AUSTRALIAN RAIL TRACK CORPORATION LTD

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Engineering Practices Manual

Civil Engineering

Track Drainage – Design and Construction

RTS 3433

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1 Purpose

The purpose of this document is to enable engineering and maintenance staff to design and construct effective track drainage.

Section 3 presents a method whereby surface and subsurface drainage systems may be designed to meet the systems requirements.

Section 4 discusses the construction of surface and subsurface drainage systems. It also looks at methods used to install the various systems used in track drainage systems.

This guide does not include culvert design or selection.

2 Reason and Nature of Change

Document reissued as ARTC Engineering Practice Manual.

June 2013 – Updated Clause 3.5 & Appendix 2 (f) to correct “0.00278 if A is ha” from “0.000278….”

3 Drainage Design

3.1 Introduction

The purpose of this section is to present design methods to enable track and related structures to be drained effectively using either surface or subsurface drainage systems.

Proper drainage design, using the design process detailed in this section, may allow problems to be discovered early and enable easier construction.

Drainage design may be done by field staff carrying out an installation (subject to the approval of a supervising engineer). The designer or a person sufficiently familiar with the design, who can make changes to the design if unforeseen problems are encountered during construction, should be on site during the construction.

This section presents two methods of designing drainage and discusses the design process from the initial concept through to the detailing of the drain capacity and components required.

3.2 The Design Process

The design process may be broken into several parts, each of which should be undertaken in order to produce the most suitable drainage system for each instance. The steps are:

a) Preliminary investigation.

b) Determination of the type of system required.

c) Estimation of capacity required.

d) Sizing the components.

e) Selecting other components required.

3.3 Preliminary Investigation

The main objective of a preliminary investigation is to establish the requirements of the drainage system and any restrictions that may be imposed on the system.

The procedure for carrying out a thorough preliminary investigation is:

a) Identification of the problem and thus the drainage objective. (i.e. what area is to be drained and for what reason).

b) Determination of the information required. (i.e. location, outside influences, fall available, possible outlets, access, site safety requirements, etc.)

c) Collection and study of all available existing information.

   All available information from adjacent sites or the locality in general should be studied before embarking on any field work. This will often save unnecessary field work or may point out particular problems or aspects that should receive special attention. Included in this stage should be a full services search. This involves the check of the location of both RIC and public services.

   Other types of information that may be of use are, aerial photographs, maps (topographic, geological, soil, etc.), charts, meteorological and hydrological information).

d) Site inspection.

   A check list should be prepared prior to the actual investigation so that the maximum amount of information may be extracted from the site in a minimum time. (See Form 1 in Appendix 1).

Items that should be looked at during a site inspection include:

i) Access to and from the proposed site and any possible restrictions.

ii) Type and location of any existing drainage systems, any possible reasons for its failure.

iii) The position and condition of any existing drainage outlets.

iv) Any other likely drainage outlets. Note the outlet conditions and any likely restrictions because these may affect the design of the drainage system.

A further inspection may be required at a later stage so that the area may be surveyed in order to establish the fall available and invert level for the inlet and outlet.

e) Catchment area estimation.

The catchment area for the drainage system needs to be estimated during the site inspection. This may be checked by comparison with maps of the area.

f) As mentioned in (c) it is necessary to conduct a site services search in order to locate any pipes, or wires in the area. This will involve site inspections with representatives from various bodies to accurately locate services, the position of which should then be marked, either on a plan or pegged.

3.4 Determination of the type of drainage system required

On completion of the preliminary investigation, information gathered may be compiled and a decision made on the type of drainage system suitable.

The type of system chosen for each location is dependent on the water source and the track structure. If possible surface drains should be used in preference to subsurface drains since they are easily seen and maintained.

Note, care must be taken to ensure that the right drainage system is designed for each location. For example-using a slotted system to drain surface runoff that could have been collected by sumps. This could lead to a quicker failure of the system by allowing an easier route for water to pass (seep) into the formation.

3.5 Estimation of the Capacity Required

At this point the site requirements, any restrictions, the type and layout of the proposed drainage system should be known.

The next step is to estimate the volume of water that the drain will need to carry, so that the size of the drain and its various components may be estimated.

The quantity of water (Q) that the drain is required to carry generally consists of:

$Q = Q_R + Q_S + Q_C$………………………………………………………..(1)

Where;

Q = water quantity (m^3/s or l/s)

Q_R = runoff quantity collected (m^3/S or l/s)

Q_S = subsurface water intercepted (m^3/s or l/s)

Q_C = collected water quantity conducted by drain from a connecting system (m^3/s or l/s).

The calculated quantity (Q) represents the peak flow that the drain will be required to carry, for a short time only. This is estimated according to the frequency of the rain using simplified procedures or the "Rational Method".

The quantity (Q_R) may be determined by using the Rational Method.

In order to use the Rational Method it is necessary to determine a relevant average recurrence interval (ARI) that can be used. This is an approximate estimate of how often a particular event will occur on average. For example, an ARI of 1 in 50 years means that a particular storm event is likely to occur on average once in fifty years.

For the interception and drainage of rainwater runoff, the ARI used in design usually increases with the importance of the track or related structure to be drained. As the recurrence interval increases there is a reduction in the risk of flooding.

Track Class	Recurrence Interval
Class 1 and higher	50 years
Class 2	25 years
Class 3	10 years
Class 4	5 years
Class 5	5 years

Table 1 Typical recurrence intervals for various track classes.

Note: The recurrence intervals listed are for guidance ONLY and should be modified in the following cases:

a) If flood hazards in the vicinity of the site are unusually severe.

b) If the track classification is likely to be upgraded or downgraded after construction.

c) If the track has a low traffic volume.

d) Once the ARI is established the volume of water that the drain will carry can be calculated.

3.5.1 The Rational Method

The Rational Method provides a method for calculating the peak rate of discharge of a storm event with a specific ARI.

The formula used in the Rational Methods is:

$Q = F \times C \times I \times A$……………………………………………………………..(2)

Where;

Q = peak flow rate (m^3/s)

F = conversion factor to balance units used.

F = 0.278 if A is in km^2

F = 0.00278 if A is in hectares (ha).

C = runoff co-efficient.

I = average intensity (mm/h).

A = catchment area (km^2 or ha).

In order to determine the average intensity (mm/h) it is necessary to know the ARI and to calculate the time of concentration.

Once the ARI and time of concentration has been determined it is possible to determine the intensity. The methods that are used to determine intensity vary depending on the duration (or t_c).

A calculation form is provided in Appendix 2. This form sets out each step, details the information required to complete each step, and provides space for the calculations involved.

3.6 Sizing Drainage System Components

Drainage systems may be sized to satisfy one of the following criteria:

(a) Sizing to satisfy flow requirements

There are two ways of sizing the components of drainage systems designed to carry a specific flow. These are:

i) Past or local experience.

If a system of similar type and size has been used successfully in the past it may be duplicated for use in the proposed new location, provided that the new location is subjected to similar conditions to the location for which the original drainage system was designed. The layout of the new system may differ from that of the existing, provided that peak capacities are similar.

Any design made using past experience or local knowledge must be checked and authorised by a competent engineer prior to the installation of the system.

ii) Calculation using the expected peak flow.

The capacity of the proposed drainage system may also be determined using the peak capacity calculated by the Rational method in the previous section, with adjustment made for subsurface water and water collected from other systems.

There are several considerations in determining the size of the drain required. These vary according to whether the system is a surface drainage system or a subsurface drainage system. These will be considered in the following sections.

(b) Sizing to satisfy-maintenance requirements

Typical maintenance requirements that may affect the design of drainage systems include:

(i) Use over sized channels to reduce maintenance requirements. For example, catch drains are usually difficult to maintain due to access problems. These drains may be over sized to allow a certain degree of sediment build up to occur, but still work effectively.

(ii) Use of larger pipes that become blocked less easily and are easier to clean. For example, a 200mm pipe may be adequate to carry the peak flow expected but a 300mm pipe is used because it is easier to maintain and blocks less frequently.

Therefore when designing a drainage system the maintenance requirements as well as the capacity must be considered, not forgetting the other important considerations of cost and constructability.

3.6.1 Sizing Surface Drains

Prior to estimating the size of a surface drain the required capacity must either be known or calculated using Equation 1.

$Q = Q_R + Q_S + Q_C$……………………………………………………………..(1)

Where;

Q = water quantity (m^3/s or l/s)

Q_R = runoff quantity collected (m^3/S or l/s)

Q_S = subsurface water intercepted (m^3/s or l/s)

Q_C = collected water quantity conducted by drain from a connecting system (m^3/s or l/s).

For surface drains "Q_S" and "Q_C" can usually be neglected. Thus Equation 1 becomes:

$Q = Q_R = Q_{PF}$ = Peak flow rate (m^3/s).

Once the capacity required is known the surface drain may be sized. The steps involved are as follows:

a) Water Velocity

The soil type through which the drain is to pass needs to be determined. Then a value for the maximum permissible velocity may be chosen from Table 2. below. A value of the roughness coefficient ’In" must then be selected from Table 3.

Channel Type	Velocity (m/s)
Fine sand	0.45
Silt loam	0.60
Fine gravel	0.75
Stiff clay	0.90
Coarse gravel	1.20
Shale, hardpan	1.50

Table 2 Suggested Maximum Permissible Velocities

Note: These values are to be used as a guide only. If problems are encountered or an area is prone to erosion problems geotechnical advice should be sought.

Channel Material	Roughness Coefficient
Closed Conduits -	
concrete pipe or box	0.012
corrugated steel pipe - helical	0.020
vitrified clay pipe	0.012
fibre cement pipe	0.010
P.V.C. pipe	0.009
steel pipe	0.009 - 0.011
Lined open channels	
concrete lining	0.013 - 0.017
gravel bottom concrete sides	0.017 - 0.020
gravel bottom rip rap sides	0.023 - 0.033
asphalt rough	0.016
asphalt smooth	0.013
Unlined channels - Earth uniform section	
clean channel	0.016 - 0.018
with short grass	0.022 - 0.027
gravelly soil	0.022 - 0.025
Unlined channels - Earth fairly uniform section	
no vegetation	0.022 - 0.025

grass plus some weeds	0.030 - 0.035
dense weeds	0.030 - 0.035
clean sides gravel bottom	0.025 - 0.030
clean sides cobble bottom	0.030 - 0.040
Rock	
smooth and uniform	0.035 - 0.040
jagged and irregular	0.040 - 0.045

Table 3 - Value for Manning's roughness co-efficient "n" for different channel types.

b) Determine the slope of the drain

ARTC standard TDS 08 recommends that a minimum slope of 1 in 200 (i.e. 1 metre fall vertically for every 200 metres horizontally) be used for drainage. Though a slope of 1 in 100 is usually used for self cleaning purposes, smaller, flatter slopes may be used where necessary for surface drains, since blockages are easily spotted and repaired. It should be noted that as the slope of the drain becomes flatter the tendency for a drain to become blocked due to sediment build-up increases. Consequently the maintenance of the drain also increases. When using flatter slopes or grades approval should be obtained from a person with design authority.

The required slope should have been determined during the preliminary investigation.

c) Select a trial drain size

Using the value of slope "S" and the roughness coefficient "n" selected previously, the capacity of the trial drain can be calculated using Equation 4 which is a simplified version of Equation 3 (Manning's equation).

$$Q = \frac{1}{n} \times A \times R^{0.67} \times S^{0.5} \quad \text{……………………………………..………(3)}$$

Where;

Q = flow rate or capacity (m^3/s)

n = roughness co-efficient. From Table 3

A = channel cross-sectional area

R = hydraulic radius - examples given in Table 4

R = A/P where P = wetted perimeter (i.e. the surface in contact with the water)

S = slope of the drain.

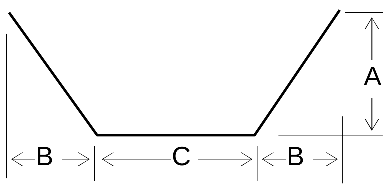
If $X = A \times R$ Equation 3 becomes:

$$Q = \frac{1}{n} \times X \times S^{0.5} \quad \text{…………………………………..……………….. (4)}$$

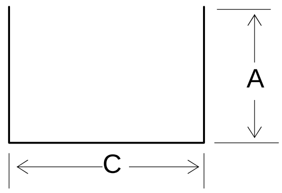
See Table 4 for values of "X" for various channels.

Channel Types:

Type 1 - Trapezoidal



Type 2 - Rectangular



Channel Dimensions (mm)				Area (m)	Wetted perimeter (m)	Hydraulic radius (m)	X Eqn 4
No	A	B	C				
1	200	-	300	0.060	0.700	0.086	0.012
2	200	-	450	0.090	0.850	0.106	0.020
3	200	200	300	0.100	0.860	0.115	0.024
4	200	300	300	0.120	1.021	0.118	0.029
5	200	200	450	0.130	1.016	0.128	0.033
6	300	-	450	0.135	1.050	0.129	0.034
7	300	200	300	0.150	1.021	0.147	0.042
8	300	300	300	0.180	1.149	0.157	0.052
9	450	-	450	0.203	1.350	0.150	0.057
10	300	200	450	0.195	1.171	0.167	0.059
11	300	450	300	0.225	1.382	0.163	0.067
12	300	300	450	0.225	1.299	0.173	0.070
13	300	200	600	0.240	1.321	0.182	0.077
14	300	450	450	0.270	1.532	0.176	0.085
15	450	-	600	0.270	1.500	0.180	0.086
16	300	300	600	0.270	1.449	0.186	0.088
17	300	450	600	0.315	1.682	0.187	0.103
18	300	200	900	0.330	1.621	0.204	0.114
19	450	300	450	0.338	1.532	0.220	0.123
20	300	300	900	0.360	1.749	0.206	0.125
21	450	-	900	0.405	1.800	0.225	0.150
22	450	450	450	0.405	1.723	0.235	0.154
23	450	300	600	0.405	1.682	0.241	0.157
24	300	450	900	0.405	1.441	0.281	0.174
25	450	450	600	0.473	1.873	0.252	0.188
26	450	300	900	0.540	1.982	0.272	0.227
27	450	450	900	0.608	2.173	0.280	0.260
28	600	600	600	0.720	2.297	0.313	0.332
29	600	600	900	0.900	2.597	0.347	0.440

Table 4 - Calculation of "X" for various channel sizes.

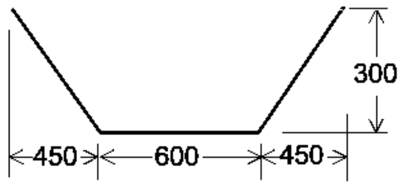
Note: Smaller channels tend to become blocked with built up sediment very quickly.

Typical examples of calculations to determine the capacity of an open channel

(i) using Equation 3 and

(ii) using Equation 4 and Table 4.

For a trapezoidal channel (shown below) with a slope of 1 in 200 and a roughness coefficient "n" of 0.030, the channel capacity is:



1. Using Equation 3

S = 1 in 200 = 0.005

n = 0.030

A = (600 × 300) + 2 × (0.5 × 300 × 450)

A = 315,000 mm^2

A = 0.315 m^2

R = A/P

$$P = 2 \times \sqrt{(300) \times 2 + (450) \times 2} + 600$$

P = 1682 mm

P = 1.682 m

R = 0.315/1.682

R = 0.187 m

$$Q = \frac{1}{n} \times A \times R^{0.67} \times S^{0.5}$$

$$Q = \frac{1}{0.03} \times 0.315 \times (0.187)^{0.67} \times (0.005)^{0.5}$$

Q = 0.243 (m^3/s)

2. Using Equation 4 and Table 4

S = 0. 005

n = 0.030

From Table 4, X = 0.103

Equation 4

$$Q = \frac{1}{n} \times X \times S^{0.5}$$

$$Q = \frac{1}{0.03} \times (0.103) \times (0.005)^{0.5}$$

Q = 0.243 (m^3/s)

d) Compare drain capacities

Once the capacity of the trial drain is determined it must be compared with the required capacity found using Equation 1. If the capacity of the trial is considerably greater or lesser than the required capacity, a new trial drain should be selected and steps (c) and (d) repeated until the trial capacity is approximately equal to or slightly greater than the required capacity.

e) Check water velocity

Once the required capacity is obtained, check that the velocity of the water in the channel is less than the maximum permissible velocity found from Table 2 in step (a).

The velocity is calculated using Equation 5 as shown below:

V=Q/A……………………………………………………………..(5)

Where:

V= velocity (m/s)

Q= flow rate (m^3/s) calculated using Equation 1

A= area of selected channel (m^2)

Example: If the required capacity is Q = 0.210m^3/s, n= 0.030 and S = 0.005, what channel size is required and what is the velocity of the water?

Channel size - choose size No. 17

X = 0.103 …………substitute this into Equation 4

This gives Q = 0.243m^3/s this is larger than the required capacity, therefore try Channel No. 16.

X = 0.088 …………substitute this into Equation 4

This gives Q = 0.207 m^3/s this is less than the required capacity, therefore use Channel size No. 17.

Check the velocity, using Equation 5

V = Q/A = 0.210/0.315

V = 0.67 m/s

Note: Q used in Equation 5 is the required capacity.

If the velocity is greater than the maximum permissible velocity then either use a larger channel or line the channel selected.

f) Channel lining

In some cases it may only be possible to install a small drain and the flow through this drain may have a velocity greater than the maximum permissible velocity and consequently the channel must be lined.

Lining a channel changes the roughness co-efficient "n"', and thus the capacity of the channel may be altered either up or down. (See Table 3)

A lining is selected such that the allowable velocity for the type of lining is greater than that calculated in step (e), this is used as a first trial value.

Lining Type	Velocitv (m/s)
Grass covered	1.8
Stones (100-150mm)	2.5 -3.0
Boulders (250mm)	5.0
Hard packed rock	6.0
Asphalt	3.0
Concrete	6.0

Table 5 Maximum permissible velocities for various types of channel lining.

g) Capacity of lined channels

Calculate the capacity of the lined channel (Q). This should be greater than the flow rate found using Equation 1.

If Q is less than that required, either use a lining with a smaller value of "n" (i.e. a smoother channel or a larger channel.

h) Completion

If all of the above steps have been completed as necessary, the channel size and/or lining is satisfactory.

Example: Channel lining selection. Using Channel No. 14 from Table 4

$A = 0.270\ m^2$

$X = 0.085$

If n = 0.030, S = 1 in 100 = 0.01 and the soil type is clay therefore from Table 2 the Maximum Permissible Velocity is V = 0.9 m/s.

Using Equation 4 $Q = 0.283\ m^3/s$

Assume the required capacity from Equation 1 is $Q = 0.260\ m^3/s$.

Using Equation 5

$V = Q/A = 0.260/0.270$

$V = 0.96$ m/s

This is greater than the maximum permissible velocity of 0.90 m/s, therefore channel lining is required.

Try grass lining - V permissible = V_P = 1.8 m/s from Table 5. From Table 3 "n"

= 0.035.

Using Equation 4

$$Q = \frac{1}{0.035} \times (0.085) \times (0.01)^{0.5}$$

Q = 0.234 m^3/s

This is less than the required capacity of Q= 0.260 m^3/s.

Therefore try a smoother channel lining.

Try asphalt n = 0.016 and V_P = 3 m/s

Q becomes:

$$Q = \frac{1}{0.016} \times (0.085) \times (0.01)^{0.5}$$

Q = 0.531 m^3/s

Therefore asphalt is a satisfactory lining.

3.6.2 Sizing Subsurface Drainage Systems

The flow of water to be conducted by a subsurface drainage system has three main-sources. These are:

a) Surface runoff (Q_R)

b) Water from other systems (Q_C)

c) Intercepted subsurface water (Q_S)

The value of surface runoff "Q_R" is determined using the methods detailed previously in Section 3.5

The value of intercepted subsurface water "Q_S" is difficult to determine, if a drainage system is required to remove intercepted subsurface water a detailed hydrological/geotechnical investigation is usually required.

The volume of water conducted from other systems, "Q_C", is estimated from the outlet capacity of the system to which the new system is being connected. The value of Q_C is estimated using the Manning equation (see Equation 3).

Using Equation 3 provided the drain area and slope are known or can be measured, the maximum value of "Q_C" can be determined.

"Q_C" may also be estimated using Table 6 in which if the pipe diameter, type and slope (or grade) are known the maximum flow can either be read directly from the table or approximated.

Once Q_R, Q_C and Q_S are known these may be substituted into Equation 1 to determine the maximum peak flow "Q". Once this has been completed the drain size required may be determined.

Pipe Dia.	Pipe Material	Drain Slope	Max Flow (L/Sec.)	Pipe Dia.	Pipe Material	Drain Slope	Max Flow (L/Sec.)
100	F.C.	1 in 100	6.7	300	Concrete	1 in 100	114.1
		200	4.7			200	80.7
		300	3.8			300	65.9
	Steel	1 in 100	5.5		P.V.C	1 in 100	138.5
		200	3.9			200	97.9
		300	3.2			300	79.5
	Concrete	1 in 100	6.0	375	F.C.	1 in 100	227.7
		200	4.3			200	161.0
		300	3.5			300	131.4
150	F.C.	1 in 100	19.7		Steel	1 in 100	175.1
		200	13.9			200	123.8
		300	11.4			300	101.1
	Steel	1 in 100	16.4		Concrete	1 in 100	207.0
		200	11.6			200	146.6
		300	9.5			300	119.5
	Concrete	1 in 100	17.9	450	F.C.	1 in 100	370.3
		200	12.7			200	261.8
		300	10.3			300	213.8
160	P.V.C.	1 in 100	26.1		Steel	1 in 100	264.5
		200	18.4			200	187.0
		300	15.0			300	152.7
200	Steel	1 in 100	35.1		Concrete	1 in 100	336.6
		200	25.0			200	238.0
		300	20.4			300	194.3
225	F.C.	1 in 100	58.3	525	F.C	1 in 100	558.7
		200	41.2			200	395.0
		300	33.6			300	322.5
	Concrete	1 in 100	53. 0		Concrete	1 in 100	507.9
		200	37.4			200	359.1
		300	30.6			300	293.2
250	P.V.C.	1 in 100	85.8	600	F.C.	1 in 100	797.7
		200	60.6			200	564.0
		300	49.5			300	460.5
300	F.C.	1 in 100	125.6		Steel	1 in 100	498.5
		200	88.8			200	352.5
		300	72.5			300	287.8
	Steel	1 in 100	104.6		Concrete	1 in 100	725.1
		200	74.0			200	512.7
		300	60.4			300	418.6

Table 6 Capacities for various pipe types and sizes. L

Notes to Table 6

1) FC = fibre cement pipe

2) Steel = corrugated steel pipe

3) Concrete = concrete or vitrified clay pipe.

4) To convert m^3/s to l/s multiply by 1000 (ie 1000 litres = 1 cubic metre)

5) The values of Mannings' roughness co-efficient used in the calculations for the values given in table 6 are as follows:

Concrete		n = 0.011
Fibre Cement		n = 0.010
P.V.C.		n = 0.009
Steel 100 -	300 dia	n = 0.012
	375 dia	n = 0.013
	450 dia	n = 0.014
	600 dia	n= 0.015

a) Pipe Drains (Slotted and unslotted)

Firstly, the pipe is sized according to the flow requirement, therefore the flow "Q", roughness "n" and slope "S" are required.

When selecting the size of the pipe required the drainage system must satisfy certain requirements, these are:

(i) Minimum pipe slope 1 in 300, though a slope of 1 in 100 is preferable for self cleaning purposes. (ie. the steeper the slope the lesser the maintenance requirements).

(ii) The minimum pipe diameter is 200mm (for maintenance purposes).

The pipe may be sized by comparing the value of peak flow "Q" calculated previously with those shown in Table 6. Select the appropriate slope and pipe material and then read the pipe diameter required to satisfy. A check should be made to ensure that the pipe selected satisfies all the above requirements.

Note: Whenever selecting a pipe size the capacity of the pipe should be equal to or greater than the required capacity.

For example: from the preliminary investigation it is established that the maximum possible slope is 1 in 200.

The peak flow to be carried by the pipeline is Q = 0.014 m^3/s or 14 l/s.

From Table 6

Q_{max} for a 150 mm diameter fibre cement pipe is Q_{max} = 13.9 l/s. This is unsatisfactory for two reasons, firstly, the value of Q_{max} is less than the required capacity, and second, the pipe diameter is less than 200 mm.

Therefore select either a 200 mm corrugated steel pipe, Q_{max} = 15.0 l/s, or, a 250 mm fibre cement pipe, Q_{max} = 41.2 l/s both of which are suitable. The choice of pipe then becomes one of cost.

b) Aggregate drains

Aggregate drains are only suitable for use where small flow or seepage are expected. If a larger flow is expected a slotted pipe should be added to the system and the drain is then sized as described in Section (a). A typical example of an aggregate drain is a blanket drain, another type of aggregate drain is a French drain.

The capacity of an aggregate drain may be determined using Darcy's equation. (Equation 6).

$Q = k \times i \times A$ ………………………………………….……………….(6)

Where:

Q = flow (m^3/s)

k = permeability of the aggregate

i = hydraulic gradient or slope.

A = cross sectional area (m^2)

The permeability of clean gravel can range from 0.01 to 1.0 m/s. The aggregates used in aggregate drains are either 20 mm nominal diameter or 53 mm diameter (ballast), the permeability of these aggregates is:

20 mm aggregate k = 0.15 m/s

53 mm aggregate k = 0.40 m/s

Equation 9 may be simplified if K = k i, and Equation 6 becomes:

$Q = K \times A$ ……………………………………………………………….(7)

Table 7 below gives values for "K" for use in Equation 7 in order to determine the capacity of aggregate drains.

Slope	K = k i (m/s)	
	20 mm	53 mm
1 in 100	0.00150	0.0040
1 in 200	0.00075	0.0020
1 in 300	0.00050	0.0013
1 in 400	0.00038	0.0010
1 in 500	0.00030	0.0008

Table 7 Values of K = k.i for various slopes.

For example: If Q = 0.01 m^3/s or 10 l/s an aggregate drain using 20 mm aggregate at a slope of 1 in 200, what size drain is required?

Q=K A this may be rearranged to: A = Q/K

Therefore:

A = 0.01 / 0.00075

A = 13.3 m^2

For the same flow using 53 mm aggregate at a slope of 1 in 200, the area required is:

A = 0.01 / 0.002 A = 5.0 m^2

Flow charts for the design of both open (surface) and subsurface drains are given in Appendix 3.

3.7 Selection of Subsurface Drainage Components

Once the layout and required capacity of the drain has been established, it is necessary to detail the various items the will make up the system. This enables the correct components to be ordered quickly in the construction phase.

Subsurface type drains generally consist of a combination of any one of the following:

a) Pipes

b) Geotextile (or geofabric)

c) Aggregate filter

d) Sumps, grates, and sump covers or cages.

e) Inlets and outlets

3.7.1 Pipes

Types: Both slotted and unslotted pipes may be used depending on the system type and its means of collecting and carrying water. Slotted pipes are the preferred type because these do not rely on surface flow between sumps to collect water.

Materials: Concrete, both slotted and unslotted. Steel, slotted, perforated and unslotted. Fibre cement, slotted and unslotted. U.P.V.C. rigid, slotted and unslotted.

Sizes: Minimum diameter 200 mm Classes: Z class or class 50

Slopes: Minimum grade 1 in 300. Preferable grade 1 in 100 because drains at this slope or grade tend to be self cleaning.

When selecting a pipe the type of environment must also be considered (i.e. is the water abrasive, acidic or alkaline). The manufactures specifications should be consulted regarding the pipes suitability to various environments.

3.7.2 Geotextiles (Geofabric)

The main purpose of a geotextile used in subsurface drainage is to act as a filter, which helps prevent silting-up of the drain it is protecting.

Selection of an appropriate geotextile should be made by reference to RIC's Geotechnical Engineer.

For subsoil drains the geotextile chosen must exhibit the following characteristics:

- good permeability through the fabric material
- good filtering qualities
- resistance to clogging by particle fines
- ability to stretch and conform to the shape of an open trench

3.7.3 Aggregate Filters

The aggregates generally used range from 20 mm nominal diameter to 53 mm diameter (ballast), though larger aggregate (100 - 150 mm) is used for large aggregate drains.

If in doubt as to the type of aggregate or the size of the aggregate to use refer to ARTC's Geotechnical Engineer for advice.

3.7.4 Sumps. Sump Cages and Covers

Sumps or inspection pits are required as access points for surface water as well as for maintenance of the drainage system. Sumps should be spaced at the following intervals:

a) 15-20 m centres where drainage is extremely poor.

b) 30-50 m centres where drainage is good.

c) 20-30 m centres through platforms.

T-pieces may also be used at a closer interval (For example every 4 pipe lengths) as access points for cleaning purposes.

The grates used to cover the sump are cast iron.

Sump covers or cages are also to be used to keep ballast out of the sump. These are generally made of grid mesh.

3.7.5 Inlets and outlets

There are various types of inlets and outlets in use.

Some typical examples of inlets and outlets are: rip-rap, grouted rip-rap, sand bags, wire baskets (ie. gabions & reno matresses), revetment mattresses, precast concrete units and cast in place concrete.

The main purpose of inlet and outlet protectors is to reduce erosion. Where outlet velocities are expected to be high, some form of energy dissipator should be installed. Also, where the sediment load of the water being discharged from a drainage system is high, a silt trap should be installed. (See Figure 1 below).

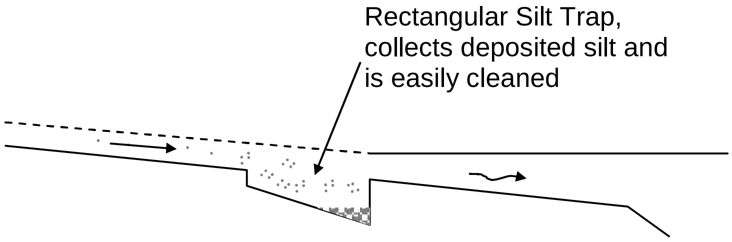


Figure 1 - Typical silt trap installed in drains with high sediment loads

See Section 4.8 for figures showing the various types of inlets and outlets.

Once all the components for the drainage system have been selected (i.e. design phase complete) the system and design should be approved by the Design Authority.

4 Drainage Construction

4.1 Introduction

This section deals briefly with the various forms of drainage construction.

One important consideration is that each and every site must be assessed on its own merits. No two sites are ever exactly the same. This must be taken into account when selecting the site protection, equipment, and personnel required for each particular site.

This section discusses the various steps involved in the construction of both surface and subsurface drainage systems.

4.2 Line and Grade

The line and grade of the drainage system, be it surface or subsurface, may be set out by one or a combination of the following methods:

a) Stakes, spikes, shiners (small reflective metal discs), marks or crosses set at the surface on an offset from the desired centre line.

b) Stakes set in the trench bottom on the pipe line as the rough grade for the pipe is completed.

c) Elevations given for the finished trench grade and pipe invert while laying the pipe or excavating the trench is in progress.

Of these three methods, method (a) is the most commonly used for track drainage.

Method (a) involves stakes, spikes, shiners, or crosses being set on the opposite side of the trench from where the excavated material is to be cast at a uniform offset, insofar as practicable, from the drain's centreline. A table known as a cut sheet is prepared. This is a tabulation of the reference points giving the offset and vertical distance from the reference point to either the trench bottom, the pipe invert or both. When laying the pipe it may be more practical to give two vertical distances, one to the trench bottom (excavation depth) and one to the top of the pipe, which is generally easier to measure to than the pipe invert. The grade and line may be transferred to the bottom of the trench by using batter boards, tape and level, or patented bar tape and plumb bob unit.

This method may be adapted to suit. For example it is common practice to have the proposed route surveyed with the reference points marked on the datum rail (either the Down rail or the low rail on a curve). The offset and vertical height may be easily transferred from the rail by use of a straight edge, spirit level and tape. (See Figure 2 below).

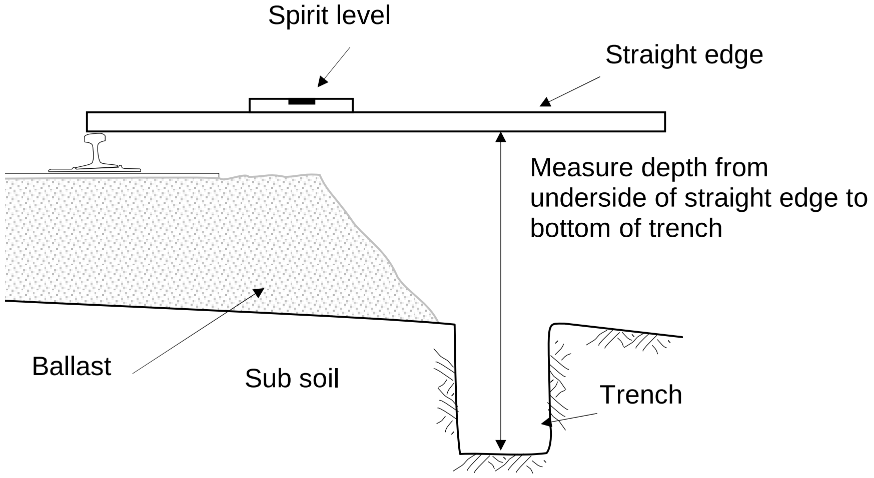


Figure 2 - Method of measuring the depth of a trench and offset to pipe centreline.

If the track is on a constant grade that is suitable for the pipe line and trench, this grade may be adopted. This gives a constant vertical depth from the datum rail to the trench bottom and pipe line, making construction and grade control much easier.

Another method of controlling the line and grade is the use of lasers. A laser beam is passed through the centre of the pipe line at the desired grade. It strikes opaque targets attached to the end of the pipe, and the pipe may then be either lifted and packed or lowered until the laser passes through the centre of the target.

4.3 Site Preparation

The amount of preparation varies from site to site. Operations which should be classified as site preparation are:

- clearing;
- removal of unsuitable soils;
- preparation of access roads;
- detours and by-passes;

- improvements to and modification of existing drainage;
- location, and protection or relocation of existing utilities.

The success of the construction phase depends to a great degree on the thoroughness of the planning and the execution of the site preparation work.

4.4 Excavation

With favourable ground conditions, excavation can be accomplished in one simple operation. Under more adverse conditions it may require several steps, such as; clearing, rock breaking, ripping or blasting and excavation. When excavating for a pipeline the trench at and below the top of the pipe should be only as wide as necessary for the proper installation and backfilling of the pipeline.

The amount of excavation and the types of equipment required may vary, so each site must be assessed on its merits to determine the type and quantity of equipment necessary.

Particular conditions that should be taken into account when selecting equipment are:

a) Site access

b) Size and amount of excavation necessary

c) Site conditions i.e. firm or boggy ground conditions

d) Location and availability of plant

e) Whether the plant item required has to be floated to the site. (If so the offloading conditions and a suitable area should be checked).

f) Services in the area.

Typical items of plant (equipment) utilised are:

a) Gradall (normal or highrail)

b) Backhoe

c) Tiltable dozers

d) Graders

e) Front end loaders

f) Tracked excavators

g) Hydraulic excavators

h) Bogie tippers and 4wd dumpers, etc.

4.5 Surface Drain Construction

4.5.1 Requirements

The main purpose of surface drains is to remove surface water from near the tracks and disperse it as quickly as possible. To do this, the drainage trench or ditch should be constructed at a uniform, even grade with no low sections where water may pond and seep into track formation, thus defeating the purpose of the drainage system.

The grade of the drainage trench should be a minimum of 1 in 200 where practicable. Flatter grades may be used but require more regular inspection and maintenance, since they tend to become blocked with sediment more quickly than drains with steeper grades.

Where the velocity of the water is greater than that shown in Table 2 some form of scour protection is required e.g. lining the channel. Where doubts exist as to the erodability of a soil RIC's Geotechnical Engineer should be consulted. Where any surfaces are cleared of vegetation these must revegetated at the end of construction, to prevent unnecessary build-up of silt in nearby drains.

4.5.2 Construction Steps

a) Survey the proposed drainage route. This may be carried out during the preliminary investigation.

b) Establish and mark out reference points for use during construction. Marking out may consist of paint marks on the datum rail or star pickets. The interval used for the reference marks depends on the length of the drainage system. For example, for a short drain the interval may be 5.0 metres.

c) Clear the site. This should be part of any site preparation work carried out. This may involve relocation of signal troughing, clearing vegetation, etc.

d) Excavate to required level. When excavating the trench, use a bucket width equal to the width of the trench base, then add a batter to the sides of the trench formed. Monitor excavation with the method described in Section 4.2. Once the trench has been constructed, level and compact the trench base making sure that no low points exist.

e) Check for risk of erosion. If this is expected to be high the drain may require lining.

f) Clean up the site and revegetate any denuded slopes.

Note: It is good practice to work from the lowest to the highest point. That way if work is interrupted for any reason at least part of the drainage system will function correctly in the event of any rainfall occurring before completion.

4.6 Subsurface Drain Construction

The following sections detail construction methods for the following subsurface drains:

a) Longitudinal drains

b) Lateral drains

c) Blanket drains

d) Horizontal and vertical drains

e) Pipe drain using unslotted pipes

f) Sump installation

4.6.1 Longitudinal Drain Construction

This is the most commonly used form of subsurface drain used for track drainage. The basic construction steps are as follows:

a) Survey the site.

b) Establish the reference points. These may be paint marks on the rails or star pickets. The purpose of these marks is to provide points from which the depth of the trench and pipe invert level may be measured accurately. (See Section 4.2).

c) Excavate to the desired level. The type of equipment used to excavate the trench differs from location to location, depending on such parameters as access, material, volume to be excavated and clearances for the safe operation of equipment.

The depth of the excavation depends on the pipe location, outlet and inlet requirements. RIC standard G.5001 requires that pipes crossing under the track should be 1200 mm below rail level for main lines and 900 mm below rail level for sidings. Pipes running parallel to the track should be 900 - 1000 mm below rail level. Elsewhere pipes should have a minimum cover of 300 mm. The width of trenches should only be as wide as necessary to ensure proper installation and compaction. See Figure 3 below.

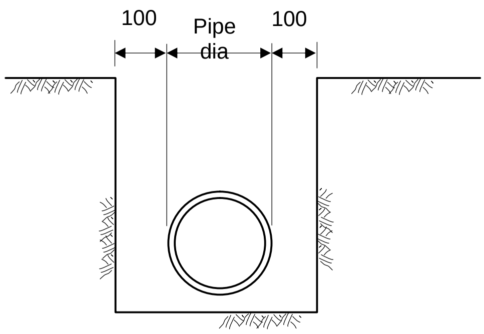


Figure 3 - Trench width

d) Installing drainage system. The method of installing this type of subsoil drain depends on the type of subsoil and other conditions encountered.

   (i) Impervious soil (that is most clays are relatively impervious).

      (a) Lay the geofabric in the bottom of the trench. Where joints need to be made in the geofabric a minimum overlap of 1 metre should be made.

(b) Place a layer of aggregate in the bottom of the trench approximately 50mm thick. The aggregate used for this should be 20mn nominal diameter aggregate.

(c) Lay the pipe sections, one section at a time on top of the aggregate.

(d) Check and adjust the pipe level and grade if necessary by packing aggregate under the pipe.

(e) Place aggregate around and over the pipe, tamping the aggregate on the sides of the pipe as the trench is filled. Once the pipe is covered, complete the filling of the trench compacting the aggregate in layers no greater than 150 mm, use a vibrating plate compactor or similar.

(f) Fold geofabric over the top of the trench, ensuring that the ends are overlapped.

(g) cover the drain or complete associated works.

(ii) Pervious soil (For example sandy soils).

When laying a drain in pervious soil it is necessary to place an impervious layer in the base of the trench. Typical impervious layers are concrete, cement or lime stabilised fill or clayey fill. Once an impervious layer is installed, sloping towards the centre of the trench, the remaining construction steps are the same as steps "a" to "g" for drains in impervious soils above.

(iii) Limited length due to outlet restrictions.

In some locations a subsoil drain cannot be located deep enough so that it is not disturbed by track maintenance machines. In this case the pipe may be wrapped in geofabric, then placed in the trench on a bed of aggregate to allow any adjustments to the level and grade of the pipe to be made, the trench may then be filled with a suitable previous fill and compacted in layers.

(iv) Ash Pockets

Where isolated pockets of ash are encountered an impervious membrane may be placed in the trench before the fabric is laid. This membrane should cover the ash pocket and extend approximately 2 metres either side of it. The rest of the drain is constructed as set out in (i) above. This method is used only where the soil on either side of the ash pocket is impervious, otherwise the drain is constructed as per (ii) above. If an impervious membrane is not available the section of the drain above the ash pocket may be constructed as for a drain in a pervious soil. See Figure 4 for the treatment of ash pockets.

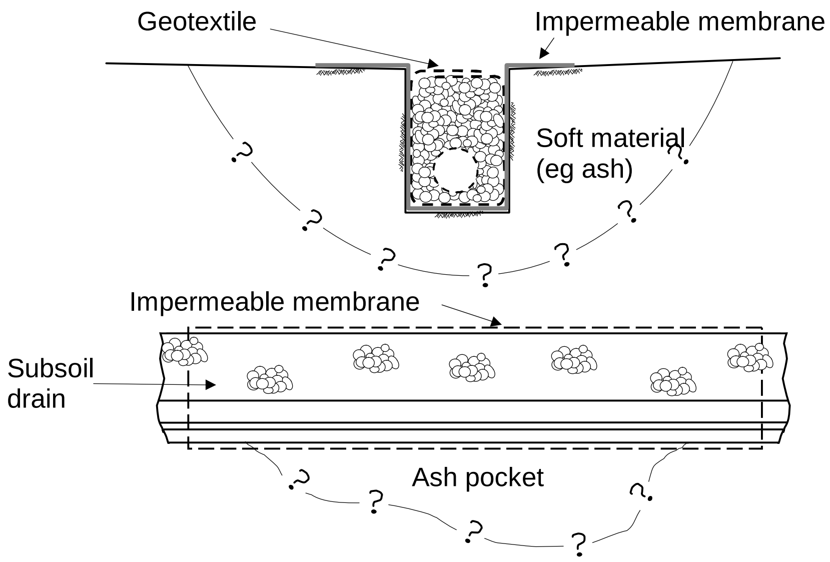


Figure 4 - Construction of a drain over an ash pocket

4.6.2 Lateral Subsurface Drain Construction

This type of drain is commonly used to drain under turnouts and isolated water pockets in embankments. For turnouts the construction of lateral drains is the same as that for longitudinal drains, the main difference is the depth of the pipe below rail level which is a minimum of 1200 mm.

For embankment drainage, a lateral trench is excavated to the desired level, using a backhoe or similar. Once the trench is excavated to the desired level, the base is graded to fall away from the embankment centre. The construction methods are the same as for longitudinal drains. Once the subsoil drain has been installed the remainder of the trench is filled with a suitable fill to the desired level and compacted in layers.

4.6.3 Blanket Drain Construction

This type of drain is most commonly found at the base of embankments. Blanket drains are usually constructed during embankment construction, embankment widening or repairs to a slip. The construction steps are as follows:

a) Excavate. For embankment widening or slip repair, steps should be cut into the existing embankment. (See ARTC standard RCP 01)

b) Level and compact the base with a fall away from the embankment centre.

c) Lay out the geofabric. Any joints should have a minimum 1 metre overlap.

d) Place aggregate, usually 20 - 53 mm aggregate up to 300mm thick. (This should be laid and compacted in layers).

e) Fold sides of geofabric up over the top of the aggregate, then cover with a layer of geofabric over the top of the aggregate.

f) Place riprap (100 - 150 mm stone) over the exposed face of the drainage blanket as protection.

g) Build up the embankment to the desired level and compact in layers.

4.6.4 Other Types

Included in this section is the construction of horizontal and vertical drains. These drains are not often used for track drainage and consequently will not be dealt with at this stage, with the exception of the following.

The most commonly used vertical drain is used to drain water from behind retaining walls and bridge abutments. This drain consists of a geotextile layer placed at the back of the wall and connected to a pipe at the base of the wall.

Water reaching the geotextile can flow along the plain of the fabric, that is down the back of the wall, and is then removed by the pipe at the base. This may also be combined with horizontal layers of geotextile to collect water seeping through the embankment or backfill behind the wall, which is conducted towards the vertical drain and then to the carrier pipe and removed.

This type of drain may be placed during construction and backfilling, or an area behind the wall can be excavated for their installation.

4.6.5 Construction of an Unslotted Pipe Drain

These are constructed in a similar manner to longitudinal subsurface drains.

a) The trench is excavated to the desired depth.

b) A layer of sand or fine aggregate 50 mm deep is placed in the bottom of the trench at approximately the correct slope.

c) The pipe is then placed on top of the sand or aggregate and packed until the correct level and slope is obtained.

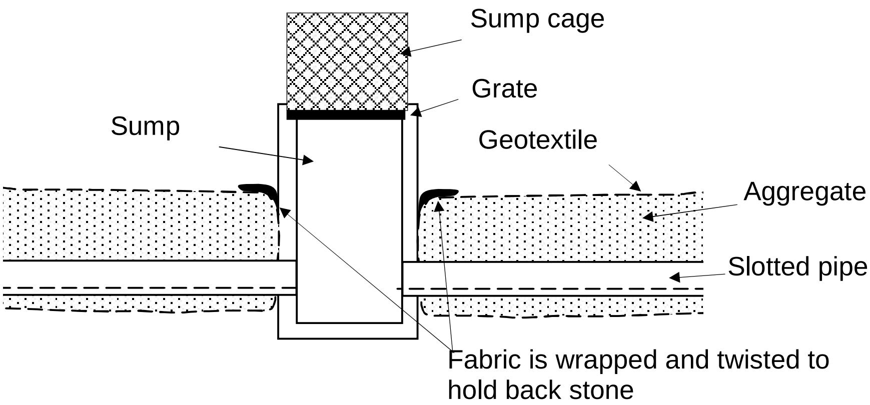
d) Remembering to tamp the fill at the sides of the pipe, the trench is filled in layers and compacted. (Note: Trench width = pipe diameter + 200 ; See Figure 3).

4.6.6 Sump Installation

Sumps are placed at intervals ranging from 10 - 50 meters depending on the system’s drainage ability or at changes in the pipe direction.

At the location at which a sump is to be placed the trench is widened and deepened to accommodate for the sump. The base of the trench is then levelled and covered with a layer of compacted sand or road base which is a minimum 150 mm deep. This layer may be added to so that the sump is positioned at the correct height.

Prior to placing the sump the wafer of concrete covering the inlet and outlet is knocked out to approximately the desired size. Drains using slotted pipes and geotextiles are connected to sumps as shown in Figure 4 below. Once the pipe is in place any remaining gaps between the pipe and the sump are grouted. The trench is then filled and compacted.



Fiqure 4 - Method of joining longitudinal subsoil drain to sumps

4.7 Other Types of Construction

Other construction methods that may be used are:

- Pipe jacking
- Tunnelling
- Augering
- Cast in place

These are seldom used for track drainage, and therefore will not be dealt with.

4.8 Inlets and Outlets

Some typical examples of inlet and outlet protection used are:

a) Precast concrete units

b) Grouted sand bags (Figure 5)

c) Concrete (Figure 6)

d) Reno mattresses and gabions (Figure 7)

e) Revetment mattress (Figure 8)

f) Spalls grouted or hand packed (Figure 9)

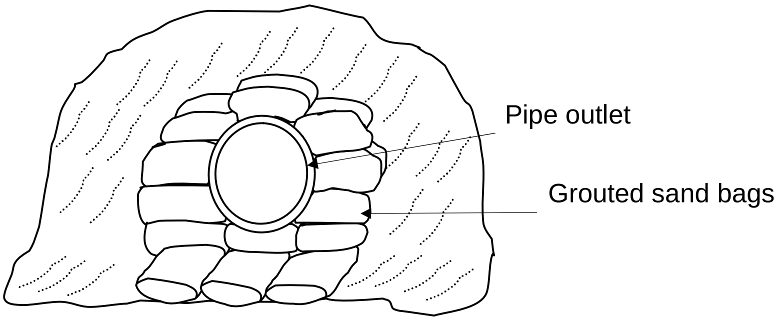


Figure 5 -Grouted Sand Walls

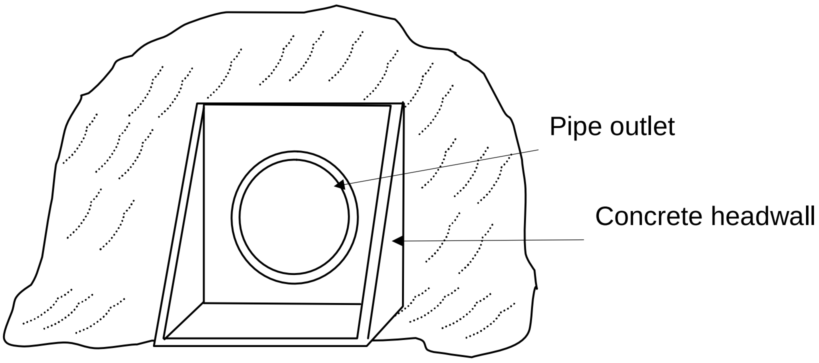


Figure 6 - Concrete Headwall

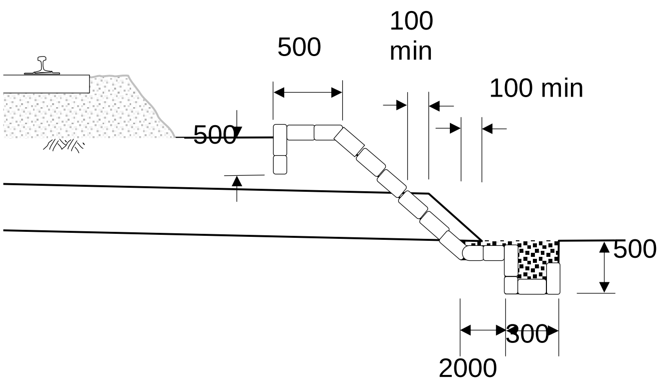
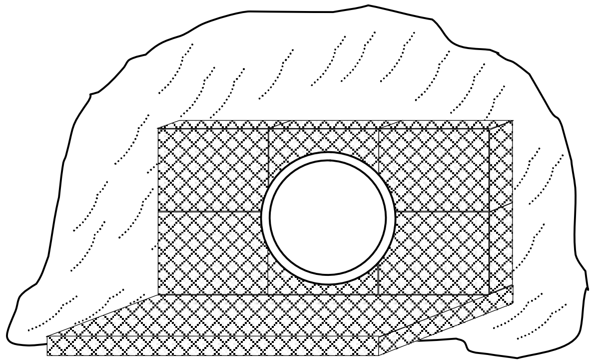
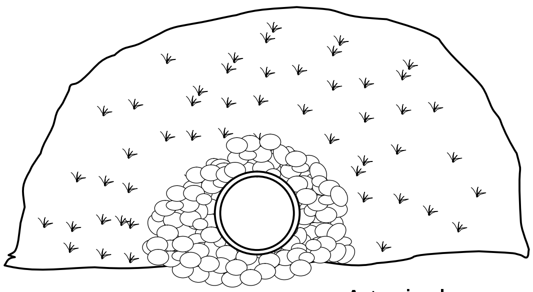


Figure 7 - Gabion Headwall



Wire basket headwall and mattress apron, Used mainly for larger pipe outlets

Figure 8 - Revetment Mattress



A typical arrangement of hand packed walls. Cutoff wall should be provided at the bottom of the headwall to prevent the wall being scoured out and washed away, particularly on the down stream side.

Figure 9 - Spalls used as a Headwall

NOTE: As mentioned in Figure 9, on the down stream side of outlet, water getting under the headwall structure and causing scouring and the eventual washaway of the headwall is a problem that must not be overlooked. The best way to help prevent this occurring is to provide a cutoff wall at the end of the headwall. (see Figure 8 for an example).

Appendix 1

Date:___/___/____

Form 1 - Preliminary Investigation

Site Investigation Form. (To be filled out during site investigation).

1	Location. (ie Track District and kilometrage).
2	Track structure to be drained.
3	Condition of existing drainage system (if any)
4	Length of drainage system.
5	Any inlet or outlet restraints
6	Estimate catchment area

7	Site access
8	Determine the site safety requirements
9	Photographs of site
10	Other comments
11	Conduct Services Search

Appendix 2

Form 2 - Calculation of Capacity Required

a) Location

____

____

____

____

b) General

Average Recurrence Interval (ARI)	ARI =		years
Mainstream Length (L).	L =		km
Catchment Area (A).	A =		km^2 or ha
Mainstream Slope (S).	S =		m/km
Regional Zone (Z) Fig 2.17	Z =		
Regional Constant (a') Table 2.3	a'=		

Note: Regional constant (a') is shown as A in AR&R (1977) all figures and tables referenced are from AR&R (1977).

c) Time of concentration (t_c).
(using the information from above and fig 2)

t_c =

(this may also be calculated using eqn 7.2 AR&R (1977)).

d) Intensity (I)

To calculate I use Figures 2.18, 2.19, 2.20, 2.21 and equations 2.3, 2.4, 2.7 and 2.8 in AR&R (1977).

I = mm/hr

e) Runoff coefficient (C).

Weight according to surface type, using Figures 7.2 and7.3 AR&R (1977).

Surface type classification.	Sub.area A x C	equivalent impervious area CA.
	……... X ……...	
	……... X ……...	
	……... X ……...	
	……... X ……...	
	……... X ……...	
	……... X ……...	
		CA. = ……………….....

f). Discharge (Q). "Capacity"

Q = F x I x (CA) Eqn 7.1 AR&R (1977)

Q = ………X ………. X …..……

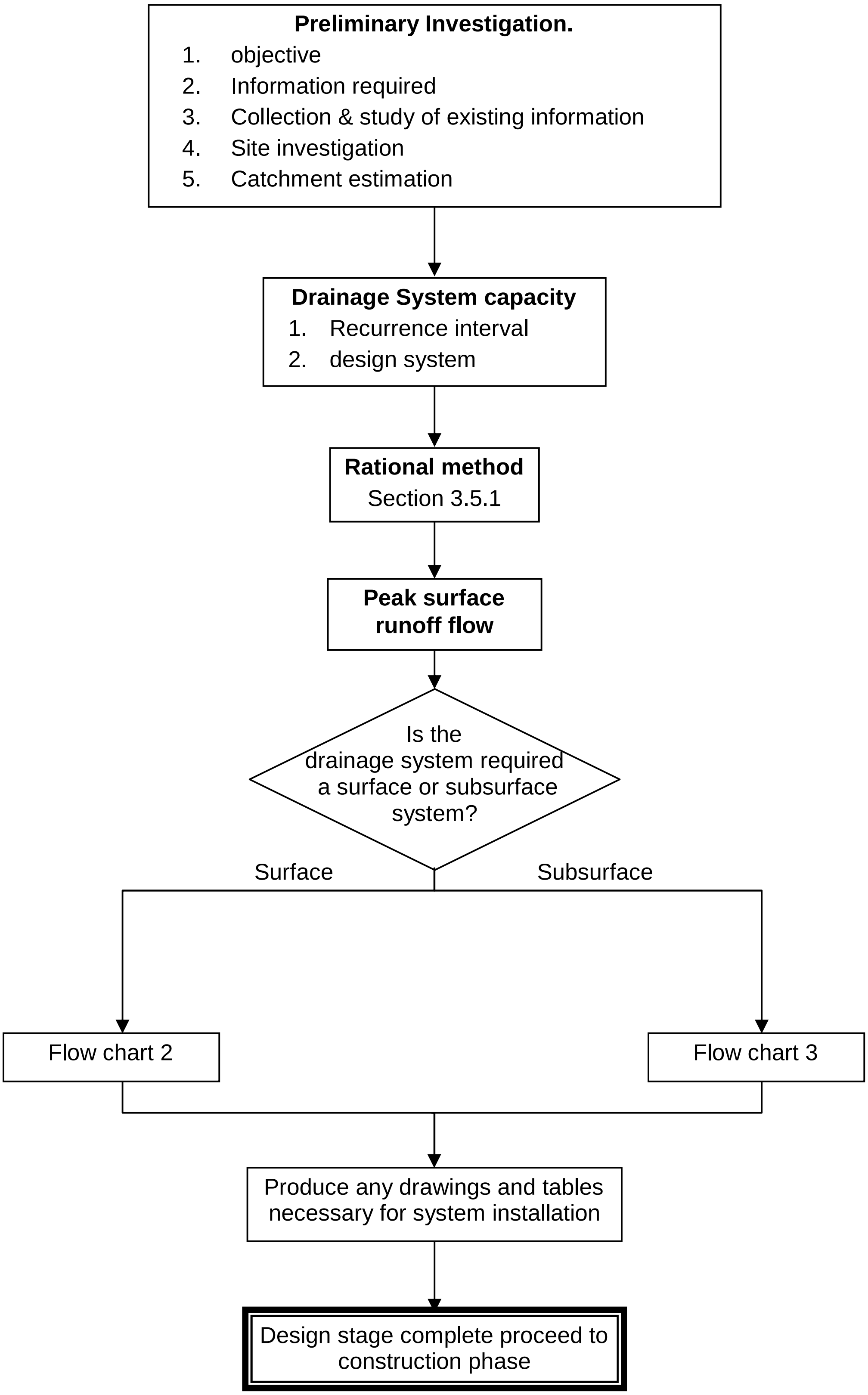
F = 0.278 if A is km^2
0.00278 if A is ha.

Q = …………………. m3/sec

Appendix 3

Flow Chart 1

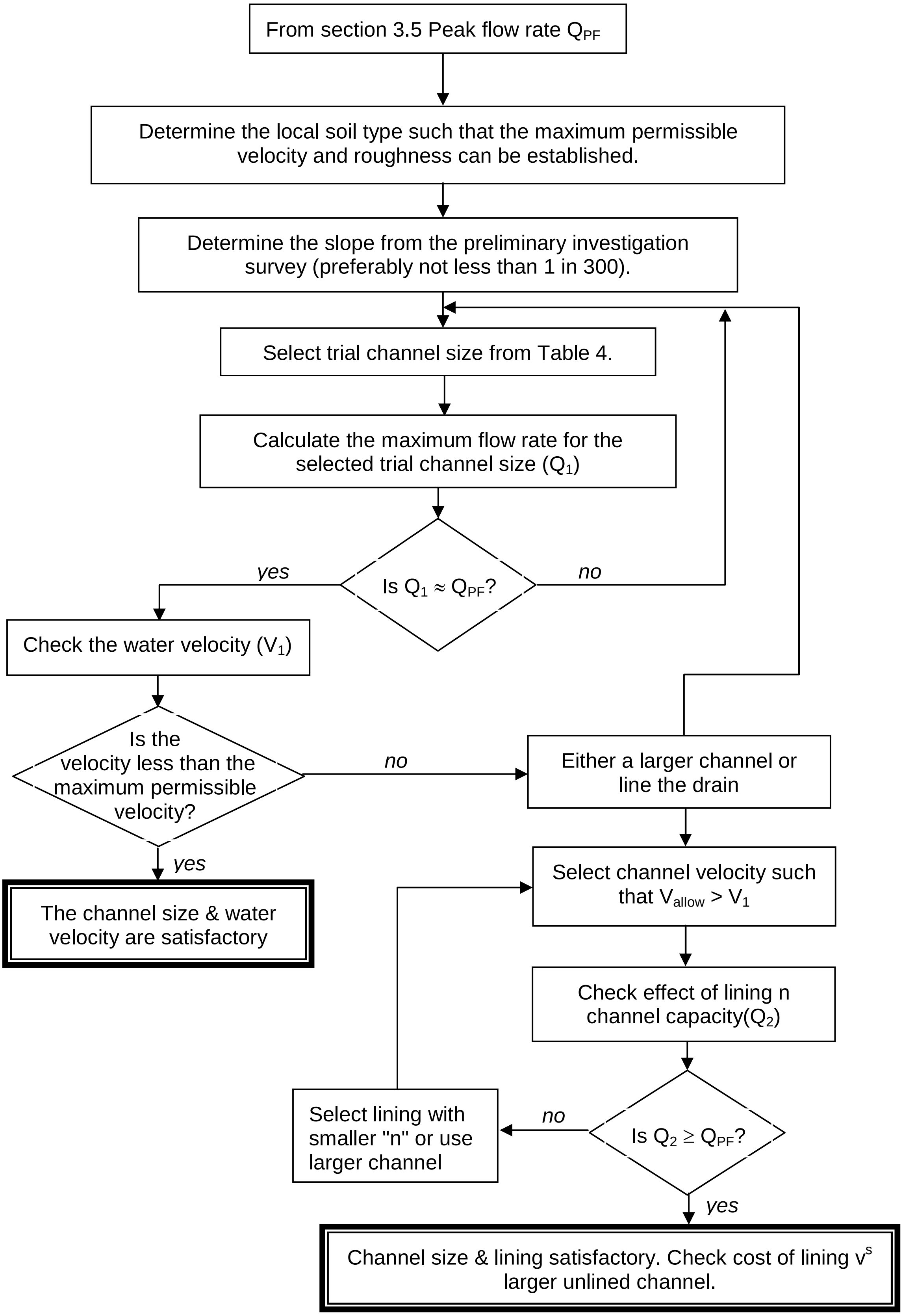
Flow chart of the overall design process



Appendix 3

Flow Chart 2.

Flow chart for surface drainage design.



Appendix 3

Flow Chart 3

Flow chart for subsurface drainage design.