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Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand

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REPORT INFORMATION SHEET

REPORT TITLE	BEST MANAGEMENT PRACTICES FOR APPLYING BIOSOLIDS TO FOREST PLANTATIONS IN NEW ZEALAND
AUTHORS	G.N. MAGESAN (SCION) HAILONG WANG (SCION) PETER CLINTON (SCION)
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OVERVIEW

Biosolids are sewage sludges that have been treated so they are suitable for beneficial use. Biosolids are commonly applied to production land in many parts of the world because they contain organic matter and macro-and micro-nutrients essential for plant growth.

This document sets out the best management practices for applying biosolids specifically to forest plantations in New Zealand. It is critically important in providing a basis for future policy and regulation of biosolids in New Zealand.

These best management practices need to be read and applied in conjunction with the *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZWWA, 2003), and the *New Zealand Environmental Code of Practice for Plantation Forestry* (NZFOA, 2007) so that appropriate best management practice is used in all aspects of the application of biosolids to forest plantations.

This document consists of five chapters and an appendix:

- The introductory chapter provides background information about biosolids production and land application in New Zealand, background to the evolution of the NZ Biosolids Guidelines published in 2003, and the reason for the development of the current document. It also looks at the benefits and impacts (or possible environmental risks) of biosolids application to forests including the effects on soil, plant and water;

- The second chapter describes how to select an appropriate forest site for application of biosolids. The site evaluation criteria include topography, soil suitability, ease of transportation and access to forests, vegetation, water resources, biodiversity, climate and the community;

- The third chapter provides information related to obtaining a resource consent, including site-specific land application planning, site management plan and community engagement and consultation;

- The fourth chapter focuses on the implementation of the plan. It covers biosolids application methodology, loading rates and silviculture management;

- The final chapter is on monitoring and reporting requirements for an established biosolids application system; and

- Information on biosolids quality and grading in New Zealand is given in the Appendix.

It is anticipated that these "*Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand"* will be used by forest owners and managers, biosolids producers, distributors and application operators, regulatory agencies (e.g. regional councils and government agencies), territorial local authorities, environmental groups, iwi and the broader community.

Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand

G. N. (Guna) Magesan, Hailong Wang, Peter W. Clinton

February 2010

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Purpose of the Document

The application of municipal biosolids to forested land provides a method of utilising wastes in a way that benefits landowners, resource managers and local authorities alike. The purpose of this document is to encourage best management practices in the application of municipal biosolids to forested land in New Zealand.

This document is needed because New Zealand currently has no specific regulations that govern all aspects of biosolids preparation and use. The critical legislation in New Zealand is the Resource Management Act 1991. Regional Council consent is required for the use of biosolids. Transport of biosolids is regulated by the Ministry of Transport. Many aspects of the use of biosolids in New Zealand are by means of voluntary codes of practice, however. Therefore, this document sets out the best management practices for applying biosolids, specifically to exotic forest plantations in New Zealand.

Separate management practices for the application of biosolids to forests are needed because the forest environment and forest management have specific characteristics. These characteristics can be harnessed to reduce some negative environmental and social impacts of biosolids. These best management practices will allow the user to: identify areas of exotic plantation forests that are suitable for the application of biosolids; choose an appropriate application method; ensure accurate monitoring and reporting; and address any community concerns.

This document is critically important in providing a basis for future policy and regulation of application of biosolids in New Zealand. Contamination by heavy metals (because of their toxicity and persistence in the soil) has been the principal driver behind regulations governing the land application of biosolids in many other countries (NZWWA, 2003). Some countries also regulate pathogen content, and a few regulate persistent organic contaminants.

These best management practices need to be read and applied in conjunction with the *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZWWA, 2003), and the *New Zealand Environmental Code of Practice for Plantation Forestry* (NZFOA, 2007) so that appropriate best management practice is used in all aspects of the application of biosolids to forest plantations.

It is anticipated that this document will be used by forest owners and managers, biosolids producers and contractors, regulatory agencies (e.g. regional councils and government agencies), territorial local authorities, environmental groups, iwi and the broader community.

Sources:
We have consulted a number of sources in preparing these best management practices but we would like to acknowledge three key publications:

- *Biosolids Management Guidelines for Washington State* (Cogger et al., 2000)
- *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZWWA, 2003); and
- *New Zealand Environmental Code of Practice for Plantation Forestry* (NZFOA, 2007).

Chapter 1: Introduction and Background

Biosolids and land application

Biosolids are potentially useful as they contain macro- and micro-nutrients essential for plant growth, and also contain organic matter that improves soil structure and water storage. Biosolids are suitable for use as fertilisers and soil conditioners (Magesan & Wang, 2003).

Heavy metals derived from biosolids can accumulate in soil if excessive amounts are applied (Speir et al., 2003; Horswell et al., 2005; Speir, 2008). Depending on the degree of treatment, biosolids can contain residual pathogenic micro-organisms (NZWWA, 2003; Horswell et al., 2007), persistent organic compounds, pharmaceuticals and personal care products (Stevens et al., 2003; Sarmah et al., 2006; Gielen et al., 2009) which may cause environmental risks.

Land application can play an important role in the management of biosolids internationally because of the following factors (NZWWA, 2003; UN-HABITAT, 2008; Wang et al., 2008):

- a ban on discharge of biosolids to the sea in most countries;
- the relatively low cost of land application;
- beneficial effects on crop growth and soil fertility;
- stringent regulations that discourage landfilling;
- regulatory pressures to reduce greenhouse gas emissions associated with organic material in landfills; and
- increased costs of landfilling and a shortage of space for new landfills.

In recent years, using biosolids beneficially has become an increasingly important to manage municipal waste in New Zealand (Magesan & Wang, 2003; Speir et al., 2004). Beneficial uses have been encouraged by various initiatives and policies from the Ministry for the Environment (MfE) and some local authorities (MfE, 2002; 2007). Some communities have either adopted, or are in the process of adopting, land application of biosolids. For example, the New Plymouth City Council uses its thermally dried biosolids as fertiliser (UN-HABITAT, 2008), and the Nelson Regional Sewerage Business Unit has been applying liquid biosolids to Rabbit Island forests since 1996 (Wilks & Wang, 2009). There is an increasing obligation for local government to engage with the community and, in particular, with Maori regarding the use of biosolids. Without community and, particularly, iwi dialogue, decisions may conflict with the values and views of the community.

Biosolids applied to the land can range in physical composition from liquid material with less than 10% solids (e.g. Nelson biosolids), through dewatered materials with about 15-30% solids (e.g. Christchurch biosolids), to dried material with more than 90% solids (e.g. New Plymouth biosolids).

In the absence of prescriptive regulation, various guidelines have been published that are designed to provide a framework for the use of biosolids in New Zealand. The aim of such guidelines has been to maximise the economic and environmental benefits of biosolids and minimise the risk of negative effects on the above as well as on human health (NZWWA, 2003). In 1975, the Department of Health (DoH) published a document with guidelines on biosolids management called *Disposal of Sewage Effluent and Sewage Sludge on Land.* These guidelines were updated in 1984 when a new document, *Disposal of Sewage Sludge on Land* was published. In 1992, the DoH published *Public Health Guidelines for the Safe Use of Sewage Effluent and Sewage Sludge on Land*,

(known as the 1992 DoH guidelines). These DoH guidelines were largely based on the 1986 Commission of European Communities Directive (CEC, 1986).

Biosolids are divided into two classes: *unrestricted-use* biosolids (Aa) and *restricted-use* biosolids (Ab, Ba, Bb) (NZWWA, 2003). The Appendix describes these classes in detail. These classes are based on their quality according to their stabilisation (A or B) and contaminant (a or b) grades (NZWWA, 2003).

In 2003, the NZWWA and the MfE jointly published a set of contaminant soil limits in a document entitled *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (the *NZ Biosolids Guidelines*) (NZWWA, 2003). The soil limits recommended in the *NZ Biosolids Guidelines* were based on a Lowest Observed Adverse Effects Concentrations (LOAEC) approach and were similar to those adopted in Australia (NZWWA, 2003).

New Zealand waste treatment plants and biosolids production

In 2007, the MfE reported that there were 320 public wastewater treatment plants in New Zealand producing total of 234,000 dry tonnes of biosolids annually. Of these, 74 were pond-based treatment plants which stored a total of 875 dry tonnes of biosolids annually. Of the biosolids produced at present, only 37,000 dry tonnes are diverted from landfill and beneficially used through land application or composting. The remainder (90%) of the biosolids are sent to landfill for disposal or used to cap a landfill (MfE, 2007; Goven & Langer, 2009).

Municipal biosolids must be adequately treated before they can be applied to land. The *NZ Biosolids Guidelines* recommends a wide range of treatment processes that can be used to achieve stabilisation grades of biosolids. Some of these processes are effective at reducing both pathogens (such as *Escherichia coli, Giardia intestinalis* and *Salmonella* species) and vector attraction[1], whereas others may be better at one or the other.

A recent survey showed that anaerobic and aerobic digestion, thermal drying, composting and lime stabilisation are the treatment technologies currently used in New Zealand. Some wastewater treatment plants are investigating the feasibility of solar drying and vermicomposting (Purchas, 2008).

New treatment methods and technologies have been employed to improve sewage effluent quality prior to discharge. As a result, the quantity of biosolids produced in New Zealand has increased. For example, after the upgrade to the Mangere wastewater treatment plant in Auckland, the volume of biosolids increased from 40,000 dry tonnes/year in the mid-1990s to 116,000 dry tonnes/year in 2006. With further upgrades to treatment plants likely, the total volume of biosolids produced in New Zealand will continue to increase (MfE, 2007).

Improvements in wastewater treatment, better source control of contaminants and enforcement of Trade Waste Bylaws have all helped to reduce levels of contaminants (e.g. heavy metals, organic contaminants and pathogens) in biosolids (NZWWA, 2003; Oliver et al., 2005). In many countries, contamination by heavy metals (because of their toxicity and persistence in the soil) has been the principal driver behind regulations governing the land application of biosolids (NZWWA, 2003). Some countries also regulate pathogen content, and a few regulate organic contaminants.

[1] *Vector attraction is the attraction of rodents, flies, mosquitoes or other organisms that can transport pathogens.*

Benefits of application of biosolids to forest plantations

Forest plantations are often established on land with low soil fertility. Consequently, there is significant opportunity to use biosolids beneficially in some of the 1.8 million ha plantation forest land in New Zealand. For example, if biosolids average 3% total nitrogen content, and were applied to land at 200 kg total nitrogen/ha/year, a total of 35,000 ha of land could benefit (NZWWA, 2003). This area is nearly equal to the area of forest harvested and replanted annually in New Zealand (NZFOA, 2007).

There are a number of benefits of applying biosolids to forest ecosystems rather than agricultural land (Cogger et al., 2000; Wang et al., 2008; Goven & Langer, 2009), namely:

- increased timber production;
- reduced likelihood of contaminants entering the human food chain; and
- lowered direct contact with humans.

Biosolids as fertilisers

When a biosolids material contains low levels of contaminants it can be used as a fertiliser because it contains most of the mineral nutrients required for plant growth (NZWWA, 2003; Speir et al., 2004; Su et al., 2007). As the organic components of the biosolids decompose, a slow release of nutrients continues for many years.

Forest production

Researchers have documented responses of up to 100% growth rate increases (over an entire rotation) for Douglas-fir and over 30% increase for radiata pine growth (over twelve years) in stands treated with biosolids (Cogger et al., 2000; Kimberley et al., 2004; Wang et al., 2006; 2009).

Tree growth can be affected by various factors including site characteristics and stand age. In a review, Cogger et al., (2000) concluded that trees often grow better when treated with biosolids instead of chemical nitrogen fertiliser, and the effect appears to last much longer.

Repeated applications of biosolids to a radiata pine plantation growing on low fertility sandy soil on Rabbit Island near Nelson have improved tree nutrition. Foliar nitrogen increased by up to 50% with a resulting 30% improvement tree growth over twelve years (Wang et al., 2006). Effectively, the site has been transformed from relatively low productivity to average, or above average, productivity. This increased productivity has also had some negative impacts on wood quality attributes with larger branches, reduced wood density and wood stiffness of the tree crop. However, the increased stem volume and greater average log diameter resulting from the biosolids treatments are predicted to far outweigh any negative effects on log value due to the reduced stiffness. The use of biosolids is predicted to increase the net stumpage value of logs by 41% at harvesting, providing a large positive impact (Wang et al., 2009).

In contrast, repeated application of biosolids to a radiata pine plantation growing on a low fertility soil near Christchurch did not significantly improve available nitrogen to trees nor increased tree growth (Clinton & Leckie, 2006). This may have been due to low rainfall being the major constraint to tree growth.

Environmental and social risks

The concentrations of contaminants in municipal biosolids depend on the degree of treatment the biosolids receive and the source of the sewage. The biosolids-borne contaminants may have environmental impacts such as adverse groundwater quality, damage to soil micro-organisms and plants, as well as risks to animal and human health (NZWWA, 2003; Speir et al., 2003; Horswell et al., 2007; Speir, 2008; Gielen et al., 2009).

The possible environmental risks of biosolids may be managed in a number of ways. The relevant risk mitigation approaches for different environmental criteria are described below.

Surface and groundwater quality

Nutrients (such as nitrate and phosphate), metals or organic substances can leach from biosolids into groundwater. Nitrate (a water soluble form of nitrogen) is mobile in soil although such leaching can be minimised by limiting the rate at which biosolids are applied to the rate of nitrogen uptake by plants (Magesan et al., 1998). Phosphate is relatively immobile in soils and most New Zealand soils have a high phosphate retention capacity so phosphate leaching is unlikely (White & Sharpley, 1996). Contaminants of biosolids, such as heavy metals and potentially harmful organic compounds, are generally retained in the surface layers of the soil (McLaren et al., 2007; Su et al., 2008). An extensive literature review by Smith (1996) concluded such contaminants are unlikely to negatively impact on groundwater quality.

The risks of contaminating surface water can be reduced by ensuring that biosolids are not spread too close to watercourses (streams, rivers or the edges of lakes), particularly on waterlogged or steeply sloping land or during or prior to forecasted heavy rainfall events (Cogger et al., 2000).

Odour generation and air quality

Odour generation from land-applied biosolids is one of the most noticeable environmental issues, and is often associated with biosolids being stored and transported in an anaerobic state. To overcome this issue, biosolids should be thoroughly aerated during storage and covered properly during transportation. Another way to minimise odour generation is the incorporation of biosolids into the soil when practicable. This approach also minimises ammonia volatilisation from biosolids to the atmosphere. For forest applications of biosolids, soil incorporation is impractical, however. This means that odour issues may occur but these are generally mitigated by ensuring application is at a considerable distance from dwellings.

Environmental and public health

Application of biosolids at rates necessary to meet the nitrogen demands of tree crops are unlikely to cause detrimental effects on soil microbial communities and tree crop health (Smith, 1996; 2009a,b). Before land application, biosolids must be sufficiently disinfected through stabilisation processes (NZWWA, 2003) to ensure no health risk to the either operators or the public. Limiting public access for an extended period to any areas where biosolids have been applied can also effectively minimise the risk to public health. Recent research (Horswell et al., 2007) supports the NZWWA (2003) guidelines to restrict public access for six months to forests where biosolids have been applied.

Occupational health and safety

In accordance with the requirements of the Health and Safety Employee Act 1992, the biosolids operators need to prepare an occupational health and safety (OSH) plan to ensure workers handling biosolids are adequately protected from health risks.

As a minimum, workers should be immunised against tetanus, and possibly consider immunisations against hepatitis A and B. The workers should also be provided with appropriate personal protective equipment, such as goggles, splash-proof face shields, respirators, liquid-repellent coveralls, and gloves. Useful guidance can be found in a National Institute of Occupational Safety and Health (NIOSH) publication (NIOSH, 2002).

The NIOSH US Centre for Disease Control guidelines for individuals handling biosolids are:

- no food or drink is consumed or smoking permitted by employees while working with biosolids or biosolids products;
- touching of face, mouth, eyes, nose, or open sores and cuts are avoided while working with biosolids;
- hands are washed thoroughly and nails scrubbed well with soap and water after contact with biosolids;
- hands are washed thoroughly before consuming food, and at the end of the working day;
- cuts and skin abrasions are covered with waterproof dressings or gloves;
- a suitable change of clothing is worn during work, and safety footwear and gloves are worn to protect against injury from sharp objects; no work clothes are worn at home or outside the work environment;
- eye protection is worn to protect against dust. If biosolids contact eyes, thoroughly but gently flush eyes with water;
- if aerosols are considered a problem, masks conforming to a recognised standard should be worn to prevent inhalation. Wherever possible, workers should be upwind of the land application process;
- on windy days, avoid spreading biosolids by high-pressure spray or disturbing dry biosolids (e.g., compost) that would create dust; and
- excess biosolids from footgear are removed prior to entering a vehicle or a building.

Community engagement

The community (including iwi, adjacent landowners, forest recreational user groups, farming groups, environmental organisations) should be made aware of proposals for biosolids application in a forest. These stakeholders should be given the opportunity to participate in decisions and raise any concerns prior to applying for resource consent.

Chapter 2: Forest Site Evaluation

Evaluating a forest site thoroughly before biosolids are applied is critical for minimising environmental risk; addressing local community concerns; obtaining necessary consents; maximising potential for tree growth response; and reducing costs.

Similar to criteria used when siting a plantation forest, key criteria to be considered are:

- topography;
- soil type;
- ease of transportation and access to forest sites;
- distance from the biosolids generation site (wastewater treatment plant);
- vegetation (characteristics of the stand and understorey) and tree/plant capacity to use biosolids-derived nutrients;
- buffers;
- on site storage;
- water resources;
- biodiversity;
- climate;
- community; and
- site surveys.

Topography

Topography of a forest site will dictate the suitability for biosolids application. Forest sites containing steep slopes are generally less desirable and may have constraints relating to forest operations under existing resource consents. Applying biosolids to steep slopes can increase the risk of run-off. Topography will have a large impact on the selection of the biosolids application method. For example, biosolids should not be applied on slopes >25° to reduce the risk of run-off (Wolstenholme et al., 1992).

Soil suitability

Soils play a significant role in the outcome of biosolids application. The soils on which most New Zealand forests are planted are typically of average to poor natural fertility and are often erosion prone (NZFOA, 2007). Forest soils are generally less compacted than similar soils under grazed pasture (NZFOA, 2007). They tend to have more macropores thus increasing the infiltration capacity.

Soil properties such as fertility, texture, structure, drainage and depth can affect the suitability of a particular site for short-term and/or long-term applications of biosolids. Soil properties may also limit the type of biosolids applied, the method and timing of application of the application.

Soil fertility: The greatest benefit to tree growth is likely when biosolids are applied to a soil deficient in nutrients, particularly nitrogen and/or phosphorus (Kimberley et al., 2004; Wang et al., 2004). Soil with low organic matter content can also greatly benefit from biosolids application increasing nutrient supply in addition to nutrient and moisture retention.

***Soil texture*:** Forest sites with sandy soils often have low productivity due to low nutrient content, low retention capacity and low moisture retention. These soils can benefit the most from biosolids application. Sandy sites also have the advantage of generally being

suitable for heavy vehicle access. However, high loading rates of biosolids should be avoided on sandy soils to minimise potential nutrient leaching. Because of their coarse-texture, such soils are often well-drained and have low retention capacities. In finer textured soils (such as clay soils), there are preferential flow paths (such as from cracking in the soil) that can enable contaminants to move rapidly through the soil. Thus, leaching of nutrients and contaminants may occur (Carrillo-González et al., 2006), if large quantities of biosolids are applied.

***Soil structure*:** Soil structure influences water movement and soil aeration. At its maximum moisture-holding capacity, a soil with good structure has half of its pore space filled with water. The other half of the pore space is filled with air which sustains biological activity. Texture, organic matter, and management practices all have an effect on soil structure. Since application machinery may cause structural damage to the soil, surface application of biosolids to poorly structured and/or poorly drained soils should be avoided (USEPA, 2006).

***Soil drainage*:** Seasonal water tables play a role in site suitability for biosolids application because pathogens tend to survive longer in saturated soils and the rate of die-off declines, increasing the risk of pathogen leaching or run-off (USEPA, 2006).

While evaluating forest site, if grey-coloured soil mottles are found, it may indicate that there may be an issue with soil drainage especially over the winter period. In such cases, surface runoff could be an issue. Water moves through sandy soils more easily as they contain large pores. However, most silt and clay (fine-textured) soils do not allow rapid infiltration because of small sized pores, and the risk of both nutrient and contaminant run-off is therefore greater (USEPA, 2006).

***Soil depth*:** Soil depth is limited by bedrock or by restrictive (compacted or dense clay) layers. Soil depth affects site productivity and increases the risk of both nutrient and contaminant runoff on some very shallow soils.

Few sites have an ideal soil for application of biosolids. A typically suitable soil usually has the following characteristics:

- deep, well-drained;
- medium textured (e.g. silt loam, loam or fine sandy loam);
- no restrictive layers (e.g. claypan or fragipan) in subsoil within 1 m of ground surface;
- no compaction zone;
- moderate to strong surface soil structure, low shrink-swell potential;
- available water-holding capacity of 300 mm or more;
- moderate to rapid infiltration;
- moderately slow to moderately rapid permeability;
- level to gently rolling land surface, 0–3% slopes; and
- not on an active floodplain.

It is prudent to involve a soil scientist for an on-site evaluation before the biosolids application programme commences.

A soil survey may be used for site evaluation. The soil survey may also show the distribution of suitable and non-suitable soils. Areas of uniform suitability are easier to manage than areas of non-uniform suitability. A soil survey usually contains three parts: maps, text and tables.

Soil maps show the spatial distribution of the different soils in an area. Forest maps may provide information on forest age, species and stocking. This information can be

combined to obtain a specific site and land use map using geographic information systems (GIS).

The *text* describes the properties of each soil type mapped in the region. Information for each soil type includes: soil name, general location and area; landscape position and slope; texture, colour and structure of each soil horizon; soil depth; soil-water relations such as drainage and permeability; use and management of the soils such as average pH and native fertility, and soil limitations and appropriate management practices.

The *tables* from a soil survey provide additional information about soil properties (such as fertility, texture, permeability, water-holding capacity, pH, and, in some cases, organic matter content, water tables and depth to bedrock) and how they may affect various land uses.

Background information on soils may be obtained from the Land Information New Zealand (LINZ) website www.linz.govt.nz or the Landcare Research websites http://smap.landcareresearch.co.nz/ or http://www.landcareresearch.co.nz/databases.

Ease of transportation and access to forest site

It is rare to have a biosolids application site near the wastewater treatment plant where the biosolids are produced. Since transporting biosolids by truck (the most common form of transport) can be the most expensive part of a land application programme, the distance and route from the treatment plant needs to be considered carefully.

When evaluating the most appropriate transport route for biosolids, important factors include: cost; distance; acceptable transport corridors; access to receiving lands; spill potential; and location of residential areas. The variable costs of haulage will be directly proportionate to the distance between the treatment plant and land application site. The shortest route may not be possible, however, because trucks driving through cities, residential areas or some neighbourhoods are not desirable. Load restrictions, either permanent or seasonal, can eliminate access along certain routes too. It is also more cost-effective to undertake volume and weight reduction processes (for example, dewatering) before transporting.

Many forest sites, especially those that are managed, usually have access roads. Trucks transporting biosolids need safe access via a public all-weather road to and from the site. When biosolids are delivered at a faster rate than they can be applied, storage areas must be identified and authorised in a site permit. The trucking companies need to have an emergency response plan in case of a vehicle accident or spill.

Vegetation

Forest density and vigour can influence both the amount of biosolids that can be applied and the application method. Young, vigorous forests that include both trees and understorey can readily assimilate nutrients so biosolids can be applied with a higher loading rate compared with bare soil (Cogger et al., 2000). A well-established understorey can also decrease the potential for run-off and nutrient leaching. Application rates may be reduced or halted on forests ready to be harvested (minimising health risks to harvesters) or on recently harvested forests – to minimise surface run off due to soil disturbance.

Riparian vegetation and indigenous vegetation also need to be mapped and excluded from the vegetation zone. All riparian vegetation, but especially indigenous species, provides a number of ecological benefits, including: stream bank stability (reduced erosion and improved water quality); sediment trapping capacity; and provision of shade, which

maintains cooler and more stable water temperatures (NZFOA, 2007; Langer et al., 2008b). Such areas need to be identified so that they can be protected from biosolids application or its impact.

Buffers

Buffers are non-application areas located within a permitted biosolids application site. They are usually adjacent to waterways, property boundaries and other features where biosolids application is not intended. The purpose of buffers is to: keep the application on the permitted site; control run-off from the treated area; protect surface water; and reduce off-site odours (Cogger et al., 2000). Buffers need to be wide enough to protect the surrounding environment in case there are over-sprays or other errors during application, and to absorb contaminants and filter run-off. Identifying buffer locations is a critical part of site evaluation as buffers may reduce the usable area of the site. Sufficient land area for buffers should be included when a site is selected.

Waterways, cliffs, or steep slopes are likely to be less accessible and require additional buffer zones. Buffers reduce the area available for biosolids application. Avoiding buffers can increase the cost of application. Buffers may already exist for consents relating to forest operations and these also need to be maintained.

Site buffers can be grouped into three categories: (i) surface water; (ii) groundwater; and (iii) property. Both surface water and groundwater buffers protect off-site water quality. Property buffers can control potential public exposure to biosolids application sites. When designing property buffers, the main objective is to reduce any nuisance to neighbours and the wider public.

A buffer is part of the permitted area. Buffers need to be clearly marked and monitored before biosolids are applied. When the biosolids applications encroach on the buffer area, the cause needs to be determined and any application problems corrected. In practice, it may be better to increase the size of the buffer beyond what is required by the site permit.

The Christchurch biosolids plantation resource consent offers examples to avoid contamination of water bodies (Table 1) (cited in Jenkins, 1998).

Table 1: Suggested buffers for a site to be applied with biosolids

Forest margins	Buffer zone width 10 m from the forest edge
Open water courses	Buffer zone width 50 m from the forest edge
Residential areas	Buffer zone width 250 m from the forest edge
Occupied dwellings	Buffer zone width 100 m from the forest edge
Drinking water bores	Buffer zone width 50 m in any direction and 250 m upgradient in the direction of groundwater movement ± 30 degrees

Water resources

Water resource issues that need to be considered during site evaluation include: depth to the water table; and distance to aquifers. It is best to maintain a height of at least one metre above the water table. When a site is near a waterway, buffers are required to protect water bodies from contaminated run-off or erosion.

Biodiversity

Many plantation forests contain areas of ecological and cultural value. Natural resources (streams, wetlands and their riparian margins), or areas of native vegetation, which were not cleared during the initial development stage need to be considered. In some cases,

plantation forests appear to provide the only known habitat for a particular indigenous species (NZFOA, 2007). For example, the critically endangered ground beetle *Holcaspis brevicula* occurs only in Eyrewell Forest on the Canterbury Plains (Brockerhoff et al., 2005). Biosolids should not be applied on such sites until the potential effects of biosolids application on endangered species are understood.

Climate

Climate, particularly rainfall, can affect application of biosolids to the land. Excessively wet conditions can increase surface run-off and also preferential flow through soils. The passage of heavy application machinery over wet soil can compact the soil through compaction, which, in turn, may lead to surface ponding and anaerobic conditions. Depending on soil type, the application of biosolids under heavy rainfall conditions should be avoided. On the other hand, the lack of adequate soil moisture prior to the application of biosolids can reduce the growth response of the tree crop.

Community

Community involvement is necessary to ensure that potential social and impacts are explained, discussed and addressed. This is particularly important when the forests likely to receive biosolids applications are within close proximity to residential areas or areas that are frequently used by the public.

Forest sites of significance to Maori have both archaeological and cultural values that will need to be taken into account during site evaluation for biosolids application. In some circumstances, the tangata whenua (local Maori community) of an area may provide information about Maori heritage places to assist with their management, whereas some prefer not to disclose wahi tapu (sacred) sites as they do not want their location to become common knowledge. If the tangata whenua provides any information about a wahi tapu site, their approval should be sought before information about these places is included in any inventory (NZFOA, 2007).

Site surveys

Field surveying is used to collect additional information for site planning. After completing field surveys and gathering relevant soil information, the operational planner will have identified any important environmental values in the area of interest and have some understanding about concerns of affected parties.

Table 2 identifies a number of factors that should be considered for evaluating the suitability of a site for biosolids application. The numbers provided are suggestions for ranking sites in the order of their desirability for biosolids applications. The system is best used when comparing two sites.

Table 2: Ranking system for forest application site evaluation*

Factor	Relative numeric rank
Topography	
Slope:	
Less than 10%	10
10-20%	5-8
20-30%	1-6
Greater than 30%	0
Site continuity:	
No streams etc., to buffer	10
1 or 2 requiring buffers	6
Numerous discontinuities	0-3
Transportation	
Distance	1-10
Condition of the roads	1-10
Travel through sensitive areas	0 - 3
Forest Access	
Per cent of access track system in place	0-10
Ease of new construction:	
Easy (suitable soils, minimal slope, young trees)	7-10
Difficult	1 - 5
Erosion hazard:	
Little (suitable soils, minimal slope)	7-10
Great	1 - 5
Soil	
Low fertility (deficient in nitrogen and phosphorus)	10
High fertility (high in nitrogen and phosphorus supply)	0-6
Soil type:	
Sandy gravel	5-10
Sandy (alluvial)	5-10
Well-graded loam	5-10
Silty	3 - 8
Clayey	1 - 5
Depth of soil:	
Deeper than 3 m	10
1 – 3 m	8
0.3 – 1 m	4
Less than 0.3 m	0
Vegetation	
Stand age:	
Hardwoods: Less than 4 years	4-10
Hardwoods: 4 years or greater	8
Conifers: 6 to 25 years	7-10
Conifers: 3 to 6 years	4-10
Conifers: 0 to 3 years	0 - 8
Greater than 30 years (minimal nutrient uptake)	0 - 6
Understorey:	
Over 90% of site	10
Over 70% of site	7

Partial vegetative cover	2 - 7
Water Resources	
Groundwater - depth to average seasonal water table:	
More than 5 m	10
1.5 – 5 m	7
1 – 1.5 m	4
Less than 0.6 m	0
Groundwater flow:	
Away from usable aquifer	10
Significant contribution to usable aquifer	2-5
Surface water channels:	
Easily to define and buffer	7-10
Difficult to define and buffer	1 - 5
Climate (e.g., frequency of storm events, etc.)	1-10

** Note: A ranking of 0 for any of the factors means the site is generally not suitable. A ranking of 1 to 3 indicates there may be some problems with the site. For a site to be considered suitable, other factors must be able to positively offset any low ranking factor (adapted from Cogger et al., 2000).*

Recommendations for forest site evaluation:

- Avoid biosolids application to wet soils, riparian areas, areas of native vegetation and high loading rates on sandy soils;
- Limit public access to the biosolids-applied area for six months to eliminate the risk to public health;
- Maintain adequate buffers between application areas and sensitive areas to minimise contamination;
- Reduce risks to surface water by ensuring that biosolids are not spread too close to watercourses, on waterlogged or steeply sloping land, and during or prior to heavy rainfall events;
- Prepare maps for inclusion in written plans (see next chapter) so the user can clearly identify the proposed site(s) where biosolids are to be stored and applied; and
- Engage the community, including iwi, in the decision-making process.

Chapter 3: The Consent Process

The Resource Management Act 1991 (RMA) requires councils to manage natural and physical resources in a sustainable manner. It states that resources must be managed so any adverse effects in the environment (including social, economic, aesthetic, and cultural conditions) are avoided, remedied or mitigated. The use of biosolids, therefore, comes under the RMA.

Assessment of environmental effects (AEE)

The pathway for processing a resource consent application is set out in sections 92–120 of the RMA. One of the key requirements for a resource consent application is an AEE. The Fourth Schedule of the RMA contains a list of the matters that should be included in an AEE and those that should (at least) be considered when preparing an AEE. For applying biosolids to forests, the AEE could cover the following areas: effects of nitrogen and phosphorus, pathogens; heavy metals; persistent organic compounds and other contaminants; and effects on the community.

Site-specific land application plans

Written plans are part of the permit requirements for all land application of *restricted use* biosolids under the RMA. Plans are not generally required for projects using *unrestricted use* biosolids. The Appendix gives the definitions of *restricted* and *unrestricted use* biosolids. The aim of planning is to ensure costs and potential pitfalls are anticipated, the project is in compliance with regulatory requirements and project managers have formal guidance.

The plan needs to acknowledge and address concerns of the community impacted by biosolids application to forests. The plan also provides an opportunity to integrate consent requirements with other desirable site management practices, such as community engagement and a complaints procedure. Regional councils generally require site-specific land application plans as part of the resource consent application for sites where *restricted use* biosolids will be applied (NZWWA, 2003).

Key elements of the site-specific plan should include:

- past biosolids applications;
- method and timing of biosolids applications;
- monitoring;
- biosolids storage;
- detailed site maps;
- groundwater and surface water management plan;
- odour management plan;
- restriction of public access; and
- community engagement and consultation.

Additional planning elements that should also be considered are: transportation and delivery site management; and administration and reporting.

Past biosolids applications

It is important to know the history of biosolids application of each site, particularly if biosolids with heavy metal contents exceeding any value in Table A.1 have been applied in the past. If this is the case, the dates and amount of application, heavy metal content,

and area where the biosolids were applied need to be noted and considered in any estimates of future biosolids application.

Method and timing of biosolids applications

Since access to a forest site treated with biosolids should be restricted for six months, it can disrupt other planned forest management activities. A schedule needs to be prepared that relates the timing of biosolids application to other forest management activities such as stand establishment, pruning or thinning activities, and harvesting.

When possible, application equipment (manufacturer and model) needs to be documented. The accuracy of the application equipment (per cent error) and the range of application rates the equipment can deliver need to be estimated and documented. A description of how the application equipment will be calibrated and how application rates will be verified is required to ensure the desired application rates are achieved.

Monitoring

Pre-application monitoring provides baseline data for each site. Any soil, groundwater, or surface water monitoring done within the last two years also needs to be reported. The schedule for monitoring the site during the life of the project needs to be described. This should include details of any monitoring required by regulatory authorities (e.g. regional councils). While biosolids applications benefit tree growth, they could also adversely affect the environment if the nutrients and contaminants present are not properly managed. For a well researched species (e.g. radiata pine) with established nutrition criteria, it is also useful to carry out regular foliage analysis to identify any nutrient imbalances that may be exacerbated by the application of biosolids.

Storage of biosolids

The consent permit for biosolids management may have only basic requirements for biosolids storage. Management practices that will protect surface and groundwater, and that will keep odours and other nuisances to a minimum during storage need to be documented. A range of information is required for the planning and construction of any biosolids storage facility. Details needed include:

- expected time of storage (i.e. when the stored biosolids will be used);
- type of biosolids in terms of solid content and levels of disinfection;
- distances to residential areas and major roads;
- distances from storage to application sites;
- storage capacity;
- management practices to control run-off and leaching;
- control of nuisances (such as dust, mud, vectors and odour);
- methods and equipment for removing biosolids from storage;
- environmental monitoring protocols; and
- engineering plans on the size of the storage facility and the risk to water sources may also be required.

Site maps

Knowledge of site location, geography and topology are essential to the correct application of biosolids (see previous chapter). The availability and use of good quality, detailed maps is important through all planning phases. It is critical to incorporate knowledge of identified environmental issues into executable operational plans. Suitable

maps need to be included so the user can clearly identify the proposed site(s) where biosolids are to be stored and used. There should be a vicinity map, which shows transportation routes, access to and the locations of application sites and individual field maps showing storage and application areas, wells, surface water, and buffers. Streams, lakes, wetlands and intermittent streams need to be noted, as do widths of buffers and biosolids application areas. A map showing site topography, property ownership (including ownership, zoning and use of adjacent properties) and soil maps for each field should also be included in the plan.

Groundwater management plan

It is important to note whether the seasonal high groundwater level is expected to be within 1 m of the soil surface at any time during the year. If this is the case, then a groundwater management plan needs to be developed, explaining how groundwater will be protected. The groundwater management plan may also be necessary in groundwater protection zones prescribed by regional councils.

Restriction of public access

All plans must specify if the public will have access to the site. It is necessary to include the location, design and size of all signs that will be posted. If signs will not be used, describe how public access will be prevented/restricted.

Transportation

The transportation of biosolids from a wastewater treatment plant to the application site poses a potential environmental impact in the event that biosolids escape from the vehicles in transit. It is essential to ensure the safe transportation of the biosolids to site. Grade B biosolids (see Appendix) are considered to be dangerous goods and their transport falls under the provision of the Land Transport Act 1993. The rules governing the transport of dangerous goods (Land Transport Rule No. 45001: Dangerous Goods 1999) requires compliance with NZS 5433:1999: *Transportation of Dangerous Goods on Land*. This document contains detailed technical standards for labelling, loading, placarding, segregation and documentation (NZWWA, 2003).

Any plan must contain guidance for transportation and delivery. Information on: proposed and alternate haul routes; vehicles; and spillage management need to be included. Detailed information regarding the proposed haul route should include details such as: its suitability and stability for truck traffic, route accessibility during bad weather, closeness to residential areas, time of the day to use routes and estimated number of trips per day.

These factors, once identified, should be evaluated and any possible risks identified then mitigated. The load capacity of the vehicles involved in hauling biosolids, plus any safety features for controlling spills and vehicle cleaning procedures all need to be described. A response plan for any emergency (e.g. a spill) needs to be developed and described.

Site management and administration

Site management plan

Having a plan for each land application site is an important way to co-ordinate the management of risks associated with a specific project.

Forest management plan

Timing of biosolids application should be coordinated with the forest manager and operational staff in order to avoid coinciding with forestry management activities.

Record keeping requirements

Record keeping is an important component of all quality assurance and risk management. The consent authority requires the maintenance of records.

Monitoring of biosolids applications

Key monitoring information, such as: how the application equipment will be calibrated; the frequency and method used for determining the per cent total solids; people responsible for monitoring buffer areas around sites; and remediation measures, needs to be recorded.

Contingency plans

Plans for a range of contingencies, such as: bad weather; accidents; and breakdowns, need to written down. The phone contacts for emergencies need to be listed and the necessary equipment available to respond to an emergency should be described.

Responsibilities

It is important to list the names and phone numbers of those who are responsible for the following: transportation and delivery of biosolids; biosolids storage; biosolids application (including calibration and adjustment of application procedures); site management and recordkeeping; monitoring site buffers; collection of samples for environmental and public health monitoring; laboratory analyses of environmental samples; and reporting to regulatory agencies.

Reporting

A list of the regulatory agencies that will receive the reports needs to be prepared and included in any plan. A template detailing the required elements of any reports should be provided, and the schedule for report submission should be included.

Community engagement and consultation

The RMA requires councils to manage natural and physical resources, including historic and heritage places, in a sustainable manner. Historic and heritage places are a non-renewable resource. Plantation forests may contain a range of such places related to pre-European Maori land use and occupation, such as pa sites, terraces and storage pits. Local and regional councils often include heritage places in their plans, although these lists are often derived from lists compiled by the New Zealand Archaeological Association and the Historic Places Trust. The majority of these places are archaeological sites through association with human activity occurring before 1900. It is advisable to invite community (including iwi) involvement in the scoping of the assessment of environmental effects (AEE) and to seek community or interest group comment on the draft of the AEE before it is finalised.

Community participation

Community participation in deciding the options for the use of biosolids will enable the regulatory authority and the community to formulate a joint strategy for biosolids management and provide acceptable solutions before the consent process is initiated. If this process leads to the decision to apply biosolids to forests/land, further community engagement is vital to ensure all relevant issues regarding land application of biosolids are considered and have community support (Langer et al., 2008a). Both direct impacts on community use of the forest land where biosolids are to be applied, and the indirect effects of the environmental consequences of biosolids application need to be considered.

Iwi consultation

There is an additional requirement under the RMA for councils to consult with iwi during the development of rules governing the application of biosolids to land (Treaty of Waitangi 1840 obligations). With any application of biosolids to land, cultural sensitivity needs to be addressed by consultation. This sensitivity may be due to location, history or current practices (Awatere, 2003).

Engagement with Maori may use a two-stage process. The first stage involves initial dialogue with the council and key members of the iwi such as the runanga environmental manager, kaumatua and other important elders. These key people will then transfer the knowledge they have gained to all members of the iwi. Once the whole community is informed, a hui is held so that the whole community has the opportunity to engage in dialogue.

Iwi issues in relation to the application of biosolids to forests/land could include (but may not be restricted to) the following (NZWWA, 2003): potential contamination of food sources; proximity to sites of food preparation; harvesting and processing; potential contamination of water bodies; the need for potential mitigation measures (riparian planting); avoiding applying biosolids on, or in the vicinity of, wahi tapu sites, potential constraints on future land uses as a consequence of biosolids applications (land subject to Treaty of Waitangi claims); and monitoring requirements.

Recommendations for the consent process:

- Prepare an AEE covering the effects of nutrients, heavy metals and other contaminants;
- Provide a site-specific plan to ensure the biosolids application is sustainable;
- Enable the community to address actual local needs and incorporate local knowledge into the decision making; and
- Involve iwi in a staged process where dialogue is first made with key members of the runanga and secondly with the full iwi at the hui process.

Chapter 4: Implementation

There are a number of factors that need to be considered when biosolids are applied to forest plantations.

Any biosolids application strategy must include: application methods and systems; application rate and timing; and nutrient and contaminant loading. Applying biosolids under appropriate climatic conditions will ensure that the biosolids remain in place and are not blown off-site or washed onto non-target or sensitive areas such as waterways (NZWWA, 2003).

Methods for applying biosolids

Application methods for biosolids depend on both the physical nature of the biosolids material and its moisture content at the time of application. In New Zealand, the typical methods for applying biosolids to forests are shown in Table 3.

Table 3: Summary of application methods used in New Zealand and suitable conditions

Type of biosolids	Application method	Range	Tree age	General comments
Liquid (<3% solids)	Spray irrigation	2 – 25 m	> 6 yrs	Any terrain. Low to moderate capital and operational costs
Semi-solid (up to 5% solids)	Spray cannon	2 – 25 m	> 6 yrs	Low to moderate capital and operational costs
Dewatered (>15% total solids)	Custom-made or manure spreader	0.25 – 25 m	> 3 yrs	Low capital and operational costs. Care should be taken to ensure minimal damage to trees.
Thermally dried biosolids	Aerial application or farm fertiliser spreader		Any age	Most suitable for steep and difficult sites. High capital and operational costs, if aerial application is employed.

Application vehicles can be custom-made and such vehicles are used in both Nelson and Christchurch.

Spray cannon: Biosolids are often applied from a tanker/sprayer vehicle. For young plantations, vehicles spraying liquid or semi-solid biosolids can apply biosolids containing up to 15% solids over the canopy. For example, liquid biosolids containing 1-3% solids treated with an Autothermal Thermophillic Aerobic Digestion (ATAD) system at the Nelson regional wastewater treatment plant have been applied to a 1000 ha radiata pine plantation on Rabbit Island near Nelson since 1996 (Wilks & Wang, 2009). These biosolids are transported by converted milk tankers to the forestry stands. The tankers are parked on the side of access roads and the biosolids pumped to a rubber-tracked vehicle known as a “Maggot”. This vehicle is fitted with a hose reel on the back and an irrigation nozzle on each side of the front crash bars. The Maggot drives into the forest and is capable of spraying up to 25 m either side of the path (Plate 1). To minimise the potential damage to the young trees, this application method has been recommended for applying biosolids to crops of six years or older.

Plate 1: The mobile, tracked spreader, known as the "maggot", has a built-in spray gun attachment that sprays liquid biosolids up to 25 m either side of the unit as it moves through the trees at Rabbit Island, Nelson.

***Custom-made or farm manure spreader*:** Biosolids containing 15-95% solids (dewatered or dried biosolids) can be applied by manure spreaders if tree rows are spaced appropriately. It has been suggested that the best age for trees is more than three years old to minimise the potential physical damage to the trees. The distribution area of biosolids can be adjusted in a properly designed biosolids spreader (Plate 2).

Plate 2: The custom-made machine with an adjustable device to control the biosolids travel distance was used to spread dewatered biosolids cake in Christchurch.

***Aerial application*:** Aerial (fixed-wing plane or helicopter) distribution is possible for thermally dried biosolids and when a ground-based application system is not economically feasible due to difficult site access. Thermally dried biosolids have an advantage over other types because of lower transport, handling and spreading costs (Peregrina et al., 2008). In the thermal-drying process, digested or undigested biosolids are dried at high temperatures (range: 120 – 600°C). This greatly reduces the volume, and such thermally

dried biosolids can then be applied like a mineral fertiliser. In New Zealand, wastewater treatment plants in Hutt Valley and New Plymouth use this technology. A number of other treatment plants are considering employing the thermal-drying process (Purchas, 2008). There are a number of New Zealand companies specialising in the spreading of agrochemicals and fertilisers using aircraft. Such companies could adapt their equipment to transport dried biosolids and apply them with reasonable accuracy (Plate 3).

Plate 3: A helicopter equipped with a fertiliser spreader can be used to apply thermally dried biosolids on difficult sites.

Major problems associated with aerial application are cost, dust/spray-drift and water contamination. Dust and spray-drift extending past the pre-determined buffer areas can be managed by specifying a maximum wind speed above which application is stopped. Water contamination can be minimised by avoiding aerial application within certain distances of public waters.

Application rate and timing

While the biosolids application can improve tree growth, it could also adversely affect the environment if the nutrients and contaminants present are not properly managed. Site-specific trials should be conducted to fine-tune application rates. Because of the nature of the material and limitations of the application equipment, it is difficult to deliver the exact application rate planned. It is reasonable to expect actual application rates to be within 10% of the planned rate. These trials would focus on nutrient transformations, uptake and losses.

Applications to forested sites can be made either annually or once every several years. In New Zealand, forest applications are often made at intervals of a few years to minimise operation cost. For example, liquid biosolids have been applied to a pine plantation every three years at the Rabbit Island site in Nelson. Additional advantages to less-than-annual

applications include a longer period for the forest floor and vegetation to return to normal conditions, and a greater time for public access.

Depending on soil type and rainfall, biosolids may be applied to forest year round based thus avoiding stocking piling of biosolids. To maximise the uptake of available nutrients, ideally, biosolids should be applied to forest when tree crops grow rapidly and have high demand for nutrients (e.g. spring and summer). Forest floors that contain a significant amount of organic matter and understorey vegetation have soil micro-organisms and plants that can temporarily store significant amounts of nitrogen until the next growing season. In following years, plants and microbes die and decompose, releasing the immobilised nitrogen for subsequent plant growth. During extreme weather conditions, especially with saturated soil conditions, biosolids applications need to be avoided to minimise the risk of surface run-off.

Nutrient and contaminant loading

For successful and sustainable biosolids application in forests, the loading of available nutrients must not exceed the nutrient uptake requirements of trees. The contaminant loading should be such that it does not affect the receiving environment. The most significant macro-nutrients associated with land application of biosolids are nitrogen and phosphorus.

***Nitrogen*:** Nitrogen is usually considered the most important nutrient when setting application rates for biosolids. A larger quantity of nitrogen than other mineral nutrients is needed as a soil supplement. Nitrogen is typically the limiting nutrient in land application of biosolids as heavy applications may result in substantial increases of nitrate in the groundwater. The biosolids guidelines (NZWWA, 2003) recommend that up to 200 kg nitrogen/ha/year of biosolids nitrogen be applied to forest soils. It is also acceptable that higher loading rates may be applied (e.g. 400 kg/ha in every two years) because the slow release nature of organic nitrogen in biosolids (Wang et al., 2003).

The amount of plant-available nitrogen in biosolids is dependent on the treatment processes (Wang et al., 2003). For example, the concentration of nitrogen in the form of ammonium ions is typically high in digested liquid biosolids, but it is much lower in biosolids that have been stabilised with lime, thermally dried, or composted.

***Phosphorus*:** The concentration of phosphorus in biosolids is usually about two-thirds that of nitrogen. However, the concentration needed by plants is only about 20-50% that of nitrogen. Therefore, application rates that are set based on nitrogen needs will seldom limit plant growth. Some phosphorus may accumulate in the soil, but the amount of phosphorus added will usually be small compared with the soil's capacity to bind phosphorus (Su et al. 2007). Loss of phosphorus to surface water will be negligible as long as application buffers are maintained.

***Contaminant loading*:** Applying biosolids to forests has a low risk because of contaminant loading limits and established management practices. The *NZ Biosolids Guidelines* (NZWWA, 2003) has set limits for contaminant loading for land applications. The limits for agriculture are the same as those for forests.

Silvicultural management

The growth behaviour of trees treated with biosolids is similar to those receiving regular nitrogen fertiliser applications. A high growth rate is typically observed in pine stands receiving regular biosolids application. Consequently, slightly increased branch size and reduced wood density and stiffness may occur in biosolids-treated trees (Wang et al.,

2006). Some special silvicultural management practices, such as selection of varieties or genotypes with known high wood density, and adjustment of initial stocking rates, can maximise the potential economic gain at harvesting.

When it is well planned and managed, application of biosolids to a nutrient-limited site can transform it from a relatively low-productivity- to a moderately high-productivity forest site (Wang et al., 2009). Forests should be managed according to the current best management practices. It is important that good communication is maintained between the biosolids application operator and the forest manager to improve management efficiency and reduce operational cost. For example, waste thinning has low environmental risks because it is generally undertaken manually and causes only minor, or no, soil disturbance. However, it can affect biosolids application by blocking or impeding land-based machinery access. It is advisable that biosolids are applied to a forest prior to waste thinning, if possible.

Recommendations for implementation:

- Ensure timing of the biosolids application is coordinated with the forest management activities;
- Avoid applying biosolids prior or during extreme climatic conditions;
- Choose an appropriate application method by considering type of biosolids and tree age;
- Conduct site-specific studies to fine-tune application rates;
- Maintain good communications between the biosolids application operator and the forest manager to maximise management efficiency and minimise operational costs; and
- Incorporate the requirements of biosolids application into plans for the establishment and management of new forests.

Chapter 5: Monitoring and Reporting

Performance monitoring needs to be an integral component of land application management. It provides the critical feedback loop to the operational planning process and performance.

This chapter deals with environmental and public health monitoring; monitoring protocols; and regular soil and nutrient analyses. This chapter also summarises record keeping and reporting requirements for a successful biosolids application programme.

Site, environmental and public health monitoring

Monitoring is best carried out both before and after the initial biosolids application, and may be repeated periodically after that. Monitoring has four major benefits (NZFOA, 2007):

- checks that compliance with resource consents has been achieved;
- checks that the plan has been followed and that the desired effects have been achieved from a forest management point of view;
- provides feedback, training, and information for future planning; and
- allows for management review.

A sampling and analysis plan for forest land application sites may need to be developed as part of the consent process. Monitoring requirements will depend on the sensitivity of the site and the approach proposed in the land application plan. A site with a conservative application plan (e.g. wide buffers, low application rates, dry season applications) will need little monitoring. Site plans that have minimum buffers or a longer season of application, sites with a greater risk of leaching or run-off, or sites with nearby neighbours require greater monitoring both pre- and post-application (Cogger et al., 2000).

The regulatory authority may require additional record keeping requirements on a case-by-case basis, depending on the conditions of the permit. Even if there are no additional record-keeping requirements, it is important to retain copies of laboratory reports of soil and water monitoring taken during the life of the project.

Responsibility for monitoring

The holder of the resource consent is responsible for any monitoring required by the consent in relation to land application activities. Consent holders may contract others to undertake activities for them, including the monitoring, but they themselves will remain ultimately responsible. All sample analysis should be conducted by competent laboratories.

Pre-application monitoring

Pre-application soil and water sampling may not be required in resource consent, but is strongly recommended. Soils need to be sampled *before* the application of biosolids to determine the existing contaminant concentration (NZWWA, 2003). In this way the accumulation of chemical contaminants in the soil as a result of biosolids application can be monitored over time. Soil from sites needs to be sampled using an unbiased pattern such as a rectangle or grid. Samples need to be taken from areas representative of the site as a whole. If a site has received biosolids application(s) previously, the application history should be noted.

The following monitoring is suggested to document existing site conditions before biosolids application.

***Soil heavy metals*:** Analyse the surface soil (0 to 20 cm) for heavy metals: e.g. arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. The pH of the sample should also be measured, because this is related to the availability of the metals.

***Soil nitrogen and phosphorus*:** Test for soil profile total nitrogen and plant-available phosphorus (e.g. Olsen P).

***Groundwater*:** When possible, analyse domestic supply wells on or near the project site for nitrate-nitrogen and faecal coliform bacteria. Ideally, samples should be taken both upgradient and down gradient of the site.

Post-application monitoring

If there is a well-designed operations plan, thorough recordkeeping of biosolids application rates, and good management of the site, then monitoring after application will be simple.

Soil: Periodic monitoring of soil is recommended for the application of *restricted use* biosolids. Regular monitoring of soil that has had *unrestricted use* biosolids applied to it is unnecessary because contaminant limits are low enough to prevent the rapid accumulation of contaminants. However, occasional monitoring of soil that has had *unrestricted use* biosolids applied to it frequently should be conducted for long-term reviews and good management practice.

Measurement of nitrate concentration below the root zone can be used to estimate the potential leaching of nitrate that can affect groundwater quality. Nitrate monitoring is important on sites with high biosolids application rates and if the site is located in a groundwater protection zone. Use of adequate samplers (e.g. ceramic suction cups) for soil water sampling beneath the root zone is a common practice (Magesan et al., 2008). Only suitably qualified personnel should install soil solution samplers, collect samples and interpret the data. The samplers must be located accurately to represent the site. Because of site variability, many soil solution samplers may be needed to characterise water quality. Periodic sampling gives only snapshots of nitrate levels. The amount of nitrogen in the nitrate leached (kg nitrate-nitrogen per hectare) may be calculated from an estimate of the volume of water moving through the soil. Whereas they are commonly used in most soils, ceramic suction cup soil solution samplers are not suitable for very sandy soils. For very sandy soils, other techniques such as soil drainage flux samplers (Gee et al., 2009) should be used.

***Surface water*:** Surface water is usually monitored upstream and downstream of the site only after biosolids application. This is because the upstream measurement acts as a control sample.

To prevent contamination by biosolids, adequate buffers between application areas and surface waters need to be maintained. In sensitive areas, surface water monitoring may be advisable or required to verify that biosolids applications are not affecting water quality. The usual approach is to monitor points both upstream and downstream from the application site. If runoff losses are suspected, monitoring the concentration of ammonium ions, nitrate, phosphate, and faecal coliform counts is necessary.

***Groundwater*:** Biosolids applied at recommended rates should not significantly impact on groundwater quality. If a detailed investigation of groundwater quality is necessary, a professional hydro-geologist should evaluate the site and design the sampling programme. Contaminants in groundwater reflect past activities, even activities from off-

site. Therefore, groundwater monitoring may not be very informative about current activities. When off-site effect of nutrients needs to be investigated, more advanced stable-nitrogen-isotope techniques may be used to trace biosolids-derived nitrogen (Tozer et al., 2005; Wang et al., 2005).

It is recommended that forest managers adopt and follow robust monitoring protocols as part of their operational planning and management activities.

Monitoring protocols

Monitoring protocols depend on the medium (i.e. soil, groundwater, surface water, and plant tissue), the purpose of the monitoring, and conditions at the site. Each site may have a specific monitoring protocol, but all aspects of a monitoring programme need to meet regulatory and management needs.

All monitoring plans are expected to address the following considerations:

- representative sampling;
- timing;
- tools; and
- sample handling and storage.

Representative sampling: The samples collected must be representative of the population that is being monitored. Specific sampling instructions depend on the site and medium sampled. For example, to obtain a representative soil sample, sub-samples could be collected either on a square grid covering the area, or from locations along several evenly-spaced transect lines crossing the area. A minimum of 20-30 soil sub-samples would be sufficient to sample a small area (e.g., a few hectares of uniform land) but greater sample numbers should be used for larger areas. Sub-samples can be combined and fully homogenised into a single composite sample. However, when an estimate of sample precision is required, the sub-samples should be formed into several composite samples which should be analysed separately. For example, when using transects or a sampling grid, the sub-samples from each transect or grid line could be combined into a composite sample. Soil cores should be taken to a depth of 20 cm.

A representative groundwater sample may come from a single well, but the well needs to be pumped for a specified period of time prior to collection to ensure that the water collected represents the aquifer at that location. Surface water samples must be paired; up and downstream samples must be taken at the same time to provide a basis for comparison.

Timing: The timing of sampling is often critical. For example, soil should be sampled at least a month prior to the next biosolids application. Stream sampling may focus on a site recently applied with biosolids, and after heavy rainfall.

Tools: Sampling tools must be capable of collecting a representative sample without contamination. For example, a representative sample for a 0 to 20 cm soil depth has the same amount of soil from the soil surface (0 to 10 cm) as from the bottom of the sampling depth (10 to 20 cm). A shovel is not an acceptable sampling tool, because it will skew the sample toward the shallower portion of the depth. Use a cylindrical soil probe which is designed to collect a soil sample that is uniform with depth.

Sample handling and storage: Containers must protect samples and be inert to components in the samples. Appropriate containers vary, depending on the medium sampled and the purpose of the analysis. A bag may be a suitable container for a soil

sample for nutrient analysis, while a water sample for coliform analysis will require a sterilised glass or plastic bottle.

Soil fertility and tree nutrition analyses

Other analyses are useful for identifying soil fertility problems that limit tree growth. Soil and plant tests can also be used to compare biosolids-treated and untreated areas on the same site. This testing is the best way to demonstrate the benefits of biosolids application as well as the environmental effects. To enable comparisons to be made over time, or between treated and untreated areas of a site, the soil sampling depth must be consistent.

***Soil fertility tests and sampling forest floor*:** Typically, soil samples are tested for: pH organic carbon content; concentrations of total nitrogen; plant-available phosphorus; and exchangeable cations. These analyses may help identify soil fertility problems such as unfavourable pH and nutrient deficiency. These problems may be corrected by the use of biosolids but they can also be remedied by other management practices.

It is relatively simple to distinguish the forest floor from the mineral soil. There are two generally accepted techniques for sampling the forest floor: soil cores or a square sampling template. Templates can be constructed with heavy-gauge metal and sharp edges at the bottom of the frame to push the frame into the forest floor until the mineral soil is reached. This is a convenient way of sampling the forest floor as it allows a measure of bulk density and water content to be collected at the same time, after the measurements of thickness and determination of wet and dry mass (Belanger & van Rees, 2008). Also, when the larger surface area is being sampled, it can reduce micro-site variability in the sample once it is air-dried, cleaned for roots and other woody materials, and mixed in the laboratory.

Plant tissue tests are commonly used for monitoring the tree nutrition status. When sampling plant tissue, several variables influence nutrient concentrations, including tree, plant part and sampling date. For valid comparisons, sampling methods must be consistent. For radiata pine forests, foliage samples (present year's secondary foliage in top third of crown) are usually collected from representative trees in February or March (Will, 1985).

Record keeping

Records are necessary to show that biosolids producers/users are meeting resource consent requirements. The type of records that need to be kept will vary depending on whether they are related to transport, storage, or discharge (NZWWA, 2003). Record keeping also varies depending on the type of biosolids concerned (*unrestricted use* or *restricted use*).

The *NZ Biosolids Guidelines* (NZWWA, 2003) provide details of the information that is required at each stage in the biosolids lifecycle. Records should be kept and maintained according to the requirement of the resource consent. Records relating to contaminant loads applied to a site should be maintained for at least as long as biosolids are applied to that site and for a five-year period after application ceases. Records need to be maintained by the person applying the biosolids to land, and a copy should also be kept by the land owner.

Dischargers of *restricted use* biosolids (Ab, Ba and Bb) should collect the following information (NZWWA, 2003):

- location of application site;
- current land use;
- name of site occupier and owner (if different);
- area of application (with an accompanying map);
- date of application;
- soil pH (before biosolids application);
- soil contaminant concentration before biosolids application;
- estimated soil contaminant concentration after biosolids application;
- method and rate of biosolids application;
- source of biosolids and batch number;
- stabilisation and contaminant grade;
- concentration of nitrogen;
- monitoring methods;
- frequency of soil sampling; and
- a description of how site and access restrictions were met. This includes public access and buffer requirements.

There is no requirement to keep records on the application of *unrestricted use* biosolids (Grade Aa). However, it is good management practice for all users of bulk quantities (> 50 m^3) of biosolids to keep records of application as above.

Forest managers generally have forest-stand record systems to keep information about management activities in each forest. Such records need to include information about biosolids application.

Recommendations for monitoring and reporting*:*

- Biosolids producers, contractors, landowners and forest managers must work together as a team to make land application programme a success;
- Resource consent holders need to follow robust monitoring processes and meet regulatory and management needs; and
- Maintain records relating to contaminant loads applied to a site until and beyond any significant land use change.

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Appendix: Biosolids Quality, Types and Grading in New Zealand

Biosolids quality

Biosolids can vary greatly in their properties. The type and concentrations of contaminants present depends on the sources of sewage entering the treatment plant and the nature of the treatment process. The quality of biosolids is usually monitored by the producer to determine the extent of vector attraction, pathogen numbers and concentrations of nutrients and contaminants. New treatment methods and technologies have improved both the quality and quantity of biosolids over time (Wang et al., 2008).

Municipal biosolids can supply a wide range of nutrients for plant growth. The nutrients include nitrogen, phosphorus, calcium, magnesium, potassium, sodium, manganese, copper, zinc, molybdenum and boron (NZWWA, 2003). Biosolids materials generally have a low nitrogen content (1–6%) relative to nitrogenous fertilisers. The organic matter in biosolids is highly stabilised, and even high rates of application pose little risk of nitrate leaching (Smith, 1996). Only a small proportion (approximately 10%) of the total nitrogen applied is available on an annual basis.

It is generally suggested that regular or continuous biosolids application should not cause soil contaminant limits to be reached for at least a 20-year application period. This is in line with the USEPA approach (NZWWA, 2003).

Types of biosolids

Biosolids are divided into two classes (*unrestricted-use* biosolids and *restricted-use* biosolids) (NZWWA, 2003) based on their physical, chemical and biological properties.

Biosolids classification

Biosolids are classified according to their stabilisation (A or B) and contaminant (a or b) grades as follows (NZWWA, 2003).

- *Unrestricted-use* biosolids: Aa
- *Restricted-use* biosolids: Ab, Ba, Bb.

Unrestricted use biosolids (Aa)

Unrestricted-use biosolids are defined as those that have been treated or processed to contain very low levels of pathogens and other contaminants. There is minimal known risk to human health, and a very low risk of the soil limit being reached at a given site, even after repeated years of application of *unrestricted-use* biosolids. The application of *unrestricted-use* biosolids to land is controlled only by conditions on a permitted activity rule governed by the requirements of the Resource Management Act (RMA) 1991. The RMA 1991 legislation promotes the sustainable management of natural and physical resources and states that resources must be managed so any adverse effects in the environment (including social, economic, aesthetic, and cultural conditions) are avoided, remedied or mitigated. The *NZ Biosolids Guidelines* suggest that there would be no need either for resource consent or to monitor environmental effects when utilising *unrestricted-use* biosolids (NZWWA, 2003).

Only biosolids that have achieved both an A grade for stabilisation and an ‘a’ grade for contaminants are classified as *unrestricted-use* biosolids (NZWWA, 2003).
Biosolids that have demonstrably achieved these standards can be safely handled by the public and applied to land without risk of significant adverse effects. Control over their

discharge to land can be exercised by way of a *permitted-activity rule* in a regional resource management plan in much the same way that fertiliser application is currently regulated.

It is important to note that the term '*unrestricted use*' can be a misnomer. The application of Aa biosolids to land would still be regulated. The discharge would be subject to meeting a number of conditions designed to minimise any risks to public health and environmental values.

From a public policy perspective there are two good reasons for having a permitted activity rule for high quality biosolids (NZWWA, 2003):

(i) sewage authorities have an incentive to improve their trade waste management practices and source controls to achieve an 'a' grade contaminant standard (consistent with waste minimisation and recycling objectives); and
(ii) the biosolids can be sold/distributed in retail outlets like other fertilisers or soil conditioners (individual users or 'dischargers', do not need to obtain a resource consent, and the range of potentially beneficial uses is increased).

Restricted use biosolids (Ab, Ba, Bb)

Restricted-use biosolids require resource consent for a specific site before they can be applied to land because they are of lower quality in terms of pathogens or contaminant content. The resource consent process provides an opportunity for public scrutiny of a land application proposal, and consent conditions allow appropriate site-specific risk management controls, such as monitoring requirements, to be placed on the discharge.

Biosolids graded Ab, Ba, or Bb are *restricted use* and should be applied to land only with site-specific controls imposed in accordance with resource consent.

If a council classifies the discharge of these grades as a discretionary activity, it can treat each proposal on its merits, applying conditions that are relevant to the particular grade and its proposed receiving environment. The council can decline the application if it is dissatisfied that the effects of the discharge can be effectively controlled.

Biosolids grading system

The *NZ Biosolids Guidelines* (NZWWA, 2003) outlines the recommended approach to the grading of biosolids in New Zealand. The implementation of these guidelines relies, in turn, on the implementation of the provisions of the Resource Management Act 1991. The principal risk management instrument is the establishment of a conservative soil limit for each of the key contaminants found in biosolids.

The biosolids grading system is made up of two parts: stabilisation grade and contaminant grade (NZWWA, 2003).

Stabilisation grade

Biosolids are stabilised by treating them in a way that reduces pathogens, vector attraction and the potential for offensive odours. Stabilisation grade depends on pathogen content and whether or not an approved pathogen reduction procedure and an approved vector attraction reduction method have been implemented.

Vectors such as flies, mosquitoes, birds and rodents are potential carriers of disease. Reduction of the attractiveness of biosolids to vectors reduces their potential for

transmitting diseases. This process is known as vector attraction reduction (VAR). Vector attraction reduction can be achieved by either subjecting the biosolids to specific physio-chemical processes or conditions, or preventing vector access to them, usually by incorporating the biosolids into soil (NZWWA, 2003).

The stabilisation grade is denoted by a capital 'A' or 'B'. A high-quality biosolid 'A' is one in which pathogens and vector-attracting compounds, such as volatile solids, have been substantially reduced or removed. Some pathogen reduction processes are also effective at reducing vector attraction. To achieve stabilisation Grade A, the biosolids must: (i) have an accredited quality assurance system; (ii) meet at least one of the accepted pathogen reduction processes; (iii) have one of the accepted vector attraction reduction methods; and (iv) have all of the pathogen standards (NZWWA, 2003).

To achieve stabilisation Grade B, the biosolids need to meet a lesser degree of stabilisation *plus* one of the VAR requirements for Grade A; no pathogen reduction processes or product standards are applicable.

Contaminant grade

Contaminant grade depends on the levels of both metals and organochlorine contaminants. The chemical contaminant grade is denoted by a lower case a or b.

To achieve contaminant Grade 'a', the concentration of all the contaminants within the biosolids must be at or below the level indicated in column 3 of Tables A.1 and A.2. A biosolid has to be classified as chemical contaminant Grade 'b' even if only one contaminant falls within that category. The available New Zealand biosolids data (Ogilvie, 1998) show that the Grade 'b' maximum limits adopted should be achievable for the majority of New Zealand wastewater treatment plants. If any contaminant concentration is above the limit given for Grade 'b' (column 4), then the product is to be considered a sludge rather than a biosolid and the sludge has to be treated, or blended with another substance, in order to become a biosolid, or otherwise disposed of.

The *NZ Biosolids Guidelines* provide two sets of soil limit values for Grade 'a' biosolids. The first set is for a 10-year transitional period which ends on 31 December 2012. The second set will be applicable from 1 January 2013. The transitional period allows for higher limits for cadmium, copper, mercury, zinc and dieldrin. This was proposed to give wastewater treatment plant operators time to set up and implement programmes for cleaner waste streams entering the plant, and to develop sludge treatment facilities. See Table A.1 for both sets of values.

Metals grading

Table A.1 gives the maximum contaminant concentrations for metals which are applicable to each of the biosolids contaminant grades.

Table A.1: Biosolids classification, by metal contaminant levels (adapted from NZWWA, 2003)

Metals	Soil limit or ceiling concentrations (mg/kg dry weight)	Biosolids limits		
		Grade a Max. concentration (mg/kg dry weight)		Grade b Max. concentration (mg/kg dry weight)
		Until 31/12/ 2012	After 31/12/ 2012	
Arsenic	20	20	20	30
Cadmium	1	3	1	10
Chromium	600	600	600	1500
Copper	100	300	100	1250
Lead	300	300	300	300
Mercury	1	2	1	7.5
Nickel	60	60	60	135
Zinc	300	600	300	1500

The metal concentrations for Grade 'a' have been set at the soil limits. Given that mass loading limits the amount of contaminants applied to land, there need not (theoretically) be a Grade 'b' maximum concentration. However, a maximum concentration is required for management controls and to reinforce the differentiation of biosolids (as a quality product) from sludges (NZWWA, 2003).

Organic compounds

Table A.2 gives the contaminant concentrations in biosolids for organic contaminants that are applicable to each of the chemical contaminant grades.

Biosolids Grade 'a' is based on the NSW EPA Contamination Grade A, which, along with the appropriate stabilisation grade, is classified for *unrestricted use* in the following applications: home lawns and gardens; public contact sites; agriculture; forestry; soil and site rehabilitation; landfill disposal; and surface land disposal within boundaries at treatment plants. Grade 'b', along with the appropriate stabilisation grade, is classified as Restricted Use 1.

Table A.2: Biosolids classification, by organic contaminant levels (adapted from NZWWA, 2003)

Parameter	Soil limit or ceiling concentrations (mg/kg dry weight)	Biosolids limits	
		Grade a max. concentration (mg/kg dry weight)	Grade b max. concentration (mg/kg dry weight)
DDT/DDD/DDE	0.5	0.5	0.5
Aldrin	0.02	0.02	0.2
Dieldrin	0.02	0.05	0.2
Chlordane	0.02	0.02	0.2
Heptachlor & Heptachlor epoxide	0.02	0.02	0.2
Hexachlorobenzene (HCB)	0.02	0.02	0.2
Hexachlorocyclohexane (Lindane)	0.02	0.02	0.2
Benzene hexachloride (BHC)	0.02	0.02	0.2
Total polychlorinated biphenyls (PCBs)	0.14	0.25	0.2
Total dioxin TEQ[1]	0.00001	0.00003	0.00005

[1] *'Dioxin' means the seventeen 2,3,7,8-chlorinated congeners of the polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. The residue limit is expressed as 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (TEQ).*

Use of blending to achieve contaminant grades

The blending of sewage sludge with other substances (e.g. pumice, sand, sub-soils, bark, sawdust, green waste) before, during or after treatment is an acceptable way of diluting contaminant levels in order to attain either the ‘b’ or ‘a’ biosolid contaminant grades.

The use of blending to remove other contaminated materials is not an acceptable practice, and the chemical nature or ‘contaminant content’ of blended materials should be declared by biosolids producers. Control can be exercised over the composition of blended materials via the quality assurance system, and in the case of *restricted-use* biosolids, a regional council can impose conditions relating to the type or composition of the blending materials used.

The potential for adverse environmental effects is governed by the quality of the product. Cleaner production and improved trade waste management (i.e. waste minimisation) will still be needed if biosolids producers are to consistently meet contaminant grade standards in the future.

Sludges

If a product fails to meet either or both of the minimum stabilisation or contaminant grade requirements, it is not a biosolid and should be referred to as sludge. Sewage sludges either require further treatment to achieve such standards, or should be disposed of via landfilling.