13 August 2008

Attention: Mr S Finnigan

Dear Sean

RE: Proposed Stormwater Treatment Pond at Area 6A and 6B Takanini

1 INTRODUCTION

Following your recent request we have completed our geotechnical assessment relating to the design and construction of the proposed Stormwater Treatment Pond at the above site and generally in accordance with the Auckland Regional Council (ARC) Publication TP109 “Dam Safety Guidelines”. It is understood that the pond will be located in the north-west corner of the proposed development as shown on the appended plan.

It will be constructed mostly from cuts of up to approximately 2.5 metres; however fill batters of up to approximately 2.5 metres will need to be constructed to form the northern pond batter.

The details provided to us indicate that the pond embankments will have a crest reduced level of 13.5 metres and the base will have a reduced level of 10.5 metres. During a 1 in 100 year storm event the reduced level of the water in the pond is calculated to reach a maximum of 13.12 metres.

2 FIELDWORK AND FINDINGS

The attached cross sections were measured on site and represent the existing ground profile. It is understood that the flat area in the vicinity of the proposed pond is at a reduced level of approximately 13 metres and our analyses have been based on this.

Anticipated subsoil conditions in the vicinity of the proposed pond have been determined based on previous hand auger boreholes carried out by this Consultancy (March 2006) and Woodward-Clyde (NZ) Limited (February 2000) as attached. The boreholes encountered soft to hard clayey silts and silty clays with occasional organic inclusions at depth.

Here the thickness of the inorganic raft is variable and significantly organic materials may be encountered away from the borehole locations.

The borehole records indicate that the depth to groundwater in the immediate vicinity of the proposed pond varies from 1.1 metres to 3.3 metres below ground level.
3 SLOPE STABILITY

Based on soil type and shear vane dial readings the following parameters have been assessed to be appropriate for the materials encountered on site:

**TABLE 1: SOIL PROPERTIES**

<table>
<thead>
<tr>
<th>Description</th>
<th>$C'$ (kPa)</th>
<th>$\phi'$ (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiff certified clay filling</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>Soft to stiff alluvial materials</td>
<td>5</td>
<td>25</td>
</tr>
</tbody>
</table>

Cross-section A-A was considered to be the worst case scenario and so was analysed using the Morganstern Price method for circular slips. The analyses assessed the worst case groundwater conditions (i.e. 1 in 100 year flood level) and determined the lowest factor of safety under these conditions as well as during normal working conditions.

Full details of the stability analyses are shown on the appended computer stability result sheets (Figures 1 to 4) and a summary of critical cases is presented in the following table:

**TABLE 2: MINIMUM FACTORS OF SAFETY**

<table>
<thead>
<tr>
<th>Case</th>
<th>Conditions of Analysis (on Cross-Section A-A)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fully saturated ground conditions after development with minimal fill operations, external batter at approximately 45 degrees - worst case scenario (Figure 1)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2</td>
<td>Fully saturated ground conditions after development with certified fill embankment, external batter at approximately 19 degrees - worst case scenario (Figure 2)</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>Assumed long-term groundwater conditions after development with certified fill embankment, external batter at approximately 19 degrees (Figure 3)</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>Rapid drawdown conditions to assess internal batter stability at a gradient of 1 in 4 - worst case scenario (Figure 4)</td>
<td>&gt;2</td>
</tr>
</tbody>
</table>

The above calculations have been carried out with the internal batters of the pond at gradients of 1 in 4 (14 degrees) which is considered the maximum gradient they can be at while maintaining adequate long term factors of safety.

As can be seen from the table 2 results (case 1), if cut to fill operations are minimised as much as possible with external batters at approximately 45 degrees, then under fully saturated conditions (during a 1 in 100 year flood) minimum factors of safety drop below 1 indicating slope failure and the requirement for easing of the external batter slopes to flatter gradients. The slip circle in case 1 extends through the batter filling into the lower strength alluvial materials beneath indicating that the existing ground here needs to be replaced with engineered filling to resist failure on this slip circle.

In case 2, the northern (stream side) embankment has been formed entirely from certified fill (as indicated by the stability results of case 1) with external gradients reduced as much as possible to approximately 1 in 3 which results in a minimum factor of safety of 1.2 being calculated under fully saturated conditions. TP109 guidelines suggest maximum batter slopes of up to 1 in 2.2.
Case 3 shows case 2 under assumed long-term groundwater conditions and demonstrates that a factor of safety of 1.5 should be available as required.

Case 4 assesses the internal batter stability under temporary rapid drawdown conditions whereby the pond is rapidly drained (e.g. maintenance) while the batters remain saturated for a short time. This represents the worst case scenario here and has returned a calculated factor of safety greater than 2 which is satisfactory.

Factors of safety of between 1.2 and 1.5 are undesirable in the long term, although they would be acceptable here under such temporary extreme groundwater conditions.

4 PROJECT EVALUATION AND RECOMMENDATIONS

4.1 General

Our findings indicate that the site is generally suitable for the proposed stormwater treatment pond provided the following specific comments and recommendations contained herein are adhered to, which are generally aligned with TP109 guidelines.

4.2 Northern Berm Construction

To limit flows beneath the northern batter a seepage control (cut off) key of engineer certified fill approximately 1 metre below the pond invert, 3 metres in width and extending the length of the ponds northern boundary should be created generally in accordance with section 3.2 of TP109 (attached). The batters of this cut off key should be no steeper than 1 in 1 (45 degrees).

Toe drainage should also be provided at the base of the external toe slope to minimise the risk of piping failure. We consider that this should take the form of a hardened toe of the embankment comprising a suitable hardfill (GAP40). See TP109 figure 3.7 (attached).

Although not shown to be necessary in the slope stability analyses the minimum width of the crest as required by section 3.3 of TP109 (attached) is 3 metres or 4 metres if it is to be used as a crossing and should be suitably protected using hardfill.

The maximum internal batter gradient is assessed to be 1 in 4 (14 degrees) and the maximum external batter gradient is approximately 1 in 3 (18 degrees).

Given the measured groundwater levels it should be expected that temporary groundwater control measures may be required during pond construction. This may include but is not limited to the use of sumps and pumps. In any event an assessment in this regard would need to be made during construction.

As discussed below the near surface site materials are generally assessed to be suitable for use as filling but as they are of low plasticity and typically comprising silts. Permeability values of these materials will need to be assessed by laboratory testing. Depending on the results it may be necessary to place a clay or synthetic liner (e.g. Bentafix) on the internal batters and base of the pond to minimise seepages and erosion. Generally speaking the clay liner should be at least 0.6 metres thick. If a synthetic liner is used it will need to be protected by a rock armour covering approx 150mm thick (gabion rock grade or similar) so that pond maintenance can be carried out without damaging the pond liner.

If a liner is to be used given the existing groundwater levels it may also be necessary to install groundwater drainage measures around the perimeter of the pond to relieve external pressures on the impermeable liner.

For clay liners we should be given the opportunity of inspecting the imported clay prior to placement to check its suitability for use here.
Precautions should also be taken to ensure that the embankment is not over-topped by an appropriately designed spillway / structure.

4.3 Earthworks

Prior to earthworks being carried out, the surrounding vicinity should be cleared of vegetation. Topsoil should be stripped from all cut and fill areas, with stripping operations being planned to extend well beyond cut and fill boundaries to avoid peripheral fill contamination. Stockpiles of topsoil and unsuitable materials should be sited well clear of the works on suitable areas of natural ground.

It is anticipated that the cut materials will be suitable for use as fill in the northern pond berm and across the remainder of the site with conditioning, however if deposits of unsuitable materials (eg. organics) that are considered unfit for reworking are identified, they should be undercut and disposed of off the site or on topsoil stockpiles if appropriate.

Due to the typically variable nature of the site materials, allowance should always be made for the presence of layers of soft sensitive materials, together with groundwater, especially in the deeper cuts. These can cause problems for earthmoving plant but usually the materials become suitable for inclusion in the earthworks after conditioning.

All benching of slopes prior to the placement of filling should be in accordance with the normal requirements of NZS 4404 and related documents and should be the subject of Engineering inspections.

4.4 Compaction Control

We propose that compaction control is principally in terms of minimum allowable shear strength and maximum allowable air voids criteria.

Based on our experience, we recommend 6% maximum allowable air voids and a minimum allowable shear strength of 140kPa. However, standard compaction testing (and permeability testing) for the borrow materials is recommended prior to construction.

The in-situ moisture content of the borrow materials is expected to be slightly higher than the optimum moisture content for maximum compaction. However, our experience will dam fills indicate that materials placed and compacted slightly ‘wet of optimum’ are preferred. Therefore, minimal conditioning of the fill materials is considered necessary prior to placement and compaction.

Compaction of the filling should be carried out to certifiable standards (NZS 4431) with conventional plant and should be under Engineering control. The Engineer should not only be given every opportunity to inspect all materials prior to placement, but also to ensure adequate compaction is being achieved throughout the works.

4.5 Outlet Conduits

To avoid piping erosion, conduits running beneath the pond should be kept to an absolute minimum. Where they do run beneath the pond bunds then conventional seepage collars should be constructed at regular intervals along the pipes as recommended in TP109 Figure 2.3 (attached).

Careful compaction and backfilling will be required around all pipes and in the pipe trenches to eliminate the possibility of future piping erosion. A specification for such works should be included with the design and construction drawings.
4.6 Plan Review and Inspections

Due to the preliminary nature of the pond proposal we would like to be given the opportunity to review the final plans and revisit our evaluations and recommendations as necessary. Careful construction observations must be undertaken during construction and appropriate an appropriate Geotechnical Completion Report should be prepared confirming the work has been completed in accordance with the recommendations contained herein and the general guidelines of TP109.

Finally, it should be noted that the above analyses have been based on boreholes which by their nature only provide information about a relatively small volume of subsoils, there may be special conditions pertaining to this site which have not been disclosed by the investigation and so our continued involvement in the design and construction of the pond is recommended. In any case, if variations in the subsoils occur from those described or assumed to exist then the matter should be referred back to us immediately.

5 LIMITATION

This report has been prepared solely for the use of our client, Takanini Structure Plan Area 6 Limited their professional advisers and the relevant Territorial Authorities in relation to the specific project described herein. No liability is accepted in respect of its use for any other purpose or by any other person or entity. All future owners of this property should seek professional geotechnical advice to satisfy themselves as to its ongoing suitability for their intended use.

If you have any further queries or comments, please do not hesitate to contact the undersigned.

For and on behalf of Coffey Geotechnics (NZ) Limited

Prepared By: D A Tookey
Project Geotechnical Engineer

Reviewed By: J L Beaumont
Senior Geotechnical Engineer

Authorised By: S G Lander
Office Manager
MIPENZ, CPEng

Copies to: Nigel Hosken
Hosken & Associates Limited
P.O Box 99387
Newmarket 1149

Peter Rawson
Harrison Grierson Consultants Limited
P.O Box 5760
Wellesley Street 1141

Attachments: Woodward-Clyde (NZ) Limited Borehole Records (February 2000)
Coffey Geotechnics Borehole Records
Site Plan and Cross-Sections
Stability Analyses Results
TP109 Supplementary Notes
Appendix 1

Woodward-Clyde (NZ) Limited
Borehole Records (February 2000)
Woodward-Clyde

DRILL HOLE LOG WCHA200

Woodward-Clyde [NZ] Ltd
355 Queen Street Auckland
Phone 09 355 1300
Fax 09 355 1333

Project No.: AAAA2747000007/002
Project Reference: Takanini Structure Plan

Drilling Contractor:
Drill Type: 50mm Handauger
Logs By: NS and LL
Checked By: MH
Log Date Started: 4-2-08
Log Date Finished: 4-2-08
Client: Papakura District Council

Relative Level: mRL
Coordinates: mN, mE
Permit No.:

<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>DRILL RUN (m)</th>
<th>FIELD SHEAR STRENGTH (kPa)</th>
<th>PENETROMETER BLOWS (n)</th>
<th>SAMPLING AND OTHER TESTING</th>
<th>GROUND WATER DATA AND COMMENTS</th>
<th>PEIZOMETER CONSTRUCTION DEPTH (m)</th>
<th>DESCRIPTION OF STRATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70/22</td>
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<td></td>
<td></td>
<td></td>
<td>0</td>
<td>Black peaty and orange Silt [FILL]</td>
</tr>
<tr>
<td></td>
<td>58/19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0m, becomes moist.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>77/32</td>
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<td></td>
<td></td>
<td></td>
<td>1.2m, becomes light cream grey.</td>
<td></td>
</tr>
<tr>
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<td>56/18</td>
<td><a href="mailto:GWL@1.5m">GWL@1.5m</a></td>
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<td></td>
<td></td>
<td>From 1.5m occasional streaks black peat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>58/35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cream CLAY, plastic, moist, moderately firm drilling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>64/24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>From 1.6m occasional peat as spongy brown wood fragments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:EOB@2.2m">EOB@2.2m</a>: TARGET DEPTH</td>
<td></td>
</tr>
</tbody>
</table>

REMARKS:
1. Shear Vane OP.2518
2. Borehole located approx 200m beyond the Northwest end of Takanini School Road
3. Scrubby area with rough surface suggesting veneer of fill
Woodward-Clyde

DRILL HOLE LOG WCHA204

Woodward-Clyde NZ Ltd
385 Queen Street, Auckland
Phone 09 355 1300
Fax 09 355 1333

Project No.: AAAAA2747000007/002
Project Reference: Takanini Structure Plan

Drilling Contractor: Papakura District Council

Drill Type: 50mm Handauger
Logged By: NS and LL
Relative Level: mRL

Checked By: MH
Coordinates: mNI

Date Started: 11-2-00
Date Finished: 11-2-00
Permit No:

TAKANINI

<table>
<thead>
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<th>SAMPLE TYPE</th>
<th>DRILL RUN (m)</th>
<th>FIELD SHEAR STRENGTH (kPa)</th>
<th>SAMPLING AND OTHER TESTING</th>
<th>GROUND WATER DATA AND COMMENTS</th>
<th>PNEUMATIC CONSTRUCTION</th>
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</thead>
<tbody>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>102/40</td>
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<td></td>
<td>110/50</td>
<td></td>
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</tr>
</tbody>
</table>

DESCRIPTION OF STRATA

0

TOPOSOIL

1

Dark brown orange SILT. Dry, stiff drilling. [TAURANGA GROUP ALLUVIALS]

2

Light grey CLAY. Moist, hard drilling

EOB @ 2.2m: TARGET DEPTH

REMARKS:

i) Shear Vane DR2918
ii) Topography lowlying, rising slightly to North
### Drill Hole Log WCHA205

**Woodward-Clyde**

**Project No.:** AAAA2747000007/002

**Client:** Papakura District Council

**Drill Type:** 50mm Handsauger

**Loggeo By:** NS and LL

**Checked By:** MH

**Date Started:** 17-1-08

**Date Finished:** 17-2-08

---

<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>DRILL RUN (m)</th>
<th>FIELD SHEAR STRENGTH (kPa)</th>
<th>PENETROMETER BLOWS (N)</th>
<th>SAMPLING AND OTHER TESTING</th>
<th>GROUND WATER DATA AND COMMENTS</th>
<th>PIEZOMETER CONSTRUCTION DEPTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>77/28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>65/28</td>
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<td></td>
<td>57/35</td>
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<td><a href="mailto:GVL@1.3m">GVL@1.3m</a> 17/2/00</td>
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<tr>
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<td>70/40</td>
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<td></td>
<td></td>
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<td>73/38</td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

---

**DESCRIPTION OF STRATA**

- **TOPSOIL**
  - Dark brown orange Silt: Dry, firm drilling (TAURANGA GROUP ALLUVIALS)

- **ORGANIC**
  - Black brown organic CLAY: Foul, moist
    - Organic content comprises amorphous matrix material

- **LIGHT GREY CLAY, FIRM**
- **NON ORGANIC**

**REMARKS:**
- i) Shear Vane DR2918
Appendix 2

Coffey Geotechnics
Borehole Records
Client: Takanini Structure Plan Area 6 Limited

Project Location: Area 6A & 6B Plan Change
Takanini Structure Plan

Job Number: 12635

Auger Borehole No. 25
Sheet 25 of 31

Drilled By: PMS
Processed By: DAB
Date: 3.3.06

Borehole Location:

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Standing Water Level</th>
<th>Vane Dial Reading</th>
<th>Soil Sensitivity</th>
<th>Sample and Laboratory Test Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>138</td>
<td>9.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>119</td>
<td>6.6</td>
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<tr>
<td>1.5</td>
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<tr>
<td>2.5</td>
<td>84</td>
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<td>3.0</td>
<td>90</td>
<td>2.1</td>
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<td>3.5</td>
<td>30</td>
<td>1.4</td>
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<td>4.0</td>
<td>50</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Topsoil
- Natural: Stiff, non-plastic, brown slightly fine sandy Silt
- Stiff, slightly plastic, light brown streaked orangish brown slightly fine sandy slightly clayey Silt
- Becoming orange/brown streaked light grey/white
- Stiff, moderately plastic, orange/brown streaked light grey/white slightly fine sandy slightly clayey Silt, with occasional minor woody inclusions
- Becoming light orange/brown streaked light grey
- Stiff, very plastic, light orange/brown streaked light grey silty CLAY, with occasional minor to moderate woody inclusions
- Stiff, moderately plastic, light orange/brown streaked grey fine sandy clayey Silt
- Becoming brown
- Becoming soft, damp
- E.O.B. at 3.0 metres.

SOIL DESCRIPTION

Comments: Groundwater not encountered

Borehole Diameter: 50mm

Checked:

Foundation Engineering
Client: Takanini Structure Plan Area 6 Limited
Project Location: Area 6A & 6B Plan Change
Takanini Structure Plan
Job Number: 12635

Borehole Location: mN  mE  Ground R.L.
Description: Refer to site plan

SOIL DESCRIPTION

TOPSOIL:
NATURAL: Stiff, non-plastic, brown slightly sandy SILT

Stiff, slightly plastic, orange streaked light brown slightly clayey very fine sandy SILT

- becoming firm
- becoming damp
- becoming light grey orange/ brown
- becoming orange/ brown and limonite stained grey with occasional minor siltstone clasts
- becoming orange/ brown streaked and limonite stained brown
- becoming brown
- with occasional major wood Inclusions

E.O.B. at 2.85 metres. Too stiff to auger further. Suspected log.

Comments: Groundwater encountered at 2.8 metres.
Client: Takanini Structure Plan Area 6 Limited
Project Location: Area 6A & 6B Plan Change
Takanini Structure Plan
Job Number: 12635

SOIL DESCRIPTION

TOPSOIL
NATURAL: Stiff, non-plastic, brown slightly fine sandy SILT
  - becoming white mottled brown ashy silt
  - becoming orange/brown

Still, slightly plastic, dark brown (organic stained) slightly fibrous clayey SILT
  Firm, moderately plastic, orange/brown streaked brown slightly fine sandy clayey SILT, with occasional minor woody inclusions
  - becoming white speckled and orange/brown streaked light grey
  - becoming damp

Still, slightly plastic, orange/brown slightly clayey very fine sandy SILT, moist
  - becoming orange/brown streaked brown/grey

E.O.B. at 1.8 metres. Too stiff to auger further.

Sample and Laboratory Test Details

Auger Borehole No. 29
Sheet 29 of 31

Drilled By: PMS
Processed By: DAB
Date: 6.3.06

Legend
Depth (m) Water Level
Standing

Sample and Laboratory Test Details

Topsoil
Fill
Gravel
Siltstone
No Core
Organic
Limestone
Pumice
Volcanic

Comments:
Groundwater not encountered
### SOIL DESCRIPTION

**TOPSOIL**

- **NATURAL**: Stiff, slightly plastic, brown mottled brown slightly fine sandy slightly clayey SILT
  - becoming limonite stained and orange/brown streaked grey
  - becoming black and orange/brown mottled
- Stiff, slightly plastic, light grey and orange/brown streaked cream clayey SILT
- Soft, moderately plastic, dark brown clayey SILT, moist with frequent black fibrous woody inclusions
- Soft, slightly plastic, brown very fine sandy slightly clayey SILT, wet
  - becoming silt grey
  - becoming saturated (seepage)

**E.O.B. at 2.2 metres. Too stiff to auger further.**

### Comments:
Groundwater encountered at 1.6 metres.
Client: Takanini Structure Plan Area 6 Limited

Project Location: Area 6A & 6B Plan Change
Takanini Structure Plan

Job Number: 12635

Auger Borehole No. 31
Sheet 31 of 31

Drilled By: PMS
Processed By: DAB
Date: 6.3.06

Legend

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sounding Water Level</th>
<th>Value</th>
<th>Soil Sensitivity</th>
<th>Sample and Laboratory Test Details</th>
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<tr>
<td>5.5</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

SOIL DESCRIPTION

TOPSOIL

NATURAL: Still, slightly plastic, orange/brown slightly fine sandy slightly clayey SILT

- becoming orange/brown streaked light orange/brown
- becoming orange/brown streaked light grey/cream

Still, slightly plastic, orange/brown streaked light grey slightly clayey fine sandy SILT

Still, slightly plastic, grey very medium slightly clayey very fine sandy SILT

- becoming orange/brown streaked grey, damp

- becoming white speckled and orange/brown streaked brown

- becoming saturated

- becoming grey streaked orange/brown

Still, slightly plastic, blue/grey slightly clayey very fine to medium sandy SILT
(weathered sandstone)

E.O.B. at 4.4 metres. Too stiff to auger further.

Comments:
Groundwater encountered at 3.2 metres.

Foundation Engineering
Appendix 3
Site Plan and Cross-Sections
Material: Certified Fill
- Strength Type: Mohr-Coulomb
- Unit Weight: 19 kN/m³
- Cohesion: 16 kPa
- Friction Angle: 32 degrees

Material: Soft Alluvium
- Strength Type: Mohr-Coulomb
- Unit Weight: 17 kN/m³
- Cohesion: 5 kPa
- Friction Angle: 25 degrees

File Name: Proposed Pond no extra filling

Analysis Methods used:
- GLE/Drainage-Para with shear force function: Half Time

---

client: Fraser Thomas Limited

project: Takanini Structure Plan

title: Fully Saturated - Minimal Filling

project no: GEOTNEWP 12635

figure no: FIG 1
Material: Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 17 kN/m^3
Cohesion: 5 kPa
Friction Angle: 25 degrees

Material: Soft Alumina
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m^3
Cohesion: 10 kPa
Friction Angle: 32 degrees

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<td>figure no</td>
<td>FIG 3</td>
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File Name: Proposed Pond Rapiddrawdown
Analysis Methods used:
GLEMarhesten Piece with interface force function: Half Sine

Material: Certified Fiss
Strength Type: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 10 kPa
Friction Angle: 32 degrees

Material: Soft Alluvial
Strength Type: Multi-Cohesion
Unit Weight: 17 kN/m³
Cohesion: 6 kPa
Friction Angle: 25 degrees

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approved
date 2/08/2008
title:
project no: GEOTNEWP 12635
software Slide Ver 5.035

client: Fraser Thomas Limited
project:
area 6
Takanini Structure Plan

Rapid Drawdown - Internal Batter Stability

figure no: FIG 4
2.0 Dam concept
The dam concept can be described as the overall type, purpose and size of the proposed dam, as well as possible effects. Questions to consider include:

1. What will the dam be used for?
2. What will any water or other stored material be used for?
3. Will the storage be permanently full, or will levels fluctuate up and down?
4. How much stored water will be required?
5. Is there sufficient stream flow to meet my needs?
6. If water is to be taken from the dam, how will this be achieved?
7. Will the extent of flooding caused by the reservoir affect others or myself?
8. How can provision for a spillway best be achieved for a given site?
9. Will the dam and ground around it provide an adequate seal?
10. How will / provide for any permanent flow bypass?

These questions must be answered during the design process. Additional questions may also arise. Often examination of other dams in the area will provide useful background knowledge for answering these questions.

3.0 Dam components
A dam consists of several main components which must work together to ensure safe operation of the structure. Often it is the connection or interface between the different components that are the weak points in the dam design. The main components of a dam and the design criteria for each are:

- Storage
- Foundation
- Embankment
- Spillways
- Pipes and conduits

In many situations the criteria given below could be unduly conservative. Obtaining expert engineering input will typically result in a more optimum, and hence cheaper design by addressing site specific issues.

3.1 Storage
The purpose of most dams is to store water for use. The volume of storage and extent of flooding caused by the storage must be assessed. In the case of decorative ponds and dams, the volume of storage may not be an issue.

To determine the approximate characteristics of the dam storage a calculation guideline is provided in Figures 2.6 and 2.7 at the back of this part of the guideline.

3.2 Dam foundation
The foundation of a dam is the natural soil or rock on which it stands. A clean stable foundation of adequate strength is vital for dam durability and performance. An adequate seal must be formed to reduce leakage from the dam - it may not fill or else the seepage may cause instability.

Key foundation requirements are:

- remove all topsoil and organic material from beneath the dam footprint;
- remove any soft materials like peat or swampy deposits (unless expert engineering advice is obtained on the design);
- excavate a cutoff trench or 'key' under the dam, more-or-less under the crest line of the dam. The cutoff should extend a minimum of 1.0m into firm natural material, be at least 3.0 m wide and have batter (side) slopes no steeper than 1 vertical to 1 horizontal (1 in 1). Extend the key right across the valley and up the side to at least the full water level;
- pipe any springs or seepages encountered in the downstream half of the dam footprint to the downstream toe.
3.3 Embankment

The dam embankment, or fill, forms the blockage behind which the stored material accumulates. The embankment must be formed from clean clays and/or silts free of topsoil or vegetation. The fill should be placed at a consistency and moisture content so as to achieve high compaction standards.

The embankment profile should meet the following minimum standards:

- **Crest**
  - width to be not less than 3.0m if not used as a crossing
  - width to be not less than 4.0m if used as a crossing
  - surface to be protected by metal or other suitable material

- **Slope angles**
  - The upstream and downstream face should be no steeper than:
    - 1 vertical to 2 horizontal for dams under 1.5m in height
    - 1 vertical to 2 horizontal for dams above 1.5m in height.

- **Additional height**
  - An allowance for settlement of the dam fill should be made by slightly increasing the dam height by an extra 10%.

Note: Tracked vehicles should not be used for compaction of dams greater than 2.5m in height.

- **Fill volumes**
  - The volume of fill required to build a dam increases rapidly with height. The cost of the dam will similarly increase. Normally, fill for the dam embankment is taken from inside the area that will become the storage reservoir. This increases the volume of stored water behind the dam without the need for increasing the dam height.
  - Approximate fill volumes can be estimated using the method in Figures 2.8 and 2.9.

3.4 Spillways

Adequate spillways are crucial for the safe operation of dams. Two spillways should be incorporated into the dam design - normal (service) and flood spillways. In some instances this may be impractical, in which case specific design input will be required. Wherever possible the spillways should be constructed in firm natural ground to the side of the dam. The gradient of the spillways should be kept as flat as possible.

1. **Normal or 'service' spillways**

This spillway takes the normal stream flows. Set the inlet of the service spillway at the normal full storage water level and size it to take several times the mean winter flow.

The service spillway should consist of:

**Table 2.1: Spillway Type and Typical Dimensions**

<table>
<thead>
<tr>
<th>Spillway Type</th>
<th>For dams with a catchment</th>
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<tbody>
<tr>
<td></td>
<td>less than 20 hectares</td>
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<tr>
<td>Either a pipe</td>
<td>200mm diameter</td>
</tr>
<tr>
<td>or a 1% round fluent</td>
<td>400mm wide</td>
</tr>
<tr>
<td>or similar sized permanently (eg concrete) sheet channel</td>
<td>300mm wide</td>
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</tbody>
</table>

*If a flume is to be used, a single section of pipe or similar should be installed at the inlet to limit the flow in to the flume.

**Construction standards:**

- Bed the downstream portion of the piped spillways from the dam crest onwards, onto a suitable drainage material such to minimise erosion/dissipate energy.

- Keep the gradient and orientation of the spillway as consistent as possible. Changes in direction can cause the flow to jump out of flume spillways or damage pipe spillways.

- Site the inlet of the spillway so as to limit the possibility of blockages.

- Locate the outlet clear of the downstream toe of the dam and align it to direct flow into the stream downstream of the dam. Position the outlet so as to minimise erosion. Discharging the flow into an old trough set in the ground, or onto large boulders can help achieve this.
3.5 Pipes and conduits

Pipes are often put through the bottom of the dam for drawing of water but pipes through dams can be weak points for seepage, causing erosion of the dam fill.

Pipes through dams should meet the following requirements:

- Dig them into the natural materials under the dam, wherever possible.
- Install cut off collars (or similar) around the pipe along the upstream half of the pipes length. Use at least one collar for dams of less than 2.5m in height, and at least two for higher dams.
- Place drainage material (e.g., mm diameter gravel) along the pipe for the downstream half of its length.
- Hand compact the fill around the pipe to ensure the pipe is not damaged.

Details for the design of conduits through an earth fill embankment are shown in Figure 2.3. Alternative designs are possible, with engineering input.

4.0 Dam construction

The following section gives brief details on good practice in small dam construction. If any difficulties are encountered during construction, an engineer experienced in dam design and construction should be contacted.
and the surrounding fill can result in differential settlement. This will produce potential leakage paths along the line of the conduit, which in the worst case will enlarge with time, leading to failure. In addition, it is very difficult to adequately compact around conduits, exacerbating the problem.

Again, the classical approach was to try and stop seepage along conduits, typically with the use of cut-off collars. Cut-off collars along the upstream portion of the conduit will retard flow and provide a degree of support for the conduit, but the same problem of adequate compaction remains for material either side of the collars. For this reason cut-off collars should not be relied on as the only means of controlling seepage, though they are still applicable in many situations. In many situations alternative measures are more applicable such as the use of concrete encaissement or bedding. Another alternative for smaller dams would be compacted soil / bentonite mixes. The downstream section should however always be drained in a controlled manner. This ensures these seepage flows that will occur do not erode the fill material around the conduit. A typical detail using collars is shown in Figure 3.8.

**Pressurised conduits**

The use of pressurised conduits through dams should be avoided whenever possible. If their use is unavoidable, their design and construction must be considered very carefully. Because settlement of the dam fill or underlying foundations can cause stress or distortions to conduits passing through the dam, in the case of pressurised conduits high water pressures, equivalent to the water level in the reservoir, could be released into the sensitive dam interior. For this reason pressurised conduits are seldom used for large dams.

There is no definitive rule for when pressurised conduits pose a significant risk. The strength of the foundations, type of conduit and conduit purpose all influence the suitability of pressurised conduits.