CHAPTER 2

LAND APPLICATION

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2.1 OVERVIEW

The soil can be considered a living filter in terms of its ability to treat farm dairy effluent. It deals with applied effluent in three ways:

1. **Physically.** Suspended solids and micro-organisms are filtered out between soil particles.
2. **Chemically.** Nutrients (e.g. nitrogen) from the effluent can be chemically processed and released (e.g. denitrification) or retained by charged soil particles.
3. **Biologically.** Organic materials are broken down by soil micro-organisms. Soil micro-organisms and plants will also remove nutrients as part of their own requirements.

Ultraviolet radiation in sunlight and the drying effect of the elements also have an effect in killing harmful micro-organisms following land application.

The nutrient value of effluent is significant (refer to 2.2 Fertiliser properties of effluent). Effluent should be thought of as a nutrient rich and **valuable by-product of the milking process rather than as waste.**

The tendency in former years was to dispose of effluent with little regard for its value and use. The possibility of using effluent as a resource increases the incentive to install a land application system.

These factors are essential for the successful use of effluent as a fertiliser:

- **nutrient application rates should be balanced to the nutrient needs of the soil-plant system and capacity for uptake**
- **a regular nutrient analysis programme for the effluent, soil and pasture is required to optimise growth and minimise animal health problems**
- **the economics must be favourable to the farmer**
- **Regional Council requirements must be met.**

Provided certain criteria are met, land application may be a permitted activity not requiring a resource consent in some regions. Criteria mainly focus on the following:

- **suitable storage facilities** where effluent can be held temporarily if the application system breaks down or soils are too waterlogged for further liquid application. Contingency measures, such as a back-up pump, are also encouraged
- **nitrogen loading** on the land and its effect on groundwater and surface water
- **ponding and runoff** into surface water
- **nuisances from odour or spray drift.** Buffer distances between adjoining properties or public roads and the application area are often required.

For the farmer, a major key to the successful management of effluent application to land is to apply effluent onto short pasture (refer to 2.6 Pasture and grazing management) at the lowest practical application rate, with a rest interval between applications (refer to 2.4 Application rate).

2.1.1 Planning for land application

Although effluent can be considered as a potential nutrient source, it is high in volume (or bulk) with a low nutrient content compared with conventional solid fertilisers. This leads to large handling and distribution costs relative to the per unit volume value of the nutrients. The challenge is to reduce the volume of effluent (refer to 1.6.8 Reducing Effluent Volume and Conserving Water) while still maintaining the nutrient content.

Capital outlay for application equipment can often be regained through fertilising benefits; however the land application system requires careful planning, design and management if it is to be practical and economical (refer to 1.8.2 System planning and design).

Farmers need to investigate their own situation and costings before deciding on an option involving land application. Figure 2.1-1 outlines the planning procedure and includes factors influencing the decision to apply effluent to the land.

FIGURE 2.1-1

PLANNING PROCEDURE

Peak volumes and nutrients

- Calculate the annual effluent loading at the farm dairy (refer to 2.2 Fertiliser properties of effluent and 1.6.1 Effluent characteristics and volumes)
- Consider future herd expansion or system intensification

Local climate and soils

- Identify the loading limitations of local soils (refer to 2.4 Application rate)

Land application regulations

- Meet Regional Council and Food Safety requirements. (refer to 2.13 Land application regulations)

Area required to receive the effluent

- Calculate the size of site required. (refer to 2.3 Application area)

Application site selection

- Select a suitable site for effluent application. (refer to 2.5 Application site selection)

System selection

- Select the most suitable land application system. (refer to 2.1.2 Land application options)

Application management

- Consider system design, soil conditions and weather (refer to 2.4 Application rate)

Pasture management

- Consider stock rotation and pasture length. (refer to 2.6 Pasture and grazing management)

2.1.2 Land application options

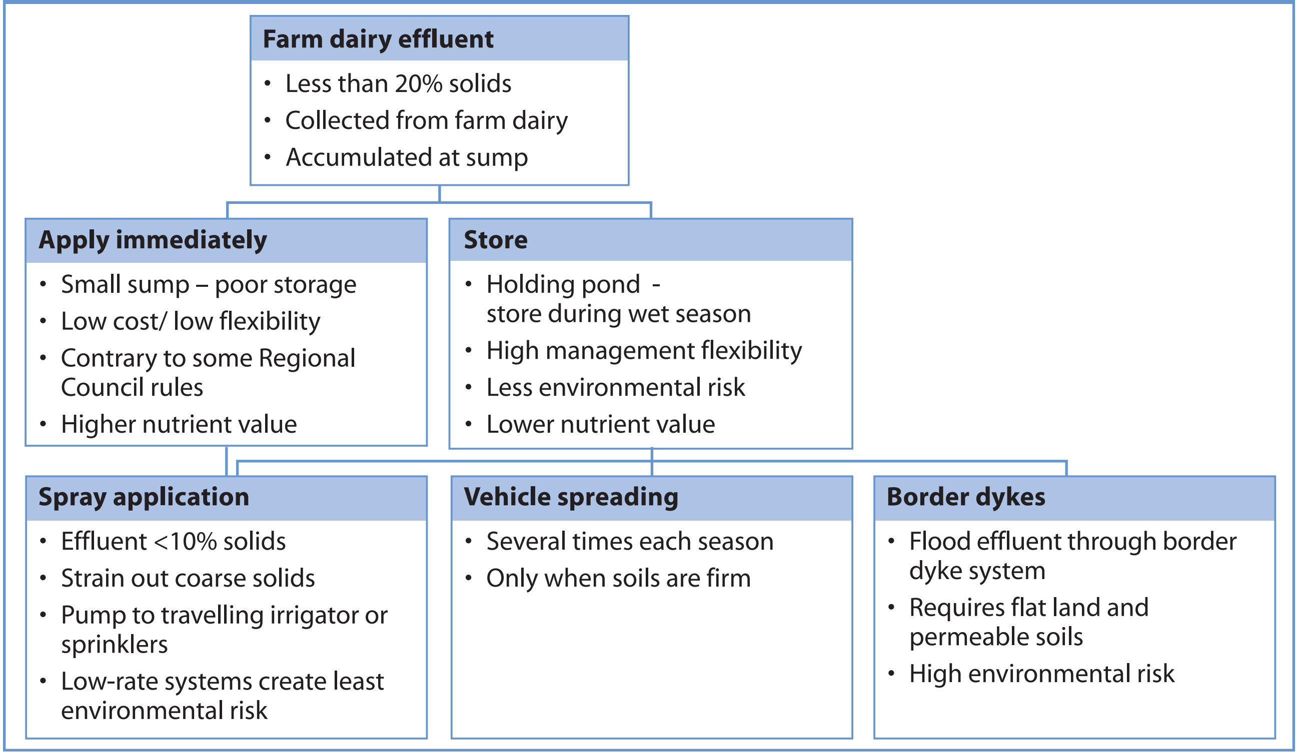
Choices of systems include **spray application by regular or low-rate systems, vehicle spreading,** and **border dyke.**

In other countries, soil injection is another option used to control odour and limit N loss through volatilisation but this has not been developed in New Zealand.

Figure 2.1-2 outlines the various land application systems currently in use and important considerations relevant to each option. The details of each system are addressed in detail within their individual sections.

FIGURE 2.1-2

SELECTION OF A LAND APPLICATION SYSTEM



The following technical factors need to be considered when deciding upon the most suitable land application technique:

- **type of pre-treatment.** Will the effluent come from ponds, barrier ditches or direct from the farm dairy?
- **type of receiving vegetation.** Application to crops as opposed to pasture requires consideration of the crop height for machine clearances; accessibility issues relating to fallow ground; and the timing of effluent application, as the system may not easily allow effluent transmission through mature foliage to the soil
- **topography.** Slopes can hinder machinery movement and affect effluent flow
- **soil type**. Heavier soils will retain moisture and once saturated, ponding and surface runoff may occur. Lighter soils are more free-draining with higher risk of groundwater pollution
- **labour requirements** for maintenance and management
- **ability to expand** with increasing herd size or system intensification (feed pads etc)
- **mechanical reliability** and the availability of parts and service
- **system cost,** including the cost of maintenance. It may be worthwhile exploring the possibility of a reduction in capital outlay with group purchases
- **risk of environmental contamination** due to equipment failure and adverse weather conditions
- **mole or tile draining** which creates 'preferential flows' underground and feeds effluent directly to waterways, increasing the risk of effluent applied to land contaminating water.

2.1.2.1 Spray application

Spray application is appropriate for the majority of New Zealand pastoral soil types during low rainfall periods. The system provides reasonably uniform application of effluent although strong winds can cause problems. Spray application is adaptable to topography, although not as adaptable as vehicle spreading. Unlike vehicle spreading, there will be no physical damage to soils once the system is in operation.

The capital outlay and labour requirement for spray application systems can be high but is dependent on the system employed. Labour requirements include:

- shifting sprinklers and stock to fit the application pattern
- cleaning the equipment, including pumps and sprinklers
- maintaining (i.e. lubrication) and repairing equipment
- recording effluent application information to meet Regional Council requirements.

Spray application can also be undertaken by contractors.

Effluent can be applied through low-rate sprinklers. This is a series of sprinklers in 'pods' fixed to a flexible pipe that can be dragged behind a farm bike or tractor. The pods provide a low rate of application, which is less likely to exceed the moisture holding capacity of soil.

Solids separation or methane digestion can be used prior to land application (refer to 2.12 Processing options prior to land application). These methods have the advantages of reducing wear and tear on irrigation equipment and producing a more dilute liquid effluent, which is easily handled and irrigated over a smaller area. Solids separation also gives a solid product that can be cultivated into the soil and is easily transported to other areas. After solids separation, effluent can be delivered by any irrigation system, including those used for clean water irrigation. However, capital inputs for these methods can be high.

2.1.2.2 Vehicle spreading

Vehicle spreader systems suction-draw the effluent from the storage facility into a mobile tank.

The effluent is then pump sprayed from the rear of the tank on to the land. The truck or tractor-towed tank can run up and down the paddocks in strips until the application area is covered.

Vehicle spreading generally offers the most flexibility when it comes to land application of effluent. However, vehicle spreading can cause significant damage to the pasture and compaction damage to the soil, especially around gate entrances. This can be overcome in some situations by using a tanker that gun-sprays the effluent from the races.

Vehicle spreading can be time consuming however their is no requirement to shift spreading equipment for irrigation. Contracting vehicle spreaders avoids capital outlay for pumps and spray application equipment but entails an ongoing cost for the service.

2.1.2.3 Border dykes

Border dyke irrigation systems can be used to control effluent flow onto pasture by the use of furrows and borders. Efficient surface coverage requires grading of the land surface to direct the flow of effluent. This system will only be applicable to properties with existing border dyke systems e.g. in Canterbury. There are a declining number of effluent discharges by border dyke.

When using surface flow to convey effluent, there is a high risk of polluting groundwater and surface water. This is due to a lack of flow control, where applied effluent is easily lost to surface runoff and to percolation below the root zone.

Effluent should be added to irrigation water to dilute the concentration of nutrients added through the border dyke system. This often requires storage to allow for water allocation rotations.

2.1.3 Top tips to avoid trouble

- **Assess the pollution risks associated with the failure of the land application system should there be a power cut, pump break down, or if the system does not operate to expectations. Plan what to do in such situations.**
- **Care should be taken to avoid effluent runoff that flows to surface water via discrete flow paths such as channels, drains or tracks. These may be considered as direct discharges to surface water and may result in Regional Council action.**
- **Even though they are below the surface, mole and tile drains can effectively deliver effluent applied to land straight to waterways and need to be monitored. If possible, avoid these areas for effluent application.**
- **Avoid applying effluent over the porous backfill of land drainage systems.**
- **Observe application areas and adjacent surface watercourses regularly, before and after effluent application.**
- **Inspect and maintain the system regularly. Look out for broken pipelines and check the system is applying effluent where it should.**
- **When considering land application as a system for treating effluent, it is wise to liaise with neighbours. Neighbours can be affected and can have a significant input into the Regional Council acceptance of individual systems.**
- **Check your local District Council rules for setback distances from boundaries and dwellings before installing any equipment.**
- **If staff are involved in managing the effluent system, make sure they are fully trained.**

2.1.4 Land application as an economic and practicable option

The motive for land application is threefold:

- **it is a complete system** for the successful treatment of effluent
- **it is the preferred option for a majority of Regional Councils** as compared to discharging treated effluent to waterways
- **the fertiliser benefit of the effluent.**

2.1.5 Further reading

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2.2 FERTILISER PROPERTIES OF EFFLUENT

Farm dairy effluent, when recycled back onto the land, **offers a source of N, P, K and S and trace elements** to enhance pasture or crop production and reduce fertiliser expenditure.

The organic matter in the effluent will improve soil water holding capacity, soil aeration and drainage, and tillage characteristics. Application of effluent onto pastoral soils may also increase earthworm numbers.

Environmental quality is the major reason for applying effluent to land, but the value of nutrients, and a minor irrigation benefit, is a significant bonus. Effluent correctly applied can substitute for some solid fertiliser use, as well as assist in the maintenance of environmental water quality.

Successful use of effluent requires assessment of its value in fertiliser terms for both pasture and crop production.

A nutrient analysis of the effluent can be carried out to ensure that effluent application rates meet plant requirements.

The fertiliser value of effluent applied to land direct from the farm dairy is typically $1200 to $1500 per 100 cows per annum under normal grazing conditions.

2.2.1 Causes of variation in nutrient value

Effluent is extremely **variable in nutrient content.** The nutrient value of effluent from a single property can vary from one milking to another and from one season to another. The characteristic of waste from dairy cows is strongly influenced by the type of feed, including the N, P and K content of the consumed pasture or feed, and the requirements of the lactating cows.

As well as seasonal variation, the nutrient content of effluent will differ from property to property. This is due to differences in feed quality, animal demand for feed and the variations in the quantity of washdown water used by the farmer. When less water is used for washdown, the concentration of nutrients will be higher but the total nutrient loading from the herd will be the same.

Effluent stored in ponds changes in nutrient composition and value. The surface liquid is very dilute compared with the more concentrated sludge at the bottom of the pond. The resulting nutrient composition is also influenced by desludging.

The collection of effluent from stand-off pads or feed pads also affects effluent qualities as well as quantity.

2.2.2 Nutrient analysis

Analysis of effluent from individual properties is recommended because of the variability in effluent composition. Due to variation throughout the year repeat analysis is recommended. The results give a measure of the N, P, K and S in the effluent and can be used to determine the most appropriate rate of application. This will ensure plant nutrient requirements are met as well as Regional Council nutrient loading regulations (refer to 2.3 Application area).

Effluent testing can provide immediate information to help farmers estimate the nutrient value of the effluent. Effluent testing prior to application will establish a baseline nutrient value. This value can assist in developing a nutrient budget and a nutrient management plan. Eventually, only occasional testing will be needed to confirm the values being used.

Any laboratory that carries out soil, herbage and fertility analysis will be able to carry out an effluent nutrient analysis. **Farmers need to supply a one-litre sample of effluent.** The analysis can cost up to $90 per sample. Other considerations include:

- **analysis should give a measure of the N, P, K and S elements in the effluent. Analysis should include total N**
- **effluent applied through spray application systems should be sampled at the sprinkler outlet**
- **if effluent from a feed pad enters the system, the sample should be taken at a time when the feed pad is in use**
- **effluent applied from a pond needs agitating prior to sampling** to develop a slurry with a representative sample of the nutrients. A typical storage pond has three layers of effluent - a heavy sludge at the bottom and sides, an intermediate layer and a layer of liquid floating on the top. Crusting may cover the upper layer. The nutrient content varies markedly from layer to layer. Samples from the lower layers of effluent will have increasing concentrations of most major nutrients important for pasture growth

- a composite sample taken over several days will take into account rainfall events and daily variation in feed value (refer to 1.3.6 How do I sample the effluent for nutrient value?).

Nutrients within the soil and plants can also be monitored to ensure that the fertiliser elements are maintained at an optimum level. Soil testing and herbage analysis can give some idea of the pH value, and the N, P, K, S, organic S and Mg content of the soil-plant system.

When taking the herbage analysis, no effluent can be present on the leaf, as this will give an incorrect reading. **Basic soil tests cost $40-50** and **herbage analysis $60 per sample.**

2.2.3 Estimating the nutrient value of effluent

To estimate the total nutrient content of effluent applied over a season, the following factors need to be known:

- **the amount of nutrient (i.e. N, P, K, and S) produced by the cow**
- **the volume of effluent produced,** which largely depends on the amount of water used for washing down the yard
- **the average lactation period.**

Table 2.2-1 gives typical quantities of various nutrients found in effluent. The nutrient values in Table 2.2-1 assume that each cow will deposit 10 to 20% of its total daily discharge in the farm dairy and assume a 270 day lactation. Both can vary according to milking practices (refer to 1.6.8 Reducing effluent volume and conserving water).

It should be noted that the nutrient values in Table 2.2-1 are 'typical values'. To obtain an accurate picture of the fertiliser potential of the effluent generated and stored on an individual property, regular nutrient analysis is required.

2.2.3.1 Effluent applied fresh from the farm dairy

TABLE 2.2-1

NUTRIENT CHARACTERISTICS OF EFFLUENT FOR LAND APPLICATION

Nutrient	Quantity per cow per day		Annually per 100 cows (For design purposes)
	Typical (For design purposes)	Range	
Total Kjeldahl N	22.0 g	7.0 - 30.0 g	590 kg
Total P	2.5 g	0.5 - 4.5 g	70 kg
Total K	20.0 g	5.5 - 26.0 g	540 kg
Total S	3.0 g	1.0 - 4.0 g	80 kg
Calcium	-	-	220 kg
Chloride	-	-	180 kg
Magnesium	-	-	100 kg
Sodium	-	-	70 kg

The nutrient value of effluent as shown in Table 2.2-1 represents effluent collected and applied to pasture within one month.

New Zealand Pastoral Agriculture Research Institute Limited, pers. comm.; New Zealand Dairy Research Institute, pers. comm; Robertson, Ryder and Associates, 1993; Lincoln University, pers. comm.; Wrigley, R., 1993; Greg and Currie, 1992; Vanderholm, D.H., 1984.

2.2.3.2 Effluent applied following a period of storage

Effluent may also be applied after a period of storage in a holding pond or pond system (refer to 1.7.6 Pond storage facilities).

Some of the fertiliser value of effluent is lost during storage because of the gaseous losses of N to the air and settling of suspended solids containing nutrients (refer to 2.2.7 Nutrient losses in various systems).

2.2.4 Fertiliser value of effluent

Table 2.2-2 gives the equivalent fertiliser value of effluent collected and applied to land.

The following fertilisers are used for the solid fertiliser comparison as they are popular and best reflect the proportion of the various elements in the effluent:

- Urea N-P-K-S-Mg rating 46-0-0-0-0
- 50% Potash Super 0-5-25-6-0
- Magnesium Oxide (i.e. Mg Oxide) 0-0-0-0-52.

TABLE 2.2-2

EQUIVALENT FERTILISER VALUE OF EFFLUENT FROM 100 COWS

Nutrient (kg/year)					**Approximate solid fertiliser equivalent (tonnes/year)**	**Value ($/year)**
N	P	K	S	Mg		
590					1.3 of Urea	700
	70	540	80		1.3 - 2.2 of 50% Potash Super	400 - 700
				100	0.2 of Mg Oxide	100
Total value per annum						**$1200 - $1500**

2.2.5 Nutrient availability to the pasture

Research shows that 1 kg N from effluent is equivalent to 1 kg N from urea, in terms of pasture production, composition and nitrate leaching. Therefore farm dairy effluent can produce a good pasture response, up to 10 to 15 kg DM per kg N applied in the effluent. Most of the potassium in effluent is also available for pasture uptake (up to 90%), however phosphorus will require time to be broken down into plant available forms. Approximately half the phosphorus value in effluent is available to plants in the first year.

2.2.6 Metabolic problems from higher potassium levels

Caution is required when managing the potassium (K) content of effluent. Over time the application of dairy effluent to land increases both soil and pasture K levels, particularly in winter and spring. This can increase the potential for metabolic problems in dairy cows at calving and in early lactation. Therefore:

- do not apply any additional K fertiliser to paddocks where effluent is applied
- avoid the grazing of effluent disposal areas by springing cows and recently calved cows to prevent milk fever and grass staggers
- where this is not possible take measures to prevent these disorders, such as increasing magnesium supplements
- consider increasing the area over which the effluent is applied. Rather than aiming to keep within N limits (which is the focus of regulation for environmental effects), farmers may need to increase the area irrigated to lower the amount of K being applied. A nutrient budget will help with this assessment. The area irrigated may need to double to bring potassium application rates down to maintenance levels. A contractor can be used to spread stored effluent to more remote paddocks outside the current irrigated area
- analyse pasture from effluent and non-effluent areas separately and check chemical composition so that magnesium supplements can be adjusted
- harvest a crop of silage or hay off effluent blocks to reduce potassium levels.

The risk of metabolic problems increases when cows are stood off on the farm dairy for extended periods of time, resulting in more effluent being collected or if feed pad effluent is also applied to land.

It is especially important to monitor K in solids separation system. As K goes through the liquid stream and is not extracted in the solid, so the liquid will have lower N and P, but still high K.

2.2.7 Nutrient losses in various systems

Nitrogen may be lost through volatilisation to the atmosphere or stored through soil uptake. Nitrogen losses vary between effluent treatment systems. Losses are advantageous where there is a discharge of treated effluent to a waterway - as with pond systems. Losses are disadvantageous where the effluent is to be applied to land to maximise fertiliser benefits.

Half or more of the nitrogen in fresh manure will be rapidly converted to ammoniacal N form (ammonium - N and ammonia - N) in a short time following excretion. Ammonia-N is volatile and so nitrogen will be lost to the air during effluent storage and application to land. This volatilisation can remove up to 60% of the N in a holding pond.

Therefore the fertiliser benefit of fresh liquid effluent is higher, but so is the pollution potential if the N reaches surface waterways or groundwater.

Nutrients that settle are in fact still available as a nutrient/fertiliser source when the pond is desludged.

Phosphorus and potassium in effluent are less affected by storage and land application than nitrogen, as they are not volatile. A proportion of both nutrients are held within suspended solids that settle out in the pond sludge during storage.

2.2.8 Costs and benefits of returning nutrients to land

A major financial benefit arises from the fertiliser gain due to land-applied effluent. This will take the form of effluent substitution for solid fertiliser applications. Areas where effluent is applied to land may require less or no extra fertilisation.

A nutrient budget will help judge the need for supplementary fertiliser. The nutrient value of applied effluent needs to be taken into account when doing nutrient budgeting. A separate nutrient budget should be carried out for areas receiving effluent. Nutrient budgeting is covered in more detail in the Farm Management Issues manual from the Dairying and the Environment Committee.

Note also the metabolic risks from over-applying potassium fertiliser in addition to effluent (refer to 2.2.6 Metabolic problems from higher potassium levels).

When evaluating the costs and benefits of returning nutrients to the land a major consideration is the capital available for a spray applicator, fixed mainlines and movable spraylines (refer to 2.9.3.2 Travelling applicators) versus the minimal investment for a contractor with a vehicle spreader (refer to 2.10 Vehicle spreading).

When deciding on application rates, it is important to avoid the substantial loss of fertiliser value that can occur if runoff or subsurface drainage carry effluent away from the plant root zone.

2.3 APPLICATION AREA

The application area is that area of pastoral land set aside for the receiving of effluent as a nutrient and irrigation treatment. The area of pastoral land required is calculated on the basis of the **nutrient** (i.e. nitrogen or potassium) **concentration** and the **hydraulic load** (i.e. amount of water) of the effluent.

Regional Councils generally focus on N loading; however in many cases achieving an acceptable K loading to avoid animal health issues will be the determining factor for farmers requiring a larger area than that which would meet Regional Council requirements.

Many land application systems have failed because they have received too much effluent, both on a nutrient loading basis and on a hydraulic loading basis. Successful land application systems will:

- have **sufficient area to deal with the nutrient and hydraulic loading**
- utilise equipment that will **apply effluent at low application rates**
- **allow for rest periods between applications** so that bacteria in the soil can break down effluent organic matter to prevent a decline in the soil infiltration. This also gives the pasture time to regain palatability for stock.

The importance of allowing a large enough area of the property for land application of effluent cannot be overemphasised. Adequate provision of land area:

- **reduces nitrate leaching** and, therefore, wasted nutrients and groundwater contamination
- **minimises metabolic problems due to excessive potassium (K)**
- **prevents ponding and surface runoff** of effluent or sealing of the soil surface
- **avoids physical deterioration of soil**
- **stops weed invasion** of the treated area
- **makes best use of the nutrients for pasture growth.**

If there is not enough suitable land, arrangements must be made to apply the excess effluent on suitable land elsewhere or have an alternative back-up effluent treatment system.

Farmers should not apply effluent to land that is already saturated with water. This is why large storage facilities are essential in most regions (refer to 2.4.3.2 Timing of application).

It is the financial outlay for basic labour and capital components that costs, rather than the outlay for an extended system to provide additional application area.

In a typical grazing situation (i.e. not intensive feedpad or feedlot systems), to meet a Regional Council effluent N limit of 200 kg/ha/yr the minimum receiving land area would be a minimum of 4 ha per 100 cows.

Best management practice suggests larger areas are desirable e.g. 8 ha per 100 cows. This will also help avoid metabolic problems from excessive potassium (K).

While these figures are a guideline it is highly recommended that areas be calculated according to each farm's effluent volume and nutrient content.

2.3.1 Matching nutrient input to plant uptake

The quantity of nutrients applied in the effluent should be closely matched to the nutrient requirement of the pasture to obtain the best value from the fertiliser and ensure minimum nutrient loss.

Table 2.3-1 compares the nutrient loading of effluent applied at the 150 and 200 kg N per ha per year rate with the nutrient requirements of pasture. It should be noted that this is a general comparison, as nutrient requirements and availability to pasture are dependent on a number of factors including:

- **soil type**
- **pasture growth stage and composition**
- **season.** (There is a lower nutrient requirement in winter.)

TABLE 2.3-1

A COMPARISON OF PASTURE ANNUAL NUTRIENT REQUIREMENT PER HECTARE WITH EFFLUENT NUTRIENT LOADING			
Pasture nutrient requirement (kg/ha/year)	**N** **200**	**P** **45**	**K** **65**
Effluent nutrients when applying to 4 ha per 100 cows	150	18	135
Effluent nutrients when applying to 3 ha per 100 cows	200	24	185

When effluent is applied at the 200 kg/ha/year rate, nitrogen and phosphorus loading is closely matched with pasture requirements, but the potassium loading is far greater than necessary. If there is a tendency to accumulate potassium in the soil, this may cause an alteration in feed quality or induce milk fever or staggers.

If soil nutrient reserves are depleted below optimum levels, additional nutrients may need to be applied as solid fertilisers. The key to matching effluent nutrient loading with pasture requirements is regular nutrient monitoring and nutrient budgeting (refer to 2.2 Fertiliser properties of effluent). This will ensure that potassium levels are kept at an optimum and that potassium overload problems do not result.

2.3.2 Hydraulic loading

To avoid surface ponding from the application of effluent, **apply several low volume applications rather than all the effluent at one time.**

The recommendations for the daily application area to avoid excessive hydraulic loading are given for all pastoral soil types (refer to 2.4.3.1 Daily area).

2.3.3 Area needed to handle the effluent effectively

The size of the application area is largely determined by the **nutrient content of the effluent** (refer to 2.2 Fertiliser Properties of Effluent) and the **receiving land restrictions bound by soil and drainage characteristics** and the possible influence on natural waterways (refer to 2.4 Application rate).

This knowledge allows recommendations to be made on rates of effluent application together with any supplementary solid fertiliser that may be required.

The following tables outline a recommendation for the minimum receiving land area for effluent applied to pasture. These figures apply only to a typical grazing system, but are not applicable to more intensive systems (e.g. with feed pads or feed lots).

Where there is a Regional Council limit of **150 kg N applied per ha per year,** refer to Table 2.3-2. For a Regional Council limit of **200 kg N applied per ha per year,** refer to Table 2.3-3.

Note: For some Regional Councils the N loading includes both effluent and fertiliser N.

TABLE 2.3-2

MINIMUM RECEIVING LAND AREA PER 100 COWS FOR EFFLUENT APPLIED FRESH FROM THE FARM DAIRY (150 kg N PER HECTARE PER YEAR REGIONAL COUNCIL LIMIT)							
Nutrient (kg/ha/year)					**Minimum application area**	**Approximate solid fertiliser equivalent (kg/ha/year)**	**Value ($/ha)**
N	P	K	S	Mg			
150					4 ha (1 ha per 25 cows)	330 of Urea	180
	18	135	20			330 - 550 of 50% Potash Super	100 - 200
				25		50 of Mg Oxide	25
Total value per annum over four hectares							$1200 - $1500

TABLE 2.3-3

MINIMUM RECEIVING LAND AREA PER 100 COWS FOR EFFLUENT APPLIED FRESH FROM THE FARM DAIRY (200 kg N PER HECTARE PER YEAR REGIONAL COUNCIL LIMIT)

Nutrient (kg/ha/year)					Minimum application area	Approximate solid fertiliser equivalent (kg/ha/year)	Value ($/ha)
N	P	K	S	Mg			
200					3 ha (1 ha per 35 cows)	430 of Urea	250
	24	185	25			430 - 730 of 50% Potash Super	100 - 200
				35		70 of Mg Oxide	30
Total value per annum over three hectares							$1200 - $1500

In regions where no nitrogen loading limits are imposed by Regional Councils (check with your Regional Council for requirements) maintain a minimum area for effluent applied direct from the farm dairy to land of **4 hectares per 100 cows. Best practice is up to double this area i.e. 8 hectares per 100 cows. As a rule of thumb, the effluent application area should not be less than 15-20% of the farm.**

Note that the possibility of metabolic problems in cows may mean that the larger area should be used for irrigation in order to keep potassium (K) levels optimum for animal health. Soil and herbage tests and nutrient budgets can help determine this (refer to 2.2.5 Nutrient availability to the pasture).

2.4 APPLICATION RATE

Ensuring design of application areas based on N loading (refer to 2.3 Application area) is the prime concern of Regional Councils and the main regulatory issue for farmers in dry areas. However, farmers in regions of high and regular rainfall or where soils are poorly drained must equally consider the hydraulic loading (amount of water being applied) when irrigating farm dairy effluent.

Sound practice when applying effluent to pasture is to **apply effluent at times when it is suitable and beneficial for both nutrients and irrigation.**

From a fertilising and irrigating point of view, effluent must be applied onto land that has a **soil moisture deficit.** This is because the water will be stored in the root zone of the soil and the nutrients will be taken up by the pasture. With conservative application rates on non-saturated soils, effluent will not pond on the surface or leach to groundwater. Areas or seasons where water tables are high should be avoided.

When farmers using vehicle spreaders are forced to apply effluent when the soil is too wet due to a lack of storage capacity, damage occurs to the grass sward and to the topsoil because of deep wheel tracks and effluent ponding in depressions.

Areas with mole or tile drains should receive light applications only, and only when soil conditions are sufficiently dry.

Adequate storage is the key to the required flexibility (refer to 1.7.6 Pond storage facilities).

The storage capacity required will depend on climate, soil types and drainage (natural and artificial), and whether the farm is on seasonal or year-round supply (refer to 2.4.3.2 Timing of application).

2.4.1 Hydrological and nutrient loading design

Hydrological design involves determination of the **volume of effluent to be applied to the soil at one time** and the **interval between successive applications.**

Since effluent is made up of solids as well as water, both the solids loading and the hydraulic loading must be considered.

Nutrient loading design involves looking at the nutrient concentration of the effluent and determining the appropriate application depth to remain within Regional Council limits and avoid animal health issues.

2.4.1.1 Solids loading

Infiltration rate is affected by the vegetation cover, slope, soil characteristics and the solids content of the effluent. The effect of solids loading on the infiltration of effluent, in particular, should not be ignored when designing an effluent disposal system. With pastoral land, a high solids content reduces the ability of the soil to take up the effluent during a single application because of a clogging effect. With poor management, infiltration of effluent into the soil will decrease over successive applications as the land is repeatedly treated.

Since clogging is a surface soil problem, the **infiltration capacity of the soil can be restored by tillage** or by a **rest interval between treatments** (refer to 2.4.2.3 Minimum application interval). The latter allows time for the soil to aerate and for organic matter left by the effluent treatment to decompose.

2.4.1.2 Hydraulic loading

Soil consists of solid, water and air components. To gain irrigation benefits from effluent application, it is necessary to provide enough water in the soil for good plant growth. Since the air and the water components compete for available pore space between the soil particles, a combination of **over-application and poor drainage will cause too much of the pore space to be filled with water, resulting in low aeration that can limit plant growth.** Hydraulic loading will also increase the risk of leaching and contamination of groundwater or surface water.

It is imperative to avoid surface ponding through too high an application depth or rate. Many application systems have failed due to the soil becoming sealed following ponding. This can create long term drainage problems. Of the problems associated with ponding, those that most affect production and management are:

- **pugging and soil damage**
- **poor pasture growth** due to poor root development, low soil oxygen levels, slower breakdown of organic matter and decreased availability of plant nutrients

- **restrictions to stock and vehicle movement**
- **increase in stock diseases** (e.g. footrot)
- **intrusion of water-tolerant weed species.**

Few regions in New Zealand are free from drainage problems, but those with permanent wetness limitations include **peat soils, heavy clays,** low lying **coastal plains** and **sand country,** poorly drained **river flood plains,** and **soils with underlying pans.**

A further consideration with hydraulic loading is **not to over-apply effluent on soils that are naturally free draining, or have artificial subsurface drainage. This will result in loss of nutrients through the soil profile to groundwater or via subsurface drains to waterways.**

2.4.1.3 Nutrient loading

The size of the application area to be irrigated is determined by the **nutrient content of the effluent** (refer to 2.3 Application area). To calculate the **effluent application depth** based on the **nitrogen concentration of your effluent,** use the following calculation:

Annual application depth =
Total nitrogen loading allowed per year by your Regional Council / nitrogen content of your effluent in kg/l / 10000 m^2 per ha

For a Regional Council with a limit of 150kgN/ha/yr, and if the nitrogen concentration in your effluent is 0.04% (0.0004kg/l):

Annual application depth =
150 kgN/ha/yr / 0.0004 kg/l / 10000 m^2/ha = 37.5 mm

The total annual depth can be compared with recommended applications for your soil type in one pass (refer to 2.4.2 Recommended applications for common soils) to determine how many times effluent will need to be irrigated during the year.

2.4.2 Recommended applications for common soils

The ideal soils for fertiliser use of effluent and maximum irrigation gain are those with **good permeability and where the water table is deep** (i.e. greater than 1 m below the root zone). A perched water table can cause problems of ponding, groundwater contamination and pugging by stock.

It is important that site conditions be regularly checked, as the existence of high water tables and impermeable soil layers can significantly affect the success of fertilising and irrigating with effluent.

Correct application of effluent in itself should not cause a rise in the water table.

Waterlogging or ponding is possible if all the effluent is applied to the land at one time, or at a very high rate. Most Regional Councils have restrictions regarding ponding (check with your Regional Council for requirements). It is recommended that effluent be applied to pasture according to the guidelines in Table 2.4-1 under the following terms:

- **maximum application depth (mm)**
- **maximum application rate (mm/h)**
- **minimum application interval (days).**

Take into account prevailing weather conditions. Figures in Table 2.4-1 refer to soils at half of their water holding capacity. Soils that are saturated cannot be expected to absorb the applications recommended in Table 2.4-1.

Land with mole or tile drainage requires specific attention to hydraulic loading to avoid effluent reaching waterways via subsurface drains.

2.4.2.1 Maximum application depth (mm)

The maximum application depth (mm) is the **amount of effluent that should be applied at any one time.** It is largely limited by hydraulic loading (amount of water being applied to the soil) and therefore is dependent on soil conditions at the time.

Over-watering will achieve nothing and can reduce pasture growth by causing saturated conditions in the root zone and damaging the pasture with an excessive build-up of solids.

These effects limit the amount of water that can be applied at any one time. The amount of effluent applied per application depends on the **water holding capacity of the soil type** and **the depth of the root zone.**

Table 2.4-1 gives the maximum application for various soil types. With these values the effluent will be kept in the effective root zone (i.e. to 20 cm depth) so that the pasture will benefit from the effluent nutrients. The values assume the soil is at 50% water holding capacity prior to effluent application.

A more accurate assessment of maximum application depth can be made by monitoring soil moisture to determine actual water holding capacity at any particular time. Some Regional Council websites carry seasonal data about rainfall and evapotranspiration that can be used to estimate soil moisture conditions on a regular basis.

To work out the application depth (mm) applied by your system refer to 2.9.3.2 Travelling applicators and 2.10.1 Application depths and rates (for vehicle spreading).

2.4.2.2 Maximum application rate (mm/h)

The maximum application rate (mm/h) is the **amount of effluent applied within a certain time period.** If effluent is applied at a greater rate than the infiltration rate of the soil, runoff can occur and water and nutrients will be lost to waterways. The maximum application rate given in Table 2.4-1 is for soils on pastoral land of up to 8° slope.

To calculate the application rate (mm per hour) of your system, refer to 2.9.3.2 Travelling applicators and 2.10.1 Application depths and rates (for vehicle spreading).

To measure the actual application in an irrigation pass, place ice-cream containers at 2 m intervals across the path of the irrigator. Use a watch to time the pass of the irrigator over the containers (noting only the time when effluent is entering the containers).

The average depth is the sum of the depth in each container divided by the number of containers. The average application rate is the average depth (mm) divided by the time during which effluent was entering the containers (hours). If an average of 18mm was collected in your containers over half an hour, the average application rate is 18 mm / 0.5 hrs = 36 mm/hr.

Do this at least once a year to check your system is giving good performance.

Compare the average application rate with the figures in Table 2.4-1 and with Regional Council regulations for your area.

Checking the depth variation between the containers will also give an indication of the uniformity of effluent application from your system. Uneven depths can occur where there is a variation in instaneous rate across the path of an irrigator. This refers to the volume applied over the contact time with the soil in a specific site. Travelling irrigators in particular have an uneven rate of application such that an instantaneous application rate of up to 120mm/hr has been measured.

2.4.2.3 Minimum application interval (days)

The effluent can be applied to land repeatedly but a **minimum interval between applications is required** to allow for infiltration and for the solids to be taken up by the soil. The minimum application interval (days) given in Table 2.4-1 considers the water and solids component of the effluent only. The decision when to reapply effluent to land also revolves around other factors:

- **stock rotation** (refer to 2.6 Pasture and grazing management)
- **pasture length**
- **prevailing weather** and its influence on applicator access, soil saturation and effluent breakdown
- **fertiliser value of the effluent** for the remaining land area
- **Regional Council regulations** (check with your Regional Council for requirements)
- **disease risk** (refer to 2.13.1 Food safety and dairy industry requirements).

TABLE 2.4-1

EFFLUENT APPLICATION RECOMMENDATIONS FOR VARIOUS SOIL TYPES UNDER PASTURE COVER			
Soil Type	**Maximum application at any one time**	**Maximum application rate**	**Minimum application interval**
Sand	15 mm	32 mm/h	5 days
Pumice	15 mm	32 mm/h	5 days
Loamy sand	18 mm	32 mm/h	5 days
Sandy loam	24 mm	20 mm/h	15 days
Fine sandy loam	24 mm	17 mm/h	15 days
Silt loam	24 mm	10 mm/h	20 days
Clay loam	18 mm	13 mm/h	20 days
Clay	18 mm	10 mm/h	20 days
Peat	20 mm	17 mm/h	15 days

Note 1: For soils at 50% Water Holding Capacity prior to effluent application.
Note 2: For land slopes up to 8°. Application onto low to steep hills should be avoided.
Note 3: Rooting depth of pasture 0.31 to 0.76 m. Effective rooting depth for nutrient uptake 0.2 m.

New Zealand Pastoral Agriculture Research Institute Limited, pers. comm.; Standards Association of New Zealand, 1973; Livingstone, 1992; Wrigley, 1993.
Water holding capacities for various soil types from Standards Association of New Zealand, 1973.

2.4.3 Planning the periods of application

In the majority of regions within New Zealand, effluent cannot be applied all year round because of climatic restrictions (i.e. high rainfall seasons). Some soil types cannot cope with a large effluent application at one time. Therefore, it is necessary to calculate the **daily area** set aside to deal with land applied effluent. It is wise to establish which months are best for applying effluent and which are best for storing effluent. This will aid with planning the **timing of application** to land and storage capacity.

2.4.3.1 Daily area

Effluent may be applied direct from the farm dairy with minimal storage **or** following a period of storage.

When using daily spray application rather than occasional vehicle spreading or deferred irrigation, the area to be treated each day needs to be calculated. The daily area is dependent on Regional Council restrictions on N loading (refer to 2.3 Application area and check with your Regional Council for requirements), and the hydraulic loading limitations for the specific soil type (refer to Table 2.4-1).

Table 2.4-2 gives the **annual application (mm)** for the recommended application areas (refer to 2.3 Application area) with regard to Regional Council annual nitrogen limits. This annual amount would need to be spread across several applications in order to meet some Regional Council rules (check with your Regional Council for requirements).

TABLE 2.4-2

MAXIMUM ANNUAL APPLICATION VOLUME OF EFFLUENT APPLIED FRESH FROM THE FARM DAIRY			
Regional Council Annual N Limit	**Effluent Volume Per 100 Cows**	**Receiving Land Area (1 ha = 10,000 m²)**	**Annual Application**
150 kg/ha/year	1350 m^3	40,000 m^2	34 mm
200 kg/ha/year	1350 m^3	30,000 m^2	45 mm

Note 1: 1,000,000 litres = 1,000 m^3
Note 2: A single cow will generate 0.05 m^3/day (i.e. 50 l/day). This quantity may reduce slightly with larger herds as more cows are milked for the same amount of water used in washdown.

With regard to the hydraulic limitations of the various soil types, the **daily area** is calculated and is presented in Table 2.4-3. The **daily application depth (mm)** is also given.

If these recommendations are adhered to, the spray applicator may rotate around the complete application site several times annually, up to the maximum in Table 2.4-2.

TABLE 2.4-3

APPLICATION AREA PER 100 COWS FOR EFFLUENT APPLIED DAILY

Soil Type	Daily Area	Daily Application Depth
Sand and pumice	330 m^2	15 mm
Loamy sand, clay loam and clay	280 m^2	18 mm
Peat	250 m^2	20 mm
Sandy loam, fine sandy loam and silt loam	200 m^2	24 mm

When emptying a storage facility two or three times annually, it is simplest to **rotate around the total application area** (refer to 2.3 Application area). In this way the application volume will not exceed the maximum application allowable for any of the soil types (refer to Table 2.4-1).

2.4.3.2 Timing of application

Application problems can occur with soils that are seasonally wet due to a regular period of excessive rainfall where a perched water table exists, or when there is a **seasonal rise in the water table within permeable soils.** Problems can also occur if applying effluent after rainfall in sites where there is **mole or tile drainage.** Effluent should not be applied unless there is a soil moisture deficit.

Care should be taken in effluent application and pasture management when soils are wet, or under intensive grazing. Compaction in the top few centimetres may seal the soil, making the situation worse with successive applications, and requiring soil ripping or cultivation to remedy the damage.

Seasonal wetness limitations can be avoided by providing storage facilities for deferred irrigation of the effluent at a later date when the land is not waterlogged (refer to 1.7.6 Pond storage facilities).

An increase in the capacity of the storage facility will mean that a smaller land application system can be utilised. This makes it possible to apply effluent throughout the day rather than just when it is being accumulated in the farm dairy.

General recommendations for the best months to plan for effluent application to land and the volume of storage required are given in Table 2.4-4. Note that these are a guideline only and specific rules or conditions may apply (check with your Regional Council for requirements).

For design recommendations of holding ponds refer to 3.5.8 Holding pond design.

The storage recommendations account for effluent volumes and rainfall volumes falling direct into the storage facility during those periods when effluent cannot be applied to land. In areas with very high rainfall, storage systems that have a large surface area will need extra storage capacity to cope with stormwater.

TABLE 2.4-4

RECOMMENDED REGIONAL STORAGE AND APPLICATION PERIODS			
Region	**Best months for application**	**Storage recommendation**	**Storage volume per 100 cows (Guideline only)**
Canterbury and North Otago	September - April	1 month	160 m^3
Auckland, Nelson and Marlborough	October - April	2 months	340 m^3
Northland, Waikato, Bay of Plenty, Manawatu, Wanganui,Taranaki, Gisborne, Hawke's Bay, Wellington, Tasman, South Otago and Southland	November - April	3 months	500 m^3
West Coast	Whenever possible	4 months	690 m^3

Note 1: Based on 50 l/cow/day and local rainfall and evaporation data.
Note 2: Assumes stormwater from the farm dairy has been diverted.
Note 3: Winter milk properties will require larger storage facilities.
Note 4: For holding pond design specifications refer to 3.5.8 Holding ponds.

Individual properties experience unique climates, so local knowledge of these, and of soil types and milking systems, should be used to adapt the recommendations in Table 2.4-4. There may be sub-regional difference for districts that have specific weather or soil conditions

Properties involved in winter milk will require larger storage facilities to hold effluent over the winter months until soil conditions are dry enough to apply effluent.

2.4.3.3 Application to land with mole and tile drains

Land with mole and tile drains **should be avoided where possible** for irrigating effluent. Where this land is used for irrigation, application rates need to be carefully managed especially during wet condition, or where cracks are visible following aeration. Paddocks should be grazed at least twice between aeration and effluent application.

Where irrigation is badly timed and applied when there is not a suitable soil moisture deficit, a high proportion of the effluent will be lost to subsurface drains and then to waterways and the nutrients will be wasted. However, if irrigation is deferred until dry conditions prevail in the soil profile, drainage losses can be low as effluent is held and used in the active root zone.

Ideally, **a low-rate system such as 'pod' type sprinkler should be used on this land** and very low depths of effluent applied. A low application (3 mm) can significantly reduce the loss of nutrients and bacteria through the mole and tile drain system in a high risk situation, or 9-12 mm can be applied over 3 to 6 hours where soil conditions allow.

Where travelling irrigators are used, two key strategies are to **increase irrigator ground speed** and to **store effluent during wet periods.** It is also preferable to run the irrigators across the drains rather than following along them (parallel).

The **non-uniform pattern of travelling irrigators** should be taken into account when planning application over mole and tile drains. A heavy (more than 20 mm) application can still exceed soil water deficits even in dry periods of summer at points close to the outside of the irrigator run that receive approximately double the mean application depth. It is better to wait until soil water deficits are much higher than the anticipated application depth. Even when travelling irrigators are set at the fastest ground speed setting (delivering 6 or 7 mm application depth), there will be days in spring and late autumn when effluent applied will still reach mole drains because of soil moisture conditions (i.e. soil moisture deficits less than 15 mm).

Ideally, **soil moisture conditions can be measured or estimated using rainfall and evapotranspiration data for that season.** Some Regional Councils carry this information on their websites.

In the absence of exact information, travelling irrigators should be set at the fastest ground speed setting, thereby reducing the risk of applying excessive applications of effluent liquid when the soil cannot retain it in the wetter periods of spring and late autumn.

To achieve this, the provision of adequate pond storage is required above and beyond the storage required for irrigating land without mole or tile drains.

A final strategy on this sort of land is to create wetlands at the end of the mole and tile drains before they discharge into waterways. These can be created at the end of the drain by providing an area of raupo or backfilling with wood chip to allow water to be held up and nutrients removed. This should not be considered as an alternative to appropriate management of effluent on mole and tile drained land.

2.5 APPLICATION SITE SELECTION

The application site will generally remain the same over several seasons, particularly where a spray application or border dyke system is employed. However, it is often feasible to change the site when a vehicle spreading unit or contractor is used.

It is advisable to **illustrate on a farm plan areas where farm dairy effluent should not be applied at any time.**

Such areas may be determined by Regional Council and District Council regulations regarding the proximity of the application site to watercourses and public amenities (check with your Regional Council for requirements).

Each District Council has its own set of requirements for the positioning of treatment systems in relation to houses, roads and boundaries. Before installing a system, check with your local District Council office for siting requirements. Effluent should not be applied to land where paddocks:

- **are likely to flood** in the month after the effluent is applied
- **have slopes** that run toward a watercourse (including open farm drains), spring or borehole
- **are pipe drained or mole ploughed,** especially if the soil is cracked down to the drains or backfilled
- **are frozen hard.**

The selection of the most suitable site for land application of effluent then centres around the convenience, cost and any hygiene considerations.

2.5.1 Hygiene

Applying effluent or having storage facilities too close to the farm dairy is a health risk (refer to 2.13 Land application regulations). Disease-causing micro-organisms exist within the effluent and may pose a risk to both animal and human health.

Effluent must not be applied within 45 m of the farm dairy.

2.5.2 Accessibility

Both the distance and the difference in height of the farm dairy from the application site influence the capital outlay and cost of laying pipes, and the power costs of pumping the effluent through the delivery pipeline. **To minimise costs the site should be in the vicinity of the farm dairy (but not within 45 m).** This will also allow the farmer to easily check that the system is working correctly and quickly identify and **respond to system failure.**

2.5.3 Wind direction and proximity to residential housing

Effluent can cause a nuisance to the public because of its odour and because it may attract flies. **Avoid applying effluent on the windward side close to dwellings, roads and other public places** unless they are protected by a hill or a heavy belt of trees.

The District Council may have regulations addressing such separation distances.

2.5.4 Topography

The site needs to be level without humps or hollows that may encourage ponding or channelling away of effluent. Steep slopes can hinder or prevent machinery movement and cause excessive surface runoff.

2.5.5 Soil properties and groundwater

Drainage and the level of biological activity of the soil at the application site are important. **Permeable soils with a deep water table and no drainage limitations are preferable** (refer to 2.4 Application rate). However on very stoney soils the risk of effluent draining directly to ground water should be considered and application depths and rates adjusted accordingly.

To protect water sources avoid applying effluent close to bores, springs and wells. Some Regions have rules specifying distances from these areas (check with your Regional Council for requirements).

Also avoid areas that are mole or tile drained if possible.

2.5.6 Location in relation to surface waterways

Do not select a site near to the banks of surface waterways as discharging effluent into a waterway without a consent is illegal. If effluent enters a waterway, it may cause a health risk. Furthermore, effluent is toxic to many aquatic animals and may decrease the ability of the waterway to sustain life.

The direct application of effluent into surface water can result in legal action by Regional Councils.

2.5.7 Application management

A primary Regional Council (and also District Council) concern regarding land application of effluent is the **generation of odour and air pollution** and nuisances such as flies. These problems are best solved by the use of **buffer zones** (i.e. minimum exposure distances) and following sensible **application management guidelines.**

Buffer zones

Most Regional Councils and District Councils have specific regulations regarding the proximity of receiving land to neighbouring properties, public roads, surface water and groundwater (check with your local District Council).

Where regulations do not exist, the size of buffer zones can be determined on a site by site basis with a conservative approach when public amenities and surface waters are close by.

In applying these buffer zones, consideration should also account for wind drift of spray from the application area.

Application management guidelines

Generally, the highest odour emissions, nuisances and hygiene problems occur while the application of effluent, particularly pond sludge, is taking place. Odour emission and drift may also be high enough to cause a nuisance for the following 8 to 12 hours. If effluent contains milk, the amount of odour released will be increased.

Aerosolising effects through spray application can produce droplets within the respirable range (i.e. 1 to 5 microns). The most practical way of avoiding this is to **use low-pressure spray nozzles** (i.e. 100 kPa to 300 kPa) **with large orifices** (i.e. between 8 mm and 16 mm). These generate large water droplets and reduce the production of too fine a mist (refer to 2.9.3.1 Sprinklers).

The following application management strategies should be followed to minimise odour, nuisance and hygiene problems:

- consult with neighbours if there is a potential for odour or if they have expressed concern previously
- avoid spraying at night. Stable atmospheric conditions, which slow micro-organism die-off, usually occur at night or during calm mornings when temperature inversions exist. The lack of sunlight and generally higher humidity also slows micro-organism die-off. Furthermore, any faults in the system are unlikely to be detected at night and permanent system damage, soil overloading and subsequent accidental breaches of regulations may result
- avoid spreading at weekends, on public holidays and in the evenings when people are around
- use a weather forecast to help choose suitable conditions for application. The best conditions for application are those causing odours to be diluted quickly, typically sunny windy days, followed by cloudy, windy nights. Weather conditions unsuitable for effluent application are those preventing odour dispersion, typically high humidity and very light winds or clear still nights
- check wind direction in relation to nearby houses before application
- avoid overfilling vehicle spreaders and spilling effluent on public roads
- avoid applying more than 10 mm of effluent at one time if odour is likely to cause a nuisance (i.e. 100,000 litres per hectare)
- plough sludge into hillsides parallel to the contours of the land to guard against the accumulation of micro-organisms and heavy metals downhill due to soil water flow, and to prevent soil erosion
- clean the outside of vehicle spreaders regularly.

2.6 PASTURE AND GRAZING MANAGEMENT

Provided suitable farm management practices are in place, **application of farm dairy effluent will result in increased pasture production.**

Farm management issues affected by effluent application include grazing rotations, control of clover and weed growth, maintenance of correct soil acidity and prevention of turf pulling.

The key is to apply effluent to short pasture, at light application rates, and then allow a suitable withholding period before grazing.

Applying effluent to short pasture, rather than long pasture, will:

- **allow better infiltration** of the solids component of effluent into the soil
- **allow pasture to recover from treatment** more quickly, maintaining clean, palatable regrowth.

Low effluent application rates and rest intervals will:

- **avoid nutrient leaching and groundwater contamination**
- **minimise the risk of surface runoff**
- **ensure that surface sealing** by effluent solids, causing compounding drainage problems, does not occur
- **allow the pasture to recover from treatment more quickly**
- ensure that the maximum amount of effluent is subject to the **sterilising action of sunlight and air exposure,** and the **biological breakdown** by soil bacteria.

It is important to avoid having springing cows and recently calved cows grazing effluent areas due to risk of metabolic problems from excessive potassium (K).

2.6.1 Grazing

Grazing stock on freshly treated pasture or crops may result in disease transfer (refer to 2.13.1.1 Human and animal health). Also there is a possibility of the pasture being trampled into the soil rather than eaten if the effluent has not quickly drained.

The solution to all these problems is to:

- **apply effluent to short pasture**
- **withhold stock from grazing the pasture for 10 day**s (refer to 2.13.1.1 Human and animal health).

Where possible, paddocks should be grazed as part of the farm's normal round with stock regularly returning to effluent treated paddocks when they are ready to be grazed. When subject to intensive and consistent effluent application, paddocks will require more regular grazing to maintain pasture quality.

Graze stock in front of the area to be treated, a few days prior to application. This will benefit:

- **the soil,** allowing the land to dry out before the stock return, thus reducing surface pugging
- **animal health,** as it gives the maximum time for destruction of any disease-causing micro-organisms that may have been carried to the pasture by the effluent
- **pasture quality,** since short pasture will trap less solids and the risk of the sward rotting at ground level is reduced
- **pasture palatability.** Application of effluent onto long pasture may result in stock rejection of the treated feed. This is because long pasture does not allow the effluent to move into the soil; it persists on the plant and is distasteful. Although some herds will graze pasture recently treated with effluent, this should be avoided for animal health reasons.

2.6.2 Clover suppression

Clover will flourish under the application of effluent, as will any legume, as long as the pasture is managed correctly. The extra pasture growth resulting from the application of effluent must be grazed off. If it is not, the pasture will become too long and the clovers will be shaded out, reducing the clover content of the pasture.

However, effluent nitrogen applications of greater than 200 kg/ha/year should be avoided as such levels will adversely affect clover growth and clover nitrogen fixation.

2.6.3 Weeds

There have been reports of an increase of some weeds (e.g. dock) in pasture subject to effluent disposal. This is because some seeds can remain fertile after passing through the digestive system of the cow. Long-term storage of effluent, such as occurs in ponds, will decrease the viability of many seeds carried within the effluent application system.

To prevent weed intrusion or rank growth, the application site should be carefully grazed to control weeds while avoiding pugging, opening the pasture up or exposing bare soil.

Avoid over-application of effluent to soils. Over-application can damage pasture species and allow weeds to take over.

2.6.4 Soil acidity and liming

Effluent has an average pH of 8.0 - 8.5 and, even after long periods of storage, should not fall below a pH of 6.0.

However, all N fertilisers slowly reduce soil pH. **Optimum pH levels are 5.8 to 6.0 for mineral soils and 5.0 to 5.5 for peat soils.** If an increase in acidity is noted the land may require liming.

Effluent applied at a rate of **150 kg of N per ha per year may require 1 tonne per ha of lime applied every 4 years.** Effluent applied at a rate of **200 kg of N per ha per year or more may require 1 tonne per ha of lime applied every 3 years.**

The application of lime will also increase the availability of the P component of the effluent to pasture.

Regular soil testing to check on fertility and pH is recommended.

2.6.5 Turf pulling

It has also been suggested that effluent application to land will result in shallow rooting pasture that is readily pulled by grazing stock. However, the problem is not so much associated with the irrigating and fertilising effect of the effluent, but rather with the management practices surrounding the grazing of treated pasture.

Turf pulling commonly occurs where the soil structure has been physically damaged (refer to 2.6.6 Avoiding pugging).

2.6.6 Avoiding pugging

Heavy machinery and stock treading on wet soil can damage soil structure.

The wetter the soil, the greater its susceptibility to damage, so grazing of heavy stock should be avoided where pastures are being irrigated in spring conditions.

Pugging reduces the air component in the soil and increases soil density. This makes soil more difficult to manage and affects pasture production. Compaction in the top few centimetres during grazing may seal the soil and the situation will become worse with successive applications.

Compaction and pugging can impact seriously on pasture, depressing production for up to 9 months after a pugging event. Preventing pugging by taking stock off wet soils is better than trying to take remedial action afterwards.

If pugging has occurred, subsoiling can sometimes be used to address the problem.

2.7 CROPPING LAND MANAGEMENT

Farm dairy effluent applied to cropping land provides large quantities of beneficial nutrients (i.e. N, P, K and S) to the crop plants.

Land used for cropping or supplements will benefit from the addition of larger quantities of effluent than those applied to pasture (refer to Table 2.7-1). Some Regional Councils allow higher applications of effluent to cropping land than pastoral land. Addition of this organic matter will improve the physical properties of the soil such as aeration, water holding capacity, and tillage characteristics, particularly where continuous cropping is practised.

Nutrient anaysis of the effluent and nutrient budget will assist in assessing appropriate application rates.

2.7.1 Applying effluent to crops

In the case of cropping, the benefits of effluent application are best achieved by **working the effluent into the topsoil before sowing and planting.**

The effluent application should be allowed to dry out over several days before working it into the soil.

TABLE 2.7-1

MAXIMUM ANNUAL APPLICATION OF EFFLUENT ONTO CROPS

Crop	N Requirement
Pasture	150 to 200 kg/ha/year
Maize (20 tonne per ha crop)	200 kg/ha/year
Pasture cut for hay or silage	250 to 400 kg/ha/year

Wrigley, 1993

With hay and silage a larger quantity of nutrients is removed from the land than under grazed pasture, and so a greater volume of effluent can be applied per hectare (refer to table 2.7-1).

For hay and silage, effluent should not be applied within 14 days prior to harvesting.

Since maize plants grow up to twice the dry matter of pasture in half the time, they will require a relatively heavy application of effluent. Typical annual N requirements for maize are around 10 kg/ha for every tonne of crop grown.

The limiting factor when applying effluent to cropping land is the ability of the soil to take up liquid effluent (i.e. the water holding capacity of the soil). Table 2.7-1 **gives the maximum annual applications for effluent applied to crops.** Effluent is usually supplied from a holding pond and applied either before sowing or during the early growth stages. Therefore, the application area is presented as hectares per 1,000,000 litres in Table 2.7-2.

These guidelines should be used **only if Regional Councils allow the heavier application** of effluent for cropping (check with your Regional Council for requirements).

TABLE 2.7-2

MINIMUM APPLICATION AREA FOR EFFLUENT APPLIED TO CROPS

Soil type	Maximum application	Application area
Sand and pumice	15 mm	7.0 ha per 1,000,000 litres
Loamy sand, clay loam and clay	18 mm	5.5 ha per 1,000,000 litres
Peat	20 mm	5.0 ha per 1,000,000 litres
Sandy loam, fine sandy loam and silt loam	24 mm	4.0 ha per 1,000,000 litres

Refer to 2.4.2 Recommended applications for common soils

2.7.2 Applying effluent to tree crops

Effluent can be applied to a tree plantation. Typically soil moisture levels under trees are lower than under pasture which means that effluent can often be safely irrigated even when conditions in adjoining pasture areas are too wet. The trees grown can supply timber or fodder. Trees generally used for such purposes include pines, eucalyptus and poplars or willows.

2.8 LAND APPLICATION OF SLUDGE

Sludge is the settled solids from farm dairy effluent that gather at the bottom of sand and stone traps and pond systems. Like the semi-solid material freshly deposited by cows in the farm dairy, sludge can be over 20% total solids. Such effluent solids will not flow in a pipeline system and must be scraped off the farm dairy yard or dredged from storage facilities and spread on land, or re-mixed with liquid effluent, stirred and sprayed onto land.

Since sludge is high in nutrient content, it is beneficial to **incorporate it into cropping soils before planting and plough it into soils during the re-sowing of pastoral land.**

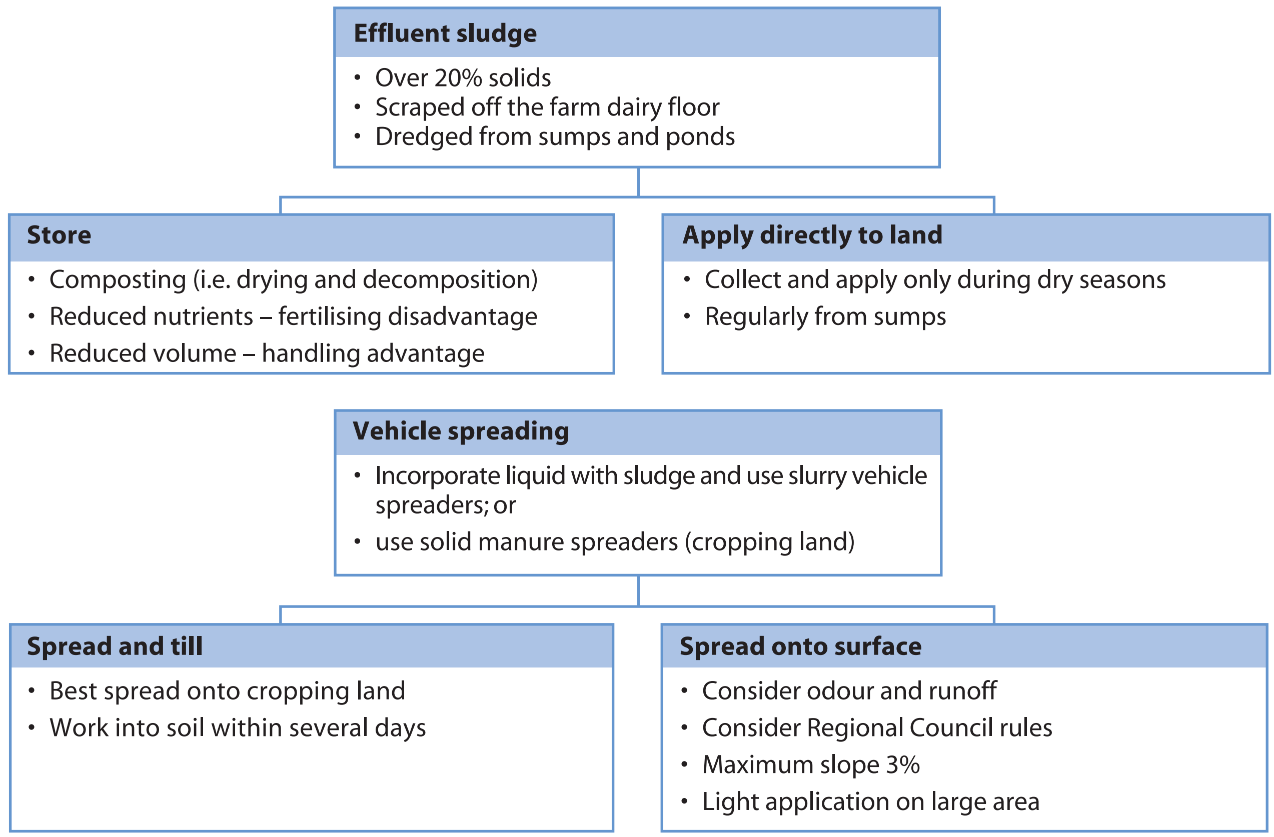
Unless it is mixed in with liquid effluent, sludge should not be spread directly on to pasture (unless at very low application rates) because it will physically damage the plants and block out light. It is also high in nitrogen and may exceed Regional Council application limits. For this reason it is best practice to apply liquid effluent to areas not receiving sludge.

Desludging (refer to 3.8.1 Desludging) and yard scraping can be followed by **direct spreading of the sludge to land** or **storage composting** where the sludge is collected and left for a period to dry and decompose (refer to Figure 2.8-1).

Regional Councils generally allow the application of sludge onto land as desludging of ponds is a necessary part of system maintenance, though in a few regions Resource Consent is required for this activity. Some Regional Councils have specific conditions for sludge application to land, in particular regarding nitrogen loading (check with your Regional Council for requirements). A nutrient analysis of the sludge and a nutrient budget will help in assessing appropriate application rates.

FIGURE 2.8-1

SELECTION OF A SLUDGE TREATMENT SYSTEM



2.8.1 Composting of sludge

Under composting some of the volatile nitrogen in the sludge will be lost, but the organic nitrogen is retained for land application, soil breakdown and plant uptake. Although this reduces the total nutrient content of the sludge, the volume is also reduced, making handling easier. The compost is also a good soil conditioner. Design considerations for the sludge storage facility are as follows:

- **ground level storage is the most practical**
- **a concrete pad with sturdy retaining walls can enclose and retain the sludge.** Vehicles can then drive into the facility to load and off-load. The concrete floor should have a **minimum fall of 1 m in 100 m** towards drainage outlets
- **a polyethylene cover or complete roof is necessary** in high rainfall areas
- **smaller, long, low narrow stores are preferable.** A series of stores will mean that one store can be filled and left to compost while another is being filled
- **drainage outlets are required** to allow liquid to escape and be collected during sludge drying. Any liquid must be channelled back to the effluent treatment system
- **a drainage channel should completely surround the store** to collect all runoff. The channel should be wide enough to allow scrape cleaning with a shovel
- **the facility should be as close as possible to the farm dairy and ponds** so that the sludge can be scraped across the concrete areas and conveyed to the store
- **above-ground storage is necessary where there is a high seasonal water table**
- **the cost** of prefabricated stores may be competitive with that of stores constructed by the farmer.

Weeping wall sludge stores are normally built above ground on a concrete base. Excess liquid drains through narrow slots in the walls, is collected in a channel, and is conveyed to effluent ponds. The contents of the store gradually dry out and the removable side panels can then be safely taken out to access the solids for spreading onto land. This is usually appropriate towards the end of the summer months. Refer to 2.12 Processing options prior to land application, for design guidelines for weeping wall structures.

2.8.2 Sludge spreading

Stored and composted sludge can usually be handled as a solid with solid manure spreaders ('muck spreaders'). These are often towed and have a rear flail spreader and a chain drag to move the sludge backward towards the flail (refer to Figure 2.8-2). Small manure spreaders usually have ground-driven spreader mechanisms whereas the larger designs drive off the PTO.

Trucks with tipping decks should not be used as the application rate cannot be easily controlled.

Open-tank spreaders can handle sludge freshly scraped or dredged from ponds. Vehicle spreaders can also be used for fresh sludge (refer to 2.10 Vehicle spreading). **Sludge transported on public roads should be in enclosed tankers or covered trucks.**

Contractors can also be used to apply sludge to land.

FIGURE 2.8-2

A 'MUCK' SPREADER

Photo provided by Bob Longhurst, AgResearch

2.8.3 Health considerations

Sludge application to land is carried out to dispose of sludge from sumps, holding ponds, oxidation ponds and barrier ditches. Storage facility treatment results in only 5% to 40% of bacteria settling in sludge and anaerobic digestion removes about 90% of viruses from sludge.

However, cysts, eggs and larvae of parasites have a high tendency to settle out in sludge during effluent storage. This results in a high proportion of disease-causing micro-organisms ending up in the sludge.

Refer to 2.13.1 Food safety and dairy industry requirements for recommendations on land application of sludge.

Septic tank sludge must not be disposed of into any effluent system or onto land because of the potential risk of human disease being transmitted to and from animals.