Stormwater Management in Areas of Shallow Groundwater

FINAL REPORT

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I. Introduction

This report has been prepared to evaluate a variety of stormwater infiltration and pretreatment practices currently in use in the northwestern United States. The goal has been to identify technologies and techniques that will be protective of Missoula's groundwater aquifer, even in areas where that groundwater can come within ten feet of the surface. The solutions presented here have been evaluated on criteria of cost-effectiveness, maintenance requirements, and aesthetics in the context of an urban or suburban setting.

Throughout much of the City of Missoula (City), it has been standard practice to discharge stormwater runoff into the ground through injection wells, commonly known as sumps or dry wells. While this practice has served the City well throughout much of the urban area, in some rapidly developing areas of the City, such as parts of the Target Range area, seasonal high groundwater can extend within ten feet of the ground surface. In these areas, there is concern that sumps are not providing adequate protection to prevent contaminants in stormwater runoff from entering the aquifer. Discharge of contaminated stormwater directly into the aquifer is specifically prohibited by Montana Department of Environmental Quality Stormwater Circular DEQ 8. The use of sumps in shallow groundwater areas is also a concern of the Missoula City/County Health Department (Health Department).

As previously rural areas become urbanized, fields and forests are gradually replaced by impervious surfaces, increasing both the amount of water that runs off the land and the speed at which it does so. Much of stormwater design is focused on mitigating the effects of this rapid runoff. Where conditions allow, infiltration is a favored stormwater management practice because it mimics the infiltration that occurs on undeveloped sites, recharging the groundwater and reducing surface flows downstream.

Current state-of-the-art practices for infiltration, as implemented across the nation, are largely driven by water quality requirements, specifically from rules under the Clean Water Act. (NPDES Phase 2 Stormwater Discharge Permits and Total Maximum Daily Loads or TMDL's are the two primary rules). Following the recommendations of national organizations such as Environmental Protection Agency and the Center for Watershed Protection, many jurisdictions, including all the ones cited in this report, have established design guidelines to promote the use of infiltration facilities to handle a portion of stormwater runoff.

Some of the design guidance reviewed for this report is not directly applicable to the circumstances in Missoula, Montana. Most design details for infiltration facilities also include a provision for excess water to overflow to surface drainages. While facilities of this type can be a great benefit to surface water quality and groundwater recharge, this report will focus on facilities that have no surface water discharge route.
In some locations, such as Eastern Washington, regulations arising through Underground Injection Control (UIC) programs have caused requirements to be placed

on infiltration that are significantly more strict than what is currently the standard practice in Montana. There are currently no plans to create UIC rules for dry well sumps or other stormwater facilities in Montana.

This report is organized into five sections:

General Infiltration Design Guidelines / Criteria identifies standard design principles and standards that are applicable for any type of infiltration facility in the Missoula area, including DEQ-8 requirements.

Infiltration Design Alternatives discusses specific infiltration practices, their costs, benefits and challenges, and recommends whether and under what conditions they ought to be used in the Missoula area.

Pretreatment Design Alternatives discusses stormwater pretreatment alternatives for use in conjunction with the infiltration design alternatives.

Model Subdivision Example applies several of the design alternatives profiles in this report to a hypothetical 5-acre subdivision with 20 homes.

Summary of Maintenance Requirements organizes the maintenance requirements for each type of system into a tabled format.

Recommended Regulations

Throughout the report, recommendations are given for design criteria that could be adopted by the City as Administrative Rules or incorporated into other regulatory guidance, such as building codes or subdivision regulations. These recommended design criteria are set apart from the general discussion in this report like this.

II. General Infiltration Design Guidelines / Criteria

Stormwater infiltration practices are designed to introduce water into the subsurface environment to charge the aquifer. In doing so, it is important to ensure that other subsurface facilities (such as drainfields, wells, and foundations) are protected from damage and that the aquifer itself is protected from contamination.

Regarding vertical separations, existing state regulations (specifically, Circular DEQ-8) require only that stormwater not be discharged directly into an aquifer. An absolute minimum separation of one foot has been recommended by the Missoula City/County Health Department, with three feet of separation being preferred.

Horizontal separations around infiltration facilities are intended to protect against contamination, but also against ill effects caused by the groundwater mounding that occurs around a functioning infiltration facility. In this sense a septic drainfield can be thought of as a specialized type of infiltration facility. As the water table is raised, the hydraulic head pushing water into the ground is reduced, slowing infiltration.

In general, infiltration facilities can be expected to infiltrate more water per square foot of infiltrative surface if the infiltrative surface is relatively small or is extended in only one dimension (linear rather than square). Water moves through soil horizontally as well as vertically, so that the effective infiltration area is significantly larger than the infiltration facility itself. Using similar logic, it is better from a functional perspective if infiltration facilities are distributed across a site, rather than centralized in one location. Distributed facilities better mimic natural infiltration and require less infiltrative area to achieve the same level of performance.

For this reason, simple and inexpensive site evaluation criteria relying on observation of soil texture and simple percolation tests are proposed as appropriate for design of facilities where each structure will receive runoff from less than one acre of impervious surface, provided that the infiltrative surface is no wider than eight feet. This rule allows for economical design of subsurface infiltration chambers, infiltration trenches and parking lot raingardens. This can be compared with current City standard practices, which typically allow one dry well sump for 10,000 square feet (just less than ¼ acre) of impervious area.

However, if it is desired to use infiltration to dispose of runoff on a larger scale, more scientifically valid methods for determining soil infiltration rates are appropriate. Where infiltration of stormwater from large areas is proposed with no surface overflow, double-ring infiltrometer testing is a more appropriate test measure to ensure that facilities are sized appropriately.

Another general consideration is soil compaction. Where surface soils are to be used for infiltration, soil compaction can dramatically reduce the permeability of the soils.

Pretreatment of stormwater prior to discharge into the ground takes on added importance when the distance from the infiltrative surface to Missoula's drinking water aquifer is less than one foot. Potential pollutants in stormwater include oil or other fluids from automobile drippings, nutrients from plant and animal wastes, salts from deicing chemicals, and silt and sand particles. Many hydrocarbons and nutrients cling to soil particles, so that removal of suspended sediments in a water stream also has a large impact on other pollutants. The removal of silts and oils can both protect the aquifer and prolong the life of the infiltration facility by minimizing the accumulation of particles that could cause clogging. The simplest forms of pretreatment involve causing water to flow across vegetated areas where sediments can be trapped and incorporated into the soil matrix. Pretreatment options are detailed later in this report.

The following rules are proposed for all infiltration facilities in areas of shallow groundwater within the City of Missoula:

General Infiltration Design Criteria

- **A minimum of one foot of vertical separation shall be required between the bottom of any constructed infiltration system and the highest known groundwater elevation at that location. Three feet of vertical separation is preferred.**
- **Infiltration practices shall be set back horizontally at least 25 feet from any private water well or sanitary drainfield, or from the nearest adjacent infiltration practice. A separation of 100 feet is required from any public water well. A separation of 25 feet from building foundations is desirable, however small sumps receiving mostly roof runoff may be located as near as ten feet to foundations.**
- **Areas proposed as surface infiltration facilities shall not be used as sediment traps during construction, and shall be protected from compaction by heavy construction equipment during construction. If there is reasonable suspicion that a surface soil area proposed to receive runoff for infiltration has supported loads from cars and trucks, construction equipment or other heavy vehicles, the infiltrative surface shall be scarified to a depth of at least 18 inches.**
- **There must be 25 feet of separation between two infiltration facilities for them to be considered separate.**
- **An approved method of stormwater pretreatment to remove grit and floating oils is required before stormwater is discharged to an infiltration facility. Pretreatment of roof or sidewalk runoff is not required.**

A. Guidelines for Determining the Infiltrative Capacity of Soils

Only a limited set of soil types is suitable for 100% infiltration of stormwater runoff. The designs proposed in this report are particularly targeted for soil types typical in Missoula valley, such as the Grantsdale series (see Appendix C for series description) that consist of loamy surface soils with coarse (gravel/sand) subsoils. Silt and clay soils will generally not provide acceptable infiltration rates. Most jurisdictions have adopted a minimum infiltration rate of 0.5 inches per hour, however these systems are typically just sized to infiltrate the "first flush" of stormwater, with large overflows directed to surface facilities. Because the systems proposed in this report have no surface overflow, a minimum infiltration rate of 1.0 inches per hour is proposed. However, in practice, it may not be economical to design 100% infiltration facilities in soils that percolate this slowly.

Percolation (perc) tests are recommended as an acceptable test of soil infiltrative capacity for individual facilties receiving runoff from less than one acre of impervious surface, provided that a factor of safety is used. A factor of safety of two is proposed in this report. This factor of safety accounts for several things:

- Infiltration practices may become clogged over time, causing infiltration to slow.
- Results of perc tests are notoriously variable over even short distances.
- Perc tests are not a true one-dimensional infiltration test – much of the infiltration measured in a perc test is through the side walls of the hole. However, this is also true of infiltration chambers and infiltration trenches in practice.

Soil testing standards have been reviewed by DEQ staff and are considered to exceed the requirements of Circular DEQ-8.

Determining the Infiltrative Capacity of Soils

As part of final design, evidence must be provided to demonstrate the infiltrative capacity of the soils in which the infiltration system will be installed. The minimum infiltration rate that can accommodate a 100% infiltration basin is one inch per hour.

Percolation tests, performed in accordance with the appendices of Montana Circular DEQ-4 are an acceptable means to measure infiltration rate for small infiltration facilities, defined as facilities receiving runoff from less than one acre of impervious surface. When using perc tests to design stormwater infiltration facilities without a surface water overflow route, a safety factor of two shall be used for design.

Percolation tests must be performed at the depth of the proposed infiltration system, within the soil horizon that will underlie the system. One percolation test must be provided within 25 feet of each proposed infiltration area. For individual infiltration areas larger than 400 square feet, at least two percolation tests are required.

Alternatively, if a small infiltration facility is to be installed in soils that are medium sand or coarser, an infiltration rate of three minutes per inch (20 inches per hour) may be used for design. If soil texture is in question, medium sand or coarser shall be defined as soils where less than 50% of material passes a no. 60 sieve (0.25 mm, or fine sand) and less than ten percent of material passes a no. 200 sieve (0.075 mm, or silt). Where fine surface soils overlay coarse subsoils, it is acceptable to remove the fine-textured native soil below the proposed infiltration system to reveal the coarse-textured subsoil. The fine soils removed shall be replaced with sand containing less than 15% gravel, and meeting the above specification. ("Gravel" is here defined using the USDA definition as material retained on a no. ten sieve, or greater than two mm diameter).

Double-Ring Infiltrometer testing, in accordance with Standard ASTM-D3385, is required for infiltration facilities with no surface water overflow under the following circumstances:

- **Any proposed facility with an infiltrative surface wider than 8 feet, OR**
- **Any proposed facility receiving runoff from more than one acre of impervious area, and with a storage volume less than the 100-year, 24 hour storm volume**

Other methods of measuring soil infiltration rate may be used, if approved by the City Engineer.

B. Guidelines for Sizing Infiltration Facilities

All stormwater facilities must demonstrate that they can meet performance criteria for all relevant design storms. In the City of Missoula, the design storms are as follows:

- two-year, one-hour storm (0.41 inches, per DEQ 8)
- ten-year, 24-hour storm (1.8 inches, per NOAA Atlas 2)
- 100-year, 24-hour storm (2.6 inches, per NOAA Atlas 2)

In all three cases, the proposed facility must accommodate the design storm through a combination of stormwater storage and infiltration. For the 24-hour storms, a ten hour infiltration period is proposed in order to account for the fact that the rainfall is not spread evenly over the 24-hour period. Montana Circular DEQ-8 requires that no overtopping of roads occur during a ten-year storm. But, during a 100-year storm, some storage of water in roads and parking areas may be acceptable.

These criteria are summarized in a table on the following page.

For example, a grassed swale and infiltration chambers are proposed to serve a parking lot. Using the Rational method, the designer has calculated that the two-year, one-hour storm will produce 1,000 cubic feet of runoff. The water storage volume of the proposed facility, including the void space in the chambers and surrounding drain rock and the storage capacity of the swale up to the elevation of the road gutter is 800 cubic feet. The chambers have a bottom area of 150 square feet and an assumed infiltration rate of 20 inches per hour. Therefore, in one hour the chambers can infiltrate 20 inches / 12 inches/foot X 150 sq.ft. = 250 cubic feet. Since the storage volume allowance (800 cubic feet) plus the infiltration volume allowance (250 cubic feet) is greater than the design storm (1000 cubic feet) the proposed facility meets the first criteria.

Infiltration Facility Sizing Criteria

All four criteria must be satisfied at each infiltration location. For each of the criteria, at each facility, the Storage Volume Allowance plus the Infiltration Volume Allowance must be greater than the Design Storm Runoff Volume. Volumes may be calculated using the Rational Method, the TR-55 Method, or another method acceptable to the City Engineering Department.

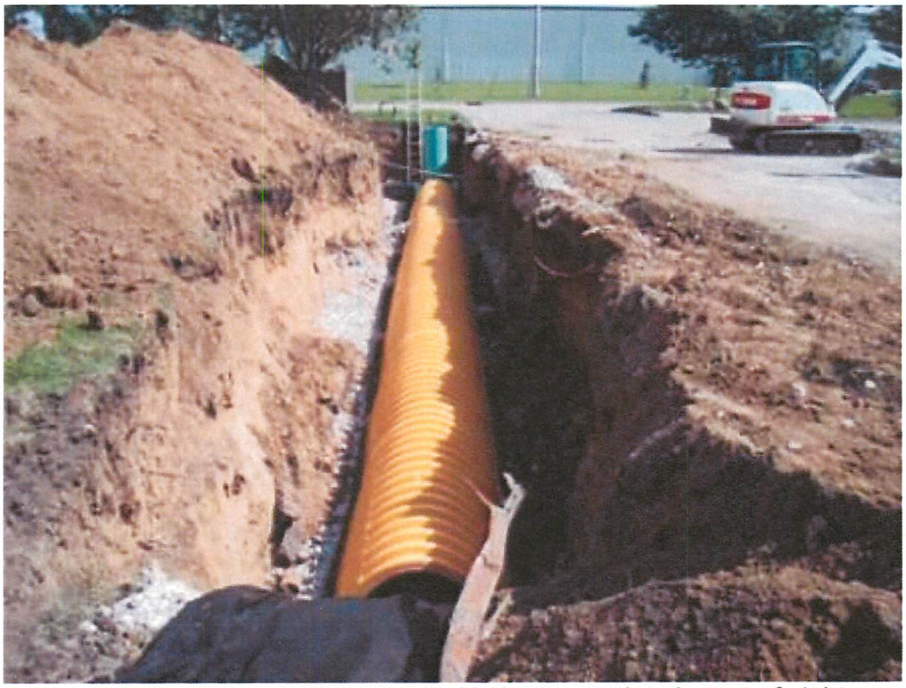
Design Storm Runoff Volume	Storage Volume Allowance	Infiltration Volume Allowance
Criteria 1: 2-year, 1-hour storm	Calculated facility storage volume, without surcharging or overtopping of roads or pedestrian facilities.	One hour of infiltration
Criteria 2: 10-year, 24-hour storm	Calculated facility storage volume, without surcharging or overtopping of roads or pedestrian facilities	Ten hours of infiltration, or successfully route a hydrograph from an SCS Type 2 storm.
Criteria 3: 100-year, 24-hour storm (short term)	Total storage volume, including storage in roads, park areas or parking lots up to 6" in depth	Ten hours of infiltration, or successfully route a hydrograph from an SCS Type 2 storm.
Criteria 4: 100-year, 24-hour storm (long term)	Zero - All stored water must be fully infiltrated after 72 hours	72 hours of infiltration

For the 100-year, 24-hour storm, the designer must show that the total storage volume used as the Storage Volume Allowance is truly contained, and that no overtopping into adjacent drainage basins will occur. Alternatively, a system may deliberately be designed for the 100-year, 24-hour storm to overtop the basin, provided an acceptable flow path exists for the water to reach surface water without causing flooding, erosion or other property damage.

III. Infiltration Design Alternatives

A. Infiltration Chambers

Infiltration chambers are a clear choice for infiltrating stormwater below ground in areas of shallow groundwater. Like dry wells, they have substantial storage volume and are located below grade, out of sight. Unlike dry wells, they are oriented parallel to the ground surface. Several national companies with a strong Missoula sales presence manufacture infiltration chambers, including ConTech (ChamberMaxx chambers) and ADS (StormTech chambers). These two products are essentially identical. Manufacturer's literature is attached for reference.



Stormwater chambers are installed below ground, to be out of sight.

Stormwater chambers can be used for sealed detention, for non-sealed detention (detention with infiltration) or for 100 % retention and infiltration. Only the last option will be discussed here. According to the manufacturer's literature (see attached), if properly installed, chambers can be placed under roads or parking lots. However, for use in Missoula in areas of shallow groundwater, it is preferable that chambers not be installed under driving areas for the following reasons:

- Subgrade compaction to 95% Proctor density is required for installations under driving surfaces. Subgrade compaction can be counterproductive for achieving stormwater infiltration.
- Manufacturers installation instructions require 18 inches of cover (not including pavement) as a minimum when chambers are placed under roads. Only 12 inches of total cover is needed for non H-20 loadings. The

additional cover places the chambers deeper underground, reducing the separation from groundwater.
- If chambers should fail, the roadway would need to be excavated to correct the situation.

It is recommended that chambers be installed beneath boulevards, sidewalks, trails or other landscaped areas that are expected to receive primarily pedestrian traffic loads. However, placement of chambers under parking lots or roads is acceptable if the structural section is reviewed and approved by an engineer.

While grasses and flowers can be planted on top of infiltration chambers, the shallow bury depth means that trees and large shrubs should not be planted where deep roots will interfere with the chambers. Because of this, locations of driveways, boulevard infiltration chambers and boulevard trees must be detailed by a designer, since standard tree spacings are unlikely to fit without some modifications.

Design Criteria for Infiltration Chambers

- **Runoff from roads or parking lots shall be pretreated by a method acceptable to the City before being released into subsurface infiltration chambers.**
- **Generally, no more than two chambers should be installed parallel as part of any one infiltration facility. There is no limit to the number of chambers that can be installed in a line. If the infiltration area is desired to be more than two chambers wide, the requirement for Double Ring Infiltrometer testing is triggered (see "Determining the Infiltrative Capacity of Soils")**
- **Chambers shall be surrounded on all sides with six inches of free draining washed stone. Filter fabric shall separate stone from native soils and other backfill on the top and sides.**
- **The infiltrative surface area used for design shall be the open bottom of the chamber plus the six-inch width of drain rock surrounding the chamber.**
- **All chambers shall be installed with a minimum of 12 inches of non-pavement cover over the surrounding drain rock.**
- **It is recommended that chambers not be located under driving or parking areas, or other areas subject to H-20 traffic loads. However, if chambers are to be so located, requirements for cover and compaction must be designed and approved by a Professional Engineer.**
- **At least one observation port shall be installed per chamber system, to enable the monitoring of drainage and rates of sediment accumulation.**

Frozen Soils

Consideration has been given to the potential for chambers to become plugged during frozen conditions. The infiltrative surface of a stormwater chamber will typically be located four feet below ground, and the air within the chamber will have a circuitous route to travel to the surface. Furthermore, the drain rock below and around the chamber will be free-draining and will not easily clog with ice. Although it is conceivable that a particularly harsh winter could lead to the ground around and below a chamber freezing, this occurrence is expected to be exceedingly rare in Missoula's climate, and is unlikely to coincide with significant quantities of surface runoff.

Costs

The cost of stormwater chambers can be compared with the cost of standard dry well sumps. Hunton Precast charges $675 for an eight-foot sump delivered in Missoula, including castings. Recent construction bid prices for installed sumps generally range from $1,500 to $2,000.

Current City of Missoula standard practices allows one sump per 10,000 square feet of impervious area. To determine the number of chambers needed for this same area, it is necessary to make some assumptions about the permeability of the soil. Let us assume that percolation tests justify the use of a percolation rate of five minutes per inch, or twelve inches per hour. At this percolation rate, four chambers are sufficient to meet all design criteria. Supporting calculations are included in Appendix A.

WGM has been quoted a delivered cost of $200 to $275 per chamber, including end caps, from Contech. HD Supply, who sells Storm Tech chambers by ADS, quotes $350 each for their chambers. Therefore, the cost of four chambers is between $1,000 and $1,400. With the costs of stone, fabric, installation and finish grading, the installed cost of the chambers is expected to come in between $2,000 and $2,500.

In addition to the chambers, some sort of catchbasin inlet is required. For chambers installed outside the road prism, the potential to save money by using a light-duty catchbasin was evaluated. Nyloplast, a division of ADS, makes small diameter PVC catchbasins with light-duty grates that sit in the pipe bell. However, WGM was quoted a cost of $750 each for a 15" diameter catchbasin with a light-duty beehive grate. This price is too high to be competitive with standard concrete catchbasins, which can be furnished and installed for $700. Therefore, when the cost for a catchbasin is added in, the total installed cost of the stormwater chambers is expected to be around $3,000, or between one-and-a-half to two times as much as a standard sump.

It should be noted that every chamber installation will need to be individually evaluated, and not all installations will require four chambers. If soils percolate faster, if significant storage can be provided in a pretreatment swale, or if the contributing area is significantly less than 10,000 square feet, fewer chambers may be needed. In these instances, the construction cost of storm chambers may be competitive with standard sumps.

Installation and Maintenance

Installation of stormwater chambers can take place at any phase of site construction. Standard Best Management Practices (BMP's) for inlet protection, including Missoula Standard Drawings STD-605, STD-606 and STD-609, should be used to protect the chambers from construction sediments.

Stormwater infiltration chambers should not require any regular maintenance. (The pretreatment used in conjunction with the chamber WILL require maintenance.) As with standard sumps, the soils below the chambers may become clogged over time. If this happens, the only recourse is to dig up the chambers, remove and replace the silted soils, and re-install the chambers. If the chambers are not installed beneath roads, the cost of digging them up should be less than or equal to the cost the City currently incurs when it is required to dig up a sump. The policies pertaining to the surface restoration of plantings or other improvements located above the chambers should be the same as the policies governing the excavation of other utilities in the right-of-way or in easements on private property.

B. Raingardens

Many stormwater facilities are buried underground; others are hidden behind buildings or in back corners where they will not be seen. A third alternative is to prominently feature the stormwater facilities above ground and turn them into beautiful amenities. A raingarden is a planted, landscaped area on a site, depressed below the surrounding ground elevation, which receives site runoff and infiltrates it directly into the ground.

A raingarden in a residential neighborhood in Maplewood, Minnesota.

For purposes of this report, raingardens are intended as landscape amenities, to be prominently featured and attractively landscaped. They are intended to receive runoff from impervious areas less than one acre, and will generally not be downstream of significant storm drain systems or engineered oil and sand separation devices. The bottom width of a raingarden is to be eight feet or less.

The intention of this limit is to prevent large expanses of ponding where water infiltration must be purely vertical and where groundwater mounding may occur. For a larger scale, more centralized facility, see *Infiltration Basins*.

Raingardens can be adapted to manage runoff from roads, parking lots or building roofs. They can parallel the road in front of businesses, apartments or institutions, or they can be incorporated into public gardens. They can also be installed as depressed islands in parking lots.

Pretreatment of runoff entering a raingarden directly from impervious areas is primarily intended to prolong the life of the raingarden by capturing sediment before it can clog the infiltrative surface.

See Appendix C for additional design details and illustrations of raingardens from Minnesota and Truckee Meadows.

This parking lot raingarden is installed in Laguna Beach, California

Frozen Soils

Because the infiltrated surface is directly exposed to winter-weather, raingardens are vulnerable to failure during winter rain-on-snow events.

Requirement for Overflow Facilities

Due to the potential for surface infiltration facilities to become frozen and impermeable during cold weather, all surface infiltration facilities receiving road or parking lot runoff must provide an overflow route. Shallow sumps or infiltration chambers may be used to provide this overflow capacity, provided that the infiltrative surface is at least four feet below the finished ground surface and is not directly open to the cold air. Assuming similar soil types, the infiltration surface area of the overflow facility must be equal to at least 12% of the infiltration surface area of the surface facility. This requirement is applicable to rain gardens, infiltration trenches, and infiltration basins.

Costs

The cost of a raingarden can be highly variable. For a project with significant decorative landscaping as part of the development plan, and with in-situ soils suitable for infiltration and planting, depressing a portion of the landscaping to allow it to serve as a raingarden could have little additional cost. Imported planting blends, drain rock and filter fabric will add to the cost. Relative to a standard sump, the greatest cost of a raingarden is the land area that must be set aside.

To gain perspective on the potential costs of raingarden, let us imagine one acre of paved parking, and assume that this area can be graded towards a central linear parking-lot raingarden like the one in the proposed standard detail, which is attached. Let us assume that surface soils are to be stripped, and that the subsoils are suitable for a design infiltration rate of six inches per hour. Calculations show that raingardens with a total bottom length of 124 feet would have sufficient storage and infiltration capacity for a 2-year, 1-hour storm and a 10-year, 24-hour storm. We can assume that additional ponding in the parking lot during a 100-year, 24-hour storm will be acceptable. This required raingarden area could be divided into two parallel parking lot median raingardens. Including sideslopes, the total footprint of each of these two raingardens would be 20 feet wide by 74 feet long, for a total of 2,960 square feet, or 6.8% of the impervious area.

A cost estimate for this raingarden has been put together and is included in Appendix A. The required emergency overflow to infiltration chambers is included, as are design and construction costs and contingencies. The costs of plants and shrubs are not included, although all mulch and grass is included. The total calculated cost is $20,452 for both raingardens, or approximately $27.50 per square foot of required infiltrative area. By comparison, five standard sumps would have been required for the same parking lot area, for a cost of $7,500 to $10,000. However, any large parking area would be expected to include some landscaping areas, and the raingardens in this example will serve multiple purposes.

Installation and Maintenance

A key to an effective raingarden is that there must be an entity willing and responsible to perform or pay for the regular landscaping maintenance needed to keep the raingarden looking like an amenity rather than a liability. For this reason, we are not recommending raingardens be used for street runoff in areas of owner-occupied and owner-maintained housing. Raingardens should only be used in commercial or institutional settings where a professionally maintained landscape is an inherent part of the site development plan, or in residential communities where a condominium association or homeowners association will have significant landscape maintenance responsibilities in addition to the raingardens.

The normal ongoing maintenance expected for a raingarden is not significantly greater than for any professionally maintained landscape, and includes weeding, mowing, trimming and replacement of mulch as it decays over time. Plants for the gardens should be selected to reduce maintenance and to tolerate snow storage and winter salt and sand.

Accumulation of trash and debris may be greater in and around a raingarden than for landscaped areas not receiving stormwater runoff. If the contribution of sand and silt to a raingarden is large, and if the grassed filters or other pretreatment is not adequate, the raingarden may periodically have to be excavated to remove silt-saturated soils and replace them with free-draining sand soils. The frequency with which this may be required is largely a function of the silt load to the basin. A best estimation is every five to ten years.

Design Criteria for Raingardens

The area for ponding should be a shallow depression of 6 to 18 inches in depth.

Runoff from roads and other impervious surfaces must be pretreated. The simplest pretreatment is for water to flow across at least four feet of turf grass that slopes no more than twelve percent. This simple pretreatment is intended for sheet flows or for small concentrated flows from impervious areas of less than 2,000 square feet. Grassed swales are recommended for pretreatment of concentrated flows.

If planting soil is to be imported, a recommended planting blend consists of 50 to 60 percent clean sand (ASTM 33 – concrete sand), 20-30 % peat or certified compost, and 20-30 % topsoil. If the in-situ subsoils are not free-draining (medium sand or coarser) an eight-inch thick layer of clean coarse aggregate shall be installed below the planting blend. Filter fabric shall separate this drain rock from the in-situ soils below and from the planting mix, above.

If in-situ soils are to be used for the raingarden, it is recommended that these soils be amended by adding six to twelve inches of organic compost and tilling it in to a depth of at least 18 inches prior to planting.

The design infiltration rate for a raingarden shall be based on the in-situ soils underlying any imported planting blend, but shall not exceed 10 inches per hour. This rate is slower than the general minimum rate for infiltration facilities to account for the affects of soil amendments or imported planting blends.

The use of weed barrier fabrics and organic mulches (particularly wood chips) to promote healthy plant growth and reduce maintenance requirements are highly recommended. Gravel mulches are also acceptable.

The bottom width of a raingarden shall not exceed eight feet, and the surface ponded width shall not exceed 20 feet. (The length can be as long as desired). Only the bottom width shall be counted towards the infiltrative surface area.

In order to avoid clogging the raingarden with sediment during the construction phase, construction runoff should be diverted away from the area where the raingarden is to be constructed at least until roads and parking areas have been paved. Straw bales or straw wattles shall be used to filter runoff draining towards the future raingarden from areas that have not achieved final stabilization.

C. Infiltration Trenches

Infiltration trenches are narrow trenches, three to five feet in depth, filled with washed gravel. These trenches are installed in the bottom of a swale. The gravel trench provides storage volume for stormwater, and also provides a pathway for the water to pass through finer surface soils and into coarser subsoils below. The grassed swale that contains the infiltration trench provides additional storage volume. Unlike raingardens, infiltration trenches are not intended to support vegetation across the infiltrative surface, as the gravel media will not retain moisture during dry periods.

A typical trench features a minimum six-inch thickness of concrete sand across the bottom of the trench to spread water evenly across the trench bottom, and to provide some filtration of pollutants, in the case of extremely gravelly subsoils. Geotextile fabric is proposed to line the sides of the trenches, to prevent the surrounding soil from infiltrating the gravel medium.

It is recommended to fill the trench with gravel to within approximately two inches of the finished ground, then wrap the drain fabric over the top of the gravel. The final two inches of gravel will cover the fabric. As silt is washed into the trench, some silt will collect on this top fabric surface. As this silt accumulates, it may impair trench functioning and necessitate maintenance, which would consist of removing and replacing the fabric and top several inches of gravel. With a well-functioning pretreatment system, the need for such maintenance can be significantly reduced.

When infiltration trenches are to receive sheet flow, for example from a parking lot, the grass sides of the swale may provide adequate pretreatment. If concentrated flows are directed to an infiltration trench, the flows must first travel along the length of a grassed swale, or other pretreatment must be provided.

If one or both side slopes of the infiltration trench are to be used as filter strips, the slope should not exceed 10:1. Otherwise, side slopes should be no steeper than 3:1. In either case, ensuring that slopes are well vegetated and fully stable is critical – loose dirt washing into the infiltration trenches could quickly cause them to fail. Irrigation of slopes is recommended to establish a healthy cover of grass. Regular mowing of the trench sides, as well as trimming and pulling of weeds along the trench bottom, will be required to maintain a neat appearance. The potential for these trenches to become overgrown and unsightly is considered to be their major drawback.

See attached for details from other jurisdictions showing the features of an infiltration trench. As with all surface infiltration facilities in Missoula, an overflow to subsurface infiltration will be required for frozen conditions.

While infiltration trenches could be an appealing option in particular circumstances, infiltration trenches are not expected to be as low-maintenance as infiltration chambers, nor as attractive as raingardens, and this option has not been fully developed in this report.

D. Infiltration Basins

Infiltration basins are used in some jurisdictions to reduce runoff volumes, remove some pollutants from stormwater and recharge the groundwater. They are large, shallow dry ponds, typically planted with grass, that receive storm runoff and infiltrate it into the ground. For purposes of this report, infiltration basins are considered to be surface infiltration facilities with a width greater than eight feet or receiving runoff from more than one acre of impervious surface.

Design and Maintenance Criteria for Infiltration Basins

The floor of the infiltration basin shall be level. Side slopes should not exceed a steepness of 3:1.

The side slopes of the infiltration basin should be planted with stabilizing vegetation. The seed mix for the side slopes of the basin should be selected to be highly drought tolerant.

An appropriately-sized pretreatment facility to remove silt must be located upstream from an infiltration basin. An engineer shall provide documentation that the proposed pretreatment facility is capable of removing 50% of 50-micron particles and 80% of 125-micron particles from stormwater at the two-year design storm, or must otherwise demonstrate that the pretreatment device meets a well-established standard for design from another jurisdiction with rigorous science-based standards, such as Washington State.

If after any storm (during non-frozen conditions), the time required for the basin to fully empty should be greater than 72 hours, the infiltrative surface shall be tilled to a depth of six inches. If tilling does not restore the permeability of the basin, then surface soils must be fully removed and replaced with free-draining soils.

It is critical to ensure that facilities intended to infiltrate runoff from large areas are carefully designed and properly maintained. The following considerations must be given full care and attention:

Design Sizing

A large infiltration facility with no surface overflow poses a real potential flooding hazard to the community. Careful hydrologic analysis and scientific measurement of infiltration rate are necessary to ensure appropriate sizing.

Compaction

The need to protect future infiltration areas from soil compaction before, during and after construction is critical to their success, particularly in soils containing significant amounts of silt or clay.

Protection From Sediments

During construction, runoff must be routed away from future infiltration basins. Areas draining to the basin must be stabilized. After construction, pretreatment of stormwater is needed to prevent basins from becoming clogged.

Maintenance

It is periodically necessary to till the top six inches of an infiltration basin surface, and to reseed turfgrass. This maintenance responsibility can be expected to recur every five to ten years.

Large, centralized infiltration basins require significant water-transporting infrastructure, carry a significant risk of failure, and can not be expected contribute to the aesthetics (or the property values) of a neighborhood. They may require significant maintenance expense. If the City of Missoula chooses to allow large infiltration basins, the City should make a point of conducting periodic inspections after large storms to stay ahead of any clogging problems. For any infiltration basin, the entity responsible for any needed maintenance or reconstruction should be clearly identified.

Frozen Soils

As with all surface infiltration facilities in Missoula, an overflow to subsurface infiltration will be required for frozen conditions.

E. Facilities with Underdrains

All of the BMP manuals reviewed for this project included stormwater BMP's that incorporate underdrains made of various configurations of gravel and perforated pipe. Unlike an infiltration chamber, the purpose of an underdrain is to collect water below gravel and direct it elsewhere. Specific BMP's with underdrains include sand filters and bioretention systems (from Minnesota) and dry swales and bio-filtration swales (from Eastern Washington). In all these applications, the idea is that the "water quality design storm" is filtered through the soil medium, while larger storms bypass the filter. All of the water is ultimately discharged to a surface outfall or sent to a drywell or a separate infiltration facility.

For purposes of this report, we are assuming that 100% of storm water is to be infiltrated. Instead of collecting water in an underdrain and sending it somewhere else, all the BMP's chosen for the City of Missoula will use direct infiltration. However, should the City encounter specific applications where there is a need to treat stormwater to a higher standard than is generally required prior to surface discharging, the BMP's identified above offer an attractive and highly effective means of pollutant removal.

IV. Pretreatment Design Alternatives

A. Grassed Swales

It is a well-established treatment practice to cause potentially contaminated stormwater runoff to flow across vegetation, particularly grass, in order to clean it. Published BMP's used by other jurisdictions as reviewed for this report include Vegetated Filter Strips and Biofiltration Swales. A Biofiltration Swale is generally an adaptation of a roadside ditch with mild side slopes and a flat bottom, designed to carry concentrated flows. Design guidance from Eastern Washington calls for a minimum length of 200 feet for a grassed swale, with a maximum flow depth of four inches for the Water Quality storm (generally a six month recurrence or a storm depth of half an inch). This BMP is well suited to treating major point sources, such as the outfall from a large storm drain network or detention pond. On the other end of the spectrum, a Vegetated Filter Strip, typically consisting of an expanse of sod at less than ten percent slope, typically has a flow path of four to fifteen feet. However, filter strips are not intended for concentrated flows – only sheet flows.

The configuration proposed here for a grassed swale to pretreat runoff prior to its entering a subsurface infiltration system is somewhat of a hybrid of the two approaches outlined above. Because of the widespread use of curbs in the City of Missoula, discharge to infiltration practices will be point sources in most instances. Because most infiltration practices are limited in size to impervious drainage areas of one acre or less, the peak flows to any one inlet will be modest.

A curb cut and grassed swale provides stormwater treatment along Riding Ring Road in the Target Range area of Missoula County. In this instance, the beehive grate provides access to a standard eight-foot sump.

Design Criteria for Grassed Swales

Concentrated runoff may be directed from roads or parking areas towards grassed areas through curb cuts and concrete channels (the channels are for carrying runoff under sidewalks). All flow areas shall have a minimum width of 12 inches and a minimum clear height of six inches. A concrete apron shall be constructed where the water is discharged to the grass, with a vertical drop of at least three inches (see detail). This apron will serve to spread the water out, but primarily will prevent thick vegetation from blocking the flow of water and causing the water to back up onto the road during storm events.

From the concrete apron where water is released to the point where water exits the grassed swale, the shortest flowpath should provide at least ten feet of travel across a generally flat, grassed route. If non-sod-forming grasses are to be planted, or if regular mowing and maintenance is not expected, it is recommended that this minimum flowpath be increased to 20 feet. Even longer flowpaths are beneficial where sites allow. "Generally flat" means having a slope that does not exceed two and one half percent in any direction.

It is desirable that the flat bottom of the swale have a width of at least three feet. Swale side-slopes should not be steeper than 3:1. Mowable slopes of 4:1 are preferable where space allows.

The finished surface of the grassed swale shall have at least six inches of topsoil, and shall be seeded with an appropriate grass mix. An erosion control blanket shall be installed on the swale bottom and side slopes, in accordance with the manufacturer's directions, in order to protect the swale from erosion during the first 12 months of plant establishment. This blanket shall be a North American Green S75BN single-net straw blanket or equivalent.

The rim of the swale outlet structure shall be set at least three inches above the bottom elevation of the swale, to allow for sediment capture and storage. The water storage capacity of the swale may be added to the storage capacity of the infiltration system in meeting the storage requirements of the design. Infiltration occurring through the bottom of the swale should not count towards total calculated infiltration capacity, but the fact of this infiltration adds an element of conservatism to the design.

The grading, topsoiling and seeding of the grassed swale is expected to cost only a small amount more than for an ordinary boulevard or lawn. The project engineer and City inspectors will need to be vigilant to ensure that the depth and grades of the swale, and the 3" difference between the outlet and the swale bottom are constructed as designed. The only special cost for the swale is the erosion control blanket. Current MDT bid tabs report costs of approximately $3.00 per square yard for erosion control blanket, installed. If a typical swale is 10 feet wide by 20 feet long, this amounts to $67 for the blanket. Actual costs are likely to be higher, given the small scale of the swales.

The City of Spokane has required these sorts of grassy swales upstream of dry wells sumps for years. One problem they have encountered is that some homeowners do not like the dip in their yard, and fill in the swales with dirt. Clearly some amount of landowner education is needed where alternative stormwater facilities are used. Perhaps, if the drainage route from a curb cut to a beehive inlet is made obvious, and the swale is located in a boulevard where it is not part of what the homeowner perceives as "their yard", this problem will be less likely.

B. Proprietary Pretreatment Structures

In heavily urbanized areas, there may not always be sufficient open land for grass to be a feasible pretreatment option. In these locations, some amount of sediment, oil and grease removal can be achieved in a contained pretreatment structure. There exists an enormous variability in the cost and complexity of stormwater treatment apparatus.

On the high end are stormwater filter units with textile media requiring frequent replacement that treat stormwater to a high standard for protecting the most fragile aquatic ecosystems. On the low end are catchbasin sumps. Some jurisdictions call for catchbasins to set the structure sump six inches to one foot below the outlet pipe invert, with the hope of capturing sediment. The weakness of this system is its vulnerability to washout, where occasional large storms re-suspend the captured sediments and wash them downstream all at once.

A number of companies manufacture specialized manhole-sized structures or catchbasin inserts that are designed to capture sediment, oil and grease while providing resistance to resuspension and washout. One such category of devices is "hydrodynamic separators". The Stormceptor, distributed locally by Rinker Materials, is one such device. The Contech CDS ("Continuous Deflective Separation") is another. Both of these devices have undergone significant independent testing of their product performance claims. Both have established design methodologies to target specific sediment removal goals, such as 80% of TSS.

The State of Washington has conducted extensive scientific testing and review on both of these products, and both have been approved as pretreatment devices as required by the State of Washington. One of the applications these devices are approved for in

Washington is for stormwater pretreatment prior to infiltration practices. See Appendix B for \published report from the Washington Department of Ecology.
The design software used by Stormceptor distributors shows that the smallest Stormceptor (STC 450i) could achieve 85% TSS removal over time for an impervious area in Missoula equal to one acre. (The design computations from this exercise, as provided by Rinker Materials, are attached to this report for reference). The maximum flowrate for the smallest CDS (CDS 2015) is over twice that for the smallest Stormceptor. The prices of the smallest versions of these products have been quoted at $8,000 for the Stormceptor and $9,000 for the CDS.

In general, these hydrodynamic separators are best suited for treating runoff collected from impervious areas larger than one acre. Infiltration, on the other hand, works best as a disbursed technology. In some instances, it may be desired to concentrate runoff from a larger area, filter it with a structural practice such as a Stormceptor or CDS, and then split the outflow into two or more separate flows to be directed to separate infiltration installations.

If large, centralized infiltration facilities are to be proposed, pretreatment of the water will be a critical consideration. Lengthy grassed swales, sediment ponds, and hydrodynamic separator devices are all feasible pretreatment options for large flows.

One option for a simpler sediment removal device that can be economic even at low flows is the Snout by Best Management Products, Inc. of Lyme, CT. ADS pipe products, among others, distribute the Snout nationally. This simple fiberglass hood costs less than $400, and is fitted to an outlet pipe within a standard manhole with a sump at least 36 inches below the outlet invert. The hood acts like a sanitary tee in a septic tank, drawing water from the clearer zone in the middle, between the floatables above and the settled material below.

A Snout installed in a manhole in Bangor, Maine

A clean Snout

The advantage of the Snout is that it is simple, inexpensive, and works in conjunction with locally precast manhole sections and standard construction methods. Two disadvantages are as follows:

- Published performance data or standardized test results, such as those from the Washington Department of Ecology cited for the hydrodynamic devices, are highly limited.
- The Snout may be vulnerable to washout, especially if its sump is not frequently cleaned with a vacuum truck.

The potential for creating mosquito breeding habitat was also considered. A Snout-equipped manhole will maintain a stagnant pool of three feet of water between storm events. There is potential that this standing water could become a breeding ground for mosquitoes. (This concern also applies to the hydrodynamic devices). One possible means for addressing this concern is to require that the Snout only be installed in standard manholes with solid, sealed covers, and not allow the use of the Snout in combination manhole/inlets. Standing water in a below-grade manhole is not a vector concern because in the Missoula climate, the expected water temperatures in a below-grade structure would be too cool to support mosquito breeding. However, the vector concern would apply to stagnant water in an above-ground location.

The limited performance data available for the Snout suggest that the device can remove 50% of TSS and phosphorous from a stormwater waste stream. See attached for manufacturer's literature about the Snout, including memoranda about pollutant removal and cold climate functioning.

It is WGM Group's recommendation that the Snout be allowed as a pretreatment device for infiltration only in redevelopment or retrofit situations. In addition, the City Engineer could approve the use of the Snout as an infiltration pretreatment device for new construction only if site constraints make grassed swales unfeasible.

Any pretreatment vault with a sump requires periodic pumping out with a vacuum truck to remove accumulated sediment and oil. Annual pump-outs to remove collected road sand in the early spring are recommended as an absolute minimum level of maintenance. Periodic inspections can help establish whether more frequent pump-outs are warranted. If a structure has accumulated more than one inch of floating oils or more than six inches of silt or sand, it requires pumping out [Eastern Washington Manual].

Comparison of Western Cities

A survey of several western cities has revealed significant variation in the frequency with which catchbasins and vaults are inspected and cleaned.

Reno, NV: Schedules quarterly inspections of all Stormceptors or sediment vaults for which they are responsible. Vaults are pumped out when inspections indicate the need, typically about twice per year.

Bozeman, MT: Schedules annual pump-outs of vaults and Stormceptors. Because they use sand on roads in the winter, they have significant sediment accumulation and would like to be able to clean their facilities more than once per year, at least at large intersection areas.

Spokane, WA: Has a standard detail featuring a catch basin with three feet of dead storage upstream of a dry well. They pump out the sediment in the catchbasin when it accumulates within 18 inches of the sump – typically every one to one-and-a-half years.

V. Model Subdivision Example

A model subdivision has been created, based on a typical five acre orchard lot with a density of four homes per acre, for a total of 20 homes. This subdivision has been laid out on a grid pattern without alleys. Most of the proposed home lots are 75 feet wide by 80 feet deep. All roads are shown with a top, back of curb (TBC) to TBC width of 30 feet, and a 60-foot right-of-way.

Two scenarios are presented to deal with the runoff from this development. The first scenario, identified as “decentralized infiltration”, makes use of boulevard swales connected to subsurface infiltration basins.

The second scenario, identified as “centralized infiltration”, uses storm sewers to carry water to a common area where a centralized infiltration basin is located. It should be noted that in shallow groundwater areas, a centralized infiltration basin may not be a feasible option because of the depth required at the outfall. The “centralized infiltration” scenario is presented for comparison and discussion purposes only.

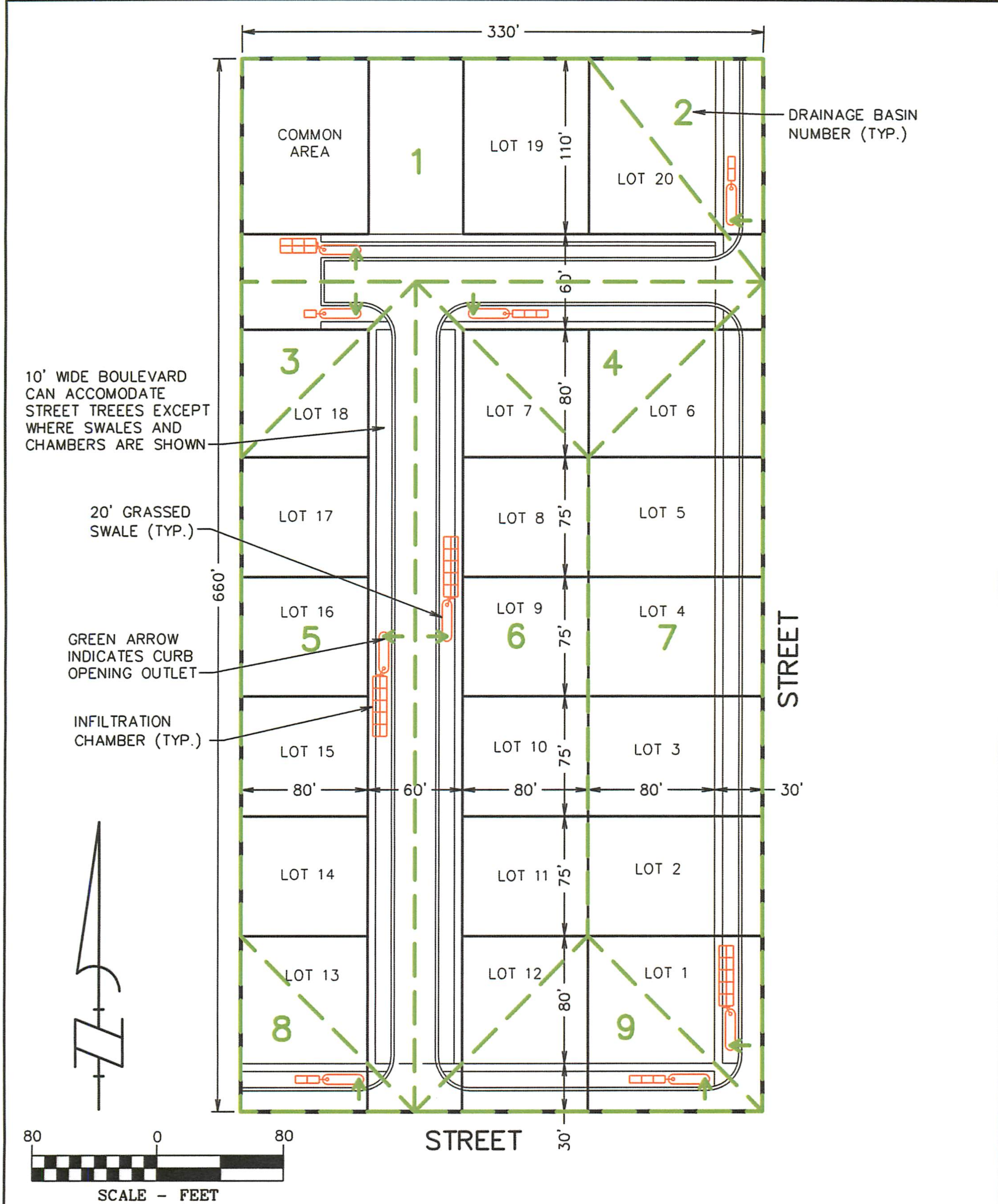
Decentralized infiltration

A total of 47 infiltration chambers were needed, located in 9 areas around the property. The sizing of the chambers assumes that they will be installed in highly permeable gravely sands, for which an infiltration rate of 20 min/inch can be used by default for design. All grassed pretreatment swales are 20 feet in length, to allow for the use of either turf grass or xeriscape-type vegetation. The single-lot-sized common area in the upper left corner of the development will contain no stormwater infrastructure and can be used for a garden or playground with no conflicts.

Drawbacks

- Ten-foot boulevards are needed to gracefully accommodate the pretreatment swales. This pushes the sidewalk to the very edge of the right-of-way. In this instance, a one-foot sidewalk easement is typically shown along the lot frontage. The lots will feel smaller with the sidewalk farther from the street.

- Wherever swales or chambers are located in the boulevard, trees cannot be planted, disrupting the potential uniformity of the streetscape. Private driveways may cross over the infiltration chambers.



DECENTRALIZED OPTION
MODEL SUBDIVISION EXHIBIT
MISSOULA COUNTY, MONTANA

WGM GROUP
ENGINEERING•SURVEYING•PLANNING
1111 EAST BROADWAY• MISSOULA, MT 59802
TEL: 406-728-4611• FAX: 406-728-2476

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DRAFT:	CEG
APPROVE:	JG
DATE:	AUGUST 11, 2010
SHEET	1 OF 1 SHEETS

Centralized Infiltration

For this option, an infiltration basin was located in the common area in the upper left corner of the development. The recommended standards in this report require double-ring infiltrometer testing for large centralized facilities of this type. For design, an infiltration rate of ten minutes per inch was assumed. This is half the rate used for the decentralized option, but the difference reflects the greater conservatism used to design centralized facilities, and the increased likelihood that the infiltration basin will be installed in shallower surface soils.

The infiltrative surface of the infiltration basin occupies half of the site common area. The other half of the common area is depressed as flood storage from large events, however this area could be used to site a playground, volleyball court, or other facility that would not suffer from being periodically underwater. An emergency overflow for the basin leads to several subsurface infiltration chambers, to accommodate storm events during frozen ground conditions. A Stormceptor-type oil-water separator is proposed, to conserve space.

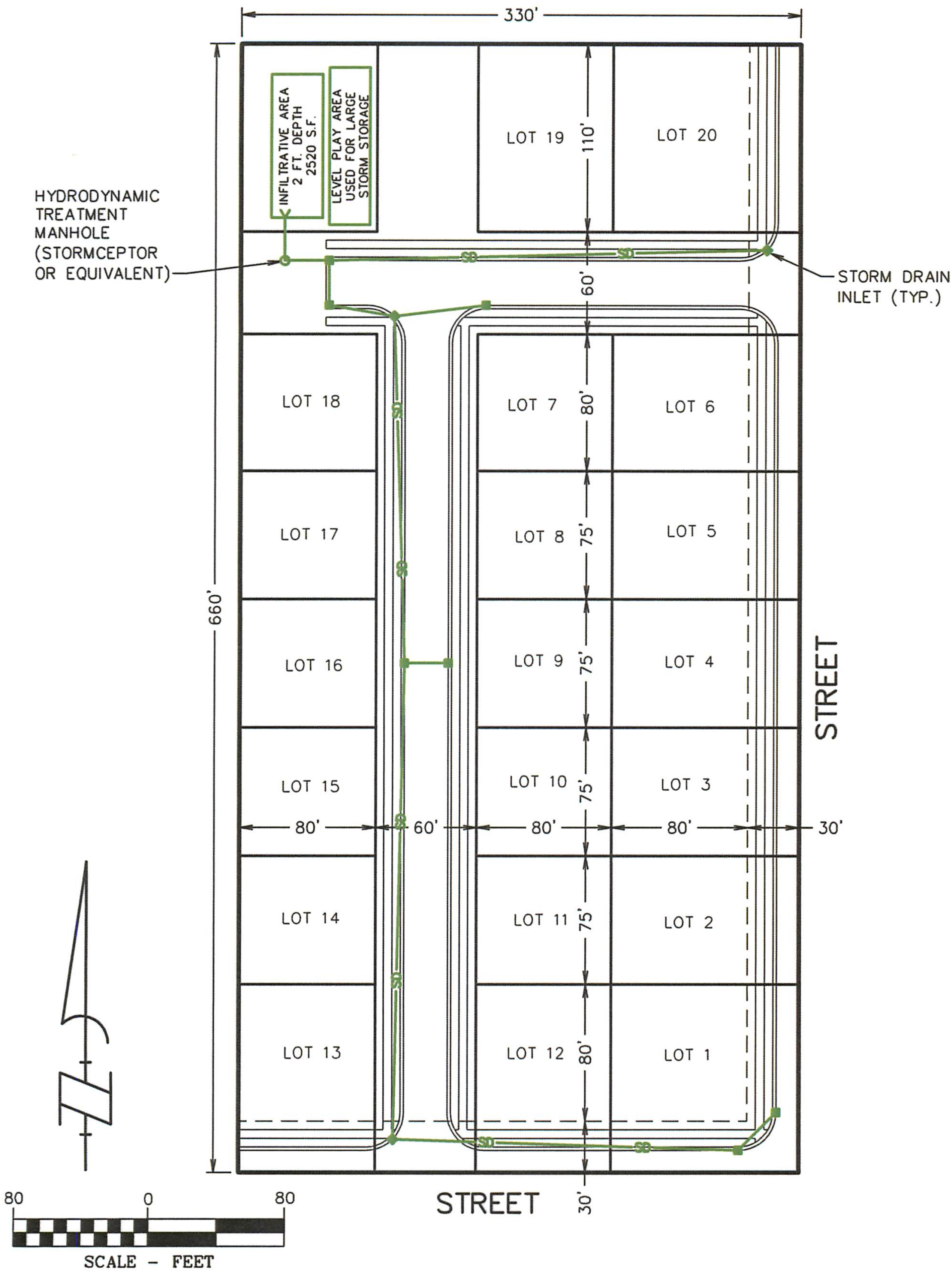
Stormwater is to be collected and conveyed to the infiltration basin with standard catchbasins and storm sewers. Standard five foot boulevards with street trees are proposed.

Drawbacks

- The entire site common area is needed to accommodate infiltration facilities.
- The expense of the storm sewer is considerable.
- Grade requirements severely limit applications of this option.

Cost Comparison

Cost estimates for both the Centralized and Decentralized options have been prepared and are included in Appendix A. The estimates suggest that the decentralized option would have significantly lower costs of just under $3,000 per lot, compared to approximately $5,400 per lot for the centralized option.



CENTRALIZED OPTION
MODEL SUBDIVISION EXHIBIT
MISSOULA COUNTY, MONTANA

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TEL: 406-728-4611• FAX: 406-728-2476

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DESIGN: ---
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APPROVE: JG
DATE: AUGUST 11, 2010
SHEET 1 OF 1 SHEETS

VI. Summary of Maintenance Requirements

It is recommended that regular maintenance such as mowing and garbage collection be made the responsibility of the adjacent property owner, either as part of the standard boulevard maintenance ordinance, or through specific development agreements. Periodic inspections should be done by the City. Infrequent maintenance could be the responsibility of a developer in a commercial development or of the City.

Facility Type	Regular Maintenance	Infrequent Maintenance
Subsurface infiltration chambers with grassed swale for pretreatment	Mow grass regularly, and remove any debris from inlet structure Inspect to ensure water is draining after large storms (1-2 x per year)	Dig up and replace chambers if they fail – expected to last longer than 10 years. Regrade swales if they become filled in – perhaps every 5-10 years.
Surface Infiltration trenches	Remove garbage from trench surface. Mow and weed-whack. Inspect to ensure water is draining after large storms. (1-2 x per year)	Dig up and replace surface gravel and fabric when silted in. Perhaps required every few years if silt load is heavy.
Raingardens	Care for plants and remove weeds, mow grass filter strips, remove accumulated garbage. Renew mulch every few years if organic mulch is used. Inspect to ensure water is draining after large storms. (1-2 x per year)	Dig up silted-in media and replace if it becomes clogged – expected to last longer than an infiltration trench but perhaps not as long as an infiltration chamber.
Infiltration basins	Mow grass regularly and pick up garbage. Because these basins are large and located out of the way, special provisions must be made to ensure this routine maintenance takes place. Inspect to ensure water is draining after large storms. (1-2 x per year)	Till surface soil when infiltration is slow – perhaps after 2-3 years. Fully remove and replace surface soils when tilling is insufficient – perhaps every 6-10 years.
Silt catchbasins or hydrodynamic separators	Remove accumulated sediments and oils with a vactor truck. Quarterly inspections are recommended to establish frequency, but annual cleanout is a minimum requirement.	None

References

EPA – Stormwater Menu of BMP's. 2008.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/

Minnesota Urban Small Sites BMP Manual – Stormwater Best Management Practices for Cold Climates. 2001. Prepared for the Metropolitan Council by Barr Engineering Company. http://www.metrocouncil.org/environment/Water/BMP/manual.htm

Montana Circulars DEQ-4 and DEQ-8. http://www.deq.state.mt.us/wqinfo/Circulars.asp

Stormwater Management Manual for Eastern Washington. Washington State Department of Ecology. 2004. http://www.ecy.wa.gov/biblio/0410076.html

The Truckee Meadows Structural Controls Design Manual. Kennedy/Jenks Consultants. April 2007 Update. http://www.cityofreno.com/index.aspx?page=366

Urban Stormwater Retrofit Practices, Manual 3, Version 1.0. Center for Watershed Protection. 2007 www.cwp.org

Virginia Stormwater Management Handbook. First Edition 1999. Volume 1. Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation. http://www.dcr.virginia.gov/soil_and_water/stormwat.shtml

Recommended Standard Details

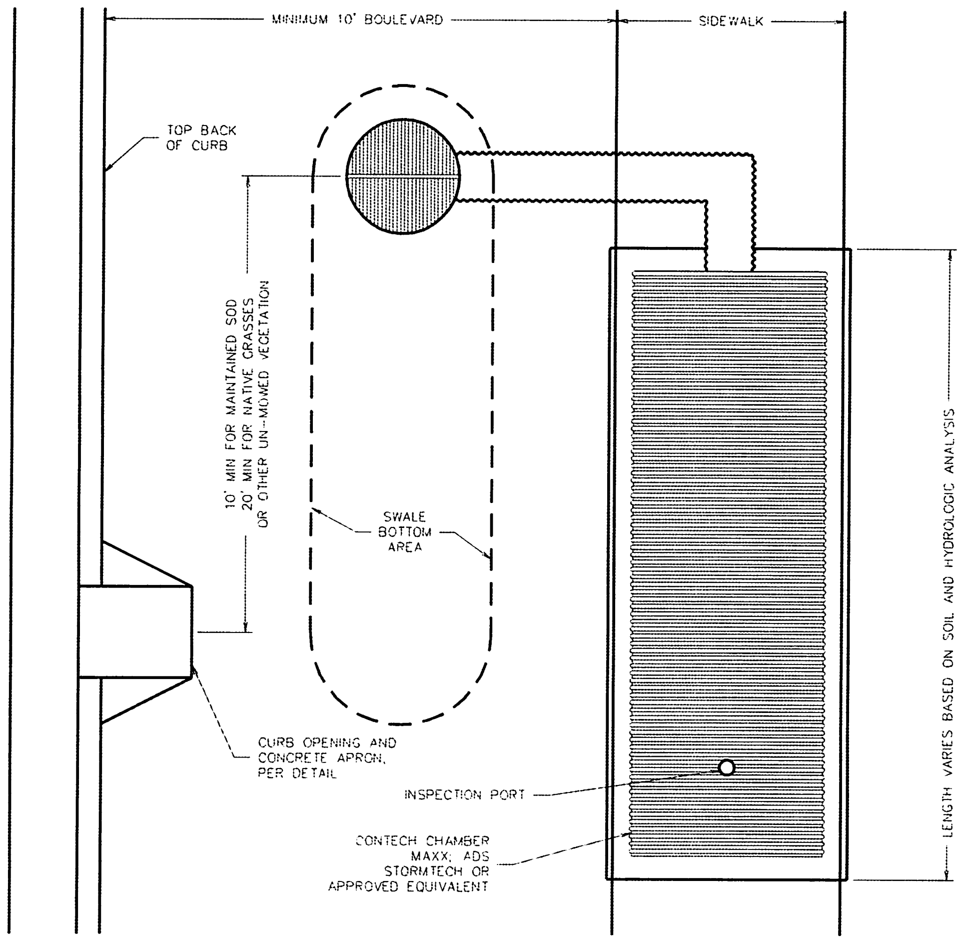
Four draft detail drawings are included with this report, and are recommended for adoption by the City of Missoula.

Subsurface Infiltration Chamber – Boulevard Installation Option
This detail shows a compact configuration of curb cut, grassed swale, catchbasin and infiltration chamber designed for installation in a wide boulevard within a City of Missoula road Right-of-Way. Although a linear configuration is also possible, the configuration shown would better accommodate street trees in the boulevard.

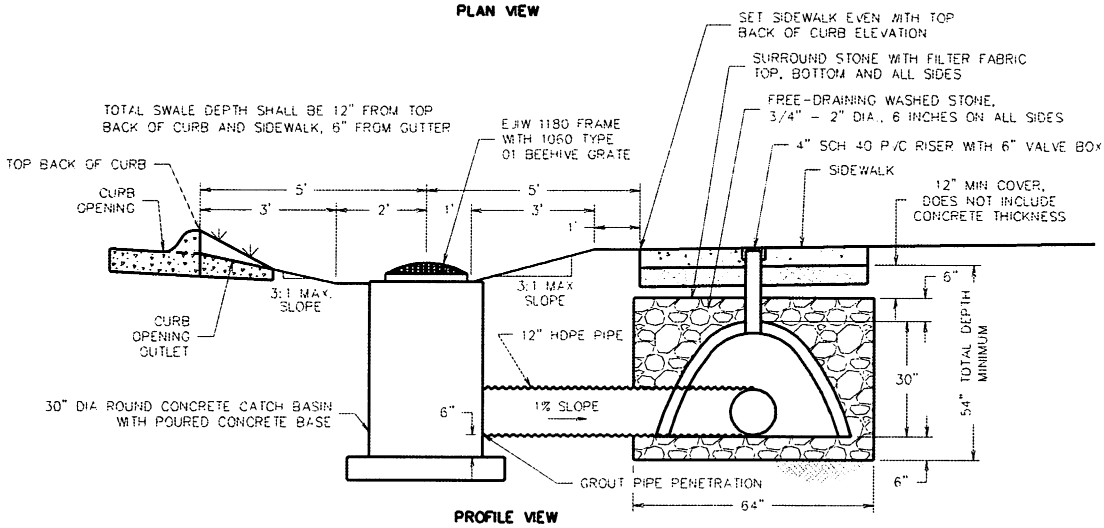
Shallow Subsurface Infiltration with Structural Pretreatment Option
This detail shows infiltration chambers used in conjunction with a Snout-equipped catchbasin. It also shows how two chambers can be manifolded together to make a more compact footprint. It is recommended that this option only be allowed for retrofitting and redevelopment, or by permission of the City Engineer due to site constraints.

Curb Opening Outlet Details
This pair of details is recommended for curb openings and channels crossing sidewalks to convey stormwater to pretreatment and infiltration areas. The purpose of the concrete apron is to avoid channel blockages caused by vegetation.

Parking Lot Rain Garden Application
This detail shows a raingarden using an imported, blended planting soil with a gravel underdrain, and using a grassed filter strip for pretreatment. The detail shows how this configuration could be used within a parking lot.



PLAN VIEW



PROFILE VIEW

SUBSURFACE INFILTRATION CHAMBER – BOULEVARD INSTALLATION OPTION

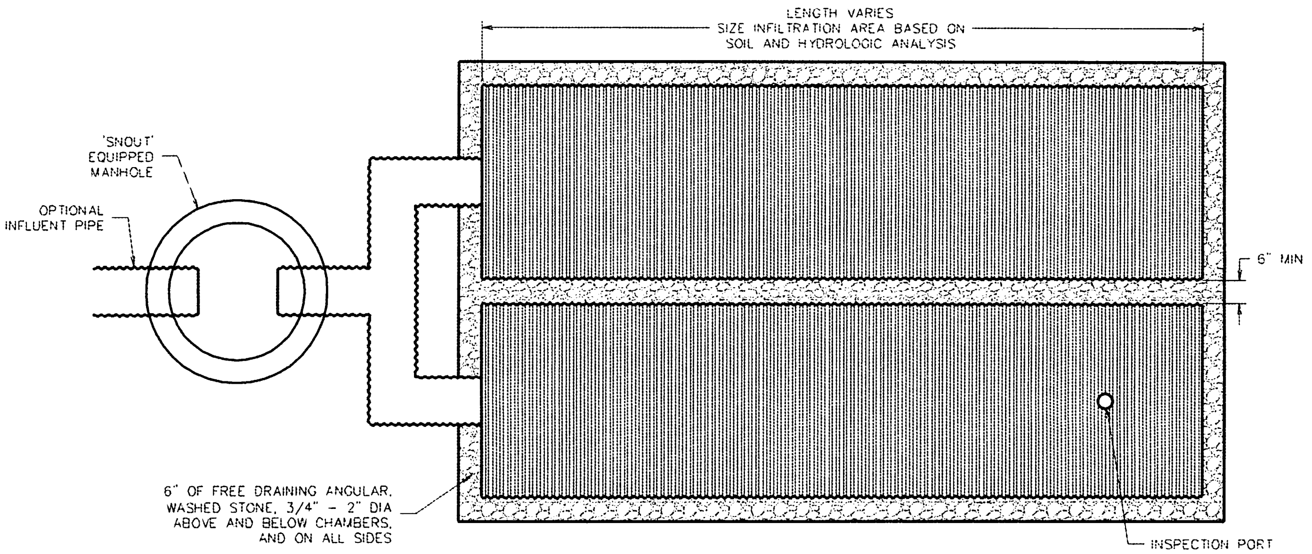
NO SCALE

THE GARDEN CITY MISSOULA HUB OF FIVE VALLEYS Engineering Division	XX XX		
		Adopted ______ Revised ______	STD-XX

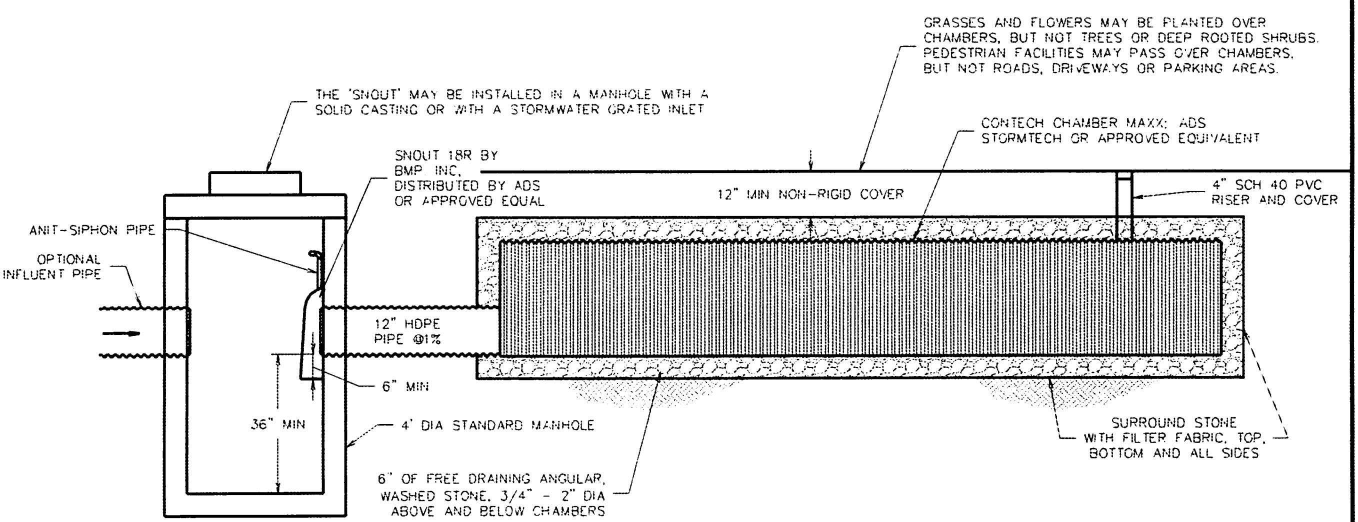
NOTES:

NO MORE THAN 2 CHAMBERS SHALL BE INSTALLED PARALLEL AT A SINGLE LOCATION

THIS OPTION CAN BE USED FOR DRAINAGE AREAS WITH UP TO ONE ACRE OF IMPERVIOUS SURFACE



PLAN VIEW



PROFILE VIEW

SHALLOW SUBSURFACE INFILTRATION WITH STRUCTURAL PRETREATMENT OPTION

NO SCALE

Engineering Division	XX XX	
	Adopted ________ Revised ________	STD-XX

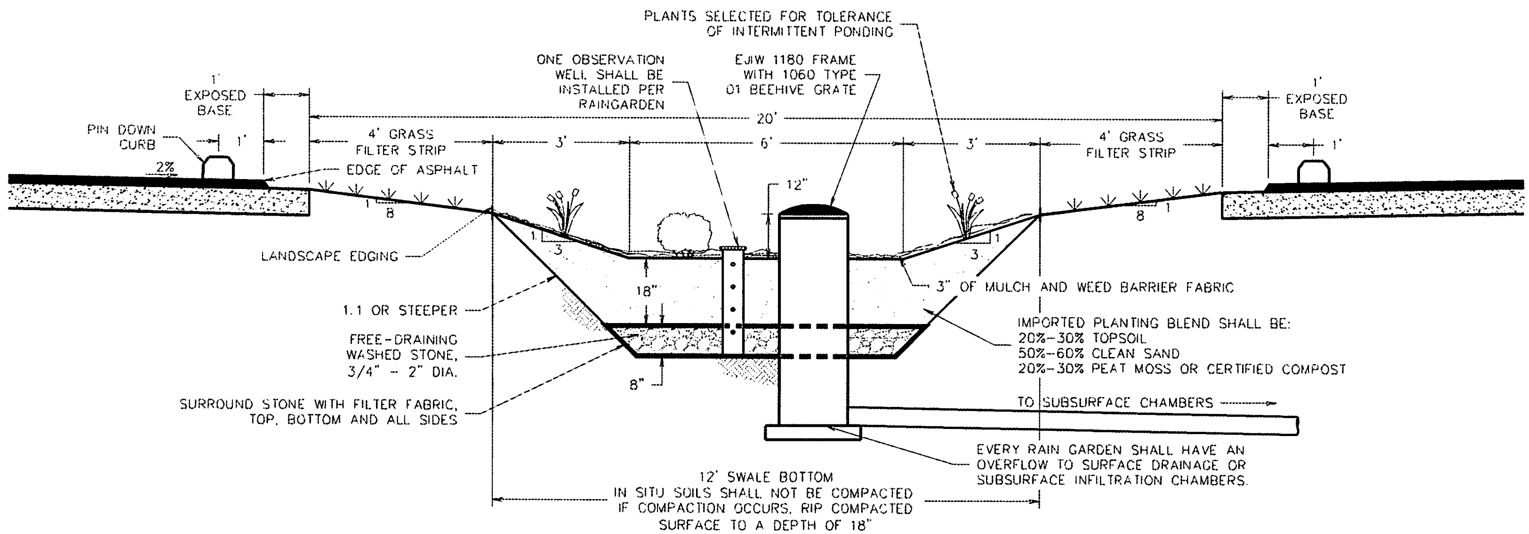
ONE OF THE FOLLOWING OPTIONS SHALL BE CHOSEN FOR GRASS FILTER STRIP INSTALLATION:

1) SOD SHALL BE LAID.

2) THE AREA SHALL BE HYDROSEEDED AND HYDROMULCHED.

3) AN EROSION CONTROL BLANKET, NAG S75BN OR EQUIVALENT, SHALL BE INSTALLED AFTER SEEDING.

SWALE STORAGE VOLUME = 17 FT^3/FT



PARKING LOT RAIN GARDEN APPLICATION

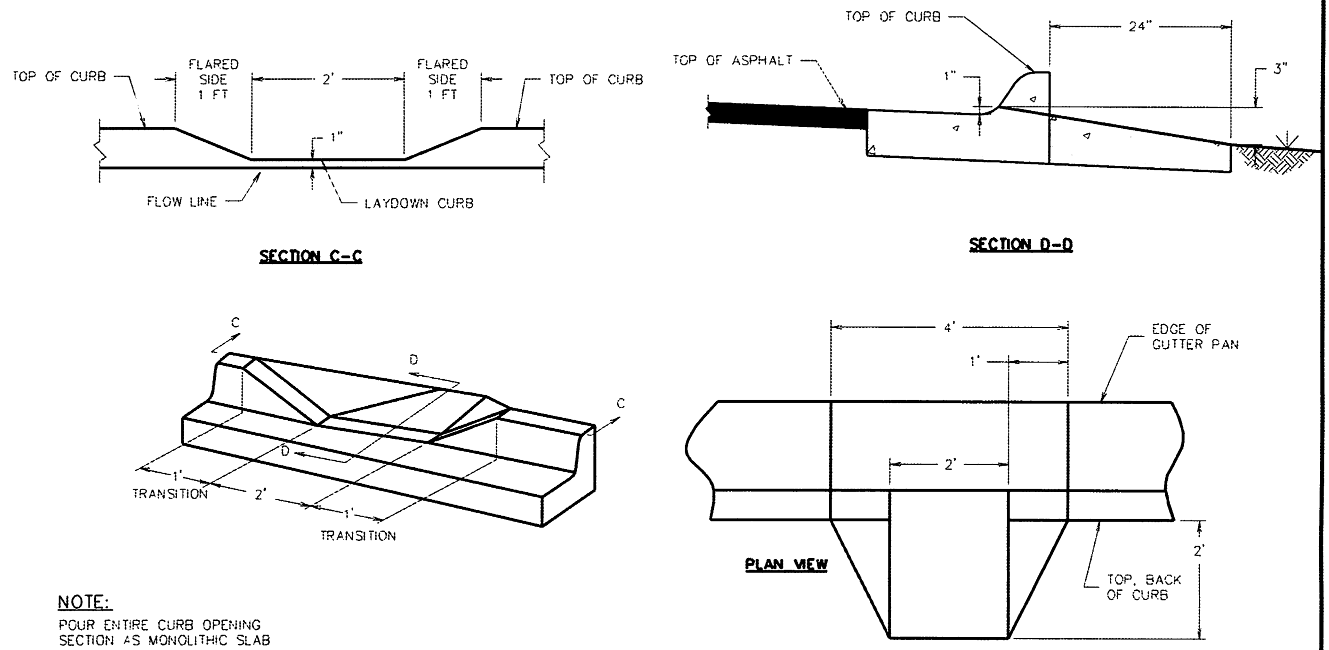
NO SCALE

MISSOULA
THE GARDEN CITY
HUB OF FIVE VALLEYS
Engineering Division

XX
XX

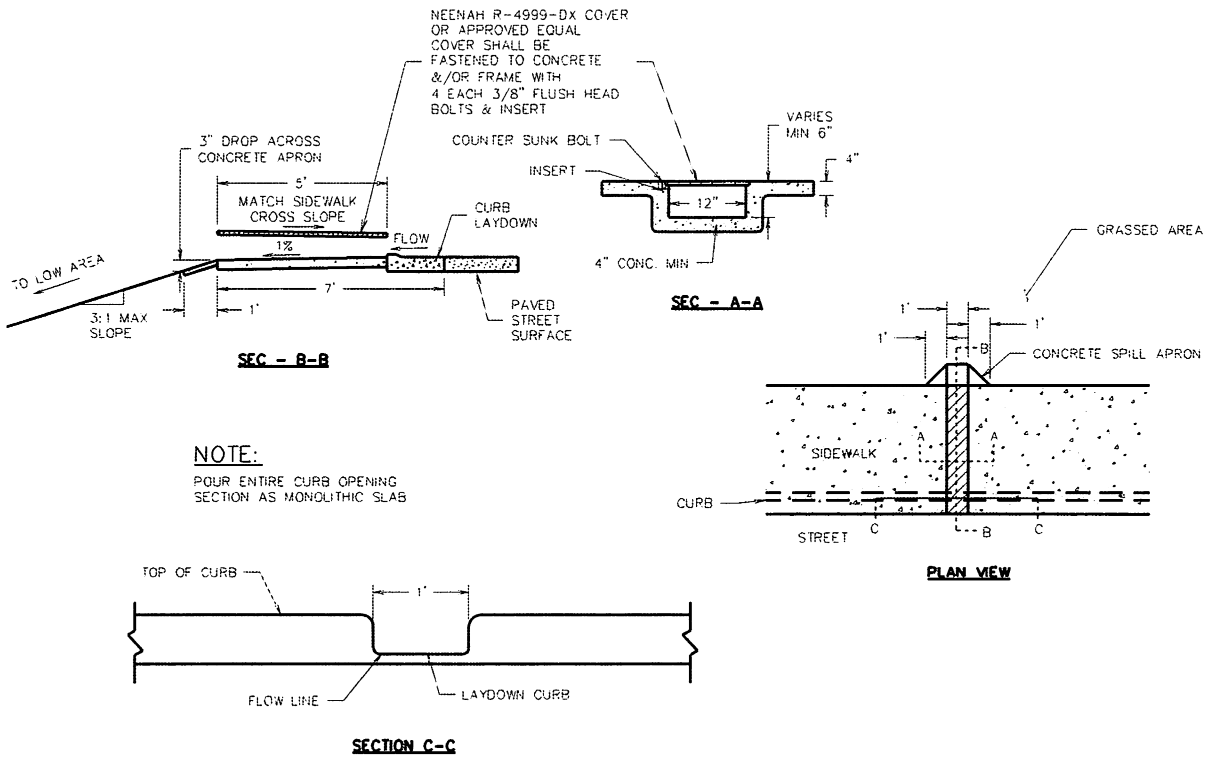
Adopted ______
Revised ______

STD-XX



CURB OPENING OUTLET DETAIL

NO SCALE



CURB OPENING OUTLET DETAIL WITH SIDEWALK

NO SCALE

THE GARDEN CITY MISSOULA HUB OF FIVE VALLEYS Engineering Division	XX XX	Adopted ______ Revised ______	STD-XX

APPENDIX A

COST ESTIMATE AND DESIGN DATA FOR DESIGN EXAMPLES PRESENTED IN THE REPORT

Stormwater Chambers Comparison to Standard Sump

2 Year 1 Hour Storm Depth:	0.42 inches
10 Year 24 Hour Storm Depth	1.8 inches
100 Year 24 Hour Storm Depth	2.6 inches
Chamber Volume:	77 cubic ft.
Chamber Infiltration Area:	34 square ft.
Design Infiltration Rate:	12 inches/hour
One Chamber Infiltration Per Hour:	34 cubic ft.

Chamber Capacity Calculations

Basin	Impervious Area	C*A	2yr 1 hr	10 yr 24 hr Runoff	100 yr 24 hr Runoff	# chambers	1-hr capacity	10-hr capacity	100-year surcharge
	SF	SF	CF	CF	CF		CF	CF	CF
1	10,000	9,000	312	1,339	1,934	4	444	1,668	266

Parking Lot Raingarden Stormwater Infiltration Calculations

2 Year 1 Hour Storm Depth:	0.42 inches
10 Year 24 Hour Storm Depth:	1.8 inches
100 Year 24 Hour Storm Depth:	2.6 inches
Assumed Infiltration Rate:	6 inches/hour
Infiltrative Area	6 SF/LF
Infiltration Volume	3 CF/hour/LF
Storage Volume	17 CF/LF
Parking Lot Imperv. Area:	1 acre
Rational Coefficient	0.9

Storm	Storm depth	Storm volume	available storage	available infiltration	total volume per LF	Required Raingarden Length
	(in)	(CF)	(CF/LF)	(CF/LF)	(CF/LF)	(LF)
2 yr 1 hr	0.42	1,361	17	3	20	68
10 yr 24 hr	2	5,832	17	30	47	124

Opinion of Probable Costs

WGM GROUP
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TEL: 406.728.4611 ▪ FAX: 406.728-2476 ▪ WWW.WGMGROUP.COM

Project: Shallow Groundwater Evaluation
Project No.: 09-07-18
Prepared By: Janet Grove
Approved By:
Date: July 21, 2010
Description: Two Parking Lot Raingardens serving one acre of impervious parking

Item Number	Description	Quantity	Unit	Unit Price	Total
1	Excavation Below Subgrade	163	CY	$ 15.00	$ 2,445.00
2	Drain Rock	20	CY	$ 30.00	$ 600.00
3	Planting Blend	70	CY	$ 30.00	$ 2,100.00
4	Filter Fabric	200	SY	$ 3.00	$ 600.00
5	Weed Barrier Fabric	220	SY	$ 3.00	$ 660.00
7	Bark Mulch, 2-inch depth	220	SY	$ 5.00	$ 1,100.00
6	Topsoil and Seed	1,200	SF	$ 1.00	$ 1,200.00
7	Emergency Overlow Inlets	2	EA	$2,000	$ 4,000.00
8	Infiltration Chambers	3	EA	600.00	1,800.00
				Subtotal	**$ 14,505.00**
	Construction Contingency			10%	$ 1,450.50
	Pre-Design Contingency			15%	$ 2,175.75
	Engineering Design Services (3)			8%	1,160.40
	Engineering Construction Services (4)			8%	1,160.40
				Total	**$ 20,452.05**

Notes: The costs of shrubs and other plants are not included in this estimate

Model Subdivision Stormwater Infiltration Calculations

2 Year 1 Hour Storm Depth:	0.42 inches
10 Year 24 Hour Storm Depth	1.8 inches
100 Year 24 Hour Storm Depth	2.6 inches
Chamber Volume:	77 cubic ft.
Chamber Infiltration Area:	34 square ft.
Design Infiltration Rate:	20 inches/hour
One Chamber Infiltration Per Hour:	57 cubic ft.

Decentralized Infiltration Calculations

Basin	Area	Lots	Halfstreet	Impervious Area	Non Imp Area	C*A	2yr 1 hr	10 yr 24 hr Runoff	100 yr 24 hr Runoff	# chambers	1-hr capacity	10-hr capacity	100-year surcharge
	SF	#	LF	SF	SF	SF	CF	CF	CF		CF	CF	CF
1	38,500	1.5	260	11,200	27,300	15,540	539	2,312	3,339	6	804	3,882	0
2	7,700	0.5	130	4,600	3,100	4,760	165	708	1,023	2	268	1,294	0
3	6,050	0.5	50	3,000	3,050	3,310	115	492	711	1	134	647	64
4	12,100	1	180	7,600	4,500	7,740	269	1,151	1,663	3	402	1,941	0
5	45,100	5	500	30,000	15,100	30,020	1,042	4,466	6,451	10	1340	6,470	0
6	45,100	5	500	30,000	15,100	30,020	1,042	4,466	6,451	10	1340	6,470	0
7	45,100	5	500	30,000	15,100	30,020	1,042	4,466	6,451	10	1340	6,470	0
8	6,050	0.5	100	4,000	2,050	4,010	139	597	862	2	268	1,294	0
9	12,100	1	200	8,000	4,100	8,020	278	1,193	1,723	3	402	1,941	0
									Total:	47			

Centralized Infiltration Calculations

	Area	Lots	Halfstreet	Impervious Area	Non Imp Area	C*A	2yr 1 hr	10 yr 24 hr Runoff	100 yr 24 hr Runoff
	SF	#	LF	SF	SF	SF	CF	CF	CF
Totals	217,800	20	2420	128,400	89,400	133,440	4,632	19,851	28,673
	(= 5 acres)								

Basin volume calculation

Depth (ft)	Width	Length	Area	Avg End Area Volume
0.0	70	100	7000	
0.5	66	96	6336	3334
< 1	62	92	5704	3010
> 1	38	92	3496	
1.5	34	88	2992	1622
2.0	30	84	2520	1378

Total storage volume:	9,344 cubic ft.
Infiltrative surface area:	2,520 square ft.
design infiltration rate:	10 inches/hour
infiltration volume per hour:	2,100 cubic ft.
1 hr. capacity:	11,444 cubic ft.
10 hr. capacity:	30,344 cubic ft.

Emergency Overflow

12% of basin surface area:	302.4 square ft.
Required infiltration:	9 chambers

Opinion of Probable Costs

Project: Shallow Groundwater Evaluation
Project No.: 09-07-18
Prepared By: Janet Grove
Approved By:
Date: July 16, 2010
Description: Centralized Infiltration System

WGM GROUP
Planning ■ Surveying ■ Engineering ■ Design
3021 Palmer Street ■ P.O. Box 16027 ■ Missoula, MT 59808-6027
Tel: 406.728.4611 ■ Fax: 406.728-2476 ■ www.wgmgroup.com

Item Number	Description	Quantity	Unit	Unit Price		Total
1	Infiltration Basin Excavation	346	CY	$10	$	3,460.00
2	Topsoil and seed basin slopes	1,500	SF	$0.50	$	750.00
3	Emergency overflow inlet	1	EA	2,000.00		2,000.00
4	Infiltration Chambers for overflow water	9	EA	600.00		5,400.00
5	Stormceptor pretreatment manhole	1	EA	10,000.00		10,000.00
6	Stormwater MH or Drop Inlet MH	10	EA	2,000.00		20,000.00
7	12" HDPE Storm Drain Pipe	1,170	LF	30.00		35,100.00
				Subtotal	**$**	**76,710.00**
	Construction Contingency			**10%**	**$**	**7,671.00**
	Pre-Design Contingency			**15%**	**$**	**11,506.50**
	Engineering Design Services (3)			**8%**		**6,136.80**
	Engineering Construction Services (4)			**8%**		**6,136.80**
				Total	**$**	**108,161.10**
				Total per Lot	**$**	**5,408.06**

Notes: This design example assumes that no replacement of unsuitable soils is required.

Opinion of Probable Costs

WGM GROUP
PLANNING ■ SURVEYING ■ ENGINEERING ■ DESIGN
3021 PALMER STREET ■ P.O. BOX 16027 ■ MISSOULA, MT 59808-6027
TEL: 406.728.4611 ■ FAX: 406.728-2476 ■ WWW.WGMGROUP.COM

Project: Shallow Groundwater Evaluation
Project No.: 09-07-18
Prepared By: Janet Grove
Approved By:
Date: July 16, 2010
Description: Decentralized Infiltration System

Item Number	Description	Quantity	Unit	Unit Price	Total
1	Boulevard Inlets	9	EA	$1,500	$ 13,500.00
2	Infiltration Chambers	47	EA	600.00	28,200.00
				Subtotal	**$ 41,700.00**
	Construction Contingency			**10%**	**$ 4,170.00**
	Pre-Design Contingency			**15%**	**$ 6,255.00**
	Engineering Design Services (3)			**8%**	**3,336.00**
	Engineering Construction Services (4)			**8%**	**3,336.00**
				Total	**$ 58,797.00**
				Total per Lot	**$ 2,939.85**

Notes: This design example assumes that no replacement of unsuitable soils is required.
Special grading costs and extra concrete costs are included as incidental to boulevard inlets.
The planting of the grassed swales is assumed to cost the same as planting grass in a conventional subdivision.

APPENDIX B

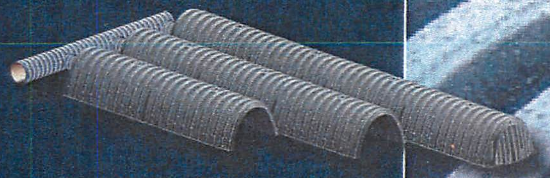
PROPRIETARY PRODUCT INFORMATION

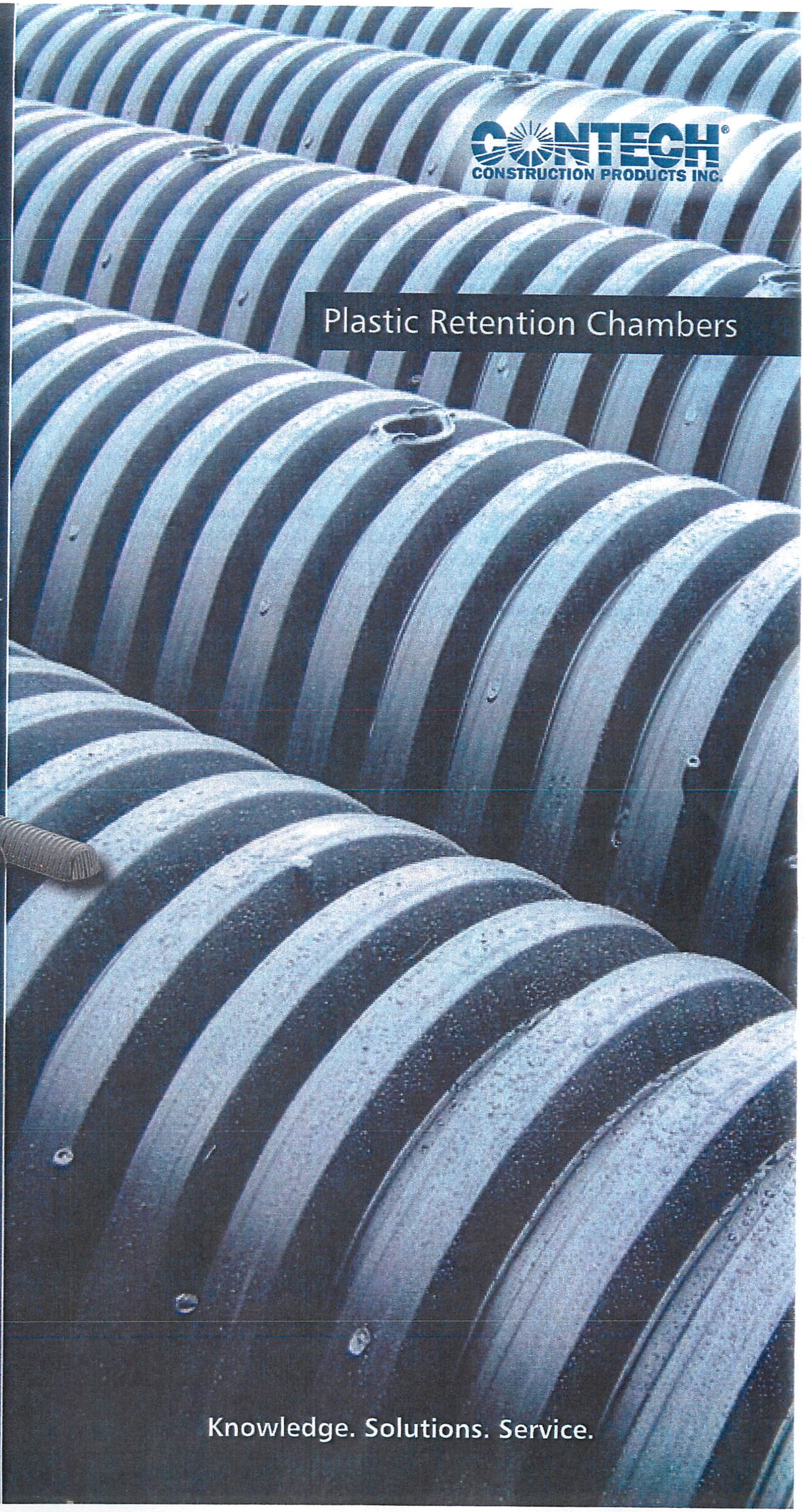
CONTECH
CONSTRUCTION PRODUCTS INC.

Plastic Retention Chambers

Retention/Detention

CHAMBERMaxx™





Knowledge. Solutions. Service.

ChamberMaxx™

ChamberMaxx is the latest in corrugated, open-bottom arch systems designed to economically collect, detain, retain and infiltrate stormwater runoff. The below-grade system maximizes available land for development, and can support traffic loading for installation under parking lots and roadways. The chambers are injection molded using structurally efficient and corrosive-resistant polypropylene resin.

In retention applications, the ChamberMaxx system effectively recharges groundwater to achieve reduced discharge objectives, including **Low Impact Development (LID)**, and **Leadership Energy and Environmental Design (LEED)**. The system is most effective on sites where the depth from finished grade to storm sewer outlet is less than 54-inches (1.37-meters). For sites with deeper applications refer to the other CONTECH family of retention/detention products, such as concrete arches and corrugated metal pipe systems.

With 49 ft^3 (1.39 m^3) of available storage per chamber, ChamberMaxx is the most cost efficient of its kind. Innovative sub-corrugations provide greater strength and the chambers utilize a resin efficient design. A short height profile optimizes stormwater storage on shallow sites. Lightweight chambers allow for placement without the use of heavy equipment.

Install a CONTECH pre-treatment water quality unit, upstream of the ChamberMaxx system for the highest level of performance at the lowest cost. This combined water quality and quantity system reduces maintenance costs by capturing the pollutants in one confined location, and extends the performance life of the overall system by reducing occlusion of the void space within the surrounding stone.

CONTECH also offers the optional ChamberMaxx Containment Row. Contact your local representative for assistance in selecting the most efficient pre-treatment solution.

Going Green?
Looking for LID Solutions?
Need LEED Credits?

Specify ChamberMaxx on Your Next Project!

Performance Testing

ChamberMaxx has undergone a thorough structural analysis by structural engineers and full scale in-ground field burial tests have been performed. The chambers are structurally designed to exceed HS-20/HS-25 live loads in accordance with AASHTO (Section 12) LRFD design specifications for stormwater chambers. Structural performance is dependent on proper installation per the ChamberMaxx installation guidelines.

Design

ChamberMaxx has a multitude of layout and configuration options. Contact your local representative for assistance optimizing your system to meet your site specific design requirements.

For flow routing see the ChamberMaxx stage-storage curve (available in this brochure) or download the ChamberMaxx stage-storage calculator at www.contechstormwater.com.

Design Your Own Detention System

Our DYODS™ (Design Your Own Detention System) sizing calculator, makes it is easy to design the right ChamberMaxx for your site.

Visit www.contechstormwater.com/dyods to:

- Size system and lay out footprint
- Quantify construction materials
- Receive graphic plan view layout

HydroCAD®

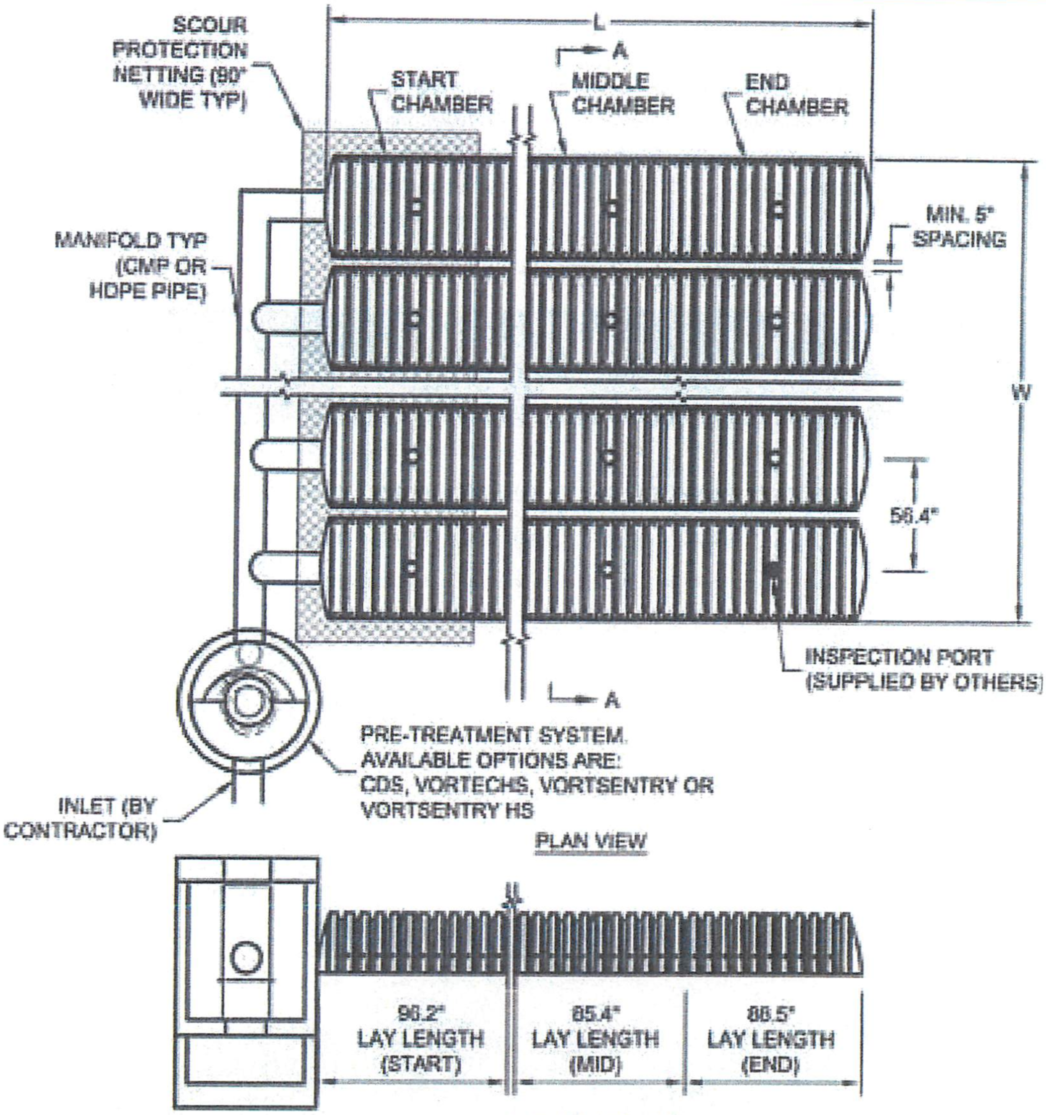
ChamberMaxx is supported in HydroCAD — a computer aided design tool for modeling stormwater runoff available from our partners at HydroCAD Software LLC.

- Download at www.hydrocad.net
- Easy modeling for stormwater flows — automatic storage calculations
- Simple to use — just select CONTECH products from drop-down menu
- Effortlessly compare systems with real time evaluation of hydraulic differences

DYODS™
Design Your Own Detention System

HydroCAD® Stormwater Modeling

Make your job easier with our design tools!

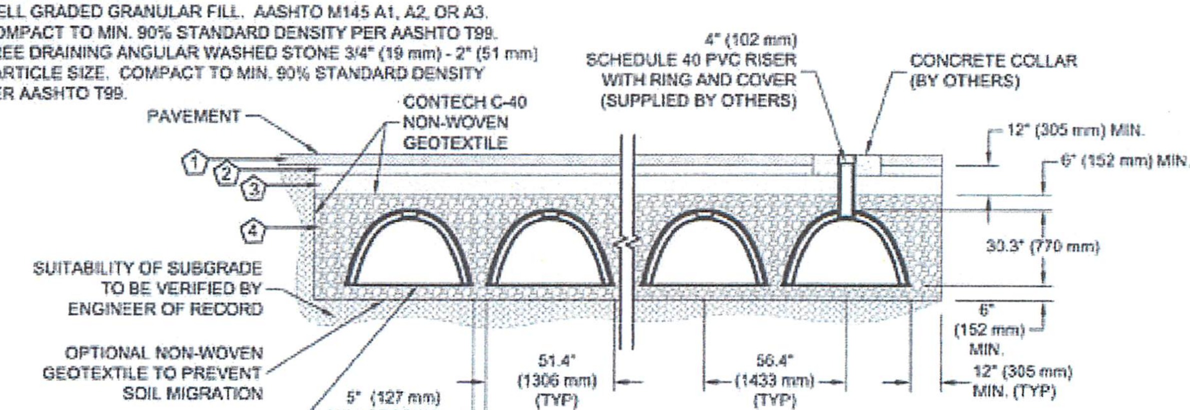


ELEVATION VIEW

TYPICAL LAYOUT

KEY

1. FLEXIBLE PAVEMENT.
2. GRANULAR ROAD BASE.
3. WELL GRADED GRANULAR FILL. AASHTO M145 A1, A2, OR A3. COMPACT TO MIN. 90% STANDARD DENSITY PER AASHTO T99.
4. FREE DRAINING ANGULAR WASHED STONE 3/4" (19 mm) - 2" (51 mm) PARTICLE SIZE. COMPACT TO MIN. 90% STANDARD DENSITY PER AASHTO T99.



SECTION A-A
(H20/H25 LIVE LOAD) PER AASHTO 12

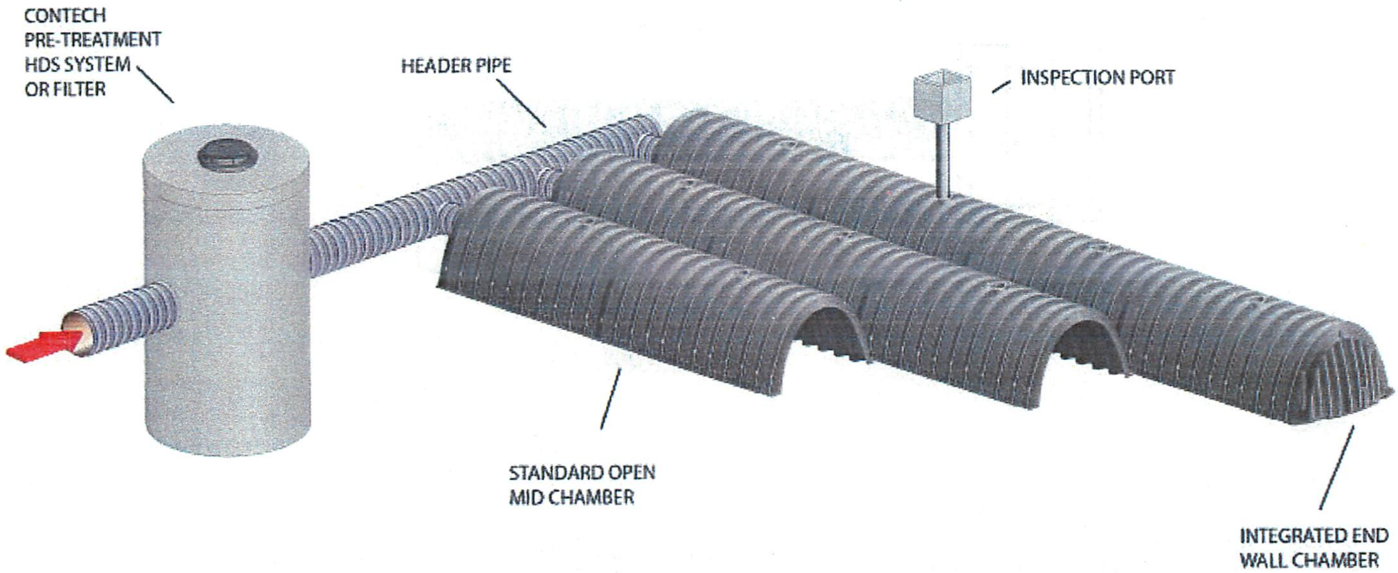
Sizing

The ChamberMaxx system combines middle chambers, which are open on both ends, with start and end chambers, which include an integral end wall. All chambers have sidewall perforations that allows water to equalize throughout the system.

ChamberMaxx utilizes a header manifold system that can be manufactured from various materials. Commonly utilized header pipe materials are corrugated metal pipe (CMP) and HDPE pipe, and are available from CONTECH in a single package. The start and end chambers can accept up to a 24-inch diameter (0.61 meter) inlet pipe.

Chamber Part	Width		Height		Weight		Actual Length		*Installed Length		Storage Volume		*Installed Storage Volume	
	in	(m)	in	(m)	lbs	(kg)	in	(m)	in	(m)	cf	(m^3)	cf	(m^3)
Start	51.4	(1.31)	30.3	(0.77)	85.0	(38.55)	98.4	(2.50)	96.2	(2.44)	52.5	(1.48)	78.7	(2.22)
Middle	51.4	(1.31)	30.3	(0.77)	77.0	(34.92)	91.0	(2.31)	85.4	(2.17)	49.3	(1.40)	76.7	(2.17)
End	51.4	(1.31)	30.3	(0.77)	76.0	(34.47)	92.0	(2.34)	88.5	(2.25)	48.2	(1.36)	76.1	(2.15)

*Six-inches (0.15 meters) of stone below and above chamber and 5-inch (0.13 meters) chamber spacing and 40% stone porosity.

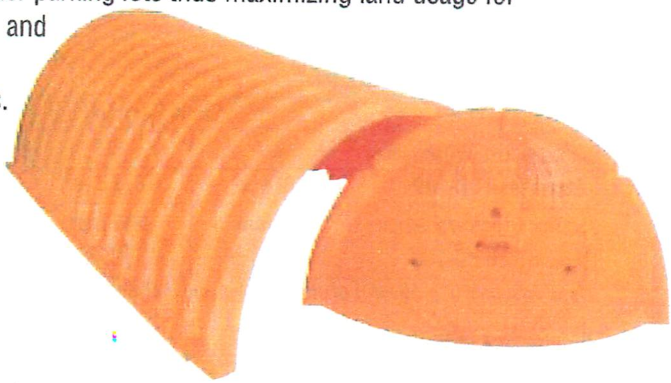


CHAMBERMaxx™

StormTech SC-740 Chamber

Designed to meet the most stringent industry performance standards for superior structural integrity while providing designers with a cost-effective method to save valuable land and protect water resources. The StormTech system is designed primarily to be used under parking lots thus maximizing land usage for commercial and municipal applications.

StormTech®
Detention • Retention • Recharge
Subsurface Stormwater Management℠



StormTech SC-740 Chamber
(not to scale)

Nominal Chamber Specifications

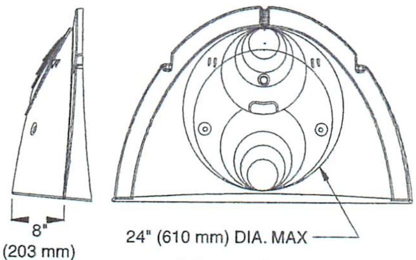
Size (L x W x H)
85.4" x 51.0" x 30.0"
(2170 x 1295 x 762 mm)

Chamber Storage
45.9 ft³ (1.30 m³)

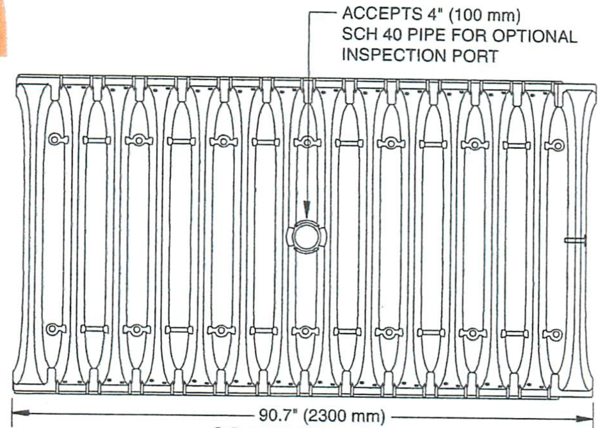
Minimum Installed Storage*
74.9 ft³ (2.12 m³)

Weight
74.0 lbs (33.6 kg)

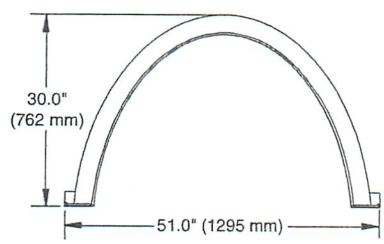
Shipping
30 chambers/pallet
60 end caps/pallet
12 pallets/truck

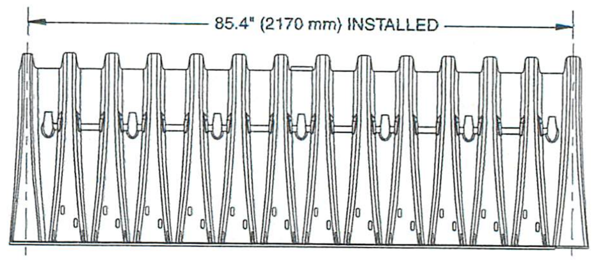


SC-740 End Cap

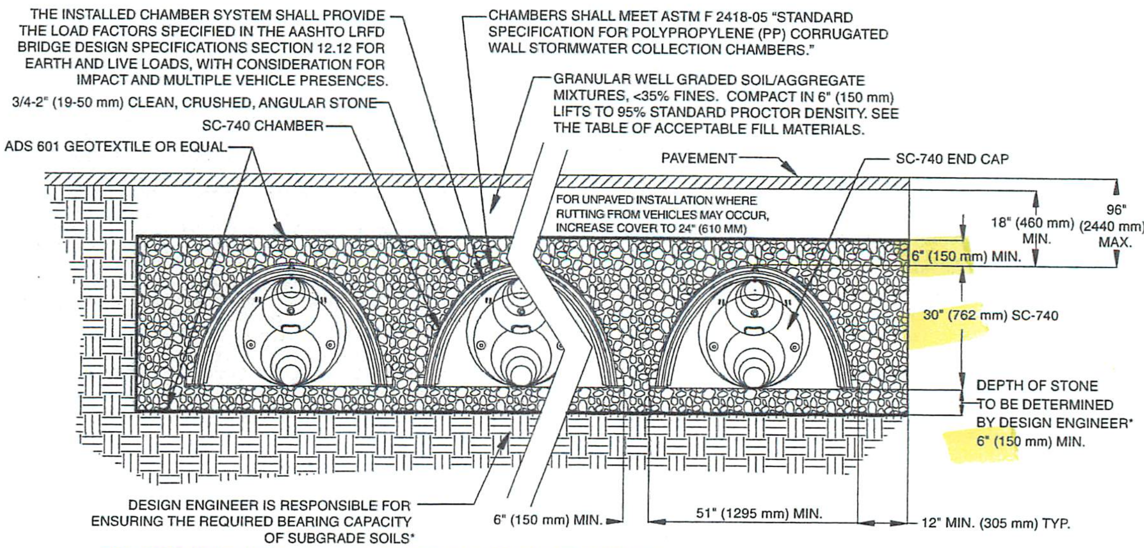


SC-740 Chamber





Typical Cross Section Detail
(not to scale)



THIS CROSS SECTION DETAILS THE REQUIREMENTS NECESSARY TO SATISFY THE LOAD FACTORS SPECIFIED IN THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS SECTION 12.12 FOR EARTH AND LIVE LOADS USING STORMTECH CHAMBERS

MADE IN THE U.S.A.

SC-740 Cumulative Storage Volumes Per Chamber

Assumes 40% Stone Porosity. Calculations are Based Upon a 6" (152 mm) Stone Base Under the Chambers.

Depth of Water in System Inches (mm)	Cumulative Chamber Storage Ft³ (m³)	Total System Cumulative Storage Ft³ (m³)
42 (1067)	↑ 45.90 (1.300)	74.90 (2.121)
41 (1041)	45.90 (1.300)	73.77 (2.089)
40 (1016)	Stone 45.90 (1.300)	72.64 (2.057)
39 (991)	Cover 45.90 (1.300)	71.52 (2.025)
38 (965)	45.90 (1.300)	70.39 (1.993)
37 (948)	↓ 45.90 (1.300)	69.26 (1.961)
36 (914)	45.90 (1.300)	68.14 (1.929)
35 (889)	45.85 (1.298)	66.98 (1.897)
34 (864)	45.69 (1.294)	65.75 (1.862)
33 (838)	45.41 (1.286)	64.46 (1.825)
32 (813)	44.81 (1.269)	62.97 (1.783)
31 (787)	44.01 (1.246)	61.36 (1.737)
30 (762)	43.06 (1.219)	59.66 (1.689)
29 (737)	41.98 (1.189)	57.89 (1.639)
28 (711)	40.80 (1.155)	56.05 (1.587)
27 (686)	39.54 (1.120)	54.17 (1.534)
26 (660)	38.18 (1.081)	52.23 (1.479)
25 (635)	36.74 (1.040)	50.23 (1.422)
24 (610)	35.22 (0.977)	48.19 (1.365)
23 (584)	33.64 (0.953)	46.11 (1.306)
22 (559)	31.99 (0.906)	44.00 (1.246)
21 (533)	30.29 (0.858)	41.85 (1.185)
20 (508)	28.54 (0.808)	39.67 (1.123)
19 (483)	26.74 (0.757)	37.47 (1.061)
18 (457)	24.89 (0.705)	35.23 (0.997)
17 (432)	23.00 (0.651)	32.96 (0.939)
16 (406)	21.06 (0.596)	30.68 (0.869)
15 (381)	19.09 (0.541)	28.36 (0.803)
14 (356)	17.08 (0.484)	26.03 (0.737)
13 (330)	15.04 (0.426)	23.68 (0.670)
12 (305)	12.97 (0.367)	21.31 (0.608)
11 (279)	10.87 (0.309)	18.92 (0.535)
10 (254)	8.74 (0.247)	16.51 (0.468)
9 (229)	6.58 (0.186)	14.09 (0.399)
8 (203)	4.41 (0.125)	11.66 (0.330)
7 (178)	2.21 (0.063)	9.21 (0.264)
6 (152)	↑ 0	6.76 (0.191)
5 (127)	0	5.63 (0.160)
4 (102)	Stone Foundation 0	4.51 (0.125)
3 (76)	0	3.38 (0.095)
2 (51)	0	2.25 (0.064)
1 (25)	↓ 0	1.13 (0.032)

Note: Add 1.13 cu. ft. (0.032 m³) of storage for each additional inch (25 mm) of stone foundation.

Storage Volume Per Chamber

	Bare Chamber Storage	Chamber and Stone Stone Foundation Depth in. (mm)		
	ft³ (m³)	6 (150)	12 (305)	18 (460)
StormTech SC-740	45.9 (1.3)	74.9 (2.1)	81.7 (2.3)	88.4 (2.5)

Note: Storage volumes are in cubic feet per chamber. Assumes 40% porosity for the stone plus the chamber volume.

Amount of Stone Per Chamber

	Stone Foundation Depth		
ENGLISH TONS (CUBIC YARDS)	6"	12"	18"
StormTech SC-740	3.8 (2.8 yd³)	4.6 (3.3 yd³)	5.5 (3.9 yd³)
METRIC KILOGRAMS (METER³)	**150 mm**	**305 mm**	**460 mm**
StormTech SC-740	3450 (2.1 m³)	4170 (2.5 m³)	4490 (3.0 m³)

Note: Assumes 6" (150 mm) of stone above, and between chambers.

Volume of Excavation Per Chamber

	Stone Foundation Depth		
	6" (150 mm)	12" (305 mm)	18" (460 mm)
StormTech SC-740	5.5 (4.2)	6.2 (4.7)	6.8 (5.2)

Note: Volumes are in cubic yards (cubic meters) per chamber. Assumes 6" (150 mm) of separation between chamber rows and 18" (460 mm) of cover. The volume of excavation will vary as the depth of the cover increases.

STANDARD LIMITED WARRANTY OF STORMTECH LLC ("STORMTECH"): PRODUCTS

(A) This Limited Warranty applies solely to the StormTech chambers and endplates manufactured by StormTech and sold to the original purchaser (the "Purchaser"). The chambers and endplates are collectively referred to as the "Products."

(B) The structural integrity of the Products, when installed strictly in accordance with StormTech's written installation instructions at the time of installation, are warranted to the Purchaser against defective materials and workmanship for one (1) year from the date of purchase. Should a defect appear in the Limited Warranty period, the Purchaser shall provide StormTech with written notice of the alleged defect at StormTech's corporate headquarters within ten (10) days of the discovery of the defect. The notice shall describe the alleged defect in reasonable detail. StormTech agrees to supply replacements for those Products determined by StormTech to be defective and covered by this Limited Warranty. The supply of replacement products is the sole remedy of the Purchaser for breaches of this Limited Warranty. StormTech's liability specifically excludes the cost of removal and/or installation of the Products.

(C) **THIS LIMITED WARRANTY IS EXCLUSIVE. THERE ARE NO OTHER WARRANTIES WITH RESPECT TO THE PRODUCTS, INCLUDING NO IMPLIED WARRANTIES OF MERCHANT-ABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE.**

(D) This Limited Warranty only applies to the Products when the Products are installed in a single layer. **UNDER NO CIRCUMSTANCES, SHALL THE PRODUCTS BE INSTALLED IN A MULTI-LAYER CONFIGURATION.**

(E) No representative of StormTech has the authority to change this Limited Warranty in any manner or to extend this Limited Warranty. This Limited Warranty does not apply to any person other than to the Purchaser.

(F) Under no circumstances shall StormTech be liable to the Purchaser or to any third party for product liability claims; claims arising from the design, shipment, or installation of the Products, or the cost of other goods or services related to the purchase and installation of the Products. For this Limited Warranty to apply, the Products must be installed in accordance with all site conditions required by state and local codes; all other applicable laws; and StormTech's written installation instructions.

(G) **THE LIMITED WARRANTY DOES NOT EXTEND TO INCIDENTAL, CONSEQUENTIAL, SPECIAL OR INDIRECT DAMAGES. STORMTECH SHALL NOT BE LIABLE FOR PENALTIES OR LIQUIDATED DAMAGES, INCLUDING LOSS OF PRODUCTION AND PROFITS; LABOR AND MATERIALS; OVERHEAD COSTS; OR OTHER LOSS OR EXPENSE INCURRED BY THE PURCHASER OR ANY THIRD PARTY. SPECIFICALLY EXCLUDED FROM LIMITED WARRANTY COVERAGE ARE DAMAGE TO THE PRODUCTS ARISING FROM ORDINARY WEAR AND TEAR; ALTERATION, ACCIDENT, MISUSE, ABUSE OR NEGLECT; THE PRODUCTS BEING SUBJECTED TO VEHICLE TRAFFIC OR OTHER CONDITIONS WHICH ARE NOT PERMITTED BY STORMTECH'S WRITTEN SPECIFICATIONS OR INSTALLATION INSTRUCTIONS; FAILURE TO MAINTAIN THE MINIMUM GROUND COVERS SET FORTH IN THE INSTALLATION INSTRUCTIONS; THE PLACEMENT OF IMPROPER MATERIALS INTO THE PRODUCTS; FAILURE OF THE PRODUCTS DUE TO IMPROPER SITING OR IMPROPER SIZING; OR ANY OTHER EVENT NOT CAUSED BY STORMTECH. THIS LIMITED WARRANTY REPRESENTS STORMTECH'S SOLE LIABILITY TO THE PURCHASER FOR CLAIMS RELATED TO THE PRODUCTS, WHETHER THE CLAIM IS BASED UPON CONTRACT, TORT, OR OTHER LEGAL THEORY.**

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Stormceptor®

Stormceptor Sizing Detailed Report

PCSWMM for Stormceptor

Project Information

Date	10/14/2009
Project Name	Missoula Sample Project
Project Number	N/A
Location	Missoula, MT

Stormwater Quality Objective

This report outlines how Stormceptor System can achieve a defined water quality objective through the removal of total suspended solids (TSS). Attached to this report is the Stormceptor Sizing Summary.

Stormceptor System Recommendation

The Stormceptor System model STC 450i achieves the water quality objective removing 85% TSS for a Fine (organics, silts and sand) particle size distribution and 88% runoff volume.

The Stormceptor System

The Stormceptor oil and sediment separator is sized to treat stormwater runoff by removing pollutants through gravity separation and flotation. Stormceptor's patented design generates positive TSS removal for all rainfall events, including large storms. Significant levels of pollutants such as heavy metals, free oils and nutrients are prevented from entering natural water resources and the re-suspension of previously captured sediment (scour) does not occur.

Stormceptor provides a high level of TSS removal for small frequent storm events that represent the majority of annual rainfall volume and pollutant load. Positive treatment continues for large infrequent events, however, such events have little impact on the average annual TSS removal as they represent a small percentage of the total runoff volume and pollutant load.

Stormceptor is the only oil and sediment separator on the market sized to remove TSS for a wide range of particle sizes, including fine sediments (clays and silts), that are often overlooked in the design of other stormwater treatment devices.

Small storms dominate hydrologic activity, US EPA reports
"Early efforts in stormwater management focused on flood events ranging from the 2-yr to the 100-yr storm. Increasingly stormwater professionals have come to realize that small storms (i.e. < 1 in. rainfall) dominate watershed hydrologic parameters typically associated with water quality management issues and BMP design. These small storms are responsible for most annual urban runoff and groundwater recharge. Likewise, with the exception of eroded sediment, they are responsible for most pollutant washoff from urban surfaces. Therefore, the small storms are of most concern for the stormwater management objectives of ground water recharge, water quality resource protection and thermal impacts control."
"Most rainfall events are much smaller than design storms used for urban drainage models. In any given area, most frequently recurrent rainfall events are small (less than 1 in. of daily rainfall)."
"Continuous simulation offers possibilities for designing and managing BMPs on an individual site-by-site basis that are not provided by other widely used simpler analysis methods. Therefore its application and use should be encouraged."
– US EPA Stormwater Best Management Practice Design Guide, Volume 1 – General Considerations, 2004

Design Methodology

Each Stormceptor system is sized using PCSWMM for Stormceptor, a continuous simulation model based on US EPA SWMM. The program calculates hydrology from up-to-date local historical rainfall data and specified site parameters. With US EPA SWMM's precision, every Stormceptor unit is designed to achieve a defined water quality objective.

The TSS removal data presented follows US EPA guidelines to reduce the average annual TSS load. Stormceptor's unit process for TSS removal is settling. The settling model calculates TSS removal by analyzing (summary of analysis presented in Appendix 2):

- Site parameters
- Continuous historical rainfall, including duration, distribution, peaks (Figure 1)
- Interevent periods
- Particle size distribution
- Particle settling velocities (Stokes Law, corrected for drag)
- TSS load (Figure 2)
- Detention time of the system

The Stormceptor System maintains continuous positive TSS removal for all influent flow rates. Figure 3 illustrates the continuous treatment by Stormceptor throughout the full range of storm events analyzed. It is clear that large events do not significantly impact the average annual TSS removal. There is no decline in cumulative TSS removal, indicating scour does not occur as the flow rate increases.

Stormceptor®

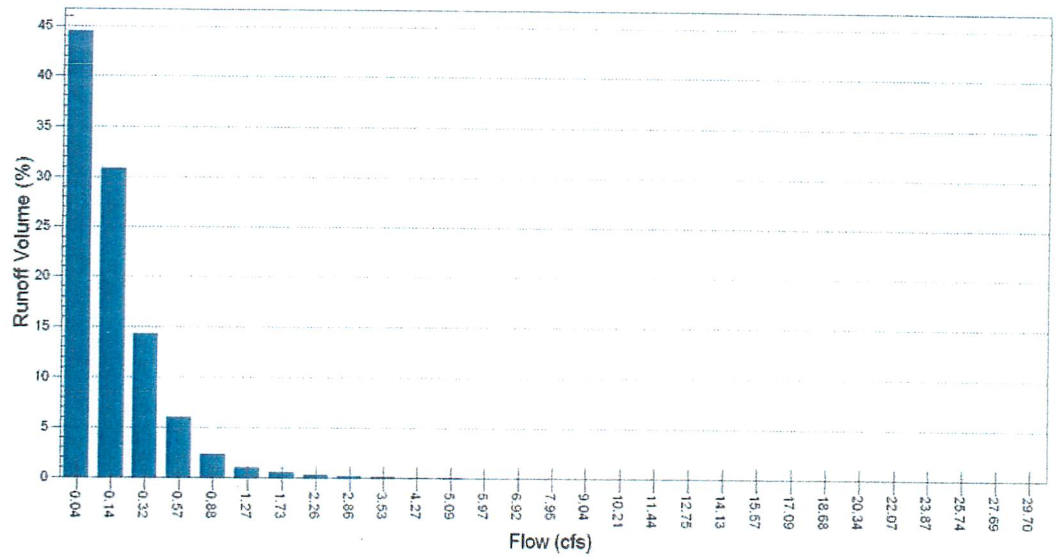


Figure 1. Runoff Volume by Flow Rate for MISSOULA INTL AP – MT 5745, 1948 to 2005 for 1 ac, 100% impervious. Small frequent storm events represent the majority of annual rainfall volume. Large infrequent events have little impact on the average annual TSS removal, as they represent a small percentage of the total annual volume of runoff.

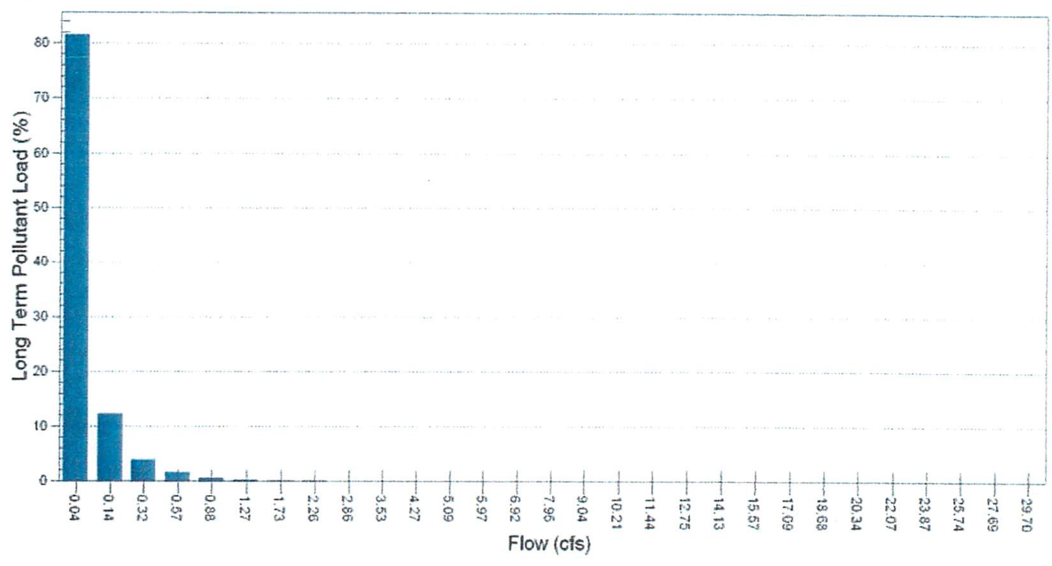
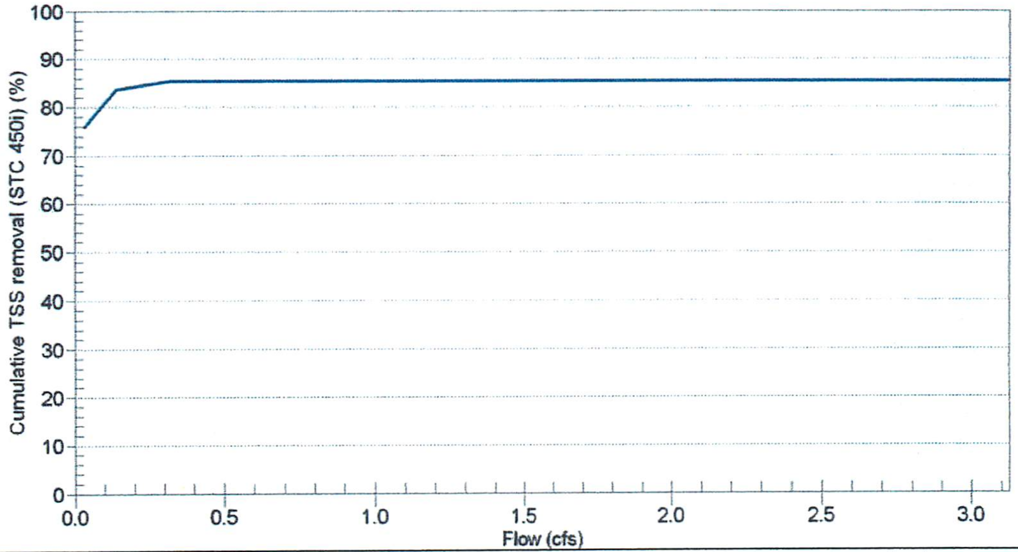


Figure 2. Long Term Pollutant Load by Flow Rate for MISSOULA INTL AP – 5745, 1948 to 2005 for 1 ac, 100% impervious. The majority of the annual pollutant load is transported by small frequent storm events. Conversely, large infrequent events carry an insignificant percentage of the total annual pollutant load.



Stormceptor Model	STC 450i	Drainage Area (ac)	1
TSS Removal (%)	85	Impervious (%)	100

Figure 3. Cumulative TSS Removal by Flow Rate for MISSOULA INTL AP – 5745, 1948 to 2005. Stormceptor continuously removes TSS throughout the full range of storm events analyzed. Note that large events do not significantly impact the average annual TSS removal. Therefore no decline in cumulative TSS removal indicates scour does not occur as the flow rate increases.

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Appendix 1
Stormceptor Design Summary

Project Information

Date	10/14/2009
Project Name	Missoula Sample Project
Project Number	N/A
Location	Missoula, MT

Designer Information

Company	WGM Group
Contact	Janet Grove

Notes

N/A

Drainage Area

Total Area (ac)	1
Imperviousness (%)	100

The Stormceptor System model STC 450i achieves the water quality objective removing 85% TSS for a Fine (organics, silts and sand) particle size distribution and 88% runoff volume.

Rainfall

Name	MISSOULA INTL AP
State	MT
ID	5745
Years of Records	1948 to 2005
Latitude	46°55'15"N
Longitude	114°5'33"W

Water Quality Objective

TSS Removal (%)	80
Runoff Volume (%)	85

Upstream Storage

Storage (ac-ft)	Discharge (cfs)
0	0

Stormceptor Sizing Summary

Stormceptor Model	TSS Removal %	Runoff Volume %
STC 450i	85	88
STC 900	91	96
STC 1200	91	96
STC 1800	92	96
STC 2400	94	99
STC 3600	94	99
STC 4800	96	99
STC 6000	96	99
STC 7200	97	100
STC 11000	98	100
STC 13000	98	100

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Particle Size Distribution

Removing silt particles from runoff ensures that the majority of the pollutants, such as hydrocarbons and heavy metals that adhere to fine particles, are not discharged into our natural water courses. The table below lists the particle size distribution used to define the annual TSS removal.

Fine (organics, silts and sand)								
Particle Size µm	Distribution %	Specific Gravity	Settling Velocity ft/s		Particle Size µm	Distribution %	Specific Gravity	Settling Velocity ft/s
20	20	1.3	0.0013					
60	20	1.8	0.0051					
150	20	2.2	0.0354					
400	20	2.65	0.2123					
2000	20	2.65	0.9417					

Stormceptor Design Notes

- Stormceptor performance estimates are based on simulations using PCSWMM for Stormceptor.
- Design estimates listed are only representative of specific project requirements based on total suspended solids (TSS) removal.
- Only the STC 450i is adaptable to function with a catch basin inlet and/or inline pipes.
- Only the Stormceptor models STC 450i to STC 7200 may accommodate multiple inlet pipes.
- Inlet and outlet invert elevation differences are as follows:

Inlet and Outlet Pipe Invert Elevations Differences

Inlet Pipe Configuration	STC 450i	STC 900 to STC 7200	STC 11000 to STC 16000
Single inlet pipe	3 in.	1 in.	3 in.
Multiple inlet pipes	3 in.	3 in.	Only one inlet pipe.

- Design estimates are based on stable site conditions only, after construction is completed.
- Design estimates assume that the storm drain is not submerged during zero flows. For submerged applications, please contact your local Stormceptor representative.
- Design estimates may be modified for specific spills controls. Please contact your local Stormceptor representative for further assistance.
- For pricing inquiries or assistance, please contact Rinker Materials 1 (800) 909-7763 www.rinkerstormceptor.com

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Appendix 2
Summary of Design Assumptions

SITE DETAILS

Site Drainage Area

Total Area (ac)	1	Imperviousness (%)	100

Surface Characteristics

Width (ft)	417
Slope (%)	2
Impervious Depression Storage (in.)	0.02
Pervious Depression Storage (in.)	0.2
Impervious Manning's n	0.015
Pervious Manning's n	0.25

Infiltration Parameters

Horton's equation is used to estimate infiltration

Max. Infiltration Rate (in/hr)	2.44
Min. Infiltration Rate (in/hr)	0.4
Decay Rate (s^{-1})	0.00055
Regeneration Rate (s^{-1})	0.01

Maintenance Frequency

Sediment build-up reduces the storage volume for sedimentation. Frequency of maintenance is assumed for TSS removal calculations.

Maintenance Frequency (months)	12

Evaporation

Daily Evaporation Rate (inches/day)	0.1

Dry Weather Flow

Dry Weather Flow (cfs)	No

Winter Months

Winter Infiltration	False

Upstream Attenuation

Stage-storage and stage-discharge relationship used to model attenuation upstream of the Stormceptor System is identified in the table below.

Storage ac-ft	Discharge cfs
0	0

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PARTICLE SIZE DISTRIBUTION

Particle Size Distribution

Removing fine particles from runoff ensures the majority of pollutants, such as heavy metals, hydrocarbons, free oils and nutrients are not discharged into natural water resources. The table below identifies the particle size distribution selected to define TSS removal for the design of the Stormceptor System.

Fine (organics, silts and sand)								
Particle Size µm	Distribution %	Specific Gravity	Settling Velocity ft/s		Particle Size µm	Distribution %	Specific Gravity	Settling Velocity ft/s
20	20	1.3	0.0013					
60	20	1.8	0.0051					
150	20	2.2	0.0354					
400	20	2.65	0.2123					
2000	20	2.65	0.9417					

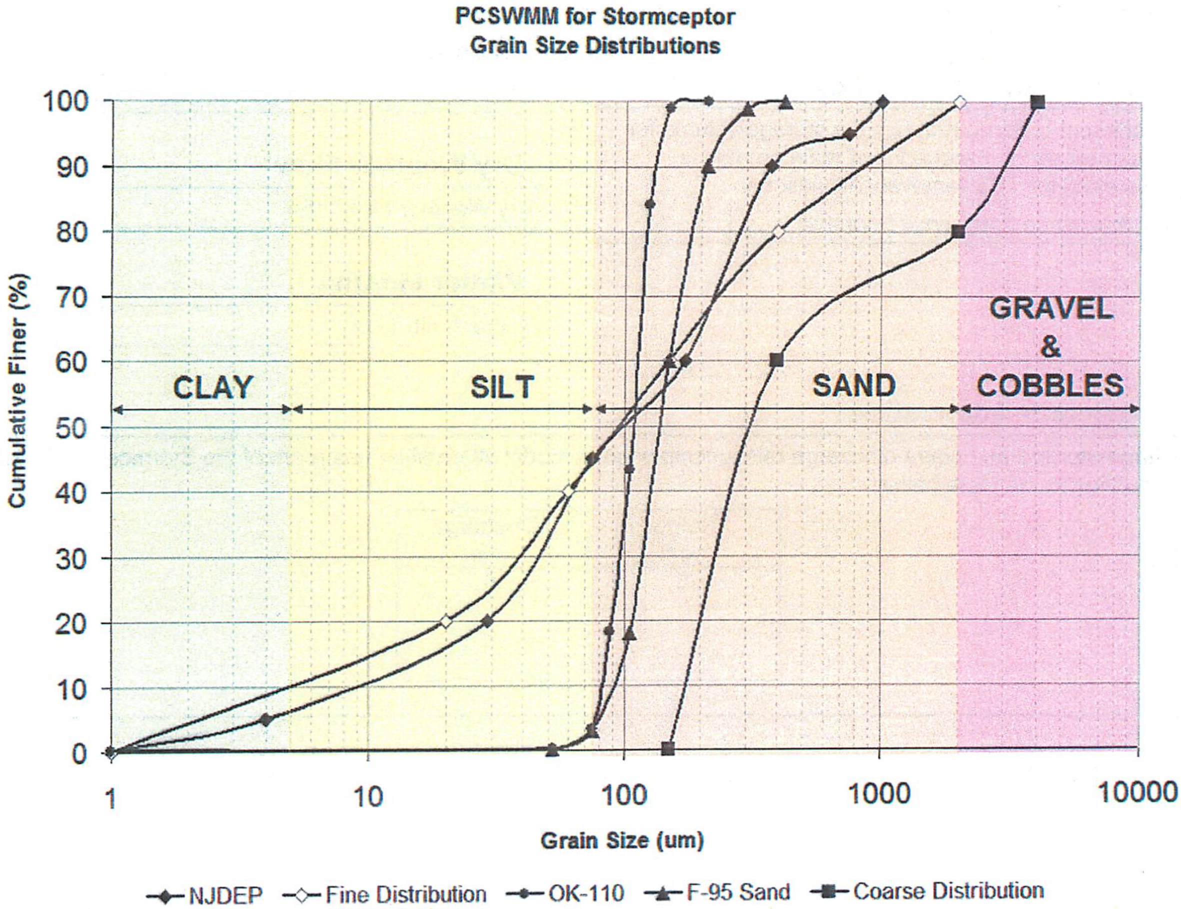

Figure 1. PCSWMM for Stormceptor standard design grain size distributions.

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TSS LOADING

TSS Loading Parameters

TSS Loading Function	Buildup / Washoff

Buildup/Washoff Parameters

Target Event Mean Concentration (EMC) (mg/L)	125
Exponential Buildup Power	0.4
Exponential Washoff Exponential	0.2

TSS Availability Parameters

Availability = A + Bi^C

Availability Constant A	0.057
Availability Factor B	0.04
Availability Exponent C	1.1
Min. Particle Size Affected by Availability (μm)	400

HYDROLOGY ANALYSIS

PCSWMM for Stormceptor calculates annual hydrology with the US EPA SWMM and local continuous historical rainfall data. Performance calculations of the Stormceptor System are based on the average annual removal of TSS for the selected site parameters. The Stormceptor System is engineered to capture fine particles (silts and sands) by focusing on average annual runoff volume ensuring positive removal efficiency is maintained during all rainfall events, while preventing the opportunity for negative removal efficiency (scour).

Smaller recurring storms account for the majority of rainfall events and average annual runoff volume, as observed in the historical rainfall data analyses presented in this section.

Rainfall Station

Rainfall Station	MISSOULA INTL AP		
Rainfall File Name	MT5745.NDC	Total Number of Events	10263
Latitude	46°55'15"N	Total Rainfall (in.)	759.2
Longitude	114°5'33"W	Average Annual Rainfall (in.)	13.1
Elevation (ft)	3192	Total Evaporation (in.)	195.6
Rainfall Period of Record (y)	58	Total Infiltration (in.)	0.0
Total Rainfall Period (y)	58	Percentage of Rainfall that is Runoff (%)	76.3

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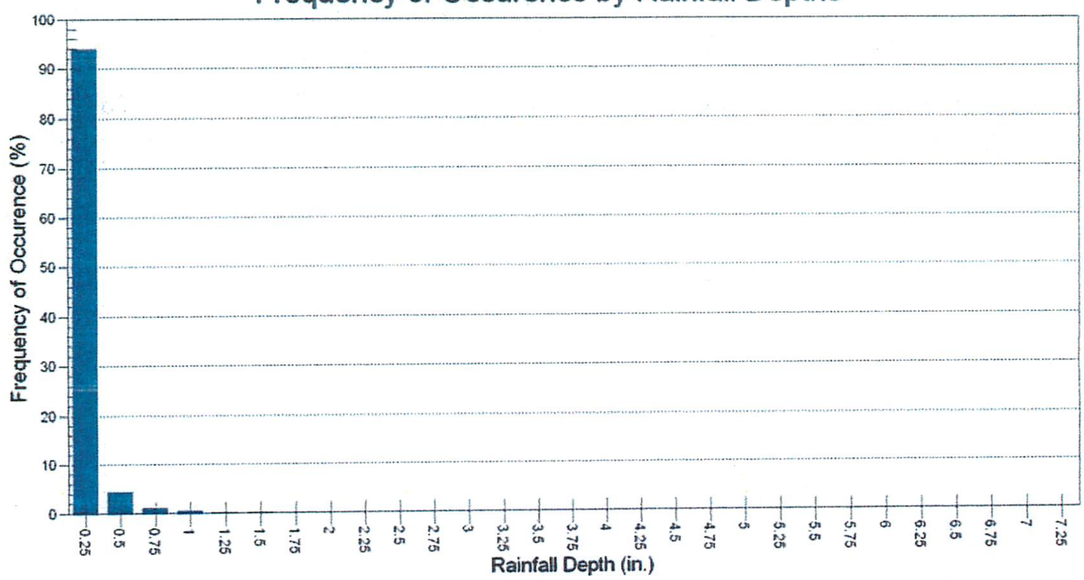
Rainfall Event Analysis

Rainfall Depth in.	No. of Events	Percentage of Total Events %	Total Volume in.	Percentage of Annual Volume %
0.25	9639	93.9	468	61.6
0.50	455	4.4	157	20.6
0.75	100	1.0	61	8.0
1.00	39	0.4	33	4.4
1.25	12	0.1	13	1.8
1.50	11	0.1	15	2.0
1.75	5	0.0	8	1.0
2.00	1	0.0	2	0.3
2.25	1	0.0	2	0.3
2.50	0	0.0	0	0.0
2.75	0	0.0	0	0.0
3.00	0	0.0	0	0.0
3.25	0	0.0	0	0.0
3.50	0	0.0	0	0.0
3.75	0	0.0	0	0.0
4.00	0	0.0	0	0.0
4.25	0	0.0	0	0.0
4.50	0	0.0	0	0.0
4.75	0	0.0	0	0.0
5.00	0	0.0	0	0.0
5.25	0	0.0	0	0.0
5.50	0	0.0	0	0.0
5.75	0	0.0	0	0.0
6.00	0	0.0	0	0.0
6.25	0	0.0	0	0.0
6.50	0	0.0	0	0.0
6.75	0	0.0	0	0.0
7.00	0	0.0	0	0.0
7.25	0	0.0	0	0.0
7.50	0	0.0	0	0.0
7.75	0	0.0	0	0.0
8.00	0	0.0	0	0.0
8.25	0	0.0	0	0.0
>8.25	0	0.0	0	0.0

Frequency of Occurence by Rainfall Depths



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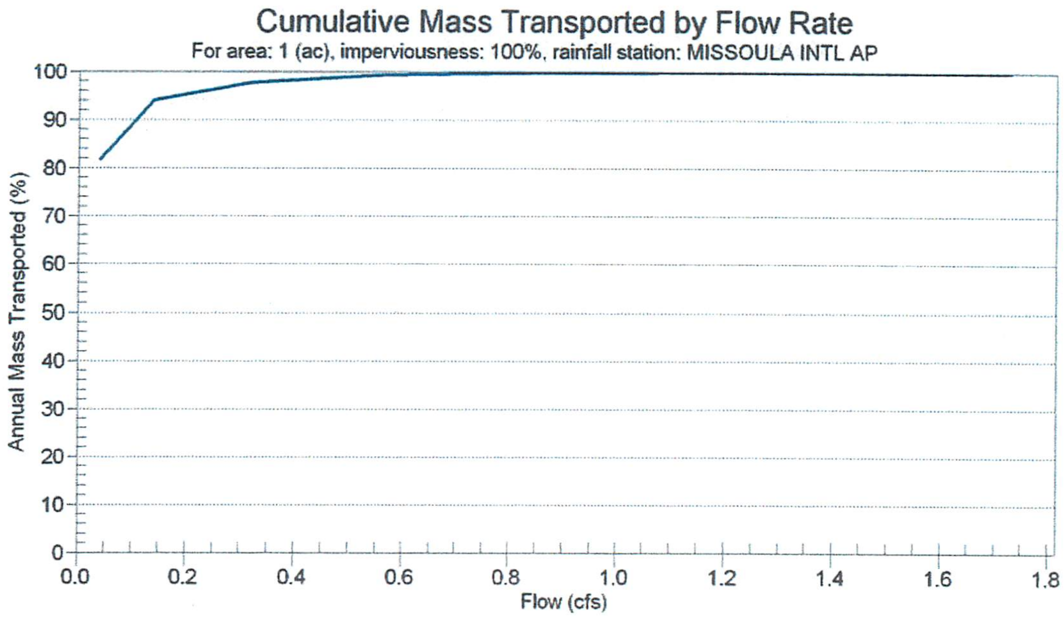
Pollutograph

Flow Rate cfs	Influent Mass ton	Effluent Mass ton	Total Mass ton	Cumulative Mass %
0.035	22.5423	5.0919	27.577	81.7
0.141	25.9226	1.6709	27.577	94.0
0.318	26.9555	0.627	27.577	97.7
0.565	27.3878	0.1903	27.577	99.3
0.883	27.5154	0.0627	27.577	99.8
1.271	27.5539	0.0231	27.577	99.9
1.73	27.5693	0.0077	27.577	100.0
2.26	27.5759	0.0011	27.577	100.0
2.86	27.577	0	27.577	100.0
3.531	27.577	0	27.577	100.0
4.273	27.577	0	27.577	100.0
5.085	27.577	0	27.577	100.0
5.968	27.577	0	27.577	100.0
6.922	27.577	0	27.577	100.0
7.946	27.577	0	27.577	100.0
9.041	27.577	0	27.577	100.0
10.206	27.577	0	27.577	100.0
11.442	27.577	0	27.577	100.0
12.749	27.577	0	27.577	100.0
14.126	27.577	0	27.577	100.0
15.574	27.577	0	27.577	100.0
17.092	27.577	0	27.577	100.0
18.681	27.577	0	27.577	100.0
20.341	27.577	0	27.577	100.0
22.072	27.577	0	27.577	100.0
23.873	27.577	0	27.577	100.0
25.744	27.577	0	27.577	100.0
27.687	27.577	0	27.577	100.0
29.7	27.577	0	27.577	100.0
31.783	27.577	0	27.577	100.0



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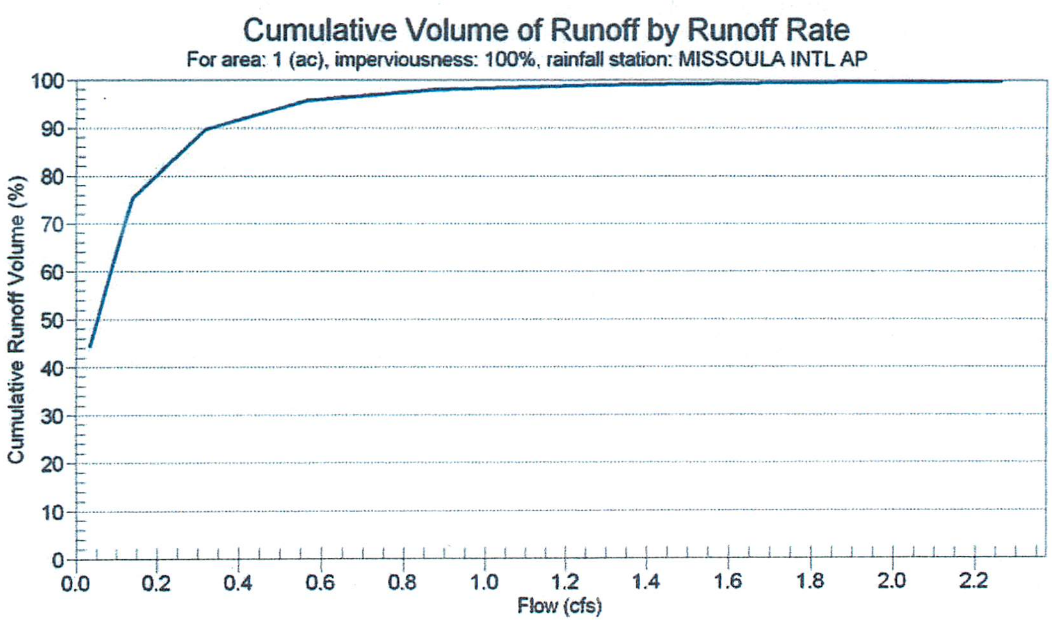
Cumulative Runoff Volume by Runoff Rate

Runoff Rate cfs	Runoff Volume ft³	Volume Overflowed ft³	Cumulative Runoff Volume %
0.035	935635	1166626	44.5
0.141	1584693	517642	75.4
0.318	1885050	217242	89.7
0.565	2010835	91446	95.7
0.883	2059578	42704	98.0
1.271	2079950	22332	98.9
1.73	2090691	11590	99.4
2.26	2096578	5704	99.7
2.86	2099436	2846	99.9
3.531	2101228	1055	99.9
4.273	2102103	179	100.0
5.085	2102282	0	100.0
5.968	2102282	0	100.0
6.922	2102282	0	100.0
7.946	2102282	0	100.0
9.041	2102282	0	100.0
10.206	2102282	0	100.0
11.442	2102282	0	100.0
12.749	2102282	0	100.0
14.126	2102282	0	100.0
15.574	2102282	0	100.0
17.092	2102282	0	100.0
18.681	2102282	0	100.0
20.341	2102282	0	100.0
22.072	2102282	0	100.0
23.873	2102282	0	100.0
25.744	2102282	0	100.0
27.687	2102282	0	100.0
29.7	2102282	0	100.0
31.783	2102282	0	100.0



Rinker

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

April 2006
(Updated September 2007)

GENERAL USE LEVEL DESIGNATION FOR PRETREATMENT (TSS)
For
Stormceptor System®

Ecology's Decision:

Based on Imbrium Systems Corporation's application submissions and recommendations by the Technical Review Committee (TRC), Ecology hereby issues the following Use Level Designation for the Imbrium Systems Corporation Stormceptor System®:

1. **General Use Level Designation (GULD) for pretreatment, as defined in the Ecology Stormwater Management Manual for Western Washington Volume V, (a) ahead of infiltration treatment, or (b) to protect and extend the maintenance cycle of a basic or enhanced treatment device (e.g., sand or media filter). This GULD applies to Stormceptor System® units sized in accordance with Table 1 (below) at the water quality design flowrate as determined using the Western Washington Hydrology Model (WWHM):**

Table 1

Unit	Treatment Flowrate (gpm)
STC 450i	143
STC 900	285
STC 1200	285
STC 1800	285
STC 2400	476
STC 3600	476
STC 4800	793
STC 6000	793
STC 7200	1110
STC 11000	1585
STC 13000	1585
STC 16000	2220

2. **The GULD has no expiration date, but may be amended or revoked by Ecology.**

3. **All designations are subject to the conditions specified below.**

4. **Properly designed and operated Stormceptor Systems® may also have applicability in other situations (example: low-head situations such as bridges or ferry docks), for TSS removal where, on a case-by-case basis, it is found to be infeasible or impracticable to use any other approved practice. Jurisdictions covered under the Phase I or II municipal stormwater permits should use variance/exception procedures and criteria as required by their NPDES permit.**

5. **Ecology finds that the Stormceptor System® could also provide water quality benefits in retrofit situations.**

Ecology's Conditions of Use:

Stormceptor Systems® shall be designed, installed, and maintained to comply with these conditions:

1. **Stormceptor Systems® must be designed, assembled, installed, operated, and maintained in accordance with Imbrium Systems Corporation's applicable manuals and documents and the Ecology decision and conditions specified herein. Ecology recommends the inspection and maintenance schedule included here:**

   Stormceptor Inspection & Maintenance

2. **Discharges from the Stormceptor System® shall not cause or contribute to water quality standards violations in receiving waters.**

Applicant: Dan Nason
Imbrium Systems Corporation

Applicant Address: 100 Grove Street
Worcester, MA, 01605

Application Documents:

- Submission for Verification Acceptance, State of Washington Department of Ecology (WADOE), dated May 2005. This document contains the following elements:
    - Submission for Verification Acceptance, including an abridged version of the application and a technical manual
    - Field data, Westwood, MA, 1997

- Field data, Seatac, WA, 1999
- Testing summary, Como Park, MN, 1998
- Testing summary, Edmonton, AB, 1994-6
- Wisconsin DNR/USGS report, conference paper, and monitoring summary, 1998
- Laboratory evaluation, done for NJDEP, 2004
- Coventry University laboratory study, 1996
- Stormwater hydrology report, Bryant et. al.
- Canada Environmental Technology Verification report, 2003
- Massachusetts Strategic Envirotechnology Partnership report, 1998
- NJCAT certification report, 2005

With the exception of any files identified as confidential, a CD-ROM containing these submittal documents is available by contacting Imbrium Systems Corporation.

- A Review of Stormceptor™ - In Contrast to Other Wet Vaults that have Received Certification under the Washington State Department of Ecology's TAPE Program for Rinker Materials, Gary Minton, July 10, 2007

Applicant's Use Level Requests:

- General Use Level Designation (GULD) for pretreatment.

Applicant's Performance Claims:

- The Stormceptor System® has been shown to attain the State of Washington's pretreatment (TSS) criteria based on analyses of data from field and laboratory studies. Laboratory studies utilized both OK-110 sand and the NJDEP particle size distribution..
- The Stormceptor System® has been proven to remove material finer than 500 microns. It is not designed to remove litter and debris.
- The Stormceptor System® removes large portions of sand and silt from stormwater on a long-term basis, thereby preventing material from entering a downstream treatment facility, thus extending the maintenance cycle of the downstream facility.
- The Stormceptor System® has demonstrated through field performance and laboratory studies its scour prevention capability. The system's unique design prevents loss of previously captured pollutants during periods with higher flowrates.
- The Stormceptor System® is an easy-to-maintain device that is much more cost-effective to maintain/clean than many alternative methods such as filtration systems and detention ponds.
- The Stormceptor System® has demonstrated through field and laboratory study its capability to function as an effective spill capture device for petroleum hydrocarbon spills, thereby preventing potentially catastrophic environmental damage from such spills.
- The Stormceptor System® is an effective treatment measure for retrofit and other space-constrained or infrastructure-constrained applications which preclude the use of other approved treatment systems.

Technical Review Committee Recommendations: The TRC, based on the weight of the evidence and using its best professional judgment, finds that:

- Pretreatment guidelines are needed to assess facilities performing at less-than-Basic treatment levels, but adequate to serve as presettling facilities ahead of infiltration treatment. The TRC recommends guidelines are set at 50% removal of 50-micron particles and 80% removal of 125-micron particles. The TRC further recommends these guidelines be applied uniformly to this and all future technology submissions, developed, and included in Ecology's stormwater manual.
- The Stormceptor System®, sized according to Table 1 (above) should provide, at a minimum, equivalent performance to a presettling basin as defined in the most recent *Stormwater Management Manual for Western Washington, Volume V, Chapter 6.*
- Imbrium Systems Corporation should be given the opportunity to demonstrate, through additional laboratory and field testing, whether the Stormceptor System® can attain Ecology's Basic (TSS) Treatment performance goal.

Findings of Fact:

- Imbrium Systems Corporation has submitted laboratory data for its Stormceptor System® STC-900, testing silica material prepared to satisfy New Jersey Department of Environmental Protection (NJDEP) standards (mean particle size 97 microns; range 1 to 1000 microns). Weighted TSS removal rates averaged 75% across a range of operating rates (25% to 125% of the design rate), with TSS influent concentrations (97 micron mean particle size) averaging 295 mg/L. Unweighted TSS removal rates averaged 74%, and the removal rate at 285 gpm was 73%.
- Scour tests were run at 125% of the design flowrate with initial sediment loading of 50% and 100% in the lower chamber of the unit. No scouring occurred at 50% loading and minimal scouring occurred at 100% loading.
- Several substantial field data sets were submitted. However, most data do not represent flow-weighted composite samples for individual storms, which are required by the WADOE protocol. The Madison site used flow-weighted composites, and TSS removal rates were in the 20% to 30% range. The Madison site is a maintenance yard with dirt and salt piles and Imbrium Systems believes the results do not represent typical system performance.
- The system is readily maintained using a vacuum truck.
- There are approximately 15,000 Stormceptor systems in use nationwide and 510 in the Pacific Northwest.

Technology Description:

Design manual and technical bulletins can be downloaded from company's web site.

Recommended Research and Development:

Ecology encourages Imbrium Systems Corporation to pursue continuous improvements to the Stormceptor System®. To that end, the following actions are recommended:

- No field-testing data are currently available to reliably ascertain the Stormceptor System®'s ability to remove the finer particles (typically represented by Sil-Co-Sil 106, a U.S. Silica product, in laboratory testing) comprising TSS found on local highways, parking lots, and other high-use areas. Design of future facilities should consider:

  a. Sizing for specific applications based on actual particle size distribution in the target runoff. Ecology's TAPE can be used as guidance on the expected particle size distributions for Basic Treatment.
  b. Laboratory and field testing to evaluate whether the Stormceptor System® can reliably achieve Basic Treatment criteria.

Contact Information:

Applicant: Pete Van Tilburg
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dnason@imbriumsystems.com

Applicant website: www.stormceptor.com

Ecology web link: http://www.ecy.wa.gov/programs/wq/stormwater/new_tech/

Ecology Contact: Mieke Hoppin
Water Quality Program
mhop461@ecy.wa.gov
(360) 407-6435

Technical Review Committee: Dave Tucker, P.E., Kitsap County,
TRC Chairperson
DTucker@co.kitsap.wa.us
(360) 337-7292

WASHINGTON STATE DEPARTMENT OF ECOLOGY

July 2008
(Updated to incorporate CONTECH'S model name change)

GENERAL USE LEVEL DESIGNATION FOR PRETREATMENT (TSS)

For

CONTECH Stormwater Solutions, Inc. CDS® System

Ecology's Decision:

Based on the CONTECH Stormwater Solutions Inc. (CONTECH) application submissions for the CDS® System and recommendations by the Technical Review Committee (TRC), Ecology hereby issues the following use designations for the CDS technology:

1. **General Use Level Designation (GULD) for pretreatment use, as defined in the Ecology Stormwater Management Manual for Western Washington Volume V, (a) ahead of infiltration treatment, or (b) to protect and extend the maintenance cycle of a basic or enhanced treatment device (e.g., sand or media filter). This GULD applies to 2400 micron screen CDS® units sized per the table below at the Water Quality design flow rate as determined using the Western Washington Hydrology Model (WWHM). The following table shows flowrates associated with various CDS models:**

Washington State System Sizing		
CDS Model ID	**Previous Model ID**	**Flowrate (cfs)**
CDS 2015	PMIU20-15	0.7
CDS 2015-4	PMSU20-15-4	0.7
CDS 2015-5	PMSU20-15	0.7
CDS 2020	PMSU20-20	1.1
CDS2025	PMSU20-25	1.6
CDS3020	PMSU30-20	2
CDS3030	PMSU30-30	3
CDS4030	PMSU40-30	4.5
CDS4040	PMSU40-40	6
CDS3020-D	PSWC30-20	2
CDS3030-D	PSWC30-30	3
CDS3030-DV	PSW30-30	3
CDS4030-D	PSWC40-30	4.5
CDS4040-D	PSWC40-40	6

3149 pm ↓

CDS5042-DV	PSW50-42	9
CDS5640-D	PSWC56-40	9
CDS5050-V	PSW50-50	11
CDS5653-D	PSWC56-53	14
CDS5668-D	PSWC56-68	19
CDS5678-D	PSWC56-78	25
CDS7070-DV	PSW70-70	26
CDS10060-DV	PSW100-60	30
CDS10080-DV	PSW100-80	50
CDS100100-DV	PSW100-100	64
	*	*

***Specially designed CDS™ may be approved by Ecology on a site-by-site basis.**

2. **The pretreatment GULD has no expiration date, but it may be amended or revoked by Ecology.**

3. **All designations are subject to the conditions specified below.**

4. **Properly designed and operated CDS® systems may also have applicability in other situations (example: low-head situations such as bridges or ferry docks), for TSS and oil/grease removal where, on a case-by-case basis, it is found to be infeasible or impracticable to use any other approved practice. Jurisdictions covered under the Phase I or II municipal stormwater permits should use variance/exception procedures and criteria as required by their NPDES permit.**

5. **Ecology finds that the CDS®, sized according to the table above, could also provide water quality benefits in retrofit situations.**

<u>Ecology's Conditions of Use:</u>

<u>CDS® systems shall be designed, installed, operated and maintained to comply with these conditions:</u>

1. **CDS® Systems must be designed, assembled, installed, operated, and maintained in accordance with Contech's applicable manuals and documents and the Ecology decision and conditions specified herein. Ecology recommends the inspection and maintenance schedule included here:**

CDS
Maintenance&Inspect

2. **Discharges from the CDS® System shall not cause or contribute to water quality standards violations in receiving waters.**

Applicant: CONTECH Stormwater Solutions, Inc., Manufacturer and Vendor

Applicant's Address: 11835 NE Glen Widing Drive
Portland, OR 97220

Application Documents:

- Contech Stormwater Solutions Application to: Washington State Department of Ecology Water Quality Program for General Use Level Designation – Pretreatment Applications and Conditional Use Level Designation – Oil Treatment of the Continuous Deflective Separation (CDS™) Technology (June 2007)
- Strynchuk, Royal, and England, "The Use of a CDS Unit for Sediment Control in Brevard County".
- Walker, Allison, Wong, and Wootton, "Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap", Cooperative Research Centre for Catchment Hydrology, Report 99/2, February 1999
- Allison, Walker, Chiew, O'Neill, McMahon, "From Roads to Rivers Gross Pollutant Removal from Urban Waterways", Cooperative Research Centre for Catchment Hydrology, Report 98/6, May 1998

Applicant's Use Level Request:

General use level designation as a pretreatment device in accordance with Ecology's 2005 Stormwater Management Manual for Western Washington.

Applicant's Performance Claims:

Based on laboratory trials, the CDS™ System will achieve 50% removal of total suspended solids with d_{50} of 50-µm and 80% removal of total suspended solids with d_{50} of 125-µm at 100% design flow rate with influent concentrations near 200 mg/L.

The CDS™ system equipped with standard oil baffle and the addition of oil sorbent is effective in the control of oil and can maintain the TPH level below 10 mg/L for applications in typical urban runoff pollution control.

Technical Review Committee's Recommendation:

The TRC finds that:

- The CDS™ system, sized per the table above, should provide, at a minimum, equivalent performance to a presettling basin as defined in the most recent *Stormwater Management Manual for Western Washington, Volume V, Chapter 6.*

Findings of Fact:

1. Laboratory testing was completed on a CDS2020 unit equipped with a 2400 micron screen using OK-110 sand (d_{50} of 106-µm) at flowrates ranging from 1 to 125% of the design flowrate (1.1 cfs) with a target influent of 200 mg/L. Laboratory results for the OK-110 sand showed removal rates from about 65% to 99% removal with 80% removal occurring near 70% of the design flowrate.
2. Laboratory testing was completed on a CDS2020 unit equipped with a 2400 micron screen using "UF" sediment (d_{50} of 20 to 30-µm) at flowrates ranging from 1 to 125% of the design flowrate (1.1 cfs) with a target influent of 200 mg/L. Laboratory results for the "UF" sediment showed removal rates from about 42% to 94% removal with 80% removal occurring at 5% of the design flowrate.
3. Laboratory testing was completed on a CDS2020 unit equipped with a 4700 micron screen using OK-110 sand (d_{50} of 106-µm) at flowrates ranging from 1 to 125% of the design flowrate (1.1 cfs) with a target influent of 200 mg/L. Laboratory results for the OK-110 sand showed removal rates from about 45% to 99% removal with an average removal of 83.1%.
4. Laboratory testing was completed on a CDS2020 unit equipped with a 2400 micron screen using "UF" sediment (d_{50} of 20 to 30-µm) at flowrates ranging from 1 to 125% of the design flowrate (1.1 cfs) with a target influent of 200 mg/L. Laboratory results for the "UF" sediment showed removal rates from about 39% to 88% removal with an average removal of 56.1%.
5. Laboratory testing was completed on a CDS2020 unit using motor oil at flowrates ranging from 25% to 75% of the design flowrate (1.1 cfs) with influents ranging from 7 to 47 mg/L. Laboratory results showed removal rates from 27% to 92% removal. A spill test was also run at 10% of the design flowrate with an influent of 82,000 mg/L with an average percent capture of 94.5%
6. Various field studies were completed by independent parties in California, Florida, and Australia. Field studies showed the potential for the unit to remove oils and grease and total suspended solids, and gross solids. A spill test was also run at 10% design flowrate with an influent of 82,000 mg/L with an average percent capture of 94.5%.
7. CDS Technology has over 6,200 installations in the United States and Canada with over 1,380 installations in Washington and Oregon.

Technology Description:

A technology description can be downloaded from the company's website.

Recommended Research and Development:

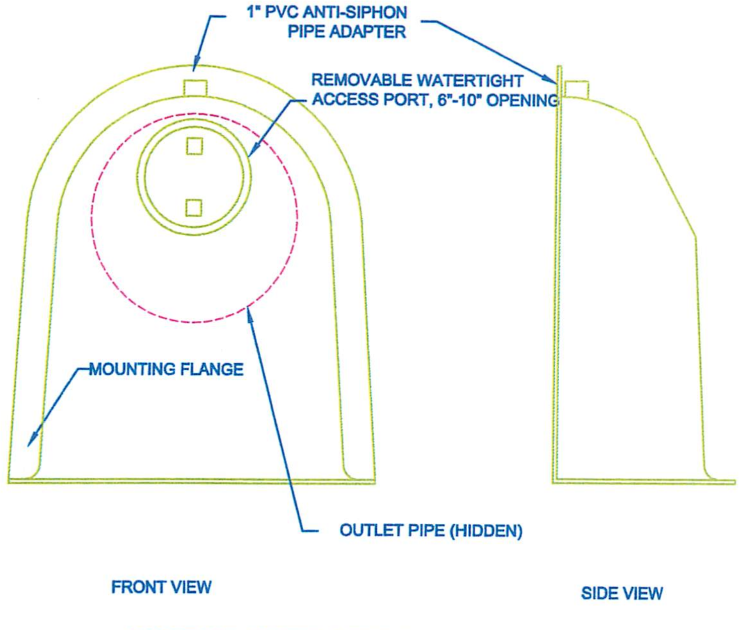
Ecology encourages Contech to pursue continuous improvements to the CDS™ system. To that end, the following actions are recommended:

1. Conduct testing to quantify the flowrate at which resuspension occurs.
2. Conduct testing on various sized CDS™ units to verify the sizing technique is appropriate.
3. The system should be tested under normal operating conditions, such that the swirl concentrator is partially filled with pollutants. Results obtained for "clean" systems may not be representative of typical performance.

Contact Information:

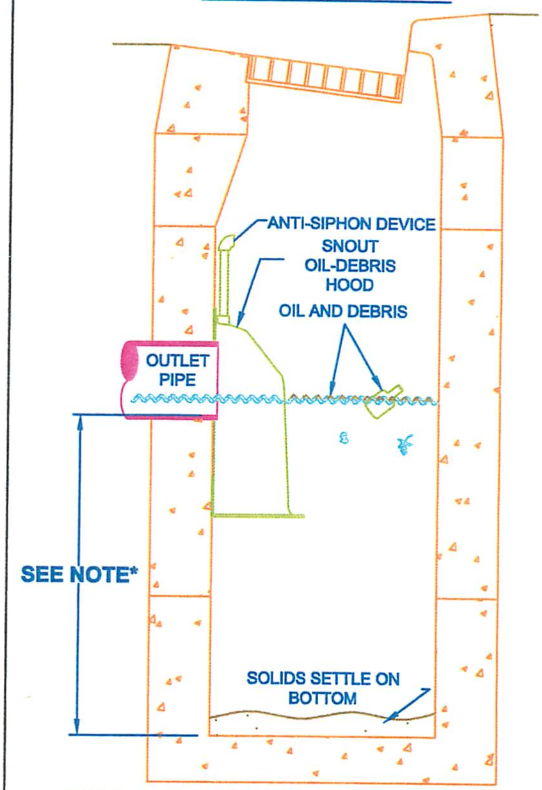
Applicant Contact:	Sean Darcy (800) 548-4667 darcys@contech-cpi.com
Applicant website:	www.contechstormwater.com
Ecology web link:	http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html
Ecology:	Foroozan Labib Water Quality Program (360) 407-6435 flab461@ecy.wa.gov
TRC:	Dave Tucker, P.E. Kitsap County (360) 337-7292 dtucker@co.kitsap.wa.us

CONFIGURATION DETAIL



SNOUT OIL-WATER-DEBRIS SEPARATOR

TYPICAL INSTALLATION



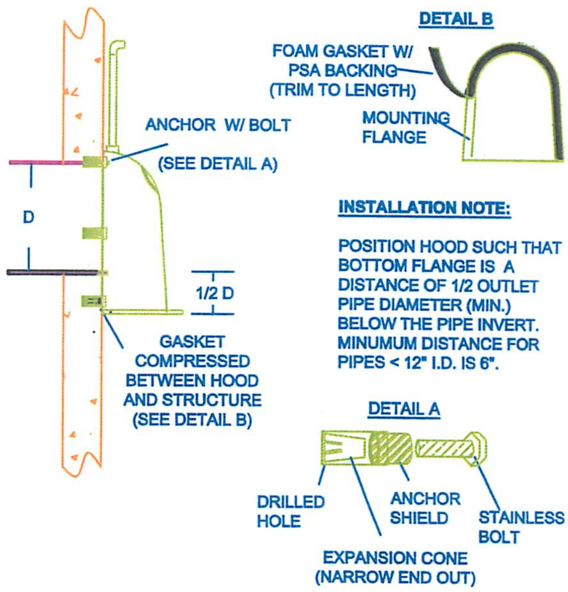
*NOTE- SUMP DEPTH OF 36" MIN. FOR < OR= 12" DIAM. OUTLET. FOR OUTLETS >OR= 15", DEPTH = 2.5-3X DIAM.

NOTES:

1. ALL HOODS AND TRAPS FOR CATCH BASINS AND WATER QUALITY STRUCTURES SHALL BE AS MANUFACTURED BY:
   BEST MANAGEMENT PRODUCTS, INC.
   53 MT. ARCHER RD.
   LYME, CT 06371
   (860) 434-0277, (860) 434-3195 FAX
   TOLL FREE: (800) 504-8008 OR (888) 354-7585
   WEB SITE: www.bestmp.com
   OR PRE-APPROVED EQUAL
2. ALL HOODS SHALL BE CONSTRUCTED OF A GLASS REINFORCED RESIN COMPOSITE WITH ISO GEL COAT EXTERIOR FINISH WITH A MINIMUM 0.125" LAMINATE THICKNESS.
3. ALL HOODS SHALL BE EQUIPPED WITH A WATERTIGHT ACCESS PORT, A MOUNTING FLANGE, AND AN ANTI-SIPHON VENT AS DRAWN. (SEE CONFIGURATION DETAIL)
4. THE SIZE AND POSITION OF THE HOOD SHALL BE DETERMINED BY OUTLET PIPE SIZE AS PER MANUFACTURER'S RECOMMENDATION.
5. THE BOTTOM OF THE HOOD SHALL EXTEND DOWNWARD A DISTANCE EQUAL TO 1/2 THE OUTLET PIPE DIAMETER WITH A MINIMUM DISTANCE OF 6" FOR PIPES <12" I.D.
6. THE ANTI-SIPHON VENT SHALL EXTEND ABOVE HOOD BY MINIMUM OF 3" AND A MAXIMUM OF 24" ACCORDING TO STRUCTURE CONFIGURATION.
7. THE SURFACE OF THE STRUCTURE WHERE THE HOOD IS MOUNTED SHALL BE FINISHED SMOOTH AND FREE OF LOOSE MATERIAL.
8. THE HOOD SHALL BE SECURELY ATTACHED TO STRUCTURE WALL WITH 3/8' STAINLESS STEEL BOLTS AND OIL-RESISTANT GASKET AS SUPPLIED BY MANUFACTURER. (SEE INSTALLATION DETAIL)
9. INSTALLATION INSTRUCTIONS SHALL BE FURNISHED WITH MANUFACTURER SUPPLIED INSTALLATION KIT.
   INSTALLATION KIT SHALL INCLUDE:
   A. INSTALLATION INSTRUCTIONS
   B. PVC ANTI-SIPHON VENT PIPE AND ADAPTER
   C. OIL-RESISTANT CRUSHED CELL FOAM GASKET WITH PSA BACKING
   D. 3/8" STAINLESS STEEL BOLTS
   E. ANCHOR SHIELDS

US Patent # 6126817

INSTALLATION DETAIL



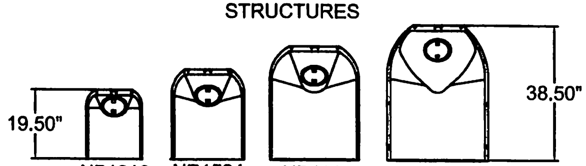
INSTALLATION NOTE:

POSITION HOOD SUCH THAT BOTTOM FLANGE IS A DISTANCE OF 1/2 OUTLET PIPE DIAMETER (MIN.) BELOW THE PIPE INVERT. MINUMUM DISTANCE FOR PIPES < 12" I.D. IS 6".

HOOD SPECIFICATION FOR CATCH BASINS AND WATER QUALITY STRUCTURES

DESCRIPTION	DATE	SCALE
OIL- DEBRIS HOOD SPECIFICATION AND INSTALLATION (TYPICAL)	09/08/00	NONE
	DRAWING NUMBER SP-SN	

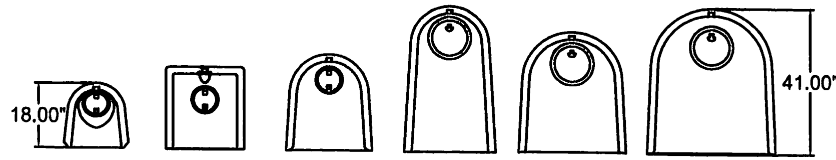
NYLOPLAST SNOUTS FOR PVC STRUCTURES



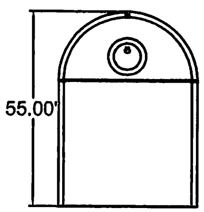
NP1218 NP1524 NP1830 NP2430

BEST MANAGEMENT PRODUCTS, INC., LYME, CT
800-504-8008 877-434-3197 FAX WWW.BMPINC.COM

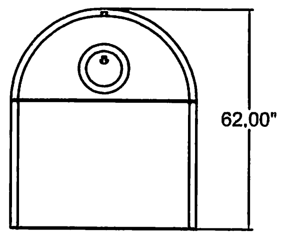
SNOUT RELATIVE SIZE COMPARISON



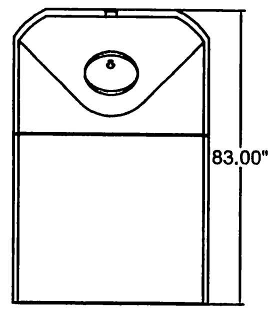
12" F or R* SERIES | LP318 F ONLY | 18" F or R* SERIES | 18R10XD R ONLY EXTRA DEEP | 24" F or R* SERIES | 30" F or R* SERIES



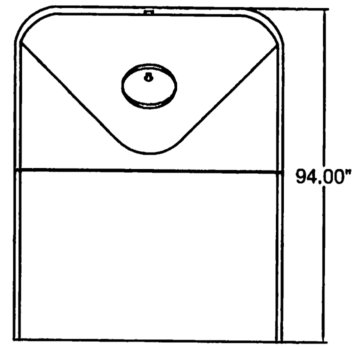
36F 2 PC
FLAT
ONLY



48F 2 PC
FLAT
ONLY



52R/72 2 PC
ROUND ONLY
(FOR 72" DIAM. STRUCTURE)



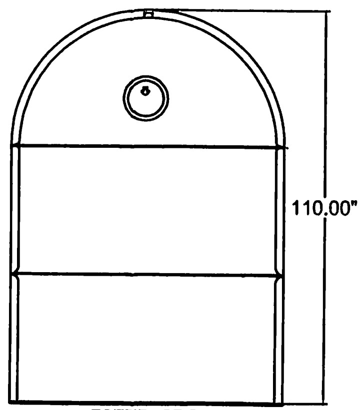
72R/96 2 PC
ROUND ONLY
(FOR 96" DIAM. STRUCTURE)

*** R SERIES STRUCTURE INSTALLATION NOTE:**

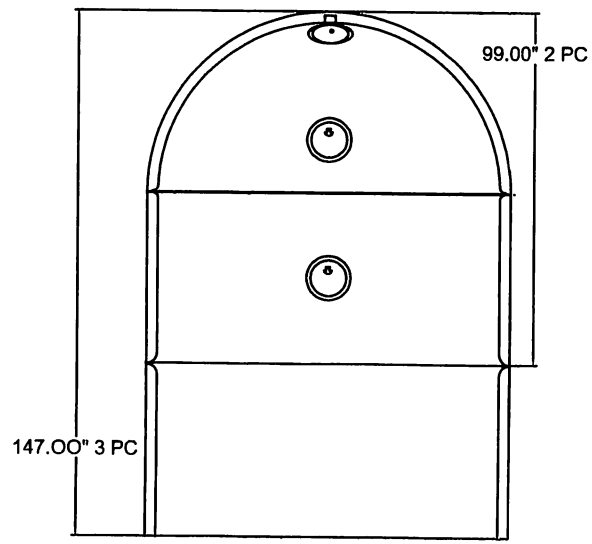
12R- FITS 36-48" DIAM.
18R- FITS 48-60" DIAM.
24R- FITS 48-60" DIAM.
30R- FITS 60-72" DIAM.
52R- FITS 72" DIAM. ONLY
72R- FITS 96" DIAM. ONLY
NP1218- FITS 18" DIAM. ONLY
NP1524- FITS 24" DIAM. ONLY
NP1830- FITS 30" DIAM. ONLY
NP2430- FITS 30" DIAM. ONLY

MAX. PIPE ID SIZE RECOMMENDATION:**

LP318 12" PIPE, *LOW FLOW ONLY*
12" SNOUT- 10" PIPE; 18" SNOUT- 15" PIPE;
24" SNOUT- 18" PIPE; 30" SNOUT- 24" PIPE;
36F SNOUT- 30" PIPE; 48F SNOUT- 36" PIPE;
52R SNOUT- 42" PIPE; 72" SNOUT- 60" PIPE;
96F- 72" PIPE
***PIPE MUST ALWAYS HAVE SMALLER OD THAN NOMINAL SNOUT SIZE REGARDLESS OF PIPE ID*



72FTB 2PC
FLAT ONLY
72FTBB 3 PC



96FTB 2 PC
FLAT ONLY
96FTBB 3PC

To: Stormwater and Resource Planning Professionals

From: T. J. Mullen, T.J. President

Date: November 18, 2007

Subj: USING THE SNOUT IN COLD WEATHER AREAS

We receive occasional requests for information about the suitability of SNOUT installations in areas where below freezing temperatures are common during winter. BMP, Inc. is headquartered in New England, where freezing conditions are normal wintertime occurrences. We have more than 10,000 SNOUTs in the northeast US and Canada with hundreds in Maine and New Hampshire alone. We also have SNOUTs in Alaska and Edmunton, Alberta. With more over 35,000 installations, we have never been notified that SNOUTs were causing any problems due to icing in catch basins or any other cold weather condition.

Here are a couple of reasons we have seen no adverse effects in cold weather climates:

- As most catch basin sumps are at least partially below the frost line, solid freezing in the sump is a rare condition at a time when liquid precipitation would occur. Even in northern Maine, where the frost line is typically believed to be around 6', we have not received any reports of problems (picture of SNOUT in Bangor, ME is on our website under "Images").

- Even when ice in the catch basin occurs, as soon as liquid precipitation enters the structure, an opening is immediately scoured around the perimeter of SNOUT and the water can flow. Within a matter of minutes, most ice is melted and full flow conditions can occur.

- As for the freeze/thaw cylce, the thick gasket supplied with all SNOUTs in the installation kits provides plenty of room for ice expansion (should it occur), resulting in an excellent long tern seal and solid installation in all conditions.

Therefore, be sure to require the factory installation kit hardware be used in every structure, and no problems should result. Feel free to contact us with questions. Thank you for the interest in our designs.

53 Mount Archer Rd., Lyme, CT, 06371 Ph. (800) 504-8008 or (888) 354-7585
www.bmpinc.com

Princeton Hydro pH

13 November 2007

Mr. T.J. Mullen
Best Management Products, Inc.
53 Mount Archer Road
Lyme, Connecticut 06371

Dear Mr. Mullen:

As part of the 2002 – 2003 watershed project for Lake Peekskill, SNOUT stormwater retrofits were installed in the Town of Putnam Valley. These retrofits were chosen since large, structural Best Management Practices (BMPs) would be difficult to install these residential areas. On 9 May 2003, the Putnam Valley Department of Public Works installed two SNOUT devices into two previously identified catch basins. The SNOUTs were monitored four times during 2003; 18 September, 25 September, 12 December, and 29 December. Stormwater samples were collected entering and exiting the SNOUT retrofitted catch basins and were analyzed for total phosphorus (TP) and total suspended solids (TSS). In order to estimate the pollutant loads entering and exiting the devices, rainfall data (Northeast Regional Climate Center: http://climod.nrcc.cornell.edu/), measured pollutant concentrations, and the immediate drainage area were used. Specifically, the following equation was used to estimate the pollutant load entering and exiting the SNOUT devices:

$$L = R * A * C$$

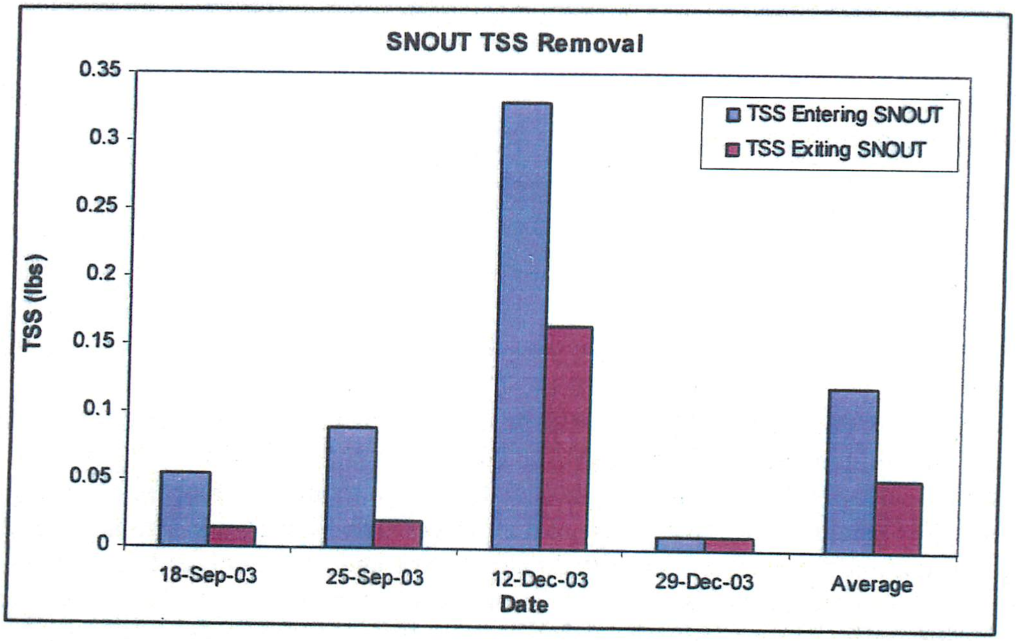
Where L = Pollutant load (lbs)
R = Rainfall during sampling event (meters)
A = Drainage area (m^2)
C = pollutant concentration (mg/ L)

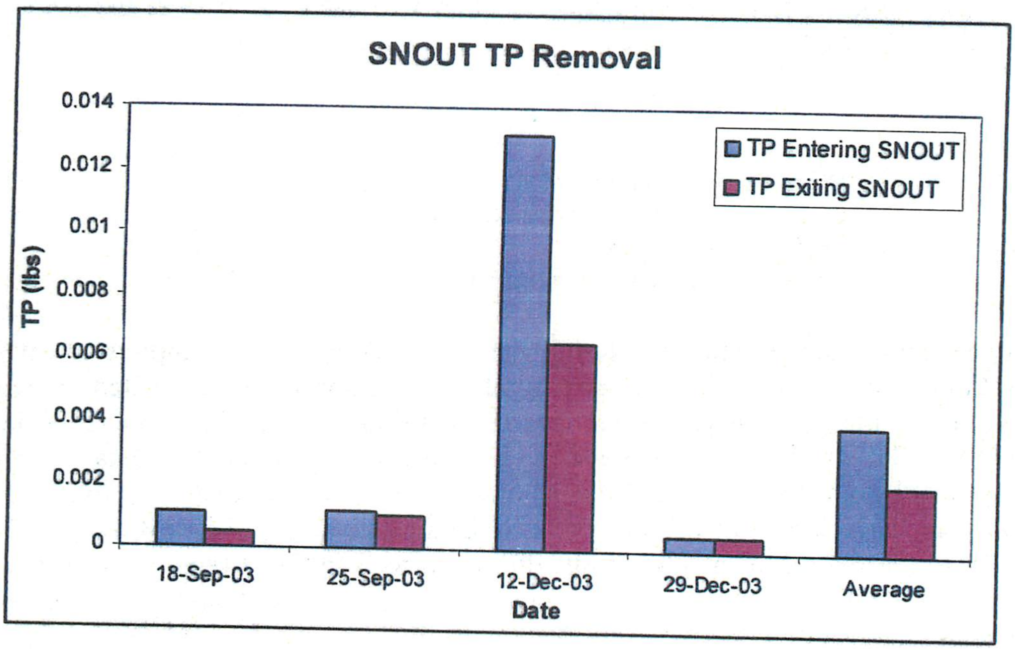
It should be noted that rainfall data during the 29 December 2003 sampling event was not available through the Cornell Climod database; thus, Princeton Hydro estimated the amount of rainfall to be 0.1 inches. In addition, the area of land draining into the SNOUT devices were estimated to be 880 m^2, using ArcGIS and the limited existing topographic data. The SNOUT devices removed both TSS and TP from stormwater entering the SNOUT devices from the surrounding drainage area. On average the SNOUTs reduced TSS by 56% and TP by 46%. Please refer to the figures at the end of this document for additional removal data. Please note that these are rough estimates since the exact drainage area and amount of rainfall were approximated.

Based on these data, the SNOUT-modified catch basins demonstrated the potential to remove the TSS and TP pollutant loads originating from surface runoff. If you have any questions or comments, please contact us at (610) 524 – 4220.

Sincerely,

Mary Lambert
GIS Specialist/ Scientist

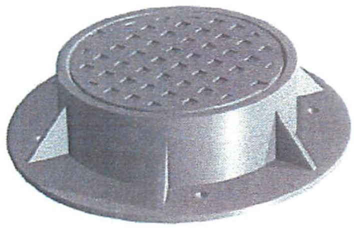

SNOUT TSS Removal
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
TSS (lbs)
TSS Entering SNOUT
TSS Exiting SNOUT
18-Sep-03
25-Sep-03
12-Dec-03
29-Dec-03
Average
Date

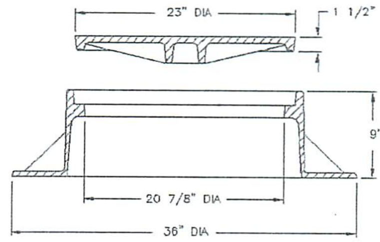

SNOUT TP Removal
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
TP (lbs)
TP Entering SNOUT
TP Exiting SNOUT
18-Sep-03
25-Sep-03
12-Dec-03
29-Dec-03
Average
Date

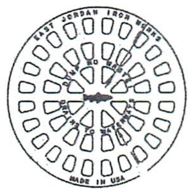
1058 FRAME & COVER

Heavy duty
Machined bearing surfaces

Options:
Solid or vented covers
Special lettered covers
Watertite assembly
Grate
Logo cover – V-1370-1





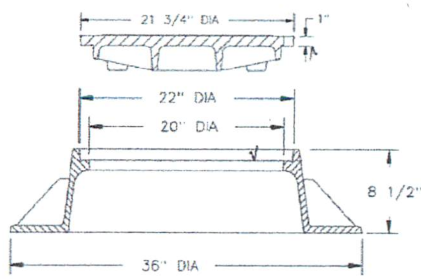


TYPE M2 Grate
Medium duty
Approx. 120 sq. in. open area
"DUMP NO WASTE!" lettering
and trout image

1060 FRAME & COVER

Heavy duty
Machined bearing surfaces
Stackable frame

Options:
Solid or vented covers
Special lettered covers
Custom logo covers
Watertite assembly
Adjusting risers
Gasket seal covers



TYPE B Vented
Cover 25 holes

TYPE M2 Radial Flat Grate
Heavy duty
Approx. 145 sq. in.
open area

TYPE M1 Flat Grate
Medium duty
Approx. 115 sq. in.
open area

All 1060 covers and grates can be used with the following frames.

Catalog Number	Base Flange Dia.	Frame Height
1171	26	5
1170	27 3/4	5
1180	34 1/4	5
1190	40	5
1030	33	6 1/2
1060	36	8 1/2
2850	34 TF	4

Note: All dimensions are in inches.

TYPE N Oval Grate
Height above frame 2 1/2"
Approx. 135 sq. in.
open area

TYPE 01 Beehive Grate
Height above frame 4"
Approx. 135 sq. in.
open area

TYPE 02 Beehive Grate
Height above frame 7"

TYPE 03 Beehive Grate
Height above frame 9"

APPENDIX C

OTHER SUPPORTING DATA

Montana Department of
ENVIRONMENTAL QUALITY

Brian Schweitzer, Governor

P.O. Box 200901 • Helena, MT 59620-0901 • (406) 444-2544 • www.deq.mt.gov

October 19, 2009

Ms. Janet Grove, PE
WGM Group
PO Box 16027
Missoula, MT 59808

RE: Stormwater Infiltration Chambers
Missoula County

Dear Ms. Grove:

The department received a letter from you requesting input regarding the siting and sizing of infiltration chambers in Missoula. As you know, our rules and Circular DEQ 8 are quite brief regarding the requirements for stormwater infiltration facilities. Our current rules require the following:

- **17.36.310(2)** Except as provided in (3), a storm drainage plan must be designed in accordance with department Circular DEQ-8, and,
  (6) Storm water that reaches state surface waters must be treated prior to discharge if the reviewing authority determines that untreated storm water is likely to degrade the receiving waters.
  - (a) minimum treatment of storm water consists of removal of settleable solids and floatable material. The reviewing authority may require more extensive treatment if deemed necessary to protect state waters from degradation;
  - (b) plans for the treatment facility must be approved by the reviewing authority.

- **DEQ 8, Section 5.1**- These facilities are now classified as injection wells by the US EPA, which should be contacted regarding any Federal rules that may apply, and,
- **Section 5.2** -The design of infiltration facilities should include a means for sediment removal and oil separation. It should also be designed to provide for other maintenance as necessary. Appropriate filter fabric shall be included to keep adjacent soils out of the infiltration Facility,and,
- **Section 5.3**-If storm inflow and outflow hydrographs are developed, infiltration into the ground can be included in the computation, and percolation tests (completed at the depth of the infiltration facility) or other appropriate testing shall be done to determine the appropriate infiltration rate to use in the design. Infiltration facilities should be located above the seasonally high ground water.

Your letter proposes requiring a minimum separation of 12-inches between the bottom of an infiltration chamber and groundwater in situations where groundwater comes within 10 feet of the ground surface. As you noted, this exceeds the requirements in DEQ 8, Section 5.3. In addition, you are proposing sizing criteria which exceeds the standards in DEQ 8. The proposed language regarding these 2 issues, (siting and sizing), is acceptable to the department.

However, please note the other requirements in the rules and DEQ 8 regarding pretreatment, consideration of potential EPA regulations, filter fabric, and the requirement of storm inflow/outflow hydrographs for sizing the facilities. These issues must be addressed for each stormwater plan proposed

If you have any questions on the above, please feel free to call me at the Permitting and Compliance Division at (406) 444-7076 or at the fax number (406) 444-1923.

Sincerely,

Deanne Fischer
Water Quality Specialist
Subdivision Section
Public Water and Subdivisions Bureau
e-mail – dfischer@mt.gov

c: file

LOCATION GRANTSDALE MT

Established Series
Rev. GLS-RJS
09/2008

GRANTSDALE SERIES

The Grantsdale series consists of very deep, well drained soils that formed in alluvium. These soils are on alluvial fans and stream terraces in intermountain valleys. Slopes are 0 to 4 percent. Mean annual precipitation is about 13 inches, and mean annual temperature is about 44 degrees F.

TAXONOMIC CLASS: Coarse-silty over sandy or sandy-skeletal, mixed, superactive, frigid Calcic Haploxerolls

TYPICAL PEDON: Grantsdale loam, cultivated. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 9 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; slightly hard, very friable, nonsticky, and nonplastic; many very fine, fine, and medium roots; common fine and medium pores; neutral (pH 6.8); clear smooth boundary. (7 to 10 inches thick)

Bw--9 to 17 inches; pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; weak fine and medium subangular blocky structure; slightly hard, very friable, nonsticky, and nonplastic; common very fine, fine, and medium roots; common fine pores; neutral (pH 7.1); gradual smooth boundary. (7 to 10 inches thick)

Bk--17 to 32 inches; light gray (2.5Y 7/2) loam, grayish brown (2.5Y 5/2) moist; weak medium and coarse subangular blocky structure; slightly hard, very friable, nonsticky, and nonplastic; few fine roots; common fine pores; disseminated lime; strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary. (6 to 20 inches thick)

2BCk--32 to 36 inches; light gray (2.5Y 7/2) very gravelly loamy sand, grayish brown (2.5Y 5/2) moist; single grain; loose, nonsticky, and nonplastic; few fine roots; thin lime coats on underside of gravel; 50 percent gravel, 10 percent cobbles; strongly effervescent; moderately alkaline (pH 8.2); gradual smooth boundary. (0 to 6 inches thick)

2C--36 to 60 inches; light brownish gray (10YR 6/2) very gravelly loamy sand, dark grayish brown (10YR 4/2) moist; single grain; loose, nonsticky, and nonplastic; 50 percent gravel, 10 percent cobbles; slightly effervescent; slightly alkaline (pH 7.5).

TYPE LOCATION: Missoula County, Montana; 2,450 feet south of the NE corner of sec. 35, T. 12 N., R. 20 W.

RANGE IN CHARACTERISTICS:

Soil temperature - 45 to 47 degrees F.
Moisture control section - approximately between the depths of 8 and 24 inches.
Mollic epipedon thickness - 7 to 16 inches
Depth to calcic horizon - 14 to 20 inches
Base saturation - 50 to 100 percent

Ap horizon - Value: 4 or 5 dry, 2 or 3 moist
Chroma: 2 or 3 dry or moist
Texture: loam or silt loam
Clay content: 10 to 18 percent
Reaction: pH 6.1 to 7.3

Bw horizon - Hue: 10YR or 2.5Y dry or moist
Value: 4, 5, or 6 dry; 3 or 4 moist
Chroma: 2 or 3 dry or moist
Texture: loam, very fine sandy loam, or silt loam
Clay content: 10 to 18 percent
Reaction: pH 6.1 to 7.3

Bk horizon - Hue: 10YR or 2.5Y dry or moist
Value: 5, 6, or 7 dry; 4, 5, or 6 moist
Chroma: 2 or 3 dry or moist
Texture: loam, very fine sandy loam, or silt loam
Clay content: 10 to 18 percent
Calcium carbonate equivalent: 5 to 15 percent
Reaction: pH 7.8 to 8.4

2BCk, 2C horizons - Hue: 10YR or 2.5Y dry or moist
Value: 5, 6, or 7 dry; 4, 5, or 6 moist
Chroma: 2 or 3 dry or moist
Texture: loamy sand or sand
Clay content: 5 to 10 percent
Rock fragments: 35 to 70 percent--5 to 20 percent cobbles; 30 to 50 percent gravel
Calcium carbonate equivalent: 5 to 15 percent
Reaction: pH 7.4 to 8.4

COMPETING SERIES: There are no competing series.

GEOGRAPHIC SETTING:

Landform- alluvial fans and stream terraces in intermountain valleys.
Elevation - 2,400 to 3,500 feet.
Slope - 0 to 4 percent.
Parent material - alluvium.
Climate - long, cold winters; moist springs; warm, dry summers.
Mean annual precipitation - 11 to 17 inches, much of which falls as snow and as spring rain.
Mean annual temperature - 43 to 45 degrees F.
Frost-free season - 90 to 125 days.

GEOGRAPHICALLY ASSOCIATED SOILS:

DRAINAGE AND PERMEABILITY: Well drained; moderate permeability in the upper 32 inches and rapid in the lower part.

USE AND VEGETATION: Grantsdale soils are used for irrigated and dryland crops and for urban development.

DISTRIBUTION AND EXTENT: Grantsdale soils are of moderate extent in mountain valleys of western Montana. MLRA 44A.

MLRA OFFICE RESPONSIBLE: Bozeman, Montana

SERIES ESTABLISHED: Bitterroot Valley Area, Montana, 1951.

REMARKS: Diagnostic horizons and features recognized in this pedon are:
Mollic epipedon - from the soil surface to 9 inches (Ap horizon);
Cambic horizon - from 9 to 17 inches (Bw horizon);

APPENDIX A

PERCOLATION TEST PROCEDURE 1

Properly conducted percolation tests are needed to determine absorption system site suitability and to size the absorption system. Percolation tests must be conducted within the boundary of the proposed absorption system. The percolation test must be completed by an individual approved by the reviewing authority.

Test hole preparation

1. Dig or bore holes 6 to 8 inches in diameter, with a maximum size of 10 inches, with vertical sides. The depth of the holes must be at the approximate depth of the proposed absorption trenches, typically 24 inches below ground. If hole is larger than 6 to 8 inches, place a piece of 4-inch diameter, perforated pipe inside the hole, and fill the space between the pipe and the walls of the hole with drain rock.

2. Roughen or scratch the bottoms and sides of the holes to provide natural unsmeared surfaces. Remove loose material. Place about 2 inches of ¾-inch washed gravel in the bottom of holes to prevent scouring during water addition.

3. Establish a reference point for measurements in or above each hole.

Soaking

1. Fill holes with clear water to a level at least 12 inches above the gravel.

2. If the first 12 inches of water seeps away in 60 minutes or less, add 12 inches of water a second time. If the second filling seeps away in 60 minutes or less, the percolation test should be run in accordance with the sandy soil test; proceed immediately with that test. As an alternative to proceeding with the test, if these conditions are met and documented, the percolation rate may be considered to be faster than 3 minutes per inch, and the test may be stopped.

3. If either the first 12 inches or the second 12 inches does not seep away in 60 minutes, the percolation test must be run in accordance with the test for other soils. In these other soils, maintain at least 12 inches of water in the hole for at least 4 hours to presoak the hole.

Test

1. Sandy soils (percolation rate of 10 minutes per inch or faster)

   Add water to provide a depth of 6 inches above gravel. Measure water level drop at least four times, in equally spaced intervals, in a 1 hour time period. Measure to nearest ¼ inch. Refill to 6-inch depth after each measurement. Do not exceed 6-inch depth of water. Use final water-level drop to calculate rate.

2. Other soils (percolation rate slower than 10 minutes per inch).

Remove loose material on top of gravel. Add water to provide a depth of 6 inches above gravel. Measure water levels for a minimum of 1 hour. A minimum of four measurements must be taken. The test must continue until two successive readings yield percolation rates that do not vary by more than 15 percent, or until measurements have been taken for four hours. Do not exceed 6-inch depth of water. Use final water-level drop to calculate rate.

Records

Record the following information on the attached form, and include as part of the application:

- Date(s) of test(s),
- Location, diameter, and depth of each test hole,
- Time of day that each soak period began and ended,
- Time of day for beginning and end of each water-level drop interval,
- Each water-level drop measurement,
- Calculated percolation rate,
- Name and signature of person performing test,
- Name of owner or project name.

Rate Calculation

Percolation Rate = Time interval in minutes/Water-level drop in inches

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
PERCOLATION TEST FORM

Owner Name ______________________________

Project Name ______________________________

Lot of Tract Number ____________________ Test Number ______________

Diameter of Test Hole ____________________ Depth of Test Hole ______________

Date and Time Soak Period Began ______________ Ended ______________

Date Test Began ______________________________

Distance of the reference point above the bottom of the hole ______________

Test Results

Start Time of Day	End Time of Day	Time Interval (Minutes)	Initial Distance Below Reference Point	Final Distance Below Reference Point	Drop in Water Level (inches)	Percolation Rate (minutes/inch)

I certify that this percolation test was done in accordance with DEQ-4, Appendix A.

______________________ ______________________ ______________
Name (printed) Signature Date

____
Company

PERCOLATION TEST PROCEDURE II

The consultant may use either or both tests in choosing the value used in site evaluation. The results of all tests must be reported in the application, and the procedure used must be specified. Test Procedure II requires substantially more data be obtained at well-defined intervals. If this information is not properly obtained, the results are not valid and will not be accepted. The percolation test must be completed by an individual approved by the reviewing authority.

Note: This test is run without a pre-soak time period, therefore results can be obtained in a shorter time period.

Depth of tests

Tests must be taken entirely within the most dense, least permeable soil identified at the approximate depth of the absorption trench, as identified from the test pit(s) on the site.

Type of test hole

The test hole must be unlined, shaped like a vertically oriented cylinder with a diameter of 6 to 8 inches.

Preparation of test hole

Using a sharp instrument, carefully scrape the side walls of the hole to remove any smeared surface. This is particularly important in soils having a significant silt or clay content. Place 1 inch of clean fine to medium gravel in the bottom of the hole to reduce scouring. After this process the evaluator may place a perforated pipe at least 4 inches in diameter in the center of the hole and surround it with the same gravel that is in the bottom. This must be done if the type of test hole required above cannot be constructed. This process will help keep the side walls from falling and causing the bottom to clog. When possible, instead of pouring water directly from a bucket into the hole, use a hose to siphon water out of a suitably located reservoir; this will provide a higher degree of control over the rate of water entering the hole, thereby minimizing scouring.

Percolation test measurements

To begin the test, fill the hole with water up to a level 6 inches above the stone and allow it to drop the distance specified in the table below for seven consecutive runs. After each run, bring the water up to the 6-inch level. The time of each run, the refill time between each run, and the total elapsed time must be accurately recorded.

	Soil Texture		
	Coarse to Medium Sand	**Fine Sand to Silt Loam**	**Silts to Clay Loam**
Anticipated Percolation Rate (min/inch)	1-10	10-60	60-120
Drop (inches)	2	1	0.5

Determining the percolation rate

The rate of drop for each run is plotted on graph paper, with logarithmic scales on both axes (log/log graph paper) against the cumulative time of the seven runs, including the refill time. The best straight line is fitted to the seven data points and extrapolated out to one day (1,440 minutes) of cumulative time. The rate of drop after 1,440 minutes is the percolation rate. A mathematical computation of the line of best fit of the seven or more data values may be used in lieu of the graphical method. The reviewing authority may require the mathematical computation of the line of best fit.

A typical data sheet is shown below, with units for each column noted below the table.

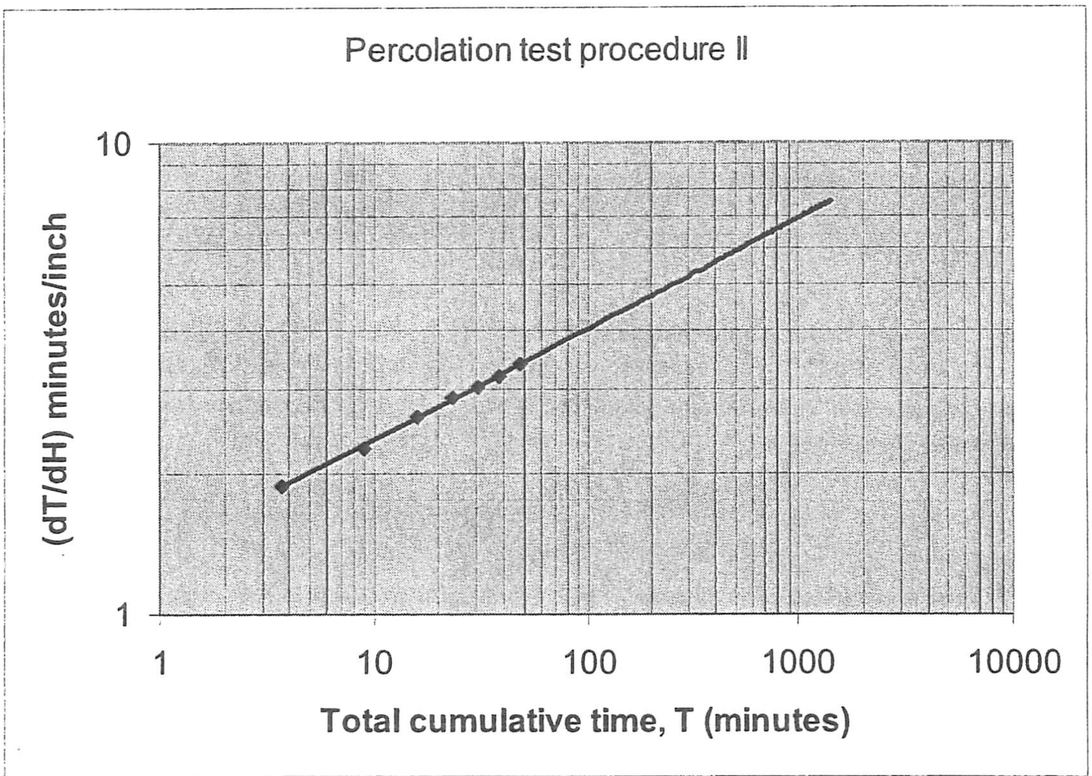
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				t	T	H	
Test #	Time @ Begin of Test Run	Time @ End of Test Run	Fill Time (sec)	Time for Specific Drop (mm)	Total Time Since Start of Test (min)	Total Drop Since Start of Test (inches)	dT/dH min/inch
1	3:32:15	3:36:00	30	3.75	3.75	2	1.88
2	3:36:30	3:41:15	45	5.25	9.00	4	2.25
3	3:42:00	3:48:00	10	6.75	15.75	6	2.63
4	3:48:10	3:55:15	45	7.25	23.00	8	2.88
5	3:56:00	4:03:30	30	7.25	30.25	10	3.03
6	4:04:00	4:11:45	35	8.25	38.50	12	3.21
7	4:12:20	4:20:45		9.00	47.50	14	3.39

Common units:

1. Number of test cycle (show all if more were run)
2. Start of test periods in hours, minutes, seconds
3. End of test periods in hours, minutes, seconds
4. Time to refill the test hole with water (seconds)
5. t – time in minutes to drop the predetermined distance for the test period
6. T – total cumulative time in minutes since the start of the first test
7. H – total measured drop in inches of water in the test hole since the start of the test
8. dT/Dt – the rate of water drop in minutes per inch

Test results

Based on the graphical plot show below, the percolation rate at 1,440 minutes is about 7.5 minutes per inch. This is the design percolation rate.


Percolation test procedure II
10
1
(dT/dH) minutes/inch
1
10
100
1000
10000
Total cumulative time, T (minutes)

On-Lot Infiltration

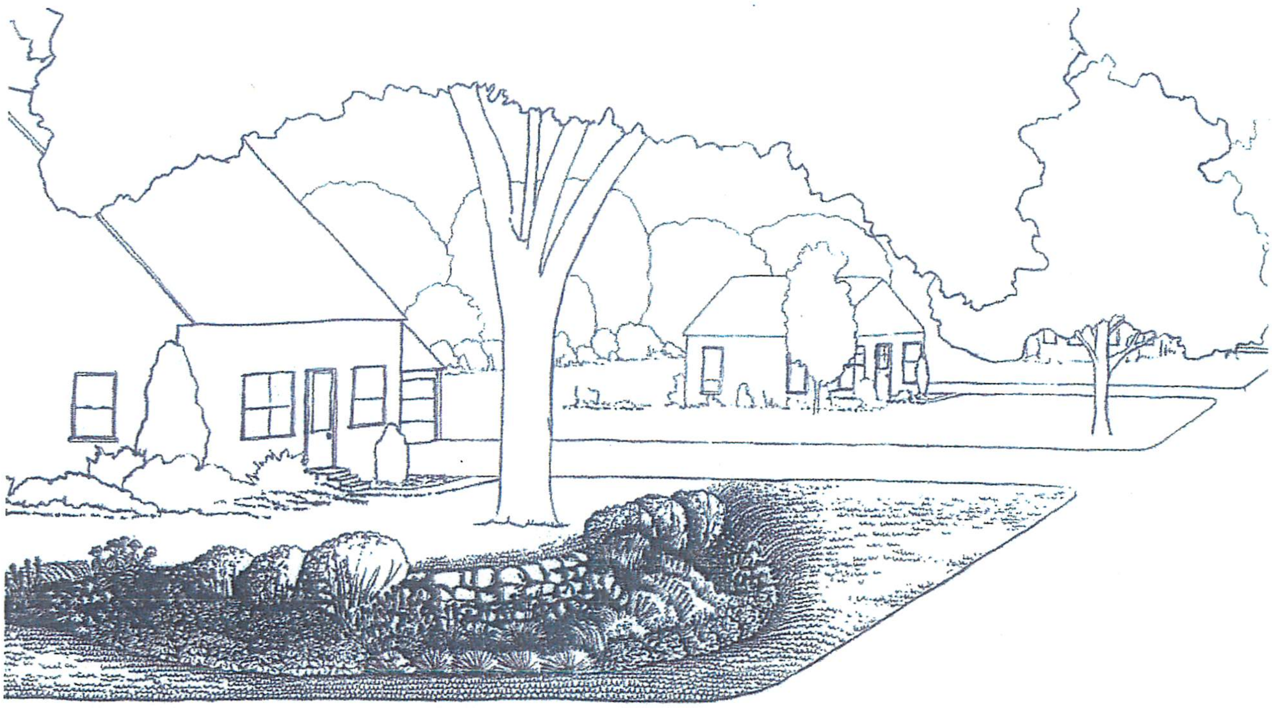


Figure 8: Typical Rainwater Garden Layout
Source: Adapted from Nassauer et al., 1997.

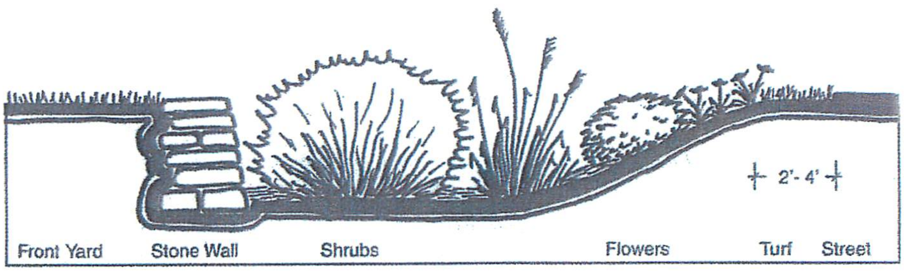


Figure 9: High-Volume, Asymmetrical Rainwater Garden with Masonry Wall
Source: Adapted from Nassauer et al., 1997.

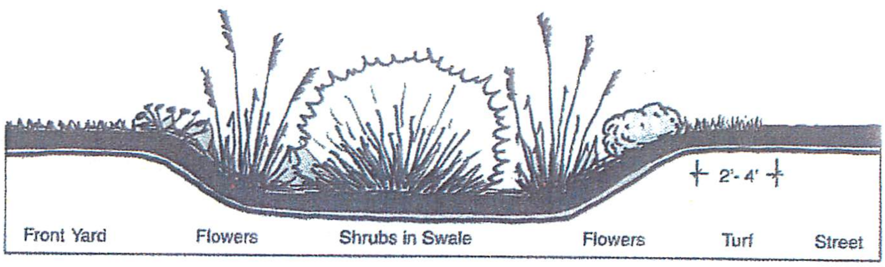


Figure 10: High-Volume, Symmetrical Rainwater Garden
Source: Adapted from Nassauer et al., 1997.

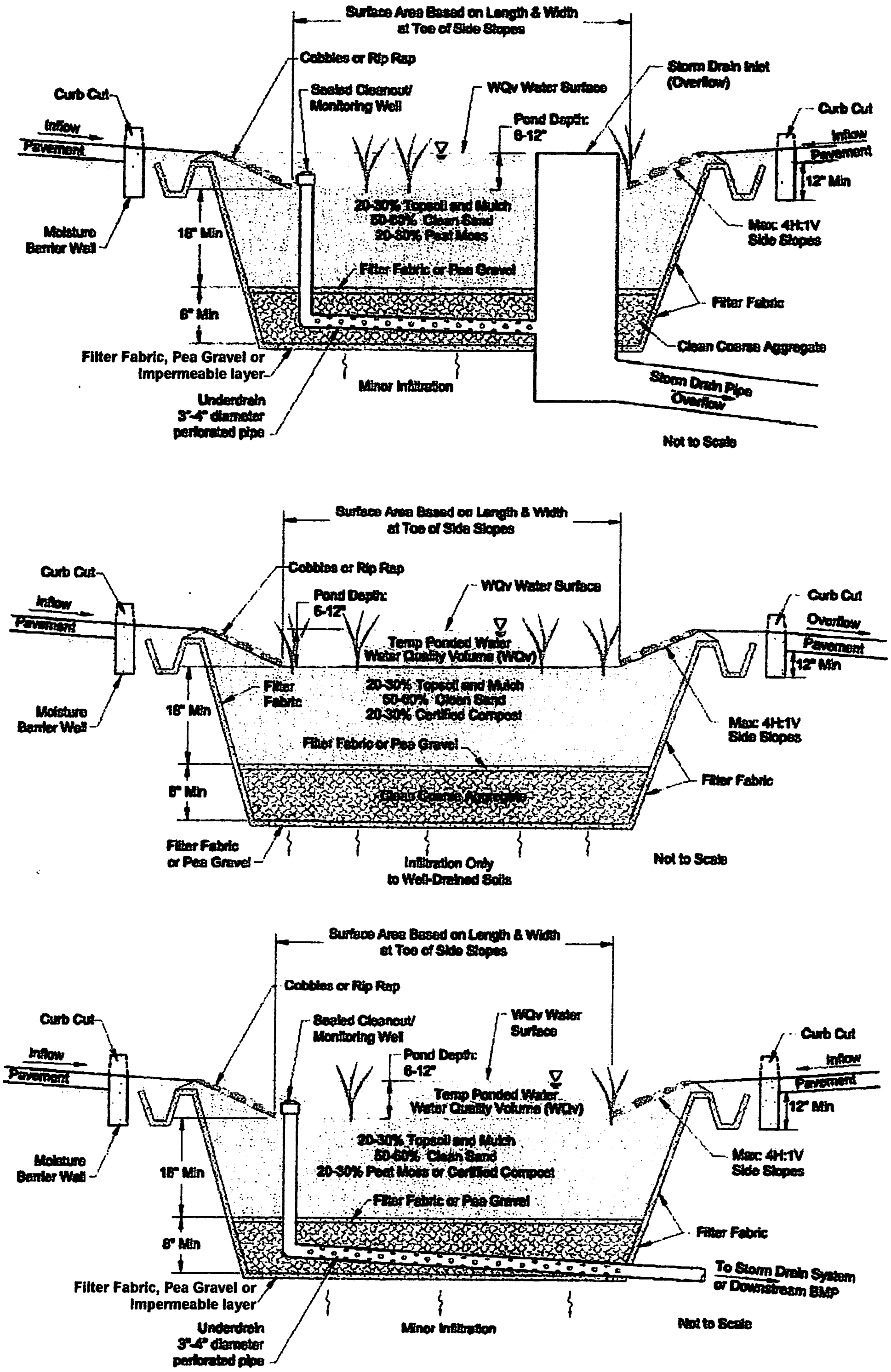


Figure TC-30. Schematics of a Landscape Detention facility

Design Requirements (continued)

Infiltration trenches can be constructed to be deeper than they need to be to fit certain site characteristics. The maximum effective depth is defined as the depth to which the design volume of runoff actually fills the trench.

Filter Fabric

The sides and bottom of the infiltration trench should be lined with geotextile fabric (filter fabric). Also, there can be a layer of nonwoven filter fabric 6 to 12 inches below the ground surface to prevent suspended solids from clogging the majority of the storage media. It should be recognized, however, that there may be a need to frequently replace this filter fabric layer depending on the volume of suspended solids transported to the trench.

The filter fabric material must be compatible with the surrounding soil textures and application purposes. The cut width of the filter fabric must have sufficient material for a minimum 12-inch overlap. When overlaps are required between rolls, the upstream roll must lap a minimum of two feet over the downstream roll to provide a shingled effect. The bottom of the infiltration trench can be covered with a six to twelve inch layer of clean sand in place of filter fabric.

Storage Media

The basic infiltration trench design utilizes stone aggregate in the top of the trench to provide storage. The trench should be filled with clean, washed stone with a diameter of 1.5 to 3 inches. This aggregate size provides a void space of 40 percent (SEWRPC, 1991, Harrington, 1989, Schueler, 1987).

This design can be modified by substituting pea gravel for stone aggregate in the top 0.3 meter (1 foot) of the trench. The pea gravel improves sediment filtering and maximizes the pollutant removal in the top of the trench.

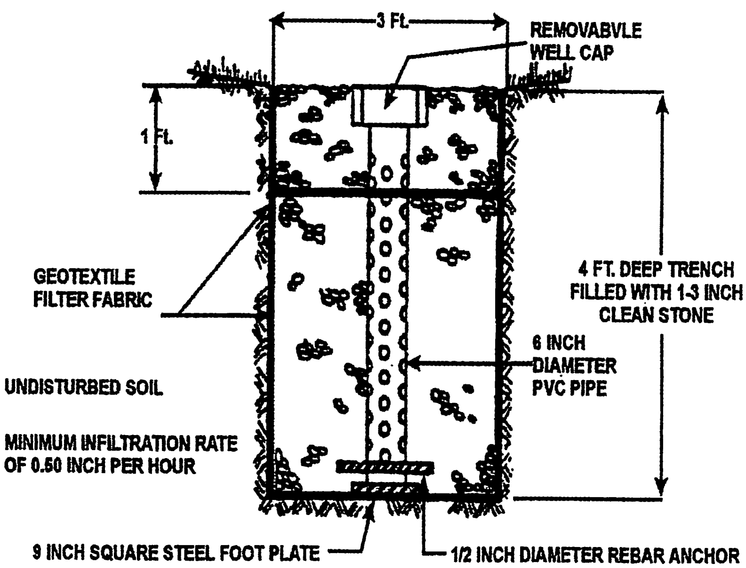


Figure 4: Observation Well Details
Source: SWRPC, 1991.

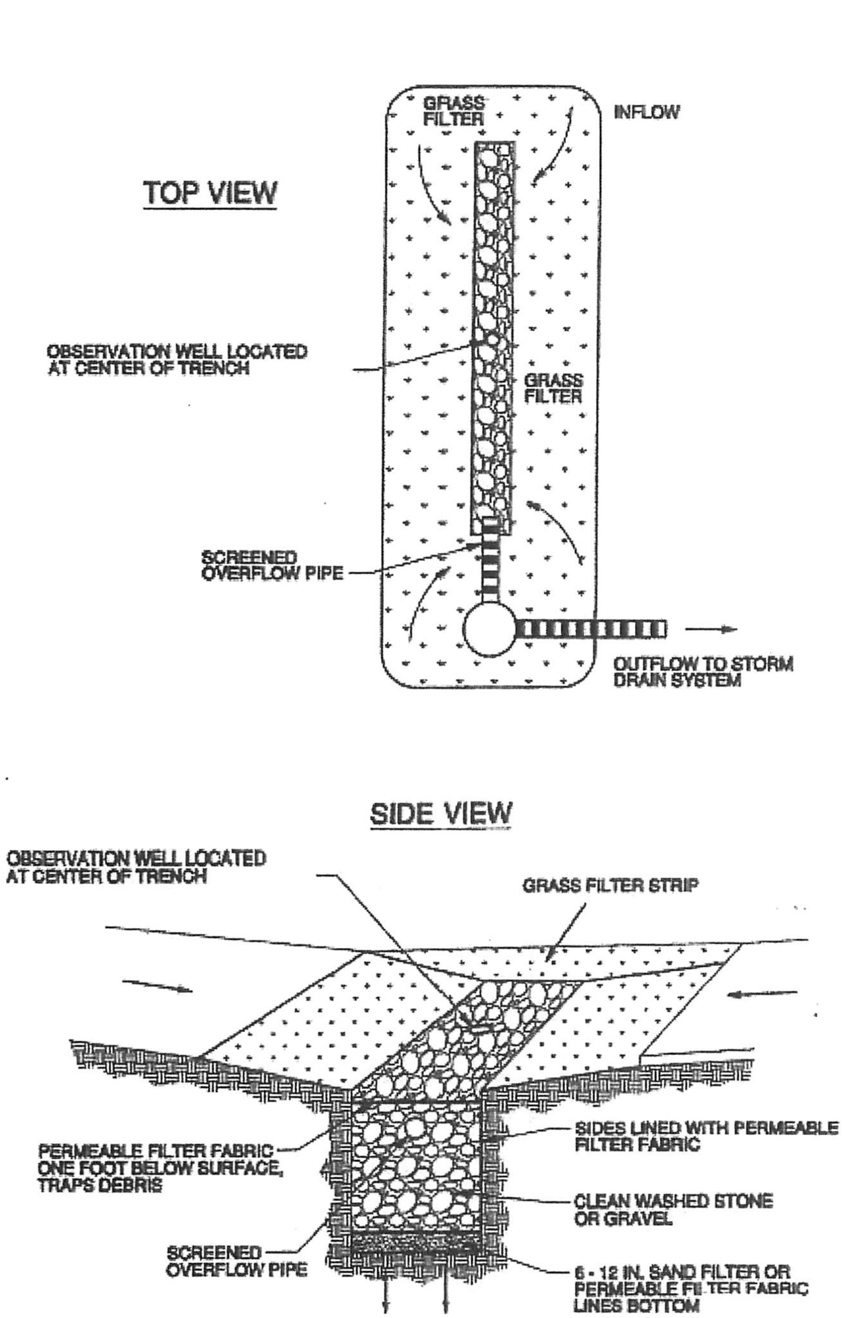


Figure TC-20B. Example of a median strip Infiltration Trench with a grass buffer strip (modified from Sacramento, 2000).