Environment Southland Code of Practice for Design and Construction of Agricultural Effluent Ponds

December 2009

1. Introduction

This Code of Practice is intended for designers and constructors of agricultural effluent ponds in the Southland region. It comprises of Sections 2 to 11 below and Chapter 3 of the Dairying and the Environment Committee's *Managing Farm Dairy Effluent Manual 2006* (refer appended). The following sections from the manual are of particular relevance:

3.4 Siting of ponds
3.5 Pond design criteria
3.6 Construction of ponds

2. Background

Agricultural effluent ponds are constructed for a range of purposes. In Southland, they are generally constructed to provide storage so that farm dairy effluent can be applied when soil conditions are suitable. Many ponds are also used to store the agricultural effluents, sludges and slurries generated from wintering pads and barns or other farm infrastructure.

Scientific research has highlighted the importance of storage to provide a buffer to avoid applying agricultural effluent to wet soils. Storage is particularly important in Southland because of our wet climate, extensive mole and tile drainage network, high water table and soil types. As a result of this scientific research, there have been many new agricultural effluent ponds constructed in Southland in recent times. With the move to the new systems, problems have arisen with leaking ponds due to poor design and/or construction and inappropriately located ponds. This Code of Practice is intended to highlight the critical elements of good pond design and construction.

3. Design Outcomes

The key design outcomes that must be achieved for an agricultural effluent pond are as follows:

(a) a pond leakage rate low enough to avoid environmental contamination;
(b) a pond floor level at a safe height above the water table;
(c) a pond that provides for ongoing maintenance; and
(d) a pond that meets regulatory requirements.

The leakage rate through a pond lining is a function of the hydraulic conductivity of the lining material and the lining thickness. **A pond lining will need to achieve a leakage rate of 3.8×10^{-8} m/s or less to prevent the leakage of contaminants to the environment**. The design process should determine the properties of the lining material so the appropriate thickness and construction processes can be specified. It should also determine the structural stability of the lining material and bank material. A number of soils in Southland, especially those with some metamorphic rock parent material, are prone to serious slaking. Sections 6.1 and 8 of this document contain more information on soil properties and the liner material.

Section 6.2 of this document contains information on water table considerations to aid with determining a safe height for a pond floor level above the water table.

Another key design outcome is allowance for pond maintenance; specifically, designers should provide for ease of maintenance and resilience to agitation or activities of heavy machinery that may occur during the maintenance process.

Finally, the pond design must meet regulatory requirements such as those imposed as resource consent conditions.

Further design outcomes are discussed in Chapter 3.5 of the *Managing Farm Dairy Effluent Manual 2006* (appended).

4. Resource Consents and Building Consents

Resource Consents
Resource consent for agricultural effluent pond construction is required under Rule 49 of Environment Southland's Proposed Regional Water Plan for Southland.

Southland District Council has advised that *Rule PRA.4 – Soil Displacement Activities* of the Southland District Plan does not apply to agricultural effluent pond construction unless extraction of the lining material breaches the limit contained in the rule (1,000 m^3 over a 12 month period up to a maximum of 3,000 m^3 from the one site), in which case a resource consent from the Southland District Council is also required. This means that resource consent is not required for digging a hole for the pond and using the displaced material to construct embankments. However, if greater than 1,000 m^3 of material is extracted for use in pond linings either for use on an individual's property or as a commercial enterprise to retail to others for pond liners, this will require resource consent from Southland District Council.

Gore District Council and Invercargill City Council have advised that there are no resource consent requirements for effluent pond construction in their districts.

Building Consents
The Building Act 2004 specifies that a building consent is required if the pond is more than 3 m deep and holds more than 20,000 m^3. It also needs to be classified and may be subject to a dam safety assurance programme (refer Subpart 7 – Safety of Dams for these requirements).

5. Pond Size

Regulatory requirements are likely to dictate the minimum agricultural effluent pond size required.

At present, Environment Southland requires farmers wanting to use a low rate effluent irrigation system to build a pond providing a minimum of 3 m^3 of storage/cow and for high rate systems a minimum of 4.5 $m^3$of storage/cow. These requirements are imposed as conditions of resource consents to discharge farm dairy effluent. Other factors that should be considered include:

- the catchment area; some dairy sheds have additional concreted areas, e.g. races, feed pads, underpasses, silage bunkers etc;
- the length of time cows are on concrete. Additional effluent can be generated if cows are fed supplement at the dairy shed for example;
- the presence or absence of rainwater diversions for roof water and storm water on concrete;
- seepage from groundwater at underpasses or lower areas at the dairy shed, e.g. pit;
- the type of shed and water management at the shed;
- local variation in climatic conditions and the effect that unusually wet years can have on storage requirements and the volume of stormwater that runs off from the catchment are;
- the difference between storage capacity and total capacity. The storage capacity is the volume of water between the 500mm free board and the minimum depth before there can be no more effluent removed. Depending on design, there may be up to 800mm that cannot be pumped out and that does not count as storage.

Further information on pond size is contained in Chapter 3.5 of the *Managing Farm Dairy Effluent Manual 2006* (appended).

6. Site Investigation

A site investigation must be carried out to assess soil properties and groundwater levels at the site.

6.1 Soil Properties

The soils in Southland are formed from a range of parent materials, particularly sedimentary and metamorphic and generally deposited by wind or water. Subsequent site effects, especially soil chemistry gives rise to a significant range in soil types and physical properties.

When assessing a site for its suitability for pond construction and the availability of materials the following factors should be considered:

- what materials are available for bank construction?
- what materials are available for lining the inside of the pond?
- how does the soil texture vary down the profile and are there inherent potential problems due to layering of the materials present?
- is there likely to be a variation in the soil profile across the pond site?
- Is the base of the pond well above the maximum predicted level of groundwater?

At least one test hole should be excavated and more if the soil profile is likely to vary so that the soil profile can be inspected. Samples of the subsoil can be taken and their physical properties checked. The test hole should be deeper than the proposed pond floor level. Once the pond is constructed, in essence the whole pond becomes a further test hole and an inspection of all surfaces can then be made for textural changes.

Further information on soil tests can be found in Section 8.1.1 of this document.

6.2 Water Table Levels

The test hole is also necessary to assess the level of the water table along with seasonal fluctuations. These fluctuations can be significant and must be determined if the floor level of the pond is to be set at a safe height. Some sites may have a temporary perched water table in winter due to an impervious subsoil which overlies the main water table. Test holes in late winter will normally show where the highest water table is, but test holes at other times of the year will require more careful interpretation and a period of monitoring may be required to obtain reliable data. Local knowledge if available should also be considered. In addition, Environment Southland has information on groundwater levels throughout the region, which is available upon request.

Where there is a subsoil, there will usually be indications down the soil profile of fluctuations in the water table. For profiles without a subsoil, (i.e. gravels), the fluctuations in the water table maybe more difficult to establish. The accumulation of iron and manganese for example can show the range in water table height. They may also show historic high water table levels which are no longer relevant.

Much of Southland has been artificially drained with tiles and moles and the presence or otherwise of drainage may also influence water table height. Pond construction must also allow for the detection and removal or replacement of tile drains that may be present under or near the pond structure.

6.3 Pond Siting

It is appropriate to undertake an investigation of the positioning of the pond and to avoid or install design features to allow for proximity to sensitive features such as surface water bodies, artificial watercourses, installed subsurface drains, groundwater, bores, registered drinking-water supplies, the coastal marine area, trees, stop banks, residential dwellings, places of assembly, urban areas, property boundaries and sites of cultural significance.

While many of the above features can be affected by agricultural effluent ponds, features such as trees can cause effects on ponds as their root systems may encroach upon embankments and create the potential for leakage through old root tracks or cracks. Sites of cultural significance are unlikely to be identified prior to works commencing. However, if discovered while a pond is being constructed, works should cease and the site should be reported immediately.

The placement and orientation of ponds should also have regard to potential slope instability, inundation from flooding, diversion of flood flows and in-flows of stormwater. In areas subject to actual or potential inundation, the crest of the pond embankments should be at least 300mm above the highest known flood level. Environment Southland can provide advice on flood levels. In such areas, it is also preferable that long ponds be orientated along the floodplain rather than across it. Pond banks must be higher than surrounding land to prevent in-flows of stormwater and scarification of the pond liner.

Siting of ponds, including industry requirements, is discussed further in Chapter 3.4 of the *Managing Farm Dairy Effluent Manual 2006* (appended). Regulatory requirements, such as those imposed as resource consent conditions, must also be met.

7. Construction Considerations

Chapter 3.6 of the *Managing Farm Dairy Effluent Manual 2006* (refer appended) contains recommendations on the construction of agricultural effluent ponds. In addition, the following recommendations are made:

- pond banks are best formed by over constructing and trimming back later to the required dimensions. The finished top bank width should be twice the roller width. For safety, the bank should be made over dimension so that the roller does not need to work right to the outer edges of the bank since these will be trimmed back later. The bank top should also be slightly sloped back to prevent precipitation falling onto to the top flowing into the pond;

- fill surfaces and materials must be protected from becoming wetter than optimum. If materials become wet, continuing with compaction becomes counterproductive and the required soil densities will not be able to be achieved. Valuable time will be lost in waiting for excessive built up pore pressures, (as evidenced by surface heaving and rutting) to dissipate. The moisture content to achieve optimum compaction needs to be continually monitored during construction;

- it is good practice to seal off and slope surfaces away from the works at the end of the day or on the onset of rain. Wet material can be dried either by, mixing in drier material or rotary hoeing up the surface on a warm or windy day. Careful mixing in of small quantities of bentonite can also be beneficial with some materials;

- the construction reviewer needs to satisfy themselves that sufficient compaction to fill material has been applied. This may be determined by a combination of laboratory and field tests, or compaction trials, together with experience of the plant and materials being used.

8. The Liner Material

Liners can be formed from compacted clay or specially manufactured materials such as polyethylene, polypropylene, synthetic rubber or concrete.

It is imperative that the type of liner selected is appropriate to the intended purpose and that due diligence is observed during preparation, installation and subsequent use. No matter what type of lining material is used, defects from inappropriate installation or use are likely to result in fines, costs of remedial work, and wasted capital invested in a structure that fails to control environmental liabilities.

To prevent environmental contamination, a liner material must be able to achieve a leakage rate of 3.8×10^{-8} m/s or less. The leakage per square metre through a liner will depend on:

- the depth (head) of water above the pond floor;
- the thickness of the material used;
- the permeability of the material used.

The permeability of a material is usually expressed in terms of a parameter called the saturated hydraulic conductivity, K_{sat}. K_{sat} is the rate water will move through a square metre of material for a 1 m head and 1 m thickness of the material.

For example, for a 600 mm clay liner with 3 m of hydraulic head to achieve a leakage rate of less than 100 mm per month (3.8×10^{-8} m/s), the clay used would have to have a K_{sat} value of less than 7.6×10^{-9} m/sec. Assuming we applied a safety factor of 1.5, then a K_{sat} value of less than 5×10^{-9} m/sec would be required.

8.1 Clay Liners

In preparing clay liners, designers must consider soil properties, the method and timing of compaction, and machinery requirements. The overall design of the pond must also be such that the clay liner does not deteriorate over time, either from wave erosion or activities carried out during pond maintenance.

8.1.1 Soil Tests

In their natural state, the permeability of soils varies from being highly permeable to 1×10^{-11} m/s with the majority of subsoils being moderately permeable. As a minimum, the following soil tests are recommended in the preparation of clay liners:

- **Soil texture** – this is the single most important test to consider. To reliably achieve a hydraulic conductivity of 1×10^{-8} m/s or less, a minimum of 20% clay and 50% silt content is suggested. Textural analysis or particle size analysis (hydrometer test) can be used to determine the sand, silt and clay percentage contents.

- **Slaking** – the stability of the soil in water must be checked. Soils may meet the textural requirement to achieve satisfactory impermeability but may weather badly leading to excessive erosion and thus be unsuitable for use in a clay lining. In some cases, slaking may be managed by decreasing the batter slope, the degree of compaction achievable or by providing a protective layer of either more stable clay or rip-rap.

- **Dispersion** – soils where the clay colloids do not readily bind to each other when in suspension are dispersive. Some dispersiveness is required to help sealing, but excessive dispersion leads to leakage through tunneling. Most Southland soils are satisfactory for dispersion. When soils are checked for stability in water their dispersivity can be also observed.

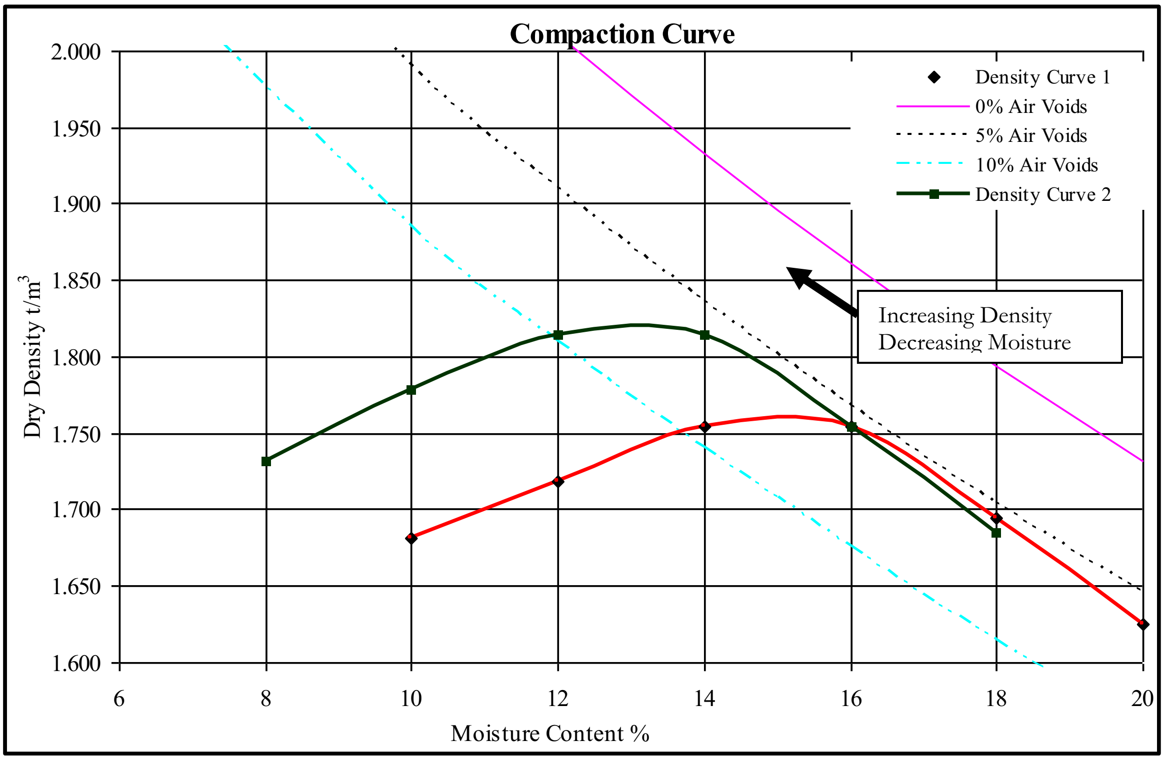
- **Shrinkage** – soils that shrink and swell excessively with drying and wetting can develop lines of weakness. Measuring linear shrinkage on a soil that has been finely worked into a fairly wet state and then allowed to air dry will indicate the potential for problems. Less than 10% shrinkage is considered low and is unlikely to be significant assuming satisfactory compaction has occurred at the appropriate moisture content.

- **Plastic Limit** – soils need to be just plastic when they are consolidated. The plastic limit is the moisture content at which soils go from being semi friable to a plastic state. As a guide if a finely worked soil with adequate clay content can be kneaded and rolled into a stable thread of approximately 3 mm in diameter and not crumble the moisture content is likely to be close to the plastic limit. Being able to roll a finer worm than this indicates excess moisture for optimum consolidation.

- **Optimum Soil Moisture Content** – to pack the soil particles as closely as possible to each other, the soil must be at the optimum moisture content. There has to be sufficient moisture for particles to move but not so much that the moisture occupies excessive pore spaces. Usually the optimum soil moisture content is close to the soils plastic limit.

8.1.2 Compaction

The relationship between moisture content, and density, for a given soil under a given level of compaction can be represented by the graph below. These graphs are not universal, they are unique to a particular soil (or mix of soils) under a given compaction effort.



Compaction curves shift up and to the left as the compaction effort increases, for example by an increase in roller size or number of passes. Note the effect of moisture on achievable density. If the material is too wet, then the maximum density cannot be achieved. For clays it is better to compact slightly dry of optimum as increased compactive effort can provide a higher density without water being trapped in pores. For sands and gravels it is better to compact at over optimum as excess water can provide particle lubrication while being able to drain away without pore pressure build up.

A dry density/moisture content curve can be produced by a laboratory by wetting up samples at different moisture contents at standard compaction. These samples can also be tested with a shear vane and so provide a comparative means to check soil strength and moisture content in the field.

The design process should confirm and specify the minimum construction requirements such as the number and depth of soil layers, the target percentage of maximum density and the moisture content required to achieve the necessary soil compaction.

8.1.3 Machinery Requirements

Construction machinery needs adequate room to work and this should be considered in site selection. Compaction equipment should be matched to the materials to be compacted as follows:

- **Steel Wheeled Rollers** – are suitable on non-cohesive materials such as gravels, but not silts and clays. Vibratory rollers are particularly effective in compacting layers of evenly graded gravels.

- **Sheepsfoot Rollers** – protruding studs on the roller drum provide a kneading action. For compaction of plastic soils like clay or silt they are very effective. On granular materials, sheepsfoot rollers tend to shove rather than compact soils.

- **Tamping (or Pad) Foot Rollers** – protruding plates on the roller combines the advantages of both the steel wheeled and sheepsfoot rollers. Like the sheepsfoot roller, it compacts from the bottom to the top of the lift for uniform density, and like the steel wheel it compacts from the top of the lift. The tamping foot roller is capable of high rolling speeds without throwing material.

8.2 Artificial Liners

A variety of manufactured materials are suitable for use as pond liners including geomembranes, geosynthetic clay liners and concrete. For good results, the liner must be fit for the intended application and able to resist any hydraulic head that exists at the base of the pond. Factors that should be considered include:

- The thickness and lifespan of the liner including its resistance to ultraviolet light and punctures. Environment Southland strongly suggests that a geotextile underliner be installed under the lining membrane to increase puncture resistance.
- Appropriate substrate selection. This should provide contiguous and uniform support for the lining membrane.

The installation of artificial liners is a specialist area and should be undertaken by a suitably qualified person experienced in the installation and use of the type of liner concerned.

Further, the use of the pond, including any maintenance activities, must be such that the integrity of the pond liner is maintained for its intended design life.

One advantage of using artificial liner materials is that many manufacturers provide service support and/or require that their products are installed to minimum standards of site preparation, and capabilities or workmanship of the installer.

An appropriately installed and fit for purpose artificial liner may also be cheaper than a clay liner in some situations, particularly where there is a need to transport clay to the site of the pond.

9. Liability

The construction of an agricultural effluent pond system is a major project that will require significant expenditure. Competent planning design and construction is essential if the work is to represent value for money, is effective, efficient and safe and does not compromise the landowner's responsibilities under the Resource Management Act 1991.

The role of Environment Southland is regulatory and it cannot become involved in the details of construction or contractual matters relating to particular ponds. However, Environment Southland does strongly suggest that many of the potential difficulties with pond construction and commissioning can be avoided if detailed consideration is given to the following points:

- The siting, design and construction of the pond must comply with Rule 49 of the Proposed Regional Water Plan for Southland and the conditions of the resource consent granted pursuant to that rule.

- The pond needs to be properly designed by a designer who has experience in the design and oversight of the construction of this type of pond in Southland.

- The construction of a pond is a job that calls for its undertaking by an experienced contractor with adequate heavy equipment.

- The preparation of proper contractual documents including specifications which are signed by all parties before the work commences is essential. There are a number of suitable standard form construction contracts available. One example is NZS 3910.

Environment Southland will, through Rule 49 and the conditions of the resource consent, require that the pond be designed and the construction supervised by a suitably qualified person. However, Environment Southland is limited as to how far it can be involved. Landowners, designers and contractors are urged to have particular regard to the above matters.

10. Certification

A qualified person must be used to design and supervise the construction of an agricultural effluent pond. That person shall, as a requirement of the resource consent, certify in writing to Environment Southland that the design and construction of the pond has been in accordance with Rule 49 of the Proposed Regional Water Plan for Southland, the resource consent, this Code of Practice or equivalent, and the prepared plans and specifications. For the purposes of the certification, a suitably qualified person shall be a person with an agricultural or civil engineering qualification, experienced with soils and earthworks.

11. Design and Construction Checklist

Pond Volume

- Per cow requirement
- Number of days storage required
- Additional volume requirement
- Freeboard and minimum pumping depth
- Pond dimensions calculated and batter requirement assessed

Pond Site

- Complies with provisions of Rule 49
- GPS coordinates of edges of pond structure
- Space available
- Access for construction and maintenance
- Freeboard requirement for site

Test Hole(s) Dug

- Water table height recorded and water table fluctuations recorded, with report
- Soil samples taken for analysis, with report on suitability of clay for use as a liner (if applicable)
- Soils classified and profile changes recorded

Design

- Complies with the provisions of Rule 49
- Bank protection for inflows, and wavelap
- Batter slope and storage volume appropriate for subsequent use
- Protection and design of sludge beds
- Lining material designed to resist hydraulic head, prevent leakage and persist for a specified period
- Necessary measures taken to protect lining material from erosion, puncturing or mechanical damage during installation or subsequent use
- Farmer reminded to fence the site

Construction

- Type of construction machinery to be used noted or specified
- Schedule of construction process provided
- Clay with properties and thickness. Clay compacted to maximum dry density (if using clay)
- Lining material installed by a person with the capability to install the particular type of material (if using an artificial liner)

Monitoring

- Monitoring devices installed as appropriate
- Proposed monitoring requirements prepared

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

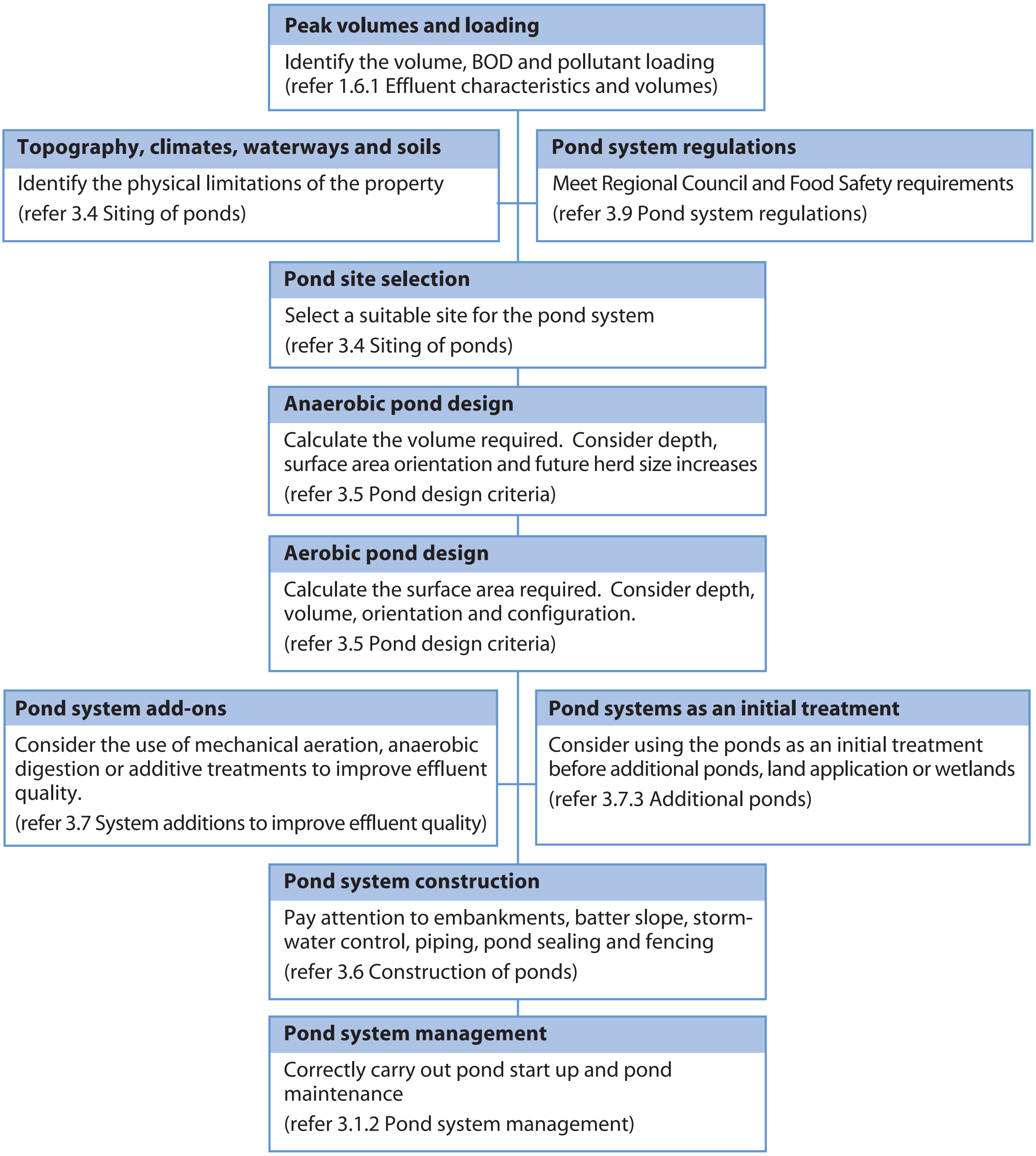
Effluent from the farm dairy is high in volume (or bulk) with significant organic matter and nutrient content. These characteristics lead to large handling, storage and treatment costs. The first challenge is to reduce the volume of effluent requiring pond system treatment (refer to 1.6.8 Reducing effluent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

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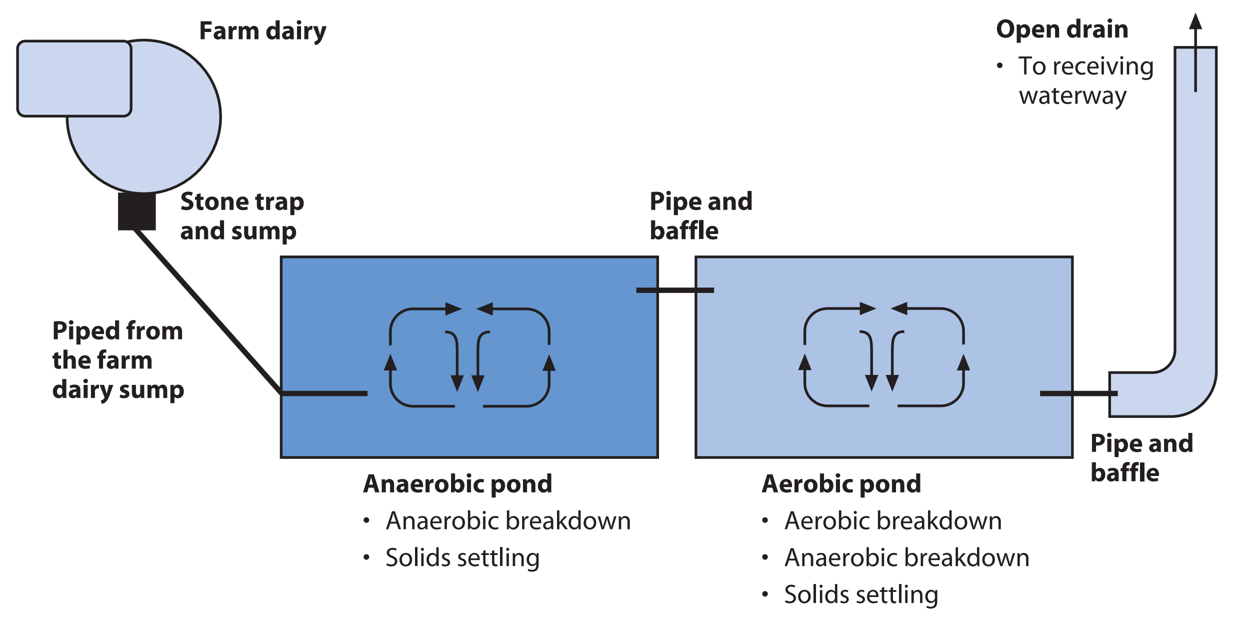
3.2 HOW POND TREATMENT SYSTEMS WORK

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.

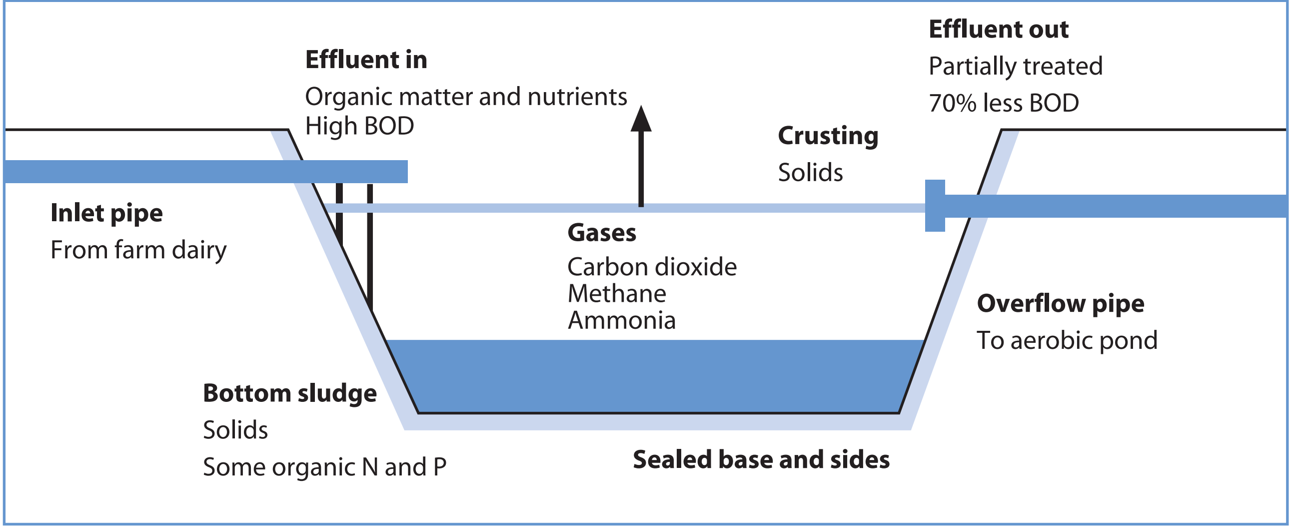
3.2.2 The anaerobic pond

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.

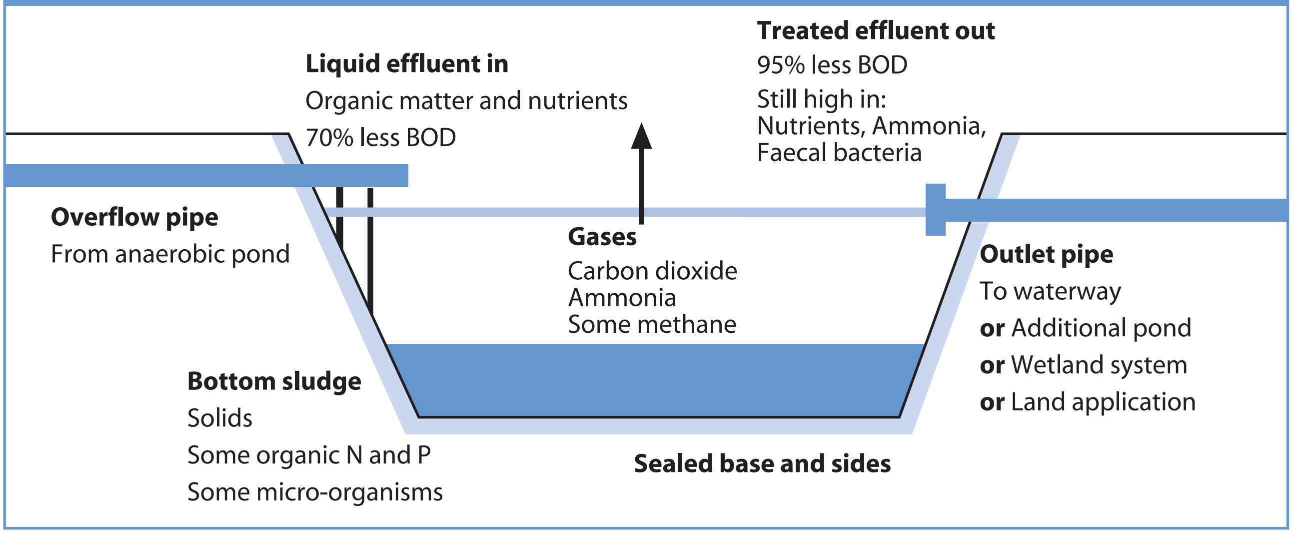
The second pond in the pond system is usually termed **'aerobic'.** However, it is more accurately termed **'facultative',** as oxygen levels cannot be maintained to the total depth of the pond, which in practice has an aerobic upper layer and an anaerobic lower layer.

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

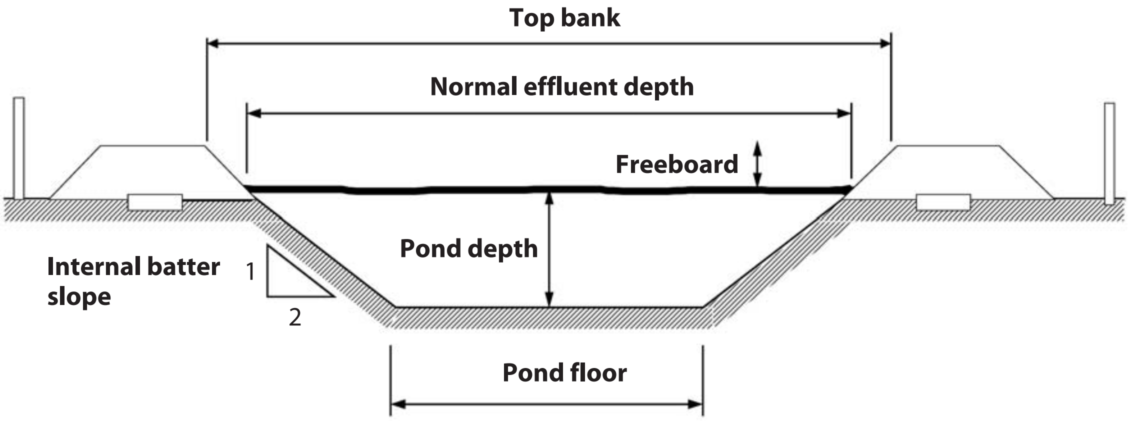
It is far more accurate to use design values, particularly effluent volumes, based on figures from individual properties than those based on general assumptions (refer to 1.5 Keeping property records and 1.6.1 Effluent characteristics and volumes). When calculating the volume of effluent flowing from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

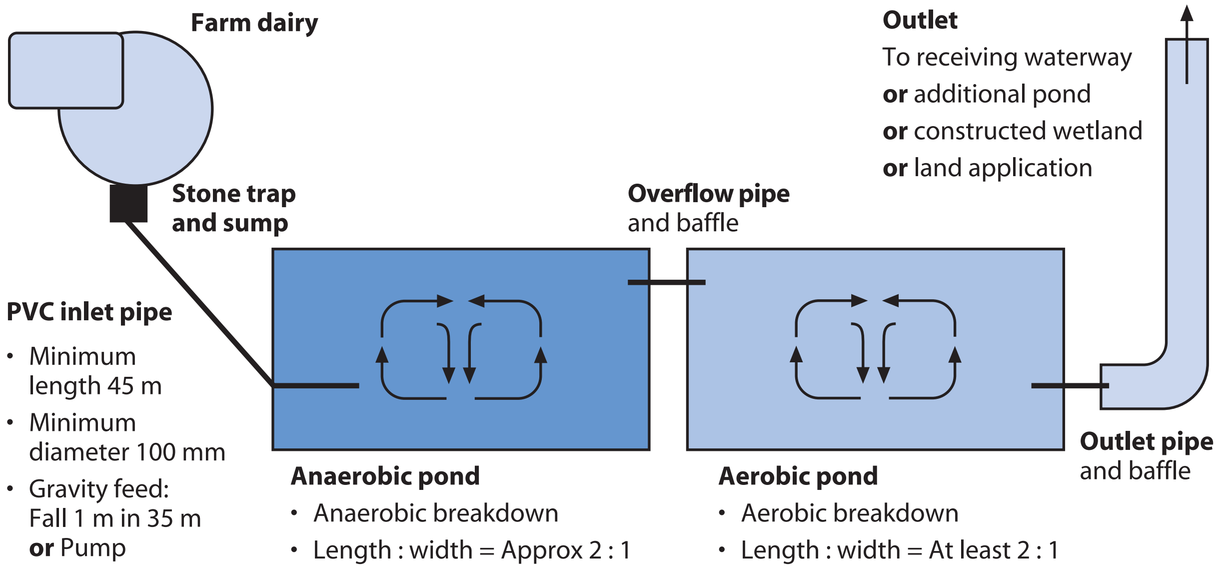
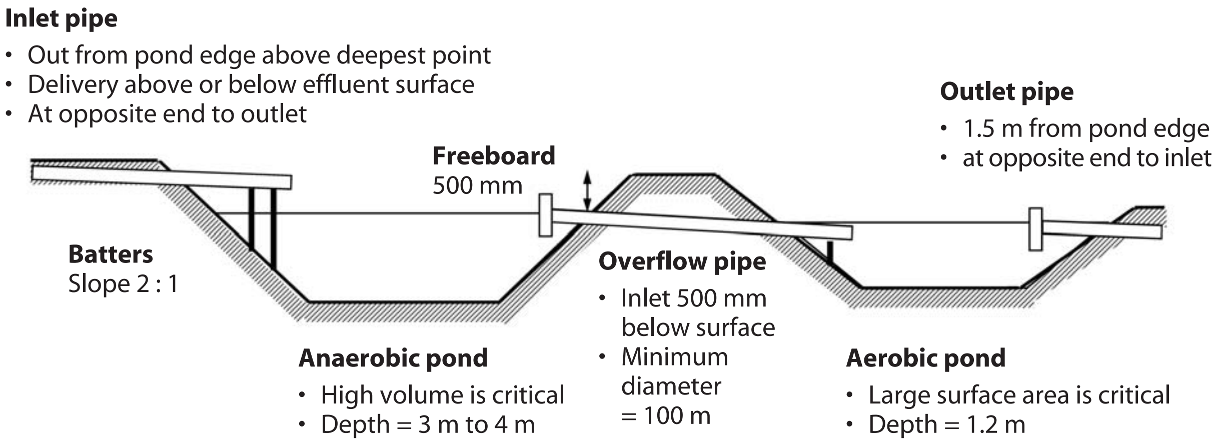


FIGURE 3.5-3

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/m^3/day
Manawatu, Wanganui, Taranaki, Wellington, Marlborough, Tasman, Nelson and Canterbury	0.024 kg/m^3/day
West Coast, Otago and Southland	0.020 kg/m^3/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

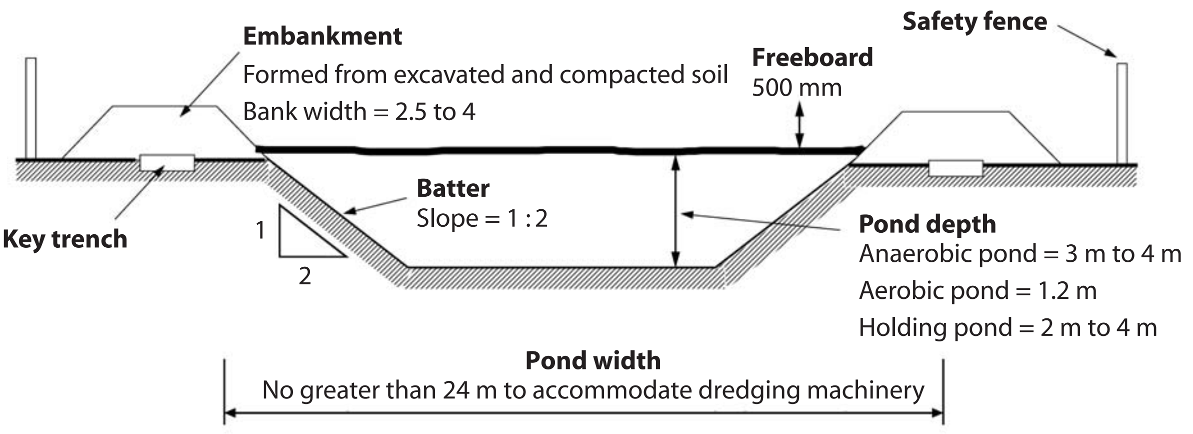


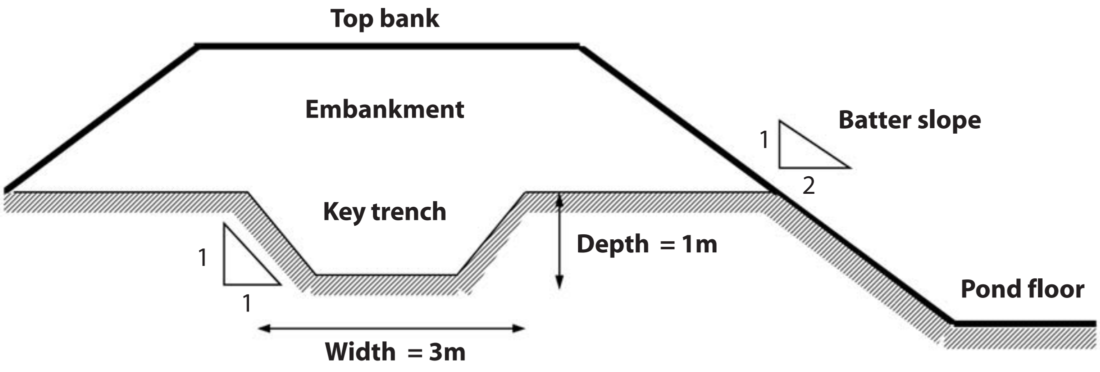
Figure 3.6-1 gives the major design specifications discussed in the following sections.

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

First pond
Crusting and solids

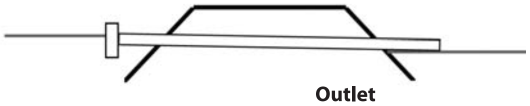
Second pond
Liquid effluent

(A) Reverse slope overflow pipe

Inlet
- 300 mm below pond surface

Outlet
- 250 mm above inlet

(B) Overflow pipe with T-piece inlet



Inlet
- T-piece
- Inlet 300 mm below surface

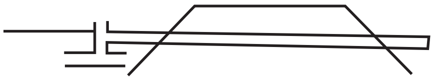
Outlet
- Vertically below inlet
- Pipe grade 1 m in 35 m

(C) Overflow pipe with timber baffle inlet

Inlet
- Post and timber baffle
- Inlet 300 mm below surface

Outlet
- Vertically below inlet
- Pipe grade 1 m in 35 m

(D) Double T



Inlet
- Double T piece
- Inlet 300 mm below surface

Outlet
- Vertically below inlet
- Pipe grade 1 m in 35 m

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.

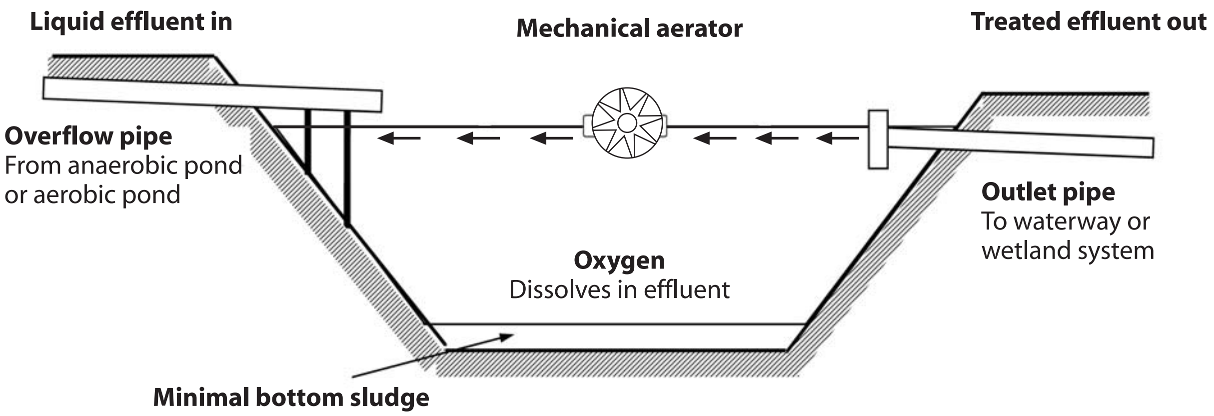
Floating pumps can be used to pump air into the effluent or, alternatively, air can be pumped through perforated pipes lying across the bottom of the pond. Venturi aerators are also available. These work by forcing a flow of effluent through a narrow nozzle. This results in a pressure drop in the pipe, 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

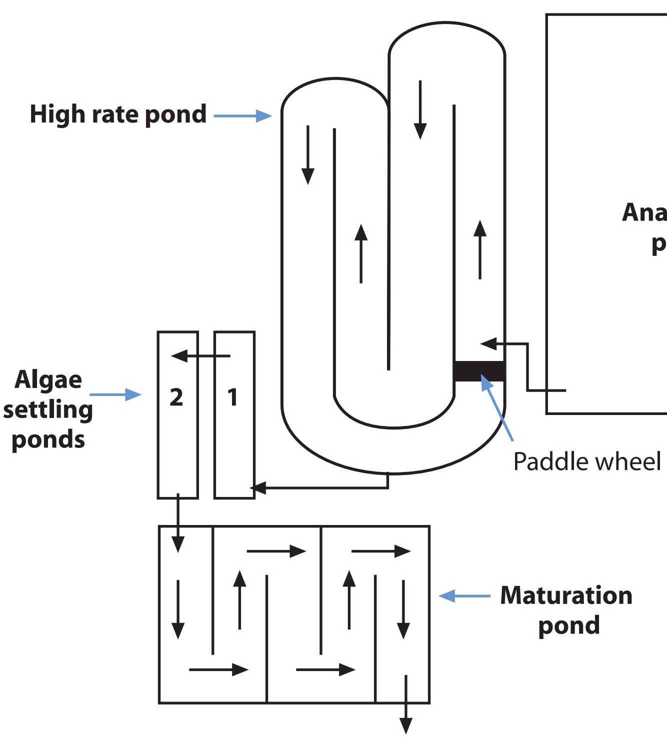
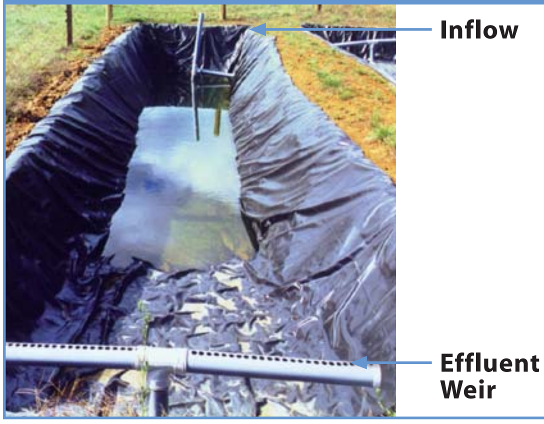


FIGURE 3.7-3

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.

3.8 POND SYSTEM MAINTENANCE

3.8.1 Desludging

Research has shown that management of sludge levels in the anaerobic pond is a key factor affecting aerobic pond performance.

If an analysis has been taken of the pond outflow and the quality is termed poor, this may indicate that the pond requires desludging. However, farmers should not wait until such a situation exists before desludging a pond.

Effluent flow will be reduced in ponds that are not regularly desludged. The outlet baffle (i.e. subsurface pipe, T-piece or timber baffle) may clog up and fall into disrepair due to sludge build-up or excessive crusting.

3.8.1.1 When to desludge

Regional Councils have different rules and consent conditions regarding desludging. It is recommended that as a minimum, **anaerobic ponds should be desludged at least once every four years but best practice is to desludge every two years or even annually.**

Desludging is less of a concern to Regional Councils if the pond is used for storage before land application, rather than discharging to a waterway.

Undersized ponds, those in colder climates and those that discharge into sensitive environments need more frequent desludging. In-flows to ponds will also influence the need for desludging e.g. if a stand-off area or feed pad is connected to the effluent system.

A useful indicator of when individual ponds may need desludging is when the sludge level is over half the normal effluent depth. This can be checked by probing with a long pole.

The aerobic pond will need desludging less frequently, depending on the rate of sediment build up. However, it may be more convenient to desludge all ponds in the system at the same time.

The consumption of poorer quality pasture by the herd (e.g. pastures high in kikuyu, paspalum and fescue) may result in excessive crusting and require more frequent desludging.

If operating barrier ditches the system, especially the first ditch sections, will need regular desludging. If they are not desludged regularly, the system will become inefficient and ineffective at treating the effluent. Effluent flow will be reduced and the outlet baffles may clog up and fall into disrepair due to sludge build-up or excessive crusting. **As a general rule, barrier ditches should be desludged annually.**

3.8.1.2 Methods of desludging

Sludge and crusts are usually removed with excavation machinery. Alternatively, a drag line can be used. Contractors in most regions have appropriate equipment and experience in desludging ponds.

If possible, **the surface liquid effluent should be removed before desludging** by suction drawing it into a vehicle spreader (refer to 2.10 Vehicle spreading).

Removal of the liquid effluent makes the sludge easier for excavators to contain and handle. The liquid can be pumped out using a vehicle spreader, where a tanker is backed close to the pond and effluent is drawn into it by a PTO-driven pump.

Pond stirring, to mix the various layers of the pond during tanker filling, can remove the need for excavators to desludge ponds (refer to Figure 3.8-1).

Effluent from the aerobic pond can also be pumped into the first pond to make it easier to dilute and remove effluent solids prior to land application.

FIGURE 3.8-1

SIMULTANEOUS POND STIRRING AND TANKER FILLING

Ponds should never be emptied out completely. A third of the sludge should be left behind as it will contain bacterial populations necessary for the continuation of anaerobic processes.

3.8.1.3 Applying pond sludge to land

Considerations when applying pond sludge to land include:

- **regional council regulations** regarding land application of effluent, and in particular the higher concentration of nutrients in sludge
- **buffer distances** from waterways and public areas
- **correct application rates** and **area requirements**
- **suitable weather and ground conditions.**

For information on the application of pond sludge to land refer to 2. Land application and 2.8 Land application of sludge.

3.8.1.4 Chemical and biological treatments

Several kinds of additives are available and are claimed to dissolve and disperse solids build-up, particularly crusting. These additives vary in their effectiveness. Current evidence shows that they are not a long-term solution to reducing sludge and crusting problems.

3.8.2 Weed control

Crusts on ponds may begin to support vegetative growth (refer to Figure 3.8-2). This can give the appearance of solid ground, creating a potential safety hazard for people and stock. Furthermore, the roots of weeds will entangle pond stirrers and interfere with desludging machinery. **Do not let weeds build up on the crust layer of ponds.**

However, **maximise weed growth in receiving drains.** The weeds will act as a filter, taking up effluent nutrients and sifting out suspended solids. Clean out only a third of the receiving drains at a time so that there is always weed present to assist with effluent filtering.

Do not spray the drains.

FIGURE 3.8-2

UNACCEPTABLE WEED GROWTH ON PONDS

3.8.3 Daily

- Before and after every milking, **check that the stormwater or washwater diversion is in the correct position.**

3.8.4 Regularly

- **Clean and clear the effluent stone trap and gratings.**
- **Check that the pipes running in and out of the ponds are not blocked.**
- **Check the effect of the discharge on the receiving waterway.**
- **Check that the pond walls are stable, and that there is no seepage.** Visible wetness or pasture that is growing exceptionally well are indicators of seepage problems.
- **Control weed growth in and around ponds** by spraying with a herbicide.
- **Check that the fencing remains stock-proof.**

3.8.5 Six monthly to annually

- **When the area around the ponds is dry, graze them.**
- **Clean out only a third of the receiving drains at a time** so that there is always weed present to assist with effluent filtering.
- **Check that there is not excessive build-up of solids in the anaerobic pond.**
- **Desludge ponds regularly, preferably annually or every two years but at least once every four years.** Dispose of sludge on to land according to recommendations in 3.8.1.3 Applying pond sludge to land.
- **Check that the pond is not becoming shaded by vegetation** as this will decrease treatment efficiency.

3.9 POND SYSTEM REGULATIONS

Pond systems are designed and constructed relative to the volume and quality of farm dairy effluent they are expected to handle, and the region in New Zealand in which they are sited. However, **Regional Councils** (and District Councils) and the **NZ Food Safety Authority in conjunction with the Dairy Industry** also have regulations governing the design of pond systems.

3.9.1 Food safety and dairy industry requirements

The health and hygiene practices on the farm, and within the farm dairy, are closely monitored by overseas markets and have a considerable effect on the saleability of New Zealand's dairy products. Hence, the Dairy Industry has worked with the NZ Food Safety Authority to put hygiene regulations in place that must be followed to help promote the industry to overseas consumers.

These regulations are focused on **human and animal health** as effluent may contain transmissible animal diseases, including bacteria, viruses, cysts, and eggs and larvae of parasites (e.g. hookworm, roundworm and tapeworm).

Disease-causing micro-organisms present in effluent originate mainly from stock and so **the levels of disease-causing microorganisms reflect the current state of health of the herd.** Therefore, with good husbandry practices, effluent originating from dairy cows should be free of major diseases.

If effluent is retained within the pond system for long enough pathogenic micro-organisms will be destroyed.

The survival of various disease-causing micro-organisms during effluent storage and treatment is summarised in 2.13.1 Food safety and dairy industry requirements.

3.9.1.1 Food safety, dairy industry and health regulations

Food Safety regulations for the dairy industry (i.e. the Farm Dairy Code of Practice NZCP1) require that **storage sumps** (where the effluent is **not** immediately pumped or gravity fed into ponds) **must not be located within 10 m of the milking area, milk receiving area or milk storage area. Sumps greater than 22500 L must not be within 45 m of the above areas.**

Effluent **may not be disposed of within 45 m of the farm dairy** (i.e. milking area, milk receiving area and milk storage area). This includes pond systems, barrier ditches, constructed wetlands and places where effluent is applied to land.

Occupational Safety and Health regulations require stock to be vaccinated against harmful animal and human diseases (e.g. leptospirosis).

Care should be taken with personal hygiene after handling effluent in any form, and when working with treated soil.

3.9.2 Regional Council requirements

Regional Council concern is primarily focused on:

- **siting, design and construction of pond and barrier ditch systems**
- the quality and quantity of the discharge
- environmental **effects that the discharged effluent may have on waterways.**

3.9.2.1 Pond siting, design, construction and operation

In light of the Resource Management Act (1991), Regional Councils have policies and rules in their Regional Plans that describe what **effluent and receiving water quality standards must be met, rather than outlining the physical design of the system itself.**

Regional Councils may also insert conditions in resource consents regarding the design of pond systems. The following is a list of those components of the system that must be taken into account in design to avoid or minimise adverse effects. Some of these aspects may also be standards for design and specified in Council rules or resource consents.

- **Stormwater control.** Stormwater originating from the farm dairy roof or yards, or from runoff from the land surrounding the pond system, will add loading and flush the pond system. This has the effect of decreasing effluent retention time and, subsequently, treatment time, effluent quality and efficiency.
- **Solid waste entry prevention.** Offal, pesticides, fertiliser and rubbish can block the treatment system as well as reduce the system's ability to treat the effluent.
- **Receiving water restrictions.** Certain surface waterways are too sensitive to receive treated effluent at any time (e.g. fresh water lakes and natural wetlands). The concentration of ammonia in receiving waters may be measured, following reasonable mixing, to determine the potential for waterway pollution.
- **Siting.** Buffer distances between ponds and surface waterways and groundwater are necessary so that the risk of contaminating water is minimised. Locations such as swampy ground and sloping ground may be subject to instability and stormwater or groundwater intrusion into the system.
- **Pond sizing.** The size of both the anaerobic pond and the aerobic pond is usually based on the BOD loading from maximum herd numbers. The depth of the ponds is important as system efficiency is largely determined by the pond depth.
- **Freeboard.** The minimum freeboard is given as insurance against flash loading and to reduce the erosion effects of wave motion.
- **Embankment construction.** The slope of batters, presence of key trenches, and the methodology in laying and compacting soil all affect the stability of the pond structure and its ability to withstand erosion and seepage.
- **Sealing.** Ponds need to be sealed so that no effluent seeps to groundwater, or through the embankment to surface water. Most Councils specify that ponds must be impermeable.
- **Inlet and outlet structures.** The design and position of the inlets and outlets can determine the efficiency of the system. Incorrect installation may result in seepage, embankment erosion, short-circuiting of the ponds and system blockages.
- **Fencing.** Fences are essential for the protection of stock and farm labour, and the protection of embankments from animal damage.
- **Desludging.** Over-accumulation of sludge or crusting decreases the treatment efficiency of effluent and increases the risk of solids passing into the system. However, the complete removal of the sludge layer can halt the operation of the pond system because of the absence of beneficial anaerobic bacteria populations living in the sludge.
- **Weed control.** Weed growth adversely affects the operation of the pond system as well as causing a physical nuisance with pipe blockages.
- **Shading.** The ponds (most importantly the second and any subsequent ponds) should not be shaded by trees or structures that can reduce the treatment of the effluent.

3.9.2.2 Measurable effects of effluent discharged into waterways

Regional Councils are responsible for the monitoring and upkeep of water quality standards. Table 3.9-1 shows a list of those factors which may be measured and used as standards for discharges to waterways and some typical critical levels for water quality (refer to 1.4 Why control the discharge of effluent? and 5.2 Resource management act (1991)).

TABLE 3.9-1

FACTORS IN MEASURING WATER QUALITY

Clarity (Hue/Horizontal Visibility)	**Significance:** clarity is important for the enjoyment of swimming, fishing, and passive recreation, and for the wellbeing of many aquatic ecosystems **Measurement:** either the concentration of suspended solids (i.e. SS), measured in grams per cubic metre of water, or as turbidity where light is scattered by undissolved particles, measured in Nephelometric Turbidity Units (i.e. NTU), or the depth at which a black disk becomes invisible, measured in metres **Indicator Concentration:** contact and passive recreation: SS = 4 g/m^3, Turbidity = 2 NTU, Black disk = 1.6 m.
Dissolved oxygen levels	**Significance:** declining dissolved oxygen levels damage aquatic ecosystems **Measurement:** dissolved oxygen measured as the percentage of saturation concentration or as grams per cubic metre of water **Indicator Concentration:** aquatic ecosystems: 80% saturation or 5 to 6 g/m^3. Water supply: 5 g/m^3
Organic matter content	**Significance:** high organic matter is associated with the growth of fungi and with fish respiratory distress and death **Measurement:** biochemical oxygen demand, measured as the amount of oxygen consumed by organisms as they degrade the organic matter, at 20°C, over 5 days (i.e. BOD_5) **Indicator Concentration:** contact and passive recreation: BOD_5 = 3 to 5 g/m^3
Acidity levels	**Significance:** extremes of acidity (i.e. high acidity or alkalinity) and rapid changes in acidity are damaging to aquatic ecosystems and are undesirable for public water supplies **Measurement:** measured as pH **Indicator Concentration:** human consumption: pH = 7.4 to 8.5. Aquatic ecosystems. pH = 6.0 to 9.0
Dissolved nutrient status	**Significance:** high levels of reactive phosphate and inorganic nitrogen are associated with water weed proliferation and algal blooms. High levels of nitrate are implicated with a form of cyanosis or poisoning in bottle-fed infants during the first six months of life (known as 'blue baby syndrome'). High levels of ammonia-N are toxic to aquatic fauna **Measurement:** levels of Dissolved Reactive Phosphate (i.e. DRP), and levels of Dissolved Inorganic Nitrogen (i.e. DIN), and levels of nitrate nitrogen, and levels of ammonia-N. All measured in grams per cubic metre of water **Indicator Concentration:** contact and passive recreation: DRP = 0.01 g/m^3, DIN = 0.10 g/m^3. Human consumption: Nitrate-N = 10 g/m^3. Stock water: Nitrate-N = 30 g/m^3. Aquatic ecosystems: Ammonia-N = varies with temperature and pH. Can be toxic at < 1 g/m^3 with high pH
Pathogenic micro-organism levels	**Significance:** pathogenic micro-organisms occur in water primarily as a result of faecal contamination, and are a public and stock health risk **Measurement:** the number of faecal coliforms or the number of enterococci or the number of E. coli, per 100 ml of water **Indicator Concentration:** contact recreation: 200 faecal coliforms or 33 enterococci or 126 E. coli per 100 ml. Stock water: 1000 faecal coliforms per 100 ml with no more than 20% over 5000 per 100 ml. Human consumption: Nil faecal coliforms per 100 ml. Irrigation: 1000 faecal coliforms per 100 ml

Ministry of Health, 1995; Department of Health, 1984; Department of Health, 1992; Ministry of Agriculture and Fisheries, 1993; Parminter, 1995.

3.9.2.3 Regional Council regulations regarding effluent discharge to surface water

Each Regional Council has different rules for the discharge of effluent to surface water. Regional Councils may also have different rules between catchments within the same region (check with the Regional Council for the relevant rules). Table 3.9-2 outlines how the activity is classified in each region. A permitted activity has certain conditions that must be met but does not require a resource consent, whereas a controlled, discretionary, restricted discretionary or non-complying activity all require a consent before the activity can commence. A prohibited activity means that it will not be possible to get a consent for the discharge of effluent to surface water. For more information on the different classifications of activities refer to section 5.3.1 What is a regional plan? If the conditions of the activity cannot be met then the classification is likely to be more restrictive. For example if the conditions of a controlled activity rule cannot be met then it is likely to be classified as a discretionary or non-complying activity.

Table 3.9-2 is a summary and should not be used for legal purposes. To obtain the information in full, request the **Regional Plan(s)** pertaining to soils, water and air quality from the Regional Council. The classifications of these activities are current (January, 2006) and may be subject to change by the Regional Councils.

TABLE 3.9-2

ACTIVITY CLASSIFICATIONS FOR THE DISCHARGE OF FARM DAIRY EFFLUENT TO SURFACE WATER

Regional Council or Unitary Authority	Type of activity
Northland Regional Council	Discretionary
Auckland Regional Council	Controlled
Environment Waikato	Discretionary
Environment BOP	Discretionary
Gisborne District Council	Non-complying
Hawke's Bay Regional Council	Discretionary
Taranaki Regional Council	Controlled
Horizons	Discretionary
Greater Wellington	Discretionary
Marlborough District Council	Discretionary
Nelson City Council	Discretionary
Tasman District Council	Unrestricted discretionary
Canterbury Regional Council	Prohibited
West Coast Regional Council	Discretionary
Otago Regional Council	Discretionary
Environment Southland	For up to 50 cows - Permitted For up to 51 - 600 cows - Controlled For 601+ cows - Discretionary

3.10 CONSTRUCTED WETLANDS

Wetlands are areas which support the growth of a variety of plant species adapted to flooded conditions for part of, or the entire, year. The plants are densely spaced and, together with the shallow water, provide good wildlife habitat as well as water purification.

Constructed wetland systems are designed to simulate and optimise the filtering and organic matter breakdown processes that occur in natural wetlands. **They are a possible solution to improve the performance of pond systems, as they can 'polish' farm dairy effluent before discharge to a waterway.**

During summer months, such a system may even result in zero discharge to waterways, due to evapotranspiration of water from the wetland.

Constructed wetlands are designed to ensure greater reliability, a low risk of environmental impact and increased control over the treatment process. The advantages of constructed wetlands are that they:

- **have the ability to treat a wide range of contaminants**
- **have the ability to handle shock loadings of effluent**
- **do not normally rely on electricity or machinery**
- **have aesthetic value and provide wildlife habitat**
- **are more acceptable to Maori than direct discharge to surface waterways**
- **require minimal ongoing capital expenditure and maintenance once established**
- **operate successfully over a wide range of climate regimes** (as long as cold temperatures do not affect the functioning of the pre-treatment ponds).

Constructed wetlands are not 'stand alone' treatment systems. They are designed to polish effluent flowing from a pond system before it reaches a surface waterway.

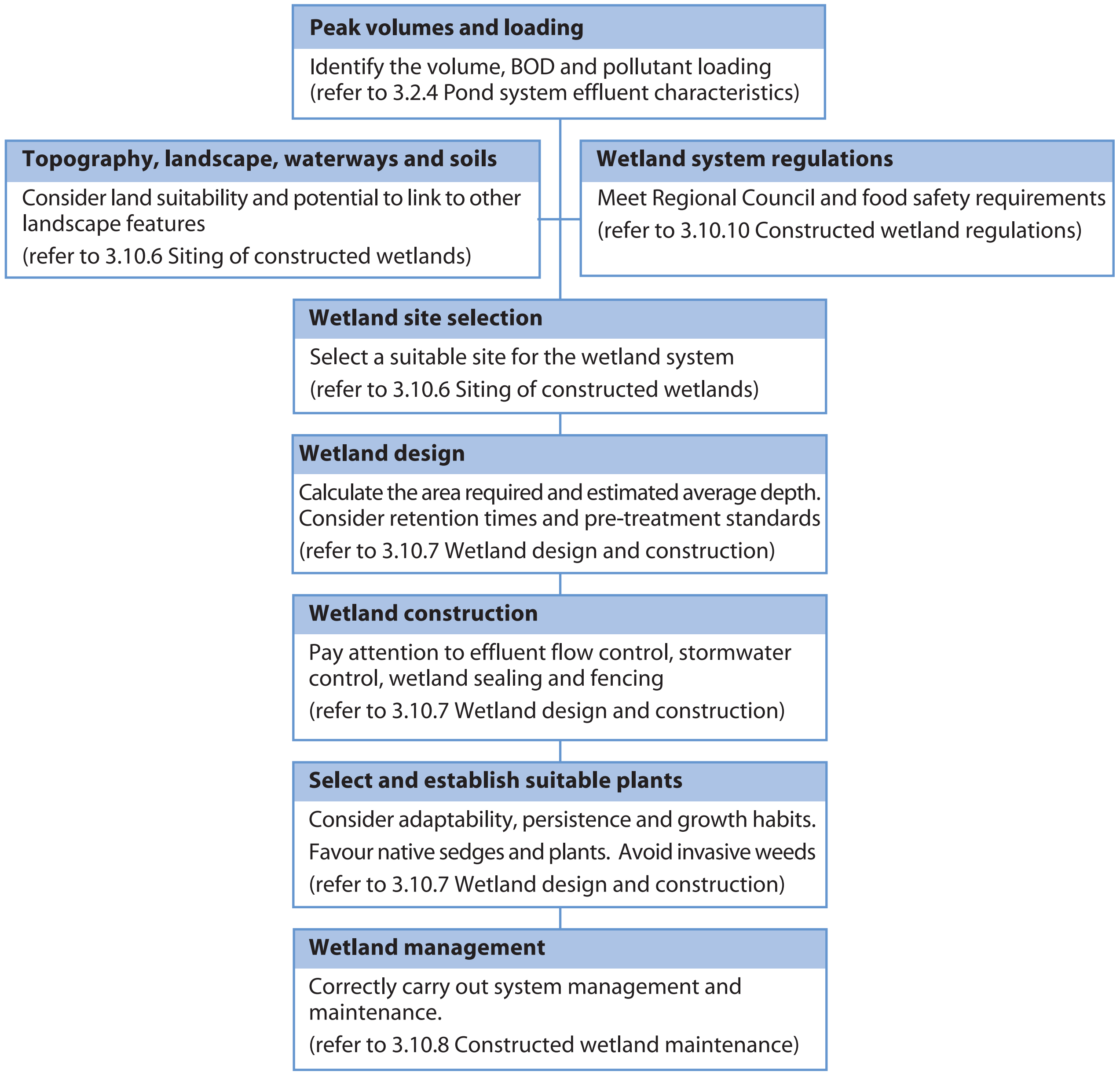
For constructed wetlands to operate successfully the pond system must be working to expectations and effluent flowing from the pond system must be treated to a high standard.

3.10.1 Planning for a constructed wetland system

Figure 3.10-1 gives the steps to follow when considering installing a constructed wetland as an additional treatment system.

FIGURE 3.10-1

PROCEDURE FOR PLANNING A CONSTRUCTED WETLAND SYSTEM



Peak volumes and loading

Identify the volume, BOD and pollutant loading (refer to 3.2.4 Pond system effluent characteristics)

Topography, landscape, waterways and soils

Consider land suitability and potential to link to other landscape features

(refer to 3.10.6 Siting of constructed wetlands)

Wetland system regulations

Meet Regional Council and food safety requirements

(refer to 3.10.10 Constructed wetland regulations)

Wetland site selection

Select a suitable site for the wetland system

(refer to 3.10.6 Siting of constructed wetlands)

Wetland design

Calculate the area required and estimated average depth. Consider retention times and pre-treatment standards

(refer to 3.10.7 Wetland design and construction)

Wetland construction

Pay attention to effluent flow control, stormwater control, wetland sealing and fencing

(refer to 3.10.7 Wetland design and construction)

Select and establish suitable plants

Consider adaptability, persistence and growth habits.

Favour native sedges and plants. Avoid invasive weeds

(refer to 3.10.7 Wetland design and construction)

Wetland management

Correctly carry out system management and maintenance.

(refer to 3.10.8 Constructed wetland maintenance)

3.10.2 Constructed wetland management

To ensure the best treatment of effluent, **both the initial pond treatment system and the constructed wetland should be designed, constructed and planted correctly from the beginning.** Constructed wetlands should not be considered as a 'patch up' system for ponds or barrier ditches that are not working properly. Wetlands are designed to function effectively only if used together with an initial treatment system that is operating adequately.

Establishing and maintaining constructed wetland plants is the critical and most difficult challenge. To achieve ongoing plant growth, the constructed wetland must be maintained regularly and properly from the time of installation.

Control of effluent levels within the wetland is also important during plant establishment. **After planting keep effluent levels to a minimum (i.e. 50 mm to 100 mm) then gradually raise them as the plants develop** (refer to Figure 3.10-2 and Figure 3.10-3).

FIGURE 3.10-2

PLANT ESTABLISHMENT

FIGURE 3.10-3

PLANT DEVELOPMENT

Waterfowl (e.g. pukeko and canada geese) can pull out and destroy young plants. Electric fencing or other deterrents may be required during the establishment phase if these birds are present.

If contractors are involved in establishing the wetland plants, make it their contractual responsibility to have a set percentage of successful and active growth by a certain time.

Maintenance involves monitoring, controlling pests and weeds, managing the plant species and repairing and maintaining pipes and embankments.

3.10.3 Costs of a constructed wetland

A basic cost for installing a 400 m^2 constructed wetland (surface flow) suitable for basic treatment of oxidation pond effluent from 200 cows will be around \$12 000 - \$15 000 including earthworks, a clay liner, inlet and outlet structures, gravel and plants. Additional establishment costs (site survey, design and resource consent processes) may be up to \$2500. Other costs depend on:

- **the site.** Obstacles such as rocks, the soil type and accessibility largely influence the time and effort required to excavate soil and seal the wetland base
- **whether any pumping facilities to and from the wetland are required**
- **the need for artificial liners.**

The expense is governed by the complexity of the system.

3.10.4 Constructed wetlands as an economic and practical option

The financial costs associated with capital outlay, ongoing maintenance and labour requirements for a constructed wetland are moderate. Furthermore, effluent discharged to waterways from an effective wetland is of a higher quality. Together, this makes incorporating a wetland into the existing/planned pond system an attractive option, especially if habitat and aesthetic improvements are valued.

For both existing and planned pond systems a constructed wetland can be introduced in an effort to obtain both the economic advantages of employing a pond system, and effluent quality standards that will satisfy Regional Councils and be of benefit to the environment.

3.10.5 How constructed wetlands work

Wetland processes treat waste in a number of ways:

- **solid particles settle out in shallow, slow-flowing waters with dense vegetation.** Algae production is also inhibited due to shading of the wetland plants. This is advantageous as algae growing within the effluent add to its BOD
- **pathogenic micro-organisms are reduced through enhanced sedimentation (settling out with the solids), natural die-off and grazing by protozoa**
- **micro-organisms break down the wastes.** Bacteria, fungi, protozoa and algae break down the organic matter. In particular, microbial slimes (biofilms) which form on the surface areas provided by plants, settled solids, soils, and gravel rapidly break down organic materials and take up nutrients. Wetlands provide a mosaic of oxygenated (aerobic) and oxygen-free (anaerobic) 'micro-environments' where different bacteria can work to break down matter and transform nutrients such as nitrogen and sulphur to gases that are released back to the atmosphere. This is assisted by the snorkel-like action of wetland plants, which transport oxygen down to the root zone
- **plants take up nutrients for their own growth** and return them back to the wetland as organic matter when they die. This is largely a recycling system and will not account for much nutrient removal. In general, nutrient uptake and storage by plants generally accounts for a small proportion of nutrient removal from the wetland (5-15% on an annual basis).

The effective 'polishing' of effluent in a wetland system depends on the design employed for maximising retention, the quality of the in-flowing effluent, the climate and season, and the plants used.

An established wetland can be expected to behave differently than a recently constructed wetland.

The two principal types of constructed wetland systems are **surface-flow wetlands** and **subsurface-flow wetlands.**

Surface-flow wetlands have effluent flowing through the stems and lower foliage of the wetland plants that are rooted in soil. Subsurface-flow wetlands have effluent percolating horizontally through the root zone of the wetland plants growing in a gravel bed.

A combination of both surface-flow and subsurface-flow systems can also be employed. This combination, when correctly loaded and designed, can significantly improve on pond systems. The figures for wetland effectiveness vary depending on whether a single wetland is used (lower range figures below) vs a combination of surface and subsurface (higher range figures below). The higher range nitrogen removal will only be achieved if mechanical aeration is part of the pre-treatment pond system.

Above and beyond pond treatment, wetlands can achieve a:

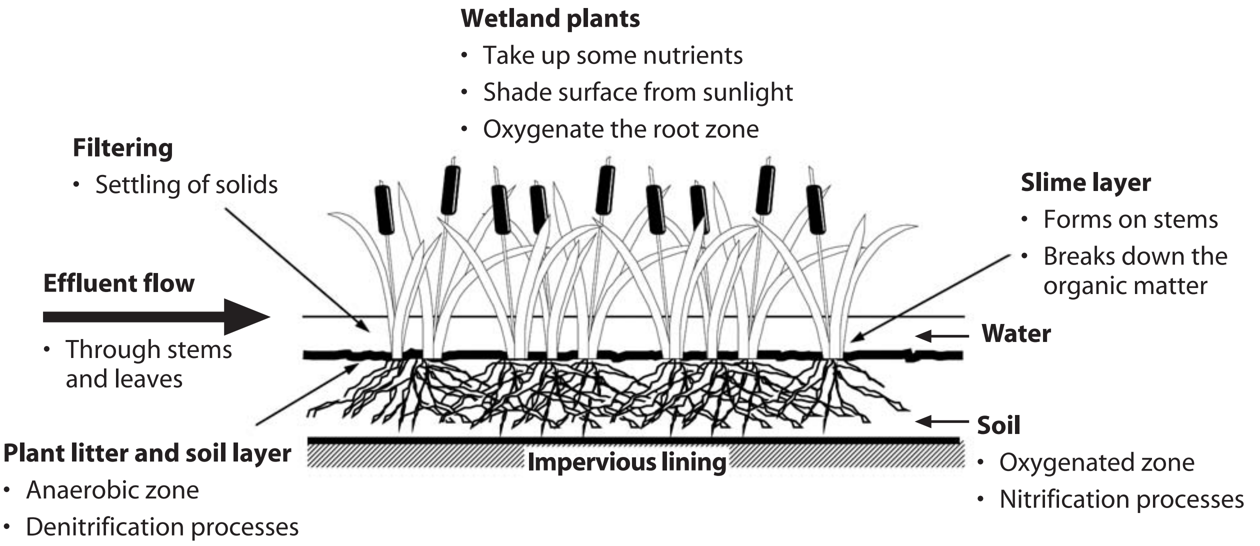
- **reduction of 35% to 75% BOD and suspended solids**
- **reduction of 15% to 80% total nitrogen** through nitrification and denitrification processes and some ammonia volatilisation. The higher rates of nitrogen removal can only be achieved with mechanical aeration in the pond or intermittient - dose vertical flow wetlands
- **reduction of 70 to 95% of pathogenic bacteria populations** by filtration, biological breakdown and plant toxin effects. However, even at the high end of microbial treatment, the outflow will still usually contain microbial contamination that exceeds 500 faecal coliforms/100 ml and therefore is not suitable for contact recreation
- **possible reduction of small and variable quantities of phosphorus and sulphur.** Initial removal may be highest (i.e. up to 75%) with continuing removal depending on the use of special substrates to absorb phosphorus and management steps such as plant harvesting and wetland dredging. Ongoing phosphorus removal could be higher if specifically absorbent soils or sediments are used (e.g. iron oxides, steel wool, bauxite clays, allophane clays, natural loam soils, bauxite, red mud, red sand, smelter slag). However, the use of these materials has not yet been sufficiently researched to make recommendations.

3.10.5.1 Surface-flow wetlands

In surface-flow wetlands (refer to Figure 3.10-4) a slime layer or bio-film develops on the plant stems and in the litter. This layer provides a habitat for bacteria that biologically break down effluent. Plants also filter out suspended solids from the effluent stream.

FIGURE 3.10-4

SURFACE-FLOW



Surface-flow wetlands are simpler to design, and less costly to construct than subsurface-flow wetlands. They can also tolerate higher suspended solids loadings and are more easily desludged and re-established.

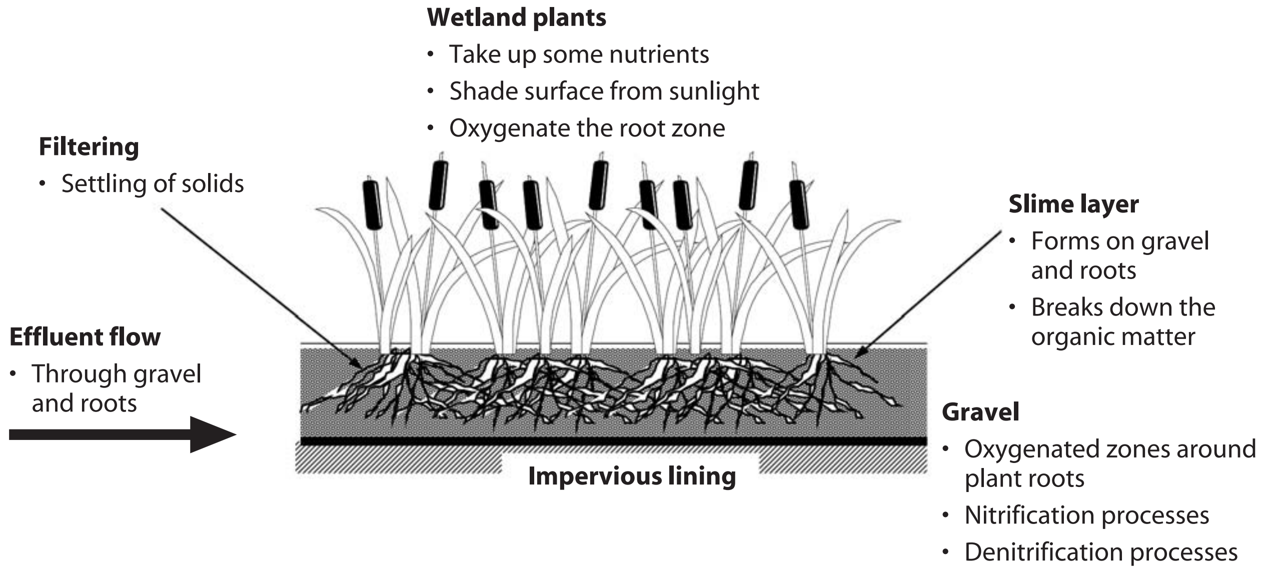
Surface-flow wetlands are readily adapted to provide a habitat for wildlife. Open, unvegetated zones can be created by providing additional deep zones within the wetland. However, effluent from the open area should pass through a densely vegetated shallow zone before discharge to a waterway.

3.10.5.2 Subsurface-flow wetlands

A subsurface-flow constructed wetland (i.e. 'root-zone' system) works similarly to 'hydroponics'. The wetland bed is excavated and lined with an impermeable layer. It is then backfilled with the gravel in which the plants root and there is no free water above the gravel surface (refer to Figure 3.10-5).

FIGURE 3.10-5

SUBSURFACE-FLOW



A slime layer develops on the gravel and plant root rhizomes, providing a habitat for bacteria and other microbes that break down effluent.

Subsurface-flow wetlands require more accurate and detailed engineering design than surface-flow wetland systems to ensure correct gradient and flow. They are more costly because suitable gravels have to be brought onto the site.

However, **subsurface-flow wetlands can treat effluent to a much higher and consistent quality.** Subsurface-flow wetlands have a high potential for suspended solid and nitrogen removal. They also have less potential for causing nuisance with insects and odours since there is no exposed water surface.

3.10.5.3 Combined systems

To reduce the potential for clogging by suspended solids, surface-flow and subsurface-flow constructed wetlands can be used in combination.

Subsurface-flow wetlands are vulnerable to clogging if loaded with high rates of suspended solids, or subject to sediment inputs from stormwater or the erosion of embankments. **Since effluent flowing from a pond system has variable and often high levels of suspended solids, subsurface-flow wetlands are best preceded by a surface-flow system.**

The surface-flow wetland can reduce levels of suspended solids that may otherwise clog up the subsurface-flow system, and can provide initial BOD reduction and a reduction of other contaminants. It can be desludged when accumulation occurs.

3.10.6 Siting of constructed wetlands

The availability of land in an appropriate location often proves to be the limiting factor when considering the installation of a constructed wetland facility. (Refer to 3.4 Siting of ponds, as this section discusses considerations when siting effluent treatment systems.)

Wherever possible, wetlands should be constructed below the initial treatment system so that gravity can be used to convey the effluent.

The contour of the land needs to be selected on the basis of the most cost-effective wetland cell arrangement. Such an arrangement should **minimise earthworks and loss of grazing area** while achieving the treatment requirement and best fit with the existing landscape. Consider surface and subsurface drainage, the location of springs and potential for flooding. Avoid springs and steep slopes, as stormwater runoff will add loading to the system, and retention of water in the wetland may be too short. Consider the outflow point and where the discharge will go.

The availability of suitable soil for the construction and sealing of the wetland is important (i.e. soil with significant day content). Suitable soil is also required for the growth of plants.

Constructed wetlands rarely cause odour and insect nuisances. However, when planning the location of wetlands it is still wise to consider the risk of such issues (refer to 3.4.3 Wind direction and proximity to residential housing). As an effluent treatment system, food safety regulations apply so the wetland should not be within 45 m of a farm dairy (refer to 2.13.1 Food safety and dairy industry requirements).

3.10.7 Wetland design and construction

Constructed wetland design does not lend itself to conventional design criteria. This is because there are site-specific details such as the standard of farm dairy effluent pre-treatment, the desired standard of wetland treatment and suitable local wetland plant species.

This chapter addresses the general design of constructed wetland systems.

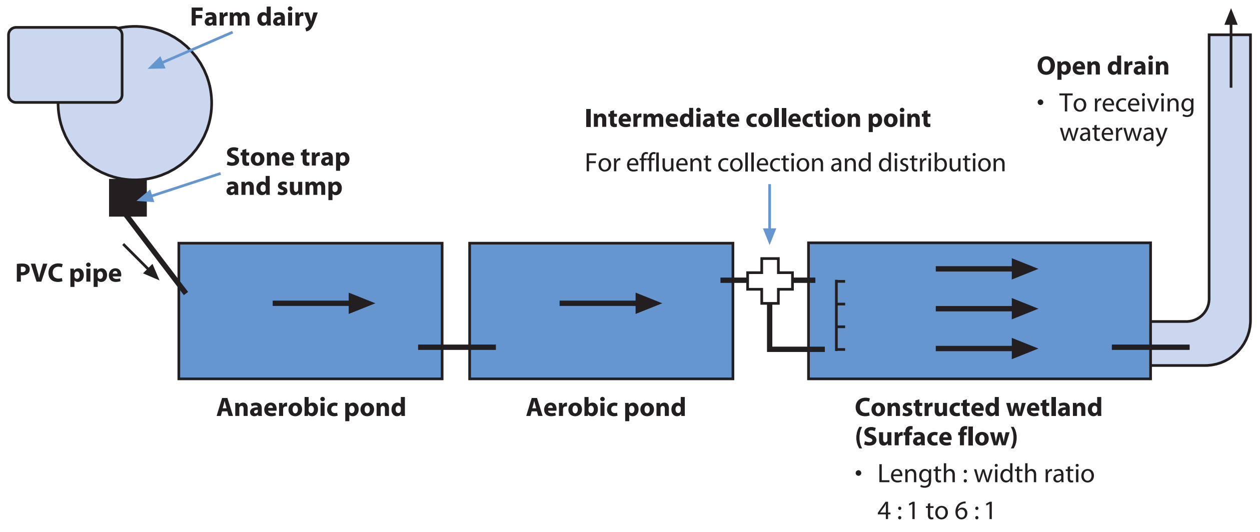
Comprehensive constructed wetland design guidelines were released by NIWA in 1997 (see the NIWA website www.niwa.cri.nz). These guidelines should be followed, along with appropriate advice from expert designers.

In constructed wetland design, the key variables on which to focus are the:

- **effluent volume and loading**
- **retention time**
- **size and configuration**
- **vegetation.**

FIGURE 3.10-6

CONSTRUCTED WETLAND SYSTEM LAYOUT



3.10.7.1 Effluent loading

The first step in constructed wetland design is to identify the treatment objectives. This is done by identifying:

- **the required quality standards of the discharged effluent.** Regional Councils have rules regulating the discharge of effluent into waterways (check with your Regional Council for requirements)
- **the original volume and characteristics of the effluent and degree of pre-treatment that the effluent has already undergone** in the pond system (refer to 1.6.1 Effluent characteristics and volumes)

The required standards at outflow and percentage decrease in key contaminants of the pond effluent will determine the wetland size and whether a combination of wetlands is required.

Table 3.10-1 shows the approximate percentage of removal for key effluent contaminants for a single wetland treatment option and a combination option of a surface-flow followed by subsurface-flow wetland.

TABLE 3.10-1

EXPECTED CONTAMINANT REMOVAL BY CONSTRUCTED WETLANDS

Contaminant	**Mean annual percentage removal** **(refer to Table 3.10-2 for wetland size according to herd size)**	
	Surface flow wetland	Combination wetlands
BOD	35-50	60-75
Suspended solids	40-65	70-75
Total nitrogen	15-35	40-50
Ammonia	10-30	35-50
Faecal coliforms	70-85	85-95

Note: Assumes both pre-treatment and wetland systems are functioning well and normal effluent volumes apply.
Adapted from Tanner and Kloosterman, 1997.

To improve pre-treatment:

- **correctly carry out pond system maintenance** (refer to 3.8 Pond system maintenance)
- **ensure the outflow pipe and baffle system from the aerobic pond is allowing only liquid effluent through.** Take effluent from below the pond surface where algae are concentrated, but above any sludge layer on the pond floor
- **provide pre-filtration of effluent** through rock filters
- **provide mechanical aeration** in the pond. This will greatly reduce total nitrogen and ammonia content in the wetland discharge.

The outflow from the wetland will be low in dissolved oxygen. Oxygenation can be enhanced by cascading the effluent over land or rocks before discharge to a waterway.

Having considered the effluent loading in and out of the system, the remaining design process revolves around obtaining **maximum retention time, simple operation and minimal maintenance.**

3.10.7.2 Retention time

Treatment efficiency of constructed wetlands is generally related to retention time.

Effluent should be maintained within the constructed wetland system for 7 to 14 days. Shorter times than this will result in poor performance.

For surface-flow wetlands, an acceptable retention time is 7-10 days.

Where a combined surface-flow and subsurface-flow system is employed to provide higher levels of treatment, the effluent should remain in the initial section for 7 - 12 days and the subsurface-flow section for 2-3 days.

3.10.7.3 Size and configuration

The size of the constructed wetland is determined by the herd size contributing to the volume of effluent flow, the average depth of the wetland and the retention time.

The depth of the wetland is largely dependent on the plants chosen and controlled by the use of adjustable swivel pipe outlets. However, it is usually between 300 mm and 400 mm deep.

Table 3.10-2 gives recommended bed surface areas for dairy farm wetlands to achieve the treatment levels given in Table 3.10-1. These surface areas do not include the area required for the embankments. For larger herds, these dimensions may be divided among multiple cells.

TABLE 3.10-2

RECOMMENDED BED AREA FOR CONSTRUCTED WETLANDS

Herd size	Area of surface flow wetland (basic treatment)[1,2]	Combined wetland (higher level of treatment)[3, 4]	
		Surface-flow	Subsurface-flow[5]
100	210 m^2	250 m^2	105 m^2
150	310 m^2	375 m^2	160 m^2
200	415 m^2	500 m^2	215 m^2
250	520 m^2	625 m^2	270 m^2
300	625 m^2	750 m^{2*}	320 m^2
350	730 m^2	875 m^{2*}	375 m^2
400	835 m^{2*}	1000 m^{2*}	430 m^{2*}
450	940 m^{2*}	1125 m^{2*}	480 m^{2*}
500	1045 m^{2*}	1250 m^{2*}	535 m^{2*}

Note 1: Effluent volumes based on 50 l/cow/day (refer to 1.6.1 Effluent volumes and characteristics).
Note 2: Assuming the surface-flow wetland has an average depth of 300 mm and a 10-day retention time.
Note 3: Assuming a combined wetland with the surface-flow section of 300 mm average depth and a 12-day retention time, and the subsurface-flow section of 400 mm average depth and a 3-day retention time.
Note 4: Assuming the mature vegetation, litter and sludge takes up 20% of the wetland volume.
Note 5: Assuming the gravel in the subsurface-flow system takes up 65% of the wetland volume.

* For these larger sizes, division into two parallel cells is recommended.

3.10.7.4 Multiple cells

The use of multiple channels or cells, rather than a single large wetland, is recommended on properties with herds of more than 200 cows to obtain maximum flexibility and facilitate maintenance. Two or three cells are adequate.

In such designs, cells can be isolated and closed down for maintenance, or rested when flows are low, without affecting the overall system. The number of cells will depend on the total size of the wetland system and site constraints. Addition of further cells can accommodate herd size increases.

3.10.7.5 Length to width ratios and shape

Appropriate length to width ratios will maximise treatment efficiency. **Ratios of between 4 : 1 and 6 : 1** (i.e. 4 m to 6 m length to every 1 m width) **are recommended for surface-flow systems and 2 : 1 for subsurface-flow systems.** Such ratios will avoid excessive loading at the inlet end while still promoting uniform flow of effluent across the width of the wetland rather than 'short-circuiting' of the system.

For subsurface-flow systems, the saturated cross-section of the bed must be sufficient to contain the design flow. Problems can occur if the beds are very long and narrow, or media with a low hydraulic permeability are used (e.g. soil or sand).

The shape of wetlands can be curved slightly to provide a more natural fit with the landscape. To ensure efficient treatment, only gentle curves should be used to avoid creating stagnant backwaters. Widths should not vary more than 20% for surface-flow wetlands and 10% for subsurface-flow wetlands.

3.10.7.6 Excavation and embankment construction

Wetland cells are best formed and separated by earthen embankments. These serve to contain flows and control the effluent level. Timber dams should not be used for dairy farm wetland systems.

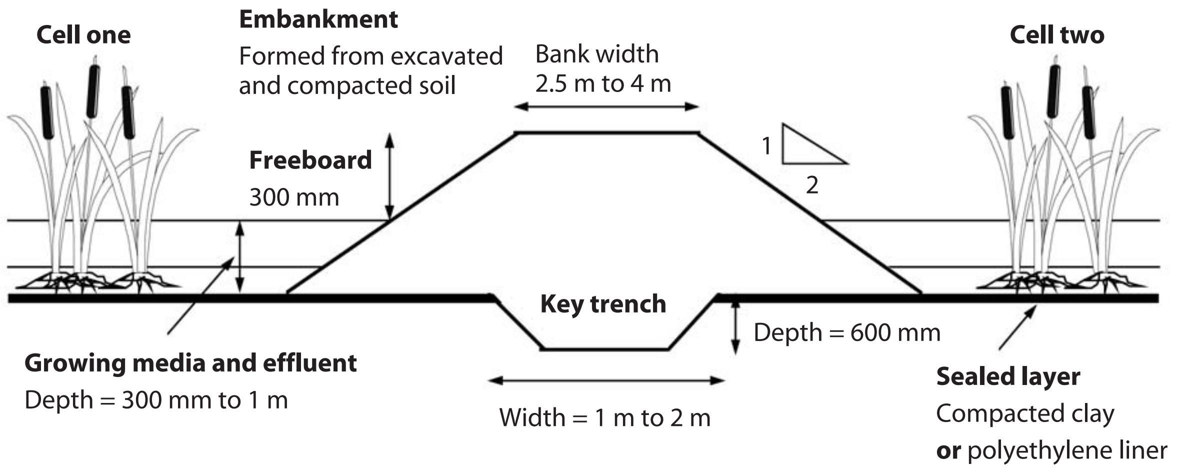
Recommended equipment for construction of embankments are a hydraulic excavator for earth moving and placement, and a rubber-tyred tractor towing a sheepsfoot roller for compaction. Embankment materials should be spread and compacted in layers of no more than 200 mm thickness.

For cell embankment construction refer to Figure 3.10-7 and Figure 3.10-8. The following design guidelines are recommended:

- **a freeboard of 300 mm**
- **the top on the embankment separating the wetland cells should be at least 2.5 m wide.** Widths can be increased to aid construction and also allow for maintenance machinery access if side access is a problem. Where soil is porous or the wetland is to be built above ground, key trenches are required (refer to 3.6 Construction of ponds)
- **the batter slope on the embankments should be 3 horizontal to 1 vertical.** This will ensure stability and allow machinery access to the wetland's edge (refer to 3.6.2 Batters). Inner embankments can have a gradient of 2:1.

FIGURE 3.10-7

DESIGN SPECIFICATIONS FOR WETLAND CONSTRUCTION



3.10.7.7 Stormwater control

In some situations wetlands may be useful for the treatment of water runoff from land. Since such water may contain large quantities of nutrients from the farm system, the wetland will provide a buffer between the land and waterways.

However, during high volume stormwater runoff from surrounding land, where the capacity of the wetland is exceeded, large increases of pollutant loading can occur. This is due to:

- **additional pollutants within the stormwater** such as soil, nutrients and pesticides
- **the incoming water disturbing already settled solids.** The solids, containing nutrients, are re-suspended within the effluent.

Therefore, there should be a diversion channel, or cut-away ditch, around the top of the wetlands to divert surface runoff (refer to 3.6.3.2 Diversion channels around the ponds).

3.10.7.8 Inlet and outlet design

The inlet and outlet structures should allow for water level control and complete draining of the cells for maintenance (refer to Figure 3.10-8). Flow velocities within the wetland system must be low to promote the sedimentation and accumulation of solids. Levels will need to rise as vegetation is established and as sediment builds up in the mature wetland system.

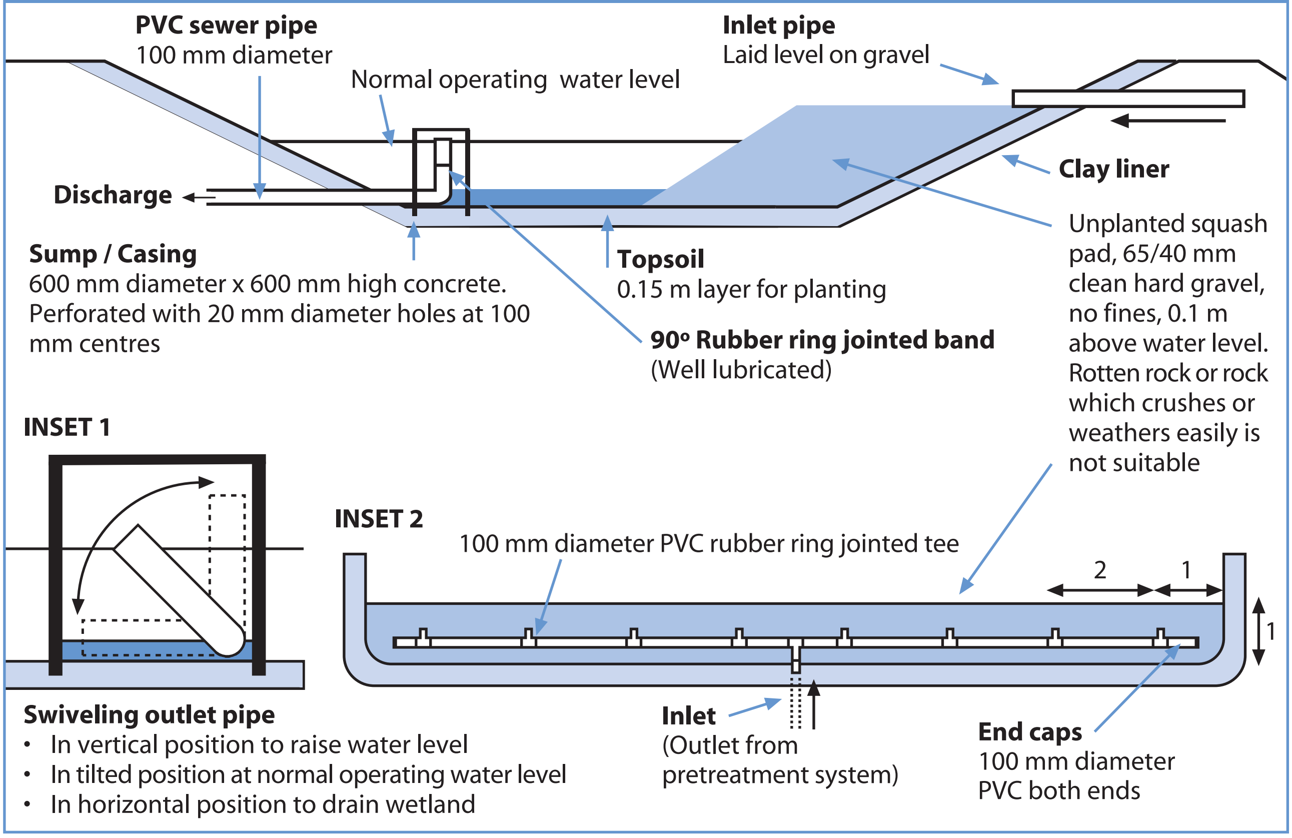
Baffled outlet structures from the initial pond treatment system should take in effluent from well below the pond surface to reduce the proliferation of algae in the wetland system. The effluent may be collected at an intermediary collection point before distribution to the wetland cells (refer to Figure 3.10-6).

The inlet system is designed to achieve even distribution of the flow across the entire wetland width. It is important that the inlet pipe is laid level so that inflows are dispersed evenly across the bed using adjustable T-pipes for final distribution of flows (refer to Figure 3.10-8).

The outlet structure can use a swivelling outlet pipe system to allow simple water level adjustment with low clogging potential. The swivel pipe should be contained within an enclosed perforated concrete sump unit or treated timber box, set in a coarse gravel zone (refer to Figure 3.10-8).

FIGURE 3.10-8

WETLAND CELL INLET AND OUTLET DESIGN



Final discharge from a wetland can be via simple overland flow, seepage fields, vegetated drains or natural wetlands. These are preferable to direct discharge to streams (refer to 3.6.5.5 Outlet pumping, drains or wetlands).

Pristine, low nutrient bogs or wetlands with high conservation values should not be used to receive a constructed wetland discharge, but most wetlands dominated by raupo on farmland will readily assimilate this type of wastewater. Check the policies of your Regional Council before proceeding with this option.

If the discharge is to a natural waterway, flowing the water over simple rock cascades or waterfalls can help aerate it, addressing the low dissolved oxygen levels that can occur in constructed wetland discharges.

Effluent can be dispersed through a perforated pipe laid along the contour of a gentle slope (2-10% gradient), allowing water to flow for at least 5-10 m before reaching a waterway. A pipe 20 m in length with 20 mm holes drilled at 200 mm spacings would be required for an average 200 cow herd. Removable end-caps can be used to allow periodic flushing of the dispersal pipe.

It is best if small intermittent doses are applied rather than continuous flows (e.g. 1 hours application followed by 3-4 hours rest). It is also good to have two or more disposal areas (e.g. 1 year's application followed by 1 year's rest period).

The dispersal area should be fenced from stock to avoid pugging.

3.10.7.9 Sealing and lining

Sealing and lining is necessary for wetlands. Sealing ensures the effluent is not lost from the wetland system through seepage.

Clay can be used to line the wetland and should be kept moist to avoid splitting. Test that the wetland is watertight before adding topsoil and planting.

Heavy-duty polyethylene lining (greater than 1 mm) is necessary where clay soils are not available for compacting and sealing. Such a liner will be subject to at least 200 mm of soil or gravel being placed upon it for plant rooting purposes.

Since some polyethylene liners are not manufactured to sustain such loadings, a geotextile or butyl rubber liner can be used as its strength will protect it from soil and gravel damage. These liners are also useful on the wetland edges where sunlight may otherwise degrade polyethylene.

The liner should be placed over a layer of sand for cushioning and protection from stones. For further sealing and lining techniques and costings refer to 3.6.4 Sealing and lining.

3.10.7.10 Wetland media

In a surface-flow wetland, topsoil is spread to a depth of 200 mm and lime incorporated to reduce toxicity to plants after flooding. The soil should be carefully levelled and lightly compacted to avoid problems with patchy plant establishment.

Uncompacted gravel is used in subsurface-flow wetlands, to a depth of 0.5 m. The top 150 mm of this should be a levelled layer of 20/12 mm gravel for plant growth with the lower layer being 65/40 coarser gravel, with no fines.

Both surface-flow and subsurface-flow wetlands need a gravel zone around the inlet and outlet structures of coarse 65/40 mm clean, hard gravel with no fines.

Gravel size and hardness are critical, as the media can be easily clogged. Avoid any soil entering the gravel as this can also cause clogging.

3.10.7.11 Vegetation

Constructed wetland vegetation:

- **assists in flow regulation and promotes settling of solids**
- **provides surfaces for bacterial films which carry out effluent treatment**
- **provides oxygen to the aerobic bacteria by releasing it to the root zone**
- **takes up nutrients**
- **shades the wetland from sunlight,** reducing algae growth
- **reduces the stirring effect of wind on the effluent surface.** This may otherwise stir up settled solids and associated nutrients.

Plant selection and establishment is important. However, **vegetation alone cannot ensure the success of a wetland system without the right quality of in-flowing effluent, system size and configuration.**

Plant establishment problems can multiply if:

- planting occurs too late in the season
- there is insufficient or excessive water
- inappropriate soils or gravels are used
- plants are damaged by livestock or pukeko
- there is weed invasion and suppression of desirable plants.

FIGURE 3.10-9

EMERGENT VEGETATION

Plants in a constructed wetland system may be floating, submerged or emergent. **Systems using emergent plants are recommended in New Zealand.**

Emergent plants are rooted in the bottom soil or gravel and have their stems and leaves extending up, through the flow, to above the effluent surface (refer to Figure 3.10-9). The stems and roots filter out suspended solids and provide sites for bacterial breakdown of the effluent.

Floating plants can be used in surface-flow wetlands. They float on the effluent surface with their roots extending down into the flow. The use of some floating plants in wetlands may be helpful.

Submerged vegetation is not widely used in constructed wetlands because it is shaded out by algae and is generally sensitive to anaerobic conditions.

Wherever possible, use native species and locally sourced plants. These are likely to do better in the local climate. Choose a selection of plants that are compatible (i.e. no single species is likely to out-compete and dominate.)

Do not grow trees on the wetland embankments as the roots will provide seepage lanes, weakening the embankment wall. However, plantings of flax and native toetoe on the embankments will provide habitat enhancement, bank stabilisation and weed exclusion.

Some guidelines for sourcing and planting wetland vegetation include:

- **for best establishment, plant vegetation from spring through to early summer (i.e. between October and Christmas), provided appropriate water conditions can be maintained.** Early spring planting will allow good growth and coverage before the following winter. It is essential that water (fresh water or effluent from the aerobic pond) is available during plant establishment. Some plants will die back during winter or in a brief period of drought but will then re-grow from underground rhizomes. Additional attention to weed control is required in this case
- **it is important to check plant availability well before the planting contract is let.** Some plants may be out of stock due to their popularity during the spring season
- wetland species can be obtained as either small plants established from seed (e.g. 1-yr-old root trainer grade) or as bare-root rhizome cuttings with shoots trimmed to 200-300 mm. Both will establish well in the right conditions. Do not bring plants in too far in advance. They must be maintained up until the time of planting in cool, semi-shaded conditions and kept watered
- **emergent wetland vegetation should initially be planted at a density of 4 plants per m^2**
- plants should be planted at 40-60 mm depth in the growth medium and be well firmed so that they are less prone to uprooting and do not float out when water levels are raised
- immediately after planting, water levels in surface-flow wetlands should be raised to 50-100 mm above the soil surface to optimise conditions for the wetland plants and suppress weed growth. Avoid flooding above the height of the plant shoots. In subsurface wetlands, water levels should be maintained within 20 mm of the gravel surface during plant establishment. Use the pond water if there is a reliable flow at this time, or supplement from another water supply
- when plants are well established, water levels can be raised in stages e.g. to 200-250 mm after one season's growth and to a final depth of 300-400 mm after the second growing season. After this time, surface-flow wetland plants can be subjected to short periods of drought, but subsurface-flow plants are more dependent on water levels being maintained due to the poor water storage capacity of gravel.

Plant establishment may be a problem where birds, small animals and stock have access to the constructed wetland. Pukeko are a particular problem as they will uproot young plants and graze the growing tips.

To exclude pukeko, install a fence with 3 horizontal trip wires approximately 100 mm above the ground and 200 mm apart. Gas bangers are sometimes effectively used to deter pukeko.

Stock need to be prevented from entering the wetland area. For these reasons **it is recommended that the constructed wetland be permanently fenced off.**

Table 3.10-3 gives recommended wetland plants commonly used in New Zealand.

TABLE 3.10-3

POPULAR CONSTRUCTED WETLAND PLANTS

Plant	**Notes**
Bulrush / Clubrush *(Schoenoplectus tabernaemontani)*	Occurs naturally from Northland to Canterbury. High ability to oxygenate its root zone and has high treatment efficiency. Foliage dies off over winter, except in northern coastal areas, so best combined with other species for winter cover.
Flax *(Phormium tenax.)*	Most suitable for wetland embankments but not permanently wet areas. Also attracts birds e.g. tui.
Kuta (tall spike rush) (*Eleocharis sphacelata)*	Found throughout NZ but less common in southern regions. Preferred species for surface-flow wetlands. Not suited to sub-surface flow wetlands. Excellent filtering capabilities.
Jointed Twig Rush *(Baumea articulata)*	Found from Northland to Manawatu. Can be slow to establish and spread. Forms dense, persistent growth that has little winter die-back – good in combination with Schoenoplectus bulrush.
Raupo *(Typha orientalis)*	Generally the dominant species in wetlands on NZ farms. Not recommended for subsurface-flow wetlands due to its thick rhizomes. High tolerance for effluent, and high ability to filter out solids. Excessive litter generation may clog and overload the system and this plant may out-compete others so not a favoured species for constructed wetlands.
Rushes *(Juncus spp.)*	Useful on the edge of wetlands as they have a low tolerance to long-term flooding. Do not die back in winter. Choose local species.
Duckweed *(Lemna spp.)*	Floating native plant, widely distributed and often introduced by waterfowl. Can provide surface cover in bare patches in surface-flow wetlands to reduce algal growth by shading the water.
Sedges *(Carex spp)*	Native sedges and tussocks that can be used around wetland margins and embankments for diversity, habitat value and landscape appeal. Classic plants of NZ streamsides and wetlands. Choose local species.
Toetoe *(Cortaderia richardii, C. fulvida, C. toetoe)*	Useful, hardy plants for bank stabilisation and landscape appeal. Do not confuse native toetoe with invasive introduced pampas grass – get expert help to identify.

Table 3.10-4 gives plant species that should be avoided and eradicated if identified. They are either unsuitable as wetland species or classed as noxious weeds.

TABLE 3.10-4

CONSTRUCTED WETLAND PLANTS TO AVOID

Plant	**Growth**	**Notes**
Pampas Grass *(Cortaderia selloana, C. jubata)*	Emergent	Forms large, dense basal clumps that restrict effluent flow and do not provide adequate surface area for bacterial slime growth. Highly invasive.
Alligator Weed *(Alternanthera philoxeroides)*	Floating	Serious weed species found from Northland to Waikato. Floats like a mat and can spread to pasture and crops. Has oval shaped leaves and white clover-like flowers. Slightly poisonous to young stock.
Manchurian Wild Rice *(Zizania latifolia)*	Emergent	Serious weed species capable of invading pasture, drains and lake margins. Dull grey/green leaves and grows to 4 m high.
Common Reed *(Phragmites australis)*	Emergent	Found in Hawkes Bay and Murchison. Serious weed species in New Zealand, although commonly used for wetland treatment overseas. Large and erect, with bamboo-like leaves and semi-woody stems.
Reed Sweet Grass *(Glyceria maxima* but previously known as *Poa aquatica*)	Emergent	Can form floating mats over open water. Quick to establish and common in drains. Very persistent non-native species, may out-compete others and will continue growing over winter. Do not introduce into new catchments. Readily eaten by stock, but can poison them with cyanide.
Yellow Flag Iris *(Iris pseudacorus)*	Emergent	Tall, yellow-flowered iris that can spread in the wild. Banned from sale and distribution.
Water Hyacinth *(Eichhornia crassipes)*	Floating	Glossy green leaves with thick runners. Delicate, mauve/blue flowers with yellow centre spot. National Surveillance Plant Pest under the Biosecurity Act (1993).
Water Fern *(Salvinia sp.)*	Floating	A water fern capable of forming thick, floating mats that choke waterways. Notifiable plant under the National Pest Management Strategy. Green to bronze coloured, spongy -leaved fern.
Water Net *(Hydrodicton reticulatum)*	Net-forming algae	Found in northern half of North Island. Can form dense filamentous nets that choke waterways. Can be spread by waterfowl or with plant material from infected areas.

3.10.8 Constructed wetland maintenance

A major goal in constructed wetland design is to minimise and simplify the maintenance needed. Once plants have been established, wetlands require minimal ongoing maintenance. With wetlands, early identification of problems is the key. Maintenance relates to:

- **care of the pre-treatment system** to ensure the pond system is discharging high quality effluent (refer to 3.8 Pond system maintenance). Maintaining high quality effluent into the wetland will greatly prolong its life as excessive solids will clog the wetland and raise the bed level, requiring overhaul and desludging
- **inlet and outlet structures.** Check that flows are evenly distributed across the wetland, adjusting T-pipes up and down until the flow is visually uniform (refer to Figure 3.10-8). Pipes should be inspected for blockages or damage. End caps of both inlet and outlet pipes should be removed annually to flush the pipes. Outlet pipes should be adjusted up or down to keep water levels at 300 mm for surface wetlands and just below the gravel surface for subsurface wetlands. Water level adjustments may be required as sludge gradually accumulates

- **embankments and fencing.** Check for weed spread from the embankments and signs of erosion or damage. Graze outer embankments very lightly (with sheep if possible) but otherwise maintain stock exclusion
- **ensure the wetland plants are growing well over the majority of the bed and check they are healthy. Plants will die off naturally in winter but stress at other times needs to be rectified.** The most likely cause is drying out at times when cows are not milking or when ponds have been drained for desludging. Replant bare areas with new plants or those carefully thinned from dense areas to fill gaps
- **ensure nuisance plants do not invade and dominate the wetland system.** Such plants will need to be removed either by hand weeding or for more extensive invasions by draining cells and physically removing the plants or applying a suitable selective herbicide. It may otherwise be possible to adjust effluent flow to drown out unwanted plants.

The following is a schedule of periodic maintenance tasks that need to be planned for.

Regularly

- **Visually inspect vegetation** for any signs of stress or invasion of unwanted species.
- **Monitor the wetland area for pests.** Pukeko may invade the wetland system, uprooting and eating wetland plants. Areas can be fenced to keep out larger wildlife, but it is more effective to ensure sufficient plant species unattractive to foraging animals are established in the wetland. Control of animal pests such as possums, rats and weasels, stoats or ferrets will also enhance bird life.
- **Monitor the wetland area for odour problems.** Standing, swampy water will cause odour problems. By ensuring good circulation and flow of effluent, dead zones will be reduced and odours should be minimised.
- **Check the effect of the discharge on the receiving waterway.**
- **Check that the pipes running in and out of the ponds are not blocked and that in-flow is uniform across the wetland.**
- **Adjust effluent levels** to maintain them at the correct depth.
- **Check that the fencing remains stock proof.**

Six monthly to annually

- **Repair and maintain inlet and outlet structures.** Clean and remove plants around outlet pipe to provide access and guard against blockages.
- **The wetland area may require desludging after ten years or move to remove accumulated sediments and associated nutrients.** This should be carried out in stages, not removing all the vegetation at a single time. Replanting should follow desludging.

3.10.9 Constructed wetlands – top tips to avoid trouble

- **Does the existing initial treatment system operate correctly? If not, the constructed wetland cannot be expected to work to its potential.**
- **Before installation, determine the likely expansions to herd and property size or intensification over the next 10 years. Ensure sufficient wetland area is part of the design.**
- **Design the wetland to be of appropriate shape and depth to minimise short-circuiting and maximise retention time.**
- **Ensure the wetland is adequately sealed to prevent water loss or groundwater intrusion.**
- **Assess the pollution risks associated with the failure of the wetland, should it be flushed during storms or not operate to expectations.**
- **Install a drainage channel around the wetland to prevent water runoff from the land entering the system. Stormwater may carry pesticides, herbicides and create excessive loading.**
- **Do not let prohibited chemical materials enter the wetland. Many chemicals can affect the breakdown of effluent and the growth of wetland plants.**

- **Check availability of planting material early on in the planning process.**
- **Establish wetland plants in shallow water before gradually introducing higher effluent volume. Maintain adequate effluent flow to ensure year-round survival of wetland plants.**
- **Waterfowl can be deterred from destroying young plants by using temporary electric fencing, trip wires and gas bangers. Fence to exclude stock.**
- **Regularly check the wetland plants and carry out maintenance on in-flow and out-flow structures.**

3.10.10 Constructed wetland regulations

Food Safety and Dairy Industry Requirements

The survival of various disease-causing micro-organisms during effluent storage and treatment is summarised in 2.13.1 Food safety and dairy industry requirements. This section also outlines their requirements surrounding effluent treatment and storage facilities. A constructed wetland system can be defined as such a facility and must not be sited within 45 m of the farm dairy facility.

Regional Council requirements

Regional Council concern is focused on the quality of effluent discharged into waterways following wetland treatment. Poorly treated and discharged effluent can cause elevated nutrient levels, suffocation and poisoning of aquatic life, increased water turbidity and increased pathogenic micro-organism levels.

While some Regional Councils do not recommend this method, others view constructed wetlands as a useful addition to the traditional pond system, especially when required dilution in the receiving water is not available.

It should be noted that although constructed wetlands offer a possible additional treatment alternative, where they discharge to a waterway a Resource Consent will still be required.

For region-specific regulations regarding the discharge of effluent to waterways check with your Regional Council.