CHAPTER 3

POND SYSTEMS

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3.1 OVERVIEW

Pond treatment systems (i.e. oxidation systems involving two or more ponds) were introduced to New Zealand dairy farmers in the 1970s and for many years this was the most commonly used system for farm dairy effluent treatment.

Ponds utilise biological processes to convert the organic content of the effluent to more stable and less offensive forms.

The first pond, commonly known as the anaerobic pond, carries out a process without oxygen and can effectively treat the initial high strength effluent while allowing solid material to settle out as sludge.

The second pond, commonly known as the aerobic pond, requires dissolved oxygen to further break down effluent flowing into it from the anaerobic pond before discharging it to a waterway.

There is a definite move away from having effluent treatment systems that discharge to waterways, and these require resource consents to ensure the effects are acceptable.

These systems have often proven poor at removing nutrients, ammonia and faecal bacteria, and have not lowered BOD to the required levels. The high level of suspended solids from pond discharges have affected clarity and colour in receiving waterways. Conventional pond systems have failed to perform adequately in cold climates such as Otago, Southland and areas where the temperature is consistently below 10ºC (though advanced pond systems are giving good results, refer to 3.7.2 Advanced pond systems).

Most Regional Councils now prefer or may even require land treatment.

Regional Councils are moving towards granting and monitoring consents on the basis of the system's ability to treat effluent for ammonia, nutrients and pathogenic micro-organisms, as well as BOD and suspended solids.

For pond systems to continue to be economical and practical, the volume of effluent generated needs to be reduced and it needs to be treated to a higher standard. The effluent can undergo further treatment in an additional pond or constructed wetland system before it is discharged into a waterway. Advanced pond systems are also being developed which are more effective.

Alternatively, the effluent from the pond system can be utilised for its significant fertiliser value, through application to pastoral land and crops (refer to Chapter 2. Land application).

The pond system was previously favoured by farmers as a method of treating effluent because it is:

- a **low cost** system
- relatively **simple in design** and **straightforward** to **install**
- **low in maintenance requirements**
- able to **readily fit into a larger effluent treatment system** as an initial treatment
- not subject to mechanical failure or periods of unavailabilty.

When **operating optimally**, the pond system can result in 95% removal of BOD. Treatment can reduce the concentration of nutrients and pathogenic micro-organisms in effluent, and decrease odours.

However, the general public, Regional Councils and farmers recognise that poor system design and inadequate management mean that the pond system is an ineffective method of treating effluent on many of New Zealand's dairy farms. This is largely because the pond size has not increased and more cows are being milked, therefore the volume per cow has reduced. In some cases feedpad effluent has been added to the system without any increase in pond size.

Furthermore, since pond systems do not usually involve the passing of effluent through soil, Maori cultural concerns about the purification of effluent are not met (refer to 5.1.1.3 Iwi authorities).

Barrier ditches are a variation on the pond system whereby effluent was held in long ditch sections separated by baffles. These systems have generally proven ineffective and usually fail to meet Regional Council discharge conditions. They are being phased out in most regions, except for temporary storage prior to land application. Barrier ditches may still be an option in some regions where water tables are high. Check with your local Regional Council for recommendations or design guidelines.

Maintenance of barrier ditches is more intensive than with ponds. It involves annual desludging, controlling weeds and repairing and maintaining pipes and structures.

3.1.1 Planning for a pond treatment system

Effluent from the farm dairy is high in volume (or bulk) with significant organic matter and nutrient content. These characteristics lead to large handling, storage and treatment costs. The first challenge is to reduce the volume of effluent requiring pond system treatment (refer to 1.6.8 Reducing effluent volume and conserving water).

Poor design and inadequate maintenance will result in poor pond performance. Therefore, the pond 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, local regulations and costings before deciding on an option involving pond systems. Figure 3.1-1 outlines the planning procedure and the factors influencing the decision to construct ponds and the design of the pond system.

FIGURE 3.1-1

PROCEDURE FOR PLANNING A POND SYSTEM

Peak volumes and loading
Identify the volume, BOD and pollutant loading
(refer 1.6.1 Effluent characteristics and volumes)

Topography, climates, waterways and soils
Identify the physical limitations of the property
(refer 3.4 Siting of ponds)

Pond system regulations
Meet Regional Council and Food Safety requirements
(refer 3.9 Pond system regulations)

Pond site selection
Select a suitable site for the pond system
(refer 3.4 Siting of ponds)

Anaerobic pond design
Calculate the volume required. Consider depth, surface area orientation and future herd size increases
(refer 3.5 Pond design criteria)

Aerobic pond design
Calculate the surface area required. Consider depth, volume, orientation and configuration.
(refer 3.5 Pond design criteria)

Pond system add-ons
Consider the use of mechanical aeration, anaerobic digestion or additive treatments to improve effluent quality.
(refer 3.7 System additions to improve effluent quality)

Pond systems as an initial treatment
Consider using the ponds as an initial treatment before additional ponds, land application or wetlands
(refer 3.7.3 Additional ponds)

Pond system construction
Pay attention to embankments, batter slope, storm-water control, piping, pond sealing and fencing
(refer 3.6 Construction of ponds)

Pond system management
Correctly carry out pond start up and pond maintenance
(refer 3.1.2 Pond system management)

3.1.2 Pond system management

To ensure optimum treatment of effluent, ponds should be designed and constructed correctly from the beginning (refer to 3.5 Pond design criteria and 3.6 Construction of ponds).

Ponds should be partially filled with water as soon as possible after completion (i.e. 500 mm depth of fresh water). This will prevent the soil seal from drying out and cracking, or the liner from being damaged. The addition of water will also decrease the odour from the effluent initially entering the pond.

Water for filling the pond could come from the farm dairy. Use washdown water or stormwater. Initially divert stormwater off the roof and yard, and towards the sump and drain designed to carry the effluent to the pond system. **Do not continue to allow clean water into the ponds once the system is operating.**

If at all possible, **plan to first fill the ponds at the beginning of the milking season in early spring.** This will allow bacteria time to build up with the warm temperatures over the summer months. Systems started in the autumn or winter may develop odour problems and bacteria important to the functioning may not establish properly.

The acidity/alkalinity of the pond is important and can be monitored (refer to 2.2.2 Nutrient analysis). **The pH of the ponds should remain above 6.5.** If the pH drops below this, add lime or caustic soda. Add 1.6 kg of lime per 1000 m^3 of pond volume daily until the pH is raised to between 6.5 and 9.0.

Ponds must be maintained regularly and properly. Maintenance involves desludging, controlling weeds and repairing and maintaining pipes and structures (refer to 3.8 Pond system maintenance). **Desludging of anaerobic ponds is the factor most likely to influence the performance of the aerobic pond.**

3.1.3 Top tips to avoid trouble

- **If planning to install a pond system, check with your Regional Council to find out their rules and recommendations in the first instance.**
- **Before installation, consider current farm operations and land use, and the influence that the introduction of a pond system may have on them. Determine the likely increases to herd and property size over the next 10 years. Consider system intensification or the addition of effluent from stand-off areas or feed pads. Is the pond system capable of expansion?**
- **It is wise to liaise with neighbours. Neighbours can have a significant input into the Regional Council planning and acceptance of individual systems.**
- **Assess the pollution risks associated with the failure of the pond system should the embankments be breached, ponds overflow, or the system not operate to expectations. Make contingency plans for any of these occurrences to ensure effluent will not reach surface or groundwater. Contact your Regional Council if a system failure occurs.**
- **Consider the seasonal changes in water tables. Ensure ponds can remain adequately sealed in all seasons and isolated from groundwater.**
- **It is best to keep the pond site as far as possible from areas that have been pipe drained or mole ploughed.**
- **Divert stormwater from the farm dairy before it reaches the pond system. Also install a channel around the pond embankments to prevent water runoff from the land entering the pond system.**
- **Do not let chemicals enter ponds. Many chemicals can affect the breakdown of effluent.**
- **Do not let plastic waste products enter ponds (e.g. AI gloves, syringes). These can block the inlet and outlet structures and reduce the effectiveness of the pond system.**
- **Where ponds are lined with a plastic liner, ensure that the pumps or other machinery never interfere with the liner. For this reason, contractors should be made aware that a liner is present.**
- **Carry out regular desludging of the anaerobic pond.**

3.1.4 Costs of a pond system

The total cost of installing a pond system will range between $6,000 and $12,000 depending on:

- **the site.** Obstacles such as rocks, the soil type and accessibility largely influence the time and effort required to excavate ponds. The steeper the site the more expensive the system is to construct
- **the size of the herd** and subsequent size of the ponds
- **whether any pumping facilities to and from the pond are required**
- **soil type** - can clay from on the farm be used or does it need to be brought in to seal the pond? Will a plastic liner or concrete interior be needed to seal the pond?

Each pond will cost roughly the same. Therefore, adding a third pond to the system will cost half this amount again.

The actual excavating costs will range (up to $5.00 per m^3 of pond volume) depending on the site. **Ponds will generally take 2 or 3 days to construct.**

Added to this are system costs such as the purchase and installation of the sump, pump and pipe materials. The expense is governed by the complexity of the system.

Desludging and removing the surface crusting from ponds is the major maintenance expense. **For a 200-cow herd, the cost of desludging will be in the range of $1500 to $2000.**

3.1.5 The pond system as an economic and practical option

The financial costs associated with capital outlay, ongoing maintenance and labour requirements for a pond system are comparatively low. This has made a pond system an attractive option for New Zealand dairy farmers.

However, poor effluent treatment and costs associated with complying with local legislation (i.e. costs of applying for a Resource Consent, plus renewing and monitoring costs) decrease the comparative value of a pond system that discharges to a waterway. In some regions these discharges are not acceptable and land application is required.

Low flow rates in receiving waters may restrict the discharge to winter only. In addition if flow rates are too low, land treatment may be the only option.

For both existing and planned pond systems, the traditional design and management techniques can be altered to maintain a cost-effective pond system, yet improve the standard of treatment for the benefit of the environment.

The challenge is to reduce the volume of effluent to be treated and treat the effluent within the pond system to a higher standard or utilise the nutrient value of the effluent.

3.1.6 Further reading

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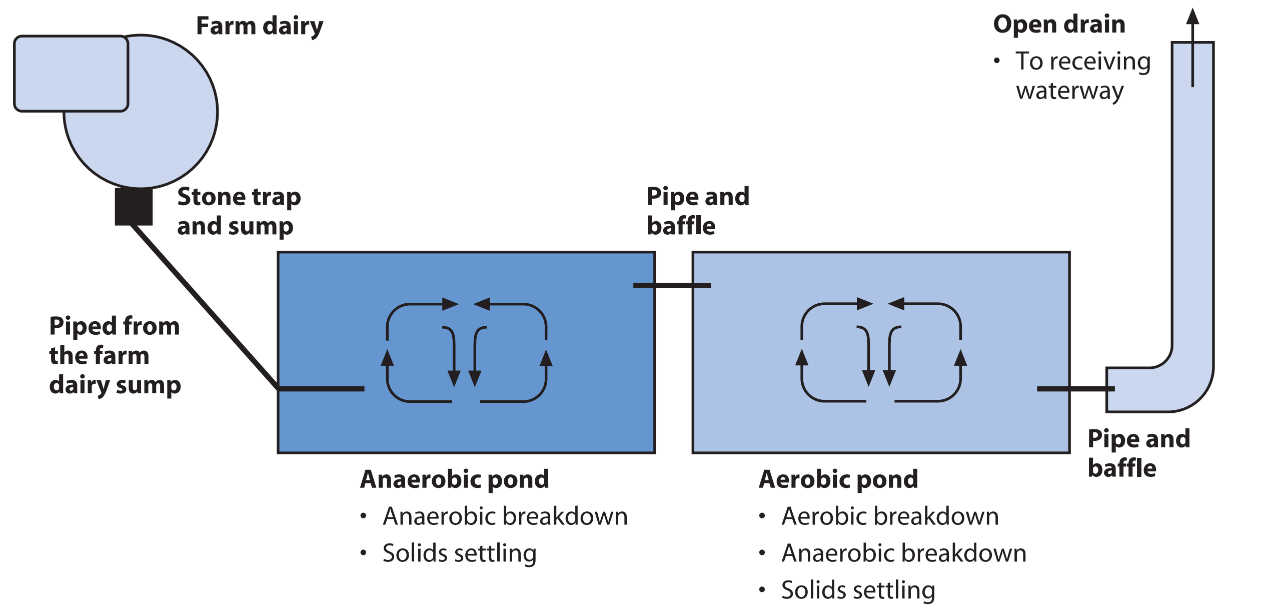
3.2 HOW POND TREATMENT SYSTEMS WORK

Effluent first enters the deep, anaerobic pond which acts like an uncovered septic tank. Bacteria break down the organic matter in the effluent, sludge is deposited on the bottom and a crust may form on the surface. The effluent then passes into the shallower, aerobic pond for further breakdown. **The aerobic pond (i.e. second pond) contains algae that produce oxygen in excess of their own requirements, which is used by bacteria to further break down organic matter.** The effluent is then directed down an open drain into a receiving waterway (refer to Figure 3.2-1).

FIGURE 3.2-1

TRADITIONAL POND SYSTEM OPERATION



3.2.1 Treatment in the total pond system

Pond systems are primarily installed to reduce the organic matter in effluent flowing from the farm dairy. For pond performance monitoring purposes, the organic matter in effluent is quantified and given in terms of BOD.

Biochemical oxygen demand (i.e. BOD) gives an estimation of the quantity of organic matter in the effluent, in terms of the amount of oxygen required by bacteria to break it down.

The oxygen used to break down organic matter would otherwise be utilised by the aquatic life within a waterway. Therefore, too much organic matter in the discharged effluent can stress the aquatic life by reducing the amount of available oxygen within the water.

BOD is usually measured in a five-day bottle test at 20°C and is referred to as BOD_5. It may express organic content in terms of concentration (i.e. BOD_5/m^3) or loading rate (i.e. BOD_5/m^3/day).

In addition to BOD, Regional Councils may also have requirements around levels of suspended solids, ammonia, nutrients and pathogenic bacteria.

The combination of the anaerobic pond and aerobic pond can produce outflowing effluent with a BOD_5 95% less than the initial level. There is also some reduction of other pollutants within the effluent.

Reduction of N and P will occur within the pond system. **Much of the N and P is removed from the effluent through settling.** The N and P are tied up as part of the organic and solid material that settles out as bottom sludge. This 'settling' occurs in both anaerobic ponds and aerobic ponds. Limited levels of K are removed from a two-pond system through this settling process. Some of the N in the settled solids is then converted to soluble ammonia through the anaerobic process. **Some of this ammonia-N is then lost to the air in gaseous form** (i.e. volatilisation), particularly from the aerobic pond.

Furthermore, pathogenic micro-organisms die off within the pond system over time. Any extension of the time that effluent remains within the system before discharge into a waterway will increase the amount of die-off and consequently reduce the concentration of disease-causing micro-organisms in the effluent.

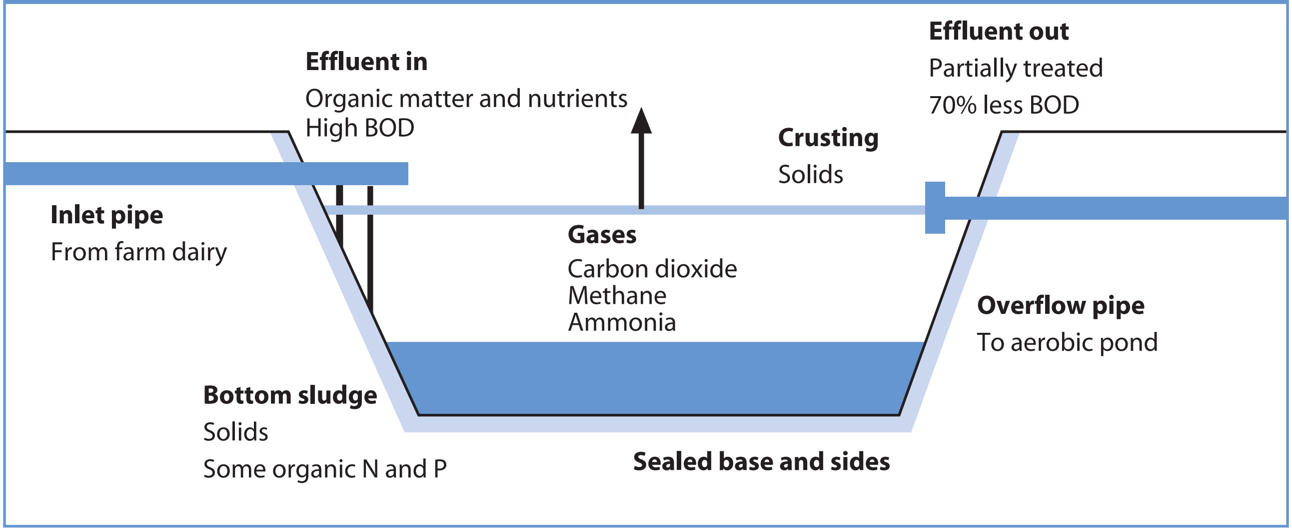
3.2.2 The anaerobic pond

Effluent is initially piped to the anaerobic pond from the farm dairy sump. **It is in the anaerobic pond that the effluent begins breaking down in the absence of oxygen - 'anaerobically'.**

Anaerobic bacteria break down the organic matter in the effluent, releasing methane and carbon dioxide. A sludge is deposited on the bottom and a crust may form on the surface (refer to Figure 3.2-2). The pond is relatively deep, 3 m to 4 m, as this concentrates the biological action and reduces heat loss. Anaerobic ponds contain an organic loading that is very high relative to the amount of oxygen entering the pond. This maintains anaerobic conditions to the pond surface.

FIGURE 3.2-2

OPERATION OF THE ANAEROBIC POND



3.2.2.1 The effect of anaerobic pond treatment

The anaerobic pond will reduce N, P, K and pathogenic micro-organisms by sludge formation and the release of ammonia into the air.

As a complete process, the anaerobic pond serves to:

- **separate out solid from dissolved material as solids settle as bottom sludge**
- **dissolve further organic material**
- **break down biodegradable organic material**
- **store undigested material and non-degradable solids as bottom sludge**
- **allow partially treated effluent to pass out.**

These fermentation processes and the activity of anaerobic digestion throughout the pond typically remove about 70% of the BOD_5 of the effluent. This is a very cost-effective method of reducing BOD.

The effluent is transferred to the aerobic pond via a baffled pipe (e.g. T-piece). The baffle prevents the movement of solids between the two ponds.

3.2.3 The aerobic pond (facultative pond)

Effluent entering the aerobic pond from the anaerobic pond is converted into carbon dioxide, water and new bacterial and algae cells in the presence of oxygen - 'aerobically'.

Algae populations within the aerobic pond use sunlight to develop and produce oxygen in excess of their own requirements. It is this excess of oxygen that is used by bacteria to further break down the organic matter within the effluent. The algal production of oxygen occurs near the surface of aerobic ponds to the depth at which light can penetrate (i.e. typically less than 300 mm). Oxygen can also be introduced by wind.

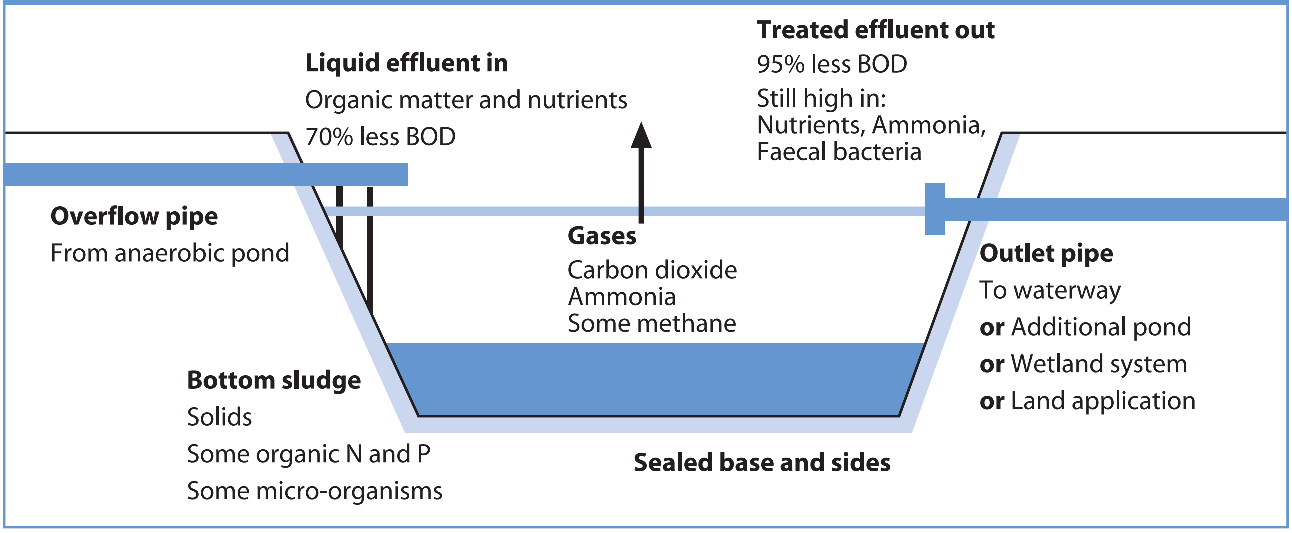
The second pond in the pond system is usually termed **'aerobic'.** However, it is more accurately termed **'facultative'**, as oxygen levels cannot be maintained to the total depth of the pond, which in practice has an aerobic upper layer and an anaerobic lower layer.

Oxygen is unable to be maintained at the lower layers if:

- **there is poor algal growth on the pond surface**
- **the pond is too deep and the colour too dark to allow light to penetrate fully for algal growth throughout the pond depth**
- **the demand for oxygen in the lower layer is higher than the supply.** Oxygen demand is increased with high organic loading resulting in a deeper anaerobic layer
- **the surface layer, rich in oxygen, is not adequately mixed with the bottom layer**
- **there is a combination of these conditions**

FIGURE 3.2-3

OPERATION OF THE AEROBIC POND



3.2.3.1 The effect of aerobic pond treatment

The aerobic pond will remove odour and kill some pathogenic micro-organisms. As a complete process, the aerobic pond serves to:

- **further treat the effluent anaerobically** through separation, dissolving and digestion of organic material
- **aerobically break down most remaining dissolved organic matter** near the pond surface
- **reduce the amount of disease-causing micro-organisms**
- **allow the loss of 20% to 30% of the ammonia** contained within the effluent to the air
- **store residues from digestion, as well as non-degradable solids, as bottom sludge**
- **allow treated effluent to pass out into a waterway or additional treatment system** (i.e. an additional pond, wetland system or for land application).

The activity of further anaerobic oxidation and the aerobic conversion of effluent to carbon dioxide, water and new bacterial and algae cells can result in removal of 80% of the BOD_5 of the effluent flowing into the aerobic pond. This removal, and the subsequent quality of the outflow, depends on:

- **an adequate oxygen supply**
- **sufficient retention time**
- **warm temperatures**
- **an absence of high concentrations of chemical pollutants**. High concentrations of cleaning chemicals and drenches will slow the system's ability to break down effluent solids.

3.2.4 Pond system effluent characteristics

Given the marked variability of contributors to the effluent load, it is difficult to accurately estimate volume and other characteristics of pond system effluent. Sludge is signifiantly more concentrated than treated effluent.

Table 3.2-1 gives a guideline on important characteristics and typical values, useful for design purposes when an on-site analysis cannot be done.

It is important that conservative parameters are adopted in design to allow for this variability.

TABLE 3.2-1

CHARACTERISTICS OF EFFLUENT IN A POND SYSTEM

Characteristic	**Ex-first pond (Anaerobic pond)**		**Ex-second pond (Aerobic/facultative pond)**	
	Typical (For design purposes)	Range	Typical (For design purposes)	Range
BOD_5	0.25 kg/m^3	0.09 - 0.50 kg/m^3	0.12 kg/m^3	0.05 - 0.20 kg/m^3
Total solids	2.20 kg/m^3	0.92 - 3.50 kg/m^3	2.00 kg/m^3	1.50 - 2.60 kg/m^3
N - Total kjeldahl	0.25 kg/m^3	0.09 - 0.50 kg/m^3	0.12 kg/m^3	0.05 - 0.20 kg/m^3
Total P	0.03 kg/m^3	0.01 - 0.07 kg/m^3	0.03 kg/m^3	0.01 - 0.05 kg/m^3
Total K	0.36 kg/m^3	0.29 - 0.43 kg/m^3	0.04 kg/m^3	0.31 - 0.49 kg/m^3
pH	7.5	6.5 - 8.0	7.9	7.0 - 9.0

Hickey et al, 1989; MAF, 1994; Robertson, Ryder and Associates, 1993; Sukias et al, 2001, Wrigley, R., 1993; Vanderholm, D.H., 1984.

3.2.5 Problems with system function

Although pond systems are a low-cost and simple technology for reducing the BOD of effluent, the pond discharge can still cause a depression of dissolved oxygen levels within a receiving waterway. If the effluent is discharged into a waterway, it is important that the receiving waters have sufficient flow (volume and velocity) to deal with the incoming effluent.

When pond systems cease to function as designed, the quality of the effluent deteriorates. The discharged effluent will have a higher BOD and will contain more suspended solids, micro-organisms and nutrients than it would if the pond system was operating optimally.

Excessive discharges relative to the waterway flow and the discharging of poor quality effluent will cause stress on the aquatic life within a receiving waterway. In addition, growth of streambed bacteria and algae will probably occur and the waterway may be discoloured or murky.

FIGURE 3.2-4

SURFACE CRUSTING

The anaerobic pond will cease to function as designed when:

- **temperatures are too low for the design volume**
- **excessive bottom sludge has built up (reducing pond retention time)**
- **excessive crusting has occurred on the pond surface** so that outlet pipes are blocked or forced to convey solids (refer to Figure 3.2-4)
- **there is a reduction in the retention and settling time** due to increased flow e.g. as a result of stormwater diversion.

Each condition will result in a poorer quality effluent flowing into the aerobic pond. In turn, the aerobic pond will discharge a poorer quality effluent into the next stage of the system, commonly a receiving waterway.

The aerobic pond will cease to function as designed when:

- **it is overloaded with effluent high in organic matter e.g. from feedpads**
- **excessive growth of algae on the pond surface that are discharged in the pond effluent, contributing to the effluent BOD and suspended solids levels**
- **there is a reduction in the retention and settling time**.

3.2.6 Improving pond system performance

To prevent excessive solids build-up, excessive crusting causing blocked baffles, overloading of the aerobic pond and a reduction in the retention time, a combination of approaches can be implemented. Pond systems, whether newly installed or existing, can be altered and managed so that they operate to design standards.

3.2.6.1 New pond systems

To ensure the newly installed pond system treats effluent to an acceptable standard:

- **check with your Regional Council** on whether ponds are acceptable and what the standards and conditions are likely to be for your situation
- in the first instance, **design the pond correctly with regard to size, shape and orientation** (refer to 3.5 Pond design criteria). Take local experience into account when designing ponds
- where possible, **obtain accurate effluent volume and BOD loading values** reflecting what the pond system will be expected to deal with
- **ensure that the ponds are sealed prior to use** (refer to 3.6.4 Sealing and lining)
- **divert clean stormwater to prevent it running into ponds** (refer to 3.6.3 Stormwater control).

3.2.6.2 Existing pond systems

Before making any changes to an existing pond system, check with the Regional Council as to what changes may be required to your resource consent.

To combat problems with an existing pond system:

- **if the effluent quality from the pond system is unsatisfactory, consider increasing pond size or adding another pond to the system** (refer to 3.7.3 Additional ponds)
- **if there are significant increases in herd size or amount of effluent collected, add another pond to the system** (refer to 3.7.3 Additional ponds)
- **desludge more frequently and remove crusting** if there is rapid sludge accumulation due to **increases in herd size or effluent volume** e.g. from a feed pad or stand-off area (refer to 3.8.1 Desludging)
- **where crusting is blocking baffles either remove crusting more frequently or use a more appropriate outflow pipe depth** (which is below the typical crust depth).

3.2.6.3 Use of advanced pond systems

In an **Advanced Pond System,** the second pond of a two-pond system is replaced with a further three ponds, each performing a different function **(refer to 3.7.2 Advanced pond systems).**

In experimental work, this system has been found to treat effluent to a high standard, including removal of BOD, nutrients and micro-organisms.

Furthermore, it has been shown to be effective in cold climates such as Southland.

3.3 HOLDING PONDS

Pond systems can achieve substantial reductions in the organic polluting potential of effluent. However, it is becoming more apparent that pond outflow quality may not be acceptable in the light of current environmental concerns, particularly regarding ammonia, nutrient and pathogenic micro-organism concentrations.

Different rules apply to ponds and surface water discharges in different regions (check with your Regional Council for requirements). In some Regions surface water discharges are unacceptable but ponds for storage purposes may still be built.

3.4 SITING OF PONDS

The importance of site choice, and good site preparation, cannot be over emphasised. The choice of a safe and practical site is a key to successful operation and maintenance, and the prevention of pollution.

Once a pond facility has been built on a poor site, there is little that can be done to remedy the situation, and pollution risks are likely to be high.

It is advisable to mark on a farm plan areas where farm dairy effluent ponds should not be constructed. Such areas are often determined by soil properties, groundwater and topography.

Regional Council regulations regarding the proximity of ponds to watercourses also help determine the most appropriate site for ponds.

Each District Council has its own set of requirements for positioning treatment systems in relation to houses, roads and boundaries. Before installing a system, check with your local District Council for siting requirements.

From there, the selection of the most suitable site for pond construction centres around convenience, cost and hygiene considerations.

3.4.1 Hygiene

Effluent ponds must be situated at least 45 m from the farm dairy (including the milking area, milk receiving area and milk storage area and milk collection point). Having ponds too close to the farm dairy is a health risk (refer to 3.9.1 Food safety and dairy industry requirements). Disease-causing micro-organisms exist within the effluent and may pose a risk to both animal and human health.

3.4.2 Accessibility

Attention should be given to the ease of conveying effluent to and from the pond system. Pipelines, scrapers, tractors and desludging vehicles should all have a straight run to the ponds. It should be sited so that it is easy for the farmer to check that the system is working correctly and quickly identify and respond to system failure.

For ease and to minimise costs, **the pond site should be in the vicinity of the farm dairy (though not closer than 45 m).**

The site should also allow access to construction machinery such as diggers, and maintenance machinery and equipment such as tractors, vehicle spreaders and pond stirrers. Such machinery may be required to get around the entire outside of the pond system. This will be made difficult if the pond system is to be built into a hillside or on steep slopes.

Distance and the difference in height of the farm dairy from the application site influence the capital outlay and cost of laying pipes. The power costs of pumping the effluent through a delivery pipeline to the pond system can be high.

Wherever possible, ponds should be constructed below the farm dairy so that gravity can be used to convey the effluent.

However, steep slopes should be avoided (refer to 3.4.4 Topography).

Where gravity fall can not be used to convey effluent, a sump and effluent pump can be used (refer to 1.7.5 The farm dairy sump).

3.4.3 Wind direction and proximity to residential housing

When planning the location of new ponds or the extension of existing ponds, consider the risk of odours causing a nuisance. Effluent can cause a nuisance to the public not only because of its odour, but because it may attract flies. A number of factors strongly influence the risk of nuisance problems arising from pond systems, including:

- **distance from neighbouring properties.** The distance from a potential complainant is very important. At greater distances the odour will be more effectively dispersed
- **prevailing wind direction in relation to neighbouring properties.** Situate ponds downwind from housing to avoid unpleasant smells

- **local topography and vegetation.** Exposed sites are best as they allow wind dispersal of odour
- **season.** Overloaded or shock-loaded pond systems are more likely to have objectionable odours. Hence, odours from anaerobic ponds are most common in the spring when the temperature rises and when effluent accumulated over winter undergoes rapid decomposition
- **management and maintenance of the pond systems**
- **type of stock feed used.** The nitrogen concentration of the grazed herbage will ultimately contribute to the ammonia within the effluent. Where the diet is high in protein, the sulphide emissions from pond effluent will be high.

Avoid siting ponds 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.

Some Regional and District Councils require farmers to have minimum buffer distances between public areas and any structure built to contain effluent (check with your Regional Council for requirements). **Where there are no Regional Council regulations, site ponds at least 300 m away from public areas.**

3.4.4 Topography

Minimise the potential for pond flooding and flushing during rainfall. Runoff from nearby waterways, catchment areas and higher terraces should be avoided. Effluent ponds should not be sited in areas that:

- **are likely to flood or receive sormwater from the surrounding catchment**
- **have steep slopes that run toward a watercourse, spring or borehole.** Steep slopes not only pose a threat if pond banks are breached, but can prevent machinery movement.

Ponds should be in a slightly elevated position and have stormwater diversion ditches around them (refer to 3.6.3 Stormwater control).

3.4.5 Soil properties and groundwater

It is advisable to take soil borings to look at underlying soil types, even well below the pond floor. From these, the depth to the water table and the permeability characteristics of the soil can be established.

Heavy, impermeable soils with a deep water table are preferable. Silt or clay soils are ideal for pond foundations and construction. The anaerobic pond will tend to self-seal on almost any soil type, but aerobic ponds require soils that are impervious when compacted. **Sites with coarse sands and gravels should be avoided. Avoid building ponds over fractured rock** or other materials that will convey any leaking effluent to groundwater.

All ponds should be sited away from high water table situations. On some properties problems have occurred where much of the storage volume has been immediately taken up by groundwater. Not only are time, money and effort wasted, but groundwater flowing so freely through the ponds will be contaminated by the effluent. This may in turn contaminate surface waterways as the groundwater moves laterally through the soil.

Where soils are permeable and water tables are seasonally high, or where this is a Regional Council requirement, ponds will need to be sealed (refer to 3.6.4 Sealing and lining and check with your Regional Council for requirements). However, it should be realised that in-flowing groundwater can lift some plastic liners, making siting of the pond all the more important to avoid high water tables. As a general rule, earth-banked ponds are not suitable for use in high water table situations and are not acceptable to some Regional Councils.

3.4.6 Location in relation to surface waterways

Selection of a site near to the banks of a surface waterway should be avoided. Some Regional Councils have regulations regarding setbacks from waterways for effluent facilities.

Should the effluent breach the pond banks and directly discharge into a waterway, it will cause environmental damage and liability for enforcement action (refer to 5.2.2 Enforcement provisions).

3.4.7 Other considerations

When selecting a site for ponds, also consider the following:

- **sites recently cleared of trees, or similarly disturbed, should be avoided**
- **overhead or underground power lines.** Avoid danger. Consult the local power company for guidance on precautions and safe working procedures near power lines
- **drainage provisions near the site should be noted.** If the area is pipe-drained or mole-ploughed, it is best to keep the ponds as far away as possible. If necessary, relocate all land drains so that they are at least 10 m clear of the proposed pond site.

3.5 POND DESIGN CRITERIA

Many pollution incidents occur because pond systems are not designed, built, maintained or used properly. **The single most common reason for poor performance in a pond system is undersized ponds.**

Ponds should be designed and constructed to cope with the waste water flow and organic load, to safely contain the polluting material and to treat the effluent to Regional Council standards. Some regions have very few or no pond systems and different rules apply to pond design in different regions.

Wherever possible, the effluent loading, and subsequent pond sizing, should be calculated on an individual property basis.

This should take into account soil conditions, temperatures, rainfall and likely outflows of effluent from the specific farm dairy (refer to 1.5 Keeping property records).

Be aware that an existing pond system, which once met MAF design criteria, may not treat effluent to today's standards. Previously recommended pond sizes, specified by MAF, have been withdrawn due to unsatisfactory treatment of effluent.

The design recommendations in this section are general and are intended to be adapted according to this local knowledge. It is assumed:

- **stormwater control and a stone trap have been installed,** minimising the entry of clean water and sediments into the pond system (refer to 3.6.3 Stormwater control)
- **the site is suitable for a pond to be built** (refer to 3.4 Siting of ponds)
- **the embankment is built properly so that the pond structure is stable** (refer to 3.6.1 Pond and embankments)
- **the pond is impermeable,** not allowing effluent to escape or groundwater to enter (refer to 3.6.4 Sealing and lining)
- **the pond has a space of 500 mm freeboard** between the highest level of the effluent and the top of the embankments
- **inlet and outlet structures have been correctly installed and positioned** (refer to 3.6.5 Inlet and outlet structures)
- **the final system is designed and constructed by a qualified and experienced person.** The designer should check the soil and site by digging trial holes. Pond design specifications should give details including the building method, the internal and external angles of the banks and the width and foundation details of the embankment. The building work should be supervised by experienced people to make sure that the standards set by the designer are met.

Key design considerations include the following:

- **it is important to design an adequately sized system. Undersized ponds are the most common reason for poor performance of the pond system**
- **when designing the pond, provide for the access of desludging and maintenance machinery on both sides of the ponds**
- **the effluent loading, and consequent pond sizing, should be calculated on an individual property basis. The figures here are a guideline only.**

These guidelines assume the ponds receive 50 litres and 0.12 kg BOD_5 loading per cow per day, and an additional loading of clean rainwater falling directly onto the system. This should be calculated from local 'rainfall less evaporation' data

- **these guidelines assume a 70% reduction of BOD_5 in the anaerobic pond and an 80% reduction of BOD_5 in the aerobic pond**
- **anaerobic ponds should be between 3 and 4 m deep. Aerobic ponds should be no deeper than 1.2 m.**

3.5.1 Pond sizing

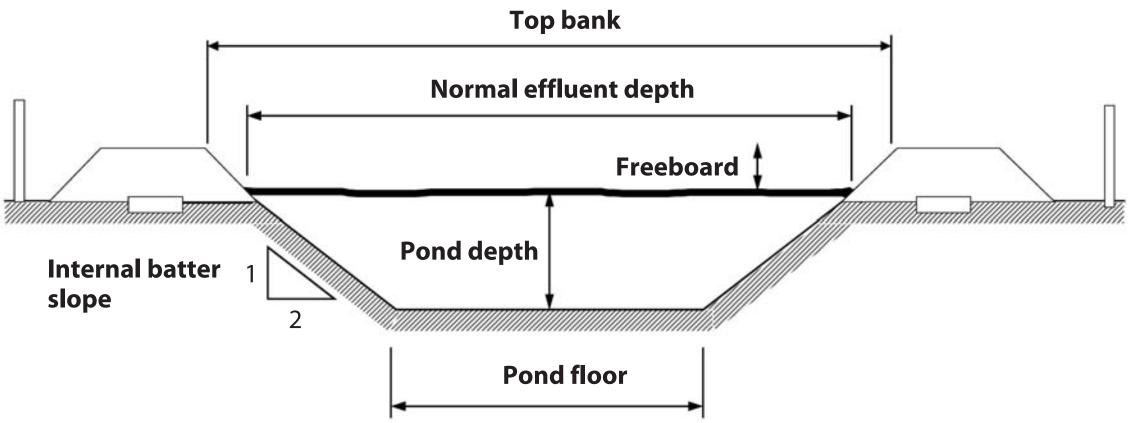
It is far more accurate to use design values, particularly effluent volumes, based on figures from individual properties than those based on general assumptions (refer to 1.5 Keeping property records and 1.6.1 Effluent characteristics and volumes). When calculating the volume of effluent flowing from the farm dairy into ponds consider water volumes used for:

- **plant rinses**
- **plant and vat washing**
- **milk cooling in the plate cooler system**
- **yard and pit washdown**
- **washing adjoining facilities** (e.g. calf facilities)
- **effluent collected from stand-off and feed pad facilities.**

Figure 3.5-1 illustrates the technical design terms used in the pond sizing recommendations given in 3.5.5.2 Anaerobic pond size, 3.5.7.2 Aerobic pond size and 3.5.8.3 Holding pond size.

FIGURE 3.5-1

TECHNICAL DESIGN TERMS



Although specific pond dimensions are recommended, it is important to note that **available machinery will have an influence on the size of the pond. Even large excavators have a limited reach.** Find out what machinery is locally available before finally settling on a pond size.

Also check the reach of dredging machinery, and the size of pond stirrers and vehicle spreaders.

Remember to provide for the access of machinery used for desludging and emptying on both sides of the ponds. There must be a way of getting to the banks, and the banks must be wide enough for the machinery to be used safely, taking into account the weight of the machine.

If the pond surrounds are likely to become muddy and slippery, provide a track or strip of loose metal. Do not use concrete as it becomes slippery, causing heavy machines to lose traction.

Although pond depth recommendations have been given, the depth will need to be related to the site conditions such as whether there are rock strata, and the height of the water table (refer to 3.4.5 Soil properties and groundwater).

3.5.2 Retention time

Any pond treatment system requires steady effluent flow to encourage the rapid and continuous growth of bacteria involved in the biological breakdown of effluent.

It is essential that the daily loading into the ponds be kept to the design standards of the pond system. A very large load may flush out important bacteria and algae eventually leading to system failure. Variation in loads will alter the retention time.

Extending the time that effluent remains within the pond system will increase the die-off of disease-causing micro-organisms. The concentration of micro-organisms within the effluent will be reduced and the effluent will be of higher microbiological quality before discharge into a waterway.

A retention time of 60 to 90 days is recommended.

3.5.3 The total pond system

Figure 3.5-2 and Figure 3.5-3 summarise the pond system layout and give the major design specifications discussed in 3.6 Construction of ponds and in the remaining sections of this chapter.

FIGURE 3.5-2

PLAN VIEW OF THE POND SYSTEM LAYOUT

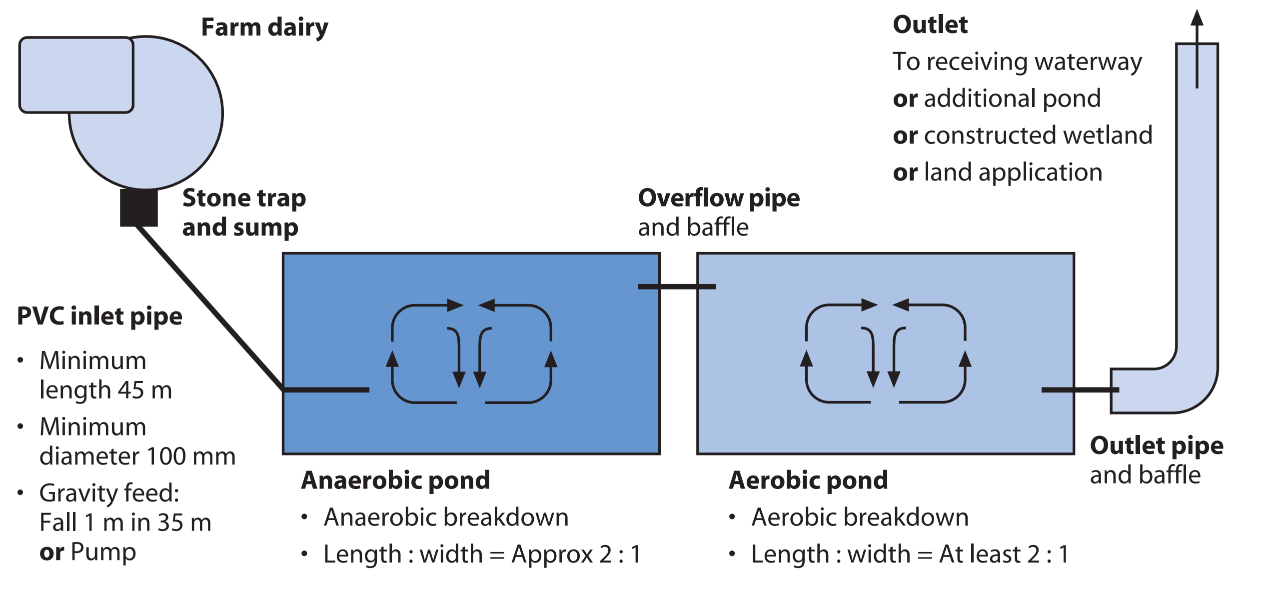
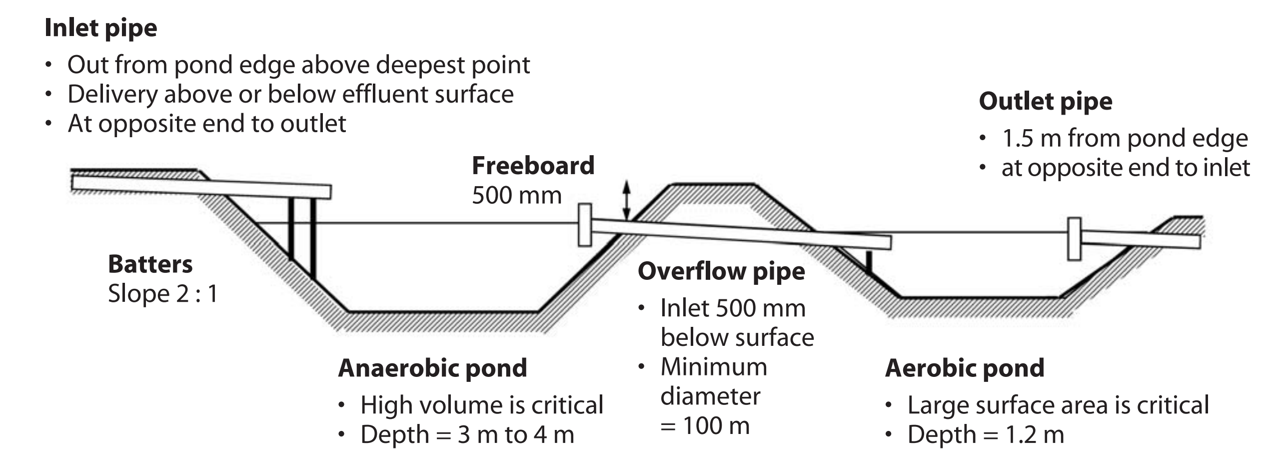


FIGURE 3.5-3

SECTIONAL VIEW OF THE POND SYSTEM LAYOUT



3.5.4 The anaerobic pond

Anaerobic ponds are deep treatment ponds that exclude oxygen and encourage the growth of bacteria to break down the effluent. They should be constructed:

- **to a depth of 3 m to 4 m.** Depths greater than 4 m should be avoided due to limitations of desludging machinery
- **with a small surface area.** A small surface area minimises the area in contact with oxygen at the pond surface, reduces heat loss, encourages mixing, promotes the formation of an undisturbed surface layer and minimises the surface area to catch rainfall
- **with the long axis perpendicular to the prevailing wind.** This will maximise the settlement of solids. If shelter is provided from the wind, the pond may be orientated otherwise.

3.5.4.1 Anaerobic pond sizing assumptions

Anaerobic pond design takes into account the **BOD loading, prevailing environmental temperatures** and **local rainfall and evaporation.**

BOD Loading

The reduction of BOD before discharge into a waterway is a prime concern.

Therefore, **the required size of the pond system is based on the BOD_5 loading per cow per day.**

For a typical grazing system this can be taken as **0.12 kg/cow/day** unless Regional Council regulations deem otherwise (refer to 1.6.1 Effluent characteristics and volumes and check with your Regional Council for requirements).

From the per-cow loading, the total daily herd loading is directly proportional to the number of cows milked. (Note this does not account for excess effluent collected in places other than the farm dairy e.g. from a feed pad or stand-off area).

The following is an example of this calculation:

300 cows are milked on a property situated in Northland. The farmer wishes to install a pond system for effluent discharge to a waterway.

From the example:

- number of cows = 300
- BOD_5 loading per cow per day = 0.12 kg/cow/day
- **total BOD_5 loading = 300 cows x 0.12 kg/cow/day = 36 kg/day.**

Prevailing Environmental Temperatures

Prevailing environmental temperatures affect anaerobic processes so pond design must take this into account (refer to 3.2.5 Problems with system function).

In regions where prevailing temperatures are low, the pond system will need to be larger than those in warmer regions.

Design criteria for pond systems in these regions are provided in Table 3.5-1.

TABLE 3.5-1

RECOMMENDED ANAEROBIC POND BOD_5 LOADING RATES

Region	BOD_5 loading
Northland, Auckland, Waikato, Bay of Plenty, Gisborne and Hawke's Bay	0.028 kg/m³/day
Manawatu, Wanganui, Taranaki, Wellington, Marlborough, Tasman, Nelson and Canterbury	0.024 kg/m³/day
West Coast, Otago and Southland	0.020 kg/m³/day

New Zealand Dairy Research Institute, pers. comm; MAF, 1994; Vanderholm, D.H., 1984.

Using the total BOD_5 loading from the herd and the regional BOD_5 loading rate, the volume of the anaerobic pond can be calculated.

From the example:

- total BOD_5 loading = 36 kg/day
- Northland region's BOD_5 loading rate = 0.028 kg/m^3/day
- **anaerobic pond volume required = 36 kg/day ÷ 0.028 kg/m^3/day = 1286 m^3.**

The regional BOD_5 loading rate should not be considered a rigid value, but can be adapted to more closely model the situation found on any specific property.

Local Rainfall and Evaporation

Rainwater falling directly into the pond system also has to be accounted for in the loading calculations, particularly in high rainfall areas. Rainwater volume can be calculated using 'rainfall less evaporation' data, the surface area exposed to the rainwater and the degree of runoff/entry actually taking place (i.e. off yards 85%, direct rainfall 100%). The pond freeboard will absorb some rainfall. However, it is wise to allow for rainfall volumes from the wettest month when designing pond capacity.

From the example:

- rainfall less evaporation for the wettest 30 days
= Aug: 176 mm - 47 mm = 0.129 m
- estimate of anaerobic pond surface area (refer to Table 3.5-2) = 690 m^2
- 100% rainfall entry
- **rainfall less evaporation**
= 0.129 m x 100% x 690 m^2 = 89 m^3.

Stormwater from the farm dairy and runoff from surrounding land have to be accounted for only if appropriate diversions are not in place (refer to 3.6.3 Stormwater control).

3.5.5 Total volume – anaerobic pond

The total volume is calculated as:

(BOD_5 loading) + (local rainfall less evaporation data).

From the example:

- from total BOD_5 loading = 1286 m^3
- from rainfall less evaporation = 89 m^3
- **total volume = 1375 m^3**
- **therefore, the anaerobic pond volume will need to be 1375 m^3 (refer to Table 3.5-2).**

3.5.5.1 Anaerobic pond specifications

Design standards can be given for a typical grazing system, but need to be adjusted for intensive systems and feed pad or stand-off areas that are connected to the effluent system. In the design standards for pond sizing for a typical grazing dairy system, assume the following:

- **a BOD_5 loading of 0.12 kg/cow/day**
- **inclusion of local rainfall and evaporation data.**

The following design specifications have been used for anaerobic pond sizing:

- **length to width ratio of the anaerobic pond is close to 2 : 1**
- **minimum pond depth is 3 m for ponds serving up to 250 cows. For larger herds, pond depth is 4 m.** This is to allow a 2 : 1 batter slope to be used with the appropriate pond width

- **freeboard is 500 mm for ponds.** This will allow for effluent lapping against the pond walls, shock loadings from rainfall or the farm dairy, and any temporary shutdown of the outflow
- **internal batter slope is 2 horizontal to 1 vertical** (i.e. slope = 2 : 1)
- **pond width does not exceed 24 m** because of the 'reach' limitations of excavator and desludging machinery.

The anaerobic pond sizing requirements given do not apply to effluent storage before land application. If all the effluent from the ponds is to be applied to land, and none is to flow to a receiving waterway, then the sizing for holding ponds should be used (refer to 3.5.8 Holding pond design).

3.5.5.2 Anaerobic pond size

For each region the table gives the '**Anaerobic pond requirements'.** These should be adhered to unless local knowledge is wisely used to adapt these specifications.

The table also gives suggested anaerobic pond sizing. These are suggested dimensions that closely fulfil the criteria given in the first table. It is recognised that there are alternative sets of dimensions that can fulfil these criteria.

TABLE 3.5-2

ANAEROBIC POND REQUIREMENTS FOR PROPERTIES IN THE NORTHLAND, AUCKLAND, WAIKATO, BAY OF PLENTY, GISBORNE AND HAWKE'S BAY REGIONS

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	470 m^3	3.0 m	15 m x 22 m	330 m^2	17 m x 24 m	3 m x 10 m
150	690 m^3	3.0 m	16 m x 28 m	450 m^2	18 m x 30 m	4 m x 16 m
200	910 m^3	3.0 m	17 m x 33 m	560 m^2	21 m x 35 m	5 m x 21 m
250	1130 m^3	3.0 m	19 m x 35 m	670 m^2	21 m x 37 m	7 m x 23 m
300	1400 m^3	4.0 m	21 m x 33 m	690 m^2	23 m x 35 m	5 m x 17 m
350	1620 m^3	4.0 m	21 m x 37 m	780 m^2	23 m x 39 m	5 m x 21 m
400	1840 m^3	4.0 m	21 m x 42 m	880 m^2	23 m x 44 m	5 m x 26 m
450	2050 m^3	4.0 m	21 m x 46 m	970 m^2	23 m x 48 m	5 m x 30 m
500	2270 m^3	4.0 m	21 m x 50 m	1050 m^2	23 m x 52 m	5 m x 34 m

Note 1: Based on BOD_5 = 0.12 kg/cow/day.
Note 2: Includes rainfall less evaporation allowance. Assumes stormwater for the farm dairy and surrounding land is NOT entering the pond. All stormwater should be diverted if possible.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

TABLE 3.5-3

ANAEROBIC POND REQUIREMENTS FOR PROPERTIES IN THE MANAWATU, WANGANUI, TARANAKI, WELLINGTON, MARLBOROUGH, TASMAN AND NELSON REGIONS.

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	550 m^3	3.0 m	16 m x 23 m	370 m^2	18 m x 25 m	4 m x 11 m
150	800 m^3	3.0 m	17 m x 30 m	510 m^2	19 m x 32 m	5 m x 18 m
200	1060 m^3	3.0 m	18 m x 35 m	630 m^2	20 m x 37 m	6 m x 23 m
250	1310 m^3	3.0 m	20 m x 37 m	740 m^2	22 m x 39 m	8 m x 25 m
300	1620 m^3	4.0 m	21 m x 37 m	780 m^2	23 m x 39 m	5 m x 21 m
350	1870 m^3	4.0 m	21 m x 42 m	880 m^2	23 m x 44 m	5 m x 26 m
400	2130 m^3	4.0 m	21 m x 47 m	990 m^2	23 m x 49 m	5 m x 31 m
450	2380 m^3	4.0 m	21 m x 52 m	1090 m^2	23 m x 54 m	5 m x 36 m
500	2640 m^3	4.0 m	21 m x 57 m	1200 m^2	23 m x 59 m	5 m x 41 m

Note 1: Based on BOD_5 = 0.12 kg/cow/day.
Note 2: Includes rainfall less evaporation allowance. Assumes stormwater for the farm dairy and surrounding land is NOT entering the pond. All stormwater should be diverted if possible.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

TABLE 3.5-4

ANAEROBIC POND REQUIREMENTS FOR PROPERTIES IN THE WEST COAST, OTAGO AND SOUTHLAND REGIONS

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	650 m^3	3.0 m	17 m x 24 m	410 m^2	19 m x 26 m	5 m x 12 m
150	960 m^3	3.0 m	18 m x 32 m	580 m^2	20 m x 34 m	6 m x 20 m
200	1260 m^3	3.0 m	19 m x 37 m	700 m^2	21 m x 39 m	7 m x 25 m
250	1570 m^3	3.0 m	21 m x 40 m	840 m^2	23 m x 42 m	9 m x 28 m
300	1920 m^3	4.0 m	21 m x 43 m	900 m^2	23 m x 45 m	5 m x 27 m
350	2230 m^3	4.0 m	21 m x 49 m	1030 m^2	23 m x 51 m	5 m x 33 m
400	2540 m^3	4.0 m	21 m x 55 m	1160 m^2	23 m x 57 m	5 m x 39 m
450	2840 m^3	4.0 m	21 m x 61 m	1280 m^2	23 m x 63 m	5 m x 45 m
500	3150 m^3	4.0 m	21 m x 67 m	1410 m^2	23 m x 69 m	5 m x 51 m

Note 1: Based on BOD_5 = 0.12 kg/cow/day.
Note 2: Includes rainfall less evaporation allowance. Assumes stormwater for the farm dairy and surrounding land is NOT entering the pond. All stormwater should be diverted if possible.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

3.5.6 The aerobic pond

When sizing aerobic ponds, **emphasis must be given to the surface area.** Increasing the surface area of the aerobic pond will improve the performance of the system. The aerobic pond sizes given in 3.5.7.2 Aerobic pond size recognise this.

When orientating the aerobic pond, **the long axis should be perpendicular to the prevailing wind.** This will maximise the settlement of solids. If shelter is provided from the wind the pond may be orientated otherwise.

Two ponds should be used to make up the required aerobic pond surface area rather than having one very large aerobic pond. Use two smaller ponds rather than a single large pond if:

- **cow numbers in the herd are over 300**
- **the pond is likely to be too large for effective desludging and stirring**
- **the pond is too long for the site and interferes with existing structures such as tracks and fences.** In the case of site restrictions to pond length, two smaller aerobic ponds could be placed side by side.

Split the flow from the anaerobic pond to the two aerobic ponds (i.e. have the aerobic ponds working in parallel). Overloading may occur, and odours may develop, in the first pond if the aerobic ponds are in series.

3.5.6.1 Aerobic pond sizing assumptions

Aerobic pond design takes into account the **BOD loading, surface area of the pond and local rainfall and evaporation.**

BOD loading

The reduction of BOD before discharge into a waterway is a prime concern. **The required size of the aerobic pond is based on the BOD_5 loading.**

The loading into the aerobic pond can be taken as 30% of the BOD_5 loading into the anaerobic pond unless Regional Council regulations deem otherwise (check with your Regional Council for requirements).

From the example:

- total BOD_5 loading at the anaerobic pond = 36 kg/day
- **total BOD_5 loading at the aerobic pond = 30% of 36 kg/day = 10.8 kg/day.**

Surface Area

The most important design feature of aerobic ponds is the surface area. It is this that affects pond system performance (refer to 3.2.5 Problems with system function).

The pond system is sized according to BOD_5 loading in relation to surface area. The guideline for the aerobic pond loading rate is **120 m^2 surface area per 1 kg of BOD_5 input** unless Regional Council regulations deem otherwise (check with your Regional Council for requirements).

Using the total BOD_5 loading into the aerobic pond and the 120 m^2 surface area per 1 kg of BOD_5 loading rate, the surface area of the aerobic pond can be calculated.

From the example:

- total BOD_5 loading at the aerobic pond = 10.8 kg/day
- **aerobic pond surface area required = 10.8 kg/day x 120 m^2/ kg BOD_5 = 1296 m^2.**

Local rainfall and evaporation

Rainwater falling directly into the pond system also has to be accounted for in the loading calculations, particularly in high rainfall areas. The rainwater volume can be calculated using 'rainfall less evaporation' data and the surface area exposed to the rainwater and the degree of runoff/entry actually taking place (i.e. off yards 85%, direct rainfall 100%).

From the example:

- rainfall less evaporation for the wettest 30 days
  = Aug: 176 mm - 47 mm
  = 0.129 m
- estimate of pond surface area
  = 1296 m^2
- 100% rainfall entry
- rainfall less evaporation volume
  = 0.129 m x 100% x 1296 m^2
  = 167 m^3
- depth = 1.2 m
- **rainfall less evaporation surface area**
  = 167 m^3 ÷ 1.2 m
  = 139 m^2

Stormwater from the farm dairy and runoff from surrounding land have to be accounted for only if appropriate diversions are not in place (refer to 3.6.3 Stormwater control).

3.5.7 Surface area required for total loading – aerobic pond

The surface area required for total loading is calculated as:

(area for BOD_5 Loading) + (area for local rainfall less evaporation data).

From the example:

- surface area for total BOD_5 loading = 1296 m^2
- rainfall less evaporation = 139 m^2
- **total surface area = 1435 m^2**
- **therefore, the aerobic pond surface area will need to be 1435 m^2.**

3.5.7.1 Aerobic pond specifications

The design standards for aerobic pond sizing assume the following:

- **a BOD_5 loading of 0.12 kg/cow/day**
- a **70% reduction of BOD_5 in the anaerobic pond**
- **inclusion of a local 'rainfall less evaporation' data component.**

The following design specifications have been used for aerobic pond sizing:

- **length to width ratio of the aerobic pond is at least 2 : 1**
- **pond depth is 1.2 m.** Do not build aerobic ponds deeper than 1.2 m unless they are mechnically aerated.
- **freeboard is 500 mm for all ponds**
- **internal batter slope is 2 horizontal to 1 vertical** (i.e. slope = 2 : 1)
- **pond width does not exceed 24 m** because of the 'reach' limitations of excavator and desludging machinery.

3.5.7.2 Aerobic pond size

Table 3.5-5 gives the **'Aerobic pond requirements'** that should be adhered to unless local knowledge is wisely used to adapt these specifications. It gives suggested dimensions that closely fulfil the criteria given. It is recognised that there are alternative sets of dimensions that can fulfil these criteria.

TABLE 3.5-5

AEROBIC POND REQUIREMENTS FOR PROPERTIES IN ALL REGIONS

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	480 m^3	1.2 m	15 m x 32 m	440 m^2	17 m x 34 m	10 m x 27 m
150	720 m^3	1.2 m	19 m x 38 m	710 m^2	21 m x 40 m	14 m x 34 m
200	950 m^3	1.2 m	22 m x 43 m	950 m^2	24 m x 45 m	17 m x 38 m
250	1190 m^3	1.2 m	22 m x 53 m	1220 m^2	24 m x 55 m	17 m x 48 m
300	*1420 m^3	1.2 m				
350	*1660 m^3	1.2 m				
400	*1900 m^3	1.2 m				
450	*2140 m^3	1.2 m				
500	*2370 m^3	1.2 m				

* Divide this dimension into two smaller aerobic ponds.

Note 1: Based on BOD = 0.12 kg/cow/day.

Note 2: Includes direct rainfall less evaporation allowance. Assumes stormwater from surrounding land is diverted.

Note 3: Batter slope on interior bank = 2 : 1.

Note 4: Freeboard = 500 mm for all herd sizes.

3.5.8 Holding pond design

Holding ponds are built to store effluent before land application. This is particularly necessary during wet seasons or where direct land application is impractical and undesirable (refer to 2.4.3.2 Timing of application).

For discussion of the benefits of employing a large pond storage facility for land application refer to 1.7.6 Pond storage facilities, Chapter 2 Land application. Other considerations include the additional capital cost, additional labour due to extra handling and maintenance, and the loss of land area. This land may be valuable as it is often sited close to the farm dairy.

When sizing holding ponds, **give emphasis to the pond volume.** The specific design loadings should come from individual property data, which should include the **number of cows**, the **volume of water off the yards and farm dairy roof,** and the estimated **volume of rainwater falling directly into the pond** (i.e. in areas with high rainfall, storage systems that have a large surface area will need extra storage capacity).

Furthermore, **two ponds should be used to make up the required volume rather than having one very large holding pond.** Have two smaller ponds rather than a single large pond if:

- **the pond is likely to be too large for effective pumping, desludging and stirring**
- **the pond is too long for the site and interferes with existing structures such as races or fences.** In the case of site restrictions to pond length, two smaller holding ponds could be placed side by side
- **herd numbers are high or there are increases in herd size or intensity (e.g. with feed pad or stand-off areas collecting effluent).**

3.5.8.1 Holding pond sizing assumptions

In 3.5.8.2 Holding pond specifications the design standards are for a typical grazing system without effluent from feed pads or stand-off areas. For pond sizing assume the following:

- **a volume loading of 50 l per cow per day**
- inclusion of **local 'rainfall less evaporation' data.**

To include in the design sufficient holding volume for rain falling directly into the facility for the wet storage months:

1) use climate data to find the rainfall less evaporation for those months (mm)
2) **multiply** this by the surface area of the proposed facility (m^2)
3) **divide** by 1000.

This is the **extra** volume (m^3) you will require on top of the volume of the proposed facility for farm dairy effluent.

3.5.8.2 Holding pond specifications

The following data and design specifications have been used for holding pond sizing given in the tables:

- **the best time effluent can be applied to land for the specific region** (refer to 2.4.3.2 Timing of application)
- **the holding pond generally approaches square** except when the 'reach' of excavator and desludging machinery limits the width
- **pond depth is 2.0 m to 4.0 m.** Depths greater than 4 m should be avoided due to limitations of desludging machinery
- **freeboard is 500 mm**
- **internal batter slope is 2 horizontal to 1 vertical** (i.e. slope = 2 : 1)
- **pond width does not exceed 24 m** because of the 'reach' limitations of excavator and desludging machinery.

3.5.8.3 Holding pond size

Refer to Table 3.5-6 to Table 3.5-9. For each region the table gives the guideline for **'Holding pond requirements'.** These should be adhered to unless local knowledge is wisely used to adapt these specifications.

The table also gives suggested holding pond sizing. These are some examples of suggested dimensions that fulfil the criteria given in the first table.

These tables are a **guideline only** and site-specific factors apply including:

- **more intensive systems, feed pads or stand-off areas**
- **heavy soils that remain waterlogged for extended periods.** If your soils are heavy and are often too wet to irrigate, talk to your Regional Council to determine how much storage may be required
- **stormwater entering a pond** can affect storage capacity significantly. Stormwater from surrounding land and the farm dairy should be diverted.

TABLE 3.5-6

HOLDING POND REQUIREMENTS FOR ONE MONTH'S STORAGE (Properties in the Canterbury and North Otago Regions)

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	160 m^3	2.0 m	12 m x 13 m	160 m^2	14 m x 15 m	4 m x 5 m
150	230 m^3	2.0 m	14 m x 15 m	210 m^2	16 m x 17 m	6 m x 7 m
200	340 m^3	3.0 m	16 m x 16 m	260 m^2	18 m x 18 m	4 m x 4 m
250	410 m^3	3.0 m	16 m x 17 m	290 m^2	19 m x 19 m	5 m x 5 m
300	490 m^3	3.0 m	18 m x 19 m	340 m^2	20 m x 21 m	6 m x 7 m
350	560 m^3	3.0 m	19 m x 19 m	360 m^2	21 m x 21 m	7 m x 7 m
400	640 m^3	3.0 m	20 m x 20 m	400 m^2	22 m x 22 m	8 m x 8 m
450	710 m^3	3.0 m	21 m x 21 m	440 m^2	23 m x 23 m	9 m x 9 m
500	790 m^3	3.0 m	23 m x 21 m	480 m^2	23 m x 25 m	9 m x 11 m

Note 1: Based on 50 l/cow/day and local rainfall, evaporation and evapotranspiration data. Assumes all stormwater from farm dairy and surrounding land is diverted.
Note 2: For regional storage requirements and application periods refer to 2.4.3.2 Timing of Application.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

TABLE 3.5-7

HOLDING POND REQUIREMENTS FOR TWO MONTHS' STORAGE (Properties in the Northland, Auckland, Nelson and Marlborough Regions)

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	340 m^3	3.0 m	16 m x 16 m	260 m^2	18 m x 18 m	4 m x 4 m
150	490 m^3	3.0 m	18 m x 19 m	330 m^2	21 m x 21 m	6 m x 7 m
200	640 m^3	3.0 m	20 m x 21 m	420 m^2	22 m x 23 m	5 m x 4 m
250	790 m^3	3.0 m	21 m x 22 m	460 m^2	23 m x 24 m	5 m x 6 m
300	990 m^3	4.0 m	21 m x 25 m	530 m^2	23 m x 27 m	5 m x 9 m
350	1140 m^3	4.0 m	21 m x 28 m	590 m^2	23 m x 30 m	5 m x 12 m
400	1290 m^3	4.0 m	21 m x 31 m	650 m^2	23 m x 33 m	5 m x 15 m
450	1440 m^3	4.0 m	21 m x 34 m	710 m^2	23 m x 36 m	5 m x 18 m
500	1590 m^3	4.0 m	21 m x 37 m	780 m^2	23 m x 39 m	5 m x 21 m

Note 1: Based on 50 l/cow/day and local rainfall, evaporation and evapotranspiration data. Assumes all stormwater from farm dairy and surrounding land is diverted.
Note 2: For regional storage requirements and application periods refer to 2.4.3.2 Timing of Application.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

TABLE 3.5-8

HOLDING POND REQUIREMENTS FOR THREE MONTHS' STORAGE (Properties in the Waikato, Taranaki, Gisborne, Hawke's Bay, Wellington, Tasman, Southland and South Otago Regions)

Cow numbers	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	500 m^3	3.0 m	18 m x 19 m	340 m^2	20 m x 21 m	6 m x 7 m
150	730 m^3	3.0 m	21 m x 21 m	440 m^2	23 m x 23 m	9 m x 9 m
200	1010 m^3	4.0 m	22 m x 24 m	530 m^2	24 m x 26 m	6 m x 8 m
250	1240 m^3	4.0 m	22 m x 29 m	640 m^2	24 m x 31 m	6 m x 13 m
300	1470 m^3	4.0 m	21 m x 35 m	740 m^2	23 m x 37 m	5 m x 19 m
350	1700 m^3	4.0 m	21 m x 39 m	820 m^2	23 m x 41 m	5 m x 23 m
400	1930 m^3	4.0 m	21 m x 43 m	900 m^2	23 m x 45 m	5 m x 27 m
450	2160 m^3	4.0 m	21 m x 48 m	1010 m^2	23 m x 50 m	5 m x 32 m
500	2390 m^3	4.0 m	21 m x 52 m	1090 m^2	23 m x 54 m	5 m x 36 m

Note 1: Based on 50 l/cow/day and local rainfall, evaporation and evapotranspiration data. Assumes all stormwater from farm dairy and surrounding land is diverted.
Note 2: For regional storage requirements and application periods refer to 2.4.3.2 Timing of Application.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

TABLE 3.5-9

HOLDING POND REQUIREMENTS FOR FOUR MONTHS' STORAGE (Properties in the Bay of Plenty, Manawatu, Wanganui and West Coast Regions)

Cow number	Required volume	At normal effluent depth	Size	Surface area	Top bank size	Pond floor size
100	690 m^3	3.0 m	20 m x 21 m	420 m^2	22 m x 23 m	8 m x 9 m
150	1060 m^3	4.0 m	22 m x 25 m	550 m^2	24 m x 27 m	6 m x 9 m
200	1390 m^3	4.0 m	22 m x 31 m	680 m^2	24 m x 33 m	6 m x 15 m
250	1710 m^3	4.0 m	22 m x 37 m	810 m^2	24 m x 39 m	6 m x 21 m
300	2040 m^3	4.0 m	21 m x 46 m	970 m^2	23 m x 48 m	5 m x 30 m
350	*2360 m^3	4.0 m				
400	*2690 m^3	4.0 m				
450	*3010 m^3	4.0 m				
500	*3340 m^3	4.0 m				

Build an appropriate combination of two of the above ponds to make up the required surface area.

* Divide this dimension into two smaller aerobic ponds. Build an appropriate combination of two of the above ponds to make up the required volume.
Note 1: Based on 50 l/cow/day and local rainfall, evaporation and evapotranspiration data. Assumes all stormwater from farm dairy and surrounding land is diverted.
Note 2: For regional storage requirements and application periods refer to 2.4.3.2 Timing of Application.
Note 3: Batter slope on interior bank = 2 : 1.
Note 4: Freeboard = 500 mm.

3.6 CONSTRUCTION OF PONDS

Pond systems are relatively inexpensive structures since raised banks can be constructed using the spoil from excavating the basin.

However, many serious pollution incidents are caused by earth-banked ponds that are too small, badly built or constructed on an unsuitable site. Ponds cannot be built properly on some sites because of unsuitable soil conditions or high water tables (refer to 3.4 Siting of Ponds).

When constructing ponds consider:

- **pond and embankment design**
- **batter slopes**
- **stormwater control**
- **sealing and lining**
- **inlet and outlet structures**
- **fencing.**

3.6.1 Pond and embankments

Ponds can be built below, above, or part below/part above ground. **Preferably, build the ponds 2/3 above and 1/3 below the ground.** The required fall from the farm dairy may not allow this.

In regions with extremely high water tables it has been known for deeper anaerobic ponds to 'pop out' of the ground. In this case it is critical to construct the pond at least partially above ground level and to seal the pond well to prevent effluent seeping out.

Embankments must be well constructed to prevent seepage, excessive settling and erosion over time. Typical depths from the base to the top of the embankment (i.e. including 500 mm freeboard) are:

- **3.5 to 4.5 m for anaerobic ponds**
- **1.7 m for aerobic ponds**
- **2.5 to 4.5 m for holding ponds.**

FIGURE 3.6-1

DESIGN SPECIFICATIONS FOR POND CONSTRUCTION

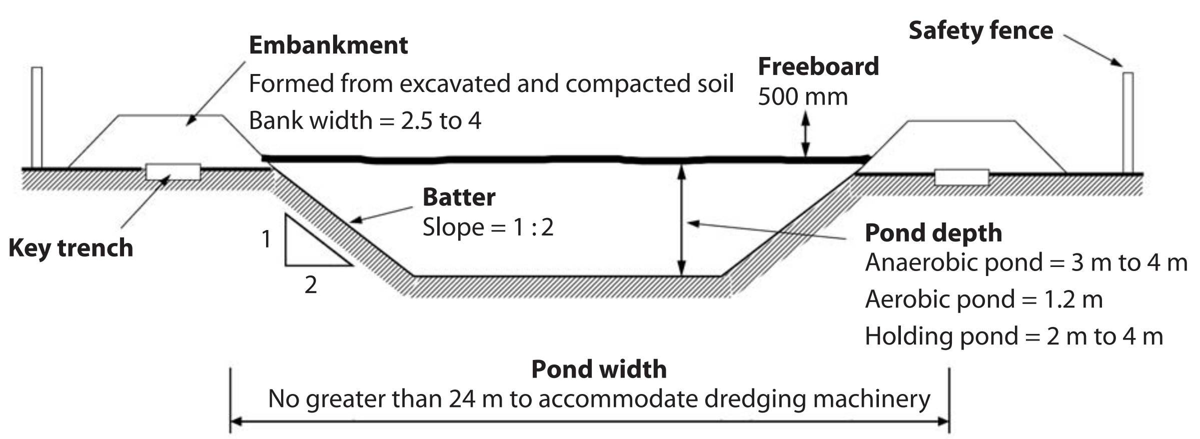


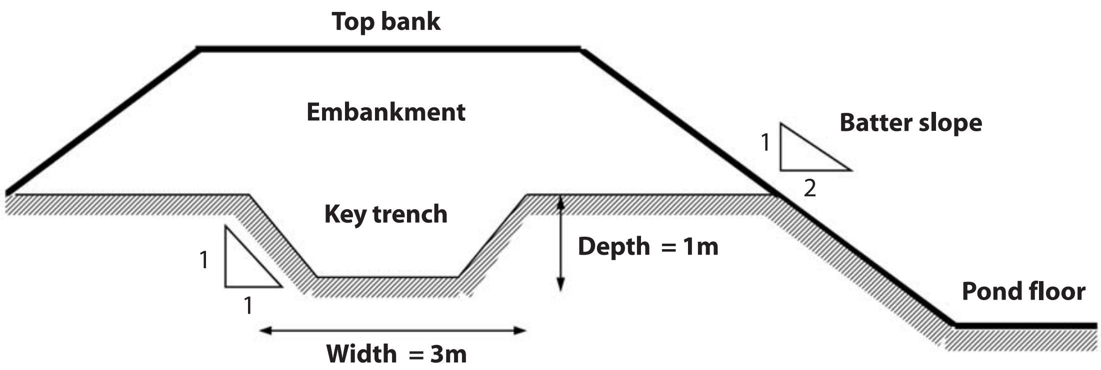
Figure 3.6-1 gives the major design specifications discussed in the following sections.

Pond and embankment construction involves the following steps (refer to Figure 3.6-3):

1. **Stripping topsoil from the pond area and stockpiling it for replacement later.** The topsoil can be used on the embankments for regrassing.
2. **Excavating.** Pond floors are best sloped towards where the outlet point is situated so that there is sufficient depth for pumping. Ground conditions should be moist, but not wet, for excavation work.
3. **Digging a key trench to a firm base, at least 1 m deep and 3 m wide, beneath the centre of the embankment** (refer to Figure 3.6-2). This is necessary if the embankment is built up above the land surface or on very porous soils. The key trench hinders flow of effluent through the ground by lengthening the seepage path, prevents erosion and offers structural stability to the embankment.
4. **Banking up and compacting the soil, while excavating the pond, to form the pond walls,** when ponds are built at least partly above the ground. Poor compaction will lead to effluent seepage and erosion of the embankment by wind and rain.
5. **Placing layers of suitable graded soil on top of each other to a 200 mm depth over the full width.**
6. **Packing the soil tight using suitable equipment.** Fill should be compacted over the entire surface after each 200 mm soil layer is added. Use water to aid compaction if the soil is too dry. Best compaction is obtained with heavy rubber-tyred vehicles and rollers. Track vehicles are unsuitable as their weight is spread over a large track surface area.

FIGURE 3.6-2

CROSS SECTION OF THE EMBANKMENT AND KEY TRENCH



7. **Building the banks with internal batters of 2 : 1 slope** (refer to 3.6.2 Batters).
8. **Building the banks high enough to allow for settling.**
9. **Building the top bank wide enough to allow for vehicle access for maintenance.** Widths of between 3.0 m and 4.0 m are usual. Use wider widths when it is known large dredging machinery will be used around the ponds. The top bank width should **not** be less than that given by the formula: **W = (H/5) + 1.5 m**, where W = Width and H = Total Embankment Height.
10. **Building an entry ramp and a loose metal platform** to provide access and a firm platform for dredging machinery, pond stirrers and vehicle spreaders. This will prevent erosion of the banks and allow for easy access regardless of the prevailing soil conditions.
11. **Grading the top bank off away from the pond** so that stormwater runoff into the pond is prevented.
12. **Installing a plastic liner** if the soil is less than 10% clay or as required by your Regional Council (refer to 3.6.4 Sealing and lining and check with your Regional Council for requirements).
13. **Covering the exposed surfaces of the embankment and external batter with a minimum 100 mm layer of topsoil.**
14. **Sowing grass to cover the embankment to the water's edge** to prevent erosion from sun, wind and rain. Phalaris, ryegrass and clover are suitable species.
15. **Filling the pond** to prevent drying and cracking of the sealed layer.
16. **Keeping plants that are growing on embankments short** so that the ponds can be inspected easily. Allow stock to graze the area occasionally.

17. **Not allowing trees to grow on, or near to, embankments.** Tree roots can pierce the embankment causing instability. If trees fall over, or roots die, the embankment will be breached. Furthermore, leaves falling into the pond system will add to the organic load, and excessive leaf drops will result in poor light penetration into aerobic ponds.
18. **Planting shrubs and small plants around the pond area to improve appearance.** Avoid plants that will harbour rats.
19. **Examining embankments after heavy rain.**
20. **Fencing the pond for human and stock safety.**

FIGURE 3.6-3

POND AND EMBANKMENT CONSTRUCTION

3.6.2 Batters

Figure 3.6-4 illustrates the batter slope. In most situations **internal batter slopes should be no steeper than 2 horizontal to 1 vertical** (i.e. slope = 2 : 1).

In some silt and clay soils the slope can be increased up to 1 : 1 but only on the recommendation of an engineer with knowledge of the specific soil type.

If the pond surrounds are to be grazed or left uncut, external batter slopes should be **sloped 2 horizontal to 1 vertical.** If the slopes are to be mowed or machinery access is required, the **external batter slopes should be sloped 3 horizontal to 1 vertical.**

FIGURE 3.6-4

INTERNAL BATTER SLOPE OF 2 : 1

3.6.3 Stormwater control

To reduce the cost of the pond system, avoid unnecessary addition of clean water. This will maximise the retention time as it will prevent flushing.

Stormwater control involves the diversion of farm dairy roof water, yard water and any runoff from the land away from the ponds.

3.6.3.1 Diverting stormwater at the farm dairy

Divert stormwater from the farm dairy and other sealed areas before it reaches the sump (refer to 1.6.2 Stormwater).

Clean rainwater from roofs and open concrete areas should not run into the farm dairy sump and then into the pond system.

3.6.3.2 Diversion channels around the ponds

There should be a diversion channel, or cut-away ditch, around the top of all ponds to divert surface runoff. The channel should be approximately 1 m out from the embankment's base. Preferably, the channel should entirely surround the pond although this may cause access problems.

From the channel, the stormwater can enter the drainage system.

Channels and drains conveying stormwater from around ponds may operate in the following ways:

- **gravity flow in an open channel** that is constructed from earth
- **gravity flow in an open channel** that is artificially lined or made of concrete
- **gravity flow in a pipeline,** flowing full or partly full.

Generally, **channel systems** are more cost-effective than pipelines. However, problems with maintenance and weed control, channel crossings, and health and safety risks limit the value of channels carrying stormwater long distances.

The least expensive option is to have an earthen channel built around the pond. Preferably however, channels should be concrete and constructed with sloping walls. The added expense is justified by a more successfully operating channel with a much lower maintenance requirement. Channel drains are available as pre-cast sections and can be installed by the farmer (refer to 1.7.3 Drains). **Gravity flow pipelines** can be a major cost, especially where large diameter gravity pipelines are used.

3.6.4 Sealing and lining

Silt or clay soils are best for pond foundations and construction as the pond floor will often tend to self-seal. This is because the soil is clogged with fines settling out from the effluent. Anaerobic ponds have more solids and will tend to self-seal more readily, whereas aerobic ponds require soils to be impervious when compacted.

The permeability requirement for ponds set out by Regional Councils (check with your Regional Council for requirements) can often be met through standard compaction procedures on soils with more than 20% clay (i.e. fine sandy loam, clay loam, silt or clay soil types).

Maximising compaction of the inside surfaces of ponds will minimise seepage and bank erosion. The use of specialised earth moving and compaction equipment will ensure the best job in the least time.

If the soil has less than 10% clay, special measures may be required such as importing soil that is high in clay content or artificially lining the pond with a plastic liner or concrete interior.

3.6.4.1 Importing clay soil for sealing

Imported clay soil should form a layer over the entire surface area of the pond and be at least 150 mm deep. This is compacted with specialised compaction equipment. It is common practice to mix a 150 mm depth of imported clay soil with 150 mm depth of existing subsoil, and to compact using an appropriate compaction machine. The use of bentonite clays may be necessary.

To prevent the clay seal from drying out and cracking, **the pond should be filled with water as soon as possible after completion.**

3.6.4.2 Liners

Liners can be an expensive option, but will be necessary if clay material for compaction is not available or if required by your Regional Council.

They are installed by the supplier because of the need for seams to be welded. The cost of a 1.5mm HPDE liner is approximately \$8 - \$19/m^2. This includes the cost of cutting, welding and pressure testing the joins on site. The cost of excavating the perimeter trench to hold the fabric in place is additional. There is a large range of products on the market and some are more cost-effective and robust than others, so talk with local farmers and advisors about what they have used.

Sandwich type liners are also commercially available combining woven polypropylene and a sodium bentonite clay in 4 m by 30 m rolls. The liner does not require specialised welding as adjacent blankets are overlapped and seal to one another when effluent is introduced to the pond and the clay swells and seals.

When installing liners consider the following:

- **vulnerability of the pond edges** to physical damage given their exposure
- **site selection.** Avoid areas subject to flooding and ground water movement (refer to 3.4 Siting of ponds)
- **site preparation.** Remove all roots, stumps and rocks. Surface water should be removed
- **all outlets and other rigid structures should be completely constructed before the liner is installed**
- **the perimeter 'anchor trench'** should be completed before liner installation. This trench takes in the liner over the lip of the pond and should allow for 500 mm backfill over the installed liner
- **for installation, liaise closely with manufacturers and distributors.**

Where ponds are lined with a plastic liner, care should be taken to ensure that the pump is situated well above the pond floor or it may interfere with the liner. Contractors should be told that a liner is present so that they can keep stirrer propellers and the suction end of vehicle spreading pumps away from the liner surface.

An alternative to plastic liners is to have a concrete pond interior. This will ensure the ponds are sealed and avoids problems with machinery ripping or splitting other forms of liner.

3.6.5 Inlet and outlet structures

PVC pipe, of at least 100 mm diameter, is recommended for carrying effluent to the pond and between ponds.

100 mm diameter pipe should have a minimum fall of 1 m in 35 m, and 150 mm pipe should have a fall of 1 m in 50 m. Do not use ribbed drainage coil as the internal ribbing inhibits effluent flow.

For buried pipes, the depth is dependent on the likelihood of disturbance from machinery. **A depth of 600 mm** is desirable for the pipeline carrying effluent to the pond, especially if mole ploughing is likely and if the pipeline is unable to be situated close to a fence line.

It is essential that all pipes and baffles are fixed and not floating on rising and falling effluent levels.

Floating pipes may cause system overflow and pipes may be damaged. Secure the pipes and baffles by fixing a wire rope on to the inlet and outlet ends, and pegging it into the ground (refer to Figure 3.6-5).

To avoid seepage from the pond along the external surface of the pipe:

- ensure that the construction material is compacted along the pipe length
- have anti-seepage collars installed.

Pipes used in buried pipelines should be laid according to the manufacturer's instructions.

FIGURE 3.6-5

SECURING PIPES AND BAFFLES

3.6.5.1 Inlets

For an anaerobic pond, the effluent should be piped towards the pond centre and then downwards into the pond, 6 m from the pond edge, or directly above the base of the batter slope (refer to Figure 3.5-2) to:

- ensure that the effluent is at the deepest part of the pond
- obtain uniform distribution of effluent into the pond
- ensure that the pipes passing through the embankment do not discharge directly onto the embankment in such a way that erosion of the embankment occurs.

The inlet may deliver the effluent above or below the pond surface. If the inlet is **above the surface,** support the pipe with a treated timber channel. The pipe can rest in the rectangular or V-shaped channel, which is in turn supported by treated timber posts every 2 m to 3 m.

Below surface inlets may be used to gain sufficient fall for gravity flow. They also guard against pipes freezing in cold conditions and can reduce nuisance problems (i.e. flies and odours). However, below surface inlets may block due to solids settling at the waterline. This can be avoided if the effluent is forced into the pond by pumping. Otherwise the pipe should be constructed to allow for regular and easy cleaning (refer to 3.6.5.3 Inspection Openings).

3.6.5.2 Outlets

Separate the **in-flow and out-flow points of ponds as much as possible to reduce short-circuiting.** The inlet should be at one end/corner of the pond and the outlet should be at the opposite end/corner (refer to Figure 3.5-3).

The anaerobic pond outlet should be 1.5 m from the far edge of the pond and at least 500 mm below the effluent surface.

3.6.5.3 Inspection openings

It is sensible to fit an inspection opening into the transfer pipe between the ponds, and also into the final discharge pipe. This allows for pipe blockages to be dealt with easily rather than having to reach out over the ponds or dig up buried pipes.

3.6.5.4 Baffles

Baffles are necessary to prevent floating solids moving from pond to pond. Various systems can be employed (refer to Figure 3.6-6).

All inlets should be 1.5 m from the pond edge and 300 mm below the pond surface.

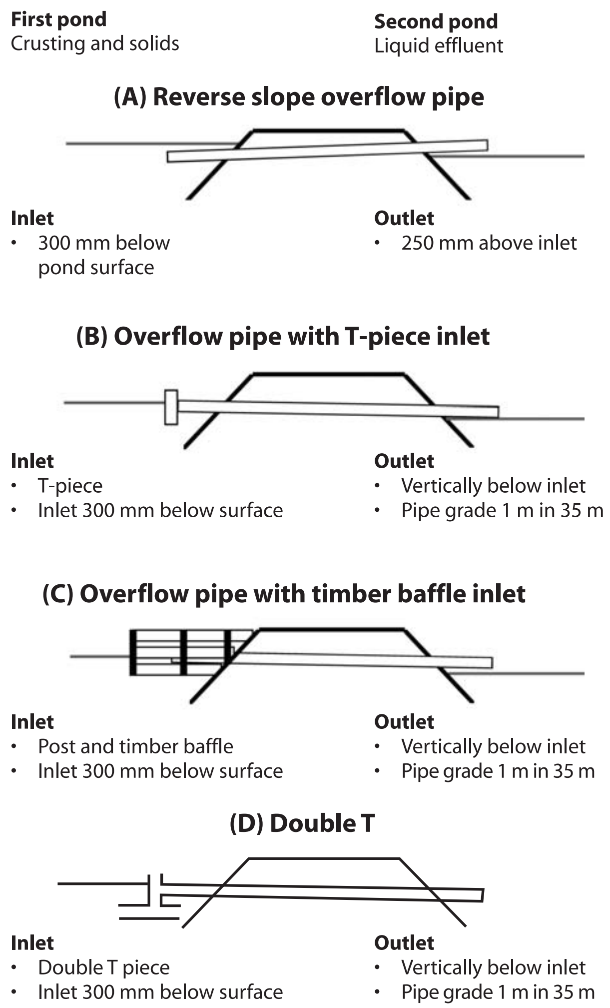
For the **reverse slope overflow pipe,** the inlet should be at least 250 mm below the outlet. If the pipe blocks up, it can be cleaned with a rod from the outlet end.

A **T-piece pipe** is the most widely used inlet baffle (refer to Figure 3.6-6B). PVC pipe can be surrounded by a drum to prevent effluent solids from blocking effluent flow (refer to Figure 3.6-6C).

For the **timber baffle inlet system,** posts are driven into the embankment to support horizontal boards at 25 mm spacings. Treated timber should be used.

FIGURE 3.6-6

BAFFLE SYSTEMS



3.6.5.5 Outlet pumping, drains or wetlands

Preferably, the effluent from the pond should be applied to land to utilise the fertiliser value of effluent nutrients (refer to Chapter 2 Land application). If effluent from the pond is to be applied to land via a spray application system it will need to be pumped (refer to 2.9.1 Pumps). Pumps are best seated on a pontoon floating freely on the pond surface (refer to 2.9.1.4 Pump installation).

Alternatively, the effluent will be eventually discharged into a receiving waterway. The amount of time that the effluent spends on land before reaching receiving waterways should be maximised. For this reason, do not pipe effluent to the receiving waterway, but allow it to flow in an open drain.

The receiving drain should be at least 300 m long. Maximise weed growth in receiving drains as the weeds will act as a filter, taking up some nutrients and sifting out suspended solids (refer to 3.8.2 Weed control).

A constructed wetland system can be used to further treat the effluent. Effluent from the aerobic pond flows into a drain leading to the wetland. Plants in the constructed wetland take up some nutrients and filter out solid material (refer to 3.10 Constructed wetlands).

Whether using a drain or wetland system, the effluent flow should be fenced off to avoid animal safety risks and bank damage.

3.6.5.6 Receiving waterway flow rates

Discharges into small and slow-flowing waterways may have a larger impact due to the waterway's limited capacity to dilute and assimilate effluent. Minimum receiving water flow rates for some typical dilutions are given in Table 3.6-1.

Regional Councils generally set site-specific conditions for assimilation of ammonia. These will not generally be below 100 times dilution (i.e. 100 litres of natural water to 1 litre of discharged effluent). 250 times dilution provides a higher degree of environmental protection from ammonia toxicity, necessary where sensitive fish populations are present.

TABLE 3.6-1

MINIMUM RECEIVING WATER FLOW RATES [1]

Cow Numbers	100 times dilution		250 times dilution	
	Peak discharge[2]	Constant discharge[3]	Peak discharge[2]	Constant discharge[3]
100	35 l/s	17 l/s	90 l/s	45 l/s
150	50 l/s	25 l/s	125 l/s	62 l/s
200	70 l/s	35 l/s	175 l/s	87 l/s
250	90 l/s	45 l/s	225 l/s	112 l/s
300	105 l/s	52 l/s	260 l/s	130 l/s
350	120 l/s	60 l/s	300 l/s	150 l/s
400	140 l/s	70 l/s	350 l/s	175 l/s
450	160 l/s	80 l/s	400 l/s	200 l/s
500	175 l/s	87 l/s	440 l/s	225 l/s

Note 1: Based on 50 l per cow per day (i.e. 25 litres per cow per milking).
Note 2: Assumed discharge running from the last hour of milking and 3 hours after washdown. Receiving water flow rates based on a 2 hour peak loading during this four hour period.
Note 3: Receiving water flow rates can be **halved** if a constant discharge (rather than a fluctuating and peak discharge) is maintained from the pond system into the waterway over the 4 hours. This may be achieved by a simple flow control device.
Grogan, 1989; Hickey et al, 1989.

Making a simple flow estimate for a particular stream requires a measure of:

- the average depth across the stream
- the channel width
- the water velocity.

Flow = average depth x width x velocity

Flow should be constant throughout a reach between inputs (e.g., from tributaries, drains, springs), so choose a point in the stream where measurements are easy to make and the channel is as uniform as possible.

Measure width with the tape. Measure depth with a ruler or tape to the nearest centimetre at ten equally-spaced points across the stream and calculate the average depth (sum of all depth measurements divided by number of measurements).

Measure the average water velocity by releasing a float (e.g. an orange) and measuring, (ideally with a stopwatch) how long it takes to move a set distance along the stream where conditions (depth and width) are similar to those at the cross-section you have measured. It is best to repeat this three or more times starting at different places across the channel to get a reliable measure of the average velocity of the water.

$$\text{Surface velocity} = \frac{\text{distance moved}}{\text{time taken (secs)}}$$

Because the velocity is faster at the surface than near the bed, the surface velocity needs to be multiplied by a correction factor of 0.8 to get the true average velocity.

If all measurements are made in cm then the flow is cm^3/sec and dividing by 1000 changes this to litres/sec. If all measurements are in metres, then the flow is in m^3/sec (cumecs) and multiplying this by 1000 converts to litres/sec.

3.6.6 Fencing

All ponds or soakage areas should be surrounded by a fence to:

- **protect workers and children.** This is significant particularly in view of Occupational Safety and Health legislation
- **protect stock**
- **avoid stock damaging pipelines and embankments.**

It is good practice to erect a warning sign on the fence indicating the dangers associated with the pond, such as depth and unsuitability for drinking.

The fence should be sited to allow easy access of machinery. Include a large gate.

3.7 SYSTEM ADDITIONS TO IMPROVE EFFLUENT QUALITY

Mechanical aeration is an addition to a pond system that may be used to improve effluent quality. Mechanical aeration can be supplemented with geotextile sheets that allow bacterial films (or slimes) which form to further enhance ammonia removal.

Biological or chemical additives are not widely used or recommended to improve pond effectiveness.

Recently, an upgrade to conventional two pond systems has been developed by NIWA known as advanced pond systems. These have been shown to dramatically increase the quality of discharge.

3.7.1 Mechanical aeration

Aeration introduces oxygen into the pond, so that bacteria can more effectively convert the organic solids to carbon dioxide, water and bacteria biomass (refer to 3.2.3 The aerobic pond (facultative pond)).

Mechanically-aerated ponds generate turbulence to mix all the effluent in the pond and raise oxygen levels through equipment that either:

- **introduces air into the effluent.**

This is commonly achieved by introducing air under the pond surface so that the air bubbles through the effluent (refer to Figure 3.7-1)

- **exposes more effluent surface area to the air.** This is commonly achieved by spraying effluent into the air or agitating the effluent.

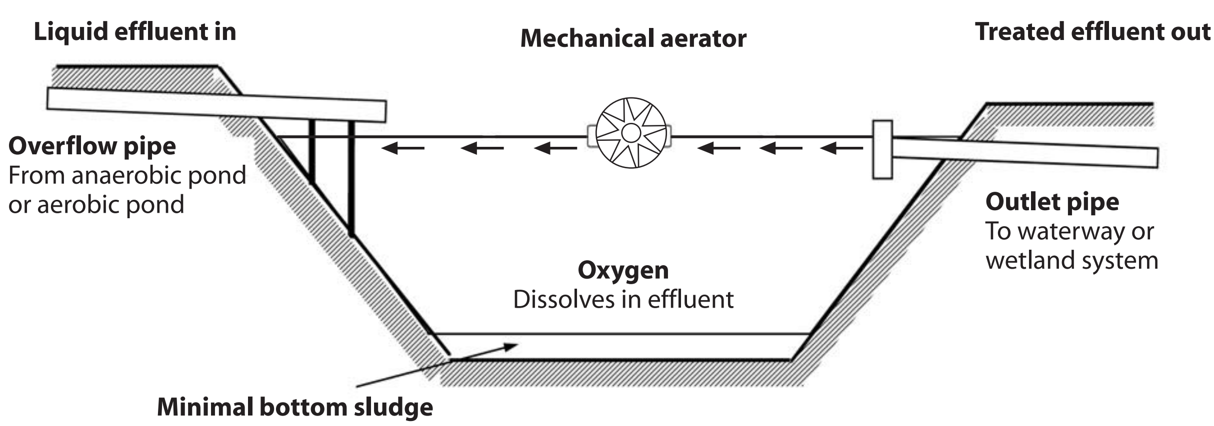
Floating pumps can be used to pump air into the effluent or, alternatively, air can be pumped through perforated pipes lying across the bottom of the pond. Venturi aerators are also available. These work by forcing a flow of effluent through a narrow nozzle. This results in a pressure drop in the pipe, creating a vacuum that draws surface air through a supply line and into the effluent in the form of fine bubbles.

Mechanical aeration is widely used to treat sewage and industrial effluent. Research in New Zealand has demonstrated that **aeration processes can significantly reduce ammonia-N and BOD levels in stored effluent.** Recent research showed that after both continuous and night-only aeration, the BOD was halved. There was also an ammonia-N reduction of 99% when an aerator was run continuously, or 90% with night-only aeration. With the addition of geotextile sheets to the night-only aeration, the reduction was 93%. Geotextile sheets act as an attachment surface upon which the slow growing bacteria which reduce the ammonia-N can grow as thin bacterial film. Any durable, non-toxic material with a high surface area can be suspended in the water for this purpose. These attachment surfaces are helpful in shallow ponds particularly when placed just below the pond surface (top 300mm of the pond). Mechanical aeration in existing pond systems has long been recognised as an effective method of reducing odours. However, long periods of storage (i.e. greater than 1 month) following aeration will eventually cause the return of odour.

Continuous aeration systems give the highest level of treatment, but **night-time aeration in ponds is also highly effective as long as the pond is not over loaded with solids.**

FIGURE 3.7-1

THE MECHANICAL AERATION PROCESS



Mechanical aeration equipment for use on dairy farms is commercially available. **Manufacturers' recommendations should be used to design the pond correctly (i.e. size, shape, depth), and select the best number and configuration of aerators, before installation.**

A 'cage-rotor' or impellor style aerator both mix the content of the pond with a good circulation pattern. Vertical axis aerators are better for deep aeration tanks which are not generally suited to New Zealand dairy farms.

The **cost of an aerator is largely determined by the amount of oxygen you want to transfer to the pond on a daily basis. The cost of an aerator could range from $5,000 - $15,000, plus the cost of electrical reticulation from the dairy shed to the second pond, if not already installed (this could cost between $2,000-$3,000).**

When using mechanical aeration in a pond or tank, the following operating principles should be adhered to:

- **aeration is most effective for dilute effluent with minimal solids.** There should be no animal bedding material or animal hair in the effluent being aerated
- **a reasonably constant supply of effluent is required to give a controlled retention time in the pond or tank**
- the most efficient oxygen transfer occurs when very small bubbles are used
- **intermittent mechanical aeration is best performed at night,** to take advantage of the oxygen production by algal photosynthesis during the day time
- **to be economical, aerators should supply a high quantity of dissolved oxygen for each kiloWatt hour they use**
- **the oxygen concentration should be kept as even as possible throughout the pond or tank, by effective mixing.**

3.7.2 Advanced pond systems

This system has been designed and evaluated for its effluent treatment effectiveness by NIWA on two properties in Waikato, one in Southland and one in Northland.

The four pond system retains the existing anaerobic (first) pond, but replaces the anaerobic (second) pond with three other types of ponds: a high rate pond, an algae settling pond and a maturation pond (which together replace the conventional aerobic pond). Table 3.7-1 shows the characteristics and the function of each pond.

TABLE 3.7-1

POND FUNCTION IN THE ADVANCED POND SYSTEM

Type of pond	Design features	Function
Anaerobic pond	Deep (4 m), rectangular in shape with a length to width ratio of 2:1	To promote sedimentation and anaerobic breakdown and to enable removal of the settled sludge
High rate pond	Shallow (0.1-0.3 m), long, meandering raceway mixed by a paddle wheel.	To promote algal growth for uptake of nutrients and release of oxygen to reduce BOD, plus disinfecting of micro-organisms by exposure to sunlight.
Algae settling pond	Deep (3 m) at in-flow end, sloping to shallow (0.5-1 m) at the out-flow end.	To promote settling of large algae in the still, deep pond conditions and enable ease of collection (allowing removal of nutrients).
Maturation pond	Depth of 1 to 3 m with baffles to raise residence time.	Polishing of effluent by allowing zooplankton to graze remaining algae, and further removal of micro-organisms by solar radiation, sedimentation and protozoan grazing.

The ponds are laid out in sequence as in Figure 3.7-2. The layout is designed to minimise short-circuiting and provide distinct environments to enhance the natural processes that promote breakdown, purification and disinfecting of effluent. Figures 3.7-3 and 3.7-4 show the different pond shapes.

FIGURE 3.7-2

THE ADVANCED POND SYSTEM LAYOUT

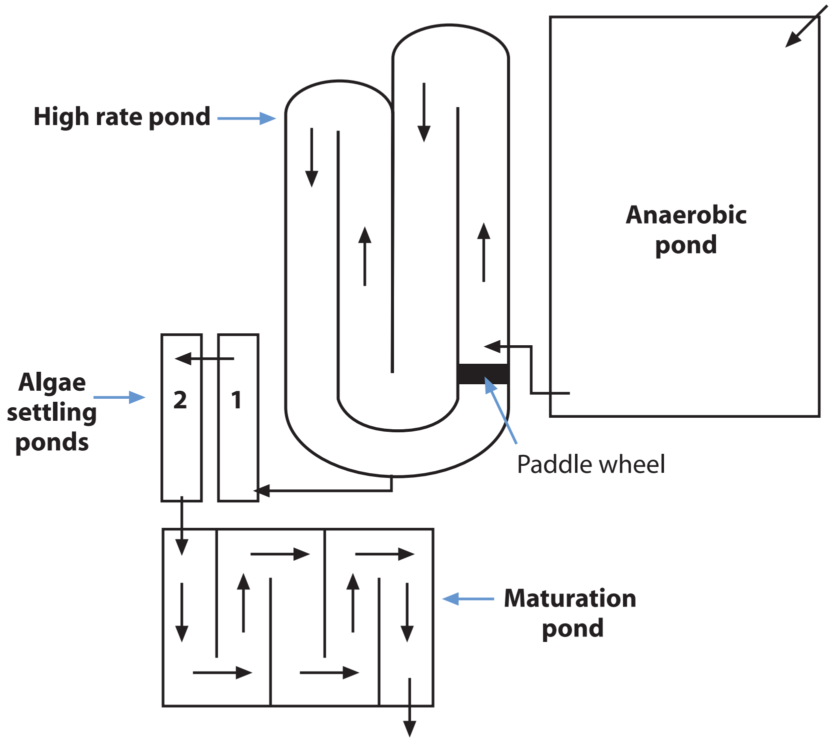
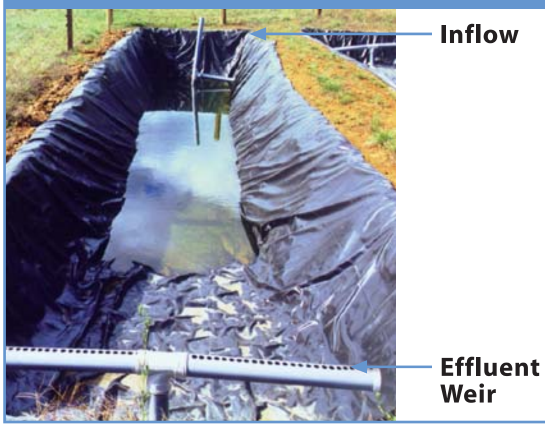


FIGURE 3.7-3

THE HIGH RATE POND
(with paddle wheel in foreground and maturation pond cells behind) in the advanced pond system built in Waikato

FIGURE 3.7-4

THE ALGAE SETTLING POND
(filling with water) Showing Inlet (at deep end) and outlet (foreground).



3.7.2.1 Advanced pond system performance

The performance of the two systems built in Waikato and Southland has been studied, with promising results in both cases, suggesting that cold temperatures will not reduce effectiveness in these systems as is the case with conventional pond systems.

Table 3.7.2 shows the performance of an advanced pond system compared to average values from a conventional system for key contaminants.

TABLE 3.7-2

MEDIAN EFFLUENT CONCENTRATIONS OF KEY CONTAMINANTS IN A CONVENTIONAL AND ADVANCED POND SYSTEM (WAIKATO)

Contaminant	Median Concentration[1] from Advanced Pond	Median Concentration[1] from Conventional Pond
BOD_5	43	98
Soluble Solids	87	198
Ammonia	39	106
Total Phosphorus	19	27
E. coli	918	70,000

Note 1: All median concentrations are in g/m^3 except for E. coli which are in MPN/100 ml

The Southland trial has proved equally, if not more effective than the initial Waikato trial.

Advanced pond systems are more effective than conventional systems because there is more sunlight in the shallow high rate pond than in a conventional aerobic pond, allowing algae to grow throughout the water column.

Nutrients are removed by uptake of the algae and by volatilisation (ammonia) or settling out (phosphorus) at the high pH that occurs with the intense algal activity.

This high pH also helps to kill pathogenic micro-organisms, as does the solar radiation and the high dissolved oxygen produced by the algae.

The paddle wheel keeps the water mixed and keeps algae suspended in the pond.

The algae settling pond allows the nutrients captured in algal material to be harvested and removed. They can be used as a fertiliser or returned to the anaerobic pond to settle there as sludge and await removal with desludging.

The maturation pond allows further polishing with removal of remaining micro-organisms and algae by protozoan grazing and zooplankton. Retention time in this pond must be limited to ensure that algae do not re-grow and increase BOD.

3.7.2.2 Advanced pond system cost

The cost of an advanced pond system for a 300 cow herd are given below. The **construction costs for earthworks, baffles, and pipework** was **$19,500.** A liner (if required) is an additional cost (refer to 3.6.4 Sealing and lining). The **mechanical components** consist of a **paddlewheel at $8000** and a **pump to remove algae** from the algae settling pond costing **$500.** Getting power to the ponds to run mechanical equipment is an additional cost.

Maintenance and operation costs are similar to conventional systems, with the only additional activity being algae removal from the algal settling ponds every six months (refer to 3.7.2.5 Advanced pond system management).

The paddlewheel requires minimal power, with typical running cost of the motor being less than $100 per year.

3.7.2.3 Advanced pond systems as an economic and practical option

The advanced pond system provides an option that retains the benefits of conventional ponds such as their ease of construction, low labour input and tolerance of shock loads. The four ponds have an overall land requirement similar to that of conventional ponds. There is also an opportunity for some nutrient harvesting through using the algae removed from the algae settling pond as a fertiliser.

While more expensive than a conventional pond system, advanced pond systems consistently produce a high effluent quality even at low temperatures.

They show great promise in areas of New Zealand where land irrigation is unsuitable or temperatures are too cold for conventional ponds.

3.7.2.4 Advanced pond system design and construction

The anaerobic pond is the same as in a conventional pond system. Out-flow from this pond into the high rate pond should be from 300 mm below the surface to avoid solids transfer.

The high rate pond should be shallow (0.1-0.3 m deep) to maintain maximum sunlight penetration. **The inlet and the outlet pipes are situated on either side of the paddlewheel to prevent short-circuiting,** a major cause of poor micro-organism removal in conventional ponds.

The design of the high rate pond is dependent on the retention time required to grow sufficient algae so that enough oxygen is released to breakdown the BOD in the effluent. **Appropriate retention times for a dairy farm system range from 5 to 10 days.** Retention times will only be achieved if the pond is level (to within 20 mm). Channel widths should ideally be no more than 6 m but can be up to 12 m for large systems (500-1000 cows).

Baffles are required in the high rate pond. These can be constructed cheaply of earth, although this will require more pond area and excavation work. Alternatively, baffles can be made from 1 mm high-density polyethylene liner attached to fencing battens.

The inlet to the high rate pond should enter at the bottom of the pond, while the outlet should take water from the pond surface.

The algae settling pond is 3 m deep at one end, rising to 0.5-1 m deep at the other end. It typically has a length to width ratio of 5:1. All sidewalls of the algae settling pond should have a slope of 2:1 vertical : horizontal gradient.

The inlet from the high rate pond enters at a depth of 1 m from the algae settling pond bottom while the outlet to the maturation pond takes water from the pond surface.

Retention time is designed to enable maximum settling of algae but restrict further algal growth. **Use of two algae settling ponds in series, each with a 2-3 day retention time can remove up to 80% of the algae by sedimentation.**

The maturation pond has a depth of 1-3 m and is designed for a residence time for maximum decay rates of faecal bacteria, which is largely dependent on temperature. **The general residence time of 10-20 days can consistently reduce faecal coliforms to below 1000/100 ml. However, long residence times can result in algal re-growth, causing solids and BOD to increase. Subdividing larger ponds into cells with 3-day retention times reduces this problem.** The inflow pipe should discharge to the bottom of the pond while the outflow takes effluent from the pond surface.

As these systems are still relatively new and rely on careful construction to specifications to achieve high levels of treatment, specialist advice should be sought (e.g. from NIWA) at both the design and construction stages.

3.7.2.5 Advanced pond system management

In addition to regular desludging of the anaerobic pond as occurs in a conventional system, algae need to be removed from the algae settling ponds by pump every 6 months. This typically takes one person 4 hours. The algae are rich in N, P and K and can be spray irrigated directly from the high rate pond or the concentrate from the algae settling pond can be diluted and sprayed onto land. Alternatively, the algae can be returned to the anaerobic pond to settle as solids and await desludging there (refer to 3.8.1 Desludging).

3.7.3 Additional ponds

A third pond, commonly referred to as a maturation pond, can be added to the existing two-pond system. The advantages of having a third pond in the system include:

- **further reduction of ammonia-N** by virtue of the additional surface area that is available for ammonia volatilisation into the atmosphere
- **improved quality of the effluent outflow in terms of suspended solids/ BOD.** A significant proportion of the total BOD in the outflow is associated with suspended solids. Further treatment to reduce the suspended solids level will improve the effluent quality in terms of BOD

Construction details of the additional pond are the same as for anaerobic ponds, aerobic ponds and holding ponds (refer to 3.6 Construction of ponds).

When a third pond is added in series it should be at least half the surface area of the aerobic pond. Design details for the additional pond can be calculated from 3.5.6 The aerobic pond.

The application of effluent to land is the preferred option of most Regional Councils, and many farmers. Storage is an essential part of the land application system. A large pond storage facility (i.e. an existing pond system or holding ponds):

- **increases flexibility,** as land application can be carried out less frequently and at the convenience of the operator, when weather and soil conditions are most suitable (i.e. during drier months). Being forced to apply effluent during winter and spring may result in drainage problems, surface runoff and damage to soil structure.
- **removes the need to operate the pump every milking.** A temporary pump installation may be possible.
- **ensures that coarse solids in the effluent have time to settle out,** reducing the possibility of damage from coarse material during pumping and irrigation.
- **allows for heavy loading.** A large proportion of sumps associated with spray application systems overflow because they are too small.
- **allows better use of plant nutrients** as the effluent can be applied when it will be of most value to the crop.
- **reduces any health risk** as storage has been shown to have a significant effect on the survival of pathogenic micro-organisms in effluent (refer to 2.13.1.1 Human and animal health).
- **can reduce the amount of odour emitted** during and after land application.

However, nutrients are lost from effluent during storage. Nitrogen, in particular, will be lost through volatilisation into the air as ammonia (i.e. NH_3). This is a continuing process in storage facilities and so the longer the effluent is stored the less nutrients are available for land application (refer to 2.2 Fertiliser properties of effluent).

For holding pond design and construction information refer to 3.5.8 Holding pond design.