Rangitaiki River Stopbanks Assessment

Moore Road Seepage Problems

Prepared for

Environment Bay of Plenty

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ICE GEO & CIVIL

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Contents

1 Introduction

The owner of the farm bounded to the south by Thornton Road and to the east by the West Bank Road, has reported springs in the base of his farm drains to Environment Bay of Plenty (EBOP) (Figure 1). Initial investigations by EBOP staff found there were six springs in a 100m length of drain issuing up to an estimated 20 litres/minute each. The farmer also commented on his inability to establish good pasture in this part of the farm. The EBOP staff found that the water in the farm drains had roughly half the salinity of salt water.

As the drains containing the springs are within 150m of the Rangitaiki River it was considered by the EBOP staff that the conditions which allow the formation of springs could pose a threat to the stability of the stopbank along the river. Ice Geo and Civil has been engaged to investigate the causes of the springs and the possible need for remedial measures to protect the integrity of the stopbank.

This report presents the following information:

- the results of insitu investigations,
- the results of seepage analyses for normal and flood conditions in the river and
- possible remedial measures to protect the stopbank.

This report is the property of our client, Environment Bay of Plenty and Ice Geo and Civil. The comments within relate only to the length of stopbank on the left bank of the Rangitaiki River between Thornton and Moore Roads.

2 Site Description and Background

The paddocks containing the farm drains and springs are within one of the lowest lying areas of the Rangitaiki Plains. They lie within a shallow basin bounded by the West Bank and Thornton Road formations and what appears to be the landward extent of the coastal dunes. The paddocks are roughly 1km from the Rangitaiki River mouth. The water level in the adjacent river varies with the tide under normal flow conditions. A small wetland area has developed in one of the paddocks about 80m from the river.

Figure 2 shows a cross section of the paddock surveyed in July 2007. It can be seen that the typical ground level is 0.1 to 0.2m below the Moturiki Datum. Mean sea level at the Moturiki Datum is 0.07m, therefore the paddocks lie just below sea level. The mean high tide level is 0.79m therefore the invert of the farm drain at 57m on Figure 2 is 2.34m below the high tide level. The road side drain at 178m is about 200mm shallower. The invert of the farm drain is 3.85m below the estimated 100 year return period flood in the river which peaks at 2.3m Moturiki. The drains flow to the south side of the highway where there is a pumping station.

The sides of the farm drains show layers of peat and clayey silts. The inverts of the deeper drains have been formed in a layer of light grey silt. Small cones of a coarser grey sand have formed in the drains around the small springs. The location of the springs appears to tend towards the river side of the drains. There is a cycle of the springs causing erosion at the base of the drains and collapse of the sides of the drains. There is evidence of springs ceasing to flow and new springs forming near by. It is considered that this could be due to the springs eroding a pipe which collapses when it reaches a certain size, blocking the flow. Water pressure would then build up until a new spring is formed at a weak point in the silt.

Inspection of the road side drain showed similar soil conditions and spring formation and collapse processes. One spring had a piped hole leading towards the river.

As salt water is heavier than fresh water it will displace fresh water. EBOP have recorded salt water below surface fresh water in the Rangitaiki River adjacent to the site. If the flow of sub-surface fresh water towards a coast is insufficient to keep the salt water at the coast, the sea water will gradually intrude landward into the ground water system. This intrusion will be accelerated by lowering of the fresh water ground water level. The ground water in the Rangitaiki Plains has been lowered by pumping over many decades for farming proposes. It is considered that in the area near the coast this pumping is accelerating the salt water intrusion process as there is minimal fall of the land, and hence fresh ground water flow, towards the coast.

The farmer in the problem area has noticed a worsening of his pasture in recent years. This could correspond to a significant lowering of the ground water level by the pump drainage system about three years ago. At the time of the July survey the water level in the drains was between -1.0 and -1.2m, thus there is a considerable head difference between the drains and the sea water at the coast or the salt water in the river. The farmer has observed that the springs in the drains respond to the tide level in the river, flowing stronger at high tide.

Another indication of salt water intrusion could be a lifting of the ground level. Comparison of a survey done in 1987 with that done in July 2007 suggests that parts of the paddocks may have lifted a little, however it is also possible that the 1987 survey was not as accurate as the 2007 survey. As salt water is denser than fresh water it has more buoyancy, therefore the effective stress on submerged soil at a given point is decreased if fresh water is replaced with salt water. A decrease in effective stress can result in rebound of the soil. In a simplistic scenario with 10m of peat and the water level at the ground surface, salt water replacement could result in a 200mm rise of the ground surface. Soils denser than peat will have a lesser response.

3 Subsurface Investigations

The subsurface investigations carried out consisted of three hand augers along the cross section shown in Figure 1, one near the small wetland and one towards the higher ground to the north. The logs of the augers are included in Appendix A.

The hand augers showed a similar soil profile, consisting of layers of peat and clayey silts, to that seen in the sides of the deeper drains. These augers are also consistent with some carried out in the small paddock between the road and the river in 2006. The light grey silt layer found in the base of the drains is 150 to 400mm thick and is underlain by 200 to 300mm of fine to medium sand. It is considered that this permeable sand (which is thought to be a volcanic ash) forms an aquifer bringing water from the river to the drains and that this sand forms the cones of grey sand found in the inverts of the drains.

As can be seen in Figure 2 the depths of the various soil layers are reasonably consistent across the basin. The top of the sand layer is at between -1.2 and -1.35m (Moturiki). Consolidation due by the road formation could be the cause of the slight deepening of the sand layer towards the road. Below the sand is further peat up to at least 2.6m deep. The hand augers were stopped when the peat squeezed into the holes.

One inconsistency in the hand augers was a 200mm thick layer of black medium grained sand found at 200mm depth in HA3. This is ash from the most recent Tarawera eruption and in most places across the plains it is less than 50mm thick. It appears that this ash has been washed from the surrounding area into a shallow depression in the HA3 location. As this layer was not found in any of the other augers it not considered to be contributing to lateral ground water flows.

It was thought that some dune sand may be encountered in HA5, however thicker layers of the upper silts were found and the sand aquifer was at about the same level (-1.3m Moturiki) as at the other auger locations.

4 Analyses

4.1 Discussion

The computer programme used to analyse the seepage problems, Geo-Slope Seep/W (2004), is a two dimensional programme. Therefore three dimensional effects, such as lateral changes in the soil profile or ground water flows coming from the coast, can not be accurately modelled. The seepage analyses carried out must therefore be considered indicative only.

As it is known that the springs respond readily to changes in the level of the river, steady state seepage analyses have been carried out. This is in contrast to transient analyses where there are gradual changes due to flow through low permeability soils.

4.2 Soil Model

As the peat found on site has a similar low permeability to the clayey silt layers, the soil model has been simplified into three soil types as given in Table 1. The soil permeabilities have been assumed from testing carried out on similar soils across the Rangitaiki Plains.

Table 1: Assumed Soil Permeabilities

soil	k_h (m/s)
peat and clayey silt	1×10^{-8}
silt	1×10^{-6}
fine to medium sand	1×10^{-3}

4.3 Existing Situation

To check the soil model an analysis was carried out of the situation at the time the survey was carried out, with the water level in the river at 0.8m and that in the drains at -1.1m. The analysis showed a hydraulic exit gradient in the road drain of 2.8 and in the farm drain 0.7. The specific gravity of a pumice sand from Edgecumbe has previously been found to be 2.44 and a critical hydraulic gradient of 0.6 has been estimated. This is the hydraulic gradient at which soil particles can be washed out from a free surface. A maximum hydraulic exit gradient of 0.4 has been considered acceptable in previous stopbank stability assessments.

The hydraulic exit gradients in both drains at high tide (0.8m, as at the time of the survey) are high enough to remove soil particles and create piping and springs. If the springs did not occur at points of weakness in the silt layer overlying the sand layer, it is probably that high pressures in the sand layer would lift and crack the silt layer, possibly causing a more rapid loss of sand and eventually stopbank collapse. The pressure loss estimated in the sand layer indicates an overall hydraulic gradient away from the river of about 1% which is similar to that measured in various studies along the river in 1968.

The above seepage analysis was repeated with the river level at 0.0m (approximately mean sea level). It was found that the hydraulic exit gradients reduced to 1.6 in the road drain and 0.4 in the farm drain. Although there may still be some flow from the springs into the farm drain it would be less noticeable and would not be sufficient to move sand grains. In contrast there could still be some sand loss in the road drain.

As there is sand loss at high tide levels there will be a much more critical situation when the river is in flood. An analysis with the 100 year flood level in the river showed there is also a potential heave problem in the paddocks between the drains due to high water pressure under the low permeability but light weight peat layers.

5 Remedial Measures

5.1 Cut-Off Through the Sand Layer

As most of the flow from the river passes through the sand layer and this layer is quite shallow, the formation of a low permeability cut off through the sand layer seems the most logical solution to the seepage problems. This cut-off option was modelled. If a cut-off is installed in the base of the road drain the seepage problems in the paddock are removed but high pressures develop under the road when the river is high. A heave problem could occur in the side of the drain. If the cut off is installed along the inland toe of the stopbank similar pressure problems could develop under the toe of the stopbank. The hydraulic exit gradients within the toe of the stopbank also increase to nearly 0.6.

If the heave and hydraulic gradient problems are solved through drainage measures the cut-off could be formed by excavating a trench down through the sand and compacting clay in the trench. The problem with this option is that the sand is likely to rapidly run into the trench as soon as the protective silt layer is removed, even when the river is below mean sea level. Therefore construction could only be carried out towards low tide when there is low flow in the river, and the trench would have to be backfilled immediately after excavation with one machine excavating and another machine backfilling.

An alternative to a clay cut-off could be sheet piling. If this is carried out through the centre of the stopbank there would be no pressure or hydraulic gradient problems. The depth to the sand layer would have to be confirmed but it is likely that the sheet piles would have to be about 5m long and hence would be expensive. Shorter sheet piles could be used if they are installed below the upstream toe of the stopbank and the sandy stopbank material at the toe of the stopbank is replaced with low permeability soil (Figure 2).

An alternative to sheet piles would be mixing bentonite with the natural soil in a trench through the sand layer. This would however be expensive and as there are high flows through the sand layer careful design of the bentonite mix would be required to ensure durability.

Another problem with a cut-off option is the determination of the lateral extent of the cut off. As the sand layer seems very permeable, water could track considerable distances from upstream or downstream over the duration of a flood. Therefore as an added precaution against piping it is considered that drainage metal should be placed in the road side drain with this option.

5.2 Turning the Paddocks into a Wetland

The seepage problems that could lead to stopbank damage are caused by the low lying nature of the adjacent paddocks and the need for deep drains with a pumped outlet. The level of the ground and low permeability surface soils have resulted in boggy paddocks in the winter and salt water intrusion. It

appears that the salt water in particular could prevent good pasture being re-established.

The head difference between the water in the river and the paddocks, and hence the heave and seepage problems, could be reduced if the paddocks are allowed to flood. If the water level in the paddocks rises to +0.5m the hydraulic gradient in the farm drain reduces to an acceptable level in the 100 year return period flood. The gradient in the road drain remains unacceptably high and the drain would have to be lined with drainage metal to prevent loss of sand.

It is important that water can flow from the sand layer into the drains as this reduces the uplift pressure under the paddocks. If the drains are filled with a low permeabilty soil the pressure that develops could result in heave of the ground surface due to the low density of the peat, and possibly accelerated piping of the sand beneath. It is therefore considered that all the deep drains within 100m of the stopbank should be lined with 400mm of drainage metal.

A wetland at 0.5m would not intrude on neighbouring properties and a small bund could be formed to restrict its western extent. However the water level would be within 300mm of the surface of the West Bank Road, which could lead to deterioration of the pavement and a 200m length of road may need to be lifted. A check would also have to be made to ensure that properties in the drainage scheme upstream do not require the water level to be below 0.5m.

To reduce the problems above, a wetland could be developed with a water level at 0.0m if an additional drain is dug down to the sand layer parallel to and about 15m from the road side drain. This additional drain is to relieve the uplift pressures under the paddock and it will require lining with drainage metal. To reduce the flooded area and drainage problems for the surrounding land, the wetland at 0.0m could extend to the line of the existing farm drain and a small bund formed beyond this drain. A second wetland with a lower water level, say -0.3m, could be formed as shown on Figure 1 to act as a buffer and to reduce the differential head at the wetland boundary.

It could be possible to line the appropriate lengths of farm drains with drainage metal, graze the paddocks normally and flood the paddocks when high river levels threaten. This, however would require some EBOP input to ensure flooding is carried out at times when staff are likely to be busy. Another problem is that cleaning of the farm drains would not be possible once they are lined with drainage metal.

5.3 Overlay

Another means of preventing uplift of the paddocks is to place a soil overlay across them. The overlay should taper from 700mm thick adjacent to the road drain to natural ground level 60m away as shown on Figure 2. All the deep drains within 150m of the stopbank should be lined with drainage metal

to prevent piping problems. This option has the possible advantage of improving some of the pasture.

6 Conclusions

1. The springs occurring in the road side drain and the farm drains could eventually lead to a piping failure and collapse of the Rangitaiki River stopbank.

2. Salt water intrusion appears to be reducing the quality of the pasture within the shallow basin area.

3. The favoured remedial measure to reduce the risk of stopbank failure is to abandon the pasture, excavate a new drain 15m from the road side drain, line all the drains within 100m of the stopbank with drainage metal and create a wetland to 0.0m Moturiki Datum.

4. The formation of the wetland could affect the upstream users of the drainage scheme.

5. Other alternative remedial measures are:

    - To form a low permeability cut-off through the critical sand layer, preferably through the stopbank. The lateral extent of this cut-off requires careful investigation.

    - To place a 60m wide soil overlay up to 700mm thick across the paddocks and line the drains within 150m of the stopbank with drainage metal.

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28 July 2007

1m Contours

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Legend

1m Conoturs

250 125 0
Meters
Scale = 1:5,064

N

Figure 1: Site Plan

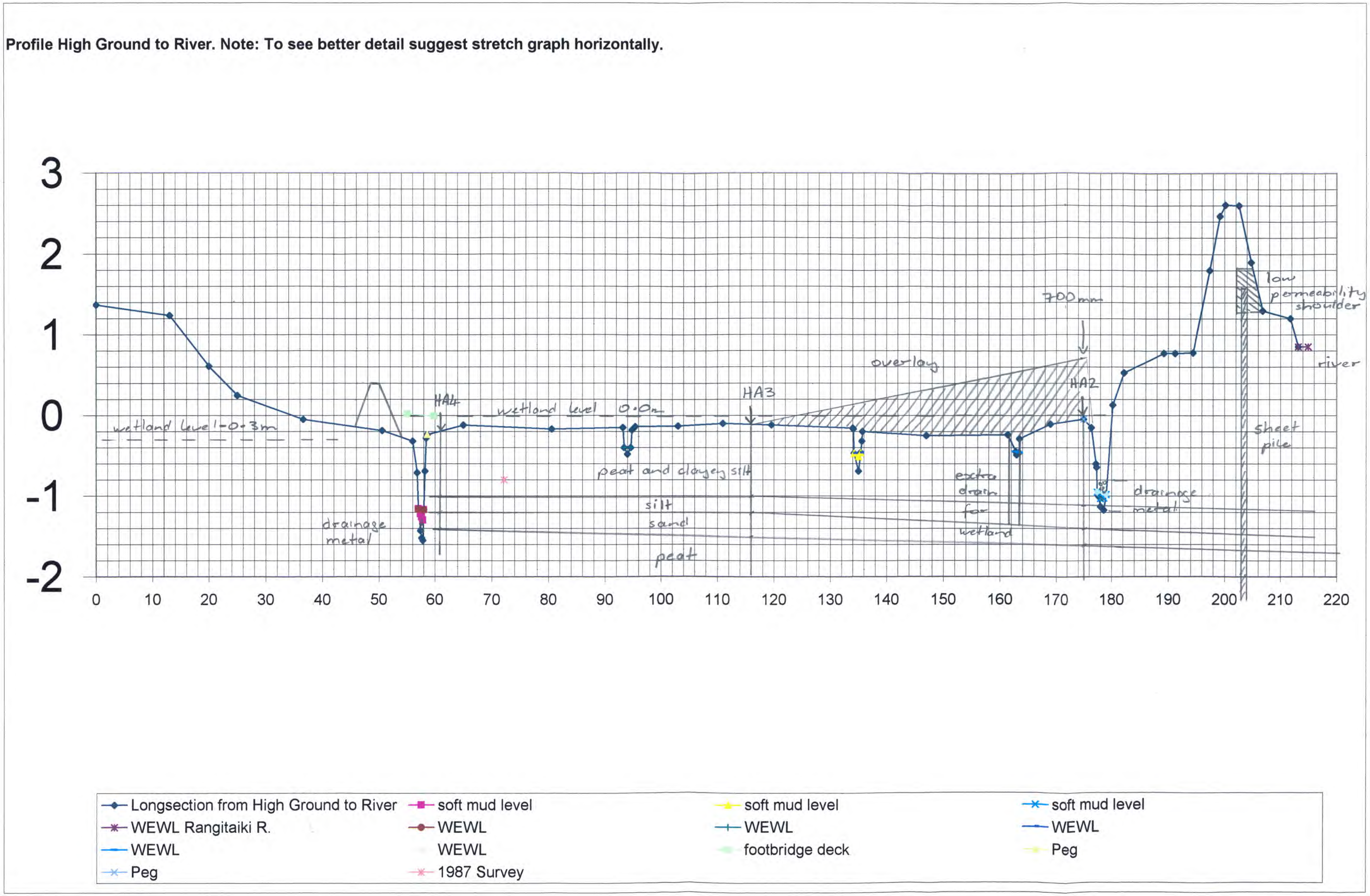

Figure 2: Long Section and Remedial Options

Appendix A

Hand Auger Logs

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Hand Auger Log

Job Name: Moore Road

Tested by: M.O'H

Test Number: HA 1

Date: 17/7/07

by springs
say RL ≈ -0.2

Blows/50mm: 0 2 4 6 8 10 12 Cu(kPa)

Depth (m)	soil description
0.00	fibrous organic material
0.05	orange stained grey clayey SILT, with fine fibrous organic material
0.35	blue grey clayey SILT
0.45	black organic clay, PEAT low perm
0.7	light grey pum. CLAY, soft
0.9	light grey pum. SILT, dilatant becoming coarser with depth
1.05	brown organic clay, PEAT, low perm
1.10	light grey fine SAND some silt over fine to medium SAND, ASH (RL -1.3)
1.3	brown fibrous homogeneous PEAT, low perm
2.6	EOB. squeezing.

Depth scale (m): 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0

C_u (kPa): 0 20 40 60 80 100 120

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Hand Auger Log

Test Number: HA2

Job Name: Moore Road

Date: 17/7/07

Tested by: M.O'H

≈RL -0.05

Blows/50mm

Depth (m)	soil description
0	brown SILT with fine organics + clayey SILT, drain cleanings
0.3	orange mottled grey clayey SILT
0.5	blue grey clayey SILT
0.7	dark brown fibrous PEAT
0.9	light grey pum. silty CLAY
1.1	light grey pum fine sandy SILT
1.25	brown PEAT
1.3	light grey silty SAND over fine → med. pum SAND, ASH (RL -1.35)
1.5	brown PEAT
2.0	brown organic clayey SILT with timber
2.2	EOB. squeezing

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0

Blows/50mm: 0, 2, 4, 6, 8, 10, 12; C_u(kPa)

C_u (kPa): 0, 20, 40, 60, 80, 100, 120

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Hand Auger Log

Test Number: HA 3

Job Name: Moore Road

Date: 17/7/07

Tested by: M.O.H

≈ RL −0.1

Blows/50mm: 0 2 4 6 8 10 12 — C_u(kPa)

Depth (m)	soil description
0.05	brown fibrous organic material
0.05 – 0.2	orange mottled grey clayey SILT, plastic
0.2 – 0.4	gritty black med. SAND, Tarawera, Ash
0.4 – 0.75	black fibrous PEAT
0.75 – 0.9	light grey pum. CLAY
0.9 – 1.05	light grey SILT
1.05 – 1.35	light grey silty SAND over fine → med. pum. SAND, ASH (RL −1.15)
1.35 – 1.7	brown PEAT
1.7	EOB

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0

C_u (kPa): 0 20 40 60 80 100 120

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Hand Auger Log

Test Number: HA4

Job Name: Moore Rd

Date: 17/7/07

Tested by: M.O.H

≈ RL −0.2

Blows/50mm: 0 2 4 6 8 10 12 — C_u(kPa)

Depth (m)	soil description
0.05	brown SILT
	cream pumiceous SILT
0.5	black fibrous PEAT
0.8	Light grey pum. SILT
0.9	Light grey pum. f sandy SILT
1.0	Light grey fine → med. SAND −1.2. ASH.
1.2	brown PEAT
1.6	EOB.

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0

C_u (kPa): 0 20 40 60 80 100 120

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Hand Auger Log

Test Number: HA5

Job Name: Moore Rd.

Date: 17/7/07

Tested by: M.O'H

≈ RL 0.5

Depth (m)	Soil description
0.0	brown SILT
0.5	orange mottled grey clayey SILT
1.15	black fibrous PEAT
1.4	light grey pum. CLAY
1.5	light grey pum. SILT
1.85	brown PEAT
1.9	light grey fine → med. SAND, ASH (≈ RL −1.3)
2.1	brown PEAT
2.55	EOB squeezing

Blows/50mm: 0 2 4 6 8 10 12; C_u (kPa): 0 20 40 60 80 100 120