Track Construction and Maintenance Guidelines

Guidelines – VC 1672





Department of Conservation
Te Papa Atawhai

CONTENTS

I. Purpose

These guidelines provide advice and technical information on the construction and maintenance of recreation tracks for walkers and off road mountain bikers. The aim is to provide best practice information that is useful to Programme Managers, Rangers, and contractors in planning and carrying out work on tracks.

Standards for tracks are set out in the Department's Track Service Standards (SNZ HB 8630:2004). While these state what a track should be like to meet the needs of different visitors, they do not describe how that can be achieved. That is the objective of this document. It is the "how to" guide for staff involved in planning for, constructing and maintaining tracks to meet the track service standards.

The guidelines are accompanied by a much shorter, waterproof and pocket-sized field guide. This contains all parts of this document likely to be useful to staff in the field.

II. About this Document

Published by:

Department of Conservation, Head Office, Wellington

Coordinator

Peter Devlin

Owner

Brian Dobbie

Approved for use

Signed *Kevin O'Connor*
Date 1 July 2008

Signed *Barbara Browne*
Date 1 July 2008

Signed *John Cumberpatch*
Date 1 July 2008

Amendments

Amendment date	Amendment details	DOCDM version	Amended by

Glossary

See Appendix 1 for all the major terms used in these guidelines.

Section One: PLANNING FOR TRACKS

1. Introduction

Tracks provide users with a unique experience. This will involve exposure to a rich combination of components including landscape, visual and sensory experiences, intellectual stimulation, and produce emotions and feelings that continually make tracks enjoyable to use time and time again.

Contemporary tracks should not just happen. They need to be planned and designed in such a way that visitors interact with the environment; well designed and constructed tracks look as though they have been there for some time.

Many Conservation Management Strategies and Management Plans refer to visitor impacts and the need to manage these impacts. Hence, there is an expectation from the public for the ongoing repair and maintenance of our walking tracks and a requirement to meet the standards contained within NZS HB 8630:2004.

2. Scope

This document provides guidelines on ways to manage the construction and maintenance of tracks. It covers a number of principles that can be applied, but best practice will often be dependent upon local materials, climate, equipment and costs.

Backcountry user groups consulted to get a user perspective on what should be in the manual expressed concern over what they consider to be “over-engineering” and “over-enthusiastic cutting” of some tracks, particularly the Great Walks and easy tramping tracks, but also some tramping tracks. They want to see construction and benching of tramping tracks, in particular, limited to where it is absolutely necessary. This is, in fact, what the standard (NZS HB 8630:2004) requires. While much of this manual is devoted to management of formed, benched tracks, it has to be borne in mind that most tracks managed by the Department are not constructed and benched and do not have to be.

The guidelines will not provide information on archaeological sites, organic wetlands, sand dunes or areas of sensitive tree root plates. Many of these locations require specific solutions for which suitable advice should be sought. Nor will it cover the scheduling and monitoring of track work. These aspects of work are covered through the Standard Operating Procedure for Track Ongoing Inspections and the scheduling of work through the Asset Management Information System. The design and construction of signs, track standards and visitor structures are covered comprehensively in other documents.

Many tracks will have historic value and often follow historic routes. Constructing and maintaining these tracks requires specialist historic advice and is not covered in these guidelines. For more information, refer to Appendix 13.

There are approximately 12,900 kilometres of track network in New Zealand on land managed by the Department, traversing a range of geological landforms and subject to diverse weather conditions. They play an important role in providing a range of outdoor recreation opportunities for a diverse and growing number of people. The type and extent of tracks provided by DOC in New Zealand is outlined in Table 1.

Conservancy	**Short Walks**	**Short Walks - disabled**	**Walking Tracks**	**Great Walks**	**Easy Tramping tracks**	**Tramping track**	**Routes**	**Total**
Northland	16	2	263	15	0	313	0	609
Auckland	6	0	148	0	12	137	0	303
Waikato	18	1	164	0	0	547	27	757
Bay of Plenty	8	1	161	40	0	362	32	604
Tongariro / Taupo	5	2	113	48	0	319	23	510
East Coast	11	1	125	46	10	1193	199	1585
Wanganui	10	2	77	56	25	576	59	805
Wellington	0	0.4	143	0	72	534	19	768
Nelson / Marlborough	16	2	188	93	150	1208	316	1973
West Coast	33	6	186	42	38	581	232	1118
Canterbury	16	4	217	0	95	760	215	1307
Otago	21	0	440	7	125	718	122	1433
Southland	3	1	83	155	61	672	207	1182
Total	163	22	2308	502	588	7920	1451	12,954

Table 1 - Location and length of tracks provided by the Department of Conservation, as at June 2008

3. Visitor Experience

The primary tool for managing visitor experience used by the Department of Conservation is the Recreation Opportunity Spectrum (ROS).

The ROS is a tool for describing, managing and maintaining a range of recreation opportunities provided by the Department.

The recreation experience is central to the ROS concept. A combination of the environmental setting and specific activity or a group of activities, provided in a setting will determine the type of experience a visitor will have.

One of the goals for recreation managers is to maintain a range of recreation opportunities and facilities that provide fulfilling and satisfying recreation experiences. To achieve this, outdoor recreation opportunities can be identified and classified along a continuum, from urban to wilderness.

ROS provides an inventory of the recreation opportunities provided. Not only should we aim to provide a spectrum of recreation opportunity across the country, but a spectrum within each ROS setting. In the case of tracks, a spectrum should exist for users from short walks through to routes. **Within some settings a range of track categories can be applied to ensure there is transition from one visitor group to the next.** For example, across the country, tracks defined in the category walking tracks need to be available from 2.0 metres wide down to 0.75 metres wide. Providing this continuum within the standard caters for a greater range of people and provides visitors a range of experiences and the opportunity to progress onto more difficult and challenging opportunities.

.

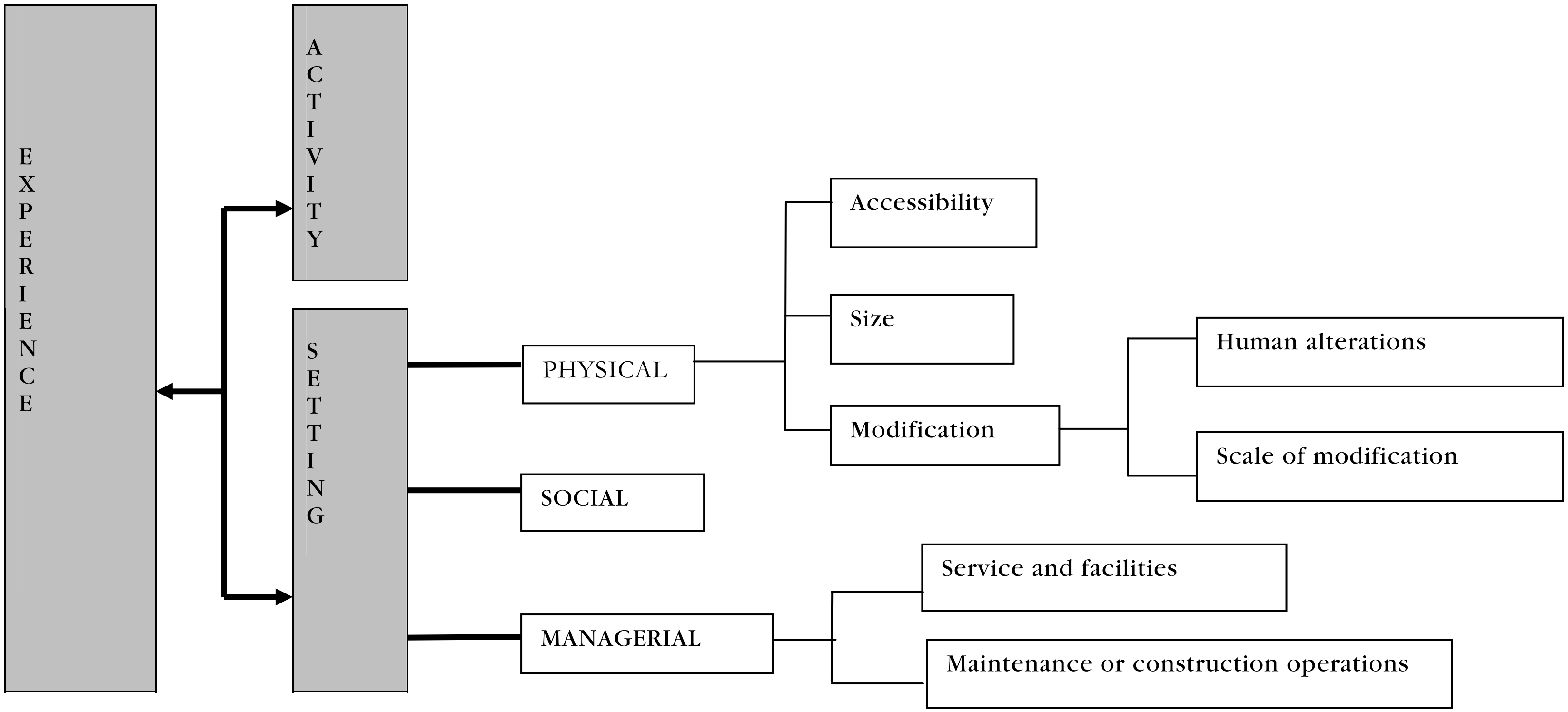


Figure 1 - ROS factors influenced by track upgrade work

Extract from - Factors that make up each ROS Opportunity

3.1 VISITOR SETTING CHARACTERISTICS

As managers, an understanding of the setting characteristics will determine whether track upgrade work will have a potentially positive or detrimental influence on the visitor's experience. In particular, the level of modification to the natural environment can have a profound effect on how visitors enjoy their experience.

In the example below, both pictures have been taken on the same Easy Tramping Track. The upgraded track has disengaged users from the environment. Furthermore, with the creation of long straight sections of track, the secrets of what might be revealed around the corner no longer exist and users can now only engage with the visual corridor which has been opened in front of them.

In contrast to the upgraded section of track, the older track offers the visitor engagement with the environment and is significantly more in tune with the topography through which they are travelling. The visitor has more opportunity to experience the natural environment and around every corner a new visual panorama unfolds.

Figure 2 – Upgraded track **Figure 3 – Track prior to upgrade**

(Photos Mick Abbott)

While SNZ HB 8630:2004 sets the parameters for track classifications it is also linked to the ROS. Therefore any track upgrade work needs to fit the ROS for that location and maintain a continuum of opportunities across the spectrum.

3.2 HISTORIC SETTING CHARACTERISTICS

Historic characteristics are another identifier for managers. Where possible retain an historic track's original profile, line and grade and minimise the loss of original material/fabric. This maintains authenticity and significantly enhances the heritage experience of visitors.

Figure 4-

1890's gold mining tramway at Wilsons River in Fiordland, its 100 year old rails covered in moss

Figure 5 -

This logging frame on Great Barrier Island is right beside a key walking track.

It is the last one left standing in NZ

4. Guiding Principles for Track Construction

KEEP WATER AWAY FROM THE TRACK SURFACE Maintain a cross fall of between 1-2º (3-4%) and maintain track shape. Remove water from the side of the track as soon as possible using a suitable water drainage system. Maintain natural waterways.
CONSTRUCT SUSTAINABLE GRADES Generally speaking, the lower the grade the more sustainable the track will be over the long term.
MAKE THE TRACK FLOW Avoid straight lines, follow the natural contour, make the track flow through the land.
PROVIDE A SUITABLE WALKING SURFACE Apply metal aggregate only where necessary. Where engineering techniques are required build on a firm foundation, ensure adequate pavement depth. Make use of suitable local materials and compact at the correct moisture content.
MAINTAIN A GOOD SURFACE Where necessary, establish a good track surface that binds together, replace lost material and maintain track shape.
MAINTAIN WHEN REQUIRED Maintain to the correct standard.
BE ENVIRONMENTALLY ASTUTE Take into account any environmental impacts caused by track work. Prepare an Assessment of Environmental Effects for all significant track construction work. Pay attention to poor maintenance practices and inadequate drainage which could cause sediment and erosion issues.
PROTECT YOUR INVESTMENT Follow the track ongoing inspection regime. It is there to help protect your tracks.
TRAIN STAFF Ensure staff are well trained and kept up to date with current best practice.
RESPECT AND KEEP HISTORIC VALUES Where the track has distinctive historic values, maintain that character.

5. Landscape

A landscape is comprised of the visible features of an area of land, including physical elements such as landforms, living elements of flora and created human elements, for instance human activity in the creation of huts, tracks and structures.

In every natural landscape there are natural shapes. Depending on the landscape, size, scale, texture and complexity will vary. The natural shape of a long sweeping shoreline contrasts significantly with a rugged mountainous landscape. To "fit", tracks need to reflect the natural shape of the landscape. Build this into your track alignment; take into consideration the type of landscape and where the track should be located within that landscape and you are well on the way to making the track "fit".

5.1 AESTHETICS

Aesthetics simply means how good the track looks. A well designed and executed track should look pleasing to the eye and "fit" with "the place". People should get a sense of being part of the place not removed from it.

How tracks are designed has a significant influence on how people feel about a place and influences the way people experience that place. A landscape that is characterised by its remoteness and feeling of isolation makes it a special place. The introduction of tracks into what is largely an unmodified landscape has a visual impact. At a simple level, tracks introduce lines into a landscape where naturally occurring straight lines are rare.

The scale of this impact can be influenced by the track's location within the landscape. Very old pack horse tracks usually followed the natural contour of the land and hugged the topography of the landscape. The advent of machinery has meant that we can now ignore many of the restraints that the old track builders had to contend with and we can put tracks up ridges, go through hillsides and tackle cuttings with relative ease.

Figure 6 -This track does not "fit" the landscape and is out of context with the environment within which it is located

Our unique and diverse landscapes are one of our biggest assets and as builders of tracks within these landscapes we need to undertake our work in a practical but sensitive way. Landscapes can be mountainous with numerous glacial valleys, or much flatter covered in low growing tussock or flax. Alternatively, they can be heavily forested. There are few places in the world where such a diverse range of landscapes can be seen in such a small geographic area. For many, the "undeveloped" feel of our landscape makes it special. **The character of these landscapes and the value placed on them by people is reflected in the vast amount of recreational use they receive.**

5.2 LANDFORMS

A landform is largely defined by its surface form and location in the landscape. Landforms are categorised by features such as elevation, slope, orientation, rock exposure, and soil type. They include mounds, hills, cliffs, valleys, rivers and numerous other elements.

5.2.1 Flat landforms

The experience of the visitor when travelling through a flat landform is generally one of scale, of being out in the open and quite exposed. The sense of size and openness is very dominant.

The simplicity of the flat landform means;

- There are few straight lines or other natural features
- Any visible features are generally low and close to the contour of the ground
- Drainage is generally poor and views tend to be generally quite long in wide open spaces

These features give us a clue as to the type of track and alignment of the track that would be appropriate in this landscape.

- A track with large and sweeping curves
- Aligned to avoid poor drainage areas where possible

The boardwalk shown in Figure 7 has introduced a strong linear element and divided the landscape. This has introduced a sense of scale to the place. Alternatively, a track that is overly intricate with numerous curves would not fit either, as this alignment would conflict with the scale and form of the landscape. Poor drainage usually leads to the solution of raising the track surface above the surrounding ground. This imposes the track upon the landscape rather than it fitting in with the landscape.

Figure 7 - While relatively simple to construct, the impact of this boardwalk on the landscape is considerable

5.2.2 Undulating landforms

Overlapping slopes create the impression of an undulating landform.

- Slopes help to give a sense of enclosure
- Lack of features makes it difficult to determine a sense of scale
- Landscape is generally open in character

An appropriate approach would be to;

- Align the track around the lie of the land, sticking to the higher ground where possible
- The inclination here would be to build a relatively straight track. However this will not fit as cut and fill areas would contrast with the convex nature of the landscape
- Avoid the lowest and wettest ground, but also avoid the prominent high areas, unless these provide the best views. This will result in a track that "fits" into the undulating landscape. While the track may be slightly longer, it will reduce the amount of cut and fill required with the overlapping nature of the landform providing some screening

5.2.3 Hummocky landforms

This landform is generally associated with glacial deposits.

- The landform is made up of quite distinctive hump-like random deposits
- Hummocks are generally quite irregular and small in size
- Tops of the hummocks often provide good lookout points to view the surrounding landscape from

When preparing to construct a track in such a landform;

- Determine whether the track can be aligned through the terrain to avoid the hummocks
- Identify an alignment that avoids an overly complex route. Alignment should not be simple or complex; it should reflect the repetitive nature of the hummocks
- A straight track through a hummocky landform would have a significant visual impact
- Follow the natural geometry of the hummocks where possible

PITFALL!

- **A track that snakes too much is just as obtrusive as a straight line track**

5.2.4 Rocky landforms

This is a very common landform in New Zealand. Rocky landforms are characterised by steep rocky outcrops.

- Exposed rocks are in direct contrast to the surrounding vegetation both in texture and colour
- Rock outcrops will be random in both size and shape

When building a track through rocky landforms it is necessary to:

- Identify a track alignment that maximises the use of easier and flatter country
- Be aware that moving rocks or disturbing rock bluffs will be in direct contrast to the undisturbed and weathered rocks that remain
- Make the maximum use of the undisturbed ground between outcrops where this exists

5.2.5 Narrow V shaped valley

Views in a narrow V shaped valley are generally confined to within the valley.

- The eye tends to be drawn down the slopes to the floor, and up toward the head of the valley
- Rivers are dominant in the valley floor and provide a focus of attention and movement. They act as a "landscape anchor" and we are naturally drawn to them

When constructing a track through a V shaped valley landform it is necessary to:

- Locate the track as close to the valley floor or the river terraces as possible
- Stay away from the river itself as the dynamic nature of river systems and their constantly changing course can cause problems in the future. Construct the track close enough to the river so the user gets a sense of enjoyment from the river, but not so close that floods will have a major impact
- Locate the track between one-third and one-quarter of the way up the valley slope

5.2.6 Broad U shaped valley

Wide open U shaped valleys were formed during periods of glaciation. These have large valley floors and sweeping valley slopes. There will generally be some form of river system or wetland present.

When constructing a track through a Broad U shaped valley it is necessary to:

- Create a simple alignment that reflects the river's course will help reinforce the landscape
- Aligning the track for the best fit between the sideslope and the valley floor

HOT TIP

- **As a general rule, tracks should be located at the junction of the valley slope with the valley floor**

Be aware that the sides of U shaped glaciated valleys are usually quite weathered and can be prone to slips and erosion.

5.2.7 Hills

Hills are very common in the landscape and we encounter them time and time again.

- Steeper hills tend to draw the eye down or up the hill slopes

- The steepness of the slope has a bearing on the way people interpret the landscape

When constructing a track through hills it is necessary to:

- Reducing interference with the natural characteristics
- Take advantage of as many of the naturally occurring features as possible

HOT TIP

- **Avoid putting a track half way up the hillside as this interrupts the visual flow of the slope**

5.2.8 Ridgelines

Ridgelines are common in almost all landscapes and are generally very prominent features. Being so prominent, it is almost inevitable that locating any track on a ridgeline will cause significant visual impacts.

When constructing a track on a ridgeline it is necessary to:

- Evaluate the location of the track, a track on a major ridge backbone, where the gradient is usually flatter will have a lower visual impact than a track descending a ridge to the bushline
- Keep any cut and fill work to the minimum as this will add to the visual impacts

5.2.9 Saddlebacks

Saddlebacks are more commonly known as passes or saddles and are areas of lower ground between two mountains or hills.

- They are well utilised by tracks to pass from one catchment system into another and the skyline is often very prominent
- The eye is naturally drawn to the low saddle and this becomes the focal point

The alignment of a track going over a saddle should reflect the symmetry of the landform.

HOT TIP

- **Ideally any track going over the pass should approach at an angle and cross over the lowest part of the pass**

5.2.10 Water – lake edge

The coming together of land and water is one of the most prominent associations in the landscape. The convergence ranges from relatively complex with lots of indents to simple with long smooth shoreline.

There are two approaches that can be taken depending upon the configuration of the shoreline.

- For simple shorelines, the track alignment should reflect the simple and relatively straightforward nature of the shore
- A more complicated shoreline needs to be treated differently. The track alignment will need to have a balance between a very simple and an overly complicated alignment that mirrors the shoreline

6. Landscape Features

In every natural landscape there are natural features and these features are present in certain shapes. Depending on the landscape, size, scale, texture and complexity will vary.

6.1 LANDSCAPE ANCHORS

There are many natural features in the landscape, vertical features such as trees and large boulders, long natural edges where valley slopes meet the valley floor or where a lake or coastline meets with the land. All of these features are particularly strong at holding our attention and are referred to as landscape anchors.

- Trees and large rock outcrops are good examples of vertical features that we are drawn towards. Utilise natural features that people are drawn to as much as possible
- People are naturally drawn to landscape anchors. People have a desire to go to that particular place or go that particular way. By not incorporating these features into the track design there will be additional problems to contend with in the future
- Many landscape anchors can be utilised, even small rocks that a track "hugs" helps to anchor the track
- The more features you can "hug" the better "feel" the track will have for its users

6.2 EDGES

Edges play an extremely important role in both making a track "fit" and hold people's attention. There are many, many different natural edges in nature. Being on the edge gives us the contrast between two sides. The greater the contrast between the two edges the greater the experience of the visitor in the setting.

6.3 GATEWAYS

A gateway is simply a place where your sense of enclosure is increased.

- Usually achieved via a pinch point on a track; it can be a track squeezing between two trees or boulders
- An edge influence can also be possible with a tree on one side of the track and the track edge on the other

- Gateways located at the junction of a car park and a bush walk introduce a much stronger sense of transition between the formal and structured shape of the car park and the natural shapes of a bush walk

6.4 HISTORIC FEATURES

Historic features are often found in natural landscapes. They provide a visible and tangible sense of history to the landscape.

Track design needs to consider the landscape holistically, taking into account the natural environment and the needs of the visitors without compromising any of its historic or cultural values.

7. Soil Types

Why is this important? **Because soil particle size is the most important factor to indicate the likely behaviour and performance of your track.** Within each landform the soil type also determines where a track is best located. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for tracks.

Soil types vary hugely throughout the country, so much so that you may encounter different soil types on the same track. Soil is characterised by its structure which in turn is determined by particle size.

There are four basic generic soil types based on particle size: clay, silt, sand, and gravels. Each one is different in size and shape and affects how your track will perform under certain conditions. The proportions of clay, silt, sand and gravel will determine the track's ability to resist deformation and erosion. Being able to determine which one you are dealing with will aid you with your track construction. The key issue for design and construction purposes is whether the soil will act as a cohesive or granular material.

Organic material (peat, topsoil) should be removed when constructing or upgrading a short walk or walking track. Avoid building a track on this material as its organic content makes it unsuitable where a high number of visitors are expected. However, it has a valuable place when landscaping and should not be discarded.

Soil types are classified as shown in Table 2.

COARSE SOILS (granular soils or non-cohesive soils)		**FINE SOILS (cohesive soils)**		**OTHER SOIL**
Gravel	Sand	Silt	Clay	Organic soils

Table 2 - Soil Groups

7.1 GRAVEL AND SAND

Gravel and sand may be either rock fragments or single materials of various sizes and shapes. If there is a narrow range of particle sizes present, the material is described as uniform. Where a broad range of particle sizes are present the material is described as well graded.

7.2 SILT

Silt particle size is between clay and very fine sand (Table 3). Silt is less plastic (unable to maintain its shape) and more permeable (allows water to pass through) than clay. It displays quick and dilatant behaviour. Quick behaviour refers to the tendency of silt to liquefy when shaken or vibrated, and dilatancy refers to the tendency to undergo volume increase when deformed.

7.3 CLAY

Clay consists of very small particles and exhibits the properties of cohesion and plasticity, which are not found in sand or gravel. Cohesion refers to the fact that the material sticks together, while plasticity is the property that allows the material to be moulded and deformed without volume change or rebound, and without cracking or crumbling.

7.4 ORGANIC SOIL

Organic soil should only be identified as such if the organic content is high and the material no longer behaves like a silt or clay. Soils containing small to moderate amounts of organic material still retain the properties of silts or clays and should be described within those categories.

	Fine Earth Fragments	Rock Earth Fragments	Type
Boulders		> 200 mm	C O A R S E
Cobbles		200-60.0 mm	
Gravel		60 mm-2.0 mm	
Coarse sand	2.0-0.6 mm		
Medium sand	0.6-0.2 mm		
Fine sand	0.2-0.06 mm		
Silt	0.06-0.002 mm		F I N E
Clay	< 0.002 mm		

Table 3 – Soil Categories

A granular soil is where all the particles are larger than silt size and a cohesive soil is where all the particles are smaller than sand. Soils containing a full range of particle sizes from clays to gravel will act cohesively if only 15% to 25% of the particles are clay or silt sized.

7.5 PLASTICITY

Plasticity is the most important property of a clay or silt. A highly plastic soil can be moulded or deformed over a wide moisture content range. It will not crack or show a tendency to reduce in volume. Highly plastic clays will become rock hard when dry while low plasticity clays will crumble quite easily.

7.6 FIELD TESTS

There are some simple tests you can carry out that will determine which soil type you are dealing with:

7.6.1 Clay soil

To determine the plasticity of clay in the field it is necessary to mould the shape of the sample over a range of moisture contents.

- **Moist clay** sticks, easily forms into a ball and leaves a stain in the palm of your hand
- **Dry clay** is very hard and almost impossible to break with your hand (if it is highly plastic)

7.6.2 Silty soil

To distinguish between silts and clay soils, place a handful of soil (sufficiently wet to be almost sticky) in the open palm of the hand. Tap the bottom of the hand with the other hand. If the sample is a **silt**, quick behaviour appears (water will appear on the surface, giving it a shiny appearance), and will then disappear if the sample is squeezed or manipulated. When it is manipulated the sample tends to dilate and draw water back into it. With clay, these characteristics are not present.

- **Moist silt** feels smooth and sticky but falls apart. Does not leave much of a stain on your hand
- **Dry silt** feels like flour, smooth and powdery

7.6.3 Sandy soil

- **Moist sand** when squeezed together in the palm of your hand will form a ball which will break apart easily and not leave a stain on your hand
- **Dry sand** feels rough and will not hold together. You can see individual particles of sand

7.6.4 Loam soil

Loam soils are a combination of all three particle types in which no particle type is dominant. As a general rule these soils are good to work with, having reasonable drainage and holding together well.

- **Wet loam** forms a ball when squeezed together in the palm of your hand. It is neither too gritty nor sticky

Property	Silt	Sand	Clay
Water holding capacity	Low	Medium to high	High
Drainage	High	Slow to medium	Very Slow
Compaction	Low	Medium	High
Susceptible to water erosion	Low	High	Low (if aggregated) High (if not)

Table 4 - Soil Properties and Behaviour Relevant to Track construction

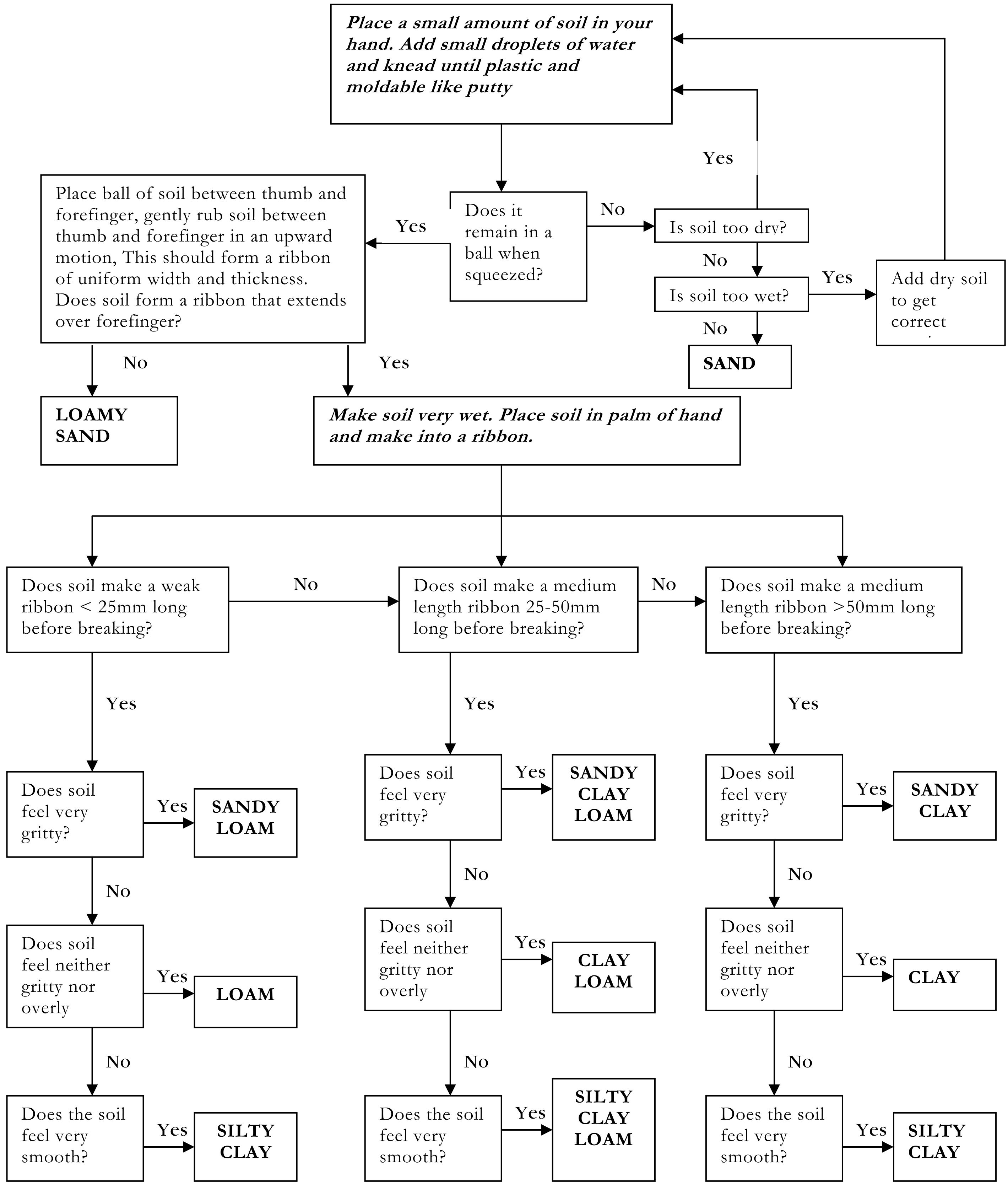
Some soils are unsuitable as a walking surface. Table 5 outlines suitable and unsuitable types.

Not suitable as track foundation	Suitable with the use of a geotextile separator	Suitable foundation
Organic humus	Peat	Firm clay/ silt soils
	Soft clay/ silt soils	Sands / gravels
		Rocks

Table 5 – Suitability of soil types as a track foundation

All leaf litter and organic matter should be removed from the cut and fill zone. The material can be used later to rehabilitate borrow pits and the impact of construction work.

Field Test for Determining Whether Soil is Clay, Silt, Sand or Loam



(Natural Surface Trails by Design)

8. Track Destruction

Why is this important? Because understanding the forces that destroy a track and the interaction of these forces will help you build a better track. The most important thing for you to understand is how water and gravity work together to move dirt. There are three key forces at work on the surface of your track; erosion, displacement and compaction.

8.1 EROSION

Water wears away the track surface by picking up soil particles and with gravity carries them over the side of your track, or into side drains and culvert heads. The greater the volume and speed of water, the larger the particle size it will move. Faster water will carry more dirt at a greater speed. The damage caused will depend on how much water is involved and how fast it is moving.

Soil, water and gravity are three important elements of track work. We move soil to achieve what we want, a certain type of track at a certain gradient. Once we have moved the soil we then need to keep it there. Water is a powerful substance and a major aspect of track work is to slow down the rate at which we lose soil through water erosion. Soil is picked up and moved every time it rains or the wind blows strongly, and particles of soil are either washed or blown away. Soil particles are taken from one place and put in another with the help of gravity. The steeper the track section the greater the influence of gravity. Gravity will speed up the rate of soil being moved or slow it down.

Figure 8 -Discoloured water is a clear indication that soil particles have been “picked up” by the water

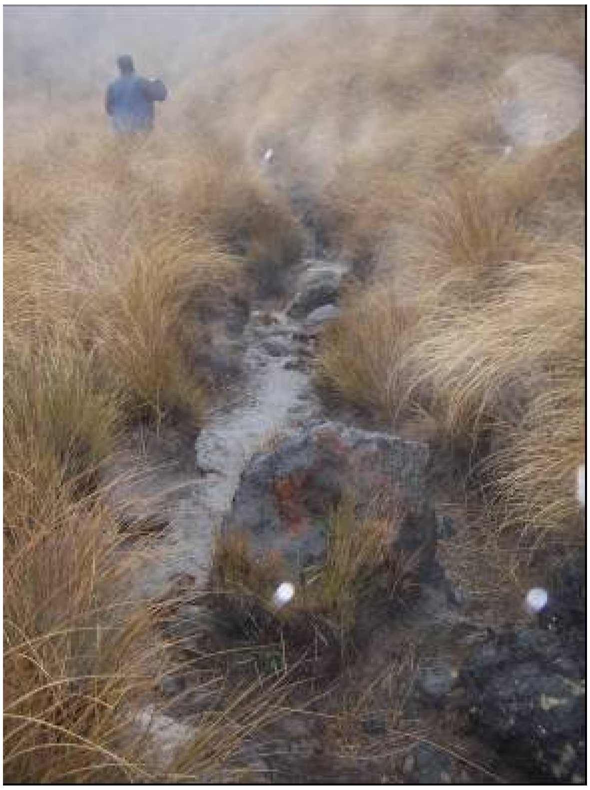


Figure 9 - Water flowing directly down a walking track. Sections of this track have been eroded to depths of 1.5 metres.

This track is now effectively the side drain with water flowing down onto the track from the sideslope

Water will also build up soil in other places when it slows down and runs out of energy to carry the soil particles. It lets them go and deposits them. Small erosion events tend to drop particles around narrow points such as culvert inlets. Repeated small events can block culverts that have been incorrectly installed. Knowing that water drops particles can be used to your advantage when building tracks, always think about slowing the water down. You will find a lot of the particles are "let go" in side drains and catch pits.

By now you should understand how important it is to get water off the track surface and stop it from removing the soil particles. Water also causes problems when it is absorbed by soil particles. Clay is a good example of when too much water is absorbed by the clay particles we get a very boggy, wet track surface.

8.2 DISPLACEMENT

Displacement is the movement of surface material (soil, gravel, stones etc) as a result of use. Displacement of naturally occurring soils generally takes place on weak cohesive soils (soil where the particle size is smaller than sand). On stone aggregate tracks, moving feet kick stones from the track surface. Mountain bike tyres dislodge and move soil particles, gravel and even small rocks. Over time, the constant moving of particles starts to wear away the track surface causing it to change shape.

Figure 10 - Note the horizontal displacement of the track surface material down to the geocells.

Sixty thousand people walk down this track annually and have displaced the track surface material when coming off the last step onto the track

On muddy surfaces, displacement is particularly evident when the surface is unable to sustain the weight of the user.

8.3 COMPACTION

This is the process by which soil particles are pressed together, forcing air out from between the particles and creating a dense compacted surface. Compaction is caused by a number of different mechanisms. We can compact a track surface using a mechanical compactor or compaction may occur through visitor use of the track. Mechanical compactors are either vibratory or static and typically come in the form of a roller or plate compactor.

Don't underestimate the compaction effect of visitors, it is very significant. The downward force of a visitor's physical weight plus the weight of their pack can be considerable. An 80 kg visitor with a 20 kg backpack exerts a considerable force over a small surface area. The 100 kg weight is further concentrated on the track surface when not all of the tread on the hiking boot comes into contact with the surface; lets say in the vicinity of 50%. So we have a 100 kg of downward force being applied on a small surface area of around 350 mm x 100 mm and this intensifies the compaction pressure. Continual compaction caused by thousands of visitors takes its toll on our tracks and as more and more air is squeezed out and the soil particles get closer together your track surface is now concave in shape and generally below the surrounding ground, and you now have the start of a rut and some track water management issues.

Figure 11 - Use of a vibrating plate compactor helps to harden the track surface and reduce erosion and displacement of material

To understand why tracks tend to get compacted in the middle of the track or the inside of corners it is useful to have an understanding of load distribution. The extent to which a load is distributed will depend on the soil type. Generally speaking, the load is distributed in relation to the thickness and quality of the soil/ pavement.

- **Nearly all track surfaces sink from compaction, including well constructed and compacted surfaces. A number of factors will determine how far a track surface will compact**
- **The centre and inside of corners will become the most compacted part of the track as this is where most activity takes place. Outer edges will generally be less compacted**
- **Non-compacted side slope tracks will often fail as a result of the centre of the track being compacted. The more susceptible your surface to compaction the faster the rate of compaction and the sooner outslope failure will occur**
- **Compaction makes the surface more resistant to erosion and displacement**
- **A compacted track surface causes more water to be shed off the track – water finds it difficult to go through the track surface, so water management becomes even more important**

9. Water, Water, Water

Predicting the volume and flow of water is a vital aspect of track construction. Water arrives in various forms, including, rain, fog and snow. It will then flow through and/or across the land depending upon the circumstances. The location of your track in the landscape and the design of your track will determine how it is influenced by water.

9.1 CATCHMENT WATERSHED

The catchment watershed is the land that drains down onto your track. There are a number of variables that come into play but generally speaking the steeper the side slope the greater the water runoff.

Figure 12 - The filtration ability of the soil will also influence how much water runs off. Exceedingly steep side slopes and the rocky nature of this landscape produce a high degree of runoff

9.2 TRACK SURFACE WATERSHED

Track surface watershed is the area of track surface that water falls directly onto before flowing off the track surface. How much water remains on the track surface is affected by the condition of the track surface and track design has a major influence.

9.3 FACTORS THAT INFLUENCE WATER IMPACT ON TRACKS

If you can manage the factors that influence water impacts, then you are creating a more sustainable track which will require minimum maintenance.

9.3.1 Watershed slope

The steeper the slope the more water will run off at a greater speed, so the position of your track on the side slope plays an important role. Whenever feasible locate your track as far up the slope as possible without having an influence on how the track "fits" the landscape.

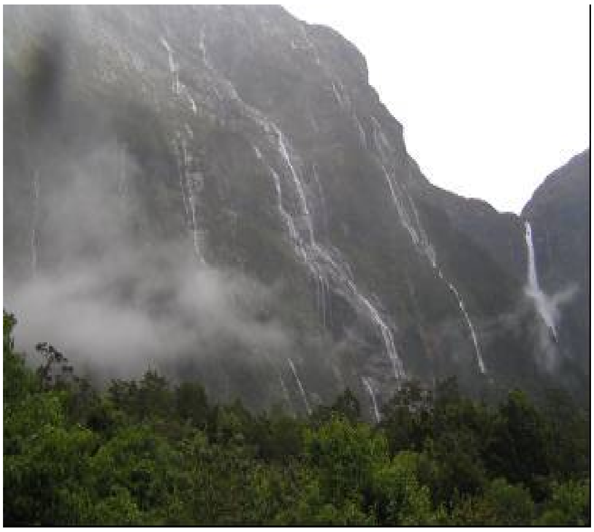


Figure 13 - A high watershed slope and impervious rock creates significant challenges for track constructors

Tracks on flat, or very close to flat, gradients present a slightly different challenge. Because of compaction and displacement, inevitably the track becomes a point where water collects as the lowest lying area of ground. This becomes an extremely difficult area to drain. In many ways these locations are more difficult than tracks on hillsides.

9.3.2 Track surface watershed size

The smaller the track watershed's size the less rain and snow melt it collects. The length of the track surface watershed is highly influenced by track design. Track surface watershed is from the top of a high point on the track to a low point where the water leaves the track. It can be as little as one metre or as much as fifty metres. It depends on the track design.

9.3.3 Surface runoff potential

Surface runoff is the water that flows over the land. It generally occurs when the soil is saturated and cannot hold any more water and all water depressions in the ground are full.

9.3.4 Tree splash erosion

While the presence of trees helps protect the track surface in certain circumstances it also facilitates erosion through splash erosion. Splash erosion is where a tree branch extends out over the track surface. Rain gathers on the tree leaves and drips to the ground. Often the size of the drip from the tree is greater than the size of the rain droplet. When the tree drops hit the track surface they literally explode on impact and force small soil particles (fines) to be washed away.

9.3.5 Track surface width

This is hugely important and has a profound influence on the erosion of your track and the volume of ongoing maintenance required. The wider the track surface, the more water it has falling on it. The greater the volume of water collected the more potential it has for erosion. One of the simplest ways to reduce erosion is to reduce width within the limits of the track service standards.

9.3.6 Weather

While some parts of the country receive less rain than others, most areas receive periods of heavy rain. No matter where you are in the country you need to design the track for these intense rain periods.

9.3.7 Water sources

There are a lot of water sources that need to be accommodated in your track design and maintenance. Water will affect the track surface through the following sources:

- Rain, snow or fog in the catchment watershed
- Rain or snow directly onto the track surface
- Springs
- Seeps (usually seasonal)
- Perched watertable. This is where there is a hard pan a short distance below the surface. Tracks cutting across the slope may cut into the water level
- Flooding from a local floodplain or similar
- Streams
- Seasonal drainage patterns
- Human e.g. District Council road cut outs, farm or other culvert outlets located above the track

9.3.8 Track surface

Some naturally occurring soil surfaces are more resistant to erosion and maintaining their shape than others. We can also manufacture aggregate mixes and import the material to certain locations when required. These manufactured mixes are very erosion resistant.

9.3.9 Visitor numbers and type of use

As we have already discussed, compaction and displacement change the shape of your track allowing water where you do not want it. The number and types of recreational use can have a dramatic impact.

9.3.10 Grade and length

Small increases in the grade of your track tend to significantly increase erosion. The important thing to remember is the steeper your track the more erosion it will be subject to.

Figure 14 - This newly constructed track has a long point to point track surface. It starts at the top of the hill and finishes at the bottom.

Maintaining track shape is critical for the sustainability of this track

Point to point track surface length is also important. A short steep section will not erode as rapidly as a long section of the same gradient. How long a section of track should be depends upon a lot of inter-related variables: grade, length, soil type, visitor numbers, type of use and the volume of water likely to fall on the track surface. These influences will vary according to your local conditions.

9.3.11 Sustainable grade dips

Grade dips remove water from the track surface and allow water to drain freely off the side of the track. A grade dip is a location on the track where there is a very subtle change in direction and elevation, dropping down very gently before rising again. Sustainable grade dips have six characteristics;

- **Minimal sediment flow:** The volume of sediment flowing into the dip needs to be minimised. This is achieved by ensuring that the track surface watersheds are kept to the minimum. If the track surface wears quickly or scours easily then the track watershed is too large
- **Correct gradients:** We already know that the track surface is going to erode and the fines are going to get washed away. As discussed earlier, if the sediment being carried in the water flowing down the track and into the dip loses speed it will drop the sediment in the dip. Water needs to flow into and out of the dip faster than it enters, otherwise it will drop the fines. So the grade of the dip outflow needs to exceed the grade of the track inflow. If the outflow grade is not sufficient a build-up of sediment will occur eventually blocking the dip and making it ineffective. If you are unable to change the track watershed then consider hardening the track surface

- **Large outflow points:** Make the outflow channels wide as this help to prevent clogging and grade dip failure
- **Resistant to compaction and displacement:** Compaction and displacement within the dip can cause the formation of a berm on the downhill side of the track. The formation of the berm will allow water to sit and form a puddle. This will further weaken the track surface and make it more vulnerable to further displacement
- **Dips are large:** Make large dips. They need to be wide and deep enough to function even if some eroded or displaced material ends up in the dip. There should be a gentle transition into and out of the dip
- **Large crests:** The crest (where you enter and exit the dip) needs to be sufficiently strong to resist displacement

A dip constructed with all six characteristics will require the least amount of maintenance. The fewer characteristics a dip has the more maintenance it will require.

Figure 15 - This very subtle grade dip produces a very short point to point track surface

Section Two: TRACK CONSTRUCTION

10. Track Construction

Any track construction work needs to be well planned and organised. Tracks are an expensive asset and good project management skills are required. Take time to plan the project well, particularly given the isolated nature of track work.

10.1 GUIDING PRINCIPLES OF TRACK CONSTRUCTION

To build or upgrade a track you need to adopt and implement a number of key construction principles. Adopting only some will not give you a truly great track. Adopt and implement all these principles and your track will last.

GUIDING PRINCIPLES FOR THE CONSTRUCTION OF TRACKS
Build on a sideslope Generally speaking, build your track on the side slope of a hill, avoid the flat. There are two distinct advantages to building on a sideslope, water management is significantly easier and users keep to the track.
Use the half rule For sustainability purposes your track grade should avoid exceeding half the grade of the sideslope it is located on. If the grade does goes over half then you are dealing with the fall line and you will encounter erosion problems earlier. As an example if you are designing a track on a hill with a sideslope of 10º (18%) then the track should not exceed a gradient of 5º (9%). It is important to apply this rule even on gentle sideslopes. **There is a maximum sustainable grade for every site, regardless of the sideslope grade and application of the half rule. Except in very rare situations where tracks may consist of rocks, the track grade should not exceed 10º (17%) even if a steeper track would still comply with the half rule. Some tracks on particularly erosion**

prone soils may be as low as 3-4º (5-7%).
Avoid the fall line Fall line tracks are tracks that exceed half the gradient of the sideslope and water particularly likes them. The issue with tracks following the fall line is that they focus the flow of water down the length of the track as opposed to across the track. Fall lines are generally steeper and allow water to gather speed and collect soil particles as discussed in section 8.1. Once a small erosion scour has formed on a track, it is almost impossible to get the water to flow off the track. There is a fall line for every slope no matter how steep or gentle the sideslope. Benched tracks should traverse the slope not descend them.
Follow the six degree (ten percent) average guideline Generally speaking, a track with an average grade of 6º (10% or less) creates the most sustainable tracks. However, this does not mean that the entire track, or indeed all tracks need to be kept under six degrees. The six degree average rule is a very good guide for designing a sustainable track. It is applicable to most soil types and minimises user erosion.
Don't always build to the maximum track grade Many tracks will need to have sections over six degrees. These should be kept as short as possible. Surface hardening, or other techniques such as the use of steps (where gradient exceeds 18º), can be implemented in these circumstances. Determining the maximum grade for your location will take into account a number of factors including: • Track service standards • Track alignment • Half rule • Soil type • Rainfall – very wet and very dry climates present their own unique issues • Vegetation cover or lack of it • Grade dips (see below) • Type of user – walker, mountain biker, tramper • Number of users- will influence track shape, displacement etc
Water management Water management is the number one priority when designing and constructing tracks. If you have determined your alignment and followed the principles outlined so far you will have gone a long way to minimising the amount of water that can affect your track. No matter how well the

track has been designed water management is still required and water will need to be removed from the track surface. Grade dips, culverts and the track shape are methods of removing water and protecting the track.

A grade dip forces water to the lowest point where the track is shaped to allow water to drain away freely to the side. The change in grade must be subtle, not allowing the water to pick up momentum and create erosion problems. Implementing frequent grade dips effectively gives the water no opportunity to increase in volume or speed. Effectively, this breaks the track up into a number of small units, so the water that lands on the track surface at the top of the hill does not have an impact at the bottom of the hill.

Creation of frequent grade dips, (section 14.3.1) and installation of culverts (section 14.7) is recommended depending on soil type and rainfall. It is easier to build these into the design of your track than to come back later and try to retrofit them.

Plan your track shape (crown, in-slope and out-slope)

Crown tracks are where the highest point of the track is in the middle with both the inside and outside edges of the track lower. The slope from centre to the side of the track should only be 2º (3-4%).

In some circumstances, the provision of an outslope or inslope track is appropriate. An outslope track is a track where the outer edge is slightly lower than the inner edge. Usually there are no side drains and water is allowed to flow freely across the track instead of travelling along it. The difference between the inside and outside of the track should only be 2º (3-4%).

Outslope tracks are not perfect and can be difficult to maintain, particularly in poor soil types or where there is high rainfall, or where there is extensive use of the track. Compaction and displacement of the centre of the track through tyres and feet can create a concave or dish shape in the tread (section 13.0).

Choosing the correct track shape to construct is important and will have a significant influence on the future maintenance requirements of the track.

A single track can have a combination of track shapes.

Design track according to soil type

There are many different types and combinations of soil (see section 7.0). The ability to determine the soil type you are dealing with and design your track accordingly will reduce future maintenance. A mix of sand, clay and silt particles in which none is dominant makes a good track surface. It drains well, holds together and is easy to work with. Adding rock and gravel can improve its strength and durability. Soils that are dominated by one soil type are the most vulnerable to erosion.

Design to minimise soil displacement Poor design can significantly contribute to track erosion by increasing displacement of soil. In the case of mountain bikes displacement is evident where hills and abrupt corners cause bikers to brake. Correct track design with respect to grade will minimise the displacement of materials. However, sometimes this is either not achievable or not enough. An additional tactic needs to be implemented such as designing inslope turns or hardening the track surface. Mountain bikers particularly like inslope turns with a built up outside edge, otherwise known as super-elevation. Bikers will naturally take this alignment as the forces at work literally fling them around and out of the corner. As a result of these forces bikers are able to negotiate the corners at higher speeds. Furthermore, they are less likely to brake before entering the corner. It is therefore essential to provide a good line of sight and create gateways to slow bikers down to minimise displacement. When designing or undertaking an upgrade of a track, where mountain biking use is permitted, think about how they might enter the turn. If upgrading an existing turn, get on a bike and see what you do when riding the turn. Is the entry speed to the turn too fast requiring you to brake heavily? Is the camber too steep or not steep enough? Think about the turn and whether any material is likely to get pushed sideways.
Consider user desire lines There are situations where users decide they do not want to walk on the track provided and decide they want to take a "short cut". This generally occurs where the user can see where the track goes and decides it is easier to take an alternative route or can see a desirable landscape anchor they want to look at more closely. To help minimise desire lines, track design needs to take into account the following: • Take your track to appealing destinations and viewpoints • Maintain a good walking surface • Make sure users get a better experience by staying on track rather than going off track
Maintenance, maintenance, maintenance The number one priority for track maintenance is drainage, drainage, drainage. You must keep water off the track in order to keep users on it.

HOT TIPS

- **If using benched tracks cut across the face of a hill**

- **Stick to the half rule as much as possible**
- **Avoid the fall line**
- **Follow the 6º (10%) average guideline**
- **Keep below the maximum sustainable grade**
- **Install regular grade dips**
- **Plan your track shape**
- **Design according to soil type**
- **Minimise soil displacement caused by users**
- **Prevent shortcuts/include appealing destinations**
- **Maintenance, maintenance, maintenance**

11. Planning for Track Construction

Recreation tracks are for people who have widely varying perspectives and expectations. A well planned, designed and constructed track will meet the needs of the users, look unobtrusive, and be environmentally sensitive.

11.1 OFFICE BASED PLANNING

These days we just don't go out and build a track, we have learnt from past mistakes that there is a considerable amount of planning required.

- Identify where the track fits within NZS HB 8630:2004 for the user group
- Determine the **track width, grade, percentage of wet and muddy or rough and uneven** for the new track or upgrade (see Figures 16 to 20)
- Utilise the Geographic Information System (GIS). A lot of useful information for track teams is now easily available. A good GIS map will identify topography, soil types, vegetation, slope gradients, archaeological sites and much more. Add these to a Global Positioning System (GPS) as waypoints; these become a useful reference when out in the field
- Identify "ideal" and "avoid" places on the map, where the track has to go and places to stay away from (Table 6)

Once you have completed this exercise you can then work out approximate grades (section 12.1). This will tell you the length of track required to achieve a gain in altitude. You can then see if this will work with the locations identified as ideal to take the track to.

Considerations	Ideal	Avoid
Topography	Good start and end points	Large flat areas
	Passes the track needs to go through	Steep slopes
	Stream crossings, lakes or tarns	Wetlands
	Scenic vistas (lookouts)	Poor views
	Swimming holes	
	Good slope aspect-North facing slopes are drier	
	Gentle sideslopes	
Visitor experience and aesthetics	For walkers keep the grade within the maximum as specified in NZS HB	Steep track grades

	8630:2004	
	For dual use tracks where mountain bikers are present keep the grade at 4° (7%) or less	Long consistent grades
	Use natural shapes	Straight lines, uniform grades, zig zags and curves
	Natural features e.g. large trees, rock outcrops	Minimise the visual impact of the track when viewed from a distance
	Locations for interpretation	
	Short side tracks to points of interest/views	
Cultural values	Consult and involve tangata whenua as early as possible.	Known sites of cultural importance e.g. urupa
Biodiversity and historic	Unique or unusual features if robust	Areas of sensitive biodiversity value unless there is a reason to visit these locations
		Archaeological sites
Safety		Natural hazards such as cliffs and loose rocks
		Steep grades

Table 6 – Essential aspects of planning your track

If you do not build "ideals" into your track, users will make their own track to the swimming hole or lookout generally realigning the track in a way you would not want.

11.1.1 Determining track width, gradient, wet and muddy and/or rough and uneven

.

There are four variables within NZS HB 8630:2004 that need to be considered, track width, track gradient, proportion of wet and muddy or rough and uneven as a percentage of the overall track length.

The examples shown for Taranaki Falls walking track, Figures 16-18, give a visual guide with marks placed in the appropriate locations for each individual question. The median, which is the middle value of observations where half of the values are larger and half are smaller, indicates that the preferred track width should be in the vicinity of 1.0 – 1.2 metres (Figure 16).

Likewise, the median cluster of marks in Figures 17 and 18 suggests that an acceptable length of walking track that may be above 15º (and less than 20º) is around 6% of total track length and approximately 10% wet and muddy or rough and uneven. An additional example has been provided for a Great Walk (Figure 19 and 20). Blank forms are available in Appendices 2-6 and provide a guideline for determining where a track should be placed within the standard.

As part of conservancy capital works programmes, Programme Managers and Technical Support Officers should work together on any track upgrade work to determine the most appropriate solution, ensuring a range of experiences is provided within SNZ HB 8630:2004.

Figure 16 - Guidelines for Walking Track upgrade- Track Width
Track name: Taranaki Falls

What is the ROS classification?

Wilderness	Remote	Backcountry		Rural	Urban fringe	Urban

What is the proportion of large groups to individuals using the track?

More individuals/couples (1-2 people)	Small families/groups (3-5 people	Medium size groups (6-10 people)	Moderately sized groups (11-19 people)	More large groups (20+ people)

What is the percentage of short stop travellers on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

Are there patterns of seasonal use?

Extremely Seasonal	High seasonality	Seasonal		Some seasonality	Year round use

What is the visual impact of increasing the track width according to the ROS classification?

Very high	High	Medium	Low	Very low

What is the visual impact of increasing the track width on non users? (eg can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very low	Low	Medium	High	Very high

What is the projected growth in visitor numbers?

Very low	Low	Medium	High	Very high

What type of track is it? One way, loop, etc

Linear / loop one way	Maze	Stacked loop	Linear two way

0.75m 1.0m 1.2m 1.5m 2.0m

Preferred track width

Note: SNZ HB 8630:2004 states that the minimum width of a walking track shall be 0.75m (reduced to 0.6m in specific circumstances) and the maximum width shall be 2.0m.

Figure 17 - Guidelines for Walking Track upgrade – Percentage of track gradient between 15-20º (must not be more than 10% of total track length)
Track name: Taranaki Falls

How sensitive to erosion is the soil type?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the proportion of large groups to individuals using the track?

More large groups (20+ people)	Moderate to large sized groups (11-19 people)	Medium size groups (6-10 people)	Small families/groups (3-5 people)	More individuals/couples (1-2 people)

What is the percentage of short stop travellers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

0% 10%	11% 20%	21% ,30%	31% 40%	41% 50%

Is it a dual use site with the activity promoting lower grades (e.g. mountain biking, buggies)? If the activity does not take place, do not mark.

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

In the type of landscape, what is the visual impact on the ROS classification?

Very high	High	Medium	Low	Very low

In the type of landscape, what is the visual impact on non users? (eg can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very High	High	Medium	Low	Very low

0% track length 5% track length 10%

Acceptable track length between 15-20°

Note: SNZ HB 8630:2004 states that up to 10% of the total track length (for a walking track) may be between 15° and 20°, as long as these steeper sections provide reasonably firm footing in wet weather conditions.

Figure 18 -Guidelines for Walking Track upgrade – Percentage of track wet and muddy/or rough and uneven (below 20% of track length)
Track name: Taranaki Falls

How sensitive is the soil to failing?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the percentage of short stop travellers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

0% <10%	11% 20%	21% ,30%	31% 40%	41% 50%

What is the proportion of large groups to individuals using the track?

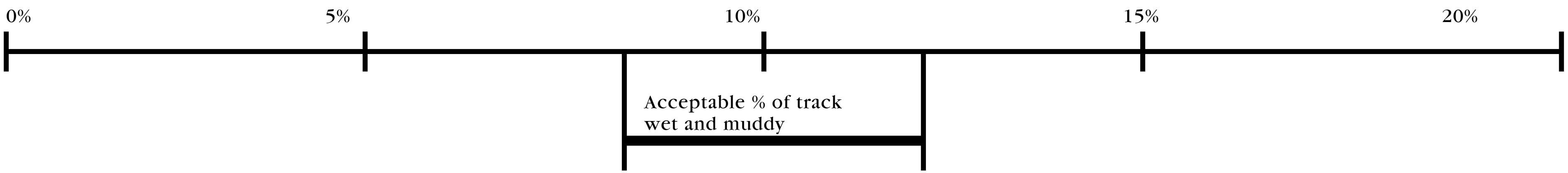
More large groups (20+ people)	Moderate to large sized groups (11-19 people)	Medium size groups (6-10 people)	Small families/groups (3-5 people	More individuals/couples (1-2 people)

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very high	High	Medium	Low	Very low



Note: SNZ HB 8630:2004 states that up to 20% of the total length of a walking track may have short wet and muddy sections (below the top of footwear) and/or rough and uneven sections.

Figure 19 - Guidelines for Great Walk and Easy Tramping Track upgrade- Track Width
Track name: Tongariro Northern Circuit-Waihohonu to Tama Lakes

What is the ROS classification?

Wilderness	Remote	Backcountry	Rural	Urban fringe

What is the proportion of large groups to individuals using the track?

More individuals/couples (1-2 people)	Small families/groups (3-5 people	Medium size groups (6-10 people)	Moderate to large sized groups (11-19 people)	More large groups (20+ people)

What is the accumulated percentage of short stop and day visitors on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the accumulated percentage of Backcountry Adventurers and Remoteness Seekers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

Are there patterns of seasonal use?

Extremely seasonal	High seasonality	Seasonal	Some seasonality	Year round use

What is the visual impact of increasing the track width according to the ROS classification?

Very high	High	Medium	Low	Very low

What is the visual impact of increasing the track width on non users? (eg can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very low	Low	Medium	High	Very high

What is the projected growth in visitor numbers?

Very low	Low	Medium	High	Very high

What type of track is it? One way, loop, etc

Linear / loop one way	Maze	Stacked loop	Linear two way

0.3m 0.45m 0.7m 0.85m 1.0m

Preferred width

Note-: SNZ HB 8630:2004 states that the minimum track surface width for a Great Walk or Easy Tramping Track is 0.3m, except on steep slopes where room is required for passing, when it is 0.6m. The maximum width is 1.0m.

Figure 20 - Guidelines for Great Walk and Easy Tramping Track upgrade – Percentage of track wet and muddy/or rough and uneven (between 30%-50% of track length)
Track name: Tongariro Northern Circuit- Waihohonu to Tama Lakes

How sensitive is the soil type to failing under a load?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the accumulated percentage of Short-stop Travellers and Day Visitors on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Adventurers and Remoteness Seekers on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the proportion of large groups to individuals using the track?

More large groups (20+ people)	Moderate sized groups (11-19 people)	Medium size groups (6-10 people)	Small families/groups (3-5 people	More individuals/couples (1-2 people)

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very high	High	Medium	Low	Very low

Great Walk

0% 7% 15% 23% 30%

Acceptable wet and muddy/rough and uneven

Easy Tramping Track

0% 12% 25% 38% 50%

Note: SNZ HB 8630:2004 states that up to 30% (Great Walks) or 50 % (Easy Tramping Track) of total length may have wet or muddy sections (below footwear) and/or rough and uneven sections.

11.2 INITIAL FIELD SURVEY

Time spent in the field is essential. But before doing this you need to check your slope inclinometer is working correctly (Appendix 7) and you know how to use it (Appendix 8) and that you have all the necessary equipment (Appendix 9).

There are a number of good reasons to undertake initial reconnaissance including:

- Determine whether it is physically possible to construct and maintain the track
- Spend time getting to know the terrain so you don't miss the best alignment
- Verify the strategic locations and identify any **further points** the track should visit that were not apparent on the map e.g. good lookout points, small flat areas for switchbacks, areas of interest
- Identify areas that will need to be **avoided** - grade could be too steep or there may be erosion prone soils
- Peg out the proposed alignment

Your initial field survey will not get into details. You are primarily going through the area and roughly marking the alignment and gradient using pegs, flags, flagging tape or other suitable markers. Whether you use pegs, flags or flagging tape will depend on the location of your track. In a forest environment flagging tape tied to trees at eye level is recommended while in an open alpine environment wire flags work well.

HOT TIP

- **Spray the top of the peg and the first 50 mm on each side of your pegs with blue dazzle prior to using them in the field. A bright blue colour will stand out and be easily visible**

Based on your knowledge of the initial line;

- Survey the routes again this time using a different colour flagging tape or wire flag to mark the alignment
- Deviate from the initial alignment when a change in grade will result in a better track
- Avoid the tendency to put in straight lines as this will look "out of place" when the track is constructed
- **Keep at this until you have the best alignment possible**

In rugged country this might take some doing and three or more alignments may be required. As you survey, adjust the grade to get around difficult terrain. Further refinements will come in the final survey where you will collect more details.

11.3 FINAL ALIGNMENT

Getting your final alignment is going to require a bit of "tweaking". Don't think you can flag the alignment once and get the best result.

- **Walk the alignment in both directions**. What works going one way may not work going the other
- Take someone who has not been involved in the initial alignment work. A new set of eyes often picks up additional improvements
- Place your flagging tape/flags at about three - five metre intervals. The more flags you use the better, this will give you a better idea of what the finished alignment will look like and alleviate the tendency for straight line construction between pegs

Figure 21 - Take the time and effort to mark your track well. It will help to avoid poor alignment by those constructing the track

11.4 SETTING OUT THE ALIGNMENT

One person is required to operate the slope inclinometer and measuring instrument (can be a wheel or GPS); the second person, who is the Marker, works with the pole and pegs.

- Prior to going into the field the Marker requires a surveyor's pole marked at the Operator's eye level
- In the field the Marker goes forward and places the pole vertically onto the ground

- Operator reads the grade through the slope inclinometer. **Both eyes need to be open (Appendix 8)**
- Marker is directed by Operator to move the pole up or down the side slope until the preferred gradient is reached. If it is less than the steepness of the desired grade the marker will step up the slope. If the grade is steeper than the desired grade then the marker will step down the slope
- When the correct gradient has been determined the Marker hits a peg into the ground in the exact place the pole was
- The Operator measures the distance between the pegs using the measuring instrument where there is a change in the track such as gradient or step junction
- Operator writes the distance on the plastic marker/peg and the track prescription recording sheet (Appendix 10)
- Operator also records locations of proposed culverts, steps and formation details on the track prescription recording sheet
- The Marker then proceeds upslope or downslope and places the pole on the slope
- The Operator reads the grade and records this on the recording sheet
- While the Operator is undertaking the above tasks the marker has proceeded to the next peg location. This distance will vary depending on the vegetation cover and terrain. When proceeding through gullies keep the distance short
- During this phase you need to consider the location of grade dips, culverts and switchbacks

HOT TIPS

- **Survey the whole track and be sure you have the best possible alignment before any construction work starts**
- **Bring in a person who has not been there before to look at the alignment with a "fresh set of eyes"**
- **Mark the area within which construction is permitted. This minimises impacts on the landscape and helps with the "fit" look**
- **Visit the site either during or shortly after extended periods of rain. This will identify required drainage**
- **Cross streams at an angle rather than going straight down into the stream and up the other side**
- **Look for natural platforms for switchbacks. Not only will this save on construction costs but more importantly will "fit" better with the landscape**
- **Identify locations for grade dips and/or culverts**

- **If you are a person who must guess the grade using your eyeball make sure you check it with your slope inclinometer**
- **Keep in mind the type of visitor you are building the track for and try to put yourself in their shoes as you plan the track**

11.5 COMPUTER PROGRAMMES

There is a number of terrain modelling programmes available and all require two essential ingredients, elevation data and computer software. Essentially they are able to provide information on a terrain surface. Once this model is available it can be analysed to provide information such as;

- Steepness of the slope; this can be estimated for each face
- Aspect of the slope face
- Volume and surface area of the terrain model
- Information can then be individually analysed and compared to understand specific details on alignment, grades and different combinations to achieve different results
- With a before and after comparison, surface cut and fill volumes can be calculated
- Location of steps
- Plans and profile drawings to aid construction
- Plans can be produced showing information such as gradient

11.6 TRACK PRESCRIPTION RECORDING SHEET

As you progressed along the final track alignment you will have recorded quite a lot of information; essentially a prescription of work has been produced. This will be valuable information for staff or contractors constructing the track, or staff supervising contractors. It gives track construction personnel enough information to work out quantities and time to complete a job. Appendix 10 is a blank version of the sheet.

TRACK PRESCRIPTION														**Date: 10/04/08**
Track Name: Ridge Track **Track Standard: Walking Track**														**Surveyed by: Joe Bloggs**
					Track				**Components**					
Peg Number	**Distance**	**Grade (degrees)**	**Grade (percentage)**	**Bearing**	**Side slope (degrees)**	**Standard**	**Widt h (mm)**	**Shape / Surface**	**Culvert**		**Steps**			**Construction comments**
1	0								Diameter (mm)	Length (mm)	Rise (mm)	Run (mm)	Stringer length (mm)	
2	10	2	3.5	183	15	Walking Tk	1000	CR/NS	225	1400				½ cut / ½ fill
3	20	1	2	192	15	Walking Tk	1000	CR/NS						½ cut / ½ fill
4	30	1	2	200	15	Walking Tk	1000	CR/NS						½ cut / ½ fill
5	35	1	2	200	15	Walking Tk	1000	CR/NS	225	1500				
6	40	7	12	184	18	Walking Tk	1000	CR/M						¾ cut /¼fill
7	60	9	16	141	19	Walking Tk	1000	CR/M	300	1400				¾ cut /¼fill
8	70	6	10.5	62	23	Walking Tk	1000	CR/M						¾ cut /¼fill
9	75	6	10.5	62	23	Walking Tk	1000	CR/M	225	1400				
10	85	10	21	50	25	Walking Tk	1000	CR/M						full bench cut
11	95	10	34	50	27	Walking Tk	1000	CR/M	225	1400				full bench cut
12	105	9	21	209	24	Walking Tk	1000	CR/M						full bench cut
13	115	12	21	187	22	Walking Tk	1000	CR/M			162	396	21.8	Start of box steps
14	125	22	40	190	18	Walking Tk	1000	CR/M						
15	135	23	42	191	18	Walking Tk	1000	CR/M						Finish of box steps
16	145	10	18	152		Tramping Tk	300	NS						Apply orange track markers
17	155	12	21	195		Tramping Tk	300	NS						Apply orange track markers
18	165	9	16	195		Tramping Tk	300	NS						Apply orange track markers
19	175	16	29	175		Tramping Tk	300	NS						Apply orange track markers

Figure 22 – Completed example of a track prescription

CR= Crowned OS= Outslope IS= Inslope NS= Natural Surface M= Metalled

12. Track Gradient

Understanding track gradient is critical and one of the most significant aspects of track design. One of the biggest mistakes made when constructing tracks is creating tracks that are too steep. Essentially, **gradient refers to the longitudinal steepness of the track and slope refers to the steepness of the ground on the fall line.** Gradient and slope are expressed as degrees (6°) or percentages (10%) or a ratio of vertical to horizontal distance expressed as single ratios (1:10). The tool most commonly used to measure grade today is the slope inclinometer. Appendix 8 explains how to use one.

HOT TIPS

- **Keep track gradient to the minimum practical for the site**
- **Lower track gradients will require less maintenance. Gravity and water will move fewer soil particles and visitors will displace less material**

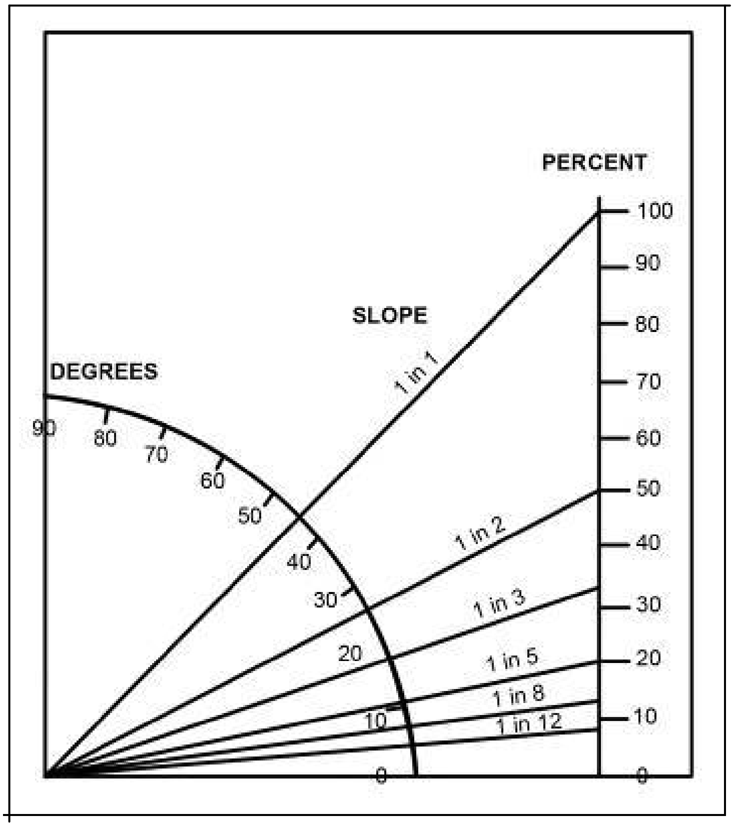


Figure 23 - Gradient Chart

DEGREES	PERCENTAGE	RISE TO RUN
1	1.7	1 in 57.3
2	3.5	1 in 28.6
3	5.3	1 in 19.1
4	7.0	1 in 14.3
5	8.7	1 in 11.4
6	10.5	1 in 10.5
7	12.3	1 in 8.2
8	14.0	1 in 7.1
9	15.8	1 in 6.3
10	17.6	1 in 5.7
11	19.4	1 in 5.1
12	21.3	1 in 4.7
13	23.1	1 in 4.3
14	25.0	1 in 4
15	26.8	1 in 3.7
16	28.7	1 in 3.5
17	30.6	1 in 3.3
18	32.5	1 in 3.1
19	34.4	1 in 2.9
20	36.4	1 in 2.7
21	38.4	1 in 2.6
22	40.4	1 in 2.5
23	42.5	1 in 2.4
24	44.5	1 in 2.2
25	46.6	1 in 2.1

Table 7 –Approximate Gradient Comparisons

NZS HB 8630:2004 specifies gradients for different track classifications as outlined in Table 8 below.

Track Classification	**Gradient**	**Comment**
Short Walk	Maximum of 10°	For step gradient refer to section 19.1.
		Grade may increase to 15° for 50 metres as long as firm footing in wet conditions is provided.
		Length of track between 10° and 15° shall not exceed 5% of track length.
Walking Track	Maximum 15°	For step gradient refer to section 19.1.
		Grade may increase to 20° for 100 metres as long as reasonably firm footing is provided in wet conditions.
		Length of track between 15° and 20° shall not exceed 10% of track length.
Great Walks/Easy Tramping Track	No maximum grade	
Tramping Track	No maximum grade	
Route	No maximum grade	

Table 8- Maximum Track Gradients as specified in NZS HB 8630:2004

12.1 CALCULATING THE LENGTH OF TRACK

This is an important aspect of track planning (section 11.0). Determining the approximate length of track required will assist you with;

- Selecting the most appropriate grade
- Determining approximate cost for draft capital business cases
- Determining whether other construction details (switchbacks, steps) are required

Enter angle of inclination (degrees)	a=	8	Enter value here in the orange box
Enter height to be gained (metres)	h=	200.00	Enter value here in the orange box
Length of track on slope (metres)	I=	1436.87	This is your answer in the yellow box
Length of track on map (metres)	m=	1422.89	This is your answer in the yellow box

Table 9- Track Length Calculator

NB: This is the minimum length of track as it assumes a constant grade. To calculate the approximate length of track required for your upgrade or construction work refer to the Track Length Calculator in the attached document "*Track length, water speed and material volumes calculators*".

13. Track Formation

SNZ HB 8630:2004 outlines track classifications and appropriate formation as outlined in Table 10.

Track Classification	Formation
Short Walk	Benched formation **may be used** on all or part of the track with a crossfall of 2° (3-4%). Crossfall may drain to one or both sides depending on the preferred track shape
Walking Track	Benched formation **may be used** with a crossfall of 2° (3-4%). Crossfall may drain to one or both sides depending on the preferred track shape
Great Walk/Easy Tramping Track	Benched formation **may be used** with a crossfall of 2° (3-4%). Crossfall may drain to one or both sides depending on the preferred track shape
Tramping Track	Bench formation is **limited to where; impacts need to be mitigated or there are no other options and there is high use**
Route	Generally unformed

Table 10- Appropriate Track Formation According to Track Classification

Track formation is the shape of the ground. Excavation to form a bench may be required as outlined in Table 10. The degree of construction required is influenced by the steepness of the sideslope. On ground that is level, little formation work will be necessary while on ground with a steep sideslope considerably more formation work is required.

There are three recognised track construction shapes; crown, outslope and inslope. In deciding which track shape to adopt you need to think about the long term **sustainability** of the track. It needs to "fit" the landscape, be designed to minimise erosion, be relatively easy to construct and maintain, and not have a significant environmental impact. Some soil types are more erosion prone than others and alignment, grade and drainage will have a significant impact on levels of track erosion.

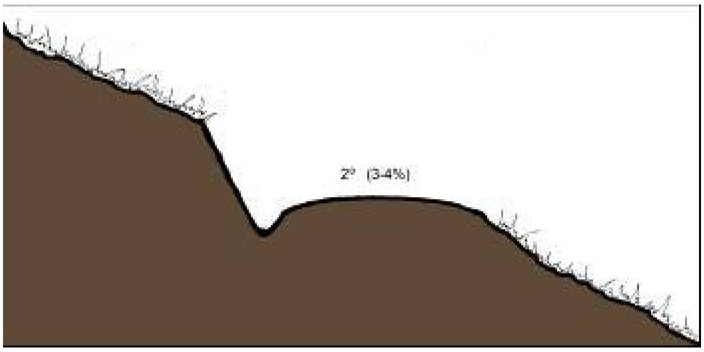


Figure 24 – Crown Track Formation

A crowned track will have a side drain on the upslope side of the track. This catches water and helps protect the track pavement. The pavement is the collective term for the layers that combine to form protection of the sub-grade. Crowned tracks are most suitable where the track gradient exceeds 3º-4º (5%-7%) and water runoff is medium to high.

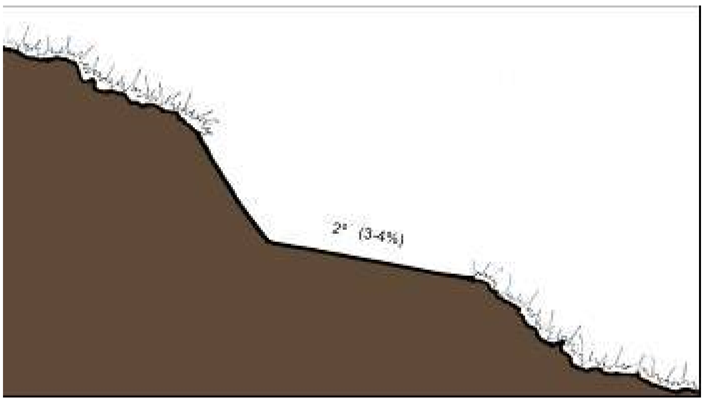


Figure 25 – Outslope Track Formation

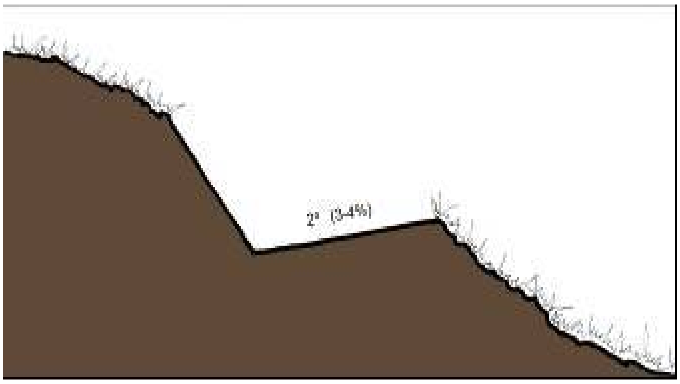


Figure 26 - Inslope Track Formation

An inslope or outslope track allows water to flow across the track surface. Inslope or outslope tracks are best suited to locations where the track gradient is 4º (7%) or less and there is low water runoff. The maximum gradient recommended for a sideslope track is 6° (10%). Depending on how erosion prone the soil is, application of stone aggregate may also be required.

Whichever track shape you decide to construct it will need to have a crossfall of approximately 2º (3-4%).

13.1 CUT CONSTRUCTION

Cut construction involves excavation, cutting into the ground to remove soil and relocating it where you want it. This results in the formation of a bench or flat surface that forms the walking track. A full cut bench track involves cutting to the full width required to construct the track surface. Full bench cuts:

- **Are necessary when sideslopes are over 25º (50%)**
- Will require less maintenance on this slope
- The batter is the excavated exposed face above the track surface and should have the top rounded, 200 mm either side of the high point, as close as possible to the original slope
- Will generally provide surplus material. This can be relocated and used as fill elsewhere on the track to even out gradients
- Should have exposed roots on the cut batter neatly trimmed flush with the batter face

13.2 CUT AND FILL CONSTRUCTION

Cut and fill construction involves cutting into the uphill sideslope and placing fill on the downhill slope. Cut and fill formation results in a bench finish. An advantage of implementing the cut and fill technique is that the volume of material moved is less and the size of the inside batter is lower in height creating a lower visual impact. Cut and fill:

When used on sideslopes between 17º - 25º (31- 47%)

- **Construction only works where the sideslope is less than the maximum fill batter slope for the soil as specified in Table 13**
- Fill placed on the downslope needs to be placed on a small bench measuring 300 mm that is sloped into the hill slightly and compacted in layers to form a stable surface
- **All fill material needs to be compacted in layers no greater than 250 mm prior to compaction**
- **Should be constructed with a ¾ bench and ¼ fill as the track walking surface**
- Needs the organic material saved, leaf litter or any topsoil, this can be used to spread over the fill and make it look as though the track has been there for some time
- Should have the top of the batter rounded, 200 mm either side of the high point, as close as possible to the original slope
- Should have exposed roots on the cut batter neatly trimmed flush with the batter face

When used on sideslopes between 6º-17º (10 – 31%)

- ½ bench and ½ fill
- Save the organic material, leaf litter or any topsoil, this can be used to spread over the fill and make it look as though the track has been there for some time
- A small bench measuring 300 mm will need to be cut downslope to provide a flat platform for the fill material
- **Fill slope shall be a maximum as specified in Table 13**
- **All fill material needs to be compacted in layers no greater than 250 mm prior to compaction**
- Should have the top of the batter rounded, 200 mm either side of the high point, as close as possible to the original slope
- Should have exposed roots on the cut batter neatly trimmed flush with the batter face

13.3 FILL CONSTRUCTION

Fill construction involves the use of material placed on site to form a walking track. There is no bench associated with this construction. Refer to Table 13 for maximum fill batter slopes.

Figure 27 - Not all tracks require formation work. This tramping track has significant lengths of unbenched track in excellent condition

! PITFALL

- **If you do not compact the fill you will get regular slumps on the track over an extended period**

Figure 28 - This is a good example of a full bench cut

13.4 CUT AND FILL MATERIAL

The following table indicates soil types that in practical terms are suitable for track construction.

Suitable for use as fill material	Not suitable for use as fill material
Firm clay/silt soils*	Peat/ organic humus
Sands/gravels	Topsoil
Boulder clay	Soft clay/silt soils
Weathered rock	

Table 11 – Soil types for track construction

(A Technical Guide to the Design and Construction of Lowland Recreation Routes)

***Highly plastic soils as discussed in section 7.5 can be used as fill material if permitted to dry out as they become very hard.**

Appendix 12 (track cross sections) drawing 1-1, shows pictorially the typical cross section of formation as specified above.

HOT TIPS

- **Excavated rock fill will occupy 1.2 to 1.5 times more space than solid rock**
- **Excavated soil will expand when loaded for transport by 1.2 to 1.7 times**
- **Excavated soil when compacted can shrink by 0.6 to 0.8 times the original volume depending on the soil type**

13.5 CHECKING FILL COMPACTION

Compaction may be checked when undertaking fill formation work. The Dynamic Cone Penetrometre can be used to indicate the compaction of soil and/or fill materials. The theory is that the resistance to penetration is an indication of the degree of compaction of the fill, and in simple applications it seems to work well.

The cone is on the end of a long rod, approximately a metre long. This means a considerable depth of soil/fill can be tested, not just the surface layer.

- If you need a large number of blows to cause the cone to penetrate a short distance the soil/material is well compacted

- If the cone penetrates easily with few blows the soil/material is poorly compacted or unsuitable
- Can indicate where soil/fill has been placed in layers which are too thick, with only the surface being compacted
- The results can be expressed as the number of blows for a measured length of penetration, or alternatively, the length of penetration for a single blow, and it is normal to plot results on a graph. This way it is possible to distinguish between different layers of fill.

! PITFALL

- **Taking only one measurement and assuming this applies everywhere. Use a number of plots to get an "overall picture". Sometimes a stone or rock can give a false impression**

13.6 BATTER STABILISATION

The batter is the excavated exposed face above the track surface. Table 12 offers a guide to maximum slopes for varying soil types. Adjustments may need to be made based on local examples. Depending on the nature of the soil a geotechnical assessment may be required.

MATERIAL	PERCENTAGE	DEGREES	HORIZONTAL VS VERTICAL
Rock		90°	vertical
Firm Clay	400%	76°	0.25 : 1
Soft Clay	100%	45°	1 : 1
Pumice		90°	vertical
Ash	100%	45°	1: 1

Table 12 – Maximum Cut Batter Slope

Figure 29 - This pumice batter is very close to the maximum recommended batter of 90º

MATERIAL	PERCENTAGE	DEGREES	HORIZONTAL VS VERTICAL
Quarry Rock	67%	34°	1.5 : 1
Clay	50%	26°	2.0 : 1
Pumice	33%	18°	3.0 : 1
Ash	33%	18°	3.0 : 1

Table 13 – Maximum Fill Batter Slope

From a landscaping perspective the objective is to make the work look as natural and unobtrusive as possible so the batter should be cut at the same angle as the surrounding sideslopes. This is particularly important where batters are visible from a considerable distance. The organic matter removed from the track surface and from the cut and fill operation can be spread over the embankment or the cut if the angle is not excessively steep.

HOT TIPS

- **Look at the surrounding landscape and observe the slope angle. A handy rule of thumb is to create a slightly gentler slope than you think is necessary. Although this will expose more soil the chance of it staying put is higher. It will potentially also revegetate more readily than one that constantly keeps slumping**
- **Retain all leaf litter, organic material and top soil for spreading over exposed earthworks. It will reduce sediment runoff and contains an enormous amount of seed that will enhance**

revegetation of the site

- **Topsoil will generally not hold on slopes steeper than 27º (47%) and cannot be normally placed by machinery on slopes greater than 19º (34%)**
- **Where stabilisation of the batter slope is required seek advice on options such as hydroseeding, planting, mulching, and matting application**

Figure 30 - The batter on this track is formed at an angle close to the sideslope angle giving the track a "softer" visual appearance

13.7 USE OF LOCAL MATERIALS

Sometimes you will need extra fill material and this is often sourced on site. Borrow pits are generally a hole dug in the ground from which material is removed and used on the track. Even on a minor scale moving material from one location can cause changes to the environment and these changes need to be managed.

Many of the potential adverse effects of borrow pits can be reduced or avoided by choosing the site carefully (Figure 31). Good planning and work on site will help to minimise any potential adverse effects. There are a few guidelines that need to be followed if using a borrow pit:

- Locate pit so as to minimise visual exposure to users
- Ensure the site is made safe

- Save all the vegetation and top soil layer removed for rehabilitation of the site. Place it in the shade and keep it moist. Cover with burlap (type of sacking) to help keep moist if necessary
- Ensure the material is suitable for the intended use
- A long shallow pit is better than a deep one
- Reinstate natural drainage patterns
- Contour the ground to look as natural as possible when finished removing material and ensure it is stable
- Replace plants and top soil layer. If necessary transplant some additional plants onto the site
- Camouflage any entrance track and transfer some plants if necessary. Be particularly diligent where the entrance track meets the main walking track

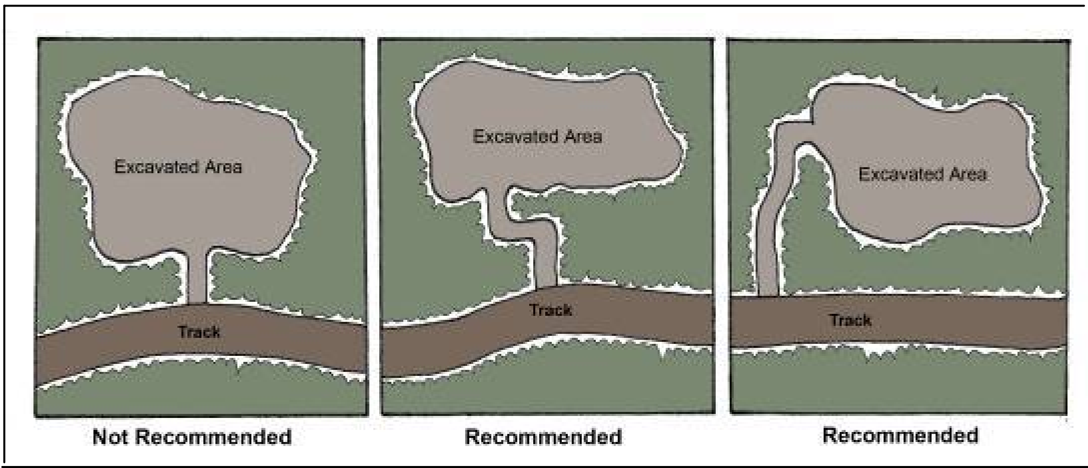


Figure 31 – Acceptable Borrow Pit Location

13.8 FORMATION CONSTRUCTION

- Ensure all alignment work has been completed and pegs are clearly marked at the level of formation
- Ensure the work site area is clearly marked. Disturbance can only take place **within** the marked area
- Remove all leaf litter and organic material as required and store in a suitable location for later use
- Where it is not practical to remove all organic material, use of a geotextile separator may be required, (section 16.1). Some settlement may occur as the organic material underneath the track decomposes

- Excavate and relocate material as required to achieve the formation and gradient specified. Relocation of material can help even out some grades, be used as cover over tree roots, or fill steps and retaining walls. Surplus material should not be sidecast
- **All fill material needs to be compacted in layers no greater than 250 mm (prior to compaction)**
- Install water management including side drains and drainage dips etc as formation takes place or at the end of each day**. Never leave a new formation without water management in place**
- Shape and compact the formation surface (crown, outslope or inslope). This is necessary even if the completed formation is the finished track surface. An un-compacted surface will quickly become concave. Strengthening of the sub-grade, the soil on which the pavement structure is constructed, is good practice as it will help maintain track shape. Track pavement is the collective term for the layers that combine to form protection of the sub-grade.
- Mark the formed surface at the correct distance in preparation for aggregate
- Shape and compact aggregate (sections 15.3 to 15.7)

14. Water Management

Why is this important? **Because keeping water off and getting it away from the track is the single most important factor that will maximise the longevity of your track.** By keeping water away we protect the pavement and decrease the rate of erosion and displacement on the track surface. Section 8 covered track destruction and discussed how water picks up soil particles and relocates them.

Do take the presence of water in places as indicative of the need to have water management. Don't take the volume of water observed as the volume that needs to be managed; you need to allow for 10 year flood peaks.

14.1 DRAINAGE SYSTEM

No factor is more important than good drainage; your track must have effective water management in place.

- Track surface shape (crowned, outslope or inslope) must be maintained with the correct crossfall
- Track surface material will influence how long a track maintains shape e.g. Pumice versus well graded aggregate

Know where your water comes from. Generally speaking there are four main sources of water that affect your track:

- Rain or snow **falling directly** onto the track
- **Surface water** from the surrounding land flowing onto the track
- **Intermittent** underground water in the form of seepages or springs. These are generally seasonal so you need to be particularly alert for these
- **Continuously flowing** streams or channels

Figure 32 - Your drainage system needs to be capable of handling ten year flood peaks

You need to design an appropriate water management system to protect the track. Surface and sub-surface drainage are generally dependent on four factors:

- The catchment's size above the track. The larger the catchment the more water that can be expected
- Topography will determine the location, direction and the rate of water flow
- The watertable is the upper surface of groundwater. Watertable depth will determine the amount of surface drainage. With a shallow watertable, increased surface drainage can be expected
- Soil types determine the rate of subsurface drainage and subsequently the amount of surface drainage:
    - cohesive soils (high in clay/silt) will result in poor drainage
    - granular soils (high in sand/gravel) will result in good drainage

!PITFALLS

There are four main reasons why your drainage system may fail to work successfully

- **Locating the drainage in the wrong place**
- **Wrong size – generally too small and not able to cope with water flows**
- **Poor design**
- **Poor construction – not able to withstand the pressure of water and climate over time**

Figure 33 - High rainfall locations with large water catchments and poor drainage create challenging conditions for track construction crews

14.2 SITE SURVEY

The site must be visited to make decisions on drainage, including how many culverts to install and where they will be located on the track. You will also need to consider the impact of the track changing the natural drainage system and this should be covered in the Assessment of Environmental Effects (AEE).

Visiting the site after an extended wet period is best. The soils will have reached maximum water holding capacity and runoff patterns should be more evident.

Walk the full length of the track in both directions; sometimes a water issue near the top can be causing additional problems further down the track.

LOOK FOR THE CLUES

- **Small gullies and erosion channels in the track surface (water flowing down or across the track)**
- **Puddles, boggy areas (water lying on the track)**
- **Water flowing onto the track from sideslope (where has this come from?)**
- **Build up of fines (clay, silt and very fine sand) either on the track or just to the side (shows where the water has gone)**
- **Some vegetation types can indicate wet ground conditions**

14.3 WATER CONTROL METHODS

There are a number of methods used either individually or combined together to manage water; grade dips (rolling dips, drainage dips, grade reversals) catch drains, side drains, catch pits, pipe culverts and drainage channels.

14.3.1 Grade dips

Grade dip locations are determined as part of the setting out stage (section 11.4) and built during the track formation. **Grade dips are used to remove the track surface water at intervals along tracks of a minor to moderate grade located on a sideslope**. Dips are built into the track at intervals dictated by the erodibility of the track surface and the track gradient.

Grade dips are a very cost effective method of managing water. They require less maintenance than a culvert and are much more effective at removing water than a waterbar and require less maintenance. (A waterbar is an obstruction to the flow of water installed across the track at an angle).

14.3.2 Rolling grade dip

A rolling grade dip is where you reverse the gradient of the track over a short distance. For example, if the track is ascending a hill at 4º (7%) a short descent of between 3 -5 metres at 2º (3.5%), followed by returning to the ascent of 4º (7%) would form a rolling grade dip. A drawing is available in Appendix 12, 2-2.

A track that lies lightly on the land will have a number of rolling grade dips and a well designed track will take advantage of the natural drainage patterns. Tracks designed in this way look good, feel right and “fit” the landscape.

14.3.3 Drainage grade dip

A drainage grade dip is a relatively large dip constructed into the track surface to shed water from the track. Drainage grade dips are very unobtrusive and constructed properly are barely noticeable but very effective at water management. In the majority of circumstances they can be constructed on existing tracks.

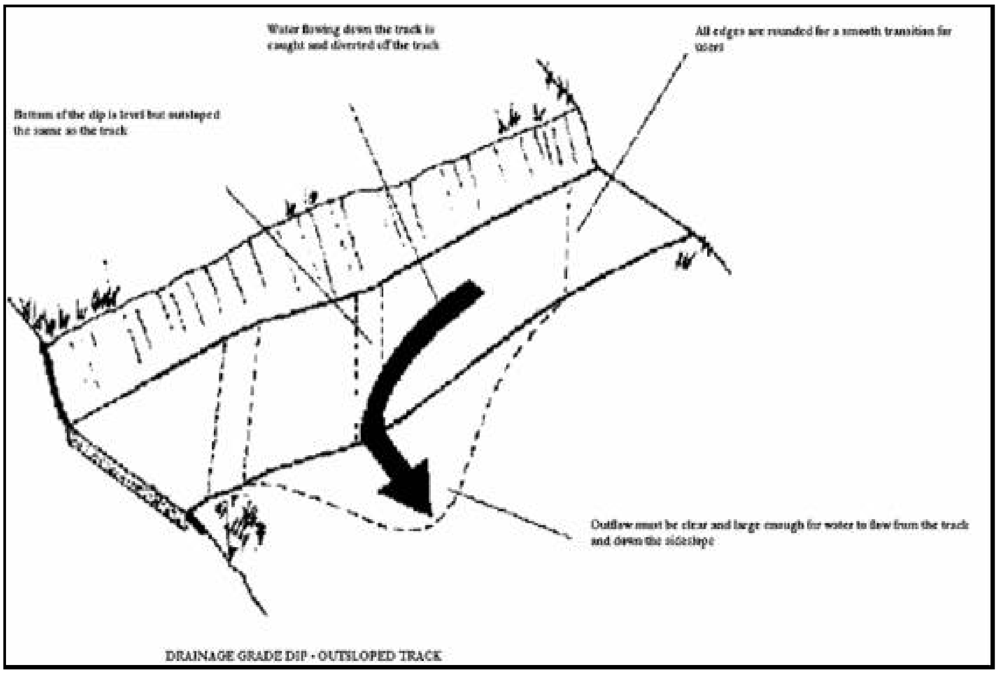


Figure 34 – Drainage Grade Dip for Outslope Track

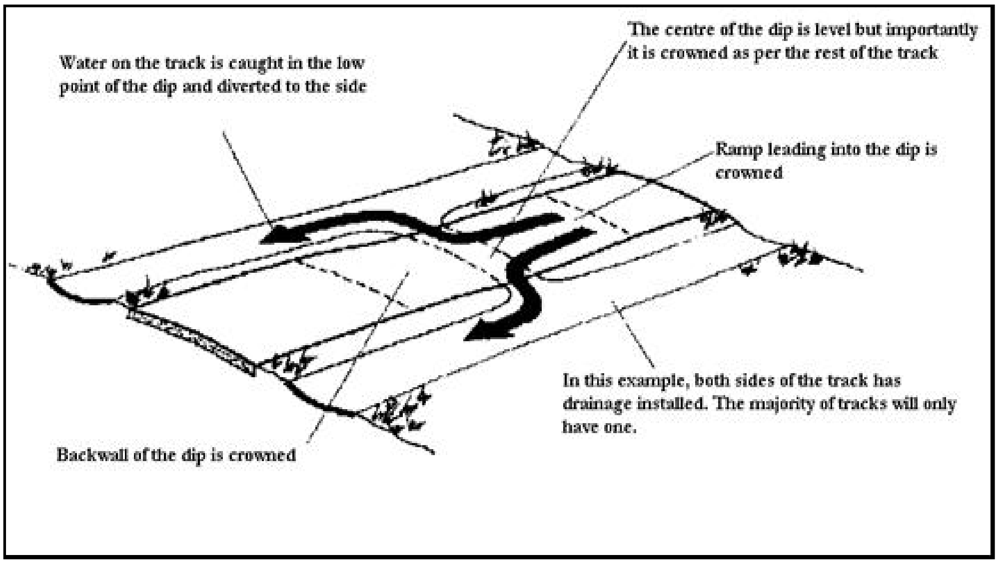


Figure 35 – Drainage Grade Dip for Crowned Track

Recommended drainage grade dip spacings are outlined in Table 14. However, this is not always going to be practical and will be influenced by the alignment of the track.

Critical points to locate a drainage dip are:

- Prior to a flight of steps

- Prior to retaining walls
- Just above the point where the track changes grade and becomes steeper
- Actual site conditions will determine exact placement. The important point is not to exceed the spacing outlined in Table 14. Where the recommended distance does not fit with the track alignment add an extra dip rather than take one away.

Track Grade Degrees	Track Grade Percent	Rise to Run ratio	Distance between Drainage Grade Dips (metres)
1°	1.7%	1:57	27
2°	3.5%	1:28	17
3°	5.3%	1;19	14
4°	7.0%	1:14	13
5°	8.7%	1:11	12
6°	10.5%	1:10	11
7°	12.3%	1:8	11
8°	14%	1:7	10
9°	15.8%	1:6	10
10°	17.5%	1:6	10

Table 14 - Recommended Drainage Grade Dip Spacing

NB: The distance between drainage grade dips is from the end of the backwall to the beginning of the ramp on the next dip.

Track grade (degrees)	Track grade (%)	Length of backing for backwall (mm)	Length of backwall (mm)	Depth of dip* (mm)	Length of ramp (mm)	Total length (mm)
	1%	N/A	1575	75	1950	3525
1º	2%	200	1525	75	2300	4025
2º	3%	300	1500	100	2600	4400
	4%	400	1425	100	2900	4725
3º	5%	500	1375	100	3250	5125
	6%	600	1325	100	3500	5425
	7%	650	1300	125	3900	6150
4º	8%	725	1250	125	4200	6175

Table 15 – Drainage Dip Grade Dimensions

* Depth of the dip is measured from the top of the finished backwall to the bottom of the dip.

A drawing is available in Appendix 12, 2-1.

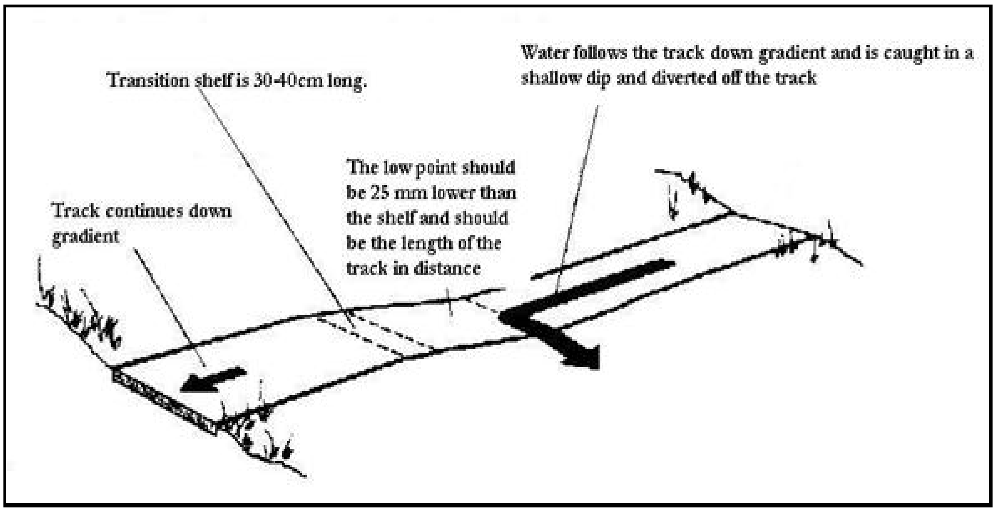
Drainage grade dip construction for outslope track

- On the track surface, mark the start and end points of the drainage dip. This will vary depending on the track grade as specified in Table 15
- From each mark, at the top edge of the track scuff a line on the track surface. This line should be down the gradient and across the track at an angle of between 15°-20°
- From the top of the ramp measure the distance to the dip low point and mark the track surface
- Scuff a line on the track surface. This line should be down the gradient and across the track at an angle of between 15°-20°
- Dig the dip low point line down to the depth specified in Table 15
- Excavate the material from the start of the ramp and backwall to the dip low point
- Create an even and nicely contoured finish
- Make sure the outflow point is clear and water can flow down the sideslope
- Compact dip if compactor is available. This will strengthen the dip and reduce potential scour

14.3.4 Grade break

Grade breaks can be used in place of drainage dips on tracks of 2°(3.5%) or less.

- Grade breaks cannot handle much water and are better suited to low use, low runoff locations
- Grade breaks need to be installed every six metres



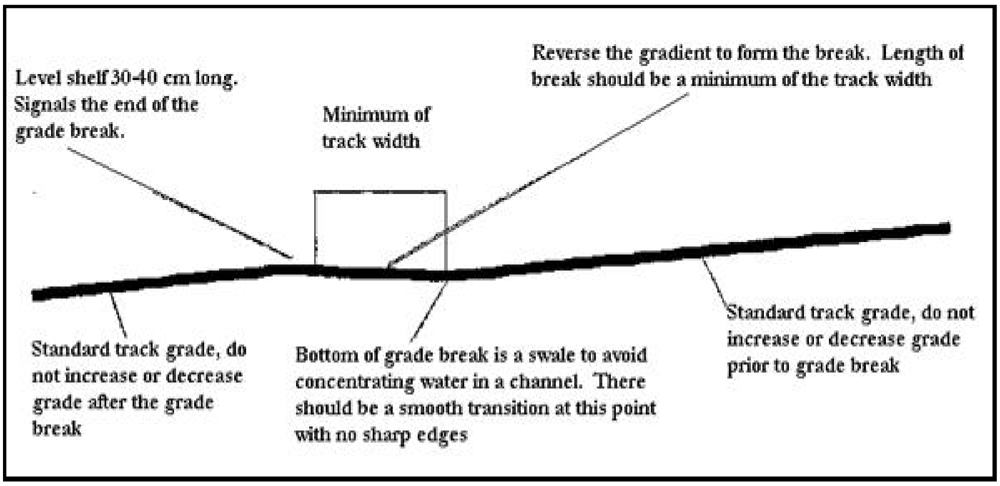


Figure 36 – Grade Break Profile

14.3.5 Grade break construction

- On the track surface, mark the location of the shelf and low point of the grade break
- The distance from the shelf to the bottom of the dip is 1.5 metres
- From each mark, at the top edge of the track scuff a line on the track surface directly across the track
- Dig the dip low point line down to the depth of 25 mm
- Excavate the material between the shelf and low point
- Create an even and nicely contoured finish
- Make sure the outflow point is clear and water can flow down the sideslope
- Compact grade break if compactor is available. This will strengthen the break and reduce potential scour

14.4 CATCH DRAINS

A catch drain is simply a drain located some distance away from the track that catches water before it reaches your track and redirects it elsewhere. It can be;

- A swale; wide and shallow depression in the ground designed to channel drainage of rainwater
- A bund; an embankment formed from natural material
- A ditch; long narrow open channel dug into the ground

14.4.1 Catch drain construction

The position of the catch drain is essential to the success of the drainage system.

- Maintain a low visual impact on the landscape
- Ensure there are no significant adverse effects on the natural land drainage
- Keep the gradient low so the ditch does not scour. It can be at a much flatter gradient than the track
- Excavate the catch drain to a depth of **300 mm x 300 mm wide**
- Excavated material can be placed on the downhill side of the ditch, this will act as a bund if the catch drain overflows and will prevent water from flowing down onto the track

Figure 37 - This catch drain is not visible from the walking track and collects water from the sideslope before it reaches the track

HOT TIPS

- **Follow the lie of the land**
- **Avoid steep gradients**
- **Avoid sharp corners or changes in direction that will erode the drain**
- **Maintain catch drain effectively**
- **Start construction at the bottom end and work uphill as this makes it easier to keep the depth consistent**

14.5 SIDE DRAINS

Side drains are constructed along the side of the track on slopes or on low wet ground where drainage is a problem.

- Side drains intercept water from the side slope and from the track surface watershed
- They carry the water down to a discharge point (short cut-out, swale or excavated trench) or culvert that directs the water to the downslope side of the track

- Table 16 provides recommended side drain armouring in relation to soil type and track gradient

Side Drain Recommendations				
Soil Type	**High Rainfall Areas**		**Medium Rainfall Areas**	
	Discharge Spacing	Armouring	Discharge Spacing	Armouring
Soft clay, ash	- For gradient < 6° (10%), 15 m maximum spacing - For gradient up to 10° (17%), 10 m spacing - Gradients over 10° (17%) not recommended	Provide rock or gravel where gradient exceeds 17% or where discharge spacing is more than 15 m	- For gradient < 6° (10%), 20 m maximum spacing - For gradient up to 10° (17%), 15 m spacing - Gradients over 11° (20%) not recommended	Provide rock or gravel where gradient exceeds 11° (20%) or where discharge spacing is more than 20 m
Firm clay	- For gradient < 6° (10%), 20 m maximum spacing - For gradient up to 11° (20%), 15 m spacing - Gradients over 11° (20%) not recommended	Provide rock or coarse gravel where gradient exceeds 11° (20%) or where discharge spacing is more than 20 m	- For gradient <6° (10%), 25 m maximum spacing - For gradient up to 11° (20%), 20 m spacing - Gradients over 11° (20%) not recommended	Provide rock or coarse gravel where gradient exceeds 11° (20%) or where discharge spacing is more than 25 m
Pumice, weathered granite	- For gradient <3° (5%), 20 m maximum spacing - For gradient up to 6° (10%), 15 m spacing - Gradients over 6° (10%) should be avoided if possible	Provide rock, coarse gravel or timber check dams where gradient exceeds 6° (10%) or where discharge spacing is more than 20 m	- For gradient <3° (5%), 20 m maximum spacing - For gradient up to 6°(10%), 15 m spacing - Gradients over 6° (10%) should be avoided if possible	Provide rock, coarse gravel or timber check dams where gradient exceeds 6° (10%) or where discharge spacing is more than 20 m
Fine gravels	- For gradient <6° (10%), 25 m maximum spacing - For gradient up to 11° (20%), 20m spacing - Gradients over 11° (20%) not recommended	Provide rock or coarse gravel where gradient exceeds 11° (20%) or where discharge spacing is more than 20 m	- For gradient <6° (10%), 30 m maximum spacing - For gradient up to 11° (20%), 25 m spacing - Gradients over 11° (20%) not recommended	Provide rock or coarse gravel where gradient exceeds 11° (20%) or where discharge spacing is more than 30 m

Coarse gravel and weathered rock	- For gradient <11° (20%), 25 m maximum spacing - Gradients over 11° (20%) not recommended		- For gradient <11° (20%), 30 m maximum spacing - Gradients over 11° (20%) not recommended	
General Notes: 1. Discharge of side drains may be via culvert, cut-out, swale or soakage pit 2. Side drains are best discharged immediately above steeper sections of track 3. Side drains with steep gradients will require increased maintenance				

Table 16 - Side Drain Guidelines

14.5.1 Side drain construction

Install side drains as follows:

- Discharge water whenever a location is available where the ground discharges to a lower point away from the track. Short cut-outs, swales or a small excavated trench, may be required to discharge the water
- Install culverts to take water under the track and discharge to a lower point. See section 14 .7.2 on recommended culvert frequency
- If it is not possible to discharge water via a cut-out or a culvert the distance between discharge points will increase. **To reduce scour due to the increased volume of water, increase the size of the side drains and provide rock armouring. Rocks should be angular to lock together and minimise the likelihood of movement**
- Side drains should be a minimum of 200 mm wide x 150 mm deep, chamfered to 250 mm wide at the top
- For aesthetic purposes, side drains should have the square edges rounded
- Excavated material can be placed on the track and used to form the desired track shape. It will need to be compacted. Surplus material should not be discarded. It can be used to even out grades or stored for maintenance purposes

In erosion prone country side drains should be;

- Constructed considerably deeper
- Lined with geotextile filter fabric
- Have loose local rocks (50 mm-100 mm in size) or gravel placed in them to slow down the speed of the water

HOT TIPS

- During construction install water management options before proceeding to the next section. This reduces the risk of water damage over the newly formed track and newly formed batters

- Ensure side drain edges are rounded to produce a softer look rather than a sharp cut look

Figure 38 - Side drains can easily collect a large amount of leaf litter in a short period of time, compromising their effectiveness. Side drains need to be maintained regularly

Figure 39 - This track has large side drains on either side of the walking track.

The drop at the end of these timber chutes and culvert can cause water to erode the soil. Some form of soil erosion protect would be required

Figure 40 - This outlet is far too small for the size of the side drain. Furthermore, beech forest drops an excessive amount of leaf litter (accumulation of material is evident in the side drain) and this will further block the outlet

14.6 CATCH PIT

A catch pit (sometimes also referred to as a sump) is an excavated hole into which water from the side drain flows. Catch pits are located at the head of a culvert. Their purpose is to slow down the velocity of water and provide a point for sediment to be deposited. Reducing the speed of water that flows through the culvert also helps prevent erosion at the culvert outlet.

14.6.1 Catch pit construction

- Excavate material at the culvert inlet
- **Excavate to a minimum depth of 475 mm (150 mm culvert cover, 225 mm pipe and 100 mm invert). Larger culvert pipes will require a deeper catch pit**
- Excavate to a minimum width of 300 mm; the catch pit should be made wider rather than deeper
- For aesthetic purposes, catch pits should have the square edges rounded
- Excavated material can be placed on the track and used to form the desired track shape. It will need to be compacted. Surplus material should not be discarded. It can be used to even out grades or stored for maintenance purposes
- The backwall, the down grade wall of the catch pit, shall be 425 mm high (as opposed to 475 mm for the other walls). This will act as an over flow into the next side drain. The surplus water can be discharged via a drainage grade dip for crowned tracks as shown in Figure 35 or via a larger culvert every third culvert
- Protect the culvert headwall with rocks or timber. Rocks are the preferred option if available. They should be embedded around the culvert mouth

14.7 PIPE CULVERTS

A pipe culvert is a closed pipe used to move water underneath impediments. This manual **does not** deal with the installation of culverts in intermittent or permanent water courses. There are specific requirements that may be necessary including consents and specific designs e.g. installation of a fish passage. **Refer to your planner and an engineer if you need to install a culvert in an intermittent or permanently flowing steam.**

14.7.1 Culvert size

For our purposes a culvert pipe takes water from one side of the track to the other. With the exception of culverts that are required for permanent or intermittent water flows, culverts should meet the following requirements;

- Recommended minimum culvert internal diameter is 225 mm
- Internal walls must be of a smooth finish. This allows material such as leaves, small stones and twigs to pass through the culvert and reduce the likelihood of blockages within the culvert wall
- Black in colour. Bright coloured culverts create a visual impact

14.7.2 Culvert frequency

The frequency with which culverts are installed depends upon the circumstances. In general, the flatter the sideslope the greater the distance between the culverts. Obviously **the frequency of the culverts will be influenced by the soil, sideslope, local weather and track design**. However, Table 17 provides recommendations on maximum culvert spacing.

(Degrees)	**(Percentage)**	**(Rise to run ratio)**	**Maximum distance between culverts (metres)**
3º	5.3%	1:19	50
6°	10%	1 :10	25
8.5°	15%	1 : 7	18
10°	17%	1:6	16
11°	20%	1 : 5	14
17°	30%	1 : 3.3	10

Table 17 – Recommended spacing between culverts

14.7.3 Culvert specifications

Specifications for installing a 250 mm external diameter culvert pipe.

Culvert external diameter	**Min. trench width**	**Min. cover**	**Compacted pipe bedding**	**Compacted pipe overlay**	**Compacted depth of fill / surface**
250 mm	560 mm	150 mm	100 mm	75 mm	75 mm

14.7.4 Culvert installation

Drawings are available in Appendix 12, 4-1 and 4-3

- Work out how deep you need to dig the trench. It consists of the compacted bedding layer (100 mm) + external diameter of pipe (250 mm) + minimum cover (150 mm) = 500 mm
- Excavate across the track at the required angle
- Excavate the trench to the minimum width (560 mm) and depth (500 mm) required
- Cut the pipe to the correct length, measure twice and cut once
- Allow for enough length (of the culvert) to extend beyond the track formation without risk of material blocking the drainage channel
- Level and compact the bedding material in the trench base with a minimum fall of 1.7º (3.0%) to the outlet, working from the outfall end to the inlet. This will help to maintain the required fall
- Install the headwall base stones
- Position the pipe and check alignment
- Place a smart level on the top of the culvert to ensure the fall is correct; adjust the fall if necessary. Getting the fall absolutely right is important. Too flat and the culvert is likely to block, too steep and the outlet is likely to scour with the increased speed of water exiting the culvert, (section 14.9)
- Set base of culvert at the outlet at ground level. Avoid vertical drops at the outlet as a small waterfall may accelerate erosion
- Pack around the sides of the culvert with the bedding material and compact in layers not exceeding 150 mm
- Continue to compact bedding material until culvert pipe is covered by 75 mm
- Compact additional pipe backfill (75 mm). This 75 mm may be comprised of the walking surface material, shape and compact to the required finish. This will give a total cover over the pipe of 150 mm
- Set headwall side stones on the base stones, ensuring they extend beyond the end of the culvert by 150 mm

- If possible use one top stone to span across to the side stones
- Wedge stones together by using smaller stones packed tightly between larger stones to prevent movement. Use a rubber mallet to hammer these into position
- Set splash stones in place. At the inlet set these above the base stone and below the base stone at the outflow
- Restore the site to as natural a condition as possible. For the visitor a well constructed culvert will not be visible

HOT TIPS

- **Etch culvert all the way around before cutting**
- **Cut culvert at least 300 mm wider than the width of your track (buried at 300 mm as per specifications this will allow for a batter of 1:1)**
- **Cut from the male end not the female end**
- **Cut with a handsaw**
- **Sandpaper or rasp every cut. This will help those maintaining the culverts to avoid getting cuts from the unfinished sharp edges**
- **Dazzle the ground or mark in some way the angle at which the culvert will cross the track**
- **Use a smart level to check culvert fall**
- **Outlet should discharge at ground level**
- **Do not use culvert socks unless they cannot be seen by the user**

! PITFALLS

- **Insufficient fill over the top of the culvert**
- **Poor headwall rock/timber work**

14.8 CULVERT HEADWALL AND OUTLET PROTECTION

Determining soil scour potential and channel erodibility should be a standard component of track design.

- Design the outfall on the basis that erosion at the outlet and downstream channel is to be expected. Provide at least minimum protection, and then inspect the outlet channel after major storms to determine if the protection must be increased or extended
- Line headwall with rocks, particularly around the culvert mouth
- Rocks lower excessive flow velocities from pipes and culverts, prevent scour, and dissipate energy. Good outlet protection will significantly reduce erosion and sedimentation by reducing flow velocities

HOT TIPS

- **Minimum fall of culvert pipe 1.7° (3%)**
- **To hide the pipe and ensure it is not visible to users the outer edge of the stone should extend 150 mm in front of the pipe, with the edge and side stones retaining the backfill**
- **Use base stones 200 mm deep if you have them available**
- **Ensure there is at least 100 mm of backfill or bedding material between the inside faces of the headwall stones and the pipe**
- **Base stones should extend 150 mm under the pipe and 300 mm in front of the pipe (this provides a splash plate for water both entering and exiting the culvert)**
- **Use only weathered stones so it looks as though the culvert has been there forever**
- **Side stones need to be large enough to support the top stones**

14.9 CULVERT OUTLET VELOCITY

When considering culvert outlet velocities, there is value in considering what velocities natural channels can tolerate prior to eroding. Collodial means particle size is even.

Material	Mean Velocity (m/sec)
Fine Sand, colloidal	0.4
Sandy loam, noncolloidal	0.5
Silt loam, noncolloidal	0.6
Alluvial silts, noncolloidal	0.6
Ordinary firm loam	0.8

Volcanic ash	0.8
Stiff clay, very colloidal	1.1
Alluvial silts, colloidal	1.1
Shales and hardpans	1.8
Fine gravel	0.8
Graded loam to cobbles, noncolloidal	1.1
Graded silts to cobbles, colloidal	1.2
Coarse gravel, noncolloidal	1.2
Cobbles and shingles	1.5

Table 18 - Maximum permissible velocities for unlined channels

Calculating outfall velocities during peak floods is complicated. Below are some simple options for you to consider:

1. All outlets with a value of < 1.1 from Table 18 shall have outlet protection installed. All other outlets can be determined on a case by case basis
2. Perform a basic calculation from the "Water Speed Calculator" in the attached document "*Track length, water speed and material volumes calculators*".

It will provide you with an estimation of the exit velocity of water from a culvert. It assumes a start speed of zero from the culvert entrance. The speed of water exiting the culvert should be considered the minimum.

3. Observe effects after storm events
4. Have an engineer do the calculations

Length of culvert (metres)	I=	1.5	Enter value in orange box
Inclination of culvert (degrees)	A=	1.7	Enter value in orange box
Speed of water (metres per second)	V=	0.94	Your answer

Table 19 - Estimated Speed of Water at Culvert Outlet

In reality the actual speed of water exiting the culvert is likely to be higher than that indicated, particularly during flood events when water will enter the culvert pipe travelling at some speed.

14.10 STORMWATER OVERFLOW

In extreme flood events catch pits and culverts may not handle the volume of water. It is necessary to build stormwater overflows into the design of your track.

Critical points for locating stormwater overflows are;

- The backwall construction of catch pits should be constructed as per section 14.6.1. This allows excess water (when the culvert is at full capacity) to spill over the backwall and into the next side drain
- Grade drainage dips for a crowned track built into the track formation as per Figure 35. These should be located no more than five metres downhill from a culvert
- Consider installing a larger culvert every third culvert to remove excess water

14.11 STONE FORDS

Stone fords provide a hard wearing surface through small streams or seasonal watercourses where a bridge is not required or a culvert is overkill for the situation. A well constructed ford will withstand fast flowing water and can help prevent erosion of the stream banks and track approach. The best place for a ford is at a wide stretch of slower flowing river where the force of the water is least.

14.11.1 Stone ford specifications

Width	Length	Edge stones	Bank edge	Stones
Extend 300 mm wider than the formed track on the upslope and downslope edges	Extend a minimum of one course of stones past the visual peak waterflow	Minimum submerged depth of all edge stones 300 mm. Upslope edge must be level with the streambed. Downslope level a maximum of 150 mm above the streambed. All downslope edge stones must be embedded at least 2/3 of their	Stones to finish flush with the track surface	All stones to have a level surface suitable for walking.

		depth		

HOT TIP

If sourcing stones from the local stream do not gather all of the stones from the one location, rather gather stones randomly over a large area

14.11.2 Stone ford construction

- Divert or block up to 50% of the water flow for a good work space
- If necessary place a large boulder upstream to reduce the force of the water
- Remove any stones that may cause an obstruction in the area the ford is to be constructed and save other suitable stones
- Start construction in the centre course of stones at the downstream edge in the lowest point of the stream bed. Work upstream and parallel to the stream bank
- Set the stones to the correct depth (section 14.11.1) to achieve the required crossing
- Stones should be offset so that joins overlap, with the top walking surface flush
- Lock all stones together by using smaller wedge stones to fill the gaps
- Re-grade and shape 3-4 metres of the walking track surface to the level of the ford on each side of the ford crossing

Where mountain bikes are not expected the design can change slightly by constructing a step where the track ends and the ford begins. Large stones fitted tightly together would need to be used.

15. Track Pavement

The pavement is the collective term for the layers that combine to form protection of the sub-grade.

15.1 TRACK SURFACE STANDARDS

The track walking surface plays an important role in meeting the track service standards and influences the type and frequency of ongoing maintenance.

Track Classification	Track Surface
Short Walk	• Well formed and even • Can be walked on comfortably without getting footwear wet and muddy (in dry weather) • Up to 10% of track may have short sections of wet and muddy (not more than 10 m in every 50 m)
Walking Track	• Mostly well formed and even • Can be walked on comfortably without getting footwear wet and muddy (in dry weather) • Up to 20% of track may have short sections of wet and muddy and/or rough and uneven (wet and muddy should not exceed 20m in every 80 m)
Great Walk / Easy Tramping Track	• Over 70% (Great Walks) and over 50% (Easy Tramping Track) will have wet areas drained and provide firm and even footing • Up to 30% (Great Walks) and up to 50% (Easy Tramping Tracks) may have: i) Uneven steep or rough sections ii) Deep muddy or wet sections (not over the top of the boot) iii) Length of wet and muddy should not exceed 400 m in every 1000 m (Great Walks) and should not exceed 600 m in every 1000 m (Easy Tramping

	Track)
Tramping Track	• Generally natural surface • May include mud, tree roots, rocks and water
Route	• Surface is natural and may be rough

Table 20 - Track Surface Standards

15.2 TRACK SURFACING

Track walking surfaces consist of the naturally occurring soil type or material that has been imported from another location. The use of imported material is generally as a result of soil erosion, displacement or wet and muddy track conditions. These three factors are the primary drivers behind the use of metal aggregate as a track walking surface.

Soil erosion (section 8.1)	There are a number of factors that determine the significance of erosion. Soil type, track gradient and weather are all important contributors. Table 17 shows the velocity of water in a natural channel a certain soil type can tolerate before it begins to erode. **The combination of gradient and soil type are significant contributors to erosion**
Wet and muddy	Tracks become muddy when the load applied on the surface exceeds the bearing capacity of the soil. How wet the soil is has an influence on how much load it can sustain
Displacement (section 8.2)	If the soil type is unable to withstand the visitor numbers then an alternative solution is required

Table 21 – Factors Contributing to the use of Metal Aggregate as a Track Walking Surface

For archaeological sites it is better to build on top of the ground surface than it is to excavate. Consult with your Technical Support Officer - Historic if undertaking work on archaeological sites.

HOT TIP

- **Good sources of suitable local material for track construction and maintenance may be found where large trees have been uprooted, on dry ridges, river terraces and in stream/creek/river beds. River gravel is NOT suitable as a track surface**

! RED ALERT

- **Resource consent is required to remove gravel from the bed of a lake or river. Gravel extracted from other sources may require consent. CHECK THE DETAILS FOR YOUR LOCATION WITH A PLANNER**

Figure 41 -This raised formation on the Milford Track works well having raised the walking surface above the surrounding ground surface. Raising the track means the pressure now applied to the natural ground surface is very low; this prevents failure of the natural ground surface

15.2.1 Stone pitching

The basic technique involves setting large to medium sized stones with their long axis into the ground, packed together as closely as possible and wedged with smaller stones to construct a walking surface. Use of the smaller stones helps lock everything together. The size of stone used depends on what's available, the only requirement being that the stone should have a reasonably level face to use as the walking surface.

Constructing a pitched track is very labour intensive and expensive. The effective use of pitched tracks is confined to certain locations. Some of the triggers that will determine whether you construct such a track are gradient and highly erodible soils. Constructed correctly this is a surface that will stand the test of time.

- **Stone pitching is most suitable for slopes between 15º and 22º**

- Below 12º pitching is generally not required because the use of stone aggregates is more cost effective
- Steeper than 22º and the track becomes less comfortable for users to walk on and the installation of steps is the better option
- Stone pitching is a good alternative solution where maintaining a durable walking surface is difficult
- There is more rock held in the ground than exposed on the surface, this helps to create a stronger track
- The stones are fitted as tightly together as possible with smaller stones used to fill the gaps. This helps to tighten the overall construction of the track
- Stone pitching is a good option where the gradient is too steep to use an aggregate or the erosion pressures of displacement and weather are significant

Figure 42 - Stone pitching, while very labour intensive to construct, will last an exceedingly long time

15.2.2 Stone pitching construction

- If required remove soil from the track alignment and to the required depth
- Anchor stones at the start of the pitching must be flush with the track surface. They must be immovable as they are the key to holding the remainder of your track in place
- Stones must be embedded no less than half the depth of the stone with the longest side into the ground
- The walking surface should be of an even gradient
- Use large deep stones at the track edge
- Join all stones tightly together on all side faces

- Overlap joins
- Use wedge stones to lock everything in place as each line is laid across the track and to prevent water getting down underneath the stones. This is essential to stop stones from loosening and minimise the effect of frost heave
- Use the excavated material to landscape the edges to give a softened appearance
- Work from the bottom up
- For a truly great finish ram gravel into all the remaining gaps

HOT TIPS

- **Use tie stones – these are large stones that span a large width of the track**
- **Use local materials**
- **Face weather side of rock to the track surface**
- **Fill the gaps**
- **Design for flow**

15.3 TRACK PAVEMENT

Track pavement is the combination of a base and wearing surface placed on a sub-grade to support loads and distribute it to the sub-grade. It generally comprises of a sub-base and surface.

The strength of the sub-grade is measured by the California Bearing Ratio (CBR). The CBR is a penetration test for evaluation of the mechanical strength of sub-grades. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured strength of the sub-grade determines the pavement solution. Options for different soil types and CBR values are recommended in Table 23.

Sub-base	This raises the track above the surrounding land. It also provides a load bearing foundation, used when constructing a track over very wet or rough ground.
Surface	Final layer over the base

Table 22 – Components of the Track Pavement

Figure 43- This raised track has a pavement consisting of a base of moraine boulders sub- base of AP65mm and surface of AP20mm

An aggregate is graded stone that can be used to form the sub-base and surface of a track. Depending on the circumstances a track may consist only of a sub-base and surface.

Each layer should have a range of stone sizes that interlock when compacted. **Constructing a track in several layers using different graded material produces a significantly stronger track than using uniformly sized material.**

The purpose of the surfacing, or wearing course is to:

- Provide an even, stable and more durable walking surface
- Resist erosion when correctly applied
- Resist displacement when correctly applied
- Protect the underlying pavement from water infiltration

The sub-base supports the track by spreading the load applied on the surface to prevent the natural ground surface from deforming. The sub-base is designed to spread the load without itself deforming. A well constructed, well compacted aggregate mix will spread the loads at an angle of between 45° and 60°.

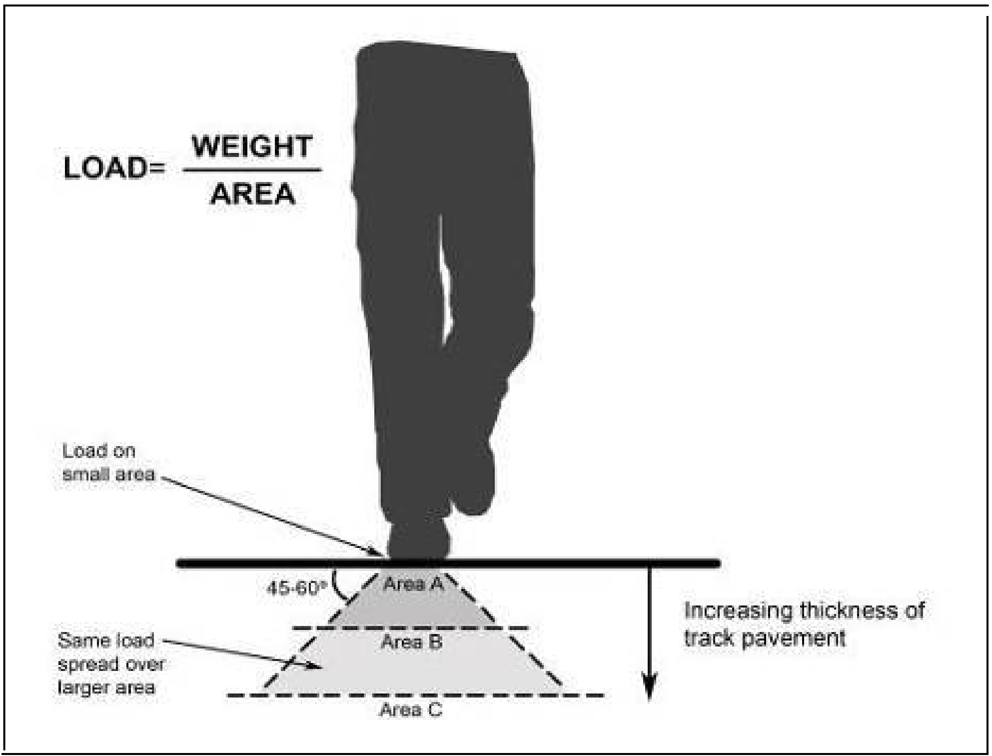


Figure 44 – Load Distribution

Where a sub-base and finished walking surface are required, due to the nature of the ground conditions, the following are the specified minimum compacted depths based on different soil types:

Track Pavement and Surface Options				
Soil Description	**Low use back country sites (typically BCC, BCA, RS)**	**High use front country sites (typically SST, DV) and/or occasional MTB use**	**Very high use sites and/or intensive MTB use**	**Comments**
Wet, soft organic soil; Soft marine sediment (CBR<3)	Install timber or similar raft type foundation; or Drain the area and provide suitable imported fill to form sub-base layer and then provide track pavement to match the sub-base material from corresponding category below; or Provide a boardwalk			Where possible, these areas should be avoided by choosing an alternative track route
Soft clay, silts and ash (CBR 3 to 5)	Provide deep side drainage and frequent grade dips; or Provide 75 mm to 100 mm compacted aggregate pavement on geotextile over the sub-grade	Provide deep side drainage and provide 100 mm to 150 mm compacted aggregate pavement on geotextile over the sub-grade	Provide deep side drainage and 150 mm or more of compacted aggregate pavement on geotextile over the sub-grade	Drainage of these soils and allowing them to dry in suitable conditions is likely to result in them becoming firmer
Firm clay, silt, or ash soils (CBR 5 to 7)	Compact the sub-grade and provide adequate drainage	Compact the sub-grade and provide 75 mm compacted aggregate pavement	Compact the sub-grade and provide 100 mm compacted aggregate pavement	A bare or grass surface may be adequate on these soils in low use sites; Adequate compaction of this category when dry may increase the CBR to 7 or more.
Well compacted clay, pumice or brown ash soils (CBR 7 or more)	None; or Provide 50 mm layer of compacted aggregate	Provide 50 mm layer of compacted aggregate	Provide 75 mm layer of compacted aggregate	A bare or grass surface may be adequate on these soils in low use sites

Loose gravel; Beach or river gravel; Scoria Sand	None	Compact the sub-grade and provide 50 mm compacted aggregate pavement	Compact the sub-grade and provide 75 mm compacted aggregate pavement	Addition of silt and clay fines to these soils, mixing and compacting may provide a suitable surface in some sites
Compact gravel; Weathered rock	None	None; or Provide 50 mm compacted surfacing aggregate layer	None; or Provide 50 mm compacted surfacing aggregate layer	Aggregate surfacing provided to level out un-evenness in the sub-grade
General Notes: CBR = Californian Bearing Ratio (can be measured using Table 23, a Scala penetrometer, Clegg Hammer or other approximate means) Pavement aggregate maximum stone size should be not more that 40% of the intended compacted layer thickness (ie 20 mm maximum stone for 50 mm thick pavement layer, 40mm maximum stone for 100 mm thick pavement layer. Where the recommended total pavement layer is 150 mm or more, there may be benefit in applying this as two layers (ie one 100mm thick layer of GAP40 aggregate and a surface layer of GAP20 at 50 mm thickness)				

Table 23 – Track Pavement Options

It is imperative that the finished surface is higher than the surrounding ground for water management purposes. This will allow water to drain away freely to the side of the track and prevent water from pooling and running down the side of your track.

! RED ALERT

- **River gravels have the potential to carry weed seeds a considerable distance from their source**
- **Managed quarries may also be a source of weed infestation. Check the quarry for potential weeds**
- **Machinery transported from one location to another is a good taxi for seed**
- **Clothing, particularly boots is another source worth checking**
- **Check Conservation Management Sratagies or Management Plans to ensure the importation of aggregate is permitted**

15.4 TRACK COMPACTION

Compaction is the process by which we squeeze air out of the material to form a dense track surface.

- This increases the density of the material by applying a force. It brings the soil particles into contact with one another
- An increase in density equals an increase in strength. As a general rule a 1% increase in density equates to an increase in strength of 10-15%. Of course this will only happen if you have suitable material
- Increased strength means the material is more stable and less likely to be as affected by displacement, foot compaction and weather than unmodified material; hence the likely maintenance is decreased. What we are endeavouring to do is maximise the performance of the material
- **Compaction is the cheapest and simplest method for increasing strength and shearing resistance**

15.4.1 Compaction of cohesive soils

Cohesive soils are typically clays and silts.

- Compacting this type of soil is **best achieved using a deadweight compactor** as we are after the kneading and pressure action
- Vibrating compactors do not work as well on these types of soils as they may cause a displacement phenomenon to occur
- If a vibrating compactor is the only one available, allow the moisture content to become quite low and reduce the revolutions on the compactor

A relatively simple field test can be carried out to determine the strength of cohesive soils.

Term	**Undrained shear (kPa)**	**Approximate CBR rating (%)**	**Field test**
Very soft	<12	<1	Exudes between fingers when squeezed in hand
Soft	12-25	1-2	Easily penetrated with thumb. Moulded by light finger pressure
Firm	25-50	2-4	Penetrated by thumb with effort. Moulded by strong finger pressure
Stiff	50-100	4-7	Indented by thumb. Cannot be moulded by fingers.

Very stiff	100-200	7-10	Indented by thumbnail. Penetrated by knife to about 15mm
Hard	>200	>10	Can be indented with difficulty by thumbnail

Table 24 - Strength of cohesive soils

(Source: after AS1726-1993)

15.4.2 Compaction of granular soils

Non-cohesive materials require a vibration action to “lock” the particles in place.

- This shaking is delivered with the use of a vibrating compactor. **The vibrating compactor should only be used to lock the particles**
- Ideally, the granular material is finished off with a deadweight roller. However, the size of most deadweight rollers and the nature of the terrain often makes them difficult to use
- **Compact until the field test as outlined in Table 27 gives a good result**

HOT TIPS

- **On cohesive soil good compaction can be achieved by allowing the soil to dry out so the moisture content is low**
- **When you are unable to use a static compactor for track compaction, use a vibrating plate compactor but reduce the revs down to the minimum**

15.5 AGGREGATE BEHAVIOR

When purchasing aggregate from a quarry it is highly recommended that prior to the purchase and application, the product is tested to determine its likely behaviour.

- Due to the volume of material being produced most quarries will have an aggregate grading analysis. This will demonstrate where the aggregate falls in relation to the required grading envelope as specified in 15.5.3. It is likely that the aggregate will lack the necessary fines. It may be necessary to have additional material added.

Some locations across the country may have access to stone that is suitable for track surfacing and get the material crushed to size.

- Minimum quantity should be no less than 2000 cubic metres. Any less than this and the establishment costs make it very expensive aggregate
- River metal should have 70% broken face to lock the material suitably and perform well
- When producing quantities of 2000 cubic metres have an aggregate grading analysis done. This should be carried out at a registered TELARC laboratory

Use of the appropriate material may result in higher initial material location and construction costs, however substantial savings in the overall life cycle costs can be expected.

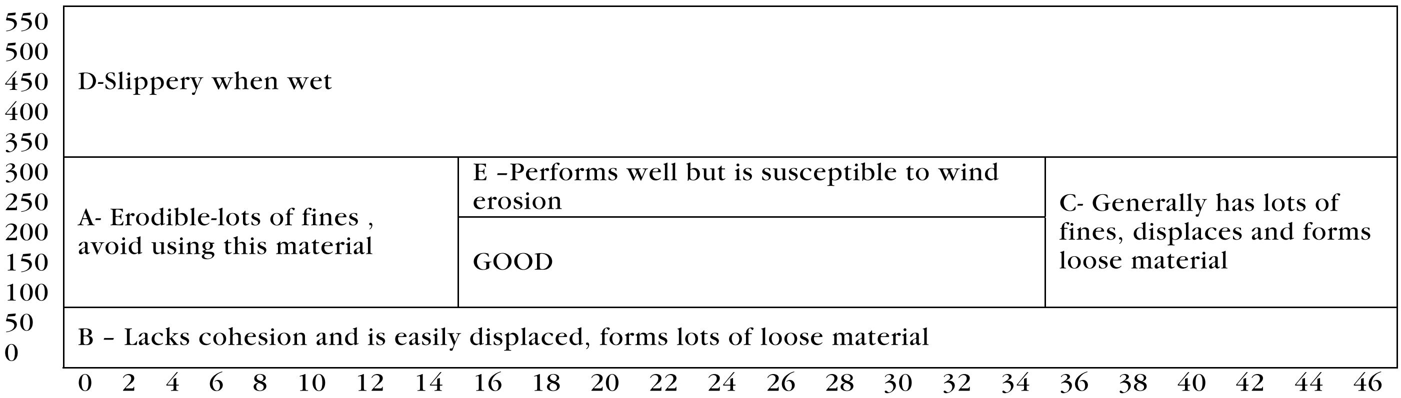


Figure 45 - Relationship between shrinkage and grading coefficient

(Source: Jones and Paige – Green 1996)

15.5.1 Poorly graded materials

Poorly graded material contains only a small proportion of the range of particle sizes. An excess of large stones means the material will not “lock” together very well and will soon get displaced.

Figure 46- Stockpile of poorly graded material ready to be used as a track surface

Figure 47 - When transported to site and compacted, poorly graded material is easily displaced

Figure 48a - Larger stones have been pushed to the side of the track when compacted as the material lacks angular stone structure (section 15.5.2)

15.5.2 Well graded materials

Well graded means having a particle size distribution that conforms to certain envelope limits when the aggregate is tested in accordance with NZS 4407:1991 (Table 25). If the grading curve (as shown in the graph in Figure 49) is within the upper and lower limits the aggregate can be expected to compact and bind well.

In the majority of situations you are going to have to make do with the type of material available to work with. However, in many of our front country sites with relatively high visitor numbers, applying a well graded metal to the track surface is appropriate.

- Material needs to be angular in shape, not rounded, as this allows the material to lock together
- Material should contain a proportion of clay fines. This helps to bind the other particles

- Maximum stone size is 20 mm. This will be suitable for almost all track work
- Rounded stones move easily and will be displaced from your track very quickly. Visitors walking on rounded material will quickly move the material off the track surface and either off the side of the track or into the side drain
- A well graded material has a range of particle sizes and this is the product we should aim to use on some of our tracks. The reason for this is that when a load is applied (static or vibrating plate compactor) the particles are able to lock together, voids are filled in by the smaller sized particles. This produces a track surface that is dense and significantly stronger than poorly graded material

Figure 48b - A well graded metal track surface. Note the stones are angular and there is a good distribution of particle sizes. The presence of fines "locks the material together". Particle sizes vary from 20 mm to 0.002 mm

15.5.3 Particle size distribution

Samples of your product sent to a registered TELARC laboratory will be tested against NZS 4407:199. The results from your product will be compared to the grading envelope outlined below and recommendations made to achieve the required aggregate mix.

	Maximum and minimum allowable percentage weight passing
Test sieve aperture	**AP20 (max size 20mm)**
37.5mm	-
19mm	100
9.5mm	55-75*
4.75mm	33-55
2.36mm	22-42
1.18mm	14-31

600µm	8-23
300µm	5-16
150µm	0-12
75µm	0-8

Table 25 - Particle Size Distribution Envelope Limits

* means that using a 9.5 mm sieve no less than 55% and no more than 75% of the sample will pass through the sieve

UNSEALED ROADS
WEARING COURSE
SAMPLE SUMMARY

Project :	
Location :	Ruapahu
Client :	Opus Rotorua
Contractor :	Unknown
Sampled by :	Department of Conservation
Date sampled :	30/03/2007
Sampling method:	Not stated
Sample decription:	Silty Sandy GRAVEL, sand and clay added
Sample condition:	Moist / Natural
Source:	Tree Trunk Quarry, Desert Road

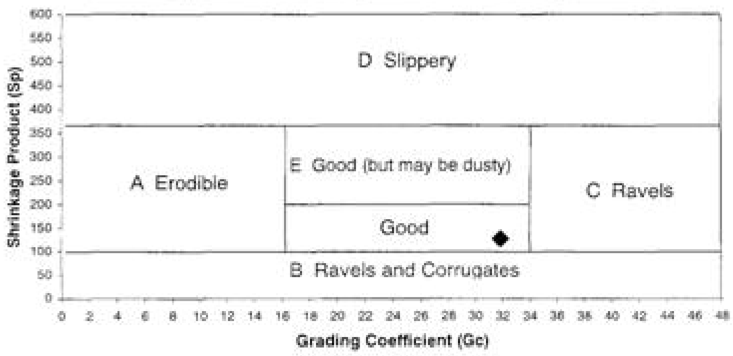
Project No :	289373
Lab Ref No :	07/136
Client Ref :	?

Sieve size (mm)	% Passing
37.5	100
26.5	100
19.0	99
9.5	74
4.75	49
2.36	35
1.18	26
0.60	21
0.425	19
0.30	17
0.075	11

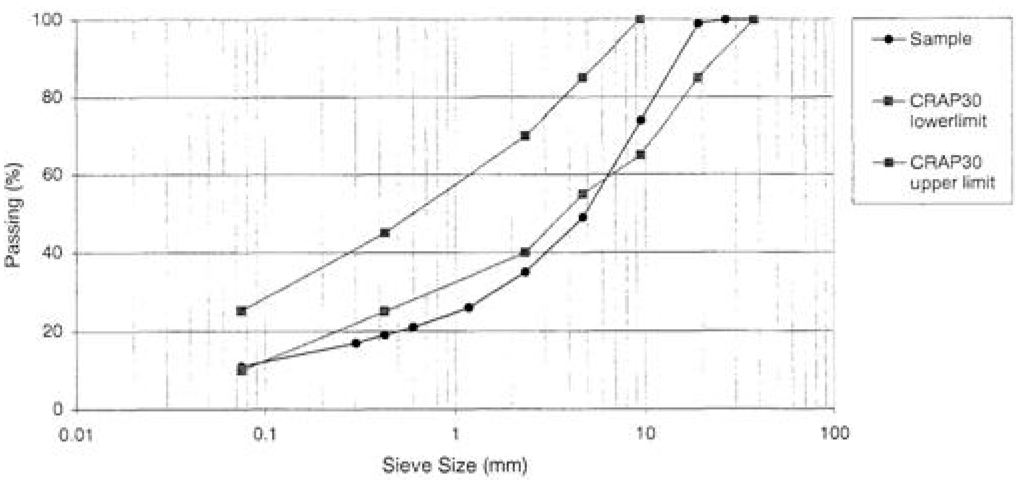
Linear Shrinkage (%)	6.70
Plasticity Index	13.10

Shrinkage Product	127.30
Grading Coefficient	31.85
Plasticity Product	249

Relationship Between Shrinkage Product and Grading Coefficient



Particle Size Distribution with CRAP30 limits



Notes

1. Shrinkage Product = Linear shrinkage x % passing 0.425
2. Grading coefficient = (% passing 26.5mm - % passing 2.0mm) x % passing 4.75mm
3. Plasticity product = plasticity index x % passing 0.425mm

File G:\Johnt\Low Volume Roads\Particle size distribution graphs\Unsealed Roads Report without log interpolations

Figure 49 – Results of a sample sent to a TELARC laboratory for analysis

Interpreting this information can be quite difficult if you are not familiar with it so let's take it step by step.

Step 1 – Our sample is analysed according to NZS 4407:1991

Sieve size	% Passing
37.5	100
26.5	100
19	99
9.5	74
4.75	49
2.36	35
1.18	26
0.60	21
0.425	19
0.30	17
0.075	11

Figure 50-The sample sent to the laboratory produced the following results when passed through the various sieve sizes.

E.g.: For the sieve size of 9.5 mm, 74% of the material passed through the sieve

Linear shrinkage (%)	6.70
Plasticity index	13.10

Shrinkage product	127.30
Grading coefficient	31.85
Plasticity product	249

Step 2 – Plot the sieve analysis results

Plot the actual results from the sample against the maximum and minimum allowable percentage as contained in NZS 4407:1991. This will produce a graph similar to that shown in Figure 49. You are able to see the particle sizes that need to be added to comply with the standard. **Make sure you ask the laboratory to provide recommendations.**

15.5.4 Optimum moisture content

The term used to describe the moisture content we are seeking is Optimum Moisture Content (OMC) and this is the key to effective compaction. Another term that relates to OMC is Maximum Dry Density (MDD). When the material at OMC is compacted it yields MDD. This is the highest density a material can achieve under a specific loading.

- A material that is ideal for compaction will reach a point of maximum strength at certain moisture content
- If the material is compacted when too dry the overall density will be less and therefore the strength of the material will be less. More effort is required to compact the material and the final density is likely to be less than if compacted at OMC
- If the material is compacted with moisture content higher than OMC then compaction will have little effect

HOT TIP

- **Stockpiled aggregate is likely to be at roadends or close to rivers. Ensure material is at OMC prior to transporting. It is easier to apply water at these locations than when the material is spread on the track surface**

15.5.5 Field test for optimum moisture content

A simple and reliable method of testing the OMC of material in the field is the squeeze test and this will work for the majority of material we deal with.

- Remove as many of the particles over 5 mm in diameter as possible, we just want the fines as the squeeze test will not work with large particles
- Squeeze a handful of material as hard as you possibly can in the palm of your hand

When you open your hand the material will fall into one of three categories:

- Falls apart and looks dry – material is too dry and needs water added
- Falls apart and looks shiny – material is too wet and needs to dry out
- Stays together in shape and has a dullish appearance – OMC

! PITFALL

- **Make sure you test four to five random locations from your pile of material. Testing from one spot may give you an incorrect result for the overall OMC of the pile**

15.6 LAYER THICKNESS

There is a simple minimum rule for working out the thickness of your finished (compacted) layer.

- If you want a finished compacted layer of 50 mm an aggregate of 20 mm particle size is needed (20 mm X 2.5 = 50 mm)
- It should be 2.5 times the thickness of the largest stone in your material

15.7 HOW MUCH MATERIAL FOR A JOB?

Calculating the volume of material you will need for a job is relatively straightforward and is calculated with a simple formula. However, there are one or two potential pitfalls.

- Un-compacted volume = length x width x depth x compaction factor
- **Compaction factor is the reduction in volume due to compaction. As the material gets squeezed together air is removed. The material reduces in volume by approximately 30%**

Therefore the volume of material required for a track 685 metres long (length) that is 800 mm wide (width) using 20 mm aggregate (20 x 2.5=50 mm depth) x 1.3 (compaction factor) is calculated as follows:

Length	**Distance over which aggregate is to be applied**	**685 metres**
Width	Width of track	0.8 metres
Depth	Stone size times 2.5	0.05 metres
Compaction factor		1.3
Total volume		35.6 cubic metres

Table 26 – Calculating the un-compacted volume of material required

- Un-compacted volume = 685 x 0.8 x 0.05 x 1.3 = 35.6 cubic metres

! PITFALL

- **Getting the decimal point in the wrong place when converting width and stone depth**

15.8 COMPACTION TECHNIQUE

We have already mentioned that compaction is the cheapest and simplest method for increasing strength. It is therefore important to follow a procedure so as to achieve satisfactory compaction uniformly across the entire track surface, while maintaining the shape and evenness of the surface.

- Pavement material should not be compacted in layers exceeding 150 mm
- Compaction should commence on the outer (lower) edge of the pavement and progress towards the centreline. Compacting from the inside to the outside will cause material to be pushed downslope resulting in a loss of shape
- A forward and reverse pass is made over the same section of pavement before moving to the adjacent section. It is important to ensure this is done. When changing direction, the compactor should be on the previously compacted section
- Each pass of the compactor should overlap the previous one by 1/3rd to ensure complete coverage
- Vibrating compactors should have the vibrator turned off when the machine is stopping or turning
- All compactors should be reversed without any jolting. Sharp turns or sudden changes in direction should be avoided
- The best speed is usually a slow walking pace
- When using a vibrating compactor, a sequence consisting of a non vibrating pass, followed by several high amplitude passes, and finishing with low amplitude passes, has been found to achieve good compaction and surface thickness
- Depending on the weather a light sprinkling of water will be necessary to maintain OMC

Figure 51 – Good compaction technique. Compaction commenced on the outside edge and each pass of the vibrating plate compactor is overlapping the previous pass

Figure 52 - Working in tandem is the vibrating plate compactor, bottom left, followed by the static roller. Note the track has been compacted from the outside edges to the centre

! PITFALL

- **Running the compactor down the centre of a crowned track. This effectively flattens the top**

15.8.1 Field test of surface compaction

The field technique used to check compaction of the track surface involves the scuff test and/or golf ball test.

		POOR	GOOD
Scuff test	Stand on ball of foot on one leg and twist	Material is easily displaced	Little difference made in track surface
Golf Ball	Drop a golf ball from waist height	Bounces back to a height lower than the knee	Bounces back to knee height or higher

Table 27 – Field test to determine walking surface compaction

Before going to the time and effort of placing material on your track it is worth taking the time and effort to test the hardness of the material being used.

This will give you some idea of how the track will perform when compared to the three key forces we have already discussed; erosion, displacement and compaction.

Term	**Point load index (MPa)**	**Field Test**
Extremely low	<0.03	Easily broken by hand to a material with soil particles
Very low	0.03-0.1	Broken by leaning on sample with hammer. Crumbles under firm blows with a pick. Can be peeled with a knife
Low	0.1-0.3	Broken in hand by hitting with hammer. Easily scored with a knife; sharp edges may be friable
Medium	0.3-1.0	Easily scored with a knife. Broken against solid object with a hammer
High	1-3	Difficult to break against solid object with hammer; rock rings under hammer
Very high	3-10	Requires more than one blow of the hammer to fracture sample; rock rings under hammer
Extremely high	>10	Sample requires many blows with the hammer

Table 28 - Strength of fragments of rock and hardened materials

(Source: after AS1726-1993 and Geological Society Engineering Group 1990)

15.9 FROST HEAVE

Frost heave is the disturbance or uplift of soil, pavement or plants caused by moisture in the soil freezing and expanding.

Heaving occurs when the right combination of fine grained soil, soil moisture and soil temperature exists.

- As the mean air temperature drops, the surface of the ground will freeze
- With the lower air temperatures, the freezing plane slowly penetrates the soil. In a fine grained moist soil the water in the soil turns to ice. This is, in effect, a drying action and water in the unfrozen soil beneath moves toward the ice in the same way that water will move from moist soil to dry soil. This water, on reaching the freezing plane, is able to flow through and around the soil particles there and to join the ice crystals above, thus adding to the growth of a layer of ice
- Pressure is developed so that the ice and soil above it are lifted
- As thawing proceeds downward from the surface, the ice crystals thaw and add water to the soil. The subsequent melting is sufficient to cause the soil to lose strength, and may cause the surface to become wet and muddy through loss of support

15.9.1 Minimising frost heave

Drainage	The presence of water in the soil is a major factor in the development of frost heave. Install drainage to help remove water
Soils containing silt and fine sands are very susceptible to frost heave.	• Ideally the soil will be removed at least down to the typical frost depth. Removing frost-susceptible soils removes frost action • As a minimum remove 10% of the typical frost depth • Replace the fine grained soil with a coarse granular material. Soils are susceptible to frost heave if 10 percent or more of the soil passes a 0.075 mm sieve or 3 percent or more passes a 0.02 mm sieve

Table 29 – Options for minimising frost heave

16. Geotextiles

The purpose of using geotextiles under the track formation is to prevent the mixing of materials. There are generally only two geotextiles used in the construction of walking tracks; filter fabrics and geocells.

16.1 FILTER FABRICS

- Use when there is a need to separate material and stop fines (clay or silt) from contaminating the track pavement material
- Is semi- permeable and allows water to seep through and drain

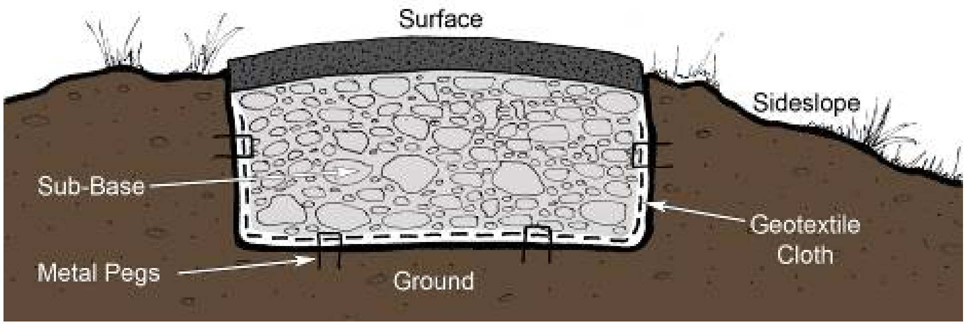


Figure 53 – Correct application of geotextile cloth

16.1.1 Construction using filter fabric

- Excavate material for track foundation as you would for the construction of an aggregate track
- Form an even and level base, remove materials that may puncture or distort the matting
- If the surface is very wet form the sides by using good size soil turves, these are laid over the top of the filter fabric edge
- To prevent the mixing of material where applicable the filter fabric may extend halfway up the formed sides

- Line the formation with the filter fabric and cut it to the required width if you have not already done so
- To navigate bends either fold or cut the filter fabric. If you cut the filter fabric then overlap the material by a minimum of 300 mm
- When encountering a culvert pipe proceed as per the installation of the culvert. When the culvert trench has been formed lay the filter fabric across the entire length of the trench
- Take care not to puncture the filter fabric when compacting the material around the culvert
- Secure all edges using ground staples and place at intervals not exceeding one metre
- Make sure no filter fabric is exposed, it should be well covered with material

16.2 GEOCELLS

HISTORY TRIVIA

In the late 1970's The US Army Corps of Engineers began research and development on a product to confine beach sand during amphibious assault. They welded strips of plastic into a rectangular, expandable honeycomb structure that when filled with sand supported the heavy loads applied by military vehicles and resisted erosion by wave action.

In 1984 the military demonstrated the effectiveness of cellular confinement in an exercise at Fort Story, Virginia involving thousands of passes by military vehicles over roads constructed of sand and cellular confinement. In 1990, 6,400,000 square feet of cellular confinement were successfully utilised during Operation Desert Storm.

http://www.usfabricsinc.com/products/cellularconfinement.shtml

Geocells are very effective at holding material in place.

- Use in very high use sites, with extreme weather conditions and erodible soils
- The objective of using geocells is to stop any erosion of soil when the track surface has lost shape or disappeared

16.2.1 Construction using geocells

- Look at the existing alignment and determine if you want to reroute the track or stay with the current alignment
- If using the existing track alignment and it is badly eroded, the track can become the side drain and a new track formed alongside
- If required, excavate to the required gradient and width removing all vegetation material

- Taking the grade out may mean the installation of short sections of steps
- Install side drains and culverts
- Ensure the sub-grade has a smooth finish with no protrusions (rocks, tree roots)
- Side edges are not necessary but if it is being installed get timber at correct level. Allow for thickness of the track surface and geocells
- Form sub-grade to required shape, crossfall and compact
- Add material to obtain required level, correct crossfall of 2° (3%-4%)
- Cut geocells and locate in place
- Complete one single pass of the compactor
- Secure geocells using 12 mm reinforcing rod and mortar
- Add suitable fill to the geocells
- Complete one single pass with the compactor
- Apply track surface material
- Shape to the correct crossfall of 2° (3%-4%) and compact

Figure 54 – Removal of organic material is required. If a track was built on top of the vegetation, movement of the track surface would take place as this decomposed

Figure 55 – Timber edging is bent to ensure the track flows and reflects the landscape

Figure 56 – Geocells are easily cut to any shape to fit the "flow" of the track

Figure 57 – To hold the cells in place a 12 mm reinforcing rod is driven into the soil. The individual cells containing the rods are then filled with a hardener to secure the geocells in place.

The local material on the side of this track can be used to fill the cells

Figure 58 – With the geocells filled the walking surface can be applied and compacted

Figure 59 – Completed section of track showing geocells and compacted walking surface.

As the track surface wears down to the geocells they will stop the loss of any further material. It is then a case of applying new surface material as opposed to considerable track reconstruction as has been the case on this track in the past

Figure 60 – While this section of track could be significantly improved aesthetically, it demonstrates that the geocells are effective in holding material. The gradient on this section of track is 13°

Figure 61 – Edging is not always necessary and these geocells will be covered with an acceptable walking surface

17. Transportation of Track Surface Materials

There are essentially three recognised methods of moving track surface material and which method is chosen depends on a number of variables. The three methods are; power carriers, fadges and hoppers.

When transporting material it is important to know **"how much"** so we know **"how far"** the material should be spread on the track. To work out the volume (how much) we need to apply a few mathematical formulas.

17.1 CALCULATING MATERIAL VOLUMES FOR POWER CARRIERS

Power carriers are in effect a motorised wheelbarrow and there are a number of makes and models available on the market, including self loading models. Their containment bin is essentially a rectangle and the formula for working out the volume of a rectangle is;

- **Volume = length(m) x width(m) x depth(m)**

Length	Distance from front of carrier bin to back of the bin	1.3 metres
Width	Width of bin	0.9 metres
Depth	Distance from top of bin to bottom of bin	0.6 metres
Total volume		**0.7 cubic metres**

Table 30 – Power carrier volume

Figure 62 – Modern power carriers have a hydraulic tilt function making the spreading of material significantly easier

17.2 CALCULATING MATERIAL VOLUME FOR A FADGE

A fadge is a large bag with reinforced webbing for additional support and handles. Use the formula;

- **Volume = length (m) x width (m) x depth (m)**

Figures 63 – Fadges are cheap and available in a number of different sizes. They can be pre- filled with material several days prior to flying

Figure 64 – Loading frame designed to be loaded by either a tractor or digger

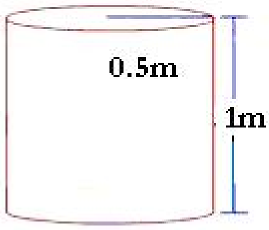
Figure 65 – Knowing the volume of material in each fadge and the distance this will cover on the track allows fadges to be placed in the correct location

17.3 CALCULATING MATERIAL VOLUMES FOR HOPPER

Basically a hopper consists of a cylinder shape and a cone shape. The cylinder shape is at the top of the hopper and the cone shape at the bottom. These hoppers are truncated but for our purposes we will use the formula for a cone and cylinder.

Figure 66 – Hoppers are available in a few different shapes and sizes. This hopper consists of a cylinder on the top and a truncated cone on the lower portion

To calculate the volume of this cylinder.



Use the following formula:

$V = \pi r^2 h$ which can be expressed as $V = \pi \times (r \times r) \times h$

V = Volume of cylinder π=3.14 r=radius of circle h= height of cylinder

Perform the calculations like this:

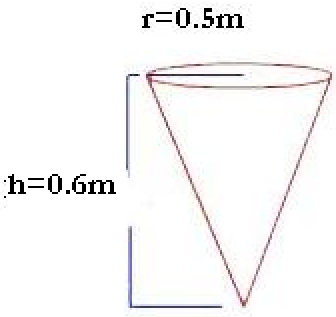
$V = \pi \times (r \times r) \times h$

V= 3.14 x (0.5m x 0.5m) x 1m

$V=0.78m^3$

The final formula we need to know is for the volume of a cone. The lower portion of the hopper is actually a truncated cone but for simplicity we will use the cone formula.

To find the volume of this cone:



Use the following formula:

V= 1/3 π r² h which can be expressed as V = 1/3 x π x (r x r) x h

V = Volume of cone   π = 3.14   r = radius of circle   h = height of cone

V = 1/3 x π x (r x r) x h

V = 1/3 x 3.14 x (0.5 m x 0.5 m) x 0.6 m

V = 0.16 m^3 (rounded! your calculator will say 0.156 but two decimal places is close enough!)

Volume of cylinder = 0.78 m^3

Volume of cone = 0.16 m^3

Total Volume = 0.78 m^3 + 0.16 m^3

= 0.94 m^3

18. Determining Track Distance Surface Cover

Now that you know the volumes, you can determine how far 20 mm aggregate should be spread on the track to achieve the finished compacted surface of 50 mm thick (uncompacted depth equals 65mm). Table 31 is an example of how this can assist with planning. The same volume and distance has been used to demonstrate the difference in the number of loads as the track width increases. Appendix 11 contains a spreadsheet with formulas that will determine the volume of material required based on the figures entered.

Track Width	Uncompacted Depth of Applied Material	Volume	Distance Covered	Total Distance	No. of Loads
0.3	0.065	0.94	48	680	14
0.4	0.065	0.94	36	680	19
0.5	0.065	0.94	29	680	24
0.6	0.065	0.94	24	680	28
0.7	0.065	0.94	21	680	33
0.8	0.065	0.94	18	680	38
0.9	0.065	0.94	18	680	38
1	0.065	0.94	14	680	47
1.1	0.065	0.94	13	680	52
1.2	0.065	0.94	12	680	56
1.3	0.065	0.94	11	680	61
1.5	0.065	0.94	10	680	71
1.6	0.065	0.94	9	680	75
1.7	0.065	0.94	9	680	80
1.8	0.065	0.94	8	680	85
1.9	0.065	0.94	8	680	89
2	0.065	0.94	7	680	94

Table 31 - Track material required for different track widths

Figure 67 – By this stage you know the volume of material to be moved and the number of loads.

Using two hoppers is significantly more efficient as the digger operator can load one hopper while the other is being transported by helicopter

Figure 68 – Loading with the correct size digger makes an efficient operation.

If fines have started to separate in the pile the digger can re- mix the material

Figure 69 -Use of a hopper is a very efficient method of spreading stone aggregate. By calculating the volume of the hopper you can determine how far one load should be spread to achieve a finished compacted surface 50mm thick

HOT TIPS

- **If stockpiling un-bagged material, lay material on top of a tarpaulin. This minimises impacts and maximises the use of material**
- **When transporting, storing or spreading metal aggregate be very careful NOT TO SEPARATE the fines. At all times you want to keep the mix well graded**

19. Additional Construction Techniques

During your office based planning (section 11.1), you may have discovered that additional techniques are required to achieve the height gain required within the available topography. There are a number of solutions available; steps, switchbacks, climbing turns and inslope turns.

19.1 STEPS

Refer to the SNZ HB 8630:2004 for step standards. Table 32 is a summarised version of the standards.

Track Classification	
Short Walk	• Minimum gradient 18°** • Maximum gradient 37° • Maximum vertical rise between landings is 2.5 m • Maximum tread riser height of 190 mm and a minimum tread going of 250 mm • Must have an even surface and not be muddy or rough
Walking Track	• Minimum gradient 18°** • Maximum gradient is 41° • Maximum vertical rise between landings is 4.0 m • Maximum tread riser height of 225 mm and a minimum tread going of 300 mm
Great Walk / Easy Tramping Track	• Minimum gradient 18°** • Steps may be used • Maximum vertical rise between landings is 4.0 m • Maximum tread riser height of 200 mm and a minimum tread going of 250 mm

Tramping Track	• Steps generally not used except where they will prevent erosion or significant visitor impacts • Maximum gradient 45° • Maximum vertical rise between landings 8.0 m • New steps shall have a maximum tread riser height of 250 mm and a minimum tread going of 250 mm
Route	• Steps shall not be used

Table 32 –Summarised Step Standards

** Not specified within SNZ HB 8630:2004. This is the minimum comfortable gradient for step construction

Steps are relatively expensive to construct but are fantastic for gaining a lot of elevation over a very short distance. However try to avoid using steps wherever possible, **consider all your options before deciding to construct steps.**

Users generally do not like steps whether they are walkers, trampers or mountain bikers. Any steps you decide to install will need to be well thought out and planned before any work is commenced.

- **Avoid constructing** long straight flights of steps
- Consider the landscape into which you are introducing straight lines. Stringer steps should be broken up with landings and bends
- By installing the appropriate number of steps at the appropriate time you are able to decrease the track gradient between flights of steps
- Go to the maximum rise where you install steps to achieve a good track gradient while balancing "how the steps fit visually within the landscape"
- View where steps will be located from above. This will give you a good idea where people may be enticed to take short cuts

Figure 70 - Steps introduce straight lines into the natural landscape, where there are few perfectly straight lines, and look out of place. When selecting the location of steps look at the site from above and below

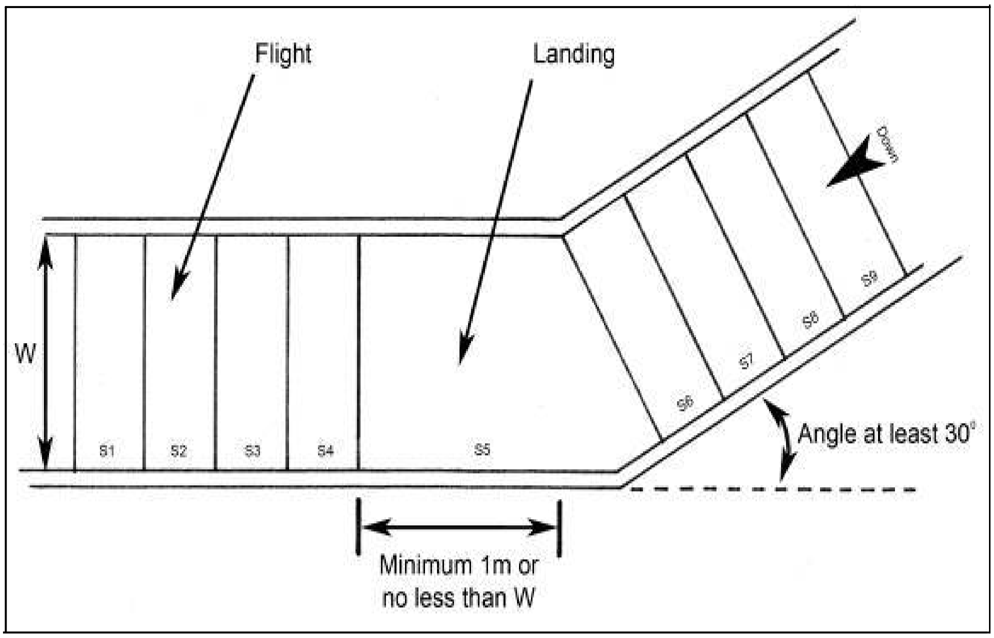


Figure 71 - Change the angle of steps to alleviate long visual lines

19.1.1 Step terminology

The terminology used to describe steps is:

- The tread rise, this is the vertical distance gained for the face of each step
- The tread going, this is the horizontal distance from the top front edge of one step to the bottom of the next step's face
- The landing, this is an area used to break a long flight and provide a short flat rest location
- Stringer is the inclined boards in which the tread risers are attached

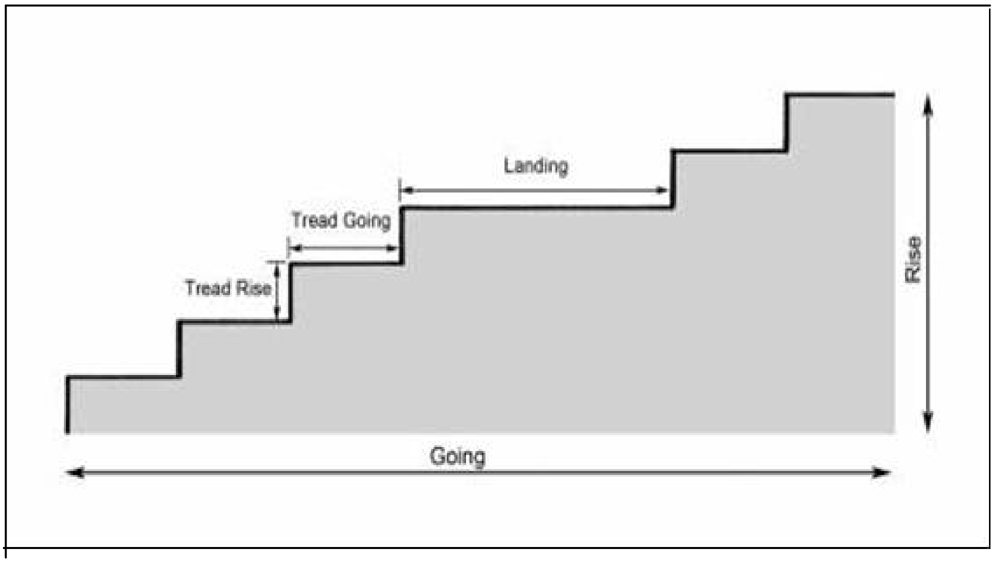


Figure 72 – Step terminology

STEP HISTORICAL TRIVIA

- Rules of thumb for determining satisfactory rise/tread ratios have existed since Classical times. In De Architectura, Vitruvius suggests a unit rise of between 23 cm and 25 cm, and a unit tread between 46 and 61 cm. To modern tastes, this proportion would create a very stately stair. Sir Henry Wooten (1568–1639) suggested that the unit rise not exceed 15 cm and that the unit tread be between 30 and 45cm. Both authors, however, are describing public buildings in urban areas
- Jacques-Francois Blondel (1705–1774) argued in his Cours d'Architecture that the rise/tread ratio should be based on the length of the human pace, which he took to be 65cm. Since in one step on a staircase a foot travels by two risers and a tread, Blondel arrived at the formula two times the unit rise, plus the unit tread = 65 cm, or unit rise = (65 cm – unit run) over 2. This formula works well only for moderate values for unit rise (or unit tread)
- In modern times, stair researchers have gone beyond observing which existing stairs cause the most accidents. They have been able to

> experiment with many combinations of unit rise and unit tread, and to capture in stroboscopic photography how missteps occur. The results largely confirm the rules of thumb, but some interesting results emerge, such as that the optimal rise/tread ratio for descent is not the same as the one for ascent. Several researchers feel that for descent the unit tread should be at least 28 cm.

There are essentially three step formations; stringer steps, in-ground boxed steps and natural rock steps. There is likely to be some variation on each of these throughout the country and a number of designs are available.

19.2 STRINGER STEP SURVEY

- Survey the slope, this will allow you to design the flights and landings
- Place a person, the Marker, at the top of the slope with a pole marked at the Observer's eye level
- Place the pole at the top of the slope
- Attach a tape to the bottom of the pole, the Observer walks to the bottom of the slope unreeling the tape
- Observer notes the slope angle with the inclinometer
- or Abney and records the slope length
- Complex slopes are measured by repeating the process at each change in the slope angle

19.3 DETERMINING TREAD RISER HEIGHT

Tables 33 and 34 provide information on tread riser and tread going for specific slope angles. Both tables work well but provide slightly different options.

INCLINATION ANGLE DEGREES A	TREAD RISER H	TREAD GOING L	INTERSTEP STRINGER LENGTH S	POSSIBLE STRINGER LENGTH										
				2 step	3 step	4 step	5 step	6 step	7 step	8 step	9 step	10 step	11 step	12 step
18-20	150	420	446	892	1338	1784	2230	2676	3122	3568	4014	4460	4906	5352
21-23	160	400	431	862	1292	1723	2154	2585	3016	3447	3877	4308	4739	5170
23-25	170	380	416	833	1249	1665	2081	2498	2914	3330	3747	4163	4579	4996
26-28	180	360	402	805	1207	1610	2012	2415	2817	3220	3622	4025	4427	4830
28-30	190	340	389	779	1168	1558	1947	2337	2726	3116	3505	3895	4284	4674
31-33	200	320	377	755	1132	1509	1887	2264	2642	3019	3396	3774	4151	4528
34-36	210	300	366	732	1099	1465	1831	2197	2563	2930	3296	3662	4028	4394
37-39	220	280	356	712	1068	1424	1780	2137	2493	2849	3205	3561	3917	4273
40-43	230	260	347	694	1041	1389	1736	2083	2430	2777	3124	3471	3818	4166
43-45	240	240	339	679	1018	1358	1697	2036	2376	2715	3055	3394	3734	4073

INCLINATION ANGLE DEGREES A	TREAD RISER H	TREAD GOING L	INTERSTEP STRINGER LENGTH S	POSSIBLE STRINGER LENGTH											
				13 step	14 step	15 step	16 step	17 step	18 step	19 step	20 step	21 step	22 step	23 step	24 step
18-20	150	420	446	5798	6244	6690	14271	22745	32111	42368	53518	62437	71357	80277	89196
21-23	160	400	431	5601	6031	6462	13786	21971	31019	40927	51698	60314	68930	77546	86163
23-25	170	380	416	5412	5828	6244	13321	21231	29973	39548	49955	58281	66607	74933	83259
26-28	180	360	402	5232	5635	6037	12880	20527	28979	38237	48299	56349	64399	72449	80498
28-30	190	340	389	5063	5453	5842	12464	19864	28043	37001	46738	54528	62318	70108	77897
31-33	200	320	377	4906	5283	5660	12075	19245	27170	35849	45283	52830	60377	67925	75472
34-36	210	300	366	4761	5127	5493	11718	18676	26366	34789	43944	51268	58591	65915	73239
37-39	220	280	356	4629	4985	5341	11395	18161	25638	33829	42731	49853	56974	64096	71218
40-43	230	260	347	4513	4860	5207	11108	17704	24993	32977	41656	48598	55541	62484	69426
43-45	240	240	339	4412	4752	5091	10861	17310	24438	32244	40729	47518	54306	61094	67882

Table 33 - Stringer steps options for a range of inclination angles

Stringer Step Options												
Step angle (degrees)	Slope %	Tread going (mm) for given tread rise				Slope length (m) for given rise between landings						
		250mm rise	200mm rise	190mm rise	150mm rise	1.0 m rise	1.5 m rise	2.0 m rise	2.5 m rise	3.0 m rise	3.5 m rise	4.0 m rise
18	32%	769	616	585	462	3.2	4.9	6.5	8.1	9.7	11.3	12.9
19	34%	726	581	552	436	3.1	4.6	6.1	7.7	9.2	10.8	12.3
20	36%	687	549	522	412	2.9	4.4	5.8	7.3	8.8	10.2	11.7
21	38%	651	521	495	391	2.8	4.2	5.6	7.0	8.4	9.8	11.2
22	40%	619	495	470	371	2.7	4.0	5.3	6.7	8.0	9.3	10.7
23	42%	589	471	448	353	2.6	3.8	5.1	6.4	7.7	9.0	10.2
24	45%	562	449	427	337	2.5	3.7	4.9	6.1	7.4	8.6	9.8
25	47%	536	429	407	322	2.5	3.5	4.7	5.9	7.1	8.3	9.5
26	49%	513	410	390	308	2.3	3.4	4.6	5.7	6.8	8.0	9.1
27	51%	491	393	373	294	2.2	3.3	4.4	5.5	6.6	7.7	8.8
28	53%	470	376	357	282	2.1	3.2	4.3	5.3	6.4	7.5	8.5
29	55%	451	361	343	271	2.1	3.1	4.1	5.2	6.2	7.2	8.3
30	58%	433	346	329	260	2.0	3.0	4.0	5.0	6.0	7.0	8.0
31	60%	416	333	316	250	1.9	2.9	3.9	4.9	5.8	6.8	7.8
32	62%	400	320	304	240	1.9	2.8	3.8	4.7	5.7	6.6	7.5
33	65%	385	308	293	231	1.8	2.8	3.7	4.6	5.5	6.4	7.3
34	67%	371	297	282	222	1.8	2.7	3.6	4.5	5.4	6.3	7.2
35	70%	357	286	271	214	1.7	2.6	3.5	4.4	5.2	6.1	7.0
36	73%	344	275	262	206	1.7	2.6	3.4	4.3	5.1	6.0	6.8
37	75%	332	265	252	199	1.7	2.5	3.3	4.2	5.0	5.8	6.6
38	78%	320	256	243	192	1.6	2.4	3.2	4.1	4.9	5.7	6.5
39	81%	309	247	235	185	1.6	2.4	3.2	4.0	4.8	5.6	6.4
40	84%	298	238	226	179	1.6	2.3	3.1	3.9	4.7	5.4	6.2
41	87%	288	230	219	173	1.5	2.3	3.0	3.8	4.6	5.3	6.1
42	90%	278	222	211	167	1.5	2.2	3.0	3.7	4.5	5.2	6.0
43	93%	268	214	204	161	1.5	2.2	2.9	3.7	4.4	5.1	5.9
44	97%	259	207	197	155	1.4	2.2	2.9	3.6	4.3	5.0	5.8
45	100%	250	200	190	150	1.4	2.1	2.8	3.5	4.2	4.9	5.7

Number of steps	250mm	4.0	6.0	8.0	10.0	12.0	14.0	16.0
	200mm	5.0	7.5	10.0	12.5	15.0	17.5	20.0
	190mm	5.3	7.9	10.5	13.2	15.8	18.4	21.1
	150mm	6.7	10.0	13.3	16.7	20.0	23.3	26.7

Table 34 – Stringer step options for specific slope angle

19.4 STRINGER STEP CONSTRUCTION

- Use the correct geometric design
- Construct steps the same width as the track
- Steps are either pre-cut in the workshop and assembled on site or prefabricated and transported to site assembled
- Prepare the location by knocking off and removing humps or other obstacles to establish the required gradient
- Sit the steps in place and install at the correct gradient
- Stand back and line up with the track
- Check the steps are level
- Secure with 50 mm x 50 mm x 750 mm pegs at a minimum of 600 mm centres
- Place geocells under the first riser to prevent soil erosion
- Backfill steps with suitable local material (will not heave with frost, turn boggy when wet etc) or if this is not available use a granular fill
- Compact in layers not exceeding 150 mm. If it is not possible to compact with a suitable compactor, compact manually with a rammer
- If the local material is not suitable and granular fill is not available cover local material with filter fabric and apply well graded aggregate mix
- If enough material is available backfill the entire external length of the stringer allowing for drainage and compact if possible
- In erosion prone soil install filter fabric and secure the fabric in place. Position locally sourced rocks (minimum size 50 mm) down the entire external length of the stringer
- Surface should be suitable local material or aggregate
- Shape finished surface to 1% outward crossfall
- Compact. If it is not possible to compact with a suitable compactor, compact manually with a rammer
- Make the track flat at the top and bottom of the step. This helps with water management and the displacement of material
- Construct either a drainage dip or grade reversal no less than one metre from the top of a flight of steps
- Re-visit steps two months after installation to check for any water management problems and refill treads if necessary

Figure 73 - During the track survey information on step construction is obtained. This allows prefabrication of stringer steps before being transported to the site

Figure 74 - Use a level with a digital display to get the steps at the correct gradient

Figure 75- Site is prepared and steps located in position ready for levelling, pegging and backfilling

Figure 76 - Backfill each tread going and the entire external length of the stringer. Compact tread goings

Figure 77 - The side drains have been lined with rocks to slow down the water in this very erosion prone volcanic ash.

Temporary water management has been put in place to protect the lower section of track (yet to be upgraded) while this section of track was under construction

Figure 78 – Geocells have been placed under the first riser to prevent track erosion. In extreme wet weather water will cascade over the riser lip and down onto the track surface

Figure 79 – Completed set of stringer box steps. These will require very little maintenance for a considerable period of time

19.5 BOXED STEPS

Boxed steps are constructed square boxes made from timber stacked one on top of the other.

19.6 BOXED STEP CONSTRUCTION

Boxed step construction is appropriate where you need to construct the step across slope and/or a visually softer appearance is preferred. Large risers to the maximum allowable in the standard look better when constructed as a box step. The gentle segmented curve fits the place better than stringer steps when a number of steps or flights are required.

- Use the correct geometric design
- Construct steps the same width as the track with a minimum depth of 750 mm
- Steps are either pre-cut in the workshop and assembled on site or prefabricated and transported to site assembled
- Start construction work from the bottom and progress up the slope
- Prepare the location by knocking off and removing humps or other obstacles to establish the required gradient
- Lay out a hose or stringline on the desire curve. This will act as a guide during construction
- Each box section should sit square and level when installed. Apart from the last step each box will sit partly on the previous step
- Place geocells under the first riser to prevent soil erosion

- In soft ground a 200 mm x 100 mm bearer plate may be installed. The plate should be wider than the constructed step width and be fixed to the first box step
- Excavate and install the first box section
- Install **two** internal 50 mm x 50 mm x 750 mm pegs and fix pegs to the internal corner of each box section. Pegs need to be installed 30 mm below tread riser height
- Sit the steps in place and install at the correct angle to achieve the desired segmented curve
- Stand back and view from a distance. This will help determine if the alignment is not quite correct
- From the top of the installed step excavate the bank ready for the next step. Material can be placed in the previously constructed step for fill. Place the next box section on top of the previous step and check it is square and level. Repeat the process until complete
- Backfill with suitable local material or if this is not available a granular fill
- If enough fill material is available backfill the entire external length of the step construction works allowing for drainage. In erosion prone soil install filter fabric and secure the fabric in place. Position locally sourced rocks down the entire external length of the construction
- Compact in layers not exceeding 150 mm. If it is not possible to compact with a suitable compactor, compact manually with a rammer
- Step surface should be suitable local material (will not heave with frost, turn boggy when wet etc) or aggregate
- Shape finished surface to 1% outward crossfall
- Construct either a drainage dip or grade reversal no less than one metre from the top of a flight of steps
- Make the track flat at the top and bottom of the step. This helps with water management and the displacement of material
- Re-visit steps two months after installation to check for any water management problems and refill treads if necessary

Figure 80 – Aesthetically boxed steps are a good option for large rises. As you are able to produce a segmented curve they are more visually acceptable within the landscape

19.7 ROCK STEPS

In a natural environment we should aim to keep things as natural as possible, even when this is not necessarily the easiest or cheapest option. Using natural rock steps as opposed to wooden steps has considerably less visual impact and when well constructed will last almost indefinitely with virtually no maintenance.

There are a number of guidelines that should be followed when using stone:

- stones need to be compatible with the environment the track passes through
- stones should be taken over a large area and not “mined” from one site
- Do not take stones that are providing shelter for alpine vegetation

19.8 ROCK STEP CONSTRUCTION

Work from the bottom of the slope upwards

- Build in a cross fall or crown to shed water
- Place weathered stone face to the surface
- Dig in a very stable anchor stone at the base of the flight of steps. Needs to be large as it is supporting the weight of additional stones
- Ensure there is stone to stone contact
- Overlap stones, stagger joins
- On steep grades embed the stone vertically with the longest end in the ground

- Use large stones on the outer edge, they are less likely to move
- Use wedge stones to lock into place
- Side drains may be required on some slopes
- Construct either a drainage dip or grade reversal no less than one metre from the top of a flight of steps
- Make the track flat at the top and bottom of the step. This helps with water management and the displacement of material

HOT TIPS

- **Be consistent, keep the tread rise and tread going the same in each flight of steps**
- **Where possible build above the ground. Occasionally some minor excavation may be required depending on the slope gradient**
- **Minimum slope when installing steps is 18º**
- **Allow for water drainage down the side of the steps**
- **Avoid long runs of stringer steps, they don't fit aesthetically**
- **Each individual step needs to be compacted. Compact loose fill in layers not exceeding 150 mm**
- **Stringer steps greater than three metres in length become difficult to handle**
- **Construct landings with a maximum slope (<2º or 3.0%) to stop water from sitting**
- **The junction at the bottom of the steps and the track should be flat. This helps to minimise user displacement of the track surface at the bottom of the step**
- **Use H5 treated timber**
- **Use suitable fill material. Allow for water drainage down the side of the stairs**
- **Construct a drainage dip or grade reversal at the top of each flight of steps; this prevents surface water from running down the steps**
- **Fill should be free from organic matter**
- **Fill step to the top of the tread riser and create a very slight outward slope to help water management**
- **Insert geocells underneath the first riser to prevent erosion at the base of the flight of steps**
- **If building stone steps construct the diagonals on an angle, this helps to counteract the structural, staircase effect. Stick to the correct tread rise and tread going design**

20. Switchbacks

A switchback reverses the direction of travel utilising a relatively level constructed landing.

20.1 SWITCHBACK CONSTRUCTION

- **Utilise the flattest location you can find for the switchback platform**
- Excavate adequately. The first step in building a switchback is to construct the turning area. The turning area on a dual purpose track should have a radius of no less than three metres. The turning area on a walking track can be significantly smaller. To facilitate water management build a small crown in the middle of the turn to help stop the creation of a fall line in the turn
- **Fill construction only works where the sideslope is less than the maximum fill batter slope for the soil (refer Table 13)**
- If it is not possible to construct with fill then a well constructed retaining wall using appropriate landscape anchors to stop people from shortcutting is required
- Remove all organic matter. This can be utilised in locations around the switchback to minimise the construction impact
- Smooth the grade out to 3°(5%) seven metres before and after the switchback
- **After the smooth grade entering and exiting the switchback make the next 20 metres of track on the upslope and downslope side of the switchback as steep as possible for the preferred users and the terrain in which you are working.** This increases the distance between the track coming into the switchback and the track going out of the switchback
- Push the corner out, don't be tempted to make the turn too soon
- The upper section of the track should have an inslope of 2º (3%) and should have a drain extending beyond the turning platform. Begin forming the inslope ten metres before the platform and ensure there is a grade dip prior to entering and just after exiting the switchback. This is critical for managing water impact of the switchback
- When completing the lower section of the switchback ensure the retaining wall tapers on an angle down to the track surface. Construction of a drainage dip or other technique for water management is required upon exiting the switchback

- Avoid stacking switchbacks one above the other. Stacking switchbacks can cause water management issues, water runs down the sideslope from one swichback to the next
- Create long legs between turn, this will help alleviate the temptation to take shortcuts
- Compact all fill material

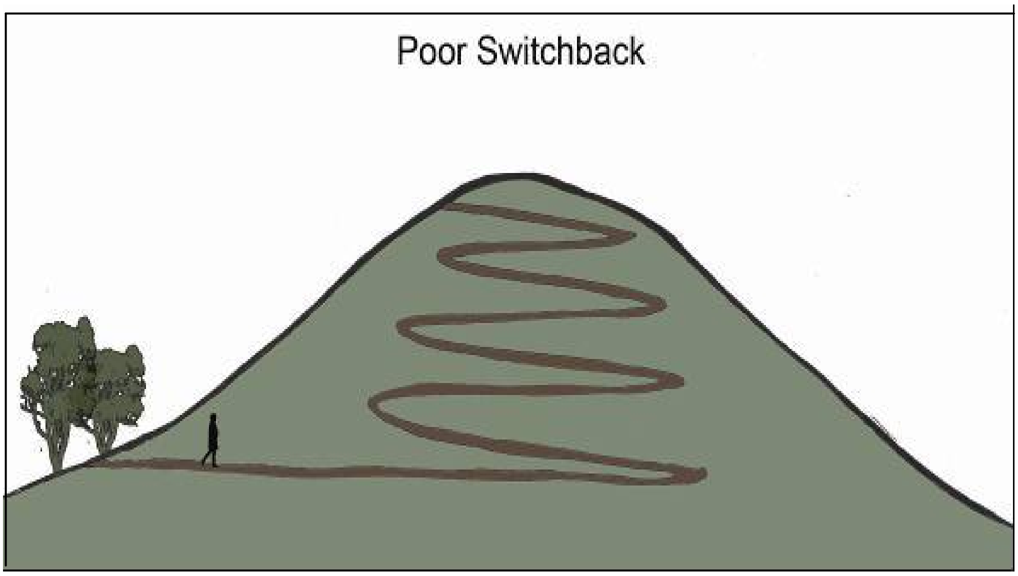


Figure 81 – Poor switchback locations leads to both user and water management issues

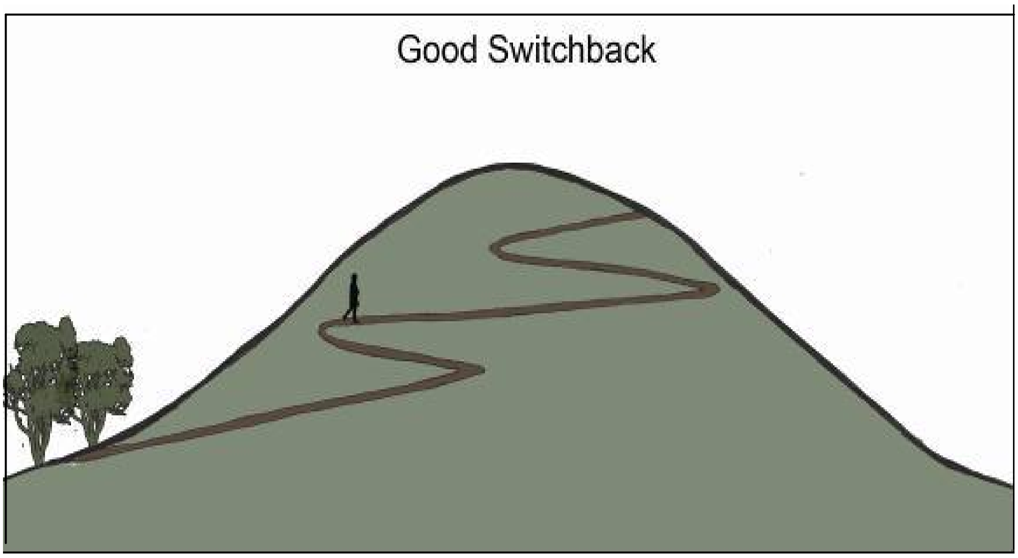


Figure 82 – Variable length between switchbacks provides for better water management, creates greater user interest and discourages shortcuts

Drawings are available in Appendix 12- 3-3, 3-4 and 3-5.

Figure 83 - By pushing the track toward the ridge in the background considerable earthwork excavation may have been avoided.

A framed view through the vegetation may also have been possible providing a better experience for users

Figure 84 – This photo was taken standing on the switchback. The section of track in the foreground when completed should be insloped to a side drain that extends and discharges well past the switchback

Figure 85 - Over clearing of vegetation has enhanced the risk of users cutting the corner on this switchback. It is now easier for them not to stay on the track

21. Climbing Turns

Climbing turns are built on the slope face and when it turns it climbs at the same rate as the slope.

- **Climbing turns do not have a platform. They have a wide radius.** For mountain bikes make the radius six metres or more where the track gradient is between 3° - 4° (6%)
- Ideally, climbing turns should be on a relatively shallow sideslope of approximately 3º (5%)
- All climbing turns have a short section on the fall line. Consequently building a climbing turn on natural surfaces in excess of 3º (5%) makes it prone to erosion. In this instance you should consider constructing a switchback or hardening the surface through the turn
- It is almost impossible to stop a climbing turn from eroding where the gradient exceeds 11º (20%)
- It is important to provide either a grade reversal or culvert just prior to entering the turn. Ideally this is just before entering the short section of fall line. If the climbing turn is located on a dual purpose track consider a gateway prior to entering the turn to slow bikes down.

Drawings are available in Appendix 12 - 3-1 and 3-2.

22. Inslope Turns

Switchbacks with a crown constructed on the platform are difficult for mountain bikers to negotiate. Inslope turns are another option where dual purpose use is provided (walking and mountain biking). The key to sustainable inslope turns is providing for the management of water and the ability to withstand the impact of users.

Correctly constructed inslope turns can reduce bikes skidding prior to entering the turn, reduce track widening and minimise soil displacement.

- Construct an inslope turn where you anticipate any potential side displacement of material
- Locate the turn around natural landscape anchors. This will help prevent people from shortcutting the corners
- Slow bikes down prior to entering an inslope curve as the forces working will fling the rider out of the corner
- Construction on a gentle sideslope is the best. Build inslope turns where the sideslope does not exceed 14º (25%)
- When approaching and exiting the turn the track should run at right angles to the sideslope
- Build the inslope section on the turn through the fall line. Correct placement of the inslope turn is critical, this means water is not trapped and is permitted to flow freely down the hill
- Create a gateway on the uphill section prior to the turn
- Create a grade dip on the uphill section prior to the turn
- Turns should have a radius of between three and five metres. Any turn tighter than this for bikes needs to be negotiated at slower speed so these tight turns do not require a built up bank. A radius any bigger than this results in increasing the length of the fall line (more potential problems), and bikes travelling at higher speeds results in greater lateral displacement of track surface material
- The steeper the sideslope, the higher and steeper you will want the bank to be. You will only need a very gentle inslope to make your turn work effectively. A slope as low as 3º (5%) from the outside to the inside of the turn will generally work well
- Cohesive soils should be used and you may need to consider importing some clay to add to your material

23. Retaining Walls

A retaining wall is a wall that is constructed to hold soil in place. **A retaining wall over 1.2 metres should be designed by an engineer and 1.5 metres or more in height will require a building consent.**

PITFALL

Make sure you check the effective fall height from the track. If the fall height exceeds 1.5 metres a barrier may be required

The purpose of a retaining wall is to withstand horizontal pressure from the soil / material it is holding. These pressures can range from zero at the top of the wall to a maximum at the bottom of the wall; there is also some vertical pressure acting near the top of the wall.

Although time consuming, where materials are available locally a stone retaining wall should be constructed. This "fits" the landscape and allows for the creation of visually nice curves. Rock walls are rustic in appearance and given the isolated location of many walls drywall construction is ideal.

23.1 SPECIFICATIONS FOR ROCK RETAINING WALL

BASE	JOINTS	OUTER FACE	HEADERS
1/3 to ½ wall height	staggered a minimum of 150 mm horizontally from the adjacent joint in the last row	Inward slope of at least 3:1	Minimum 25% of the wall and have a length of 2.5 times their thickness (at corners alternate headers should cross)

23.1.1 Stone retaining wall construction

- Establish a solid foundation on firm soil or rock
- Inslope the foundation to match the desired batter of the wall, excavating the shelf slightly wider than the average width of the rocks being used
- Work from the low end of the foundation and build towards the high end; use the largest rocks you have available
- Dig the foundation stones fully into the ground where possible. Foundation stones are usually the largest stones used in the construction of the retaining wall.

- At least 50% of the stones should weigh 60 kg
- Ideally the remainder of stones should weigh 20 kg
- Ideal stone is rectangular with flat surfaces on four sides. The worst rocks to use are rounded river rocks
- Each tier's facestone overlaps the gaps between the stones on the next tier down
- Each tier includes header stones
- Each successive tier should be set back slightly to achieve the desired batter
- Stones in each tier should have three points of contact with the stones below. There should be no "wobble"
- Place wedges only on the inside of the wall, not the outside face. This makes them less visible and when backfilled they won't fall out, unlike placing them on the front face of the wall
- Backfill and compact as you build
- Place a final layer of capstones of a suitable size so they will not be easily dislodged on the top

A drawing is available in Appendix 12, 5-1

HOT TIPS

- **Save some large rocks for the top capping stones**
- **You are more likely to break the rock where you want to when you place it on dirt to break as opposed to on another rock**

24. Timber Retaining Walls

There are a number of good internet sites that provide good technical information and specifications for the construction of timber retaining walls. Check out the following sites, www.pinepac.co.nz and www.unilog.co.nz

24.1 SPECIFICATIONS FOR TIMBER RETAINING WALL

Below is an example of just some of the information that is available on these sites. There is a whole raft of technical information available and the wooden retaining wall you build will depend on the soil type and slope.

Retaining on level ground with no traffic loading						
Height maximum	**Depth minimum**	**Post length**	**Small End Diameter H5 Post**	**H5 Posts**	**B (hole diameter)**	**Rails**
	metres	**metres**	**metres**	**Diameter (mm)**	**Diameter (mm)**	**metre s**
1.2	1.1	2.4	150	155	350	150 x 50 mm RS H5
1.4	1.3	2.7	175	180	350	

(http://www.unilog.co.nz)

Table 35 - Specifications for timber retaining wall with concrete encased timber posts at 1.2 m centres

Retaining on sloping ground at 20º maximum						
Height maximu m	**Depth minimu m**	**Post lengt h**	**Small End Diamete r H5 Post**	**H5 Posts**	**B (hole diameter)**	**Rails**
	metres	**metre s**	**metres**	**Diamete r (mm)**	**Diamete r (mm)**	**metres**
1.0	1.0	2.1	150	155	350	150x50m m H5RS
1.2	1.2	2.4	175	180	350	
1.4	1.4	2.7	200	200	400	

(http://www.unilog.co.nz)

Table 36 - Specifications for timber retaining wall, with concrete encased timber posts at 1.2m centres on sloping ground

24.1.1 Timber retaining wall construction

- Determine the soil type. A firm clay soil is required**. For sand, gravel, soft or organic soils or compacted fill refer to a consulting engineer for specific design**
- Determine the dimensions of the wall, so that quantities of materials can be calculated
- Excavate and cut earth face no steeper than 60° to horizontal
- To prevent slips fresh excavations should not be left exposed to wet weather
- Cut bank back a minimum of 400 mm to allow access for nailing. This will provide working space
- Ensure ground behind wall line slopes towards drainage. Follow natural fall
- Dig the specified diameter holes at the specified centres, without disturbing surrounding soil
- Use of an Auger or powered posthole borer is recommended
- Prior to setting posts, remove or compact loose soil in holes
- Set posts by adding or removing base metal. Set end posts in holes with specified lean-back. A post slope of 1 in 10 will improve the appearance and strength of the wall
- Place concrete around posts at each end of the wall first. Erect a string line

HOT TIP

Brace posts: Using hex-head TEK screws is easier on the construction than hammering in nails. If using nails, leave the heads proud and partly bent over for easy removal

- Check you have exactly the same lean on both posts. Use level and hold plumb, measure back to post 100 mm
- Set two string lines between two end posts, first at 100 mm from top of post, second 100 mm from ground level. Pack string lines off the posts to give an offset line
- Use string line to assist in lining up intermediate posts
- Place concrete around all intermediate posts, ensuring maximum spacings are not exceeded. Concrete in posts, using one part cement to six parts building mix or use pre-bagged concrete mix. Concrete should be placed around posts and well compacted by tamping. Use temporary bracing to protect posts against disturbance for at least two days after placement of concrete
- Use ground treated H5 rails as specified in Tables 35 and 36
- Fix with 150 mm galvanised nails to back of posts

- Fix horizontal retaining wall timber to poles with galvanised nails. Joints in the timber will need to be made at the centre of the post or poles. Stagger the joints at different posts
- Ensure that preservative is applied to the end of every length of retaining wall timber that has been cut on site. The cut ends of posts will require preservative as well
- Use 50 mm bed of drainage metal, slope it in the direction of the water flow outlet and leave the ends protruding a little to enable cleaning
- Install 100 mm perforated drain pipe with a filtersok installed over it at the base of the retaining wall below adjacent ground level, and surround with AP20 scoria or other free draining material
- Lay drain/coil, behind wall, so it slightly falls in direction of water flow outlet
- Cover coil with 250 mm of drainage metal

Now you can either

- Position sheets of hardboard, cardboard or plasterboard 250 mm behind the wall
- Ensure sheets are positioned at same level
- Fill between the sheets and wall with drainage metal to within 300 mm of ground level at top of wall, at the same time filling behind the sheets with soil or clay

Or you can

- Cut the POLYFLOW® polystyrene sheets to shape with a handsaw or other cutting device. Position the POLYFLOW® sheets directly against the retaining wall with the POLYFLOW® sheet edge sitting on the drain. Cover the entire wall with up to 150 mm from the top of the wall
- EPS contact adhesive may be used to temporarily hold POLYFLOW® in place before backfilling
- Backfill initially with a 200 mm layer of scoria or gravel, followed by free draining material. If excavated material from the site is to be used, ensure that it has the necessary free-draining characteristics
- Top with free draining gravel and cover with weedmat. Place topsoil on surface

HOT TIPS

- **Check with local Council for retaining wall requirements**
- **Generally a retaining wall less than 1.5 m high does not require consent**
- **If wall is 1.2 m or higher consult an engineer**
- **Soft ground may require advice from an engineer**

- **Ground must be firm and compact (virgin ground) e.g. not filled ground or loose**
- **Determine where you are going to drain seepage water to**
- **Decide how many posts and rails are required, and the amount of backfill required**
- **It is essential that the backfill allows water to soak through to drain**
- **Cut ends and notches must be kept clear of ground, cut faces must be coated with a suitable preservative**
- **Only embed uncut end in the ground**
- **All bolts and nails must be hot dipped galvanised**
- **Recess bolts and punch nails below surface; use preservative in recesses**

Section Three: MAINTENANCE

25. Track Maintenance

Maintenance is defined as the tasks required to maintain the sustainability of the walking track, due to its deterioration caused by climate and use from its original condition.

Effective maintenance relies on sound technical knowledge and good management practices

25.1 SUSTAINABLE MAINTENANCE

A change of thinking is taking place when we talk about track maintenance. There is a change taking place from simply repairing tracks at regular intervals to making tracks more sustainable. The notion that a bit more effort today will save considerable time and money in the future has significant merit. An example of this is a high maintenance wooden waterbar may be replaced with a well constructed grade dip or culvert.

The most challenging and most significant aspect of track work is ongoing maintenance. However, many of our current tracks are not sustainable in the long term. Many started as minor tracks walked by a few individuals and often the most direct route was chosen. There was little or no consideration given to design or sustainability. Today these tracks are popular destinations for thousands of individuals and maintenance of these walking tracks is a significant challenge.

It is therefore important to recognise that the amount and severity of our maintenance problems may be an outcome of the components that make up a track.

Figure 86 below shows the factors contributing to maintenance. As the individual key actions listed improve, the amount of maintenance will reduce. To demonstrate the importance of this approach, take the example of a culvert that has been incorrectly installed and constantly gets blocked. Traditionally, we would have simply cleared the culvert and this would have worked for a short period of time before the culvert became blocked once again. A significantly better approach would be to find out why the culvert continually gets blocked (usually insufficient fall and angle) and to correct the cause of the problem, rather than spending time constantly unblocking the culvert. This approach may cost more to fix, but in the longer term is the best solution.

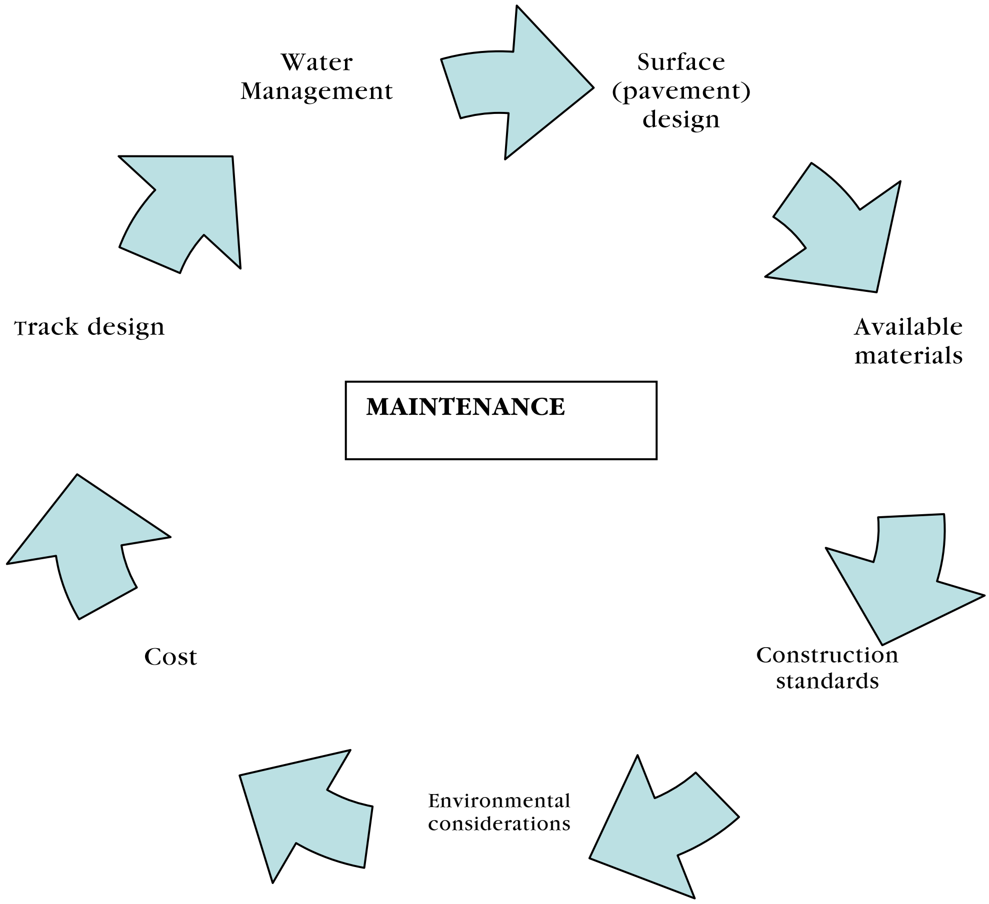


Figure 86 – Factors contributing to maintenance

Each of the factors identified in Figure 86 if well addressed will slow down the rate of track deterioration. In particular, walking tracks are most susceptible to deterioration as a result of losing the track shape and damage from water.

KEY POINTS FOR EFFECTIVE MAINTENANCE OF WALKING TRACKS
• Walking tracks **DO NOT** remain the same
• Deterioration of walking tracks should be expected
• Causes of deterioration include amount of use, weather conditions, standards and quality of construction, availability of suitable materials and the absence of adequate maintenance
• Good maintenance practices are there to protect the investment and meet the standards
• Restoration of the correct crossfall during periods of maintenance and resurfacing is critical
• Correct diagnosis of the problem is essential for effective treatment. The wrong diagnosis is costly in both labour and materials
• Where installed, maintain a good drainage system that protects the pavement

26. Track Marking

SNZ HB-8630: 2004 contains specifications for track marking:

Track Category	Specification
Short Walk	Markers not usually required
Walking track	Clearly marked where necessary so inexperienced users can find their way in either direction in all weather conditions
Great Walk / Easy Tramping Track	Marking to be poles or markers
Tramping track	Markers, poles or cairns must be clearly seen from one to the next, in either direction, in all but the worst weather conditions
Route	Must be clearly visible from one to the next, in either direction, in all weather conditions except moderate to heavy mist

Table 37 – Specifications for track marking

Tracks can be marked in a number of different ways depending upon the environment in which it is located. Table 38 specifies options for different environments.

Environment	Type of marker	Size	Colour
Forest	Orange triangle markers	Refer SNZ HB-8630	Refer SNZ HB-8630
Alpine	Pole	19 mm x 19 mm x 3 mm boxed aluminium	Orica (brand) Sky 58613
	Post	Deer post	Blue/Yellow
	Warratah with cap	300 mm cap	Orange sleeve
Open grass valleys	Large orange triangle	Refer SNZ HB-8630	Refer SNZ HB-8630
	Pole	19 mmx19 mmx3 mm boxed aluminium	Orica(brand) Sky 58613
Farmland	Alkathene water pipe with cap	300 mm cap	Orange sleeve

Table 38 – Track marker options for different environments

Figure 87 - A case of over-marking. Even in view of the road three orange markers are visible and one old marker is clearly visible

A figure 88 - Placing a marker on narrow trees makes both markers visible. This approach is not recommended as it effectively doubles the number of markers required

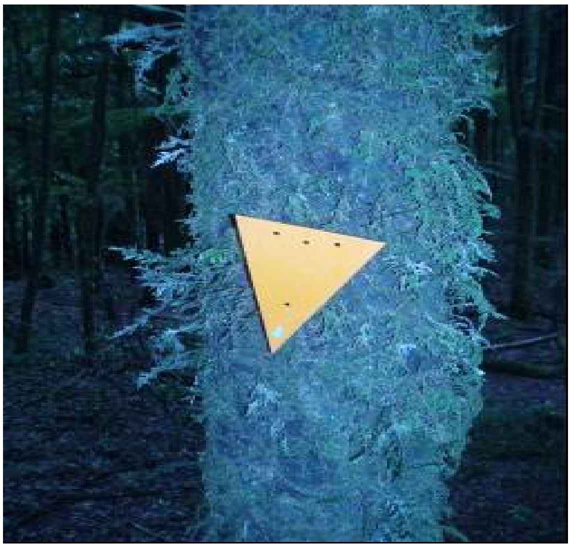


Figure 89 - Two nails should be used when securing markers onto trees. It is easy for people or animals to move the direction in which they are pointing if not secured properly

26.1 ORANGE TRIANGLE MARKERS

Marker specifications	Nails	Maximum clearance between tree trunk and marker	Minimum clearance between the tree trunk and marker	Height above track surface
Refer SNZ HB-8630 for specification on track markers	Galvanised 75 mm x 3.15 mm galvanised flat head.	50 mm	15 mm	1500-1800 mm or to the comfortable sight level on steep ground

Table 39 – Specifications for application of orange track marker

- Remove all non-standard track markers and nails from tree carefully and remove them from the site
- Replace with orange plastic triangle markers as per specifications
- Use at least two nails in each marker
- Markers must be affixed so that at any point on the track the next marker is clearly visible and is within the comfortable sight line
- Markers should be fixed with the apex pointing in the direction of travel

HOT TIP

- **Don't drive nails flush with the tree, allow for tree growth. Markers will pop off in a few years and need replacing if fixed flush with tree**

Track markers have a textured side and a smooth side. You need to decide which surface should be visible to the user. In certain light situations, particularly when the sun hits the marker, markers with the smooth side placed out are very difficult to see.

HOT TIPS

- **Existing markers with less than 5 mm clearance between the marker and tree trunk can have the nails pulled out to 30mm without undue damage to the tree, marker or nail**
- **Pay particular attention to track junctions and points of entry into the bush from tops, rivers and slips etc**
- **Large orange markers are to be used where points of entry to**

bush are confusing or could prove so in extreme weather conditions

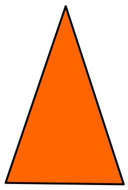
- **Don't attach markers to Department of Conservation signs, bridges or other structures. It looks unprofessional and is unnecessary**

26.1.1 Track marker orientation

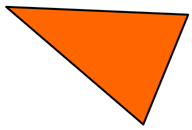
Fix with the apex, pointed tip upright. Markers shall be used with the apex pointing in the correct direction whenever there is a significant change in track direction that may cause people to walk off the track.

As a general rule place markers as follows:

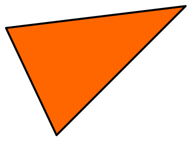
If the track is straight, uphill or downhill place markers like so



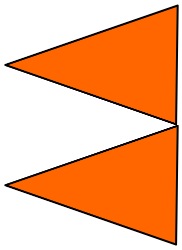
If the track has a slight change in direction to the left place the markers like so:



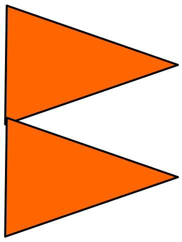
If the track has a slight change in direction to the right place the markers like so:



If the track takes a major turn to the left place two markers like so. The addition of an extra marker will act as an alert for visitors.



If the track takes a major turn to the right place two markers like so:



26.2 ALPINE POLES

Marker specifications	Length (metres)	Maximum clearance between ground and top of marker (metres)	Minimum clearance between ground and top of marker (metres)
Refer Table 38	2.4	1.8	1.6

Table 40- Specification for application of alpine poles

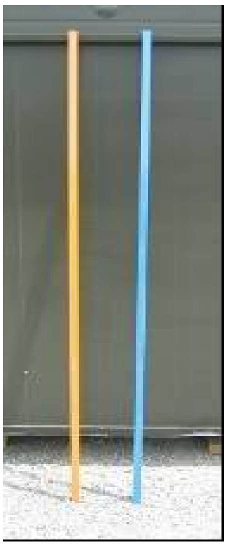


Figure 90 - Powdercoated boxed aluminium. Blue is used for alpine environments and orange for large open valleys

Figure 91 - Modified warratah rammer.

In the majority of locations poles are easily driven in with a maul

HOT TIP

- **Where there are a number of leading ridges and no clearly defined prominent track heading to the bushline, erect two large markers, one on the bushline and a second 100 metres up from the bushline. This ensures people get on the correct ridge**

Figure 92 – In wide landscapes placement of large poles on the bushline can help trampers identify the correct ridge to descend

In addition to the specifications outlined in SNZ HB-8630: 2004 locate markers in locations where navigation is difficult, there is a change in direction or there are a number of leading ridges. Prominent tracks on ridgelines may not require markers and we don't want the place visually polluted with markers.

26.3 OPEN GRASS VALLEYS

Marker specifications	**Length (metres)**	**Maximum clearance between ground and top of marker (metres)**	**Minimum clearance between ground and top of marker (metres)**
Refer Table 38	2.4	1.8	1.6

Table 41 – Marker specifications for open grass valleys

Figure 93 - Warratah with orange sleeve attached

26.4 FARMLAND

Marker specifications	Length (metres)	Maximum clearance between ground and top of marker (metres)	Minimum clearance between ground and top of marker (metres)
Refer Table 38	1.8	1.2	0.9

Table 42 – Specifications for marker poles on farmland

Figure 94 – Poles through farmland can be particularly troublesome where cattle are present. A good alternative is alkathene pipe with an orange cap attached. These bend when cattle us them as a rubbing post

27. Vegetation Maintenance

Vegetation maintenance can be broken down into a number of groups, each requiring different skills and tasks including vegetation clearance, windfall removal, vista maintenance and the felling and removal of hazardous trees.

27.1 MINOR VEGETATION CLEARANCE

Cutting back the biomass is a never ending battle. However, we should not fall into the trap of over cutting vegetation as this can have an immediate impact for the visitor; they want to interact with the environment, not be removed from it. Over-cutting can have a profound effect on this interaction and should be avoided. There are a few guiding principles that should be followed:

GUIDING PRINCIPLES	
1	Consider the kind of experience the track is offering and cut accordingly
2	Observe and understand the nature of the vegetation on the track
3	Don’t prune if you don’t have to
4	If you have to prune make sure it is not obvious
5	Sometimes it may be better to remove the tree

Refer to the NZSHB 8630:2004 for standards on vegetation clearance. Below is a summary of the vegetation clearance maximum limits.

	MAXIMUM WIDTH	**HEIGHT**
Short Walk	Maximum of one metre either side of the track centre line	2.5 metres
Walking Track	Maximum of one metre either side of the track centre line	2.5 metres
Great Walk/ Easy Tramping Track	Maximum of 0.5 metres either side of the track centre line. Ensure clear passage and clear view of markers	

Tramping Track	Ensure clear passage and clear view of markers	
Route	Adequate vision of markers or route	

Table 43 – Track vegetation clearance maximum limits

Figure 95 – This track is cut over the maximum allowable limit contained within SNZ HB 8630: 2004 and outlined in Table 43

HOT TIP

The intent of the track clearance standards is to reduce the width of cut vegetation progressing from short walk to route. While the tramping track standard does not specify a maximum width, common sense dictates it should be no greater than a Great Walk / Easy Tramping Track

27.1.1 Minor vegetation cutting

- Use a nylon flail cord on the scrub cutter for clearing grass and vegetation up to approximately 8-10 mm (thickness of a pencil)
- All cut vegetation should be removed from the track surface and side drains
- Cut vegetation can be removed from the track surface on easily accessible tracks, short walks and walking tracks, with a motorised blower. Tracks that are difficult to access can have the vegetation removed from the track surface using a rake
- Difficult vegetation to cut with the scrubcutter such as flax should be cut with a knife, or some other sharp bladed tool, as close to the ground as possible
- Scenic vista maintenance can be achieved by hand pulling seedlings

Figure 96 – Motorised scrub cutters are an effective method for vegetation maintenance

27.1.2 Pruning

Trees and shrubs should be cut as close to the ground as possible using pruners, pruning saw or some other similar cutting tool.

Figure 97 - For the same effort this "hanger" could have been cut at ground level giving a considerably neater appearance to the finished track

Use the three cut method (B in Figure 98) to remove large limbs from trees. This minimises the risk of damage to the tree and reduces the likelihood of disease.

A – Undesirable technique

B – Best Practice

1	Undercut the branch approximately 20-30 cm from the trunk
2	Second cut should be 30-40 cm back from the trunk of the tree on the upper surface of the limb
3	Final cut is as close as possible to the trunk

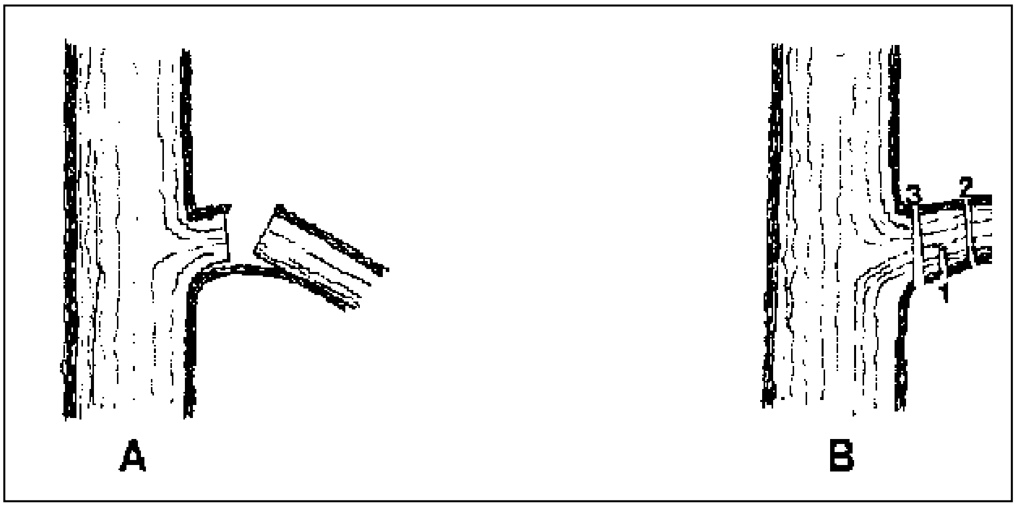


Figure 98 – Incorrect and correct tree branch pruning technique

27.1.3 Windfalls

Large trees or limbs that fall across the track should be:

- Cut back 300 mm from each side of the track edge and be cut parallel to the track
- Large trees with trunks should have the cut made at a sloping angle; this helps to reduce the visual impact of clearing fallen trees
- When large trees require pruning on scenic vista points a professional arborist should be employed to undertake this specialist work
- Large limbs should be removed so they are out of sight from the track. The cut end should face away from track so it is not visible by users

HOT TIP

- **If possible, time vegetation cutting to allow for optimal flowering of plants e.g. alpine plants should be cut at the end of the season**
- **Slower growing vegetation does not need to be cut to the maximum width allowable in the track standards**

27.1.4 Minor vegetation spraying

Chemical sprays should only be used when absolutely necessary. Some examples of when the use of chemicals is appropriate include:

- When grass and plants start to emerge through the track surface
- Where plants such as stinging nettle, hook grass and toe toe are prolific on short walks or walking tracks

- Where the control of introduced exotic plants such as gorse and broom is required

!! RED ALERT

- **Resource consent may be required when removing vegetation and undertaking earthworks**

Vegetation spraying should only be used where manual methods of control are impractical.

- Where vegetation is emerging through the track surface spray only the gravel surface in accordance with the track standard. The exception to this is where a non grass killing herbicide is used to kill weeds on or adjacent to the track
- Tall vegetation should first be cut and removed from sight. This avoids large amounts of dying and dead vegetation along the track. Leave enough foliage to kill the vegetation when sprayed
- Spray the **minimum** area for good control

27.2 VISTA MAINTENANCE

In the planning for track construction (section 11.0) we cover the very important "ideals" when planning tracks. One of these was taking people to scenic vistas. There are many viewing platforms and scenic lookouts constructed throughout the country. An **important** and often overlooked aspect of this is the long term management of the scenic view. There are a number of important aspects to consider;

- All plant species must be in character with the site
- Plants must be capable of growing in an often exposed location
- Rather than maintaining a clear view consider **framing the view**
- Plant species that grow to their maximum height and will not obstruct the view
- Remove a percentage of self-germinating seedlings annually that will eventually obstruct the view
- For particularly difficult terrain and/or vegetation get in a professional arborist

28. Drainage System Maintenance

Maintenance of the drainage system is the single most important maintenance function to protect the investment made in the track asset.

28.1 CATCH PITS AND SIDE DRAINS

Catch pits and side drains require regular maintenance. Keeping them free of sediment reduces the likelihood of culverts getting blocked. How they are maintained and how often will be determined by a number of local factors including forest type, rainfall and track gradient.

- The ideal time to undertake maintenance is during wet weather
- Remove debris; it is likely to contain vegetative material, in which case it should be disposed of
- Check for scouring and protect if evident
- Where scouring of the side drains is evident line with filter fabric and install local rocks (50 - 100 mm). You will need to make the side drains larger to accommodate the extra volume taken up by the rocks
- Reform shape and re-establish to the specified width and depth
- Repair catch pit walls where there is evidence of material collapse. Protect the walls by lining with rock
- Re-establish the culvert invert. The bottom of the catch pit should be a minimum of 100 mm below the bottom of the culvert
- Remove vegetation that may have established on the shoulder between track surface and side drain
- **Start from the culvert catch pit and work up towards the next culvert. This gives you the correct starting level**
- A motorised blower is an effective tool for removing leaves and light twigs from side drains. Material is simply blown out of the drain and off to the downslope side of the track. However, this does not remove fine soil particles that may have built up in some locations in the side drain. This material needs to be removed to allow the free flow of water and not act like a dam to facilitate the build up of additional material

HOT TIPS

- **Maintain side drains when it is raining**
- **Discard material removed from the catch pit as it contains organic debris**
- **Get the drainage levels right with no small rises that will act as a**

dam. Use a long profile and check cleared depths for consistency

!PITFALL

- **Making the side drains deeper each time the drains are maintained. Maintain to the correct depth**

In extreme situations, such as Fiordland, with large and deep side drains a small mechanised digger is the most appropriate method for maintenance purposes. However, the majority of side drains can be cleared manually with shovels and rakes.

Figure 99 – In extreme rain events this side drain has been almost full

HOT TIP

- **Clear catch pits after significant rain events of 100 mm or more**

28.2 CULVERTS

- **Add additional culverts where evidence indicates they are required**
- Repair or replace culverts that are in poor repair
- Clean out all debris at the culvert entrance and exit
- Dispose of vegetation out of sight
- Extend or widen culvert discharge if there is evidence of inadequate discharge. Landscape the area to create a low area for the water to flow
- Check culvert has 150 mm of cover over the pipe. Add additional material when 100 mm minimum cover remains
- Check culverts are not visible when walking the track. Check from both directions

- Check the culvert before proceeding to the next that there are no blockages at the inlet and outlet

28.3 FORD CROSSINGS

Well constructed ford crossings should require little maintenance if constructed soundly and properly.

- Check for loose stones and re-pack
- Check all wedge stones and re-pack
- Check the stream level has not exceeded the level of the constructed ford. If it has, extend the construction of the ford
- Maintain the track leading onto the ford

29. Geotextiles

If filter fabric becomes exposed make sure it gets covered. It is not UV stabilised and exposed matting looks awful.

30. Stone Pitching

Stone pitching should require minimal maintenance due to the hardened nature of the materials. The main maintenance tasks are:

- Check the stonework for any loose stones
- Re-set and repack any loose stones
- Check anchor stone is flush with track surface. If not place additional material in place until anchor stone and track surface are flush

31. Track Surface

Your track surface may develop a number of surface conditions and unless completely hardened, is going to wear and will need some maintenance. If well constructed the surface should not require as much maintenance as your drainage system. You will need to:

- Replace material where it has been displaced, eroded or compacted, getting the track back to its original shape
- Pull back material that has worked its way to the outer edge of your track and reshape the walking surface
- Look for locations on the downslope side of the track where water is having trouble getting away and modifying drainage system
- Scarify the existing metal surface before adding new material (use the teeth on a digger rock bucket, rotary hoe etc), this will allow the product to lock together when compacted. If you just place the material on top of the existing metal surface and compact the material will not lock together very well and you can expect the new material to disappear more rapidly

Table 44 offers a number of possible solutions for numerous track surface conditions.

Surface Condition Observations	**Likely Reasons**	**Possible Improvement Option**
Loose aggregate surface; Full depth of aggregate layer can be scuffed through by rubbing boot on surface Surface is easily scoured by water running over surface	Poor grading of aggregate; or Lack of fines in the aggregate; or Aggregate stones are rounded	Add a uniform sprinkling of sand/silt/clay fines to the surface (one shovel per square metre) and then provide vibrating plate compaction after rain has washed the fines into the aggregate
Loose stones on the surface over compact pavement layer which cause a slipping hazard	Poor placement and compaction of original pavement layer, or Poor grading of aggregate layer; or Surface has been scuffed by high use	Sweep loose stones from surface to expose compacted surface; or Add 25 mm layer of well graded surface aggregate (GAP10), rake into loose material and then compact with vibrating plate

		compactor
Rutted uneven surface; Cycle wheel ruts	Poorly bound pavement aggregate; or	Add fines and compact aggregate pavement with vibrating plate compactor
	Soft Sub-grade	Deepen side drains; and/or Add additional pavement depth and compact.
Surface is soft to walk on; Water can be brought to the surface by pumping your feet at the same spot Clay is appearing through the aggregate	Wet/soft sub-grade; or Inadequate pavement depth; or Pavement surface thickness has been lost through wear	Deepen side drains; and/or Provide geotextile separation layer on existing surface and add additional pavement depth and compact
Rough surface with large stones protruding from the surface; Tripping hazards on the track surface; Very bumpy surface for wheelchair use	Pavement aggregate has stone that is too large for the layer depth; Poor pavement aggregate placement and compaction Loss of fines from aggregate due to wear	Provide a new surfacing layer, typically 50 mm layer of GAP20 aggregate.
Sub-grade soil showing though aggregate surface and surface is soft in wet conditions	Original pavement layer too thin; or Pavement layer has worn out from pedestrian use, or wind/water/frost erosion	Provide a new surfacing layer, typically 50 mm layer of GAP20 aggregate

Table 44 - Track surfacing evaluation and improvement options

Figure 100 - This poorly graded material has been transported to the side of the track through displacement and erosion.

The aggregate was applied one year prior to this photo being taken

HOT TIPS

- **Where a large proportion of fines have disappeared and the surface is looking "boney" apply a mix of sand and clay and compact the surface to form the desired seal**
- **If the track is a crown shape it is important, when finishing compacting, that a final pass down the centre of the track is not made as this will remove the crown and accelerate deterioration**
- **Maintaining super-elevation on curves for mountain bikes is as important as maintaining the crown**

31.1 SURFACE SCOURING AND TRENCHING

Scour is the loss of surface material caused by the flow of water along and/or over the track surface eventually forming a trench. This can be a serious problem on steep tracks and tracks of a constant gradient that have not had the necessary maintenance input. Scouring can be minimised by:

- Increasing the strength of the pavement
- Decreasing the shear force caused by the flow of water. This can be minimised through good design

Walking surfaces with a high content of fines and small aggregates are more inclined to scour than those with well graded material.

PITFALLS !

Scouring is caused by:

- **Erosion prone soil**
- **Steep track gradients**

- **Lack of compaction; the surface has little strength and therefore material is picked up and moved by visitors and water**
- **Excessive long consistent gradients**
- **Debris or berm on track shoulder preventing surface water from flowing off to the side**

Scouring of the surface leads to further deterioration of the track through exposure to the environment. Scouring can become very pronounced when combined with material that is susceptible to movement.

Begin maintenance of a track that has scoured by dealing with the cause of the erosion by slowing down or diverting water from the track.

- Look for locations where you are able to install an effective grade dip (rolling dip, drainage dip, grade break)
- When the track is too steep and goes straight down the fall line, install steps (gradient must be over 18º)
- Sometimes re-routing a section of track is the best long term solution

HOT TIP

The most cost effective precaution against scouring is to pay attention to drainage, material grading and track shape

Figure 101 - Several factors are contributing to the scouring evident on this track. A seepage spring has surfaced in the middle of the track, the track is poorly shaped and erodible track surface material has been used

32. Slough and Berm

On tracks that traverse hillsides, slough is the term used for rock, soil and organic debris that accumulates in the side drain or on the inside of the track if there is no side drain. Berm is material that has accumulated on the outside or downslope side of the track forming a dam that prevents water from shedding off the track.

- Removal of slough and berm is one of the most unglamorous but critical tasks for maintenance and must be repeated again and again
- Slough forces people to the outside of the track (potentially the weakest part of the track)
- The amount of slough will depend on the soil type, weather and the batter slope. For tracks with side drains slough can be a real problem blocking the flow of water down the drain and forcing it across the track

As discussed previously, over time the track will change shape, material will get displaced and the track surface will compact further. This forms a berm on the outside edge of the track.

- Berm formation is one of the biggest factors contributing to scouring and trenching of the walking surface
- Once the berm is formed water is unable to get off the track, it increases in volume and runs down the track gathering soil as it goes causing surface scouring and trenching
- Loosen compacted slough and berm with a grubber or McLeod tool
- Remove slough and berm and reshape the track back to its original formation so water will run off
- If you have a surplus of material, consider storing this for the future. It will be required at some point in time to re-establish your track shape

Not all slough is going to be suitable to use a track surface material, some of it will contain organic material and should be scattered some distance from the edge of the track.

33. Steps

Well constructed steps (stringer, boxed and rock) should be almost maintenance free.

- Check drainage down the side of the steps
- If there is evidence of scouring, increase width of drainage channel, line with filter fabric and fill with rocks (minimum 50 mm)
- Refill steps if material is sitting below the top of the tread riser

Figure 102 - These boxed steps have been nicely constructed. All fixings have been "hidden" and they have a segmented curved appearance.

Ongoing maintenance will be minimal due to the confined nature of construction. Material is effectively contained within each constructed step.

There are examples of this type of construction made 25 years ago that are still in very good condition

Figure 103 - In stark contrast to boxed steps the board and peg method is not effective in the long term.

Over 400 mm of soil has been eroded from beneath this step as water has cascaded over the riser.

Effectively this track is a drain

Figure 104 - Natural steps also have a place on tramping tracks. With the placement of some additional stones a series of steps could be constructed suitable for the user

Figure 105 - It is difficult to determine whether these were built primarily as steps or as dams to try and ease the erosion taking place.

Clearly they are not effective steps, users are skirting around the edge as this is perceived as an easier option. Over time this will erode and there will be a second erosion ditch alongside the first

34. Switchbacks

Switchbacks require a high degree of maintenance, even more than a standard section of track. Maintaining the shape of a switchback is absolutely critical to its effectiveness and durability.

- Remove slough and berm to restore original construction size
- Regrade the outslope of the lower track section and the inslope on the upper track section
- Remove all debris to ensure effective drainage
- Check retaining wall

Appendices

APPENDIX 1 - GLOSSARY

Aggregate

Graded stone used to form the sub-base, base and surface of a track. Imported materials available in a variety of grades.

Archaeological site

A place containing relics and ruins of our past. Be aware that if an archaeological site is dated pre-1900, it will require an authorisation from the Historic Places Trust before it can be modified, damaged or destroyed. It is best to avoid archaeological sites where possible.

Backfill

Mixed spoil - stone, minerals and soil, used to infill gap or space behind, or between stone work after pinning; also use to infill a borrow pit prior to turfing over.

Batter

An artificial, uniform, steep slope or its inclination, expressed as one horizontal to so many vertical units

Benching

Excavation to build a track traversing a steep slope; maintains a flat surface (bench) by digging into the slope or building up lower edge.

Borrow pit

Small scale excavation, mini quarry, for winning materials (aggregate and surfacing), for track construction.

Camber

Track surfaced with middle slightly higher than the sides; allows surface water to flow off to both sides.

Catchment

Area of ground around track where water collects in the form of bogs, surface water, springs, streams; affects track drainage.

Catchment watershed

The land area that drains into a stream. An area of land that contributes runoff to one specific delivery point; large watersheds may be composed of several smaller "subsheds", each of which contributes runoff to different locations that ultimately combine at a common delivery point.

Catch pit

An excavated hole into which water flows.

Chamfer

Cut back or bevel the sides of ditching and embankments, to give sloping surface (batter) and avoid unstable vertical sides.

Crossfall

Track surfaced with one edge higher than the other; allows surface water to flow off to the naturally draining slope or side drain.

Cross-slope

Slope across which the track traverses; land slopes up on one side of the track, and down on the other side.

Culvert

Drainage channel taking water from one side of the track to the other.

Desire line

Preferred, or easiest line taken by walkers, often to landscape feature; not necessarily following the main track line.

Ditch/drain

Open channel used to catch, direct and disperse water flow.

Drainage grade dip

A relatively large dip constructed into the track surface to shed water from the track

Fall-line

Most direct line from the top of a slope downwards.

Fines

Smallest size of stone in graded aggregate; helps in compaction and used alone for binding the top surface of track.

Ford

Raised bed of watercourse taking track line through; often pitched to provide a good walking surface and to dissipate power of water flow.

Frost heave

Freeze effect of water under and through the track pavement; lifts and breaks up the surface or drainage features.

Geotextiles

Synthetic, or man-made materials used in track construction and landscaping; meshes and matting adapted to float tracks over areas of deep peat; biodegradable meshes used in site restoration.

Grade dip

A grade dip is a location on the track where there is a very subtle change in direction and elevation, dropping down very gently before rising again which acts to remove water from the track side

Gradient

Angle or slope of the ground or track; long gradient refers to the slope along the track line.

Inclinometer

Small instrument for measuring gradients (calibrated spirit level).

In-fill

See back-fill.

In-flow/out-flow

Water channelled into and out of a track drainage feature by ditching.

Keystone

Final, or first stone, that is used to lock together a section of stonework, or provide a firm base stone e.g. in pitching or revetments.

Maintenance

Minor repair of tracks on a regular basis; includes clearing out drains, surface repair, site restoration.

Outslope

The outside edge of a track being lower than the inside edge to promote drainage

Pavement

The durable surface for an area intended to sustain traffic, which can be either vehicular traffic or foot traffic.

Piped culvert

Drain channelling water across and under the track by means of a pipe; comes in a variety of materials, most commonly plastic.

Retaining wall

Wall built to hold up unstable banks and steeply sloping ground; may be single or multiple course and above or below the track edge.

Scour

Water erosion of the track surface; forms small channels which may lead to severe gullying.

Splash plate

Stone placed at the outflow end of a culvert, waterbar or cross-drain; prevents water eroding the track edge at the end of the drain.

Stone pitching

The setting of large stones with their long axis into the ground, packed together as close as possible and wedged with smaller stones to construct a walking surface.

Sub-grade

The soil on which the pavement structure is constructed upon.

Superelevation

Banking of a track on curves.

Traverse

Track alignment which crosses a side slope, avoiding the straight down route of the fall-line.

Tray

Excavation for the new track surface along its length and width, prior to filling with aggregate or pitching.

Tread going

Top surface of a step riser, which is used by walkers as a foothold to “tread” on.

µm

Symbol for micron. One micrometre; one millionth of a metre; one thousandth of a millimetre

Waterbar

An obstruction to the flow of water across a track at an angle to prevent excessive flow down the track surface and erosion of track surface materials

Watertable

The watertable is the upper surface of groundwater

Weathered stone

Stone with a natural appearance caused by exposure to the elements for many years; may have lichens growing on its surface.

APPENDIX 2 - GUIDELINES FOR WALKING TRACK UPGRADE- TRACK WIDTH

What is the ROS classification?

Wilderness	Remote	Backcountry	Rural	Urban fringe	Urban

What is the proportion of large groups to individuals using the track?

More individuals/couples (1-2 people)	Small families/groups (3-5 people	Medium size groups (6-10 people)	Moderate sized groups (11-19 people)	More large groups (20+ people)

What is the percentage of Short Stop Travellers on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

Are there patterns of seasonal use?

Extremely Seasonal	High seasonality	Seasonal	Some seasonality	Year round use

What is the visual impact of increasing the track width according to the ROS classification?

Very high	High	Medium	Low	Very low

What is the visual impact of increasing the track width on non users? (eg can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very low	Low	Medium	High	Very high

What is the projected growth in visitor numbers?

Very low	Low	Medium	High	Very high

What type of track is it? One way, loop, etc

Linear / loop one way	Maze	Stacked loop	Linear two way

0.75m 1.0m 1.2m 1.5m 2.0m

Note: SNZ HB 8630:2004 states the minimum width of a walking track shall be 0.75m (reduced to 0.6m in specific circumstances) and the maximum shall be 2.0m.

APPENDIX 3 - GUIDELINES FOR WALKING TRACK UPGRADE – GRADIENT

Percentage of track gradient between 15 – 20 degrees (must not be more than 10% of total track length)

How sensitive to erosion is the soil type?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the proportion of large groups to individuals using the track?

More large groups (20+ people)	Moderate to large sized groups (11-19 people)	Medium size groups (6-10 people)	Small families/groups (3-5 people)	More individuals/couples (1-2 people)

What is the percentage of short stop travellers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

Is it a dual use site with the activity promoting lower grades (e.g. mountain biking, buggies)? If the activity does not take place, do not mark.

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

In the type of landscape, what is the visual impact on the ROS classification?

Very high	High	Medium	Low	Very low

In the type of landscape, what is the visual impact on non users? (eg can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very High	High	Medium	Low		Very low

0% track length 5% track length 10%

Note: SNZ HB 8630:2004 states that up to 10% of the total track length (for a walking track) may be between 15° and 20°, as long as these steeper sections provide reasonably firm footing in wet weather conditions.

APPENDIX 4 - GUIDELINES FOR WALKING TRACK UPGRADE – WET/ROUGH

Percentage of track wet and muddy and/or rough and uneven (below 20% of total track length)

How sensitive is the soil to failing?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the percentage of Short Stop Travellers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Comfort Seekers, Backcountry Adventurers and Remoteness Seekers on the site?

0% <10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the proportion of large groups to individuals using the track?

More large groups (20+ people)	Moderate to large sized groups (11-19 people)	Medium size groups (6-10 people)	Small families/groups (3-5 people	More individuals/couples (1-2 people)

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very high	High	Medium	Low	Very low

0% 5% 10% 15% 20%

Note: SNZ HB 8630:2004 states that up to 20% of the total length of a walking track may have short wet and muddy sections (below the top of footwear) and/or rough and uneven sections.

APPENDIX 5 - GUIDELINES FOR GREAT WALK/EASY TRAMPING TRACK UPGRADE- TRACK WIDTH

What is the ROS classification?

Wilderness	Remote	Backcountry	Rural	Urban fringe

What is the proportion of large groups to individuals using the track?

More individuals/couples (1-2 people)	Small families/groups (3-5 people	Medium size groups(6-10 people)	Moderate to large sized groups (11-19 people)	More large groups (20+ people)

What is the accumulated percentage of Short Stop Travellers and Day Visitors on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the accumulated percentage of Backcountry Adventurers and Remoteness Seekers on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

Are there patterns of seasonal use?

Extremely seasonal	High seasonality	Seasonal	Some seasonality	Year round use

What is the visual impact of increasing the track width according to the ROS classification?

Very high	High	Medium	Low	Very low

What is the visual impact of increasing the track width on non users? (eg Can it be seen from the highway or from the sea?)

Very high	High	Medium	Low	Very low

What are the visitor numbers to the site?

Very low	Low	Medium	High	Very high

What is the projected growth in visitor numbers?

Very low	Low	Medium	High	Very high

What type of track is it? One way, loop, etc

Linear / loop one way	Maze	Stacked loop	Linear two way

0.3m 0.45m 0.7m 0.85m 1.0m

Note-: SNZ HB 8630:2004 states that the minimum track surface width for a Great Walk or Easy Tramping Track is 0.3m, except on steep slopes where room is required for passing, when it is 0.6m. The maximum width is 1.0m.

APPENDIX 6 - GUIDELINES FOR GREAT WALK/EASY TRAMPING TRACK UPGRADE – WET/ROUGH

Percentage of track wet and muddy and/or rough and uneven (between 30 and 50% of total track length)

How sensitive is the soil type to failing under a load?

Highly sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive

What is the accumulated percentage of Short Stop Travellers and Day Visitors on the site?

50% 41%	40% 31%	30% 21%	20% 11%	10% 0%

What is the accumulated percentage of Backcountry Adventurers and Remoteness Seekers on the site?

0% 10%	11% 20%	21% 30%	31% 40%	41% 50%

What is the proportion of large groups to individuals using the track?

More large groups (20+ people)	Moderate sized groups (11-19 people)	Medium size groups(6-10 people)	Small families/groups (3-5 people	More individuals/couples (1-2 people)

What are the visitor numbers to the site?

Very high	High	Medium	Low	Very low

What is the projected growth in visitor numbers?

Very high	High	Medium	Low	Very low

Great Walk

0%	7%	15%	23%	30%

Easy Tramping Track

0%	12%	25%	38%	50%

Note: SNZ HB 8630:2004 states that up to 30% (Great Walks) or 50 % (Easy Tramping Track) of total length may have wet or muddy sections (below footwear) and/or rough and uneven sections

APPENDIX 7 - HOW TO CHECK ACCURACY OF A SLOPE INCLINOMETER.

A slope inclinometer is unlikely to fall out of adjustment unless it has sustained a knock of some sort. Dropping it on the ground is enough to knock it out of adjustment.

- To check for accuracy select two objects approximately 10 metres apart
- Mark one of the objects at your eye level
- Walk to the second object and mark it at eye level
- Hold the inclinometer next to the mark and shoot the grade back to the mark on the first object. Take note of the reading.
- Return to the first object and take a reading back to the second object, shooting the inclinometer at the mark you made. Take note of the reading

The two readings should be the same except one will have a positive reading and the second a negative reading (both may be zero if the ground was flat). A small difference of 1º (1-2%) may be a small matter of handling technique rather than the instrument. However, if the difference is greater, or you do the exercise again with greater accuracy and cannot erase the deviation, then you should suspect that the inclinometer is out of adjustment. The bad news is there is no way of adjusting the inclinometer and it will need to be returned to the manufacturer for repair or replacement.

APPENDIX 8 - HOW TO USE A SLOPE INCLINOMETER

Slope inclinometers have both percentage and degrees marked on them. Make sure you use the scale you are working with or you will get quite a different result from what you may have anticipated.

- Hold the inclinometer in your hand with the eyehole facing toward you and the lanyard ring hanging down toward the ground
- Ensure you do not block any of the natural light with your hand, as the natural light illuminates the internal disc
- Raise the inclinometer and look through it with your right eye, keep your left eye open
- As you look through the inclinometer with both eyes open you will see that a line extends out across and into the landscape
- Choose something on the horizon and line up with the horizontal mark in the inclinometer with the target
- Move the inclinometer up and down and see the grade change
- The plus or minus sign tells you whether the grade is rising or falling
- Read grade where the horizontal line crosses the scale

APPENDIX 9 - CHECKLIST OF SURVEY EQUIPMENT

X	Track survey equipment check list:	
	Equipment	**Comments**
	Slope inclinometer /or Abney level	
	Compass	
	Pole or a roll up pocket surveyor's pole or a folding aluminium tent pole	clearly marked at the eye level of the person using the slope inclinometer
	Pegs	50 x 25mm
	Wire flags	Of numerous colours
	Flagging tape	Numerous colours
	Maul	
	Plastic tags	
	Global Positioning System	
	GPS Batteries	
	Measuring wheel	
	Hammer	
	Nails	
	Permanent marker pen	
	Recording sheet	
	Crayons	For writing on pegs and markers
	Pen	For recording details on track prescription sheet
	Track prescription sheets	Take lots
	Dazzle spray	only for marking the wooden stakes so they can be easily seen, not for anything else
	Camera	
	Camera batteries	
	Dynamic Cone Penetrometer (or similar probe)	

APPENDIX 10 - TRACK PRESCRIPTION TEMPLATE

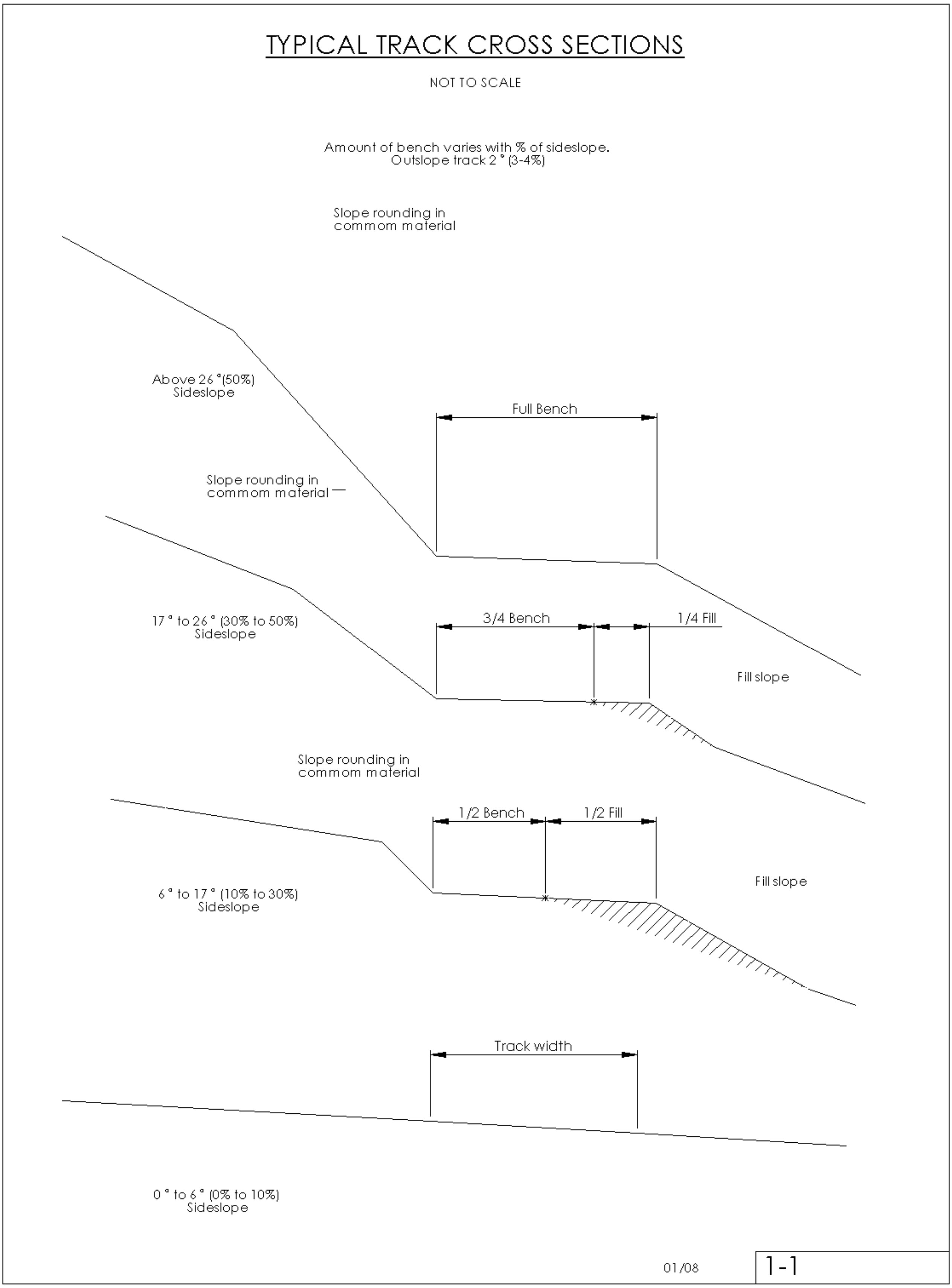
TRACK PRESCRIPTION														Date:
Track Name:														Surveyed by:
					Track				Components					
Peg Number	Distance	Grade (degrees)	Grade (percentage)	Bearing	Side slope (degrees)	Standard	Width (mm)	Shape / Surface	Culvert		Steps			Construction comments
	0								Diameter (mm)	Length (mm)	Rise (mm)	Run (mm)	Stringer length (mm)	

APPENDIX 11 - HOW TO CALCULATE SURFACE MATERIAL VOLUMES

Go to the "Calculating material volumes" worksheet in the attached Excel document "*Track length, water speed and calculating material volumes*".

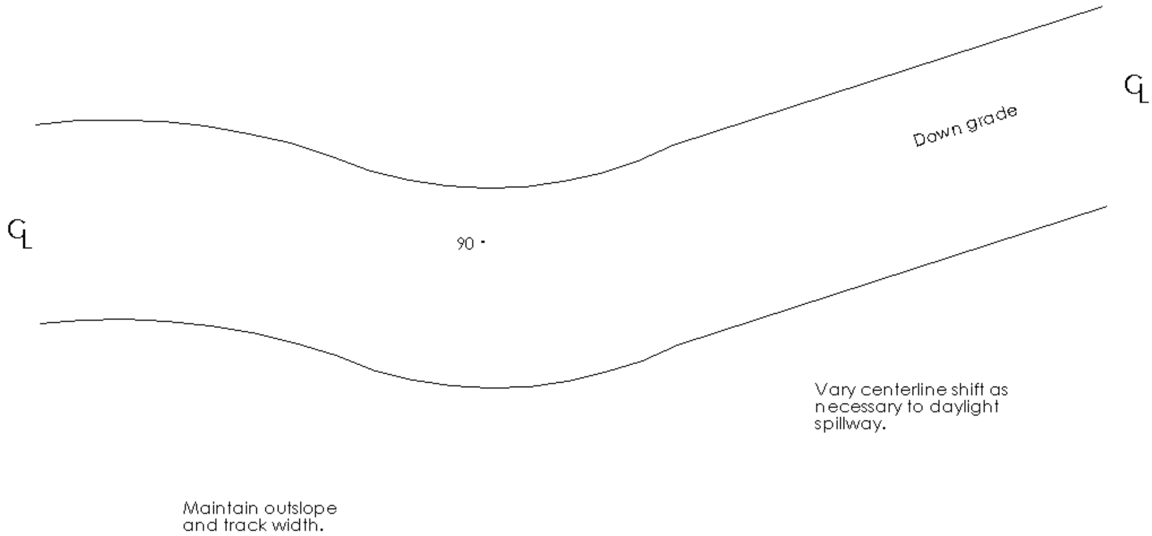
Simply enter the volume figure you have worked out for your machinery, place that figure in the correct cell according to the width of the track being constructed, hit enter and it will show you the distance of track it will cover. Next enter the total distance of track that needs surfacing and hit enter. You now have the total number of loads required to complete the track.

APPENDIX 12 - TRACK CONSTRUCTION DRAWINGS


TYPICAL TRACK CROSS SECTIONS
NOT TO SCALE
Amount of bench varies with % of sideslope.
Outslope track 2 ° (3-4%)
Slope rounding in
commom material
Above 26 °(50%)
Sideslope
Full Bench
Slope rounding in
commom material
17 ° to 26 ° (30% to 50%)
Sideslope
3/4 Bench
1/4 Fill
Fill slope
Slope rounding in
commom material
1/2 Bench
1/2 Fill
6 ° to 17 ° (10% to 30%)
Sideslope
Fill slope
Track width
0 ° to 6 ° (0% to 10%)
Sideslope
01/08
1-1

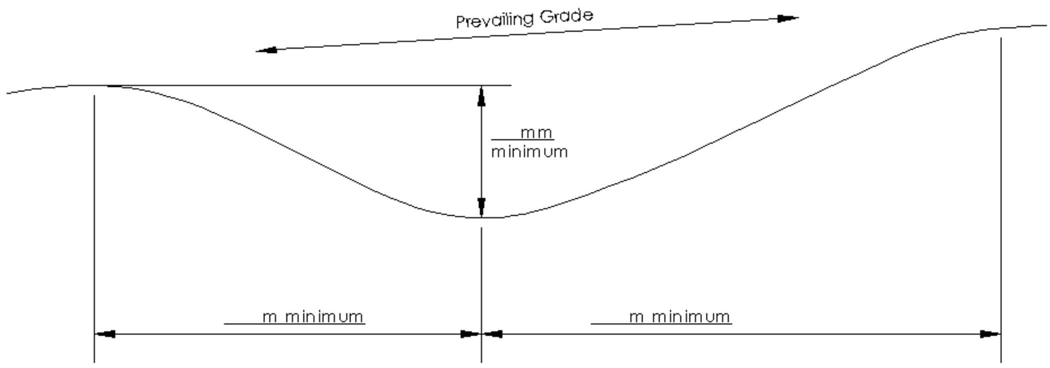
Drainage DIP

NOT TO SCALE



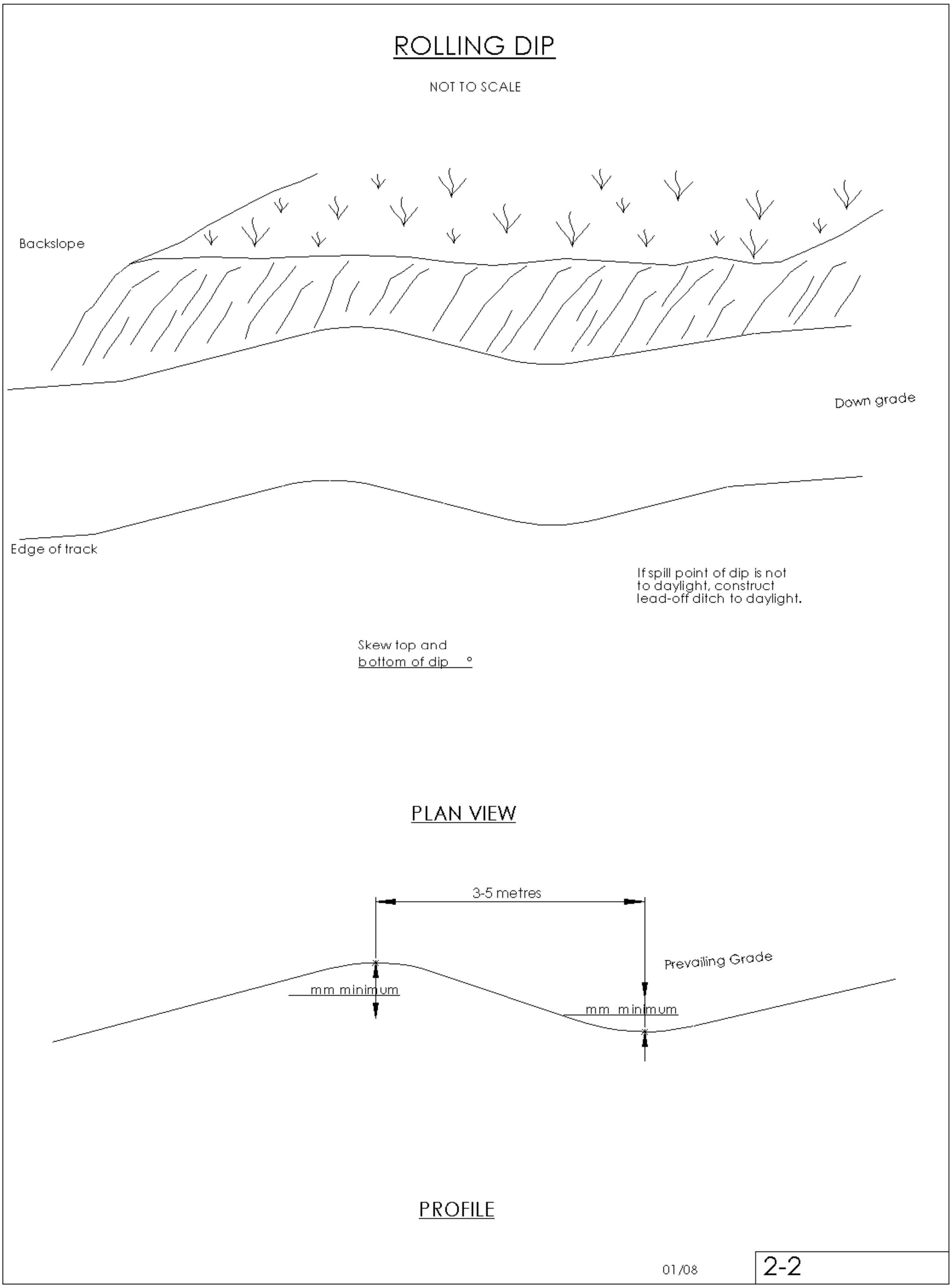
PLAN VIEW

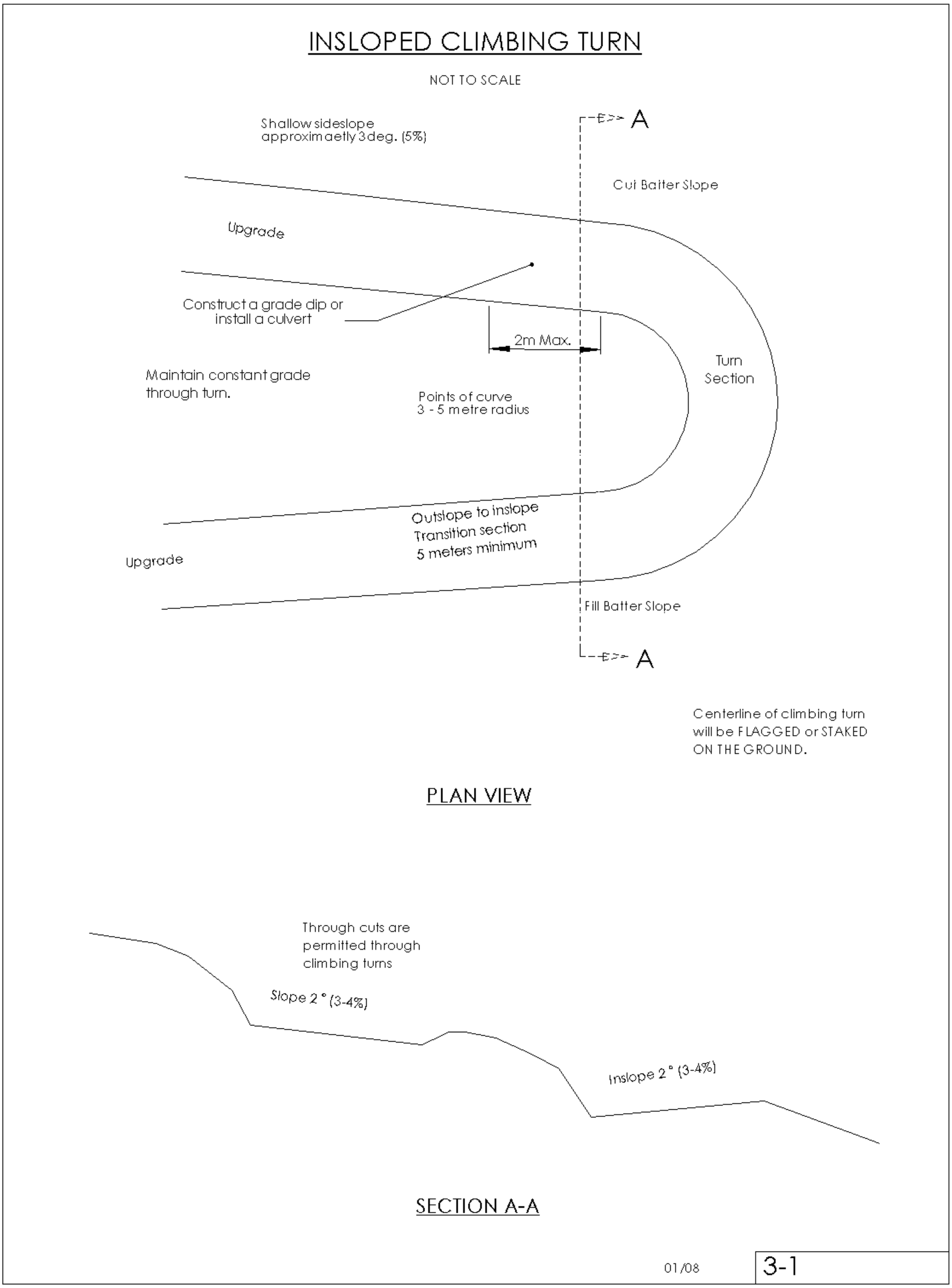
Refer 'Drainage Dip' table for dimensions under Water Management

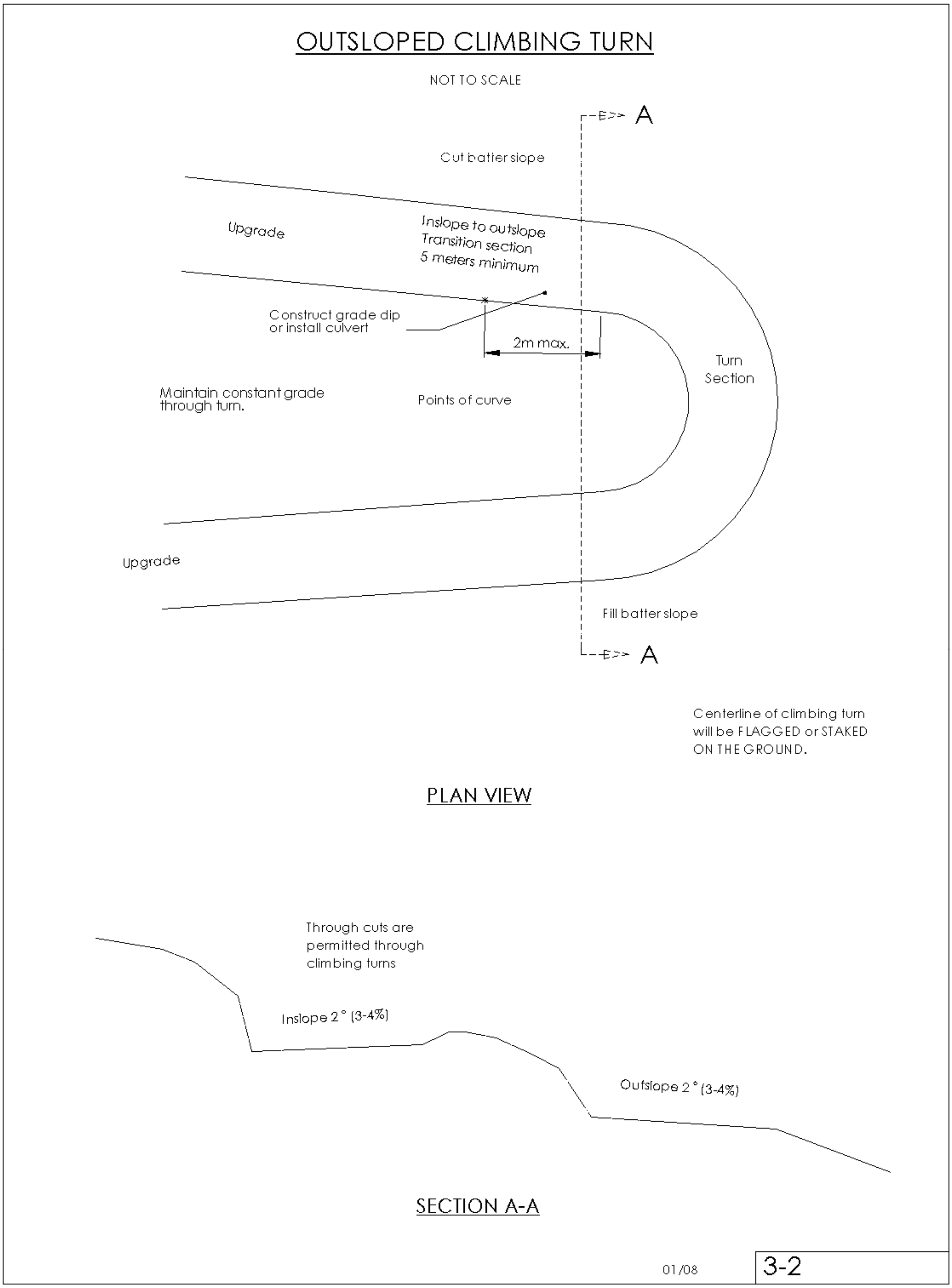


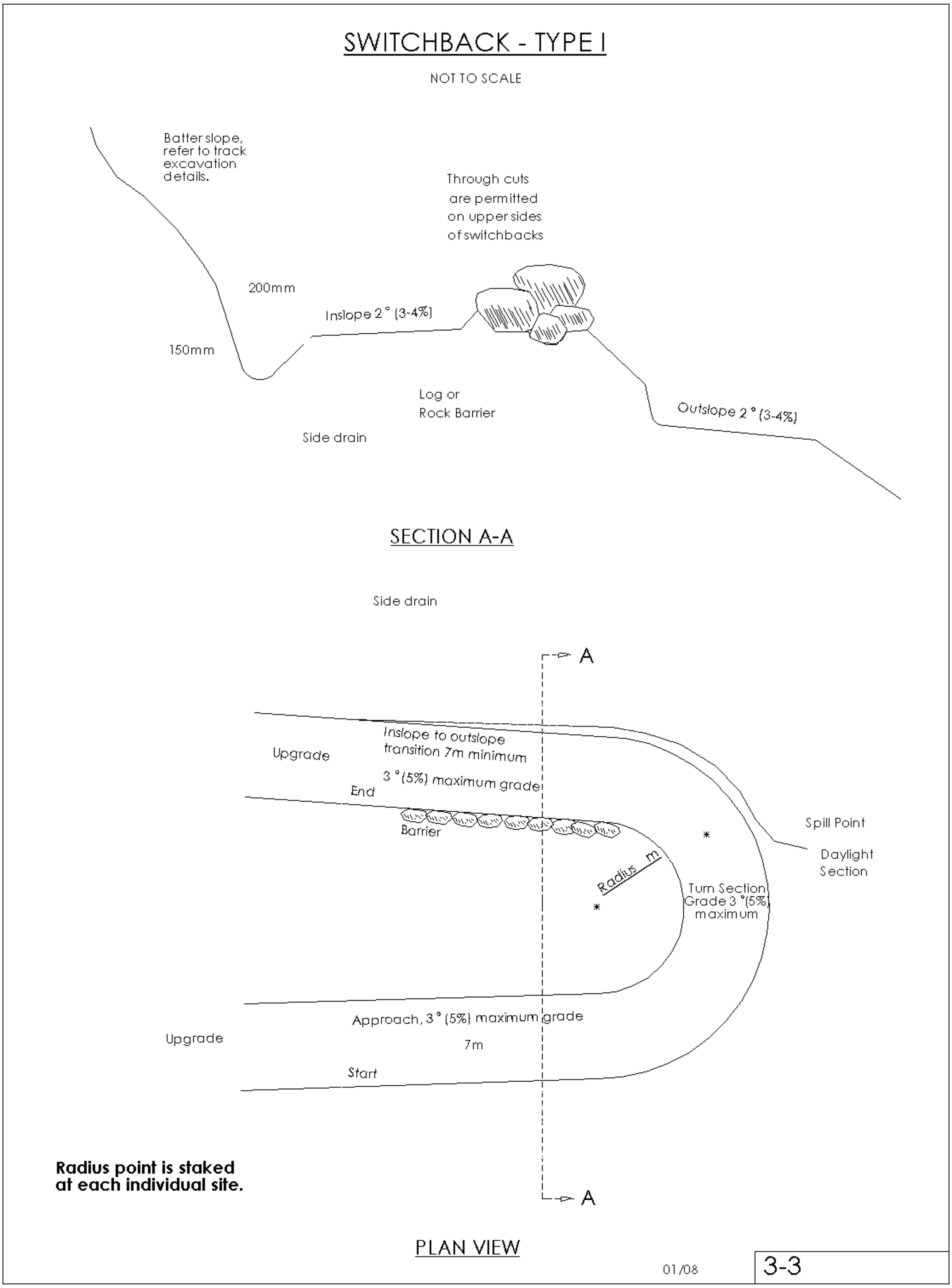
PROFILE

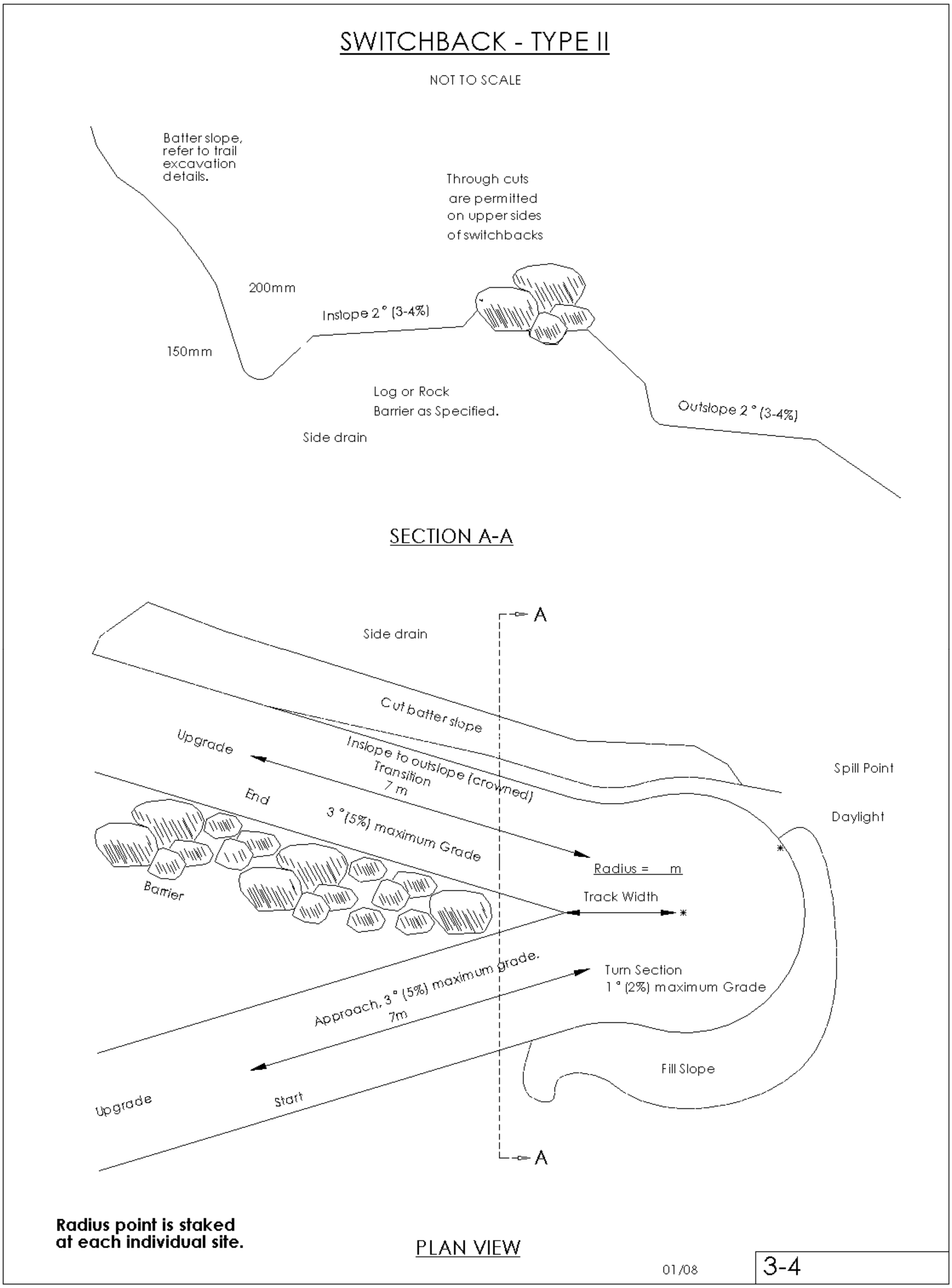
01/08 | 2-1

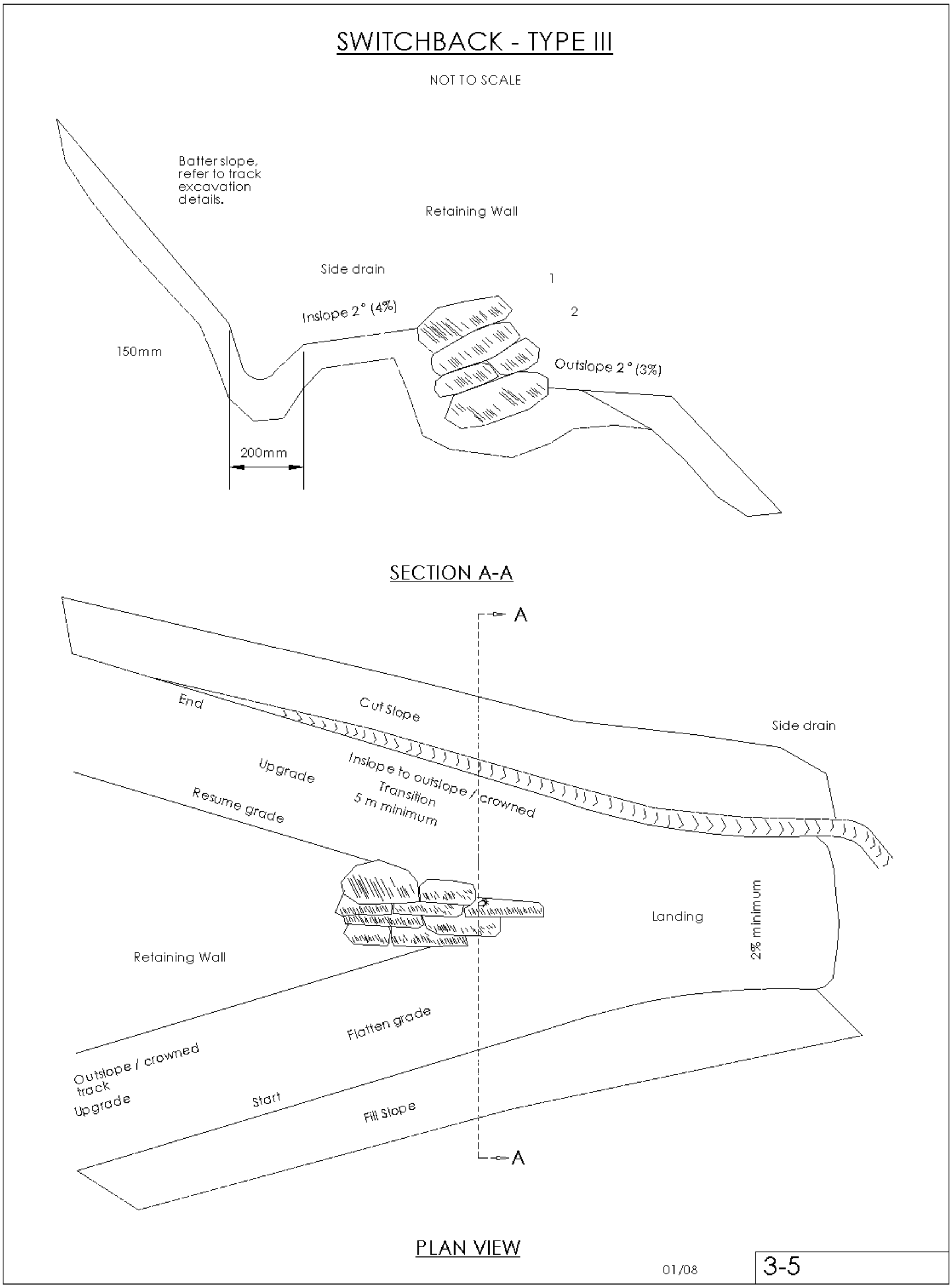

ROLLING DIP
NOT TO SCALE
Backslope
Down grade
Edge of track
If spill point of dip is not to daylight, construct lead-off ditch to daylight.
Skew top and bottom of dip °
PLAN VIEW
3-5 metres
Prevailing Grade
mm minimum
mm minimum
PROFILE
01/08
2-2

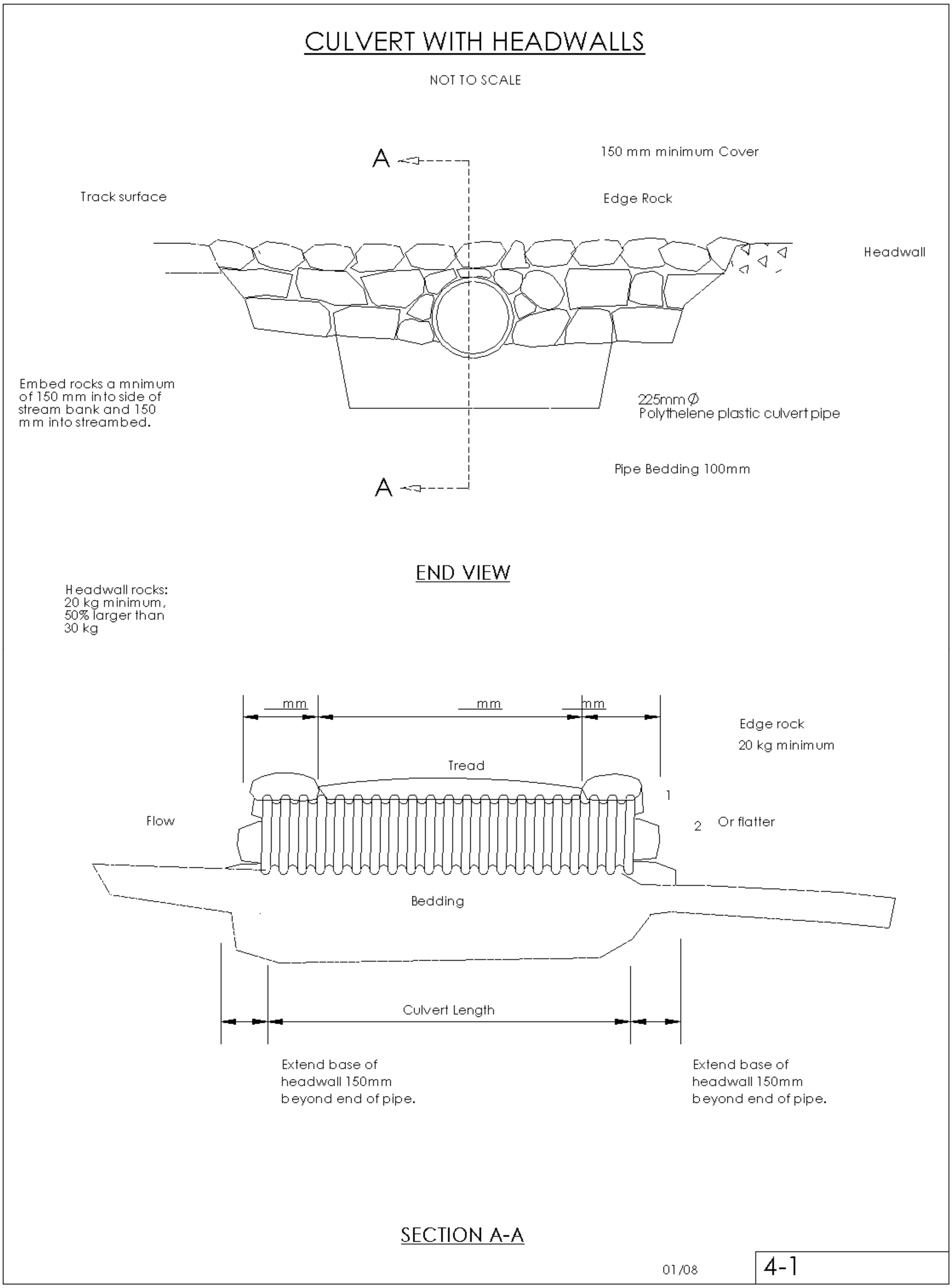

INSLOPED CLIMBING TURN
NOT TO SCALE
Shallow sideslope approximaetly 3deg. (5%)
A
Cut Batter Slope
Upgrade
Construct a grade dip or install a culvert
2m Max.
Turn Section
Maintain constant grade through turn.
Points of curve 3 - 5 metre radius
Outslope to inslope Transition section 5 meters minimum
Upgrade
Fill Batter Slope
A
Centerline of climbing turn will be FLAGGED or STAKED ON THE GROUND.
PLAN VIEW
Through cuts are permitted through climbing turns
Slope 2 ° (3-4%)
Inslope 2 ° (3-4%)
SECTION A-A
01/08
3-1

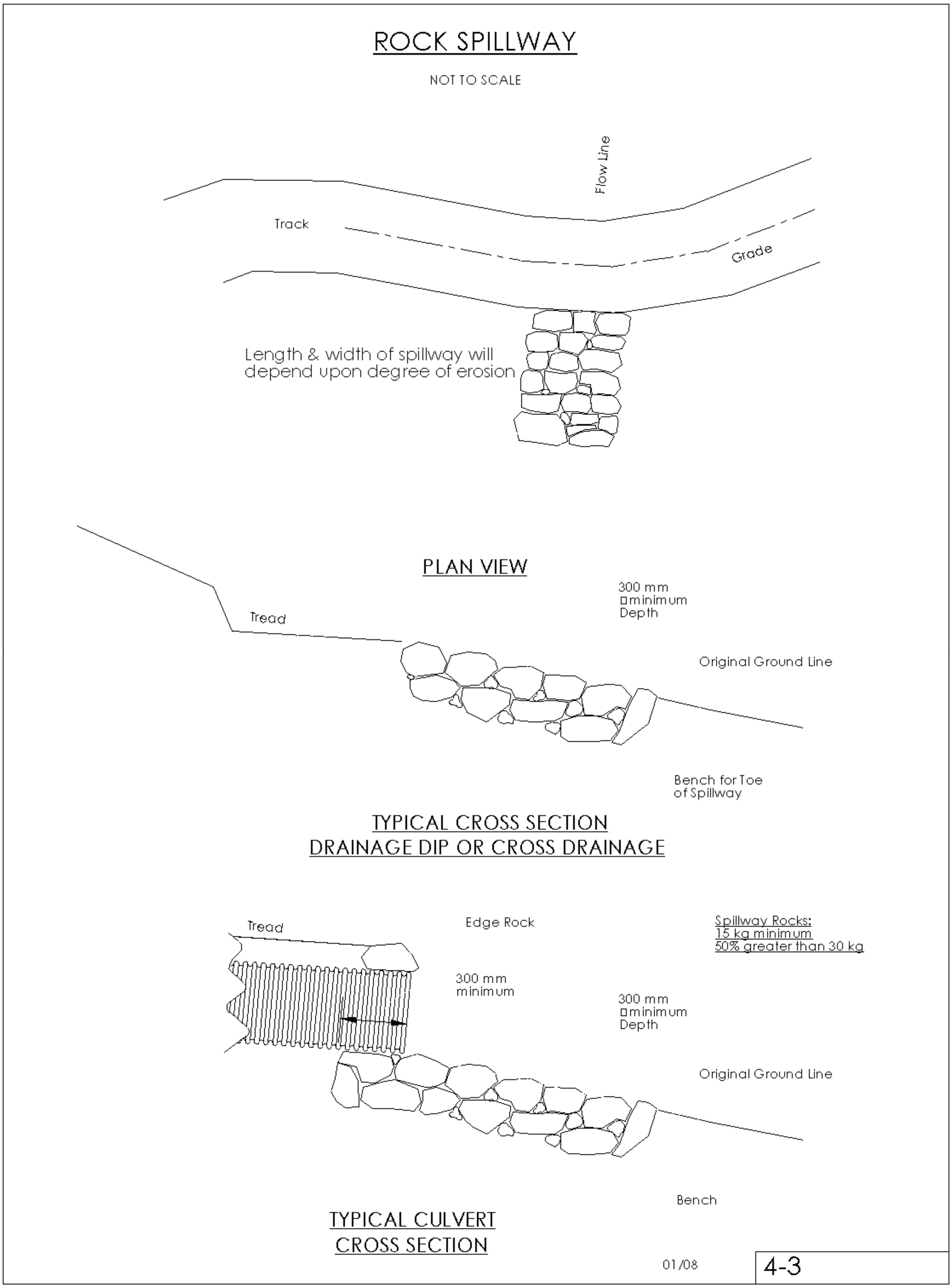

OUTSLOPED CLIMBING TURN
NOT TO SCALE
A
Cut batter slope
Upgrade
Inslope to outslope
Transition section
5 meters minimum
Construct grade dip
or install culvert
2m max.
Turn
Section
Maintain constant grade
through turn.
Points of curve
Upgrade
Fill batter slope
A
Centerline of climbing turn
will be FLAGGED or STAKED
ON THE GROUND.
PLAN VIEW
Through cuts are
permitted through
climbing turns
Inslope 2° (3-4%)
Outslope 2° (3-4%)
SECTION A-A
01/08
3-2

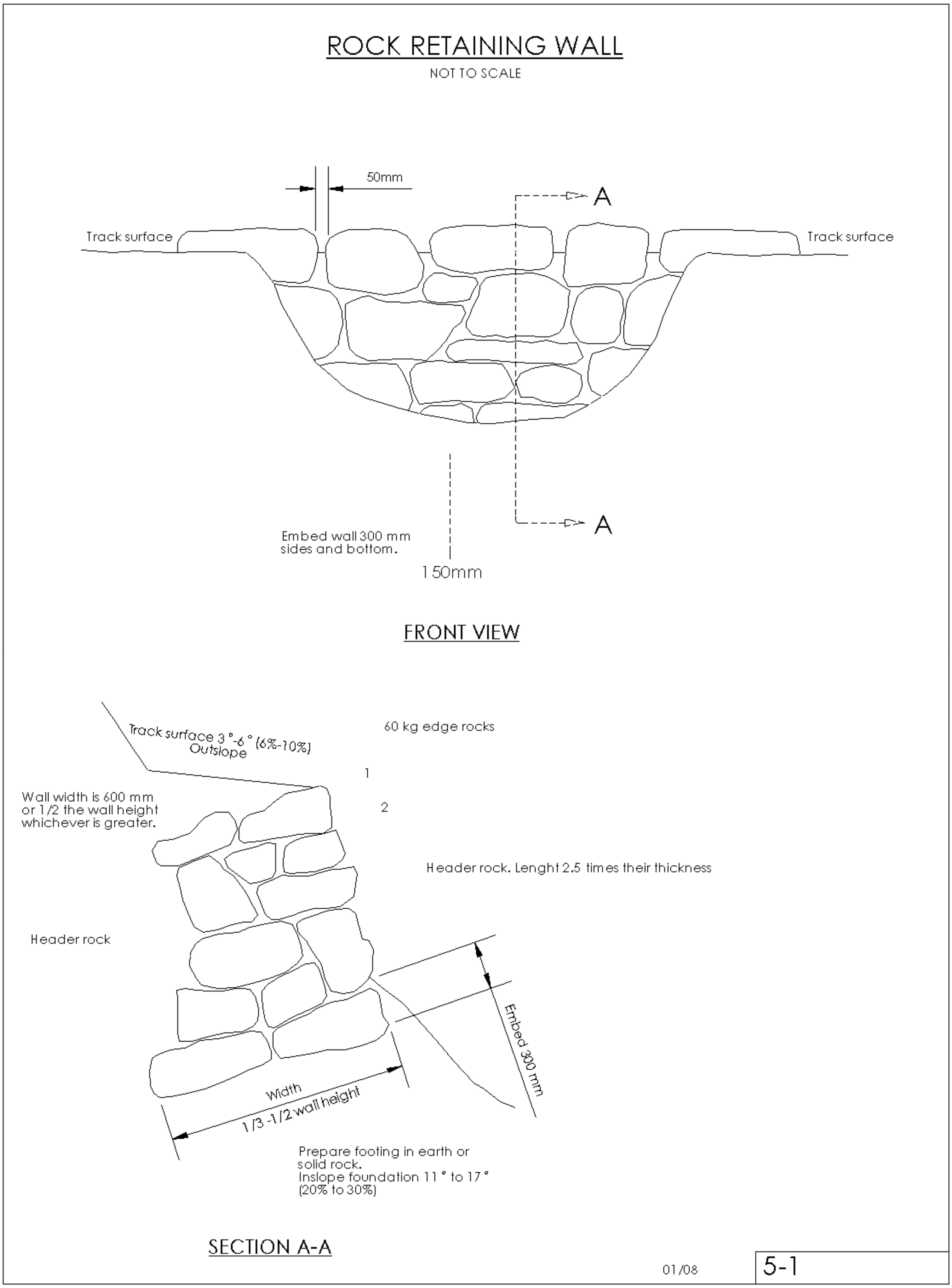

SWITCHBACK - TYPE I
NOT TO SCALE
Batter slope, refer to track excavation details.
Through cuts are permitted on upper sides of switchbacks
200mm
Inslope 2 ° (3-4%)
150mm
Log or Rock Barrier
Outslope 2 ° (3-4%)
Side drain
SECTION A-A
Side drain
A
Inslope to outslope transition 7m minimum
Upgrade
3 °(5%) maximum grade
End
Barrier
Spill Point
Daylight Section
Radius m
Turn Section Grade 3 °(5%) maximum
Approach, 3 ° (5%) maximum grade
Upgrade
7m
Start
Radius point is staked at each individual site.
A
PLAN VIEW
01/08
3-3


SWITCHBACK - TYPE II
NOT TO SCALE
Batter slope, refer to trail excavation details.
Through cuts are permitted on upper sides of switchbacks
200mm
Inslope 2° (3-4%)
150mm
Log or Rock Barrier as Specified.
Side drain
Outslope 2° (3-4%)
SECTION A-A
A
Side drain
Cut batter slope
Upgrade
Inslope to outslope (crowned) Transition 7 m
End
3° (5%) maximum Grade
Spill Point
Daylight
Radius = m
Barrier
Track Width
Approach, 3° (5%) maximum grade. 7m
Turn Section 1° (2%) maximum Grade
Fill Slope
Upgrade
Start
A
Radius point is staked at each individual site.
PLAN VIEW
01/08
3-4


SWITCHBACK - TYPE III
NOT TO SCALE
Batter slope, refer to track excavation details.
Retaining Wall
Side drain
1
2
Inslope 2° (4%)
150mm
Outslope 2° (3%)
200mm
SECTION A-A
A
End
Cut Slope
Side drain
Upgrade
Inslope to outslope / crowned
Transition
5 m minimum
Resume grade
Landing
2% minimum
Retaining Wall
Flatten grade
Outslope / crowned track
Upgrade
Start
Fill Slope
A
PLAN VIEW
01/08
3-5


CULVERT WITH HEADWALLS
NOT TO SCALE
A
150 mm minimum Cover
Track surface
Edge Rock
Headwall
Embed rocks a mnimum of 150 mm into side of stream bank and 150 mm into streambed.
225mm Ø
Polythelene plastic culvert pipe
Pipe Bedding 100mm
A
END VIEW
Headwall rocks:
20 kg minimum,
50% larger than
30 kg
mm
mm
mm
Edge rock
20 kg minimum
Tread
1
Flow
2
Or flatter
Bedding
Culvert Length
Extend base of headwall 150mm beyond end of pipe.
Extend base of headwall 150mm beyond end of pipe.
SECTION A-A
01/08
4-1


ROCK SPILLWAY
NOT TO SCALE
Flow Line
Track
Grade
Length & width of spillway will depend upon degree of erosion
PLAN VIEW
Tread
300 mm minimum Depth
Original Ground Line
Bench for Toe of Spillway
TYPICAL CROSS SECTION
DRAINAGE DIP OR CROSS DRAINAGE
Tread
Edge Rock
Spillway Rocks:
15 kg minimum
50% greater than 30 kg
300 mm minimum
300 mm minimum Depth
Original Ground Line
Bench
TYPICAL CULVERT
CROSS SECTION
01/08
4-3


ROCK RETAINING WALL
NOT TO SCALE
50mm
A
Track surface
Track surface
A
Embed wall 300 mm
sides and bottom.
150mm
FRONT VIEW
Track surface 3°-6° (6%-10%)
Outslope
60 kg edge rocks
1
2
Wall width is 600 mm
or 1/2 the wall height
whichever is greater.
Header rock. Lenght 2.5 times their thickness
Header rock
Embed 300 mm
Width
1/3 -1/2 wall height
Prepare footing in earth or
solid rock.
Inslope foundation 11° to 17°
(20% to 30%)
SECTION A-A
01/08
5-1

APPENDIX 13 - HOW TO FIND OUT MORE ABOUT HISTORIC VALUES AND SITES

Historic values

When planning and undertaking work on your track it is important to consider, and take into account, historic values.

Historic tracks

Some existing tracks have historic values themselves. Upgrading and maintaining these types of tracks requires specialist historic advice. They are mainly the routes of railways, tramways, roads, graded horse tracks and water races.

Find historic sites

Find the location of historic and archaeological sites on the route of the track so that they can be protected from harm during work.

Consult your Historic TSO

Your conservancy Historic TSO can tell you:

- The location of historic and archaeological sites in your area
- How to avoid any threats or issues related to these
- Historic Places Act legal requirements
- How to prepare the historic heritage section of an "Assessment of Environmental Effects" document when planning work

Find out more

Find out more about historic using the DOC Intranet:

➔ Go to Search and type in "Historic Heritage".

The pages contain information that will help you with planning, managing and working with historic heritage and historic tracks.

Retain the character and minimise loss of material

Where possible retain an historic track's original profile, line and grade and minimise the loss of original material/fabric. This maintains authenticity and significantly enhances the heritage experience of visitors. See SNZ HB 8630:2004, sections 2.5.7, 2.6.7, 2.7.8 and 2.8.7.