Erosion and Sediment Control Guidelines for the Cook Islands

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Tonkin+Taylor

Preface – Purpose and scope of this document

This document provides technical guidance for erosion and sediment control (ESC) measures for earthwork activities in a Cook Island context. Earthwork activities covered in this document comprise:

- Vegetation removal and subsequent soil/ground disturbance for residential, commercial and infrastructure developments (including roads, utility trenches); and
- Earthworks associated with permitted Quarrying and Sand mining activities, such as overburden excavation and disposal.

The intended audience of this document are designers, contractors and other implementers who are responsible for operating and maintaining ESC measures for earthworks. This document also provides useful information for:

- Developers and designers, in planning of works which may have sediment impacts to the environment; and
- Regulatory officers, who assess and approve earth working activities where sediment impacts to the environment need to be managed.

Links and references to relevant technical resources are compiled in Section 6.

Terminology

Terminology and acronyms used in this document are set out below. The first use of these terms and acronyms are highlighted bold in the subsequent sections.

Clean water	Water that is free of sediment or pollutants. In the ESC context, this typically is the water from above a work site that has not run through the works area. This water could be in contained in streams or channels, or stormwater runon.
Construction staging	Earthworks are undertake (or staged) over smaller areas in a site, with progressive revegetation to limit erosion
Decanting earth bund (DEB)	An area to temporarily store water, formed from a temporary bund or ridge of compacted earth. The bund provides an area where dirty water runoff can be ponded, and suspended sediment can settle out before runoff is discharged.
Dirty water	Water that contains soil/sediment, and is typically discoloured. In the ESC context this usually water that requires treatment prior to discharge.
Discharge or Discharge point	The point where water (either clean or dirty) leaves the boundary of a site, and enters into streams, channels or ground beyond the boundary.
Erosion	The process of wearing away the land surface by running water, wind and/or ice.
ESC	Erosion and Sediment Control
ESC Designer	The author of the Erosion and Sediment Control Plan
ESCP	Erosion and Sediment Control Plan. Best practise would be to have this plan approved by a permitting authority prior to Works commencing
Receiving waters	A natural water body or drainage feature that receives the site discharge
Runoff	Surface flow of water that occurs when precipitation occurs (primarily rain).
Runon	Surface flow of water that enters into a site boundary
Sediment control structures	Constructed ESC measures (e.g. DEB, SRP) that installed, monitored and maintained for the purpose of capturing eroded sediment
Sedimentation	The process where sediment particles enter and move through the water column, typically accumulating at the bottom
Silt fence	A temporary barrier of woven geotextile fabric that is used to capture mainly coarse sediments carried in sheet flow runoff. Silt fences provides impoundment and allows sediment to settle out of the water.
Site	The extent and boundary of Works that is addressed by the ESCP
Site erodiability	The amount of sediment generated by a site (with or without erosion controls). This depends on the erodibility of the soil, the energy of the rainfall and the site conditions (vegetation cover, slope, amount of earthworks)
Stabilised entrance	AA protected entry or exit point of a construction site. These points are typically stabilised through measures such large rocks and are designed to prevent site access points becoming sources of sediment, and/or assist in minimising dust generation and disturbance of areas adjacent to the road frontage by providing a defined entry and exit point.
Treatment	The practise of constructing structural measures for sediment removal from water.
Works	Activities requiring ESC practises. This typically comprises construction activities that remove vegetation to expose erodible soil, and/or disturbs the underlying soil

1. Why is erosion and sediment control important

The Cook Islands has experienced an increase in land use and development, resulting in more construction earthworks being permitted and carried out.

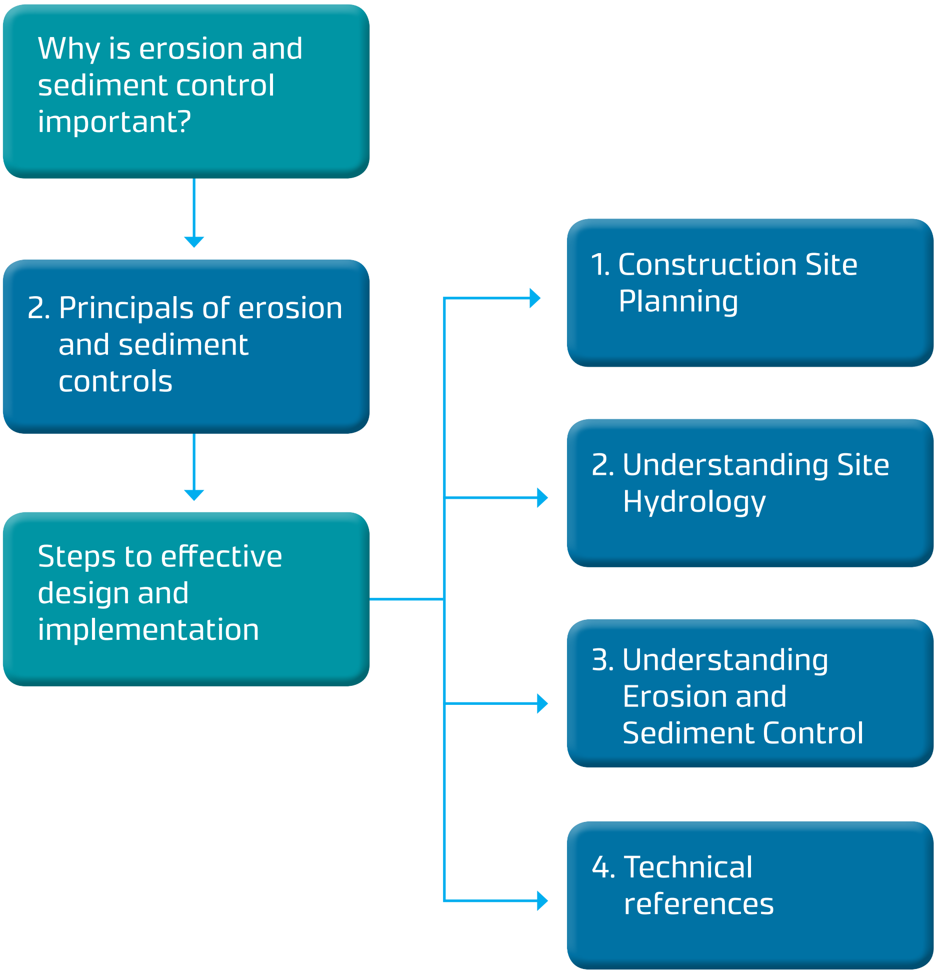
Without measures to minimise erosion, the impact on fresh water and coastal environments can be significant.

Environmental effects associated with sediment release have been documented both globally, and for the Cook Islands. They include:

- Build-up of sediment in the stream bed
- Alteration of aquatic habitats (e.g. smothering spawning areas, changing light penetration, temperature change)
- Accumulation of pollutants transported by sediments (e.g. hydrocarbons, agricultural nutrients and toxic substances)
- Blocking water flows, increasing susceptibility to flooding and consequent damage to property
- Effects on water quality used for irrigation, stock and domestic water supplies (e.g. clogging of pumps, filters and sprinkle nozzles, increased water treatment required)
- Reduced appearance of water for recreational use (e.g. swimming, fishing)
- Physical changes to the stream channel and banks.

This document set outs a systematic approach for designing and implementing Erosion and Sediment Control (ESC).,The intention of effective ESC is to minimise erosion and the subsequent amount of sediment discharged from Works, which generate sediment. This document has been structured as follows:

Diagram 1.1: Document flowchart



2. Principles of erosion and sediment controls

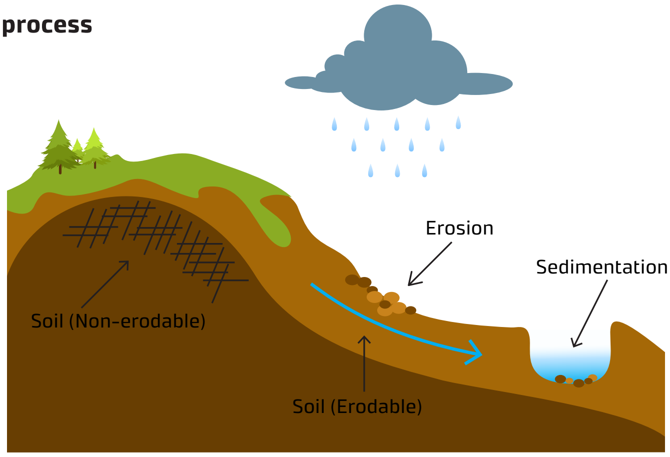
2.1 Understanding erosion

Erosion and sedimentation are related processes. Erosion is the process of wearing away the land surface by running water, wind and/or ice. Through the erosion process, soil particles are dislodged and mobilised, generally from rainfall. The amount of sediment generated depends on the erodibility of the soil, the energy of the rainfall and the site conditions (referred hereafter as site erodabilitiy).

Typically, the steeper the site and the longer the flow lengths, the more energy will be created by rainfall flowing across the ground, and sediment is more likely to be generated. Modifying site conditions (e.g. excavating and loosening soil, removing vegetation covering) increases the site erodabilty, and further increases the likelihood of sediment generation.

Once soil particles are dislodged, sedimentation is the process where these particles enter and move through the water column, typically accumulating at the bottom (refer Figure 2.1).

Figure 2.1: The erosion and sedimentation process



The adverse environmental effects resulting from this process (refer Section 1) are the reasons to understand what influence soil erosion, and implement effective ESC during activities that can increase the site erodability.

2.1.1 Geology

The Cook Islands are the result of volcanic activity and coral growth (ref 1). Rarotonga is the largest of the Cook Islands, and has been broadly classified into three zones:

- Coastal margins, comprising the estuarine and beach ridges;
- Flood plains, on slopes typically less than 5 degrees; and
- Interior fans, terraces and upland hilly and steep land (moderately sloping to steep).

A typical geological cross section for Rarotonga is illustrated below (refer Figure 2.2).

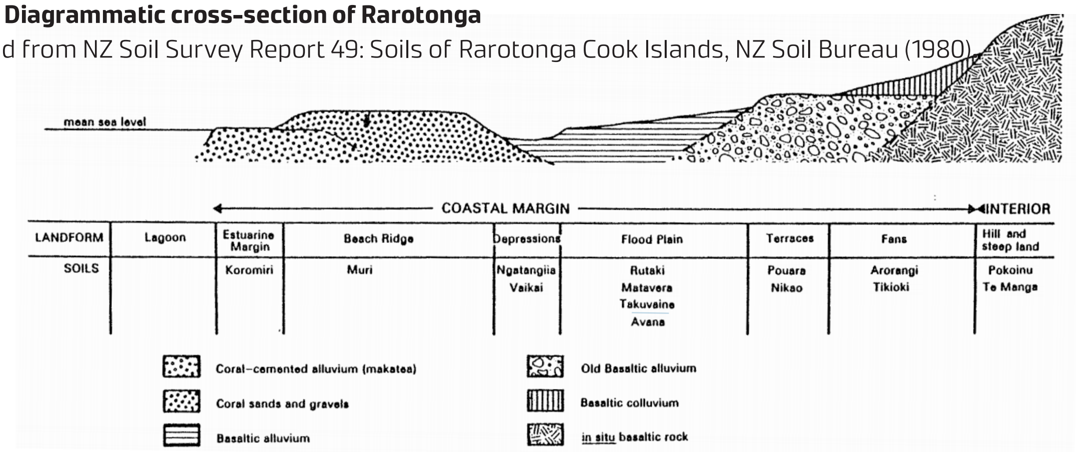
Based on this cross section, and supporting information contained in the soil survey report (ref 2), erodible soils re present at Rarotonga and likely to be exposed during vegetation removal and/or earthworks (even shallow earthworks). Unless basaltic rock is being exposed, most soils are likely to be susceptible to natural erosion. These soils could range from yellow beach sands (for the beach ridge areas) to alluvial and colluvium silts and clay deposits of brown, grey/dark grey and red in colour (in the flood plains and interior land).

The loosening of these soil through human activities such has earthworks has the potential to further increase its erodability and result in sedimentation. Well implemented erosion controls can reduce this increase.

Specific geological information for the outer islands is not available. Unless specific planning and/or investigations demonstrates site erodabiltiy will not increase because of the Works, planning of Works must consider erosion controls.

Figure 2.2: Diagrammatic cross-section of Rarotonga

Reproduced from NZ Soil Survey Report 49: Soils of Rarotonga Cook Islands, NZ Soil Bureau (1980)



LANDFORM	Lagoon	Estuarine Margin	Beach Ridge	Depressions	Flood Plain	Terraces	Fans	Hill and steep land
SOILS		Koromiri	Muri	Ngatangiia Vaikai	Rutaki Matavera Takuvaine Avana	Pouara Nikao	Arorangi Tikioki	Pokoinu Te Manga

2.1.2 Climate

The Cook Islands experiences a tropical climate with two seasons:

- Wet season: Typically November to May, characterised by high humidity, sudden downpours, strong winds and tropical cyclones (hurricanes).
- Dry season: Typically June to October, characterised by cooler temperatures.

In the Northern Cooks Islands, the temperature can remain mostly constant throughout the year, while in the Southern Cooks (including Rarotonga and Aitutaki) there is slight difference between the wet (warmer) and dry (cooler) months.

Climate outlooks and forecasts provide valuable guidance for construction planning, as they can guide start and duration of Works.

Climate outlooks and forecasts are available on The Cook Islands Meteorological Service website: https://www.met.gov.ck/

Works should always be timed to start in periods of forecasted dry weather (i.e. no rain). If Works cannot be completed within the same period of dry, ESC measures are required unless it is demonstrated that site erodability will not increase because of the Works.

2.1.3 Ground cover

Vegetation is the most effective form of erosion control, in preventing or reducing erodabilty of soil surfaces. Vegetation provides a shield to the energy of falling rain, slows the velocity of rainfall runoff, holds soil particles together, and increases the capacity of soil to absorb water. While Works are occurring, artificial shields can be created using mulch, geotextiles or similar to temporarily cover the ground. Once complete, the ground cover should be replaced either through paving, or re-grassing where otherwise exposed soil would remain.

For Works that include removal of existing vegetation ground cover (e.g. grass), planning of the Works must consider erosion controls.

2.2 Understanding Sedimentation

Erosion control is the most effective way to minimise the effects from sedimentations. However in most cases, increasing of site erodability cannot be completely eliminated and some sedimentation will occur (as sedimentation results when erosion occurs).

The sedimentation process can be managed to reduce its impacts through artificial structures (sediment controls) which allow eroded soil in dirty water to be "trapped" before being carried into receiving waters which have human and environmental value (refer Figure 2.3).

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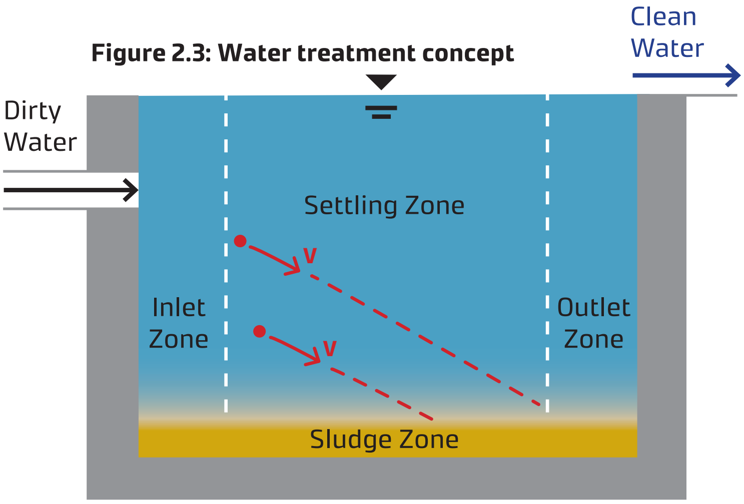
Figure 2.3: Water treatment concept



Soil particle settles to the sludge zone

*Dashed lines are imaginary

2.3 Construction planning

Construction planning is an important part of understanding how Works can be carried out to maximum erosion control and minimise sediment control.

Earthworks carried out over the entire site maximises the time and area that soil is exposed and prone to erosion. Construction staging is useful for large projects. This involves completing earthworks in smaller areas, with progressive revegetation to limit erosion, reducing the level of sediment control necessary.

Construction planning shall consider:

- How Works are sequenced. This can be done through illustrative sketches showing the construction steps.
- Duration and timing of Works, including timing of ground cover is removed and subsequently replaced.
- Site erodability, and level of ESC required.
- Site specific considerations e.g.

– Protecting steep slopes, either through avoiding ground cover clearance, or by diverting water around cleared slopes

– Protecting waterbodies within the site, by establishing "no-go" zones for vegetation clearance.

- The risk to all waterbodies and public drainage infrastructure within and around the Site, in particular

– How can site discharges enter streams

– How can site discharges enter public drainage infrastructure

Construction planning shall also consider how temporary stockpiles, site access and utility service installation are managed so not to increase site erodability. Covering stockpiles, maintaining designated access points, and timing of service installation to dry weather are examples of how this could be achieved.

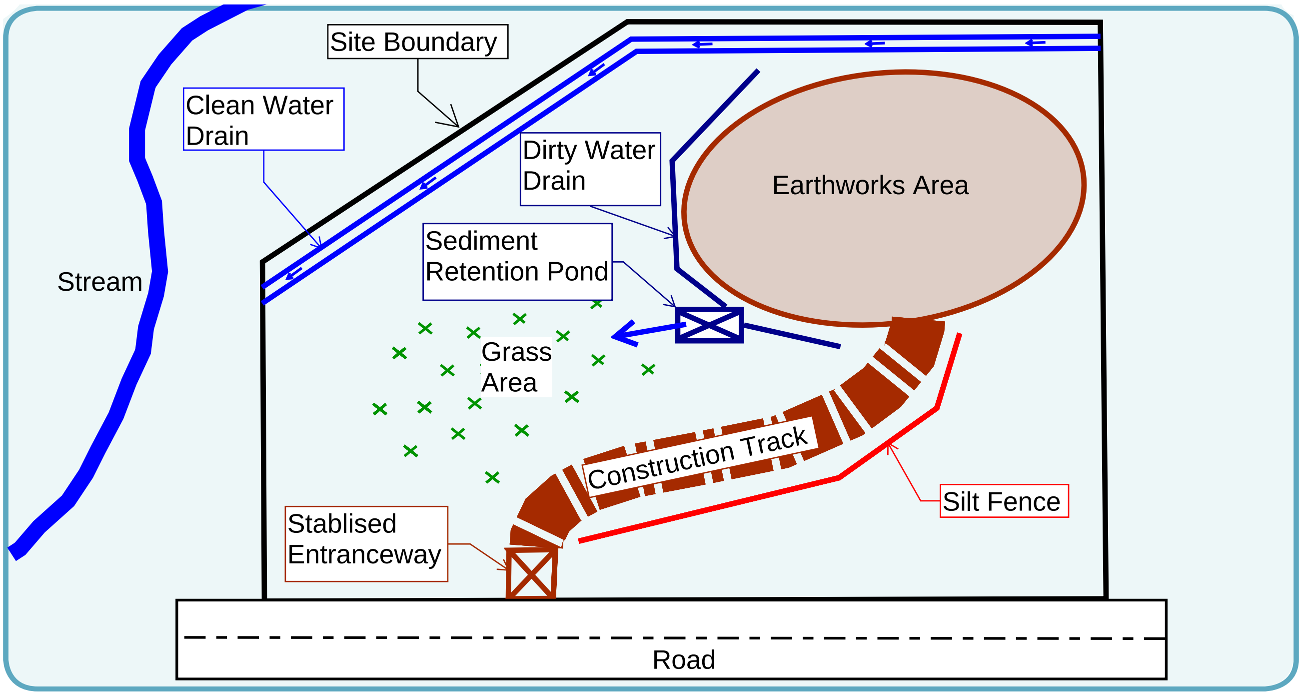
The construction planning considerations and the Works sequencing shall be set out in a site specific Erosion and Sediment Control Plan (ESCP).

The ESC designer (i.e. the author of the ESCP) shall be suitability experienced and able to:

- Understand the nature of Works and assess site erodability accordingly
- Set out the construction planning
- Select and design ESC measures in accordance with this guideline
- Supervise and monitor the implementation of ESC in accordance with the approved ESCP and relevant permit requirements.

The subsequent sections have been prepared to guide the ESC designer, and provide a framework of minimum requirements for a permitting authority to approve the ESCP.

Figure 2.4: Site Plan Sketch with ESC



3. Erosion and sediment control (ESC) design

3.1 Understanding site hydrology

It is important to quantify the amount of water entering into (runon), and running off from a site (runoff) when selecting appropriate ESC.

To assess site hydrology for an ESC context, the following must first be determined:

- Duration of works =

– Less than 1 month

– 1 to 6 months

– More than 6 months

- Catchment Area =

Site Area (A s, in hectares)

+ Upstream Catchment entering site (A u-in, in hectares)

+ Upstream Catchment diverted around site (A u-out, in hectares)

- ESC design Area A esc =

Catchment Area - A u-out

3.1.1 Acceptable rainfall risk

A design storm can be defined to achieve a set level of protection for the protection of downstream water bodies. Typically, the 20 year ARI event is adopted as the design storm in an ESC context. However, Works with shorter duration has reduced exposure (and so susceptibility) to soil erosion, and a lower design storm may be acceptable (refer Figure 3.1), though this must be balanced by the sensitivity of receiving waters.

The following provides guidance for the ESC designer to determine the design storm for Works of varying durations:

- Less than 1 month: no less than the 1 year event
- 1 to 6 months: 2 - 10 year event, depending on sensitivity of receiving waters.
- More than 6 months: 10 -20 year event, depending on sensitivity of receiving waters

3.1.2 Estimating design runoff

The rational method provides a simple empirical model suitable for estimating peak flow from storm water runoff (refer Eq. 1) and is widely accepted in New Zealand applications for runoff flow estimations.

Eq. 1:

$$Q = \frac{CiA}{360}$$

Where:

Q = Peak discharge (m^3/s)

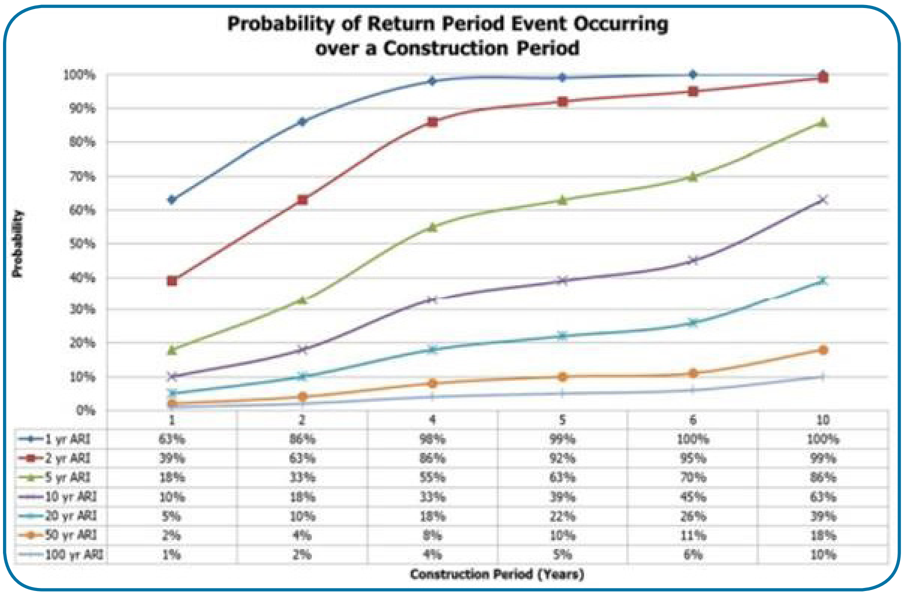
C = Runoff coefficient (see section 4.3.1.2)

i = Rainfall intensity (mm/hour)

A = Area of catchment (hectares)

Rainfall intensity is a function of the time of concentration (i.e. the shortest time for water to travel over the longest path within your site). For small sites typically < 0.5 ha (5,000 m2), a 10 min time of concentration is appropriate in most cases. For larger sites, the ESC designer shall calculate a site-specific time of concentration. High intensity rainfall data (e.g. HIRDs, or similar) is used to determine the rainfall intensity which corresponds to the time of concentration.

Figure 3.1: Rainfall probability graph (based on New Zealand data)



	1	2	4	5	6	10
1 yr ARI	63%	86%	98%	99%	100%	100%
2 yr ARI	39%	63%	86%	92%	95%	99%
5 yr ARI	18%	33%	55%	63%	70%	86%
10 yr ARI	10%	18%	33%	39%	45%	63%
20 yr ARI	5%	10%	18%	22%	26%	39%
50 yr ARI	2%	4%	8%	10%	11%	18%
100 yr ARI	1%	2%	4%	5%	6%	10%

Note: HIRDs data for Cook Islands is under development. It is recommended the New Zealand HIRDs or Australian equivalent for regions of comparable climate is adopted in the interim (refer Section 7). For ESC design, climate change factors may be ignored.

3.1.2 Estimating design runoff cont...

Table 3.1 provides values for typical runoff coefficients (C) by soil type. A high level understanding of site soil and its erodability is recommended before selecting an appropriate C value. For large sites, multiple C values may be appropriate. In this case, Area (A) in Eq. 1 should be adjusted to reflect the extent that the C-value would apply to.

Table 3.1: Runoff co-efficient 'C'

Runoff Co-efficient by soil type	
Topsoil	0.4
Flat sand (<5°)	0.15
Flat bare silt (<5°)	0.3
Moderately sloping bare silt (10-20°)	0.4
Moderate sloping bare clay (<10°)	0.65
Steep bare clay (>10°)	0.75
Gently sloping grass cover (<10°, sand or clay)	0.1 - 0.2
Steep steep bush	0.6

A design runoff estimate is required for sizing the following ESC measures:

- Cleanwater diversion drains (refer section 4.1): Use A u-out in Eq. 1
- Dirty water diversion drains (refer section 5.1): Use Aesc Eq. 1

Worked example:

Step 1: Assess acceptable risk

Works duration: 1 month in October (dry season)

Receiving water sensitivity: Stream -> Coastal Lagoon; High

Design storm: 5 year (18% chance of exceedance, considered acceptable)

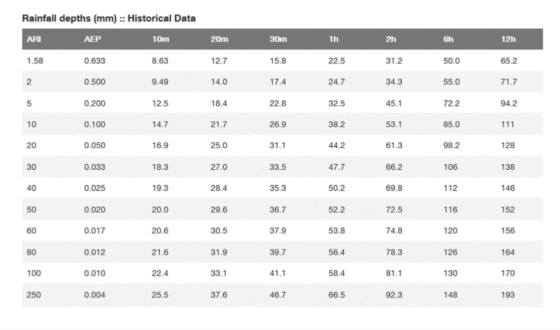
Step 2: Estimate design run off

Site extents: 50 m wide x 100 m long, so site area = 5000 m2, 0.5 ha

For 0.5 ha, adopt time of concentration (tc) of 10 min.

For tc of 10 min, design storm of 5 year, rainfall intensity i (refer Figure 3.1) = 75 mm/hr

Figure 3.2: NZ HIRDs data table from Northland (considered to have comparable climate)



Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h
1.58	0.633	8.63	12.7	15.8	22.5	31.2	50.0	65.2
2	0.500	9.49	14.0	17.4	24.7	34.3	55.0	71.7
5	0.200	12.5	18.4	22.8	32.5	45.1	72.2	94.2
10	0.100	14.7	21.7	26.9	38.2	53.1	85.0	111
20	0.050	16.9	25.0	31.1	44.2	61.3	98.2	128
30	0.033	18.3	27.0	33.5	47.7	66.2	106	138
40	0.025	19.3	28.4	35.3	50.2	69.8	112	146
50	0.020	20.0	29.6	36.7	52.2	72.5	116	152
60	0.017	20.6	30.5	37.9	53.8	74.8	120	156
80	0.012	21.6	31.9	39.7	56.4	78.3	126	164
100	0.010	22.4	33.1	41.1	58.4	81.1	130	170
250	0.004	25.5	37.6	46.7	66.5	92.3	148	193

Site soils = sand, C = 0.15 (from Table 3.1)

Run-off to size dirty water channel

= C x i x Aesc /360

= 0.15 x 75 x 0.5/360

= 0.015 m3/s

4. Erosion control measures

Erosion controls act to limit the amount of sediment eroded. As discussed above, construction planning should place emphasis on erosion control to minimise the mobilisation of sediment. By this, less sediment is required to be captured and treated through the control measures compared to relying solely on sediment control.

Effective erosion control is about reducing the energy of runon water to dislodge sediment and/or providing greater protection to "shield" soil from it energy. This is achieved through:

- Minimising the volume and velocity of water entering, and subsequently existing the site; and
- Maintaining or providing a protective layer against soil erosion through existing vegetation or using soil stabilisation techniques.

For most activities, a combination of both techniques will need to be applied. Specific guidance on these techniques are set out below.

Stockpiled material for site without sediment controls

Covered rainfall protection to site materials

4.1 Clean water diversion channels

Clean water diversion channels are used to divert clean water away from the site, which subsequently reduces the volume of dirty water required to be treated through sediment controls (refer Figure 4.1). Cleanwater drains need to discharge to a protected area of ground , which can be formed using sandbags, pinned geotextile and/or loose rock.

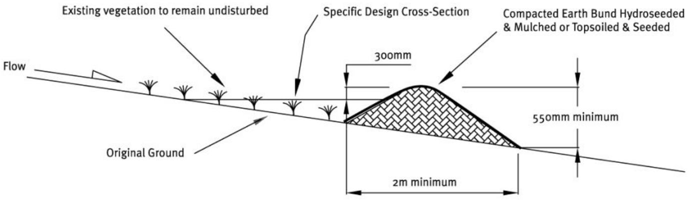
Figure 4.1: Cleanwater diversion channels

Clean water diversion drain under construction

Design

Clean water diversion are designed to convey runoff to a stabilised point, without resulting in channel scour and erosion. Clean water diversions comprise of lined channels (e.g. through pinned geotextiles) or non-perforated pipes. The size of the diversion is governed by the catchment area being collected.

Detail 4.1- Cross section of a clean water drain - from GD05



While the slope of the drain is largely governed by the natural slope of the ground, it should be steep enough for water to flow without ponding but not so steep that erosion and scour occurs. Typically, slopes should be between 1-5%. If lining of the channel (or other velocity control measures) are not proposed, the channel velocity shall be no more than 0.5 m/s, to prevent scour.

A example of selecting a design storm and determinig run off was provided in Section 3.1. The worked example is continued to provide further guideance for sizing a clean water drain

Worked example:

A catchment upslope of the site comprises 2 ha of grass pasture, gently sloping (at about 2%) towards the site (which is 0.5 ha). Of this, 3000 m2 (0.3 ha) cannot be diverted around the site.

The flow requiring diversion is calculated in the same manner as the example in Section 3.1:

Total upstream area = 2 ha

Upstream Catchment entering site (A u-in)
= 0.3 ha

Upstream Catchment diverted around site (A u-out) = 2 - 0.3 = 1.7 ha

For 1.7 ha of grass pasture, the time of concentration (tc) is calculated as 30 min.

For tc of 30 min, design storm of 5 year, rainfall intensity i (from NZ HIRDS, Northland)
= 47 mm/hr

Site soils = moderate sloping grass (silt/topsoil), C = 0.4 (from Table 3.1)

Run-off to size clean water channel
= C x i x Au-off /360

= 0.4 x 47 x 1.7/360

= 0.09 m3/s

Natural slope = 2- 3%, constructed drain slope
= 2% (1 in 50)

Channel lining: smooth earth (manning n =0.018)

[1] Reference: https://www.engineeringtoolbox.com/mannings-roughness-d_799.html

Summary of design:	
Channel dimensions	Top width: 3.5 m Base width: 1.4m
Freeboard:	0.3 m (standard)
Flow depth:	0.01 m (calculated for design flow)
Flow velocity	1.1 m/s (geotextile lining or check dams required)

A calculation sheet to support this specific drain design is included as Appendix A.

4.2 Check dams

Check dams are small temporary dams constructed across an open drain or small water channel, usually comprise of multiple in series. Their primary purpose is to slow down water velocity and prevent channel scour and may be used for drain catchments less than 1 ha. Where catchments exceed 1ha, drain lining should be adopted.

As a rule of thumb, flow velocities exceeding 0.5 m/s in sand, or 1 m/s in clay are likely to cause scour.

They are made from non-erodible material such as, sandbags and loose rocks (rip-rap).


A series of rock check dams


A temporary sandbag check dam - Auckland GD05

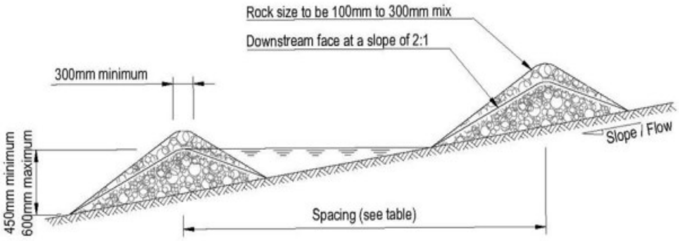
Design

Check dams are typically constructed with either 450 or 600 mm high centres, the maximum height of check dams should be 200 mm below the top of the channel. The spacing of the check dams is dictated by the slope of the channel; a steep slope will have faster flows and require more dams to reduce velocity.

Table 4.1 Silt fence return calculation

Slope of site (%)	Spacing (m) between dams with a 450 mm centre height	Spacing (m) between dams with a 600 mm centre height
Less than 2%	24	30
2 - 4%	12	15
4 - 7%	8	11
7 - 10%	5	6
>10%	Unsuitable - use stabilised channel or specific engineered design	Unsuitable - use stabilised channel or specific engineered design

Detail 4.2: Check dam cross-section



Worked example:

A temporary clean water diversion drain is required for 2 weeks to divert water over a 6% slope. The clean water drain has already been sized for the catchment area; 1.2 m wide and 0.6 m in height, and needs to be 20 m long. The flow velocity is much higher than 0.5 m/s and channel scour is considered likely.

Lining the channel is an expensive option as the channel will only be required for 2 weeks. Instead, check dams created from sandbags are proposed.

- Step 1: Check Dam height. The centre dam height must be lower than the channel height, the channel height is 600 mm (0.6m) so 450 mm is selected as the check dam height.
- Step 2: Spacing between Check dams. The slope of the channel is 6% and the height is 450 mm. From Table 3.1, the required spacing between dams is 5 m. As our slope length is 20 m this would require 4 check dams (20 / 5). If 0 m is the start of the slope and 20 m is the end, the dams would be located at 5m, 10m, 15m and 20m.

4.3 Stabilised entranceways

A stabilised entranceway is designed to stop site access ways becoming sources of sediment. They are located at any entry and exit points to the construction site. Design of a stabilised entryway need to consider:

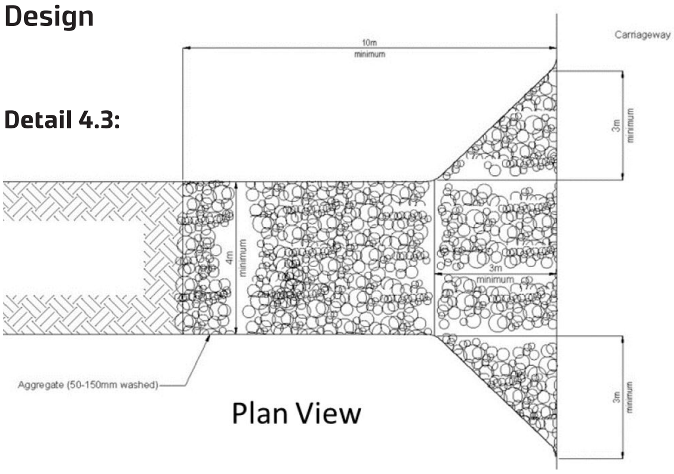
- Location of permanent entry/exit points;
- Length of the entrance way; and
- The expected daily traffic volumes.

Wheel wash to remove sediment from tires

A grid to remove sediment from tires

Design

Detail 4.3:



Detail 4.4:

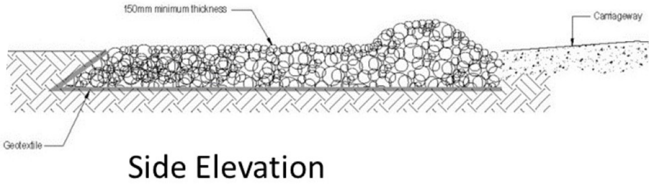


Table 4.2: Stabilised entranceways specifications

Design parameter	Specification
Aggregate size	50 - 150 mm washed aggregate
Minimum thickness	150 mm
Minimum length	10 m
Minimum width	4 m

Worked example:

The earthworks site is close to the main village and construction vehicles will be using the main road to get to and from site. This activity is likely to track mud and dirt along the main road and result in complaints from the community.

A stabilised entrance will reduce the quantity of mud and dirt leaving the site and being tracked on the main road.

The size of the stabilised entranceway is constrained by the site conditions, however the minimum distances can be met (shown in the table above).

4.4 Soil surface stabilisation

A site that can reduces the area of exposed soil is one that has reduced its erodabilty, and is sometimes necessary.

- For large sites, greater than 2 ha;
- Where implemented sediment control are not proving effective.

Techniques to stabilise (or provide temporary ground cover) include grassing, mulching and geotextile placement.

4.4.1 Grassing

Grass and vegetation is often the simplest way to achieve stabilisation. However, it is only effective if good grass strike is achieved with at least 80% coverage, so it is important to time the seeding with the seasons and achieve good seed coverage. Grassing is primarily used as a medium to long term solution.

Initial hydro seeding and slope planting

Well struck hydroseed

4.4.2 Mulching

This involves covering the disturbed soil with a layer of mulch which includes wood pulp, hay, bark and straw creates a protective layer over the soil. Mulching is primarily used to achieve rapid stabilisation for a short to medium term solution.

Hay mulching next to stream

Bark mulching, retaining moisture for plants

4.4.3 Geotextile placement

his involves placing and pinning geotextile fabric over the top of the disturbed soil. Once applied this control will immediately reduce the erodability of disturbed soil. This can be a short term, or long term (semi-permanent) solution depending on the geotextile chosen.

Geotextile fabrics cover a range products. Biodegradable geotextiles provide temporary erosion protection allowing time for vegetation to establish itself before breaking down into the environment. Non-biodegradable geotextiles should be removed after their use, they are typically used to stabilise short steep slopes, on batters and stockpiles.


Biodegradable coconut matting


Non-biodegradable geotextile

Worked example:

Earthworks for a new house site have been conducted at the end dry season but the new house will not be built until after the wet season. During the wet season, sediment will be washed from the site and enter the nearby stream, if the soil is left exposed.

The soil surface should be stabilised to prevent rainfall washing away the soil. As the site will not be worked on for another 6 months, grass stabilisation is chosen to achieve this. Grass will take approximately 6-8 weeks to establish. So a temporary cover is required to protect the soil while the grass establishes. A biodegradable matting or 50 mm layer of mulch can be used. In this case, the mulch is readily available and the matting is not, so mulch has been chosen.

Solution: Apply grass seed to the soil, and covering with a thin layer of mulch to protect the seed as the grass strike is established.

5. Sediment controls

Sediment controls act to remove sediment once it has been dislodged and mobilised in rainfall runoff. Sediment controls must be applied before dirty water runoff leaves a site and enters receiving waters.

Effective sediment controls focuses on the two keys aspects of sedimentation transportation:

- Capture and convey dirty water to sediment control structures; and
- Reduce its velocity to allow enable sedimentation to occur at these sediment control structures.

The amount of sediment control required is governed by the ESC design area (Aesc), and a larger area will always result in a greater amount of sediment control necessary. Sediment controls should always be applied with erosion control methods outlined earlier in this guidance.


Earthworks (which increase site erodibility) carried out without sediment controls


Site fence to control dirty water from slope earthworks

5.1 Dirty water conveyance

Dirty water drains are used to collect and carry dirty water (runoff with sediment) from a site area to an appropriate sediment treatment pond. Dirty water drains are normally constructed across a slope, at a grade of 2% and discharge to a treatment structure (sediment retention pond, or decanting earth bund)

Dirty water drains are typically unlined, unless notable scouring of the drain base is observed.


Example of a dirty water drain

Design

- Drain are often constructed from a combination of a back or bund with the excavation upslope, or an earthen back constructed from compacted earth (refer Detail 5.1 below)
- For larger sites areas (typically >2ha, 20,000 m2) or drains steeper than >2% (1 in 50), the same design process for cleanwater drain sizing shall be carried out for dirty water drains.
- Where possible, choose a route to the sediment treatment device that avoids trees, infrastructure, fence lines and other features
- Like clean water drains, dirty water drains must 300 mm freeboard.

Once implemented, if scour of the drain invert is observed on more than 3 occasions, or compromises the drain function (e.g. allows water to escape), geotextile lining or check dams should be considered.

Worked example:

A catchment upslope of the site comprises 2 ha of grass pasture, gently sloping (at about 2%) towards the site which is 0.5 ha. Of this, 3000 m2 (0.3 ha) cannot be diverted around the site. The site area falls at 6% grade (3.5°), and it is not practical to construct a dirty water drain at a shallower grade.

Dirty water drains are sized in the same manner as clean water diversion drains.

Total upstream area = 2 ha

Upstream Catchment entering site (A u-in) = 0.3 ha

Upstream Catchment diverted around site
(A u-out) = 2 - 0.3 = 1.7 ha

ESC design Area A esc

= Site Area + A u-in

= 0.5 + 0.3 = 0.7 ha

For 0.7 ha of bare earth (silt) the time of concentration (tc) is calculated as 10 min.

For tc of 10 min, design storm of 5 year, rainfall intensity i (from NZ HIRDS, Northland) = 75 mm/hr

Site soils = flat bare silt (<5°), C = 0.3
(from Table 3.1)

Run-off to size dirty water channel

= C x i x Au-off /360

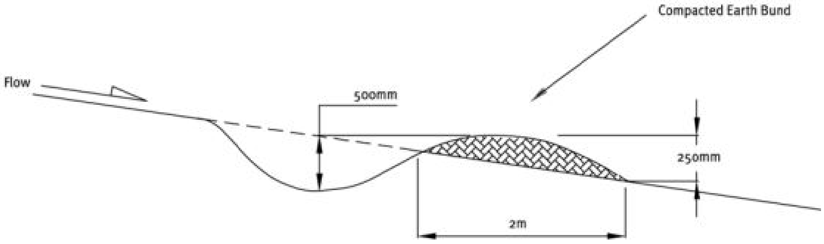
= 0.3 x 75 x 0.7/360

= 0.04 m3/s

Constructed drain slope = 6% (1 in 16.7, or 3.5°)

Channel lining: smooth earth (manning n =0.018)

Check against hydraulic performance for the standard cross-section detail:



Detail 5.1: Standard cross section of dirty water drain

Table below is produced for a U channel, 0.6 m width, allowing for 0.3 m freeboard (approximate standard detail

Slope	Design depth	Design flow capacity	Design flow capacity	Comments
1 in 50 (2%)	0.08	0.024 m/s	1.0 m/s	Standard detail
1 in 16.7 (6%)	0.08	0.041 m/s - ok	1.8 m/s - not ok	Velocities too high. Need specific design

A calculation sheet to support this design check is included as Appendix A.

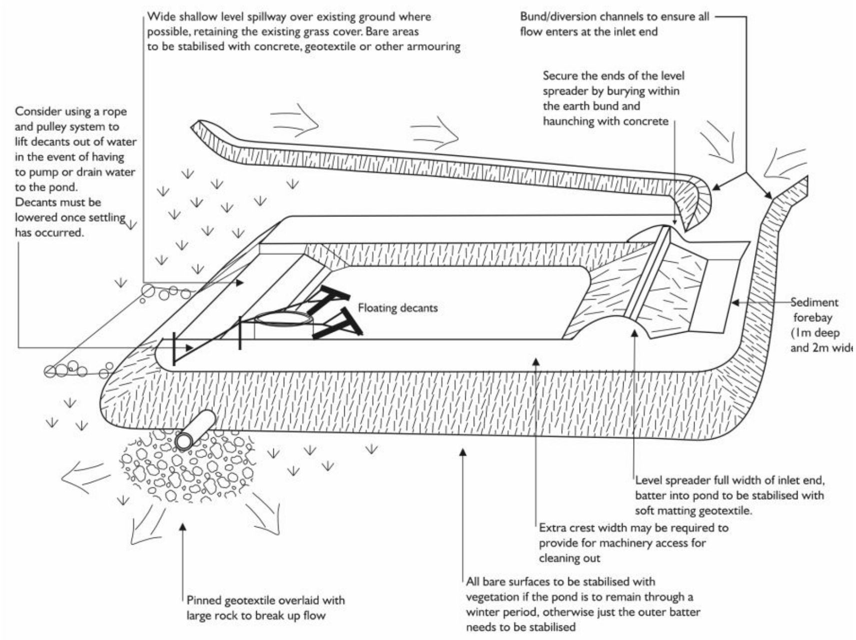
5.2 Sediment retention ponds

A sediment retention pond (SRP) is a constructed ponding area to allow sediment to settle out (sedimentation). It is constructed by excavating to natural ground, or forming an embankment, or a combination of both (depending on the site slope).

An SRP must be located so that dirty water can pass through it, before leaving the site boundary.

Sediment retention pond (SRP) in New Zealand

Detail 5.2: Sediment pond detail. Reproduced from Auckland Guidance Document 05 (GD05)



Design

Sediment retention ponds must contain a forebay, a main bay and a decanting structure. These work together to maximise sediment removal from the water.

A critical component of the SRP's performance is the distance between the inlet and outlet of the SRP which should be maximised. The width to length ratio should be between 1:3 and 1:5 (measured at the primary spillway).

The size of an SRP is based on the ESC design area which contributes to that specific SRP (Aesc –x), and the slope of surrounding ground. A maximum of 3 ha can be treated by a single SPR.

As guidance:

- For sites with slopes less than 10% grade the main bay size is a 200 m3 per ha
- For sites with slopes greater that 10% the main bay should 300 m3 per ha
- The forebay should be 10% of the final main bay volume.

This gives the total capacity required of an SRP.

A standard drawing and design requirements for SRP are in Appendix B.

Note: *Many other countries utilise concrete manholes as their dewatering / outlet devices. This option has not been shown here due to supply availability in the Cook Islands. Please refer to the reference section for further information on the use of concrete manholes as dewatering devices.*

Worked example:

A catchment upslope of the site comprises 2 ha of grass pasture, gently sloping (at about 2%) towards the site which is 0.5 ha. Of this, 3000 m2 (0.3 ha) cannot be diverted around the site. The site area falls at 6% grade (3.5°), and it is not practical to construct a dirty water drain at a shallower grade. The maximum overland flow path is 100 m (which includes 20 m of dirty water diversion drain).

ESC design Area A esc = 0.7 ha (<3.0 ha, so only 1 SRP required).

A calculation sheet for this design is included as Appendix A. In summary:

- Main bay volume = 140 m3, Forebay = 7m3
- Main bay dimensions (top, for 3:1 side slope batters): 10 .1 m (wide) x 21.2 m (long).
- Forebay dimensions (top): 7.1 m (wide) x 2.3 m (long)

5.3 Decanting earth bunds

A decanting earth bund (DEB) is ponding area constructed from a temporary compacted earth bund. A DEB has the same function as SRP, however is only appropriate for treating up to 3000 m2 (0.3 ha). DEB's purpose is to reduce the amount of sediment contained within runoff before leaving the work site.

DEB from - Ecan ESC 2007

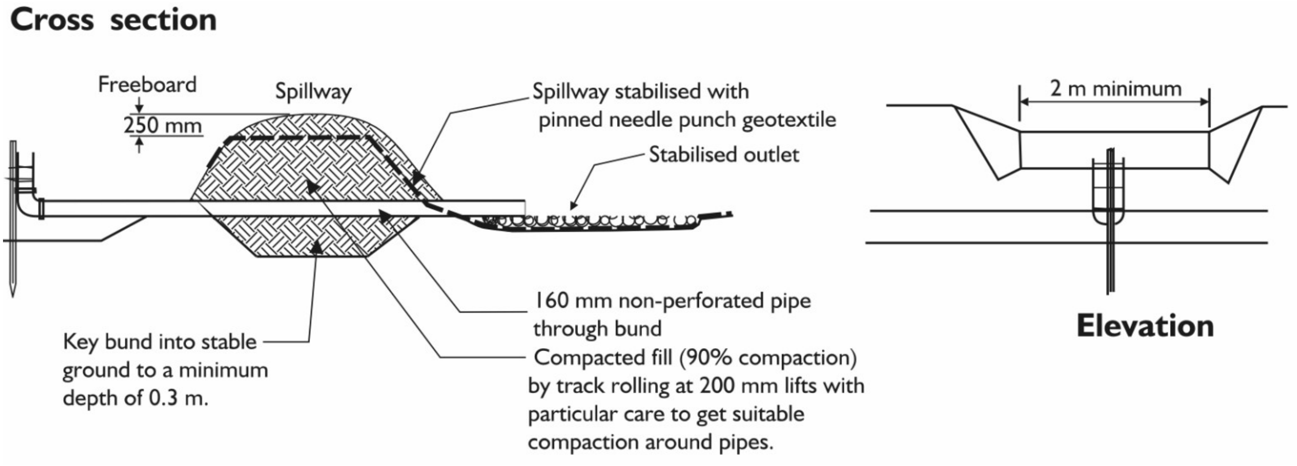
DEB shall remain until the contributing catchment has been stabilised.

Design

- A pipe should pass through the DEB to allow clean water to discharge downstream.
- The inlet of the pipe should be 150mm lower than the spillway.
- The maximum catchment area contributing to a DEB should not exceed 0.3 ha. DEBs shall be sized to store 30 m3 for every 100 m2 (0.1 ha) of the catchment.
- The DEB should be no more than 1.2 m deep

The cross section and elevation drawings below, illustrates the key design parameters for a decanting earth bund.

Detail 5.3 - Decanting earth bund. Reproduced from Environment Canterbury Guidelines (Ecan ESC 2007)



Worked example:

A new stockpiling area is required for excavated soil. A flat area of 2000 m2 is available adjacent to the site, and is proposed to hold the stockpile material, but also to park dirty machinery at the end of each working day. A DEB is proposed at the lowest point of the site to provide treatment of the full area.

ESC design Area A esc = 0.2 ha (2000 m2)

DEB volume = 30/100 x 2000

= 60 m3

DEB Area = 60 m3/ 1.2 m

= 50 m2

Dimensions = 7.1 m x 7.1 m
(assuming a square shape)

5.4 Silt fences

Silt fences act as temporary barriers to capture coarse sediment carried by surface water. Silt fences slow down the water and allow the sediment to settle out of the water. Silt fences are best used for containing stockpiles of earth or for areas where site runoff tends to spread out, and cannot be captured by a dirty water drain.

Silt fence with warratahs

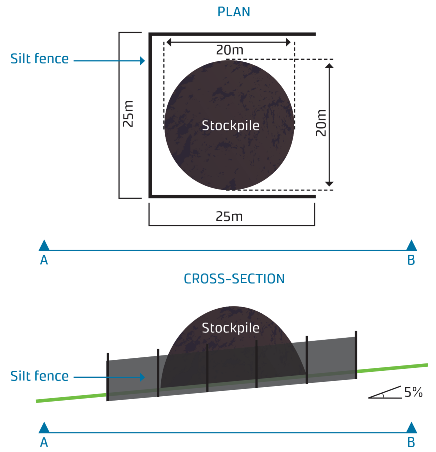
Silt fence with timber pegs

Design

Silt fences should be:

- Minimum of 600 mm high above ground and 200 mm below
- Maximum post spacing of 2 m
- Have returns every 20 - 60m along the length of the Silt fence depending on the slope

Sketch 3 - Example for a silt fence design



Detail 5.4: Silt fence schematic from Auckland ESC for building on small site

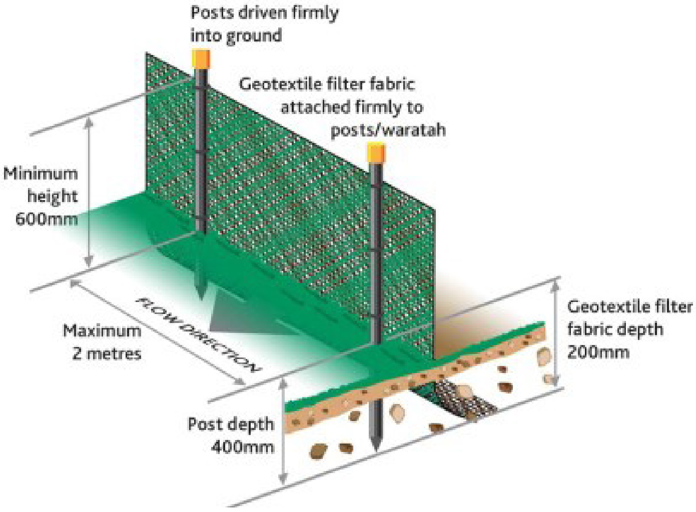


Table 5.1: Silt fence specifications

Slope steepness %	Slope length (m) (maximum)	Spacing of returns (m)	Silt fence length (m) (maximum)
Flatter than 2%	Unlimited	N/A	Unlimited
2 – 10%	40	60	300
10 – 20%	30	50	230
20 – 33%	20	40	150
33 – 50%	15	30	75
> 50%	6	20	40

Worked example:

A large quantity excavated material needs to be stockpiled in an area 20 m by 20 m on a 5% slope for a couple of months until it can be used at another site for fill. This soil is likely to erode and cause uncontrolled sediment to enter the road drainage system. The road drainage goes to the marine lagoon area, and can impact the marine environment.

A silt fence can be installed around the stockpile area to stop the soil and sediment moving towards the drainage inlet. The silt fence should completely surround the stockpiled material on three sides (there is no need for a silt fence upslope of the stockpile as the sediment will only move downwards). This will require a total of 75 m of silt fence of which 25 m is perpendicular to the slope (refer **Sketch 3**)

Using Table 4.1, the slope is 5%, so a row of silt fence is required for each 40 m length of slope. The slope length for the stockpile area is 20 m, so only one row of fence is necessary.

Using Table 4.1, 2m returns are required for every 60 m length of fence that is perpendicular to the slope. Returns are not required (only 25 m is perpendicular).

5.5 Silk socks

Silt socks are a tubular mesh tube filled with a porus material such as compost, sawdust, wood bark, or straw and are used to incept and filter runoff. Silt socks have a limited capacity for water treatment and are typically used on small flat (<5°) catchment areas, or around localised points such as a drainage sump inlet. They allow water to be slowed down (similar to check dams) and silt trapped within the porus material of the sock.


Silt sock protecting drainage inlet


Silt sock intercepting sheet flow

Silt socks are commonly used to:

- Intercept and slow runoff that has spread
- Intercept and slow flow before it enters a catch pit or drainage inlet
- Reduce water velocity within a channel (check dam)

Requirements

The filter median should be clean and free of containments, including chemicals such as treated wood sawdust

- The sock fabric should be constructed from a UV stabilised material
- Where long sections of silt socks are used, 2 m (min) returns should also be installed.
- Where more than one length of silt sock is used joins should overlap by 1 m
- Silt socks should be secured by stakes alternating either side of the sock where required


Long silt sock with returns

Table 5.2: 300mm dia silt sock design table – from GD05

Slope steepness (%)	Maximum slope length (m)	Spacing of returns (m)
Flatter than 2%	100	N/A
2% - 10%	40	30
10% - 20%	30	25
20% - 33%	10	10
33% - 50%	5	10
>50%	2	5

Table 5.3: 450mm dia silt sock design table - from GD05

Slope steepness (%)	Maximum slope length (m)	Spacing of returns (m)
Flatter than 2%	150	N/A
2% - 10%	60	30
10% - 20%	40	25
20% - 33%	20	10
33% - 50%	10	10
>50%	5	5

Worked example:

An earthworks site is complete and waiting for the grass to strike. Earthworks have profiled the slope to be gently sloping (3%) over 100 m length. Runoff is observed to spread over the area. Grass seed has just recently been planted, and scouring of the soil was observed following the last rain. It is proposed to pin silt socks to slow down runoff, and prevent further scour. 300 mm tubes are available.

Using Table 4.2 for slopes of 3%, the maximum distance between rows of silt sock is 40 m. 3 silt socks are required along the 100 m slope (100/40 = 2.5). They can be pinned on the slope at even distances; one sock will go at the bottom of the slope, one a third of the way up and the last two thirds of the way up.

6. Supplementary drainage structures

6.1 Pipe drop structures and flumes

The sections above set out the design open channel drains, which are largely the same for cleanwater and dirtywater purposes. A pipe drop or flume is a drainage structure that allows water to be carried down steep slopes, without causing erosion of the slope. They are typically established on slopes steeper than 1V:3H., and is used in conjunction with diversions channels (either clean or dirty), as outlined earlier in the document (i.e. drain comes into it at the top, and a second drain collects the water at the bottom). These structure may be constructed as a temporary or permanent fixtures depending on their application

Typically, the steeper the site and the longer the flow lengths, the more energy will be created by rainfall flowing across the ground, and sediment is more likely to be generated. Modifying site conditions (e.g. excavating and loosening soil, removing vegetation covering) increases the site erodabilty, and further increases the likelihood of sediment generation.

Once soil particles are dislodged, sedimentation is the process where these particles enter and move through the water column, typically accumulating at the bottom (refer Figure 2.1).

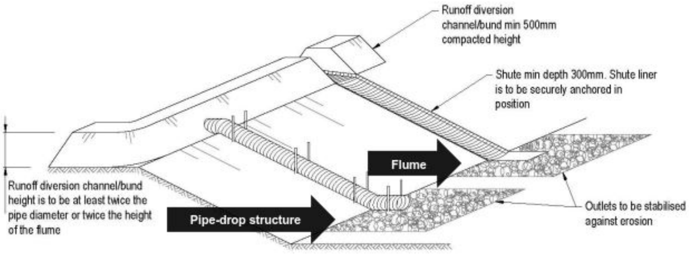
Temporary pipe drop (flexible pipe)

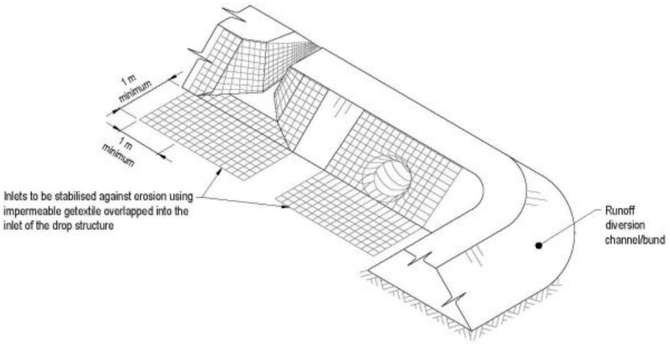
Permeant concrete flume let down

Design

Detail 5.1 – pipe drop and flume schematic taken from GD05

Pipe diameter (mm)	Maximum catchment area (ha)
150 mm	0.05 ha
300 mm	0.20 ha
450 mm	0.60 ha
600 mm	1.00 ha
Specific design required	>1.00 ha





6.2 Stormwater inlet protection

Stormwater inlet protection is providing a permeable barrier around a drainage inlet, which intercepts and filters dirty water runoff before it enters the drainage network. The barrier must be routinely cleaned (following every rainfall), so that is doesn’t create blockage of the inlet point.

Stormwater inlet protection is not approprirate as a stand-alone ESC measure for an earthworks site.

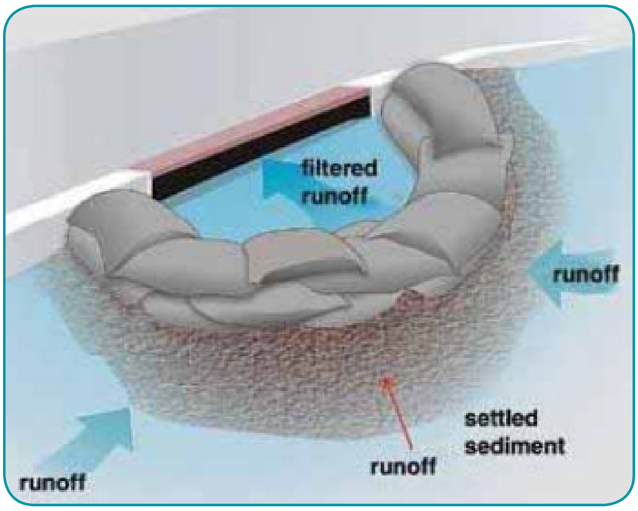
It is to be used in conjunction with other ESC measures as a final level of protection for site discharge entering receiving waters.

Bad stormwater protection

Good stormwater protection

Design

Detail 5.2 - schematic of inlet protection principles



Key design constrains:

- Completing blocking water flows should be avoided (water bypasses inlet)
- The height of the inlet protection should be low enough to avoid flooding above curbs level
- Ensure emergency bypass is included if the inlet protection blocks the flow
- Ensure Inlet protection is reassess after each rainfall event for issue
- Devices must be removed when not required, these are not permanent sediment controls

Worked example:

Treated water runoff from the SRP (Aesc -x =0.7) needs to go down a steep slope (approx. 15%) that is 10 m long, before it can discharge into a drainage inlet. The steep slope will cause the water to scour and get dirty again. If dirty water is discharged to the drainage inlet, it will enter the lagoon.

As the slope is greater than 10% check dams are not an appropriate. A pipe drop or flume channel is proposed, with the bottom located at the road channel.

Step 1: Select from a pipe or a flume option.

As the site area is less than 1 ha, both a pipe or flume can be used (if it was larger than only a flume could have been chosen). HDPE lining is available on site so a flume is selected.

Step 2: Design the flume size.

The width of the flume should be 1.5 m per ha of catchment area: 1.5 x 0.7 = 1.1 m in width

The depth of the flume is a minimum of 0.3 m.

The length of the flume should cover be the entire slope length plus a 1 m at the inlet and 1m at the outlet. The total flume length is 10 + 1 + 1 = 12 m.

Over this length the liner should be pinned either size of the flume every 0.5 m down the entire length.

Step 3: Inlet and outlet protection
A stabilised inlet is required as per Detail 5.1 above.

A stabilised outlet is also required to protect the drainage channel from scour as water exists the flume. Placing sandbags or loose rock over 1m of lining will achieved this. As a final level of protection, silt socks are placed around the adjacent drainage sump for stormwater inlet protection.

7. Guidance for Permit Authorities

These Erosion and Sediment Control Guidelines for the Cook Islands should be referenced in conditions for permits which involve earthworks.

Suggested permit conditions could include:

All earthworks shall be managed in accordance with the Erosion and Sediment Control Guidelines for the Cook Islands.

Earthworks shall minimise any discharge of sediment or sediment-laden water beyond the subject site to either land, stormwater drainage systems, watercourses or receiving waters.

In the event that a discharge occurs, works shall cease immediately and the discharge shall be mitigated and/or rectified to the satisfaction of the permitting authority.

For larger / more complex sites:

At least 15 working days prior to the commencement of earthworks activity, an Erosion and Sediment Control Management Plan shall be submitted to the permitting authority for review and approval.

All required erosion and sediment control measures on the subject site shall be constructed and carried out in accordance with the approved Erosion and Sediment Control Management Plan.

8. Further technical resources

8.1 Weather

Cook Island Meteorological Services

https://www.met.gov.ck/

8.2 Technical Reports

Soils of Rarotonga, Cook Islands

http://digitallibrary.landcareresearch.co.nz/cdm/ref/collection/p20022coll4/id/91

Soil map of Rarotonga, Cook Islands (Available from ICI)

8.3 Design Guidance

Compliance Document for New Zealand Building Code, Clause E1 Surface Water (2017)

https://www.building.govt.nz/assets/Uploads/building-code-compliance/e-moisture/e1-surface-water/asvm/e1-surface-water-1st-edition-amendment10.pdf

Manning's roughness Co-efficients

https://www.engineeringtoolbox.com/mannings-roughness-d_799.html

New Zealand HIRDs:
https://www.niwa.co.nz/information-services/hirds

Australian Design rainfall service:
http://www.bom.gov.au/water/designRainfalls/revised-ifd/

8.4 ESC guidelines from New Zealand Erosion and Sediment Control Guide for Land Disturbing Activities in the Auckland Region

http://content.aucklanddesignmanual.co.nz/regulations/technical-guidance/Documents/GD05%20Erosion%20and%20Sediment%20Control.pdf

Erosion and Sediment Control Guidelines for the Wellington Region

http://www.gw.govt.nz/assets/Resource-Consents/Erosion-and-sediment-control-guidelines-2002.PDF

Erosion and Sediment Control Guidelines for Land Disturbing Activities, Environment Bay of Plenty

https://www.boprc.govt.nz/media/29555/Guideline-100624-ErosionandSedimentControl.pdf

Environment Canterbury Regional Council Erosion and Sediment Control Website

https://www.esccanterbury.co.nz/yourproject/

Building on small sites, doing it right. Erosion and Sediment controls for small site in Auckland

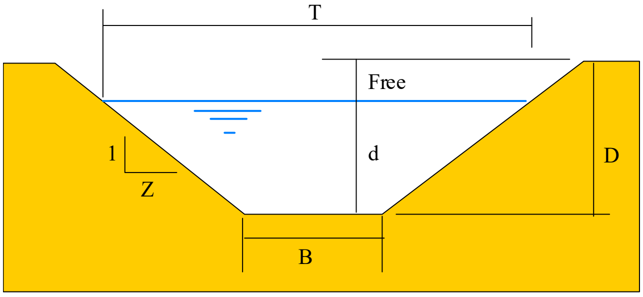
https://www.aucklandcouncil.govt.nz/building-and-consents/understanding-building-consents-process/starting-building-renovation-work/Documents/bc5850-building-small-sites-brochure.pdf

Appendix A: Example calculations

03 TRAPEZOIDAL CHANNEL

Design of a channel based on the
- required discharge
- gradient of the channel
- side slope
- maximum desired top width
- freeboard.

Therefore the depth of the channel can be determined using an iterative solution to Manning's equation.



Parameters

Roughness coefficient (concrete lined channels, fair condition)		$n := 0.018\cdot s\cdot m^{-\frac{1}{3}}$
Design flow		$Q := 0.09\cdot m^{3}\cdot s^{-1}$
Gradient of channel side slopes	(1 : Z)	$Z := 3.0$
Gradient of channel	(1 : X)	$X := 50$
Maximum top width		$T := 3.5\cdot m$
Freeboard		$Free := 0.3\cdot m$

Hydraulic Equations

Base width	$B(d) := T - 2\cdot Z\cdot(d + Free)$
Wetted Area	$A(d) := [T - 2\cdot Z\cdot(d + Free) + Z\cdot d]\cdot d$
Wetted Perimeter	$P(d) := T - 2\cdot Z\cdot(d + Free) + 2\cdot d\cdot\sqrt{1 + Z^{2}}$
Hydraulic Radius	$R(d) := A(d)\cdot P(d)^{-1}$
Velocity	$v(d) := Q\cdot A(d)^{-1}$
Manning's formula	$f(q,d) := q - A(d)\cdot n^{-1}\cdot R(d)^{\frac{2}{3}}\cdot\left(X^{-1}\right)^{0.5}$

Solve for the total depth of the channel using iteration	Seed the root with an initial guess	$D := 0.1\cdot m$
	$D := \mathrm{root}(f(Q,D),D)$	

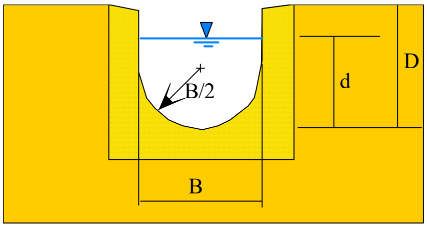
Results

Flow depth	$\boxed{D = 0.055\,m}$
Base width	$\boxed{B(D) = 1.367\,m}$
Flow velocity	$\boxed{v(D) = 1.059\,m\cdot s^{-1}}$

02 U CHANNEL FLOW

Determine the hydraulic characteristics of a U channel. The cross section consists of a semi circular invert and vertical straight sides above this.

An efficient cross section minimises the slope required to carry a given flow. This is provided by minimising the wetted perimeter (frictional resistance) for a cross sectional area of flow.



Slope of channel (1 : x)

Units

$L := 10^{-3}\,m^{3}$

Parameters

Design freeboard

$Free := 300mm$

Channel depth

Genrally $D = B$ this allows the channel to be defined with a single dimension

Roughness coefficient (n)

$n := 0.018 \cdot s \cdot m^{\frac{-1}{3}}$

Mannings Equation

Velocity of flow

$$V(d, B, x) := \left|\begin{array}{l} \theta \leftarrow \begin{cases} 2 \cdot acos\left(1 - \dfrac{2 \cdot d}{B}\right) & \text{if } d < \dfrac{B}{2} \\ \pi & \text{otherwise} \end{cases} \\ A \leftarrow \begin{cases} \left[\dfrac{B^{2}}{8} \cdot (\theta - \sin(\theta))\right] & \text{if } d < \dfrac{B}{2} \\ \left[\dfrac{\pi \cdot B^{2}}{8} + \left(d - \dfrac{B}{2}\right) \cdot B\right] & \text{otherwise} \end{cases} \\ P \leftarrow \begin{cases} \dfrac{B \cdot \theta}{2} & \text{if } d < \dfrac{B}{2} \\ \left[\dfrac{\pi \cdot B}{2} + 2 \cdot \left(d - \dfrac{B}{2}\right)\right] & \text{otherwise} \end{cases} \\ R \leftarrow \dfrac{A}{P} \\ s \leftarrow \dfrac{1}{x} \\ \dfrac{1}{n} \cdot (R)^{\frac{2}{3}} \cdot (s)^{\frac{1}{2}} \end{array}\right.$$

Flow

$$Q(d,B,x) := \left|\begin{array}{l} \theta \leftarrow \left|\begin{array}{ll} 2\cdot \operatorname{acos}\left(1-\dfrac{2\cdot d}{B}\right) & \text{if } d<\dfrac{B}{2} \\ \pi & \text{otherwise} \end{array}\right. \\ A \leftarrow \left|\begin{array}{ll} \left[\dfrac{B^2}{8}\cdot(\theta-\sin(\theta))\right] & \text{if } d<\dfrac{B}{2} \\ \left[\dfrac{\pi\cdot B^2}{8}+\left(d-\dfrac{B}{2}\right)\cdot B\right] & \text{otherwise} \end{array}\right. \\ A\cdot V(d,B,x) \end{array}\right.$$

Results

Base width of channel $B := 600\text{mm}$

Hydraulic design depth

$$d := \left|\begin{array}{l} D \leftarrow B \\ D - \text{Free} \end{array}\right.$$

$d = 0.3\,\text{m}$

Slope $x := 100$

$V(d,B,x) = 1.568\,\text{m}\cdot\text{s}^{-1}$

$Q(d,B,x) = 0.222\,\text{m}^{3.000}\cdot\text{s}^{-1.}$

Slope $x := 75$

$V(d,B,x) = 1.811\,\text{m}\cdot\text{s}^{-1}$

$Q(d,B,x) = 0.256\,\text{m}^{3.000}\cdot\text{s}^{-1.}$

Slope $x := 50$

$V(d,B,x) = 2.218\,\text{m}\cdot\text{s}^{-1}$

$Q(d,B,x) = 0.314\,\text{m}^{3.000}\cdot\text{s}^{-1.}$

Slope $x := 20$

$V(d,B,x) = 3.507\,\text{m}\cdot\text{s}^{-1}$

$Q(d,B,x) = 0.496\,\text{m}^{3.000}\cdot\text{s}^{-1.}$

Slope $x := 10$

$V(d,B,x) = 4.96\,\text{m}\cdot\text{s}^{-1}$

$Q(d,B,x) = 0.701\,\text{m}^{3.000}\cdot\text{s}^{-1.}$

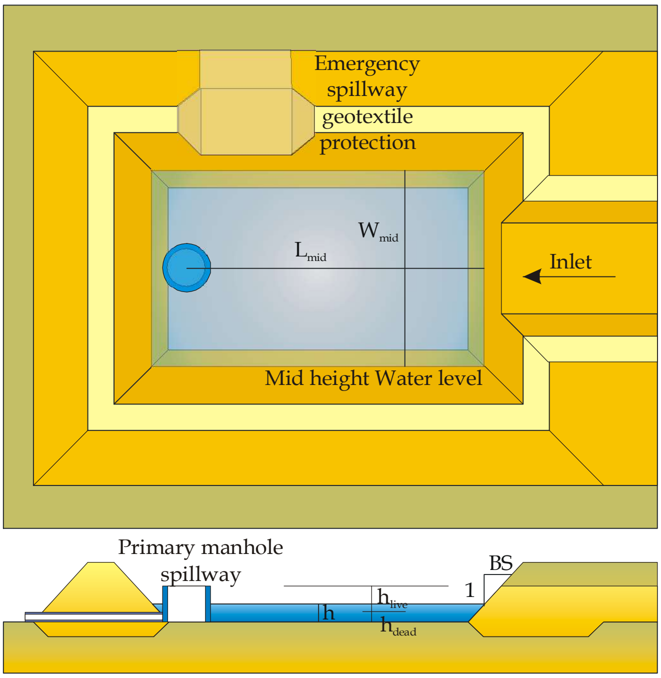
10 TEMPORARY SEDIMENT RETENTION POND

Greater Wellington Regional Council recommends temporary sediment retention ponds for construction sites where the area is between 0.3ha and 5ha.

For construction sites the ARC provides criteria for the design of sediment retention ponds in ARC TP90.

The criteria are dependent on the size of the catchment area for the pond. differences primarily relate to the type of spillway provision and the capacity of these spillways.

Experience with these ponds suggest that failures of the ponds that do occur are generally related to the control of seepage. This arises as a consequence of a lack of formation preparation and inadequate control of the construction of the embankments forming the ponds. _



ADDITIONAL FOREBAY

References

Greater Wellington Regional Council (2002) "Erosion and Sediment Control Guidelines for the Wellington Region", Section 5.1.

Units

$ha := 10^4 m^2$

Parameters

Catchment Area		$Catch_{Area} := 1 \times 0.7ha$
Slope of catchment	Ave slope of existing ground	$S_1 := 6\%$
Slope Length	Max overland flow path	$LoS := 100m$
Water depth in pond	typ. 1m to 2m (no greater than 2m)	$h := 1.5m$
Length : Width ratio of pond (LWR:1)	Between 3:1 and 5:1	$ratio_{LW} := 3$
Pond batters slope (BS:1)	typically. 2:1 to 3:1 H:V	$BS := 3$

Applicability

A retention pond is applicable to a range of catchment areas.
(Section 5.1 page 51)

$$Check1 := \left| \begin{array}{ll} \text{"Pond applicable"} & \text{if } 0.3ha < Catch_{Area} \le 3ha \\ \text{"Area small adopt alternative"} & \text{if } Catch_{Area} \le 0.3ha \\ \text{"Spilt the catchment into smaller areas"} & \text{otherwise} \end{array} \right.$$

$\boxed{Check1 = \text{"Pond applicable"}}$

The design water depth should be less than 2m. Deeper ponds are more susceptible to flow short circulating across the pond and be less efficient in depositing suspended sediment.
(Section 5.1, l) page 56)

$$check2 := \left| \begin{array}{ll} \text{"Design pond depth too great"} & \text{if } h > 2m \\ \text{"Design pond depth OK"} & \text{otherwise} \end{array} \right.$$

$\boxed{check2 = \text{"Design pond depth OK"}}$

Volume of Main bay pond

Volume of pond (minimum)
Guidelines provide minima criteria based on the slope of the catchment

$$V_{pond} := \left| \begin{array}{ll} Catch_{Area}(2\%)m & \text{if } (S_1 < 10\%) \\ Catch_{Area}(3\%)m & \text{otherwise} \end{array} \right.$$

Minimum pond volume to meet the criteria $\boxed{V_{pond} = 140\,m^3}$

For sandy soils (less than 8% clay and less than 40% silt) the pond volume may be calculated using the formula:

- pond surface area = 1.5 peak inflow rate (5% AEP). Ensure that the pond has a minimum depth of 1m. Calculate the inflow rates using HIRD (high intensity rainfall data).

Dimensions of Main bay pond

A trapezoidal cross-section is the most common form of section for a retention pond. This section results from the use of earth embankments to retaining the pond. The dimensions are determined based on a rectangular pond of trapezoidal cross section in both directions.

Area of pond (at mid-depth) $A_{mid} := V_{pond} \cdot h^{-1}$ $A_{mid} = 93.333\,m^2$

Width of pond (at mid-depth) $W_{mid} := \sqrt{\dfrac{A_{mid}}{ratio_{LW}}}$ $W_{mid} = 5.6\,m$

Length of pond (minimum at mid-depth) $L_{mid} := ratio_{LW} \cdot W_{mid}$ $L_{mid} = 16.7\,m$

Base dimensions: $W_{base} := W_{mid} - BS \cdot h$ $\boxed{W_{base} = 1.1\,m}$

$L_{base} := L_{mid} - BS \cdot h$ $\boxed{L_{base} = 12.2\,m}$

Top of water surface dimensions $W_{top} := W_{mid} + BS \cdot h$ $\boxed{W_{top} = 10.1\,m}$

$L_{top} := L_{mid} + BS \cdot h$ $\boxed{L_{top} = 21.2\,m}$

$A_{top} := W_{top} \cdot L_{top}$ $\boxed{A_{top} = 214\,m^2}$

Forebay Design

Volume of forebay (minimum)
Guidelines provide minima criteria based on the slope of the catchment
(Section 5.1, a) & i) pages 52 & 55)

$$V_{fore} := \left| \begin{array}{ll} Catch_{Area}(0.1\%)m & \text{if } (S_1 < 10\%) \\ Catch_{Area}(0.3\%)m & \text{otherwise} \end{array} \right.$$

Minimum forebay volume to meet the criteria. $\boxed{V_{fore} = 7\,m^3}$

Total volume of ppnd & forebay $\boxed{V_{tot} := V_{pond} + V_{fore}}$ $\boxed{V_{tot} = 147\,m^3}$

Dimensions of forebay

Calculated as above for pond dimensions.
Width of forebay is the same as the width of the pond.

Area of bay (at mid-depth) $A_{fmid} := V_{fore} \cdot h^{-1}$ $A_{fmid} = 4.667\,m^{2}$

Width of bay (at mid-depth) same as pond $W_{fmid} := W_{mid}$ $W_{fmid} = 5.6\,m$

Length of bay (minimum at mid-depth) $L_{fmid} := \dfrac{A_{fmid}}{W_{fmid}}$ $L_{fmid} = 0.8\,m$

Forebay is to be 0.5 to 1 m deep. $H := 0.5m$

Base dimensions: $W_{fbase} := W_{base}$ $W_{fbase} = 1.1\,m$

$L_{fbase} := L_{fmid} - BS \cdot H$ $L_{fbase} = -0.7\,m$

Top of water surface dimensions $W_{ftop} := W_{fmid} + BS \cdot H$ $W_{ftop} = 7.1\,m$

$L_{ftop} := L_{fmid} + BS \cdot H$ $L_{ftop} = 2.3\,m$

$A_{ftop} := W_{ftop} \cdot L_{ftop}$ $A_{ftop} = 17\,m^{2}$

Dead storage (permanent storage)

The dead storage is that volume of storage below the minimum decant level in the pond. This is for the storage of precipitated sediment. GWRC recommends that this volume is 30% of the total design storage (Section 5.1, e) page 53)

Dead storage volume $V_{dead} := 30\% \cdot V_{tot}$ $V_{dead} = 44.1\,m^{3}$

Dead storage depth $Q(h_{dead}) := \left[V_{dead} - (L_{base} + 2h_{dead} \cdot BS) \cdot (W_{base} + 2h_{dead} \cdot BS) \cdot h_{dead}\right]$

$h_{dead} := \mathrm{root}(Q(h_{dead}), h_{dead}, 0, h)$

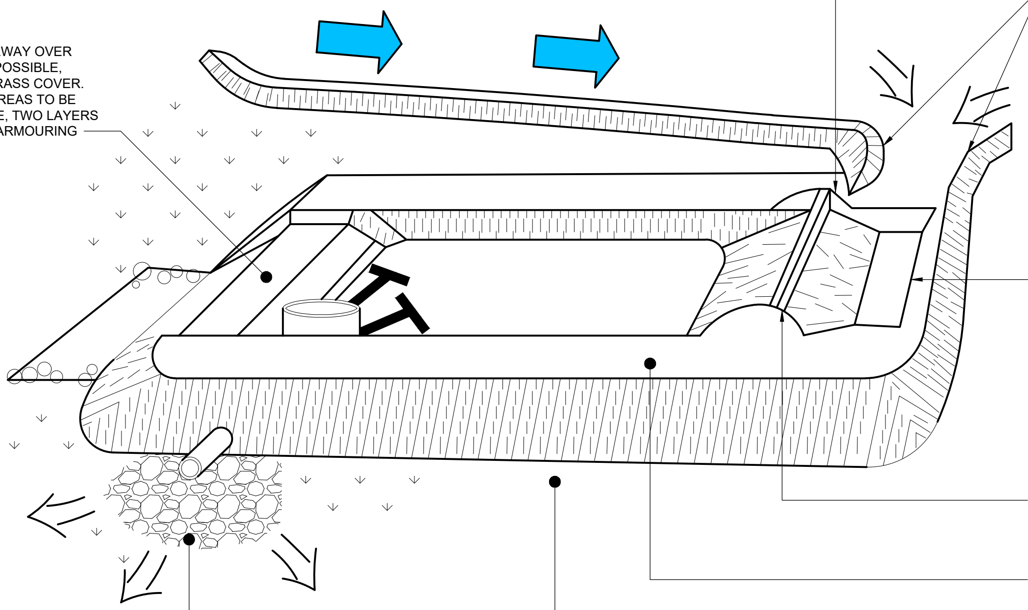
Dead storage depth
(TP90 suggests that this is typically be between 0.4m and 0.8m) $h_{dead} = 0.598\,m$

Appendix B: Standard drawings

NOTES

1. REFER TO NZTA EROSION AND SEDIMENT CONTROL GUIDELINES FOR STATE HIGHWAY INFRASTRUCTURE (NZTA GUIDELINES)

2. PRIOR TO SEDIMENT RETENTION POND CONSTRUCTION:
- CHECK GROUND CONDITIONS TO ENSURE STABLE AND GEOTECHNICAL ASSESSMENT OCCURS.
- CONFIRM DESIGN IS NOT IN THE FLOOD PLAIN.
- INSTALL SILT FENCE OR SUPER SILT FENCE BELOW WORKS AREA.
- REMOVE UNSUITABLE MATERIAL AND CONFIRM APPROPRIATE LOCATION.



WIDE SHALLOW LEVEL SPILLWAY OVER EXISTING GROUND WHERE POSSIBLE, RETAINING THE EXISTING GRASS COVER. MINIMUM WIDTH 6m. BARE AREAS TO BE STABILISED WITH CONCRETE, TWO LAYERS OF GEOTEXTILE OR OTHER ARMOURING

SECURE THE ENDS OF THE LEVEL SPREADER BY BURYING WITHIN THE EARTH BUND AND HAUNCHING WITH CONCRETE

BUND/DIVERSION CHANNELS TO ENSURE ALL FLOW ENTERS AT THE INLET END

SEDIMENT FOREBAY (1m DEEP AND 2m WIDE)

LEVEL SPREADER FULL WIDTH OF INLET END, BATTER INTO POND TO BE STABILISED WITH SOFT MATTING GEOTEXTILE

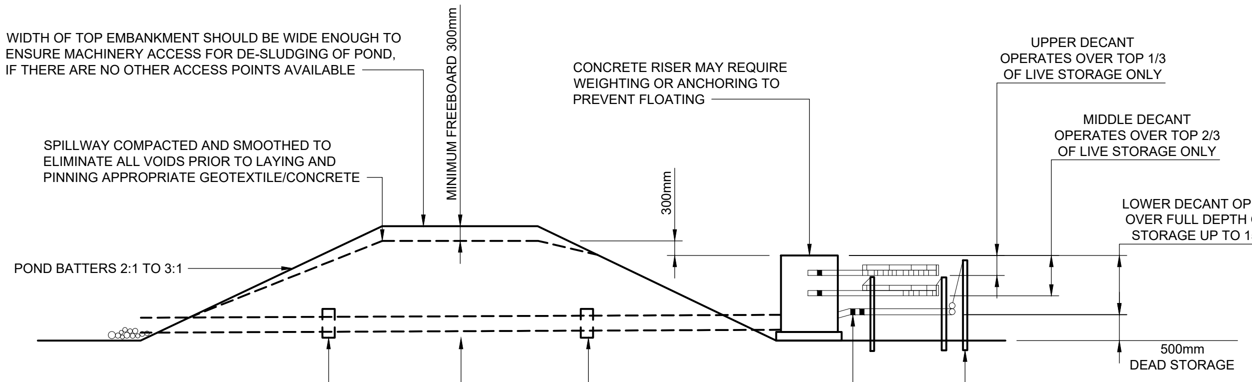
EXTRA CREST WIDTH MAY BE REQUIRED TO PROVIDE FOR MACHINERY ACCESS FOR CLEANING OUT

PINNED GEOTEXTILE OVERLAID WITH LARGE ROCK TO BREAK UP FLOW

ALL BARE SURFACES TO BE STABILISED WITH VEGETATION IF THE POND IS TO REMAIN THROUGH A WINTER PERIOD, OTHERWISE JUST THE OUTER BATTER NEEDS TO BE STABILISED

SCHEMATIC - SEDIMENT RETENTION POND

N.T.S.



WIDTH OF TOP EMBANKMENT SHOULD BE WIDE ENOUGH TO ENSURE MACHINERY ACCESS FOR DE-SLUDGING OF POND, IF THERE ARE NO OTHER ACCESS POINTS AVAILABLE

CONCRETE RISER MAY REQUIRE WEIGHTING OR ANCHORING TO PREVENT FLOATING

UPPER DECANT OPERATES OVER TOP 1/3 OF LIVE STORAGE ONLY

MIDDLE DECANT OPERATES OVER TOP 2/3 OF LIVE STORAGE ONLY

LOWER DECANT OPERATES OVER FULL DEPTH OF LIVE STORAGE UP TO 1500mm

SPILLWAY COMPACTED AND SMOOTHED TO ELIMINATE ALL VOIDS PRIOR TO LAYING AND PINNING APPROPRIATE GEOTEXTILE/CONCRETE

POND BATTERS 2:1 TO 3:1

POURED CONCRETE ANTI-SEEP COLLAR

300mmØ DISCHARGE PIPE LAID AT 1 TO 2% GRADIENT

POURED CONCRETE ANTI-SEEP COLLAR

WARATAH STAKES REQUIRED FOR ALL DECANTS

LOWEST INLET PIPE TO RISER IS ANGLED UPWARD AT 15° TO EASE TENSION ON FLEXIBLE JOINT

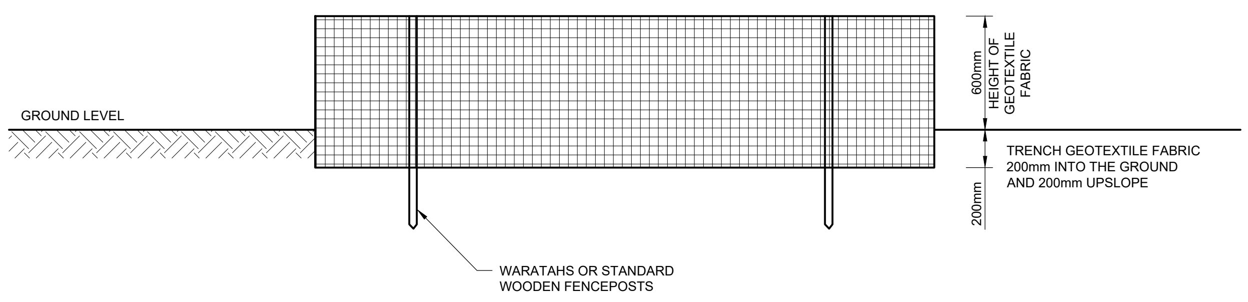
SECTION - SEDIMENT RETENTION POND FOR THREE DECANTS

N.T.S.

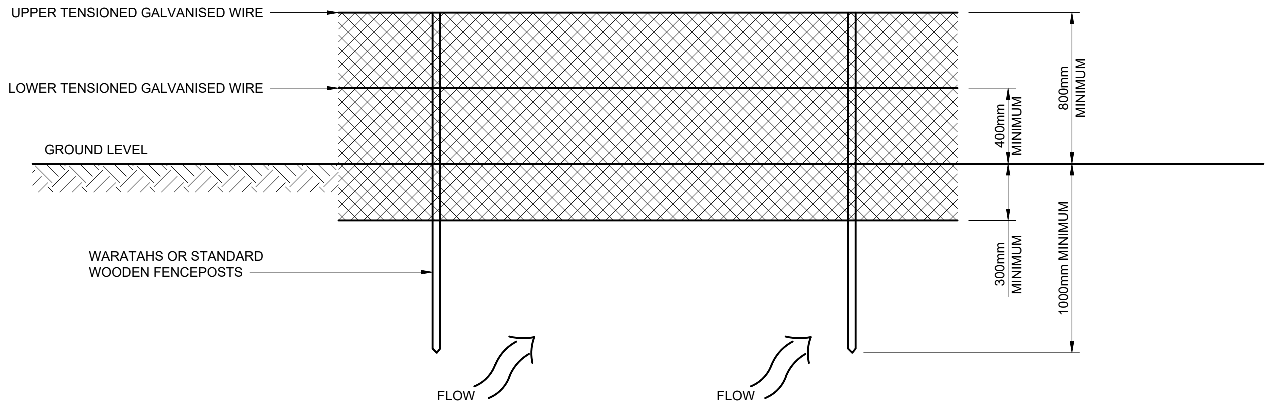
EROSION AND SEDIMENT CONTROL
TYPICAL DETAILS
SEDIMENT RETENTION POND

NOTES

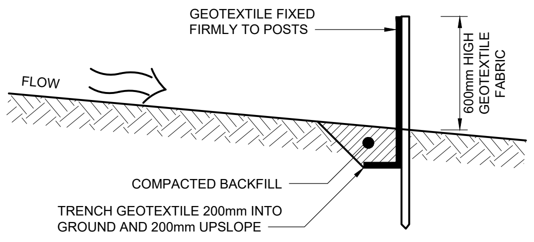
1. REFER TO NZTA EROSION AND SEDIMENT CONTROL GUIDELINES FOR STATE HIGHWAY INFRASTRUCTURE (NZTA GUIDELINES)



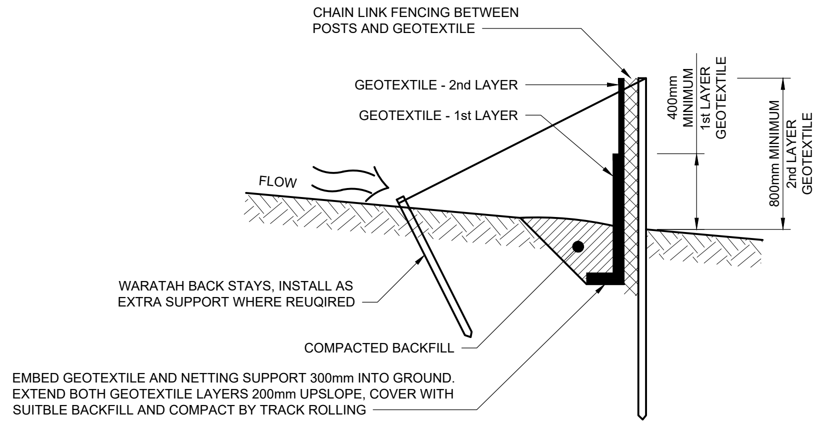
ELEVATION - SILT FENCE
SCALE 1:20 (A1)



ELEVATION - SUPER SILT FENCE
SCALE 1:20 (A1)



TYPICAL SECTION - SILT FENCE
SCALE 1:20 (A1)



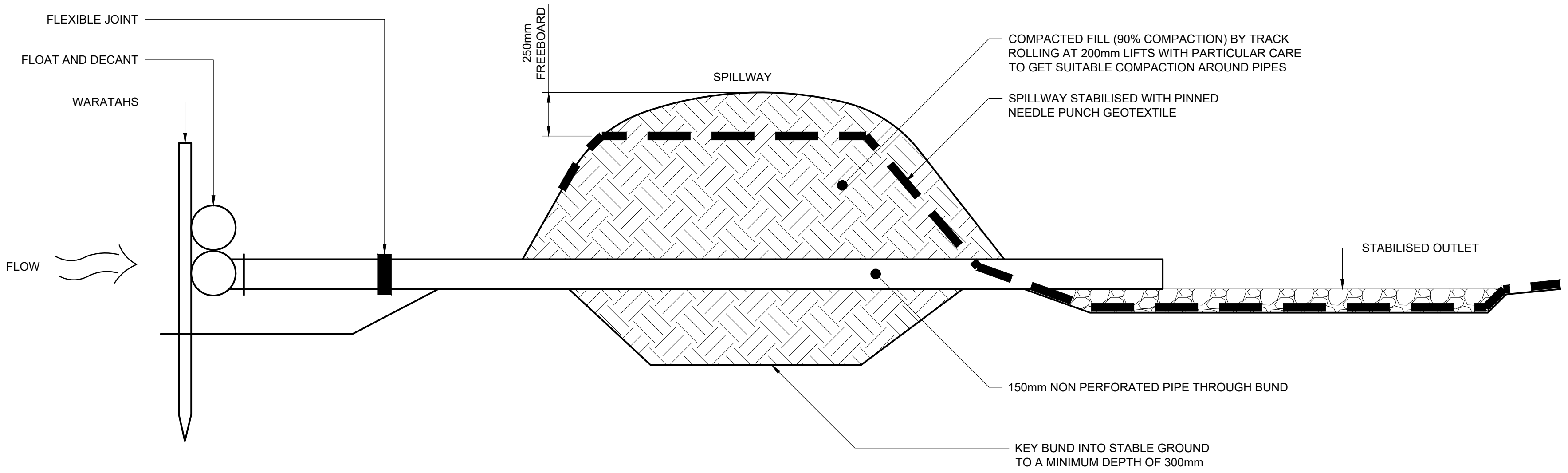
TYPICAL SECTION - SUPER SILT FENCE
SCALE 1:20 (A1)

EROSION AND SEDIMENT CONTROL
TYPICAL DETAILS
SILT FENCE

NOTES

1. REFER TO NZTA EROSION AND SEDIMENT CONTROL GUIDELINES
   FOR STATE HIGHWAY INFRASTRUCTURE (NZTA GUIDELINES)

2. DECANTING EARTH BUNS TO HAVE:
- 3:1 TO 5:1 LENGTH TO WIDTH RATIO
- FLOATING DECANTS
- ABILITY TO SAFELY PASS 1% AEP RAIN EVENT.

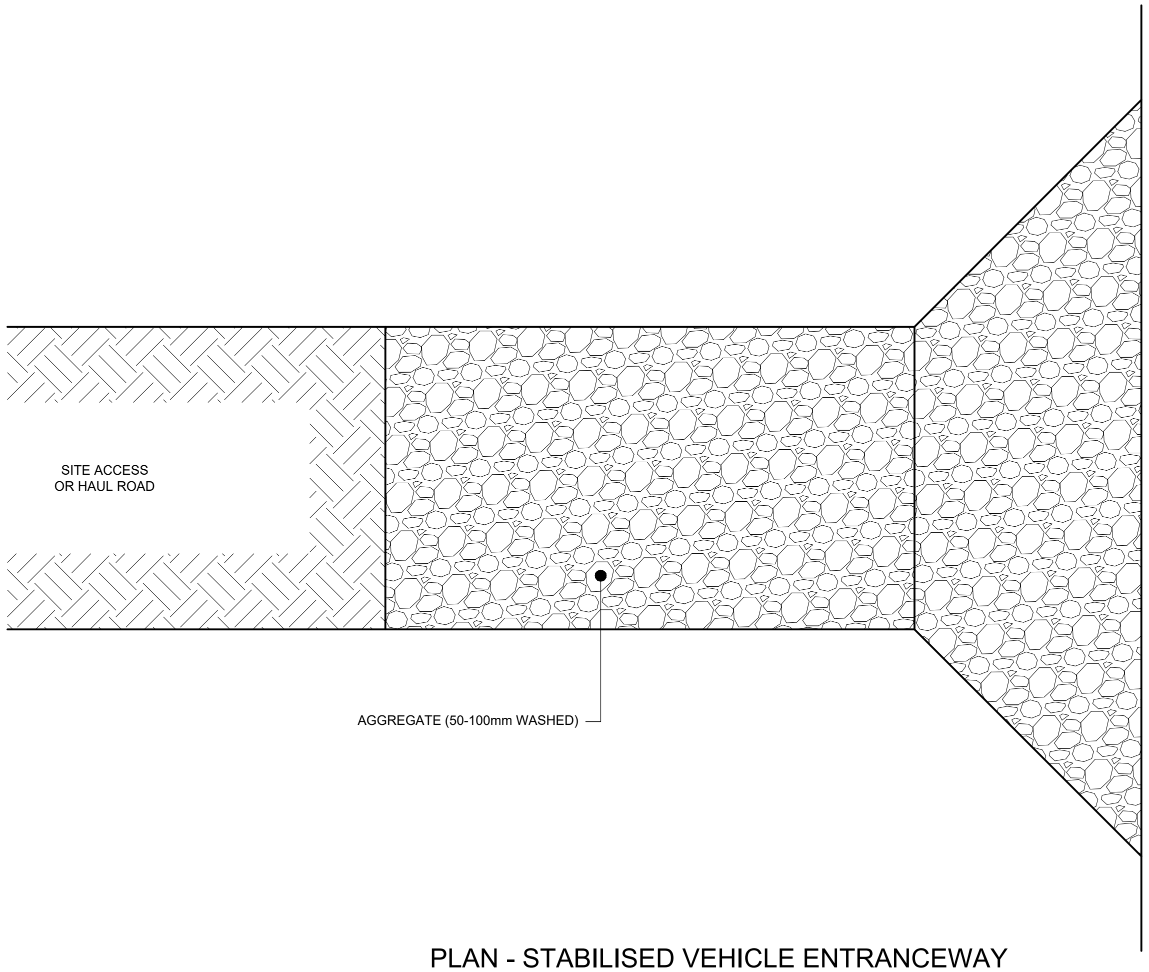


DECANTING EARTH BUND
N.T.S.

EROSION AND SEDIMENT CONTROL
TYPICAL DETAILS
DECANTING EARTH BUND

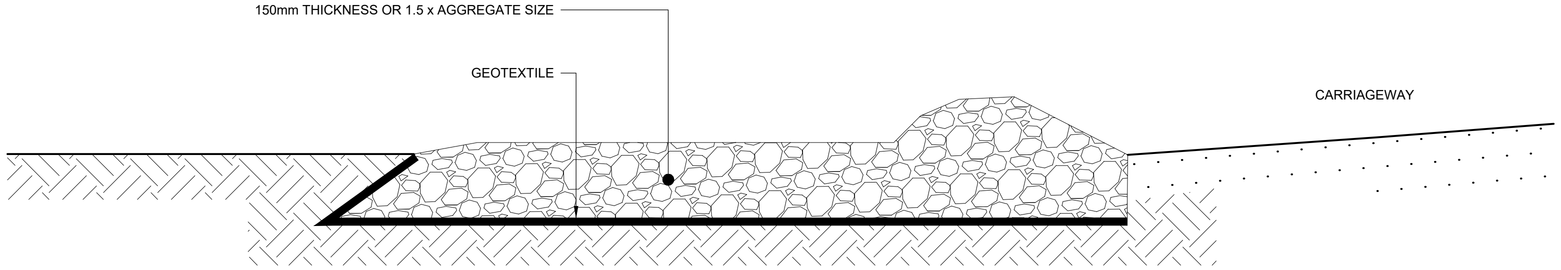
NOTES

1. REFER TO NZTA EROSION AND SEDIMENT CONTROL GUIDELINES FOR STATE HIGHWAY INFRASTRUCTURE (NZTA GUIDELINES)



PLAN - STABILISED VEHICLE ENTRANCEWAY

NOT TO SCALE



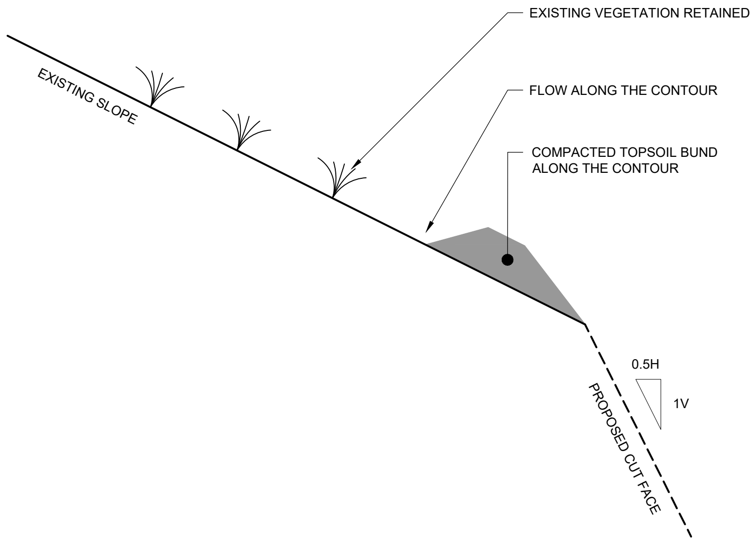
SECTION - STABILISED VEHICLE ENTRANCEWAY

NOT TO SCALE

EROSION AND SEDIMENT CONTROL
TYPICAL DETAILS
STABILISED VEHICLE ENTRANCEWAY

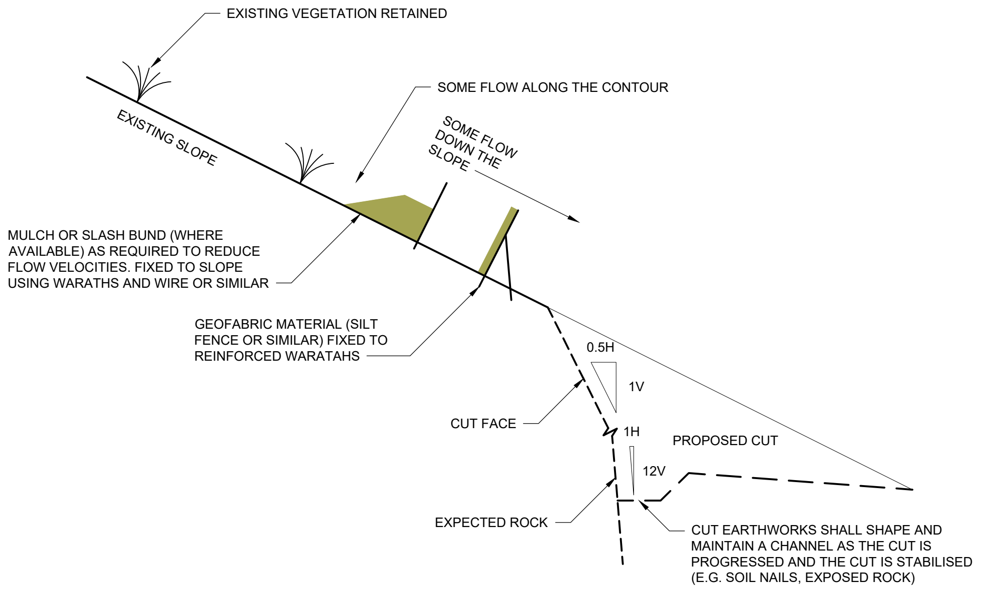
NOTES

1. REFER TO NZTA EROSION AND SEDIMENT CONTROL GUIDELINES FOR STATE HIGHWAY INFRASTRUCTURE (NZTA GUIDELINES)
2. DESIGN DIMENSIONS SUBJECT TO SPECIFIC DESIGN WITHIN CWMP AND SITE SPECIFIC MANAGEMENT PLAN DETAILS.



SECTION - CLEAN WATER DIVERSION TYPE A

N.T.S.



SECTION - CLEAN WATER DIVERSION TYPE B

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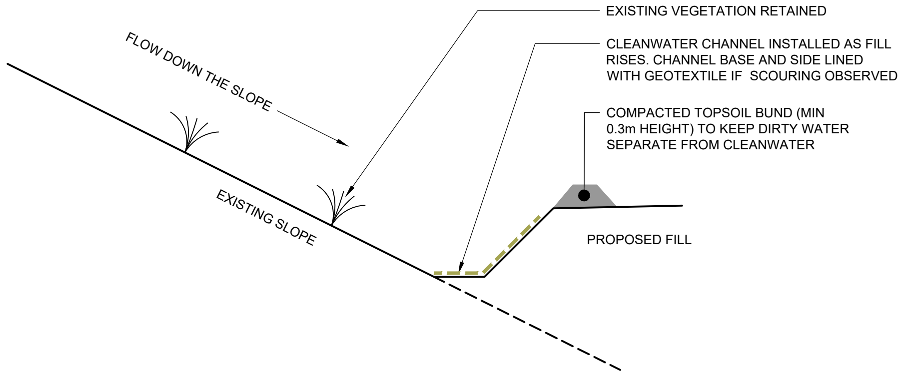
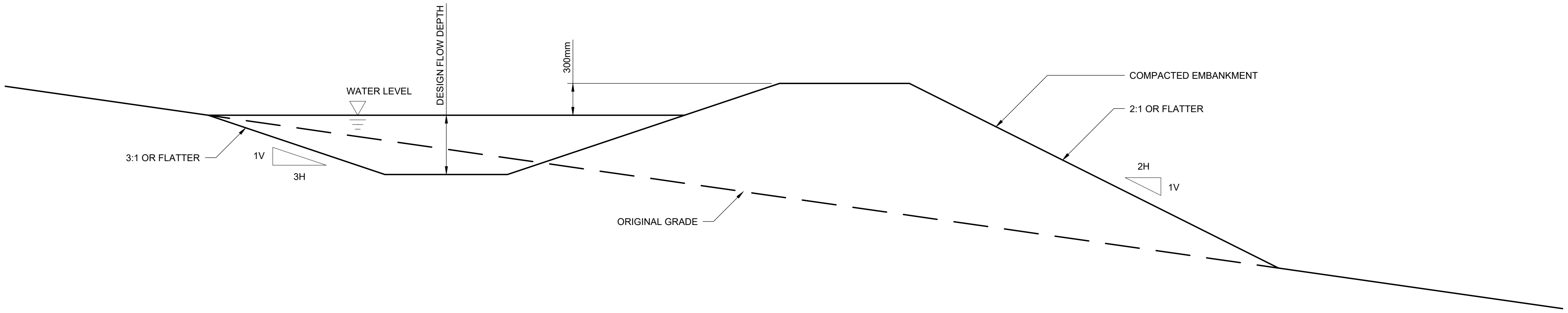


SECTION - CLEAN WATER DIVERSION TYPE C

N.T.S.



SECTION - DIRTY WATER DIVERSION

N.T.S.

EROSION AND SEDIMENT CONTROL
TYPICAL DETAILS
WATER DIVERSION

Tonkin+Taylor