AUSTRALIAN RAIL TRACK CORPORATION LTD

This document has been adopted by the ARTC with the permission of the NSW Government and will continue to apply under the authority of the ARTC General Manager Infrastructure, Strategy & Performance until further notice

Engineering Practices Manual

Civil Engineering

Track Drainage – Inspection and Maintenance

RTS 3432

Issue A, Revision 0

March 2006

1 Scope

The purpose of this drainage guide is to enable engineering and maintenance staff to inspect and maintain effective track drainage.

Regular examination, inspection and routine maintenance of drainage systems is essential.

Neglect of drainage problems will inevitably lead to track problems.

The methods of designing drainage systems, from the initial concept through to specification of various components required and methods of construction are detailed in RTS.3433.

2 Reason and nature of change

Document reissued as ARTC Engineering Practice Manual.

3 Introduction

Without adequate track drainage, track formation may become saturated leading to weakening and subsequent failure. Formation failure may be indicated by any of the following; mud pumping up through the ballast, repeated top and line problems, bog holes, or heaving of the formation.

If the permanent way or track structure is to be maintained at a suitable standard for the passage of freight or high speed passenger trains, adequate drainage must be installed in new or upgraded track and existing drainage must be maintained so that it works effectively.

The document is divided into the following sections:

- Section 4 looks at the various types of track drainage, both surface and subsurface. The application of these drains to track drainage is also discussed.
- Section 5 deals with inspection and assessment of drainage condition and effectiveness
- Section 6 looks at the various methods used to maintain track drainage systems.

4 Types of Drainage

The types of track drainage fall under two broad headings:

1) Surface drainage

2) Subsurface drainage.

4.1 Surface Drainage

Surface drainage works used by the ARTC consist of trench type open drains.

These remove surface runoff before it enters the track structure, as well as carrying off water percolating out of the track structure.

The three types of surface drains used are:

1) Cess drains.

2) Catch drains.

3) Mitre drains.

Another form of surface drainage is the basic grading of the ground on either side of the tracks so that it falls away from the track, and allows water flowing out of the track structure to be removed. (See Figure 1).

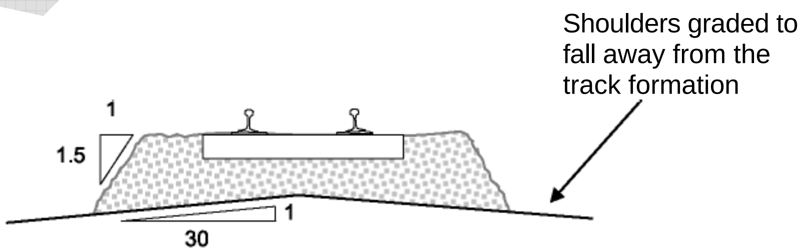


Figure 1 Typical Track Formation

Grading may be used in very flat areas where it is difficult to get sufficient fall for either surface or subsurface drains.

4.1.1 Cess Drains

Cess drains are surface drains located at formation level at the side of tracks, to remove water that has percolated through the ballast and is flowing.along the capping layer towards the outside of the track formation.

They are most frequently found in cuttings where water running off the formation cannot freely drain away. (See Figure 2).

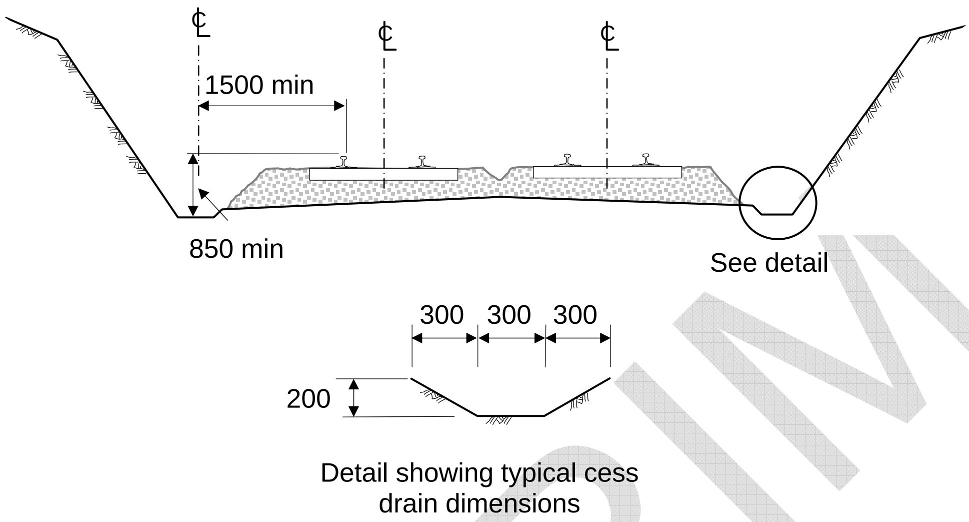


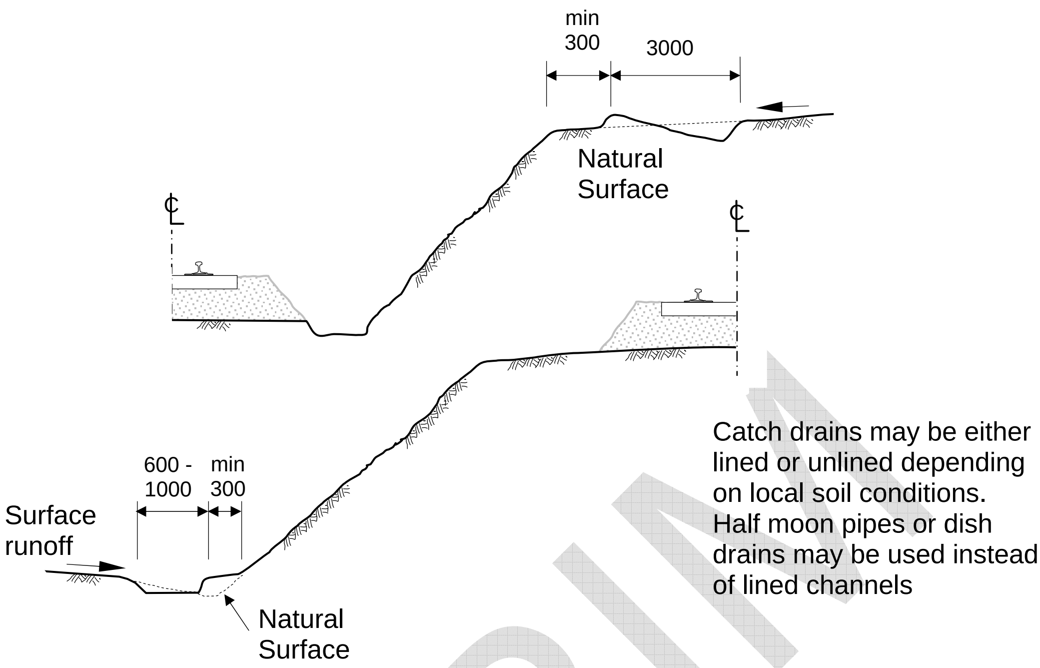
Figure 2 - Cess drain - Typical location

Cess drains should be constructed with a minimum grade of 1 in 200. Surface drains can be constructed at flatter grades, as they are easily cleared of any sediment which may collect in them.

4.1.2 Catch Drains

These may also be called top drains or surface drains. The purpose of catch drains is to intercept overland flow or runoff before it reaches the track and causes damage to the track or related structures, such as cuttings or embankments.

For example, catch drains are generally located on the uphill side of a cutting to catch water flowing down the hill and remove it prior to reaching the cutting. If this water was allowed to flow over the cutting face it may cause excessive erosion and subsequent silting up of cess drains. (See Figure 3).



This type of drain may also be used on the uphill side of other track formations, such as embankments. Catch drains may be used to remove water and prevent ponding at the base of embankments or alongside tracks that cut across a slight downhill grade.

4.1.3 Mitre Drains

Mitre drains are connected to cess, catch and surface drains to remove water, or to provide an escape for water from these drains. (See Figure 4).

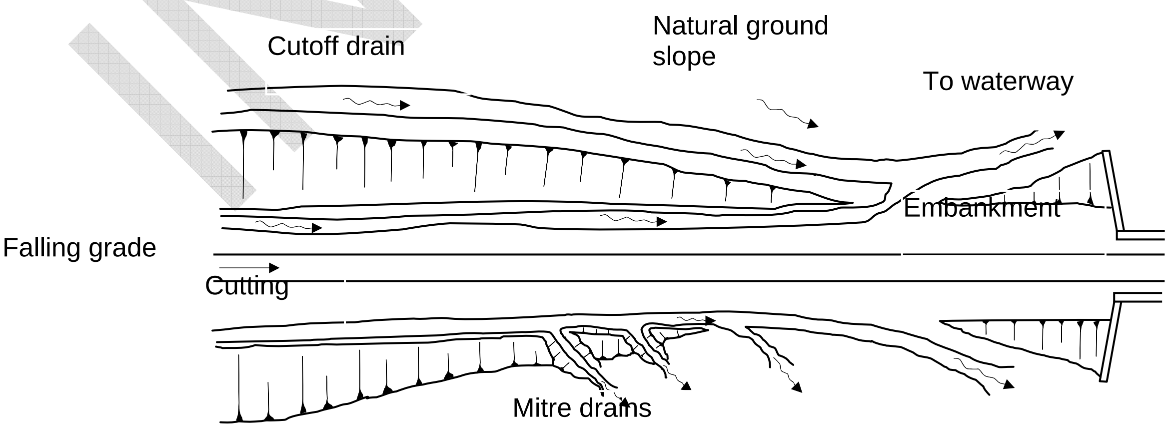


Figure 4 - Mitre drain

Mitre drains should be provided at regular intervals to remove water before it slows down and starts to deposit any sediment that it may be carrying. As the grade of the drain decreases (i.e. it becomes flatter) mitre drains should be provided at closer intervals.

A typical interval for mitre drains is one drain approximately every 100 metres for a drain with a slope of 1 in 200.

Where practicable, mitre drains should be installed at the ends of cuttings. The inlets and outlets should be splayed to allow water to be gathered or dispersed quickly.

4.2 Subsurface Drainage

Adequate subsurface drainage is necessary for maintaining the integrity of the track formation and ensuring the stability of earth slopes. Subsurface drainage is used only where surface drains are inadequate. For example, through platforms or under multiple tracks.

Subsurface drainage is used for:

- drainage of the track structure
- control of ground water
- the drainage of slopes

These requirements may overlap considerably in any given drainage system.

4.2.1 Function of Subsurface Drains

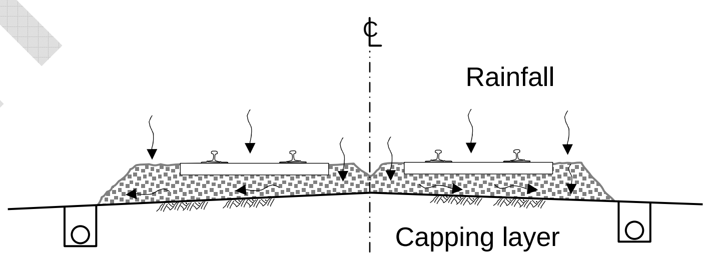
Subsurface drainage systems perform the following functions:

a) Collection of infiltration water that seeps into the formation (capping layer), as shown in Figure 5.

b) Drawdown or lowering of the watertable, as illustrated in Figure 6.

c) Interception or cutoff of water seepage along an impervious boundary, as illustrated in Figure 7.

d) Drainage of local seepage such as spring inflow, as shown in Figure 8.



Collector drains

Figure 5 - Collection of water seeping into the ballast structure.

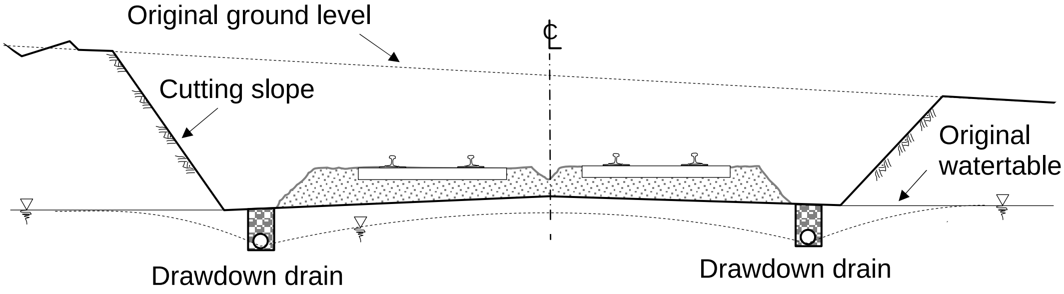
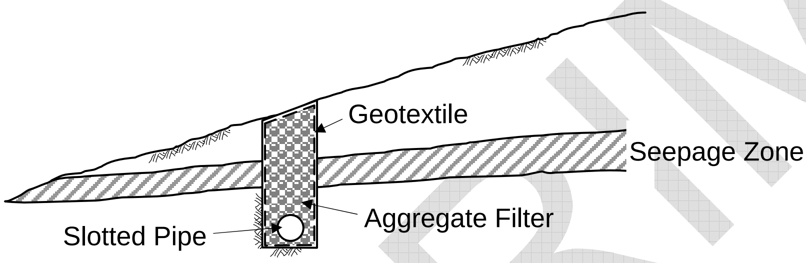
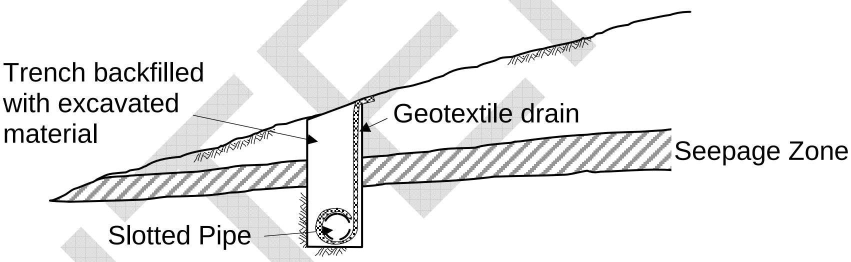


Figure 6 - Lowering the watertable

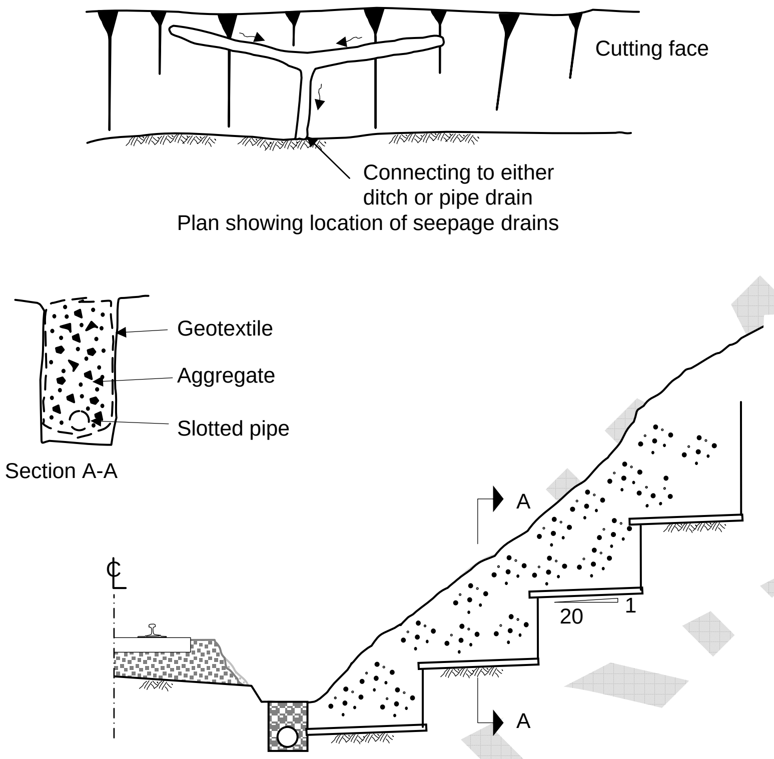


Type 1 Aggregate, geotextile and slotted pipe drain



Type 2 Geotextile drain

Figure 7 - Interception and cutoff of seepage water



Cross Section of Seepage drain

Figure 8 - Drainage of local seepage

4.2.2 Types of Subsurface Drainage

Subsurface Drains can be classified into five types according to their location and geometry.

1) Longitudinal drain (Figure 9).
2) Transverse drain (Figure 10).
3) Drainage blankets (Figure 11).
4) Horizontal drains (Figure 12).
5) Vertical drains (Figure 12).

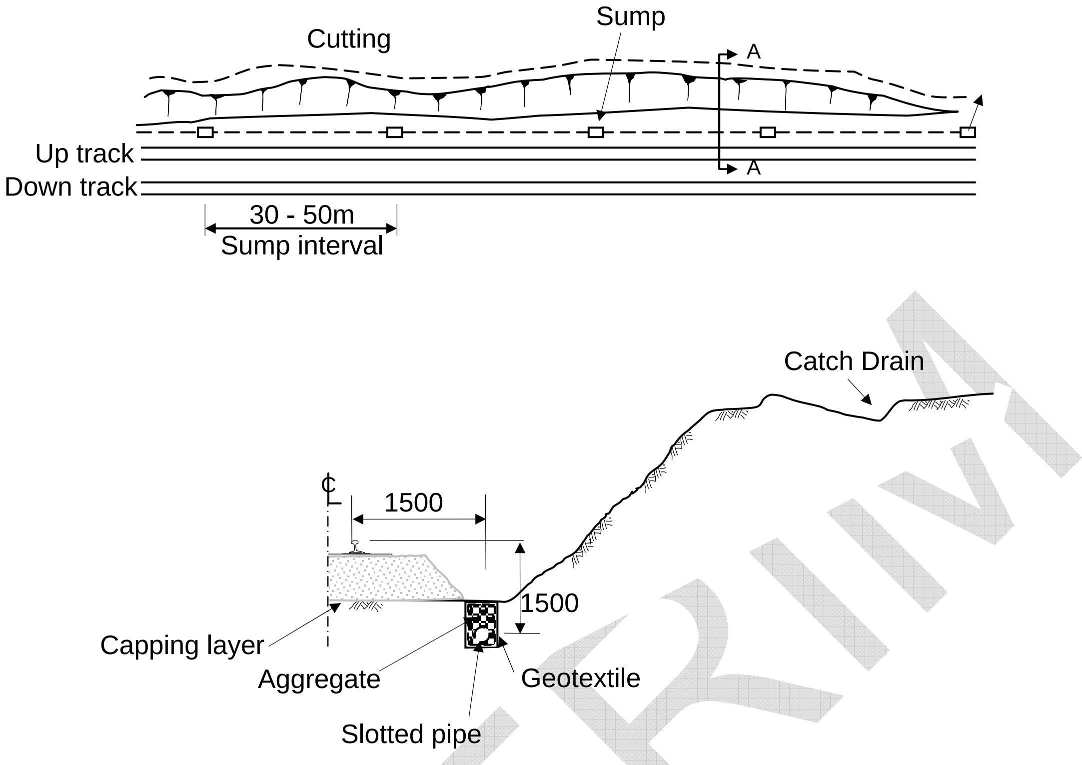


Figure 9 - Typical longitudinal drain arrangement

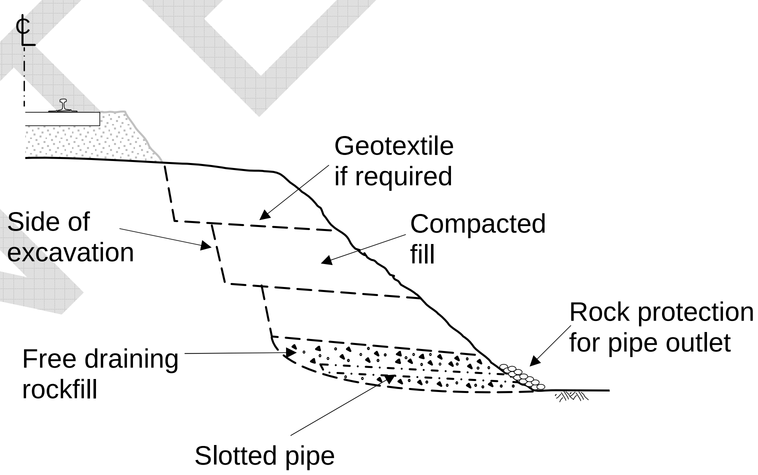


Figure 10 - Typical transverse drain

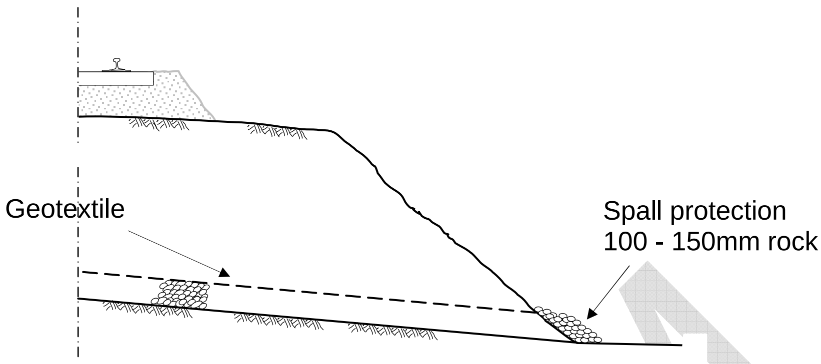


Figure 11 - Typical drainage blanket

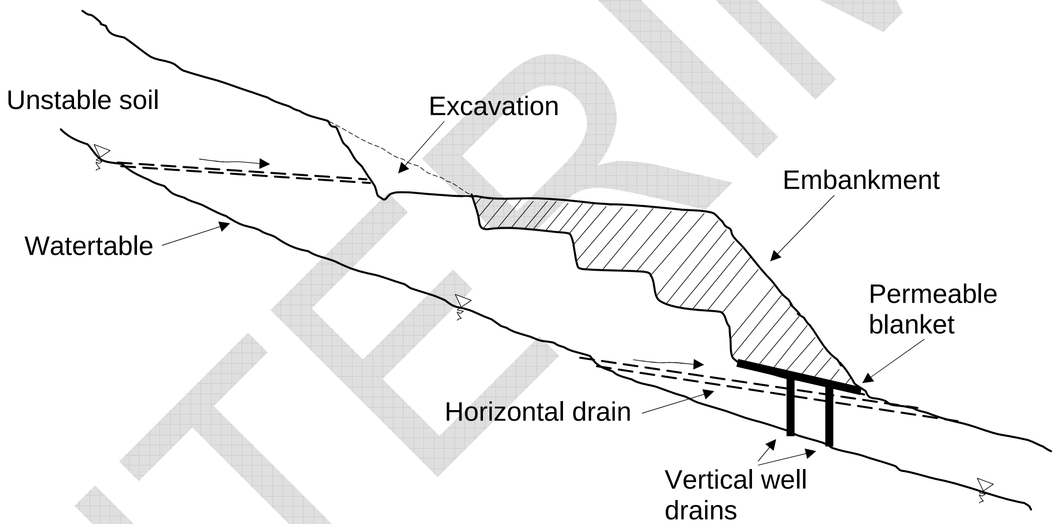


Figure 12 - Typical horizontal and vertical drain arrangement

Horizontal and vertical drains are more specialised and are seldom used for track drainage. Horizontal drains are generally used to drain wet soils and speed consolidation of earth structures. Vertical drains may also be used to speed consolidation. Another type of vertical drain is used to drain water from behind retaining walls or bridge abutments.

Subsurface drains may also be classified according to the materials used in the drain. For example:

a) Aggregate drains.

b) Pipe drains.

c) Geofabric (or geotextile) drains.

d) A combination of the above.

Aggregate Drains

These drains consist of permeable granular material. The aggregate should be coarse enough to be free-draining but not so coarse as to allow the migration of fines into or through the permeable material. If this cannot be achieved by suitable grading, a filter of either granular material or geofabric may be required. Aggregate drains can be used for both drainage blankets or French drains (Figure 13).

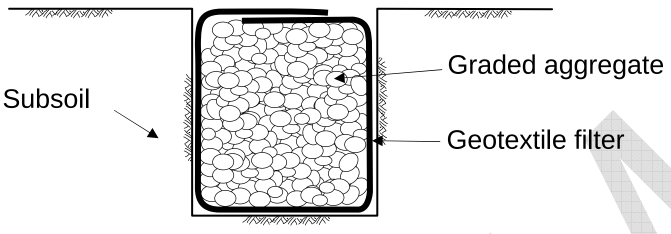


Figure 13 - Cross-section of a French drain

Pipe Drains

These consist of perforated or slotted pipes, installed by trenching and backfilling. Some type of filter material around the pipe or permeable backfill is normally required to minimise clogging of the drain perforations or slots. (See Figures 14(a), 14(b), 14(c)).

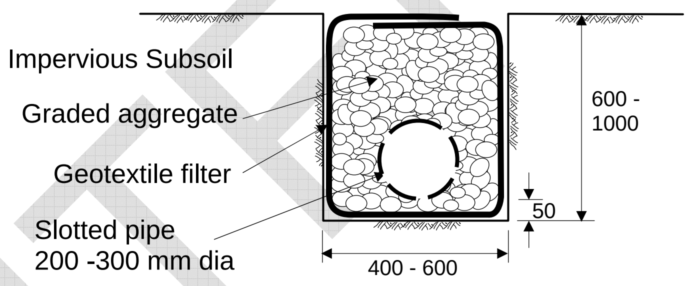


Figure 14(a) - Cross-section of a typical pipe drain with aggregate and geotextile envelope. Used where the surrounding soil is impervious

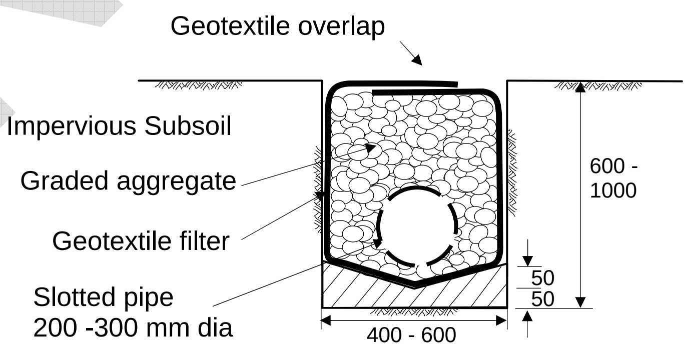


Figure 14(b) - Cross-section of a typical subsoil drain used in pervious soil

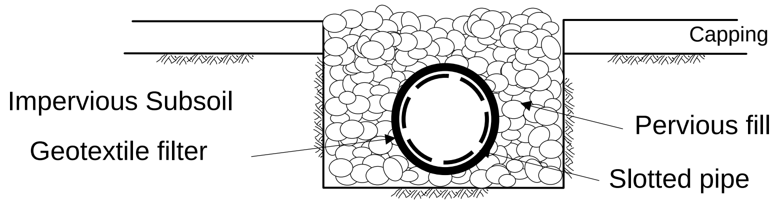


Figure 14(c) - Cross-section of a subsoil drain where the pipe is wrapped in geotextile. (Used where the depth of the pipe is limited so that pervious subsoil drains cannot be used).

Geotextile Drains

A geotextile drain may be a horizontal, vertical, or inclined blanket whose purpose is to collect subsurface water and convey it along the plain of the fabric to an outlet. The drain must also act as a filter to keep soil particles out of pores and prevent clogging. An example is shown in Figure 15.

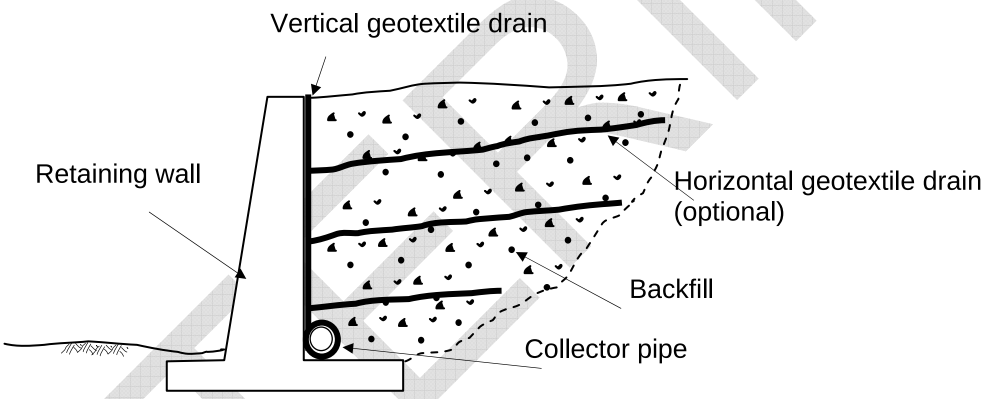


Figure 15 - Geotextile (or geofabric) drain behind a retaining wall. A similar arrangement may be used behind bridge abutments.

Other Types of Subsurface Drain

Where large volumes of water may need to be removed by subsurface drains, a carrier pipe may be used in conjunction with a collector drain, as shown in Figure 16. With this arrangement the collector drain does not need to carry all the water. The advantage of this arrangement is that excess (large volumes) water is removed from the collector drain thus preventing it seeping into the subgrade again at a point further down the drainage route.

Figure 16 shows a typical arrangement for a collector drain and carrier pipe located between two tracks. The subsurface water is collected by the collector drain between the two sumps shown, it is then conducted to the down stream sump where it can enter the carrier pipe and be removed without any risk of it re-entering the subgrade. (See Figure 18 for an example of this system used in yard drainage).

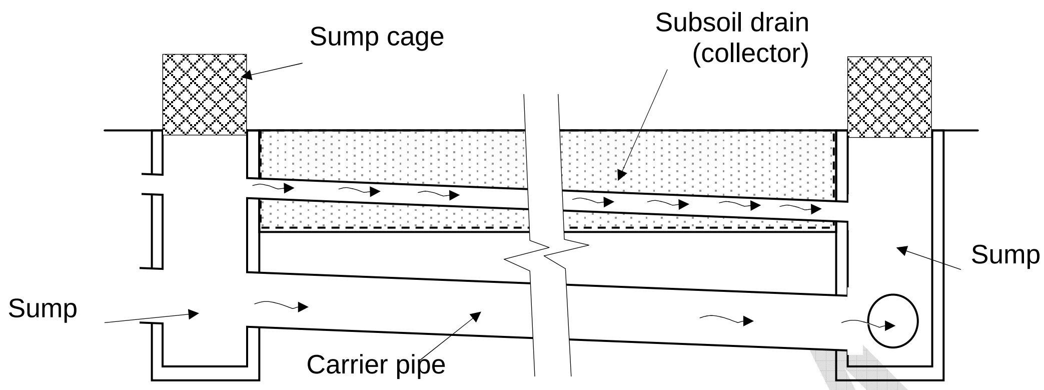


Figure 16 - Subsoil collector drain plus a larger carrier pipe

4.3 Typical Applications of Subsurface Drainage

Subsurface drains are used where adequate surface drainage cannot be provided due to some restriction, or lack of available fall due to outlet restrictions. Locations where these circumstances may occur are, track junctions, turnouts, platforms, multiple tracks and cuttings.

a) Platforms

b) Cuttings

c) Junctions

d) Multiple tracks

e) Bridges

5 Inspection of Drainage Systems

5.1 Introduction

In order to have good quality track it is necessary not only to install adequate drainage but to regularly inspect it and undertake any necessary maintenance to ensure its effectiveness.

ARTC standard TEP 05 sets out the formal policy for drainage inspection. This section gives more details on how to implement that policy.

Inspections of drainage systems should be carried out at regular intervals. Inspections of cess drains, sump covers, inlets and outlets may be undertaken during routine track inspections. Detailed inspections of all the components of drainage systems are best carried out prior to the wettest period of the year.

Without regular inspections and routine maintenance of drains, they may eventually become blocked with either sediment, debris or weed growth. If drains are allowed to become blocked or damaged they will fail in their function of draining the formation. They may even make matters worse, as water standing or ponding in parts of the drainage system may seep into the formation, via pipe slots or through the base of drainage trenches. This may lead to softening and loss of firm support for the track.

5.2 Inspections

In order to have an effective drainage maintenance system it is necessary to carry out inspections, once a year. This inspection should take place in the drier part of the year.

In addition to a yearly inspection of drainage, the condition of track side drainage should be inspected during routine track inspections. Track side drainage includes cess drains, sump covers and sump grates. During a drainage inspection the following items should be noted:

a) Bog holes, heaves and slips.

b) Foul ballast, mud pumping and its severity i.e. mud around the sleeper ends or mud volcanos.

c) Poor track alignment (line) and level (top) at locations where Item (b) exists.

d) Water ponding in drains or near the track or at the base of cuttings and embankments.

e) Erosion of cutting and/or embankment faces.

f) Erosion of drainage channels, inlets or outlets.

g) Blocked drains due to weed growth, debris from track maintenance (old sleepers and rails) and or sediment build-up.

h) Blocked sumps, grates and/or covers.

i) The amount of sediment in silt traps

j) Broken pipes or sumps.

k) Missing sump covers or grates as well as covers and grates not correctly replaced after track maintenance work.

The occurrence and extent of any of the above items should be noted on the Drainage Inspection Form (See TEP 05).

i) The location and type of drain being inspected should be noted in the appropriate sections of the Form

ii) Assess whether the drain being inspected is satisfactory or unsatisfactory. If a drain does not appear to be blocked and seems to be transporting water adequately (i.e. there is no water ponding or evidence of water ponding) the drain is satisfactory. If the drain is blocked with sediment, debris, or weed growth to such an extent that water is unable to flow through the drain is unsatisfactory.

iii) Note whether the drain is satisfactory or unsatisfactory

iv) If the drain is unsatisfactory note why this is so. This should be noted in the column headed "Comments"

v) The last column is headed "Comments/Work Required" In this column the type of any maintenance work carried out should be noted as well as the date of this work.

Once completed, inspection forms may then be retained as a record to establish a drainage history for each particular area. This will assist in assessing the suitability of maintenance work and drainage systems as well as ranking any maintenance work required.

5.2.1 Drainage Inspection Procedure

A study of all plans and records should be made to establish what drainage was actually installed. If no records exist the following assumptions should be made (i.e. the types of drainage that should be encountered in various locations):

a) Cuttings; cess drains, catch drains on the high side of the cutting and mitre drains at regular intervals. In newer or recently upgraded cuttings subsoil drains may be found.

b) Embankments; graded shoulders and catch drains.

c) Platforms; subsurface type drains in the six foot and/or along the edge of the platform base.

d) Turnouts; graded shoulders, cess and/or subsurface drains.

e) Tunnels; open drains along the sides or centre drains. In newer or recently upgraded tunnels there may be either centre or side subsurface drains.

f) Bridges; weep holes in abutments, and in ballast top bridges there may be weep holes in the parapet wall and/or subsurface drains.

g) Other track location; graded shoulders.

5.2.2 Setting Priorities for Drainage Maintenance

It is necessary to set priorities for drainage maintenance so that the worst locations are repaired first.

In order to establish to what extent the condition of the existing drainage system is affecting the track formation and/or its supporting earth structures (e.g. cuttings and embankments), it may be necessary to examine track recording data to establish whether there has been any repeated problems for top end line in areas corresponding with poor drainage. If so this may suggest the likelihood of more severe problems in the future if the drainage system is not repaired.

Areas may be ranked according to the effect they have on the surrounding track formation or surrounding earth structures.

For example the following situations are listed in order of decreasing importance:

a) Bog holes, heaves (i.e. severe formation failures).

b) Slips and slumping of slopes (saturation of slopes).

c) Mud pumping up through ballast, top and line problems.

d) Foul ballast plus top and line problems.

e) Water ponding alongside track or at the base of earth structures.

f) Erosion of cutting face (i.e. ineffective catch drains).

g) Minor blockages and sediment build-up.

h) Rubbish lying in drains.

Take for example an area in which the drainage is blocked, mud is pumping up through the ballast and there is poor top and line. This would not be ranked as high as a complete formation failure, but would have a higher priority than a blocked (top) catch drain causing minor cutting face erosion.

6 Maintenance of Drainage Systems

6.1 Surface Drainage

6.1.1 Maintenance Considerations

Maintenance operations carried out on surface drains usually fall into one, or a combination of the following:

a) Weed control.

b) Removal of debris from other track maintenance activities.

c) Removal of sediment.

d) Regrading.

A build-up of weeds within the surface drain tends to slow the passage of water through the drain, which, in turn, allows sediment to settle leading to a blockage of the drain. Such a blockage can render a drain useless and lead to a decay in the effectiveness of other drains in the system. For example, if a cutoff drain at the top of a cutting becomes blocked water may overflow the drain, run down the cutting face increasing erosion of the face and the cess drain will eventually block up due to the additional sediment load.

Weeds may be removed using normal weed control practices.

Sleepers and rails, for example, left in the cess drains after maintenance work tend to act as dams allowing water to pond alongside the track and seep into the formation. This will also allow sediment to settle. Thus old sleepers and rails should be removed to a suitable dump at the completion of any track work.

When a drain fills with sediment, whether it is due to a blockage or a flat grade, this sediment should be removed and the drain regraded if necessary. The type of equipment used to remove the sediment depends on the extent of the blockage and the accessibility. (equipment used may range from a shovel to a gradall). Regrading is sometimes necessary due to scouring or to increase the grade of the drain slightly to reduce the amount of sediment that can settle in the ditch (channel).

See Table 1 for a summary of Surface Drain Maintenance.

Where cutting faces are exposed, thus undergoing unnecessary cutting face erosion leading to an acceleration of sediment build-up in cesses, these should be protected. Forms of protection commonly used are spray grasses, or seeding, sodding and shotcrete.

Type of drain	Problems encountered	Possible remedies
CESS DRAIN	**Blockages** **-** weeds	Poison
	- old sleepers and rail etc	Should be removed and cess regraded. Old sleepers and rails should be removed when replaced and not left lying in the cess drain, if not removed from site sleepers should be gathered up and burned.
	- Other Branches	Approach other branches about equipment relocation.
	Spillages and Spent ballast.	Remove and regrade cess.
	Blockages may lead to **-** Silt build up - water ponding - overflow	Clean out cess drain and regrade if necessary.
	Uneven grades	Regrade cess.
	Scour **-** Due to high water velocities Often found on down stream side of blockages	May be possible to widen cess or regrade cess to decrease water velocity, if not the cess should be regraded and/or lined.
CATCH DRAIN	As above	
	Animal (rabbit) burrows are also a problem in some areas	Eradicate or remove animals and fill in burrows
	Poorly graded	Regrade the drain
	Scour **-** especially at outlets for catch drains above cuttings, where drains tend to be steep producing high velocities	Use more regular outlets. Therefore, producing less water at lower velocities at each outlet. Or regrade and/or line the drain.
MITRE DRAINS generally used as outlets for cess and catch drains	As above for cess drains Greatest problem is Scour	Regrade or line the drain. If necessary provide some means of retarding the flow out of these drains
GRADED SHOULDER	**Water ponding**	Regrade the shoulders so that they fall away from the track.

Table 1 - Summary of maintenance of surface drains.

6.2 Subsurface Drainage

6.2.1 Outlets

Outlets are the most critical element of a subsurface drainage system because they are susceptible to events which can impede the free flow of water. The main concerns are blockages due to weed growth, siltation of the adjacent ditch or stream, debris from the track or slope and the activities of animals or man. A system of marking outlets of subsurface drains should be implemented to enable easy location of outlets.

It is recommended that outlets and outlet markers be inspected and repaired, if necessary, as part of routine maintenance at least once a year. As with the inspection of other drainage system components this should preferably be carried out in the period of least rainfall.

6.2.2 Pipes and Sumps

Pipes and sumps are susceptible to blockages due to ballast and rubbish from the track, tree roots in search of water, siltation and pipe breakages or crushing.

Sumps may be cleaned by either digging the sediment, ballast and rubbish out of the silt traps or by using a vacuum device (mainly used for deep sumps). Sumps filled with ballast are most effectively cleaned using post hole shovels, but these are ineffective for the removal of fine non-cohesive silt. Square nose shovels of varying widths are suitable only where sediment fills the silt trap. Where a sump is deeper than two metres it becomes too difficult to clean using shovels. In this case a vacuum device may be used.

Once the sumps have been cleaned the adjoining pipes may be cleaned if necessary, by either rodding, hydroblasting or similar.

Rodding the pipes involves the pushing of a circular plug, of approximately but slightly less diameter than the inside of the pipe, through the pipe using flexible rods. Rodding is done working from sump to sump starting at the downstream end. Any sediment or other debris pushed out of the pipe is then cleaned out of the sumps.

Hydroblasting involves the removal of sediment by using a low pressure, high volume water jet, since high pressure low volume water jets tend to damage pipes. Hydroblasting is most effectively carried out using experienced Contractors. The process involved is as follows:

i) Sections of the pipe network are cleaned from sump to sump working from the outlet pipe.

ii) various nozzles are used to break up any encrustations and remove debris by either jetting it out into the sump or by relying on the volume of water and the grade of the pipe to create a self cleaning effect and remove any sediment.

iii) Once this operation is completed the sumps are cleaned either by the methods previously mentioned or by sludge pumps.

iv) This process is then repeated in the next pair of sumps and so on.

Care must be taken to replace any displaced sump grates or covers removed during the cleaning and inspection of the drainage system.

See Table 2 for a summary of Subsurface Drainage Maintenance.

Type Of Drain	Problems Encountered	Possible Remedies
Pipe, Aggregate Geotextile Filter and Sump Type Drain (Longitudinal Drains)	Blockages: - Rubbish & Ballast	Clean out rubbish and ballast.
	- Silt	Hydroblast pipe or rod pipe. Remove sludge with sludge pump or shovel.
	Scour outlet	Provide scour protection and/or decrease water velocity.
Sump Grates and Covers	Blocked by Rubbish and Silt	Remove cover and or grate, clean sump if necessary. Clean and replace grates and cover. Remove rubbish etc. from site.
Aggregate & Geotextile Drains e.g. Blankets	Blocked Outlets	Remove vegetation. Clean outlets ensure no water ponds at outlets.
Outlets	Scour	Provide scour protection and or decrease water velocity.
	Blockages	Clear away vegetationfrom outlet. Clear any other debris away from outlet e.g. spent ballast etc.

Table 2 - Summary of Maintenance of Subsurface Drains

6.3 Typical Problems and Solutions

This section looks at typical drainage problems, suggests possible reasons for their occurrence and practical maintenance solutions which range from simple cleaning to upgrading drainage.

6.3.1 Cuttings

Drainage problems are exhibited by:

a) Water ponding.

b) Poor track alignment and level through the cutting.

c) Pumping of mud up through the ballast.

d) Rock pumping.

The main causes of these problems are:

i) Poorly graded cess drains.

ii) Blocked cess drains i.e. drains silted up due to cutting face erosion or debris (e.g. sleepers and spent ballast etc.).

iii) Foul ballast i.e. spillages from coal and wheat trains or mud causing the water to be trapped in the ballast. Another possible cause is the damming of water caused by the dumping of spoil by ballast cleaners at the ballast toe.

Another problem associated with cuttings is where cut off drains have been provided but not maintained. Thus water can pond within these drains resulting in the saturation of the cutting face which would lead to slipping, slumping or piping of the cutting face. This may also allow water to overflow the drains and run down the cutting face causing excessive cutting face erosion, which in turn causes the cess drain to silt up quicker.

There are a number of solutions to these problems depending on the size of the cutting and the number of tracks. These are:

Narrow or Steep Cuttings

Depending on the severity of the problem it may only be necessary to clean, regrade the cess and ballast clean the problem section.

The other alternative is to install subsoil drains. The cess is deepened and a subsoil drain installed, the ballast is then allowed to fall over the drain. Thus if the surface (cess) drain becomes blocked (i.e. silted up) the subsurface water is still being drained away from the formation. This system can also be used on multiple track provided the formation is in good condition and graded towards the cess drains. Otherwise the formation may need to be reconstructed.

Wide Cuttings

In wider cuttings or if widening of the cutting is possible, the cess drains need only be deepened and widened so that water is drained out of and away from the track and does not prevent water flowing away from the track.

This method should be used where easy access is available allowing regular maintenance to be carried out.

Note: Cutting faces should be stabilised to reduce erosion and subsequent silting up of cess drains. For example spray grassing.

6.3.2 Embankments

The main drainage problems associated with embankments are; water being trapped in the ballast due to fouling of the ballast (either from spillages or mud) and the build up of spoils from previous ballast cleaning operations.

Another problem is that of water ponding at the embankment base, which may lead to slips. This water may cause saturation of the embankment base consequently causing further consolidation and settlement of the embankment.

To prevent water being trapped in the ballast, leading to formation failures, the shoulders of the embankment must be kept clean and graded away from the track. Thus windrows of spend ballast must not be allowed to build up on embankment shoulders. Depositing ballast cleaning spoil over the side of the embankment stops water being trapped in the ballast but can cause water to be trapped in the embankment itself. The spent ballast tends to from an impermeable layer over the outside of the embankment.

Catch drains must be installed and maintained such that water is prevented from ponding at the embankment base. An alternative to catch drains in flat areas is to grade surrounding ground away from the embankment such that if water does pond in the area, it is away from the embankment base.

At areas of heavy seepage through embankments, a transverse subsoil drain should be installed to drain the water from the embankment, thus reducing the possibility of embankment saturation and any resulting problems.

On multiple tracks where drainage problems have been encountered it may be necessary to install a transverse drain with suitable outlets to effectively drain water from the ballast.

Note: Embankment faces should be stabilised to reduce erosion problems (e.g. spray grassing or sodding or geofabric, etc.).

6.3.3 Platforms

The main problem associated with platforms is the ponding of water which consequently causes formation failures, exhibited as poor track alignment, pumping sleepers and bog holes.

The solutions available depend upon the severity of the problem. These are:

a) Clean all sumps and pipes.

b) Install a suitable drainage system in the six foot.

c) Recondition track and install subsurface drainage system.

d) Completely excavate problem area and replace with densely compacted fill up to the next formation level, then provide a 150 mm compacted granular capping layer and 300 mm of ballast cover. During reconstruction install a subsurface drainage system.

Also at stations with island platforms there is often a problem with water ponding at the ends of the platform. This can be remedied by placing a sump in the six foot connected to an existing drainage system or suitable outlet.

Note: Runoff from station buildings and platforms may be piped into sumps. This provides relatively clean water which can be used to help flush drainage systems.

6.3.4 Turnouts

With the increased axle loads and cyclic forces exerted on turnouts it takes very little water for them to start pumping mud up through the ballast, consequently fouling the ballast and compounding the problem.

Some solutions to this problem are as follows:

a) Deepen and widen the cess drains on each side to drain water from the ballast and keep it clear of the formation.

b) Install subsurface drains under problem areas during turnout reconditioning or renewal. Major problem areas are under heel blocks and crossings, these are points where the most pounding (greatest impact load) tends to occur.

In come cases during turnout and crossing renewals asphaltic concrete has been used as a capping layer to help increase the impermeability of the formation thus giving it a longer life.

6.3.5 Yard Drainage

The problems associated with yard drainage are similar to those of any other trackwork except on a larger scale. Where on most lines the drainage must cater for between one and four tracks in yards there are usually many more. Also yards tend to be constructed on very flat areas, thus there is very little fall available for surface and subsurface drainage systems.

The simplest solution for any drainage problems in yards is to clean and regrade cesses and provide regular outlets in the form of sumps such that the best possible grades can be applied to the surface drains.

The most effective method is to have the formation graded as shown in Figure 17 below.

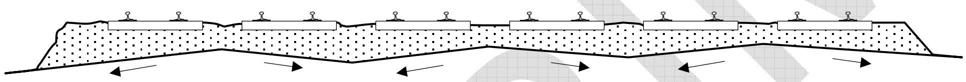


Figure.17 - Typical "saw tooth" formation used in yards

Subsurface drains are located at the low points. If large flows are expected it may be necessary to install carrier pipes. Carrier pipes may be placed at a deeper level thus allowing the grades of subsoil drains to be increased between sumps.

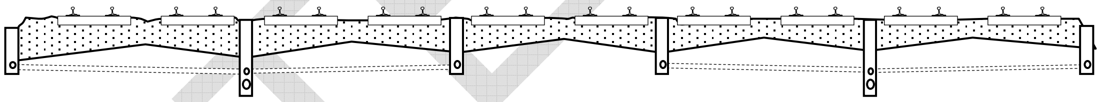


Figure 18 - Carrier Pipe Arrangement

6.3.6 Bridge Abutments and Retaining Walls

Unless adequate weep holes are installed during construction and kept clear by routine maintenance, weep holes tend to block, trapping water behind the abutment or retaining wall. This causes saturation of the earth (fill) behind the walls which can lead to further consolidation and settlement of the fill.

Weep holes are required at and above the capping layer level as well as at the base of a wall. Weep holes should also be located at regular intervals down the wall, thus if the bottom holes become blocked the upper ones can still allow some water to escape.

Existing weep holes should be cleared during regular bridge inspections. New holes should be bored through the wall if no holes exist or the existing holes are inadequate, especially if there are no weep holes present above the capping layer level.