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Storm Water O&M Fact Sheet
Handling and Disposal of Residuals

DESCRIPTION

Polluted urban runoff can be a major source of water quality problems in receiving waters. Road deicing activities, automobiles, atmospheric deposition, chemicals used in homes and offices, erosion from construction sites, discharges from industrial plants, wastes from pets, wastes from processing and salvage facilities, and chemical spills can all contaminate storm water runoff. These sources can contribute sediment (organic and inorganic), nutrients, bacteria, oil and grease, and heavy metals to receiving waters. Urban storm water Best Management Practices, or BMPs, are intended to remove these pollutants from runoff and to improve water quality in downstream waters. Yet if storm water BMPs are not properly operated and maintained, the BMPs themselves can become sources of storm water pollutants, as the material removed during previous storms becomes re-suspended by subsequent storm events. To prevent this, structural storm water BMPs must be periodically inspected and cleaned of residual materials and sediments. As described above, these residuals may contain a variety of pollutants, and thus proper handling and disposal of these materials is essential. This fact sheet describes structural BMP maintenance programs and discusses methods for handling and disposing of residual materials from storm water BMPs.

Properties of Storm Water Residuals

Storm water solids/residuals have properties that are very site specific, and it is difficult to precisely estimate "typical" storm water or sediment residual properties by the BMP employed or even by site classification. Therefore, this fact sheet presents information from several site-specific studies of the properties of storm water solids/residuals presented. A summary of this data is presented in Table 1.

A 1982 study performed at Marquette University, Milwaukee, Wisconsin, examined urban runoff residuals from a field-assembled sedimentation basin in Racine, Wisconsin, swirl and helical bend solids separators in Boston, Massachusetts, and an in-line upsized storm conduit in Lansing, Michigan. The residual samples from Racine and Boston were obtained from individual storms, while the Lansing samples represent a six- month accumulation of residuals. All of the sample locations were primarily residential (Marquette University, 1982). Results from the sampling are shown in Table 1. Table 1 also summarizes the findings presented in two other technical papers (Schueler and Yousef, 1994, and Field and O'Shea, 1992).

The 1994 study by Schueler and Yousef reviewed bottom sediment chemistry data from 37 wet ponds, 11 detention basins, and two wetland systems, as reported from 14 different researchers. This research covered a broad geographic range, although nearly half of the sites were located in Florida or in the Mid-Atlantic states. These storm water ponds had been in use from three to 25 years. Sampling and analysis were restricted to mean dry weight concentrations of the surface sediments that comprise the muck layer, which is usually the top five centimeters (Schueler and Yousef, 1994).

Schueler and Yousef gathered data for nutrients, trace metals (cadmium, copper, lead, zinc, nickel, chromium), hydrocarbons, and priority pollutants, and indicate that the properties of the solids/residuals from all BMPs are similar except for those from oil/grit separators. A noted exception was that grassed swale soils tend to have about

TABLE 1 PROPERTIES OF URBAN STORM WATER SOLIDS/RESIDUALS

Properties of Residuals	Wet Ponds[1]	Sedimentation Basin [2]	Swirl and Helical Bend Solids Separators[3]	In-Line Upsized Storm Conduit[4]	Urban Storm Water Runoff Residuals[5]
Solids					
Volatile Suspended Solids	6%	104 - 155 mg/l	107 310 mg/l	25,800 mg/l	90 mg/l
Total Suspended Solids	43%	233-793 mg/l	344 - 1,140 mg/l	161,000 mg/l	415 mg/l
Nutrients					
Phosphorus	583 mg/kg	< 5 mg/l	< 5 mg/l	0.3 - 2,250 mg/l	502 - 1,270 mg/kg
Total Kjeldahl Nitrogen	2,931 mg/kg	<5 mg/l	< 5 mg/l	0.3 - 2,250 mg/l	1,140 - 3,370 mg/kg
Heavy Metals					
Zinc	6 - 3,171 mg/kg	-	-	-	302 - 352 mg/kg
Lead	11 - 748 mg/kg	-	-	-	251 - 294 mg/kg
Chromium	4.8 - 120 mg/kg	-	-	-	168 - 458 mg/kg
Nickel	3 - 52 mg/kg	-	-	-	69 - 143 mg/kg
Copper	2 - 173 mg/kg	-	-	-	251 - 294 mg/kg
Cadmium	ND - 15 mg/kg	-	-	-	-
Iron	-	6.1 - 2,970 mg/l	6.1- 2,970 mg/l	6.1 - 2,970 mg/l	-
Hydrocarbons	2,087 - 12,892 mg/kg	-	-	-	-
Poly Chlorinated Biphenyls	-	0.19 - 24.6 ϒg/l	-	0.19 - 24.6 ϒg/l	-

(1) Schueler and Yousef, 1994.
(2) Marquette University, 1982 (Racine, Wisconsin).
(3) Marquette University, 1982 (Boston, Massachusetts).
(4) Marquette University, 1982 (Lansing, Michigan).
(5) Field and O'Shea, 1992.

twice as much phosphorus and lead as detention ponds. Only one sand filter had been sampled, but these characteristics in its residuals appeared similar to those of other BMPs (Schueler and Yousef, 1994). Characteristics of solids/residuals from BMPs are discussed in the following sections, with the exception of oil/grit separators, which are covered in a separate subsection.

Solids-General Composition

Solids from storm water and sediment BMPs can consist of organic and inorganic material. According to Schueler and Yousef (1994), the muck layer of a pond is high in organic matter. An average of nearly six percent volatile suspended solids was reported. Pond muck solids have a very soupy texture, with an average total solids content of 43 percent, although this parameter was reported from only 15 out of the 50 site locations. These solids have a distinctive grey to black color and a low density, averaging approximately 1.3 g/cm^3.

According to the 1982 EPA study at Marquette University, total solids concentration of residuals samples from a sedimentation basin in Racine, Wisconsin, ranged from 233 to 793 mg/l, with 104 to 155 mg/l being volatile. Concentrations of total solids from swirl and helical bend solids separators in Boston, Massachusetts, ranged from 344 to 1,140 mg/l, with 107 to 310 mg/l being volatile. The six-month accumulated samples from the in-line upsized storm conduit in Lansing, Michigan had a total solids concentration of 161,000 mg/l with 25,800 mg/l being volatile. The 1992 paper by Field and O'Shea reported estimated annual residual/sludge volumes for urban storm runoff in the United States ranging from 27 to 547 million cubic meters (35 to 715 million cubic yards) at an average total solids content ranging from 0.5 to 12 percent.

Nutrients

The muck layer is enriched with nutrients. In the 1994 paper by Schueler and Yousef, phosphorus concentrations for 23 studies ranged from 110 to 1,936 mg/kg, with an average concentration of 583 mg/kg. Nearly all of the nitrogen found in pond muck is organic in nature. Total Kjeldahl nitrogen (TKN) concentrations were reported for 20 studies and ranged from 219 to 11,200 mg/kg, with an average concentration of 2,931 mg/kg. Nitrate was found to be present in very small quantities, indicating either that some denitrification is occurring in the sediments or perhaps that very little nitrate is initially trapped in the muck layer.

The nitrogen-to-phosphorus ratio in this pond study averages five to one. In comparison, the nitrogen to phosphorus ratio for incoming storm water usually averages about seven to one. Ponds appear to be more effective in trapping phosphorus-containing compounds than in trapping nitrogen-containing compounds. It is also possible that nitrogen-containing compounds decay faster than phosphorus-containing compounds in the muck layer. (Schueler and Yousef, 1994).

The 1982 Marquette University EPA report and the 1992 paper by Field and O'Shea reported urban sludge nutrient concentrations ranging from 502 to 1,270 mg/kg total phosphorus as P and 1,140 to 3,370 mg/kg TKN. These nutrient concentrations were reported as being lower than nutrient concentrations found in combined sewer overflows (CSOs) and in raw primary sludges (Rexnord, Inc., 1982 and Field and O'Shea, 1992). The 1982 Marquette University/EPA report presented the concentration of individual nutrients [total phosphorus, TKN, ammonia-nitrogen (NH_3), nitrite-nitrogen (NO_2), and nitrate-nitrogen (NO_3)] in storm water sediment samples from Boston, Massachusetts, and Racine, Wisconsin, as never exceeding 5 mg/l. Urban storm water sediment samples taken from Lansing, Michigan, were between 0.3 and 2,250 mg/l for individual nutrients (total phosphorus, TKN, NH_3, NO_2, and NO_3) (Marquette University, 1982).

Heavy Metals

Trace metal levels are typically 5 to 30 times higher in the muck layer of a pond than in the parent soil below the muck layer (Schueler and Yousef, 1994). Trace metal levels were also reported to follow a consistent pattern and distribution, with zinc having the highest concentration in the muck layer, followed by lead. Zinc and lead concentrations were much greater than chromium, nickel, and copper concentrations, which were approximately equal. Cadmium had the lowest concentration in the muck layer. In the 1994 Schueler and Yousef study, 50 ponds and wetlands were examined and found to have zinc concentrations ranging from 6 to 3,171 mg/kg (dry weight). Lead and chromium concentrations ranged from 11 to 748 mg/kg, and from 4.8 to 120 mg/kg, respectively. Nickel and copper concentrations ranged from 3 to 52 mg/kg, and from 2 to 173 mg/kg, respectively. Cadmium concentrations ranged from being non-detectable to 15 mg/kg (Schueler and Yousef, 1994).

Field and O'Shea reported that median concentrations of zinc, lead, copper, nickel, and chromium in urban runoff sludges and residuals were reported as 316, 268, 263, 131, and 189 mg/kg, respectively (Field and O'Shea, 1992). In the 1982 study at Marquette University, iron was found as the highest concentration of metals in all of the samples ranging in concentration from 6.1 to 2,970 mg/l. Lead and zinc concentrations ranked second and third, respectively (Marquette University, 1982).

As with all pond parameters, trace metal concentrations are site specific. Ponds that primarily service roadways and highways are enriched with trace metals which are presumably associated with automotive loading sources (e.g., cadmium, copper, lead, nickel, and chromium). On the other hand, storm water ponds that service primarily residential areas have the lowest trace metal concentrations (Schueler and Yousef, 1994). In general, the muck layer is highly enriched with metals; however, in most cases it should not be considered an especially toxic or hazardous material. For example, none of over 400 muck layer samples from any of the 50 pond sites examined in the referenced 1994 study exceeded EPA's current land application criteria for metals (Schueler and Yousef, 1994).

The Northern Virginia District Planning Commission (NVPDC) also examined the toxicty of trace metals from pond sediments (NVPDC, 1995). One study, entitled "Investigation of Potential Sediment Toxicity From BMP Ponds," (Dewberry and Davis, 1990) analyzed sediments from 21 ponds in Northern Virginia under various land use conditions. Many of these ponds are owned and maintained by property owners or homeowners' associations. Testing was performed for the presence, concentration, and toxicity of metals found in the analyzed sediments. The report indicates that the storm water sediments tested were not hazardous and could be safely disposed of on-site or in a landfill. While Dewberry and Davis' study determined the specific material tested to be non-hazardous, they recommend that sediments should be tested further for their use as backfill material or for topsoil maintenance (Dewberry and Davis, 1990).

Hydrocarbons

There is limited data on hydrocarbon and poly-aromatic hydrocarbon (PAH) concentration in the muck layer of ponds. It was reported that the concentrations of total PAH and aliphatic hydrocarbons in the muck layer of a 120 year old London basin were three and 10 times greater, respectively, than the base "parent" sediments. Minor degradation of the hydrocarbons trapped in the muck layer appeared to have occurred in the basin in recent years. On the other hand, hydrocarbons were rarely detected in the muck of Florida ponds. Hydrocarbon concentrations were reported for two out of the 50 sites in the 1994 report by Schueler and Yousef. These concentrations were reported for an industrial and a residential site as 12,892 and 2,087 mg/kg, respectively (Schueler and Yousef, 1994).

Bacteria

Urban storm water solids may contain high levels of bacteria and viruses, including fecal streptococcus and fecal coliform from animal and human wastes. These microrganisms have the potential to be spread from land application of residuals or landfill sites unless the proper precautions are taken. Measures that reduce their concentration in the residuals and minimize any residuals-vector contact include stabilization of the solids; immediate covering of landfill trenches after disposal of solids; treatment by pasteurization, heat treatment, irradiation, etc.; and public and animal access control away from the site (Field and O'Shea, 1992).

Oil/Grit

As previously mentioned, the storm water and sediment solids collected by an oil/grit separator are often more heavily contaminated than solids from other storm water BMPs. The metal content of trapped sediments in an oil/grit separator may be up to 20 times higher than in other BMPs, especially if the separator services a gas station. Priority pollutant and hydrocarbon levels are also much higher, because most oil/grit separators service areas that may discharge higher pollutant levels, such as gas stations and industrial sites, and are designed to trap lighter fractions of oil than are usually trapped by other BMPs. Other BMPs, such as detention basins, usually drain larger watersheds, which causes dilution of the hydrocarbons and metals from gas stations or industries. Therefore, it is doubtful that solids from other BMPs would approach metal and hydrocarbon concentrations as high as those recorded with oil/grit separators (Schueler and Yousef, 1994).

Other Pollutants

Other potentially toxic pollutants that may be found in storm water BMP sediments include pesticides and polychlorinated biphenyls (PCBs). Toxic wastes in fertilizers, herbicides, and household substances such as paints and cleaning materials may find their way into storm water solids/residuals. In the 1982 report from Marquette University, PCBs were observed in measurable concentrations in the Racine, Wisconsin and the Lansing, Michigan samples. These concentrations ranged from 0.19 to 24.6 μg/l. Of eight pesticides surveyed, only three (DDT, DDD, and Dieldrin) were observed in measurable concentrations (Marquette University, 1982).

APPLICABILITY

For any BMP to achieve maximum pollutant removal, storm water residuals and sediment solids must be periodically removed from the system. O&M procedures for removing and for handling storm water solids/residuals from BMPs should be planned in the design stages of the BMP. The removal frequency depends on many factors; however, some generalized O&M requirements for each of the structural BMP categories (i.e., detention basins, retention/infiltration devices, and vegetative controls) are provided below.

Detention Basins

Wet ponds will eventually accumulate enough sediment to significantly reduce the storage capacity of the permanent pool. This loss of capacity can affect both the appearance and the pollution removal efficiency of the pond. The best available estimate is that approximately one percent of the storage volume capacity associated with the two-year design storm can be lost annually (MWCOG, 1987). Even more storage capacity can be lost if the pond receives extra sediment input during the construction phase. A sediment clean-out cycle of 10 to 20 years is frequently recommended in the Washington, D.C., metropolitan area (MWCOG, 1987). According to the Center for Watershed Protection, storm water ponds require sediment clean-out every 15 to 25 years (Schueler and Yousef, 1994).

Most ponds are now designed with a forebay to capture the majority of sediments, decreasing the solids load to the wet pond. A common forebay sizing criterion is that it should constitute at least 10 percent of the total pool volume (Schueler and Yousef, 1994). This forebay could lose 25 percent of its capacity within 5 to 7 years based on a 1.25 cm/year (0.5 inch/year) muck deposition rate and the assumption that a forebay traps 50 percent of all muck deposited in the pond (Schueler and Yousef, 1994). However, using a forebay may extend the sediment removal interval for the main pond to 50 years (Schueler and Yousef, 1994).

To clean out a large wet pond, dragline or hydraulic dredge methods may be necessary. In ponds not large enough to warrant a hydraulic dredge method, mechanical dredge methods, such as dipper, clamshell, and bucket dredges are sometimes used. In smaller wet ponds, the pond level may be drawn down to a point where the residuals can begin to dry in place. After the material is dried, a front end loader can be used to remove it from the pond bottom.

Dry ponds and extended detention dry ponds also accumulate significant quantities of sediments over time. This sediment gradually reduces the available storage capacity within the pond and also reduces pollutant removal efficiency. In addition, sediment may tend to accumulate around the control device of the dry extended detention ponds. This sediment deposition increases the risk that either the orifice or the filter medium will become clogged. Sediment accumulation also gradually reduces storage capacity reserved for pollutant removal in the lower stage. Therefore, in an extended detention dry pond it is recommended that sediment be removed from the lower stage every five to ten years (MWCOG, 1987). Sediment removal from these systems is simple if access is available for the equipment. Therefore, access should be included in the pond design. Front-end loaders or backhoes can be used to remove the accumulated sediment.

Retention/Infiltration Devices

Infiltration basins are usually located in small residential watersheds that either do not generate large sediment loads or are equipped with some kind of sediment trap. Even when the sediment loads are low, they still impair the basin's performance: the sediment deposits reduce the storage capacity reserved for exfiltration and may also clog the surface soils.

Methods to remove sediment from infiltration devices are different from those utilized for detention basins. Removal should not begin until the basin has thoroughly dried out, preferably to the point where the top layer begins to crack. The top layer should then be removed using lightweight equipment, with care being taken not to unduly compact the basin surface. The remaining soil can then be deeply tilled with a rotary tiller or disc harrow to restore infiltration capacity. Vegetated areas disturbed during sediment removal should be replanted immediately to prevent erosion.

In infiltration trenches, the pretreatment inlets of underground trenches must be checked periodically and cleaned out when sediment depletes more than 10 percent of the available trench capacity. This can be done using a vacuum pump or it can be done manually. Inlet and outlet pipes should also be checked for clogging and vandalism. Dry wells should also be checked periodically for clogging.

Performance of sand filter systems may be sustained through frequent inspections and replacement of the filter medium every three to five years, depending on the pollutant load. Accumulated trash and debris should be removed from the sand filters every 6 months or as necessary. Sand filter systems are usually cleaned manually (Parsons ES, 1995).

Maintenance of porous pavement involves removing sediment from the pavement using vacuum sweeping. It has been recommended that the porous pavement be vacuum swept and hosed down by a high-pressure jet four times per year to keep the pores in the asphalt open (MWCOG, 1987).

Ideally, oil/grit separators should be cleaned out after every storm to prevent re-entry of any residuals or pollutants into the storm sewer system during the next storm. However, because of the O&M costs and manpower requirements associated with this schedule, in reality cleaning is less frequent--it may occur only when an oil/grit separator is no longer operating effectively. The Metropolitan Washington Council of Governments recommends that oil/grit separators be cleaned out at least twice per year (MWCOG, 1987). As with all BMPs, the cleaning frequency depends upon the site-specific pollutant load.

Oil/grit separators can be cleaned out using several methods. One method is to pump out the contents of each chamber. The turbulence of the vacuum pump in the chamber produces a slurry of water and sediment that can then be transferred to a tanker truck. Another method involves carefully siphoning or pumping out the liquid from each chamber (without creating a slurry). If needed, chemicals can then be added to help solidify the residuals. The solidified solids/residuals can then be removed manually from the separator.

Vegetative Controls

Vegetative controls (basin landscaping, filter strips, grassed swales, and riparian reforestation) rely on various forms of vegetation to enhance pollutant removal, habitat value, or appearance of a development site. Some natural systems require periodic sediment removal. For example, accumulated sediments deposited near the top of a filter strip will periodically need to be removed manually to keep the original grade.

ADVANTAGES AND DISADVANTAGES

Proper O&M of storm water BMPs and proper handling and disposal of storm water residuals will result in a greater efficiency of BMP pollutants and will help prevent resuspension of residuals during subsequent storms. This will protect the water quality of receiving waters. If BMPs are not properly maintained, pollutants removed during one storm may become resuspended during another storm and may pollute receiving waters. Improper disposal of storm water residuals may have the same result. If the residuals are stored too close to an area that tends to become flooded, they may return directly into the storm flow. Finally, there has been no evidence to show that storm water residuals should be considered hazardous waste; however, many states have regulations that residuals be tested before they are disposed.

KEY PROGRAM COMPONENTS

As described above, the key to ensuring that storm water BMPs do not become a source of runoff pollutants is proper operation and maintenance (O&M), including periodic clean out to remove any accumulated residual materials. While the pollutant removal capabilities and efficiencies and the quantities and types of residuals generated are specific to each BMP, structural storm water BMPs can be grouped into categories based on the design of their pollutant removal mechanisms. The general categories of structural storm water BMPs, including detention basins, retention/infiltration devices, and vegetative controls, each have different design characteristics and removal mechanisms that will effect the types and quantities of residuals they generate. Some of the general characteristics of these categories of structural BMPs are provided below.

Detention basins are widely used and are very effective in reducing suspended solid particles. By temporarily holding the storm water runoff and allowing the sediments to settle, detention basins can reduce suspended solids concentrations by 50 to 90 percent. Examples of detention basins include dry ponds, wet ponds, and extended detention dry ponds.

Retention/infiltration devices retain runoff and allow it to percolate into the ground, thereby reducing the amount of pollutants released into the receiving water. Filtration and adsorption occur as the runoff percolates into the ground, trapping many pollutants (e.g., suspended solids, bacteria, heavy metals, and phosphorus) in the upper soil layers and preventing them from reaching groundwater. These devices, which can include infiltration basins, infiltration trenches, dry wells, and porous pavement, can remove up to 99 percent of some runoff pollutants, depending on the percolation rate and area, the soil type, the types of pollutants in the runoff, and the available storage volume.

Other types of retention devices, such as sand filters and oil/grit separators, can be used to pre-treat runoff before it enters the collection system or infiltrates into the ground. However, relative to the successes with other infiltration/retention structures, there has been limited success with some of these devices. For example, because of low average detention times, oil/grit separators are limited in their ability to remove pollutants. Further, these devices have the added risk that settled material may be resuspended or released during later storms.

Vegetative BMPs, which can include basin landscaping, filter strips, grassed swales, and riparian reforestation, are used to decrease the velocity of storm water runoff. This promotes infiltration and settling of suspended solids and also prevents erosion. Vegetative BMPs also remove organic material, nutrients, and trace metals. For maximum effectiveness, vegetative controls should be used as a first line of defense in removing pollutants in combination with other BMPs.

As described above, each of these BMP types has specific removal abilities, and thus each generates slightly different residual material. In most states, the responsibility for operating and maintaining these BMPs falls on the local jurisdiction, which is responsible for inspecting, maintaining, and ensuring proper operation of storm water BMPs. However, in reality, many local jurisdictions do not have the manpower to inspect all BMPs regularly. For example, many of the detention basins installed by local jurisdictions in the l980s are now requiring, or soon will require, cleaning and/or dredging for the first time. This will require these communities to develop a plan to handle and dispose of residuals from these O&M activities.

Storm water and sediment solids/residuals must be handled and disposed of properly. All sediment solids/residuals should first be tested to determine if they are hazardous. If the material is determined to be hazardous, it must be disposed as such. Even if the solids/residuals are determined not to be hazardous, they will usually require dewatering prior to disposal.

Historically, and in most cases, the disposal of sediments removed through BMPs has posed no special regulatory or legal difficulty. Many municipalities and industries have disposed of such sediments in the same way that they would have any uncontaminated soil (Jones, *et al.*, 1994). In fact, after drying, storm water sediment has been mixed with other soil and reused as backfill on construction projects (Jones, *et al.*, 1994) as well as cover for landfills (State of Florida, 1995).

However, if the residuals/solids from a BMP are determined to be hazardous, they must be managed according to the Resource Conservation and Recovery Act of 1976 (RCRA) requirements, which would require either treatment to decrease the concentration of the hazardous constituent or disposal in a hazardous waste landfill. RCRA defines waste as hazardous either because the waste has certain characteristics (such as ignitability, corrositivity, explositivity, or toxicity) or because the waste contains constituents specifically listed in the RCRA regulations. In nearly all cases involving storm water BMP solids, the sediments contain listed chemicals (Jones, *et al.*, 1994). However, if no sample contains more than ten percent of the listed chemical (by volume), or if contact with precipitation/runoff is unlikely, the sediment would not be classified as hazardous (Jones, *et al.*, 1994).

IMPLEMENTATION

The implementation of a storm water residual handling and disposal program will be site-specific and will depend on the types of BMPs used and the residuals that they generate. However, some generalized information on implementing a handling and disposal program, as well as some specific information from case studies, is provided below:

Storm Water/Sludge Handling Alternatives

Centralized Treatment (Bleed/Pump Back to the Dry Weather Treatment Plant): Centralized treatment involves temporary storage of storm water solids followed by their regulated release into a sanitary sewer during dry weather flow conditions. Advantages of this residuals handling alternative include the potential flow equalization through the timed addition of urban storm runoff to the dry weather influent, and the use of a central, pre-existing treatment facility and transportation system for solids handling. Disadvantages of this system include: the deposition of large amounts of grit in the sewer system; the potential for exceeding the capacity of the dry weather treatment facility; possible interference with the treatment plant's operation and efficiency due to differences in the characteristics of sanitary wastewater and urban storm runoff residuals; and additional cost for pumping and treatment (Field and O'Shea, 1992). The problems associated with bleed or pump back solids storm water sediment and solids are similar to those evaluated with regard to CSO solids.

Huibregtse determined that "centralized treatment" of solids was generally not practical (Huibregtse, *et al.*, 1977). In addition to the disadvantages already listed, some problems that may be associated with this type of system include: difficulties in effectively equalizing flow to the dry weather treatment plant due to the high solids/low volume characteristic of residual flow, and difficulties maintaining the quality of treatment plant residuals. Further, significant increases in heavy solids and toxic substance loadings will affect a treatment plant's operation and its effluent's quality. The addition of large amounts of gritty solids can grossly overload solids handling facilities at treatment plants and can impair overall solids quality. Moreover, the addition of these storm water and sediment residuals to the treatment system will increase the quantity of residuals that must be handled (Field and O'Shea, 1992). In a 1982 EPA report, research indicated that the number of days required for bleed/pump back of the residuals without overloading the dry weather treatment facility ranged from 2.8 to 3.9 (Huibregtse and Geinopolos, 1992). This is considered an unacceptable bleed/pump back period, considering the likelihood of overlapping rainfall events (Huibregtse *et al.*, 1977).

Storm Water Solids Handling at Satellite Treatment Facilities: Another handling alternative for urban storm water and sediment solids is treatment at a satellite facility. As described above, average characteristics of urban storm runoff differ substantially from those of sanitary wastewater. Because of the intermittent and varying quantity and quality of storm flow, as well as its low organic and nutrient content, biological processes are generally not employed for the treatment of storm water runoff. The major design concerns for treatment of storm water flows are the runoff's high grit content, its low organic content, and the flow's intermittent nature and short flow duration (Field and O'Shea, 1992).

Evaluation of several CSO solids handling processes by Huibregtse found the most effective unit processes to be: conditioning through chemical treatment; gravity thickening; stabilization through lime addition; dewatering through vacuum or pressure filtration; and disposal through land application or landfill (Huibregtse et al, 1977).

On-Site Handling of Storm Water Solids/Sludge: The third alternative for handling/disposal of storm water runoff residuals in on-site handling. On-site handling of this material is usually very cost effective as it avoids transportation costs and landfill tipping fees. This option may be used after the residuals have been analyzed and determined to be composed of non-hazardous material. If this disposal method is intended for implementation, a dedicated area on the site should be set aside for land application or land disposal of the residuals during the design stage of a BMP. The area for disposal of residual material should be carefully selected to prevent residuals from flowing back into the BMP during rainfall events.

To dispose of residuals on- site, residuals must first be removed from the storm water runoff. Alternatives for removing solids were discussed previously. After the solids are removed they will usually require dewatering. Dewatering is accomplished by spreading the material out on the ground and occasionally turning it to help it dry. This material is then either land applied or land disposed. Land application involves spreading the material on dedicated land at approved application rates. This material cannot be applied to cropland and would probably be applied to a meadow or vegetated area. There is very little nutrient value associated with storm water residuals.

In some cases it may not be feasible to land apply or land dispose of the material on-site. This may be due to limited space. In any case, after the residuals are removed from the storm water runoff, they should be dewatered on-site if this is feasible. This will cut down on the volume of material to be transported. The material can then be loaded using a front-end loader and transported to either a landfill or another site for land application or land disposal.

The following sections describe specific case studies of BMP residual management programs. This section is not all-inclusive, but is presented to illustrate how some states, municipalities, and industries manage the solids/sediments from BMPs.

Waste Reduction, Disposal, and Recycling Services

A Baltimore, Maryland, firm cleans oil/grit separators for many commercial industries. They use a three man crew and two trucks. A liquid tanker truck is used to pump the oil and water out of the separator. This mixture is transported to their facility in Baltimore for treatment (All Waste-Clean America, 1995).

The solids in the oil/grit separator are further solidified using chemical addition. Once the material is solidified, it is shoveled out of the separator into 55-gallon drums. A composite sample is taken from each drum. This material is analyzed for toxicity, ignitability (flash test), and PCBs. If the material is determined to be non-hazardous, it is loaded into roll-off dumpsters and transported to an incinerator, where the company receives a certificate of destruction for the material (All Waste-Clean America, 1995).

If the solidified separator residuals are determined to be hazardous, treatment depends on the hazardous constituent of the waste. Analytical results are faxed to the generator. Additional testing is usually required to determine what constituent(s) make the sediment hazardous (All Waste-Clean America, 1995). Hazardous material is then handled on a case-by-case basis. In most cases, treatment to lower the hazardous chemical concentration to a non-hazardous level is preferred over landfilling in a hazardous waste landfill. For example, a sediment that contained a high hydrocarbon content, which may occur at a service station, would be spread out on an approved site for a period of time sufficient to allow the concentration to decrease in the sediment (All Waste-Clean America, 1995).

As each cleaning and maintenance job is site specific, this firm charges by the hour. The cost for cleaning is $202/hr for the three employees and two trucks. In addition, the charge for disposal of the liquid waste is $0.09/liter, the charge for the chemical that aids in solidification is $9.95/bag, drum purchase cost is $25/drum, drum disposal cost is $100/full drum, analytical charge is $145, and transportation charge is $250. Additional analytical testing and handling will increase costs.

Prince George's County, Maryland

In Prince George's County, Maryland, ponds are dredged on an as-needed basis. In some cases, on-site disposal of the sediment was planned for in the design of the BMP. However, if on-site disposal is not possible then a disposal site must be located. Residual sand and gravel material from the BMP may be landfilled or transported to construction-sites for use (Prince Georges County, MD, 1999).

Prince Georges County is also experiencing problems with oil/grit separators and is phasing them out. Most of the problems pertain to residuals management, and include: problems with landfills accepting residual material from oil/grit separators; the frequent maintenance and cleaning requirements; difficulties in dewatering material generated from the separators; and the expenses assocaited with dewatering, hauling, and landfilling. In addition, the county does not have the personnel to routinely inspect and enforce the cleaning of oil/grit separators. As an alternative to this BMP, the county is focusing on pollution prevention and other structural BMPs (Prince Georges County, 1999).

Fairfax County, Virginia

Most of the wet ponds in Fairfax County are privately owned, and the owners are required to maintain the ponds. The regional wet ponds maintained by the county are designed to be fully functional even when filled with sediment, and the county does not have a formal dredging program. Individual ponds are dredged on an as-needed basis; the county is planning on dredging one pond in the fall of 1999 to remove an island that has formed in the pond. Removed residual material is retained in a decanting basin for a period oif time until it is landfilled (Fairfax County, VA, 1999).

Montgomery County, Maryland

Montgomery County has updated its guidance for the dredging of wet and dry ponds to require dredging if wet and dry ponds reach greater than 50 percent or greater than 30 percent of storage capacity, respectively. The State of Maryland has determined that the sediments from these ponds are a non-hazardous material; however, inspectors have the discretion to require testing of the residuals depending on the suspected content of the runoff. If the material is determined to be non-hazardous, it can be disposed of either on-site or in a landfill. State law requires that these ponds be inspected once every three years. Since November, 1998, the county has inspected approximately 1,000 ponds, and is currently in the process of searching its records to identify remaining ponds in the county (Montgomery County, MD, 1999).

Typical oil/grit separators require much maintenance attention, and Montgomery County is trying to phase them out. The county has many sand filters proposed to replace the oil/grit separators, but information on their maintenance is not available due to the limited experience with cleaning and maintaining these filters (Montgomery County, MD, 1995).

State of Florida

Many storm water BMPs in Florida were implemented in the early 1980s, and are just to the point where they require dredging (State of Florida, 1995). However, Florida does not have a specific regulation stating that each jurisdiction must dredge or remove material from BMPs periodically. Instead they have issued a "Guidance Manual" as a supplement to the regulations, which are considered inadequate for handling storm water sediments for BMPs.

The guidance manual recommends testing all BMP sediments using the Toxicity Characteristics Leaching Procedure (TCLP), before disposal. The state has performed numerous analytical studies on this material, and in no cases was BMP sediment from any location determined to be hazardous. However, oil/grit separators were not tested as part of this study.

Material must have the appropriate laboratory TCLP paperwork before most landfills in Florida will accept it. Some cities and counties avoid this testing by sending BMP residuals to construction/debris landfills, which are not as stringent. This practice is not supported by the state (State of Florida, 1995).

In addition to screening by the TCLP test, Florida has implemented a clean soil criterion to protect communities from exposure to elevated concentrations of materials which might not be classified hazardous. If a material does not pass the clean soil criterion, (e.g., if metal concentrations are high, but not hazardous) then it can be used only in an area where public access is controlled. Material such as this can be used as a landfill cover because public access is limited to most landfills.

Sediments from dry ponds in Florida are removed using a front-end loader and a dump truck. As discussed above, it is then recommended that a TCLP test be conducted on this material before either disposing on-site, landfilling, or disposing of in another manner. Wet ponds are dredged; however, these ponds are sometimes directly connected to a waterway so caution is needed to ensure solids are not resuspended in this operation. This material is usually spread out on the site to allow drying and is then disposed of on-site. If on-site disposal is not possible, then the sediments are usually transported to a landfill (State of Florida, 1995).

State of Delaware

The State of Delaware has followed Florida's lead in handling and disposal of storm water BMP residuals. The State of Delaware has conducted its own tests on storm water BMP sediments, but considers the material to be non-hazardous based on Florida's research and other research/reports. The state also has a storm water management program in which local jurisdictions are required to inspect BMPs on an annual basis (State of Delaware, 1995).

The state's storm water management plan includes BMP construction guidelines for ease of BMP maintenance and for on-site disposal of the storm water residuals. Oil/grit separators are not a BMP alternative in Delaware. In addition to detention basins, sand filters are commonly used. The cleaning schedule for a sand filter is site specific, but three to four times a year is a general estimate. Typically, a team of three is used to clean a Delaware filter manually by shoveling out the material. This process takes approximately 4 hours. Labor cost to clean the filter is approximately $120. The material is then transported to a landfill for disposal (State of Delaware, 1995).

State of Maryland

The State of Maryland conducted a four-year study on oil/grit separators with the Metropolitan Washington Council of Governments. This study evaluated material from oil/grit separators in Maryland to determine if it was hazardous. The study also evaluated maintenance of oil/grit separators, as well as disposal of the residuals/solids from an oil/grit separator. Results from the study indicated that the solids from oil/grit separators were not hazardous; therefore, this material could be disposed of at a landfill after dewatering. However, as this material is site specific it was recommended that it be tested before being sent to a landfill (State of Maryland, 1995).

All local jurisdictions are required to inspect BMPs. Every three years, the state reviews storm water programs and procedures utilized by the local jurisdiction. The state has noted that many BMPs are not being properly maintained, and attributes this to the cost and manpower requirements associated with regularly inspecting all BMPs. Further, many homeowner associations have BMP facilities on their property. Maintenance of these BMPs is another area of concern for the state because homeowner associations often do not implement proper O&M procedures to maintain the

BMP facility on their property (State of Maryland, 1995).

As long as they are not hazardous, sediments from wet ponds and dry ponds are usually dewatered and then disposed of on-site or landfilled. It is a common practice to spread this material out on a site for use as a soil amendment (State of Maryland, 1995).

COSTS

In a 1982 report by Huibregtse and Geinopolos, a cost analysis was performed specifically for the handling and disposal of urban storm runoff residuals. This cost analysis compared the following six alternative residuals handling scenarios for either swirl or sedimentation concentrated solids:

> Gravity thickening, vacuum filtration and landfill.
>
> Gravity thickening, vacuum filtration and landspreading.
>
> Gravity thickening, pressure filtration and landfill.
>
> Gravity thickening, pressure filtration and landspreading.
>
> Gravity thickening and landspreading.
>
> Landspreading.

These cost estimates are presented in terms of dollars per hectare for residuals handling in an urban storm runoff area of 6,000 hectares (15,000 acres). These estimates were updated to July 1995 dollars and are presented in Table 2.

As shown on Table 2, the most cost effective solids handling scenario based on annual costs is lime stabilization, gravity thickening, pressure filtration, and landfilling.

The 1982 EPA report from Marquette University concluded that, of the options evaluated, the most cost-effective means for handling and disposal of urban storm water runoff residuals is gravity thickening followed by lime stabilization and landspreading or landfilling (Marquette University, 1982). This conclusion was based on urban storm water studies from Boston, Massachusetts, Racine, Wisconsin, and Lansing, Michigan involving solids sampling, characterization, analysis, and treatability. The characterization study included analyses for nine metals, eight pesticides and PCBs, solids, nutrients, and organics. The treatability study included bench scale sedimentation tests, centrifugation tests, lime stabilization tests and capillary suction time tests (Marquette University, 1982).

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TABLE 2 COST ESTIMATE ($/HECTARE) FOR RESIDUALS HANDLING IN AN URBAN STORM WATER RUNOFF AREA OF 6071 HECTARES[1]

Sludge Handling Method	Capital	Sedimentation O&M	Annual	Capital	Swirl Concentration O&M	Annual
Lime Stabilization Gravity Thickening Vacuum Filtration Landfill	1174	176	331	1252	158	321
Lime Stabilization Gra Thickening Vacuum Filtration Landspreading	1253	188	423	1312	166	383
Lime Stabilization Gravity Thickening Pressure Filtration Landfill	1216	148	306	1359	121	289
Lime Stabilization Gravity Thickening Pressure Filtration Landfill	1290	158	385	1406	124	343
Lime Stabilization Gravity Thickening Landfill	-	-	-	974	215	410
Lime Stabilization Landfill	761	257	460	2533	2115	2950

(1) Huibregtse et al, 1982. Costs have been updated to July 1995 dollars using the Engineering News Record.

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