REPORT

Taranaki Regional Council

Dairy Effluent Pond Guidelines Update

Report prepared for:

Taranaki Regional Council

Report prepared by:

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1 Introduction

Taranaki Regional Council (TRC) is updating its guidelines for dairy effluent ponds (DEPs). Tonkin & Taylor (T&T) has been engaged to review certain aspects regarding the siting, design, and construction of new ponds, and assessment of leakage from existing ponds. The work was carried out in accordance with our letter of engagement dated 6 June 2012.

1.1 Background

TRC currently has guidelines addressing design and construction of oxidation ponds. We understand TRC wishes to update its existing guidelines for the development of future DEPs in Taranaki. The update reflects a change in effluent management philosophy, away from treatment and discharge to waterways and toward storage of effluent with irrigation to land.

We understand TRC wants to retain a flexible approach to pond construction, recognising that mandating a single specific pond design/type is not appropriate for all situations. TRC recognises that different solutions to pond design will achieve environmental protection in different situations. TRC does not want to force a particular type of pond design onto all situations.

The focus of the guideline update is not to make recommendations on upgrading existing ponds, but to provide some guidance and direction to farmers in the development of new ponds within the region. To this end, TRC is seeking pragmatic, sensible guidelines for siting and construction of new ponds. To support this, our report provides:

- A summary of geological conditions in the Taranaki Region to identify zones of high and low permeability subsurface soil (i.e. high and low risk areas for existing ponds and new ponds, and sources of low permeability material for new ponds) (see Section 2).
- A description of the types of existing ponds currently being used around Taranaki (see Section 3).
- Discussion of performance standards for new ponds, and how the guidelines can be updated to reflect appropriate requirements. This includes specifications for materials and liner installation construction details for new ponds. For existing ponds, we provide estimated leak rates and comments on leak detection monitoring and maintenance (see Section 4).
- Environmental considerations for siting new ponds (see Section 5).

1.2 Scope of work

We have carried out the following:

- Desk top review of available geological information including:
  - Townsend et al., 2008. Geology of Taranaki Area. Institute of Geological and Nuclear Sciences 1: 250, 000 Geological Map 7.
  - Edbrooke, S. W (compiler). 2005. Geology of the Waikato area. Institute of Geological and Nuclear Sciences 1: 250,000 Geological Map 4.
  - Soil Bureau Bulletin No 5 (General Survey of the Soils of North Island, New Zealand) by the New Zealand Department of Scientific and Industrial Research.
- Aerial photographs.
- Geotechnical investigation data in the Taranaki region from T&T files.
- Meeting with TRC and inspection of existing pond sites on 27 November 2012.

- Site inspection of different geological terrains and different pond construction types across Taranaki from Stratford to Warea on 27 November 2012 by an Engineering Geologist.
- Prepare a map showing zones of different geological terrains with different geological materials that dictate pond liner construction. This is based on work by GNS.
- Review of current TRC guidelines for DEPs (*Design, Construction and Maintenance Guidelines for Oxidation Pond Treatment of Dairyshed Wastes*) and guidelines from other organisations, including:
  - IPENZ Practice Note 21: Farm Dairy Effluent Ponds, Version 2 (December 2012). The December 2012 updated included addition of sections on soil liners and selection of synthetic liners.
  - Dairy New Zealand: Dairying and the Environment, 3rd Edition (2006): Chapter 1: Managing Farm Dairy Effluent; Chapter 3: Pond Systems.
  - Environment Southland Code of Practice for Design and Construction of Agricultural Effluent Ponds (December 2009).
  - Waikato Regional Council. Farm Dairy Effluent Frequently Asked Questions (February 2012).
- Prepare recommendations for updates to the existing TRC guidelines.

2 Taranaki geology: soil permeability

The objective of the geological assessment is to assess whether it is possible to identify zones within the region where different levels of control are appropriate for pond construction based on the nature of naturally occurring soil.

2.1 Geological zones

Based on work by GNS, we have subdivided potential dairying areas of the region into three broad geological zones (see Figure 1):

- Zone A: Dissected mudstone hill country.
- Zone B: Lowland coastal terraces.
- Zone C: Mt Taranaki volcanic ring plain:
    - i. Sub Zone C1: Holocene deposits (coarse grained)
    - ii. Sub Zone C2: Pleistocene deposits (fine grained)

Within these broad zones are areas of localised variability. This variability means that broadscale assumptions on the geological materials cannot be made for each zone. It is not possible to conclude that all the dissected hill country contains low permeability siltstones and mudstones, or that the ring plain contains only high permeability sands and gravels.

During our site visit, different materials of each zone were observed at various locations between Stratford and Warea, and south to Patea.

The major underlying geology in each terrain, minor geological units identified from the 1:250,000 geological map, and our observations of soil cover are summarised in Table 1.

2.2 Typical material permeability

The permeability of the underlying soils at any pond site is critical in defining the type of pond liner that is required.

Indicative permeabilities of materials that may be encountered in each terrain zone are provided in Table 2. Table 2 highlights that each zone has a number of different soil types and each soil type can have a range of permeabilities.

Because there is significant variability in the type of material within each zone, both high and low permeability materials may be encountered in any one zone.

Table 1: Taranaki terrain zones

Zone	Description, geomorphology	Major geological units	Minor units	General soil cover
A) Dissected hill country	Vast area of inland hill country that stretches into the Wanganui and Waikato regions. Contains relatively low hill topography and flat benches dissected by streams and rivers.	Late Miocene-Early Pliocene marine deposits comprising grey–brown mudstone and siltstone with minor sandstone, shell beds, conglomerate. The deposits will contain a weathering profile and be covered by variable thickness of soil, loess and colluvium. Deposits in low lying alluvial areas are likely to be reworked combinations of marine deposits and can be highly variable. Locally deposits could be gravelly, and in other areas, clayey and silty.	Loess Colluvium Swamp deposits east of Eltham. River valley flood plain deposits (reworked deposits)	FINE Soils (light grey to brown silt loam with minor brown sandy loam from andesitic ash). Locally variable. Combinations of clayey, silty and sandy with gravelly soils overlaying siltstones, sandstones and mudstones on the hill slopes. Silty, sandy soils with clays and organics locally present in lower flat lying alluvial / swampy areas. The soils are typically loess / tephra or colluvium. The top of the siltstones, sandstones and mudstones are typically weathered to a soil.
B) Coastal lowlands	Sets of uplifted marine terraces that stretch from south Taranaki Bight inland for approx. 20km. Terraces can be traced from Waingongoro River south into Wanganui, and are dissected by major rivers (Waitotara, Whenuakura, Patea) producing flat bottomed valleys with steep sides.	Pleistocene beach deposits represented as beds of conglomerate, sand, peat, and clay. Often mantled by loess and dunes near the coast comprising titano-magnetite sands. Deposits in low lying alluvial areas are likely to be reworked and highly variable.	Loess River valley flood plain deposits (reworked deposits) Coastal sand dune deposits.	FINE and COARSE soils (dark brown to brown loam). Locally variable with typically a fine silty mantle of loess / tephra or grey dune sands (on coastal margin) overlying interbedded marine sands and silts.
C) Mt Taranaki ring plain	Circular area around Mt Taranaki with radius of approximately 30km. Comprises undulating terrain incised by more than 300 small streams sourcing from the slope of Mt Taranaki.	<u>Sub Zone C1: Holocene Deposits</u> Volcanic flow deposits comprising gravels (cobbles and boulders) and sand with thin to no covering of silt and clay ash deposits. Deposits in low lying alluvial areas are likely to be reworked and highly variable. <u>Sub Zone C2: Pleistocene Deposits</u> Weathered volcanic flow deposits comprising gravels (cobbles and boulders) and sand overlain by relatively thick layers of silt and clay ash deposits. Deposits in low lying alluvial areas are likely to be reworked and highly variable.	Sandy volcaniclastic (mainly pyroclastic and reworked alluvial deposits).	COARSE GRANULAR soils (predominately brown loam and bouldery loam, and minor sandy loam). Locally variable. Predominantly they are lahar / volcaniclastic based deposits, comprising fine to coarse gravels, cobbles and boulders mixed in with mainly sands and lesser silts and clays. These deposits are locally overlain by ash / tephra comprising gravely fine silts and sands. In some places, the tephra is over 2m thick. Lahar mounds to south west of Mt Taranaki have little or no soil cover. Quarries and road cut exposures on the south western side of Mt Taranaki are very sandy and gravelly with little fines.

Table 2: Expected permeability of soil types in Taranaki Region

Terrain zone	Soil types	Soil description	Range of permeability (m/s)
A: Dissected hill country	Mudstone/siltstone derived	Very fine grained soil with individual grains not visible to the naked eye. Free of gravel. Brown or grey. Very sticky when wet and can easily be rolled into long thin threads with fingers. May contain small shells.	1 x 10^{-6} to 1 x 10^{-9}
	Sandstone derived	Fine grained soil with some grains visible to the naked eye. Free of gravel. Brown or grey. Crumbles when rolling in fingers. Feels rougher than mudstone/siltsone. May contain small shells.	1 x 10^{-4} to 1 x 10^{-6}
	Volcanic Ash	Fine grained soil with some grains visible to the naked eye. Free of gravel. Colours range from orange-brown to dark brown. Sticky when wet and can be rolled into threads with fingers.	1 x 10^{-5} to 1 x 10^{-9}
B: Coastal lowlands	Fine grained marine terrace deposits (silt and fine sand)	Fine grained soil with grains visible to the naked eye. Free of gravel. Light brown to grey colouring. Crumbles when rolling in fingers. May contain small shells.	1 x 10^{-5} to 1 x 10^{-7}
	Coarse grained marine terrace deposits (coarse sand and gravel)	Coarse grained soil with sand and gravel mixtures. Light brown to grey colouring. Range in gravel size from a few millimetres to 5-10cm. Gravels rounded. May contain small shells.	1 x 10^{-2} to 1 x 10^{-5}
	Dune sand	Fine grained soil with sand grains visible to the naked eye. All sand grains have a uniform size. Crumbles in fingers. Gritty.	1 x 10^{-2} to 1 x 10^{-4}
	Loess	Fine grained soil with some grains visible to the naked eye. Free of gravel. Colours range from orange-brown to dark brown. Some stickiness when wet, but cannot be rolled into thin threads in fingers.	1 x 10^{-6} to 1 x 10^{-8}
	Volcanic Ash	Fine grained soil with some grains visible to the naked eye. Free of gravel. Colours range from orange-brown to dark brown. Sticky when wet and can be rolled into threads with fingers.	1 x 10^{-5} to 1 x 10^{-9}
C: Mt Taranaki ring plain	Laharic deposits	Individual grains ranging from clay to large rounded gravel (boulders). Varying proportions of clay and gravel. Colours ranging from red-brown to light brown. Gravel/boulders comprise very hard rock. Clay is sticky when wet and can be rolled into thin threads with fingers.	1 x 10^{-1} to 1 x 10^{-8}
	Volcaniclastic deposits	Fine grained soil with most of the grains visible to the naked eye. May contain very fine gravel up to 1cm in size. Grey colouring. Crumbles when rolling in fingers.	1 x 10^{-4} to 1 x 10^{-8}
	Volcanic Ash	Fine grained soil with some grains visible to the naked eye. Free of gravel. Colours range from orange-brown to dark brown. Sticky when wet and can be rolled into threads with fingers.	1 x 10^{-5} to 1 x 10^{-9}

Notes: permeabilities sourced from IPENZ Practice Note 21, Part 2 Clay Liners for Ponds. These values are a general guide and should not be relied upon for site specific design.

3 DEP types in the Taranaki region

3.1 Existing ponds

Based on our discussions with TRC staff, we understand that:

- Within Taranaki, DEPs are constructed in different ways. The type of pond construction is mainly a function of the suitability and availability of on-site materials to create a low permeability liner. From experience, farmers and local contractors are able to anticipate what liner is likely to be required at a specific site to create a contained pond.
- Soil lined ponds are used where suitable onsite soils are available. Where onsite soils are unsuitable, farmers will import suitable soils from local borrow areas, or they will artificially line their ponds. Farmers in the dissected hill country and coastal lowlands are more likely to have suitably lower permeability soils on their land than in the ring plain.
- Instances where soil lined ponds have leaked are mainly due to poor construction control e.g., timber / ponga logs have been incorporated into the liner and these have rotted, creating cavities / conduits.
- Pond sludge acts as an additional liner material (i.e., the ponds "self-line" in time). If soil lined ponds are cleaned out, they should not be fully cleaned out. A residual amount of sludge should be retained in the pond to keep its sealed properties.

3.2 Pond types observed

During our site visit on 27 November 2012 we observed a number of different pond types constructed around the Taranaki region. Red Jacket Ltd completed additional site inspections in January and February 2013.

The locations of inspected ponds are shown on Figure 1. A summary of liner type and surrounding geology is provided in Table 3. These are considered to be characteristic of ponds constructed around the region, but are not an exhaustive sample of pond types.

Table 3: Examples of DEPs in Taranaki

Liner type	Liner description	Figure 1 ref.	Geological terrain and observed geology
Soil	Reworked and compacted, slightly clayey, fine silt with sandy, fine gravely sized pumice and andesite (tephra). Sourced from site (where no organic impurities) or from adjacent borrow area. Compacted soils are 0.5m thick. Also self lined with pond sludge.	Site 1	Dissected Hill Country (within relatively flat lying alluvial deposits). Insitu soils comprise alluvial or tephra based clayey silts and fine sands with pumice gravel and organics (timber / wood).
	Imported ash to create compacted soil liner. Thickness unknown. Faced with coarse gravels.	Site 2	Mt Taranaki Ring Plain. Soils in adjacent road cutting comprise brown grey gravelly silts.
	Unlined. Appears to be excavated straight into natural soils.	Site 2	Mt Taranaki Ring Plain. Stockpiled materials adjacent to pond comprise silty, sandy gravels.
	Unlined. Pond created from compacted local soils.	Site 5	Lowland coastal terrace

Liner type	**Liner description**	**Figure 1 ref.**	**Geological terrain and observed geology**
	Unlined. Appears to be excavated straight into natural soils	Site 8	Mt Taranaki Ring Plain. Soils are orange weathered ash.
	Unlined. Pond created from compacted local soils.	Site 9	Mt Taranaki Ring Plain. Soils are orange brown ash.
	Unlined. Appears to be excavated straight into natural soils	Site 10	Mt Taranaki Ring Plain. Soils are brown grey ash.
Geo-membrane	Butyl rubber liner with geotextile protection	Site 4	Mt Taranaki Ring Plain. Pond is constructed in silty, sandy gravel deposits with silty sandy tephra mantle.
	HDPE liner used due to high groundwater and springs	Site 6	Dissected Hill Country with minor ash soil cover
	Existing pond lined with HDPE after leak occurred	Site 7	Mt Taranaki Ring Plain. Pond is constructed on ash soil cover
Concrete	Pre-cast concrete walled Megapond	Site 3	Mt Taranaki Ring Plain. Surrounding exposures are in gravely sandy silt with pumice gravel.

4 Engineering considerations

The existing TRC guidelines do not include specific guidance on the required performance of pond liners. This section provides recommendations regarding performance standards for DEPs and construction.

4.1 Summary of existing TRC guidelines

The existing TRC guidelines include a general description of the operation of anaerobic ponds, aerobic ponds, and tertiary treatment and recommended pond sizes, including the volume and dimensions required for aerobic and anaerobic ponds, based on herd size.

The guidelines provide some guidance on pond construction, including: site preparation, compaction, and machinery; shape, bank gradients and fencing; freeboard and overflow contingency; and sandtraps, pipes, and baffles.

4.2 Performance standard for new ponds

The existing TRC guidelines require that soils in which ponds are formed (or pond liners) are "impermeable" to prevent seepage of contaminated water to groundwater. In practice no pond or pond lining is completely impermeable. Even ponds lined with a geomembrane are likely to have leaks due to construction defects and/or damage (see Section 4.3.3).

We recommend defining a performance standard that limits leakage/seepage. An appropriate performance standard should have the following characteristics:

- Ensure an acceptable level of environmental protection.
- Be reasonably achievable.
- Compliance with the standard should be able to be checked during construction.

Local experience has shown that well constructed ponds in low permeability soils or with an imported low permeability soil liner have performed adequately (refer to Section 3.2). It is therefore reasonable to base a performance standard on:

- Ponds lined with low permeability soil[1].
- Good practice design and construction.
- Typical soils in the Taranaki region.
- Reference to standards in other regions of New Zealand.
- Locations with 'normal' environmental sensitivity.

4.2.1 Examples of performance standards used by others

The simplest approach is to specify the maximum acceptable permeability of soil used in a pond lining in association with a minimum liner thickness. Examples include:

- Waikato Regional Council (WRC) requires soil liners to have a permeability of $\leq 1 \times 10^{-9}$ m/s and a minimum thickness of 450 mm (by reference to IPENZ Practice Note 21). If it is assumed that the effective liner thickness is 300 mm (based on a 'factor of safety' of 1.5 to allow for damage or other liner defects) this means that the water level of a pond will drop, due to seepage, at a rate of 1 mm per day or 30 mm per month. For a typical 1000 m^2 pond this means a leakage from the pond of 1 m^3 per day or 30 m^3 per month.

[1] The term "soil" is used because suitable material may comprise clay, ash, silt, or other low permeability material.

- IPENZ Practice Note 21 recommends that soil liners are a minimum of 450 mm thick and have a permeability of ≤$1x10^{-9}$ m/s (i.e., same as WRC). Soil liners require a minimum 200 mm thick soil protection layer to prevent drying out and cracking and in some cases a scour protection layer may be required.

An alternative approach is to specify a maximum seepage rate through the liner.

- Environmental Southland set a required standard in terms of leakage rate per m^2 of pond liner of $3.8x10^{-8}$ m/s or about 3.5 mm/day, 100 mm/month. This is a leakage rate of 3.5 m^3/day for a 1000 m^2 pond or $100m^3$ per month. For a 3 m depth of water and 300 mm effective thickness of liner, a permeability of $3.5x10^{-9}$ m/s is required to meet this standard.

4.2.2 Recommended performance standard

We recommend the base standard for new DEPs should be:

- Compacted soil liner, minimum thickness 450 mm, permeability ≤$1x10^{-9}$ m/s.

Due to the variability of materials within each Terrain Zone (refer Section 2), suitable ground conditions may be present in any of the Terrain Zones. Of all the zones, Zone A (Dissected Hill Country) is most likely to have suitable low permeability soil.

4.3 'Best Practice' pond liners

This section establishes performance standards and considerations for a range of liner designs that are equivalent to the base standard (refer Section 4.2.2).

4.3.1 Compacted soil liner (base standard)

The term "compacted soil liner" means a liner formed from suitable soil that has been either:

- Brought onto the site from elsewhere; or
- Excavated out from the pond location and replaced in compacted layers.

A compacted soil liner is the base standard (from section 4.2.2) against which other liner designs are compared. Key components are:

- A liner of compacted soil of minimum thickness 450 mm and permeability ≤$1x10^{-9}$ m/s.
- A 200 mm thick topsoil protection layer is required to prevent drying out and cracking when the pond is empty.
- Good construction practices must be implemented (see Section 4.5).

To achieve the required low permeability, a soil containing clay is likely to be required, compacted to a high standard.

4.3.2 In situ soil liner

For sites where the natural ground has a low permeability, it may be adequate to simply excavate a pond into the ground without addition of a liner. To account for natural material variability we recommend the following performance standards:

- For in situ ground with a permeability ≤$1x10^{-9}$ m/s, the thickness of suitable material beneath the pond base must be at least 1 m (to be confirmed by site investigations). The extra thickness compared with a compacted soil liner (see Section 4.3.1) is to allow for the natural variability of in situ soil.

- For in situ ground with a permeability of ≤$5x10^{-9}$m/s the material must be at least 2 m thick.
- The top 150 mm must be scarified and re-compacted to homogenise it.
- Soil must be homogeneous and without defects such as fissures or layering.
- For mudstones and siltstones in Terrain Zone A, the in situ material should be sufficiently weathered such that there are no open joints.
- Scour protection may be required.

Other considerations:

- A cover layer to the pond base and sides will not generally be required. Due to the thickness of material, some drying or cracking of the surface layer should not affect performance significantly.
- Soils that are likely to be suitable for this type of pond include:
  - Zone A (dissected hill country) mudstone, siltstone, colluvium and ash deposits
  - Zone B (coastal lowlands) ash deposits
  - Zone C (ring plain) volcanic ash, volcaniclastic, and lahar deposits with relatively high silt and clay content and low gravel and sand content.
- Due to the variability of materials within each Terrain Zone (refer Section 2), suitable ground conditions may be present in any of the Terrain Zones. Zone A is likely to have a greater proportion of suitable low permeability soil than the other zones.

4.3.3 Geomembrane liners

A thin (1-2 mm) geomembrane, without defects, will have a very low leakage rate, effectively zero. However geomembranes often have defects (such as holes, tears and leaking welds) and are relatively vulnerable to damage. We recommend the performance standard assumes defects exist in a geomembrane pond liner similar to those typically found in geomembrane landfill liners.

The degree of leakage through defects in geomembranes depends upon the permeability of the underlying material. If it is very permeable (such as a clean sand or gravel) leakage through even a small defect can be significant.

The recommended performance standard assumes a high standard of workmanship and quality control during installation. Poorly installed geomembrane liners may not perform as well as a low permeability soil liner.

The recommended performance standard for geomembrane liners is:

Either:

- Soil is placed and compacted under the geomembrane on the pond floor and sides with a permeability of $\leq 5 \times 10^{-6}$ m/s to a depth of at least 300 mm. Silts and loams found in many locations in Taranaki will be suitable for this application.

Or:

- If the underlying soil layer is to be undisturbed in-situ natural ground:
  - There should be a minimum thickness of 1 m of soil with a permeability of ≤$5x10^{-6}$ m/s. The minimum thickness of 1 m is to account for natural variability.
  - The top 150 mm should be scarified and re-compacted.

In both situations, no geotextile ‘cushion’ or sand blinding layer should be placed beneath the geomembrane for the following reasons:

- Even thin relatively high permeability layers between geomembrane and soil subgrade can increase leakage through geomembrane defects by allowing water to move laterally under the geomembrane before seeping into the underlying soil, thereby increasing the effective size of defects.
- To minimise leakage through defects, intimate contact between the geomembrane liner and underlying soil subgrade is important.

If a blinding layer is required for geomembrane protection, a silty material is recommended. We note that soil meeting the permeability requirement for the layer beneath a geomembrane is unlikely to contain materials that may cause damage and therefore an additional blinding layer should not be required.

If gas is anticipated and a permeable gas drainage layer (e.g., geotextile or granular layer) is necessary to vent gas and prevent gas pressure build-up under the geomembrane, this should be provided beneath the soil layer.

Any groundwater drainage required should be installed below the soil layer

4.3.4 Bentonite-enhanced soil liners

Bentonite-enhanced soil liners should be constructed by a specialist contractor to ensure the required performance is achieved,

Bentonite powder may be used as an additive to the site soil or mixed with an imported soil (typically a sand) to form a low permeability soil liner confirming to the standard set out in Section 4.3.1. Bentonite is typically added at a mixing rate of up to 10% by dry weight of soil. Intimate and even mixing of the bentonite with the soil is necessary to achieve consistent results. This is normally done in the base of the pond, in layers and dry conditions. Suitable soils are necessary to achieve acceptable results.

Bentonite slurry from well construction is used in Taranaki to improve sandy soils. It may be possible to use the slurry to form a soil liner. Due to the variable nature of the material, and uncertainty regarding the practicality of mixing the slurry with soil, trials and testing would be needed to confirm performance. Considerations for use of bentonite slurry include the following:

- The slurry-amended soil would have to achieve the same permeability standard as a bentonite or compacted soil liner. Sampling and testing would be needed to confirm the required permeability can be achieved.
- The slurry may contain residual hydrocarbon contamination. It should be tested and results compared with guidelines that are appropriate for the way it is to be used (i.e., whether it is to be placed beneath a geomembrane or in direct contact with the effluent that is to be discharged to land). Material containing free hydrocarbons would not be acceptable.
- If the slurry-amended soil is to be used beneath a geomembrane, the compatibility of materials should be checked. Geomembrane liners can be damaged by hydrocarbons. Residual hydrocarbon contamination in soil (i.e., not free product) is unlikely to adversely affect a geomembrane liner, however, this should be checked with the liner manufacturer.

4.3.5 Concrete liners

Concrete liners may be appropriate in some circumstances. IPENZ Practice Note 21 gives little detail on minimum standards for concrete liners.

There are two different types of concrete pond liner that may be appropriate: conventional concrete lining and engineered composite concrete (ECC). EEC is a relatively new product sometimes known as ‘bendable’ concrete. ECC is normally applied as a ‘shotcrete’ and incorporates polymer fibres and other additives that make it more flexible than conventional concrete. When deformed, ECC tends to develop multiple micro cracks rather than a small member of larger cracks reducing the potential for leakage. We are not aware of any experience with this material in New Zealand although it is available and promoted for use in DEPs.

Concrete liners are less flexible than other options and more susceptible to cracking and consequent leakage. Therefore:

- Subgrade preparation as for geomembrane liners is required.
- Concrete liners are not recommended where settlement is expected (ECC can accommodated some movement without cracking).
- Site specific design is required.

Minimum criteria for good performance for concrete liners are:

- For imported subgrade soil, subgrade must have permeability of ≤ 5×10^{-6} m/s to a depth of at least 300 mm.
- For in-situ soil, minimum thickness is 1 m and the top 150 mm should be scarified and re-compacted.
- Blinding layer to be silty material only (no sand blinding layer).
- Any gas drainage layer must be beneath the compacted soil layer.
- Conventional Concrete Liners:
  - Minimum concrete thickness: 100mm.
  - Reinforced with rebar mesh or steel fibres (not synthetic fibres).
  - Construction joints at appropriate centres to prevent cracking. Joints to incorporate water stop details to prevent leakage.
  - Not to be used where settlement is expected.
- ECC Liners: site specific specialist advice and design required.

4.3.6 Pre-cast concrete tanks

Above ground pre-cast concrete tanks may also be used. These tanks will impose a considerable load onto the ground. It is therefore important that the ground is strong enough to accept this load without failure or excessive settlement. Sites with soft clays or peaty soils are unlikely to be suitable for pre-cast concrete tanks without special measures to address these issues.

4.3.7 Summary

The liners discussed above are summarised in Table 4. A flow chart for selection of suitable pond liner design is provided in Figure 2.

These standard best practice pond liner designs are appropriate for sites of 'normal' environmental sensitivity i.e. sites without a high risk of adverse environmental impact. For ponds located in higher sensitivity locations (e.g., close to a watercourse or well), it is recommend that a site specific assessment of environmental impact to determine the standard required.

Table 4: Best Practice Pond Liners for 'normal' sensitivity locations.

Best Practice Liner	Minimum Liner Requirements	Comments[1]
Compacted soil	Minimum 450mm thickness of soil with permeability of $\leq 1x10^{-9}$m/s	Cover soil layer required to prevent drying out and cracking when pond empty.
In situ soil (natural ground)	Minimum 1 m thickness of soil with permeability of $\leq 1x10^{-9}$ m/s; or Minimum 2 m thickness of soil with permeability of $\leq 5x10^{-9}$ m/s	Scarify and re-compact top 150 mm of in situ soil. Cover soil not generally required. If the pond includes constructed bunds around its perimeter, these must be considered separately.
Geo-membrane	Geomembrane over: Minimum 450 mm thickness of compacted soil with permeability of $\leq 5x10^{-6}$ m/s; or Minimum 1m thickness in situ soil with a permeability of $\leq 5x10^{-6}$ m/s	No cover layer required. Scarify and re-compact top 150 mm if in situ.
Concrete	Minimum 100mm thickness of reinforced concrete over: Minimum 450mm thickness of compacted soil with permeability of $\leq 5x10^{-6}$ m/s; or Minimum 1m thickness in situ soil with a permeability of $\leq 5x10^{-6}$ m/s	Site specific design required. No cover layer required. Scarify and re-compact top 150mm of soil if in situ. Not suitable if settlement expected.
Bentonite enhanced soil liners	450 mm thick with permeability of $\leq 1x10^{-9}$m/s Bentonite is mixed with soil to achieve desired permeability at a rate of 10% of the dry weight of soil.	Intimate and even mixing required. Normally done in-situ, in layers and dry conditions. Suitable soil necessary to achieve results (often a sand).
Pre-cast concrete tanks	Not applicable	Underlying soils must be strong enough to take the weight. Soft clay or peaty soils are unlikely to be suitable without special design.

[1.] Detailed design information and construction details for each pond type are provided in IPENZ Practice Note 21.

4.4 Site investigation

The existing TRC guidelines do not provide guidance regarding site investigation. Variable soil types are present in all terrain zones of the region. Some level of investigation is required for all pond types. This may involve testing or some other assessment to confirm the pond will meet performance standards.

Investigation and testing requirements will vary for different pond liner types.

- If in situ material is used (in situ liner or secondary liner under a geomembrane or concrete liner), investigation to the appropriate depth beneath the pond base must be carried out to confirm the acceptability (particularly permeability) of the in situ materials.
- If an imported soil is proposed, investigation of potential sources of material will need to be carried out to confirm the suitability of the material and parameters for compaction of the material into a liner.

A cross-reference to further detail in Section 4.0 of IPENZ Practice Note 21 would be appropriate for general advice on site investigation and to Part 2 of the same document for advice specific to compacted soil liners.

4.5 Construction

The existing TRC guidelines contain some information on construction of soil lined ponds. Key aspects of construction vary for the different pond types and will also vary from site to site.

A fundamental requirement for construction of all ponds is a specification and drawings and an agreed methodology for construction to comply with the requirements of the specification and achieve the required quality of materials and construction. These documents form the basis for execution and control of construction. In conjunction with this documentation it is essential that there are quality control procedures in place during construction to ensure that the requirements of the agreed methodology are followed and the requirements of the specification are achieved. This should include keeping records of the construction and may include various forms of testing. These records then form the basis for 'sign off' by the regulatory authority.

Without this documentation the desired outcome (compliant pond performance) may not be achieved and/or verification of adequate pond construction may not be possible. Key aspects of construction vary for the different pond liner types as below:

- Compacted soil lined ponds
    - Construction by an experienced contractor with appropriate plant.
    - Control over the material used (must not contain deleterious material such as organics, must comply with the specification).
    - Placement and compaction of material in maximum 150 mm thick layers.
    - Adequate compaction to achieve the required permeability including an appropriate methodology to ensure adequate compaction on the internal pond slopes.
    - A quality control testing programme during construction to ensure and verify that appropriate soil materials have been used, appropriate compaction methodologies followed and acceptable liner material properties achieved.
- In situ soil lined ponds
    - Construction by an experienced contractor with appropriate plant.
    - Verification by inspection (and perhaps testing as necessary) to confirm that in situ materials meet the design requirement as they are exposed in the excavation.
    - Adequate compaction of the top 150 mm of in situ material.
- Geomembrane lined ponds
    - For compacted soil secondary liner layers beneath geomembranes refer to "compacted soil lined ponds" section above.
    - For in situ ground beneath geomembranes refer to "in situ soil lined ponds" section above.
    - Preparation of the subgrade for geomembrane placement to achieve a smooth firm surface with no materials that may damage the geomembrane.
    - Installation of the geomembrane by an experienced specialist contractor.
    - A high standard of workmanship for geomembrane installation, particularly welding of joints and pipe penetrations.
    - A high standard of quality control and verification testing, particularly for welding of joints, to ensure, as far as possible, that the geomembrane liner is free of defects.

- Concrete liners
  - For compacted soil secondary liner layers beneath concrete liners refer to “compacted soil lined ponds” above.
  - For in situ ground beneath concrete liners refer to “in situ soil lined ponds”, above.
  - Preparation of the subgrade to result in a smooth firm surface.
  - Construction by an experienced specialist contractor.
  - Quality control (including testing) of concrete material used to ensure compliance with the specification.
  - A high standard of workmanship particularly in relation to joints.
  - Quality control procedures to ensure the required concrete thickness is placed and details e.g. pipe penetrations correctly constructed.
- Bentonite enhanced soil lined ponds
  - As for compacted soil liners.
  - Specialist contractor required.
  - Trials and testing to determine suitability of mixing soil and required bentonite content.
  - Essential to control bentonite application rate and thorough mixing.
- Pre-cast concrete tanks
  - Tanks to be designed to appropriate standards.
  - Site investigation and design of foundations by a geotechnical specialist.

A cross reference to further detail in Section 6.0 of IPENZ Practice Note 21 would be appropriate and to Parts 2 and 3 specifically for low permeability soil liners and geomembranes. Part 4 provides advice for ponds and tanks on peat and contains general information particularly relevant to pre-cast concrete tanks.

4.6 Leak detection systems

The intention of the performance standard approach is that DEPs are designed and robustly constructed to minimise leakage. Therefore it is not envisaged that a leak detection system will be required for most ponds.

For ponds in particularly sensitive locations a leak detection system may be appropriate, but this is expected to be in exceptional circumstances and subject to site-specific design.

4.7 Existing ponds: estimated leakage

Estimated leakage from existing ponds has been calculated for a conventional 250 cow, two pond treatment system when the ponds are full (Table 5). The ponds are assumed to have a permeability of $1x10^{-9}$. Estimated leakage from the anaerobic pond (smaller area, greater depth/head) is similar to leakage from the aerobic pond (smaller head/driving force, but larger surface area).

Based on a per cow effluent estimate of 50-70 L/day (IPENZ Practice Note 21, Part 1, Section 5.6.3) the effluent going into the treatment system per day would be between 12-18 m^3/day. The estimated leakage is therefore 2-3%.

Table 5: calculated leakage rates

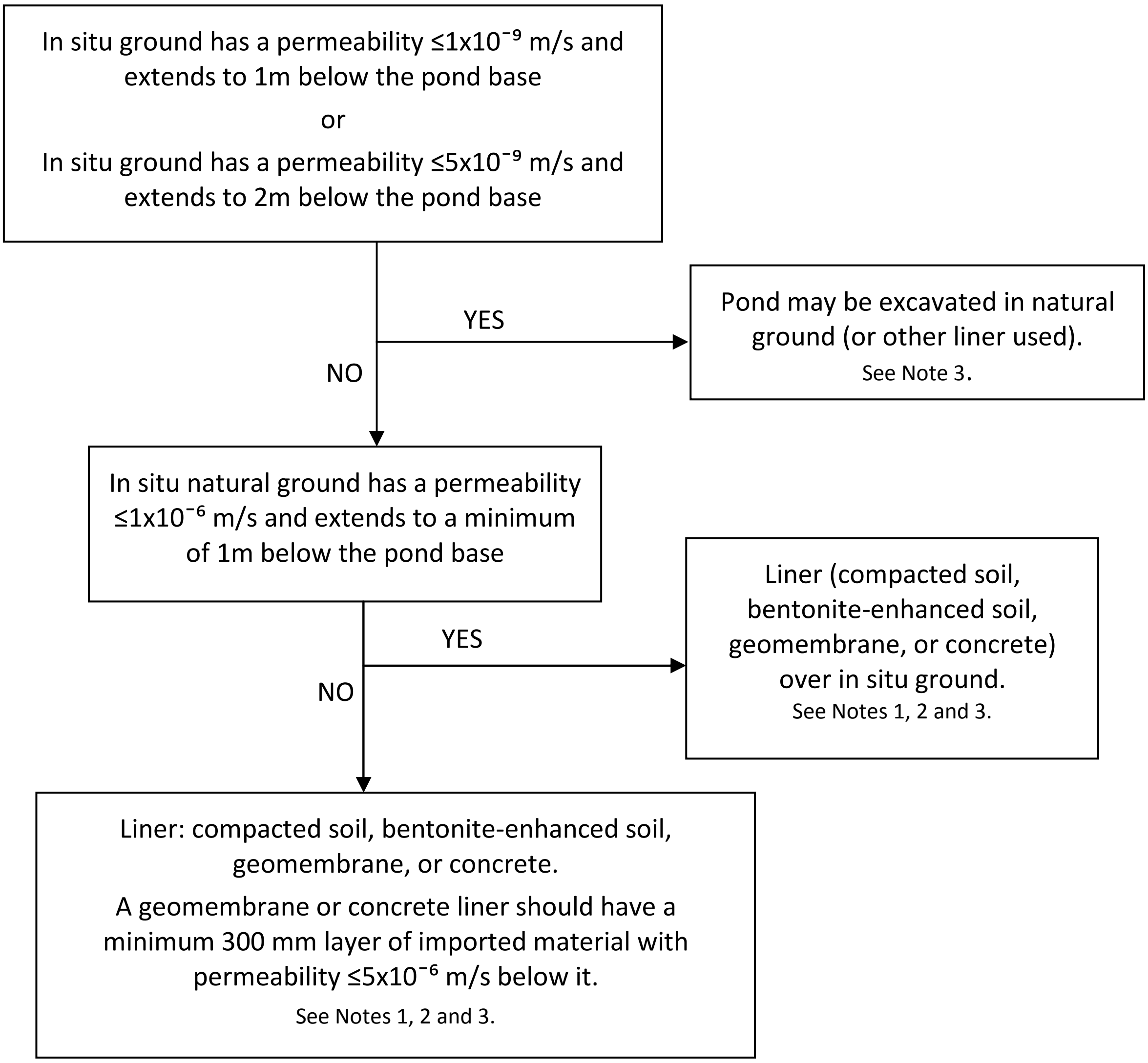
Pond	Depth (m)	Surface area (m^2)	Average depth (m)	Leakage (m^3/s)	Total leakage (m^3/day)
Anaerobic: 4 m water depth, top bank dimensions 20x33m, slope 2:1 (i.e., approx. 9 m from top of bank to base of pond), pond floor dimensions 2x15, approximate pond surface area 540 m^2.	Base	30	4	4×10^{-7}	0.37
	Side slopes	590	2	3.9×10^{-6}	
Aerobic: 1.2 m water depth, top bank 24 x 55 m, pond floor 17 x 48, approximate pond surface area 1,190 m^2.	Base	816	1.2	3.2×10^{-6}	0.35
	Side slopes	418	0.6	8.4×10^{-7}	

4.8 Recommendations

We recommend the DEP guidelines are updated to include a performance standard for leakage from new ponds (see Section 4.2.2). The performance standard can be provided as a set of minimum standards for different liner types (see Section 4.3).

Good construction practices and quality control are required to ensure a new pond meets the performance standards (see Section 4.5). Documentation of construction can then be provided to TRC to demonstrate compliance. This provides a verifiable method to ensure that a new DEP meets the leakage performance standard.

The appropriate pond liner type for a given site is based on the permeability of the in situ material, as shown in the flow chart (see Figure 2).



Notes:

1. If ground settlement is expected, a concrete liner is not recommended.
2. If ground gas is expected and a gas venting layer is required, and/or groundwater drainage is required, this should not be directly beneath a geomembrane or concrete liner but should be beneath the secondary soil liner.
3. Precast concrete tanks may be used in any location subject to design of suitable foundations to ensure stability and to prevent unacceptable settlement.

Figure 2: Flow chart for selection of suitable pond liner (normal environmental sensitivity)

5 Environmental considerations for siting new DEPs

5.1 Summary of existing TRC guidelines

The existing TRC guidelines include a brief section on positioning the pond system. The main guidelines and recommendations are:

- Buffer distances: pond must be more than:
  - 150 m from a dwelling.
  - 45 m from the farm dairy.
  - 20 m from the boundary.
- Discharge to surface water requires 1:100 dilution at all times.
- Soils must be impermeable or the ponds must be made impermeable using imported material.
- Aerobic ponds should be in open (wind and sun) areas and both ponds must be accessible to desludging vehicles.
- Minimise stormwater catchment and divert roof runoff away from ponds.
- Avoid:
  - Areas prone to flooding or freezing.
  - Steep slopes running toward a waterway.
  - Springs and boreholes.
  - Areas that are pipe-drained, mole ploughed, or have been recently disturbed.

5.2 Additional considerations

We recommend that the guidelines should also consider the following environmental siting considerations:

- Acknowledgement that design controls required to ensure environmental protection depend on where a pond is sited in relation to sensitive features. "High end" design controls may not provide any additional protection if a pond is well sited, and some design elements may not be required for good environmental performance. This is acknowledged in IPENZ Practice Note 21, Section 4.3.
- **Sensitivity of location**. In some instances it may be appropriate to have a higher level of control on pond design to ensure a lower level of seepage, e.g., a combination of highly permeable gravels, high groundwater table, proximity to a groundwater bore, proximity to a groundwater-fed stream.
- **Depth to groundwater**. Ponds must be above the water table. If this is not possible, specific controls must be implemented (refer IPENZ Practice Note 21 Section 5.10.1).
- **Distance from groundwater wells**. The IPENZ Practice Note 21 recommends ponds are more than 90 m from drinking water wells. In highly permeable soils (e.g., Coastal Lowlands), a greater distance may be appropriate.
- **Distance from surface water**. The guidelines acknowledge some ponds are designed to discharge to surface water, and that site specific assessment of effects and resource consent is required for new ponds that are designed to discharge to surface water. If ponds are not designed to discharge to surface water, it may be appropriate to include a buffer distance from surface water. None of the guidelines reviewed include a recommended buffer distance from surface water. An appropriate buffer distance would be site specific.

- **Size of pond.** Potential risk to the environment will be partly based on the size of the pond. Larger ponds have potential for greater environmental effects, and extra care should be taken in selecting an appropriate site to minimise this risk.
- **Distance from trees**. IPENZ Practice Note 21 recommends ponds are at least 20 m or two-thirds of the tree height from trees, to prevent debris and damage from roots penetrating pond walls.
- **Odour**. With respect to the prevailing wind direction, preferably locate ponds downwind of dwellings where possible.

5.3 Recommendations for additions to TRC guidelines

TRC may wish to include the following additional guidelines regarding siting new ponds:

- The appropriate level of design control depends on where the pond is sited in relation to potential environmental receptors (depth to groundwater and distance to wells, proximity of groundwater-fed streams, permeability of soils).
- The pond base must be at least 1 m above the high water table. If this is not possible specific controls must be implemented (refer IPENZ Practice Note 21 (2012) Section 5.10.1).
- On the ring plain, ponds must be more than 90 m from a drinking water well. In more permeable soil, a site specific assessment should be carried out if a well is within 200 m of the proposed pond location.
- Ponds that are not designed to discharge to water must be more than 50 m from surface water.
- Ponds must be more than 20 m from trees, or two-thirds the expected height of the mature tree.
- Where possible, ponds should be downwind of dwellings with respect to the prevailing wind direction.

6 Applicability

This report has been prepared for the benefit of Taranaki Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

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Project Director

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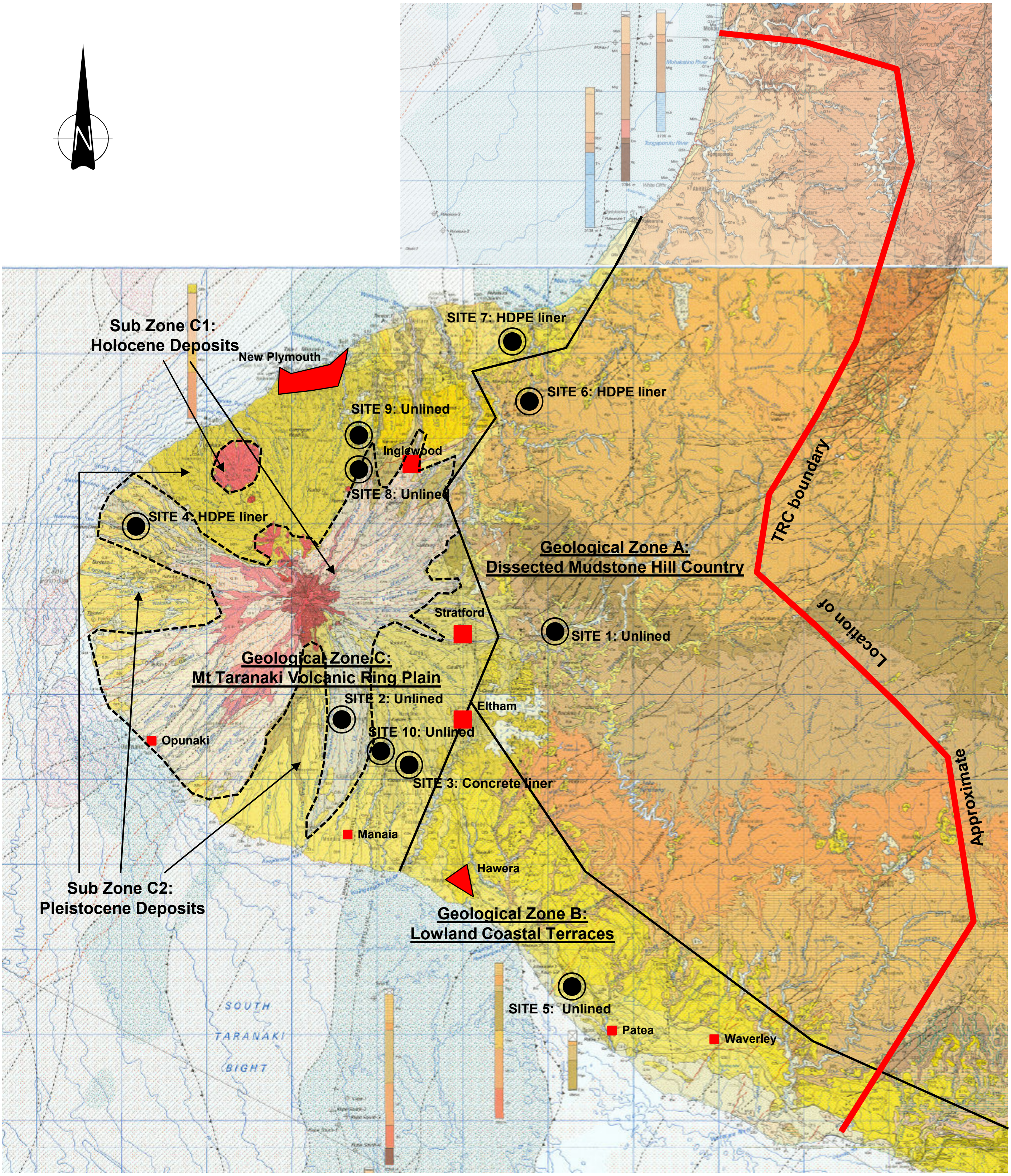
Appendix A: Figure



Sources:
Townsend et al., 2008. Geology of Taranaki Area. Institute if Geological and Nuclear Sciences 1: 250,000 Geological Map 7.

Edbrooke, S. W (compiler). 2005. Geology of the Waikato area. Institute of Geological and Nuclear Sciences 1: 250,000 Geological Map 4.

Approx Re-sized Scale (Original scale 1:250,000)

0 10 20 30 40 50 (km)

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SCALES (AT A4 SIZE)	As Shown	
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TARANAKI REGIONAL COUNCIL

Geotechnical Assessment of Dairy Effluent Ponds
Taranaki

REV. 0

FIG. No. Figure 1: Geological Terrain Zones and DEP inspection locations

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