Slope Drains

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short Term	✓
Steep Gradient	✓	Channel Lining		Medium-Long Term	✓
Outlet Control	[1]	Soil Treatment		Permanent	

[1] Slope drains can act as outlet structures for *Catch Drains, Flow Diversion Banks*.

Symbol → SD →

Photo 1 – Flexible, plastic slope drain

Photo 2 – Corrugated, steel pipe slope drain

Key Principles

1. Critical design parameter is the hydraulic capacity of the pipe's inlet, which is governed by the pipe diameter (D) and the relative upstream water level (H).
2. Critical operational factor is the control of leakages and flow bypassing around the pipe entrance. It is essential for adequate flow controls (e.g. *Flow Diversion Banks*) to exist at the pipe's entrance to control water movement and prevent wash-outs.
3. The pipe must not release the water part way down the embankment, but must release the water at a stable outlet (e.g. *Outlet Structure*), at the base of the slope.

Design Information

The material contained within this fact sheet has been supplied for use by persons experienced in hydraulic design.

The hydraulic capacity of a drop pipe is normally controlled by the inlet hydraulics. The inlet capacity is normally limited by either:

- the maximum allowable water level elevation at the entrance to the drop pipe, which is controlled by the height of the associated *Flow Diversion Bank*, and the required freeboard for this bank; or
- flow restrictions at the pipe's entrance (inlet control hydraulics), which may result from either weir flow conditions (H<D), or orifice flow conditions (H>D).

In the latter case, hydraulic capacity can be determined using a standard pipe culvert 'inlet-control' design chart. Inlet control conditions are normally based on the design line (3) for a *socket-end projecting* pipe.

Table 1 provides inlet flow capacities for two standard pipe sizes of 300 and 375mm.

Tables 2 and 3 provide mean rock size, d_{50} (mm) and length, L (m) of rock protection required at the outlet of the slope drain.

Table 1 – Hydraulic capacity (L/s) of slope drains with 300 and 375mm diameter pipe [1]

Pipe dia "D"	Upstream water level 'H' (m) relative to the slope drain invert at its inlet												
	0.20	**0.25**	**0.30**	**0.32**	**0.34**	**0.36**	**0.38**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.70**
300mm	36	49	62	67	72	76	81	85	96	106	115	123	138
375mm	43	63	82	89	96	104	11	118	134	150	166	180	207

[1] Tabulated flow rates assume partial full flow conditions exist within the pipe. If the inlet and outlet are drowned, full-pipe siphon flow conditions may commence within the pipe, in which case the flow rate will be governed by the total fall in water level from inlet to outlet. In such cases, 'gulping' (air entrainment) can occur at the inlet causing highly irregular flow conditions and highly variable upstream water levels.

Details of associated Flow Diversion Bank:

Minimum 500mm high, and 2:1(H:V) side slopes (maximum grade).

Embankment crest at least 300mm above inlet pipe obvert (not to be confused with 'freeboard').

Minimum hydraulic freeboard of 300mm for non-vegetated embankments, otherwise 150mm.

Well-compacted (at least by hand-tamping around the pipe) and in 100mm layers.

Pipe inlet:

Inlet section laid at a minimum 3% slope.

An excavated sediment trap may be constructed at the pipe entrance to reduce sedimentation problems within the pipe.

Pipe geometry:

Bends in the pipe should be avoided down the slope.

Anchor points provided at approximately 3m intervals.

Outlets should (ideally) extend at least 1.5m on a grade no steeper than 1%.

Slope drains must **not** discharge onto a fill slope or unstable ground.

Typical outlet structure (energy dissipater):

Level bed of rock (*Rock Pad*).

Minimum bed thickness of 250mm, but at least 1.5 times the nominal d_{50} rock size.

Refer to Tables 2 and 3 for design information.

In theory, the required rock size and length of rock protection decreases with the increasing length of a low gradient section of pipe at the toe of the embankment (as seen in Photo 2).

Additional design notes:

Debris collection bars or trash racks may need to be considered on the entrance of some slope drains to avoid blockage of the inlet. If required, debris bars typically should be placed at least three pipe diameters away from the pipe entrance, with scour protection placed between the bars and pipe entrance.

Collapsible or 'lay-flat' pipes (Figure 2) should be securely attached to a solid, ribbed pipe embedded within the *Flow Diversion Bank*. The pipe may need to be secured at regular intervals down the slope. At the outlet, the lay-flat pipe may need to be modified to dissipate outflow energy (e.g. a perforated pipe outlet manifold), otherwise the outlet will need to be anchored to a standard *Outlet Structure*.

Table 2 – Mean rock size (mm) and length (m) of rock pad outlet structure for smooth internal sidewall slope drain

Pipe diameter: 300 and 375mm							Smooth internal sidewall: n = 0.01						
Pipe slope (X:1)	Pipe discharge (L/s)												
	30	40	50	60	70	80	100	120	140	160	180	200	220
10	150	150	150	150	150	150	200	200	200	200	200	300	300
8	150	150	150	150	150	150	200	200	200	200	300	300	300
7	150	150	150	150	150	150	200	200	200	300	300	300	300
6	150	150	150	150	150	200	200	200	300	300	300	300	300
5	150	150	150	150	200	200	200	200	300	300	300	300	300
4	150	150	150	200	200	200	200	300	300	300	300	300	300
3	150	150	200	200	200	200	300	300	300	300	300	300	300
2	150	200	200	200	200	300	300	300	300	300	400	400	400
1	200	200	300	300	300	300	300	400	400	400	400	400	400
L [1]	**1.1**	**1.2**	**1.5**	**1.5**	**1.5**	**1.5**	**1.7**	**2.0**	**2.0**	**2.0**	**2.1**	**2.1**	**2.5**

[1] Recommended minimum length (m) of rock pad outlet structure.

Table 3 – Mean rock size (mm) and length (m) of rock pad outlet structure for rough internal sidewall slope drain

Pipe diameter: 300 and 375mm							Rough internal sidewall: n = 0.03						
Pipe slope (X:1)	Pipe discharge (L/s)												
	30	40	50	60	70	80	100	120	140	160	180	200	220
10	150	150	150	150	150	150	150	150	150	150	150	150	150
8	150	150	150	150	150	150	150	150	150	150	150	150	150
7	150	150	150	150	150	150	150	150	150	150	150	150	150
6	150	150	150	150	150	150	150	150	150	150	150	150	150
5	150	150	150	150	150	150	150	150	150	150	150	150	150
4	150	150	150	150	150	150	150	150	150	150	150	150	200
3	150	150	150	150	150	150	150	150	150	150	200	200	200
2	150	150	150	150	150	150	150	150	200	200	200	200	200
1	150	150	150	150	150	150	200	200	200	200	300	300	300
L [1]	**1.6**	**1.8**	**1.9**	**2.1**	**2.2**	**2.3**	**2.5**	**2.6**	**2.8**	**2.9**	**3.1**	**3.2**	**3.3**

[1] Recommended minimum length (m) of rock pad outlet structure.

Technical Note – Development of Tables 2 and 3

Many of the rock sizing charts traditionally presented for the design outlet structures can attribute their origins to the published work of Bohan (1970). This research work was based on low gradient flow conditions where the pipe is flowing full just upstream of the outlet, and during low tailwater conditions, the flow passed through critical depth at or near the outlet of the pipe. Such flow conditions are not consistent with the high-velocity, partial-full flow expected at the base of a slope drain.

The rock sizes and pad lengths presented in Tables 2 and 3 have been determined by firstly determining the partial-full, supercritical flow velocity expected at the base of a slope drain for a given discharge, internal pipe roughness, and slope gradient. Secondly an equivalent pipe diameter was determined that would have a full-pipe discharge and velocity equivalent to that determined above. Using this equivalent pipe diameter and actual discharge velocity, the design charts presented by Bohan for low tailwater conditions were used to determine the required mean rock size and length of rock protection. The rock sizes where then rounded up to the nearest 100mm rock size, with a minimum rock size set as 150mm.

Figure 1 shows the typical layout of solid wall, flexible pipe, slope drains. These pipes are usually available in sizes of 300 and 375mm. Larger diameter, steel wall pipes (Photo 2) can also be used.

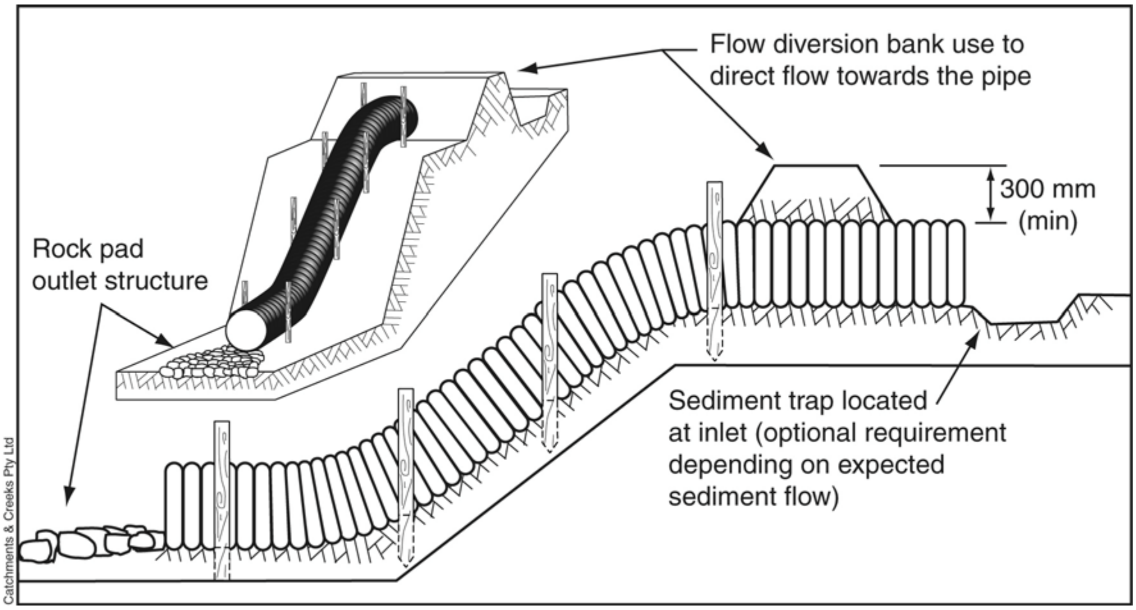

Figure 1 – Slope drain formed from flexible PVC pipe

Figure 2 and Photo 3 show examples of lay-flat pipes, which can also be used as slope drains.

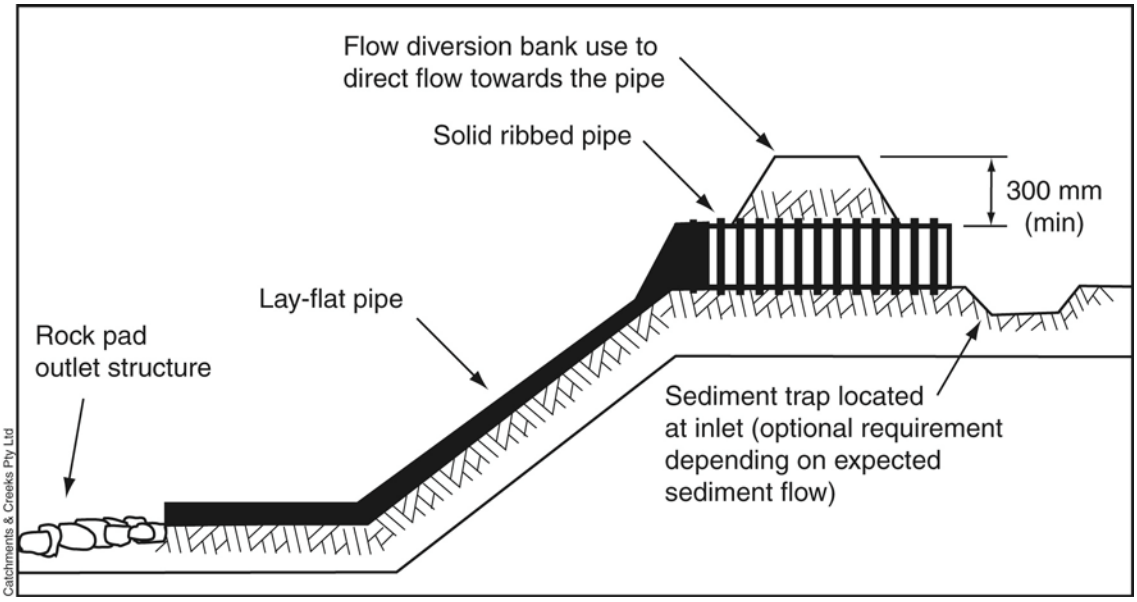

Figure 2 – Slope drain formed from lay-flat pipe

Design example:

Design a slope drain to carry a flow rate of 100L/s down a 1 in 4 slope.

Solution:

Choose a 500mm high earth embankment to collect and direct stormwater runoff towards the drop pipe/s. Choosing a 300mm pipe and allowing 300mm freeboard, the maximum upstream water level (H) relative to the pipe invert would be 500 - 300 = 200mm. From Table 1 the flow capacity for a 300mm pipe with H = 0.2m is 36L/s. Therefore, three pipes will be required to take the required flow rate of 100L/s.

Also, if we assume a rough internal wall PVC pipe, Table 3 indicates a rock pad outlet structure with mean rock of 150mm, a length of 1.8m, and a depth of rock protection of at least 225mm.

Photo 3 – Lay-flat pipe

Photo 4 – Slope drains (right) used as an outlet structure for a sediment trap

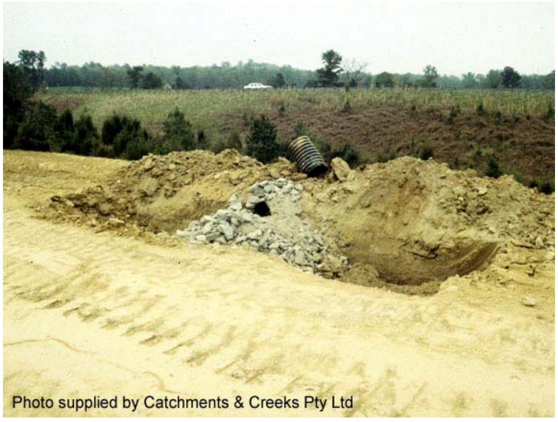

Photo 5 – Inlet sediment trap

Photo 6 – Flow diversion bank

Photo 7 – Pipe directing flow to a sediment basin

Photo 8 – Outlet sediment trap

Photo 9 – Inappropriate flow release

Photo 10 – Inappropriate flow release

Description

Slope drains (also known as *Drop Pipes*) consist of a flexible, prefabricated, solid-wall or lay-flat pipe, anchored to the side of an embankment, with a stabilised inlet and outlet (*Outlet Structure*).

Flow Diversion Banks are normally used to direct water to the slope drain.

Purpose

Typically used to:

- transportation of concentrated flow down embankments usually greater than 3m in height;
- diversion of 'clean' water around a work site;
- movement of stormwater down newly formed earth embankments prior to installation of the permanent drainage system.

Limitations

Up-slope topography must allow collection of surface water at the pipe inlet without causing traffic safety (flooding) problems or flow bypassing.

Usually only economical for low flows. *Chutes* are preferred in high flow situations.

Commercially available flexible pipes are usually limited to around 300 to 375mm diameter.

Advantages

Very effective for the temporary diversion of water through bushland where site disturbance is to be minimised.

Economical for low flows and high, irregular drops.

Can be relocated with relative ease.

The pipes are generally reusable.

Disadvantages

High rise of theft or vandalism when used in some urban areas.

Pipe entrance may be subject to blockage by sediment and debris.

Wash-outs during severe storms.

Only suitable as a temporary structure.

Special Requirements

Slope drains must be adequately size to avoid flow bypassing (wash-outs).

Slope Drains must be securely anchored down the slope to avoid movement.

Trash racks/bars may need to be considered at the entrance of the pipe to avoid debris blockage.

Soil around the inlet must be well compacted and stabilised.

Most outlets require an energy dissipater such as a rock pad.

Location

Located at regular intervals along the road embankment where runoff can successfully collect and enter the pipe.

Site Inspection

Check for adequate freeboard at the inlet.

Check for obstructions or damage at the inlet.

Check for watertightness.

Check for excessive sedimentation at the inlet and outlet.

Check for excessive erosion at the outlet.

Materials (Outlet rock pads)

- Rock: hard, angular, durable, weather resistant and evenly graded with 50% by weight larger than the specified nominal rock size and sufficient small rock to fill the voids between the larger rock. The diameter of the largest rock size should be no larger than 1.5 times the nominal rock size. Specific gravity to be at least 2.5.
- Geotextile fabric: heavy-duty, needle-punched, non-woven filter cloth, minimum bidim A24 or equivalent.

Installation

1. Refer to approved plans for location and installation details. If there are questions or problems with the location, extent, or method of installation contact the engineer or responsible on-site officer for assistance.
2. Place pipes on undisturbed soil or well-compacted fill at locations shown on the approved plan.
3. Excavate suitable bedding for the slope drain inlet. If it is necessary to cut through a flow diversion bank at the top of the slope, then limit the disturbance to the absolute minimum.
4. Slightly grade (minimum 3% slope in the direction of flow) the section of pipe up-slope of the crest of the embankment.
5. Re-establish the flow diversion bank so as to firmly anchor the inlet of the slope drain. Firmly hand-tamp the soil under and around the inlet section of pipe in lifts not to exceed 100mm. If necessary, drive stakes on both sides of the inlet a minimum of 450mm into the ground. Secure the pipe to the stakes with wire or cord.
6. Ensure that the embankment (flow diversion bank) formed over the inlet of the pipe has minimum dimensions of 500mm height, 300mm clearance over pipe obvert, and maximum 2:1(H:V) side slopes.
7. Extend the slope drain down the slope ensuring that it is placed perpendicular to the slope contours.
8. Ensure that all pipe connections are watertight.
9. Ensure that all fill material is well-compacted.
10. Securely fasten the pipe down the slope with anchors spaced no more than 3m apart.
11. Extend the pipe beyond the toe of the slope and adequately protect the outlet of the pipe from erosion. Do not direct the outlet to a fill slope or unstable ground.
12. Construct a stabilised outlet structure, such as a rock pad (as detailed on the plans), to control soil scour.
13. Immediately stabilise all disturbed areas following installation of the slope drain.

Maintenance

1. While construction works continue on the site, inspect all slope drains prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing rainfall, and on a weekly basis.
2. Inspect for:

- soil erosion at the inlet and outlet;
- sediment or debris blockage of the inlet;
- water damage cause by leakage form pipe joints;
- damage or slumping of the associated inlet control flow diversion bank;
- leakage of water through the flow diversion bank along the outer surface of the pipe.

3. Promptly make all necessary repairs.

Removal

1. Slope drains should be removed only when an alternative, stable, drainage path is available.
2. Remove all materials and collected sediment and dispose of in a suitable manner that will not cause an erosion or pollution hazard.
3. Grade the area and smooth it out in preparation for stabilisation.
4. Stabilise the area as specified in the approved plan.