

Principles of Exterior Drainage



Short Course

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Foreword

Text is available on many subjects relative to site development for a variety of land uses. However, drainage is a subject which is often overlooked or downplayed. Adequate drainage is more than a necessary evil, it is a major influence on proper water management. The *“Principles of Exterior Drainage – Short Course”* is a condensed version of the *“Principles of Exterior Drainage”*. It focuses solely on all aspects of exterior drainage, from the identification of the problem to the design and installation of the solution.

The information contained in this manual was created to further the knowledge and professionalism of individuals involved in drainage projects. The expense and effort to compile the material in this manual is our contribution to the drainage industry that has been so generous to the employee owners of NDS, Inc.

The information in this manual is intended as a guideline for exterior drainage. A landscape architect or engineer should be consulted in critical areas or matters of drainage design.

Section I:

Background Information

Necessity for Drainage in Relation to Healthy Soil/Plant Life

Capillary moisture is essential to the maintenance of good soil characteristics and healthy turf. Gravitational moisture, and in many cases surface runoff, constitute excess water that is detrimental to the turf and other plant life. This excess water retards plant growth.

Therefore, gravitational water must be removed from the soil if healthy turf and plant life conditions are to exist. Surface runoff must be removed from all areas such that erosion will not occur and water will not be retained in surface depressions.

Sources of Water

Surface Water Sources

Water from a rainfall or irrigation event that does not infiltrate the soil appears as surface water. Surface water runoff is a major concern in urbanized areas, where development results in a high percentage of impervious surfaces such as roofs, driveways, and streets. Surface water may be free to flow to adjacent areas (runoff) and contribute to soil saturation in another zone. Some surface water is retained on the ground surface in depressions which, if soil permeability is extremely low, will pond.

Subsurface Water Sources

Most subsurface water results from surface infiltration, although water can enter the subsoil from aquifers or adjacent areas. Another potential contributor to excess soil wetness is a perched water table that generally forms above an impermeable soil layer.

Benefits of drainage in relation to healthy soil and plant life

Surface Drainage

Benefits that occur due to the controlled removal of surface water by surface drainage systems are:

1. Erosion control.
2. Removal of surface water. Excess rain or irrigation water will naturally flow to areas of lower elevation. The excess water may remain ponded, causing poor aesthetic conditions as well as destroying turf or damaging buildings, homes and hardscapes. Surface drainage structures can prevent these undesirable conditions and can often be located so they will not interfere with the planned use of the site.

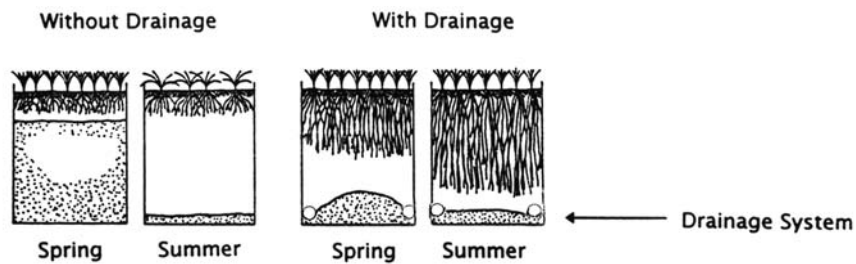
Subsurface Drainage

Removal of gravitational water from the soil profile provides many benefits. These benefits are often inconspicuous because they occur within the soil and the root zone. The benefits of subsurface drainage include:

1. Maintain soil's structural capability and improving trafficability.
2. Timeliness of maintenance operations. Continued removal of excessive soil water during the recreation season permits extended, more intensive use, resulting in increased revenue.
3. Helps the soil warm earlier in the spring.
4. Provides increased aeration in the root zone. Air is necessary in the root zone for healthy growth.
5. Deepens the root zone. **Figure I-1** shows the progression of root development during the spring and summer seasons under conditions of drained and undrained land.
6. Increases the supply of available plant food by increasing the presence of air in the root zone. Many plant nutrients must change in their chemical form during the period between when they are applied to the soil until they become available to the plants.

Figure I-1: Interaction between root development and subsurface

Proper drainage may help plants adapt healthily to the underground water and nutrients available in different seasons of the year



7. Decreases the damage due to freezing. Frost heaving can raise and buckle concrete slabs, sidewalks, and hardscapes. Drained soils have less water to freeze and frost heaving is less of a problem.

Common Applications

- | | |
|------------------------------|--------------------------------------|
| Subsurface Foundation Drains | Landfills |
| Retaining Wall Drainage | Swimming Pool Drains |
| Landscape Surface Drains | Parking Areas |
| Swales | Floor Drains |
| Dry Wells | Path Drains |
| Driveways | Tennis Courts |
| Planter Drainage | Soccer Fields |
| Children's Play Areas | Spring Interception or Collection |
| Baseball Fields | Road Bed Underlayment |
| Football Fields | Mines |
| Slope Retention | Golf Courses: Greens, Tees, Fairways |
| Highway Edge Drains | and Sand traps |

Leading Indicators of Drainage Problems

- Client observations.
- Your personal observations.
- Standing water 24 hours after a hard rain or irrigation.
- Concentrations of yellowing or patches of turf that has minimal original turf.
- Yellowing plant life.
- Thin areas of turf, although there is plenty of sun and no obvious disease.

- Areas that are constantly being treated for fungus problems.
- Debris, such as leaves, pine straw, trash, etc., accumulated in affected areas
- Water stains on fences, buildings, etc.
- Stagnate water smell.
- Trees and landscape material that are dying for no obvious reasons.
- Mud or silt deposits on flatwork, porches, etc.
- Structural damage related to moisture or excess water problems.
- Water intrusion into the home through doors sills, basements, garages, etc.

Drainage Problems Caused by Surface Obstructions

1. Soil level and topography — If the property is not graded correctly then it will not drain properly.
2. Tree root systems may cause impediments to surface and subsurface water flow.
3. Shrubbery root systems and certain types of ground cover will block or impede surface water flow.
4. Landscape timber, bricks, etc., will cause water flow obstructions and will inhibit or create directional water paths on the surface.
5. Plastic edging as well as a wide variety of other types of edging may affect surface drainage problems.
6. Flat work or hardscapes such as sidewalks, driveways, patios, etc., may have been installed to high and either inhibit, block, or retain water.

Drainage Problems Caused by Subsurface Obstructions

1. Poor soil conditions that are indigenous to the region or brought in for construction purposes.
2. Swimming pools or buried structures that severely limit the soils holding capacity.
3. Root barriers that may have been installed will inhibit and block water movement.
4. Broken or poorly adjusted irrigation systems.
5. Adjoining properties that may have all of the above potential problems that are routed onto your clients property.

Degree of Drainage Problem

Drainage problems are broken into different categories. Until you determine what the base problem is, you cannot begin to determine the root cause of the drainage problem.

1. **Nuisance** – This type of problem is generally water standing for extended periods of time. This will cause a mosquito infestation, will be harmful to the turf and shrubs, and limit the use of the affected area.
2. **Potential Damage** – This type of problem will generally have the same problems associated with a nuisance water problem but will be expanded to include water damage to out buildings, such as storage sheds, fences, flooded patios, etc.
3. **Damage** – This type of problem may be combined with nuisance and potential damage categories or may have specific problems and symptoms. This category will cover all instances where there is water intrusion into the home or outbuildings and/or plant damage.

Chapter 1:

Soil and Water Relationship

Soils

What is soil?

Soil is a mixture of inorganic solids: air, water, and microorganisms. All of these phases affect one another. How soil reacts to water induced by rainfall and irrigation will influence your drainage parameters.

One of the most important aspects of soil is texture, the relationship of percentages of sand, silt and clay, the basic aggregate portions of any soil. The structure of the soil is also important. Structure is the combination of the soil texture and organic matter. Whereas texture is the more mechanical form of the soil, namely the relationship of its mineral aggregate, the presence of its organic matter is again critical in good soils for drainage and erosion control.

Soil Function

Soil basically acts as a pervious medium that provides passageways (voids in the soils) for water to move into the subsurface. The effectiveness of the soil to transport water depends upon the size and permeability of these passageways.

Permeability is used as a measure of the soil's ability to transmit gravitational water. Generally, coarse materials such as sand are highly permeable and have good transmission rates. Clay soils, however, are usually relatively impermeable and water retention is long-term in the absence of a drainage system. The passage of water depends greatly upon the size of the voids in the soil structure, granular soils with higher void sizes like sand move water better than compact soils like clay with a flat configuration and small grain sizes, and therefore smaller void sizes. Water has an electrical attraction to smaller particles such as clay. Therefore, clay holds onto the water droplets, inhibiting flow through the soil. Loam soils are comprised of medium-sized particles.

Soil Compaction

How tightly packed the soils are depends on the size of the soil particles and the volume of traffic traveling over the area. Clay is a very tight soil. Heavy traffic compounds the problems by increasing the tightness of the soil. The tighter the soil, the smaller the voids between soil particles which increases drainage problems.

When all voids in the soil are filled with water, the soil is considered to be "saturated" or "impervious." Soils that are totally saturated may not be able to absorb any water until it dries out. If this situation occurs, then water will run off or pond on the surface as it can no longer be absorbed below ground. General drainage and erosion control procedures try to deal with water before it gets into the soil. Drainage systems collect excessive surface or subsurface water before erosion or soil saturation can occur.

Gathering Soils Information

Information about soils can be gained through a number of simple methodologies. Perhaps the most efficient is soil mapping information provided by the U.S. Department of Agricultural Soil Conservation Service.

Soil Probing and Analysis

The best way to determine drainage needs in the site analysis stage is to probe and analyze existing site soils. The best tool for determining subsurface soil layer is the soil auger or probe, with a minimum three foot long auger or coring tool. It may be necessary to pre-irrigate the top 6" of the soil surface so that the soil can be probed easily. A good rule of thumb for probing depth is that the soil should be evaluated to at least 6" below the proposed foundation depth for any site building. The designer should be looking for thick soil areas that might have a tendency to be impervious to water and allow it to flow laterally towards buildings.

Soil types should be analyzed for their (mechanical) relative proportions of sand, silt, and clay, or *soil texture* components and evaluated for infiltration rates and permeability.

The drainage designer may also take advantage of any soil boring information necessary for the design and construction of the buildings.

Soil Modification

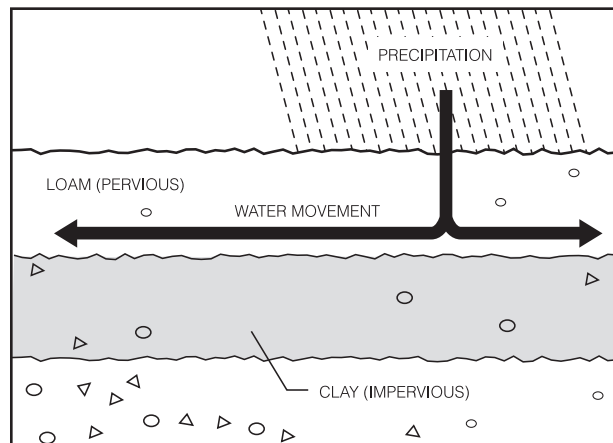
In some applications soil may be imported for leveling or other landscape functions. Even if the imported soil quality is good, the original soil underneath may be a densely packed clay. Water may penetrate the topsoil, but it comes to a standstill when it reaches the clay. For this common scenario, soil types need to be analyzed at three foot and six foot depths when designing a drainage system (**Figure 1-1**).

Vegetation Influence

Vegetation influences soil in many ways. One, the denser and larger the vegetative cover, the more rain will be intercepted and not reach the soil surface. Two, the presence of deep-rooted vegetation tends to improve soil structure, which increases infiltration. Thirdly, heavy vegetation can help retain moisture. Most importantly, vegetation prevents erosion.

Figure 1-1: Impervious soil layer

Natural ability of the soil to absorb water may depend on soil composition 3' to 6' beneath the surface. This is a good reason to sample the soil at 3' and 6' depths.



Coefficient of Runoff

One of the most critical aspects of calculating drainage for drainage design is the coefficient of runoff, or the C-factor. Coefficient of runoff is almost one hundred percent in urban areas. Rooftops, concrete sidewalks, asphalt parking lots, roads, etc. refuse to let water pass through them, and consequently the water that hits these surfaces runs off.

Soil Texture	Coefficient of Runoff	Soil Texture	Coefficient of Runoff
Concrete or Asphalt	1.00	Loam - Bare	.60
Gravel - Compact	.70	Loam - Light Vegetation	.45
Clay - Bare	.75	Loam - Dense Vegetation	.35
Clay - Light Vegetation	.60	Sand - Bare	.50
Clay - Dense Vegetation	.50	Sand - Light Vegetation	.40
Gravel - Bare	.65	Sand - Dense Vegetation	.30
Gravel - Light Vegetation	.50	Grass Areas	.35
Gravel - Dense Vegetation	.40		

Note: The above data is approximate. Coefficient of Runoff = Runoff/Rainfall

Table 1-1:

Chapter 2:

Topography and Grades

Topography

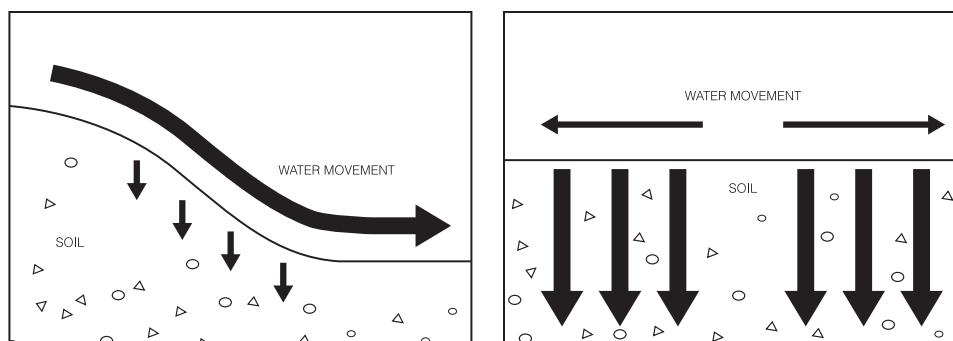
The length and steepness of slopes influence the amount and rate of storm water runoff. As the extent and gradient of slope increase, the amount, rate, and velocity of runoff increase, thereby increasing the potential for erosion. On the other hand, soils that are flat, or with relatively no relief, do not drain well, but they seldom provide any threat in terms of erosion.

Slopes' influence on surface runoff and subsurface ground water (**Figure 2-1**). The greater the slope the more surface runoff and less soil absorption. Conversely, the lesser the slope the more soil absorption and less surface runoff are experienced. The boldness of the arrows illustrates runoff and infiltration potentials.

Figure 2-1: Influence of slope

More surface water runoff, less soil penetration (left)

Less surface water runoff, more soil penetration (right)

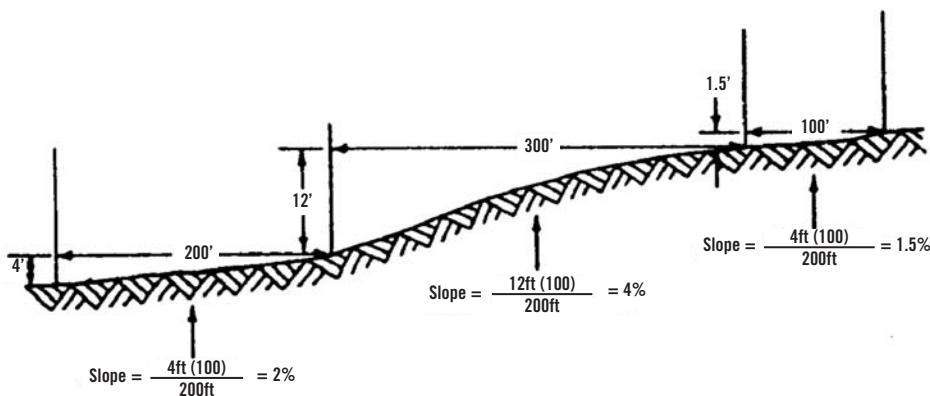


Slopes

Few areas on the earth's surface are horizontal or level planes. In most situations this can be seen by the eye. However, the eye is often not a reliable guide to the direction of fall and gives no information about the magnitude of the fall.

The deviation from a horizontal plane is called slope. It is commonly expressed as feet of vertical rise or fall per 100 feet of horizontal distance, which is referred to as percent slope. Mathematically, percent slope can be determined by multiplying the feet of vertical rise or fall by 100 and dividing by the horizontal distance in feet (**Figure 2-2**).

Figure 2-2: Determined slope from elevation difference and distance



Leveling

Leveling can be done using a simple carpenter's level or line level if the slope of the line is not critical. As the desire for precision increases, more sophisticated equipment is required to produce the desired results. A hand level or abney level will give accurate results as long as the line of sight does not exceed 100 feet. Larger projects will require the use of a tripod level.

Line Level

A line level is a small level bubble enclosed in a metal case, which can be hooked over a taut string. With the string tied to a stake or held to the ground at one point and adjusted until it is level, the difference in elevation between the string and the ground can be measured with a rule (Figure 2-3). The line level must be placed near the center of the string so any sag in the string will not cause false readings. This method is suitable for distances up to 50 feet where great precision is not required.

Tripod Levels

These instruments vary in cost from \$100 for a farm level to \$800 or more for an engineer's level. The most inexpensive type of tripod level, the farm level, is adequate for most turf drainage work.

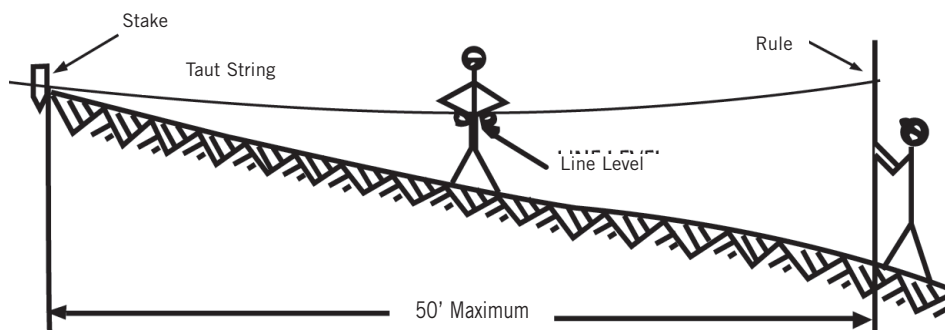


Figure 2-3: Measuring elevation difference with a line level

To find the difference in elevation between two points with a tripod level, set the instrument about half way between the two points and adjust the level so the bubble is centered regardless of horizontal direction sighted (Figure 2-4). Hold the rod vertically with the zero-end of the rod at the bottom, on point A. Sight at the rod through the level telescope and read the rod at the horizontal cross-hair location (0.4 feet). Then hold the rod on point B, sight at the rod, and read the rod (2.5 feet). The values read with the rod located on points A and B are the vertical distances from the bottom of the rod to the horizontal plane of the telescope.

The elevation of point A is 100.0 feet, the elevation of the line-of-sight through the

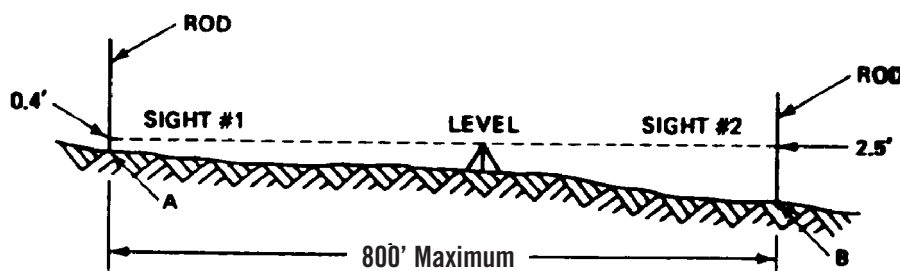


Figure 2-4: Determining elevation difference with a tripod level

level is 100.4 feet. The elevation of point B is, therefore, 2.5 feet below the line-of-sight, or 97.9 feet. If the two rod readings are subtracted, the result is the difference in elevation between points A and B, or 2.1 feet.

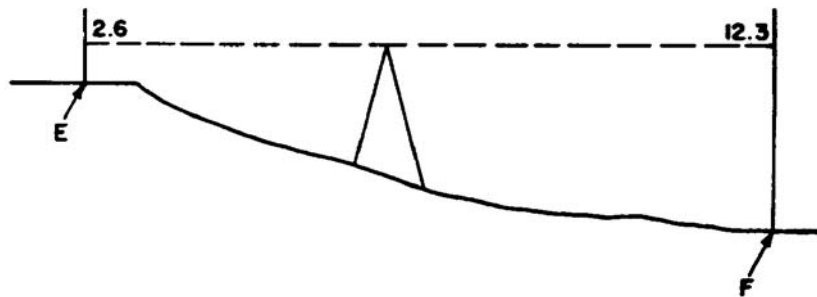
Problems

If two points are 200 feet apart horizontally and 10 feet apart vertically, what is the slope in percent of a line between these points?

A drain line has a grade of 3%. If two points of interest along the drain are 400 feet apart, what is the elevation difference between the two points?

Determine the elevation difference between points E and F (Figure 2-5).

Figure 2-5: Sample problem



Drainage Considerations

There are three basic forms of drainage control on a steep slope: above ground drainage diversion above the cut slope area; sub-surface drainage within the slope; and pipe drainage from within the steep slope, primarily for draining active seepage such as springs.

By far the most beneficial and effective of these drainage techniques is the entrapment of surface water above the steep slope and the transportation of it to a safe area. Entrapment of up slope waters can be accomplished through a number of different drainage methodologies, including berming, use of concrete-lined or grass-lined ditches. Entrapment water can thereafter be transported to a point away from the slope and safely released.

A secondary, and overall less effective method of entrapping and diverting drainage water on the slope is the use of sub-surface interception ditches parallel to the contours of the slope. Improvements have been made, however, through the use of geo-textile fabrics and gravel envelope drains to make sure that if these systems have to be relied upon that they have a more predictable life.

Lastly, rigid perforated pipe can be installed in seepage areas on a slope, especially in any area that perpetually weeps water, and can be drained out beyond the toe of the slope to keep water from degrading the hillside. These rigid pipes are buried into the slope perpendicular to its face.

Many times all three of these methodologies are utilized on one project.

Chapter 3:

Drainage Materials and Applications

Drain Pipe

The two most frequently used type of drain pipe systems for residential and commercial drainage applications are Corrugated and Sewer & Drain (smooth wall) pipe (**Figure 3-1**). In general terms, whether using corrugated or sewer and drain pipe, perforated pipe is used for subsurface drainage and solid pipe is used to convey water from surface and/or subsurface drainage systems.

Corrugated Pipe

Corrugated pipe is manufactured from high density polyethylene (HDPE) and is available from 10 foot lengths to coils up to 1,000 feet long. The longer the coil the fewer couplings necessary and the less labor required. Since corrugated pipe is flexible, it can follow the contours of the ground, change directions in the trench, and adapt to underground obstacles more easily than rigid pipe. Labor savings and flexibility are two important advantages of corrugated pipe. Several disadvantages of corrugated pipe are prevalent. Plumber's snakes cannot be used to clean out the pipe as they get caught in the pipe's corrugations. Corrugated pipe and fittings snap together and, henceforth, are not watertight. If slope is critical, the flexibility of corrugated pipe makes it difficult to obtain constant slope unless the trench bed is sloped properly **Figure 3-2**. Corrugated pipe has more friction loss than smooth wall sewer and drain pipe reducing flow and increasing sediment deposits in the drain pipe.

Corrugated Plastic Tubing:	Manning "n"
a. 3 - 8 in.	(0.01 - 0.016)
b. 10 - 12 in.	(0.016 - 0.018)
c. Larger than	(0.019 - 0.021)

Corrugated pipe is available in solid or perforated. The perforated version is sometimes known as slotted drain tubing. Perforated pipes are used for subsurface drainage applications.

Coextruded dual wall corrugated pipe is a variation to single wall corrugated pipe. It is more rigid and has a smooth interior wall which gives it the characteristics of Sewer & Drain pipe.

Smooth Wall Sewer & Drain Pipe

Sewer and Drain pipe is much more rigid than corrugated pipe and manufactured from PVC, ABS and Polyethylene. It is easier to maintain a continuous slope in critical areas with sewer and drain pipe or coextruded dual wall corrugated pipe. They will compensate for peaks and valleys in the trench bed (**Figure 3-2**). PVC and ABS connections can be solvent welded or glued together ensuring watertight connections. Drain snakes can be used on Sewer and Drain pipe if the pipe line becomes clogged. However, Sewer and Drain Pipe is more labor intensive and less flexible than

corrugated pipe. Sewer and Drain pipe is available as ASTM 2729, ASTM F810 or SDR 35. SDR 35 has a thicker wall and stronger crush strength than 2729 or smooth wall polyethylene pipe. Polyethylene smooth wall sewer & drain pipe, common in some geographical regions is more flexible than PVC or ABS, with connections that cannot be glued together. SDR 35 pipe is more expensive than ASTM 2729 or polyethylene pipe.

Smooth wall plastic pipe or
Dual Wall Smooth Interior Corrugated pipe

Manning “n”
0.010-0.013

Manning “n” values are used for estimating internal volume flow rates. Typically, the lower the “n” value the greater the flow volumes. Drain pipe with a smooth interior wall has greater flow characteristics than single wall corrugated drain pipe.

DWV (Drain Waste & Vent) and PVC schedule 40 pipe may also be used in drainage applications. They are, however, more expensive and an unnecessary expense for the task of draining surface or ground water. DWV pipe is typically used in indoor sewer applications, while schedule 40 pipe is commonly used in pressure applications such as lawn sprinkler systems.

Figure 3-1: Type of drain pipes

Smooth wall sewer & drain pipe (left)

HDPE corrugated pipe (right)

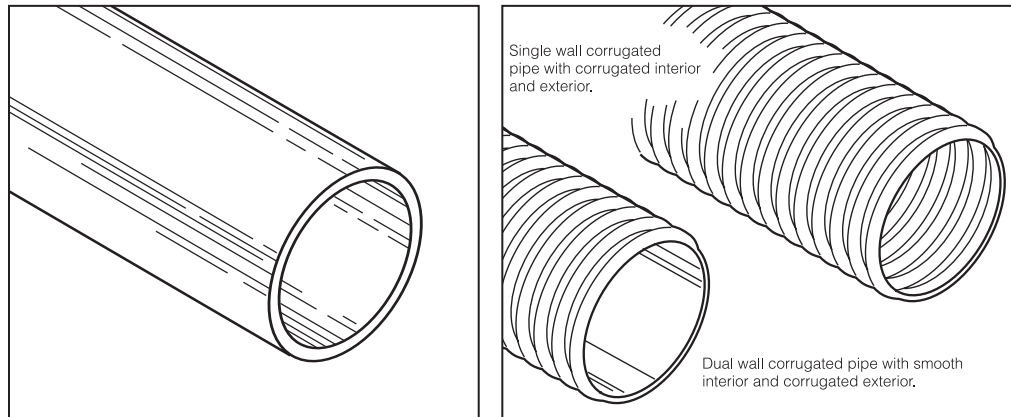
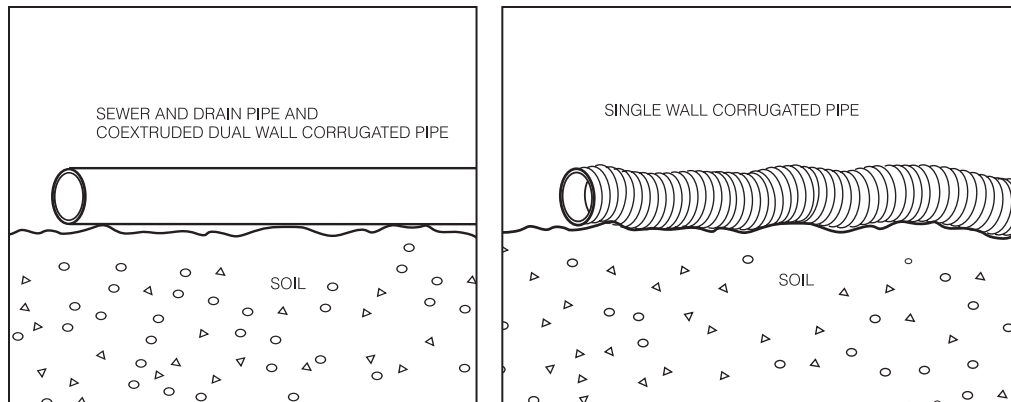


Figure 3-2: Influence of trenches

Sewer drain pipe and coextruded dual wall corrugated pipe can maintain a continuous slope on uneven trench beds. (left)

Single wall corrugated pipe conforms to an uneven trench bed, making it important to have consistently smooth sloped trench beds. If trench is uneven, pipe will have peaks and valleys, inhibiting flow. (right)



French Drain

French drains, a form of subsurface drain, utilizes a buried perforated pipe installed in a gravel bed with a filter sock or geotextile fabric envelope lining the trench. Water from the surrounding soil enters the gravel bed, flows into the drain pipe and utilizes gravity to flow towards the discharge point (**Figure 3-3**).

Perforations in single wall corrugated pipe are slits surrounding all sides of the pipe. Perforations in smooth wall drain pipe and coextruded dual wall corrugated pipe are small diameter holes located in rows on one side of the pipe which should always face downward to prevent soil from infiltrating the pipe.

French drains are the most common method for evacuating excess ground water which has infiltrated into the soil. However, french drains require labor, large trenches, rock or stone, filter fabric and therefore are more expensive than surface drainage systems. Also migrating soil fines will accumulate on the filter fabric or in the drain pipe, potentially inhibiting water flow and eventually clogging, limiting the life of the drain system.

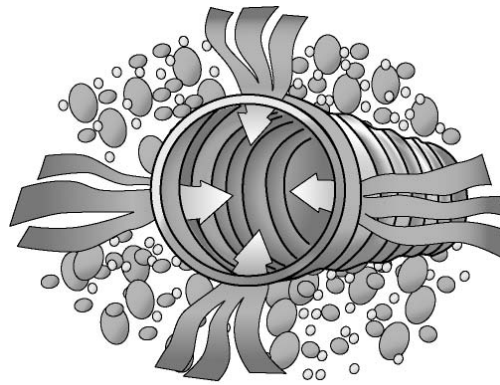


Figure 3-3: French drain

Filters and Envelopes for French Drains

General

Filters are permeable materials, typically non-woven fabric (**Figure 3-4**), but may include sand and gravel, placed around the drainage pipe or envelope to restrict migration of non-colloidal particles from the surrounding soils.

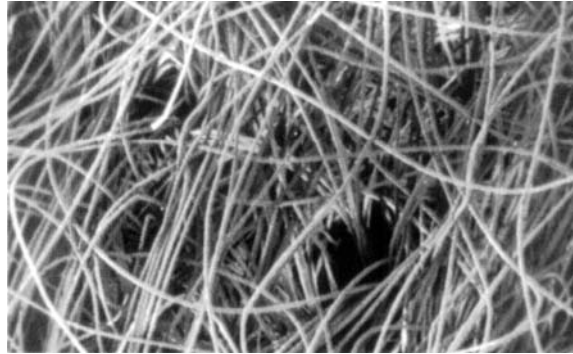
Envelopes for french drains are gravel, stone, rock or sock surrounding pipe. These are permeable materials placed around pipe or drainage products to improve flow conditions in the area immediately around the drain and for improving bedding and structural backfill conditions.

Most geotextiles used during drainage applications are used to prevent contamination of soils into aggregate backfill materials or perforated drain pipe. Using geotextiles as a screen helps maintain the natural integrity of the products used in your project. The need for geotextiles as a screen should be evaluated for each particular site, especially french drain applications. The solution is as easy as wrapping the perforated pipe or aggregate backfill material with non-woven geotextiles. Very light weight geotextiles should be used to cover the top gravel layer. Light weight geotextiles should be used to line the sides and bottom of a french drain. It will be important to know the K factor of the soil, relating the K factor to the fabric “permeability factor.” To select the proper screen AOS opening size of the fabric,

consider the following: Pick the soils' gradation sieve size (inches/min) for which 85% of the soil (by weight) will pass. Multiply the sieve size (inches/min) by two. This value should be greater than the AOS of the fabric. AASHTMO M288 sets standards for selection of the proper geotextiles.

non-woven fabrics are used in subsurface drainage applications because of their high flow capacity and small pore size. non-woven fabrics are produced by a variety of processes. Geotextiles are frequently produced by a combination of two different type processes. The first process is fiber formation and results in either a continuous filament or a staple fiber (a short fiber). Fibers are then bonded by needling, heated calendar or other processes or combinations.

Figure 3-4: non-woven geotextile



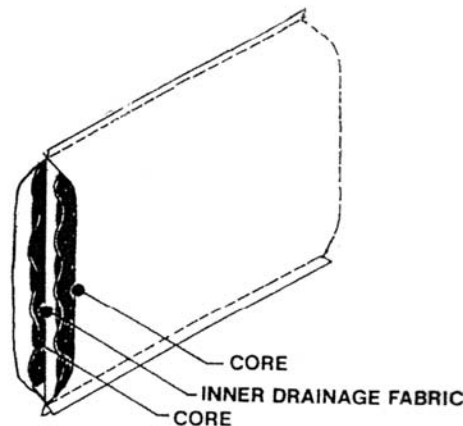
Prefabricated Drain Systems

A prefabricated drain system usually consists of a cusped plastic core which is completely wrapped in a geotextile fabric (Figure 3-5). The fabric may be glued to the core or sewn. The geotextile prevents intrusion of fine soils into the drainage core. Water passes through the fabric and flows through the core to the discharge point. The geotextile filters the fine-grained soil particles leading to the development of a stable filter cake.

Prefabricated drain systems are typically rectangular with a narrow profile and available in 4" through 60' depths. Common lengths are 10 ft. to over 100 ft. They are used in both natural and synthetic turf applications to collect and convey water away from the problem areas. Compared to french drains, their narrow cross-section allows them to be installed in more narrow trenches without significantly disrupting natural turf areas. In many cases, the area can be returned to play the same day.

Prefabricated drain systems can be installed in lieu of a French Drain and offer the same or slightly better results. As compared to french drains, they convey a relatively high volume of water at low hydraulic gradients due to the large degree of open surface area.

Figure 3-5: Prefabricated drain



Composite Drain

Geocomposites or subsurface interceptor drains (Figure 3-6), are a type of prefabricated drain systems. Large sheets of drainage core are wrapped in drainage fabric and are often directly attached to standard drain pipe at the bottom. They are hung and staked into place. This type of drain provides an impervious barrier to ground water. The ground water flows vertically down the core to the drain pipe which conveys it to a discharge point. They are most commonly used for spring interception and water table problems.

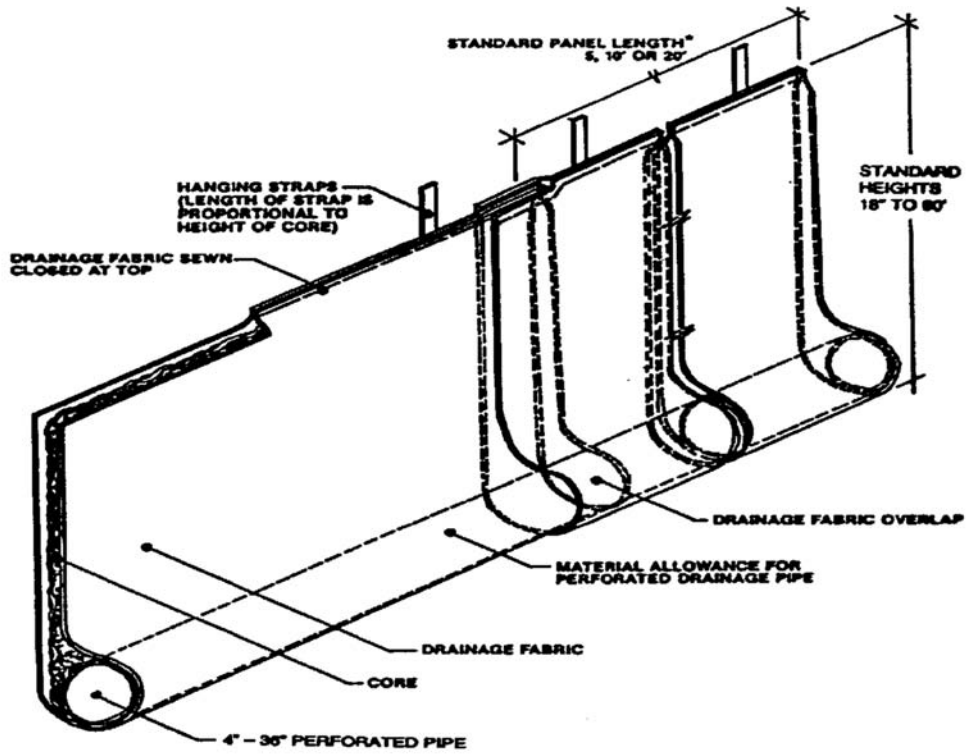


Figure 3-6: Composite drain

Catch Basins and Inlets

Catch basins or inlets, surface drains, used in conjunction with a drain pipe system will remove large amounts of surface water from an affected area. These are typically used in low areas of turf landscapes, hardscapes, driveways, parking lots, etc. Catch basins and inlets are traditionally available in sizes from 3" round to 48" square and different materials including concrete, brick, and plastic basins, cast iron, steel, brass and plastic grates.

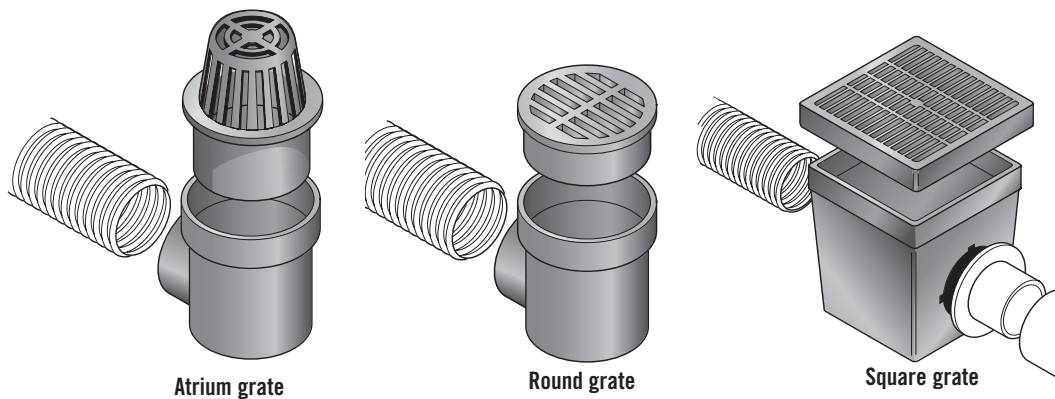


Figure 3-7: Surface drain grate configurations

Many configurations for grates are available (**Figure 3-7**). Atrium grates are used in landscape areas, planter beds, window wells or where debris like mulch and leaves might clog a flat grate. They required less maintenance as a result. Atrium grates have larger open surface areas to handle more runoff as well. Round grates are used often in landscapes while square grates are easier to form around in concrete, pavers and other pavement applications.

For instruction purposes, a catch basin differs from an inlet in that an inlet is located on top of a pipe riser and does not have a sump area. However, inlet is also a term that may be used to describe all surface drains. The sump area of a catch basin collects debris from runoff water that might clog drain lines. The debris is cleaned out periodically. A catch basin should be used in areas where debris like mulch, leaves, sand, silt or grass clippings are prevalent.

Channel Drains

Channel drains are linear surface drains connected together to a length appropriate for the specific installation (**Figure 3-8**). Runoff water collected in the drain is discharged to bottom or end outlets, or catch basins all of which are connected to drain pipe. They are available in widths from 1” to 16” wide and different materials including concrete, steel, plastic or formed in place. Grates are available in cast iron, steel, brass and plastic.

Channel Systems operate on the same principle as a roof gutter. Instead of grading a deck surface to a low area, the deck is gradually sloped in one direction or plane, and the channel drain acts as a perimeter drain at the edge of the slope.

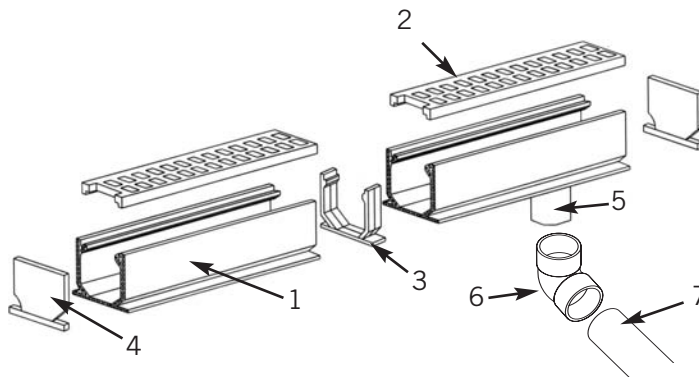
Hardscapes generate more runoff than landscapes due to the lack of water absorption. Channel drain systems provide more overall open surface area than conventional area grates (basins and inlets) to handle the larger volume of runoff. Ideal applications for channel drains are hardscapes or large flat work areas of concrete, asphalt, brick, pavers, etc.

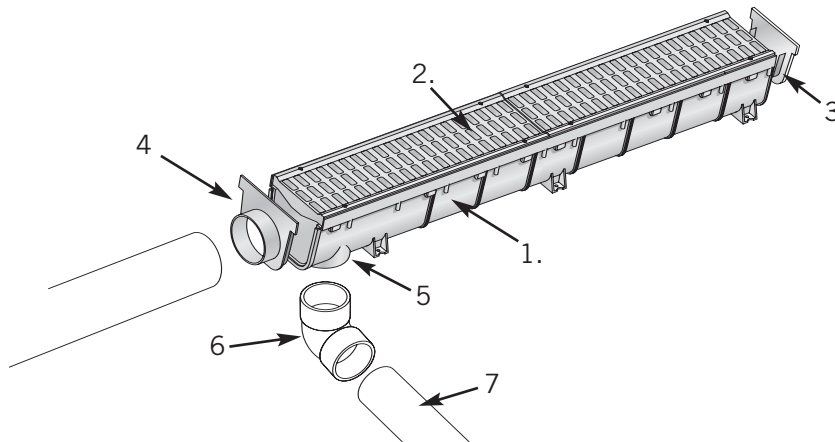
Recommended Applications:

- | | |
|-------------------------|---------------------------|
| Driveways | Tennis courts |
| Parking lots | Sidewalks |
| Warehouses | Patios |
| Swimming pools and spas | Sports facilities |
| Washdown areas | Nurseries and greenhouses |

Profile Channel Drain

1. Channel
2. Grate
3. Coupling
4. End Cap or End Outlet
5. Bottom Outlet
6. Drain Fitting
7. Drain Pipe



**Modular Channel Drain**

1. Channel
2. Grate
3. End Cap (or End Outlet)
4. End Outlet (or End Cap)
5. Bottom Outlet
6. Drain Fitting
7. Drain Pipe

Swales

Natural surface drain swales are the least expensive method of removing undesired surface water run off. A typical swale can be approximately 2' - 60' wide and can have a depth from 2" to 60".

Terraces

The primary purpose of terracing is to move surface runoff water from sloping areas. Bench terraces and tile outlet terraces are the two types of terraces that have been used in turf drainage.

Fill Dirt

Generally speaking fill dirt is not a positive solution to addressing drainage problems, as it generally routes the water problems to another area. However; there are times where fill dirt, preferable a mixture of humus and sand, will be used to fill in minor low areas and direct water to safe areas.

Culverts

Culverts can be installed under flat work, gravel or dirt to allow water to pass under an obstruction.

Dynamic Boost

Preferred for moving water and adding a boost. This system is totally dependent on rainfall and gravity. Boost is gained via connecting all of the gutter downspouts into the drain.

Electrical Boost

Use of a submersible pump is a last resort if there are no other options available. Runoff water may need to be pumped uphill to a higher elevation safe area if adequate fall is not available for a sloped, gravity flow, drain pipe.

Section II:

Design

Introduction

Surface Drainage

Engineers and architects divide drainage into surface and subsurface. Surface drainage begins with shaping and smoothing the land into a watershed that directs runoff to ditches, catch basins, storm sewers or other drainage systems. Without proper surface drainage, subsurface drainage efforts are considerably more difficult. Surface drainage has been defined as the controlled removal of surface runoff resulting from precipitation, irrigation, spring thaws, or hillside seeps. In more severe cases, turf will not survive or hardscapes and buildings may be damaged.

Subsurface Drainage

Subsurface drainage has previously been defined as the removal of gravitational water from the soil. The source of subsurface water is percolation (water moving vertically and laterally underground) that is generally attributable to precipitation or irrigation. The lack of volume and velocity at which water flows through a subsurface perforated drain pipe allows sediment to settle and potentially clog (or reduce flow in) the pipeline, limiting the lifespan of the system. When soil becomes saturated, water movement is reduced and water may be unable to flow to the subsurface drain. These shortcomings underscore the need to install surface drains in conjunction with subsurface drains, in order to minimize the ground water volume introduced into a subsurface drain.

Comprehensive Drainage System

A complete drainage system incorporates both surface and subsurface drains. Surface drains to remove heavy volumes of rainfall that fall in short spans of time and subsurface drains to remove water which percolates into the soil. Soil has a natural ability to absorb just so much water. At the point the soil becomes 100% saturated with water, it cannot absorb anymore. With no place to go, additional rainfall accumulates on the surface resulting in flooding and erosion. This is another reason it is critical to incorporate surface drains into any drainage plan.

Drainage Design Simplified

Drainage in its most simplified form is a process of collecting, conducting, and disposing of drainage water. The design process is simply a continuation of what size the catchment system needs to be, what size and type the conducting system needs to be, and what format the disposal system should take.

Checklist for Drainage Design

1. Analyze topography.
 - a) Check off-site drainage pattern. Where is water coming onto site? Where is water leaving the site? Water flows perpendicular to contour lines.
 - b) Check on-site topography for surface runoff and percolation.
 1. Determine runoff pattern; high points, ridges, valleys, streams, and swales. Where is the water going?
 2. Overlay the grading plan and indicate watershed areas; calculate square footage (acreage), points of concentration, low points, etc.
 - c) Check means of disposal (also check local codes).
 1. On-site (pond, creek, retention basin)
 2. Off-site (street, storm drains)
 3. Natural drainage system (swales)
 4. Existing drainage system (drain pipe)
 5. Proposed drainage system
2. Analyze other site conditions.
 - a) Land use and physical obstructions such as walks, drives, parking, patios, landscape edging, fencing, grassy area, landscaped area, tree roots, etc.
 - b) Soil type determines the amount of water that can be absorbed by the soil.
 - c) Vegetative cover will determine the amount of slope possible without erosion.
3. Analyze areas for probable location of drainage structures.
4. Identify what type and size drains are required. Design the system using a combination of surface and subsurface drain systems and underground pipes. Design pipe layout to convey water from the drains to the discharge point in the most direct and simple manner possible.

Combining Surface and Subsurface Drain Systems

Surface water should not be connected directly to a subsurface drainage system, unless it is designed for it. The excessive volume and velocity of water from a surface drain system tied directly to a french drain may actually leach out of the perforated pipe defeating its function as a ground water collection device. It is possible to join non-perforated pipe conveying water from surface drainage systems and subsurface drainage systems when the junction is at an elevation lower than any perforated pipe. The most cost-efficient system in terms of life-cycle costs may include completely separate systems, one to collect and convey surface water and one to collect and convey subsurface water.

Chapter 4:

Surface Drainage Design

Good Surface Drainage Design Practices

1. Gravity is the primary vehicle for carrying runoff away. There must be a continuous minimum fall in the ground level to assure drainage, and a minimum slope of 1% to 5% for grass swales. 1/8" per foot or 1% minimum slope for smooth interior pipe are general guidelines for pipe conveying runoff water to a discharge point. Consult an engineer or architect for minimum slope in critical applications.
2. Large amounts of water should not cross a sidewalk to reach the street storm drain. Use drains or install piping to cross walks or other pedestrian walkways to prevent hazards.
3. Break up one large drain to several smaller drains to:
 - a) Prevent erosion on steep landscapes by intercepting water before it accumulates too much volume and velocity.
 - b) Provide a safety factor. If a drain inlet clogs, the water may be picked up by the other surface drains.
 - c) Improve aesthetics. Several smaller drains will be less obvious than one large drain.
 - d) Spacing smaller drain inlets will give surface runoff a better chance of reaching the drain. Water will have farther to travel to reach one large drain inlet.
4. Erosion is a big problem in drainage - slopes must be carefully calculated to ensure continuous flow, yet not steep enough to erode.
5. Slow moving water will create a bog, while water moving too fast will cause erosion, form gullies and weaken foundations. Design a drainage system that will eliminate both extremes.
6. Design paved areas so they are graded almost level — avoid wildly sloping paved areas or dramatic changes in slope.
7. Runoff water must never be directed purposefully from one property onto another property. It is acceptable for water which flows naturally from one property to the other to continue, but you must never increase this flow artificially through grading and piping.
8. Check local code requirements and their applications.
9. When designing a system, work from the discharge point towards the highest elevation.
10. Design a secondary drain route to allow for overflow conditions during severe rainfall or in case the primary drain system fails.
11. Many systems require a grate or "clean out" fitting every 50 to 100 feet or at alignment changes of 45 degrees or greater to clean out the pipeline. Clean outs are normally constructed at grade.
12. Keep it simple. Over-design in storm water systems is expensive.

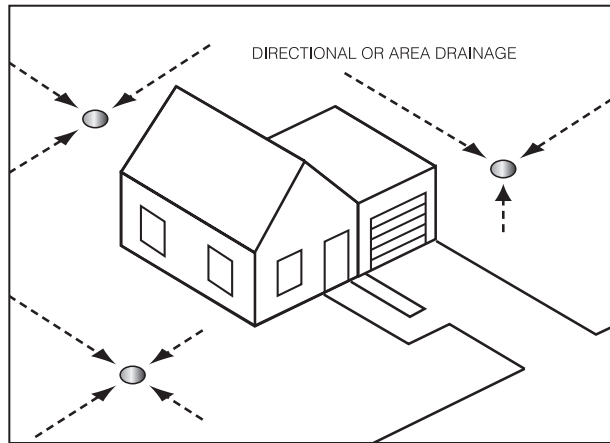
Directional Drains vs. Trench Drains

Directional drains, basins or inlets (**Figure 4-1**), are ideal for landscaping applications. Water is directed to the drain by the contours of the landscape. Directional drains are located at low spots or interception points (swales). Typically, the basin or inlet is connected to a main or sub-main utilizing a lateral pipe line. Locating basins and inlets

directly on top of mains or sub-mains is less desirable because they create more turbulence in the flow of runoff water through the pipe system.

Figure 4-1: Directional drainage

Directional drains or area drains are ideal for landscaping applications. Water is directed to the area drain by the contours of the landscape. Area drains are located at low spots or interception points (swales)

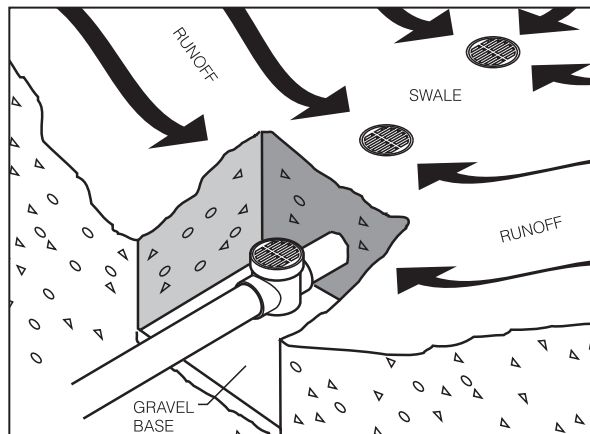


Catch Basins in a Series

Using one large basin to collect water at the bottom of a steep swale allows for erosion. Spacing a series of smaller basins in the swale is preferable to prevent erosion (Figure 4-2).

Figure 4-2: Drains in a series

Using one large basin to collect water at the bottom of a swale permits erosion. Spacing a series of smaller basins in the swale prevents erosion.



Channel Drains

Trench or channel drains are ideal for hardscape applications (Figure 4-3). Sheets of water are intercepted by these linear drains. The open surface area of a trench drain is much greater than that of an area drain. Since hardscapes absorb so little runoff, the greater volume of surface runoff generated is better handled by the additional open surface area of a trench drain. Trench drains enable the designer to modestly slope hardscapes in one direction or grade as opposed to designing directional drains which require numerous slopes which are often more extreme and difficult to install.

Trench or channel drains are ideal for hardscape applications. Sheets of water are intercepted by these linear drains. The open surface area of a trench drain is much greater than that of an area drain. Since hardscapes absorb so little runoff, the greater volume of surface runoff generated is better handled by the additional open surface area of a trench drain.

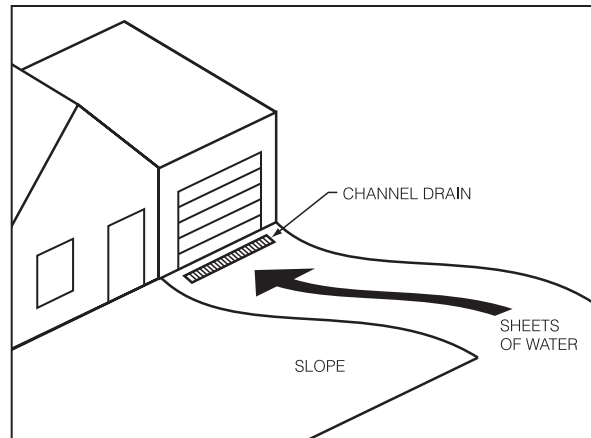


Figure 4-3: Trench drainage

Trench drains enable the designer to modestly slope hardscapes rather than shape extreme slopes to area grates.

Computing the Runoff Potential

Rational Method

A frequently used formula for computing the peak rate of runoff from small drainage areas (i.e., less than about 200 acres) is the Rational Method. The equation is:

$$q = CiA$$

- where:
- q = peak runoff rate, cubic feet per second (cfs) or gallons per minute (gpm)
 - C = Runoff coefficient (between 0 and 1)
 - i = rainfall intensity, inches per hour (iph) for the design storm frequency and for the time of concentration of the drainage area
 - A = area of drainage area (in acres or square feet)

The equation is based on the theory that the peak rate of runoff from a small area is equal to the intensity of rainfall multiplied by a coefficient which depends on the characteristics of the drainage area, including land use, soils and slope, and by the size of the area.

Drainage area boundaries are independent of property lines. It is important to consider all parts of a drainage area, even if they are beyond the property line. Take into account sources of surface and subsurface water.

Sample Calculation

How to calculate the pipe size and grate size for exterior drainage applications.

Step 1: Calculate the total surface area to be drained. (Feet length x Feet width)

Step 2: Determine the coefficient of runoff for the type of soil (**see chart below**).

Table 4-1

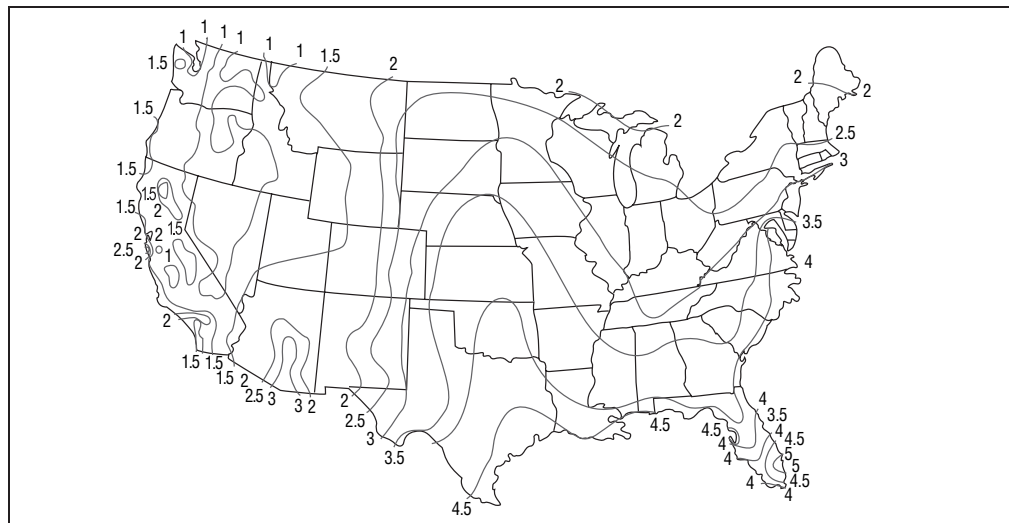
Soil Texture	Coefficient of Runoff	Soil Texture	Coefficient of Runoff
Concrete or Asphalt	1.00	Loam - Bare	.60
Gravel - Compact	.70	Loam - Light Vegetation	.45
Clay - Bare	.75	Loam - Dense Vegetation	.35
Clay - Light Vegetation	.60	Sand - Bare	.50
Clay - Dense Vegetation	.50	Sand - Light Vegetation	.40
Gravel - Bare	.65	Sand - Dense Vegetation	.30
Gravel - Light Vegetation	.50	Grass Areas	.35
Gravel - Dense Vegetation	.40		

Note: The above data is approximate. Coefficient of Runoff = Runoff/Rainfall

Step 3: Determine the maximum 1 hour rainfall expected in 100 years.

Figure 4-4: 100 Year Rainfall Map

One hour rainfall in inches to be expected once in 100 years



Step 4: Compute the total gallons per minute runoff using the following formula:

Rational Formula: $Q = CiA/96.23$

- Where:
- Q** = the runoff from an area, in gallons per minute
 - A** = the areas to be drained (Step 1)
 - C** = the coefficient of runoff (Step 2)
 - i** = the intensity of rainfall, in inches per hour (Step 3)

Step 5: Select the pipe size by using the following table. Table based on smooth wall sewer and drain pipe or coextruded dual wall corrugated pipe.

Table 4-2

3" Pipe < 46 gal/minute	6" Pipe < 180 gal/minute
4" Pipe < 79 gal/minute	8" Pipe < 316 gal/minute

Table assumes flow velocity of 2 feet per second

An adjustment for single wall corrugated pipe can be calculated comparing the manning “n” values below. For example, single wall corrugated pipe could conduct approximately 25% less gpm than smooth wall or dual wall corrugated pipe.

	<u>Manning “n”</u>
Smooth wall sewer and drain pipe or dual wall corrugated pipe	0.010 - 0.013
Single Wall Corrugated Plastic Pipe, 3-8 in.	0.01 - 0.016

Step 6: Select the appropriate grate or combination of grates required (See chart.).

Capacity GPM	NDS Part Numbers			Grate Fits Pipe Size	Grate Open Surface Area (in ²)
	Green	Black	Gray		
3.4	16	14	15	3"	2.6
4.5	01	02	03	3"	3.5
5.0	13	11	12	4"	3.8
5.6	07	08	09	4"	4.2
12.0	50	40	60	6"	9.1
12.5	70	74	—	3"	9.5
13.6	05	04	06	3,4"	10.4
15.0	20	10	30	6"	11.5
17.8	772	771	773	6"	13.6
19.0	75	78	—	4"	14.5
33.4	80	90	—	6"	25.5
37.2	950	970	960	6"	28.4
45.2	990	980	999	3, 4, 6"	34.4
61.7	1212	1211	1210	3, 4, 6"	47.0
78.7	1280	1290	—	3, 4, 6"	60.0
136.5	1812	1811	1810	3, 4, 6, 8"	104.0

* Use with Spec-D Basin

Area grate selection chart

Capacity GPM	NDS Part Numbers Various Colors	Outlet Fits Pipe Size	Grate Open Surface Area (in ²)
25.2/ft	240, 241, 242, 243, 244, 251	3, 4"	19.3/ft
14.7/ft	541, 542, 543, 544, 551	2"	11.3/ft
2.6/ft	8001, 8002, 8003	1 1/2"	2.0/ft

Channel grate selection chart

See sample surface drain design problem, Appendix B.

Subsurface Drainage Design

Design and Layout of Subsurface Drainage Systems

Basic Subsurface Drainage Theory

Subsurface drainage is accomplished by placing an artificial channel below the water table so that the hydraulic head of the channel is less than that of the soil to be drained.

Subsurface Drainage

The purpose of subsurface drainage is to maintain the water table at a level that provides desirable plant growth conditions, increases the usability of areas for recreational or other purposes, and prevents structural damage. Subsurface drains remove only excess water and not water plants can use. Water available to plants is held in the soil by capillary, or surface tension forces, whereas excess water flows by gravity into the drains. Subsurface drainage is accomplished by means of a French Drain or prefabricated drain system laid in a continuous line at a specified depth and grade. Free water enters the drains through hydrostatic pressure and flows out by gravity.

The major components of a subsurface drainage systems are mains, sub-mains, laterals, and drainage outlets. The laterals collect the free water from the soil and carry it to the sub-mains and mains. These, in turn, conduct the water to the drainage outlet.

Designing Subsurface French Drain Systems

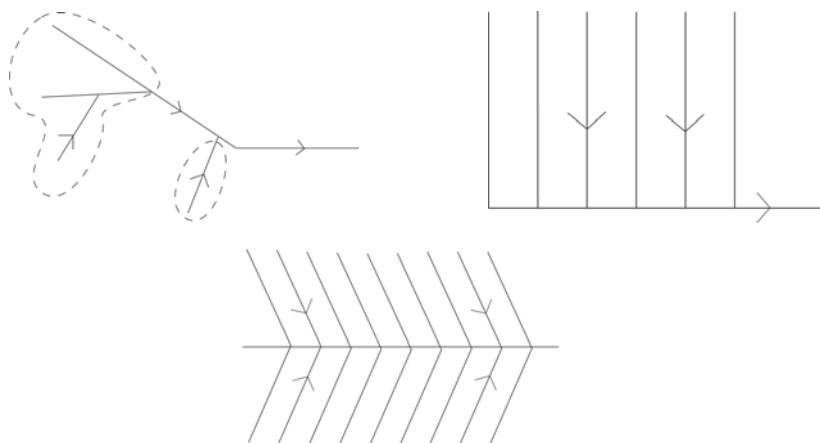
Subsurface systems may be laid out either to collect water from poorly drained, wet areas or to drain complete areas. The system pattern for the former condition is usually random, whereas gridiron or herringbone arrangements are typical for the latter (Figure 5-1).

Piping Patterns for Subsurface Drainage

Random system (top left)

Gridiron system (right)

Herringbone system (bottom left)



The pipe size required to drain a certain acreage depends on the pipe gradient, since an increase in gradient results in a greater velocity of flow and permits the pipe to drain a larger area. Pipes are placed at constant gradients, or variable gradients with the gradient increasing toward the outlet. The gradients should never decrease, since the velocity of flow would decrease and silt would be deposited in the pipe. Typically pipe gradients for lawn areas vary from a minimum of 0.1% to a maximum of 1.0%. Tables 5-1 and 5-2 shows the relationships of pipe size, gradient, and maximum acreage drained for smooth wall plastic, clay or concrete drainage lines and corrugated plastic tubing. These tables were computed by Manning’s equation. A drainage coefficient (DC) of 3/8 in. was used. *Drainage coefficient* is defined as the depth of water removed over the drainage area in 24 hr. In humid areas of the United States a DC of 3/8 in. is normally used for mineral soils. For organic soils, the acreage of the tables should be reduced by one-half. This may also be done for mineral soils if more rapid drainage is desired.

Maximum Acreage* Drained by Various Pipe Sizes: Smooth Wall Sewer and Drain Pipe or Dual Wall Corrugated Pipe (n = 0.011, DC = 3/8 in./24 hr.)										
Pipe Size (inches)	Slope (%)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
4	4.51	6.38	7.82	9.03	10.1	11.1	11.9	12.8	13.5	14.3
5	8.19	11.6	14.2	16.4	18.3	20.0	21.7	23.2	24.6	25.9
6	13.3	18.8	23.1	26.6	29.8	32.6	35.2	37.6	39.9	42.1
8	28.7	40.5	49.6	57.3	64.1	70.2	75.8	81.1	86.0	90.6
10	52.0	73.5	90.0	104	116	127	138	147	156	164
12	84.5	120	146	169	189	207	224	239	254	267

* Reduce this acreage by one-half for a 3/4 in D.C.

Table 5-1

Maximum Acreage* Drained by Various Pipe Sizes: Single Wall Corrugated Plastic Pipe (n = 0.016, DC = 3/8 in./24 hr.)										
Pipe Size (inches)	Slope (%)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
4	3.10	4.39	5.38	6.21	6.94	7.60	8.21	8.78	9.31	9.81
5	5.62	7.96	9.75	11.3	12.6	13.8	14.9	15.9	16.9	17.8
6	9.15	12.9	15.8	18.3	20.5	22.4	24.2	25.9	27.5	28.9
8	19.7	27.9	34.1	39.4	44.1	48.3	52.1	55.7	59.1	62.3
10	35.7	50.5	61.9	71.5	79.9	87.5	94.5	101	107	113
12	58.1	82.2	101	116	130	142	154	164	174	184

* Reduce this acreage by one-half for a 3/4 in D.C.

Table 5-2

See sample subsurface drainage design problem on Appendix B.

Depth and Spacing

The depth at which drainage lines are installed generally depends on the outlet conditions. Drainage lines should always be deep enough to prevent possible frost damage.

The spacing of drainage lines depends on the texture of the soil to be drained. Sandy soils permit more rapid movement of water than do heavy clay soils, and therefore lines may be spaced farther apart and deeper in sandy soils than in clay soils. If drains are spaced too far apart, the central portion between lines will remain poorly drained (**Figure 5-2**). A very general guideline for recreational turf applications, the 3” and/or 4” perforated drain pipe should be buried from 18 inches to 3 feet deep and 15 to 20 feet apart. For rapid drainage of rainfall on areas such as golf course greens, subsurface drain pipe may be placed 18 inches deep with four to ten foot spacing.

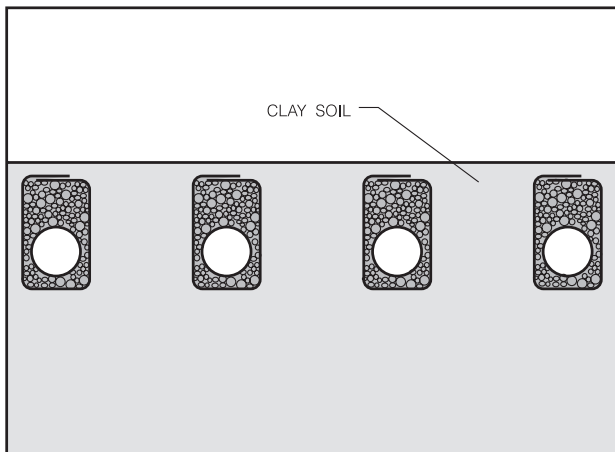
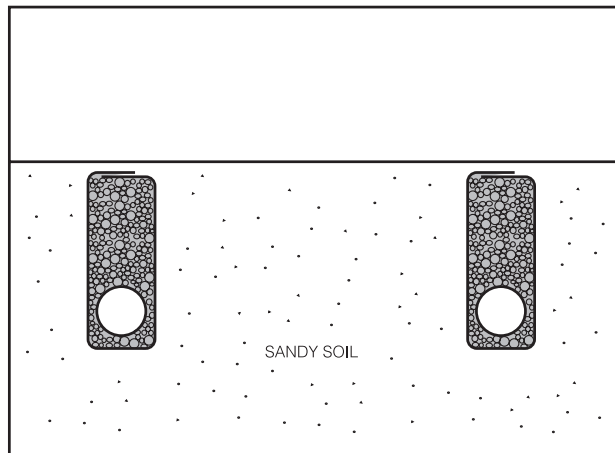
Where there is a question of adequacy, it is safer to specify the next larger size tubing, increase the grade if practical, or place the lines closer together to reduce the GPM per line requirement.

To design subsurface drainage systems for some soils or critical areas, a qualified engineer should be consulted, since special precautions may be necessary.

Figure 5-2: Spacing for subsurface drains

For sandy soil, use wide spacings and deep trenches (top)

For sandy soil, use wide spacings and deep trenches (bottom)



Interceptor drains are pipes placed across a slope to intercept water that would otherwise be forced to the surface by an outcropping of an impermeable layer such as a tight subsoil (**Figure 5-3**).

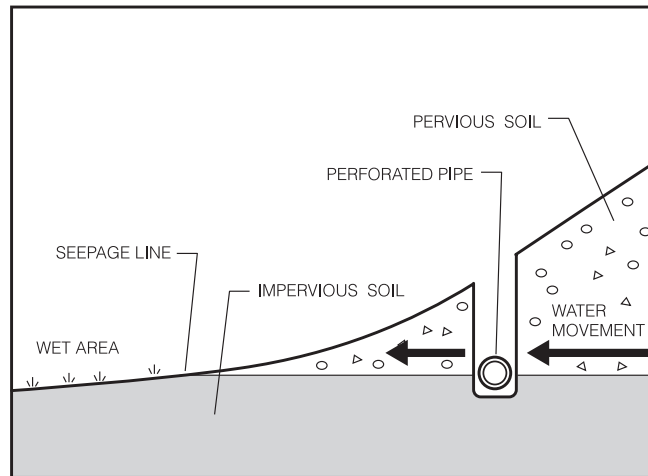


Figure 5-3: Interceptor drain

Prefabricated Drain System Design

A complete prefabricated drainage system consists of lateral drainage trenches, sub-main and main collectors. In some cases, particularly in relatively small areas, sub-main and main collectors may not be required. The lateral drainage trenches are normally 3 to 4 in. wide and minimum of 12 in. deep. These trenches are installed perpendicular to the direction of surface runoff. The bases of the trenches are sloped at about 1 percent towards the collector.

The sub-main takes flow from the lateral drainage trenches and conveys it to the main collector. The sub-main typically consists of one or more layers of prefabricated drains placed in a 4" wide trench. The depth of the sub-main collector trench varies depending on the geometry of the drainage area. The sub-main collector trench typically has about a 1 percent slope towards the main collector.

General Rules for Designing Prefabricated Drain Systems

1. Trenches should maintain at least 1% slope.
2. Maximum length of laterals should be 50' unless slope or size of drain is increased.
3. Sub-main collectors (those fed by laterals) should be not more than 100'.
4. Main collectors should be able to effectively handle the total water volume of laterals and sub-mains as well as inflow on their own.

If these simple criteria are used, the subsurface water from a two-year or two-day storm event will be able to properly drain if the following spacing/time guide is used. This spacing applies to laterals in permeable soils.

Lateral Spacing	Time to Drain
6' to 10' apart	30 minutes
20' apart	2 hours
30' apart	4 hours

Section III:

Installation

Chapter 6:

Discharge Outlet Design

Discharge Collected Water

Once the storm water is collected and conveyed in the drain pipe, it must be discharged to a safe location. The final design of subsurface or surface drainage systems concerns disposal of the water. The outflow rate potential must at least equal the expected inflow rate.

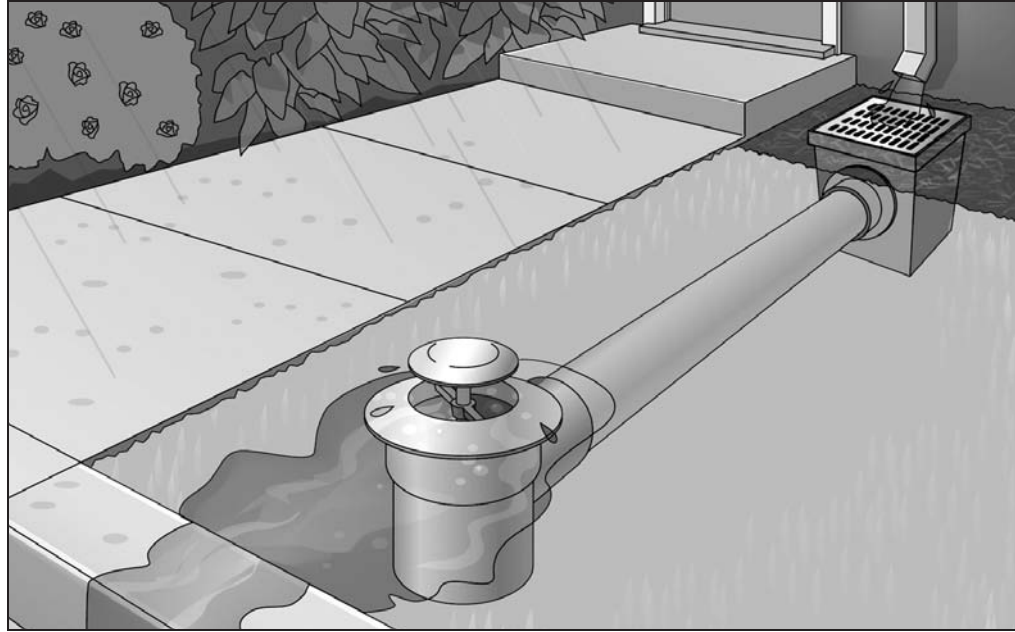
Several options are available to discharge water. You can discharge on site, into a pond for example, or discharge off site, into the street gutter or directly into the storm sewer for example. You can combine different options for the best solution. The best solution is often the simplest solution.

Pop-Up Drainage Emitter

Pop-Up Drainage Emitter (**Figure 6-1**), allows water to be diverted and released to water-safe areas away from structures, erosion-prone landscapes and poor drainage areas. Water captured by grates, catch basins, channel drains, downspouts and roof gutter systems flow through the drainage pipe and away from structural foundations to safe or useful areas. For example, water can be routed from a low area next to a foundation to a water safe area such as a street curb, or the center lawn area with a sloped grade which will ensure flow of the water from the emitter to a safe area.

Install 10 feet of perforated pipe prior to the pop-up emitter. This will allow any water remaining in the pipe to leach into the soil. It is opened by the hydrostatic pressure of water flowing through the drain pipe. As flow diminishes the emitter closes again. For ideal performance, the top of the emitter should be installed at a lower elevation than the invert of the pipe inlet (downspout connection, connection to a basin, etc.), to ensure proper flow. Maintain a minimum slope in the drain pipe. Since the emitter is closed during dry weather, debris and rodents cannot enter the drain pipes. The emitter can be connected to a catch basin located directly below the downspout, intercepting debris such as leaves before it enters the pipe. This is also a recommended application for severe cold weather climates. Water in the pipe may freeze, backing up into the catch basin. If this is a possibility, an alternative route for downspout water flow should be established.

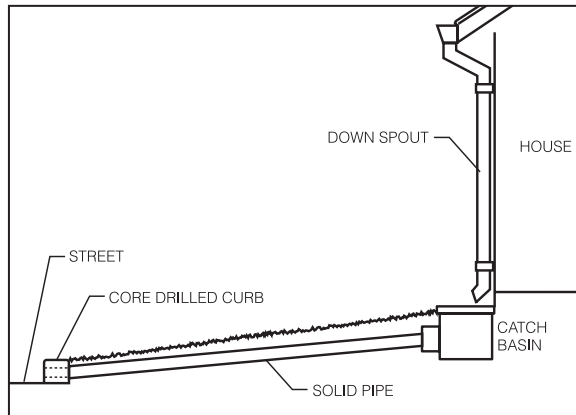
Figure 6-1 Pop-up Emitter



Water is discharged near the street gutter using a Pop-Up Emitter.

Figure 6-2 Downspout to core drilled curb

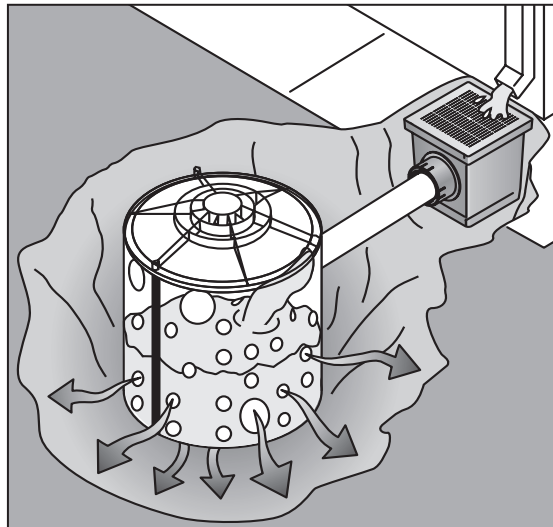
Drain system connected to a street curb. The top of the discharge outlet must be lower than the bottom of the 90° elbow downspout connection.



Runoff water leaches out of the Flo-Well™ into the surrounding soil. Gravel backfill will increase capacity.

Figure 6-3: Flo-Well®

Drain system connected to a Flo-Well®. Poorer soils will require multiple Flo-Wells® to be effective



Runoff water percolates into the soil adjacent to the leach lines. Gravel backfill will increase capacity. The poorer soils, i.e., clay will require larger multiple of leach lines.

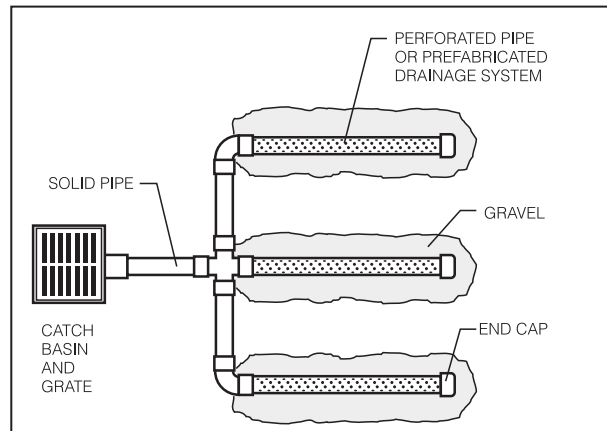


Figure 6-4: Leach fields

Drainage system using leach fields.

Wet Ponds

Retention (or wet) ponds are basins which contain a permanent pool of water.

Dry Ponds

Detention facilities, or dry basins, are used as a means of controlling peak discharge rates through the temporary storage of storm runoff.

Culvert Outfall

Discharging collected water into swales, drainage ditches, creeks, ponds, etc. (Figure 6-5).

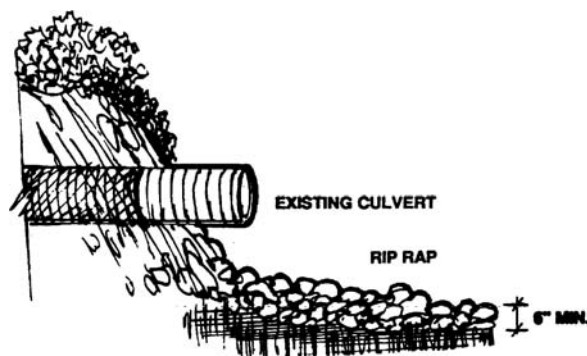


Figure 6-5: Culvert outfall

Avoid the following when designing discharge outlets:

- Never route surface water onto adjoining property.
- Never route surface water into a sanitary sewer system.
- Never route water into a drainage ditch without installing a backwater valve.
- Never cross property lines with any drainage system without written consent of the property owner.
- Never route drainage water so that it causes an erosion problem.

Surface Drainage Installation

Catch Basin and Inlet Installation

1. Choose an inlet or basin size according to the amount of rainfall, surface area and soil type. It may be necessary to install more than one inlet or basin to accommodate excessive runoff or a combination of low spots. An inlet is often installed directly on top of the drain line (**Figure 7-1**). Use catch basins in applications where it is necessary to collect debris from runoff water in a sump area (**Figure 7-2**). This helps minimize clogging of drainage pipes.
2. Locate low spot or any area where excess water will accumulate.
3. Dig a hole deep enough for overall height of basin and grate. Install basin in hole on top of a firm base. Work from the discharge point back to the grate. Excavate the base of the trench with a minimum 1% to 2% slope to ensure drain pipe slopes to the discharge point.
4. Connect pipe to the basin. Backfill trench and area around basin.
5. Ideally, the catch basin incoming drain line should be at an elevation equal to or higher than the outlet drain line.
6. Ideally, the catch basin outlet should be equipped with an elbow facing down to prevent debris from washing into the outlet drain line (**Figure 7-3**).
7. For hardscape installations, the grate should be installed and taped over prior to pouring concrete or backfill to prevent debris from entering drain. The tape is removed immediately after installation. In landscape installations, straw bales or fabric can be used to protect the grate during construction.
8. Grates should be recessed below grade a minimum of 1/8" for non-traffic installations and 1/4" for traffic installations
9. Basins or inlets may be encased in concrete for heavier load applications.
10. In asphalt or hot mastic applications the basin should be encased in concrete for strength and to prevent distortion.
11. PVC primer and medium body fast set PVC solvent cement should be used to cement all components. Tape should be used to connect corrugated pipe to components.
12. Basins should be installed on top of compacted gravel, sand or concrete.
13. To avoid standing water in the basin, drill holes in the basin bottom. This will allow excess water to leach out. A gravel base is recommended for this application.
14. Finish grade should slope a minimum 1% to 2% to the grate.

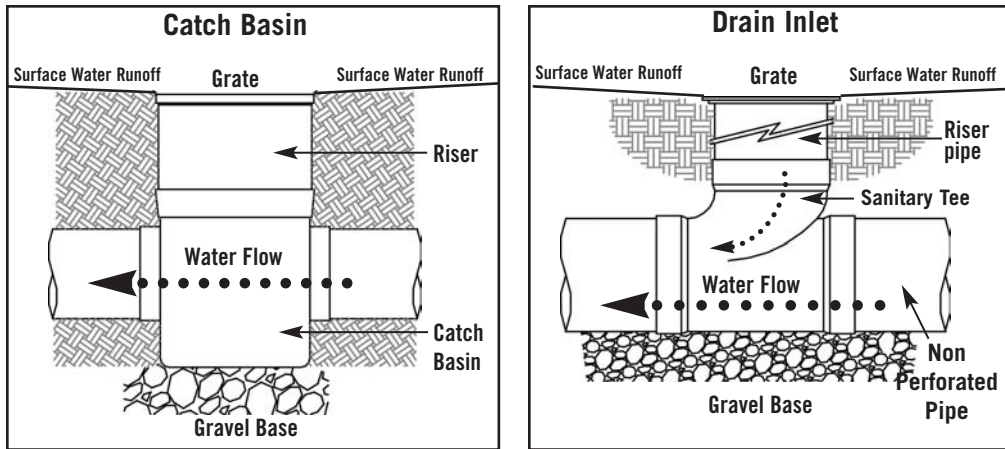


Figure 7-1: Surface drains

Catch basin (left)

Figure 7-2: Surface drains

Drain inlet (right)

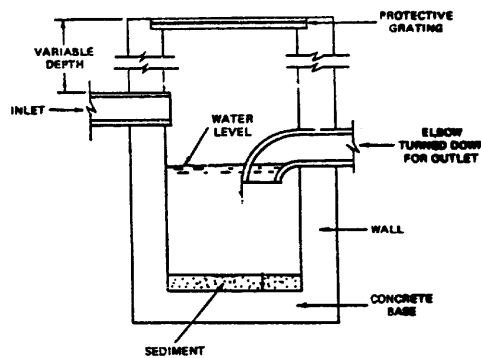


Figure 7-3: Large scale commercial catch basin

Channel Drains

Channel drains are a variation of surface drains, ideal in hardscapes such as patios, walkways, swimming pools, parking lots and driveways. The hardscape surface is slightly sloped in one direction or plane to the perimeter channel drain with the same principle as a gutter on the roof of a building.

Channel Drain Installation

1. Standard Installation

Excavate a wide and deep trench to accommodate the channel and bedding concrete or sand. Erect a string line at each end of the drain run as a guide for laying the channels to the required level. Begin channel installation at the evacuation or discharge end of the run where the outlet or outlets are located.

Install channel end-to-end PVC cementing sections together. Design bottom or end outlets into the channel run in the appropriate location and glue to the drain pipe or fittings. PVC cement end caps where appropriate.

Using either wood, plastic or steel stakes, 1/2" or 5/8" rebar, anchor channel to the trench bed every 24" on each side of channel. Backfill with either concrete, sand, or soil depending on the application. Pour slab to grade and finish concrete.

Figure 7-4 illustrates a non-vehicular traffic installation in which a concrete base is not required. Compact soil and a 1" sand base.

Figure 7-5 illustrates a concrete base underneath the channel recommended for light traffic and heavy load applications or freeze/thaw zones where heaving may be a problem.

Figure 7-4: Channel drains

Non-vehicular traffic installation (left)

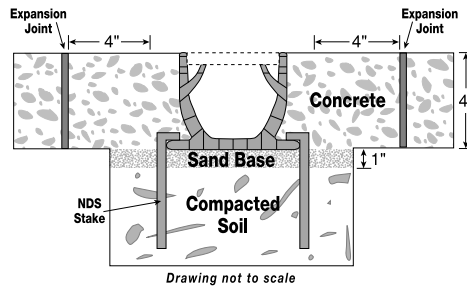
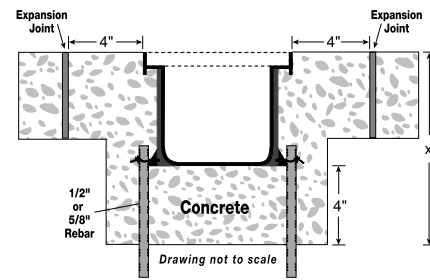


Figure 7-5: Channel drains

Vehicular traffic standard installation (right)



2. Suspended Installation

Suspended installation is ideal for retrofitting an existing concrete slab or new construction where forms can be used to suspend the channels. Prepare the trench excavation. Using 2" x 4" boards span the width of the trench and bolt the channel grates to the boards. Pour and compact concrete under and around the channel. Finish to the proper grade (**Figure 7-6**).

3. Slurry Installation

This installation may be used in lieu of the standard installation. Prepare the trench excavation and pull a stringline to the proper elevation. Pour a slurry of concrete in the trench to a depth that will insure at least 4" of concrete underneath the channels. Lay the channels in the bedding slurry. Check channel alignment and grade again. After the slurry sets, concrete can be poured around the channel and finished to the proper grade (**Figure 7-7**).

Figure 7-6: Channel drains

Suspended installation (left)

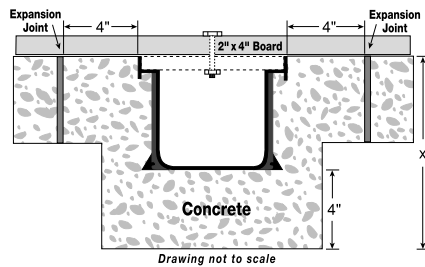
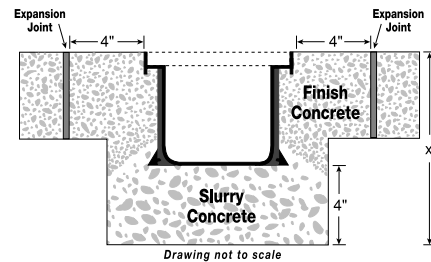


Figure 7-7: Channel drains

Slurry installation (right)



Notes:

1. Grate must be installed prior to pouring concrete or backfill.
2. Grate should be recessed below grade a minimum of 1/8" for non-traffic installations and 1/4" for traffic installations.
3. Grates should be taped prior to pouring concrete to prevent debris from entering channel during installation.
4. In asphalt or hot mastic applications, the channel must be encased in concrete for strength and to prevent distortion.
5. Refer to manufacturer's load classification charts for proper application.
6. Expansion joints must be provided parallel, but not immediately adjacent to each side of the drain run and crack control joints utilized at right angles to the channel.
7. PVC primer and medium body fast set PVC solvent cement must be used to cement all components.

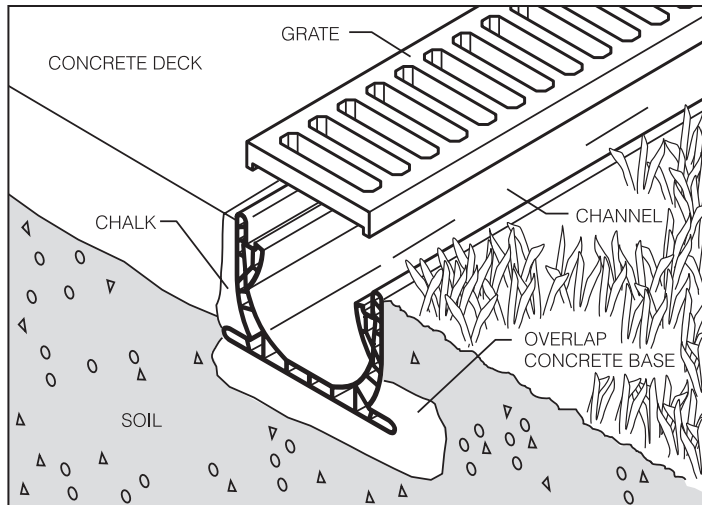


Figure 7-8: Channel installation between hardscape and landscape

Use an overlapping concrete base for installation next to a concrete deck. This installation will pin the channel against the concrete deck.

Roof Drainage

Roof drains are a form of surface drainage, removing water from the impermeable surfaces on top of buildings and homes (**Figure 7-9**). Down spout water should be discharged away from the house to a pop-up emitter, natural channel, street, or dry well. If permitted to discharge near the foundation, it will seep along the foundation wall, probably find a weak spot in the joint between the foundation and the basement floor, and seep into the basement. Excess water may cause foundation walls and floors to bulge, heave and crack.

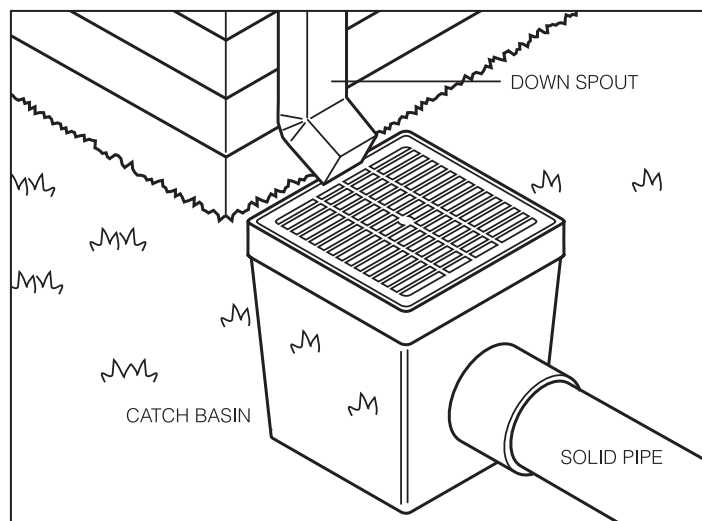


Figure 7-3: Downspout

Subsurface Drainage Installation

Common French Drain Installation - Corrugated Pipe

1. Backfill

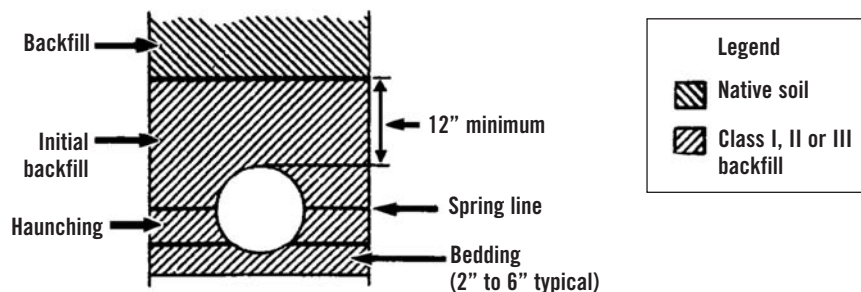
Care should be taken during installation to prevent damage to the tubing during the back filling operation. Avoid dropping large clods or rocks directly on tubing. Impact loads of all types should be avoided until tubing is properly bedded. Gravel backfill for French drains should be clean and void of silts which will clog the drain system.

2. Bedding

General rule of thumb is to excavate the trench twice the width of the pipe itself to ensure proper backfill support. It is preferred that tubing be bedded in a gravel envelope. However, selected soil backfill material may also be used with satisfactory results. When selected soil bedding material from the trench excavation is used, small loose particles of soil that will flow around the tubing and minimize soil settling should be chosen. Avoid large rocks that may damage the tubing or large clods of soil that cause voids and subsequent excessive settling. Selected soil bedding materials should be tamped.

Common practice is to place the pipe on the bedding and carefully tamp the fill under the haunches to the specified compaction. The next layer of backfill, the haunching, is the most important since it is this layer that provides the pipe with support against the soil and traffic loadings. Initial backfill extends from the spring line to a minimum of twelve inches above the crown of the pipe. This area of the backfill anchors the pipe and ensures that loads are distributed as evenly as possible. This layer should be compacted. Final backfill, which extends from the initial backfill layer up to the ground surface, does not, directly support the pipe (**Figure 8-1**). For french drains, it is ideal to backfill drain trench with a gradation of gravel and stone, the coarser material at the bottom near the pipe followed by gradually finer material as the trench is filled.

Figure 8-1: Typical backfill structure



3. Depth of Cover

If vehicular traffic is expected over tubing there should be a minimum of 12” of cover over tubing if gravel bedding is used and 24” of cover if selected soil bedding material is used. Typical recommended gravel envelope materials would be pea gravel, 6A stone or pit run coarse sand and gravel mixes.

4. Proper Grade

The grade or “fall” on which tubing is laid is critical in that reversal in grade will greatly reduce the effectiveness of the system. Best drainage practice calls for a continuous downhill fall, or grade over the entire length of the drain line. A fall of 0.2 inches per 10 feet of length may be considered adequate. However, greater degrees of fall may be required in critical applications and an engineer should be consulted. Greater amounts of fall will promote more rapid drainage.

Common French Drain Installation — Smooth Wall Sewer and Drain Pipe

When burial depth is limited to four feet (**Figure 8-2**), the pipe can be back filled with the excavated soils, providing large rocks, clods, or extraneous materials have been removed. If the trench foundation is uneven, create the required uniformity. Placement of initial backfill should continue up to the spring line of the pipe. Compaction should be achieved with a hand tamping device or machine. Fill should be worked under the haunches to provide adequate side support. Initial backfill placement and compaction should continue by device or machine. Fill should be worked under the haunches to provide adequate side support. Initial back fill placement and compaction should continue up to six inches over the pipe crown. Remaining backfill should continue up to the top of the trench. About four to six inches of overfill should be provided to accommodate settling.

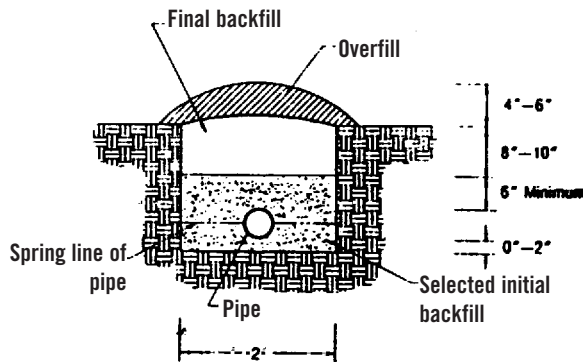
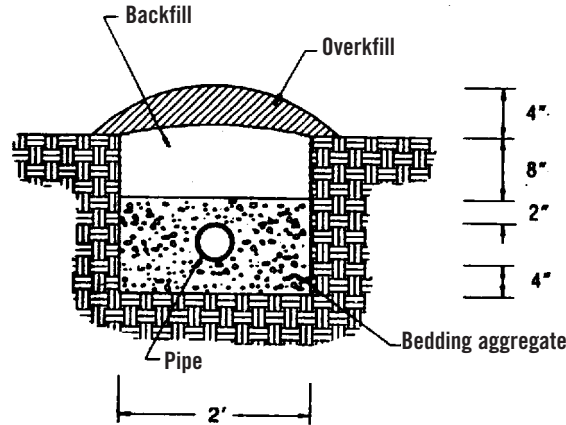


Figure 8-2: Typical backfill structure
Native soil

Smooth wall sewer and drain pipe used in applications deeper than four feet should be installed in a gravel envelope (**Figure 8-3**).

Figure 8-3: Typical backfill structure

Gravel envelope



Proper selection of material is determined by the application. If the line is to serve as a French drain, perforated tubing should be used. Non-perforated tubing should also be used if the line runs close to trees where root penetration may be a problem. If the drain pipe selected includes bell ends, install the non-bell end of the pipe towards the discharge end of the drain system.

For sandy and silty soils either a sock pipe (Figure 8-4), or geotextile filter fabric lining the gravel envelope (Figure 8-5), should be used to prevent clogging and sediment build up. In some applications the sock pipe eliminates the need for a gravel envelope so soil can be used as backfill. Critical installations may require a combination of sock pipe and filter fabric gravel envelope to prevent soil fines from clogging the drain.

Figure 8-4: Sock pipe

(left)

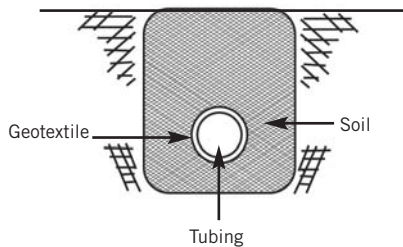
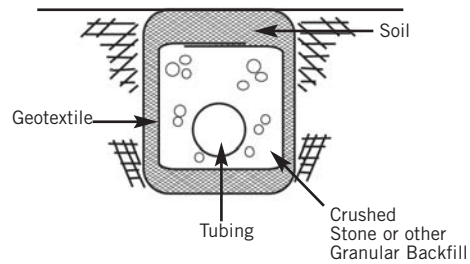


Figure 8-5: Geotextile filter with fabric envelope

(right)



Connections

Soil-tight connections are generally a minimum requirement of pipe connections in order to reduce the degradation of the soil envelope and reduce soil deposits along the pipe invert.

Water-tight performance is becoming more and more common in drainage systems. The reasons for this requirement may be that native soils are extremely fine and run a high risk of migrating into the system or that the storm water is considered to be a potential pollutant and must not be allowed to infiltrate the groundwater. Styrene, PVC, ABS smooth wall sewer and drain pipe and gasketed pipe systems are water-tight. Dual wall coextruded corrugated pipe is available with water tight connections as well.

- Do not route any lateral lines into the main line at a 90 degree angle. The preferred method is either with a 45 degree angle or a sanitary tee.
- All ABS, PVC, and Styrene fittings should be glued. As an option, corrugated pipe fittings may be wrapped with tape to ensure soil tight installation.
- Work from the discharge point toward the highest drain elevation.

Calculating Rock Quantities for Subsurface Drain Envelopes

Rock is usually sold by the ton. There are approximately 1.5 tons of 3/4-inch washed rock per cubic yard.

When figuring rock, figure the total cubic yards needed for the entire ditch less the space taken up by the pipe (in cubic yards) and multiply by 1.5 for tons of rock needed.

Following is a formula for figuring rock required:

- Where: **L** = Length of trench or drainage tubing in feet.
- W** = Width of trench in feet.
- D** = Depth of trench in feet.
- Diam** = Outside diameter of drainage tubing in inches.
- 1.5** = Tons of rock per cubic yard.

$$\text{Tons of Rock} = \frac{(L \times W \times D) - \left[L \times \left(\frac{\text{Diam}^2 \times .7854}{144} \right) \right]}{27} \times 1.5$$

Cost of Labor

General guideline for cost of labor for a surface drainage job in good soil is 3” pipe = \$4 per foot plus cost of materials, and 4” pipe = \$5 per foot plus cost of materials. With poor soils or unforeseen obstacles, labor for 3” pipe could = \$8 per foot plus cost of materials, and 4” pipe = \$10 per foot plus cost of materials. Labor for french drains is higher than surface drains as a result of the additional trench excavation, rock and fabric materials. These guidelines vary greatly with the many different circumstances involved in each project.

Prefabricated Drain Systems

Prefabricated Drain Systems (Figure 8-6), are an alternative to french drains. They are sometimes called vertical or strip drains. They are ideal for heavy use areas such as athletic fields and golf courses. For surface drainage, the drain should not be covered with soil. Instead, cover it with sand to the surface. Proper installation will prevent unhealthy turf directly above the subsurface drain lines.

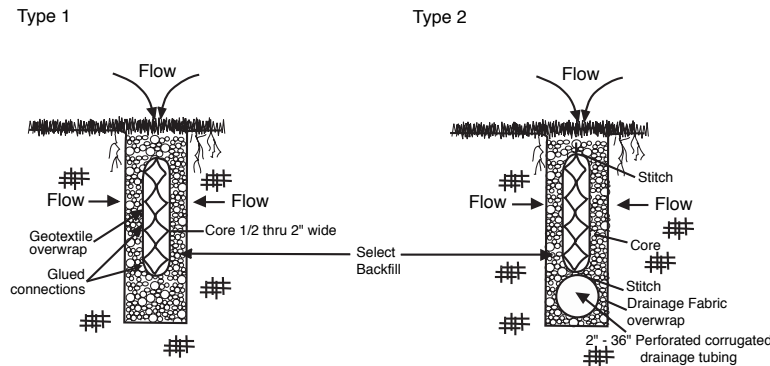


Figure 8-6: Drainage from natural turf to lateral prefabricated drains

Installation of a Prefabricated Drainage System

The primary steps in the installation process are as follows:

1. The sod is cut and removed from the trench.
2. Drainage trenches should be deep enough to allow appropriate soil cover over the drain to establish healthy turf and a minimum 2" space below aerifier tines. The drain should be at a depth to collect the ground water desired.
3. The drain is placed in the trench and may be centered using temporary wood stakes. On hillsides, the drain is placed on the uphill side of the trench.
4. The trench is backfilled with select sand backfill. If soil from the trench is a porous granular media, the trench may be backfilled with soil excavated from the trench. Excavated soil should not be used as backfill unless it has minimal silt or fines. The use of excavated soil for backfill prevents drainage of the surface and sod. See backfill specifications below.
5. The temporary wood stakes are removed.
6. The sand is flooded with water, not tamped, to promote proper compaction.
7. For surface water installations, the trench is topped off with sand to bring the backfill up to the top of the trench, allowing for sod. Subsurface installations can be topped off with soil and sod.
8. The sod is then placed back over the trench.

Backfill Specifications

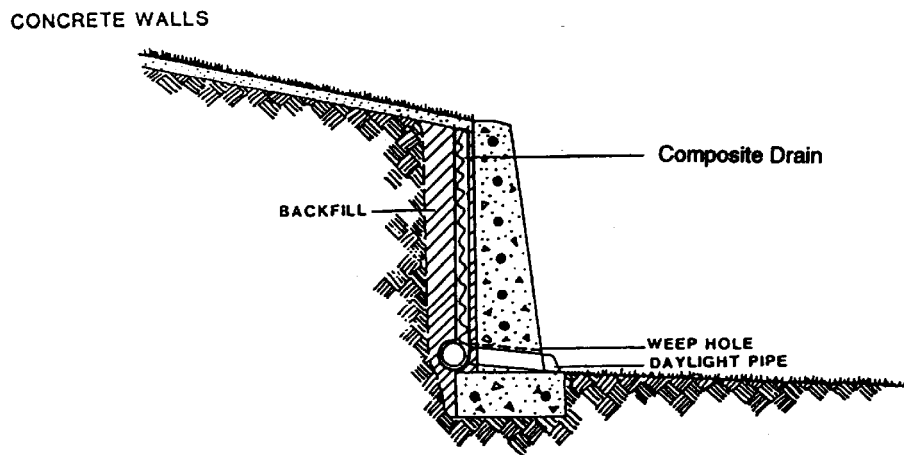
Minimal sand requirement; the sand must contain less than 2%, passing the #200 sieve and no particle sizes greater than the #10 sieve. A good clean washed sand is required.

Composite Drains

Composite drains are a type of prefabricated drain system. They typically include large sheets of plastic core covered by fabric on both sides attached to drain pipe at the bottom. The drain removes the hydrostatic pressure behind foundation walls, retaining walls and other structures.

Figure 8-7: Composite drain installation

Retaining Wall



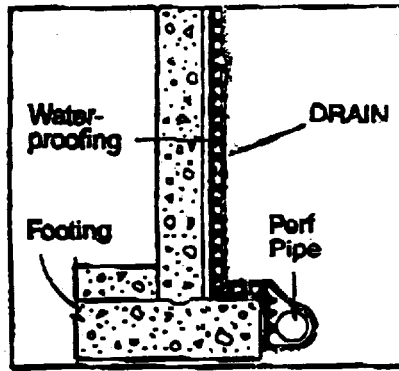


Figure 8-8: Composite drain installation
Basement Wall

Foundation or Footing Drains

Of the many home and construction uses for drainage tubing and composite drains, two of the most common are footing and curtain drains. The footing drain is designed to prevent ground water from entering either the basement or the foundation of a building. It should be installed slightly below the base of the footing, (Figure 8-9), completely around the building at a slight slope. Footing drains using drain tubing must be covered with three to five inches of washed gravel with no fines. Footing drains using composite drains do not require gravel. It should then run to a storm sewer or other disposal area. The most important and often overlooked point to be considered in footing drain installation is slope.

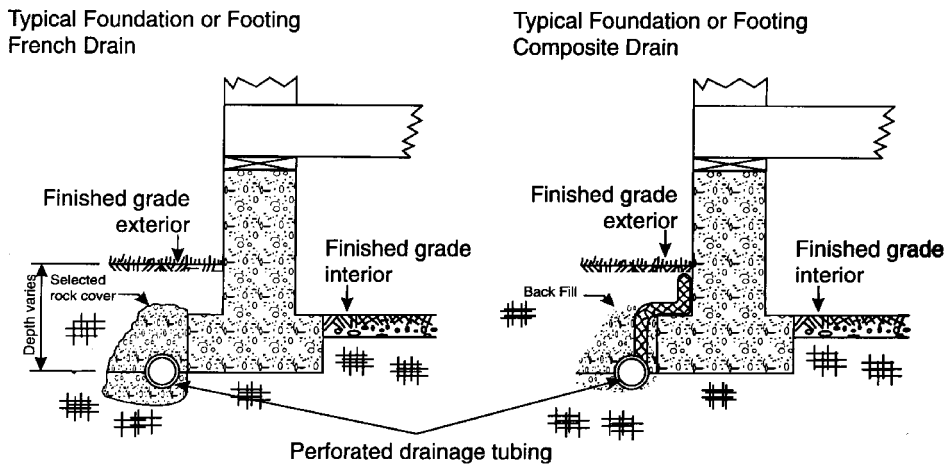


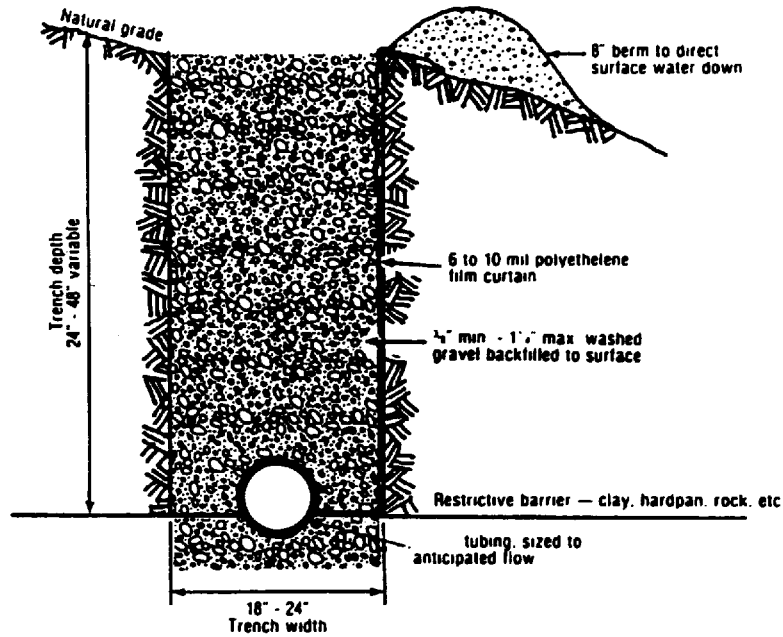
Figure 8-9: Cross-section of footing or foundation drains

Curtain Drain

Curtain drains intercept surface runoff on slopes and ground water in the soil. Curtain drains can be constructed using french or composite drains. A sloping lot often needs more drainage than can be provided by footing drains alone.

A curtain drain (Figure 8-10), placed on a slope above and parallel to a building will intercept run-off water before it reaches the foundation or creates wet spots in the yard. The “curtain” is created by the polyethylene film lining the downhill side of the trench.

Figure 8-10: Typical curtain drain

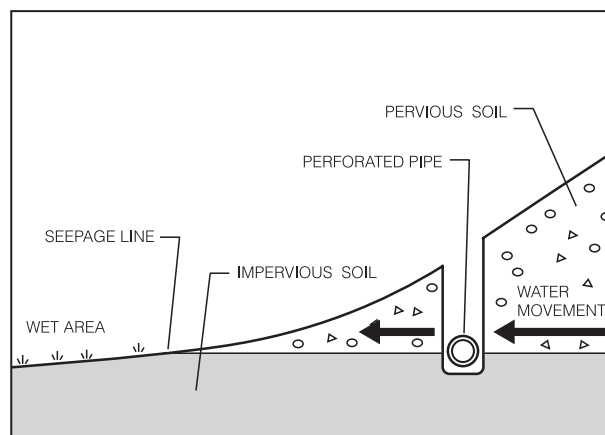


Interceptor Drains

Interceptor drains can be constructed of either french drains or composite drains. These drains intercept ground water flowing laterally on top of impervious layers of soil. The placement of the interceptor drain can best be determined by digging test holes when most of the area is ready to use, but the seep area is still wet. By observing the water level in the test holes a day after they are dug, the position of the water table or the water flowing over the tight layer in the ground can be located. As an example installation, the drain line should be installed where the water table is 1 to 2 feet below the soil surface. The trench should be dug to approximately a 2.5-foot depth. The trench, therefore, will extend below the water table (Figure 8-11). Additional interceptor drains may be needed farther up or down the slope. Water may flow on top of more than one soil layer.

Figure 8-11: Interceptor drain intercepts water flowing laterally in the soil

The size, depth and height of the drainage system is controlled by the depth of the water bearing strata.



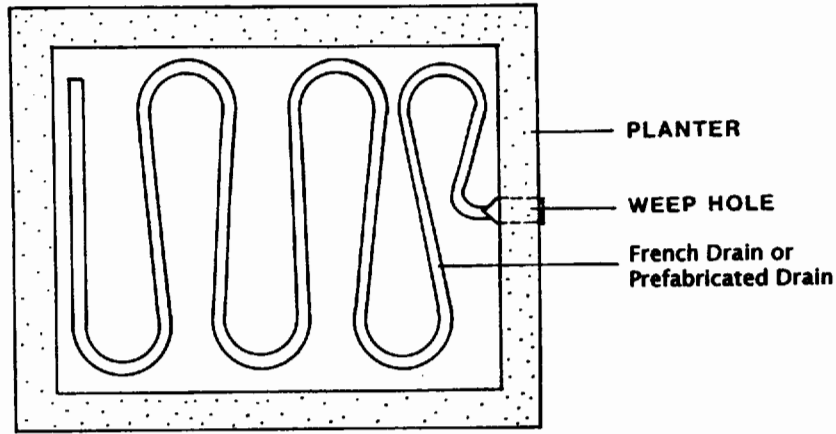


Figure 8-12: Raised planter installation
Top view

The size of the drain is correlated to the size of the planting pit and the percolation rate of the soil.

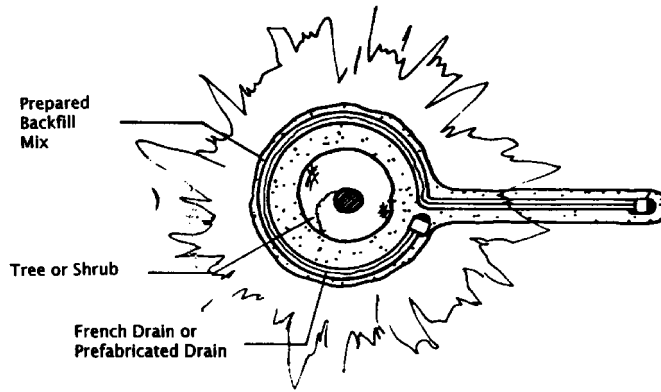


Figure 8-13: Tree root drain
Top view

Pavement Under Drainage

To prevent walks and driveways from frost damage, install perforated tubing or prefabricated drain in gravel beneath the flagstone, concrete or other paving material. Drain to a convenient disposal area.

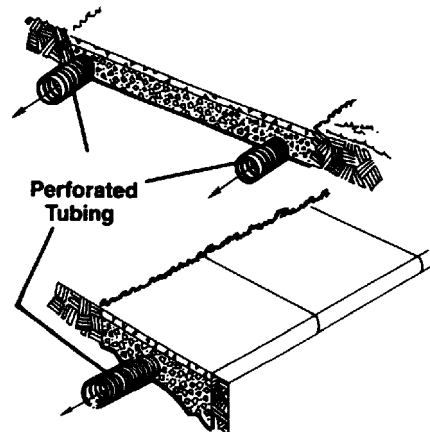


Figure 8-14: Walks/driveways/parking areas drains

Appendix A:

Glossary

Backfill – Earth or other material used to replace material removed during construction, such as in pipeline and culvert trenches and behind retaining walls.

Backwater Valves – These are used to protect low areas or basements from the back flow of waste from street sewers. The flapper situated inside the valve will not permit the water flow to be reversed. These valves can be used for storm drains and rodent protection as well.

Catch Basin – A structure with a grate on top used to collect and divert surface runoff to an underground drain pipe system. At the base of the catch basin is a sump or sediment trap to collect debris.

Channel Drains – A linear perimeter drain with a grate on top used to collect surface water along flatwork or hardscapes, such as: driveways, patios, parking lots, swimming pools, etc.

Compaction – The densification of a soil by a mechanical process.

Contour Line – An imaginary line, or its representation on a map, following all points at the same elevation above or below a given datum.

Culvert – Any structure not classified as a bridge which provides a waterway or other opening under a road.

Daylighting – The act of discharging water from drain pipe onto the surface or ditches.

Detention Basin (dry pond) – An impoundment, normally dry, for temporarily storing storm runoff from a drainage area to reduce the peak rate of flow.

Detention and Retention Basin – An area made to collect storm water runoff from a management system for the purpose of reducing peak flow and controlling rate of flow. A retention basin can be defined as having a permanent pool, whereas, a detention basin is normally dry.

Drain Inlet – A grate on top of a pipe riser that allows water runoff to enter directly into a drain pipe and does not contain a sump.

Drainable water – Water that readily drains from soil under the influence of gravity.

Drainage – Drainage is the act or process of draining, a system of drains, artificial or natural. Interception and removal of surface or groundwater. Conveyance of unwanted water from one point to another.

Electrical Boost – A method whereby water flow is increased by a sump pump that is electrically charged.

Erosion – Detachment and movement of soil or rock fragments by water, wind, ice, and gravity.

Foundation – The portion of a structure (usually below ground level) that distributes the pressure to the soil or to artificial supports.

Free Water – Water that moves by gravity, in contrast to capillary and hydroscopic water.

French Drains – A trench filled with coarse aggregate (with or without a pipe) for intercepting and conveying ground water.

Gabion – A compartmented rectangular container, made of steel wire mesh and filled with stone; used for erosion control and retaining wall purposes.

Geosynthetic – Synthetic material or structure used as an integral part of a project, structure, or system. Within this category are subsurface drainage and water control materials such as geomembranes, geotextiles, and geocomposites.

Geomembrane – A thermoplastic solid sheet material intended to block the passage of ground water.

Geotextile – A woven or non-woven thermoplastic sheet material intended to allow the passage of water, but not fines, and without collecting fines at the soil-textile interface.

Grade

Finished Grade – The completed surfaces of lawns, walks, and roads brought to grades as designed.

Natural Grade – The undisturbed natural surface of the ground.

Subgrade – The grade established in preparation for top surfacing of roads, lawns, etc.

Gradient – The degree of inclination of a surface, road, or pipe, usually expressed as a percentage.

Grading – Modification of the ground surface by cuts and/or fills. Fine or finish grading is light or thin grading to finish a prepared earth surface.

Grates – These are strainer covers that are installed on the top of catch basins or drainage pipe. They are used to filter any large pieces of debris that may otherwise enter the catch basin or piping system. They are available in round, square and atrium configurations.

Groundwater – Free subsurface water, the top of which is the water table.

Gutter Downspouts – This is the attachment from the gutters that run vertically down the building or structure in which rain water is routed from the roof mounted gutters to grade level.

Hardscape – A surface made of concrete, blacktop, wood, or rock, such as sidewalks, driveways, patios, etc.

Hydraulic conductivity – See Permeability.

Hydrology – See Permeability.

Hydrologic Condition – Vegetative cover, residue, and surface roughness of a soil as they may affect potential runoff.

Hydrology Imperviousness – The property of a material through which water will not flow under ordinary hydrostatic pressure.

Infiltration – The downward entry of water into the surface of a soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Invert – The lowest point of the internal cross section of a pipe or of a channel.

Landscape – Improvement of the natural beauty of a tract of land by grading, clearing

or decorative planting.

Manning's Equation – A formula for calculating the velocity of flow in a channel as a function of relative roughness, cross-sectional configuration, and gradient.

Mechanical Boost – An introduction of water flow that would increase the water's velocity without the aid of any electrical or motorized method.

Percolation – Movement of soil water toward the water table.

Percolation Rate – Downward movement of water into a soil, measured by the rate at which the water level drops in an augured hole.

Perforated Pipe – Pipe that is manufactured with holes or slits.

Permeability – The rate at which water passes through a material.

Pervious – The property of a material which permits movement of water through it under ordinary hydrostatic pressure.

Polyethylene Coextruded Dual Wall Corrugated Pipe – Dual wall corrugated pipe with a smooth interior wall and a corrugated exterior wall.

Polyethylene Single Wall Corrugated Pipe – Drain pipe that is corrugated, available in solid or perforated, and in various size diameters.

Polyethylene Coextruded Smooth Wall Pipe – A type of smooth wall pipe manufactured using polyethylene, which is accepted for drainage applications.

Porous – Having many small openings through which liquids may pass.

Prefabricated Drain System – Primarily a subsurface drain with plastic core interior and fabric exterior. Available in rolls, with a narrow rectangular configuration.

PVC Pipe – A type of smooth wall thermoplastic pipe manufactured using Poly Vinyl Chloride, which is widely accepted for drainage applications due to its cost, longevity, and application.

Rainfall Intensity (i) – The rate at which rain falls. In the United States usually measured in inches per hour (iph).

Rational Method – A formula for calculating the peak runoff rate from a drainage area based on land use, soils, land slope, rainfall intensity, and drainage area.

Retaining Wall – A wall built to support a bank of earth.

Riprap – Stones or other material placed on a slope to prevent erosion by water.

Runoff – that part of precipitation carried off from the area on which it falls. Also, the rate of surface discharge of the above.

Sanitary Tee – A type of fitting that forms a "T", when the inlet is formed at a sweeping angle. This allows water to be directed toward water flow and removes friction and turbulence created in a straight tee.

SDR – The SDR stands for Standard Dimension Ratio. The wall thickness of the pipe has a direct ratio to the diameter of the pipe.

Sediment Basin – An impoundment area or Structure that slows the velocity of runoff to allow sediment particles to settle out. Retention basins also function as sediment basins, although the reverse is not necessarily true. Retention, detention, and sediment basins require periodic cleaning to remove sediment.

Sheet Flow – Flow over plane, sloped surfaces in a thin layer.

Slope – The face of an embankment or cut section; any ground whose surface makes an angle with the horizontal plane.

Smooth Wall Drain Pipe – PVC, ABS or polyethylene smooth wall drain pipe.

Soil Texture – The relative proportions of sand, silt, and clay particles in a soil mass.

Solid Pipe – Pipe manufactured without holes or slots.

Splash Block – A masonry or plastic block which receives roof drainage and prevents erosion below the down spout.

Stagnate Water – Standing water that is not capable of being drained off or being absorbed, becoming foul.

Standing Water – Water that is not in motion and remains in place for some time after a hard rain due to poor surface and subsurface drainage problems. If not absorbed, evaporated, or drained, it can become stagnate water.

Storm Sewer – A conduit used for conveyance of rain water.

Straight Tee – A fitting that forms a “T” configuration at a 90(angle.

Styrene Fitting – A type of thermoplastic fitting that is used with PVC or polyethylene smooth wall pipe.

Subsurface Water – That water that is below the first layer of soil, turf; etc., but cannot permeate any lower due to the tightness of the soil. (It is not part of the water table.) Sometimes referred to as ground water.

Sump Box – Retains water which is pumped into a discharge pipe once the water reaches a high level in the sump box.

Surface Water – Water that is deposited by rainfall or irrigation which has not permeated the soil, flowing on top of turf, landscapes and hardscapes.

Swale – A constructed or natural drainage channel used to direct surface flow. Constructed swales have parabolic, trapezoidal, or triangular cross sections.

Terrace – An essentially level and defined area, usually raised, either paved or planted, forming part of a garden or building setting.

Transit – A type of survey instrument that can be used to establish exact elevation changes and heights.

Transverse Drainage System – A drainage system usually at some angle to a roadway, etc.

Trench Drain – A linear drain structure with grate used to collect sheets of runoff water in paved areas.

Water Table – The upper limit of water in a saturated soil or underlying material.

Watershed – Region or area contributing to the supply of a stream or lake.

Weephole – A small hole, as in a retaining wall, to drain water to the outside.

Troubleshooting Sample Problems

Troubleshooting Drainage Problems

Surface Drains

Regular maintenance requires removal of debris like leaves, grass, mulch, etc. Many problems are associated with debris reducing flow. Catch basin sumps need periodic cleaning. Sediment and heavy debris can collect in the sump over long periods of time. The sediment can accumulate to the level where it restricts the outlet flow.

Clogged Pipelines

If all of the surface inlets and basin sumps are clear, the pipe line may be clogged. A high pressure water device or snake can be used to clean the pipe line. Clean outs should be available at appropriate intervals to service the pipe line. **Note:** Clean-out snakes are not recommended for corrugated pipe without a smooth interior.

Outlets

The drain outlet, where the drain line comes to the surface to discharge water, is usually the weakest part of the drainage structure.

Common causes of failure:

1. Clogged outlet. Outlet must be kept clear of weeds and debris that may cause the discharged water to pond and back up into the outlet. Outlets should receive maintenance at least once each year.
2. Dead rodents or animal nests. Rodents and other small animals often crawl into the outlet to build nests if the outlet is an open pipe. Install a rodent prevention device.
3. Broken or crushed pipe. The outlet may be broken or crushed by heavy equipment. Use an outlet pipe of sufficient strength.
4. Erosion of soil from the outlet. Water flowing from the outlet may cause erosion and cause the pipe to move out of alignment. To prevent this, use erosion control fabric and large size rock or rip rap to stabilize the outlet pipe.

Common Drainage Problems and Solutions	
Down spouts from gutters empty near foundations	Tie down spouts into a drainage system.
Ground water around foundations.	Surface and subsurface drainage.
Low spots in yard.	Surface drains.
Contoured landscape design.	Surface drains.
Driveway slopes into garage.	Install channel drain in front of garage.
Hardscape slopes toward building.	Install channel drain next to building.
Retaining walls.	Weep holds, french drains and surface drains.
Raised planters.	Weep holes, french drains and surface drains.
Soggy non sloped or flat surface.	French drain.

Drainage Problems

Surface Drainage Design Problem

50' x 50' area, clay-light vegetation soil, Atlanta, GA

Step 1: Surface area = 2,500 square feet

Step 2: Coefficient of runoff = .60

Step 3: 1 Hour Maximum Rainfall = 3.50 inches

Step 4: $Q = (2500) (.60) (3.50/96.23) = 55 \text{ Gal/Min}$

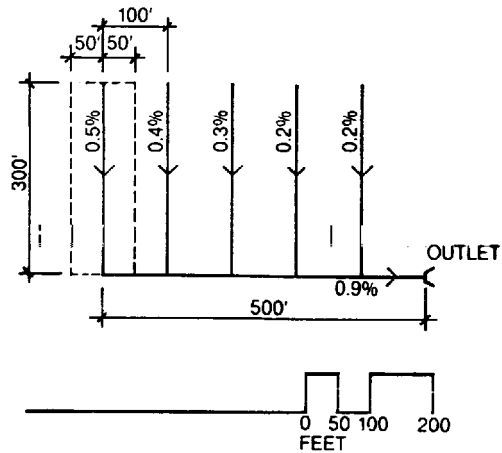
Possibilities

- 1) 4" or larger pipe and a grate with 47 sq. in of open surface area or greater (NDS 1210, 1211, 1212).
- 2) A multiple of smaller size pipes and or grates which together achieve adequate flow in gallons per minute. 2 each 3" pipe lines, 4 each of a grate with 11.5 sq. in. of open surface area each (NDS 40,50, or 60).
- 3) 3 feet of a channel drain with 19.3 sq. in. of open surface area per foot of grate.

Subsurface Drainage Design Problem

In order to determine the size of pipe, the acreage that each line has to drain must be known. For a gridiron or herringbone system, the area drained by each line may be computed by multiplying the length of the individual lines by the spacing between lines.

Figure B-1: Piping plan for example



Example

A plan for a gridiron drainage system with proposed pipe gradients indicated is illustrated in **Figure C-1**. Determine the pipe sizes for the various parts of the system for a mineral soil and smooth wall plastic pipe. For simplicity, there are no surface inlets.

Solution. The laterals are 300 ft. long and spaced 100 ft. apart. This means that each line drains 50 ft. on either side. Therefore, the drainage area for each lateral is 300 ft. by 100 ft. (50 + 50), which equals 30,000 ft.², or approximately 0.69 ac. On the basis of **Table 5-1**, a 4-in. pipe is sufficient for all laterals. The main line at the outlet must accommodate the flow from the five laterals (or approximately 3.44 ac) plus its own drainage area of 500 ft. by 50 ft., which equals 25,000 ft.², or about 0.57 ac, since it provides drainage on one side. The total drainage area of the system is about 4.0 ac (3.44 + 0.57). **Table 5-1** shows that a 4 in. pipe is also sufficient for the main line.

Sample Problem

Design a surface drainage system with area drains, channel drains and pipe based on clay light vegetation soil in Atlanta, GA. Use the design guidelines on **Chapter 4**.

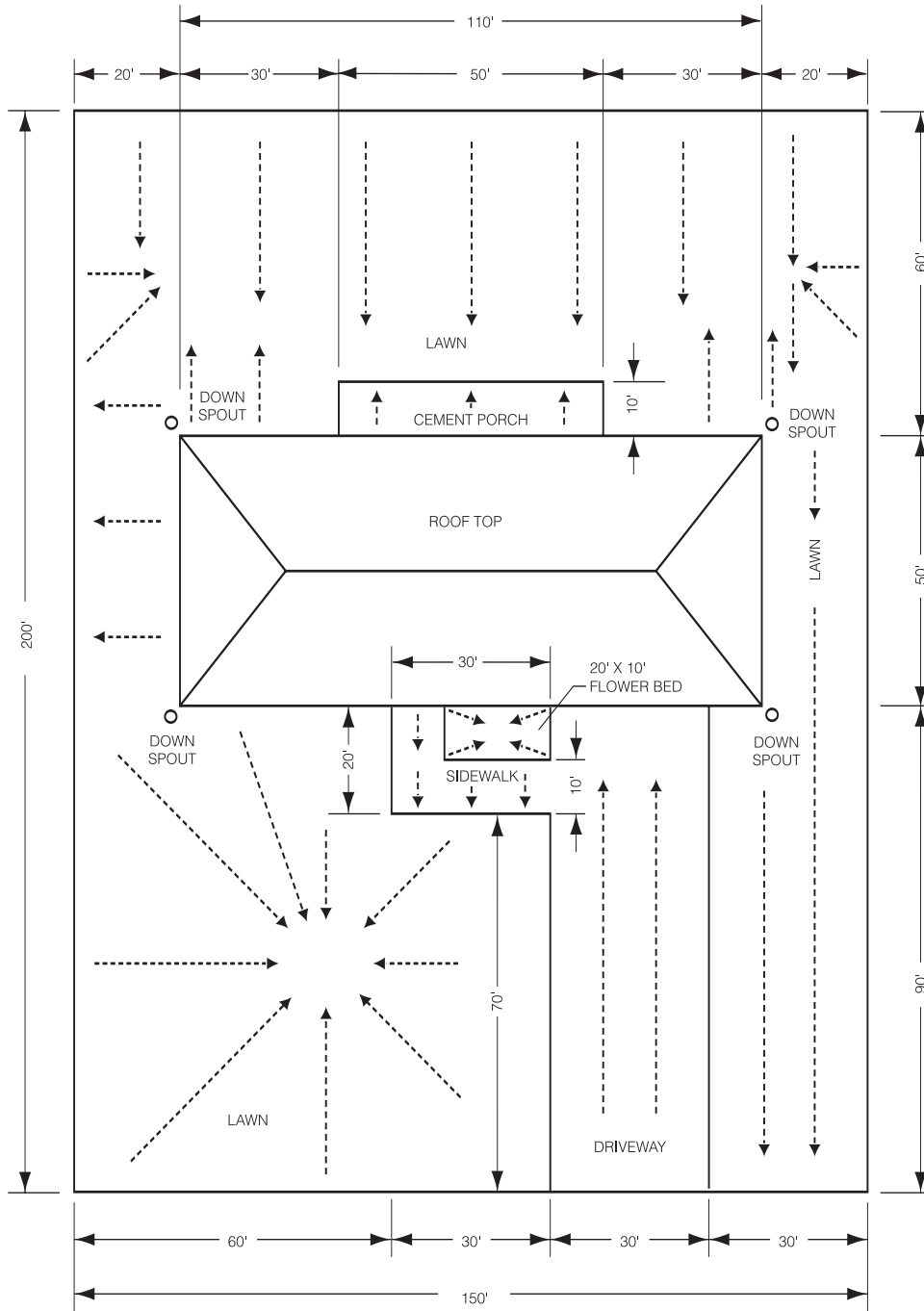


Figure B-2: Piping plan for example

Appendix C:

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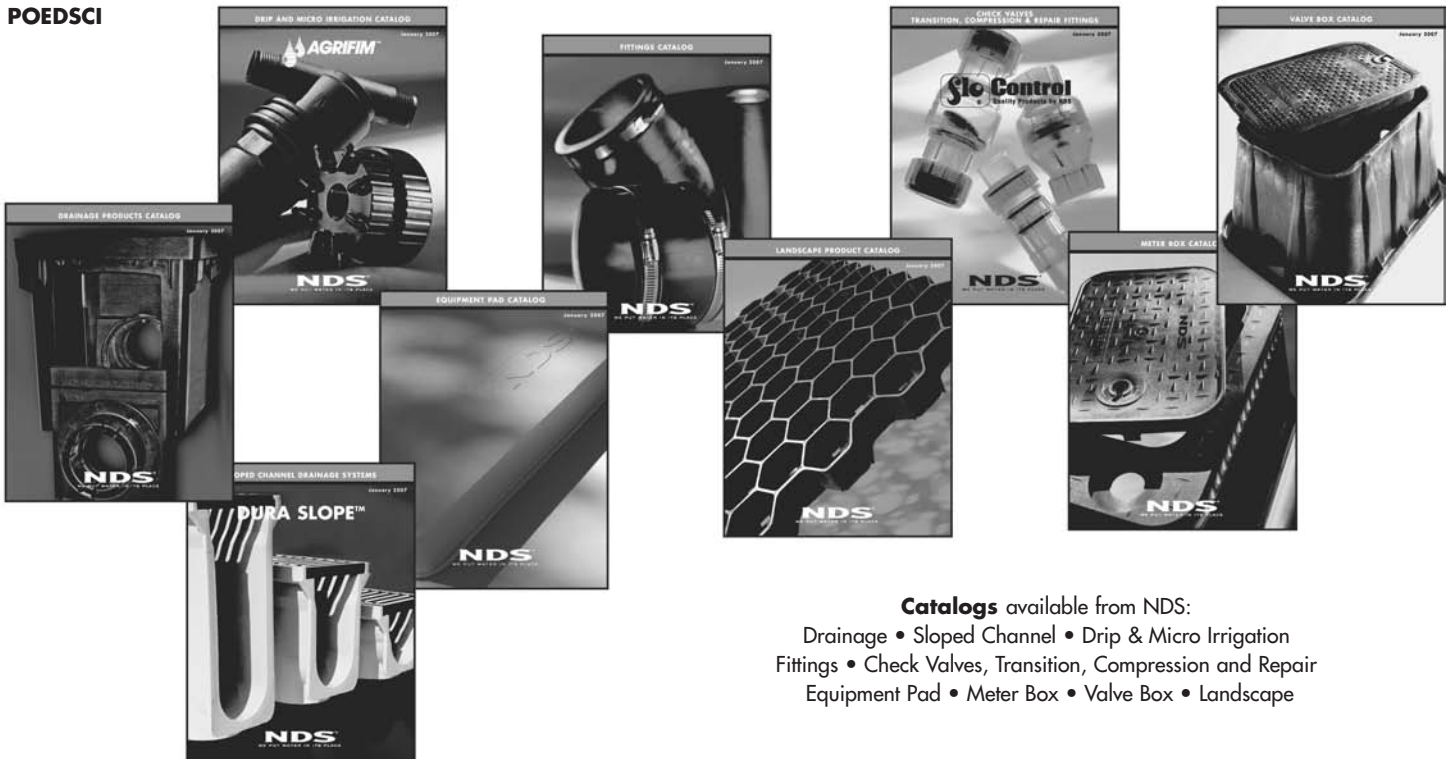
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