

CHAPTER 1

**MANAGING FARM DAIRY EFFLUENT**



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## 1.1 OVERVIEW

In New Zealand, farm dairy effluent management is a rapidly changing field. The Resource Management Act (1991), was created to provide a framework to **promote the sustainable management of natural and physical resources**. Regional Councils apply the Resource Management Act (1991) with guidelines, recommendations and regulations for the acceptable management of effluent.

Technologies developed to manage effluent acceptably can make valuable use of the fertiliser value of effluent and improve the long-term marketability of export dairy products.

This manual addresses the safe, hygienic, economic and practical aspects of effluent management. It provides current technical information for Regional Councils, Dairy Industry consultants, contractors and dairy farmers.

The manual as a whole relates specifically to New Zealand in terms of regulatory requirements.

## 1.2 LOCAL GOVERNMENT

Under the Resource Management Act (1991) the major responsibility for natural resource management was passed to 'Local Authorities'. Local authorities include Regional Councils and District Council or City Councils. Unitary Authorities combine the functions of Regional and District/City Councils. The Unitary Authorities are Gisborne, Nelson, Marlborough and Tasman.

Regional Councils are charged with controlling the use of water (i.e. damming, taking or diverting water and discharging contaminants into water) while District Councils have control over the use of land (e.g. rules about subdivision and development). Regional Councils may control some activities on land if they are likely to have an impact on natural resources. Together, Regional and District Councils are responsible for the mitigation of natural hazards such as flooding. For the purpose of this manual, any reference to Regional Councils will include Unitary Authorities. Where District Councils are referred to in this manual, this is also inclusive of City Councils.

## 1.3 QUESTIONS AND ANSWERS FOR FARMERS

### 1.3.1 What is the best system for my property?

**Each property should be examined on its own merit.** Some systems, especially those that eventually discharge treated effluent to waterways, have been unsuccessful on some properties.

**The best systems are the flexible ones with a suite of options** (e.g. a holding pond with land application during suitable weather conditions).

**The trend is towards land application as the preferred farm dairy effluent treatment method of both farmers and Regional Councils** (refer to Chapter 2. Land application). Where new systems are being planned, land application must be given due consideration. On existing properties, phasing in a land application system may be appropriate.

### 1.3.2 Where can I get advice on what system to install and the appropriate design specifications?

**Check out [www.envirodirect.co.nz](http://www.envirodirect.co.nz) for consultants in your area.**

**Dexcel Consulting Officers or agricultural consultants may be able to help you find an effluent management consultant.**

Your **Regional Council** can supply the appropriate rules regarding your intended system. Some also provide advice on best practicable options for your individual farm situation and information on management to protect the environment. Keep in close contact with them.

### 1.3.3 How do I reduce the effluent generated at the farm dairy?

Reduce the amount of manure deposited on the farm dairy floor by:

- treating the herd gently before yarding and milking
- being even tempered
- not using dogs in or near the farm dairy
- reducing excessive or unusual noise
- preventing troughs from overflowing and hoses from constantly running.

Options for reducing the total volume of effluent include:

- diverting water from roofs, yards and plate coolers. Do not let clean water enter the effluent treatment system
- using less water for washdown
- scraping the farm dairy yard prior to washdown
- installing a footbath at the yard entrance
- once-a-day milking

Refer also to 1.6.7 Dairy cow and washdown effluent.

### 1.3.4 How do I manage effluent in a high rainfall area?

Reduce the amount of effluent generated at the farm dairy (refer to 1.3.3 How do I reduce the effluent generated at the farm dairy?)

If applying effluent to land, consider a low-rate system such as 'pod' type sprinkler system or set your travelling irrigator on high speed to apply a minimum depth of effluent.

Make sure you have sufficient pond storage during the wet months when land application is undesirable. Pond storage may utilise existing oxidation ponds that have been blocked off or capped, or a newly constructed holding pond.

If utilising a holding pond for land application or a pond treatment system, include in the design sufficient holding volume for rain falling directly into the facility for the wettest months in the year.

- Use climate data to find the rainfall for the wet months (mm). **Multiply** this by the surface area of the proposed holding facility (m<sup>2</sup>) and **Divide** by 1000.
- This is the **extra** volume you will require **on top of** the volume of the proposed facility for effluent (m<sup>3</sup>).

### 1.3.5 What makes a good land application system?

The best land application systems:

- have sufficient pond storage during those wet months when land application is undesirable
- contract a vehicle spreader to empty the storage ponds (i.e. holding ponds or existing oxidation ponds) several times annually **or** operate a travelling applicator or low rate system from storage ponds
- apply effluent to short pasture using a low application rate
- enforce a 10-day stock withholding period following effluent application. Dexcel recommend withholding for 10 days for animal health or 15-20 days to avoid reduced pasture intakes.

### 1.3.6 How do I sample the effluent for nutrient value?

**Any laboratory that carries out soil, herbage and fertility analysis should be able to carry out an effluent nutrient analysis.** They will be able to provide you with appropriate sampling containers. The cost will depend on what nutrients are analysed. If testing for nitrate, nitrite, total Kjeldahl N, P, K and Mg this will cost approximately \$90. Analysis must include total Kjeldahl N (and not just nitrate N) since nitrification does not occur until the effluent is incorporated into the soil.

Either take a sample from the irrigator, (e.g. by placing an ice cream container under the irrigation path) or, if taking a sample from storage ponds, agitate the effluent before sampling. This will produce a slurry with a more representative sample of the effluent nutrients. If sampling from a feed pad storage facility where the yard is scraped/cleaned periodically, it may be more appropriate to provide a composite sample taken over an extended period of time to give average values.

A composite sample can be taken by putting a 2-litre container in the freezer and each day adding a few hundred mls of agitated effluent to it. Once the container is full it can be delivered to the laboratory for testing.

More than one composite sample will need to be taken throughout the year e.g. spring and again in summer. If effluent volumes and strengths change significantly through the year (e.g. because of use of feed pad for winter months) it will be necessary to sample effluent at quarterly intervals.

### 1.3.7 How much nitrogen applied to land is too much?

Some Regional Councils have rules regarding the amount of effluent nitrogen that is applied to land. A Regional Council limit of either 150 kg/ha/year or 200 kg/ha/year is common.

Rates higher than these may result in elevated nitrate levels in groundwater. Also, the clover content of pasture may be substantially reduced, as may the amount of nitrogen fixed by clover (refer to 2.4.1.3 Nutrient loading).

The following figures provide a general guideline, but need to be adjusted for intensive systems (e.g. feed pad or cut and carry maize situations) and also depending on whether effluent is sprayed from a sump or a storage pond, as this affects N concentration.

150 kg/ha of nitrogen each year is roughly equivalent to having an application area of 4 hectares per 100 cows.

200 kg/ha of nitrogen each year is roughly equivalent to having an application area of 3 hectares per 100 cows.

Some Regional Councils also have rules or recommendations regarding the land area for application, and these vary significantly between regions (check with your Regional Council for requirements). The best practice is to sample the nutrient value of your own effluent (refer to 1.3.6 How do I sample the effluent for nutrient value?) and work out the area required for application to achieve the rates specified by your Regional Council (refer to 2.4.1.3 Nutrient loading). A nutrient budget will assist in determining this.

Caution is also required with application rates to avoid build up of excessive potassium (K) in soils and pasture, which can result in metabolic problems for cows. This may require a larger area to be irrigated (up to double) than that which would comply with N loading requirements (refer to 2.2.5 Nutrient availability to the pasture).

### 1.3.8 How much effluent can I apply at one time?

**The maximum application is largely dependent on the soil type and vegetation. As a general rule, no more than 20 mm should be applied to pasture at one time.** Refer to 2.4.2.1 Maximum application depth for details for various soil types. Note that some Regional Councils specify a maximum application depth, commonly between 20 and 25 mm. There are also often conditions around ponding and flooding of pasture surfaces (check with your Regional Council for requirements).

Consider soil conditions when deciding on the maximum application for that particular irrigation pass. In wet conditions, the soil will absorb less and there is more risk of surface runoff or leaching to groundwater.

Maximum application is also dependent on the concentration of nutrients (especially N) in the effluent (refer to 1.3.7 How much nitrogen applied to land is too much?). Sludge, in particular, if applied at 20 mm may be in excess of your Regional Council's maximum N application rates or recommended upper limit.

A very heavy application of effluent may result in surface ponding and runoff into waterways with clay soils, or leaching and groundwater contamination with sands. Furthermore, the loading may damage the pasture, blocking out light and rotting the sward at ground level.

For cropping land, larger volumes of effluent may be applied to the bare soil. However, the application will have to be allowed to dry out, over several days, before working it into the soil.

### 1.3.9 Does effluent carry diseases that can infect my stock?

Disease-causing micro-organisms present in effluent originate from the stock, and so micro-organism levels will reflect the current state of health of the herd. Therefore, with good husbandry practices, effluent originating from dairy cows should be free of major diseases (refer to 2.13.1 Food safety and dairy industry requirements).

However, effluent can contain a wide variety of pathogens including bacteria, viruses, cysts, and eggs and larvae of parasites (e.g. hookworm, roundworm and tapeworm).

If the effluent is applied correctly, with **suitable stock withholding periods prior to grazing (i.e. at least 10 days)** no health problems should occur. A withholding period allows maximum exposure to sunlight, which will kill most bacteria, viruses and cysts as well as provide the opportunity for the effluent to be washed into the soil by rain.

**A period of storage prior to land application will reduce the number of disease-causing micro-organisms in the effluent.**

Unfortunately, eggs and larvae of parasites are stable in the soil environment and may remain viable for a long time. Therefore, a problem with worms could occur. This is most likely if the property is heavily stocked and carries a high percentage of younger cows.

**Calf paddocks should not be treated with effluent** as calves have not developed immune responses to the degree of older animals and are more susceptible to infection.

### 1.3.10 For spray application, what pumps, pipes and applicators are best?

**Travelling applicators are recommended in preference to stationary applicator systems.** Stationary applicators are often not shifted regularly and so they have traditionally failed, especially when other farm duties require time. Consideration is needed of who will operate and maintain the system and when it will be done.

A travelling applicator system must have the ability to expand with increasing herd size or intensification.

The applicator needs to be able to meet Regional Council application rate and depth requirements (check with your Regional Council for requirements) and should have the capacity to apply at low rates when soil moisture is higher or on heavy soil types.

Alternative, low-rate systems are preferable for heavy soil types, or for land with mole and tile drains e.g. 'pod' type sprinkler irrigation systems.

The effluent should first be screened through a solids trap at the farm dairy sump and then gravity fed to a pond where it can be pumped to the application site. Pumps operating from a pond should be seated on a float so the pump is positioned centrally rather than only moving effluent that gathers on the pond sides. **Electric motor driven pumps are preferable where there is existing power to the site.**



The delivery pipeline is made up of the mainline carrying effluent to the application site, and the sprayline carrying effluent from the hydrants to the applicator. **The delivery pipeline should utilise swept 'bend' fittings in preference to sharp 'elbow' fittings** since flow is seriously restricted by the latter.

The mainline should be placed along a fence so it can service two adjacent paddocks and is away from cultivating machinery. When the land around the hydrant is to be treated, the hydrant is coupled to the sprayline. Place hydrants in underground boxes to prevent damage and so the hydrant is not in the way of farm machinery.

The travelling applicator is fed by a portable polyethylene sprayline that is connected to the hydrant in the mainline.

For ease of handling the sprayline can be broken down to sections with camlock joints.

**The sprayline between the applicator and hydrant should not be greater than 150 m** as pressure loss increases with distance. Furthermore, many travelling applicators are not designed to drag a long sprayline full of effluent (refer to 2.9.3.2 Travelling applicators).

**Select a travelling applicator that applies effluent low to the ground, has a wide wetted width and variable travel speeds.** The applicator should automatically shut down at the end of a run. Galvanising is also important, as the effluent is very corrosive.

### 1.3.11 Do pond treatment systems work in the lower regions of the South Island?

The cooler climates of Southland and Otago are less conducive to a pond system than the rest of the country because such systems operate better at higher temperatures. Anaerobic breakdown will almost cease at temperatures below 10°C (refer to 3.2 How pond treatment systems work).

**However, advanced pond systems have been shown to work just as well in Southland as in warmer climates like Waikato** (refer to 3.7.2 Advanced pond systems).

**The design of the pond system must take into account the prevailing environmental temperatures.**

### 1.3.12 How do I know if my pond treatment system is working?

An analysis can be taken of the pond outflow and the quality assessed. However, the following visual guides are indicative of poorly operating ponds:

- **sludge build-up or excessive crusting** a useful indicator of when individual ponds may need desludging is when the sludge level is over half the normal effluent depth when a pole is dipped in
- **soilds** are obvious in the second or third pond
- **baffle** is not working or is blocked
- **bubbling has stopped in the anaerobic pond**
- **discoloration** in the receiving waterway
- **odours** from the receiving waterway.

### 1.3.13 How can I improve my pond treatment system?

In the first instance, **divert stormwater to prevent it running into ponds** (refer to 3.6.3 Stormwater control). Clean rainwater from the farm dairy roof and concrete should not run into the sump and ponds. A diversion channel or cut-away ditch can be constructed around the pond system to divert surface run-off.

Take the following steps to ensure your pond works well:

- prevent chemicals from entering ponds (e.g. copper sulphate/foot treatments) as these can affect effluent breakdown
- ensure plastics do not enter ponds (e.g. gloves, syringes) as they can block inlets and outlets
- ensure groundwater is not entering through pond floor/ walls and that plastic liners are intact
- ensure inlet and outlet pipes are in the right position so that effluent retention time is maximised
- keep stock away from the ponds and embankments
- control weeds and maintain pipes and structures

- **desludge ponds as necessary and follow your Regional Council's rules or recommendations** (check your consent conditions or discuss with your Regional Council). Recommendations for desludging frequency vary from every two years to every four years, and more frequently if there is crusting or rapid sludge accumulation (e.g. sludge above half the pond depth) (refer to 3.8.1 Desludging)
- When desludging leave one third to maintain the base community of bacteria.

Mechanical aeration can be undertaken to improve the system's performance (refer to 3.7 System additions to improve effluent quality).

If effluent treatment is still poor, or if there are increases in herd size, **add additional ponds to the system** and/or extend the size of the aerobic pond or anaerobic pond (refer to 3.7.3 Additional ponds and 3.5 Pond design criteria).

A constructed wetland can be added as an additional treatment before discharging to a waterway (refer to 3.10 Constructed wetlands), but only if the pond system already works well (i.e. as a 'polishing treatment').

A common approach is to close the discharge off and use the pond system as a storage facility for land application. Where this is not appropriate, due to farm topography or rainfall, an advanced pond system can also be considered (refer to 3.7.2 Advanced pond systems).

### 1.3.14 Are bacterial additives effective when applied to ponds?

Additive bacteria are more often used in septic tanks but can be introduced to ponds to liquify the crusts and sludge in ponds. Liquified effluent can be more easily applied to land through a vehicle spreader or spray application system than can effluent solids. Ponds can also be more easily stirred once the crust layer has been liquified.

**Additives do not significantly reduce the BOD<sub>5</sub>, phosphorus content, or any other polluting property. Instead they may make the effluent more manageable.**

Current evidence suggests that bacterial additives are not a long-term solution to reducing odour problems or improving pond system performance.

Additives are not commonly used by farmers and vary in their effectiveness. Always ask manufacturers or suppliers of additives to provide independent proof of their products' effectiveness.

### 1.3.15 Can human wastes or dead animals be placed in the effluent treatment system?

**No.** Under no circumstances should human waste or dead animals be placed in the pond system. Of particular concern are health risks associated with human waste.

If the system is designed specifically for farm dairy effluent then it will be adversely affected by the addition of other waste, with a resulting outflow of reduced quality.

### 1.3.16 Can I add feed pad effluent to my existing system?

In most cases, introducing effluent from a feed pad or stand-off area will require a system upgrade and potentially a consent variation to deal with the increased volume of effluent which has higher solids content and high nutrient concentration (refer to Chapter 4 Effluent from feed pads, stand-off areas and other sources).

The quantity of effluent from the pad must be assessed for adequate design of the upgrade. This may require an additional pond, or additional screening and land area if irrigating. More frequent desludging of anaerobic ponds will also be required. Solids separation or methane digestion should be considered as a way to deal with the high solids content of this effluent (refer to 2.12 Processing options prior to land application). All effluent from feed pads and stand-off areas should be collected and treated appropriately.

### 1.3.17 What is an advanced pond system?

An advanced pond system replaces the second pond of the traditional pond system with a series of ponds designed to carry out particular functions (refer to 3.7.2 Advanced pond systems). In pilot trials in Southland and Waikato, these systems have been shown to successfully treat effluent to high standards, removing suspended solids, BOD and a high proportion of faecal bacteria. They function well in a cold climate, unlike traditional pond systems. However they have higher nutrient outputs compared to most land-based effluent systems.

### **1.3.18 Why do I have to control the discharge of effluent?**

Legally, under the Resource Management Act (1991), discharges must be managed to avoid effects on the environment. Regional Councils have the delegated authority to ensure this happens and have rules regarding discharges.

Effluent discharge into waterways can result in excessive plant and algae growth, toxic algal blooms, fish kills, problems with human and animal health due to faecal bacteria, and associated nuisances such as flies, odours and water colour changes (refer to 1.4 Why control the discharge of effluent?).

Effluent discharge into waterways is offensive to the New Zealand public and to visitors.

### **1.3.19 What rules do I have to comply with?**

All dairy farmers have to comply with Food Safety regulations produced in collaboration with the dairy industry (i.e. the Farm Dairy Code of Practice NZCP1).

The Regional Council regulations also have to be complied with, but these differ in each region.

Resource consents are one of the tools used to ensure the rules in Regional and District Plans are met. The resource consent will set out the way in which the activity will be managed in order to avoid any harmful effects on the environment. Even where a resource consent is not necessary, farmers will also need to know the conditions of any permitted activity rules.

### **1.3.20 Will current Regional Council regulations change?**

Some Regional Councils have still to produce regional plans or have regional plans in draft or proposed forms. However, the majority of these plans are now operative.

Once Regional Councils have brought in rules that comply with the intentions of the Resource Management Act (1991), these rules may still change if:

- a change is seen as necessary when the regional plan undergoes its 10 yearly review
- within 10 years, there is sufficient public pressure to change the regional plan
- within 10 years, the Regional Council believes a change in the regional plan is necessary.

### **1.3.21 What legal rights do Regional Councils have to enforce the Resource Management Act (1991)?**

The Regional Council is the level of government with a major responsibility for policing farm dairy effluent management under the Resource Management Act (1991). There are several methods of enforcement:

- serving an Infringement Notice with an instant fine (for minor offences)
- serving an Abatement Notice directing a farmer to cease an activity immediately and/or carry out certain actions e.g. empty a pond
- undertaking urgent preventative or remedial action or requiring the farmer to do so
- exercising an 'Enforcement Order' or an 'Interim Enforcement Order' issued by the courts. Anybody can apply for an enforcement order against someone else and it is issued by the Environment Court rather than the council. A hearing will be held about an Enforcement Order that has been issued
- prosecuting, with a maximum possible fine not exceeding \$200,000 or imprisonment for a period not exceeding two years.

Several people can be fined or prosecuted for the same offence e.g. the sharemilker, farm owner and farm worker can all receive separate fines.

For more details on enforcement refer to 5.2.2 Enforcement provisions.

### **1.3.22 How do I get resource consent?**

Check with your Regional and District Councils to see if resource consent is required. Most Regional Councils have forms with clear and direct questions that can be easily answered and additional information sheets.

Fill out the application form and an Assessment of Environmental Effects (AEE) report if necessary. You may need to get help from a specialist consultant if you are unsure how to do this (see [www.envirodirect.co.nz](http://www.envirodirect.co.nz) for consultants in your area).

Talk with and get approval from those people who may be affected by your activity (e.g. neighbours, downstream users, iwi).

Return the application with the deposit to the Council for processing. Respond to any requests for further information.

For information regarding consents, refer to 5.3 Regional plans and resource consents. If you have a specific question relating to your system, contact your Regional Council.

## 1.4 WHY CONTROL THE DISCHARGE OF EFFLUENT?

**New Zealand's clean, green and unpolluted status is invaluable. It must be protected through farm management practices.** World markets are becoming increasingly interested in the cleanliness of the farm dairy and the practices that are carried out there.

Currently, concern is being expressed about the impact of both treated and untreated farm dairy effluent on the environment. Particular attention is given to water quality and the need to keep untreated effluent out of natural underground and surface waterways.

These concerns are reflected in the implementation of the Resource Management Act (1991).

Effluent can contain stormwater, spilled milk, soil and feed residue, detergents and other chemicals, in addition to the faeces, urine and washdown water. These constituents carry sediments, nutrients, organic matter, disease-causing micro-organisms and toxins which can pollute natural water if they are inappropriately managed.

'Inappropriate effluent management' results in **direct discharge into waterways** or **indirect entry into surface water following poor initial treatment**. In brief, 'effluent pollution' can be described as the **degradation of natural waterways as a result of inappropriate effluent management activities**.

**Direct discharge of both treated and untreated effluent to waterways is offensive to the New Zealand public and to visitors.**

**Making good use of the nutrient value of effluent is also a positive benefit to farmers.**

### 1.4.1 Adverse physical effects

Sediment may alter the colour, turbidity or temperature of a waterway. This can upset aquatic ecosystems as well as reduce the aesthetic value of the water. Sediment will smother water plants and may reduce light infiltration, adversely affecting plant photosynthesis. Sediment can also smother insects on stream beds and clog up the gills of fish. Sedimentation of waterways can raise the bed levels, causing flooding.

### 1.4.2 Adverse biological effects

Effluent organic matter requires oxygen to break it down, which is measured in terms of its Biological Oxygen Demand. The oxygen needed to break down organic matter in effluent could otherwise be used by aquatic life. Therefore, effluent breakdown poses a threat to plant and animal life within a waterway. This is why Biological Oxygen Demand (BOD) is an important concept in effluent treatment. The organic content can cause excessive growth of bacterial and fungal slimes. These growths, and their associated effects, can change the quality of aquatic ecosystems, raise the pH of the water, and cause the death of sensitive animals and plants.

Discharge of effluent into a waterway can pose a health threat to downstream users, since disease-causing micro-organisms can be transmitted via water. Such micro-organisms make water unsafe for drinking or recreational use. They can even reach levels where stock will refuse to drink.

### 1.4.3 Adverse chemical effects

Chemicals, such as pharmaceuticals and cleaning agents, can act as poisons to aquatic plants and animals.

Inorganic nutrients, such as nitrogen and phosphorus, can enhance the rate of plant and algae growth (i.e. algal bloom) within a waterway. Such growths affect the aquatic ecosystem, clog pumps and water intakes and reduce the aesthetic and recreational value of waterways.

Ammonia-N is highly toxic to fish and aquatic animals, even at low concentrations (i.e. 0.2 to 1.0 g/m<sup>3</sup>). Furthermore, ammonia requires large quantities of oxygen to break it down. Therefore, ammonia breakdown depletes the oxygen levels of the receiving waterway.

### 1.4.4 Adverse social effects

The presence of effluent in New Zealand's natural waterways, and the effect that it has, can upset local residents and will give a poor impression to overseas visitors. Farm dairy discharges compromise Maori cultural and spiritual values. For example, direct discharges of treated or untreated effluent to waterways are culturally offensive.

### 1.4.5 Further reading

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## 1.5 KEEPING PROPERTY RECORDS

It is sensible to keep good records of a farm's effluent management strategy as it develops.

The information is useful for monitoring the success of the system employed, and can be helpful to designers and researchers. Records are useful for providing information necessary for a resource consent application and may provide evidence should the farmer be faced with legal proceedings regarding the effluent treatment system. It is good practice to keep your resource consent or permitted activity requirements accessible.

General recommendations on the effluent generated by herds of various sizes are available. However, for accurate design of effluent treatment systems, information from the herd and management systems on the individual property should be used.

While some recommendations can be correctly calculated with general data, volumes in particular are highly variable. Storage facilities, for example, can be designed too small and overflow.

### 1.5.1 What should be recorded

Recorded information is best kept in the farm dairy where it can be easily accessed and regularly updated.

Information should include such aspects as:

- **changes in the herd size, with dates**
- **increases in land area, with dates**
- **periods of the year that the herd is in milk**
- **dry matter production per hectare**
- **changes in supplementary feeds**
- **the volume of water** used for yard, vat and machine washdown (refer to 1.6.1 Effluent characteristics and volumes)
- **months when storage is required.** What months have traditionally been too wet for land application?
- **when the oxidation or holding ponds were last emptied**
- **ongoing maintenance of the system** e.g. when pumps and applicators were last stripped, painted and oiled
- **paddocks receiving effluent application, when and in which order**
- **fertiliser application, quantities, areas, types**
- **any effluent analysis, soil tests or herbage analysis taken.**

**Record fencing layout and mole and tile drains on a map. Changes to paddock size through fencing, or to drainage conditions through mole or tile draining can impact on land application and should be recorded.**

## 1.6 FARM DAIRY MANAGEMENT

An effective farm dairy effluent management and treatment system will **meet Regional Council and Food Safety regulations** and **minimise the amount of effluent generated at the farm dairy**.

Significant savings can be made in terms of storage facilities and handling costs by reducing the amount of effluent generated at the farm dairy.

Ways to reduce the volume of effluent include stock management in the yards and dairy, water conservation, scraping systems, stormwater diversion and mechanical aeration.

### 1.6.1 Effluent characteristics and volumes

Effluent can be dealt with as liquids, slurry or solids. In general, raw effluent takes the form of slurry.

**Liquid effluent is defined as material containing less than 10% solids.** Such material can be conveyed through piping systems by gravity or pumps, and is treated in oxidation ponds or by land application.

**Slurry contains between 10 and 20% total solids and will flow.** It is generally spread on land using vehicle spreaders (refer to 2.10 Vehicle spreading).

**Effluent exceeding 20% total solids is sludge and will not flow.** It requires mechanical spreading equipment - usually with scrapers, buckets and front-end loaders (refer to 2.8 Land application of sludge).

The physical, chemical and biological characteristics of effluent are extremely variable, changing from farm to farm, and from milking to milking.

The amount of manure deposited in the farm dairy by the single milking cow is 10 to 20% of that produced on a daily basis. The volume of total effluent varies, and depends largely on the quantity of washdown water applied as well as the amount of manure deposited on the milking area.

Farm management issues and techniques have a profound effect on the amount of effluent generated at the farm dairy. Factors affecting the amount and the polluting potential of effluent include:

- **intensification of production.** The use of fertilisers, supplements and irrigation will indirectly increase the quantity and strength of effluent produced
- **winter milking**
- **once-a-day milking. This can reduce effluent volumes by around 40%**
- **increases in herd size**
- **calving patterns**
- **feed pads, stand-off and wintering facilities**
- **detergents and other chemicals used.**

Because site conditions vary, it is useful to do an on-site analysis of effluent characteristics if possible.

Table 1.6-1 gives typical values for important characteristics of effluent, useful for design purposes when an on-site analysis cannot be done.

It is important to adopt conservative parameters in design to allow for variability as seen in the range of figures in Table 1.6-1.



### CHARACTERISTICS OF FRESH EFFLUENT AT THE FARM DAIRY

Characteristic	Typical (Guideline Only)	Range
Total Volume Produced	50 l/cow/day*	30 - 100 l/cow/day
Total Solids	0.55 kg/cow/day	0.3 - 0.6 kg/cow/day
BOD <sub>5</sub>	0.12 kg/cow/day	0.04 - 0.13 kg/cow/day
pH	8.5	8.0 - 8.5

**Note:** For nutrient values refer to 2.2 Fertiliser properties of effluent.

\* 50 litres per cow per day is a typical amount, but as herd size increases the per cow volume will drop slightly. The conservative figure of 50 is useful for design purposes.

New Zealand Dairy Research Institute, pers. comm; Robertson, Ryder and Associates, 1993; Wrigley, R., 1993; Vanderholm, D.H., 1984.

#### 1.6.1.1 Measuring water use at the farm dairy

To determine how much water the farm dairy contributes to effluent volume, water use from machine, yard washdown and vat cooling can be measured.

**To convert gallons (imperial) to litres, multiply by 4.546.**

- Work out the amount of water in the tank prior to milking  
e.g. a full 5000 gallon tank x 4.546 = 22,730 litres
- Work out how much water is left in the tank after milking  
e.g. a quarter tank left (1250 gallons) x 4.546 = 5683 litres
- Calculate the amount of water used  
e.g. 22,730 – 5683 = 17,047 litres
- Multiply this amount by 2 (2 milkings per day) to give a total daily amount  
e.g. 17,047 litres x 2 = 34,094 litres (3.4094 m<sup>3</sup>) per day
- Divide by the number of cows you milk to give litres per cow per day  
e.g.  $\frac{34,094 \text{ litres}}{450 \text{ cows}} = 76 \text{ litres of water per cow per day}$

Factors influencing the amount of water used include:

- yard gradient – the flatter the yard, the more water used for washdown
- yard area – greater yard area requires more washdown water
- speed of washdown – technique is important for the most efficient washdown
- temperature – effluent may stick to concrete on a hot day and require more water to shift it
- washdown method – hosing vs flooding methods influence water used.

#### 1.6.2 Stormwater

The amount of water used in the farm dairy must be added to any rainfall on the roof area and/or yards where stormwater diversion and guttering is not in place. To work this out, multiply your annual rainfall by surface area of the roof and/or yards.

e.g. 1200mm rainfall = 1.2 m x 250 m<sup>2</sup> surface area of yards = 300m<sup>3</sup> per year stormwater added to the effluent system.

By reducing the volume of effluent to be stored, **significant savings can be made in terms of storage facilities, pumping and handling costs.** The performance of the treatment system is also improved as retention times in pond systems are increased when volumes are lower.

Clean rainwater from roofs and open concrete areas, such as the farm dairy yard, should not be allowed to run into the storage facilities unless **the areas are small, storage is adequate, or water is needed to dilute the effluent.**

The cost of diverting uncontaminated stormwater is usually minimal, and should be a key feature of the farm dairy design. Strategies to reduce the amount of water added to the effluent treatment system include:

- **installing guttering and piping as part of the farm dairy roof**, to collect and convey the stormwater to a single point
- **critically examining existing gutters, down pipes, and the drainage system and refurbishing and reorganising them** to minimise the amount of clean water flowing freely across yards and into the farm dairy sump. Figure 1.6-1 shows how stormwater can be piped away directly through a sealed system
- **directing this clean water into a natural waterway, ditch, drain or soak hole**
- **not allowing stormwater from the roof to flow across any dirty areas**, as it will become contaminated and will require treatment. This will increase the effluent storage requirements and ultimately costs.

FIGURE 1.6-1

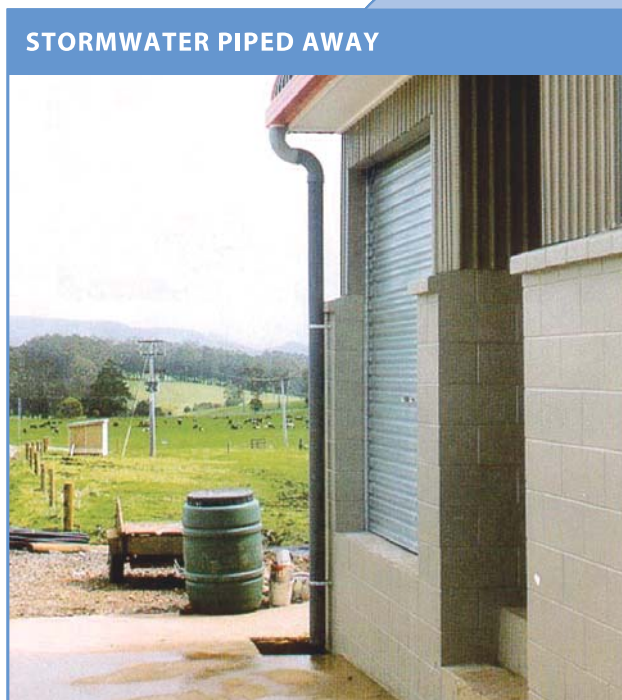
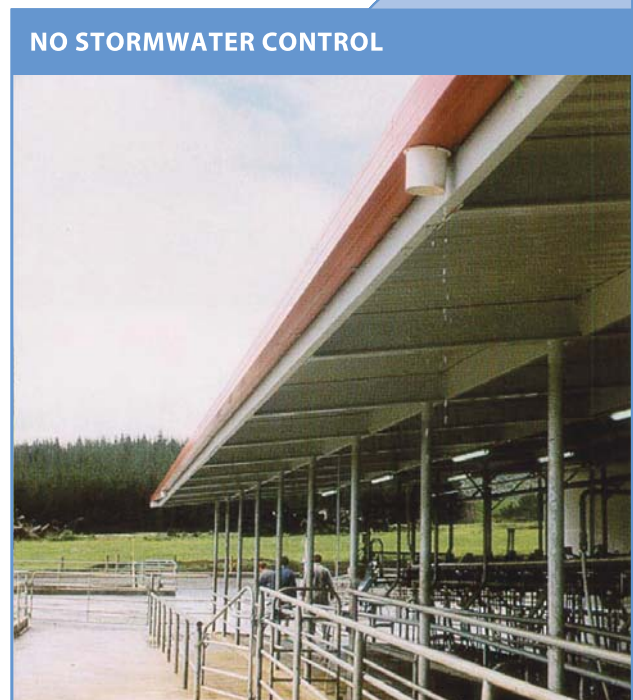


FIGURE 1.6-2



Clean stormwater can be:

- **diverted before the sump and directed to a waterway**
- **directed into the sump and used to flush pipes in a land application system.** In this way it is ultimately land applied
- **collected and used as washdown water** in a flood washing system (refer to 1.6.8 Reducing effluent volume and conserving water).

### 1.6.2.1 Stormwater diversion

Stormwater diversions, or bypasses, are a very effective way of minimising the amount of effluent entering the farm dairy sump and requiring storage and treatment. They control run-off from the yard surfaces.

Some Regional Councils require stormwater diversion to be in place and used.

There are many innovative designs ranging from a timber block hinged at the stone trap entry to a stormwater diversion incorporated as part of the stone trap itself. Often a trap door is used where a plate is lifted to divert stormwater into a drain. During milking and washdown the plate is lowered to allow effluent to flow freely into the stone trap and sump.

## STORMWATER DIVERSION



Figure 1.6-3 shows another type of stormwater diversion. The inlet (right) remains open, while either the outlet to the waterway (top) or the outlet to the sump (left) is closed off with a PVC cap.

Care needs to be taken to ensure that the stormwater diversion is:

- **closed during the day and night** to prevent stormwater entering a storage facility that was not designed to hold it
- **open during milking and washdown** to prevent effluent entering a drain leading to a waterway which would be polluted
- **open when stock are on the yard or the yards have not been cleaned**
- **ensure all staff are aware of stormwater diversion operation.**

To eliminate the risk of not managing the system properly, it may be appropriate to install an automatic facility (e.g. operated by a lever connected to the washdown system). Alternatively, **operate a stormwater diversion only during the months of particularly high rainfall or if there is promise of heavy rain.**

### 1.6.3 Milk spillage and disposal

At certain times of the year, it is possible that milk will have to be disposed of (e.g. if it cannot be sold or collected due to poor weather, industrial action or milk contamination).

Milk spillage and emergency milk disposal is a serious concern as **milk has an extremely high BOD<sub>5</sub> and so there is a very high risk of it causing problems** if it reaches surface waterways.

The choices of milk disposal include:

- feeding milk to livestock
- land application of diluted milk
- adding the milk to the effluent treatment facility.

**If at all possible, feed the surplus milk to livestock.** Nutritionally, milk is low in dry matter content (i.e. approximately 13%), and is high in energy (i.e. 20 to 23 MJME per kg of DM), protein and fat. However milk contaminated with veterinary medicines should not be fed to animals going to slaughter within 28 days.

Calves can consume between 8 and 12 litres of whole milk per day before weaning. After weaning, up to 4 litres per day can replace 1 kg of concentrate feed. However, the use of milk should be limited to minimise the risk of digestive disorders, and be supplemented with digestible fibre-based feed to encourage proper rumen function.

Dairy cows can be fed up to 10 litres in a day. The milk could be fed via water troughs or spread on silage if it is suitably contained.

Milk may also be transported to piggeries. Check local papers as there are often many people looking for waste milk including piggeries and calf rearers.

Milk is best fed consistently fresh or consistently sour to dairying stock. Souring in a storage facility can be prevented for up to one week by adding 1 litre of 40% formaldehyde solution (i.e. commercial formalin) to 1000 litres of milk. At this concentration it is safe to feed the milk over the week. Citric acid or acetic acid may also be added to milk to prevent souring. A veterinary surgeon should be consulted on the animal health aspects before milk is fed to the animals.

Alternatively, **milk can be applied directly to land**. The following guidelines should be followed when applying milk to land (similar guidelines apply to the disposing of whey or any other liquid dairy products):

- **dilute the milk with the same volume of water** (i.e. 1 : 1 dilution) before applying it directly to land. Dilutions up to 10 : 1 water to milk should be considered to reduce the possibility of odour problems and pasture damage
- **do not apply more than 50,000 litres of the diluted milk per hectare** to pasture (i.e. 5 litres per m<sup>2</sup>). Use as much land area as practically possible
- **flush with fresh water following application**. This will wash the milk off the pasture and into the soil
- if possible **use land that can be worked** following application
- diluted milk should not be applied to paddocks which are **likely to flood**, have **steep slopes**, are **pipe drained or mole ploughed** or are **frozen hard**
- **do not apply diluted milk to land that is close to public areas or neighbours** because of possible odour problems.

**Milk can be control-fed into a pond system**. The milk can be treated in the same way as effluent, but preferably applied to land rather than discharged to a waterway. Properly designed systems can cope with milk from four consecutive milkings. After this, another option should be utilised.

Odour problems may occur 5 days after milk has entered the system. Be aware that a mixture of milk and effluent can give off lethal or explosive gases. Do not mix them in confined spaces or buildings, or enter any enclosed effluent storage facility.

Organic acids can be added to the milk prior to treatment. Acids will cause the separation of milk solids and liquids. The liquids can then undergo treatment in the farm dairy effluent treatment system and the solids can be more easily buried as they have reduced bulk.

#### 1.6.4 Imported material

Imported material generally consists of soil, gravel and feed residue. The amount of material brought into the milking area by cows can be extremely high. It largely **depends on the condition of raceways, yard surface materials** and **whether the cows are fed supplements, such as hay, shortly before milking**.

A grate and stone trap placed before the sump is essential to hold back imported debris. For further strategies to reduce the amount of material brought into the farm dairy yard and allowed into the effluent treatment system, refer to 1.7.2 Effluent collection.

#### 1.6.5 Chemicals

**Keep agricultural chemicals well away from milk and milking equipment, and keep the farm dairy free from litter.**

To maintain New Zealand's 'clean, green' status, Food Safety regulations require that **only approved detergents, sanitisers and equipment be used in the farm dairy**. This will help avoid contamination of milk as such chemicals have been approved for their cleaning ability and safety for use in milking plants.

**Cleaning materials should be used at the correct strength, at the correct temperature and in the correct combinations**. Ensure that powdered detergents have completely dissolved before use. All detergent containers should be labelled and tightly closed to retain the material in good condition and for safety.

**No other chemicals (e.g. pesticides) should be stored in the farm dairy**. The Food Safety regulations in the Farm Dairy Code of Practice (NZCP1) require that pesticides and similar high-risk substances, unless required for farm dairy management purposes, shall not be stored or mixed in farm dairies and shall not be stored with animal remedy dispensing units or within 50 m of the farm dairy water source (for surface waters only). Animal remedies are excluded from this requirement.

It is essential to **collect water polluted with dairy chemicals and not to let it enter any waterway**.

From a practical viewpoint, it is inevitable that effluent containing chemicals used at normal recommended concentrations will enter the effluent treatment system. However, it should be noted that **very strongly concentrated chemical solutions may slow down or detrimentally affect the effluent treatment system**.

### 1.6.6 General cleanliness

Food Safety regulations require that litter shall not accumulate or be scattered inside or surrounding the farm dairy. This is because litter is unsightly, can encourage rodents, and may enter and block the effluent treatment system. Litter is defined as:

- old milking equipment and utensils, rubber ware, and used milk filter socks
- empty containers
- used syringes and AB gloves
- clothes
- timber
- afterbirth, offal and food
- general rubbish.

It is advisable to have a facility for collecting rubbish outside the farm dairy to dispose of litter. The facility and its contents should not smell and so it should be emptied and cleaned at regular intervals. A cover will prevent rainwater from entering the facility.

A grate placed before the sump is essential to hold back debris such as gloves, syringes and plastic bags. For further strategies to reduce the amount of litter allowed into the effluent treatment system, refer to 1.7.2 Effluent collection.

Other hygiene considerations covered by Food Safety regulations include:

- dead animals and birds shall not be left within 45 m of the farm dairy
- vermin should be eliminated and birds and insects discouraged
- rank growth and ponding near the farm dairy and tanker loop should be addressed
- the farm dairy is to be used only for the purpose of milking, breeding, veterinary treatment and animal husbandry of dairy stock. Animal slaughter is not to be carried out on the premises.

All livestock, pigs and poultry must be housed, fed and controlled at specified distances from the farm dairy and its water supply. These areas shall be clean and well maintained. Distances from the milking area are:

- 45 m for effluent ponds, offal holes, whey pits, silage, baleage, pigs and dead animals
- 20 m for poultry housing, livestock housing, loafing barns, hay barns/hay, feed pads, dog housing, fertiliser bins/storage and other supplementary feed storage (not over a concrete pad)
- 10 m for sumps and sewerage tanks.

Any farmer wishing to maintain the above facilities at closer distances is required to have the written approval of a NZ recognised farm dairy assessor.

### 1.6.7 Dairy cow and washdown effluent

The volume of washdown water used and the characteristics of that water are dependent on:

- **the volume of manure** generated in the milking area/ feed pad or stand-off area
- **frequency of washdown**
- **the area, design and fall of the yard** to be washed down and the time this takes
- **the water from plate coolers and from cleaning milking equipment.**

To comply with Food Safety regulations (i.e. the Farm Dairy Code of Practice NZCP1), the farm dairy must be washed down after each milking. These regulations require that:

- **the farm dairy be kept free of soil manure and milk residues** which could affect milk quality through odours, airborne contamination or flies. Besides the aesthetic factor, uncleanness can allow the colonisation of bacteria and possible Dairy Company penalties
- **adequate cold water be used to flush milk residues from the plant to the stage where the discharge of liquid runs clear** (usually 10-20 litres per cluster and 4% of vat volume is sufficient but a higher volume may be required for larger vats)

- **any area within 10 m of the farm dairy be cleaned after each milking** and kept in such a state
- **the farm dairy have an adequate supply of good quality hot and cold water** which is free from sediment and organic matter, and which has as few bacteria as possible. The minimum amount of hot water available is 10 litres per set of cups and 2% of the vat volume with a minimum volume for vats of 120 litres.
- **all concrete be kept clean and have algal growth removed.** To remove and prevent further algal growth, occasionally scrub and chlorinate the concrete surface. Make sure such chemicals are left on the concrete for several hours before hosing them off. This will avoid entry of an excessive amount of chemical into the effluent treatment system
- wastewater from the farm dairy effluent not be re-used for cleaning the yards and premises.

### 1.6.8 Reducing effluent volume and conserving water

The following practices and design considerations will help reduce the amount of effluent produced and therefore save on cost:

- **diverting stormwater runoff** (refer to 1.6.2 Stormwater)
- **maintaining diversion drains around effluent treatment and storage ponds to avoid overland flow of water**
- **building a footbath at the yard entrance**
- **using a minimal amount of washdown water.** This will increase the retention time of effluent in pond treatment systems
- **designing the farm dairy so that cow flow is maximised.** Time spent on the yard and raceways is a major factor in determining the amount of effluent generated at the farm dairy. Using farm dairy yards as a wintering pad or as a stand-off pad will mean that more effluent has to be treated
- **designing the race and wintering pad or feed pad to prevent rainwater from washing down the race and into the system**
- **covering the wintering pad or feed pad,** or using slatted floors in a herd shelter
- **once-a-day milking and scraping rather than washing pads**
- **diverting the water from plate coolers into reuse as washdown water.** By redirecting water from the plate cooler to a storage tank for washing down, large amounts of water can be saved. Do not recycle water through the plate cooler
- **checking for stray electricity.** Electricity may feed through yard rails and other surfaces that cows may be in contact with. A meter will help locate the source. Mesh should be laid in all concrete in the bail area and 3 m to 4 m out into the yard for voltage protection.

Ways to reduce the amount of water required for washdown and subsequent storage include aspects of **milking management, water conservation, scraping systems and mechanical solids separation.**

#### 1.6.8.1 Milking management

Age, breed and weight of the cows in the herd, and milking management influence the amount of effluent generated by the herd.

To reduce the amount of effluent consider the following management techniques:

- **treat the stock gently before yarding and milking**
- **split the herd** during milking
- **be even tempered** to minimise cow stress
- **take advantage of new machine technology and milking methods when upgrading,** to decrease the stress on cows
- **do not use dogs in and near the farm dairy**
- **reduce excessive or unusual noise.**
- **prevent troughs from overflowing and do not have constantly running hoses** in the farm dairy.

### 1.6.8.2 Water conservation

Inadequate water volume or pressure makes washing down tedious. To speed up the cleaning method and minimise total water use, **'pre-wet' the yard before milking.**

**Do not allow water to flow continuously across the yard.** Pre-wet at the beginning of milking, and perhaps once again later.

Ensure holding tanks, troughs, hoses and other clean water systems do not overflow or flow continuously.

Do not use a drip system to pre-wet the yard. The water will not move solids and will not wet the entire yard.

**Water from the effluent system cannot be re-used in washdown. However, whenever you need dilution water to assist in effluent mixing or pumping operations, use already dirty water.**

**Hose washdown** is the most common method of cleaning the farm dairy. The most water-efficient system is to have high flow water volume (i.e. 3.5 to 4.5 l/s) at low pressure (i.e. 100 to 150 kPa). Although the high flow rates required for low-pressure systems would suggest higher water usage, this is offset by reduced washing time.

Figure 1.6-5 illustrates the type of nozzle best used for yard washdown. This system will produce a high volume of washdown that will effectively move effluent solids.

Figure 1.6-6 shows the type of nozzle that is not recommended for yard washdown. These nozzles do not effectively move effluent solids. However, they are very good for hoses situated in the milking pit. High-pressure, low-volume hose washdown is also an effective method for thorough cleaning of ingrained soiling. High water velocities can be obtained by fitting a nozzle, or partially flattened stainless steel pipe, to the delivery end.

Guidelines for designing an efficient hose washdown system include:

- **install a centrifugal pump which will deliver a flow at the nozzle of 3.5 to 4.5 l/s at 100 to 150 kPa pressure**
- **place the pump as close as possible to the base of the water tank** to minimise the suction pressure necessary to lift the washdown water
- **if there is a delivery line between the pump and the washdown hose, this should have a minimum diameter of 50 mm.** For existing systems, increase the bore of the suction and delivery line. Keep the length of all hose lines as short as possible
- **the washdown hose should have a minimum diameter of 40 mm and be no longer than 10 m.** A quick action valve should be fitted between the hose and nozzle (refer to Figure 1.6-5)
- **the nozzle diameter should be between 20 and 25 mm** (refer to Figure 1.6-5)
- **provide an overhead gantry or hooks along the yard wall to lift the hose off the floor** during use and storage.

FIGURE 1.6-4

#### POOR PRE-WETTING AND WASHDOWN TREATMENT



FIGURE 1.6-5

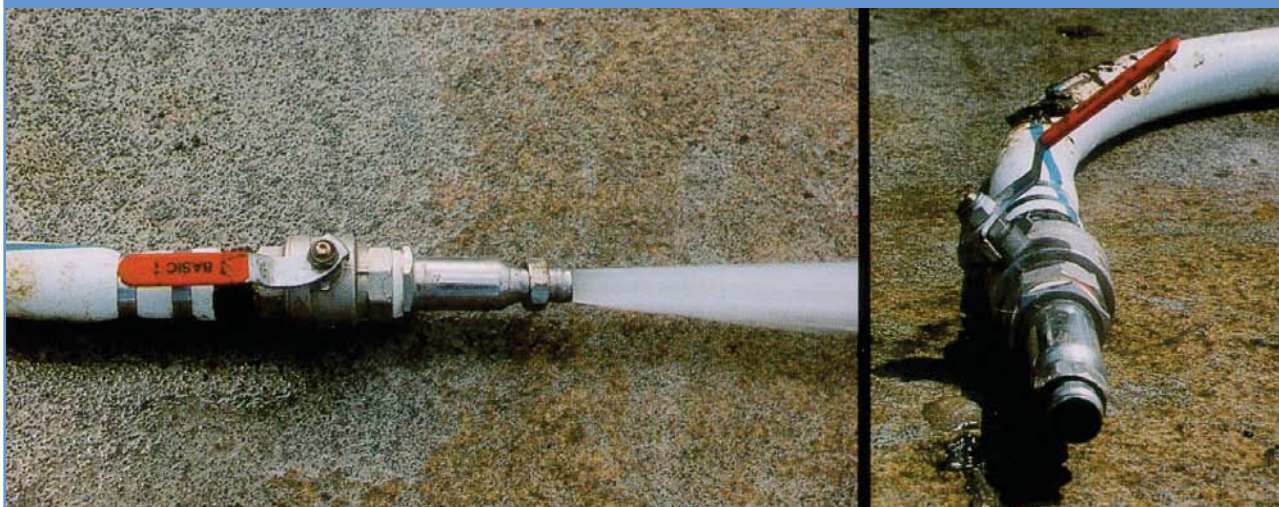
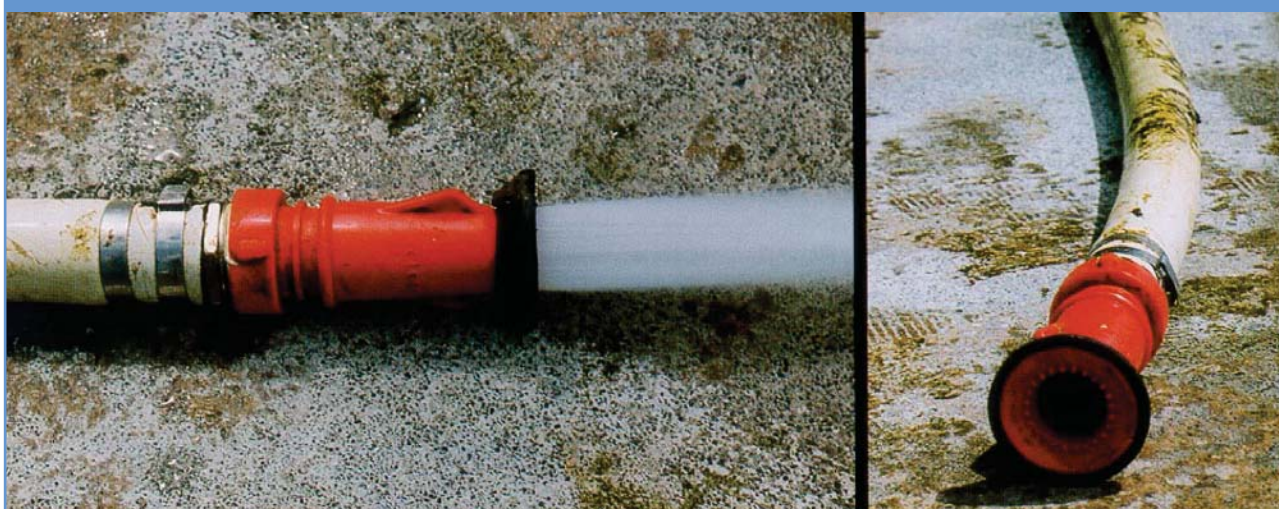
**EXCELLENT FOR YARD WASHDOWN - HIGH VOLUME, LOW PRESSURE**

FIGURE 1.6-6

**POOR FOR YARD WASHDOWN - LOW VOLUME, HIGH PRESSURE**

**With flood washing systems, yard washing times can be reduced to less than one minute.** Flood washing systems **rely on surges of water dislodging and removing the effluent from the yard surface. These systems generally use fresh water, water from the plate cooler, or water from stormwater runoff.**

Where pipe and riser flood washing systems are employed, a large delivery pipe is laid under the concrete yard. Risers of diameter 100 to 150 mm bring washdown water up from the delivery line. The risers are situated at the top of the yard and water is forced through them by pump or gravity pressure. Risers are spaced according to where the greatest amount of manure is deposited. This is usually at the entry and exit races.

Alternatively, tipping drums can be strategically placed around the farm dairy. These need to be placed at the highest point in the yard, at the top of the slope that runs to the yard drainage points.

**A minimum flow of 500 litres per metre width of yard is recommended.** Table 1.6-2 gives design criteria for flood washing systems.

The shallower the yard slope, the greater the flow rate necessary to maintain an effective water velocity. The water should be delivered at a velocity of at least 1 m/s. The velocity can be checked by floating a leaf and measuring its speed.



TABLE 1.6-2

FLOOD WASHING DESIGN CRITERIA				
Yard Width	Yard Fall	Delivery of Washdown Water		
		Velocity	Depth	Volume
10 m	2% <b>or</b> 1 m in 50 m	1 m/s 2 m/s	35 mm 100 mm	5000 l/milking 5000 l/milking
	1% <b>or</b> 1 m in 100 m	1 m/s 2 m/s	60 mm 160 mm	5000 l/milking 5000 l/milking
15 m	2% <b>or</b> 1 m in 50 m	1 m/s 2 m/s	35 mm 100 mm	7500 l/milking 7500 l/milking
	1% <b>or</b> 1 m in 100 m	1 m/s 2 m/s	60 mm 160 mm	7500 l/milking 7500 l/milking

Wrigley, R., 1993

Since flood washing involves large volumes of water delivered over a short time, the farm dairy yard needs to be designed to handle and contain the water. For this reason, sensible placement and design of nib walls is necessary, and the sump capacity and pipes need to be able to handle large water volumes and flows.

**Water jets can also be placed on the bottom rail of the backing gate** (refer to Figure 1.6-7). These pre-wet the yard surface and can be followed up with yard hose down.

In a circular yard, it is important not to have too many jets, otherwise the pressure and volume through each jet drops considerably. Two are sufficient, as the top jet will move effluent to the central jet. From there the effluent can be flushed to the sump.

FIGURE 1.6-7



### 1.6.8.3 Scraping systems

**To speed up the cleaning method and minimise the amount of washdown water, use manual scrapers and squeegees, and shovel off the manure pats.** The build-up of manure can then be quickly washed into the sump or carried to a storage area used for the composting of sludge (refer to 2.8.1 Composting of sludge).

**Scraper and squeegee frames should be galvanised**, as effluent can cause rapid rusting of metal. Check also that the squeegee blade is made of hardy material. Pure rubber blades tend to deform and wear very quickly.

Figure 1.6-8 shows a yard scraper with a squeegee mounted on wheels.

**A squeegee, or inch link galvanised chain, can also be placed on the bottom of the backing gate.** This will smear and break up heavy pats so that cleaning time is considerably reduced.

Scrapers are also available that can be attached to motorbikes or tractors and used for other concrete surfaces such as feed pads and stand-off pads.

The use of scrapers on hot days will cause manure that is left behind to quickly dry on to the yard floor. Therefore, the yard should be washed down shortly after scraping.

#### 1.6.8.4 Separating solids

Coarse solids can be removed from the effluent, giving a liquid fraction that can be easily pumped, and a solid fraction. The separated solids are either immediately spread on land or composted and spread on land (refer to 2.8 Land application of sludge).

The advantages of solids separation include:

- **the volume of liquid effluent that needs to be stored is reduced by up to 20%**
- **crusts or sediments are less likely to form** in storage facilities
- the liquid effluent can be **stored without having to be stirred regularly**, reducing the amount of odour released
- the liquid effluent can be **applied to pasture through any land application system** and with **less chance of smothering pasture or of solids building up**.

**Solids separation is particularly advantageous when using a feed pad due to the high level of fibre and solid content.**

**The use of an anaerobic pond prior to an aerobic pond largely negates the need for mechanical solids separation systems used in conjunction with oxidation ponds.**

For detail on methods of solids separation refer to 2.12 Processing options prior to land application.

#### 1.6.9 Further reading

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FIGURE 1.6-8

#### YARD SCRAPER

