs	--	--	--	--	--	--
CSOs[b]	401	0.16 - 30	2	346	10-1,827	40
Urban storm water[c]	2,582	0.04 - 16,000	1	2,728	0.6 - 1,360	16
Treated wastewater[d]	465	0.01 - 3.0	0.04	596	2.8-16.0	5.2

[a] AMSA 2003a. 101 and 109 facilities reported annual average Cd and Cu concentrations, respectively; each facility based its value on an unspecified amount of monitoring
[b] Data collected as part of municipal interviews
[c] Pitt et al. 2003
[d] WERF 2000

Table 4.5

Lead and Zinc Concentrations in Municipal Discharges

Municipal wastewater treatment facilities are reported to be the largest point source for zinc discharges to surface waters (WSDOH 1996).

Municipal Sources	Lead (μg/l)			Zinc (μg/l)		
	Number of Samples	Range	Median	Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs[a]	--	0.5 -250	--	--	9.7 - 1,850	--
Wet weather SSOs	--	--	--	--	--	159
CSOs[b]	438	5 - 1,013	48	442	10 - 3,740	156
Urban storm water[c]	2,954	0.2 - 1200	16	3,016	0.1 - 22,500	117
Treated wastewater[d]	21	0.2 - 1.4	0.6	530	20.0 - 57.5	51.9

[a] AMSA 2003a. 106 and 109 facilities reported annual average Pb and Zn concentrations, respectively; each facility based its value on an unspecified amount of monitoring
[b] Data collected as part of municipal interviews
[c] Pitt et al. 2003
[d] WERF 2000

or short-term exposure at higher concentrations causing increased mortality. Chronic effects are subtle and difficult to identify, but can be observed by lower productivity and biomass (numbers of organisms), bioaccumulation of chemicals, or reduced biological diversity. Acute effects can be observed as immediate fish kills or severely reduced biologic diversity.

4.1.5 Nutrients

Nutrients is the term generally applied to nitrogen and phosphorus. Untreated wastewater contains significant amounts of nitrogen and phosphorus from domestic and industrial sources. CSSs also receive nutrients contained in urban runoff from street litter and chemical fertilizers applied to landscaped areas, lawns, and gardens. Nutrients are essential to the growth of plants and animals. Excess amounts of nitrogen and phosphorus can cause rapid growth of algae and nuisance plants, as well as eutrophic conditions that can lead to oxygen depletion.

Total phosphorus and total kjeldahl nitrogen (a measure of ammonia and organic nitrogen) concentrations from municipal sources are presented in Table 4.6. As shown for total phosphorus, wet weather SSO concentrations are roughly equivalent to treated wastewater concentrations and are approximately one-third of untreated wastewater concentrations. Total phosphorus concentrations in CSO and urban stormwater are generally less than those in wet weather SSOs.

4.1.6 Floatables

Floatables is the term used to describe the trash, debris, and other visible material discharged when sewers overflow. In SSSs, floatables generally include sanitary products and other wastes commonly flushed down a toilet. In CSSs, floatables include litter and detritus that accumulate on streets and other paved areas that wash into CSSs during rainfall or snowmelt events. Floatables can have an adverse impact on wildlife, primarily through entanglement or ingestion. Floatables

Table 4.6

Nutrient Concentrations in Municipal Discharges

Nutrient additions can cause increased algae or aquatic weed growth that, in turn, can deplete dissolved oxygen, reduce biologic diversity, worsen aesthetics, and impair use for water supply (Moffa 1997).

Municipal Sources	Total Phosphorus (mg/l)			Total Kjeldahl Nitrogen (mg/l)		
	Number of Samples	Range	Median	Number of Samples	Range	Median
Untreated wastewater/dry weather SSOs[a]	--	1.3 - 15.7	5.8	59	11.4 - 61	33
Wet weather SSOs[b]	--	--	2	--	--	--
CSOs[c]	43	0.1 - 20.8	0.7	373	0 -82.1	3.6
Urban storm water[d]	3,283	0.01 - 15.4	0.27	3,199	0.05 - 66.4	1.4
Treated wastewater[a]	72	0.07 - 6	1.65	64	0.5 - 32	3.95

[a] AMSA 2003a. 59 facilities reported annual average total P and TKN concentrations; each facility based its value on an unspecified amount of monitoring
[b] WDNR 2001
[c] Data collected as part of municipal interviews
[d] Pitt et al. 2003

can also contribute to aesthetic impacts in recreation areas.

An extensive monitoring program conducted in New York City suggests that more than 90 percent of floatables in the city's CSOs originate as street litter (NYCDEP 1997). The monitoring program specifically found that street trash, including plastics, polystyrene, and paper, accounted for approximately 93 percent of the floatables discharged. Personal hygiene items and medical materials accounted for approximately one percent of all floatables discharged into New York Harbor through CSOs. The remaining six percent of floatable items included glass, metal, wood, and cloth.

4.2 What Factors Influence the Concentrations of the Pollutants in CSOs and SSOs?

The pollutant concentrations associated with CSO and SSO discharges are highly variable. Pollutant concentrations vary not only from site to site and event to event, but also within a given overflow event. Brief descriptions of some of the factors that influence pollutant concentrations in CSOs and SSOs are described in the following subsections.

4.2.1 Factors Influencing Pollutant Concentrations in CSOs

The relative amounts of domestic, commercial, and industrial wastewater, and urban storm water carried by a CSS during specific wet weather events are the primary driver of pollutant concentrations in CSOs. Other factors that contribute to the variability include:

- Elapsed time since the wet weather event began, with higher pollutant concentrations expected during the early stages of a CSO event (often termed the "first flush");
- Time between the current and most recent wet weather events, with higher pollutant concentrations expected in CSOs occurring after lengthier dry periods; and
- Intensity and duration of the wet weather event.

The sudden rush of flow into a CSS brought on by rainfall, or in some instances, snowmelt, can create a first flush effect. The first flush effect occurs when pollutants washed from city streets and parking lots combine with pollutants re-suspended from settled deposits within the CSS. This combination can produce peak pollutant concentrations at the beginning of the CSO event, particularly if rainfall is intense. First flush effects are typically observed during the first 30 to 60 minutes of a CSO discharge (Moffa 1997). They are generally more pronounced after an extended dry period and in sewer systems with low gradients (slope). Many CSO control programs have been designed specifically to capture the first flush.

4.2.2 Factors Influencing Pollutant Concentrations in SSOs

Wastewater flows generated by domestic, commercial, and industrial sources fluctuate on diurnal, weekend/weekday, and seasonal cycles. Periods of low and high flows are associated with water demand and use. SSSs carry varying amounts of I/I during wet weather periods, when the ground is saturated, and when the water table is elevated. The amount of I/I entering an SSS is influenced by:

- Age and condition of SSS components
- Local use of SSS for roof and foundation drainage
- Location of sewer pipes relative to the water table
- Characteristics of recent rainfall events
- Soil type and antecedent soil moisture conditions

The amount of I/I, in turn, influences the concentration of pollutants in SSO discharges.

Dry weather SSOs consist mainly of domestic, commercial, and industrial wastewater, with limited amounts of I/I. Therefore, the pollutant concentrations in dry weather SSOs are most heavily influenced by the relative contribution from domestic, commercial, and industrial customers to the total flow.

4.3 What Other Point and Nonpoint Sources Might Discharge These Pollutants to Waterbodies Receiving CSOs and SSOs?

CSOs and SSOs contribute to pollutant loadings where discharges occur. Waterbodies also receive pollutants of the types found in CSOs and SSOs from other point and nonpoint sources including:

- Wastewater treatment facilities
- Decentralized wastewater treatment systems
- Industrial point sources
- Urban storm water
- Agriculture
- Domestic animals and wildlife
- Commercial and recreational vessels

The contribution of pollutant loads from CSOs and SSOs relative to other point and nonpoint sources varies widely depending on the characteristics of the waterbody and the volume, frequency, and duration of CSO and SSO events. Each of these sources is discussed briefly below.

CSO-related Bypass at Wastewater Treatment Facility: Augusta, ME

In 1999, the Augusta Sanitary District completed the first phase of a $40-million five-phase CSO Long Term Control Plan as part of an Administrative Order (AO). Phase One involved a $12.2-million upgrade of the wastewater treatment plant to increase the treatment capacity and to better treat excess wet weather flows from the CSS. Prior to the upgrade, excess wet weather flows received minimal treatment (sometimes bypassing primary and secondary treatment processes entirely) and were not disinfected prior to discharge. Since completion of the treatment plant upgrade, the District bypasses secondary treatment processes only during wet weather events, and has the capacity to provide primary treatment, chlorination, and dechlorination to the bypassed flows. Bypassing frequency has decreased by 70 percent.

Wet Weather Bypass at Wastewater Treatment Facility Serving SSS: Jefferson County, AL

The Village Creek Wastewater Treatment Plant in Jefferson County, Alabama, routinely experienced peak wet weather flows greater than 10 times its annual average flow of 40 mgd. Due to extreme peak wet weather flows in the system, untreated wastewater was frequently diverted from the Village Creek plant and discharged without treatment. Between 1997 and 2001, excess wastewater flow was diverted and discharged an average of 41 times per year. Under a Consent Decree issued in 1996, Jefferson Country initiated corrective actions to address diversions of untreated wastewater from the Village Creek facility, as well as other problems within the system. The total cost for the improvements are estimated to approach $2.5 billion.

4.3.1 Wastewater Treatment Facilities

Wastewater treatment facilities are designed to receive domestic, commercial, and industrial wastewater, and to treat it to the level specified in an NPDES permit. Permits typically define effluent concentration limits for BOD_5 and TSS, and for indicator bacteria (typically fecal coliform, *E. coli*, or enterococci) when disinfection is required. Wastewater treatment facilities that discharge to impaired or sensitive waters may have more stringent effluent limits for BOD_5, TSS, or additional parameters (e.g., additional reduction of nutrients and metals).

Wastewater treatment facilities in the United States are estimated to contribute to the impairment of four percent of the nation's assessed rivers and streams; five percent of the nation's assessed lakes, ponds, and reservoirs; and 19 percent of assessed estuaries (EPA 2002c). The concentrations of fecal coliform, BOD_5, TSS, metals, and nutrients in treated and untreated wastewater can be compared using the tables in Section 4.1 of this report.

Untreated and Partially Treated Discharges from Wastewater Treatment Facilities

In CSSs and to a lesser degree in SSSs, flows to wastewater treatment facilities increase during periods of wet weather. Significant increases in influent flow caused by wet weather conditions (e.g., due to I/I into the sewer system) can create operational challenges for treatment facilities and can adversely affect treatment efficiency, reliability, and control of treatment processes. Excess wet weather flows can result in discharges of untreated or partially treated wastewater at the treatment facility.

Treatment plants are sometimes designed to route peak wet weather flows that exceed capacity around secondary treatment units and then blend them with treated wastewater to meet permit limits. Volumes associated with wet weather discharges can be substantial.

Treatment facilities serving CSSs may be allowed to discharge partially treated wastewater (e.g., wastewater having received primary treatment and disinfection, if necessary) during periods of wet weather, according to the terms of their permit. Untreated wet weather discharges at treatment facilities serving CSSs are not permitted and are required to be reported to the NPDES authority within 24 hours of their occurrence.

With rare exception, treatment facilities serving SSSs are only permitted to discharge wastewater that has received appropriate treatment. Discharges of untreated wastewater at treatment facilities serving SSSs are required to be reported to the NPDES authority within 24 hours of their occurrence.

4.3.2 Decentralized Wastewater Treatment Systems

Decentralized wastewater treatment systems are on-site or clustered wastewater systems used to treat and dispose of relatively small volumes of wastewater, generally from private residences and businesses that are located in close proximity to each other. These systems serve individual residences as well as trailer parks, recreational vehicle parks, and campgrounds. They are commonly referred to as septic systems, private sewage systems, or individual sewage systems. Some decentralized systems are designed to have a surface discharge. Approximately 25 percent of the total population of the United States is served by decentralized wastewater treatment systems, and about 33 percent of new residential construction employs this type of treatment (EPA 2003g). The 2001 American Housing Survey for the United States reported that approximately 6 percent of decentralized wastewater treatment systems fail annually. Depending on assumptions about persons per household and water use, these failures may result in improper treatment of 180 to 396 million gallons of wastewater daily, or 66 to 144 billion gallons discharged annually. Failing decentralized wastewater treatment systems can contribute to pathogen and nutrient contamination of surface water and groundwater (Bowers 2001).

4.3.3 Industrial Point Sources

Industrial point sources include non-municipal industrial and commercial facilities that treat and discharge wastewater, with attendant pollutants, directly to receiving waters. Unlike municipal wastewater treatment facilities, the types of raw materials, production processes, and treatment technologies utilized by industrial and commercial facilities vary widely. Consequently, the pollutants discharged by industrial point sources vary considerably and are dependent on specific facility characteristics (EPA 1996b). In addition to wastewater, industrial point sources can also collect and discharge storm water runoff generated at their facility. Industrial point sources are regulated under the NPDES point source and storm water programs. Many discharges are governed by industry-specific effluent guidelines. Industrial point sources can be a major source of pollutants, particularly nutrients and toxics, in waters receiving the discharges.

4.3.4 Urban Storm Water

Urban storm water runoff occurs when rainfall does not infiltrate into the ground or evaporate. Urban storm water runoff flows onto adjacent land, directly into a waterbody, or is collected and routed through a separate storm sewer system. Urban storm water runoff is principally generated from impervious surfaces such as city streets and sidewalks, parking lots, and rooftops. In general, the degree of urbanization increases the variety and amount of pollutants carried by storm water runoff. Although concentrations of specific pollutants in urban storm water runoff vary widely, the most common pollutants include microbial pathogens from pet and wildlife wastes; TSS; metals, oil, grease, and hydrocarbons from motor vehicles; and nutrients, pesticides, and fertilizers from lawns and gardens (EPA 2003h).

Urban storm water discharges are a leading cause of impairment of the nation's surface waters (EPA 2002c). Storm water is estimated to contribute to the impairment of 5 percent of assessed river miles nationwide, 8 percent of assessed lake acres, and 16 percent of assessed estuarine square miles (EPA 2002). EPA has estimated that approximately 27.6 billion gallons of storm water runoff are generated daily from urbanized areas nationwide (EPA 2002c).

4.3.5 Agriculture

Agriculture is a major source of pollution in the United States and the leading source of impairment in assessed rivers and streams, as well as in assessed lakes, ponds, and reservoirs (EPA 2002c). Agricultural sources that contribute pollutant loads to waterbodies include row crops, pastures, feed lots, and holding pens. Agricultural practices that add pollution include over-application of manure, other fertilizers, and pesticides; tillage practices that leave the earth exposed to erosion; and pasture and range practices that provide livestock with direct access to waterways. These practices add microbial pathogens, BOD_5, TSS, toxics, and nutrients to runoff from agricultural areas. More than 150 microbial pathogens found in livestock manure are associated with health risks to humans. This includes the microbial pathogens that account for more than 90 percent of food and waterborne diseases in humans (EPA 2003i). These pathogens are *Campylobacter, Salmonella* (non-typhoid), *Listeria monoctyogenes*, pathogenic *E. coli, Cryptosporidium,* and *Giardia*.

4.3.6 Domestic Animals and Wildlife

Although livestock are believed to be the greatest contributor of animal waste to receiving waters, loads from pets, wild birds, and other mammals can be significant (EPA 2001d). This is particularly true in urban areas where there are no livestock, but pets and wildlife are common. In addition, the feces of waterfowl (e.g., geese and ducks) can contribute significant nutrient loads to waterbodies (Manny et al. 1994).

Animal waste associated with pets, wild birds, and small mammals can present significant risk to humans. Between 15 and 50 percent of pets and 10 percent of mice and rats may be infected with *Salmonella* (NAS 1993). In addition, many wildlife species are reservoirs of microorganisms that can be pathogenic to humans. Beaver and deer are large contributors of *Giardia* and *Cryptosporidium*, respectively (EPA 2001d). Waterfowl such as geese, ducks, and heron can also contaminate surface waters with microbial pathogens (Graczyk et al. 1998).

Bacteria source-tracking can be employed to establish the relative contribution of human and non-human sources to levels of indicator bacteria measured in a given waterbody. For example, watershed studies in the Seattle, Washington area found that nearly 20 percent of bacteria in receiving water samples were traceable to dogs (EPA 2001d). A study of Four Mile Run in Northern Virginia found that waterfowl accounted for 37 percent, humans and dogs together accounted for 26 percent, and raccoons accounted for 15 percent of the bacteria. Deer and rats contributed smaller percentages (NVPDC 2000).

4.3.7 Commercial and Recreational Vessels

Improper disposal of sewage by commercial and recreational vessels can spread disease, contaminate shellfish beds, and lower oxygen levels in receiving waters (CFWS 2003). Improper disposal is also a problem in marinas and harbors, despite the prohibition on the discharge of untreated sewage in the Great Lakes, in all navigable rivers, and within three miles of the U.S. coastline. Improper disposal of sewage occurs largely as a result of inadequate facilities on-board vessels and at docks, and a lack of education about safe handling and disposal of sewage. Boaters often illegally dump or dispose sewage improperly in marina toilets, overloading them (Baasel-Tillis 1998). Impacts due to pollution from commercial and recreational vessels are highly localized.

4.4 What is the Universe of CSSs?

Most CSSs are located in the Northeast and Great Lakes regions. Thirty-two states (including the District of Columbia) have permitted CSSs in their jurisdiction. As of July 2004, these 32 states had issued 828 active CSO permits to 746 communities. These permits regulate 9,348 CSO discharge points. The distribution of CSO permits and CSO outfalls in each state are shown in Figures 4.1 and 4.2, respectively. About 46 million people are served by CSSs, which include an estimated 140,000 miles of municipally-owned sewers.

CSO permits have been issued to the owners and operators of two types of CSSs:

- CSSs owned and operated by the same entity that owns and operates the receiving POTW; and
- CSSs that convey flows to a POTW owned and operated by a separate entity under a different permit.

Communities that operate and maintain a sewer system but send wastewater flows to a treatment plant owned and operated by another entity are referred to as "satellite systems." The 828 active CSO permits include 616 combined systems with POTWs, 176 satellite systems, and 36 systems that EPA has been unable to classify due to insufficient data.

Figure 4.1

Distribution of CSO Permits by Region and by State

More than half of the nation's 828 active CSO permits are held by communities in four states: Illinois, Indiana, Ohio, and Pennsylvania.

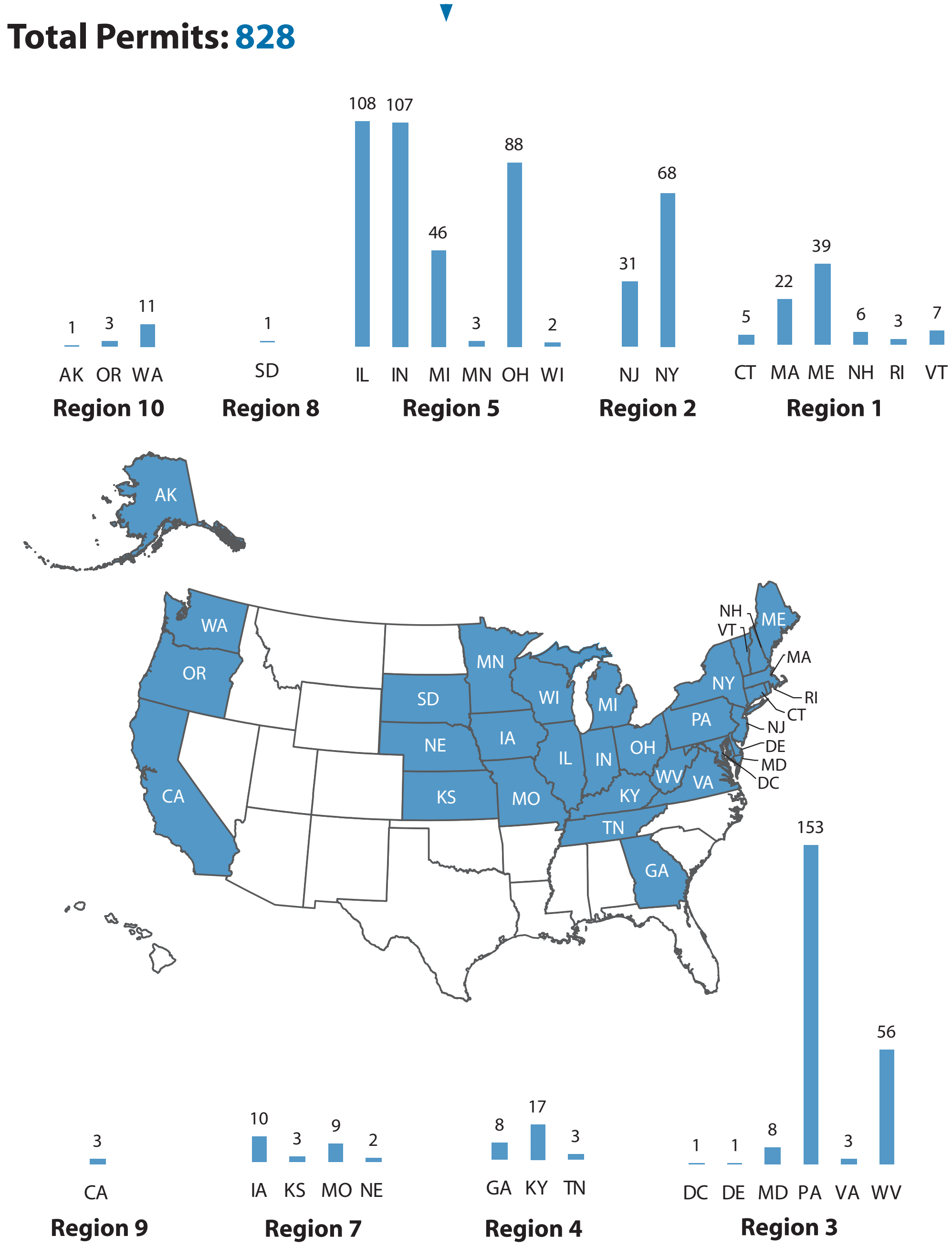
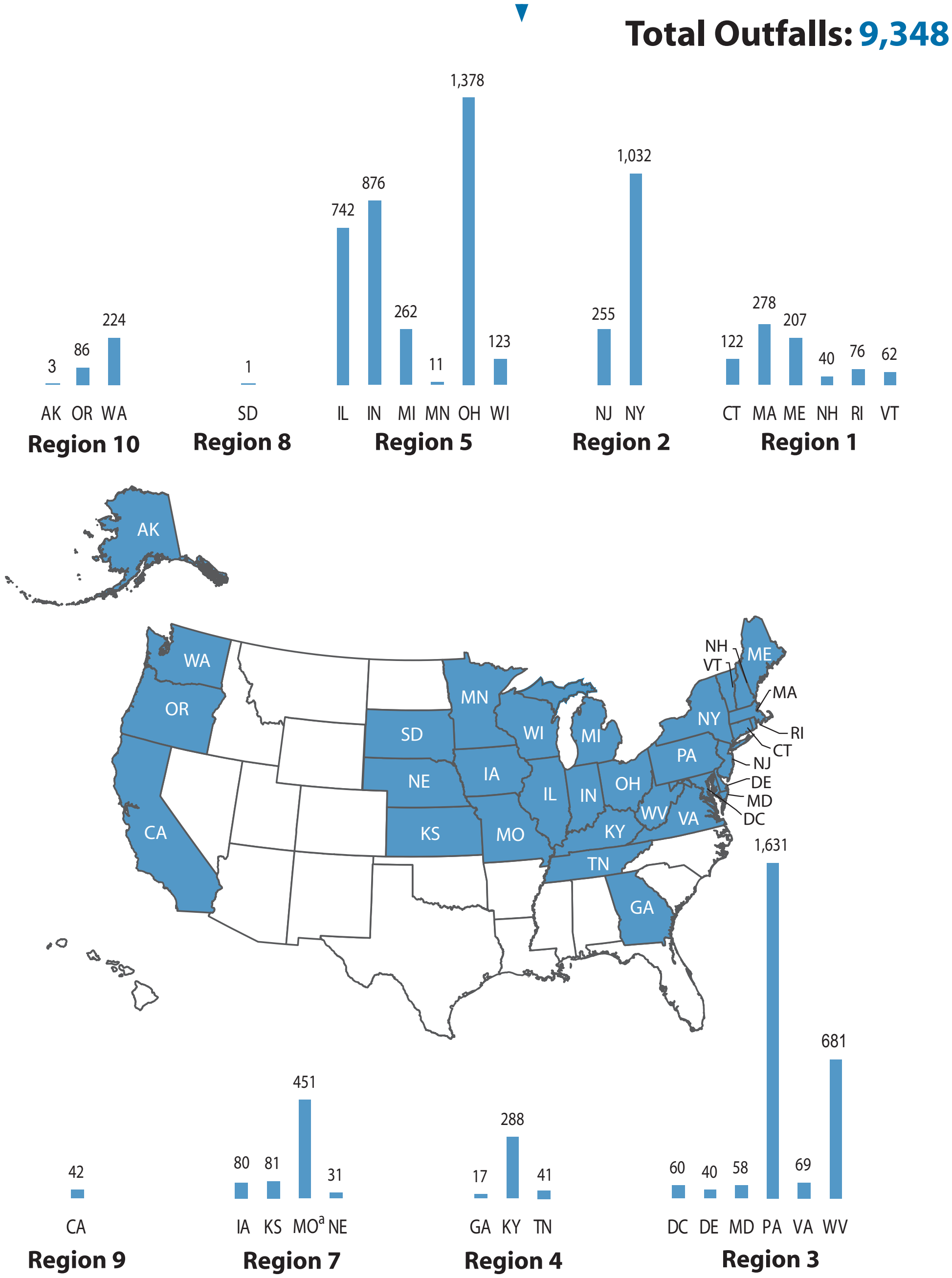


Figure 4.2

Distribution of CSO Outfalls by Region and by State

Similar to the distribution of CSO permits, CSO outfalls are also concentrated in the Northeast and Great Lakes regions.



[a]Since the 2001 *Report to Congress—Implementation and Enforcement of the Combined Sewer Overflow Control Policy*, the Missouri Department of Natural Resources has been working with its CSO communities to confirm the number of CSO outfalls for each NPDES permit. The significant increase in the number of CSO outfalls in Missouri is a result of this effort.

NPDES permittees are classified by regulatory authorities as "major" or "minor" dischargers. Facilities are classified as "major" when the wastewater treatment plant is designed to discharge more than 1 mgd. Facilities with flows less than 1 mgd may be classified as "major" when the NPDES authority determines that a specific permit needs a stronger regulatory focus. Classification as "major" is used to guide permitting, compliance, and enforcement activities to ensure that larger sources of pollutants are given priority. Major facilities are typically inspected annually and must report monthly effluent concentrations and loadings. Based on information available in EPA's PCS for the 828 active CSO permits, EPA found that 57 percent were classified as major facilities. Facilities classified as "minor" usually have design flows less than 1 mgd.

The CSO Control Policy established a population threshold of 75,000 to define small jurisdictions that may be held to less rigorous requirements in developing an LTCP for CSO control. EPA does not have population data by permit for CSSs. EPA has previously estimated that average daily wastewater flows are approximately 100 gallons per capita per day (EPA 1985). As a surrogate, plants treating 7.5 mgd (75,000 x 100 gallons per capita per day) are used to define the upper limit of a small jurisdiction.

EPA obtained flow data for 398 of the 616 permits for CSSs that include a POTW. As shown in Figure 4.3, 73 percent of CSO permits (with available flow data) are for POTWs with design flows less than 7.5 mgd, and therefore an estimated service population of less than 75,000.

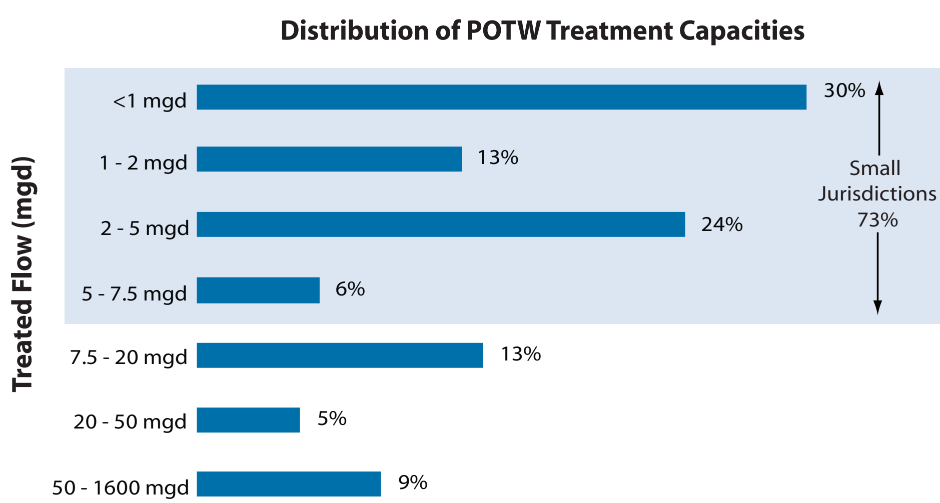
4.5 What are the Characteristics of CSOs?

An accurate characterization of the frequency, volume, and location of CSO discharges, coupled with information on the pollutants present in the discharges, is

Figure 4.3

Distribution of POTW Facility Sizes Serving CSSs

POTWs serving CSSs are designed to treat flows ranging from 0.1 mgd to 1,600 mgd, but most treat less than 7.5 mgd.



needed to fully evaluate the potential for environmental and human health impacts from CSOs. This section describes the process EPA used to characterize CSO discharges at the national level.

4.5.1 Volume of CSOs

EPA applied the previously developed GPRACSO model to estimate the volume and pollutant loads attributable to CSOs nationwide. A summary of the GPRACSO model and how it was used to derive the national estimates presented in this report is provided in Appendix E.

The GPRACSO model was applied to estimate the CSO volume associated with three planning-level scenarios. Corresponding BOD_5 loads associated with the CSO volumes were also estimated. The three scenarios modeled are:

- Baseline scenario (1992) representing CSO volumes and pollutant loads prior to issuance of the CSO Control Policy.
- Current implementation scenario (2002) representing estimates of CSO volumes and pollutant loads with CSO controls that are currently in place.
- Full CSO Control Policy implementation scenario representing future CSO volume and pollutant loads assuming full implementation of the CSO Control Policy (e.g., four to six untreated overflows per year).

The three scenarios are compared in terms of CSO volume and pollutant load reduction in Table 4.7. National estimates of the annual volume of combined wastewater generated and treated are added for context. The volume of combined wastewater generated represents the volume of domestic, commercial, and industrial wastewater and storm water runoff that enters CSSs across the nation during wet weather periods under annual average conditions. The estimate of combined wastewater treated represents the amount of combined wastewater that receives the minimum treatment specified under

Table 4.7

Volume Reduction Estimates Based on Implementation of CSO Control Policy

EPA's GPRACSO model was used to evaluate the potential reduction in discharges of untreated CSO and the attendant BOD_5 loads based on current and future expected implementation of CSO controls.

Scenario	Annual Volume (billion gallons/yr)			Annual Load (million pounds/yr)
	Combined Wastewater Generated	Combined Wastewater Treated	Untreated CSO Discharged	BOD_5 from Untreated CSO Discharges
Baseline, prior to CSO Control Policy	4,250	3,180	1,070	445
Current level of CSO control	4,230	3,380	850	367
Full CSO Control Policy implementation	4,230[a]	4,070[a]	160	159

[a] Assumes that the areas and populations served by CSSs will remain relatively constant at current levels through full implementation of the CSO Control Policy.

the CSO Control Policy (primary clarification or equivalent and disinfection, as necessary). The volume of combined wastewater treated under the three scenarios is not constant, as each reflects a different control condition.

EPA took a conservative approach in using the GPRACSO model to estimate reductions in CSO volumes and BOD_5 loads. Only structural CSO controls, such as expanded capacity at a wastewater treatment facility, were considered. Non-structural controls, such as enhanced pretreatment requirements, inflow reduction, and pollution prevention, were not simulated with the GPRACSO model. The fact that sewer separation can lead to increased storm water volumes and loads was not factored into this analysis.

The GPRACSO model estimates that prior to issuance of the CSO Control Policy (baseline scenario) approximately 1,070 billion gallons of untreated CSO and 445 million pounds of BOD_5 were discharged annually from CSSs. Under the current implementation scenario, the GPRACSO model estimates that approximately 850 billion gallons of untreated combined sewage and 367 million pounds of BOD_5 are discharged from CSSs annually. The GPRACSO model estimates that the national CSO volume and associated BOD_5 loads have decreased by 21 percent and 18 percent, respectively, since issuance of the CSO Control Policy.

The full CSO Control Policy implementation scenario assumes that all CSO communities have, at a minimum, implemented the controls necessary to reduce the frequency of CSO events to an average of four to six untreated CSO events per year. The actual level of control needed to meet water quality standards may require measures beyond those needed for an average of four to six events per year. When full implementation is achieved under this scenario, the GPRACSO model predicts that approximately 160 billion gallons of untreated CSO and 159 million pounds of BOD_5 would be discharged annually from CSSs. Reaching a full implementation of CSO control will require communities with CSSs to provide the equivalent of primary clarification and disinfection, as necessary, to an estimated additional 690 billion gallons of currently untreated CSO discharges.

4.5.2 Frequency of CSOs

In the CSO Control Policy, a "CSO event" is defined as a discharge from one or more CSO outfalls in response to a single wet weather event. The frequency of CSO events in a given community can range from zero events to 80 or more per year. The frequency of CSO events in a given community can also vary considerably from year to year depending on weather conditions. The CSO Control Policy specifies that the evaluation of CSO control alternatives and development of LTCPs should be on a system-wide, annual average basis. Annual average conditions are typically established by performing a statistical analysis on local, long-term precipitation records that consider the number of precipitation events per year, maximum rainfall intensity, and average storm duration.

In addition to estimating national CSO volumes and pollutant loads, the GPRACSO model was used to estimate the frequency of CSO events. Under the baseline scenario, prior to issuance of the CSO Control Policy, the GPRACSO model estimates that there were approximately 60,000 CSO events per year nationwide. Under the current implementation scenario with the current level of CSO control, the GPRACSO model estimates there are 43,000 CSO events per year nationwide, a reduction of 28 percent since the issuance of the CSO Control Policy.

4.5.3 Location of CSOs

A key EPA initiative undertaken as part of this Report to Congress was to update, verify, and digitally georeference the inventory of CSO outfalls documented as part of EPA's 2001 *Report to Congress-Implementation and Enforcement of the CSO Control Policy*. This effort resulted in establishing latitude and longitude coordinates for more than 90 percent of CSO outfalls.

With this new information, EPA was able to associate those CSO outfalls with latitude and longitude coordinates with specific waterbody segments (reaches) identified in the NHD. The NHD is a comprehensive set of digital spatial data of surface water features that enables analysis of water-related data in upstream and downstream order. Associating CSO outfall locations with the NHD-indexed assessed waters allowed analysis of the types of waterbodies receiving CSO discharges. Through this analysis, EPA found:

- 75 percent of CSOs discharge to rivers, streams, or creeks;
- 10 percent of CSOs discharge to oceans, bays, or estuaries;
- 8 percent of CSOs discharge to waters that are unclassified or unidentified in the NHD;
- 5 percent of CSOs discharge to other types of waters (unnamed tributaries, canals, etc.); and
- 2 percent of CSOs discharge to ponds, lakes, or reservoirs.

Further, associating CSO outfall locations with the NHD-indexed assessed waters allowed comparison with impairments reported by states in the 303(d) program (waters not meeting water quality standards or not supporting their designated uses), and the location of protected resources and sensitive areas. These analyses are discussed in more detail in Section 5.3 of this report. Additional detail on the CSO analysis using the NHD is presented in Appendix F.

4.6 What is the Universe of SSSs?

EPA's 2000 CWNS reported 15,582 municipal SSSs with wastewater treatment facilities across the nation (EPA 2003b). EPA has also identified an additional 4,846 satellite SSSs that collect and transport wastewater to regional treatment facilities (EPA 2003b). The number of SSSs with wastewater treatment facilities and the number of satellite systems are shown for each state in Figures 4.4 and 4.5, respectively.

Figure 4.4

Distribution of SSSs with Wastewater Treatment Facilities by EPA Region and by State

SSSs are located in all 50 states. EPA's 2000 CWNS reported 15,582 municipal SSSs with wastewater treatment facilities across the nation.

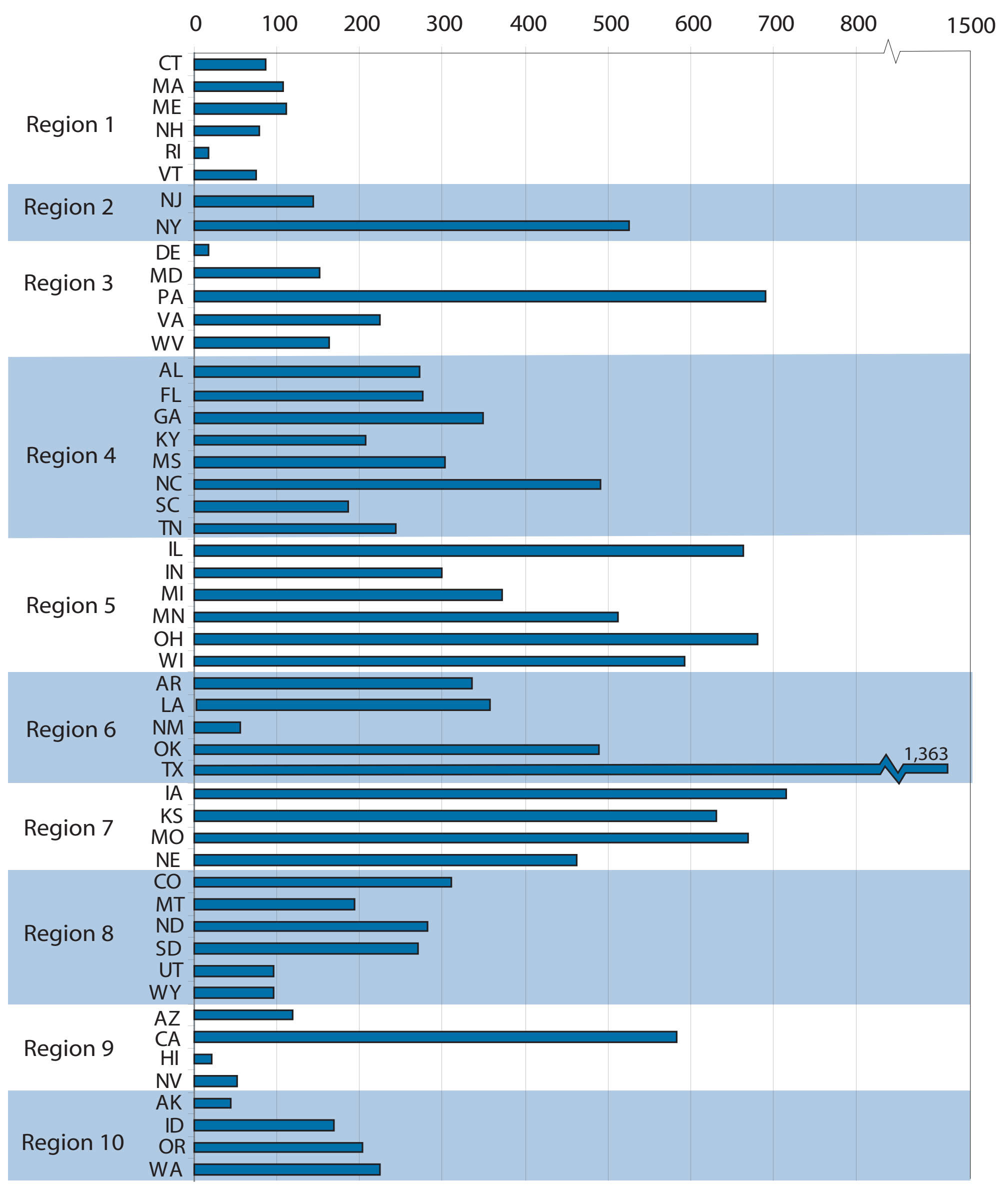
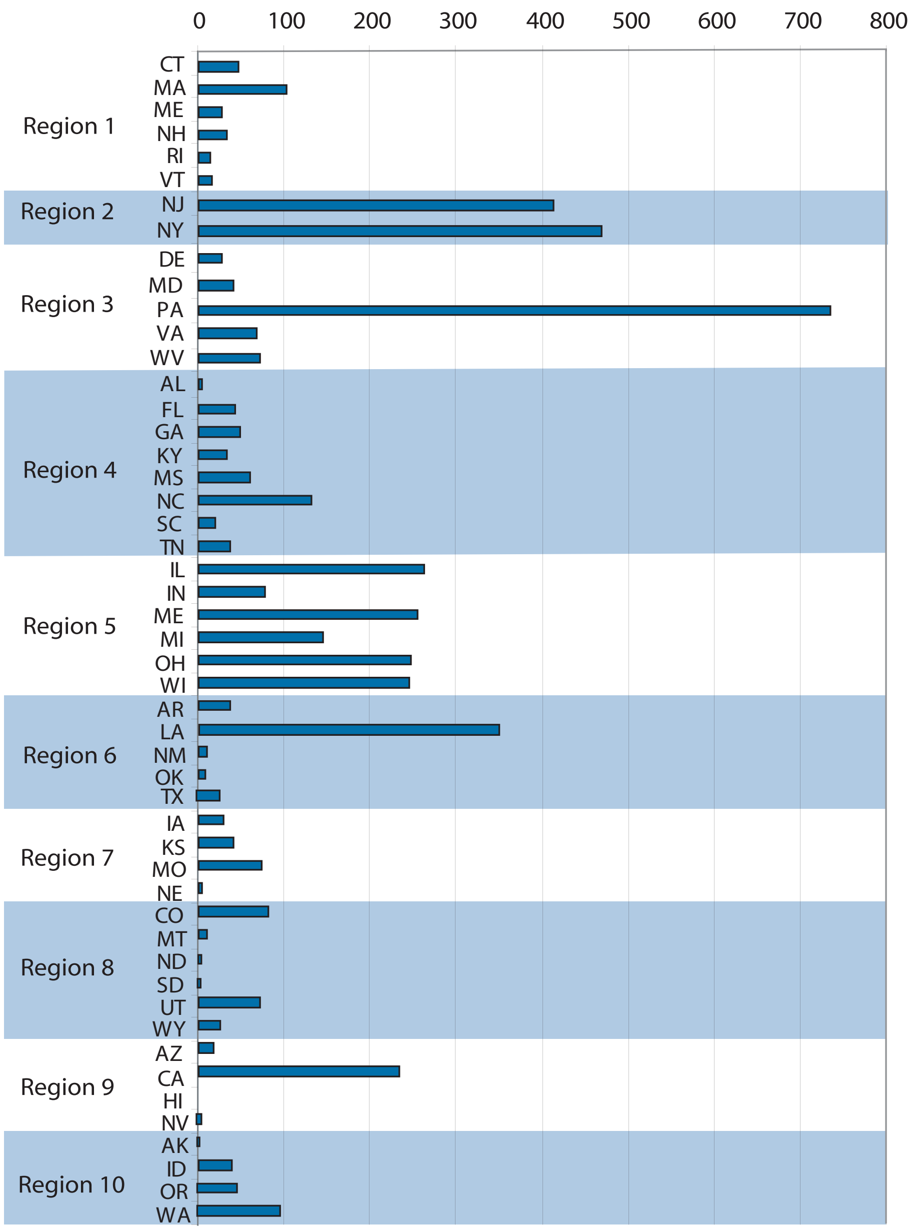


Figure 4.5

Distribution of Satellite SSSs by Region and by State

EPA identified 4,846 satellite SSSs that collect and transport flows to regional wastewater treatment facilities; such systems exist in all states, with the exception of Hawaii.



EPA estimates that 164 million people are served by municipal SSSs. EPA estimates that SSSs contain 584,000 miles of municipally-owned sewer pipes and that approximately 500,000 miles of privately-owned pipes deliver wastewater into SSSs (EPA 2003b).

As described in Section 4.4, NPDES permittees are commonly classified by NPDES authorities as “major” or “minor” dischargers. Based on information available in PCS for permits issued to SSSs with wastewater treatment facilities, EPA found that 80 percent were classified as minor facilities, with average daily discharges less than 1 mgd.

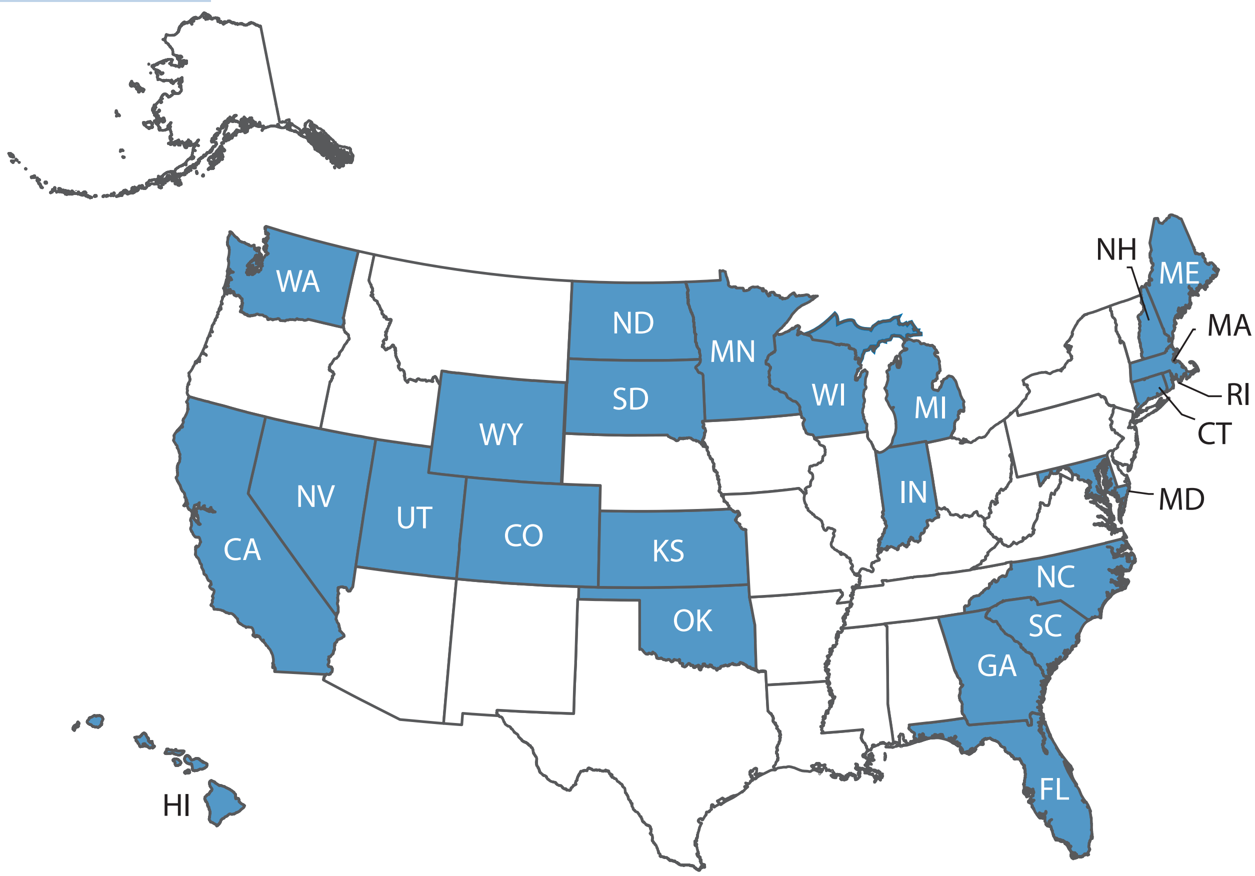
4.7 What are the Characteristics of SSOs?

An accurate characterization of the frequency, volume, and location of SSO discharges, coupled with information on the pollutants present in the discharges, is needed to fully evaluate the potential for environmental and human health impacts from SSOs. Currently, there are no federal systems in place to compile data on the frequency, volume, and location of SSO discharges. This section describes the processes EPA used to characterize SSOs.

Figure 4.6

States Providing Electronic Data on SSO Discharges

EPA identified 25 states in which the NPDES authority is using an electronic data system to track the volume, frequency, location, and cause of SSO discharges within its jurisdiction. Data from these states were used to develop national estimates of SSO frequency and volume.



4.7.1 SSO Data Management System

For the purposes of this report, EPA identified 25 states where the NPDES authority is using an electronic data system to track the volume, frequency, location, and cause of SSO discharges within its jurisdiction. As shown in Figure 4.6, these 25 states are spread across the nation.

EPA collected the individual state datasets and compiled them in a single SSO data management system. In its collection of SSO data from the states, EPA found that the definition of an "SSO event" varied. For example, some states include incidents such as secondary treatment bypasses which exceed NPDES permit limits by more than 50 percent at the main outfall, and spills from septic haulers as SSO events in their data systems. EPA also found that backups into buildings caused by problems in the publicly-owned portion of an SSS are not tracked by states.

SSOs are untreated or partially treated releases from an SSS. The discussion of SSOs in this report does not include discharges occurring after the headworks of the treatment plant, regardless of the level of treatment; or backups into buildings caused by problems in the publicly-owned portion of an SSS. Datasets for each state were screened using these qualifiers. SSO events that did not meet the above criteria were omitted from the SSO data management system and from the analyses of SSO frequency, volume, and cause presented later in this chapter. Additional information on the data management system is provided in Appendix G of this report.

4.7.2 Statistical Technique Used to Estimate Annual National SSO Frequency and Volume

National estimates of SSO frequency and volume were generated using reported data on 33,213 SSO events in 25 states that occurred in calendar years 2001, 2002, and 2003, combined with basic information describing the sewered universe in each state from the 2000 CWNS. This basic state information included:

- Total number of sewer systems by state (combined and separate sanitary);
- Number of SSSs by state; and
- Population served by SSSs by state.

To account for the uncertainty in the data reported by states, two separate scenarios were evaluated:

- The first scenario assumed that SSO events tracked in the state's data system include all of the SSO events that occurred statewide during the reporting period.
- The second scenario assumed that SSO events tracked in the state's data system include SSO events from only those communities that chose to report and are therefore a fraction of SSO events that occurred statewide during the reporting period.

Regression analyses demonstrated that the frequency of SSO events in a state is correlated both to the total number of SSSs as well as to the population served, although neither parameter is a perfect predictor. To account for the uncertainty as to which provides the better national estimate of SSO frequency, two additional sub-scenarios were analyzed:

- Estimating SSO event frequency for non-reporting states based on total number of SSSs in each state; and
- Estimating SSO event frequency for non-reporting states based on the total population served by SSSs in each state.

National estimates of SSO volume were generated using the following five-step procedure:

1. Tabulate the total number of events and SSO volume for each of the reporting states.
2. Estimate the total number of SSO events per year for each non-reporting state based on a) the number of SSSs in the state, and b) the population served by SSSs in the state.
3. Divide the total number of events in each non-reporting state into different categories describing the cause of the SSO event, accounting for observed regional differences from the 25 reporting states.
4. Calculate SSO volume for each cause category in each non-reporting state, accounting for observed regional differences.
5. Calculate national estimates by summing the total number of events by state and the total volume across all states.

A detailed explanation of the statistical techniques applied to the SSO data provided by the 25 states is presented in Appendix G.

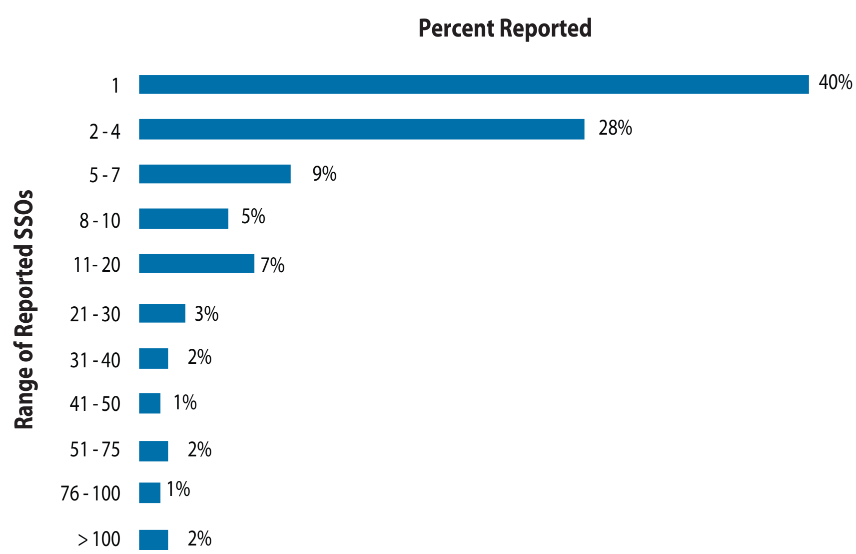
4.7.3 Frequency of SSOs

Between January 1, 2001, and December 31, 2003, 33,213 SSO events were reported by individual communities in the 25 states. During this three-year period, 2,663 communities reported one or more SSO discharges. The number of SSO discharges reported by each community is presented in Figure 4.7. As shown, most of the 2,663

Figure 4.7

Total Number of SSO Events Reported by Individual Communities, January 1, 2001 - December 31, 2003

Nearly 70 percent of the communities in the 25 states reported between one and four SSO events during the three-year reporting period.



communities reported between one and four SSO events during the three-year reporting period. One community reported more than 1,300 SSOs over the three years.

Using the statistical techniques described previously, and in Appendix G, SSO frequency information in the SSO data management system was extrapolated into a national estimate. This analysis suggests that between 23,000 and 75,000 SSO events per year occur in the United States. EPA evaluated the SSO frequency information in the SSO data management system for regional trends and found only marginal regional effects for overall event frequency. Therefore, EPA did not make adjustments to the estimated number of SSO events in non-reporting states based on geographic location.

4.7.4 Volume of SSOs

Estimated SSO volumes were reported and available for 28,708 (86 percent) of the 33,213 events included in the SSO data management system. Between January 1, 2001, and December 31, 2003, a total of 2.7 billion gallons of SSO was reported discharged in the 25 states. The reported volume for individual SSO events ranged from one gallon to 88 million gallons. The distribution of reported SSO volumes for these events is presented in Figure 4.8. As shown:

- More than half of the reported SSOs were less than 1,000 gallons;
- More than 80 percent of the SSOs were less than 10,000 gallons; and
- Approximately 2 percent of the SSOs were greater than 1 million gallons.

Further, the 1,000 largest SSO events (3 percent of reported events) accounted for almost 90 percent of the total SSO volume reported.

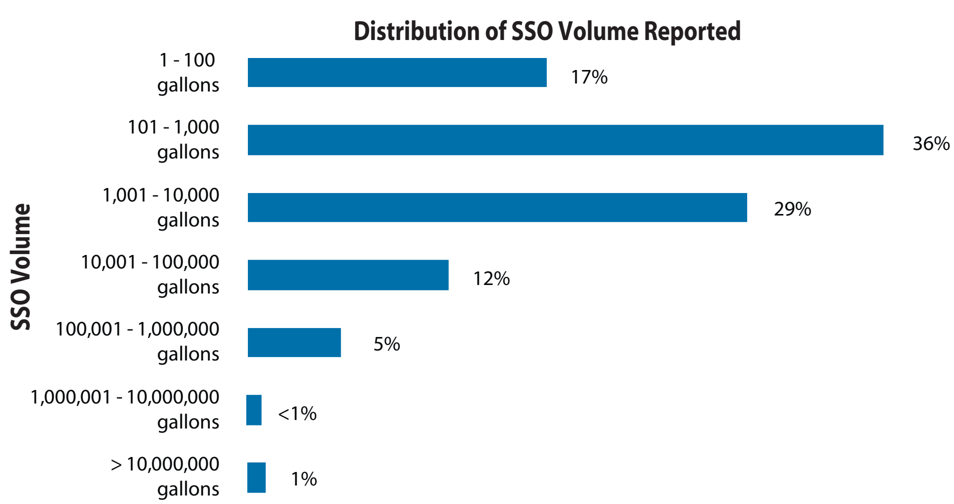


Figure 4.8

Distribution of SSO Volume Reported Per Event

Estimated SSO volumes were available for 86 percent of events in the SSO data management system. The reported volumes for individual SSO events ranged from one gallon to 88 million gallons.

Using the statistical techniques described in Appendix G, data on the volume discharged during individual SSO events were extrapolated into a national estimate of the annual volume of SSO discharged. This analysis suggests that the total SSO volume discharged annually is between three and 10 billion gallons.

In an unpublished EPA report supporting a draft rulemaking on SSOs, EPA previously estimated that the national volume of SSO discharges caused by wet weather totaled 311 billion gallons per year. That estimate was derived from a model designed to predict the relationship between the frequency of wet weather SSO events and the required national investment in SSO control measures. The model was based on variables such as sewer system capacity, acreage served by SSSs, and the percentage of rainfall that became I/I. Values assigned to each of these variables were based on very little empirical data, and the output of the model was not verified. EPA has a much higher degree of confidence in the national SSO volume estimates presented in this Report to Congress because the new estimates are based on a much larger empirical data set and rely on a simplified approach for extrapolating to a national estimate.

4.7.5 Location of SSOs

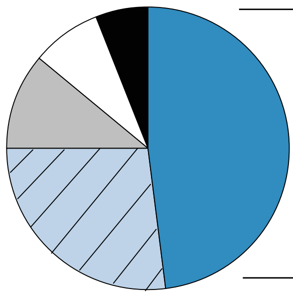
SSOs can occur at any location in the SSS, including: manholes, cracks and other defects in sewer lines, emergency relief outlets, and elsewhere. Reports of SSO events often include street addresses where the spill occurred. Because SSO events can occur at so many locations, gathering latitude and longitude for SSOs at a national level is impractical. Rather, it is more useful to look at the cause of the events, which is often linked to the type of location where it occurs. EPA grouped the reported SSO events into five broad cause categories:

- Blockages
- Wet weather and I/I
- Power and mechanical failures
- Line breaks
- Miscellaneous (e.g., vandalism, contractor error)

In general, SSOs attributed to wet weather and I/I are caused by insufficient sewer system capacity, while the other types of spills are attributable to sewer system operation and maintenance.

Cause information was available for 77 percent of the SSO events included in the SSO data management system. As shown in Figure 4.9, 48 percent of all SSO events with a known cause were the result of the complete or partial blockage of a sewer line, and 26 percent of SSO events were caused by wet weather and I/I. In general, the communities reporting large numbers of SSO events have programs that place a strong emphasis on tracking. As a result, EPA believes that these communities are likely to identify additional low-volume SSO events (e.g., SSOs resulting from blockages) that have the potential to go unnoticed or unreported in other jurisdictions.

EPA evaluated the reported causes of SSO events in the SSO data management system for regional trends and found significant



Causes of SSO Events	Percent
Blockages	48%
Wet weather and I/I	26%
Mechanical or power failures	11%
Line breaks	10%
Miscellaneous	5%
Total	**100%**

Figure 4.9

Most Common Reported Causes of SSO Events

Nearly 50 percent of all SSO events with a known cause were the result of complete or partial blockage of a sewer line.

differences in the cause of SSO events between EPA regions. Specifically, EPA found that nearly three-quarters of SSO events in the arid Southwest were caused by blockages, while more than half of SSO events in Great Lakes states were attributed to wet weather and I/I. Therefore, average regional distributions for SSO cause were developed and applied in the estimation of SSO volume in non-reporting states. More information on regional trends in SSO cause is presented in Appendix G.

EPA found that individual SSO event volumes show a strong correlation with cause, with the smallest events attributed to blockages and the largest events occurring as a result of wet weather or excessive I/I. As shown in Table 4.8, the average volume of SSO events caused by wet weather or excessive I/I is much greater than the average volume for any other type of SSO event.

Additional analysis was performed on the cause of SSO events in those communities reporting more than 100 events during a calendar year (either 2001 or 2002); this analysis was done to determine whether the distribution of causes was markedly different in municipalities reporting higher numbers of SSO events. As shown in Figure 4.10, EPA found that communities reporting higher numbers of SSO events attributed a significantly higher percentage of their SSO events to blockages and a correspondingly lower percentage of SSO events to wet weather and I/I.

More detailed information on cause was available for approximately 80 percent of the more than 12,000 SSO events attributed to the complete or

Cause	Average SSO Event Volume (gallons)	Median SSO Event Volume (gallons)	Total Volume (million gallons)	Percent of Total Volume
Blockages	5,900	500	69	3
Wet weather and I/I	360,000	14,400	1,860	74
Mechanical or power failures	63,000	2,000	157	6
Line breaks	172,000	1,500	239	9
Miscellaneous	260,000	1,200	199	8

Table 4.8

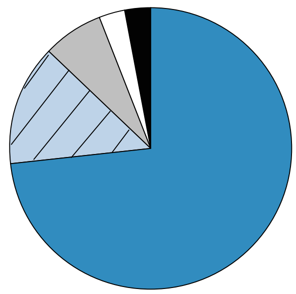
SSO Event Volume by Cause

Although wet weather and I/I was listed as the cause for one-quarter of SSO events, these events account for nearly three-quarters of the total SSO volume discharged.

Figure 4.10

Reported Causes of SSOs in Communities Reporting More than 100 SSO Events During a Single Calendar Year

EPA found that communities reporting higher numbers of SSO events (>100 per year) attributed a significantly higher percentage of their SSO events to blockages.



Causes of SSO Events	Percent
Blockages	74%
Wet weather and I/I	14%
Line breaks	7%
Mechanical or power failures	3%
Miscellaneous	2%
Total	**100%**

partial blockage of a sewer line. As shown in Figure 4.11, grease from restaurants, homes, and industrial sources is the most common cause of reported blockages. Grease is problematic because it solidifies, reduces conveyance capacity, and blocks flow. Grit, rocks, and other debris that find their way into the sewer system account for nearly a third of the reported blockages. Roots are responsible for approximately one quarter of reported blockages. Roots are problematic because they penetrate weaknesses in sewer lines at joints and other stress points, and cause blockages.

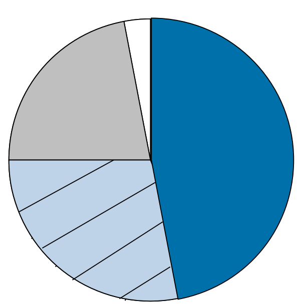
4.8 How Do the Volumes and Pollutant Loads from CSOs and SSOs Compare to Those from Other Municipal Point Sources?

As described in Section 4.3, waterbodies receive pollutant loads of the types found in CSOs and SSOs from other urban and rural sources. Responsibility for two of these sources—wastewater treatment plants and urban storm water runoff—belongs almost exclusively to municipalities. Comparing information on annual discharges from municipal sources gives context

Figure 4.11

Reported Cause of Blockage Events

Grease--the most common cause of blockage--solidifies, reduces conveyance capacity, and can eventually block flow in sewers.



Causes of Blockage Events	Percent
Grease	47%
Grit, rock, and other debris	27%
Roots	22%
Roots and grease	4%
Total	**100%**

to the magnitude of CSO and SSO discharges. At a national level, as shown in Table 4.9, the volume of CSOs and SSOs discharged is one to two orders of magnitude less than the total flow processed at wastewater treatment plants. The volume of urban storm water runoff generated annually is nearly equivalent to the volume of treated wastewater.

In addition to considering the volumes discharged by various municipal sources, it is also informative to consider their relative contributions in terms of pollutant loads at the national level. The comparisons of BOD_5, TSS, and fecal coliform loads presented in Tables 4.10, 4.11, and 4.12 are based on the volumes presented in

Table 4.9

Estimated Annual Municipal Point Source Discharges

On an annual basis, the volume of CSO and SSO discharged is a proportionally small amount of the total flow processed at municipal wastewater treatment facilities.

Source	Average Discharge Volume (billion gallons)	Percent of Total Municipal Discharges
Treated wastewater[a]	11,425	51%
CSO[b]	850	4%
SSO[c]	10	<1%
Urban storm water runoff[d]	10,068	45%

[a] EPA 2000a
[b] GPRACSO model, Section 4.5.1
[c] High estimate, Section 4.7.4

Table 4.10

Estimated Annual BOD_5 Load from Municipal Point Sources

CSOs and SSOs contribute to a relatively low percentage of the total municipal BOD_5 load disharged annually.

Source	Annual Discharge Volume (billion gallons)	Median BOD_5 Concentration (mg/L)	Total BOD_5 Load (lbs. x 10^8)	% of Total Municipal BOD_5 Load
Treated wastewater	11,425	30	28.5	72%
CSO	850	15-215[a]	3.7	9%
SSO	10	42	<0.1	<1%
Urban storm water runoff	10,068	8.6	7.2	19%

[a] BOD_5 concentrations taken from the GPRACSO model vary with time, as described in Appendix E.

Table 4.11

Estimated Annual TSS Load from Municipal Point Sources

Storm water discharges account for nearly 60 percent of the municipal TSS load discharged annually.

Source	Annual Discharge Volume (billion gallons)	Median TSS Concentration (mg/L)	Total TSS Load (lbs x 10^8)	% of Total Municipal TSS Load
Treated wastewater	11,425	30	28.5	33%
CSO	850	127	8.9	10%
SSO	10	91	< 0.1	< 1%
Urban storm water runoff	10,068	58	48.6	56%

Table 4.12

Estimated Annual Fecal Coliform Load from Municipal Point Sources

CSOs appear to be the most significant source of fecal coliform when compared to other municipal point sources on an annual basis.

Source	Annual Discharge Volume (billion gallons)	Median FC Concentration (#/100 ml)	Total FC Load (MPN x 10^{14})	% of Total Municipal FC Load
Treated wastewater	11,425	200[a]	865	1%
CSO	850	215,000	69,172	76%
SSO	10	500,000	1,892	2%
Urban storm water runoff	10,068	5,081	19,362	21%

[a] Assumes wastewater treatment includes disinfection

Table 4.9, and on the concentrations presented in Tables 4.1, 4.2, and 4.3. As shown, CSOs and SSOs contribute a relatively low percentage of the total municipal BOD_5 and TSS load discharged annually. CSOs, however appear to be the most significant municipal source of fecal coliform. Further, as shown earlier in Figure 4.1, most CSSs are located in the Northeast and Great Lakes regions. Therefore, the fraction of discharge volume and pollutant load attributed to CSOs in states with many CSSs and locally in communities with CSSs is likely to be much higher. Similarly, communities experiencing frequent and/or high volume SSO events are likely to attribute a larger percentage of the discharge volume and pollutant load to SSOs.

BOD_5 , TSS, and fecal coliform loads from several important watershed sources of pollutants identified in Section 4.3 of this report, including agricultural practices and animal feeding operations, domestic animals and wildlife, and decentralized wastewater treatment systems, are not reflected in these comparisons. It is not practical to estimate the contributions of these various sources to the total annual load of BOD_5, TSS, or fecal coliform on a national level; however, local examples provide some context.

Relative Contribution of CSOs to Bacterial Loads: Rouge River, MI

A recent study on Michigan's Rouge River (a river with a long history of CSOs and pollution problems) assessed the relative contributions of CSOs to overall bacterial indicator loads in the river (Murray and Bona 2001). This study conducted sampling for fecal coliform and fecal streptococci bacteria at 28 sites within the watershed. The results of the study suggest that CSOs contribute 10 to 15 percent of the total bacterial load in the watershed. The authors acknowledge the contributions of a variety of other sources, including non-CSO municipal sources and nonpoint sources. The nonpoint sources mentioned as other contributors included wildlife, domestic animals, rural runoff, contaminated groundwater, and faulty septic systems.

Relative Contribution of CSOs to Bacterial and BOD_5 Loads: Washington, D.C.

The District of Columbia Water and Sewer Authority quantified pollutant loads to receiving waters as part of its modeling analysis to support development of a CSO LTCP (DCWASA 2002). The CSO contribution to the tidal Anacostia River in Washington, D.C., was estimated to be 61 percent for fecal coliform and 14 percent for BOD_5. Similarly, the CSO contribution to Rock Creek was estimated to be 41 percent for fecal coliform and 6 percent for BOD_5. Storm water from Washington, D.C., and suburban areas in Maryland as well as other upstream nonpoint sources accounted for the remaining loads in both watersheds.