REVEGETATION OF ALLUVIAL GOLD MINES

A prescription for the

West Coast Tai Poutini

REVEGETATION OF ALLUVIAL GOLD MINES

A prescription for the West Coast

Department of Conservation

Hokitika

November 2010

TABLE OF CONTENTS

INTRODUCTION

This guide is intended to be of assistance to those planning to conduct alluvial gold mining on public conservation land which, prior to mining, contained a dominant vegetation cover of indigenous woody species. However, the general principles are also applicable to any alluvial gold mine site at any stage of its life-time.

There need to be clear objectives in order for miners and the Department of Conservation (DOC) to assess the success of the revegetation work. These objectives have been kept deliberately simple, and reflect the goal to give former mine sites a "leg up" on the way to natural regeneration. In order to satisfy the conditions attached to the access arrangement the post-mining goals will need to be achieved.

To achieve post-mining revegetation objectives and meet the 'success criteria', mining operations will be required to be carried out in a planned and systematic manner. The miner will need to have a clear view as to how site revegetation is to be achieved and the path to reach this. Success will often depend upon how the mining operation sequence is undertaken.

What is the best way to achieve the revegetation objective? There are no doubt a number of ways in which this can be achieved, but outlined here are mining practices and guidelines, in the wider sense, that will likely be successful in the scenario of alluvial gold mining. The miner will need to integrate the physical act of recovering gold from alluvial gravels with operational aspects of moving soil and vegetation to meet revegetation objectives required by DOC as the land administrator.

OBJECTIVES OF REVEGETATION

Public conservation land is administered to protect natural vegetation and wildlife values so post-mining objectives must aim for the return of the mine site to a condition comparable to adjoining vegetation in the shortest possible time period.

Natural revegetation to a dense cover, of even pioneering plant species, of an area that has been disturbed by mining, requires decades or tens of decades. To replace a tall structured forest requires centuries, yet alluvial mining operations are normally of short duration. DOC realises it is unrealistic to expect an alluvial gold miner to be committed to long-term post-mining site maintenance.

Revegetation to a condition acceptable to DOC that allows the miner to relinquish responsibility for a mined site must therefore be achieved within short time frames. The idea is to set in place a natural process for the reversion of the mined area to native vegetation by providing the conditions and a basic plant cover that will facilitate this process.

The **objectives** of revegetation are therefore met where:

A core of healthy fast growing native shrubs & trees are established, that can be left without further human assistance to aid the development of the site into a complete indigenous woody plant cover, and eventually forest similar to the surrounding area.

This can be achieved in a number of ways, such as transfer of clumps of vegetation and soil, planting saplings or layering seed bearing slash. Factors such as terrain and soil conditions play important parts in revegetation success, as do type and size of machinery used but ultimately success is dependent on how the mining operation is planned and undertaken.

PLANNING

A plan is essential and will be required, outlining how revegetation is to be achieved and how wider mining operations are to be undertaken to optimise conditions for both, short and long term development of a naturally sustaining ecosystem.

The miner will need to integrate the physical act of recovering gold from alluvial gravels, with operational aspects of moving soil and vegetation, to meet revegetation objectives required by DoC as the land administrator.

OPERATIONAL PLAN
Theoretical Mines Ltd

Preparation
Year 1: Planning & paperwork
Access Arrangement

Mineral Extraction Plan
Year 2: Strip Block 1
Year 3: Strip Block 2

Revegetation Plan
Year 1: Source seed & supply to nursery
Year 2: Separate & store blk 1 vege/soil/stone
Year 3: Direct transfer blk 2 vege to blk 1
Plant nursery raised saplings

SITE DESCRIPTION

The typical alluvial gold mine site is approximately 30 ha in size. The **current vegetation** cover on most sites where alluvial gold mining is permitted in the public conservation land is likely to have resulted from a combination of logging, fire or other past land uses, and can be grouped in one of three broad vegetation types depending upon the locality;

- **beech dominated** – typically a cover of poles or small trees, with scattered larger dead spars and pockets of scrub hardwood species (*e.g.* manuka, *Coprosma* spp),
- **beech and scattered podocarp** (*e.g.* rimu, kahikatea) regeneration – typically likely to carry pole or small tree regeneration, and pockets of scrub hardwoods
- **scrub hardwoods** with podocarp regeneration at varying densities – it is likely vegetation will comprise predominantly scrub hardwoods (*e.g.* kamahi, wineberry, quintinia) on drier sites or 'grey scrub'(e.g. *Coprosma* spp., *Myrsine divaricata*) on wetter terraces, with varying quantities of podocarp regeneration.

There is likely to be a component of unwanted exotic **plant pests** *i.e.* gorse, European broom, and heath-rush (*Junqus squarrosus*), if not within the mining area, then adjacent to or along access roads.

Terrain is likely to be flat to gently sloping, often as part of a valley floor, or on a terrace level. On wetter sites upper soil layers will generally be organic in nature (dark coloured with a significant amount of vegetation material) over a water-logged gleyed (grey) layer with few nutrients and difficult structural properties; on drier sites upper soil layers will generally be yellow-brown in colour which grade with depth into gravels.

SITE PREPARATION FOR MINING

Traditionally preparing the site for mining involves the strip clearing of all vegetation, topsoil and upper soil horizons, to gold bearing gravel, and stockpiling these materials to one side. Normally there was little attempt to separate layers of vegetation, organic topsoil or underlying mineral soils.

At sites where gravel, subsoil and vegetation are stockpiled together and redistributed evenly at the completion of mining, colonisation by competitive exotic weeds such as pasture species, rushes and other exotic herbaceous plants occurs quickly. Natural regeneration of native saplings and seedlings, from the stockpiled material, is minimal at best.

For the purposes of revegetation best practise dictates that this method of handling vegetation and upper soil horizons is less than ideal because of the loss of natural soil structure, mixing of soil horizons, loss of valuable plant regeneration potential and beneficial soil organisms which assist in plant growth.

VEGETATION AND SOIL STRIPPING

Generally the best success in revegetation is achieved where post mining soil profiles are broadly reconstructed to approximate a natural profile. Separate stripping and stockpiling of each vegetation and soil component is required to be done to achieve this. Stripping should therefore, where practicable, recover soil and vegetation in three broad groups

- **large woody material** that cannot be easily managed because of the size i.e. logs
- **shrubs, stumps, root plates and organic soil**, the dark brown upper layer of soil which supports the root boles and most of the soil nutrients.
- **subsoil**, normally yellow brown earths resting on or mixed with the upper gravels.

Separate stock piles of sawn logs (above) and gravel/subsoil (below)

In wet areas a grey, water logged horizon may also be present. This gleyed soil horizon can be mixed, either during storage or in soil profile reconstruction. In a sequenced operation each layer is ideally handled just once, with stripped material transferred directly onto re-contoured surfaces. If however storage of subsoil and organic soil-vegetation is required, the height of the stockpile should not exceed four metres in height and the storage period should not exceed one year.

From a practical and economic point of view it is likely to be very difficult to create a specific soil structure for the establishment of a special vegetation type, *e.g.* creating a fertile but water logged soil for the purpose of establishing a kahikatea forest. The objective should be to recreate a soil structure with a simple profile.

Recreating a soil profile and structure provides optimum opportunity for development of regenerating forest. Larger woody material, such as logs, provides microsites for protection of seedlings, habitat for forest fauna and eventually will rot to provide organic material for soil development.

Recreation of a simple soil profile on a re contoured site.

REVEGETATION METHODS

1) DIRECT TRANSFER

Direct transfer involves the movement of intact sods of vegetation and underlying organic soil to prepared rehabilitation sites. The transferred clumps of vegetation will include stumps and root plates of large trees, standing small trees and shrubs, but also lower growing non-woody plants, along with a layer of organic soil. This is an equivalent technique to laying instant lawn.

By felling larger trees separately by hand prior or during the recovery the height of the transfer material is kept manageable. This will make upright placement of the sods easier and increase the chances of survival for the remaining plants. The salvaged logs should be temporarily stockpiled to be used as slash in the spaces between clumps of transferred vegetation.

Direct transfer material; stumps, root plates, and surrounding plants.

The intact sods of vegetation should preferably be moved to a site that has already been re-contoured so that it is only handled once and no storage is required. To increase the chance of transferred vegetation establishing, at least three to four excavator bucket fills of transfer material should be placed as close as possible next to each other. Stumps and other vegetation on the sod should be placed or manipulated into an upright position on the re-contoured site. Generally it is best to create 'islands' of this material on the re-contoured site, infilling gaps with planted seedlings and slash if necessary.

Access ways between clumps need to be left un-compacted. The larger logs and heads that are stored can be placed on the ground between clumps. Longer logs should be cut by power saw or crushed with the excavator bucket to lengths of no longer than about 4m to allow for rapid decomposition of the wood.

There are significant disadvantages to storage, including multiple handling, compaction of material, loss of vegetation, mixing of components, loss of biological activity and most importantly the likely loss of most viable seed and seedlings. It is unlikely seedlings will be viable, even after short term stockpiling, and so to achieve revegetation objectives more planting of nursery raised seedlings will be required.

Some losses will occur with the handling of plant materials for direct transfer, so at best, there is often only enough salvageable plant material to cover 50% of the re-contoured ground, but it is normally less. Prioritising the use of this material may therefore be an important part of the revegetation plan.

Scheduling of the mining sequences is critical to the success of this method as ideally there must be sites available where mining has been completed, the surface re-contoured, and subsoil spread.
Where the mining scheduling does not permit the immediate transfer of vegetation and organic soil to a restructured surface, this material will need to be stockpiled for later use.

Direct transfer of vegetation on to re-contoured site

12 years after direct transfer, 5m tall pockets of beech saplings now occupy much of the site without the need for planting

2) PLANTING

Inevitably most sites will require techniques additional to direct transfer on order to achieve a good healthy core of fast growing species including individually planted seedlings and saplings, there are two options to source seedlings for planting.

Nursery raised seedlings

Nursery raised seedlings carry a good probability of success, however forward planning is required to ensure stock is available for planting when required. For scrub species (*e*.g. manuka, *Coprosma* spp.) a nursery will need to grow stock for at least one to two years to get seedlings of sufficient size, this process will take longer for tree species. Nurseries can obtain material for growing by collection of seeds, from cuttings or from collection of small wildings. Collection from public land requires a permit and when planting into public conservation land the plants must be locally sourced

- Cuttings are the most versatile option.
- Most of the common tree species (*e.g.* beech or rimu) produce seeds at infrequent intervals, between 3 to 5 years. This means there is no guarantee that a source of seeds will be available in any particular year.
- Wilding seedlings will need to be grown in a nursery for 2 to 5 years to be of sufficient size for planting. Seedlings will normally be grown in a container of some kind, although if large numbers are required and the nursery is suitably set up, bare rooted stock may be an option.

Usually, nurseries do not hold large quantities of suitable seedling stock that would be available for a planting programme. For one-off mining operations nursery raised seedlings are an option only when forward planning for a number of years has been done.

3 year old nursery raised beech seedlings

Nursery raised beech at 16 years

Wilding seedlings

Where nursery-raised stock is not available seedlings may be collected as wildings, however permission is required to remove plants from the surrounding public conservation land. There needs to be a readily available source of suitably sized seedlings (between 30cm to 50cm) that can be easily dug up and transported. These must be growing in a high light situation. Seedlings from strongly shaded sites such as those growing under a forest canopy should not be used as they are unlikely to survive the transplanting shock. Seedlings should ideally not contain soft new growth. They must also be growing in a medium that allows for easy digging (*e.g.* road spoil) to be able to excavate a soil encased root bole with each plant.

During transport and planting, care needs to be taken that the soil from the root bole is not lost and does not dry out. Careful handling and transport is critical to survival. Seedlings should be lifted directly into containers, such as fish crates, stored away from direct sunlight and remain in these until planting. Long roots may need to be pruned with secateurs to form a more compact root bole, and excessive crown height or branching pruned to allow for easier handling and reduced transpiration when replanted.

Suitable weather conditions are more critical to success than with nursery raised stock, so working when it is overcast or raining will ensure exposed roots do not dry out, and a good rainfall after planting is important. If this is not achieved manual watering will be required. Stocking should be the same as for planting of nursery raised seedlings. A lower survival rate than with nursery raised seedlings can however be expected, so some replanting will most likely be required.

Where to plant

Site selection is the most important factor in seedling survival, and subsequent growth. Compacted or wet sites should be avoided, and choosing slightly raised sites with a good soil medium should be the priority. Normal planting techniques, such as cultivation of the planting site and appropriate planting depth are also important factors to success.

When to plant

Planting of seedlings can be done at various times of the year provided environmental conditions during and following planting will not compromise survival and growth (*e.g.* don't plant in the middle of a hot summer). Planting is best done from late autumn to early spring; frost or drought periods should always be avoided.

How to plant

Seedlings may be planted individually, in rows or some other pattern, but for mutual support and optimum use of seedlings the creation of seedling islands is recommended, with ten seedlings per island, about 1 m. apart. This spacing will in good conditions enable crown coalescence within a few years to form a compact clump of shrubs.

Clumps should be spaced about 10 m. apart. This intensity equates to 1000 seedlings per hectare (Fig. 1). Where the site is fringed by mature forest, or maintains pockets of mature trees, a 20m buffer can be left unplanted as these areas are most likely to be colonised quickly by natural regeneration.

What to plant

Although plants that naturally colonise disturbed areas give an indication which species might be suitable for use in revegetation, past planting efforts show that there is actually only a narrow range of species that can be successfully used in open mine site situations. Ideal characteristics of such species are that they; can be readily cultivated in a nursery, or collected as wildings, exhibit a relatively
fast growth rate, have expansive crowns, produce viable seed in a relatively short time, have bird distributed seed, and most importantly

can be successfully planted into an open site. Generally only shrub species meet these requirements, however, to provide some species diversity and enhance the regeneration into forest, larger forest tree species should be also considered.

Recommended shrub and tree species, depending on locality and vegetation type:

Aristotelia serrata	wineberry
Carpodetus serratus	marble leaf
Coprosma robusta	karamu
C. foetidisima	stinkwood
C. propinqua	small-leaved *Coprosma*
C. tayloriae	small-leaved *Coprosma*
Coriaria arborea	tutu
Griselinea littoralis	broadleaf
Hebe salicifolia	koromiko
Kunzea ericoides	kanuka
Leptospermum scoparium	manuka
Myrsine salicina	toro
Pittosporum eugenoides	lemonwood
Psuedopanax colensoi	five finger
Schefflera digitata	pate
Weinmania racemosa	kamahi
Dacrydium cupressinum	rimu
Dacrycarpus dacrydioides	kahikatea
Nothofagus menzeisii	silver beech
Nothofagus fusca	red beech
Podocarpus totara	totara
Podocarpus cunninghamii	Hall’s totara

koromiko

broadleaf, kapuka

Lemonwood, tarata

manuka

Coprosma tayloriae

five finger

Quick growing native species suitable for revegetation.

3) LAYERING

This method involves the laying of cut vegetation or slash of **seed bearing foliage** across the area to be revegetated to allow for seed fall, germination and seedling establishment.

Typically, the most successful species for this method are manuka or kanuka, although no doubt species such as the large leaved *Coprosmas* also have potential. One of the most obvious requirements for the success of this method is that the cut foliage must contain viable seeds, so timing of foliage collection is therefore critical.

For manuka, the best foliage to collect is from small plants from road edge localities, as these are the easiest to cut, transport and handle, and usually have good crown density that provides sheltered sites for germination and seedling growth. Plants on the mine site are an obvious resource as well.

The density of slash layered depends largely on the site to be revegetated, but normally slash is laid by overlapping branches. Where collection material is limited, islands of slash may be created across the site. For manuka, if seedlings survive for two years they are likely to become established plants. After this period, a plant stocking at least equivalent to that for planted seedlings is required. In reality, significantly greater seedling density is normally achieved because of the quantity of seed released.

As with the other revegetation techniques the origin of the plant material is important, however please remember that collecting any plant material from the public conservation lands requires permission.

Progression from bare overburden slopes

A good cover of manuka within in 6 years of layering of slash

4) NATURAL REGENERATION

The process of natural regeneration will occur in two ways on a successfully managed site; either seeds and seedlings will survive the transfer of topsoil and vegetation during site stripping, or seed from the adjoining vegetation will disperse into the area (*e.g.* by wind, birds or simply gravity).

Seeds of native plants generally do not remain viable for long periods of time in the ground, so it is unlikely that forest duff and vegetation that have been stockpiled or heavily mixed will result in a significant number of seedlings.

Most seed therefore has to come from a fresh source, which is normally along the margins of the mined area. The width of this margin varies according to vegetation however on general it allows for approximately 20 m of border, around the forested edge of the mine site, or around pockets of mature seed producing trees, which can be left unplanted with the process of natural seed fall relied upon to re-vegetate the area.

Pockets of scrub or little disturbed forest, or even individual trees within the mined area are therefore very important in encouraging natural regeneration. Suitable weed free sites are also required to be present. Natural regeneration can be included in the rehabilitation plan for sites adjacent to existing native vegetation and in sites where mature vegetation has been retained within the mining footprint. However, in most cases it will need to be complemented by other techniques.

Natural regeneration of beech seedlings adjoining a tall forest seed source.

Scrub hardwood seedlings (wineberry, marble leaf) establishing amongst fern and native grasses.

MANAGEMENT OF REVEGETATED AREAS

1) WEED CONTROL

In many circumstances the revegetation program will encounter the problem of competition with weeds, potentially to such an extent that success of the plantings is limited. Competition for light, moisture, nutrients and space can affect the establishment, survival and growth of native seedlings and saplings. Where there is the potential for this to occur weed competition will need to be controlled by the use of either herbicide sprays or manual methods. Control may be required at both the pre-planting stage and later, for releasing plants.

Where invasive weeds such as gorse, broom or heath-rush are present as either scattered clumps or isolated bushes prior to mining, or where they are introduced to a weed free site, a programme is required that will provide effective weed control for at least two years after mining operations cease.

Where invasive weeds are present at high densities at the site prior to mining it would be unreasonable to require the site to be left clear of invasive weeds at the cessation of mining. In these instances revegetation will still be required however the density of weeds on site at the end of mine life will not be a criterion for judging the success of the revegetation programme. Weed control will only be required in order to allow native plants to establish unhindered by weeds (e.g. releasing of individual plants).

Gorse is a particularly common weed of disturbed sites. Although gorse is a pioneering species that has a number of positive attributes, it does inhibit growth of planted seedlings and natural regeneration, and carries a high fire risk. Control will normally involve an initial spraying of gorse regeneration with herbicide, with a subsequent spot spraying to maintain control. Care must be taken to minimise the impact of spray on native regeneration (*e.g.* hand spot spray rather than aerial spray). Where only scattered seedlings or bushes are present simple grubbing, or cutting stumps and applying herbicide may be successful. Control of

other competing weeds e.g. releasing planting from rank grass may also require the use of herbicides or hand control methods to allow native vegetation to flourish**.**

Isolated bushes of gorse are a common problem

Other troublesome weed species:

Leycesteria formosa	Himalayan honey suckle
Cytisus scoparius	broom
Reynoutria japonica	Japanese knotweed
Buddleja salvifolia	buddleja

2) FERTILISER APPLICATION

All seedlings will be fertilised with slow-release fertiliser. For nursery raised seedlings this should be done at the beginning of spring, which may coincide with planting. Wildings should however be fertilised in the year following planting to allow time for the seedling to recover from planting shock and establish new roots. Generally, a good rule to follow is to place fertiliser in a spade slot about 15cm from the seedling stem collar, situated either level or uphill of the seedling.

3) ANIMAL CONTROL

In many situations wild or domestic animals may be a threat to the successful establishment of plants, especially planted seedlings, through browsing, trampling, pulling out and crushing. They may also introduce weed species and encourage weed growth (*e.g.* by grazing).

The main species of concern are hares, goats, deer and domestic stock, but might also include pukeko. The two most important in terms of their potential impact are hares and domestic stock, particularly cattle. It is normally a relatively easy task to exclude stock through the construction or maintenance of a fence. Hares are much more difficult however, with shooting often the best method, but still usually only partially successful and often quite impractical to do. Other methods like the application of animal repellent works for a short time, but rain is normally a problem, protective sleeves over planted seedlings are expensive. Temporary fencing of the "vegetation islands" may be the most effective method of managing hares.

Animal control or exclusion will be required if they threaten the success of revegetation.

SUCCESS CRITERIA

The objective of the revegetation programme is to establish a core of self-sustaining vegetation created by direct transfer of established plants, planting seedlings, layering of slash or encouraging natural regeneration, that can develop with time to a complete cover of native woody plants and eventually forest similar to that which might exist on such sites within the locality.

Ecological restoration programmes, often last many years to decades (i.e. Tiritiri maatangi), and require many hundreds of (volunteer) people hours. These programmes will often plant a high density of plants to acquire significant vegetation cover within relatively quick time, this approach is not necessary for the objectives here.

Success criteria have been kept very simple to clearly identify when adequate revegetation for this purpose has been achieved. It has also been constrained to a short time frame, which compliments the life of a normal alluvial mine operation.

PLANTING GOALS

The goal is to have sustaining nuclei of vegetation within the mine footprint;

A minimum stocking rate of **1000 viable plants per hectare**, at two years post mining is required; this can be achieved by planting 100 “islands” per hectare with 10 plants per “island”.

This is actually a very low stocking rate in terms of achieving vegetation cover, however even this stocking rate will kick start the process of natural regeneration by many years.

The source of these plant nuclei will be any or all of the three revegetation methods described and each revegetation method will be assessed for successful establishment and growth of the vegetation. Most sites will require and benefit from a mixed method approach as all methods have the same ultimate objective of facilitating natural regeneration.

Direct transfer of stumps and root plates containing seedlings or clumps of excavated vegetation that:

- *exhibit positive growth, or*
- *has foliage that is of a normal healthy colour, and*
- *are not suppressed by weed competition, and*
- *give the same stocking rate as for planted seedlings.*

Planted seedlings from a nursery or wildings that:

- *are exhibiting positive growth, or*
- *have foliage that is of a normal healthy colour and density, and*
- *are not suppressed by weed competition.*

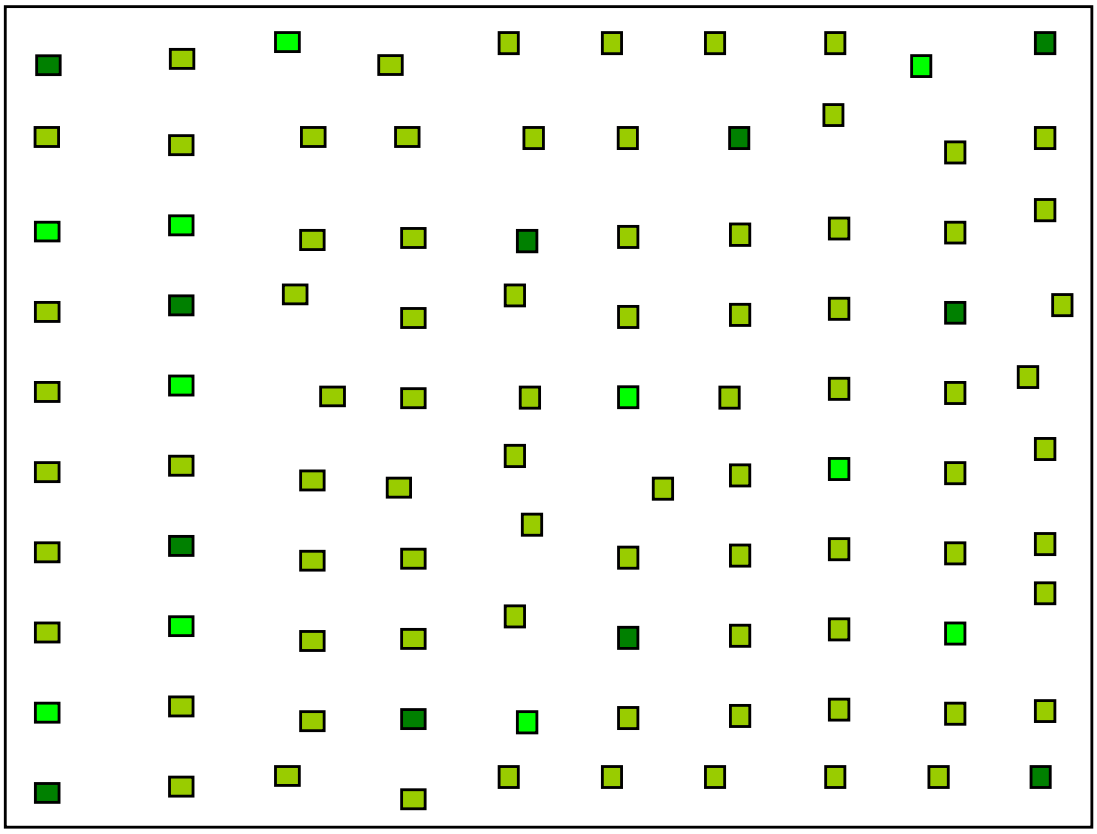
Layering of slash so that**:**

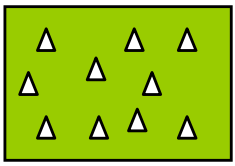
- *a seedling stocking rate at least equivalent to that for the planting of seedlings is achieved, and*
- *seedlings are exhibiting positive growth, or*
- *have foliage that is of a normal healthy colour and density, and*
- *are not suppressed by weed competition or likely to be to a level that would not allow seedling survival.*

If successful revegetation has not been achieved, as measured by the criteria above, additional planting will be required to attain the minimum stocking rate and seedling health.

Satisfactorily meeting the requirement of a successful revegetation programme will allow for the release of the performance bond held by DoC, providing all other conditions of the Access Arrangement have been met.

Figure 1: Potential planting pattern for 1 ha of re-contoured mine surface with no forest edge





- planting points with 10 plants each
- plants approx. 1m apart (approx 2 x3m^2)
- equates to 1000 plants per hectare

direct transfer clumps

seed bearing slash

planted saplings

Glossary

Conservation: preservation and protection of natural and historic resources for the purpose of maintaining their intrinsic values, providing for their appreciation and recreational enjoyment and safeguarding the options of future generations (Conservation Act 1987)

Revegetation: re-establishing plant cover. It may be done for a variety of reasons, such as erosion control, or beautifying an unattractive area.

Rehabilitation: to return a degraded ecosystem or population to a non-degraded condition; this may be different from its original condition.

Restoration: active management of modified or degraded habitats, ecosystems, landforms and landscapes in order to restore indigenous natural character, ecological and physical processes and their cultural and visual qualities.

Other Sources of Information

Atkinson, I.A.E 1994: Guidelines to the development and monitoring of ecological restoration
http://www.doc.govt.nz/conservation/native-plants/podocarp-hardwood-forests/

New Zealand Ecological Restoration Network:
http://www.bush.org.nz/

Ross, C. et al. 2000 Salvage and direct transfer for accelerating restoration of massive ecosystems on mine sites in New Zealand. Ministry for Economic Development
www.crownminerals.govt.nz/cms/minerals/conferences/2000-new-zealand-minerals-mining-conference-proceedings
Crown Minerals — 2000 New Zealand Minerals & Mining Conference Proceedings