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AN EVALUATION OF STORM DRAINAGE INLET DEVICES FOR STORMWATER QUALITY TREATMENT

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ABSTRACT

The activities summarized in this paper included the testing of three representative stormwater control devices that were located at storm drainage inlets. The two proprietary devices utilized screening and filtering (using filter fabric and a coarser mesh). A conventional catchbasin inlet, having a sump, was also tested for comparison. These devices were monitored in Stafford Township, NJ, to evaluate their removal effectiveness for stormwater pollutants. Twelve paired samples collected at each device represented composite inflow and outflow stormwater. The samples were split into filtered and unfiltered components for extensive analyses of conventional and toxic pollutants. The experimental design was capable of identifying significant pollutant removals of at least 15 to 50% at a 95% confidence level, depending on the pollutant. The only significant pollutant removals were found during tests of a conventional catchbasin having a suitable sump. The median removal rates were about 30% for suspended solids, about 40% for turbidity, about 15% for color, and about 20% for total solids. No other pollutants were found to be significantly reduced. However, the coarse screened inlet device was found to significantly reduce the discharges of trash and other large debris. Unfortunately, flows passing through trapped material caught on the screen had increased concentrations of suspended solids and volatile solids, probably due to washing of decomposing large organic material through the screen. The filter fabrics tested in the laboratory showed about 50% removals for suspended solids and COD, but they rapidly clogged, significantly shortening their run times and minimizing any benefit from their use. This research was conducted in partial fulfillment of cooperative agreement no. CR 819573 under the sponsorship of the U.S. Environmental Protection Agency.

BACKGROUND

Storm drainage system inlet structures can be separated into three general categories. The first category is a simple inlet that is comprised of a grating at the curb and a box, with the discharge located at the bottom of the box which connects directly to the main storm drainage or combined sewerage. This inlet simply directs the runoff to the drainage system and contains no attributes that would improve water quality. However, large debris (several cm in size) may accumulate (if present in the stormwater, which is unlikely). The second type of inlet is similar to the simple inlet, but it contains a sump that typically extends 0.5 to 1 m below the bottom of the outlet. This is termed a catchbasin in the U.S., or a gully pot in the U.K., and has been shown to trap appreciable portions of the course sediment. The third category is also similar to the simple inlet, but contains some type of screening to trap debris. These include small cast iron perforated buckets placed under the street grating, as used in Germany, large perforated and lipped stainless steel plates placed under the street grating, as used in Austin, Texas, and a number of proprietary devices incorporating filter fabric or other types of screening placed to intercept the stormwater flow.

Over the past 85 years, there has been extensive use of catchbasins for coarse material removal from stormwater runoff (Lager, *et al*. 1977), mainly to reduce sedimentation problems in the storm drainage system. Catchbasins have also been utilized in Europe for over a century. The purpose of catchbasins historically has been to prevent the clogging of sewer lines with sediment and organic debris, and to prevent odors from escaping from the sewers by creating a water seal. Over the years, many different styles of catchbasins have been used, and many different enhancement devices have been added to increase their effectiveness. According to Lager, *et al*. (1977)*,* catchbasins were considered marginal in performance as early as the turn of the century. They felt that the use of catchbasins may be more of a tradition for most municipalities rather than a practice based on performance. Sartor and Boyd (1972) suggested that all catchbasins should be filled in, citing their ineffectiveness at removal of pollutants and the threat of slug pollution of the scoured material. Grottker (1990) was more positive. He reports of an inlet design in Germany that is modified with sumps and a primary filter to screen out the larger debris. He recommended the modified device as a cost-saving device that improves water quality.

Catchbasin performance has been investigated for some time in the U.S. Sartor and Boyd (1972) conducted controlled field tests of a catchbasin in San Francisco, using simulated sediment in fire hydrant water flows. They sampled water flowing into and out of a catchbasin for sediment and basic pollutant analyses. Lager, *et al.* (1977) was the first EPA funded research effort that included a theoretical laboratory investigation to evaluate sedimentation in catchbasins and to develop effective designs. They also conducted extensive laboratory tests using simulated runoff.

The mobility of catchbasin sediments was investigated by Pitt (1979). Long-duration tests were conducted using an “idealized” catchbasin (based on Lager, *et al*.’s 1977 design), retro-fitted in San Jose, CA. The research focused on re-suspension of sediment from a full catchbasin over an extended time period. It was concluded that the amount of catchbasin and sewerage sediment was very large in comparison with storm runoff yields, but was not very mobile. Cleaning catchbasins would enable them to continue to trap sediment, instead of reaching a steady-state loading and allowing subsequent stormwater flows to pass through untreated.

Pitt (1985) statistically compared catchbasin supernatant with outfall water quality and did not detect any significant differences. However, Butler, *et al.* (1995) have recently investigated gully pot supernatant water and have found that it may contribute to the more greatly polluted first flush of stormwater reported for some locations. Specific problems have been associated with the anaerobic conditions that rapidly form in the supernatant water during dry weather, causing the release of oxygen demanding material, ammonium, and possible sulfides. These anaerobic conditions also affect the bioavailability of the heavy metals in the flushed water.

Catchbasins, simple inlets, man-holes, and sewerage sediment accumulations were monitored at more than 200 locations in Bellevue, Washington, in two mixed residential and commercial study areas (Pitt 1985). These locations were studied over three years to monitor accumulation of sediment and sediment quality. The sediment in the catchbasins and the sewerage was found to be the largest particles that were washed from the streets. The sewerage and catchbasin sediments had a much smaller median particle size than the street dirt and were therefore more potentially polluting than the particulates that can be removed by street cleaning. Cleaning catchbasins twice a year was found to allow the catchbasins to capture particulates most effectively. This cleaning schedule was found to reduce the total residue and lead urban runoff yields by between 10 and 25 percent, and COD, total Kjeldahl nitrogen, total phosphorus, and zinc by between 5 and 10 percent (Pitt and Shawley 1982).

Catchbasins have been found to be effective in removing pollutants associated with coarser runoff solids (Pitt 1985). High reductions in total and suspended solids (up to 45% reduction for low gutter flows) were indicated by a number of prior studies (such as Pitt 1979, Aronson, *et al*. 1983, and Pitt 1985). However, relatively few pollutants are associated with these coarser solids (Pitt 1979 and Pitt 1985). Pitt (1985) found that catchbasins will accumulate sediments until the sediments reach about 60% of the total sump capacity (or to about 0.3 m under the catchbasin outlet). After that level, the sediment is at an equilibrium, with scour balancing new deposition. Earlier EPA research (Lager, *et al*. 1977) found that an optimal catchbasin design should have the following dimensions: if the outlet pipe is D in diameter, its bottom should be located about 2.5D below the street level and 4D from the bottom of the catchbasin sump. The overall height of the catchbasin should therefore be 6.5D, with a diameter of 4D.

Butler, *et al.* (1995) found that the median particle size of the sump particles was between about 300 and 3000 µm, with less than 10% of the particles smaller than 100 µm, near the typical upper limit of particles found in stormwater. Catchbasin sumps therefore trap the largest particles that are flowing in the water, and allow the more contaminated finer particles to flow through the inlet structure. Butler, *et al*. (1995) and Butler and Karunaratne (1995) present sediment trapping equations for sediment in gully pots, based on detailed laboratory tests. The sediment trapping performance was found to be dependent on the flow rate passing through the gully pot, and to the particle sizes of the sediment. The depth of sediment in the gully pot had a lesser effect on the capture performance. In all cases, decreased flows substantially increased the trapping efficiency and larger particles had substantially greater trapping efficiency than smaller particles, as expected.

METHODOLOGY

Three storm drain inlet devices were evaluated in Stafford Township, New Jersey. An optimally designed catchbasin with a sump and two representative designs that used filter material. Henderson & Breen Environmental Engineers of Forked River, New Jersey, oversaw the field installations, sampling, and shipping of the samples to the University of Alabama at Birmingham (UAB) for analyses. The inlet devices were located in a residential area. The monitoring program included 12 inlet and effluent samples from these devices over several different storms. Complete organic and metallic toxicant analyses, in addition to conventional pollutants, were included in the analytical program. A total of 144 analyses were therefore conducted for each parameter that was partitioned into unfiltered and filtered portions, and 72 analyses were conducted for the samples that were not partitioned. In addition to these field tests, controlled tests were also conducted in the laboratory to further evaluate filter fabrics used in some inlet devices.

Samples were analyzed for a wide range of toxicants using very low detection limits (about 1 to 10 µg/L). The constituents analyzed include heavy metals and organics (phenols, PAHs, phthalate esters, and chlorinated pesticides). Particle size distributions, using a Coulter Multi-Sizer II, were also made, in addition to conventional analyses for COD, major ions, nutrients, suspended and dissolved solids, turbidity, color, pH, and conductivity. All samples were also partitioned into filterable and non-filterable components before COD and toxicant analyses to better estimate fate and treatability. All samples were also screened using the Microtox toxicity test to measure relative reductions in toxicity associated with the inlet devices.

Description of Inlet Devices Tested

Conventional Catchbasin with Sump

A sump was installed in the bottom of an existing storm drain inlet by digging out the bottom and placing a section of 36 inch concrete pipe on end. The outlet pipe was reduced to 8 inches and the sump depth was 36 inches. Inlet water was sampled before entering the catchbasin, while outlet water was sampled after passing through the unit.

Filter Fabric Unit

A filter fabric unit, having a set of dual horizontal trays, each containing about 0.1 m^2 of filter fabric, was retro-fitted into one of the existing inlets for testing. When the filter fabric clogs on the upper tray, the stormwater overflows a small rectangular weir, onto another similar tray located beneath the upper tray. Again, paired samples were obtained above and under the unit for analyses. According to the manufacturer, this system can handle up to 300 gallons per minute. The unit tested has mostly been replaced by the manufacture with a new type of catchbasin filter that also includes a selection of filtering media.

Coarse Filter Unit

A coarse filter was also retro-fitted into an existing stormdrain inlet. This unit uses a relatively coarse foam material (about 1mm cell diameter and 8 mm thick) that is sandwiched between two pieces of galvanized screening for support. This unit was fitted in the inlet, sealed along the bottom and sides on the outlet side, forcing any water through the unit before it is discharged. The filter was placed in front of the catchbasin outlet in a near vertical position. Its main purpose is to filter debris, including leaves and grass clippings, from stormwater. As with the other units, the inlet and outlet water was simultaneously sampled for analyses.

RESULTS

Measuring the reduction of pollutants by the storm drainage inlet devices was the primary objective of this study. Table 1 indicates the percent reduction in pollutant concentrations from influent to effluent. The numbers in parenthesis indicate the probability that the influent is equal to the effluent. Probability values less than 0.05 are indicated in bold print. Table 2 lists the mean concentrations in the influent and effluent samples, along with the observed coefficients of variations. The catchbasin with the sump was the only device that showed important and significant removals for several pollutants:

total solids (0 to 50%, average 22%).
suspended solids (0 to 55%, average 32%).
turbidity (0 to 65%, average 38%).
color (0 to 50%, average 24%).

Figures 1 through 3 are example box plots for the three inlet devices for suspended solids and COD.

Table 1 highlights the significant concentration changes observed for the three storm drain inlet devices tested, using a paired sample, Wilcoxon Signed Rank test. Only the catchbasin with a sump was found to have significant (and important) concentration reductions for major parameters. The coarse screen unit showed consistent washout of material, while both the coarse screen unit and the catchbasin showed slight increases for several major ions, most likely associated with contact with concrete and other drainage system materials. The catchbasin performance (32% removal for suspended solids) is within the range reported during earlier studies, as reported previously.

None of the other parameters or inlet devices demonstrated significant differences between the influent and effluent water (at the 95% confidence level, or better), except for the filter fabric unit which showed a small removal for nitrate. Several significant and large increases in major ion concentrations were noted for the catchbasin (bicarbonate, magnesium, and calcium) and for the coarse screen unit (bicarbonate, and potassium). These increases, which are not believed to be very important, may have been due to the runoff water being affected by the concrete in the inlet devices. These increases are likely part of the general process where runoff water increases its alkalinity and buffer capacity as it flows through urban areas.

The significant and large increases in total solids, suspended solids, volatile solids, and conductivity for the coarse screen unit imply washout of decomposing collected organic solids (mostly leaves). The coarse screen unit traps large debris, including decomposable organic material, behind the screen. Stormwater then flows through this material as it passes through the screen, as in most inlet screening/filtering devices. If not frequently removed, this organic material may decompose and wash through the screen in subsequent storms. The large debris was not represented in the influent water samples, but after partial decomposition, this material could have added to the solids concentrations in the effluent samples.

The catchbasin did not exhibit this increase in solids concentrations likely because the collected material is trapped in the sump and not subjected to water passing through the material. Previous catchbasin tests found that catchbasin supernatant water quality is not significantly different from runoff water quality, nor is the collected debris easily or commonly scoured from the sump. The filter fabric unit did not exhibit this increase in solids, possibly because it trapped relatively small amounts of debris, and the overflow weirs allowed the subsequent stormwater to flow over the trapped debris instead of being forced through the debris.

SUGGESTIONS FOR OPTIMAL STORM DRAINAGE INLET USE

The best catchbasin configuration for a specific location would be dependent on site conditions and would probably incorporate a combination of features from several different inlet designs. The primary design should incorporate a catchbasin with a sump, as described by Lager, *et al.* (1977), with an inverted (hooded) outlet. If large enough, catchbasins with sumps have been shown to provide a moderate level of suspended solids reductions in stormwater under a wide range of conditions in many studies in the U.S. and Europe. The use of filter fabrics in catchbasins is not likely to be beneficial because of their rapid clogging from retained sediment and trash. The use of coarser screens in catchbasin inlets is also not likely to result in water quality improvements, based on conventional water pollutant analyses. However, well designed and maintained screens can result in substantial trash and litter reductions. It is important that the screen not trap organic material in the flow path of the stormwater. Prior research (Pitt 1979 and 1985) has shown that if most of the trapped material is contained in the catchbasin sump, it is out of the direct flow path and unlikely to be scoured during high flows, or to degrade overlying supernatant water. Storm drainage inlet devices also should not be considered as leaf control options, or used in areas having very heavy trash loadings, unless they can be cleaned after practically every storm.

The goal is a storm drainage inlet device that:

- does not cause flooding when it clogs with debris,
- does not force stormwater through the captured material,
- does not have adverse hydraulic head loss properties,
- maximizes pollutant reductions, and
- requires inexpensive and infrequent maintenance.

The following suggestions and design guidelines should meet some of these criteria. These options are all suitable for retro-fitting into existing simple storm drainage inlets. However, the materials used should be concrete, plastic, aluminum or stainless steel; especially do not use galvanized metal or treated woods. Catchbasins in newly developing areas could be more optimally designed than the suggestions below, especially by enlarging the sumps and by providing large and separate offset litter traps.

1) The basic catchbasin (having an appropriately sized sump with a hooded outlet) should be used in most areas. This is the most robust configuration. In almost all full-scale field investigations, this design has been shown to withstand extreme flows with little scouring losses, no significant differences between supernatant water quality and runoff quality, and minimal insect problems. It will trap the bed-load from the stormwater (especially important in areas using sand for traction control) and will trap a low to moderate amount of suspended solids (about 30 to 45% of the annual loadings). The largest fraction of the sediment in the flowing stormwater will be trapped, in preference to the finer material that has greater amounts of associated pollutants. Their hydraulic capacities are designed using conventional procedures (grating and outlet dimensions), while the sump is designed based on the desired cleaning frequency. Figure 4 is this basic recommended configuration.

An estimate of the required catchbasin sump volume and cleanout frequency can be estimated. For example, assume the following conditions:

- paved drainage area: 1.3 ha (3.3 acres),
- 250 mg/L suspended solids concentration, and
- 640 mm (25 in) of rain per year.

The sediment accumulation rate in the catchbasin sump would be about 0.24 m^3/ha (3.4 ft^3/acre) of pavement per year. For a 1.3 ha (3.3 acre) paved drainage area, the annual accumulation would therefore be about 0.3 m^3 (10 ft^3). The catchbasin sump diameter should be at least four times the diameter of the outlet pipe. Therefore, if the outlet from the catchbasin is a 250 mm (10 in) diameter pipe, the sump should be at least 1 m (40 in) in diameter (having a surface area of 0.8 m^3, or 9 ft^2). The annual accumulation of sediment in the sump for this situation would therefore be about 0.4 m (1.3 ft). If the sump was to be cleaned about every two years, the total accumulation between cleanings would therefore be about 0.8 m (2.6 ft). An extra 0.3 m (1 ft) of sump depth should be provided as a safety factor because of potential scour during unusual rains. Therefore, a total sump depth of at least 1.1 m (3.6 ft) should be used. In no case should the total sump depth be less than about 1 m (3 ft) and the sump diameter less than about 0.75 m (2.5 ft). This would provide an effective sump volume of about 0.8 m^3 (9 ft^3) assuming a safety factor of about 1.6.

2) A relatively safe add-on to the basic recommended configuration is an adverse slope inclined screen covering the outlet side of the catchbasin, as shown in Figure 5. The inclined screen would be a relatively coarse screening that should trap practically all trash of concern. The bottom edge of the inclined screen would be solidly attached to the inside wall of the catchbasin below the inverted outlet. The screen would tilt outwards so it covers the hooded outlet. The sides of the screen need to be sealed against the side of the catchbasin. The top edge of the screen would extend slightly above the normal water surface. A solid top plate would extend out from the catchbasin wall on the outlet side covering the top opening of the inclined screen. This plate would overhang the top of the screen, but provide a slot opening above the screen for an overflow in case the screen was clogged. The slot opening should be several inches high and extend the width of the catchbasin. This design will also capture grit and the largest suspended solids, plus much of the trash. This design would allow the trapped material to fall into the sump instead of being forced against the screen by out-flowing water.

3) Another option that may be suitable for trapping large litter, such as Styrofoam cups and fast food wrappings, and that also minimizes flow obstructions, uses a bar screen. The inclined coarse screen, described in the above option, will trap smaller litter, such as cigarette butts. This is the same catchbasin inlet with sump and inclined coarse screen as shown above, but it also has a bar screen under the whole area of the inlet grating, especially under large curb openings. In almost all cases, storm drainage inlets have gratings that have moderate sized openings which would prevent large trash from entering the inlet. However, most also have wide openings along the curb face where litter can be washed into the inlet. The bar screen is designed to capture litter that would enter through the wide openings. The bar screen is steeply sloped towards a covered litter trap, preferably in an adjacent chamber.

The bars should be spaced no less than ¼ inch and possibly as much as one inch apart, as the objective is to capture large debris. Water passing through the bars should wash the debris towards the covered litter trap, with minimal clogging problems. The covered litter trap should be as large as possible and located above the water level, with drain holes. Since much of the debris would be floatables, any underwater storage volume would have minimal benefit. A nylon net bag, for example, could be inserted into a frame to make litter removal easy and to allow drainage. The litter trap is covered and offset to minimize water flowing directly through it and it is held above the water to minimize water contact with the litter before it is removed.

Plastic bags, large pieces of paper, and large leaves may still fall through the bar screen, or wrap around the bars and cause partial blockages. Therefore, frequent inspections and cleanups will be needed. In addition, the size of the trap is limited and may fill quickly, also requiring frequent inspections and cleanups. This option should only be used in areas having trash that needs to be controlled, not in areas having large amounts of leaf or other vegetative trash that would overload the unit. The obvious locations for this option would be in strip commercial and other downtown areas having minimal landscaping that would contribute organic debris, but having large amounts of litter. Urban freeways, downtown malls and night club districts would be examples of suitable locations. Commitments to inspect (and possibly clean) after most storms, especially those having long interevent periods where trash accumulations may be high, must be made before this option is viable.

4) The use of filter fabrics as an integral part of a storm drain inlet is not recommended. Their biggest problem is their likelihood of quickly clogging. Tests during this research showed that they may provide

important reductions (about 50%) in suspended solids and COD. However, the filter fabrics can only withstand about 1 to 2 mm accumulation of sediment before they clog. This is about 4 kg of sediment per square meter of fabric. If runoff had a suspended solids concentration of 100 mg/L, the maximum loading of stormwater tolerated would be about 40 meters. For a typical application (1 ha paved drainage area to a 1 m^2 filter fabric in an inlet box), only about 5 to 10 mm of runoff could be filtered before absolute clogging.

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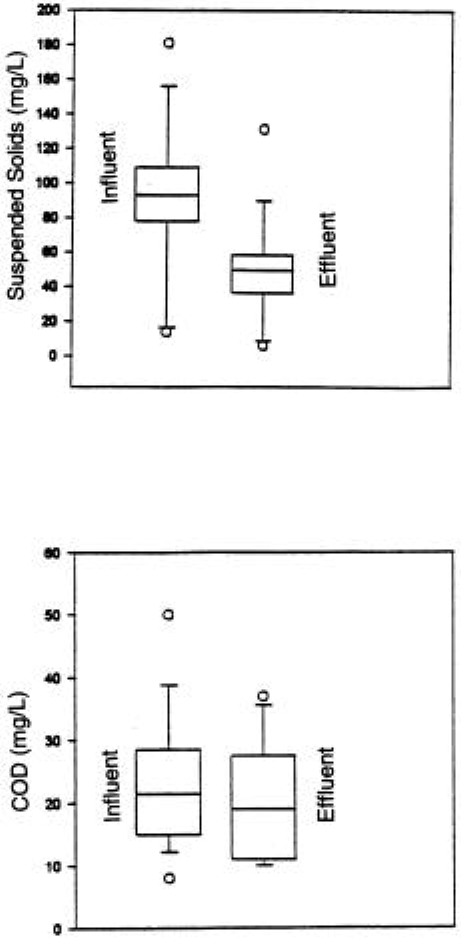

Figure 1. Box and whisker plot
for catchbasin with sump.

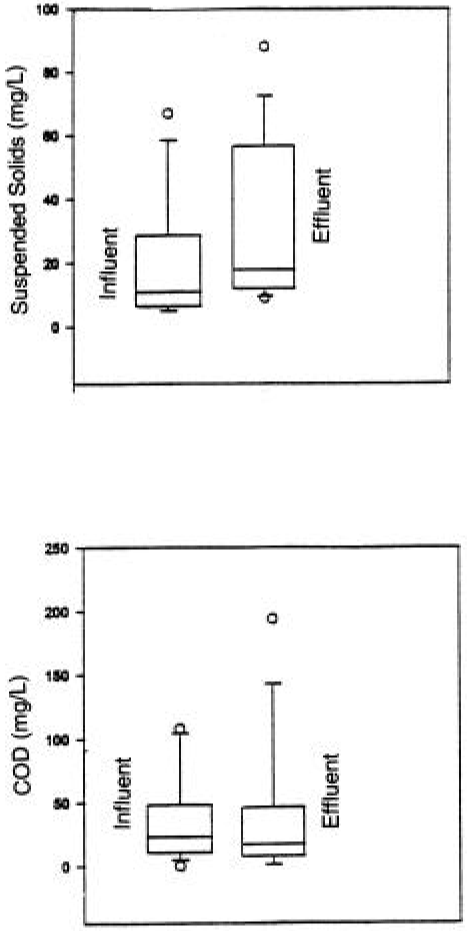

Figure 2. Box and whisker plot
for coarse screen unit.

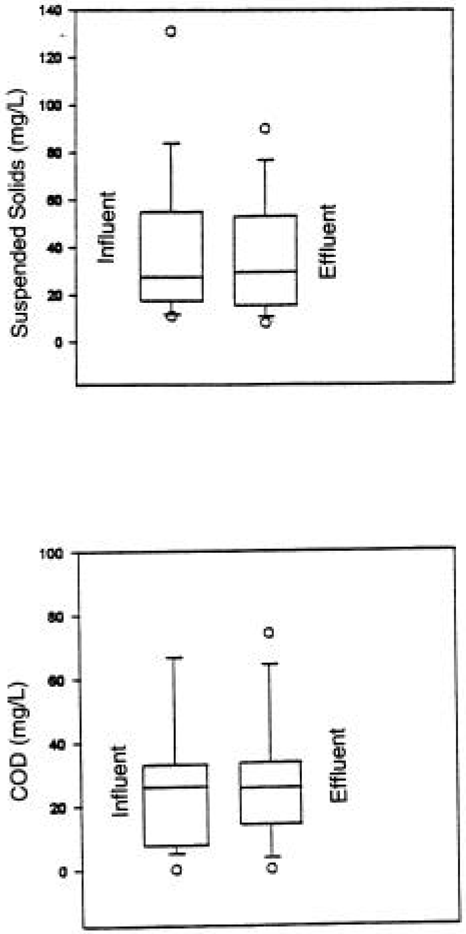

Figure 3. Box and whisker plot
for filter fabric unit.

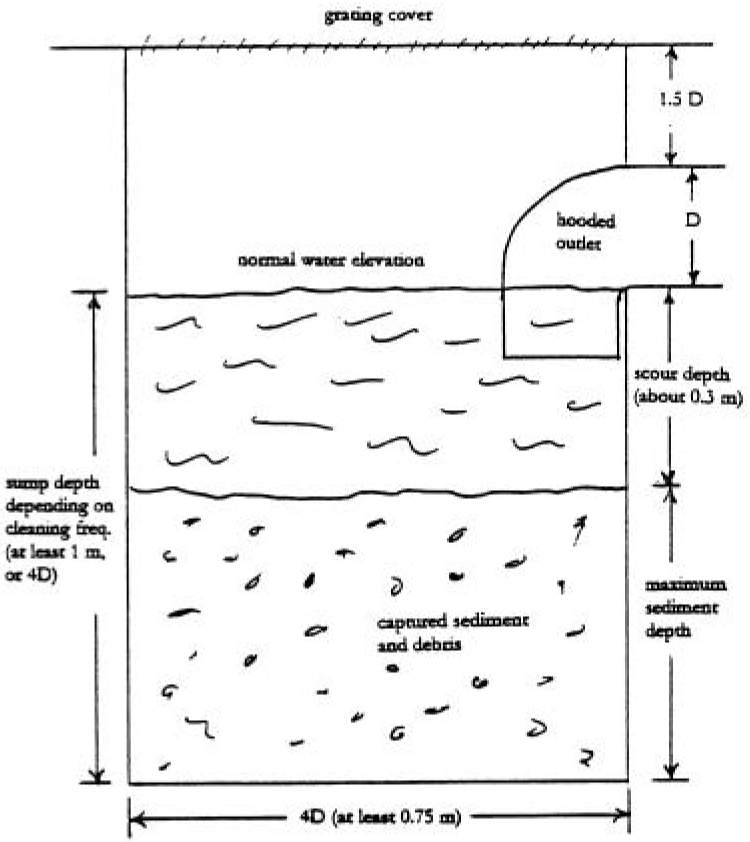

Figure 4. Conventional catchbasin with inverted sump and hooded outlet.

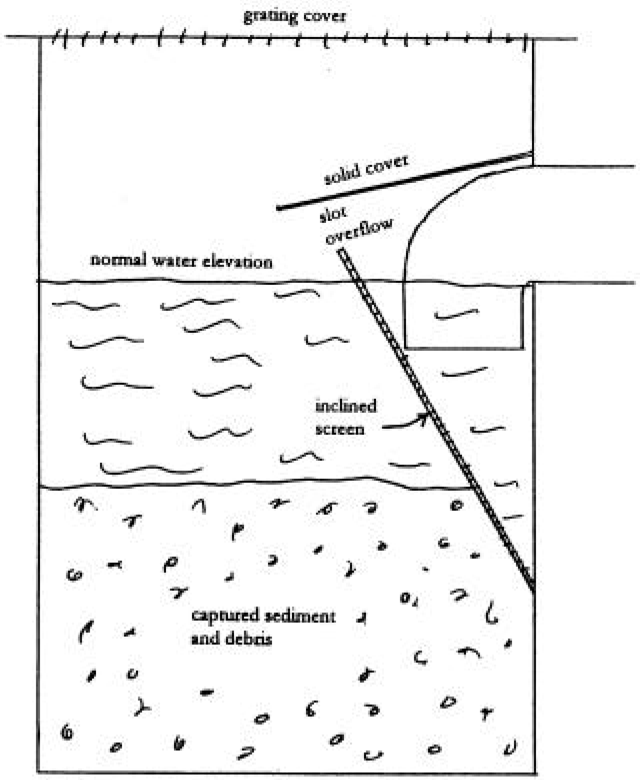

Figure 5. Conventional catchbasin with inverted sump, hooded outlet, and inclined screen.

Table 1. Storm Drain Inlet Device Performance Summary for Selected Pollutants (Percent Reduction and Statistical Probability that Difference is Random)

Pollutant	**Catchbasin with Sump % Reduction (p)**	**Coarse Screen Unit % Reduction (p)**	**Filter Fabric Unit % Reduction (p)**
Total Solids	22 (**0.03**)	-28 (**0.014**)	5.6 (0.28)
Dissolved Solids	8.3 (0.68)	-16 (0.13)	3.4 (0.32)
Suspended Solids	32 (**0.0098**)	-56 (**0.054**)	8.1 (0.70)
Volatile Total Solids	6.3 (0.62)	-40 (**0.049**)	0.0 (0.95)
Volatile Dissolved Solids	6.8 (0.77)	-21 (0.32)	4.4 (0.97)
Volatile Suspended Solids	34 (0.43)	-42 (0.55)	-8.3 (1.00)
Differential Volume >4 and <5	-46 (0.81)	-67 (1.00)	-2.2 (1.00)
Differential Volume >15 and <20	26 (1.00)	-23 (0.44)	43 (0.22)
Differential Volume >50 and <65	-46 (0.13)	-87 (0.23)	-23 (0.69)
Toxicity - unfiltered	7.8 (0.91)	-33 (0.15)	18 (0.20)
Toxicity - filtered	1.6 (0.92)	-2.9 (0.57)	-18 (0.62)
Turbidity - unfiltered	38 (**0.019**)	-6.6 (0.30)	0.95 (0.32)
Turbidity - filtered	34 (0.70)	12 (0.27)	-18 (0.62)
Color - unfiltered	16 (0.083)	-14 (0.15)	-1.1 (0.73)
Color - filtered	24 (**0.052**)	-36 (0.68)	-3.0 (0.85)
Conductivity - unfiltered	-11 (0.084)	-14 (**0.052**)	1.2 (0.91)
pH - unfiltered	0.2 (0.64)	-1.0 (0.10)	-0.58 (0.13)
COD - unfiltered	11 (0.47)	-19 (0.58)	-0.91 (0.85)
COD - filtered	-49 (0.42)	-36 (0.41)	19 (0.79)
Carbonate - unfiltered	-42 (0.27)	-22 (0.56)	14 (0.43)
Bicarbonate - unfiltered	-27 (**0.0024**)	-21 (**0.019**)	0.08 (0.52)
Fluoride - filtered	-5.6 (0.44)	-114 (1.00)	86 (1.00)
Chloride - filtered	-4.8 (0.97)	-11 (0.46)	0.08 (0.65)
Nitrite - filtered	all nd	all nd	all nd
Nitrate - filtered	-17 (0.12)	-12 (0.28)	6.1 (**0.0024%**)
Sulfate - filtered	-12 (0.79)	-15 (0.41)	2.6 (0.34)
Lithium - filtered	all nd	all nd	all nd
Sodium - filtered	2.8 (0.70)	-9.7 (0.30)	-1.8 (0.32)
Ammonium - filtered	-13 (0.84)	5.2 (0.64)	-19 (0.50)
Potassium - filtered	-6.6 (0.47)	-17 (**0.042**)	-7.1 (0.34)
Magnesium - filtered	-15 (**0.0034**)	-25 (0.24)	2.7 (0.91)
Calcium - filtered	-31 (**0.0005**)	-24 (0.21)	0.8 (0.52)

Table 2. Mean and Coefficient of Variation of Influent and Effluent Samples

		Catchbasin		Coarse Screen Unit		Filter Fabric Unit	
		Mean	**COV**	**Mean**	**COV**	**Mean**	**COV**
Total Solids, mg/L	Influent	122	0.54	73	0.94	86.1	0.57
	Effluent	95	0.52	93	0.92	81.2	0.56
Dissolved Solids, mg/L	Influent	48	0.51	51	1.00	46.2	0.71
	Effluent	44	0.49	59	1.08	44.6	0.76
Suspended Solids, mg/L	Influent	75	0.75	22	0.96	39.9	0.85
	Effluent	51	0.62	34	0.79	36.7	0.72
Volatile Total Solids, mg/L	Influent	28	0.52	20	0.85	21.9	0.49
	Effluent	26	0.51	28	0.77	21.9	0.46
Volatile Dissolved Solids, mg/L	Influent	12	0.41	9	0.87	9.58	0.74
	Effluent	11	0.78	11	1.00	9.17	0.66
Volatile Suspended Solids, mg/L	Influent	16	0.90	12	1.03	12	0.86
	Effluent	15	0.59	17	0.83	13	0.59
Differential Solids Volume >4 and <5 um	Influent	2,219,178	0.89	405,759	0.75	3,477,951	0.92
	Effluent	3,250,458	0.68	678,747	0.95	3,553,763	0.86
Differential Solids Volume >15 and >20 um	Influent	2,821,656	1.47	3,019,100	0.85	2,341,839	0.88
	Effluent	2,096,122	1.15	3,715,339	0.83	1,328,777	0.28
Differential Solids Volume >50 and >65um	Influent	706,713	1.62	1,144,943	0.82	288,749	0.66
	Effluent	1,034,633	1.66	2,139,047	0.97	354,953	0.82
Toxicity - unfiltered, I25% reduction	Influent	9.7	0.92	14.7	0.55	19.3	0.69
	Effluent	8.9	0.91	19.5	0.80	15.8	1.69
Toxicity - filtered, I25% reduction	Influent	15.3	0.60	20.0	0.81	20.3	0.49
	Effluent	15.1	0.67	20.6	0.71	23.9	0.69
Turbidity - unfiltered, NTU	Influent	59.9	0.79	6.9	0.94	21.0	0.69
	Effluent	37.1	0.79	7.3	0.78	20.8	0.78
Turbidity - filtered, NTU	Influent	5.0	0.98	0.678	0.77	1.7	0.92
	Effluent	3.3	1.38	0.597	0.59	1.4	0.72
Color - unfiltered, HACH	Influent	62.6	0.54	25.0	0.85	37.3	0.43
	Effluent	52.6	0.56	28.6	0.83	37.7	0.46
Color - filtered, HACH	Influent	26.2	0.43	19.2	1.19	16.9	0.40
	Effluent	19.9	0.40	20.3	1.18	16.4	0.38
Conductivity - unfiltered, ㎜S/cm	Influent	56.3	0.61	79.0	0.93	71.8	0.69
	Effluent	62.6	0.55	90.4	0.99	71.0	0.71

Table 2. Mean and Coefficient of Variation of Influent and Effluent Samples (Continued)

		Catchbasin		Coarse Screen Unit		Filter Fabric Unit	
		Mean	**COV**	**Mean**	**COV**	**Mean**	**COV**
pH - Unfiltered	Influent	6.96	0.02	6.66	0.03	6.89	0.02
	Effluent	6.95	0.03	6.73	0.03	6.93	0.02
COD - unfiltered, mg/L	Influent	22.8	0.50	35.8	1.03	27.3	0.92
	Effluent	20.3	0.48	42.6	1.38	27.6	0.78
COD - filtered, mg/L	Influent	10.0	0.86	26.6	1.32	15.2	1.20
	Effluent	14.9	1.00	36.1	1.72	12.3	1.29
Carbonate - unfiltered, mg/L	Influent	0.01	0.97	0.005	0.44	0.012	0.72
	Effluent	0.02	0.73	0.006	0.72	0.010	0.65
Bicarbonate - unfiltered, mg/L	Influent	22.26	0.22	14.28	0.28	18.27	0.27
	Effluent	28.20	0.25	17.31	0.32	18.26	0.23
Fluoride - filtered, mg/L	Influent	0.018	2.04	0.003	1.99	0.007	2.30
	Effluent	0.019	2.04	0.011	1.70	0.001	2.38
Chloride - filtered, mg/L	Influent	4.951	0.62	5.151	1.15	7.11	1.17
	Effluent	5.187	0.61	5.739	1.09	7.11	1.17
Nitrate - filtered mg/L	Influent	1.067	0.82	2.457	1.24	1.07	1.29
	Effluent	1.247	0.72	2.749	1.30	1.59	1.37
Sulfate - filtered mg/L	Influent	3.856	0.49	5.800	1.06	4.07	1.08
	Effluent	4.328	0.59	6.651	1.18	3.96	1.14
Sodium - filtered, mg/L	Influent	3.771	0.49	3.946	1.14	6.67	0.88
	Effluent	3.665	0.50	4.327	1.16	6.79	0.87
Ammonium - filtered, mg/L	Influent	0.219	1.03	0.287	1.01	0.37	1.01
	Effluent	0.248	0.91	0.272	1.01	0.44	0.93
Potassium - filtered, mg/L	Influent	0.834	0.37	0.443	0.67	0.48	0.78
	Effluent	0.889	0.44	0.519	0.71	0.51	0.70
Magnesium - filtered, mg/L	Influent	0.725	0.60	0.645	0.78	0.51	0.71
	Effluent	0.834	0.55	0.808	1.06	0.50	0.76
Calcium - filtered, mg/L	Influent	3.60	0.35	3.438	0.65	2.82	0.54
	Effluent	4.72	0.32	4.247	0.82	2.84	0.57
Lead - unfiltered µg/L	Influent	5.28	1.06	3.45	1.79	6.25	1.30
	Effluent	3.36	0.74	4.97	1.41	7.04	0.92
Lead - filtered µg/L	Influent	1.37	1.15	0.944	1.65	0.60	1.11
	Effluent	1.25	1.17	0.587	1.98	0.79	1.31
Copper - unfiltered µg/L	Influent	30.63	0.26	37.79	0.49	24.9	0.38
	Effluent	25.58	0.32	36.34	0.48	24.6	0.39
Copper - filtered µg/L	Influent	15.5	0.59	21.62	0.92	15.8	0.70
	Effluent	16.5	0.55	20.79	0.74	16.5	0.60