United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-040 September 1999

Combined Sewer Overflow Technology Fact Sheet
Screens

DESCRIPTION

In 1994, the U.S. Environmental Protection Agency (EPA) recognized the importance of controlling solid and floatable materials under the "nine minimum controls" described in the Combined Sewer Overflow (CSO) Control Policy. CSOs can contain high levels of floatable materials, suspended solids, biochemical oxygen demand (BOD), oils and grease, toxic pollutants, and pathogenic microorganisms. Floatables are often the most noticeable and problematic CSO pollutant. They create aesthetic problems and boating hazards, threaten wildlife, foul recreational areas, and cause beach closures. There are numerous methods available for floatables control, including baffles, catch basin modifications, netting systems, containment booms, skimming processes, and screening and trash rack devices. These technologies are summarized in EPA's CSO Technology Fact Sheet entitled "Floatables Control" (EPA 832-F-99-008). This fact sheet focuses on screens and trash racks for CSO floatables control.

Screens are considered an effective and economically efficient method of removing solids and floatables from CSOs. CSO screens are typically constructed of steel parallel bars or wires, wire mesh (wedgewire), grating, or perforated plate; some screens, however, are constructed of milled bronze or copper plates. In general, the openings are circular or rectangular slots, varying in size from 0.25 to 15.24 centimeter (0.1 to 6 inch) spacings. The amount and size of the solids and floatables removed is dependent on the type of screen and the size of the screen openings. Solids are removed from the flow by two basic treatment mechanisms:

- Direct straining of all particles larger than the screen openings.
- Filtering of smaller particles by straining flow through the mat of solids already deposited on the screen.

Generally there are two types of bar screens- coarse and fine. Both are used at CSO control facilities, with each different type providing a different level of removal efficiency. While there is no industry standard for classifying screens based on aperture size coarse bar screens generally have 0.04 to 0.08 meter (1.5 to 3.0 inch) clear spacing between bars and fine screens generally have rounded or slotted openings of 0.3 to 1.3 centimeters (0.1 to 0.5 inch) clear space.

Coarse Screens

Course screens are constructed of parallel vertical bars and are often referred to as bar racks or bar screens. In CSO control and treatment facilities, coarse screens are usually the first unit of equipment in the system. These screens are usually set at 0 to 30 degrees from vertical and are cleaned by an electrically or hydraulically driven rake mechanism that removes the material entrained on the screen on a continuous or periodic basis. There are three types of bar screens used at CSO control facilities: trash racks; manually cleaned screens; and mechanically cleaned screens.

Trash racks

Trash racks (also known as trash grates) are intended to remove only very large objects from the flow stream. Trash racks are generally provided at the intersection of the combined sewer and the sanitary interceptor to prevent major blockages in the interceptor or to protect pumping equipment. Since both dry and wet weather flows pass through this type of screening device, daily cleaning is usually required. Trash racks typically have 0.04 to 0.08 meter (1.5 to 3.0 inch) clear spacing between bars. Figure 1 is a diagram of a typical trash rack.

Manually cleaned bar screens

Manually cleaned bar screens have a 2.54 to 5.08 centimeter (1.0 to 2.0 inches) clear spacing between bars. The bars are set 30 to 45 degrees from the vertical and the screenings are manually raked onto a perforated plate for drainage prior to disposal.

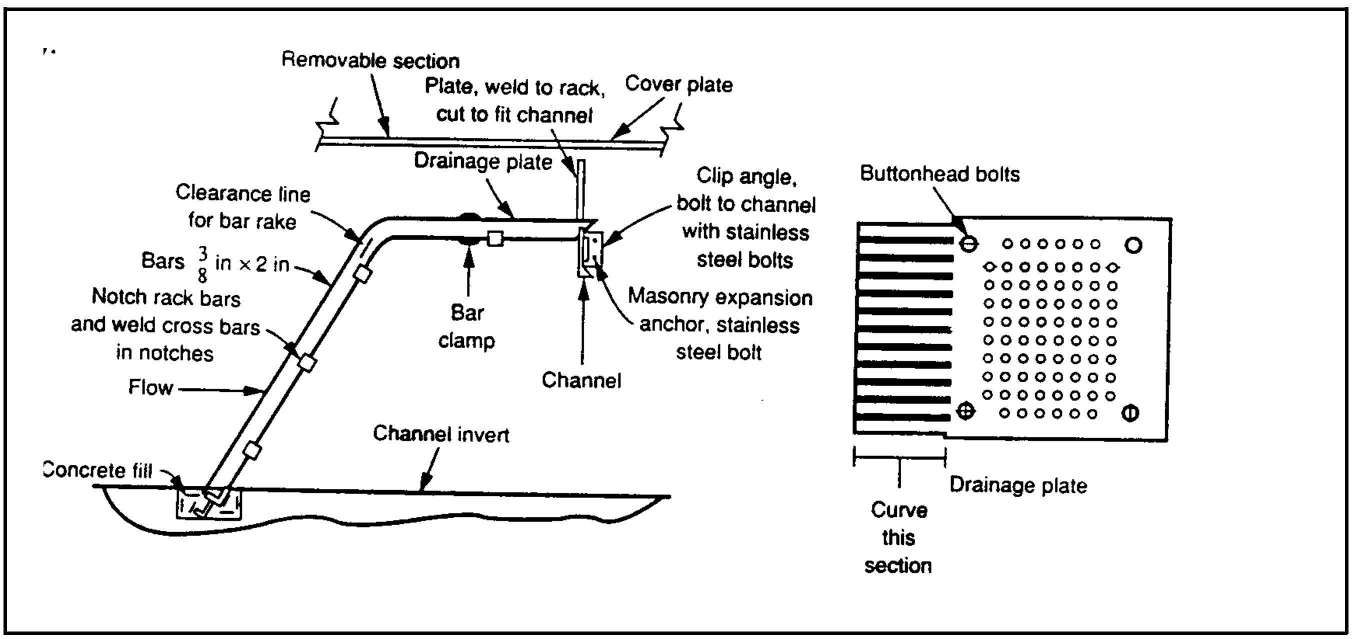
Mechanically cleaned bar screens

Mechanically cleaned bar screens have a 0.64 to 2.54 centimeter (0.25 to 1.0 inch) clear spacing between bars. The bars are set 0 to 30 degrees from the vertical. Electrically driven rake mechanisms will either continuously or periodically remove material entrained on the bar screen itself. The three common types of mechanically cleaned screens are: (1) chain driven, (2) climber type rake, and (3) catenary.

Chain driven mechanical raking systems consist of a series of bar rakes connected to chains on each side of the bar rack. During the cleaning cycle, the rakes travel in a continuous circuit from the bottom to the top of the bar rack, removing materials retained on the bars and discharging them at the top of the rack. A disadvantage of chain-driven systems is that the lower bearings and sprockets are submerged in the flow and are susceptible to blockage and damage from grit and other materials. Accelerated chain wear and corrosion can also be a problem.

Climber-type systems employ a single rake mechanism mounted on a gear driven rack and pinion system. The gear drive turns cogwheels that move along a pin rack mounted on each side of the bar rack. During the cleaning cycle, the rake mechanism travels up and down the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. This type of bar screen has no submerged bearings or sprockets and is, therefore, less susceptible to blockages, damage and corrosion than chain driven units.

Catenary systems also employ chain-driven rake mechanisms, but all sprockets, bearings, and shafts are located above the flow level in the screenings



Source: Metcalf and Eddy, 1991.

FIGURE 1 DIAGRAM OF TRASH RACK USED FOR TREATMENT OF CSOs

channel. This in turn reduces the potential for damage and corrosion and facilitates routine maintenance. During the cleaning cycle, the rakes travel in a continuous circuit from the bottom to the top of the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. The cleaning rake is held against the bars by the weight of its chains, allowing the rake to be pulled over large objects that are lodged in the bars and that might otherwise jam the rake mechanism.

Fine Screens

Fine screens at CSO facilities typically follow coarse bar screening equipment and provide the next level of physical treatment in removing the smaller solid particles from the waste stream. Both fixed (static) and rotary screens have been used in CSO treatment facilities.

Fixed fine screens are typically provided with horizontal or rounded slotted openings of 0.02 to 1.27 centimeters (0.010 to 0.5 inches). The screens are usually constructed of stainless steel in a concave configuration, at a slope of approximately 30 degrees. Flow is discharged across the top of the screen. The flow then passes through the slotted openings and solids are retained on the screen surface. Solids are discharged from the screen surface by gravity and by washing onto a conveyer belt or other collecting system.

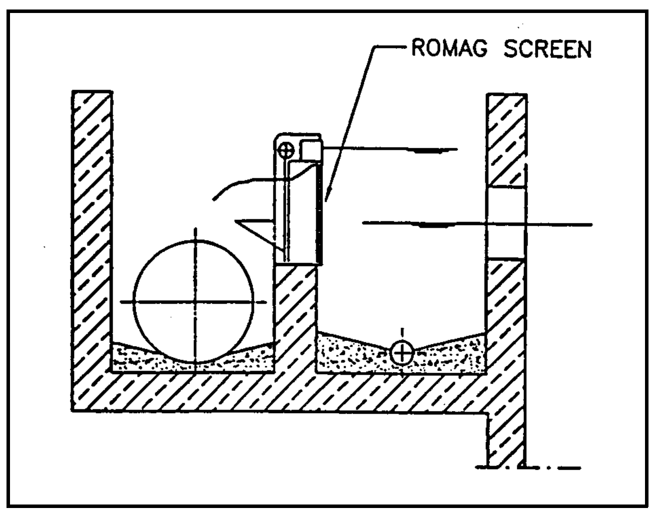
Rotary fine screens include externally and internally fed screens. Externally fed screens allow wastewater to flow over the top of the drum mechanism and through the screens while collecting solids on the screen surface. As the screen rotates, a system of cleaning brushes or sprayed water removes debris from the drum. Internally fed systems discharge wastewater in the center of the drum, allowing water to pass through the screen into a discharge channel, while solids are removed from the screen surface by cleaning brushes or a water spray. Screened material is usually washed from the screen with a high pressure spray into a discharge trough. Screen diameters can range from 0.5 to 2 meters (1.6 to 6.6 feet), while the lengths can vary from 2 to 6 meters (6.6 to 19.7 feet). There are three modes of operation which include:

- Low Flow- no drum movement.
- Intermediate Flow- drum moves a short distance and stops with brush coming on as head loss rises.
- High Flows- continuous operation where the drum rotates at 1 rpm and brush at 10 rpm.

In response to the need for solids and floatables control during storm events, proprietary screen products, such as the ROMAG™ screen (Figure 2), have been designed for wet weather applications. The ROMAG™ screen partitions the flow, sending screened flow to the CSO discharge point, while keeping solids and floatables in the flow directed towards the sanitary sewer.

The ROMAG™ screen works as follows: excess flow enters the screening chamber, flows over a spill weir and proceeds through the screen into a channel which discharges flow to a receiving water body. Floatables trapped by the screen move laterally along the face of the screen via combs/separators to the transverse end section of the pipe where they can be directed to the sanitary sewer line for ultimate removal at the wastewater treatment plant. Screen blinding is prevented by a hydraulically-driven rake assembly.

The ROMAG™ screen surface is accessible from



Source: Pisano, 1995.

FIGURE 2 ROMAG™ "COMBING" MECHANICAL SCREEN (VERTICAL) FOR CSO FLOATABLES CONTROL

both sides to facilitate inspections and maintenance. The screen consists of horizontal bars with 4 mm (0.16 inches) openings that are mounted on a weir in the collection system. Screens range from 2 to 9 meters (6.6-29.5 feet) in length and 330-1200 mm (13- 47.2 inches) in height. Units can be stacked to create a customized mesh opening for a specified design flow at a particular location. The nominal velocity through the bar openings is approximately 1.5 meters per second (4.9 feet per second).

The hydraulically driven mechanical combs used to clean the screen move laterally along the front face of the screen when activated by a level control, which detects rising water. As the screen surface is cleaned, captured material is transported forward to the end section for storage and subsequent removal. The hydraulic combing unit is located outside the screen and consists of an oil tank, pump and control valves.

The ROMAG™ screen may be designed for a variety of flow scenarios. Water may pass through the screen horizontally (RSW type), as shown in Figure 2; over the top of the screen (RSO type) or up from under the screen (RSU) type. This unit has proven useful in remote settings and is capable of handling flows from 300-6100 L/sec (6-140 MGD).

APPLICABILITY

While screening is widely used to control solids and floatables at the headworks of wastewater treatment plants, screening for solids at remote locations, such as at CSO or storm water overflow points, is less common. However, some types of screens are effective for remote solids and floatables control due to their large aperture size and self-cleaning ability. As a result, mechanically-cleaned bar screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids. They are typically the screen of choice in many CSO treatment facilities, and are widely used or implemented at a large number of CSO facilities across the country and abroad.

There has been less success in removing fine solids from storm water and CSO overflows. However, proprietary methods, such as the Romag™ screen, have addressed this issue. More than 250 Romag™ screens have been installed in Europe since 1990. Recently, several Romag™ screens have been installed in the U.S. The first was installed in Rahway, NJ, in 1997.

In addition, Deerfield, Illinois has had success utilizing rotating fine screens at their overflow facilities. Their fine screens have 1.02 millimeter (0.04 inch) openings that remove all large solids and floatables. The screened wastewater is discharged inside the screen and conveyed to a chlorine contact tank for disinfection prior to discharge to the receiving stream. The screenings are conveyed by internal conveyors to a discharge chute for storage and eventual return to the POTW at the end of the overflow event. The entire operation is automatic (West et al., 1990).

ADVANTAGES AND DISADVANTAGES

Since screening is a physical treatment process, it will remove only those objects that are larger than the screen openings. Screening systems are very effective in removing floatable and visible solids, but do not remove a significant amount of suspended solids. In cases where water quality evaluations indicate the need for removal of suspended solids or oxygen demanding materials, additional treatment processes downstream from the screening units would be required.

Because screens at CSO control facilities remove debris, rags, and other floatables that would otherwise be discharged into a receiving stream, they are vital in preserving water quality and aesthetics. Unscreened material in CSOs can become a nuisance if the floatables, and other solids end up in receiving waters. They can create navigational hazards, attract nuisance vectors, and retain bacteria and other pollutants.

Properly screened and removed materials in CSSs prevent materials from settling out in the system, thus preventing potential back ups and possible overflows elsewhere. The screenings and debris that are removed from the screens are typically not hazardous and can be disposed of in a licensed landfill or incinerated. Negative environmental impacts can occur from improper disposal of screened materials, such as by stockpiling in areas adjacent to receiving waters or in areas where they may be seen by the public.

DESIGN CRITERIA

Hydraulic losses through bar screens are a function of approach velocity and the velocity through the bars. The headloss through a clean bar screen can be estimated using the following equation:

$$h_L = (1/0.7) * ((V^2 - v^2)/ 2g)$$

where:

h_L = headloss, ft (m)

0.7 = an empirical discharge coefficient to account to turbulence and eddy losses

V = velocity of flow through the openings of the bar racks, ft/s (m/s)

v = approach velocity in upstream channel, ft/s (m/s)

g = acceleration due to gravity, ft/s^2 (m/s^2)

Headloss increases as the bar screen becomes clogged, or *blinded*. For coarse screens, the approach velocity should be at least 0.38 meters per second (1.25 feet per second) to minimize deposition, while the velocity through the bars should be less than 0.91 meters per second (3 feet per second) to prevent entrained solids from being forced through the bars. Instrumentation provided with mechanically-cleaned screens is configured to send a signal to the cleaning mechanism so the headloss across the screen is limited to 6 inches.

The following general factors should be considered in the design and operation of coarse and fine screens:

- Grit will tend to accumulate upstream and downstream of screens. Provisions must be made for easy access to such areas and alternative methods of grit removal, including vacuum systems, high pressure water cannons or spray systems.
- Grit classifiers are effective in separating, washing, and dewatering grit, sand, finds, and silt from an effluent flow normally downstream form the screens.
- Coarse screens with moving parts out of the flow stream are preferable to coarse screens with submerged parts.
- Fine screens using steel wire mesh or perforated panels are very prone to clogging from fibrous materials and are not easily cleaned. Plastic mesh panels have proven to be effective, are resistant to clogging and are easily cleaned with water sprays.

Pumping or conveying large amounts of large and small solids typically removed by screening systems has proven to be very difficult and a major maintenance problem. Screw conveyors and compactor type screws have been shown to be effective in handling solids, especially those removed by fine screens. Design parameters for different types of screens are given on Tables 1, 2, and 3.

Additional design issues to consider include:

- Backwater from a storage/sedimentation tank effluent weir can create quiescent settling conditions in the bar screen channel. Therefore, a means of flushing or backwashing the screenings channel should be provided.
- A redundant or back-up bar screen should be provided so that peak flow to the facility can be maintained with one unit out of service. Providing stop grooves or slide

TABLE 1 DESIGN PARAMETERS FOR STATIC SCREENS

Hydraulic loading, gal/min/ft of width	100-180
Incline of screens, degrees from vertical*	35
Slot space, µm	250-1600
Automatic controls	None

*Bauer Hydrasieves TM have 3-stage slopes on each screen: 25°, 35°, 45°.

Note: gal/min/ft X 0.207 = l/m/s

gates in the channel allows the user to isolate the screen from the flow for maintenance.

- Guards, railings, and gratings should be provided in the area around the screening equipment to ensure operator safety. Electrical fittings and equipment associated with the screening equipment must conform to the exposure rating for the space in which the equipment is located.

PERFORMANCE

Removal efficiency is a function of bar screen spacing and floatable solids characteristics. Removal efficiency increases as the size and concentration of the solids increases and the spacing dimension decreases. Screenings typically containing 10-20 percent dry solids will typically have a bulk density ranging from 640 to 1100 kilograms per cubic meter (40 to 70 pounds per cubic foot). Typical floatable removal rates for coarse screens range from 3.5 to 84 liters per 1000 cubic meters (0.469 to 11.2 cubic feet per MG).

The quantity of screenings can vary greatly and, in general, depends on the following factors:

- Configuration of the drainage system.
- Time of year.
- Interval between storms.
- Intensity of the storm.

TABLE 2 DESIGN PARAMETERS FOR DRUM SCREENS AND ROTARY SCREEN

Parameter	Drum/Band Screen	Rotary Screen
Screen spacing, μm	100-420	74-167 105 recommended
Screen material	stainless steel or plastic	stainless steel or plastic
Drum speed, r/min		
Speed range	2-7	30-65
Recommended speed	5	55
Peripheral speed, ft/s		14-16
Submergence of drum, %	60-70	
Flux density, gal/ft^2/min of submergence screen	20-50	70-150
Hydraulic efficiency, % of inflow		75-90
Headloss, in.	6-24	
Backwash		
Volume, % of inflow	0.5-3	0.02-2.5
Pressure, lb/in^2	30-50	50

Note: gal/ ft^2/ min x 2.44 = m^3/h/m^2
in. X 2.54 = cm
ft X 0.305 = cm; lb/in.^{2} X 0.0703 = kg/cm^2

- Velocity of the flow through the screens.
- Screen aperture.

Studies have found average CSO screenings loads varying from approximately 3.7×10^{-9}- 8.23×10^{-8} cubic meters per liter (0.5 to 11 cubic feet per million gallons), with peaking factors based on hourly flows ranging from 2:1 to greater than 20:1.

Field studies performed in Canada and Europe have revealed the following floatable removal efficiencies:

- Samplings taken at different CSO outfalls in Montreal, Canada showed that up to 80 percent of floatable material can be retained by properly designed bar screens with 6.35 millimeters (0.25 inch) bar spacing.

- A year-long study was conducted in Germany to determine the efficiency of an externally fed rotary screen in controlling downstream floatable pollution. The screen, which was activated by high flows, received 42 percent of the CSO discharge, with no visible solids reported after frequent inspections of river banks.

- A pilot study in Great Britain tested a 4 mm ROMAG^{TM} bar spaced "weir mount" storm overflow screen. The average solids loading before the screen was 2369 grams per minute, while the solids concentration after the screen was 3.5 grams per minute, exhibiting a 98.5 percent deflection rate. In a similar study, on 11 different occasions during a 12 week period, average mass reduction of floatables and solids material greater than 6 millimeters (0.24 inches) was 98.5 percent.

OPERATION AND MAINTENANCE

Instrumentation and control of screens typically includes some combination of the following:

- Manual start/stop.

- Automatic start/stop on timer.

- Automatic start/stop on differential head.

Activation of mechanically cleaned screens is triggered by remote sensing of flow into the screenings channel, or the water level in the screening channel.

As screens are subject to blinding from grease and the "first flush" in a CSO event, the screen should be kept clean to minimize headloss. Due to the intermittent nature of CSOs it is important for the screening units spray system to be working properly to prevent solids from drying and sticking to the screens, thus increasing headlosses. Fine screens can be cleaned with high pressure water, steam, or cleaning agents to maintain performance. Screening systems should be regularly inspected to ensure that chains and roller mechanisms are lubricated and functioning. The trunnions associated with fine screens are the least reliable component due to the abusive forces they receive. The manufacturer's operation and maintenance manual should be consulted for the maintenance requirements and schedules.

COSTS

The cost for CSO screens varies and depends on such factors as:

- The size of the screen.

- The means of cleaning (manual or automatic).

- The materials of construction (e.g., aluminum or stainless steel).

- The flow rate that the screen will be required to physically treat.

- Whether the construction is new or retrofit construction.

The costs included in Table 4 are presented as a guide only and may not be applicable for all conditions. Other costs may include costs for handling and disposal of residual solids. EPA has summarized this data in the Storm Water O&M Fact Sheet “Handling and Disposal of Collected Solids/Residuals from Storm Water and Sediment Control Practices” (EPA 832-F-99-032).

TABLE 4
COST SUMMARY OF SELECTED SCREENING ALTERNATIVES

Type of Screen	Project Location	Screening Capacity (MG/d)	Capital Cost ($)	Cost ($/MG/d)	Annual O&M ($1,000 gal)
Climber Bar Screen (5 mm plastic media rotary drum)	Atlanta, GA	375	2,230,300	5,948	0.08
		300	1,926,200	6,421	0.08
		200	1,774,150	8,900	0.08
Rotary screen	Belleville, Ont. *(1)*	1.8	91,800	51,000	0.23
		5.4	267,800	49,600	0.23
		7.2	352,000	48,900	0.23
	Seattle, WA *(2)*	25	1,645,200	65,800	0.27
	Syracuse, NY *(3)*[a]	5	355,000	71,000	
	Fort Wayne, IN *(4)*	18	1,603,300	89,100	0.13
Drum screen	Cleveland, OH *(5)*	25	1,668,600	66,700	
		50	2,434,200	48,700	
		100	4,785,300	47,900	
		200	9,159,200	45,800	
	Racine, WI *(4)*	3.9	62,000	15,900	
	Syracuse, NY *(3)*[a]	10	704,700	70,500	
	Fort Wayne, IN *(4)*	18	697,900	38,700	0.11
Static screen	Fort Wayne, IN *(4)*	18	746,900	41,500	0.06
	Belleville, Ont *(1)*	0.75	40,800	54,400	0.12
		5.3	262,100	49,500	0.12
		7.5	358,400	47,800	0.12
Microstrainer	Mount Clemens, MI *(6)*	1.0	71,800	71,80	
with chemical addition	Philadelphia, PA *(4)*	7.4	249,000	33,600	0.13
without chemical addition		7.4	405,800	54,800	0.13
ROMAG™ RSW 2X2	Vendor Specified	5.9	55,000[b]		
5X5		40	105,000[b]		
8X8		100	185,000[b]		

ENR = 5484
(a) Estimates not including supplemental pumping stations and appurtenances.
(b) Unit cost and does not include installation, freight or start-up assistance.
(1) Operational data for the Belleville Screening Project, Ontario Ministry of the Environment, August 6, 1976.
(2) EPA 11023fdd03/70
(3) EPA 600/2-76-826
(4) EPA 60018-77-014. As provided in EPA 960018-77-014.
(5) EPA 11023EY104/72
(6) EPA 670/2-75-010
Note: Conversion factors: MG/d x 0.0438 = m^3/s; \$/1,000 gal x 0.264 = \$/m^3

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ADDITIONAL INFORMATION

Deerfield Wastewater Reclamation Facility
Jon Kaeding
Chief Operator and Foreman
850 Waukegan Rd.
Deerfield, IL 60015

City of Kingston, New York
Paul Van Wagen
Brinnier & Larios
Hasbrouck and Wilbur Avenues
Kingston, NY 12401

North Vernon Wastewater Department
Russell Vaught
Wastewater Treatment Plant Superintendent
725 N. Greensburg St.
North Vernon, IN 47265

Rahway Valley Sewerage Authority
Artie Wright
Plant Superintendent
1050 East Hazelwood Ave.
Rahway, NJ 07065

City of Savannah, Georgia
Don Atwell
City of Savannah Stormwater Management
P.O. Box 1027
Savannah, GA 31402

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
401 M St., S.W.
Washington, D.C., 20460

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