
44 SUBSOIL DRAINAGE

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44.1 INTRODUCTION

44.1.1 Purpose

The purpose of this Chapter is to provide a general introduction to the topic of subsoil drainage for the urban stormwater engineer.

Subsoil drainage systems are provided to drain away subsurface water in order to:

- increase the stability of the ground and footings of buildings by inducing a more stable moisture regime and reducing foundation movements due to the variations in the soil moisture content;
- mitigate surface water ponding and waterlogging of soils by lowering watertables;
- alleviate ground water pressures likely to cause dampness in below-ground internal parts of buildings or damage to foundations of buildings, other structures, or pavements; and/or
- increase soil strength by reducing the moisture content.

Subsoil drainage is an important part of road construction. Vehicular traffic on pavement with a saturated subbase results in rapid deterioration of the pavement. Entrapped water that is subject to vehicular loadings creates large hydrostatic and hydrodynamic pressures within the subbase, reducing its ability to provide stable support for the pavement. Correctly designed roads and paved areas have a highly permeable base or subbase construction and may include subsoil drains to promote the rapid outflow of subsurface water.

One important factor indicating a need for subsoil drainage is the presence of a watertable high enough to have an adverse effect on buildings and infrastructure within urban developments. Subsoil drainage is particularly important in hillside areas due to the potential to create land instability (Chapter 47). Drains behind retaining walls are designed using similar principles as other subsoil drains.

44.1.2 Scope of this Manual

The design principles and methods set out herein will be useful for many applications. However, this Chapter does not provide detailed advice for all situations. Specialist advice should be obtained for large or complex applications. Some applications, such as road and highway subsoil drainage, are covered in more detail in other Manuals or publications.

44.2 THEORETICAL PRINCIPLES

44.2.1 General Principles

Subsurface drainage is accomplished by placing an artificial conduit or flowpath below the water table so the hydraulic

head of the conduit is less than that of the soil to be drained (ASCE, 1998). The hydraulic head differential creates a hydraulic gradient towards the flow channel, depressing the phreatic line (also called the free water surface) in the vicinity of the conduit. Water is removed from the conduit at its downstream end, thus maintaining a flow system. It can therefore be seen that subsurface drainage involves principles of hydraulics and flow through porous media. The hydraulic gradient and the hydraulic conductivity of the soil govern the rate of subsurface drainage.

44.2.2 Other Design Considerations

In evaluating the need to remove subsurface water, consideration must be given to surface water runoff from buildings, road pavements and subgrades, and other impervious surfaces which is allowed to enter subsurface zones and contribute to soil saturation.

In clay soils, subsoil drains can alter long-term soil moisture regimes so that building foundations can be adversely affected by removing water, or some cases, by introducing water. In such conditions, subsoil drains should only be used where there are no other options for solving a dampness problem.

Consideration should be given to the possible effects of intermittent or permanent reduction in groundwater levels on adjacent lands when designing subsoil drainage. In soils with clay content exceeding 20%, lowering watertables can cause soil shrinkage and damage to structures. It is recommended that subsoil drains should not be placed too close to buildings on clayey sites.

44.3 DRAIN TYPES

The types of subsoil drains that are commonly used are shown in Figure 44.1. These may be installed on flat ground, in a sag or depression, or on sloping ground. The basic parts of a subsoil drain are shown in Figure 44.1(a) which is a trench with fill or filter material (commonly sand or gravel). This simple arrangement is called a rubble drain or French drain.

Figure 44.1(b) shows the addition of a geotextile lining to prevent external fine soil particles being washed into the filter material and clogging it. Both this and the unlined rubble drain have only limited effectiveness due to their limited ability to convey water.

Figure 44.1(c) shows the addition of a pipe to promote more rapid drainage. This is the most common type of subsoil drain. The pipe is perforated to allow easy entry of water and can be rigid or flexible. Figure 44.1(d) shows two further variations – an impervious cap for situations where the drain is intended to collect only subsurface flows, and bedding material for cases where the base of the excavation is unsuitable as a pipe support.

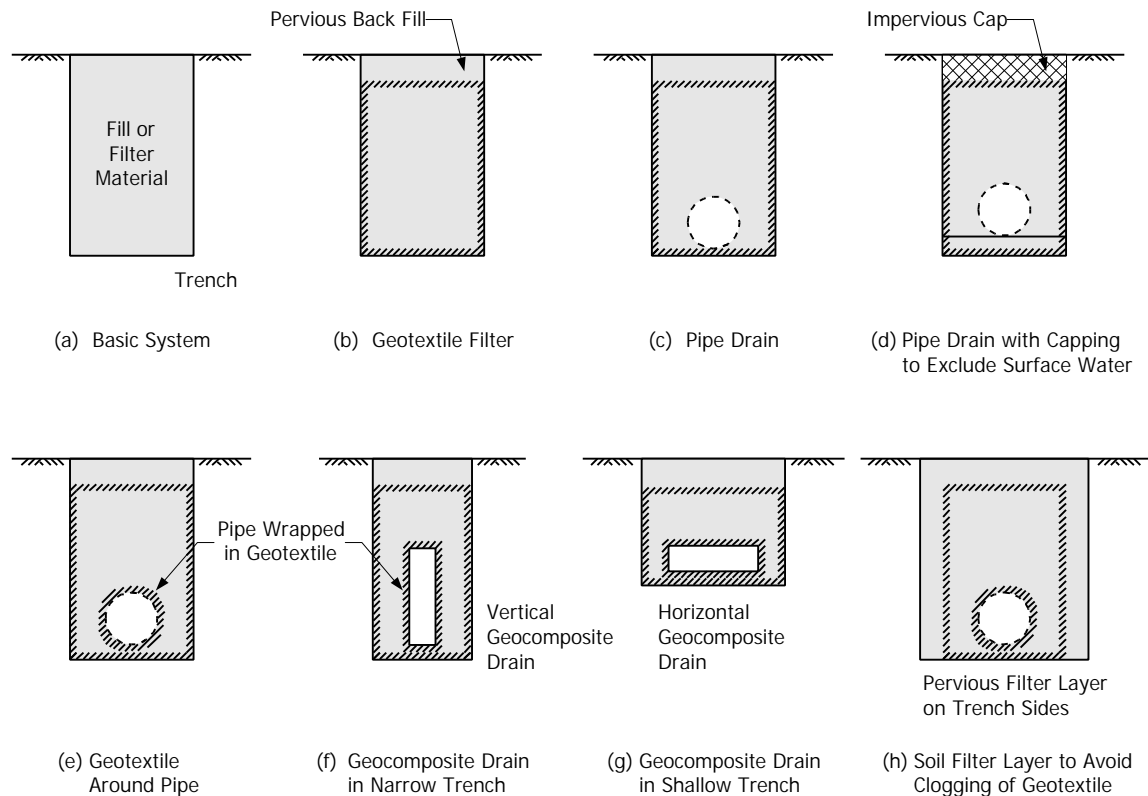


Figure 44.1 Types of Subsoil Drains

Figures 44.1(e), (f), and (g) show more elaboration. The pipe can be wrapped in geotextile to prevent piping and loss of filter material. Geocomposite drains of various configurations and manufacture can be provided. These are usually of plastic wrapped in geotextile and various proprietary systems are available. Finally, Figure 44.1(h) shows an external layer of filter material provided around the geotextile encompassing the filter material. This might be used where there is a likelihood of fine particles or deposits, e.g. iron precipitates, clogging the geotextile.

In general, subsoil drains connect either into a stormwater pit (Chapter 24) or an open channel which is part of a surface water drainage system, with the subsoil drain pipe or strip drain penetrating the pit wall. Weepholes with a suitable geotextile filter may also be used to admit water from the filter materials into the pit.

44.4 LAYOUT

The layout is directly related to the topography, the location of buildings and access points, the geology (nature of subsoil and level of groundwater) and area of a property. Main subsoil drains often follow natural

depressions. Subsoil drains should connect to a stormwater pit or a point of connection, and be consistent with the layouts for the site stormwater drain and the external stormwater drainage network.

Relevant layouts for the types of subsoil drainage systems covered in this chapter include:

- subsoil drains on one or more sides of a building or cutting, including cut-off drains for interception of groundwater flows from higher land;
- drainage systems for mitigating waterlogging or lowering watertables on small to medium areas of land, e.g. less than 500 m²

These layouts may involve branch subsoil drains connecting to a main subsoil drain. Manholes (Chapter 24) should be provided at main junction points to facilitate inspection and cleaning.

Suggested maximum spacings for branch subsoil drains are as given in Table 44.1.

Table 44.1 Maximum Spacing of Branch Subsoil Drains

Soil Type	Depth of Invert of Main Subsoil Drains	
	0.8 to 1.0 m	1.0 to 1.5 m
	Maximum Spacing (m)	
Sand	—	45 – 90
Sandy loam	—	30 – 45
Loam	16 – 20	20 – 30
Clay loam	12 – 16	15 – 20
Sandy clay	6 – 12	—
Clay	2 – 6	—

Source: BS 8301 (1985)

44.5 DESIGN CONSIDERATIONS

The design and investigation of subsoil drainage systems are uncertain processes. Only in a very limited number of situations can the need for subsoil drainage be identified without detailed subsurface investigations involving excavations, field observations, and soil tests. This Manual provides an introduction only. For many applications, specialist advice should be obtained.

44.5.1 Drain Dimensions and Spacings

The depth of a subsoil drain is dictated by the groundwater conditions, the amount by which the groundwater level is to be lowered, and the available hydraulic gradient. The following requirements are recommended:

- Interceptor drains that aim to remove flows from a particular soil stratum or an aquifer should clearly penetrate the stratum and should extend to a depth of 150 mm to 300 mm into the impervious strata below.

- Where the subsoil drain is intended to lower the general groundwater level, the determination of the depth of drain depends on whether there is a single or a multi-drain system as shown in Figure 44.2.

Analysis in these cases depends on knowledge of the hydraulic properties of the soil, and on theoretical solutions. A professional engineer with geotechnical expertise should carry out the design work in critical cases.

For less critical situations, the drawdown curve for a single drain can be assumed to have the characteristics given in Table 44.2.

For multi-drain systems, the drain spacings given in Table 44.3 can be used in less critical applications.

Clay soils present particular problems as they may be too impermeable for any drawdown to occur and expert geotechnical advice should be sought.

- Trench widths shall be a minimum of 300 mm where circular pipes are used. A minimum width of 450 mm is required where human access is required. Where a trench is deeper than 1.5 m, shoring as specified by relevant construction safety acts and regulations shall be used.

For geocomposite drains set vertically, as shown in Figure 44.1(f), the minimum trench width shall be 100 mm.

- Drains should be constructed with the base of the trench at an even slope, so that the trench acts as a rubble drain even if the pipe or geocomposite drain is blocked.
- Where a subsoil drain pipe or geocomposite drain connects to a pit or a pump-out sump, access for easy inspection of flows should be provided so that the performance of the subsoil drain can be monitored. For drains in critical locations, a means of backflushing should be provided to clear blockages.

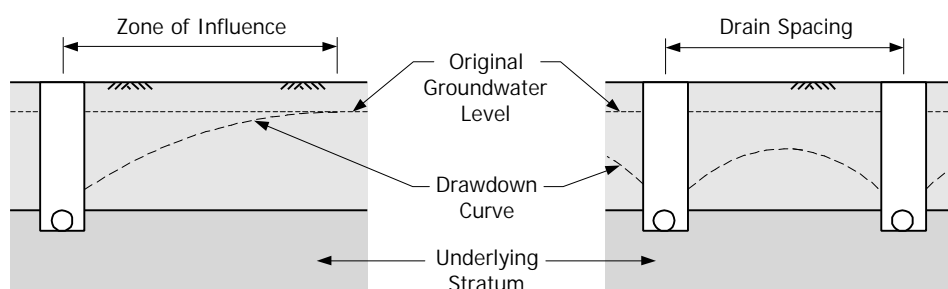


Figure 44.2 Water Table Drawdown to Single and Multi-Drain Systems

Table 44.2 Typical Single Drain Drawdown Values

Soil Type	Zone of Influence (m)	Typical Gradient of Drawdown Curve
Coarse gravel	150	—
Medium gravel	50	1:200 – 1:100
Coarse sand	40	1:100 – 1:33
Medium sand	15 – 30	1:50 – 1:20
Fine sand	8 – 15	1:20 – 1:5
Silt/clay	Variable	1:5 – 1:2.5

Source: AS/NZ 3500.3.2 (1998)

Table 44.3 Typical Drain Spacings

Soil Type	Depth (m)	Spacing (m)
Sand	1 – 2	50 – 90
Sandy loam	1 – 1.5	30 – 40
Clay loam (i.e. a clayey silt)	0.5 – 1	12 – 16

Source: AS/NZ 3500.3.2 (1998)

44.5.2 Design of Conduits

Pipes or other conduits are often provided in subsoil drains for two purposes: (i) for collection and (ii) for conveyance. A range of geocomposite materials, many of proprietary design, is also available and can be used for the same purpose.

Pipes or other conduits associated with subsoil drains should meet the following requirements:

- The size of the conduits is to be related to the expected flows through them. These flows will be very small in fine-grained soils, but will be larger where:
 - the drain is located in a pervious stratum such as a sand that is permanently fed by a nearby water body or by heavy rainfall over a prolonged period
 - the drain cuts off flow in an aquifer that is carrying a significant flow
- Where circular pipes are used in subsurface drains, normally, a minimum pipe size of 100 mm is employed, with larger sizes required for long runs of drains or in situation such as those described above. In cases of the larger flows, advice shall be sought

from a professional engineer with geotechnical expertise.

- Rigid or flexible pipes must be designed and installed to suit the relevant loading condition. Rigid pipes transmit most of the applied load through the pipe wall to the bedding material. Flexible pipes transfer the load to the backfill material by deflection. Design principles are the same as for stormwater pipes (Chapter 25).

44.5.3 Pipe Gradient

The gradients of subsoil drains shall be determined by the topography of the site. Subsoil pipe drains shall be designed with a fall toward the outlet. High points must be avoided because they will trap air, causing an air blockage.

44.5.4 Drain Envelopes

(a) General

Drain envelopes are placed around a subsoil drain such as a pipe, for several purposes. These purposes include (ASCE, 1998):

- to prevent excessive movement of soil material into the drain;
- to increase the permeability and hydraulic performance of the material near the subsoil drain;
- to increase the effective surface area of the drain;
- to stabilise the soil in which the drain is being placed; and
- to support and provide structural bedding for the pipe or conduit.

The use of drain envelopes avoids the risk of high hydraulic gradients close to the subsoil drain pipe, which can cause soil instability. It also increases the effectiveness of the drain by increasing its surface area.

The material in the drain envelope is often called a filter, although this is not strictly correct. It is not necessary for the envelope to retain all soil material. Such a filter would rapidly become clogged. Nevertheless, the term “filter” is widely used and it has been adopted in this Chapter.

(b) Filter Material

Filter material consisting of natural clean washed sands and gravels and screened crushed rock should be:

- well graded with a mix of different sizes of sand particles and an adequate permeability with:
 - natural sand, less than 5% passing a 75 µm sieve
 - screened crushed rock, sizes 3 mm to 20 mm
- sufficiently coarse not to wash into the subsoil drain, or through pores in a geotextile cover to such drain;

- chemically stable and inert to possible actions of soil and groundwater

(c) *Geotextile Filters*

The permeability of geotextiles used in subsoil drains should be greater than that of the native soil. The following general requirements should be considered:

- a desirable permeability for geotextiles is 10 times that of the native soil
- there is a tendency for geotextiles to clog at some locations, particularly where iron salts are present, e.g. scoria. Oxidation and biologically related actions can cause plate-like deposits of ferruginous particles on filter surfaces, rapidly clogging them. In such areas, carefully selected granular filters should be used instead of geotextiles. Advice from a professional engineer with geotechnical expertise should be sought in such situations.

44.6 INSTALLATION

44.6.1 General

Any pipes, conduits and fittings in such drains shall be:

- cleaned internally prior to installation and commissioning
- continuously supported by embedment (see Section 44.6.2)
- jointed with elastomeric seals, solvent cement or joints complying with the manufacturer's recommendations and/or requirements of the Local Authority

Installation of subsoil drains may include either of the following:

- pre-wrapping of the pipes or geocomposite drains with geotextile material prior to placement of the embedment, or
- wrapping of all or part of the embedment with geotextile material

The manufacturer's recommendations should be followed where applicable. Joint overlaps for geotextile material should not be less than 300 mm.

Subsoil drains shall be laid:

- so any pipe or geocomposite drain employed can be flushed out
- with clean-out points for pipes or geocomposite drains:
 - located at their topmost ends (or heads) and at each change of direction greater than 70°
 - constructed so that they intersect the drain at an angle not greater than 45°, extend vertically to the top of paved surfaces or within 300 mm of an

unpaved finished surface, and terminate with a screw cap legibly marked 'SS'

Manholes may be constructed of concrete or other approved material. Manhole construction requirements are outlined in Chapter 24. Pipe to manhole connections should allow flexibility at the interface. Manholes on subsoil drains are normally capped with a metal casting that has a removable lid, or with a concrete cover. It is desirable for manholes on subsoil drains to be identified as such, for example by the marking 'SS' on the cover.

44.6.2 Embedment

(a) *Materials*

The material for bedding, haunch support, side support, and overlay is determined by:

- the characteristics of the ground in which the subsoil drain is located
- the type of geotextile material used (if applicable)

Where the conduit consists of a pipe, the embedment material shall be crushed hard rock or natural gravel with not less than 90% by mass retained on a 9.5 mm sieve. Where the conduit is a geocomposite drain the material may be a coarse washed sand.

Requirements for sizing and determining arrangements of filter material are as follows:

- (i) For proper performance, the filter material (or backfill) should usually surround the drain, under as well as over. However, this will depend on the nature of the strata being drained and the depth of drain.

If a drain penetrates a water-bearing layer, and is socketed into an impervious zone below, then the filter material only needs to be placed in contact with the pervious soil and a suitable pipe bedding material could surround the pipe.

If a drain only partially penetrates a pervious layer such that water would be expected to flow into a drain over its entire depth, then the filter material would need to surround the pipe and also to act as the pipe bedding material.

- (ii) Where pipe bedding is a different material to the filter material, it should be coarser grained than the filter material and its particles have to be greater in size than the perforations in the pipe unless a geotextile wrapping is provided. Ideally, the grain size distribution of the bedding material should be chosen so that it itself acts as a filter to the filter zone.

Common practice is to choose a free-draining, stable and inert material with a larger grain size than the filter, such as good quality, screened, crushed rock.

(iii) A coarse washed sand should be used as a backfill when geocomposite subsurface drains are used. The coarse sand acts as the primary filter and the geotextile wrap on the drain as a secondary filter.

(b) *Installation*

Subsoil drains shall be laid:

- with embedment installed so that a subsoil drain is neither dislodged nor damaged
- so as to prevent the ingress of embedment and trench fill

44.6.3 Monitoring Wells

On large or important installations, provision should be made to monitor subsurface water levels by installing monitoring wells or piezometers. Monitoring wells allow both the level and water quality of the subsurface water to be checked. Piezometers can consist of a length of plastic tube, 25 mm to 38 mm in diameter, with holes to admit water. Both monitoring wells and piezometers should be capped to exclude surface water.