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Storm Water Technology Fact Sheet

On-Site Underground Retention/Detention

DESCRIPTION

One of the major components of storm water management is flow control, particularly in newly-developed areas where buildings, parking lots, roads, and other impervious surfaces replace open space. As imperviousness increases, there is less area available for infiltration, and the amount of runoff increases. This may cause streams to be more prone to flash floods. Many municipalities now require newly-developed areas to maintain pre-development runoff conditions and to implement measures to capture or control the increase in peak runoff for a design storm event.

Several different types of storm water Best Management Practices (BMPs), including retention/detention ponds, storm water wetlands, and underground storage structures, can provide storm water volume control. These BMPs capture flow and retain it until it infiltrates into the soil (storm water retention) or release it slowly over time, thereby decreasing peak flows and associated flooding problems (storm water detention). Several of these options, including storm water wetlands and large detention ponds, require relatively large land areas, making them less of an option in areas where land costs are high or where land availability is a problem. In many of these areas, such as parking lots for malls or other developed sites in highly urbanized areas, storing storm water underground on the site may be the best option.

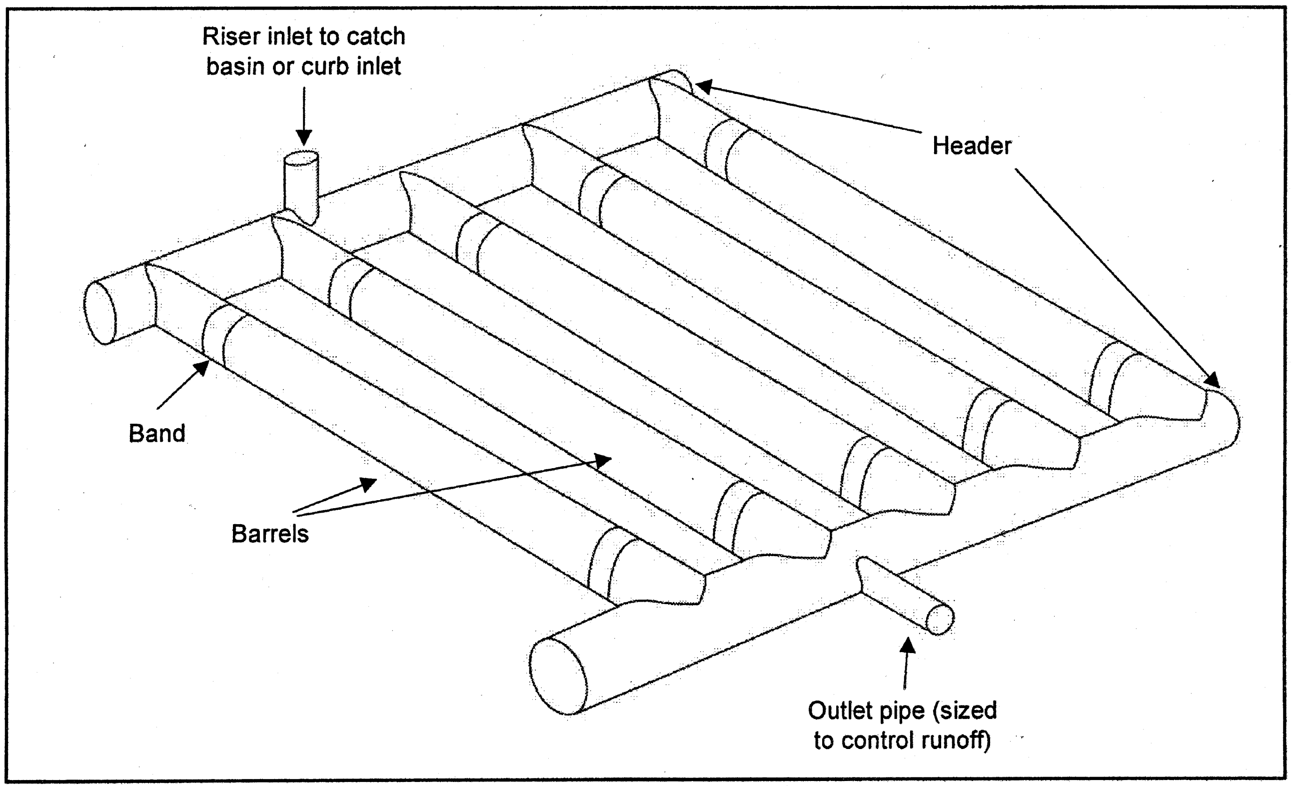
Underground storm water retention/detention systems capture and store runoff in large pipes or other subsurface structures (see Figure 1). Storm water enters the system through a riser pipe connected to a catch basin or curb inlet and flows into a series of chambers or compartments for storage. Captured runoff is retained throughout the storm event, and can be released directly back into surface waters through an outlet pipe. Outlet pipes are sized to release stored runoff at pre-development flow rates. This ensures that there is no net increase in peak runoff and that receiving waters are not adversely impacted by high flows from the site. Some systems are also designed to exfiltrate stored runoff into the surrounding soil, where it helps to recharge the groundwater table.

Underground retention/detention systems can be constructed from concrete, steel, or plastic materials. Each material has advantages and disadvantages and specific applicabilities, which are discussed in the following sections.

APPLICABILITY

Underground retention/detention systems are primarily used in newly-developed areas where land cost and/or availability are major concerns. They are not usually designed for retrofit applications. Most systems are built under parking lots or other paved surfaces in commercial, industrial, and residential areas. Perforated underground retention systems that release stored storm water into the subsoil are recommended only for areas with well-drained soils and where the water table is low enough to permit recharge. Some pretreatment such as sediment traps or sand filters may be necessary for infiltration to eliminate sediment and other solids that could clog the system.

On-site underground retention/detention systems provide peak runoff flow control and can store storm water for future release back into the environment. However, they are not designed



Source: Modified from Contech Construction Products, Inc., 2000.

FIGURE 1 SCHEMATIC OF PIPE-BASED UNDERGROUND STORM WATER DETENTION SYSTEM

specifically to enhance water quality; therefore, other storm water BMPs may be required to provide storm water treatment. Underground retention/detention systems are often used in "treatment trains," which consist of a number of storm water BMPs that provide both storm water treatment and storage. For example, storm water entering the underground detention structure in Hauge Homestead Park in Everett, Washington, is first collected from a parking area through a catch basin, then flows through a series of vegetated swales, then into a storm water pipe with a sump, all of which filter out sediment and pollutants before the runoff reaches the detention chambers. Runoff is then released into a pond at a controlled rate, where further pollutant removal occurs (City of Everett, Washington, Department of Parks and Recreation, 2000).

ADVANTAGES AND DISADVANTAGES

This Section presents the overall advantages and disadvantages of on-site underground retention/detention systems. The advantages and disadvantages of specific designs and construction materials (concrete, steel, plastic) for underground retention/detention systems are discussed in the Design section.

Advantages

- The primary advantage of the on-site underground storm water retention/detention system is that it captures and stores runoff, thus helping meet the requirement to maintain pre-development runoff conditions at newly-developed sites.

- These systems are ideal for highly urbanized areas, particularly in areas where land is expensive or may not be available for ponds or wetlands.

- These systems can be installed quickly. For example, construction and installation of a 6' by 4' by 156' concrete system was installed under a car dealership in Tennessee in 3 days (Sherman Dixie Concrete Industries, Inc., 2000).

- These systems are very durable. Once in the ground, most systems can last more than 50 years.

- Because these systems are underground, local residents are less likely to have access to them, making them safer than ponds or other aboveground storm water BMPs.

Disadvantages

- The primary disadvantage of the on-site underground storm water detention structures is that they are not designed to provide storm water quality benefits. However, if they are included in a treatment-train type system, underground detention systems can be an important part of an overall storm water management process.

- These systems may require more excavation than surface ponds or wetlands.

- Recharge of the groundwater from an underground retention unit may contribute to groundwater contamination if flow from the site is directly discharged into the retention system before pretreatment. Therefore, EPA does not recommend that percolation systems be designed for sites with coarse soils or high groundwater tables.

- These systems are more difficult to maintain and clean than aboveground systems.

DESIGN CRITERIA

On-site underground retention/detention systems are designed to provide a predetermined amount of storage volume within a specified area. System designs can range from simple storage pipes or chambers to complex systems consisting of multiple pipes or chambers, with accompanying joints, crossovers, multiple inlets and access points. At a minimum, each system must have an inlet, an outlet, and a structure to access the chamber (Pacific Corrugated Pipe, 2000). All other design elements are site, project, and material-specific, as described below.

Among the most important elements to consider when designing underground retention/detention systems are the size, shape, and physical characteristics of available space available for the system. These factors will influence how the system is constructed and what type of construction material is chosen. Depending on the specific application, design engineers have utilized different materials, including concrete pipes and other concrete structures, steel pipes, and plastic pipes, in designing underground retention/detention structures. Each material has different advantages and disadvantages under different scenarios. The type of material to be used in any individual application should be determined by site and application-specific conditions.

Site-specific considerations that may influence the type of material used in an individual application include:

- The depth and area of allowable excavation space. For example, to maintain the structural integrity of corrugated steel and high density polyethylene pipe systems, more fill is required below, between, and above the pipes than when using concrete.

- The shape of the area available for the system. For example, is the available space one continuous area where a large vault could be placed, or does it have angles which might make a pipe system more appropriate?

- The depth of the water table. For example, there are some concerns that plastic pipes may float upward in areas with high water tables.

- The construction costs (including material and labor costs) for different materials.

Table 1 summarizes the physical characteristics of these materials. Additional considerations include local ordinances, which may preclude the use of some types of materials for certain applications. For example, Fairfax County, Virginia, does not

TABLE 1 COMPARISON OF DESIGN CONSIDERATIONS FOR CONSTRUCTION MATERIALS FOR UNDERGROUND STORM WATER RETENTION/DETENTION SYSTEMS

	Construction Material		
	Concrete	**Plastic (HDPE)**	**Steel and Aluminum (CMP)**
Shapes	Rectangular vaults or circular pipes	Circular pipes	Circular pipes, semi-circular pipe-arches, or other special shapes
Spatial Requirements	Primarily continuous space with no angles	Can be fitted into irregular and angled spaces	Can be fitted into irregular and angled spaces
Rigidity/Flexibility	Very rigid, does not require fill to maintain rigidity; not flexible	Rigid, requires fill for stability; not flexible	Rigid, requires fill for stability; can withstand some shifting without breaking or buckling
Fill Requirements	Requires minimum fill above structure	Requires minimum fill between and above pipes	Requires minimum fill between and above pipes
Other Requirements	None	Requires minimum spacing between pipes. Water table must be below level of pipe	Requires minimum spacing between pipes
Available Sizes	Multiple sizes that can be pre-cast or cast-in-place	Multiple pipe diameters are available; all are pre-manufactured	12" to 144" diameters and pipe arches are available pre-assembled. Larger diameter pipe and pipe-arches are available for assembly on-site
Handling	Requires moving equipment	Can be moved by hand	Requires moving equipment

Source: Compiled by Parsons Engineering Science, Inc., 2000.

allow plastic pipes to be used for underground retention/detention systems for residential areas. In contrast, plastic pipe has been the favored option for systems built by the Department of Parks and Recreation in Everett, Washington.

Once appropriate construction materials are determined for a specific application, design must determine the amount of storage volume required by the system. As discussed above, many areas have adopted a policy of no net increase in runoff for a design storm event for newly-developed areas. Thus, the required storage volume is the difference between pre and post-development runoff. In other areas, local requirements dictate how much of a given storm must be captured and treated, and the required storage volume can be calculated using this value. For example, the City of Malibu, California requires post-construction treatment control BMPs to treat the first 0.75 inches of rainfall over a 24-hour period (City of Malibu, 2000b). In contrast, the Department of Public Works in Everett, Washington, requires systems to be designed for the 6-month, 24-hour storm (City of Everett, Washington, Department of Public Works, 2000).

After the required storage volume has been determined, the design engineer can examine the site to determine what configuration will maximize storage while minimizing the size of the excavated area. Concrete structures, such as box culverts, tend to provide greater storage volume per excavated area because of their rectangular shape (allowing more storage volume per cross-sectional area) and the fact that they can provide one continuous chamber. Pipe systems, on the other hand, tend to store less runoff per excavated area. There are several reasons for this. First, round pipes and pipe arches have less storage volume per cross-sectional area than do square structures, such as box culverts. In addition, pipes are often laid parallel or at intersecting angles, reducing the amount of storage per excavated area. Pipes also require specific amounts of space for fill between them. While this promotes the structural integrity of the pipes, it reduces the amount of excavated area available for storage. These requirements make the largest diameter pipe that meets the minimum cover requirements the most economical. For example, doubling the diameter of the pipe usually doubles the cost of the pipe, but quadruples the storage volume. In addition, the ability to angle and arrange pipes in series of different lengths may make them good choices when the space available for storage is not continuous. Several manufacturers have produced CD-ROMs to aid in the design and configuration of pipe systems.

PERFORMANCE

On-site runoff controls, such as underground storm water retention/detention systems, are designed to control storm water quantity and they have little impact on storm water quality. Thus, underground storm water retention/detention systems alone will not satisfy most local storm water regulations. For example, Fairfax County, Virginia, requires both storm water management (i.e., storm water volume control) and storm water BMPs (i.e., storm water quality control) (Fairfax County, Virginia, 2000). Therefore, most underground retention/detention systems are coupled with other water quality BMPs, such as catch basins, curb inlets, water quality inlets, sand filters, or sumps. This "treatment train" can help to improve the water quality of the overall storm water control system, particularly during the first part of a rain event when pollutants may be at their highest concentrations. BMPs may be located either upstream or downstream from the retention/detention system. Fairfax County, which reviews storm water plans for new development, encourages planners to include sand filters or other water quality control devices upstream of an underground detention system. The City of Malibu, California, recommends a treatment train system (City of Malibu, California, 2000b). One system that the city has looked at includes a sedimentation basin, a detention basin, then a sand filter (City of Malibu, California, 2000a). A new project in Hauge Homestead Park in Everett, Washington, includes storm water BMPs both upstream and downstream of the detention area.

When designing a treatment train, design engineers must ensure that downstream BMPs are designed for the appropriate flow from the underground retention/detention system. For example, the City of Alexandria, Virginia, found that long drawdown times from underground retention/detention systems could result in continuous flow into downstream sand filters, which could cause the resuspension of accumulated phosphorous (City of Alexandria, VA, 2000). Therefore, Alexandria does not recommend the use of sand filters downstream from most retention/detention systems.

While underground storm water retention/detention systems are not specifically designed to provide water quality benefits, they do often improve water quality. As storm water is retained before it is released back into the environment, suspended solids may settle out, thereby reducing the overall pollutant load. For example, in the City of Everett, Washington, local regulations require that at least 15 percent of the 6-month, 24-hour storm runoff be retained above ground, usually in a biofiltration area. The remainder of the runoff can be stored below ground, where suspended solids are allowed to settle out before the water is released back into the environment (City of Everett, Washington, Department of Public Works, 2000). However, unless the system is properly maintained, settled solids may eventually fill the system.

OPERATION AND MAINTENANCE

Once underground storm water retention/detention systems are installed, they require very little maintenance. They have no moving parts and remain intact for many years. A major concern with the use of corrugated steel or polyethylene pipes has been that the pipes might crack or buckle over time because of the weight of the soil surrounding them. However, a study of corrugated steel pipe (CSP) underground storm water detention structures in the Washington, D.C., metropolitan area conducted by the National Corrugated Steel Pipe Association (NCSPA)(NCSPA, 1999) found that all of the systems were performing well. None of the pipe systems inspected, some of which had been in place for up to 25 years, showed signs of buckling, cracking, or bending. In only one case had the joints of pipe sections separated.

Underground storm water retention/detention structures must be cleaned periodically to remove accumulated trash, grit, sediments, and other debris. The installation of catch basins or grates at the inlet will reduce trash accumulation, but suspended solids will still be carried into the storage area, where they may settle out and accumulate on the bottom of the structure. The structures need to be cleaned to remove this accumulated material, which should be tested to determine if it contains any toxic or hazardous materials, and then disposed according to local regulations regarding storm water residuals.

In Fairfax County, Virginia, where there are over 300 underground storm water retention/detention structures installed at commercial/industrial sites, private owners of the structures are required to sign a maintenance contract with the County that commits the owner to maintain the structure appropriately. Fairfax County also provides owners with a maintenance checklist and plans to inspect these structures regularly (i.e., at least once every five years) to ensure that they are functioning adequately. If an owner fails to maintain the structures, the maintenance agreement allows the County to perform the required maintenance at the expense of the owner.

The City of Everett, Washington, takes ownership of underground storm water detention systems constructed in residential developments under existing rights-of-way, such as sidewalks or streets. The city conducts annual inspections of system outlet structures and looks for an accumulation of sediment at the outlet as an indicator that the system needs to be cleaned. Crews are then dispatched to perform the clean-outs. The City also regularly inspects private systems and issue notices to owners when sediment accumulation is noted (City of Everett, Washington, Department of Public Works, 2000).

COSTS

Costs for underground storm water retention/detention structures are highly variable and depend primarily on the types of materials used (concrete vaults, metal or plastic pipes) and the amount of storage volume desired. The type of materials used will greatly affect construction and installation costs, because they dictate the size of the excavation required to achieve the necessary storage volume. As discussed in the Design section, to ensure their strength and rigidity, plastic and steel pipes have specific requirements for spacing, fill type and fill volume, all of which effect the size of the excavation. Concrete structures do not have the same level of fill requirements. Another consideration is the amount of time required to handle and assemble the various pieces of the system. Steel and plastic pipes tend to be lighter and easier to handle than concrete vaults; however, large diameter pipes and "pipe arch" structures (which are delivered as separate sheets and must be bolted in place) may increase handling time requirements.

While costs for specific types of underground detention systems can be highly variable, they can be very economical, especially compared with alternatives. The primary alternative to an underground storm water detention structures is an aboveground wet detention pond. While construction costs for ponds are generally lower than for underground storage units (ponds can cost between $17.50 and $35 per cubic meter of storage area [Center for Watershed Protection, 1998]), land used for a surface pond cannot be used for any other purpose. This is not true for underground retention/detention systems, where the land above can be utilized for parking lots or other purposes, maximizing the economic potential of the land. In Everett, Washington, underground detention structures are often used in conjunction with aboveground ponds in storm water management. While local regulations require some surface treatment of storm water, the majority of runoff can be stored underground, minimizing the need for large surface ponds that are both costly and require economically-valuable land. Everett also encourages the use of concrete underground storage systems, which allows the pond to actually be placed directly on top of the underground storage area, again making maximum use of the available land (City of Everett, Washington, Department of Public Works, 2000). Underground retention/detention systems can also be economical when compared to infiltration trenches. An engineering estimate prepared for a commercial installation in Glen Burnie, Maryland, showed that a 150,000 cubic feet detention system consisting of 60" corrugated steel pipe covered by stone would cost approximately $453,000 and occupy only 0.94 acres, while a stone infiltration trench that could store the same volume would occupy 1.43 acres and cost $576,000 (Contech, Inc., 2000). The major differences in cost between these two options were that using only stone required a larger excavation, and the stone fill and increased labor for placing the stone fill was more costly than the cost of material and labor for installing the pipe.

As discussed above, underground storm water retention/detention structures can vary greatly in cost, depending on the materials utilized, the excavation, construction, and installation costs, and the storage volume required. For example, construction of the underground storm water retention/detention segment of the Boneyard Creek project in Champaign, Illinois, which consisted of the installation of six 11-foot diameter corrugated steel pipes (comprising 24,600 cubic meters of storage) cost approximately $9 million, plus contingencies (City of Champaign, Illinois, 2000). When combined with a larger, aboveground storm water retention/detention pond, this project provides enough retention/detention for a 25-year storm event, preventing the perennial flooding of Champaign's Campustown section and saving local businesses from flood damage and lost business.

Engineer's estimates for installation of CSP systems in Arizona are approximately $84 per cubic meter of storage (Pacific Corrugated Pipe Co., 2000). For example, to capture the first inch of runoff from a one acre plot, 72 feet of 96-inch CSP would be installed at a cost of $8,650. Costs are scalable and increase proportionally to increases in the amount of land served or the amount of runoff stored.

High Density Polyethylene (HDPE) pipe was utilized to construct an underground storm water detention system at the T.F. Green Airport in Providence, Rhode Island. The parking lot was created when an existing neighborhood was demolished to create extra parking areas. The site had a high water table and no runoff was allowed to leave the site. The contractor designed five separate systems of 24-inch HDPE pipe, with the largest systems consisting of approximately 2,500 linear feet of pipe each, to contain the runoff. The total storage volume was 1,420 cubic meters. While the contractor determined that 36-inch pipe was the most cost effective option, this would have had required regrading before installation while maintaining three feet of soil between the pipe and the groundwater as required by Rhode Island regulations. The total project cost was $250,000, which included 9,200 linear feet of 24-inch HDPE pipe, inspection ports, filter fabric, filter sand bedding, nine inches of stone fill around each pipe, and almost three feet of fill over the pipes (D'Ambra Construction Co., Inc., 2000, and Vanasse Hangen Brustlin, Inc., 2000).

There are trade-offs in costs between pipes and other systems, such as concrete vaults. In some cases, costs for concrete storage structures can be lower than those for plastic or corrugated steel pipes. Because they require less area to achieve the same storage volume, less area may need to be excavated for concrete structures than for pipe systems. This may reduce excavation costs. Using complete precast concrete sections can decrease assembly time, further reducing costs. However, these low costs may be offset by the higher costs of handling concrete. Installation of a 156-foot long section of 6-foot by 4-foot concrete precast box culvert (106 cubic meters) at a car dealership in Knoxville, Tennessee, was completed in 3 days and cost approximately $85,000 (Sherman Dixie Concrete Industries, Inc., 2000).

Case Study: Hauge Homestead Park, Everett, Washington

The City of Everett, Washington, undertook a project to detain increased runoff generated from new facilities (including a dock, a pier, restrooms, and walkways) in Hauge Homestead Park on Silver Lake. Only 4 acres of land was available for the park, some of which was required for a wet detention pond to capture runoff generated from the facilities. However, because space was so limited, the Parks and Recreation Department wanted to minimize the size of the pond while still providing the required treatment. The solution was to build an underground storm water retention/detention system upstream of the pond to store excess runoff until it was released at a controlled rate into the pond. Because the flow into the pond was controlled, engineers could design a smaller pond that still achieved the same pollutant removal efficiency. The underground retention/detention system was composed of 350 feet of 36-inch HDPE pipe, which provided 2,847 cubic feet (80.6 cubic meters) of storage. When added to the 804 cubic feet of shallow pond and 1,869 cubic feet of deep pond, the storage capacity exceeded the 5,130 cubic feet required to handle a 25-year storm event. The total cost for the underground detention system, including materials and installation, was $28,190 (City of Everett, Washington, Department of Parks and Recreation, 2000).

Case Study: Homestead Village Hotel, Brookfield, Wisconsin

In order to meet the requirements for no net increases in runoff volume from the construction of the Homestead Village Hotel in Brookfield, Wisconsin, engineers designed an underground retention/detention system consisting of 549 feet of 72-inch concrete pipe. Many new development projects in the suburban Milwaukee area utilize retention/detention ponds to control runoff because land is usually available; however, in this case, the hotel was built into the side of a hill, and construction of a pond required re-grading the site and increased costs. Thus, the system was built in a ring around the hotel, with all roof and floor drains connected to the system. The designers chose concrete pipe for several reasons:

- The large size requirement (72 inch pipe);
- The owners wanted a 100-year plus product lifespan;
- Multiple openings were required in the pipe for the drain inlets and the designers felt that concrete pipe would maintain its strength under these conditions;
- This pipe required a relatively small amount of fill.
- Both HDPE pipe and CSP were eliminated as alternatives based on concerns that the soil conditions would corrode CSP pipe and seals required for HDPE pipe did not meet the State pressure-testing requirements.

The system storage capacity is 120,000 gallons, with outlets through 7-inch diffuser perforations and also through a 12-inch outlet pipe, which eventually flows into a roadside ditch, then into a nearby stream. Overall project costs were approximately $267,000, including sanitary and storm sewers (APS Concrete Products, Inc., 2000, and National Survey & Engineering, Inc., 2000). Material costs for the concrete pipe accounted for approximately $75,000 of this total.

Case Study: Jordan Landing, West Jordan, Utah

Jordan Landing is a retail mall in West Jordan, Utah, covering 80 acres and consisting of retail stores and parking lots. The complex had no requirement to detain runoff onsite. One option for runoff generated by the site was to divert the runoff to storm water structures downstream. However, these structures were not large enough to handle the increased flows, and the cost of constructing the piping to convey the runoff downstream and enlarging the downstream controls was deemed too high. Therefore, the owners opted to detain the runoff onsite.

Because space was at a premium on the site, the designers chose on underground retention/detention as the best option to control runoff. They considered several options for the detention system, including corrugated steel pipe, aluminum pipe, HDPE pipe, concrete vaults, and reinforced concrete boxes, before deciding that 48-inch aluminum pipe was the best option. The other options all had major drawbacks: CSP required an expensive coating to protect it from site soil conditions, significantly increasing costs; costs for HDPE pipe were high because the system design required numerous expensive "T" fittings; the only reinforced concrete boxes immediately available came in specific pre-manufactured sizes that did not fit the site (in some places on the site there was only six feet of allowable excavation); and concrete vaults were too large and expensive.

The selected system utilized helical aluminum pipes fastened with aluminum bands. The system was installed by first laying down the header pipes, which were designed so that the barrel pipes could be laid directly into them, saving costly fittings. The barrels were then fitted into the header, and bands were used to connect the pipes together.

Six separate galleries of aluminum pipe were initially constructed. A seventh was added later. Altogether, the project utilized 20,000 feet of pipe and achieved 7,120 cubic meters in storage volume. The overall construction costs for the project were $1.2 million (Nolte Associates, 2000).

A summary of comparative costing information for on-site underground storm water retention/detention systems is provided in Table 2.

REFERENCES

Other Related Fact Sheets

Handling and Disposal of Residuals
EPA 832-F-99-015
September, 1999

Water Quality Inlets
EPA 832-F-99-029
September 1999

Wet Detention Ponds
EPA 832-F-99-048
September 1999

Other EPA Fact Sheets can be found at the following web address: http://www.epa.gov/owmitnet/mtbfact.htm

1. Advanced Drainage Systems, Inc., 1997. Technical Note 2.120 Re: Storm Water Detention/Retention System Design.

2. Advanced Drainage Systems, Inc., 2000. Materials provided to Parsons Engineering Science, Inc., by Steven Marsh, Advanced Drainage Systems, Inc.

3. APS Concrete Products, Inc., 2000. Dennis Stevens, APS Concrete Products, Inc., personal communication with Parsons Engineering Science, Inc.

4. Center for Watershed Protection, 1998. *Costs and Benefits for Storm Water BMPs*.

TABLE 2 COMPARATIVE COST INFORMATION FOR ON-SITE UNDERGROUND STORM WATER RETENTION/DETENTION PROJECTS

	Boneyard Creek, Champaign, IL	Jordan Landing Mall, West Jordan, UT	T.F. Green Airport, Providence, RI	Hauge Homestead State Park, Everett, WA	Homestead Village Hotel, Brookfield, WI	Car Dealership, Knoxville, TN
Material	CSP	Aluminum	HDPE	HDPE	Concrete	Concrete Box Culvert
Length of Pipe (feet)	8,600	20,000	12,500	350	549	156
Diameter of Pipe (inches)	132	48	24	36	72	6' x 4' box
Maximum Instantaneous Storage Volume (cubic meters)	24,600	7,120	1,420	81	454	106
Overall Cost	$9,000,000	$1,200,000	$250,000	$28,190	$267,000	$85,000

Source: Compiled by Parsons Engineering Science, Inc., 2000.

5. City of Alexandria, VA, 2000. Bill Hicks, Department of Public Works, personal communication with Parsons Engineering Science, Inc.

6. City of Champaign, IL, 2000. Jeff Smith, Department of Public Works, personal communication with Parsons Engineering Science, Inc.

7. Contech Construction Products, Inc., 2000. Patrick Pusey and Dutch Van Schoonveld, Contech Construction Products, Inc., personal communication with Parsons Engineering Science, Inc.

8. D'Ambra Construction Co., Inc., 2000. John Oliver, D'Ambra Construction Co., Inc., personal communication with Parsons Engineering Science, Inc.

9. Dewberry & Davis, Inc., 2000. George Kovats, Dewberry & Davis, Inc., personal communication with Parsons Engineering Science, Inc.

10. Everett, Washington, Department of Parks and Recreation, 2000. Ryan Sass, City of Everett, Washington, Department of Parks and Recreation, personal communication with Parsons Engineering Science, Inc.

11. Everett, Washington, Department of Public Works, 2000. Jane Zimmerman, City of Everett, Washington, Department of Public Works, personal communication with Parsons Engineering Science, Inc.

12. Fairfax County, Virginia, 2000. Steve Aitcheson, Fairfax County Municipal Water Management, personal communication with Parsons Engineering Science, Inc.

13. Malibu, California, 2000a. Rick Morgan, City of Malibu Department of Public Works, personal communication with Parsons Engineering Science, Inc.

14. Malibu, California, 2000b. Rick Morgan, City of Malibu Department of Public Works, memorandum to applicants for new development regarding New Development Standards to Reduce Water Pollution, March 3, 2000.

15. National Corrugated Steel Pipe Association, 1999. "Condition Survey of Corrugated Steel Pipe Detention Systems."

16. National Survey & Engineering, Inc., 2000. Fred Spelshaus, National Survey & Engineering, Inc., personal communication with Parsons Engineering Science, Inc.

17. Nolte Associates, 2000. Paul Hacunda, Nolte Associates, personal communication with Parsons Engineering Science, Inc.

18. Pacific Corrugated Pipe Company, 2000. Darwin Dizon, Pacific Corrugated Pipe Company, personal communication with Parsons Engineering Science, Inc.

19. Sherman Dixie Concrete Industries, Inc., 2000. Al Hogan, Sherman Dixie Concrete Industries, Inc., personal communication with Parsons Engineering Science, Inc.

20. Thompson Culvert Company, 2000. Chris Hill, Thompson Culvert Company, personal communication with Parsons Engineering Science, Inc.

21. Vanasse Hangen Brustlin, Inc., 2000. Molly Rogers, Vanasse Hangen Brustlin, Inc., personal communication with Parsons Engineering Science, Inc.

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