Appendix L

Erosion, Sediment and Stormwater Management Plan

Sediment, Erosion and Stormwater Management Plan

Mt Emerald Wind Farm, Herberton Range, North Queensland

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Name	Signature	Date
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1.0 Introduction

This Sediment, Erosion and Stormwater Management Plan (SWMP) has been prepared for RATCH Australia Corporation Limited (RACL) for construction and operational activities proposed to be carried out on the Mount Emerald Wind Farm (MEWF) site. This SWMP is required in accordance with Condition 13(a)iii of Ministerial Decision Notice on 24 April 2015.

The objectives of this SWMP are to:

- Gain an understanding of the site and the degree of potential for erosion to occur;
- Provide a set of Best Practice Site Management Procedures to minimise soil erosion and transport during the earthworks and construction phase;
- Provide techniques to control sediment so that it does not cause detrimental impacts to water quality;
- Provide a monitoring plan to ensure detrimental impacts to water quality are not occurring; and
- Ensure staff are adequately trained and capable of implementing this plan.

2.0 Site Description

The project area comprises Lot 7 on SP235224, Easements A, C & E in Lots 1, 2 & 3 on SP231871 and part of Lot 905 on CP896501. The project involves the construction and operation of a wind farm located approximately 20 km SSW of Mareeba on the Atherton Tablelands in north Queensland. The project approval allows for the construction of up to 63 wind turbines, associated access tracks and an electricity substation that will feed into the main electricity grid (Powerlink's Chalumbin – Woree 275 kV transmission line).

Lot 7 is a large rural allotment, situated (at its closest point) approximately 3.5 km south-west of Walkamin, off Springmount Road at Arriga on the Atherton Tablelands. The site is characterised by rugged terrain with elevations of between 540m up to 1089m above sea level (ASL). Virtually the entire site is covered by remnant vegetation, as defined under Queensland's *Vegetation Management Act 1999* (VMA).

The main construction and operational processes that could potentially lead to water contamination are:

- Sediment transport off-site due to exposed soils as part of earthworks in construction
- Hydrocarbons from fuels and oil/grease used in machinery.

2.1 Waterways and Catchments

A number of defined watercourses are present across the site; these waterways are seasonal and generally only flow during the wet season. During the dry season minor pools may remain in the Granite Creek tributary at the lower northern part of the site, depending on the duration and intensity of the season. A search of the Department of Environment and Heritage Protection (DEHP) referable wetlands database did not identify any referable wetlands within the project area. The nearest referable wetland is the freshwater Nardello's Lagoon, which is located 2km away.

Figure 1 depicts the sites location in respect to this wetland, along with all major watercourses in and around the site. As shown in **Figure 1**, all runoff from the construction footprint will eventually drain into Granite Creek. Therefore water quality within this creek will be closely monitored pre-construction through to post construction.

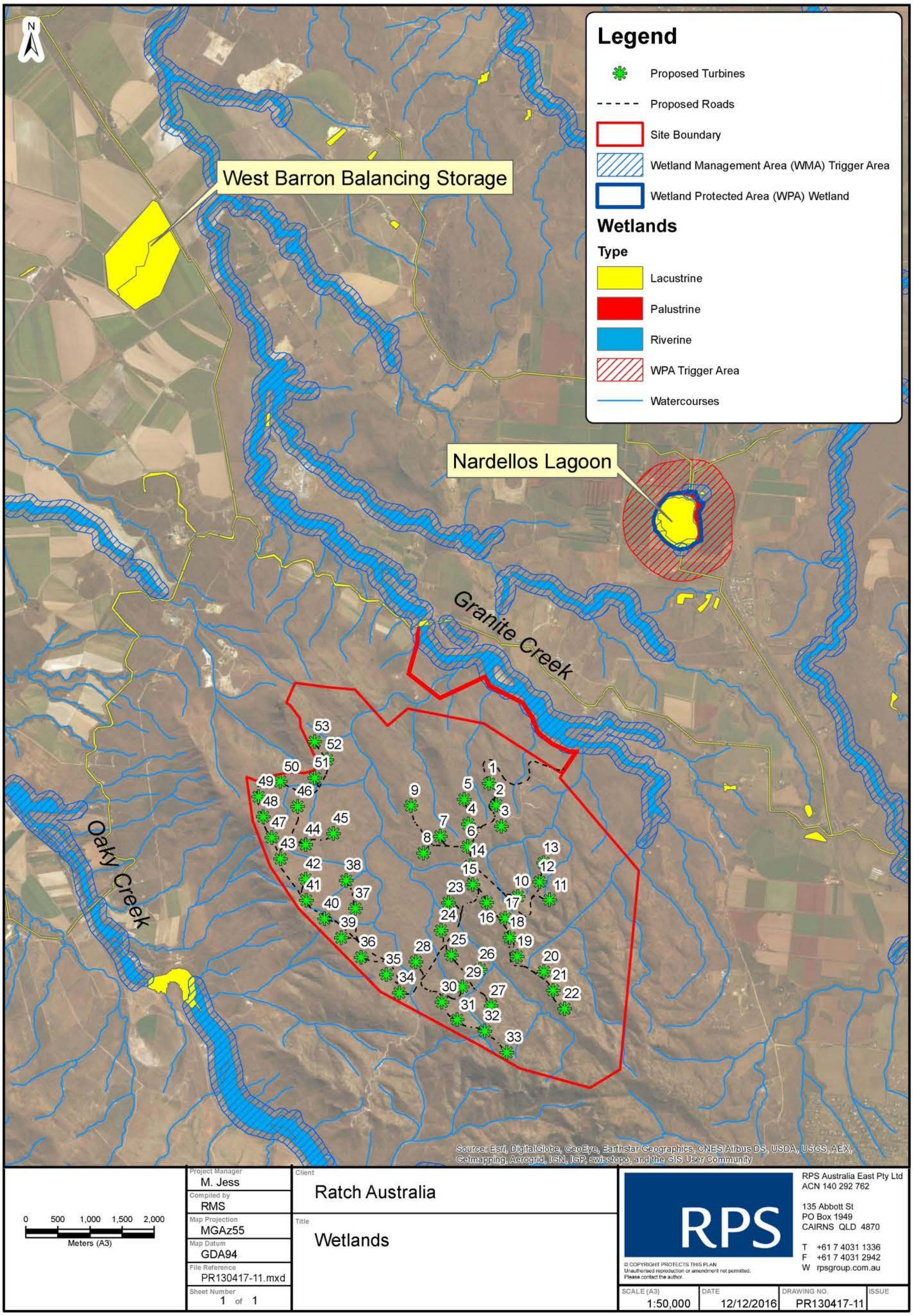


Figure 1 Wetlands and Major Watercourses Located within and nearby to the site.

2.2 Rainfall

The dominant rainfall pattern of the local area is monsoonal, with alternating wet and dry seasons that typically last for four and eight months respectively. The Walkamin Research Station (station number 031108, elevation 594m) has been selected as a suitable reference site, due to its close proximity (situated 6km from the wind farm) and availability of long term climate records. A summary of the weather data from this station is presented in **Table 1**.

Table 1 Summary of Weather Data for Walkamin Research Station (BoM, 1965 - 2016)

Weather Conditions	Measurements
Mean Annual Rainfall	1022.3mm
Highest Annual Rainfall	1750.5mm (1974)
Lowest Annual Rainfall	470.2mm (2002)
Highest Monthly Rainfall	894.1mm (Feb 2000)
Highest Daily Rainfall	284.8mm (28 Feb 2000)
Lowest Monthly Rainfall	0.0mm (May 2001)
Mean Annual Minimum/Maximum Temperature	17.0°C/27.4°C

Bureau of Meteorology (2013).

Average annual rainfall in the area is 1032.4mm with the wettest month being February (248.9mm), and the driest month being September (8.4mm). The majority of rain (80%) falls within the months of December to March. This rainfall distribution over the year is displayed in **Figure 2** (BoM, 1965 – 2016):

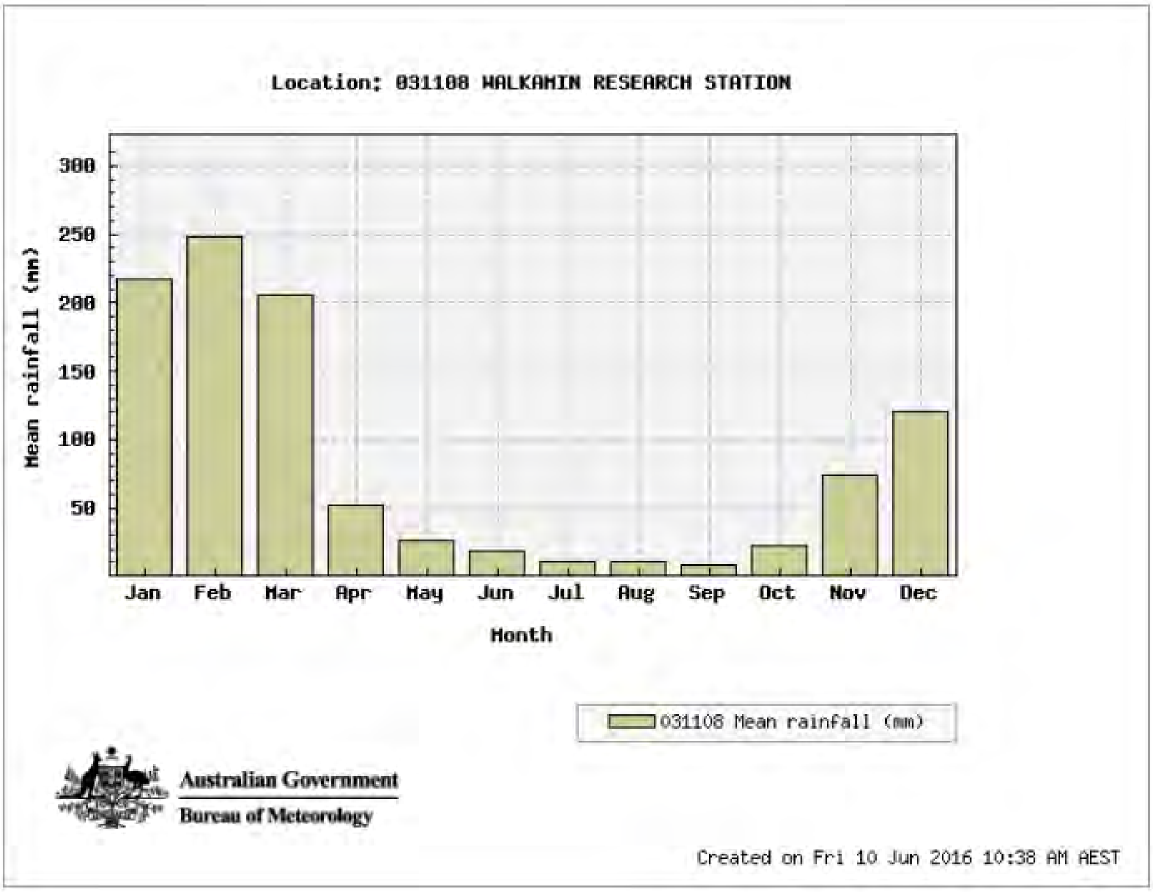


Figure 2 Mean monthly rainfall for Walkamin Research Station (BoM, 1965 – 2016)

The highest aspects of the site are 1089m ASL, which are 550m higher in altitude than the Walkamin Monitoring Station. The change in temperature as a function of elevation is typically between 0.6^{o}C and 1^{o}C (BOM, 2013), but this can vary significantly by factors such as wind speed, moisture and daily temperatures. Some of the highest elevated parts of the site also experience higher precipitation and ground moisture due to cloud stripping, as clouds intersect the landform.

2.3 Geology and Soils

The MEWF project site is situated over mountainous terrain coinciding with the northern extent of the Herberton Range. The site is characterised by acid igneous rhyolite geology forming windswept ridges and rocky outcrops interspersed with rock pavements, which support skeletal soils. Between these prominent features are undulating valleys with sheltered aspects and with deeper, more structured soils.

Thin veneers of soil with low fertility, wind-shearing and exposure to extremes of temperature and solar radiation prevent the growth of tall vegetation on ridges and rock pavements. Soils developed from rhyolite parent rock are naturally low in important plant nutrients such as nitrogen and phosphorus. The primary geological unit described for the entire site is the Walsh Bluff Volcanics. The Walsh Bluff Volcanics (Pb) are included in the Early Permian, Koolmoon Volcanic Group and described as "Buff, greenish-grey or dark grey, welded rhyolitic ignimbrite; minor rhyolite lava, quartzose sandstone, volcanic breccia, tuff." (Donchack & Bultitude, 1998).

Regionally, the Walsh Bluff Volcanics (Pb) unit is not represented elsewhere on the ATHERTON 1:250 000 geological series map sheet (Donchak, *et al*., 1997). The unit's northern limit is the landmark of Walsh Bluff. It extends southwards to incorporate Hoot Hill and Mount Emerald, east to Bones Knob, and includes parts of the ranges west of Atherton, and Rocky Bluff north of the Walsh River.

A shallow soil profile (generally <1m thick) has been recorded at borehole locations. Soils consisted of Sandy Silt (ML) with low plasticity with fine to coarse sand of stiff consistency. Soils were underlain by slightly weathered to fresh rhyolitic ignimbrite with minor moderately and highly weathered zones. Initial assessment of rock strength, later confirmed by laboratory analysis, was of high to very high strength.

Although there is only considered to be a low to moderate erosion risk across the study area, during construction and maintenance there is an increased potential for erosion in steep terrain where soil, particularly finer subsoil is exposed and/or excavated for new access tracks and tower locations. Gully erosion is most likely to occur on hilly and steep terrain, while areas of lower relief are potentially more susceptible to sheet erosion and rill erosion.

Fine sediments displaced as a result of erosion may be carried downstream and potentially adversely affect the water quality of Granite Creek and dependent aquatic ecosystems.

3.0 Stormwater Quality Management Strategy

3.1 Erosion and Sediment Control Techniques

In general, best practice erosion and sedimentation control involves the principles of (in order of preference):

- Avoidance;
- Minimisation; and
- Treatment.

A primary objective for erosion control is avoidance by limiting the amount of exposed soil subject to erosion. This should be achieved through measures such as minimising clearing extents, staging clearing and progressively revegetating areas as soon as practicable. Planning to ensure works requiring the most exposed soil are completed during the dry season months with lower rainfall. However, where avoidance is not possible the following erosion and sediment control mitigation measures should be implemented:

- Install clean water diversions upslope of sloping Wind Turbine Generation (WTG) sites to direct clean stormwater away from work/bare areas. Where possible, runoff from access tracks will also be directed away from WTG sites;
- Direct all uncontaminated (clean) stormwater to stable land, ensuring water is dispersed / diffused to prevent erosion. Examples of Flow Control Berms, Catch Drains, Flow Diversion Banks, Level Spreaders and Energy Dissipators which could be utilised to achieve this are detailed in **Appendix 4**;
- Strip topsoil (~200mm depth) separately and retained for rehabilitation/stabilisation activities. It is important to ensure separate soil horizons are retained in separate stockpiles and not mixed. These stockpiles must be located away from drainage lines and have appropriate controls to ensure sediment is not lost (e.g. sediment fence/geotextile covers);
- Respread/cover tower and permanent pad batters with topsoil and rehabilitate as soon as practicable on completion of pads;
- Stabilise pad surfaces using methods such as topsoiling and revegetation or gravelling, where there is a risk of erosion of the pad;
- Do not carry out clearing activities within 50 metres of a watercourse; where required, improve or develop appropriately designed watercourse crossings that prevent erosion;
- Maintain vegetation cover along hardstands and access tracks where possible. Reduce damage to grass cover and sensitive heath vegetation types by limiting vehicle movements to work areas and approved access tracks;
- Prepare and implement a dewatering plan or work procedure (if required);
- Keep off site sealed public roadways clean and free of sediment. Tracking of soil onto local roads will be prevented by:
    - Limiting off road vehicle movements after rainfall events to those essential for efficient and safe construction activities;
    - Installing in areas with problematic soil types, a rock rumble pad or similar device in accordance with the International Erosion Control Association *Best Practice Guidelines* (2008) near the intersection of the access track and the sealed road. This entry/exit point must have a vibration grid and rock pad as detailed in **Appendix 3**. Having a split entry/exit, whereby the vibration grid and rock pad are on the "exit only" lane, is not advisable, as this creates potential for users to circumnavigate the sediment trap control.

- » Providing brush/wash down equipment to remove loose soil from wheels, wheel arches, tracks, augers and under bodies; and
- » Limiting access during and immediately after wet weather, when access tracks may be severely damaged by vehicle movements and there is a high possibility of the transport of soil materials onto sealed public roads.

- Sediment fences should be constructed/maintained as per the diagrams and instructional text in **Appendix 1**.
- Retain sediment fences and other temporary erosion and sediment controls in place and maintained until the site has been successfully stabilised. On successful stabilisation, the temporary controls will be removed; and
- If wind erosion occurs, water trucks or geotextile silt fences should be installed to minimise soil loss and soil movement away from the construction site.
- All long term stockpiles must have appropriate controls installed (i.e. geotextile silt fence and covers) to ensure they do not erode and cause sediment releases. They also need to be located away from drainage lines.
- All domestic waste skips onsite are required to be covered to avoid the egress of stormwater.
- Bunded areas associated with fuel and generator storage must be bunded in such a way that limits standing water (ponding) of stormwater contacting potentially oily generators/tanks and not allowed to overflow (i.e. covered areas or raised rock/gravel pads with PVC standpipe/valves or similar). Bunded areas are to be keep free of contaminates at all times. Dry cleaning techniques shall be prioritised over wet cleaning techniques at all times.
- All vehicle maintenance should be completed offsite. If onsite maintenance is required it must be completed within a bunded area with an impermeable base (e.g. geotextile lined). Spill kits must be available to ensure spills are not allowed to escape.
- Vehicle refuelling must occur within a bunded area with an impermeable base (e.g. geotextile lined). Spill kits must be available to ensure spills are not allowed to escape.
- Temporary drain crossing(s) should be constructed as per design and details in **Appendix 5**.

Minimise Disturbance, Stage and Revegetate

The area of soil disturbance should be minimized as much as possible. The smaller the area disturbed the less erosion and sediment controls required, including revegetation. Ideally, earthworks should be staged for winter dry season works.

In any area where soils are disturbed and construction activities are completed, revegetation should be undertaken as soon as possible to achieve a ground cover of at least 70%. This is particularly important prior to the start of the wet season (October). This may be completed progressively as works are completed.

Before seeding, soil testing should be completed to ensure the soil does not have nutrient deficiencies or unfavourable conditions (e.g. soil pH too low). This testing should guide the application of soil conditioners and fertilizer in conjunction with drill seeding. Revegetation with plant species of local provenance should be used wherever possible. A revegetation specialist may need to be consulted prior to completing revegetation.

Watering following drill seeding should start immediately after planting and continue at the following rate:

- 25mm every second day for the first three weeks;
- 25mm twice a week for the next 3 weeks; and
- 25mm once weekly for a further two weeks.

If the required amount of water above is received naturally (i.e. rainfall events) then watering can be reduced accordingly.

3.1.1 Monitoring of Sediment Controls

Erosion and sediment controls should be inspected weekly by the Site Manager (or nominated representative), immediately prior to anticipated runoff producing rain or immediately following runoff-producing rainfall. Any issues affecting erosion and sediment control effectiveness will be repaired and amended as appropriate to maintain the water quality objectives.

Weekly site inspections (or following runoff-producing rainfall) must include:

- All drainage, erosion and sediment control measures;
- Occurrences of excessive sediment deposition (whether on-site or off-site);
- All site discharge points;
- Occurrences of excessive erosion, sedimentation, or mud;
- Occurrences of construction materials, litter or sediment placed, deposited, washed or blown from the site, including deposition by vehicular movements;
- Litter and waste receptors;
- Bunded oil, fuel and chemical storage facilities;
- Health of recently established vegetation; and
- Proposed staging of future site clearing, earthworks and site/soil stabilisation.

Site inspections immediately prior to anticipated runoff-producing rainfall must include:

- All drainage, erosion and sediment control measures; and
- All temporary flow diversion and drainage works.

Note that additional water quality monitoring maybe required if the Water Quality Objectives (WQO) in **Table 3** are not being met

3.2 Non-compliance

Non-compliance with agreed performance criteria by visual inspections identifying:

- Build-up of sediment off the site (i.e. roads and watercourses);
- Excessive sediment build-up on the site (i.e. check dams, sediment fences etc.);
- Excessive erosion on the site;
- Release of construction material from the site;
- Poor vegetation establishment;
- Poorly maintained, damaged or failed Erosion and Sediment Control (ESC) devices; or
- Deteriorated water quality identified by the Environmental Consultant as being attributable to the construction activities.

3.3 Corrective Actions

After any identification of incident or failure, the source/cause is to be immediately identified and the following measures implemented:

- Build-up of sediment off the site – the material must be collected and disposed of in a manner that will not cause ongoing environmental nuisance or harm; then on-site ESC measures amended, where appropriate, to reduce the risk of further sedimentation.
- Excessive sediment build-up in the site controls – collect and dispose of material, then amend up-slope drainage and/or erosion control measures as appropriate to reduce further occurrence.
- Severe or excessive rill erosion – investigate cause, control up-slope water movement, re-profile surface, cover dispersive soils with a minimum 100mm layer of non-dispersive soil, and stabilise with erosion control blankets and vegetation as necessary.
- Release of construction material from the site – collected and disposed of in a manner that will not cause ongoing environmental nuisance or harm; then inspect litter and waste receptors.
- Poor vegetation growth or soil coverage – plant new vegetation and/or mulch as required. Newly planted and previously planted areas may require supplementary watering and replanting.
- Sediment control failure – replace and monitor more frequently. Regular failures may mean that the sediment control, location, alignment or installation may need to be amended.

If the release of excessive sediment and/or other materials off the site is identified during site inspections, or water quality monitoring indicates levels not within the WQOs, then review and revise the Erosion and Sediment Control Plan (ESCP), or otherwise reduce the extent and/or duration of soil exposure.

3.4 Reporting

All weekly monitoring, non-compliance and corrective actions reporting should be stored with this SWMP and be available for auditing.

4.0 Water Quality Monitoring and Control

4.1 Monitoring Protocol

4.1.1 Timing and Forecasting

Monitoring will be undertaken immediately following rainfall event which causes runoff. Monitoring will be undertaken by an Environmental Scientist who will be responsible for monitoring the Bureau of Meteorology's rainfall predictions/outlook for seven days in advance. The Environmental Scientist will also be responsible for ensuring they personally, or another suitably qualified person (SQP), will be available at all times to complete sampling, particularly during forecasted periods of increased rainfall.

4.1.2 Water Quality Sample Collection

Sufficient laboratory sample containers for two sampling events shall be kept at the local office at all times. Spare equipment (such as star pickets, container holders and specially designed sample containers) will also be kept in case sample structures are damaged during flooding events.

Once a rainfall event which causes sufficient runoff to fill sample containers has occurred, an Environmental Scientist will mobilise to site with laboratory sample containers, spare structural material for sampling apparatus, field sheets (Field Sheets provided in **Appendix 4**), a sealable container (such as an esky) with ice and a water quality meter to analyse key physio-chemical parameters such as pH, EC and turbidity. Samples will then be taken from each surface water monitoring location as shown in **Figure 3**, with field physio-chemical results noted on field sheets. The samples collected from each surface water location will be immediately stored in a sealable container with crushed ice and replacement sample bottles will be installed at the sites. Samples will then transported to the laboratory, where a Chain of Custody requesting analysis for total suspended solids will be completed.

Two types of in-stream samplers are being utilised.

(1) Rising Stage Samplers (RSS1 and RSS2) are being utilized upstream and downstream of the site on Granite Creek as shown in Figure 2. These samplers consist of three 1L bottles at heights of approximately 50cm, 1m and 1.5m above regular stream flow.

(2) Surface water sites (SW1, SW2, SW3) which are located in-stream on major drainage lines will utilise 1L Thermofisher Nalgene HDPE sampler bottle's to automatically collect sample once the stream rises high enough to fill the bottle (approximately 30cm above base stream height). Physio-chemical parameters and sample for laboratory analysis will be taken from the 1L containers retrieved at both the Rising Stage Samplers and the Nalgene automatic sampler sites.

Co-ordinates for sample sites are:

Table 2 Co-ordinates for Sample Sites

Name	Elevation (m)	Longitude (Decimal Degrees, GCS WGS 1984)	Latitude (Decimal Degrees, GCS WGS 1984)
RSS1	541.12	145.380664	-17.13217
RSS2	564.95	145.404239	-17.149893
SW1	561.44	145.382138	-17.142495
SW2	559.15	145.390973	-17.142175
SW3	578.85	145.401904	-17.15599

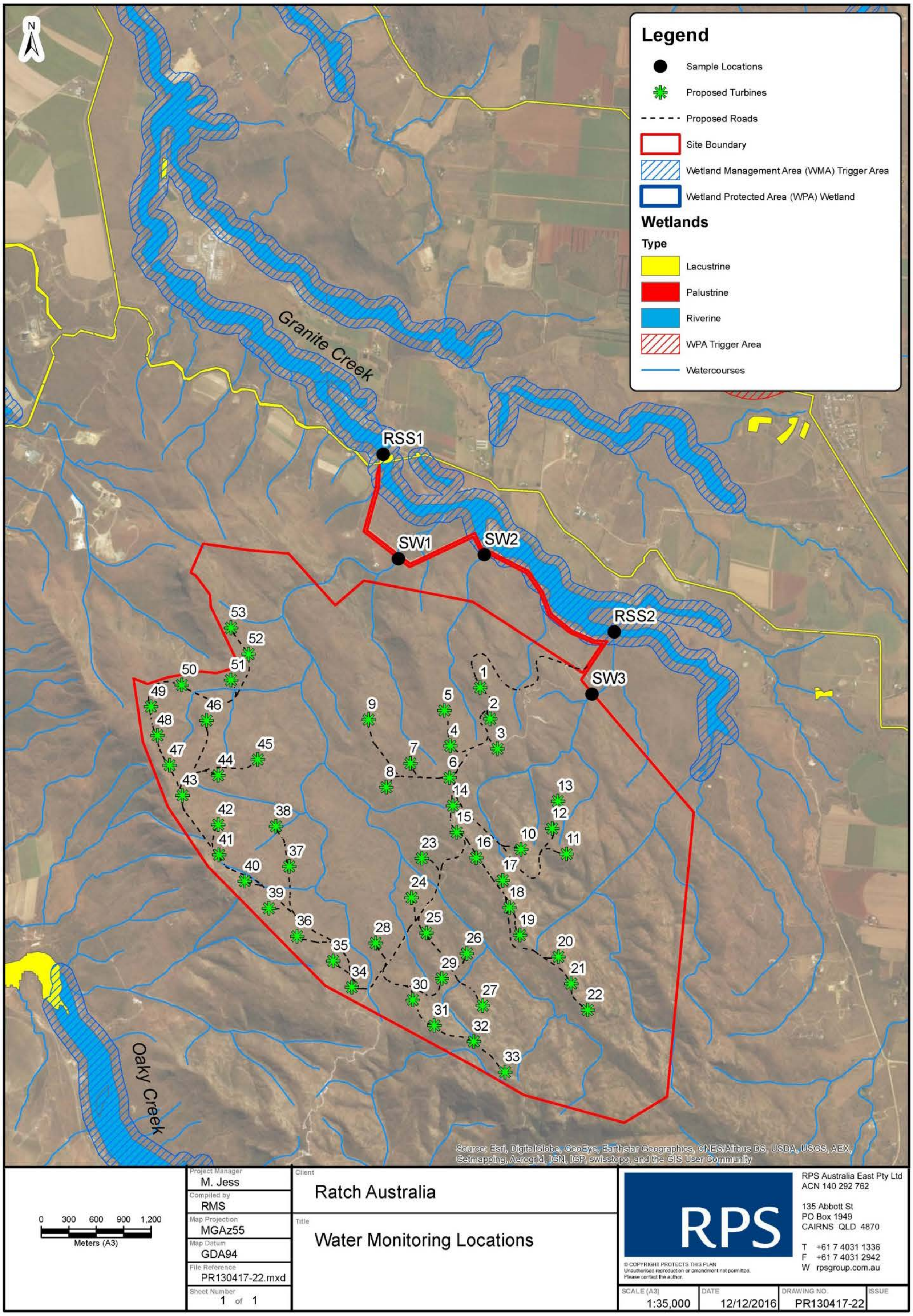


Figure 3 Water Quality Monitoring Locations

4.1.3 Trigger Levels

The Australia and New Zealand Environment Conservation Council (ANZECC) water quality guidelines for Fresh and Marine Water Quality (2000), which are widely adopted by regulatory authorities as the default guidelines, stipulate a minimum of two years of contiguous monthly data at the reference site is required before a valid trigger value can be established. Once 2 years of data has been collected the 80th percentile of the background data will be compared against the median of the test sites. If the median of the test sites is greater than 80th percentile of the background site than the trigger level will have been exceeded.

In the absence of this locally specific data, the Queensland Department of Environment and Heritage Protection (DEHP) Queensland Water Quality Guidelines 2009 (QWQG) have addressed the need identified in the ANZECC Guidelines by:

- Providing guideline values (numbers) that are tailored to Queensland regions and water types; and
- Providing a process/framework for deriving and applying local guidelines for waters in Queensland (i.e. more specific guidelines than those in the ANZECC).

Water quality guideline values presented in The Queensland Water Quality Guidelines (QWQG) will therefore be adopted as interim values until sufficient data has been collected to calculate locally relevant guideline values. Water Quality Objectives (WQO) are identified in **Table 3**.

Table 3 Water Quality Objectives

Parameter	Triggers	Guideline
Temp (^{0}C)	**22-32**	Based on Table 3.3.1a QWQG Regional guideline values for physico-chemical indicators – Wet Tropics region fresh and estuarine waters.
Electrical Conductivity (uS/cm)	**100**	Based on Table G.1: EC percentiles for Queensland salinity zones – 80th percentile
pH units	**6-8.0**	Based on Table 3.3.1a QWQG Regional guideline values for physico-chemical indicators – Wet Tropics region fresh and estuarine waters.
Turbidity (NTU)	**>10%**	Released waters from the discharge point(s) have turbidity (NTU) less than 10% above receiving waters turbidity. Based on Table 8.2.1 QWQG – Summary of design objectives for management of stormwater quality and flow.
Total Suspended Solids	**<50mg/L**	Based on Table 8.2.1 QWQG – Summary of design objectives for management of stormwater quality and flow.
Oils and Grease	**None**	No Visible films or odour
Litter	**None**	No visible litter washed or blown from the site

Source: Queensland Water Quality Guidelines 2009

4.2 Responsibilities

4.2.1 Water Quality Monitoring

A Environmental Scientist will be responsible for the implementation of the Water Quality Monitoring Program described in section 4 during the course of all construction activities. The Environmental Scientist will report to the Construction Contractor Manager and the MEWF Project Manager. These managers will ensure any necessary corrective actions are undertaken.

4.2.2 Erosion and Sediment Controls

Environmental Officers will be appointed by the Construction Contractor Manager. The Construction Contractor Environmental Officers (EO) will be responsible for monitoring and reporting the implementation of the Sediment, Erosion and Stormwater Management Plan. The Construction Contractor Environmental Officers will report to the Construction Contractor Project Manager.

5.0 Training

MEWF and its contractors will be responsible for ensuring project personnel have sufficient knowledge and awareness to identify potential environmental issues relating to soil erosion and stormwater management, and they are trained to take appropriate corrective action.

It is essential all personnel are familiar with the procedures and strategies within this document, and are able to report on issues that may result in environmental degradation.

5.1 Induction

All staff, including field staff, will complete a comprehensive Project Induction prior to commencing work on the Project. The induction will include safety, access and a comprehensive review of environmental requirements, which will be documented in an Induction Manual to be issued to all site personnel. All Project personnel from supervisory to managerial level will have an additional detailed training session on the use and implementation of this SWMP along with the EMP. It is the responsibility of the EPC managers to ensure records of training are maintained.

5.2 Toolbox Meetings

The EPC Manager will ensure supervisors hold at least weekly toolbox talks with staff and crews to discuss issues associated with the scheduled work.

This will include highlighting and discussing relevant erosion and stormwater management issues as required. The sessions will include discussion of strategies to be implemented and maintenance / construction of appropriate controls as necessary.

6.0 Conclusion

It is considered this SWMP will adequately manage water quality and soil erosion, along with the risk of adverse impacts associated with the proposed works on the site and receiving environment. In the instance management practices and procedures have been determined to be ineffective, corrective actions are to be identified and implemented. Following the identification of corrective actions, the SWMP will be updated to reflect these improvements.

Appendix I

Flow Diversion and Dissipation Examples

Outlet Structures

DRAINAGE CONTROL TECHNIQUE

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

Symbol

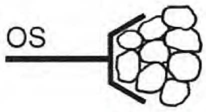


Photo 1 – Temporary *Slope Drain* with rock stabilisation at inlet and outlet

Photo 2 – Temporary rock mattress outlet structure at end of a *Chute*

Key Principles

1. The primary performance objectives generally relate to minimising the risk of soil erosion at the outlet, and preventing excessive undermining of the pipe and/or headwall.
2. Critical design parameters are the mean rock size (d_{50}) and length of rock protection (L).
3. The recommended rock sizing design charts/tables are based on the acceptance of some degree of rock movement (rearrangement) following initial storm events.
4. Critical construction issues relate to the provision of suitable rock (size and density), suitable pad dimensions (width, length and depth), and suitably recessing/integrating the rocks into the outlet channel to allow outflows to pass evenly over the rocks.

Design Information – General:

The design procedures presented in this fact sheet are <u>not</u> appropriate for the design of energy dissipaters for Sediment Basin spillways. Designers are advised to always seek expert hydraulic advice regarding the appropriate use of the material supplied within this fact sheet.

The following information is appropriate for the design of loose rock outlet structures for small Slope Drains (300/375mm diameter) and minor batter Chutes (<300mm flow depth).

Recommended mean (d_{50}) rock sizes and length (L) of rock protection for ***Slope Drain*** outlets are presented in Tables 2 and 3 for smooth and rough internal sidewall pipes respectively.

Recommended mean (d_{50}) rock sizes and length (L) of rock protection for minor batter ***Chute*** outlets are presented in Tables 4 and 5. These rock sizes are based on information presented within ASCE (1992) rounded up to the next 100mm increment, with a minimum rock size set as 100mm.

The thickness of the rock pad should be based on at least two layers of rock. This typically results in a minimum thickness as presented in Table 1.

Table 1 – Minimum thickness (T) of rock pad

Min. Thickness (T)	Size distribution (d_{50}/d_{90})	Description
1.4 d_{50}	1.0	Highly uniform rock size
1.6 d_{50}	0.8	Typical upper limit of quarry rock
1.8 d_{50}	0.67	Recommended lower limit of distribution
2.1 d_{50}	0.5	Typical lower limit of quarry rock

[1] d_{50} = nominal rock size (diameter) of which 50% of the rocks are smaller (i.e. the mean rock size).

Design Information – Outlet structures for Slope Drains:

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.

The typical layouts of a rock pad for a *Slope Drain* is shown in Figure 1. The rock pad should straight and align with the direction of the pipe outlet.

If the width of the rock pad is governed by the width of the receiving channel, then the rock protection should ideally extend up the banks of the channel to a height no less than the central elevation of the pipe outlet, but no more than the expected depth of flow.

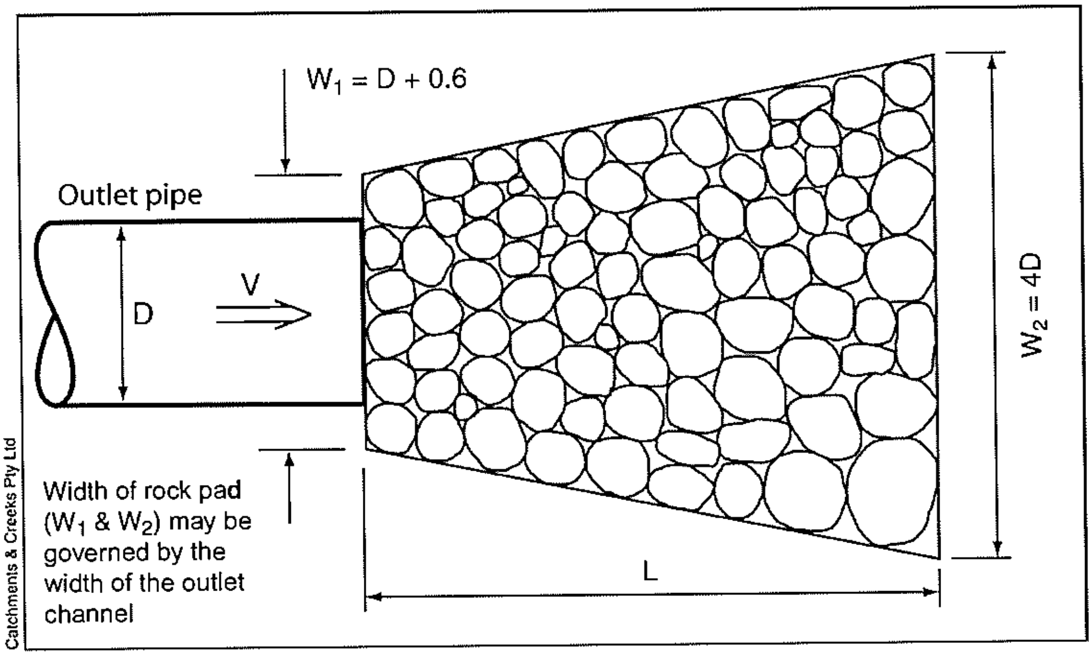


Figure 1 – Typical layout of a rock pad for a single pipe outlet (plan view)

The outlet structure for *Slope Drains* should be constructed at a level grade, or a gradient equal to that of the receiving channel.

The surface level of the downstream end of the rock pad should be level with the invert of the receiving channel, i.e. the rocks should be recessed into the outlet channel to minimise the risk of erosion around the outer edges of the rock pad.

The placement of filter cloth under the rock pad is generally considered optional for temporary outlet structures placed at the end of *Slope Drains*.

Design Information – Outlet structures for temporary drainage Chutes:

Table 4 – Mean rock size, d_{50} (mm) for batter *Chute* outlet protection [1]

Depth of approach flow (mm) [2]	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	100	100	100	200	200	200	300
100	100	100	200	200	300	300	400
200	100	200	300	300	400	[3]	[3]
300	200	200	300	400	[3]	[3]	[3]

[1] For exit flow velocities not exceeding 1.5m/s, and where growing conditions allow, loose 100mm rock may be replaced with 75mm rock stabilised with a good cover of grass.

[2] Flow depth is based on the maximum depth, not the average flow depth.

[3] Consider using 400mm grouted rock pad, or a rock-filled mattress outlet.

The outlet pad lengths provided in Table 5 are suitable for temporary, rock-lined outlet structures only. These rock pad length will not necessarily fully contain all energy dissipation and flow turbulence; therefore, some degree of scour may still occur downstream of the outlet structure.

For permanent structures, or concrete-lined energy dissipaters, the length of the dissipater should be based on the estimated length of the resulting hydraulic jump. Also, in circumstances where the outlet structure is located downstream of a smooth surface chute, e.g. concrete-lined chutes, then the rocks should be grouted in place to avoid displacement.

Table 5 – Recommended length, L (m) of rock pad for batter *Chute* outlet protection [1]

Depth of approach flow (mm)	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	1.0	1.5	2.1	2.6	3.1	3.6	4.2
100	1.3	2.0	2.7	3.4	4.1	4.8	5.5
200	2.1	2.7	3.4	4.3	5.2	6.1	7.0
300	2.7	3.6	4.3	4.8	5.8	6.8	7.9

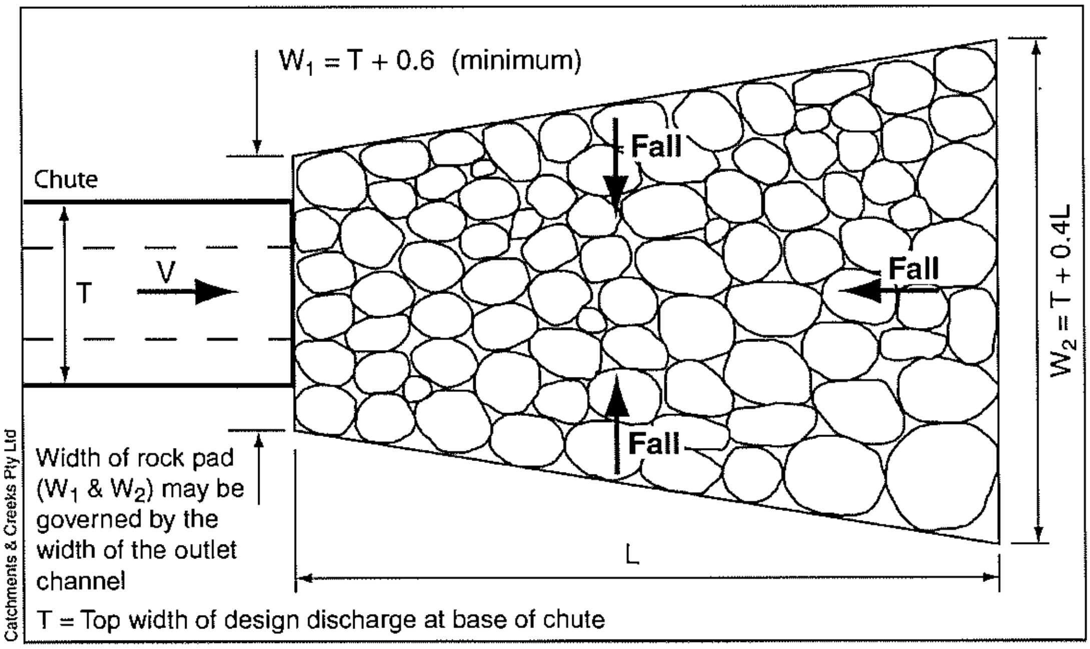


Figure 2 – Typical layout of a recessed rock pad for a *Chute* (plan view)

As indicated in Figures 2, 3 and 4, outlet structures for minor batter *Chutes* should be recessed below the surrounding ground level to promote effective energy dissipation. The recommended recess depth (Z) can be determined from Table 6.

Table 6 – Recommended recess depth, Z (m) for batter *Chute* outlet protection

Depth of approach flow (mm)	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	0.13	0.20	0.28	0.36	0.43	0.50	0.60
100	0.14	0.23	0.32	0.42	0.50	0.60	0.70
200	0.12	0.21	0.31	0.42	0.50	0.60	0.70
300	0.07	0.16	0.25	0.35	0.44	0.55	0.65

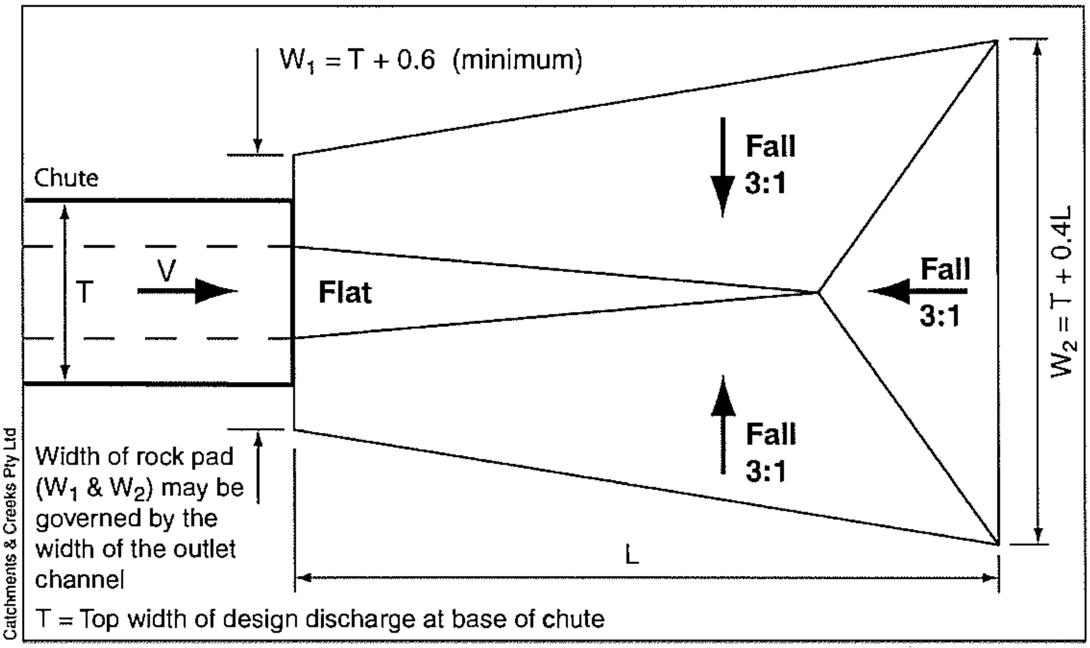


Figure 3 – Typical arrangement of recessed outlet structure for minor *Chutes*

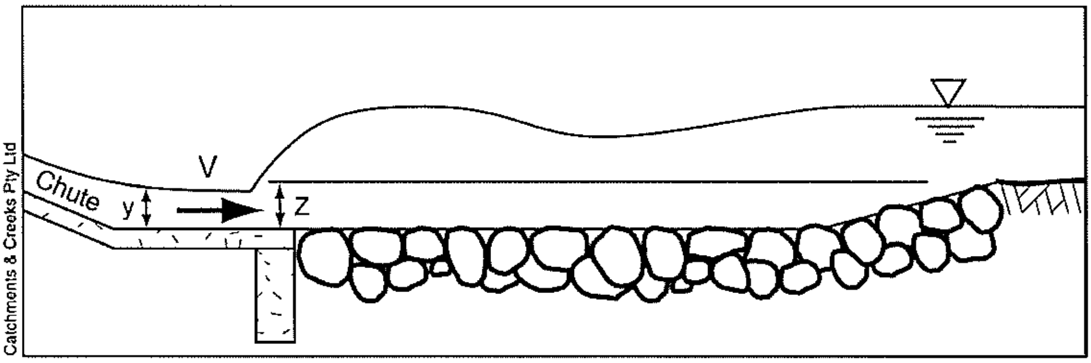


Figure 4 – Typical profile of recessed outlet structure for minor *Chutes*

References:

ASCE 1992, *Design and construction of urban stormwater management systems.* ASCE Manuals and Reports of Engineering Practice No. 77, and Water Environment Federation Manual of Practice FD-20, American Society of Civil Engineers, New York.

Bohan, J.P. 1970, *Erosion and riprap requirements at culvert and storm-drain outlets.* Research Report H-70-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Design example 1 – Slope drain outlet structure:

Design the outlet protection for a temporary slope drain with a diameter (D) of 300mm, smooth internal sidewall, and design discharge of 100L/s.

Solution

Given D = 300mm and Q = 100L/s, the recommended mean rock size as obtained from Table 2 is d_{50} = 300mm and L = 1.7m.

Upstream width of the rock pad, W1 = D + 0.6 = 0.9m (see Figure 1).

Downstream width of the rock pad, W2 = 4D = 1.2m

If it is assumed that the largest rock is likely to be around 1.5 times the size of the average rock size, i.e. d_{50}/d_{90} approximately equals 0.67, then from Table 1 we can obtain the required depth of rock protection as, T = 1.8(d_{50}) = 0.54m. In any case, a minimum of two layers of rock should be specified on the construction plans.

Design example 2 – Chute outlet structure:

Design the outlet protection for a temporary, trapezoidal chute lined with filter cloth on a 3:1 batter slope with a base width of 1.0m, side slopes of 2:1, and design discharge of 600L/s.

Solution

Adopting a Manning's roughness of, n = 0.022 for the filter cloth, the flow conditions at the base of the chute can be determined from Manning's equation as:

Discharge, Q = 0.6m^3/s

Manning's roughness, n = 0.022 (based on an expected flow depth > 0.1m)

Channel slope, S = 0.333 (m/m)

Bed width, b = 1.0m

Channel side slope, m = 2:1

Flow depth, y = 0.1m

Flow top width, T = b + 2my = 1.4m

Hydraulic radius, R = 0.083m

Velocity, $$V = \frac{1}{n}R^{2/3}S^{1/2} = \frac{1}{0.022}(0.083)^{2/3}(0.333)^{1/2} = 5.0\text{m/s}$$

From Table 4 the mean rock size, d_{50} = 200mm

From Table 5 the length of the rock pad, L = 3.4m

From Table 6 the recommended recess depth, Z = 0.42m

From Figure 3 the upstream width of the rock pad, W1 = T + 0.6 = 2.0m

From Figure 3 the downstream width of the rock pad, W2 = T + 0.4L = 2.8m

If it is assumed that the largest rock is likely to be around 1.5 times the size of the average rock size, i.e. d_{50}/d_{90} approximately equals 0.67, then from Table 1 we can obtain the required depth of rock protection as, T = 1.8(d_{50}) = 0.36m. In any case, a minimum of two layers of rock should be specified on the construction plans.

Note, the symbol 'T' has traditionally been used for both the depth of rock protection (as in Example 1), and the top width of flow (as in Example 2).

Description

The term *Outlet Structure* refers to a wide range of outlet control devices including rock pads, rock mattress aprons, and various impact-type energy dissipaters.

The standard outlet structure consists of a pad of medium sized rock placed at the outlet of *Slope Drain*, *Chute*, stormwater pipe or culvert.

Purpose

Used to control soil erosion adjacent to the outlet and to dissipate flow energy.

Limitations

These rock pads are generally ineffective in controlling erosion caused by high-velocity outlet 'jetting' occurring during high tailwater conditions.

Advantages

Quick to install.

The rock can often be retained as a permanent erosion control measure.

Disadvantages

If the rock is not appropriately recessed into the surrounding soil, erosion can occur around the edge of the rock pad.

Common Problems

Inadequate rock size.

Inadequate length, width or depth of rock protection.

Rock not recessed into the channel bed.

Erosion along the outer edge of the rock pad caused by lateral inflows (i.e. water flowing towards the outlet from a location other than the pipe).

Special Requirements

Important to recess the rock so that the top of the rock pad is level with the surrounding earth surface.

The rock should extend downstream until non-erosive flow conditions are achieved. In some cases this may require the rock protection to be extended beyond standards outlet dimensions determined from the attached design tables.

Location

Rock pad outlet structures are constructed downstream of temporary *Chutes* and *Slope Drains*, as well as permanent stormwater outlets and culverts.

Site Inspection

Check for erosion around the edge of the rock pad.

Ensure the rocks are adequately recessed into the earth.

Check for excessive displacement of rocks. Some degree of rock movement should be expected, especially immediately downstream of the pipe or concrete apron.

Check for excessive sediment deposition.

Materials (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 (Rock pads)

1. Refer to approved plans for location and construction details. If there are questions or problems with the location, dimensions or method of installation contact the engineer or responsible on-site officer for assistance.
2. The dimensions of the outlet structure must align with the dominant flow direction.
3. Excavate the outlet pad footprint to the specified dimension such the when the rock is placed in the excavated pit the top of the rocks will be level with the surrounding ground, unless otherwise directed.
4. If the excavated soils are dispersive, over-excavated the rock pad by at least 300mm and backfill with stable, non-dispersive material.
5. Line the excavated pit with geotextile filter cloth, preferably using a single sheet. If joints are required, overlap the fabric at least 300mm.
6. Ensure the filter cloth is protected from punching or tearing during installation of the fabric and the rock. Repair any damage by removing the rock and placing with another piece of filter cloth over the damaged area overlapping the existing fabric a minimum of 300mm.
7. Ensure there are at least two layers of rocks. Where necessary, reposition the larger rocks to ensure two layers of rocks are achieved without elevating the upper surface above the pipe invert.
8. Ensure the rock is placed in a manner that will allow water to discharge freely from the pipe.
9. Ensure the upper surface of the rock pad does not cause water to be deflected around the edge of the rock pad.
10. Immediately after construction, appropriately stabilise all disturbed areas.

Maintenance

1. While construction works continue on the site, inspect the outlet structure prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing rainfall, and on at least a weekly basis.
2. Replace any displaced rock with rock of a significantly (minimum 110%) larger size than the displaced rock.

Removal

1. Temporary outlet structures should be completely removed, or where appropriate, rehabilitated so as not to cause ongoing environmental nuisance or harm.
2. Following removal of the device, the disturbed area must be appropriately rehabilitated so as not to cause ongoing environmental nuisance or harm.
3. Remove materials and collected sediment and dispose of in a suitable manner that will not cause an erosion or pollution hazard.

Level Spreaders

DRAINAGE CONTROL TECHNIQUE

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

[1] Level spreaders can release sheet flow down steep slopes, but the level spreader itself must be constructed across a level gradient.

Symbol

Photo 1 – Diversion drains (centre) collect stormwater from roadside table drains, then releases the water as sheet flow via a level spreader

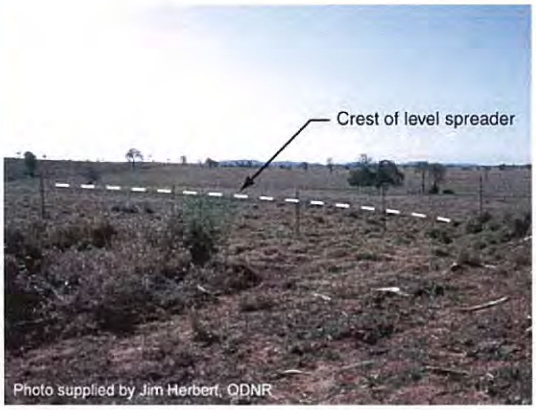


Photo 2 – Level spreader established to discharge stormwater from a diversion drain into the roadside property

Key Principles

1. Flow must be released from the level spreader as *sheet flow*.
2. Flow must be released over a stable, well-grassed surface that will maintain suitable flow conditions down the slope.
3. Critical design parameter is the length of the outlet sill.
4. Critical operational parameter is the level construction of the outlet sill.

Design Information

The length of the outlet sill (weir) of the level spreader is governed by the design discharge, and the allowable flow velocity of the down-slope area.

Allowable flow velocity for grassed surfaces can be determined from Table 1.

Minimum dimension can be determined from Tables 2 and 3.

Minimum sill length is 4m.

Maximum sill length is 25m. If a longer sill length is required, then the inflow must be spilt and released through more than one level spreader.

Up-slope channel grade should not exceed 1% for the last 6m before entering the level spreader.

Discharge must release evenly along a level surface (sill) of 0% cross gradient.

Caution the use of a design discharge exceeding 0.85m ^{3}/s.

Caution the release of water onto grass slopes steeper than 10%.

Table 1 – Allowable flow velocity (m/s) for grassed surfaces [1]

Percentage grass cover	Gradient of grass surface (%)									
	1	2	3	4	5	6	8	10	15	20
70% [2]	2.0	1.8	1.7	1.6	1.6	1.5	1.5	1.4	1.3	1.3
100% [3]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.7
Poor soils [3]	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.1	1.0	0.9

[1] Maximum allowable flow velocity limited to 2.0m/s due to shallow water flow and resulting high shear stress. High flow velocities are allowable on reinforced grass.

[2] 70% cover would be typical for most grasses recently established by seed, but only when there is sufficient plant establishment time.

[3] 'Poor soils' refers to the soil's high erosion potential, such as dispersive clays (Emerson Class 1 and 2) such as sodic, yellow and red soils. Unstable, dispersible clayey sands and sandy clays, such as yellow and grey massive earths formed on sandstones and some granites. Highly erodible soils may include: lithosols, alluvials, podzols, siliceous sands, soloths, solodized solonetz, grey podzolics, some black earths, fine surface texture-contrast soils, and Soil Groups ML and CL.

Table 2 – Level spreader sill length – metres per unit discharge (m per m³/s) [1]

Land slope (%)	Allowable down-slope velocity over well grassed surface (m/s)						
	1.0	1.2	1.5	1.8	2.0	2.2	2.5
1.0	3.5*	2.5*	1.6*	1.1*	0.9*	0.8*	0.6*
2.0	5.2	3.8*	2.5*	1.8*	1.4*	1.2*	0.9*
3.0	6.6	4.8	3.2*	2.3*	1.8*	1.5*	1.2*
4.0	7.7	5.6	3.8*	2.7*	2.2*	1.8*	1.4*
5.0	8.7	6.3	4.3*	3.1*	2.5*	2.1*	1.6*
6.0	9.5	7.0	4.7	3.4*	2.8*	2.3*	1.8*
7.0	10.3	7.6	5.2	3.7*	3.1*	2.6*	2.0*
8.0	11.0	8.2	5.6	4.0*	3.3*	2.8*	2.2*
9.0	11.8	8.7	6.0	4.3*	3.5*	3.0*	2.4*
10.0	12.4	9.2	6.3	4.6*	3.8*	3.2*	2.5*
Caution the release of water onto grass slopes steeper than 10%.							
15.0	15.2	11.3	7.8	5.7	4.8	4.0*	3.2*
20.0	17.4	13.1	9.1	6.7	5.6	4.7	3.7*
25.0	19.4	14.6	10.3	7.6	6.3	5.3	4.3*
33.3	22.1	16.8	11.9	8.8	7.4	6.2	5.0
50.0	26.6	20.3	14.5	10.8	9.1	7.8	6.3

* Sill length limited to minimum 4m for discharges less than $0.85m^3/s$.

Design example:

Design a level spreader to release a flow rate of $0.5m^3/s$ down a 10% slope containing a good (70%) grass cover on moderately erodible soil.

Solution:

From Table 1, choose a maximum flow velocity of 1.4m/s as best representative of a good grass cover on a moderately erodible soil.

From Table 2, select a sill width per unit flow rate of $7.3m/m^3/s$.

Therefore, the sill length would need to be 0.5 x 7.3 = 3.65m < 4m (minimum).

Conclusion, specify a sill length of 4m.

The minimum sill lengths presented in Table 2 have been determined assuming a Manning's roughness for 50-150mm (Class D) grassed surfaces based on Equation 1. The sill length is sensitive to the selection of Manning's roughness. Variations between Table 2 and other published design tables for is due to variations in the assumed Manning's roughness, which is highly variable depending on the type and length of grass, and local growing conditions.

Class D roughness:

$$n = \frac{R^{1/6}}{51.24 + 20.77\log_{10}(R^{1.4}.S^{0.4})} \quad \text{(Eqn 1)}$$

Table 3 – Minimum dimension of level spreader

Discharge (m^3/s)	Entrance width (m)	Depth (m)	End width (m)
0 to 0.28	3.0	0.15	0.9
0.29 to 0.57	4.9	0.18	0.9
0.58 to 0.85	7.3	0.21	0.9

Construction of a level spreader may require formation of flow control banks as shown in Figures 1 to 3.

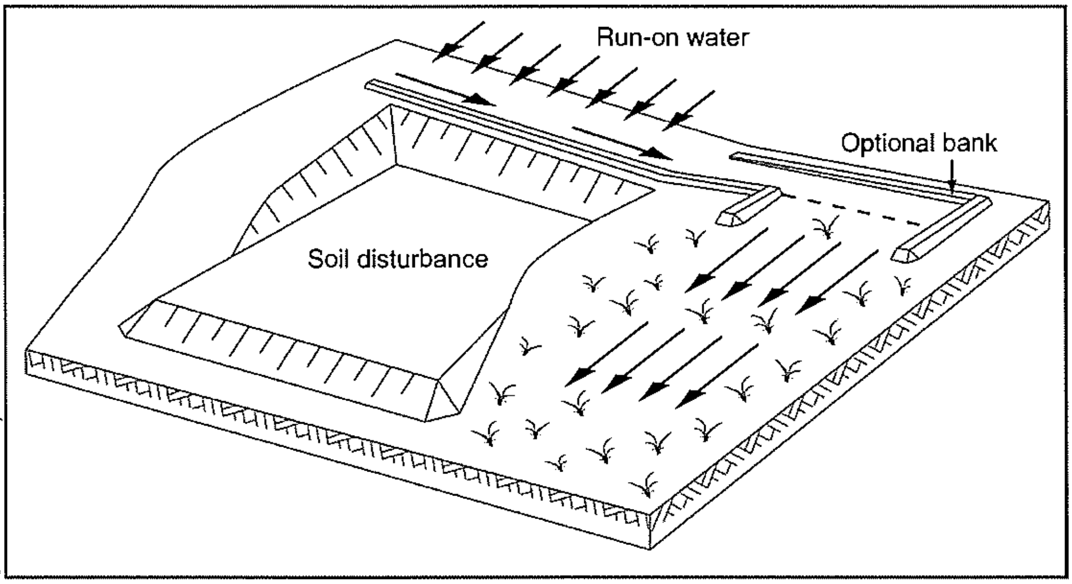


Figure 1 – Example of a level spreader used for flow diversion around a soil disturbance

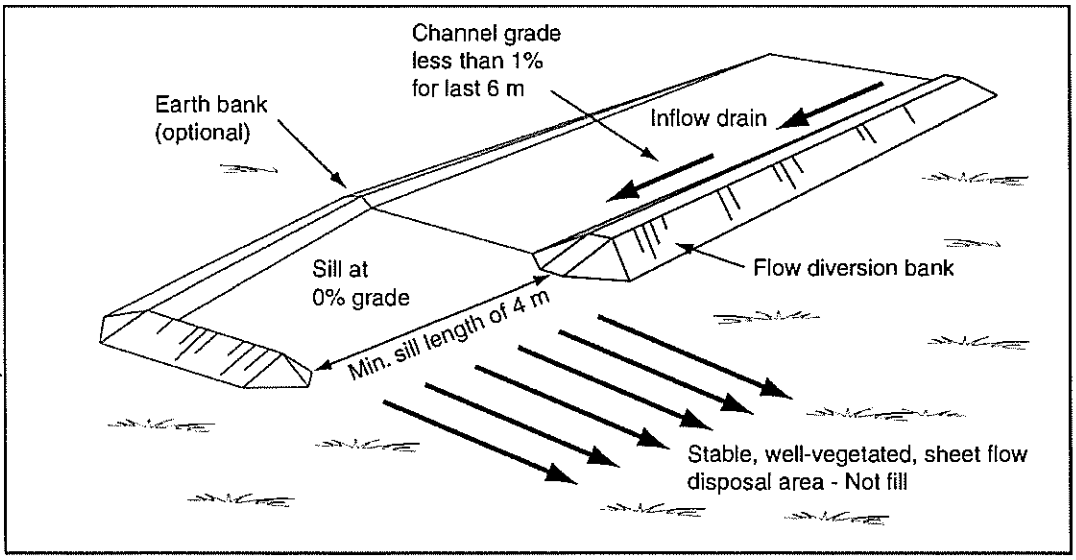


Figure 2 – Typical layout of level spreader

Description

Level spreaders consist of a level, grassed, side-flow weir (i.e. water discharges at 90 degrees to the inflow direction) constructed along the contour.

Purpose

Used to allow concentrated inflow to be released as *sheet flow* down a stable, vegetated slope.

Can be used as an outlet for *Catch Drains* and *Flow Diversion Banks*.

Level spreaders are commonly used in rural areas to discharge stormwater from roadside table drains into an adjacent property (Photos 1 & 2).

Limitations

Minimum sill length of 4m.

Maximum sill length of 25m.

Maximum discharge of around $0.85m^3/s$.

Must only be used where the outflow can be discharged to an undisturbed; stable, grassed surface.

Construction traffic should be prohibited from the area of the level spreader.

Not suitable for highly erosive soils, dispersive soils, or soils with poor vegetation cover.

Advantages

Inexpensive to construct and maintain.

Disadvantages

Can be difficult to construct the outlet sill to the required precision.

May require a considerable width of undisturbed land.

May require the land to be free of trees, shrubs and other surface irregularities to avoid local erosion problems.

Common Problems

The most common problems result from damage to the outlet sill either from erosion, sedimentation, or stock.

Other problems can result from water flow concentrating below the level spreader due to the existence of a concave surface, vehicular tracks, or uneven vegetation cover.

Special Requirements

Outlet area must be free of depressions that may concentrate the outflow.

Extra erosion protection using jute mesh, *Erosion Control Mats*, turf, rock etc. may be required at the sill (Figure 4).

Generally constructed by dozers no larger than D5 or equivalent.

Extreme caution must be exercised when attempting to discharge *sheet flow* down a steep gradient (>10%) to ensure that the sedimentation or damage to the outlet sill does not concentrate the outflow.

Site Inspection

Check for sediment build-up on the sill, or the concentration of outflow.

Check for erosion down-slope of the sill.

Installation

1. Refer to approved plans for location, dimensions and construction details. If there are questions or problems with the location, dimensions, or method of installation contact the engineer or responsible on-site officer for assistance.
2. Wherever practical, locate the level spreader on undisturbed, stable soil.
3. Ensure flow discharging from the level spreader will disperse across a properly stabilised slope not exceeding 10:1 (H:V) and sufficiently even in grade across the slope to avoid concentrating the outflow.
4. The outlet sill of the spreader should be protected with erosion control matting to prevent erosion during the establishment of vegetation. The matting should be a minimum of 1200mm wide extending at least 300mm upstream of the edge of the outlet crest and buried at least 150mm in a vertical trench. The downstream edge should be securely held in place with closely spaced heavy-duty wire staples at least 150mm long.
5. Ensure that the outlet sill (crest) is level for the specified length.
6. Immediately after construction, turf, or seed and mulch where appropriate, the level spreader.

Maintenance

1. Inspect the level spreader after every rainfall event until vegetation is established.
2. After establishment of vegetation over the level spreader, inspections should be made on a regular basis and after runoff-producing rainfall.
3. Ensure that there is no soil erosion and that sediment deposition is not causing the concentration of flow.
4. Ensure that there is no soil erosion or channel damage upstream of the level spreader, or soil erosion or vegetation damage downstream of the level spreader.
5. Investigate the source of any excessive sedimentation.
6. Maintain grass in a health condition with no less than 90% cover unless current weather conditions require otherwise.
7. Grass height should be maintained at a minimum 50mm blade length within the level spreader and downstream discharge area, and a maximum blade length no greater than adjacent grasses.

Removal

1. Temporary level spreaders should be decommissioned only after an alternative stable outlet is operational, or when the inflow channel is decommissioned.
2. Remove collected sediment and dispose of in a suitable manner that will not cause an erosion or pollution hazard.
3. Remove and appropriately dispose of any exposed geotextile.
4. Grade the area and smooth it out in preparation for stabilisation.
5. Stabilise the area as specified on the approved plan.

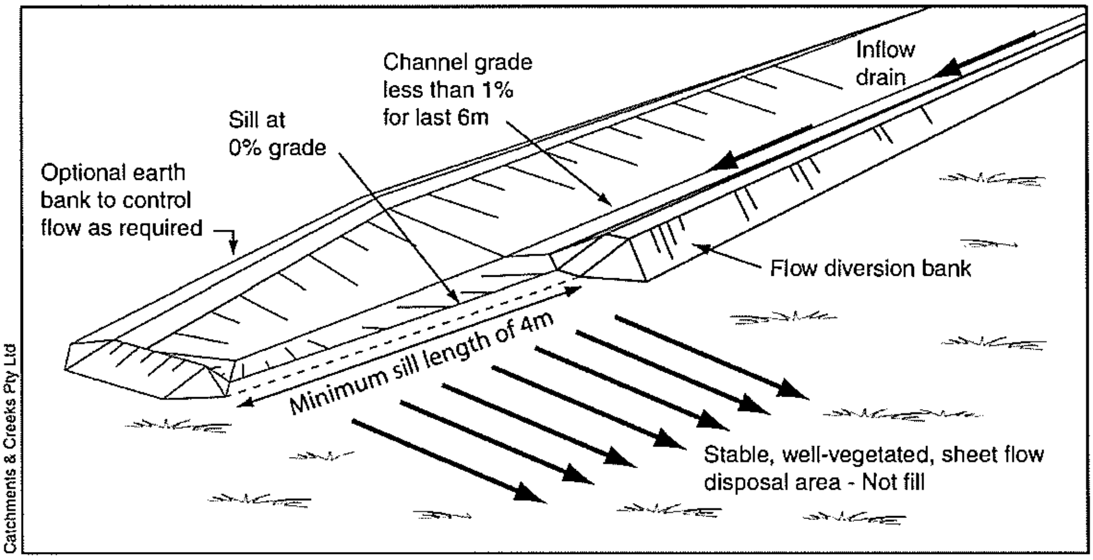


Figure 3 – Alternative level spreader layout

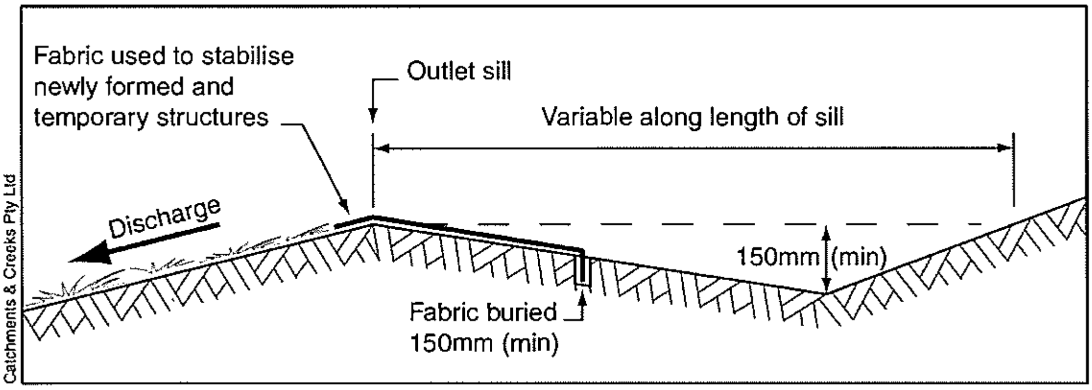


Figure 4 – Cross-sectional profile of end sill

Flow Diversion Banks Part 1: General

DRAINAGE CONTROL TECHNIQUE

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

[1] Flow diversion banks are not commonly used as permanent drainage structures.

Symbol ⟶ DB ⟶

Photo 1 – Flow diversion bank down-slope of a future pipeline installation

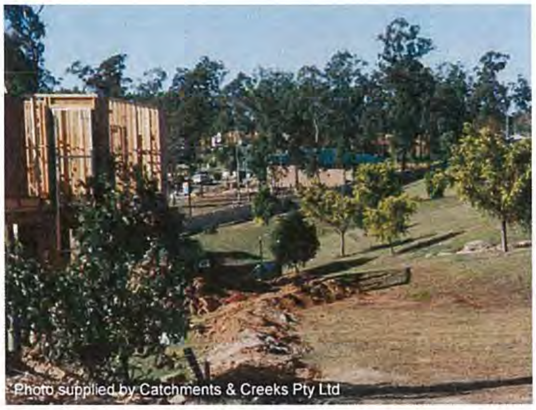


Photo 2 – Flow diversion bank up-slope of a building site

Key Principles

1. Key design parameters are the effective flow capacity of the structure, and the scour resistance of the embankment material.
2. The critical operational issue is usually preventing structural damage to the embankment as a result of high velocity flows or construction traffic.
3. Flow diversion banks are often favoured over *Catch Drains* in areas containing dispersive subsoil because their construction does not require exposure of the subsoils.

Design Information

Dimensional requirements of flow diversion banks and berms vary with the type of embankment. The recommended values are outlined in Table 1.

Table 1 – Recommended dimensional requirements of flow diversion banks/berms

Parameter	Earth banks	Compost berms [1]	Sandbag berms
Height (min)	500mm	300mm (450mm)	N/A
Top width (min)	500mm [2]	100mm (100mm)	N/A
Base width (min)	2500mm [2]	600mm (900mm)	N/A
Side slope (max)	2:1 (H:V)	1:1 (H:V)	N/A
Hydraulic freeboard	150mm (300mm) [3]	100mm	50mm

[1] Values in brackets apply to berms placed across land slopes steeper than 4:1 (H:V).

[2] Top width may be reduced in those non-critical situations in which overtopping will not cause excessive erosion and the banks are unlikely to experience damage from construction equipment.

[3] A minimum freeboard of 300mm applies to non-vegetated earth embankments.

Free standing earth embankments may be stabilised with rock, vegetation, or *Erosion Control Blankets*; however, unprotected topsoil embankments are also acceptable for short-term applications.

Maximum recommended spacing of flow diversion banks down long continuous slopes is provided in Table 2. The actual spacing specified for a given site may need to be less than that presented in Table 2 if the soils are highly susceptible to erosion, or if intense storm events are expected (i.e. northern parts of Australia during the wet season).

Table 2 – Maximum recommended spacing of flow diversion banks down slopes

Open Earth Slopes						Vegetated Slopes		
Slope	**Horiz.**	**Vert.**	**Slope**	**Horiz.**	**Vert.**	**Slope**	**Horiz.**	**Vert.**
1%	80m	0.9m	15%	19m	2.9m	< 10%	No maximum	
2%	60m	1.2m	20%	16m	3.2m	12%	100m	12m
4%	40m	1.6m	25%	14m	3.5m	15%	80m	12m
6%	32m	1.9m	30%	12m	3.5m	20%	55m	11m
8%	28m	2.2m	35%	10m	3.5m	25%	40m	10m
10%	25m	2.5m	40%	9m	3.5m	30%	30m	9m
12%	22m	2.6m	50%	6m	3.0m	> 36%	Case specific	

Photo 3 – Flow diversion berm used to minimise road runoff flowing down a steep, unstable section of the embankment

Photo 4 – Sandbag flow diversion berm used to minimise surface flow over a recently seeded embankment

Photo 5 – Earth flow diversion bank used to direct runoff towards the entrance of a *Slope Drain*

Photo 6 – Turf-lined flow diversion bank with grass-lined outlet chutes at regular intervals along the embankment

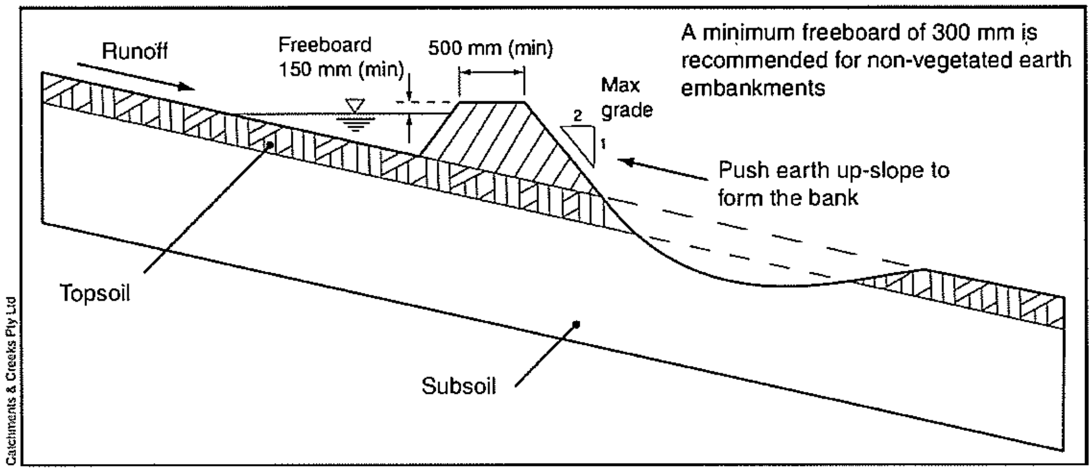
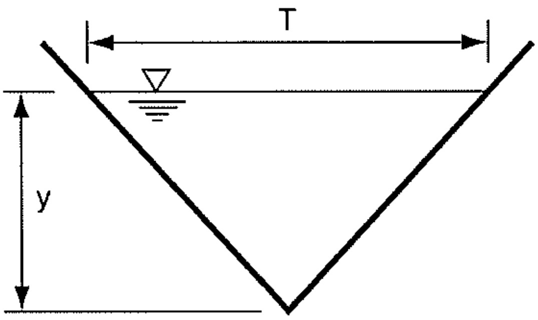
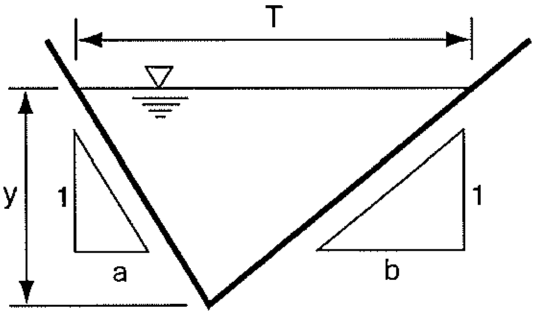


Figure 1 – Profile of 'back-push' bank

The hydraulic capacity of a flow diversion bank normally needs to be assessed on a case-by-case basis; however, the associated fact sheets *"Part 2: On earth slopes"* and *"Part 3: On grassed slopes"* provide the hydraulic capacity for drains with a standard triangular profile established on earth and grassed slopes respectively.

The geometric properties of triangular drainage channels formed by the construction of a flow diversion bank are provided in Table 3.

Table 3 – Geometric properties of triangular drainage profiles

Symmetrical or asymmetric V-drain: 	**Area (A):** $A = 0.5\,T\,y$
	Wetted perimeter (P): $P = \sqrt{T^2 + 4y^2}$
	Hydraulics radius (R): $R = \dfrac{Ty}{2\sqrt{T^2 + 4y^2}}$
Asymmetric V-drain: **where flow top width, T = y(a + b)** 	**Area (A):** $A = \left(\dfrac{a+b}{2}\right)y^2$
	Wetted perimeter (P): $P = y\left[\sqrt{(1+a^2)} + \sqrt{(1+b^2)}\right]$
	Hydraulics radius (R): $R = \dfrac{0.5(a+b)y}{\sqrt{(1+a^2)} + \sqrt{(1+b^2)}}$

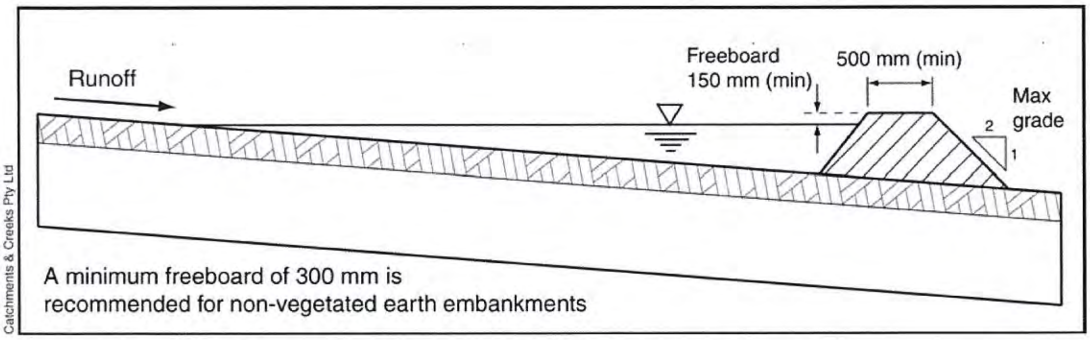


Figure 2 – Flow diversion bank formed from earth

Photo 7 – Flow diversion banks placed each side of drainage line passing through road construction site

Types of flow diversion banks:

The following provides a brief description of some of the flow diversion banks used within rural and construction land management.

Absorption bank	A level bank turned up at each end to promote water infiltration.
Back-push bank	A bank formed by moving in-situ earth up a slope.
Conventional bank	A bank formed by moving in-situ earth down thus forming an excavated drain up-slope of the bank. Also known as a 'catch bank'.
Diversion bank	A graded bank used to collect and divert water away from a soil disturbance, or to a dam, drainage channel, or sediment trap.
Graded bank	A bank constructed with a positive gradient to promote water movement.
Level bank	A bank constructed along a contour. Discharge usually occurs at each end of the bank.
Perimeter bank	A bank located along the upper or lower perimeter of a well-defined area, such as a building site, or along the top edge of a batter.
Trainer bank	A bank used to divert water away from unstable land.
Water-spreading bank	Banks used to collect and distribute surface runoff over an increased flow width. Typically used on low-gradient, marginal arable land.

Description

Flow diversion banks typically consist of a raised earth embankment normally placed along level or near level ground. Minor flow diversion berms can also be formed from tightly packed sandbags, or compost.

Short-term flow diversion banks can also be constructed from tightly packed straw bales. Such banks are often constructed prior to an impending storm.

The term *perimeter bank* is often used to describe an embankment constructed around the 'perimeter' of a work site. These are used to either prevent clean water entering the site, or to prevent the uncontrolled release of dirty water from a site.

The term *back-push bank* is used to describe an embankment formed by pushing in-situ soils up a slope to from an earth embankment.

Purpose

Flow diversion banks and berms are used as temporary drainage systems to:

- collect sheet runoff (clean or dirty) from slopes and transport it across the slope to a stable outlet (Photo 1);
- divert up-slope runoff around a stockpile or soil disturbance (Photo 2);
- divert stormwater away from an unstable slope (Photos 3 & 4);
- direct water to the inlet of a *Chute* or *Slope Drain* (Photos 5 & 6);
- control the depth of ponding around a sediment trap such as a stormwater drop (field) inlet.

Flow diversion banks can also act as a form of topsoil stockpile. Topsoil can be stripped from a site and used to form flow diversion banks either up-slope and/or down-slope of the soil disturbance (Photo 1). Such a practice can be very space effective when conducting 'strip' construction such as roadways and pipeline installation.

Limitations

Catchment area is limited by the allowable flow capacity of the diversion bank and the allowable flow velocity of the surface material.

Not used on slopes steeper than 10% (10:1).

Advantages

Quick to establish or re-establish if disturbed.

Generally inexpensive to construct and remove.

Allows for the management of stormwater flow without the need to excavate a drainage channel. This can be a significant advantage in areas that have highly erosive or dispersive subsoils.

Disadvantages

Can cause sediment problems and flow concentration if overtopped during a severe storm.

Can restrict the movement of equipment around the site.

Can be highly susceptible to damage by construction equipment.

Common Problems

Damaged by construction traffic.

Scour along the base of the embankment caused by excessive flow velocity or an unstable outlet.

Overtopping flows caused by the deposition of sediment up-slope of the bank.

Special Requirements

All flow diversion banks must have a stable outlet.

Flow diversion banks should be seeded and mulched if their working life is expected to exceed 30 days, or as required by the erosion control standard.

Banks should **not** be constructed of unstable, non-cohesive, or dispersive soil.

Location

When flow diversion banks are required and their locations are not shown on the approved plans, their location on the ground should be determined after taking into consideration the following:

- the bank must discharge to a stabilised outlet;
- the bank should drain to a sediment trap if the diverted water is expected to be contaminated with sediment;
- stormwater must not be unnaturally diverted or concentrated onto an adjacent property.

Site Inspection

Check for slumps, wheel track damage, or loss of freeboard.

Check for excessive sediment deposition.

Check for erosion along the bank.

Installation

1. Refer to approved plans for location, extent, and construction 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. Clear the location for the bank, clearing only the area that is needed to provide access for personnel and equipment.
3. Remove roots, stumps, and other debris and dispose of them properly. Do not use debris to build the bank.
4. Form the bank from the material, and to the dimension specified in the approved plans.
5. If earth is used, then ensure the sides of the bank are no steeper than a 2:1 (H:V) slope, and the completed bank must be at least 500mm high.
6. If formed from sandbags, then ensure the bags are tightly packed such that water leakage through the bags is minimised.
7. Check the bank alignment to ensure positive drainage in the desired direction.
8. The bank should be vegetated (turfed, seeded and mulched), or otherwise stabilised immediately, unless it will operate for less than 30 days or if significant rainfall is not expected during the life of the bank.
9. Ensure the embankment drains to a stable outlet, and does not discharge to an unstable fill slope.

Maintenance

1. Inspect flow diversion banks at least weekly and after runoff-producing rainfall.
2. Inspect the bank for any slumps, wheel track damage or loss of freeboard. Make repairs as necessary.
3. Check that fill material or sediment has not partially blocked the drainage path up-slope of the embankment. Where necessary, remove any deposited material to allow free drainage.
4. Dispose of any collected sediment or fill in a manner that will not create an erosion or pollution hazard.
5. Repair any places in the bank that are weakened or in risk of failure.

Removal

1. When the soil disturbance above the bank is finished and the area is stabilised, the flow diversion bank should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area and smooth it out in preparation for stabilisation.
4. Stabilise the area by grassing or as specified in the approved plan.

Flow Control Berms

DRAINAGE CONTROL TECHNIQUE

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

[1] It is common practice for the berms to be retained on-site and allowed to integrate into the general topography. Over time the height and hydraulic impact of the berms diminishes until their existence completely disappears.

Symbol → CB →

Photo 1 – Flow diversion berm used to minimise road runoff flowing down a steep, unstable section of the embankment

Photo 2 – Sandbag flow diversion berm used to minimise surface flow over a recently seeded embankment

Key Principles

1. Key design parameters are the effective flow capacity of the structure, and the scour resistance of the berm.
2. Key operational features are the height and alignment of the berms such that water flow is directed to the appropriate location in a non-erosive manner.

Design Information

The recommended dimensional requirements of flow control berms are outlined in Table 1.

Table 1 – Recommended dimensional requirements of flow control berms

Parameter	Topsoil berms	Compost berms [1]	Sandbag berms
Height (min)	300mm (450mm)	300mm (450mm)	N/A
Top width (min)	100mm (100mm)	100mm (100mm)	N/A
Base width (min)	600mm (900mm)	600mm (900mm)	N/A
Side slope (max)	1:1 (H:V)	1:1 (H:V)	N/A
Hydraulic freeboard	100mm	100mm	50mm

[1] Values in brackets apply to berms placed across land slopes steeper than 4:1 (H:V).

The fact sheets prepared for *Flow Diversion Banks* provide guidance on estimating the hydraulic capacity of flow control berms.

Description

Flow control berms typically consist of minor earth, compost or sandbag embankment placed in a manner to collect and divert minor flows.

Purpose

Flow control berms are used as temporary drainage systems to:

- divert up-slope runoff around a stockpile or soil disturbance;
- divert stormwater away from an unstable slope;
- direct minor flows to the inlet of a drainage *Chute*.

Limitations

Allowable catchment area is usually very limited due to the very limited flow capacity of a berm. Formally design *Flow Diversion Banks* are normally required to manage runoff from large catchment.

Catchment area is limited by the allowable flow capacity of the berm and the allowable flow velocity of the surface material.

Not used on slopes steeper than 10% (10:1).

Advantages

Quick to establish or re-establish if disturbed.

Generally inexpensive to construct and remove.

Allows for the management of stormwater flow without the need to excavate a drainage channel. This can be a significant advantage in areas that have highly erosive or dispersive subsoils.

Disadvantages

Can cause sediment problems and flow concentration if overtopped during a severe storm.

Can restrict the movement of equipment around the site.

Can be highly susceptible to damage by construction equipment.

Common Problems

Damaged by construction traffic.

Scour along the base of the embankment caused by excessive flow velocity or an unstable outlet.

Overtopping flows caused by the deposition of sediment up-slope of the bank.

Special Requirements

All flow control berms must have a stable outlet.

Earth berms should **not** be constructed of unstable, non-cohesive, or dispersive soil.

Location

When flow control berms are required and their locations are not shown on the approved plans, their location on the ground should be determined after taking into consideration the following:

- the berm must discharge to a stabilised outlet;
- the berm should drain to a sediment trap if the diverted water is expected to be contaminated with sediment;
- stormwater must not be unnaturally diverted or concentrated onto an adjacent property.

Site Inspection

Check for slumps, wheel track damage, or loss of freeboard.

Check for excessive sediment deposition.

Check for erosion along the berm.

Installation

1. Refer to approved plans for location, extent, and construction 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. Clear the location for the berm, clearing only the area that is needed to provide access for personnel and equipment.
3. Remove roots, stumps, and other debris and dispose of them properly.
4. Form the berm from the material, and to the dimension specified in the approved plans.
5. If formed from sandbags, then ensure the bags are tightly packed such that water leakage through the bags is minimised.
6. Check the alignment of the berm to ensure positive drainage in the desired direction.
7. Ensure the berm discharges to a stable outlet.
8. Ensure the berm does not discharge to an unstable fill slope.

Maintenance

1. Inspect flow control berms at least weekly and after runoff-producing rainfall.
2. Inspect the berm for any slumps, wheel track damage or loss of freeboard. Make repairs as necessary.
3. Check that fill material or sediment has not partially blocked the drainage path up-slope of the embankment. Where necessary, remove any deposited material to allow free drainage.
4. Dispose of any collected sediment or fill in a manner that will not create an erosion or pollution hazard.
5. Repair any places in the berm that are weakened or in risk of failure.

Removal

1. When the soil disturbance above the bank is finished and the area is stabilised, the flow control berm should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area and smooth it out in preparation for stabilisation.
4. Stabilise the area by grassing or as specified in the approved plan.

Diversion Channels

DRAINAGE CONTROL TECHNIQUE

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

[1] The design of permanent diversion channels requires consideration of issues not discussed within this fact sheet, such as safety and maintenance requirements.

Symbol → DC →

Photo 1 – Temporary diversion channel collecting 'dirty' water down-slope of a soil disturbance

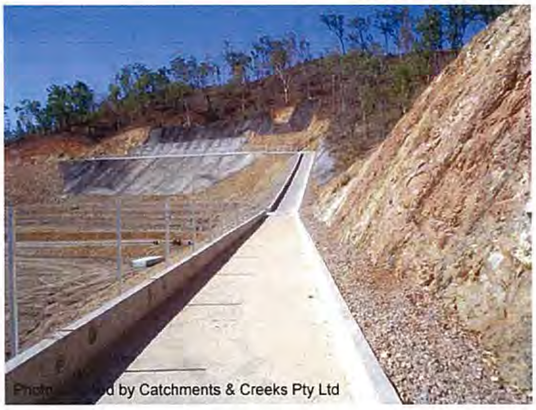


Photo 2 – Permanent diversion channel collecting stormwater runoff up-slope of a subdivision

Key Principles

1. Diversion channels are sized for a specific design flow rate based on the catchment area, topography, soil and hydrologic conditions.
2. Critical design parameters are the choice of surface lining, hydraulic capacity and stability of the discharge point.
3. Critical operation issues are usually related to controlling sediment, vegetation and debris collection within the channel, and maintaining a stable outlet.

Design Information

Diversion channels are usually major hydraulic structures requiring design input from an experienced hydraulics specialist. This fact sheet does **not** provide sufficient information to allow diversion channels to be designed by inexperienced persons.

The design of permanent drainage channels requires consideration of issues not discussed within this fact sheet, such as safety and maintenance requirements.

The design discharge (Q) must reflect the specified drainage control standard of the site. Refer to the relevant regulating authority for relevant design standards. Where such standards do not exist, then refer to IECA (2008) Chapter 4 – *Design standards and technique selection*.

Typical design standards are presented in Table 1.

Refer to the various fact sheets under the sub-heading *Channel Linings* for velocity calculations and guidelines on the design of rock, grass or mat lining of the channel.

Recommended maximum bank slopes are provided in Table 2.

Table 1 – Typical design standards for temporary diversion channels

Parameter	Design standard
Design discharge	• Refer to IECA (2008) Table 4.3.1, Chapter 4 – *Design standards and technique selection*
Channel depth	• Minimum channel depth of 300mm
Freeboard	• Minimum freeboard being the greater of 150mm, 10% of channel depth, or the velocity head ($V^2/2g$) • Allow embankment settlement of 10% of fill height (in addition to freeboard) if the embankment's design life exceeds 1 year
Embankment	• Optional embankment formed down-slope of the channel (Figure 1). • Minimum crest width of 600mm, and down-slope bank gradient of 2:1 for reasons of stability against overtopping flows
Safety	• Safety requirements, such as the depth*velocity product (d.V), generally do not apply to drainage channels • Safety considerations generally focus on allowing good egress from the channel, and ensuring safety risks are obvious
Maintenance berm	• Desirable 1.5m wide (min) maintenance berm on at least one side of the channel (not always practicable in short-term projects)

Table 2 – Typical maximum bank slopes [1]

Site conditions	Max bank slope (H:V)
Highly compacted clay (hard, pick required)	1:1 to 1.25:1
Medium compact sandy clay	1.2:1 to 1.5:1
Slightly compact silty clay or sandy clay (soft, spade required)	1.5:1 to 2:1
Non-cohesive fine sandy soil or soils with humus or peat content	2:1 to 3:1
Non mowable vegetated slopes	3:1
Permanent, mowable, grass slopes (maximum grade)	4:1
Permanent, mowable grass slopes (recommended grade)	6:1
Rock lined channels	1.5:1 [2]

[1] Bank slopes provided as a guide only. Actual bank slope should be based on geotechnical and landscaping advice wherever practicable.

[2] Desirable maximum bank slope is 2:1 for dumped rock; however, with increased placement effort and skills, rock may be placed on bank slopes up to 1.5:1 in low velocity channels.

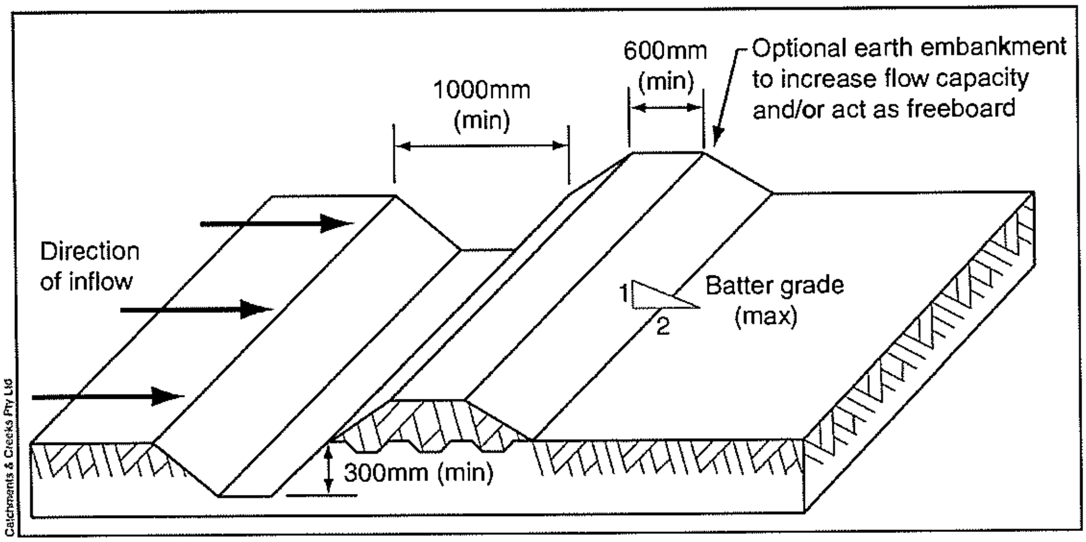


Figure 1 – Typical profile of temporary diversion channels

Hydraulic design of diversion channels:

Step 1 Determine the required design discharge (Q).

If the channel gradient varies significantly along its length, then it may be desirable to split the channel into individual sections and determine an appropriate design discharge at the downstream end of each of these sections.

Step 2 Nominate the channel profile: parabolic or triangular (V-drain). Parabolic channel are generally less susceptible to invert erosion.

Step 3 Choose the preferred surface condition of the channel (e.g. earth, grass, rock).

The design information provided in the *Catch Drain* fact sheets can be used as a guide in selecting a surface lining and trial channel size.

Step 4 Select a bank slope (m) using Table 2 as a guide. Do **not** necessarily select the maximum bank slope, but consider such issues as safety and maintenance access.

Step 5 Determine the Manning's roughness (n) and allowable flow velocity (V_{allow}) using the relevant fact sheet (refer to channel linings) or Tables A17 to A20, and Tables A23 to A28 in IECA 2008, Appendix A – *Construction site hydrology and hydraulics.*

For grass and rock-lined channels it may be necessary to estimate a channel depth, and hydraulic radius (Steps 6 to 8) before determining Manning's roughness.

Step 6 Determine the minimum required flow area ($A = Q/V_{allow}$).

The design flow area does not have to be equal to this minimum flow area, but of course it must not be less than this area. It depends on how confident the designer is in the determination of the design discharge and the allowable flow velocity.

Step 7 Choose a trial channel size (depth, y; bed width, b; and flow top width, T) and the required freeboard (refer to Table 1).

Ultimately this may require an iterative process where various channel profiles are tested for hydraulic capacity.

Step 8 Determine the hydraulic radius (R) of the channel (based on flow area, **not** the overall channel dimension, which would include freeboard). Refer to Table A30 in IECA (2008) Appendix A.

Step 9a **If the channel gradient is <u>not</u> set by site conditions, then:**

Determine the channel gradient (S) using Manning's equation.

$$S = (n\,.V)^2/(R)^{4/3} \qquad \text{(S has units of m/m)}$$

Step 9b **If the channel gradient is set by site conditions, then:**

Determine the actual flow velocity (V) and compare this with the allowable flow velocity (V_{allow}).

$$V = (1/n)\,R^{2/3}\,S^{1/2}$$

If $V < V_{allow}$, then accept the design, or repeat Steps 7 & 9 for a smaller channel.

If $V > V_{allow}$, then repeat Steps 7 & 9 selecting a larger channel.

Step 10 Confirm final freeboard requirements given final depth and velocity head (Table 1).

Step 11 Ensure suitable conditions exist (e.g. machinery access) to construct and maintain the channel, otherwise a narrower channel width may be required.

Step 12 Given the final channel depth and velocity, check the required freeboard.

Specify the overall dimensions of the diversion channel, including freeboard.

Step 13 Ensure appropriate, non-erosive, flow conditions exist at the points of flow entry into the channel.

Step 14 Ensure the channel discharges to an appropriate, stable outlet structure.

Step 15 Appropriately consider all likely safety issues, and modify the channel design and/or surrounding environment where required.

Design example:

Design an earth-lined channel of trapezoidal cross-section to carry $0.5m^3/s$ located within a moderately erodible soil.

Step 1 The required design discharge is given as, $Q = 0.5m^3/s$.

Step 2 The question specifies a trapezoidal channel profile.

Step 3 The surface condition has been specified as earth-lined.

Step 4 For a slightly compacted soil (typical for a temporary drain), the maximum bank slope is likely to be around 1.5:1 or 2:1 (from Table 2).

If the drain was going to be deep (say, y > 0.5m) a flatter slope of 3:1 would be desirable for reasons of safety; however, this drain is likely to be relatively shallow, so choose a bank slope of 2:1 (i.e. m = 2).

Warning: 'm' is the term used for both bank slope, and the metric unit of metres!

Step 5 Select a Manning's "n" for an earth lined channel, n = 0.02 from Table A17 of IECA (2008) Appendix A – *Construction site hydrology and hydraulics*.

For a moderately erodible soil, choose a maximum allowable velocity, $V_{allow} = 0.6m/s$ from Table A23 of Appendix A.

Step 6 The minimum required flow area, $A_{min} = Q/V_{allow} = 0.5/0.6 = 0.833m^2$.

Step 7 For this example it will be assumed that the designer has confidence in the determination of the design discharge and the selection of an allowable flow velocity for the given soil conditions. Therefore, a design flow area of $0.84m^2$ is chosen (only slightly greater than the minimum value determined in Step 6).

Choose: $A = 0.84m^2$

Trial flow depth and bed width: Given that maximum depth of the excavated channel may be limited by existing site conditions, a first guess of the channel dimensions can be obtained by adopting one of the following options:

(i) try a <u>flow</u> depth, y = maximum allowable channel depth - 150mm; or

(ii) try a bed width, $b = (A/(1 + m))^{1/2}$

If we choose the latter option, then: $b = \sqrt{\frac{A}{(1+m)}} = \sqrt{\frac{0.84}{(1+2)}} = 0.53m$

For small channels it is good practice to select a bed width equal to the width of a typical excavator bucket. The most common bucket widths are 450, 600 and 900mm. So, for this example a bed width, b = 0.6m will be chosen.

If a flow depth (y) is chosen, then $b = \frac{A}{y} - y(m)$

If a bed width (b) is chosen, then: $y = \frac{\sqrt{(b^2 + 4(m)A)} - b}{2m}$

Thus for this example: $y = \frac{\sqrt{(0.6^2 + 4(2)0.84)} - 0.6}{2(2)} = 0.515m$

Step 8 From Table A30 of Appendix A, the hydraulic radius (R) is given by:

$$R = \frac{y(b + my)}{b + 2y\sqrt{(1+m^2)}} = \frac{0.515(0.6 + (2)0.515)}{0.6 + 2(0.515)\sqrt{(1+2^2)}} = 0.289m$$

Step 9a If its assumed that the channel slope is not governed by existing site conditions (i.e. the designer is free to determine a preferred channel slope), then the desired channel slope can be determined from Manning's equation:

Desired channel slope: $$S = \frac{n^2.V^2}{R^{4/3}} = \frac{(0.02)^2.(0.6)^2}{(0.289)^{4/3}} = 0.00075$$

The above equation provides slope in units or [m/m], thus the channel slope is equivalent to, S = 0.075%.

Step 10 Freeboard requirements will be defined by the greater of:

(i) 150mm

(ii) 10% of channel depth, = 0.1(0.515 + 0.15) = 0.067m, or

(iii) the velocity head ($V^2/2g$) = $(0.6)^2/19.6$ = 0.018m

Therefore, choose a freeboard of 150mm.

Final channel dimension:

Discharge, Q = 0.5m^3/s

Channel slope, S = 0.075%

Bank slope, m = 2 or (2:1) (H:V)

Maximum design flow depth, y = 0.515m

Freeboard = 0.15m

Excavated channel depth = 0.515 + 0.15 = 0.665m

Bed width, b = 0.6m

Top width of excavated channel = 0.6 + 2(2)(0.515 + 0.15) = 3.26m

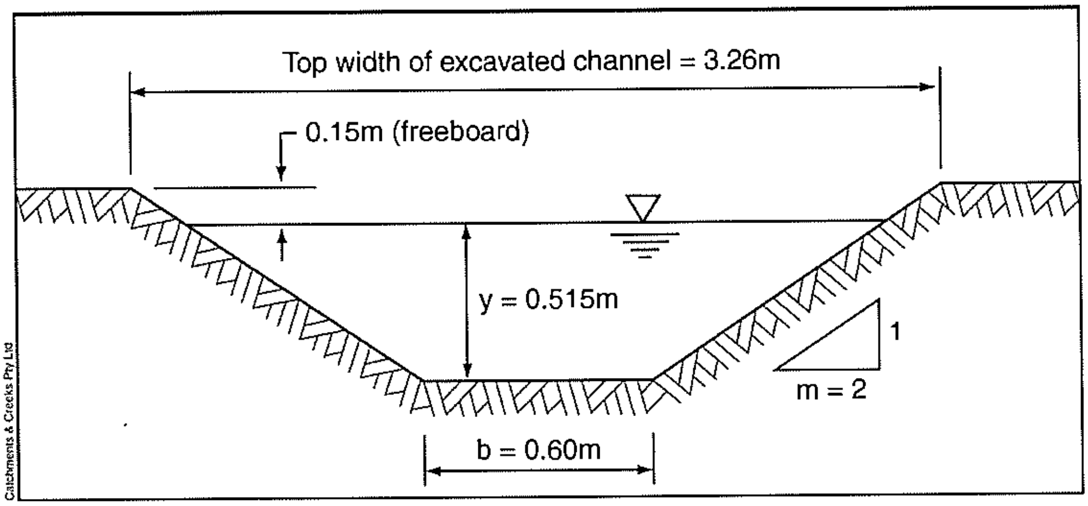


Figure 2 – Final channel dimensions

Description

Diversion channels are formally designed temporary or permanent excavated drainage channels usually with well-defined bed and banks.

Diversion channels are normally stabilised with a healthy and complete coverage of vegetation, primarily consisting of grasses. However, this should not prevent the use of alternative channel lining as appropriate for the site conditions.

Diversion channels can be formed with or without an associated down-slope flow diversion bank. The inclusion of a down-slope bank can significantly increase the hydraulic capacity of the channel.

Purpose

Diversion channels are used to:

- collect and transport stormwater runoff around or through a work site;
- collect sediment laden runoff down-slope of a disturbance and direct it to a sediment trap;
- temporarily divert a existing drainage channel while construction activities are occurring.

Limitations

Channel size and gradient are governed by the allowable flow velocity of the surface material.

Advantages

Low maintenance requirements.

On larger catchments, the cost savings resulting from the diversion of uncontaminated 'clean' flow around a soil disturbance and/or sediment trap can be significant.

Disadvantages

May restrict vehicular movements around the site, possibly requiring the construction of *Temporary Watercourse Crossings* over the channel.

Can cause significant erosion problems and flow concentration if overtopped during heavy storms.

Common Problems

The low channel gradient can cause long-term ponding and mosquito breeding.

Soil erosion at points of water inflow and at the channel outlet.

Special Requirements

The erosion-resistance of the local subsoils should be investigated before planning or designing any drainage channels.

Diversion channels should be vegetated if the expected working life exceeds 30 days. Exception may apply in arid and semi-arid regions.

If the channel is to be vegetated using grass seeding, then the channel should be established well before high flows are expected within the channel.

All diversion channels **must** have a stable outlet.

The channel must have positive gradient along its full length to allow free drainage.

Sufficient space must be provided to allow construction and maintenance access.

Site Inspection

Check that the drain has a stable, positive grade along its length.

Check for a stable drain outlet.

Check if the associated embankment is free of damage (e.g. damage caused by construction traffic).

Check that the drain has adequate hydraulic capacity given the catchment area (general observations based on past experience).

Check for sediment accumulation within the channel.

Check for excessive settlement of any associated fill embankments.

Check the channel lining (if any) for damage or displacement. If *Erosion Control Mats* have been used, check that they are correctly overlapped in direction of flow.

If the channel is lined with rock, check that the rock is not reducing the channel's required hydraulic capacity.

Installation

1. Refer to approved plans for location, extent, and construction 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. Ensure all necessary soil testing (e.g. soil pH, nutrient levels) and analysis has been completed, and required soil adjustments performed prior to planting.
3. Clear the location for the channel, clearing only what is needed to provide access for personnel and construction equipment.
4. Remove roots, stumps, and other debris and dispose of them properly. Do not use debris to build any associated embankments.
5. Excavate the diversion channel to the specified shape, elevation and gradient. The sides of the channel should be no steeper than a 2:1 (H:V) if constructed in earth, unless specifically directed within the approved plans.
6. Stabilise the channel and banks immediately unless it will operate for less than 30 days. In either case, temporary erosion protection (matting, rock, etc.) will be required as specified within the approved plans or as directed.
7. Ensure the channel discharges to a stable area.

Additional requirements for turf placement:

1. Turf should be used within 12 hours of delivery, otherwise ensure the turf is stored in conditions appropriate for the weather conditions (e.g. a shaded area).
2. Moistening the turf after it is unrolled will help maintain its viability.
3. Turf should be laid on a minimum 75mm bed of adequately fertilised topsoil. Rake the soil surface to break the crust just before laying the turf.
4. During the warmer months, lightly irrigate the soil immediately before laying the turf.
5. Ensure the turf is not laid on gravel, heavily compacted soils, or soils that have been recently treated with herbicides.
6. Ensure the turf extends up the sides of the drain at least 100mm above the elevation of the channel invert, or at least to a sufficient elevation to fully contain expected channel flow.
7. On channel gradients of 3:1(H:V) or steeper, or in situations where high flow velocities (i.e. velocity >1.5m/s) are likely within the first two week following placement, secure the individual turf strips with wooden or plastic pegs.
8. Ensure that intimate contact is achieved and maintained between the turf and the soil such that seepage flow beneath the turf is avoided.
9. Water until the soil is wet 100mm below the turf. Thereafter, watering should be sufficient to maintain and promote healthy growth

Maintenance

1. During the site's construction period, inspect the diversion channel weekly and after any increase in flows within the channel. Repair any slumps, wheel track damage or loss of freeboard.
2. Ensure fill material or sediment is not partially blocking the channel. Where necessary, remove any deposited material to allow free drainage.
3. Dispose of any collected sediment or fill in a manner that will not create an erosion or pollution hazard.

Removal

1. When the construction work above a temporary diversion channel is finished and the area is stabilised, the area should be appropriately rehabilitated.
2. Dispose of any collected sediment or fill in a manner that will not create 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.

Catch Drains Part 1: General Information

DRAINAGE CONTROL TECHNIQUE

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

[1] The design of permanent catch drains requires consideration of issues not discussed within this fact sheet, such as maintenance requirements. This fact sheet should not be used for the design of permanent drains.

Symbol ⟶ CD ⟶

Photo 1 – Unlined catch drain

Photo 2 – Large rural catch drain (channel-bank)

Key Principles

1. Catch drains typically have standardised cross-sectional dimensions. Rather than uniquely sizing each catch drain to a given catchment, standard-sized drains are used based on a maximum allowable catchment area for a given rainfall intensity.
2. The **maximum** recommended spacing of catch drains down a slope (Table 3) is based on the aim of avoiding rill erosion within the up-slope drainage slope. It should be noted that the **actual** spacing of catch drains down a given slope may need to be less than the specified maximum spacing if the soils are highly erosive soils, or if rilling begins to occur between two existing drains.
3. The critical design parameters are the spacing of the drains down a slope, the maximum allowable catchment area, the choice of lining material (e.g. earth, turf, rock or erosion control mats), and the required channel gradient.

Design Information

Catch drains are drainage structures, as such, their design (i.e. maximum catchment area and horizontal spacing) must be based on local hydrologic and soil conditions.

Catch drains must have sufficient cross-sectional dimensions to fully contain the design flow with a minimum freeboard of 0.15m. This fact sheet provides design information on three standard parabolic-profile catch drains referred to as Type-A, Type-B and Type-C, and three triangular-profile V-drains; Type-AV, Type-BV and Type-CV.

The minimum dimensions of these catch drains are provided in Tables 1 and 2.

The cross-sectional profile can be parabolic (U-shape), trapezoidal, or triangular (V-drain). Cut slopes (channel banks) should be no steeper than 1.5:1(H:V) and fill slopes (typically associated with a down-slope embankment) no steeper than 2:1 (H:V).

Table 1 – Dimensions of standard parabolic catch drains (Figures 1 & 3)

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain [1]	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-A	1.0m	0.15m	1.6m	0.30m	0.094m	0.100m^2
Type-B	1.8m	0.30m	2.4m	0.45m	0.186m	0.360m^2
Type-C	3.0m	0.50m	3.6m	0.65m	0.310m	1.000m^2

[1] Top width of the formed drain assumes the upper bank slope is limited to a maximum of 2:1.

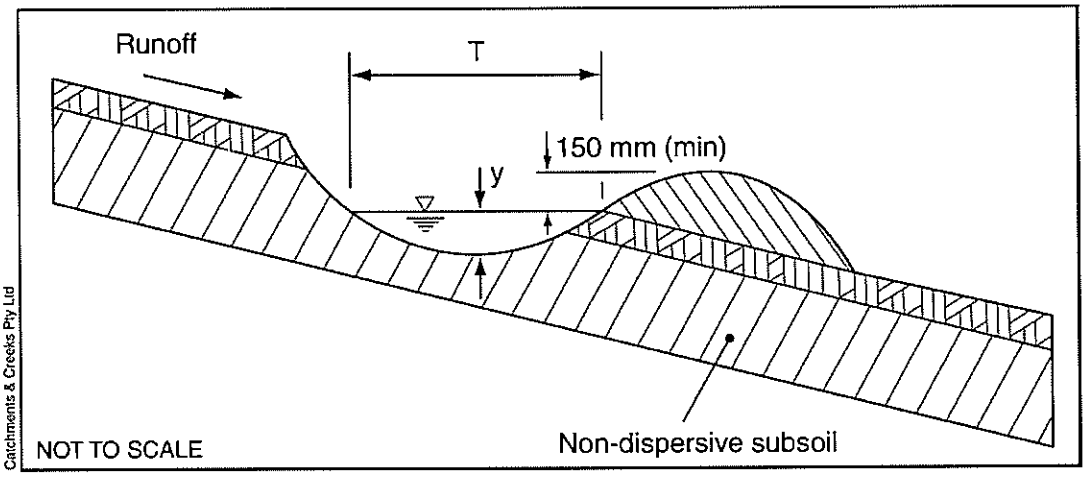


Figure 1 – Parabolic catch drain with bank

Table 2 – Dimensions of standard triangular V-drains (Figure 2)

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-AV	1.0m	0.15m	2.0m	0.30m	0.072m	0.075m^2
Type-BV	1.8m	0.30m	2.7m	0.45m	0.142m	0.270m^2
Type-CV	3.0m	0.50m	3.9m	0.65m	0.237m	0.750m^2

Maximum spacing of catch drains:

Maximum recommended spacing of catch drains down slopes is presented in Table 3. The actual spacing specified for a given site may need to be less than that presented in Table 3 if the soils are highly susceptible to erosion, or if intense storm events are expected (i.e. northern parts of Australia during the wet season).

Table 3 – Maximum recommended spacing of catch drains down slopes

Open Earth Slopes						Vegetated Slopes		
Slope	Horiz.	Vert.	Slope	Horiz.	Vert.	Slope	Horiz.	Vert.
1%	80m	0.9m	15%	19m	2.9m	< 10%	No maximum	
2%	60m	1.2m	20%	16m	3.2m	12%	100m	12m
4%	40m	1.6m	25%	14m	3.5m	15%	80m	12m
6%	32m	1.9m	30%	12m	3.5m	20%	55m	11m
8%	28m	2.2m	35%	10m	3.5m	25%	40m	10m
10%	25m	2.5m	40%	9m	3.5m	30%	30m	9m
12%	22m	2.6m	50%	6m	3.0m	> 36%	Case specific	

Table 4 – Drain profile parameters for catch drains

Parabolic: $y = C_1.T^2$	C_1	V-drain: $y = C_2.T$	C_2
Type-A	0.1500	Type-AV	0.1500
Type-B	0.0926	Type-BV	0.1667
Type-C	0.0556	Type-CV	0.1667

Channel lining:

If high flow velocities are expected, then the drain must be appropriately stabilised with geotextile fabric, *Erosion Control Mats/Mesh*, grass or rock. Alternatively, *Check Dams* can be placed at appropriate intervals to control the flow velocity; however, the impact of these *Check Dams* on the hydraulic capacity of the drain **must** be considered.

Photo 3 – Rock lined catch drain

Photo 4 – Permanent catch drain

Gradient:

The longitudinal gradient of catch drains primarily depends on the allowable flow velocity and Manning's roughness of the drainage channel. Excess channel gradient can initiate undesirable erosion (Photos 5 & 6).

Photo 5 – Upper limit of erosion within a catch drain

Photo 6 – Velocity-induced bed scour within a catch drain

Outlet Structures:

Catch drains must discharge to a stabilised outlet, such as a road, permanent drainage channel, *Chute*, *Slope Drain*, or *Level Spreader*. *Level Spreaders* are used when the flow is to be released as 'sheet' flow.

At the immediate outlet of the catch drain it may be necessary to construct an energy dissipater or rock pad to control soil scour (refer to the Fact Sheet on *Outlet Structures*).

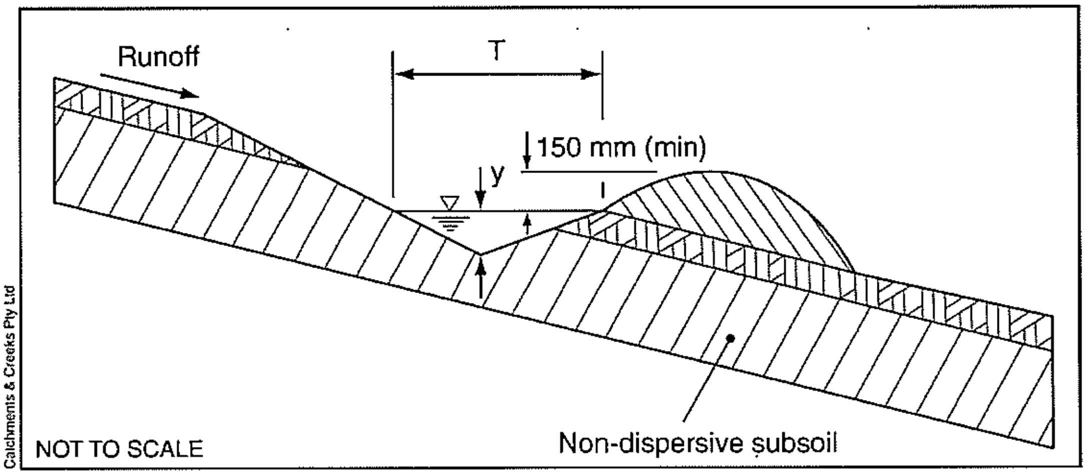


Figure 2 – Triangular V-drain with down-slope bank

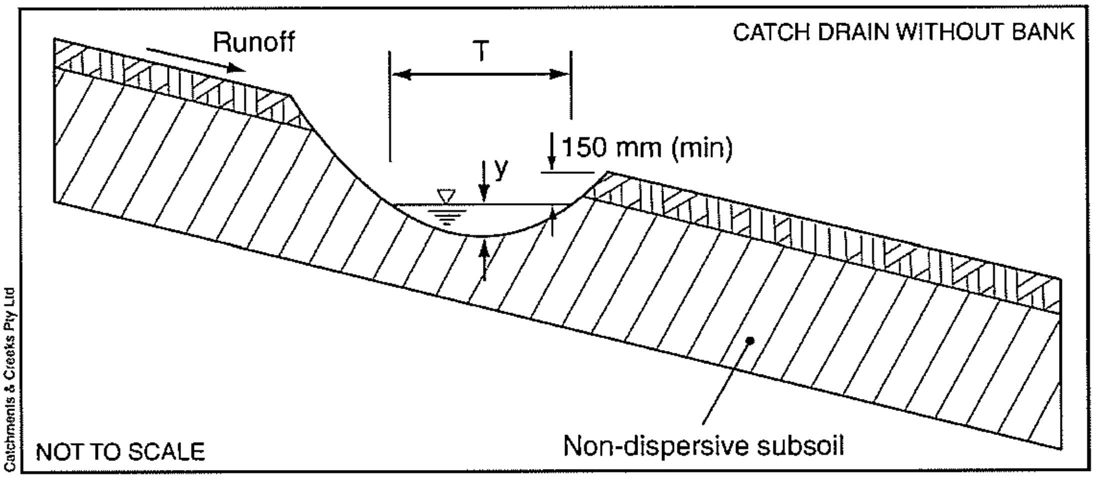


Figure 3 – Parabolic catch drain without bank

Types of drains:

The following provides a brief description of some of the drains used within rural and construction land management.

Berm drain:	A drain formed by a berm located between the top and bottom of a batter.
Catch drain:	A drain adjacent to a batter or embankment.
	Also, the generic term used for all temporary drains on construction sites.
Contour drain:	A drain formed along the contour (zero fall). Such drains act as infiltration trenches, similar (but not the same) as contour furrowing or deep ripping.
Cross drain:	A drain directing surface runoff across a road or track.
Diversion drain:	A drain used to collect and divert water from an adjacent catchment.
Mitre drain:	A drain used to direct road runoff away from the road alignment.
Spoon drain:	A minor drain of semi-circular cross-section and no associated embankment.
Table drain:	A drain that has one bank consisting of the shoulder of a roadway.
Windrow drain:	A drain formed by an earth windrow located along the edge of a road or trail.
Rubble drain:	A sub-surface drain formed by a gravel-filled trench.

Description

Catch drains are small open channels formed at regular intervals down a slope, or immediately up-slope or down-slope of a soil disturbance. They are usually excavated with a grader blade, or U-shaped cutting/excavation tools.

Catch drains can be formed with or without an associated down-slope bank. The inclusion of a down-slope bank significantly increases the hydraulic capacity of the drain; however, these banks are susceptible to damage by vehicles resulting in hydraulic failure of the drain.

Channel-banks (push-down) catch drains are formed by pushing the excavated material down-slope of the drain. These drains should only be used in areas that have good, erosion-resistant subsoils.

'Back-Push' banks are formed by pushing the excavated material up-slope to form a *Flow Diversion Bank*. In such cases the diverted water flows up-slope of the embankment instead of within the excavated trench (refer to the fact sheet on *Flow Diversion Banks*).

Back-push banks are used in preference to catch drains in areas that have highly erosive or dispersible subsoils.

Catch drains are usually significantly smaller than formally designed *Diversion Channels*.

The term 'catch drain' is also used in the stormwater industry to refer to permanent drainage channels placed above cut batters to prevent uncontrolled discharge down the batter.

Purpose

Catch drains can be used to:

- direct stormwater runoff around a soil disturbance, or an unstable slope;
- collect sheet-flow runoff from an unstable slope before it is allowed to concentrate and cause rill erosion;
- collect sediment laden runoff down-slope of a disturbance and direct it to a sediment trap;
- collect and divert up-slope water around stockpiles and excavations.

Limitations

Catch drains are only suitable for relatively small flow rates. For the management of high flow rates a formally designed *Diversion Channel* may be required.

The maximum catchment area depends on the type of drain (i.e. Type A/AV, B/BV or C/CV), and the local hydrologic conditions.

Advantages

Quick and inexpensive to establish, or re-establish if disturbed.

Usually do not require complex formal design if based on standard design tables.

If constructed at appropriate gradients, flow velocities are usually small enough to avoid the need for special channel linings.

Disadvantages

Can cause significant erosion problems and flow concentration if overtopped during heavy storms.

Can restrict the movement of earthmoving equipment around the site, including access to stockpiles. Thus, catch drains may have limited use within active construction areas until earthworks are completed.

Common Problems

Installed at incorrect gradient. If the gradient is too shallow, it causes a reduction in the hydraulic capacity, if too steep it causes an increase in flow velocity.

Damage to associated flow diversion bank (rutting) caused by vehicles.

Catch drains that do not discharge to a stable outlet, causing downstream erosion, or initiating scour within the drain (Photo 5).

Special Requirements

The erosion-resistance of the local subsoils should be investigated before planning or designing any excavated drains.

Straw bales or other sediment traps should **not** be placed within these drains due to the risk of causing surcharging of the drain.

Catch drains need to be appropriately stabilised (e.g. compacted and/or lined with a suitable channel lining) within a specified period from the time of construction.

Catch drain should drain to a suitable sediment trap if the diverted water is expected to contain sediment. 'Clean' water should divert around sediment traps.

The drain must have positive gradient along its full length to allow free drainage.

Sufficient space must be provided to allow maintenance access.

Location

Typically used up-slope of cut batters, intermittently down long, exposed slopes, and up-slope of those stockpiles located within overland flow paths.

Catch drains are generally required up-slope of all cut and fill batters with a height greater than 2 metres and where run-on water is expected.

Site Inspection

Check that the drain has a stable, positive grade along its length.

Check for a stable drain outlet.

Check if the associated embankment is free of damage (e.g. damage caused by construction traffic).

Check that the drain has adequate hydraulic capacity given the catchment area (general observations based on past experience).

Check if rill erosion is occurring within the catchment area up-slope of the drain. If rilling is occurring, then the lateral spacing of the drains will need to be reduced. However, some degree of rill erosion should be expected if recent storms exceeded the intensity of the nominated design storm.

Inspect for evidence of water spilling out (overtopping) of the drain, or erosion down-slope of the drain.

Inspect for erosion along the bed (invert) of the drain. Investigate the reasons for any erosion before recommending solutions. Bed erosion can result from either excessive channel velocities, or an unstable outlet, which causes bed erosion (head-cut) to migrate up the channel.

Possible solutions to channel erosion include:

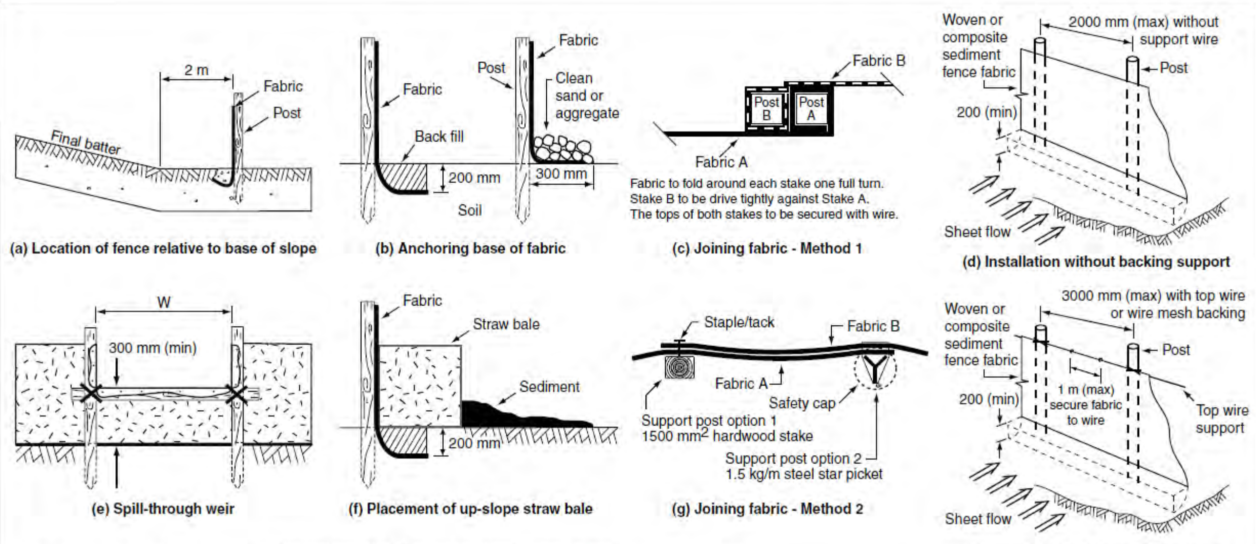
- reduce effective catchment area;
- increase channel width;
- increase channel roughness;
- stabilise bed with mats or mesh;
- stabilise bed with turf or rock;
- stabilise the outlet.

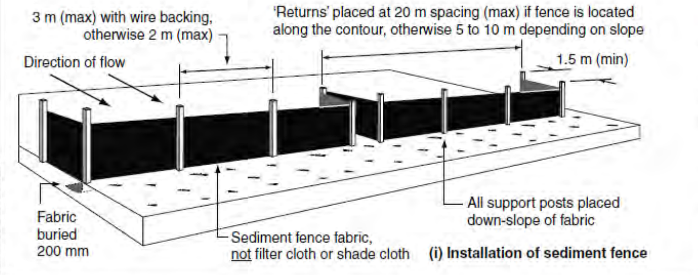
Check the channel lining (if any) for damage or displacement. If *Erosion Control Mats* have been used, check that they are correctly overlapped in direction of flow.

If the drain is lined with rock, check that the rock is not reducing the drain's required hydraulic capacity.

Appendix 2

Sediment Fence Detail





Notes:

1. Sediment fence to be installed along a line of constant ground elevation wherever practical.
2. Both end of the sediment fence to extend up the slope at least 1m.
3. Support post to be spaced a maximum 2m unless the fence is supported by a top wire or wire mesh backing, in which case 3m maximum spacing.
4. Fence 'returns' shall be installed at maximum 20m spacing if fence is installed along the contour, otherwise 5 to 10m maximum spacing.
5. Minimum 4 staples or tie wires per stake.

Drawn:	Date:		
GMW	Dec-09	Sediment Fence	SF-01

MATERIALS

FABRIC: POLYPROPYLENE, POLYAMIDE, NYLON, POLYESTER, OR POLYETHYLENE WOVEN OR NON-WOVEN FABRIC, AT LEAST 700mm IN WIDTH AND A MINIMUM UNIT WEIGHT OF 140GSM. ALL FABRICS TO CONTAIN ULTRAVIOLET INHIBITORS AND STABILISERS TO PROVIDE A MINIMUM OF 6 MONTHS OF USEABLE CONSTRUCTION LIFE (ULTRAVIOLET STABILITY EXCEEDING 70%).

FABRIC REINFORCEMENT: WIRE OR STEEL MESH MINIMUM 14-GAUGE WITH A MAXIMUM MESH SPACING OF 200mm.

SUPPORT POSTS/STAKES: 1500mm^2 (MIN) HARDWOOD, 2500mm^2 (MIN) SOFTWOOD, OR 1.5kg/m (MIN) STEEL STAR PICKETS SUITABLE FOR ATTACHING FABRIC.

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND REQUIRED TYPE OF FABRIC (IF SPECIFIED). IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, FABRIC TYPE, OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. TO THE MAXIMUM DEGREE PRACTICAL, AND WHERE THE PLANS ALLOW, ENSURE THE FENCE IS LOCATED:
(i) TOTALLY WITHIN THE PROPERTY BOUNDARIES;
(ii) ALONG A LINE OF CONSTANT ELEVATION WHEREVER PRACTICAL;
(iii) AT LEAST 2m FROM THE TOE OF ANY FILLING OPERATIONS THAT MAY RESULT IN SHIFTING SOIL/FILL DAMAGING THE FENCE.

3. INSTALL RETURNS WITHIN THE FENCE AT MAXIMUM 20m INTERVALS IF THE FENCE IS INSTALLED ALONG THE CONTOUR, OR 5 TO 10m MAXIMUM SPACING (DEPENDING ON SLOPE) IF THE FENCE IS INSTALLED AT AN ANGLE TO THE CONTOUR. THE 'RETURNS' SHALL CONSIST OF EITHER:
(i) V-SHAPED SECTION EXTENDING AT LEAST 1.5m UP THE SLOPE; OR
(ii) SANDBAG OR ROCK/AGGREGATE CHECK DAM A MINIMUM 1/3 AND MAXIMUM 1/2 FENCE HEIGHT, AND EXTENDING AT LEAST 1.5m UP THE SLOPE.

4. ENSURE THE EXTREME ENDS OF THE FENCE ARE TURNED UP THE SLOPE AT LEAST 1.5m, OR AS NECESSARY, TO MINIMISE WATER BYPASSING AROUND THE FENCE.

5. ENSURE THE SEDIMENT FENCE IS INSTALLED IN A MANNER THAT AVOIDS THE CONCENTRATION OF FLOW ALONG THE FENCE, AND THE UNDESIRABLE DISCHARGE OF WATER AROUND THE ENDS OF THE FENCE.

6. IF THE SEDIMENT FENCE IS TO BE INSTALLED ALONG THE EDGE OF EXISTING TREES, ENSURE CARE IS TAKEN TO PROTECT THE TREES AND THEIR ROOT SYSTEMS DURING INSTALLATION OF THE FENCE. DO NOT ATTACH THE FABRIC TO THE TREES.

7. UNLESS DIRECTED BY THE SITE SUPERVISOR OR THE APPROVED PLANS, EXCAVATE A 200mm WIDE BY 200mm DEEP TRENCH ALONG THE PROPOSED FENCE LINE, PLACING THE EXCAVATED MATERIAL ON THE UP-SLOPE SIDE OF THE TRENCH.

8. ALONG THE LOWER SIDE OF THE TRENCH, APPROPRIATELY SECURE THE STAKES INTO THE GROUND SPACED NO GREATER THAN 3m IF SUPPORTED BY A TOP SUPPORT WIRE OR WEIR MESH BACKING, OTHERWISE NO GREATER THAN 2m.

9. IF SPECIFIED, SECURELY ATTACH THE SUPPORT WIRE OR MESH TO THE UP-SLOPE SIDE OF THE STAKES WITH THE MESH EXTENDING AT LEAST 200mm INTO THE EXCAVATED TRENCH. ENSURE THE MESH AND FABRIC IS ATTACHED TO THE UP-SLOPE SIDE OF THE STAKES EVEN WHEN DIRECTING A FENCE AROUND A CORNER OR SHARP CHANGE OF DIRECTION.

10. WHEREVER POSSIBLE, CONSTRUCT THE SEDIMENT FENCE FROM A CONTINUOUS ROLL OF FABRIC. TO JOIN FABRIC EITHER:
(i) ATTACH EACH END TO TWO OVERLAPPING STAKES WITH THE FABRIC FOLDING AROUND THE ASSOCIATED STAKE ONE TURN, AND WITH THE TWO STAKES TIED TOGETHER WITH WIRE; OR
(ii) OVERLAP THE FABRIC TO THE NEXT ADJACENT SUPPORT POST.

11. SECURELY ATTACH THE FABRIC TO THE SUPPORT POSTS USING 25 X 12.5mm STAPLES, OR TIE WIRE AT MAXIMUM 150mm SPACING.

12. SECURELY ATTACH THE FABRIC TO THE SUPPORT WIRE/MESH (IF ANY) AT A MAXIMUM SPACING OF 1m.

13. ENSURE THE COMPLETED SEDIMENT FENCE IS AT LEAST 450mm, BUT NOT MORE THAN 700mm HIGH. IF A SPILL-THOUGH WEIR IS INSTALLED, ENSURE THE CREST OF THE WEIR IS AT LEAST 300mm ABOVE GROUND LEVEL.

14. BACKFILL THE TRENCH AND TAMP THE FILL TO FIRMLY ANCHOR THE BOTTOM OF THE FABRIC AND MESH TO PREVENT WATER FROM FLOWING UNDER THE FENCE.

ADDITIONAL REQUIREMENTS FOR THE INSTALLATION OF A SPILL-THROUGH WEIR

1. LOCATE THE SPILL-THROUGH WEIR SUCH THAT THE WEIR CREST WILL BE LOWER THAN THE GROUND LEVEL AT EACH END OF THE FENCE.

2. ENSURE THE CREST OF THE SPILL-THROUGH WEIR IS AT LEAST 300mm THE GROUND ELEVATION.

3. SECURELY TIE A HORIZONTAL CROSS MEMBER (WEIR) TO THE SUPPORT POSTS/ STAKES EACH SIDE OF THE WEIR. CUT THE FABRIC DOWN THE SIDE OF EACH POST AND FOLD THE FABRIC OVER THE CROSS MEMBER AND APPROPRIATELY SECURE THE FABRIC.

4. INSTALL A SUITABLE SPLASH PAD AND/OR CHUTE IMMEDIATELY DOWN-SLOPE OF THE SPILL-THROUGH WEIR TO CONTROL SOIL EROSION AND APPROPRIATELY DISCHARGE THE CONCENTRATED FLOW PASSING OVER THE WEIR.

MAINTENANCE

1. INSPECT THE SEDIMENT FENCE AT LEAST WEEKLY AND AFTER ANY SIGNIFICANT RAIN. MAKE NECESSARY REPAIRS IMMEDIATELY.

2. REPAIR ANY TORN SECTIONS WITH A CONTINUOUS PIECE OF FABRIC FROM POST TO POST.

3. WHEN MAKING REPAIRS, ALWAYS RESTORE THE SYSTEM TO ITS ORIGINAL CONFIGURATION UNLESS AN AMENDED LAYOUT IS REQUIRED OR SPECIFIED.

4. IF THE FENCE IS SAGGING BETWEEN STAKES, INSTALL ADDITIONAL SUPPORT POSTS.

5. REMOVE ACCUMULATED SEDIMENT IF THE SEDIMENT DEPOSIT EXCEEDS A DEPTH OF 1/3 THE HEIGHT OF THE FENCE.

6. DISPOSE OF SEDIMENT IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

7. REPLACE THE FABRIC IF THE SERVICE LIFE OF THE EXISTING FABRIC EXCEEDS 6-MONTHS.

REMOVAL

1. WHEN DISTURBED AREAS UP-SLOPE OF THE SEDIMENT FENCE ARE SUFFICIENTLY STABILISED TO RESTRAIN EROSION, THE FENCE MUST BE REMOVED.

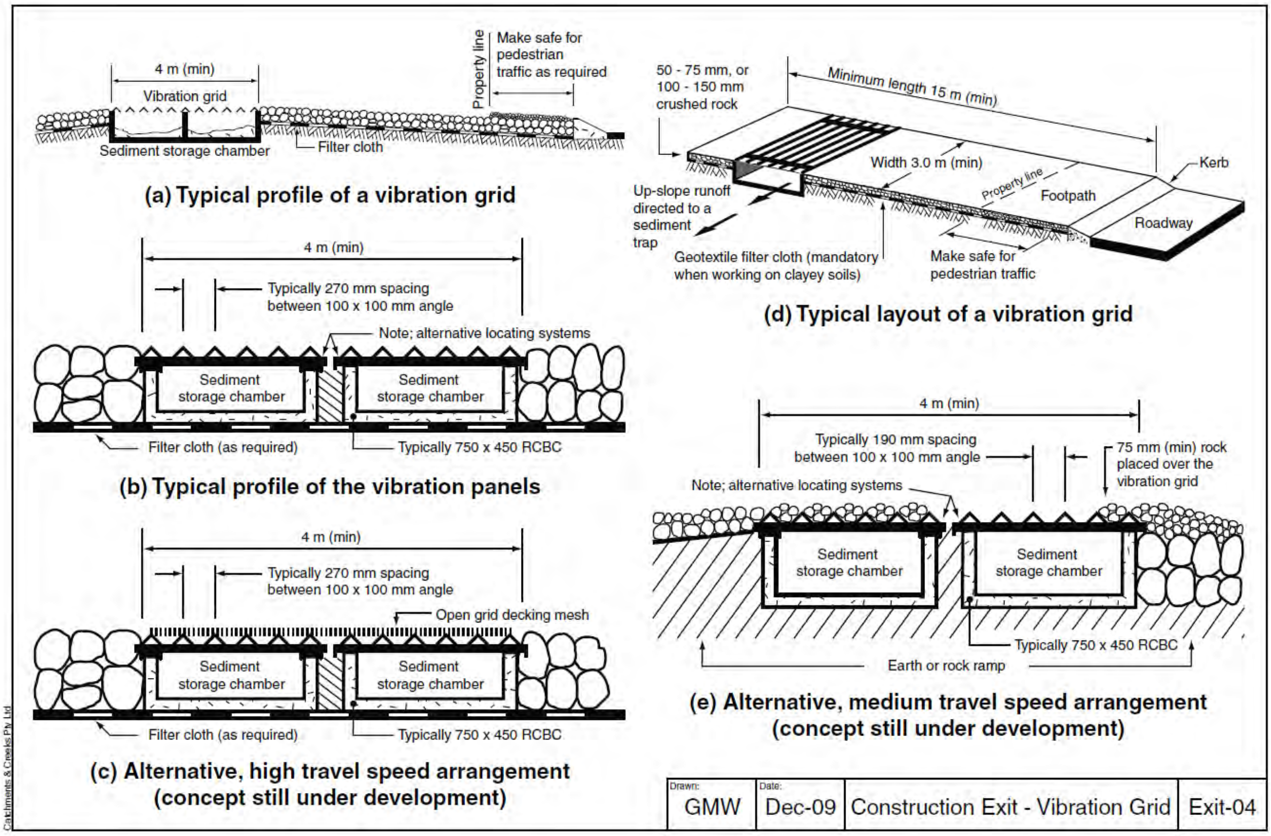
2. REMOVE MATERIALS AND COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. REHABILITATE/REVEGETATE THE DISTURBED GROUND AS NECESSARY TO MINIMISE THE EROSION HAZARD.

Drawn:	Date:		
GMW	Apr-10	Sediment Fence	SF-02

Appendix 3

Entry/Exit Detail



MATERIALS

ROCK: WELL GRADED, HARD, ANGULAR, EROSION RESISTANT ROCK, NOMINAL DIAMETER OF 50 TO 75mm (SMALL DISTURBANCES) OR 100 TO 150mm (LARGE DISTURBANCES). ALL REASONABLE MEASURES MUST BE TAKEN TO OBTAIN ROCK OF NEAR UNIFORM SIZE.

FOOTPATH STABILISING AGGREGATE: 25 TO 50mm GRAVEL OR AGGREGATE.

GEOTEXTILE FABRIC: HEAVY-DUTY, NEEDLE-PUNCHED, NON-WOVEN FILTER CLOTH ('BIDIM' A24 OR EQUIVALENT).

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION AND DIMENSIONAL DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, DIMENSIONS, OR METHOD OF INSTALLATION, CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. CLEAR THE LOCATION OF THE VIBRATION GRID, REMOVING STUMPS, ROOTS AND OTHER VEGETATION TO PROVIDE A FIRM FOUNDATION SO THAT THE ROCK IS NOT PRESSED INTO SOFT GROUND. CLEAR SUFFICIENT WIDTH TO ALLOW PASSAGE OF LARGE VEHICLES, BUT CLEAR ONLY THAT NECESSARY FOR THE EXIT. DO NOT CLEAR ADJACENT AREAS UNTIL THE REQUIRED EROSION AND SEDIMENT CONTROL DEVICES ARE IN PLACE.

3. GRADE THE LOCATION OF THE VIBRATION GRID SO THAT RUNOFF FROM THE UNIT WILL NOT FLOW INTO THE STREET, BUT WILL FLOW TOWARDS AN APPROPRIATE SEDIMENT-TRAPPING DEVICE.

4. ENSURE THAT THE INSTALLATION OF THE VIBRATION GRID HAS ADEQUATE SEDIMENT STORAGE VOLUME UNDER THE GRID. WHERE NECESSARY, INSTALL SUITABLE PRECAST SEDIMENT COLLECTION CHAMBERS.

5. PLACE A ROCK PAD/RAMP FORMING A MINIMUM 200mm THICK LAYER OF CLEAN, OPEN-VOID ROCK OVER THE ROADWAY BETWEEN THE VIBRATION GRID AND THE SEALED STREET TO PREVENT TYRES FROM PICKING UP MORE SOIL AFTER THEY HAVE BEEN CLEANED.

6. THE TOTAL LENGTH OF THE VIBRATION GRID AND ROCK RAMPS SHOULD BE AT LEAST 15m WHERE PRACTICABLE, AND AS WIDE AS THE FULL WIDTH OF THE ENTRY OR EXIT AND AT LEAST 3m. THE ROCK RAMP SHOULD COMMENCE AT THE EDGE OF THE OFF-SITE SEALED ROAD OR PAVEMENT.

7. FLARE THE END OF THE ROCK PAD WHERE IT MEETS THE PAVEMENT SO THAT THE WHEELS OF TURNING VEHICLES DO NOT TRAVEL OVER UNPROTECTED SOIL.

8. IF THE FOOTPATH IS OPEN TO PEDESTRIAN MOVEMENT, THEN COVER THE COARSE ROCK WITH FINE AGGREGATE OR GRAVEL, OR OTHERWISE TAKE WHATEVER MEASURES ARE NEEDED TO MAKE THE AREA SAFE

MAINTENANCE

1. INSPECT VIBRATION GRID PRIOR TO FORECAST RAIN, DAILY DURING EXTENDED PERIODS OF RAINFALL, AFTER SIGNIFICANT RUNOFF-PRODUCING RAINFALL, OR OTHERWISE AT FORTNIGHTLY INTERVALS.

2. IF SAND, SOIL, SEDIMENT OR MUD IS TRACKED OR WASHED ONTO THE ADJACENT SEALED ROADWAY, THEN SUCH MATERIAL MUST BE PHYSICALLY REMOVED, FIRST USING A SQUARE-EDGED SHOVEL, AND THEN A STIFF-BRISTLED BROOM, AND THEN BY A MECHANICAL VACUUM UNIT, IF AVAILABLE.

3. IF NECESSARY FOR SAFETY REASONS, THE ROADWAY SHALL ONLY BE WASHED CLEAN AFTER ALL REASONABLE EFFORTS HAVE BEEN TAKEN TO SHOVEL AND SWEEP THE MATERIAL FROM THE ROADWAY.

4. WHEN THE VOIDS BETWEEN THE ROCK BECOMES FILLED WITH MATERIAL AND THE EFFECTIVENESS OF THE ROCK RAMPS ARE REDUCED TO A POINT WHERE SEDIMENT IS BEING TRACKED OFF THE SITE, A NEW 100mm LAYER OF ROCK MUST BE ADDED AND/OR THE ROCK PAD MUST BE EXTENDED.

5. ENSURE ANY ASSOCIATED DRAINAGE CONTROL MEASURES ARE MAINTAINED IN ACCORDANCE WITH THEIR DESIRED OPERATIONAL CONDITION.

6. DISPOSE OF SEDIMENT AND DEBRIS IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

REMOVAL

1. THE VIBRATION GRID SHOULD BE REMOVED ONLY AFTER IT IS NO LONGER NEEDED AS A SEDIMENT CONTROL DEVICE.

2. REMOVE MATERIALS AND COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. RE-GRADE AND STABILISE THE DISTURBED GROUND AS NECESSARY TO MINIMISE THE EROSION HAZARD.

Drawn:	Date:		
GMW	Apr-10	Construction Exit - Vibration Grid	Exit-05

Appendix 4

Field Data Sheet

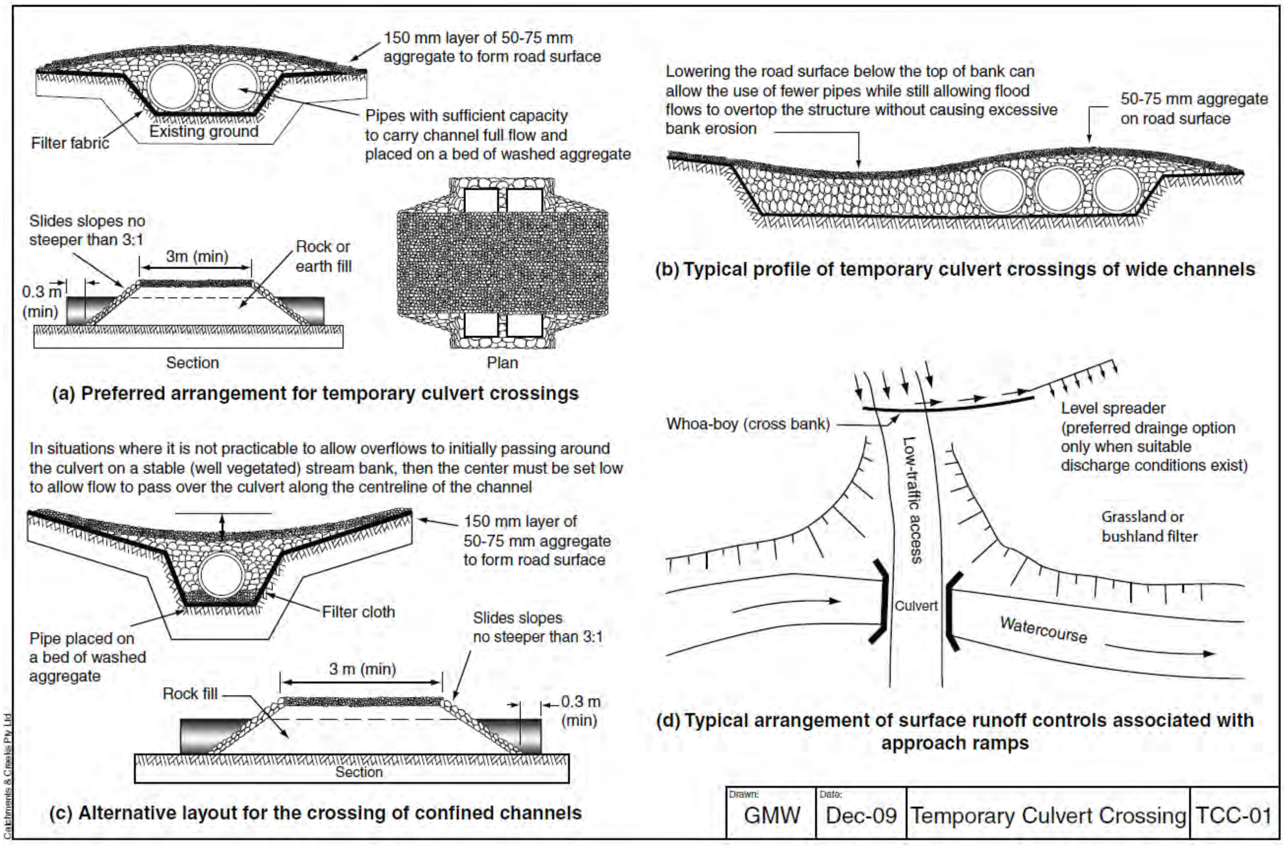
RATCH **Mt Emerald Windfarm**

Sampler Name :		Weather:	
Date:		Comments:	

Parameter	SW1 (downstream)	SW2	SW3	SW4	SW5 (upstream)
pH					
ORP (mv)					
DO % sat					
DO mg/L					
Turbidity (ntu)					
Temp					
EC (us/cm)					
Salinity (ppt)					
Sample taken?					
Comments:					

Appendix 5

Temporary Culvert Crossing Detail



MATERIALS

CULVERTS: ANY COMMERCIAL CONDUIT THAT IS SUITABLE FOR THE REQUIRED TRAFFIC LOADING.

ROCK: MINIMUM 150mm NOMINAL ROCK SIZE.

AGGREGATE: 50–75mm CLEAN AGGREGATE.

GEOTEXTILE FABRIC: HEAVY-DUTY, NEEDLE-PUNCHED, NON-WOVEN FILTER CLOTH (MINIMUM BIDIM A34 OR EQUIVALENT).

INSTALLATION

1. PRIOR TO COMMENCING ANY WORKS, OBTAIN ALL NECESSARY APPROVALS AND PERMITS REQUIRED TO CONSTRUCT THE TEMPORARY WATERCOURSE CROSSING, INCLUDING PERMITS FOR THE DISTURBANCE OF BANK VEGETATION, AQUATIC VEGETATION (e.g. MANGROVES) AND ANY TEMPORARY INSTREAM FLOW DIVERSION BARRIERS OR SEDIMENT CONTROL MEASURES.

2. REFER TO APPROVED PLANS FOR LOCATION AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION OR METHOD OF INSTALLATION, CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

3. ENSURE THAT THE LOCATION OF THE CROSSING WILL NOT INTERFERE WITH FUTURE CONSTRUCTION WORKS.

4. PRIOR TO SIGNIFICANT LAND CLEARING OR CONSTRUCTION OF THE APPROACH RAMPS, ESTABLISH ALL NECESSARY SEDIMENT CONTROL MEASURES AND FLOW DIVERSION WORKS (INSTREAM AND OFF-STREAM AS REQUIRED), CLEARING ONLY THOSE AREAS NECESSARY FOR INSTALLATION OF THESE MEASURES.

5. TO THE MAXIMUM DEGREE PRACTICABLE, CONSTRUCTION ACTIVITIES AND EQUIPMENT MUST NOT OPERATE WITHIN OPEN FLOWING WATERS.

6. MAINTAIN CLEARING AND EXCAVATION OF THE WATERCOURSE BED AND BANKS TO A MINIMUM. INITIALLY CLEAR ONLY THE AREA NECESSARY TO ALLOW ACCESS FOR CONSTRUCTION. CLEAR THE REMAINDER OF THE APPROACH RAMPS ONLY WHEN ADEQUATE DRAINAGE AND SEDIMENT CONTROLS ARE IN PLACE.

7. IF FLOW DIVERSION SYSTEMS CANNOT BE INSTALLED, THEN CONDUCT BANK EXCAVATIONS BY PULLING THE SOIL AWAY FROM THE CHANNEL.

8. WHERE PRACTICABLE, CONSTRUCT THE WATERCOURSE CROSSING PERPENDICULAR TO THE CHANNEL.

9. WHERE PRACTICABLE, THE APPROACH RAMPS SHOULD BE STRAIGHT FOR AT LEAST 10m AND SHOULD BE ALIGNED WITH THE CROSSING.

10. WHERE PRACTICABLE, DIRECT STORMWATER RUNOFF FROM THE APPROACH RAMPS INTO STABLE DRAINS, ADJACENT VEGETATION, OR APPROPRIATE SEDIMENT TRAPS TO MINIMISE THE RELEASE OF SEDIMENT INTO THE WATERCOURSE.

11. SHAPE THE CHANNEL, IF NECESSARY, TO RECEIVE THE PIPE/S.

12. IF HIGHLY EROSIVE SOILS ARE DETECTED, THEN APPROPRIATELY STABILISE SUCH SOILS AS SOON AS PRACTICABLE.

13. COVER THE CROSSING FOOTING WITH HEAVY-DUTY FILTER CLOTH.

14. COVER THE FILTER CLOTH WITH A MINIMUM 150mm OF CLEAN, 50 TO 75mm AGGREGATE.

15. PLACE THE SPECIFIED SIZE AND NUMBER OF CULVERT CELLS AND ALIGN THEM WITH THE DIRECTION OF THE DOWNSTREAM CHANNEL.

16. ENSURE THE PIPES EXTEND AT LEAST 300mm BEYOND THE PROPOSED EXTEND OF ROCK FILL.

17. FILL BETWEEN THE PIPE/S WITH 75 TO 100mm AGGREGATE.

18. COVER PIPE/S WITH SUFFICIENT ROCK (MINIMUM 300mm LAYER) TO SATISFY MANUFACTURER'S LOADING REQUIREMENTS TO AVOID DAMAGE TO THE PIPE/S RESULTING FROM THE EXPECTED TRAFFIC LOAD. SLOPE OF ROCK FACE UPSTREAM AND DOWNSTREAM OF THE CULVERT NO STEEPER THAN 3:1 (H:V).

19. FORM THE SHAPE OF THE ROAD SURFACE IN ACCORDANCE WITH THE PLANS AND/OR STANDARD DRAWINGS.

20. APPLY A SUITABLE COVER OF AGGREGATE OVER THE ROCK FILL TO FORM THE TRAFFICABLE ROAD SURFACE.

21. FINISH CONSTRUCTION AND STABILISATION OF THE APPROACH ROADS INCLUDING THE APPROACH RAMPS EACH SIDE OF THE BRIDGE CROSSING.

22. TAKE ALL REASONABLE MEASURES TO PREVENT EXCESS ROCK, DEBRIS AND CONSTRUCTION MATERIAL FROM ENTERING THE WATERCOURSE, ESPECIALLY ANY STILL OR FLOWING WATER.

23. IF IT IS NOT PRACTICABLE TO STABILISE THE ACCESS RAMPS AGAINST EROSION, THEN INSTALL FLOW DIVERSION BANKS ACROSS THE WIDTH OF EACH ACCESS RAMP ADJACENT THE TOP OF THE CHANNEL BANK, AND AT REGULAR INTERVALS DOWN THE RAMPS (AS REQUIRED) TO PREVENT OR MINIMISE SEDIMENT-LADEN RUNOFF FLOWING DIRECTLY INTO THE WATERCOURSE.

24. APPROPRIATELY STABILISE ANY DISTURBED WATERCOURSE BANKS.

25. STABILISE ALL DISTURBED AREAS THAT ARE LIKELY TO BE SUBJECTED TO FLOWING WATER, INCLUDING BYPASS AND OVERFLOW AREAS, WITH ROCK OR OTHER SUITABLE MATERIALS.

MAINTENANCE

1. TEMPORARY WATERCOURSE CROSSINGS SHOULD BE INSPECTED WEEKLY AND AFTER ANY SIGNIFICANT CHANGE IN STREAM FLOW.

2. DEBRIS TRAPPED ON OR UPSTREAM OF THE CROSSING SHOULD BE REMOVED.

3. REPAIR ANY DAMAGE CAUSED BY CONSTRUCTION TRAFFIC. IF TRAFFIC HAS EXPOSED BARE SOIL, STABILISED AS APPROPRIATE. MAINTAIN A MINIMUM 200mm COVER OVER THE CULVERTS.

4. CHECK FOR EROSION OF THE FORMED EMBANKMENT, CHANNEL SCOUR, OR ROCK DISPLACEMENT. MAKE ALL NECESSARY REPAIRS IMMEDIATELY.

5. CHECK THE BYPASS FLOODWAY MAKING SURE THE BANKS ARE STABLE.

6. CHECK FOR EXCESSIVE EROSION ON THE APPROACH ROADS.

7. CHECK THE CONDITIONS OF ANY FLOW DIVERSION CHANNELS/BANKS AND THE OPERATING CONDITIONS OF ASSOCIATED SEDIMENT TRAPS.

REMOVAL

1. TEMPORARY WATERCOURSE CROSSINGS SHOULD BE REMOVED AS SOON AS POSSIBLE AFTER ALTERNATIVE ACCESS IS ACHIEVED OR THE CULVERT IS NO LONGER NEEDED.

2. REMOVE ALL SPECIFIED MATERIALS AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. RESTORE THE WATERCOURSE CHANNEL TO ITS ORIGINAL CROSS-SECTION, AND SMOOTH AND APPROPRIATELY STABILISE AND REVEGETATE ALL DISTURBED AREAS.

Drawn:	Date:		
GMW	Dec-09	Temporary Culvert Crossing	TCC-02