Kowhai Park Stopbank Upgrading

Whanganui River

Geotechnical Assessment

Prepared for

Horizons Regional Council

November 2012

ICE GEO & CIVIL

Contents

1 Introduction

The stopbank along the Whanganui River through Kowhai Park has been built and in stages over a long period resulting in an inconsistent standard of flood protection for the local area[1]. At present much of the stopbank over this 2.1km length is not of sufficient height to provide protection in the estimated 30 year return period flood. Ice Geo and Civil Ltd has been engaged by the Horizons Regional Council to:

- assess the geotechnical aspects of the raising the stopbank to provide protection in a 30 year return period flood with 300mm freeboard and
- to comment on the security of the stopbank if it is overtopped in a greater flood.

The length of stopbank being investigated is shown on Horizons Drawings 4958 Sheet 1 and the long section showing the meterages and existing stopbank level is on Sheets 2 and 2A. The meterages referred to in this report are in accordance with these drawings. Matarawa Stream meterages are preceded by an "M".

The stopbank starts at the southern end of Kowhai Park and follows up the Matarawa Stream to the Anzac Parade Bridge; it then follows the right bank of the stream to the internal Kowhai Park Road where it turns to follow parallel to the river until it runs into higher ground about 850m upstream of the Dublin Street Bridge.

This report follows that prepared by Opus[2] following a flood in 2000 during which various areas of distress where observed along the stopbank. This report includes the following;

- a summary of Opus' findings
- information on the sub surface soil profile gained from in situ investigations,
- laboratory test results,
- the results of seepage analyses for the estimated 50 year return period flood (this level is approximately equivalent to the 30 year flood level with 300mm freeboard),
- an assessment on the slope stability of the stopbanks under normal river, peak flood and drawdown conditions,

[1] Horizons Regional Council (December 2007) Lower Whanganui River Flood Protection Investigations, Stage Two: Assessment of Flood Mitigation Options.

[2] Opus International Consultants Ltd (January 2001) Kowhai Park Stopbank, Dublin Street Bridge to Georgetti Road.

- recommendations for the design of the stopbank,
- an assessment of the damage that could be caused by overtopping and suitable preventative measures,
- comment on possible settlements due to stopbank raising and
- the estimated construction costs.

Due to the complexity of the stopbank geometry and the geology along the study length, these parameters, the seepage analyses and the construction recommendations are described in sections along the stopbank length.

This report is the property of our client, Horizons Regional Council and Ice Geo and Civil Ltd. The comments within relate only to the length of stopbank along the Whanganui River and Matarawa Stream through Kowhai Park to 850m upstream of the Dublin Street Bridge.

The conclusions of this report are based on a site walkover, the interpretation of investigations carried out at isolated points only and limited laboratory testing. Therefore there could be ground or other conditions which have an effect on the integrity of the stopbanks that have not been identified.

2 Previous Investigations

The Opus report[2] states that during the October 2000 flood a small slump occurred in the land side of the stopbank near 600m, a crack developed in the top of the stopbank at 150m and a small amount of piping was observed at 30m. Piping occurs when soil particles are washed out from the stopbank or its foundations to form a pipe allowing concentrated water flow. To investigate these areas Opus excavated four test pits in the inland side of the stopbank and 1m into the foundations soils at the stopbank toe. The approximate locations of these pits are shown marked up on Drawing 4958 Sheet 1. These test pits showed that the stopbank is constructed of locally won sands and silts. The findings of these test pits have been used in the seepage analyses discussed in following sections.

Opus also carried out scala penetrometer tests to 1.5m depth through the top of the stopbank at 50m intervals up to the Dublin Street Bridge. These identified poorly compacted layers within the stopbank along most of the length. The loosest layers were found along the Matarawa Stream, between the internal park road and Anzac Parade and between 500 and 700m. Opus recommended various options to improve the integrity of the stopbank and ranked the order of priority for the improvement work in four sections.

Four scala penetrometer tests were carried out upstream of the Motor Boat Club building for comparison purposes as it was known that this section of stopbank had been properly designed and constructed. The results were comparable to the better compacted sections of stopbank downstream.

Opus carried out some nuclear densometer tests in the test pits and some particle grading and compaction tests on various soils in the laboratory.

Following the Opus report stopbank upgrading was carried out in 2001 along the Matarawa Stream section (M96 to M220m) and from 480 to 660m[3]. The work consisted of building a new stopbank along the right bank of the Matarawa Stream with a broad (6m) crest. A 1m high, 2m wide buttress was built along the inland toe of the stopbank from 480 to 660m where space allowed. There is insufficient width for a buttress between the park road and the stopbank near the bridge over the stream.

3 Geology and Soil Investigations

3.1 Geology

The geology through the park consists predominantly of alluvial sands, silts, clays and gravels. These have been laid down by the river and stream in flood and then erosion and scouring have occurred before the next layer is laid down. This process leads to large changes in particle size within small horizontal and vertical distances.

There have been some significant amounts of fill and roading material placed along the riverbank since European settlement. Much of this was found upstream of the Dublin Street bridge and around the playground area. Aerial photographs taken in 1942 appear to show several small drainage channels joining the river. These have been replaced with many stormwater pipes passing beneath the stopbank to discharge into the river and stream. The remnant drainage channels may have been filled with landfill type material such as broken brick, clay and gravel.

Some organic rich clay layers were found at depth but no peat was found and the surface soil is predominantly silt with a low organic content.

3.2 Subsurface Investigations

The in situ investigations carried out for this report consisted of 26 hand augers and three constant head permeability tests. The locations of the hand augers were chosen to investigate the areas of stopbank problems identified by Opus and to provide a good coverage of the study area. The locations of the augers are shown marked up on Drawing 4958 Sheet 1 and the auger logs are included in Appendix A. The soils have been logged generally in accordance with the New Zealand Geotechnical Society Guidelines[4]. The co-ordinates given on the auger logs are in terms of the New Zealand Transverse Mercator grid.

[3] Opus Drawings 5/1562/10, 7404 Sheets 1 to 4, Whanganui District Council Kowhai park Stopbank Repairs 2000/2001.
[4] NZ Geotechnical Society (December 2005) Guideline for the field description of soil and rock for engineering purposes.

The hand augers were carried out to 4m depth or until the hole collapsed due to the presence of sand below the ground water level or the holes queezed in due to the presence of soft clays. Many holes encountered hard gravel or fill layers which could not be penetrated. Several attempts near the chosen location were tried before the hole was abandoned. Some holes were augered close to the river bank as this was the only area where the auger could penetrate through to the natural soils. No augers where augered through the stopbank in the Arboretum (0 to 700m) due the presence of a gravel path at the surface. Holes which encountered sand layers on the inside of stopbanks were backfilled with bentonite.

3.3 Constant Head Permeability Tests

Constant head permeability tests were carried out in two silty fine sand layers found at the HA13 location next to the Matarawa Stream. A third test was carried out in a fine sand layer at the HA17 location at the toe of the buttress fill. Coarser sand layers were found at some other locations but these could not be tested due the sand washing into and rising up the hole, apparently under a reasonable pressure in HA19. The results of the tests are given in Table 1.

Table 1: Constant head test results

test	soil	**k** (m/s)
HA13 1.6 to 1.9m	silty fine sand	6.5×10^{-7}
HA13 2.8 to 3.2m	silty fine sand	4.6×10^{-7}
HA17 1.2 to 1.6m	fine sand some silt	1.2×10^{-6}

It can be seen from Table 1 that even though these soils are described as sands their permeability is reasonably low. These permeabilities are based on the assumption that the soils above and below the sand layers are impermeable. Therefore the derived permeabilities are slightly higher than in reality.

3.4 Laboratory Grading Tests

Six laboratory particle grading tests were carried out on sand samples taken from the hand augers to enable an estimation of their permeability using Hazen's formula.

$$k=0.01d_{10}^2$$

The test results are included in Appendix B and the results summarised in Table 2. It can be seen from Table 2 that fine sands with some silt have low permeability but the permeability increases significantly in medium sands where the voids between sand grains are incompletely filled by the silt particles.

Table 2: Estimated permeabilities

test	soil	d_{10} (mm)	d_{60} (mm)	k (m/s)
HA6 1.5m	silty fine sand, minor clay	0.003	0.09	9.0×10^{-8}
HA9a 0.3m	medium sand, trace silt	0.1	0.22	1.0×10^{-4}
HA9a 1.4m	fine sand, some silt, minor clay	0.0065	0.11	4.2×10^{-7}
HA23 1.5m	fine sand, some silt, minor clay	0.011	0.105	1.2×10^{-6}
HA23 2.1m	fine to medium sand, some silt, trace clay	0.04	0.21	1.6×10^{-5}

3.5 Critical Hydraulic Gradient

The critical hydraulic gradient is that at which soil particles begin to move as water flows through the soil. Hydraulic gradient is given by the difference in water pressure across a given distance of soil. If soil particles can move through an open soil structure or are exposed to a free surface, continued removal can lead to the formation of pipes.

For stopbanks the highest hydraulic gradient where water flows from the ground is typically at the inland toe. This is one reason for toe drains in some stopbanks and earth dams. These drains allow water to escape without losing soil particles. If a pipe is allowed to form under a stopbank or dam it can allow excess water to escape and the pipe may widen sufficiently to cause an internal collapse and breach of the structure. Therefore it is necessary to check the hydraulic exit gradients on the inland side of a stopbank to determine if piping could become a problem.

The critical hydraulic gradient of a soil is determined by its grain size, grading, density and whether it has any cohesion. Flume tests have been carried out to determine a relationship between the uniformity coefficient of a soil (d_{60}/d_{10}) and the critical hydraulic gradient[5]. The critical gradient for all the fine sands given in Table 2 is greater than 1.0, that for the fine to medium sand is 0.8 and that for the medium sand only 0.27.

This gradient can also be estimated from the following formula:

$$i_{crit} = (1 - n) \times (S_s - 1)$$

where n = soil porosity
S_s= soil particle specific gravity

Opus carried out density tests on the surface silts found at the TP3 and TP4 locations. The results of these tests gave a critical gradient of 0.84. In the seepage analyses discussed in following sections a maximum allowable hydraulic exit gradient of 0.6 has been assumed for all silty soils at the ground

[5] Fell R (2007) The mechanics of internal erosion and piping of embankment dams and their foundations. Proc. 10th Australia New Zealand Conference on Geomechanics. (Figures 16 and 18).

surface. Any sand layers that run very close to the ground surface should be removed or a low permeability cut off installed through them.

The probability of internal instability due to water flow within the soils in Table 2 is between 10 and 50%[5] (when fine soil particles are washed into voids between larger particles). Therefore the greatest risk of piping appears to be where soil can wash out from the ground surface.

4 Stopbank Geometry

Horizons has provided 25 cross sections through the stopbank in the locations shown on Drawing 4958 Sheet 1. These have been used in the seepage analyses discussed in Section 6 and in the calculation of earthworks volumes.

The crest width of the stopbank varies from about 1.2m to more than 10m. Most of the stopbank crest forms a highly used gravel footpath and this is to be re-instated following stopbank raising. The New Zealand Handbook for Tracks and Outdoor Visitor Structures[6] recommends a 2m width for urban footpaths but the Whanganui District Council requested a minimum 2.5m path along the stopbank at Balgownie in 2009. The minimum width for the use of conventional earthworks machinery is about 3m, therefore this has been adopted for the crest width of the raised stopbank.

Where the existing stopbank has steep batters, such as through the Arboretum, 2H:1V side batters have been assumed to lift the stopbank level. These batters are usually stable in most soils and hydraulic conditions; they are however quite steep and cannot be mowed by tractors. In this public area flatter batters may be more desirable from a maintenance and recreation perspective. Flatter batters will however require significantly more fill and take up more space.

It is more efficient to place one wide strip of fill rather than two narrow strips, therefore in most places it is considered that the earthworks required to lift the stopbank level should be on one or other side of the stopbank. In terms of lengthening the seepage path to the river it is better to widen on the land side of the river but due to the relatively small size of the stopbanks at this site this is not considered to be a significant issue.

To reduce the number of grade changes in the sides of stopbanks, where there is a flatter batter on one side of the stopbank, such as near the adventure playground, it has been assumed that this batter will be extended to the new design level and a 2H:1V batter used on the opposite side.

The buttressed section of the stopbank through the Arboretum is already above the 50 year return period flood level; however the crest is narrow. Therefore an upgrade option to widen the crest to 3m to allow for a wider footpath has been discussed in Section 6 and the cost given in Appendix F.

[6] SNZ HB 8603:2004

In places, particularly through the Arboretum, there are space restrictions due to large trees and other structures. In particularly confined spaces it is proposed to use planter box type additions to the top of the traditional stopbank. This type of construction consists of two post and rail timber retaining walls with fill between them. It has previously been used in tight areas in Balgownie. The walls could also be built using reinforced earth. The areas where these could be needed are discussed in Section 6.

If there is public access to the top of the planter box walls, as on the footpath, Building Code fall height requirements must be complied with. The maximum height of box that can be built without a handrail on a 2H:1V batter is 0.75m. This requirement should be met in all areas with public access except at the Multi Sport Club where a hand rail will be required. The handrail will have to be child proof with small spaces between vertical battens.

5 Seepage Analysis Method

5.1 Discussion

The in situ investigations carried out provide subsoil profiles at isolated locations only. Although an effort has been made to build a degree of conservatism into the analysis of the stopbank cross sections discussed in following sections, the subsurface investigations show considerable variation in the soil layers and it is possible that in terms of the seepage response to a flood there are worse combinations of soil layers than those assumed.

The computer programme used to analyse the seepage through and under the stopbanks, Geo-Studio Seep/W (2012), is a two dimensional programme; therefore three dimensional effects such as seepage parallel to the river or across bends, cannot be accurately modelled. The seepage analyses carried out must therefore be considered indicative only.

Five possible problems could arise due to a flood in the river;

- excessive flows under the stopbank,
- the removal of soil particles due to high hydraulic gradients, resulting in piping and collapse of the stopbank,
- heave of upper soil layers due to high water pressures beneath them, resulting in the exposure of high permeability soils, rapid piping and stopbank collapse,
- failure of either face of the stopbank due to high water level or draw down conditions and
- over-topping of the stopbank causing rapid erosion of the stopbank.

The most common remedial measures for heave problems are the addition of an overlay on the ground surface or the construction of a pressure relief trench (or wells).

The risk of piping can be reduced by increasing the length of the seepage path by the addition of overlays, or by installing a drain in the area susceptible to piping to allow seepage without the removal of soil particles. These drains also reduce the uplift pressures and risk of heave. Once piping is initiated by the lifting and cracking of surface low permeability layers, average hydraulic gradients across a stopbank as low as 0.1 can cause pipe formation to continue[5].

Seepage of only small volumes of water from the ground surface can significantly reduce the uplift pressures acting on a low permeability surface layer with a higher permeability layer beneath it. Seepage from the ground surface behind the stopbank has therefore been allowed for in the computer models except where there are buildings or pavements.

5.2 Flood Hydrograph

Horizons has provided flood hydrographs for two sections across the river within the study length of stopbank, 86.84km and 87.74km. The 50 year return period and 100 year return period with 300mm freeboard hydrographs for each section are shown in Figure 1. The 50 year return period hydrograph corresponds closely to the 30 year return period hydrograph with 300mm freeboard. The freeboard allows for inaccuracies in the flood flow model, small waves and any small depressions in the stopbank crest due to settlement or wear. The 100year plus 300mm hydrograph is close to the 200 year hydrograph.

It can be seen from Figure 1 that there are tidal fluctuations in this section of river. The normal tidal fluctuation in water level is about 2.3m. At the peak of the 100 year flood this fluctuation is reduced to 0.5m. In the seepage analysis of the stopbank the hydrograph has been simplified to that shown in Figure 2. The peak flood level at each cross section analysed was adjusted in accordance with its location relative to the 86.84km or 87.74km sections.

The Seep/W computer programme requires a steady state seepage analysis to give the initial pore water pressure for a transient flood flow analysis. This was carried out assuming the mean tide level (RL1.35) and the ground water level measured in the hand augers.

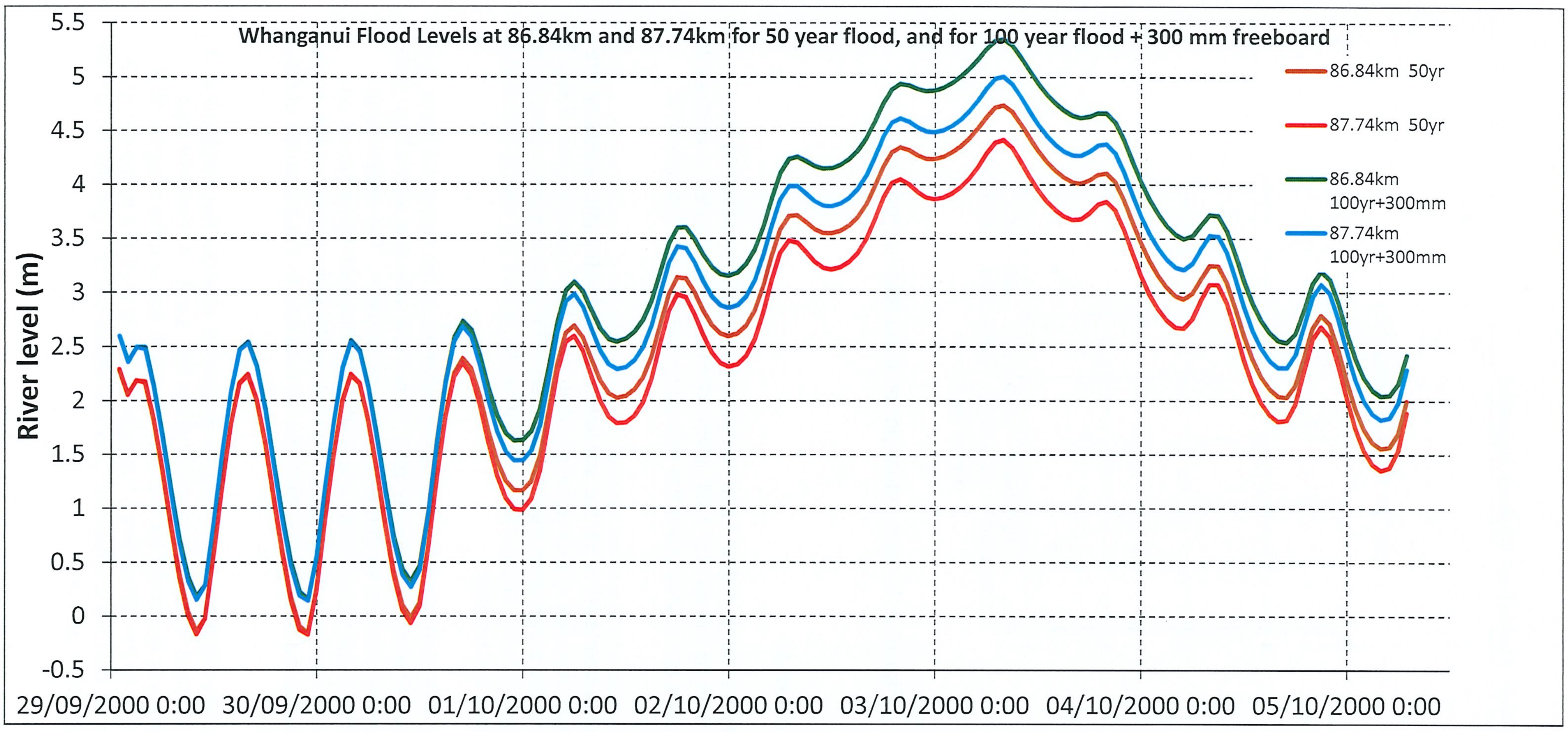


Figure 1: Flood flow hydrographs

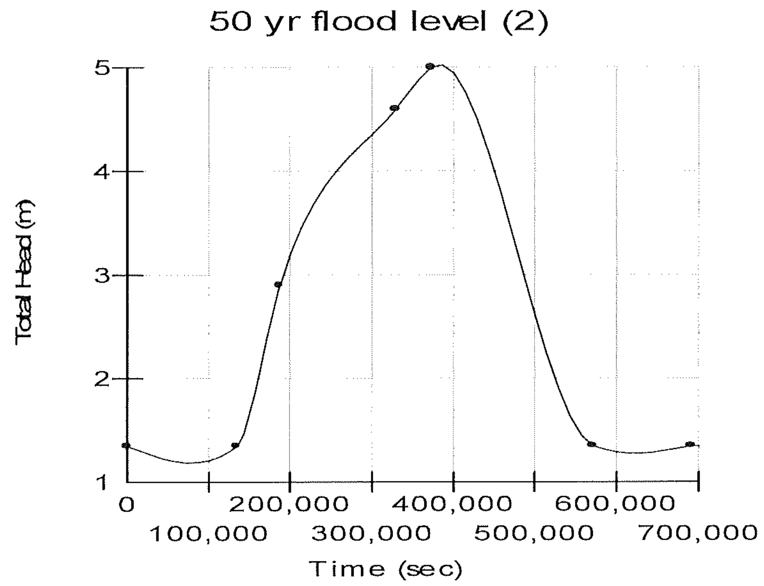


Figure 2: 50 year return period flood flow hydrograph

5.3 Soil Model

The soil layers found in the in situ investigations were simplified to form seepage analysis models for each of the stopbank cross sections analysed. These models are discussed in the following sections and are shown in Appendix C.

Below the surface layer of silt the soil layers were divided into layers on the basis of their seepage characteristics rather than their descriptions. Table 3 summarises the soil permeabilities assumed. The permeabilities were based on the constant head and particle grading tests carried out during this study plus previous experience.

In terms of the assessment of the heave potential of the upper silt layer, it is conservative to assume a permeability on the low side and on the high side for the more permeable sand layers acting as aquifers. The relationship between horizontal permeability and vertical permeability was based on observation from the hand augers. The horizontal permeability of the in situ silts was assumed to be higher than the vertical due to the presence of clayey silt layers.

The Opus investigations were used to determine whether the stopbank in a particular location was predominantly silt or fine sand. A relatively high permeability was assumed for the new stopbank soil in case a sandy fill is used and due to the difficulties of compacting soils well in a narrow strip. It was assumed that the compaction process would cause a greater horizontal permeability than vertical.

Table 3: Assumed Soil Permeabilities

soil	k_h (m/s)	k_v (m/s)
existing stopbank fill – fine sand	1×10^{-6}	5×10^{-7}
existing stopbank fill – silt	5×10^{-7}	2×10^{-7}
new stopbank fill	1×10^{-6}	0.5×10^{-6}
surface silt	1×10^{-7}	5×10^{-8}
silty fine sand	2×10^{-6}	2×10^{-6}
clayey silt and clay	5×10^{-8}	5×10^{-8}
fine sand	2×10^{-6}	2×10^{-6}
fine to medium sand	5×10^{-5}	5×10^{-5}
medium to coarse sand	1×10^{-4}	1×10^{-4}
river bank silts	1×10^{-6}	1×10^{-6}

The Geo-Studio Seep/W (2004) computer package used for the seepage analyses contains a library of soil grading curves, with corresponding hydraulic conductivity and water content versus water pressure relationships. The particle gradings observed on site were compared to those in the Seep library and the closest fit chosen as the soil model to be used in the seepage analyses.

The stopbank cross sections were generally modelled to at least 50m beyond the inland toe of the stopbank to prevent any boundary effects on seepage characteristics. Based on observations on site it was assumed that there would be at least 0.5m of silt lying across the ends of any sand layers in the river bank and bed for the duration of the flood.

The weight of the upper silt layers measured by Opus was used when heave potential was being checked (16.5kN/m^3).

6 Seepage Analysis Results and Stopbank Design

6.1 0 to 480m

6.1.1 Description

This downstream length of stopbank lies within the Arboretum and most of it runs along the left bank of the Matarawa Stream. There is a narrow gravel path running along the top of the stopbank except for at the most downstream 35m which turns to join the higher ground at Anzac Parade. The stopbank is typically less than 1.5m high and has to be lifted up to 0.8m to reach the 50 year return period flood level. As the stopbank has been built between trees in places it has side batters as steep as 1H:1V and is as narrow as 1.4m at the crest.

Photo 1: Typical Arboretum section

Photo 2: Downstream section joining Anzac Parade

Over much of this length there is rough vegetation, including bamboo, along the river or stream side of the stopbank. It is proposed that most of the stopbank widening work should be carried out on this side to minimise disturbance to the Arboretum trees. Where there are valuable trees on both sides of the stopbank it is proposed that the stopbank level be lifted with planter box type construction.

Photo 3: Typical stream bank vegetation

Photo 4: Typical stream bank vegetation

In some areas the ground on the inside of the stopbank is very wet and some shallow drainage swales and sumps have been installed. There are also hollows in the ground near the stopbank which could be the result of old stumps rotting beneath the ground surface. If there are old stumps which reach down to sand layer they could create a short circuit beneath the stopbank by allowing water to flow along the sand layer and up the hole left by the stump.

Photo 5: Very steep section due to the proximity of trees

6.1.2 Seepage Analyses

Seepage analyses have been carried out on stopbank cross sections at 77m, 220m and 430m.

77m

The Opus test pits showed that the stopbank is built of silt at 77m. HA23 showed silt and clayey silt to 1.5m depth, underlain by 0.4m of fine sand, 0.25m of clayey silt and then fine to medium sand. The soil model developed for the seepage analysis is included in Appendix C. It was assumed that the fine to medium sand layer at the base of the auger is 1.5m thick and is underlain by silty sand. Analyses of both the 50 year and 100 year flood levels showed that there should be no problems with uplift or high hydraulic exit gradients.

Further analyses were carried out assuming that the sand layer is very thick. In the 50 year flood the factor of safety against uplift is marginal but as this is a very conservative analysis it is considered acceptable. If the full 100 year pressures develop there could be uplift and piping problems. As the stopbank will overtop in a 100 year flood ponding 2m deep should develop inside the stopbank which will minimise the pressure difference across it and prevent uplift[1]. If at a future stage it is proposed to provide 100 year flood protection deep investigations will be required to confirm the thickness and nature of the sand layers beneath the stopbank.

Opus reported observations of some piping in the October 2000 flood near 15m. There is a hollow about 0.5m below the typical ground level inside the stopbank at this location which could be a remnant stream channel. It contains some trees and possibly old stumps. Hand augers 21 and 24 were located on the inside of the hollow and outside the stopbank. No sand layers were found within 2.5m of the ground surface and no piping issues are expected here. The observed piping could have been water ponding in the hollow or perhaps water coming up an old stump. It is recommended that this area be inspected when the river is in flood. If it appears that there is concentrated seepage piping can be prevented by building a sand bag ring wall around the seepage area so that a head can develop. Investigations and possibly overlay placement could be carried out in the hollow at a later date.

220m

At this point the stopbank needs to be lifted by 0.4m to reach the 50 year flood level. The soil model derived from hand augers 20, 22 and 23 for this seepage analysis consists of 1.4m of silt overlying 0.7m of silty fine sand and 1.5m of fine to medium sand. The Opus report shows that this section of the existing stopbank is constructed from silt.

The seepage analysis of the 50 year flood showed that no problems are expected here. If the fine to medium sand layer is very thick and has a permeability of over 4 x 10^{-5}m/s there could be high exit gradients and uplift pressures for about a 24 hour period during the flood. This is a very conservative analysis but it is recommended that a deep soil test be carried out here to confirm the depth and permeability of the sand layer. A small overlay at the inland toe or a pressure relief trench may be required.

430m

At 430m the stopbank crest level is already at the design 50 year flood level, however the crest needs to be widened to accommodate a 2.5m wide path. The Opus test pit results show that the stopbank is built of silty fine sand in this location. Medium to coarse grained sand was found at 2.9m depth in HA19. This is overlain by various silt layers and two fine sand layers between 1.3 and 1.9m depth. The following soil model was developed from hand augers 19, 20 and 22:

- 0.0m layered silts
- 1.4m fine sand
- 1.8m layered silts
- 2.1m layered fine to medium sand and silty sand ($k_x=5x10^{-5}$, $k_y=5x10^{-6}$)
- 3.0m medium to coarse sand

It was assumed that the coarse sand layer is 2m thick.

The seepage analysis of the 50 year design flood showed that no problems are expected at this cross section; however the maximum hydraulic exit gradient reaches 0.6. It is therefore recommended that no swale drains be excavated within 30m of the inland toe of the stopbank.

An analysis with the 100 year flood level showed potential for uplift of the surface silt layers if there is no surface ponding. Therefore if the stopbank is to be lifted above the 50 year level at some future stage some deep investigations are recommended.

6.1.3 Construction Issues

To minimise the disturbance to the Arboretum it is recommended that the stopbanks be raised by placing fill on the river / stream side (outside) of the stopbank where-ever the vegetation permits (Figure 3). There are some short lengths of open lawn in the Arboretum where fill could be placed on the inside of the stopbank if there are large trees on the outside.

There are some tight places where there are large trees on each side of the stopbank and planter box construction may be necessary. It has been assumed that a total of 50m of planter box construction will be required in this section.

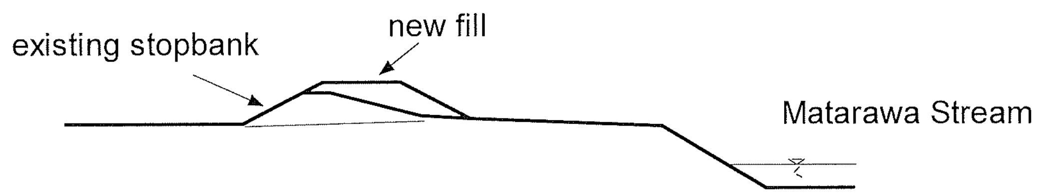


Figure 3: Typical Arboretum section

6.2 480m to 723m Buttress Section

6.2.1 Description

This section of stopbank slumped in the flood of October 2000 due to being steep, narrow and constructed of silty fine sand. Most of it has been strengthened by a toe buttress. The crest is above the 50 year flood level. There are some trees growing from the buttress.

To provide a consistent footpath width the crest of this section of stopbank needs to be widened. The easiest way to do this is to add fill to the existing buttress. An arborist would need to check whether the trees can survive this; if so, the path could be split to go around the trees. If the trees won't survive the added fill, fill could be placed on the outside of the stopbank which is predominantly covered in bamboo.

The crest level of the stopbank drops beyond 664m and there is no buttress due to there being no space between the stopbank and the road (Photo 7). The crest of the stopbank is wider here and it should be possible to add sufficient fill on the outside of the stopbank to achieve the required stopbank height and but not a 2.5m wide footpath. According to the Opus drawings the ground is as low as RL2.1 inside this section of stopbank. This is 0.4 to 0.6m lower than elsewhere in the Arboretum.

Photo 6: Buttress section with bamboo

Horizons surveyed one cross section through this buttress section and from comparison to the Opus design drawings it appears that the buttress has settled about 100mm in the last 10 years. There is a reasonable thickness of clayey silt in this area, as can be seen by water ponding at the ground surface. Most of the settlement is considered to be due to consolidation of this soil.

Photo 7: Low area

The road leading to the Matarawa Stream bridge forms the last part of this section of stopbank. The road is up to 0.9m below the design 50 year flood level. It is considered that a water inflated barrier could be placed here across the gap in the stopbank when a flood threatens. Details of this type of barrier are given in Appendix D. The barrier would have to be about 30m long.

6.2.2 Seepage Analyses

Seepage analyses have been carried out at 600 and 660m to check the security of the stopbank. The soil profile was derived from hand augers 16, 17, 18 and 19.

- 0.0m layered clayey silt and silts
- 1.4m fine sand
- 1.5m clay
- 2.3m fine to medium sand

At 600m there should be no problems in the 50 year return period flood if the lower sand layer is 2m thick. If the sand layer is thicker the uplift pressures are approximately equal to the weight of the surface silt layers. The hydraulic exit gradients are also above 0.6 for about 28 hours during the flood but as the surface soils are predominantly clayey, piping is not expected to develop.

At 660m the ground level is as low as RL2.1. The soil model was adjusted to allow for this and no seepage from the ground surface was allowed within 4m of the stopbank toe due to the presence of the road. It was found that high uplift pressures developed to 20m from the toe of the stopbank and high hydraulic exit gradients occurred beyond the seal. An overlay to bring this area up to a similar level to that around it would solve these problems but it would be quite extensive and would involve re-aligning the road. Further investigations are recommended to refine the soil model and necessary remedial measures.

6.2.3 Construction Issues

Construction of a widened stopbank crest should be quite straight forward along the existing buttress but towards the bridge there appears to be insufficient width to achieve a 2.5mwide path and at the required crest level by extending the existing batters. It may be necessary to build a small retaining wall on one side of the stopbank as filling down to the stream bank close to the bridge may not be advisable.

The end of the stopbank should be tapered to allow good seating of the water filled barrier when required. As this taper will also form a ramp for the footpath it should not be any steeper than 8H:1V[6].

6.3 M0 to M215m Matarawa Stream Section

6.3.1 Description

The stopbank on the left bank of this section of the Matarawa Stream needs to be raised by up to 600mm to reach the 50 year return period flood level. It has a broad rounded profile and there is room for fill on the inland side.

Photo 8: Left bank Matarawa Stream

Photo 9: Right bank Matarawa Stream

The right stopbank has a much more formal profile having been built in 2001. It was designed to curve around trees and there is a drainage sump between the stopbank and the Tot Town fence. This section needs to be raised by up to 400mm. The crest width of the stopbank is sufficient to allow raising without placing fill on the sides of the stopbank.

The stopbanks will have to be raised by 600mm where they butt into the Anzac Parade bridge abutments.

Photo 10: Anzac Parade Bridge left abutment

Photo 11: Anzac Parade Bridge right abutment

6.3.2 Seepage Analysis

HA15 was augered through the stopbank at about M50m. No sand layers were found within 2m of the natural ground surface therefore it is considered that there will be no heave or piping problems in this area. A sand layer was found at the base of the stopbank fill. Some investigations should be carried out to see if this is a uniform layer under the stopbank or just an isolated pocket. If it is a uniform layer a low permeability overlay should be placed on the upstream side.

A seepage analysis was carried out on a cross section of the right stopbank at M173m using the soil profile found in HA13. No problems are expected in the 50 year flood if it is assumed there are no sand layers beneath the depth of the auger. If a fine to medium sand layer is assumed just below the depth of the auger (3.5m), no uplift problems are expected but the hydraulic exit gradient is above 0.6 for about 18 hours. As the surface soils are clayey there is considered to be a very low risk of piping occurring.

6.3.3 Construction Issues

The raising of the stopbanks on both sides of the stream is considered to be straight forward in this section; however it will also be necessary to install floodwalls along both sides of the stream on the upstream side of the bridge to prevent water flowing into the neighbouring properties. These walls will have to be about 100m long. The access to and construction of floodwalls upstream of the Anzac Parade bridge could be difficult. These issues are not addressed in this report.

There will be a very short seepage path at the bridge abutments therefore it is recommended that 3m long concrete wingwall be cast onto the ends of the solid bridge rail and buried in the stopbank.

A manhole will have to be raised in the right stopbank.

6.4 M215 to 1045m Playground Carpark Area

6.4.1 Description

As the right stopbank leaves the Matarawa Stream it becomes the access road to the main carpark area. Near the stream the road will have to be lifted by about 300mm to reach the 50 year design flood level. This is just the freeboard of the actual 30 year design flood, therefore temporary measures during a flood are an option. These are discussed in Section 6.4.2.

As the road drops down to the riverbank it will need to be lifted by 600mm. This section of road forms part of a speed skating circuit so changing the road profile is unlikely to be popular.

Photo 12: Matarawa Stream transition

There is a short length of low narrow grassed stopbank beyond the river bank access road, then the stopbank crest is formed by the car park and adjacent plantings. The stopbank level needs to be raised by up to 1.0m along this length. At the far end of the carpark there is another access road, also part of the skating circuit, where the level needs to be raised by nearly 600mm.

Photo 13: Skating track and short grassed stopbank

Photo 14: Main carpark

6.4.2 Seepage Analysis

HA12 encountered a 200mm fine sand layer at 0.8m depth, however this was overlying topsoil and is considered to be fill or a relatively recent river deposit that does not extend under the stopbank. Another fine sand layer was found below a thick clayey silt layer at 2.9m depth and beneath it medium to coarse sand.

Several attempts were made to auger HA11 at the far end of the car park but stiff gravelly fill was encountered at 300mm depth.

The ground level inside this section of stopbank is above RL3.0 and it is considered that there will not be any sub surface seepage related problems.

6.4.3 Construction

The stopbank between the Matarawa Stream and the near end of the car park could be raised by extensive road realignment or by a combination of gate structures and perhaps a short length of planter box wall running parallel to the road; however in view of the various constraints and the low head involved, it is considered a long water filled barrier could be the easiest option. This could extend diagonally from the tapered end of the Matarawa Stream stopbank to the tapered end of the short section of grassed stopbank before the carpark. The barrier would have to be about 50m long therefore two or three shorter sections which overlap may be easier to handle.

The length of the barrier could be reduced by swinging the end of the stream stopbank around to run upstream between the edge of the road and the Tot

Town fence as far as possible. The barrier may then be able to run perpendicularly across the road to the stopbank on the opposite side.

The short grassed stopbank can form the transition from the temporary barrier to a low concrete floodwall running along the kerb line of the road and carpark to the far end. The wall would have to be embedded into the end of the stopbank to produce a long seepage path. An alternative to a concrete floodwall is a low planter box, however this would have to be reasonably wide to reduce the seepage through the fill.

At the far end of the carpark a conventional floodgate or stoplogs could extend across the access road from the floodwall to an abutment formed within the end of the stopbank on the far side. These options may however require disturbance of the skate track to form a seat for the gates or stoplogs. An alternative option would be to remove some of the planting at the end of the car park and to build another tapered length of stopbank so that a water filled barrier can be used. The barrier would need to be about 10m long.

6.5 1045 to 1288m (Dublin Street Bridge)

6.5.1 Description

This length of stopbank runs from the playground carpark to the Dublin Street Bridge. It is about 50m from the river bank in normal flow conditions and consists of a rounded grass covered mound about 2m wide and up to 1.5m above the surrounding ground. The stopbank only needs to be raised 200 to 300mm along this length. If there was no requirement for a 3m width for a footpath this could be readily achieved by steepening the crest part of the stopbank. Fill can be placed on either side of the stopbank to achieve the 3m crest width except at the upstream end where the skateboard park concrete extends onto the top of the stopbank and there are several trees close to the river side.

At the skateboard park there is damage to the stopbank from high usage. This needs to be repaired and the area protected in future to prevent concentrated erosion occurring.

6.5.2 Seepage Assessment

HA9 was augered in the top of the stopbank at 1140m. It was found that the stopbank is constructed of silt and silty fine sand as elsewhere and is underlain by a hard gravelly layer that could not be penetrated. HA9a was augered on the inland side of the stopbank to determine the underlying soils. A fine to medium grained black sand, similar to that found in HA12, was found just below the ground surface. This is a highly permeable layer and if it extends under the stopbank a low permeability cut off should be formed through it. Complex layers of silt, sandy silt, silty fine sand and clay were found beneath the black sand.

No seepage related problems are expected here due to the depth to the silty sand layers, the elevation of the land inside the stopbank and the distance to the river bank.

Photo 15 : Grass covered stopbank

Photo 16: Stopbank damage near skateboard park

6.5.3 Construction

The main consideration for construction along this length is the need to trace the location of the near surface black sand layer. If it is found on the outside of the stopbank a 2m wide trench should be excavated through the river side of the stopbank and sand layer down to the underlying silt, then it should be backfilled with well compacted low permeability material.

At the skateboard park the stopbank crest should be moved slightly towards the river, and the whole stopbank crest and face of the stopbank covered with a cohesive soil and a geofabric such as Enkamat to promote good grass root structure (Figure 4).

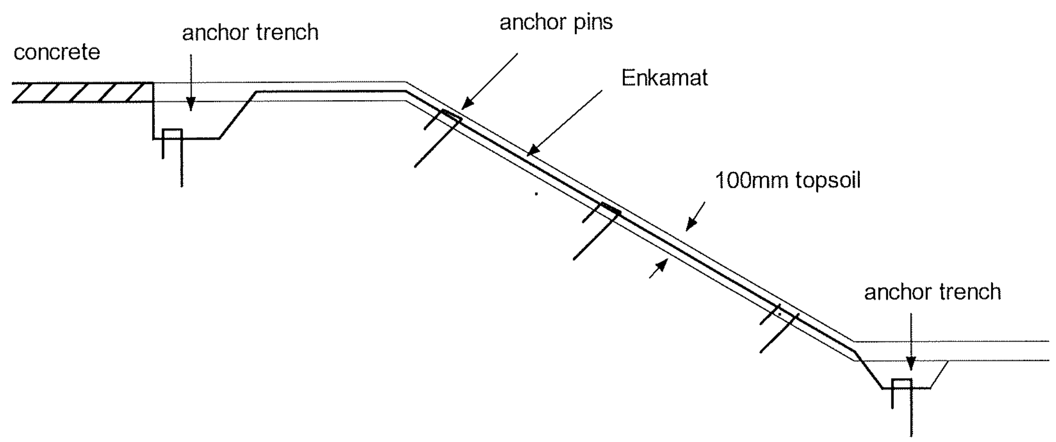


Figure 4: Skate board park area stopbank protection

6.6 1288m to 1800m

6.6.1 Description

A park access road crosses the stopbank as it swings closer to the river under the Dublin Street bridge. The stopbank needs to be raised 700mm in this location. The remainder of the stopbank consists of a broad crest with a gravel path, a few seats and trees. There is no large vegetation on the river side of the stopbank. There are some trees near the land side toe and a section of garden close to the crest. The stopbank needs to be raised up to 850mm. It is considered that the raising can be carried out without encroaching on the trees and garden due to the broad crest and flat stopbank batters.

The stopbank nears the river bank until at the upstream end of this length it is only about 8m from the river

Photo 17: Dublin Street Bridge crossing

Photo 18: Garden section

6.6.2 Seepage Assessment

HA4 was augered through the stopbank at 1340m but could not penetrate beyond 0.9m depth due to the hard gravelly fill in the stopbank. HA5 at the inland toe of the stopbank hit the same fill at 0.6m depth. HA14 was augered close to the river bank to find the soil profile beneath the stopbank. Low permeability clays and silts were found to 3.1m depth, where the hole started squeezing in. No seepage problems are expected here due to this thickness of low permeability soil.

Photo 19: Typical section

At 1510m gravelly fill was found at 1.8m depth below the stopbank crest (HA3). At the inland toe of the stopbank a silty fine sand layer was found at 1.6m depth but the auger could not penetrate beyond 1.9m depth. A seepage analysis was carried out on this cross section on the basis that no high permeability sand layers were found in this area above RL-1.3. If a medium to coarse grained sand is assumed below this depth high hydraulic exit gradients and uplift pressure could develop beneath the small swale at the inland toe of the stopbank. It is therefore recommended that this swale be brought up to the surrounding ground level.

At 1670 similar impenetrable fill was found in the stopbank and again on the inland side of the stopbank (HA7). The depression here seems to be filled with landfill debris with pieces of brick and gravel being hit repetitively. A 300mm thick silty sand layer was found at 0.8m depth in HA8 near the river bank, with low permeability soils extending to 4.0m depth. It is considered following assessment of these soils layers and the stopbank geometry that there should be no seepage problems in this area.

6.6.3 Construction Issues

A check should be made on the vehicle clearance under the bridge before the stopbank is raised in this location. It may be necessary to change the stopbank alignment so that the road crosses it upstream or downstream of the bridge. The gravel road surface should be built up from the general stopbank level so that future wheel tracking does not compromise the stopbank crest.

Due to the thickness of clayey soils under this stopbank it is recommended that the crest be built 100mm higher than design to allow for settlement.

6.7 1800m to 2070m

6.7.1 Description

This section of stopbank is complicated by the Motor Boat and Multi Sport club buildings and a boat ramp. Photo 20 shows the proximity of the Motor Boat Club building to the stopbank. It can be seen that there are small drainage sumps at each end of the concrete slab. The building is effectively in a hole surrounded by stopbanks and pavement (Photo 21). There is little room between the stopbank crest and the river bank and erosion is occurring in this area (Photo 22). It is not known if this erosion is due to turbulence created by the adjacent boat ramp or by boat wash. It is considered that some erosion protection work should be carried out here before the stopbank is compromised.

Photo 20: Motorboat Club building

The stopbank needs to be raised by 800mm in this location. Due to the space restrictions it is considered that planter box type of construction should be used in front of the building and along the side of the boat ramp. The height of the box and the stopbank grades are such that a hand rail should be unnecessary

The inland end of the boat ramp is below the design flood level by about 1m. Several options to provide flood protection to the design level are discussed in Section 6.7.3.

Photo 21: Motorboat Club and boat ramp

Photo 22: River bank erosion in near boat ramp

Between the boat ramp and the Multi Sport Club building the stopbank is similar to that further downstream, with a gravel path on a broad grassy crest. There is however little space between the toe of the stopbank and the riverbank. This length of stopbank needs to be raised by about 600mm.

At the Multi Sport Club building there is a very light 1.1m high timber retaining wall on the inside of the stopbank and another smaller wall on the outside, with a path leading down to the river bank (Photos 24 and 25). The stopbank is therefore very narrow here and needs to be lifted by 500mm using a planter box arrangement. Due to the fall height a hand rail will be required on each side of the footpath.

Photo 23: Boat ramp

Photo 24: Multi Sport Club Building

Beyond the Multi Sport building the stopbank swings towards Anzac Parade, which is at the design flood level at this point.

Photo 25: Multi Sport building river access

6.7.2 Seepage Assessment

A seepage analysis was carried out on a cross section through the Motor Boat Club building, using the soils information from the hand augers upstream and downstream and assuming no seepage from the ground beneath the building. No seepage problems were identified in the design 50 year return period flood.

No seepage problems are expected anywhere along this length.

6.7.3 Construction Issues

An effort should be made to find the details of the drainage system around the Motor Boat Club building. The trenches associated with this system could form a weakness in the stopbank.

Flood protection could be provided at the boat ramp by lengthening it and lifting the adjacent access road level; there is however limited space between the end of the ramp and Anzac Parade. Steepening the ramp is another option but it may not be popular with the ramp uses. Either of these options could be combined with raising the road level behind the Motor Boat Club building so that the stopbank in front of the building does not have to be raised. This means that the building would be partially underwater in the design flood but the need for planter box type construction and any issues relating to the drainage would be avoided.

The most cost effective options for the boat ramp are probably the insertion of stoplogs between the existing concrete walls (Photo 23) or the use of another water filled barrier between the grassed stopbanks on either side of the ramp. As stoplogs would be long and under a reasonable pressure, one or more supporting posts may need to be fitted in cut outs across the boat ramp. A water filled barrier would need to be about 25m long.

It may be necessary to keep the boat ramp open when the river is in flood in case river rescues are required. One of the earthworks options to lift the stopbank level would then be needed instead of a temporary barrier.

Between the boat ramp and the Multi Sports Club building it is suggested that the batter on the stopbank from the carpark be maintained and a 2H:1V batter be built on the unused river side.

Some liaison will be required with the Multi Sports Club to sort out how their access to the river and boat handling arrangements will fit in with the raised stopbank. The posts supporting the retained box will need to be designed so that no reliance is placed on the strength of the existing retaining walls.

7 Slope Stability

A representative cross section of the stopbank has been assessed for slope stability under normal river level, high river level and rapid draw down conditions using the Geo-Studio Slope /W computer programme in conjunction with the Seep/w programme. The following parameters were assumed as shown in Figure 5:

- stopbank height 3m
- distance to river bank 5m
- river invert RL-2.0
- stopbank batters 2H:1V

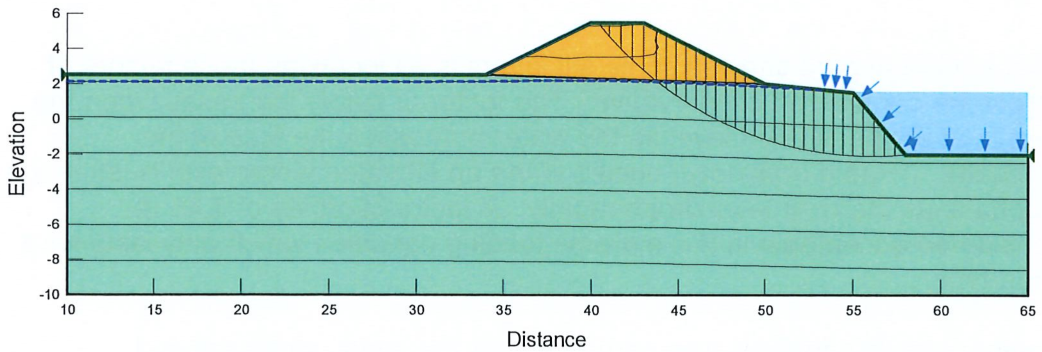


Figure 5: Slope stability assessment

The analyses were repeated with for the following soil types:

- sandy stopbank on sandy foundation
- sandy stopbank on silt foundation

- silt stopbank on silt foundation
- silt stopbank on sandy foundation

The soil parameters are given in Table 4

Table 4: Assumed soil properties

soil	ρ_b bulk density (kN/m^3)	c' effective cohesion (kPa)	ϕ friction angle (o)
stopbank silt fill	16.5	10	24
stopbank sand fill	16.5	2	35
in situ silt	16.5	10	24
in situ sands	16.5	0	35

High water pressures are not developed in the inland face of the stopbank due to the nature of the flood hydrograph, therefore only river side failures which reached the crest of the stopbank were considered. The lowest factors of safety are given in Table 5.

Table 5: Lowest factors of safety for slope stability

water level	soils	FOS stopbank	FOS planter box and stopbank
normal river level	sandy stopbank and foundation	1.6	1.55
50 year design flood level	sandy stopbank and foundation	2.8	2.4
rapid drawdown	sandy stopbank and foundation	1.45	1.4

As the hand augers showed some silt layers in all locations these factors of safety are considered conservative. The factor of safety increases when the river is at the peak flood level as the water buttresses the face of the stopbank. Rapid drawdown occurs when an elevated water level is left in the stopbank as the river level drops rapidly. A factor of safety of 1.45 is considered acceptable in this extreme loading condition which only lasts for a short time.

Another stability analysis was carried out for the sandy stopbank and foundation case with a 1.0m high, 3m wide planter box structure on top of 2H:1V batters (Figure 6). It can be seen from Table 5 that the factors of safety reduce from the stopbank option but they are still considered acceptable. Therefore no slope stability type problems are expected along the stopbank provided there is no excessive river bank erosion.

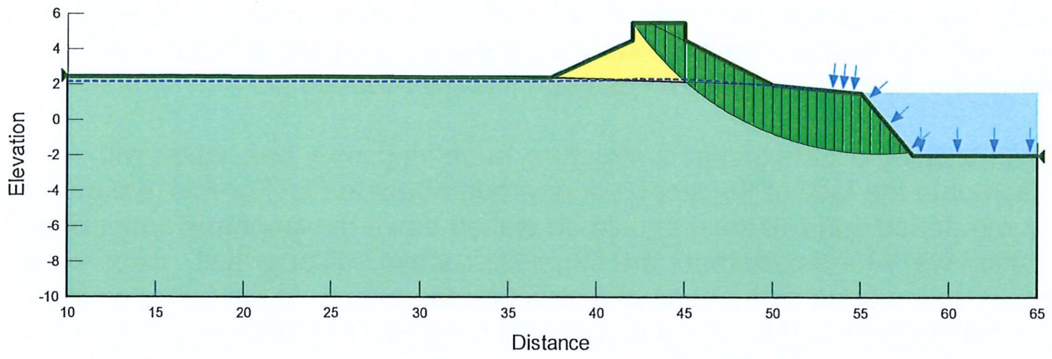


Figure 6: Planter box stability assessment

8 Response to Over-topping

The stopbank could be over-topped by waves or by a flood greater than the design flood. A flood equivalent to the 100 year return period flood with 300mm freeboard would over-top a stopbank built to a 50 year design level by up to 600mm for a period of about 21 hours. Over-topping can lead to rapid erosion and breaching of the stopbank if the crest and inland foundations are not protected. The main form of surface protection for most stopbanks is a good well established grass cover. Redaelli presents a plot of the probability of breaching a stopbank with initial grass cover, 2H:1V batters and a 6m deep river section against the duration of over-topping[7]. The probability of breaching with 21 hours of over-topping and good grass cover is about 4%. The probability increases to about 80% if there is poor grass cover (The soil from which the stopbank is constructed is not given.)

A gravel path is unlikely to provide as good erosion protection as a good grass root mat due to its lack of cohesion. It is therefore recommended that wherever there is a gravel path it should be underlain by an erosion protection geofabric, such as Enkamat 7018, which will help to bind the gravel and protect the stopbank crest. A crest detail is given in Section 9 and information on the Enkamat product is given in Appendix E. This grade of Enkamat is designed for the flow velocities that could develop over the stopbank in the 100 year plus 300mm flood.

Paved surfaces should resist erosion provided water does not get beneath the pavement and lift it.

If there are dips in the stopbank crest or anything which may concentrate flow, such as the edge of a structure, water velocities can be increased and erosion occur at an accelerated rate; hence the recommendation to build the stopbank high in some areas to allow for settlement and reduce the risk of a localised depression.

It is considered that Enkamat should be placed under grassed surfaces to bind with the grass roots if there is concern about the integrity of the grass

[7] Redaelli M (2012) Reliability of flood embankments: a new methodology, Proc. of the Institute of Civil Engineers, Geotechnical Engineering, Vol. 165 Issue GE3

cover, such as around the skate board park. Enkamat could also be used in the remaining grassed areas to increase the integrity of the stopbank and reduce the scale of the repairs needed if it is over-topped,.

If over-topping occurs across a structure, such as planter box, water will splash onto the face of the stopbank or ground beneath it. For this reason it is recommended that Enkamat should be placed down the stopbank batter or at ground level where-ever there are structures above soil or gravel. Once water has started to pond at the base of a structure the energy of the falling water will be dissipated and the erosion potential reduced. The flood wall in the car park area can be built along the kerb line so that water falls onto seal or concrete. At the Multi Sport Club it is recommended that concrete be placed between the building and retaining walls.

9 Stopbank Construction

The stopbank areas which require filling should be prepared by stripping all the vegetation and removing large roots and stumps (larger than say 30mm diameter). All topsoil should be removed and the ground surface benched. Any near surface sand layers exposed in this excavation should be excavated and replaced with compacted low permeability fill (Figure 7). Excavated inorganic soil can be mixed and replaced as fill.

The fill should be spread and compacted in layers in accordance with standard earthworks practices. The minimum compacted dry density should be 98% of the Standard Proctor compacted density. Extra width of fill should be placed so that the batters can be trimmed with an excavator back to a well compacted surface. The final crest level of the stopbank should be 100mm higher than design where stated in Section 6 to allow for some long term settlement of the clayey foundation soils.

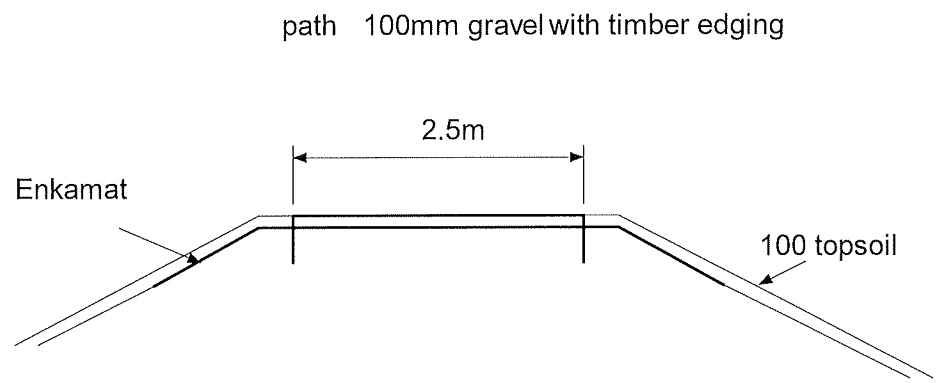


Figure 7: Typical stopbank detail

A minimum of 100mm of topsoil should be spread on the batters and the 2.5m wide gravel path re-instated on the surface where required. It is recommended that Enkamat or an equivalent geotextile should be placed across the crest of the stopbank beneath the paths and adjacent topsoil (Figure 7, Note some topsoil should be placed below the Enkamat). It is important to maintain a good grass cover on the stopbanks.

Where planter boxes are required they should be designed as retaining walls with compaction pressures during construction, at rest soil pressures when dry and full hydrostatic pressures when the river is in flood. Care should be taken to provide sufficiently long supporting posts when the walls are on top of stopbanks.

Geotextile should be placed against the planking on both faces of the planter box to prevent the loss of fines as water seeps through or drains from the walls (Figure 8). The walls should be at least as wide as they are high to reduce the hydraulic exit gradients at the inland toe of the wall. The wall facings should be embedded 100mm into the ground (to the solid fill below the topsoil).

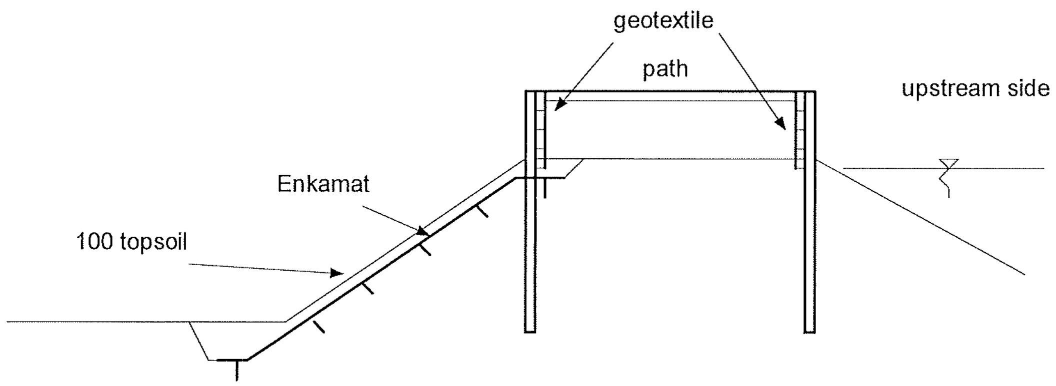


Figure 8: Typical planter box section

10 Cost Estimate

An estimate of the cost of raising the stopbank to the 30 year return period plus 300 freeboard level is included in Appendix F. The estimated $1.21 million is based on the following assumptions:

- The end of the Matarawa Stream right stopbank will be extended about 30m parallel to the park road.
- All sealed roads and the boat ramp will have water filled flood protection barriers installed when a flood threatens.
- A concrete floodwall is constructed through the main carpark area.
- Gravel paths will be re-instated to their existing width
- Erosion protection is installed in the skate board park area.

The estimated cost does not include:

- Erosion protection along the stopbank crest or beneath planter boxes.
- Any work on the floodwalls upstream of the Anzac Parade Bridge.
- The further investigations that are recommended (approximate cost $15,000).
- Any design or surveying.
- Any consultation with affected parties.
- Any Resource Consents or Building Permits.
- Any service location or relocation.
- Construction contract preparation, administration or supervision.
- Any replanting other than grass.

The cost of widening the buttress section, widening the path and providing erosion protection is an estimated $420,000. Details are given in Appendix F.

It is considered that the expenditure on erosion protection would be worthwhile as it will significantly reduce the risk of serious damage and stopbank breach if it is over-topped. Retro-fitting the erosion protection at a later date will be much more expensive.

11 Conclusions

i. The cost of raising the stopbank to the 30 year plus 300 freeboard level has been estimated at $1.21 million. This includes the water filled barriers, various floodwalls and planter boxes.

ii. It is recommended that the integrity of the stopbank be further improved by placing a geofabric across the stopbank crest and beneath planter boxes. The extra cost to carry this out has been estimated at $334,000.

iii. Options have been given for barriers across various gaps in the stopbank. The cost estimate has been based on the use of water filled barriers at all the locations. Their use is dependent on the availability of sufficient warning time and staff before the flood peak arrives. Other options, such as floodgates and stoplogs, may be quicker to install.

iv. No investigations or assessment of the required floodwalls upstream on the Anzac Parade bridge have been carried out.

v. There is potential for heave and the development of piping in some areas if the differential water pressure across the stopbank exceeds that in the 50 year return period flood. If the stopbank is overtopped ponding should reduce this risk however if the stopbank is raised in the future further investigations and design are needed.

vi. To reduce the risk of heave and no swale drains should be allowed within 30m of the inland stopbank toe.

vii. Some deep investigations are required near 220 and 660m to confirm the nature of any sand layers present and enable the stopbank security to be checked.

viii. Shallow investigations are required at M50 and 1140m to determine the extent of a near surface sand layer.

ix. The clearance under the Dublin Street Bridge should be checked to see whether the stopbank needs to be re-aligned before it is raised.

x. The erosion in the river bank near the boat ramp needs to be investigated and repaired if necessary.

xi. The hollow at 15m should be inspected when the river is in flood to see if there is any sign of seepage as reported by Opus.

xii. Consideration should be given as to whether the boat ramp needs to be kept operational for rescue purposes when the river is in flood.

M. O'Halloran 13 November 2012
BE, PhD, Dip BA, MIPENZ (Geotechnical), CPEng IntPE

Appendix A

Hand Auger Logs

Appendix B

Particle Grading Tests Results

Appendix C

Stopbank Soil Models

Appendix D

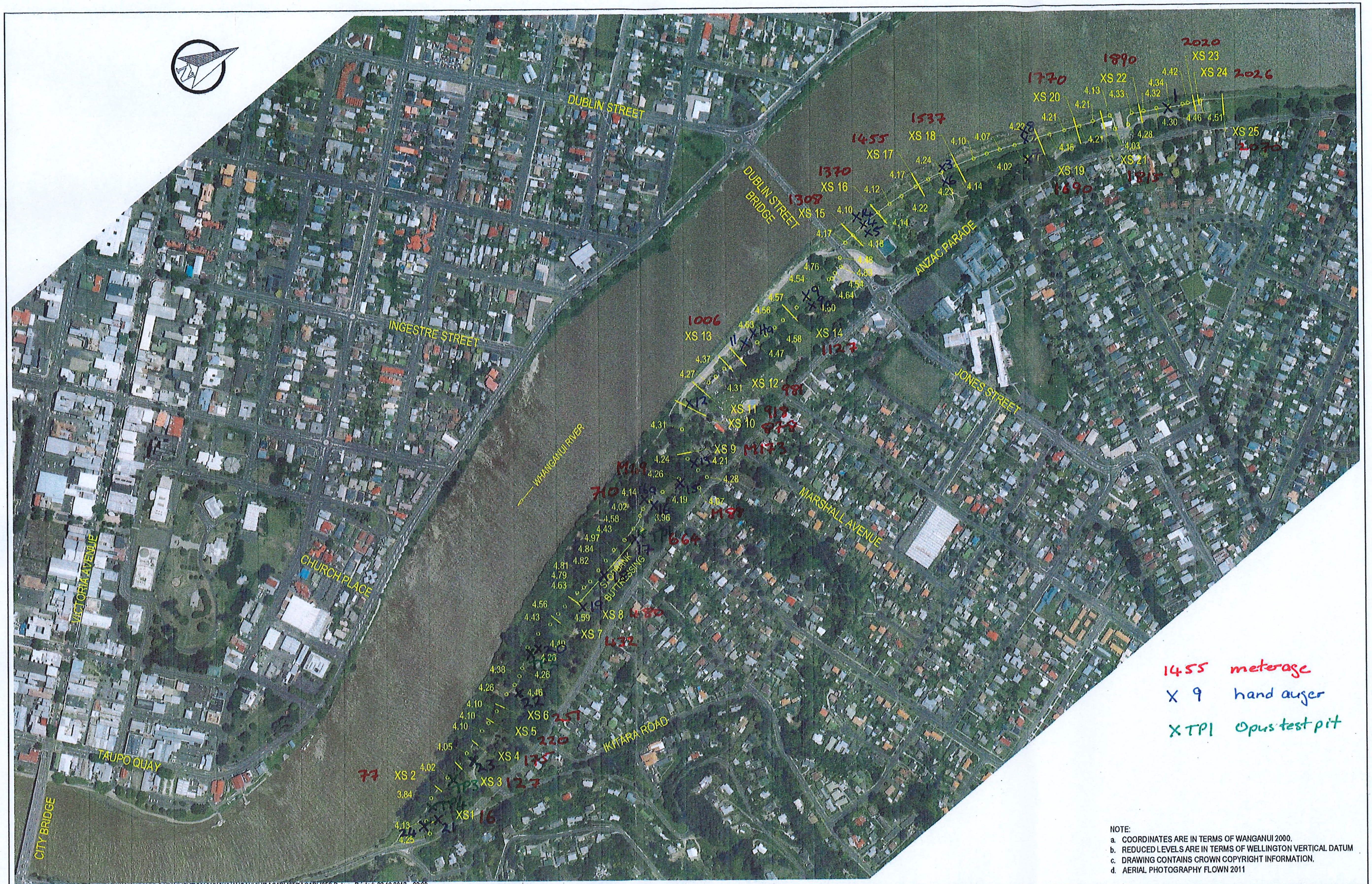
Water Filled Flood Barriers

Appendix E

Enkamat Information

Appendix F

Construction Cost Estimate



NOTE:
a. COORDINATES ARE IN TERMS OF WANGANUI 2000.
b. REDUCED LEVELS ARE IN TERMS OF WELLINGTON VERTICAL DATUM
c. DRAWING CONTAINS CROWN COPYRIGHT INFORMATION.
d. AERIAL PHOTOGRAPHY FLOWN 2011

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				DRAWN	G GILRISON	SEP 2012
				TRACED	AutoCAD	SEP 2012
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DATE

LEVEL FIELD BOOK

FILE REF

horizons regional council

WHANGANUI RIVER
KOWHAI PARK STOPBANK
INVESTIGATION SURVEY
SITE PLAN

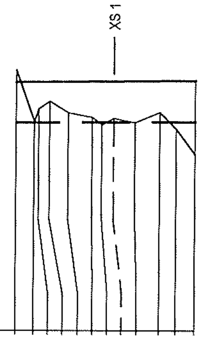
SCALES:
ORIGINAL DRAWING SIZE A1
1:3,000

DRAWING No.
4958

SHEET 1 OF SHEETS

DOWNSTREAM RETURN (STOPBANK DISTANCES)

L50 - NO FREEBOARD
L30 - NO FREEBOARD

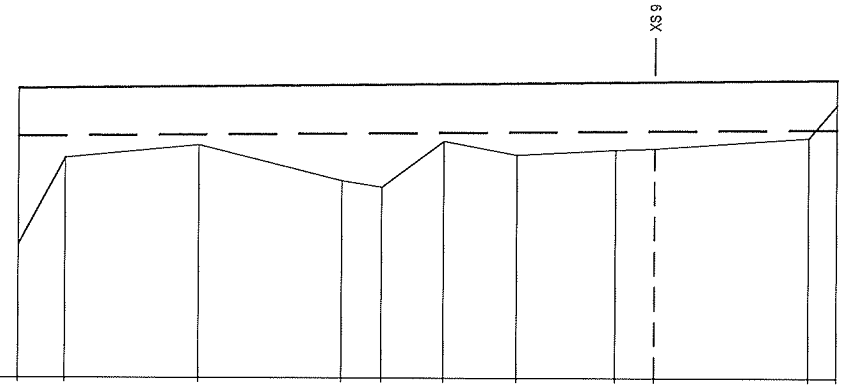


Datum R.L. 3.000
H Scale 1:1000
V Scale 1:20

DISTANCE	STOPBANK ELEVATION	L50 - NO FREEBOARD	L30 - NO FREEBOARD
0.00	4.42	4.35	4.13
4.87	4.14		
6.19	4.21		
9.11	4.25		
14.15	4.18		
20.60	4.16		
23.26	4.12		
26.47	4.15		
32.31	4.13		
39.10	4.19		
43.59	4.09		
48.78	3.96	4.36	4.14

MATARAWA STREAM STOPBANK (STOPBANK DISTANCES)

L50 - NO FREEBOARD
L30 - NO FREEBOARD

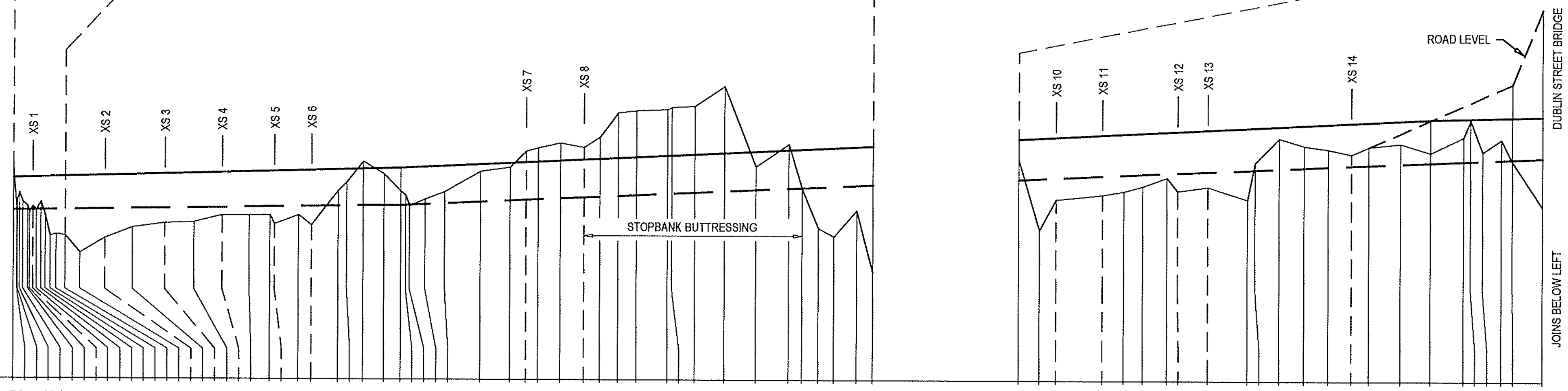


Datum R.L. 3.000
H Scale 1:1000
V Scale 1:20

DISTANCE	STOPBANK ELEVATION	L50 - NO FREEBOARD	L30 - NO FREEBOARD
0.00	3.72	4.57	4.31
12.76	4.19		
49.11	4.26		
88.24	4.07		
98.94	4.03		
115.76	4.29		
135.65	4.21		
162.68	4.24		
173.24	4.25		
215.17	4.31		
222.76	4.49	4.62	4.35

STOPBANK CREST (RIVER DISTANCE)

L50 - NO FREEBOARD
L30 - NO FREEBOARD



Datum R.L. 3.000
H Scale 1:2500
V Scale 1:20

DISTANCE	STOPBANK ELEVATION	ROAD ELEVATION	L50 - NO FREEBOARD	L30 - NO FREEBOARD
0.00	4.42		4.35	4.13
2.77	4.14			
3.41	4.21			
4.92	4.25			
8.04	4.18			
12.03	4.16			
13.71	4.12			
16.20	4.15			
19.29	4.13			
23.30	4.19			
26.75	4.09			
30.98	3.96			
36.08	3.97			
43.47	3.96			
55.79	3.84			
76.82	3.95			
100.02	4.02			
127.54	4.05			
152.19	4.05			
175.52	4.10			
198.35	4.10			
215.62	4.10			
219.52	4.04			
239.72	4.10			
250.71	4.03			
273.34	4.26			
280.49	4.32			
294.24	4.46			
311.90	4.38			
326.31	4.26		4.42	4.17
330.45	4.24			
333.72	4.16			
346.77	4.21			
363.02	4.26			
393.12	4.40			
418.36	4.43			
431.78	4.53			
441.86	4.56			
460.63	4.59			
480.08	4.56			
493.65	4.63			
509.15	4.79			
524.92	4.81			
551.01	4.82			
554.74	4.83			
573.88	4.84			
598.87	4.97			
625.29	4.43			
653.01	4.58			
664.22	4.29			
678.12	4.02			
691.25	3.96			
710.42	4.14			
723.86	3.72		4.57	4.31
846.81	4.49		4.62	4.35
864.60	4.01			
878.49	4.22			
917.72	4.25			
935.64	4.27			
951.67	4.31			
971.60	4.37			
980.73	4.28			
1005.94	4.30			
1039.59	4.22			
1045.65	4.47			
1066.10	4.63			
1087.21	4.58			
1107.88	4.56			
1127.19	4.53			
1141.91	4.57	4.57		
1168.50	4.60			
1193.90	4.54		4.76	4.47
1221.58	4.64			
1227.48	4.76			
1237.94	4.54			
1253.54	4.63			
1262.93	4.48	5.00		
1288.41	4.17	5.50	4.78	4.50

NOTE:
a. REDUCED LEVELS ARE IN TERMS OF WELLINGTON VERTICAL DATUM

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ISSUE	AMENDMENT	BY	DATE
0	ISSUE FOR SURVEY INFORMATION	QG	SEP 12

	NAME	DATE
SURVEYED	W DE JONGE	JUL 2012
DESIGNED		
DRAWN	Q GILKISON	SEP 2012
TRACED	AutoCAD	SEP 2012
CHECKED		

APPROVED ______

DATE ______

LEVEL FIELD BOOK

FILE REF

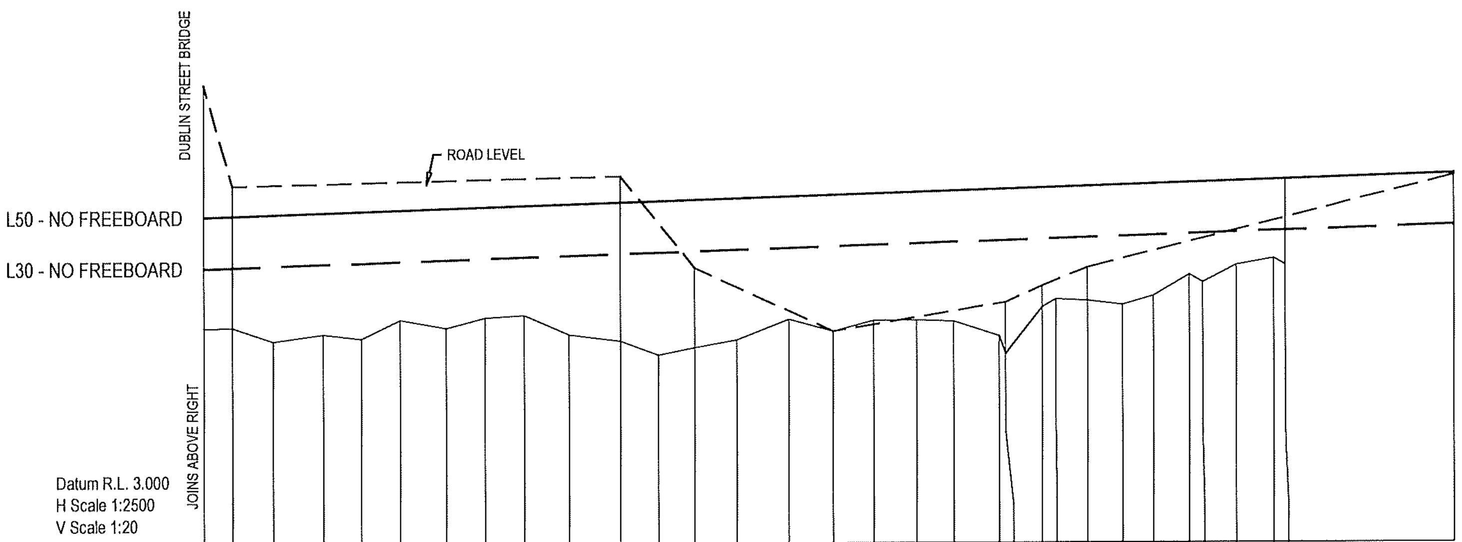
horizons regional council

WHANGANUI RIVER
KOWHAI PARK STOPBANK
INVESTIGATION SURVEY
STOPBANK CREST LONGSECTION

SCALES: ORIGINAL DRAWING SIZE A1 AS SHOWN

DRAWING No. 4958

SHEET 2 OF SHEETS



STOPBANK CREST (RIVER DISTANCE)

DISTANCE	STOPBANK ELEVATION	ROAD ELEVATION	L50 - NO FREEBOARD	L30 - NO FREEBOARD
1288.41	4.17	5.50	4.78	4.50
1307.92	4.18	4.95		
1335.66	4.10			
1369.71	4.14			
1395.61	4.12			
1422.14	4.22			
1453.35	4.17			
1479.91	4.23			
1507.07	4.24			
1537.74	4.14			
1572.80	4.10	5.00		
1598.41	4.03			
1622.99	4.07	4.50		
1651.77	4.11			
1687.30	4.22			
1717.47	4.15	4.14		
1745.38	4.21			
1774.83	4.21			
1799.86	4.21			
1830.71	4.13			
1835.34	4.03	4.31		
1860.02	4.28			
1869.56	4.33	4.40		
1891.06	4.32	4.50		
1914.95	4.30			
1936.29	4.34			
1960.66	4.46			
1969.59	4.42			
1992.32	4.51			
2018.09	4.55			
2025.95	4.51	4.77	4.98	4.70
2141.00		5.00	5.01	4.73

NOTE:
a. REDUCED LEVELS ARE IN TERMS OF WELLINGTON VERTICAL DATUM

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ISSUE	AMENDMENT	BY	DATE
0	ISSUE FOR SURVEY INFORMATION	QG	SEP 12

	NAME	DATE
SURVEYED	W DE JONGE	JUL 2012
DESIGNED		
DRAWN	Q GILKISON	SEP 2012
TRACED	AutoCAD	SEP 2012
CHECKED		

APPROVED ____________

DATE ____________

LEVEL FIELD BOOK

FILE REF

horizons regional council

WHANGANUI RIVER
KOWHAI PARK STOPBANK
INVESTIGATION SURVEY
STOPBANK CREST LONGSECTION

SCALES: ORIGINAL DRAWING SIZE A1
AS SHOWN

DRAWING No. 4958

SHEET 2A OF SHEETS

Addendum 1

Anzac Parade Option

1 Alignment

Upstream of the Dublin Street Bridge there is a 300m length of Anzac Parade which is above the 30 year flood level plus 300mm freeboard. This section of road could be used to protect the adjacent houses from floods instead of upgrading the existing stopbank along the river bank. The upgraded stopbank could be tied into the road beneath the Dublin Street Bridge along the skateboard park. Further upstream of this 300m length the ground level adjacent to the road is typically at RL4.0; therefore a small stopbank (0.9m high) is all that is required to achieve flood protection up to where the road rises again at the upstream end of the study area (Figure A1). Horizons[1] investigated this alignment option in 2007 except that Anzac Parade was not approached until upstream of the go-cart track. If this alignment is adopted this track, the Motor Boat Club building and the Multi Sports Club building would be flooded when the river is above RL4.0.

Figure A1: Anzac Parade Alignment

2 Seepage Analysis

No sub surface investigations have been carried out along this alignment therefore some representative cross sections have been analysed. As there is no need for a path on top of this section of stopbank a 2m wide crest has been assumed. The investigations carried out near-by found landfill type material which could form a high permeability layer beneath the stopbank. The analyses showed that if there is a high permeability layer less than 0.5m below the ground surface there could be high hydraulic exit gradients during a flood. The presence of shallow high permeability layers should be checked prior to or early in construction. Any layers found should be excavated and a low permeability cut off formed beneath the stopbank.

3 Costing

This upgrading alignment requires less earthworks than the existing alignment along the river bank. As this alignment avoids the two buildings there is no need for the planter box sections of stopbank improvement. There will also be no need for the flood barrier at the boat ramp as there is room for a stopbank to be built between the boat ramp manoeuvring area and Anzac Parade. Some of the new stopbank will have to be built around mature trees but this should not be too difficult due to its small size.

Due to the reductions in earthworks volumes and other costs resulting from the Anzac Parade alignment, the estimated cost of the basic upgrading of the whole Kowhai Park length of stopbank (without widening the footpath or protecting the stopbank crest from erosion) is reduced from $1.21 million to $0.92million. As the length of footpath affected by the works and the crest length of the stopbank have been reduced, the extra cost of the footpath widening and erosion protection options is reduced from $420,000 to $360,000.

Addendum 2

30 Year Return Period Flood Protection

1 Introduction

The work discussed in the body of the report is based on the provision of flood protection for a 30 year return period flood with 300mm of freeboard. This level roughly corresponds with the 50 year return period flood level, therefore the seepage analyses and stopbank design have been based on the 50 year return period flood flow hydrograph. Considerably less stopbank upgrading work would be required if the design flood level is taken as the 30 year return period level without any freeboard as much of the existing stopbank is already at this level. If the Anzac Parade alignment is used upstream of the Dublin Street Bridge, the lengths of stopbank requiring upgrading are those given in Table A1 (Drawing 4958 Sheets 2 and 2A).

Table A1: Length below 30 year return period flood level

location	length
40 to 270m	230m
664 to M0m	60m
M0 to M217m 847 to 1045m	207m 198m
1263 to Anzac Parade (skateboard park)	50m
1615 to 1992m	377m
Total length	**1,122m**

Downstream of the Dublin Street Bridge the crest level of the stopbank needs to be lifted less than 300mm. Upstream of the bridge a new stopbank typically 600mm high is required.

2 Seepage Analyses

The seepage analyses of all the cross sections discussed in Section 6 of the report were repeated using the 30 year flood flow hydrograph. This was to check that those existing sections which do not require lifting for this design flood level have sufficient security against piping and uplift without the need for any improvement work. A minimum 2m crest width was assumed for those lengths of stopbank requiring lifting by widening on one side of the existing stopbank. Where the stopbank is already wide, such as along the Matarawa Stream, it was assumed that a 2m wide strip of fill would be placed down the centre of the stopbank.

The only cross section analysed which could have some high uplift pressures and hydraulic exit gradients in the design flood is that at 660m. Further investigations are required here to confirm the extent of sand layers beneath the stopbank and whether an overlay or pressure relief system is needed. At 600m the uplift pressures and hydraulic gradients at the shallow swale drain were assessed as being just acceptable.

Upstream of the bridge the presence of near surface high permeability layers needs to be checked as discussed in Addendum 1.

3 Costing

Although there is not a great quantity of fill to be placed for this option there is still a reasonable area of topsoil to be stripped and reinstated. The water filled barriers, concrete flood wall and wing walls on the Anzac Parade Bridge are also still required. In the costing analysis it has been assumed that 600mm diameter water filled barriers would be used. The basic costs to upgrade the stopbank to the 30 year return period flood level without any freeboard have been estimated at $570,000. Placing erosion protection matting along the sections that are lifted would cost a further $140,000.

Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA1**

Elevation: 4.1
Date: 16/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**clayey SILT,** brown, firm, damp	
0.5				
	3.3		fine to medium **sandy SILT**, some hard rounded gravel to 19mm, some brick fragments, dark brown, firm, fill	
1.0				
1.5				
	2.3		**SILT**, some fine sand, brown, firm, damp	
	2.2		fine **sandy SILT**, brown, firm, dense, damp	
2.0				
	1.9		**clayey SILT**, Fe stained grey, firm, damp	
	1.8		**silty fine SAND**, brown, mod. dense, moist	
	1.7		fine **sandy SILT**, brown, firm, moist	
2.5				
	1.3		fine to medium **sandy SILT**, some hard rounded gravel to 19mm, some brick fragments, dark brown, firm, fill	
3.0				
	1		**clayey SILT**, trace sand, green grey. soft, wet	
3.5				
	0.5		EOB sucking in	
4.0			river side of stopbank crest	

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA2**
Client:	Horizons MW	Elevation:	4.1
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, brown, firm, damp	
			0.4 some fine sand, rare fine gravel	
0.5	3.6		fine **sandy SILT**, some gravel, brown	
	3.4		UTP, gravel	
1.0			stopbank crest	
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA3**

Elevation: 4.1
Date: 16/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, some clay, brown, firm, damp	
0.5				
	3.3		fine **sandy SILT**, brown grey, firm, mod. dense, damp	
1.0	3.05		**SILT**, Fe stained grey, firm, damp	
	2.85		**sandy SILT**, some fine gravel, grey, dense, old road?	
	2.8		EOB UTP	
1.5				
			stopbank crest	
2.0				
2.5				
3.0				
3.5				
4.0				

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA4**
Elevation: 4.1
Date: 16/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			fine **sandy SILT**, trace gravel to 50mm, brown grey, firm, damp	
0.5	3.6		**silty fine SAND**, trace clay, trace hard rounded gravel to 15mm, brown, firm	dis.
			0.8 becoming gravelly	
1.0	3.2		EOB UTP	
			stopbank crest	
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA5**
Client:	Horizons MW	Elevation:	2.6
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**clayey SILT**, brown, firm, damp	
	2.3		**silty fine to medium SAND**, brown, firm, damp	
	2.27		**clayey SILT**, brown, firm, damp	
0.5	2.2		**gravelly silty fine SAND**, rounded gravel to 10mm, dark brown, dense	
	2		EOB UTP	
1.0			inland toe of stopbank	
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Sheet 1 of 1

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA6**
Client:	Horizons MW	Elevation:	2.6
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, some clay, brown, firm, damp	
0.5	2.1		**SILT**, brown, grey, firm, damp	
1.0				
1.5	1.15		**fine sandy SILT / silty fine SAND**, grey	dis.
▼	1		**silty fine SAND**, blue grey	
	0.7		EOB UTP	
2.0			inland toe of stopbank	
2.5				
3.0				
3.5				
4.0				

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA7**

Elevation: 2.5
Date: 16/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, brown, damp	
	2.3		**sandy SILT and brick**, dark brown, old land fill??	
	2.2		EOB UTP	
0.5			14m inland from toe of stopbank	
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA8**
Client:	Horizons MW	Elevation:	2.7
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, some clay, brown, firm, damp	
	1.9		**silty fine SAND**, grey brown	
	1.6		**clayey SILT**, Fe stained grey, soft, damp to moist	
	0.8		**clayey SILT**, Fe stained blue grey, some rotten timber, soft, damp to moist	
	0.2		**SILT**, some fine sand, blue grey, soft, moist	
	-1.3		EOB 5m from stopbank toe on river side	

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA9**
Elevation: 4.5
Date: 18/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, brown, firm, damp	
	4.3		fine **sandy SILT,** brown, firm, damp	
0.5				
	3.7		**silty fine SAND**, brown, dense, damp	
1.0	3.5		**SILT**, some fine sand, clay and round hard gravel, orange and brown mottled stiff, damp	
	3.2		EOP UTP top of stopbank	
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA9a**
Client:	Horizons MW	Elevation:	3.0
Location:	Wanganui	Date:	18/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	2.95		**organic SILT,** brown, moist	
	2.8		**sandy SILT,** brown, firm, damp	dis.
			fine to medium **SAND**, black	
0.5	2.6		**silty fine SAND**, brown, mod. dense, damp	
	2.45		**SILT**, some sand, Fe stained grey, firm, damp	
	2.3		fine **sandy SILT**, brown, firm, damp	
1.0	2		**clayey SILT**, Fe stained grey, firm, damp	
1.5	1.6		**silty fine SAND**, brown, mod. dense, damp	dis.
2.0	1.1		**clayey SILT**, Fe stained grey, firm, damp	
2.5	0.7		**CLAY**, blue grey, soft to firm, plastic, moist	
	0.3		**CLAY**, brown, soft, moist	
3.0	0		**SILT**, blue grey, firm, moist	
▼	-0.1		**silty fine SAND**, blue grey	
3.5	-0.6		fine **sandy SILT,** blue grey	
	-0.7		EOB squeezing	
4.0			inland toe	

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA11**
Client:	Horizons MW	Elevation:	3.0
Location:	Wanganui	Date:	19/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, brown, firm, damp	
	2.7		**clayey SILT**, orange and brown, fill	
	2.65		EOB UTP gravel	
0.5			river side toe of stopbank	
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA11a**

Elevation: 3.1
Date: 19/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT,** brown, damp, firm	
	2.9		**sandy SILT,** orange and brown mottled, fill, firm, damp	
	2.7		**gravelly clayey SILT**, gravel to 20mm, brown, firm	
0.5	2.5		EOB UTP	
			river side of stopbank toe	
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA12**
Elevation: 3.0
Date: 17/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Description	Sample
0.0		**clayey SILT,** brown, firm to stiff, damp	
		0.4 some rounded gravel	
0.5	2.5	fine **sandy SILT**, brown	
	2.2	fine **SAND**, some silt, brown	
1.0	2	**organic fine sandy SILT**, dark brown, firm, damp	
	1.8	**clayey SILT**, some fine sand, brown, firm, damp	
1.5		1.5 moist	
2.0	0.9	**clayey SILT**, grey, soft to firm, moist	
2.5			
3.0 (water level)	0.1	fine **SAND**, grey, dense, wet	
	-0.2	medium to coarse **SAND**, black and white speckled	
3.5	-0.4	EOB washing in	
		river side toe of stopbank	
4.0			

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Sheet 1 of 1

Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA13**

Elevation: 2.7
Date: 18/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	2.6		**organic SILT**, brown, moist	
			clayey SILT, rare fine gravel, orange and brown mottled, firm, moist, fill?	
0.5	2		**clayey SILT**, brown, moist, firm	
1.0				
			1.3m some pumice gravel to 10mm	
1.5	1.2		**SILT**, some fine sand, some clay, brown, firm, moist	
	1		**silty fine SAND**, brown / grey, moist	
▼				
2.0	0.75		**clayey SILT**, trace fine sand, Fe stained grey, soft to firm, moist	
	0.5		**clayey SILT**, brown / grey, soft, wet	
2.5				
	-0.15		**silty fine SAND**, grey	
3.0	-0.5		EOB loosing sample	
			inland toe of stopbank	
3.5				
4.0				

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA14**
Client:	Horizons MW	Elevation:	2.5
Location:	Wanganui	Date:	19/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, some clay, brown, firm, damp	
0.6	1.9		**SILT**, brown, firm, damp 0.9 rare pumice gravel to 5mm	
1.1	1.4		**clayey SILT**, brown, firm, moist	
1.7	0.8		fine **sandy clayey SILT**, brown, soft, moist 1.8 iron pan?	
1.9	0.6		**clayey SILT**, trace fine sand, blue grey, iron layers, soft to hard, wet	
2.2	0.3		**SILT**, some clay and fine sand, blue grey, soft	
3.1	-0.6		EOB squeezing river bank	

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

HAND AUGER HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA15**

Elevation: 4.2
Date: 17/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**silty fine SAND**, grey brown, mod. dense, damp	
0.5	3.45		**fine sandy SILT**, rare rounded gravel, blue grey, moist	
	3.3		**CLAY**, brown, soft, moist	
1.0	3.2		**clayey SILT**, green grey, firm, moist	
1.5	2.75		fine to medium **SAND**, some silt and rounded gravel, black, dense 1.6 some clayey SILT with some gravel, firm, **fill**	
	2.5		**clayey SILT**, dark green grey, firm to stiff, damp 2.1m some hard rounded gravel to 10mm 2.2m some pumice gravel to 5mm	
2.0				
2.5	1.7		**clayey SILT**, some fine sand, grey, firm to stiff, moist	
	1.4		**fine sandy SILT**, grey, moist, firm	
3.0				
	1		**clayey SILT**, grey, firm, moist	
3.5	0.6		**silty fine SAND**, grey, wet	
	0.5		**CLAY**, brown, plastic	
	0.4		fine **sandy SILT**, grey, wet	
4.0	0.2		EOB stopbank crest	

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA16**
Client:	Horizons MW	Elevation:	4.1
Location:	Wanganui	Date:	17/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	4.05		**organic SILT** brown, topsoil	
	3.95		fine to medium **SAND**, black	
			EOB UTP **gravelly clayey SILT**	
0.5			stopbank crest	
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA16a**
Client:	Horizons MW	Elevation:	2.0
Location:	Wanganui	Date:	17/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**clayey SILT**, brown, firm, damp	
0.8	1.2		**clayey SILT**, some fine sand, Fe stained grey, soft, moist	
0.9	1.1		fine **SAND**, some silt, brown	
1.4	0.6		**CLAY**, some organic matter, brown	
1.7	0.3		EOB squeezing	
			river side toe of stopbank	

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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Sheet 1 of 1

Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA17**

Elevation: 2.6
Date: 17/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**clayey SILT**, some fine sand lenses, brown / cream / orange mottled, soft to firm, plastic, moist, fill	
	2.2		**clayey SILT**, orange stained grey, firm, damp	
0.5	2.1		**SILT**, orange stained grey, firm, damp	
	1.7		**silty fine to medium SAND**, brown, mod. dense, damp	
1.0	1.5		fine **sandy SILT**, brown, firm, damp	
	1.4		fine **SAND**, some silt, grey, mod. dense, damp	
1.5	1		**clayey SILT**, Fe stained blue grey, soft to firm, damp to moist	
2.0	0.5		**SILT**, some fine sand, brown grey, soft to firm, moist	
	0.4		**CLAY**, brown, soft, moist	
2.5	0.15		fine to medium **SAND**, grey	
	-0.1		EOB washing in - loosing sample toe of buttress	
3.0				
3.5				
4.0				

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Sheet 1 of 1

HAND AUGER HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

Project:	Kowhai Park Stopbank Upgrade	Test: **HA18**
Client:	Horizons MW	Elevation: 2.5
Location:	Wanganui	Date: 17/10/2012
Number:		Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**clayey SILT**, some fine sand lenses, brown / cream / orange mottled, soft to firm, plastic, moist, fill	
0.5	2.1		**clayey SILT**, dark grey, firm, damp	
1.0	1.6		**SILT**, some fine sand, grey, firm, damp	
1.5	1.1		fine **sandy SILT**, grey, firm, damp	
	1		**SILT**, some clay and fine sand, grey, firm, damp to moist	
	0.7		fine **SAND**, trace silt, grey, mod. dense, moist	
2.0	0.35		**clayey SILT**, grey, firm, moist	
	0.1		**CLAY**, some organic matter, brown, soft to firm	
2.5	-0.3		fine to medium **SAND**, dark grey	
	-0.4		bands **silty fine SAND** and **clayey SILT**, grey	
3.0	-0.8		fine to medium **SAND**, dark grey	
3.5	-1.1		EOB washing in toe of buttress	
4.0				

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Sheet 1 of 1

HAND AUGER HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA19**
Elevation: 2.5
Date: 17/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			clayey **SILT**, brown, firm, damp	
	2.3		**SILT**, some clay, orange mottled grey, firm, damp	
0.5	2		**SILT,** some fine sand, brown, firm, damp	
	1.8		fine **sandy SILT**, brown, firm, damp	
1.0				
	1.2		fine **SAND**, some silt, grey brown, mod. dense, damp	
1.5	1		clayey **SILT**, some fine sand, Fe stained grey, firm, moist	
▼	0.8		fine **SAND**, some silt, brown, mod. dense, moist to wet	
	0.6		clayey **SILT**, Fe stained blue grey, soft to firm, moist	
2.0	0.5		fine **sandy SILT**, blue grey, soft to firm	
	0.3		**CLAY,** some organic material, brown, soft	
2.5				
	-0.35		medium to coarse **gravelly SAND**, black, rounded gravel to 10mm, under pressure, washing in	
3.0	-0.4		EOB	
			toe of buttress, down stream end	
3.5				
4.0				

HAND AUGER HAND AUGER HAND AUGER BASIC HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

ICE GEO & CIVIL
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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA20**
Client:	Horizons MW	Elevation:	2.9
Location:	Wanganui	Date:	17/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	2.85		**organic SILT**, dark brown, topsoil	
	2.75		**clayey SILT**, some sand, mixed orange / grey / brown, firm, damp, fill	
	2.5		**silty fine gravelly SAND**, mottled brown, firm, damp	
0.5			**SILT**, some fine sand, brown, firm, damp	
1.0	2		**SILT,** some clay, rare pumice gravel to 10mm, brown, firm, damp	
1.5	1.4		**silty fine SAND**, brown, mod. dense	
2.0	1		**clayey fine sandy SILT**, Fe stained grey, soft to firm, moist to wet	
	0.9		**silty fine SAND**, Fe stained grey, mod. dense, wet	
	0.6		**clayey SILT**, grey, wet	
2.5	0.55		bands fine to medium **SAND**, black and **silty fine SAND**, grey, mod. dense, wet	
	0.2		**clayey SILT**, some fine sand, grey, soft	
	0.1		**silty fine SAND**, grey, mod. dense	
3.0	-0.15		EOB washing in	
3.5			inland toe of stopbank	
4.0				

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ICE GEO & CIVIL
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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA21**

Elevation: 2.3
Date: 19/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			**SILT**, some clay, grey brown, firm, damp	
0.5			0.8 some fine pumice gravel to 5mm	
1.0	1.4		**clayey SILT**, Fe stained grey, firm, moist	
	1		**silty fine SAND**, Fe stained grey, dense, moist	
1.5	0.7		**clayey SILT**, Fe stained blue grey, some fine roots, soft, moist	
	0.5		**SILT**, trace fine sand, blue grey, firm, moist	
2.0	0.3		EOB	
2.5			hollow among trees about 0.5m below typical ground level old stumps?	
3.0				
3.5				
4.0				

ICE GEO & CIVIL
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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA22**
Client:	Horizons MW	Elevation:	3.1
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	3.05		**organic SILT**, brown, topsoil	
			fine to medium **sandy SILT**, some rounded gravel to 5mm, grey, firm, damp	
	2.8		**SILT**, Fe stained grey, firm to stiff, damp	
0.5	2.6		**SILT**, brown, firm to stiff, damp	
1.0	2		**silty fine SAND**, brown, mod. dense	
1.5	1.6		**SILT,** some clay, rare pumice gravel to 5mm, brown, firm, damp	
	1.3		**fine SAND**, some silt, brown, mod. dense	
2.0	0.8		fine **sandy SILT**, brown, firm, damp	
▼ 2.5	0.65		fine to medium **SAND**, black, wet	
3.0	0		EOB washing in	
3.5			inland toe of stopbank	
4.0				

HAND AUGER HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

ICE GEO & CIVIL
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Project: **Kowhai Park Stopbank Upgrade**
Client: Horizons MW
Location: Wanganui
Number:

Test: **HA23**

Elevation: 2.8
Date: 16/10/2012
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	2.75		**organic SILT**, brown, topsoil	
			fine **sandy SILT**, brown, firm, damp	
0.5	2.35		**silty fine SAND**, brown, mod. loose	dis.
	2.2		**clayey SILT**, brown, firm, damp	
1.0	1.9		**SILT**, some fine sand, brown, firm, damp 1.2 some pumice gravel to 10mm	
1.5	1.35		**fine SAND**, some silt, brown, damp 1.7 moist	dis.
2.0	0.95		**clayey SILT**, Fe stained grey, firm, plastic, damp	
	0.7		fine to medium **SAND**, some silt, Fe stained grey, dense, wet	dis.
2.5				
3.0	-0.2		EOB washing in inland toe	
3.5				
4.0				

HAND AUGER HAND AUGER LOGS.GPJ HAND AUGER BASIC.GDT 15/11/12

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Project:	**Kowhai Park Stopbank Upgrade**	Test:	**HA24**
Client:	Horizons MW	Elevation:	3.4
Location:	Wanganui	Date:	16/10/2012
Number:		Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	3.35		**organic SILT**, brown, topsoil, damp	
	3.15		**SILT**, grey brown 0.15 some fine rounded gravel to 3mm	
			medium **sandy SILT**, some fine gravel to 3mm, orange and brown, firm, damp	
0.5	2.8		**silty fine SAND**, brown	dis.
	2.5		**clayey SILT,** brown, firm, damp	
1.0				
1.5				
	1.5		**CLAY**, brown, plastic, soft, moist	
2.0				
	1.1		**SILT**, some sand, brown, soft, moist	
2.5	0.9		fine **sandy SILT**, grey, soft, wet	
	0.7		**clayey SILT**, some fibrous material, grey, soft, wet	
3.0				
3.5	-0.2		EOB squeezing in outside toe of stopbank	
4.0				

ICE GEO & CIVIL
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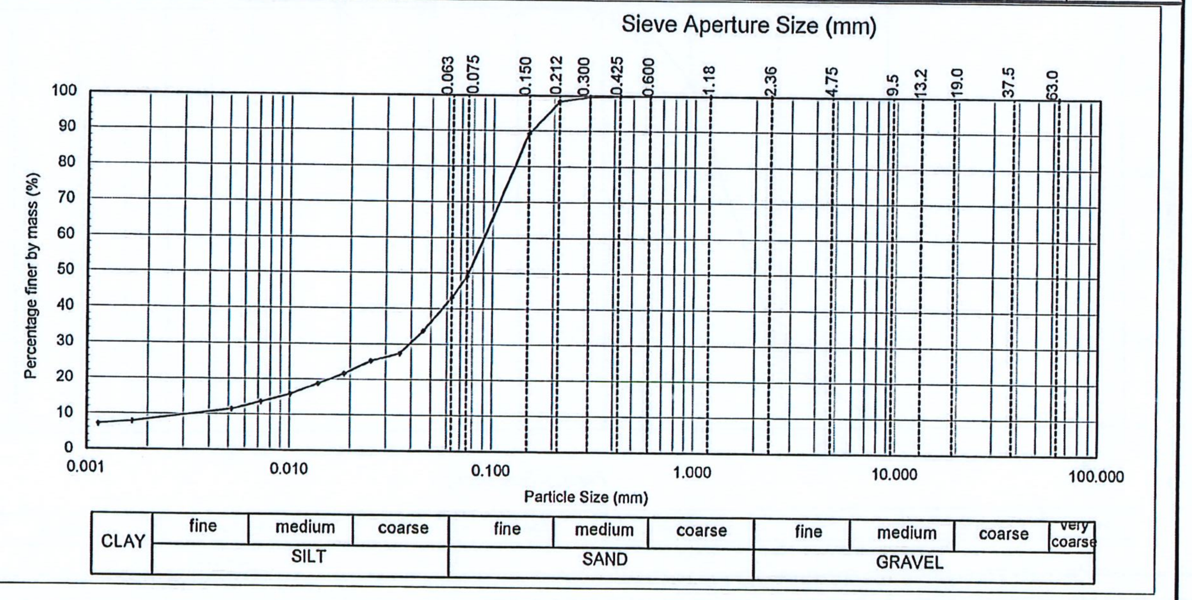
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD)
TEST REPORT

Project :	Kowhai Park Stop Banks
Location :	Wanganui
Client :	Ice Geo & Civil Ltd
Client/Sample Ref :	--
Contractor :	N/A
Borehole No:	HA6 Depth: 1.50m
Sampled by :	Dr M O'Halloran
Date received :	24 October 2012
Sampling method :	Unknown
Sample condition :	Natural State
Sample description :	Fine Silty SAND with Minor Clay
Solid Particle Density (t/m^3):	2.65
Water Content (as received):	33.2 %

Project No:	255549.00/0TL
Lab Ref No:	12/574A
Client Ref:	--

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	100	0.0456	34	0.0072	14
37.5	--	2.36	100	0.212	98	0.0349	27	0.0051	12
19.0	--	1.18	100	0.150	89	0.0253	25	0.0017	8
13.2	--	0.600	100	0.075	49	0.0185	22	0.0011	7
9.5	--	0.425	100	0.063	43	0.0138	19	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0100	16		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Washed Grading & Hydrometer Method)	pH of suspension : 9.0 (Whatmans Full Range pH Indicator paper) This report may only be reproduced in full.

Date Tested: 27 October 2012

Date Reported: 7 November 2012

Preliminary report only - subject to checking.

Approved

Designation : *Laboratory Technician*

Date : 7 November 2012

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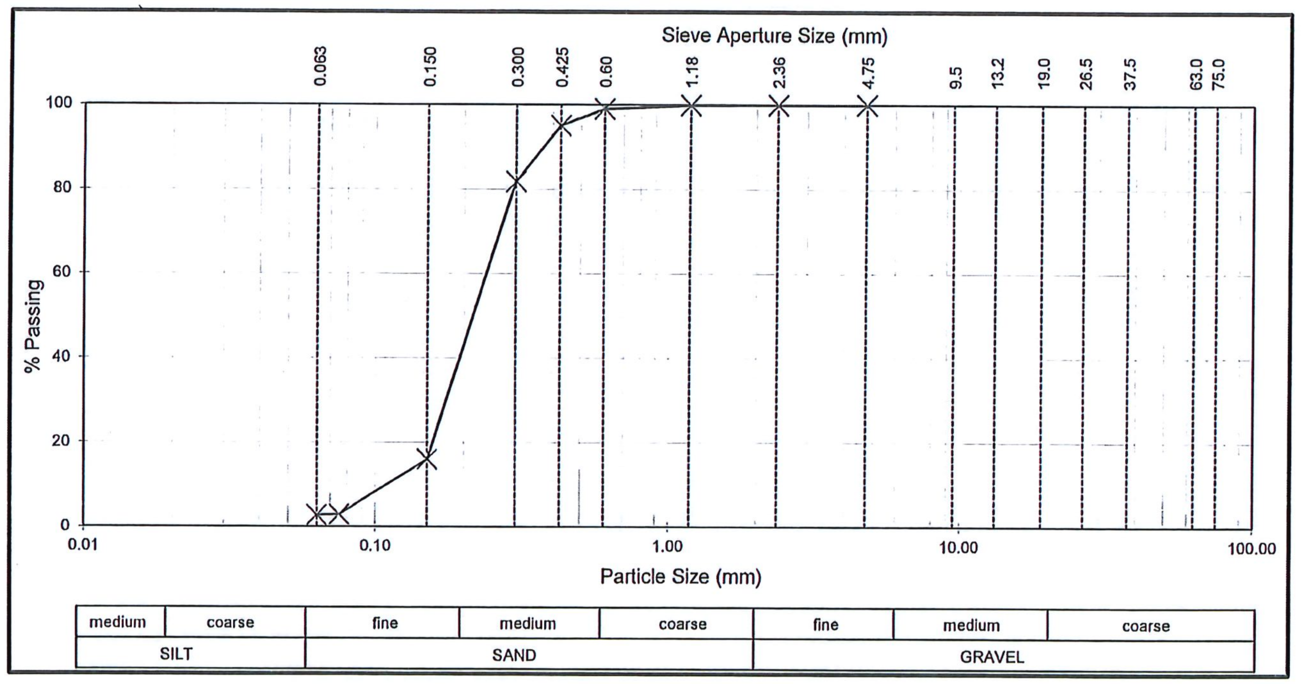
PARTICLE SIZE DISTRIBUTION
TEST REPORT

Project :	**Kowhai Park Stop Banks**
Location :	**Wanganui**
Client :	**Ice Geo & Civil Ltd**
Contractor :	**N/A**
Sampled by :	**Dr M O'Halloran**
Date sampled :	**Unknown**
Sampling method :	**Unknown**
Sample description :	**Medium Fine SAND with a trace of Silt**
Sample condition	**Natural State (as received)**
Bore hole no :	**HA6**
Depth (m) :	**1.50**

Project No :	**255549.00/0TL**
Lab Ref No :	**12/574B**
Client Ref No :	**--**

Sieve Analysis

Size (mm)	% Passing	Size (mm)	% Passing	Size (mm)	% Passing	Size (mm)	% Passing
75.00	-	19.00	-	2.36	**100**	0.300	**82**
63.00	-	13.20	-	1.18	**100**	0.150	**16**
37.50	-	9.50	-	0.60	**99**	0.075	**3**
26.50	-	4.75	**100**	0.425	**95**	0.063	**3**



Test Method		Notes
Particle Size Distribution	NZS 4402 1991 Test 2.8.1	The percentage passing the finest seive was obtained by difference. This report may only be reproduced in full.

Date tested : 25 October 2012
Date reported : 7 December 2012

Preliminary report only - subject to checking.

Approved

Designation : *Laboratory Technician*
Date : 7 December 2012

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PARTICLE SIZE ANALYSIS (HYDROMETER METHOD)

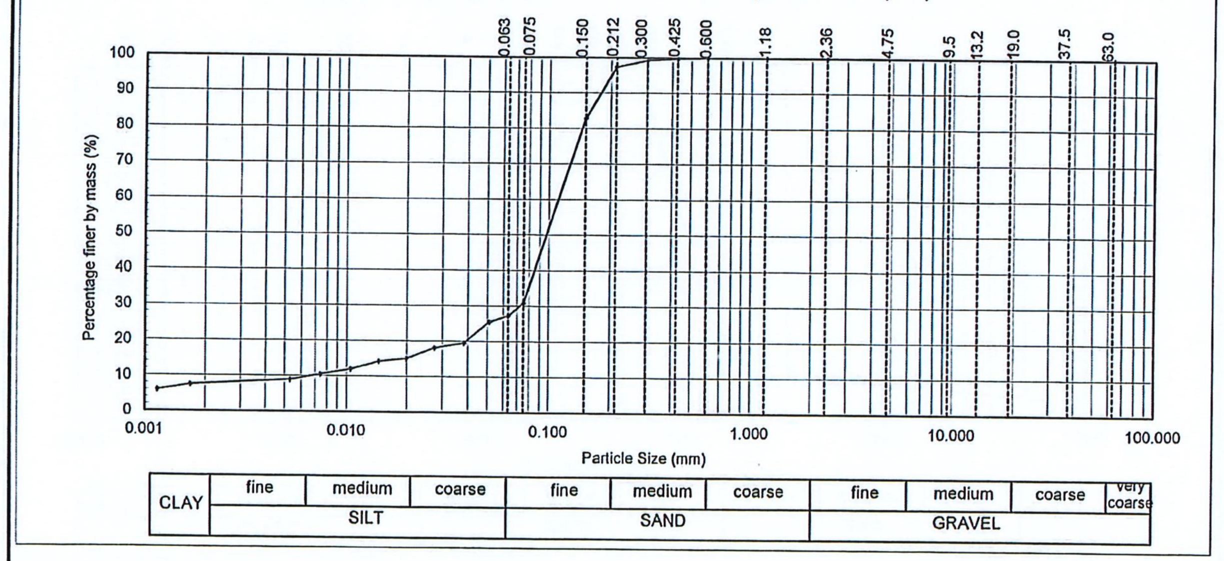
TEST REPORT

Project :	Kowhai Park Stop Banks
Location :	Wanganui
Client :	Ice Geo & Civil Ltd
Client/Sample Ref :	--
Contractor :	N/A
Borehole No:	HA9a Depth: 1.40 metres
Sampled by :	Dr M O'Halloran
Date received :	24 October 2012
Sampling method :	Unknown
Sample condition :	Natural State
Sample description :	Fine SAND with some Silt and minor Clay
Solid Particle Density (t/m^3):	2.65
Water Content (as received):	21.1 %

OPUS

Project No: 255549.00/0TL
Lab Ref No: 12/574C
Client Ref: --

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	99	0.0509	26	0.0074	11
37.5	--	2.36	100	0.212	97	0.0381	20	0.0053	9
19.0	--	1.18	100	0.150	83	0.0273	18	0.0017	8
13.2	--	0.600	100	0.075	31	0.0198	15	0.0012	6
9.5	--	0.425	100	0.063	27	0.0145	14	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0104	12		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Washed Grading & Hydrometer Method)	pH of suspension : 9.0 (Whatmans Full Range pH Indicator paper) This report may only be reproduced in full.

Date Tested: 27 October 2012

Date Reported: 7 December 2012

Preliminary report only - subject to checking.

Approved

Designation : *Laboratory Technician*

Date : 7 December 2012

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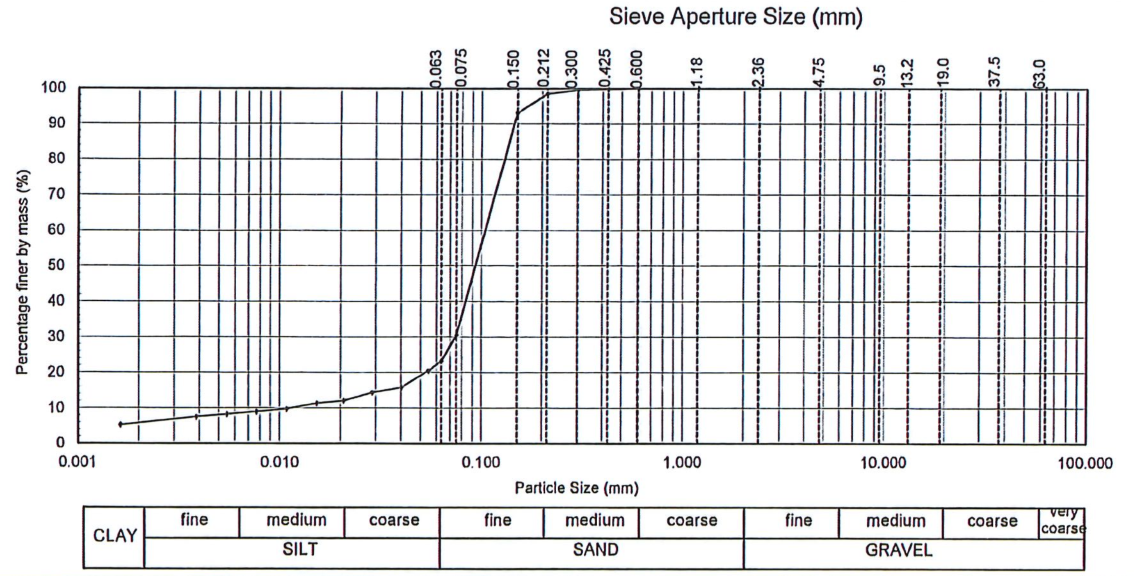
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD)
TEST REPORT

OPUS

Project :	Kowhai Park Stop Banks
Location :	Wanganui
Client :	Ice Geo & Civil Ltd
Client/Sample Ref :	--
Contractor :	N/A
Borehole No:	HA23 Depth: 1.50 metres
Sampled by :	Dr M O'Halloran
Date received :	24 October 2012
Sampling method :	Unknown
Sample condition :	Natural State
Sample description :	Fine SAND with some Silt and minor Clay
Solid Particle Density (t/m^3):	2.65
Water Content (as received):	27.6 %

Project No:	255549.00/0TL
Lab Ref No:	12/574E
Client Ref:	--

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	--	0.300	100	0.0545	20	0.0077	9
37.5	--	2.36	100	0.212	98	0.0401	16	0.0055	8
19.0	--	1.18	100	0.150	93	0.0287	14	0.0039	8
13.2	--	0.600	100	0.075	31	0.0207	12	0.0016	5
9.5	--	0.425	100	0.063	23	0.0152	11	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0108	10		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Washed Grading & Hydrometer Method)	pH of suspension : 9.0 (Whatmans Full Range pH Indicator paper) This report may only be reproduced in full.

Date Tested: 5 November 2012

Date Reported: 5 November 2012

Preliminary report only - subject to checking.

Approved

Designation : *Laboratory Technician*

Date : 5 November 2012

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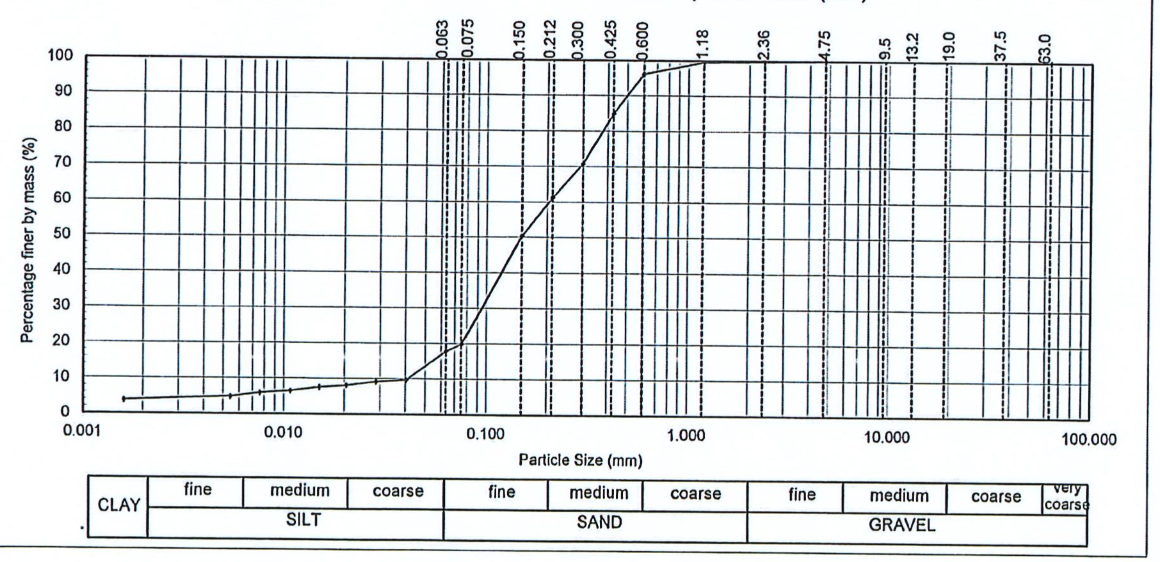
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD)
TEST REPORT

Project :	Kowhai Park Stop Banks
Location :	Wanganui
Client :	Ice Geo & Civil Ltd
Client/Sample Ref :	--
Contractor :	N/A
Borehole No:	HA23 Depth: 2.10 metres
Sampled by :	Dr M O'Halloran
Date received :	24 October 2012
Sampling method :	Unknown
Sample condition :	Natural State
Sample description :	Medium Fine SAND with some Silt and a trace of Clay
Solid Particle Density (t/m^3):	2.65
Water Content (as received):	28.8 %

Project No:	255549.00/0TL
Lab Ref No:	12/574F
Client Ref:	--

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	71	0.0401	10	0.0054	5
37.5	--	2.36	100	0.212	61	0.0285	9	0.0016	4
19.0	--	1.18	100	0.150	50	0.0204	8	--	--
13.2	--	0.600	96	0.075	20	0.0150	8	--	--
9.5	--	0.425	85	0.063	18	0.0107	7	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0076	6		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Washed Grading & Hydrometer Method)	pH of suspension : 9.0 (Whatmans Full Range pH Indicator paper)

Date Tested: 6 November 2012

Date Reported: 7 November 2012

Preliminary report only - subject to checking.

Approved

Designation : *Laboratory Technician*

Date : 7 November 2012

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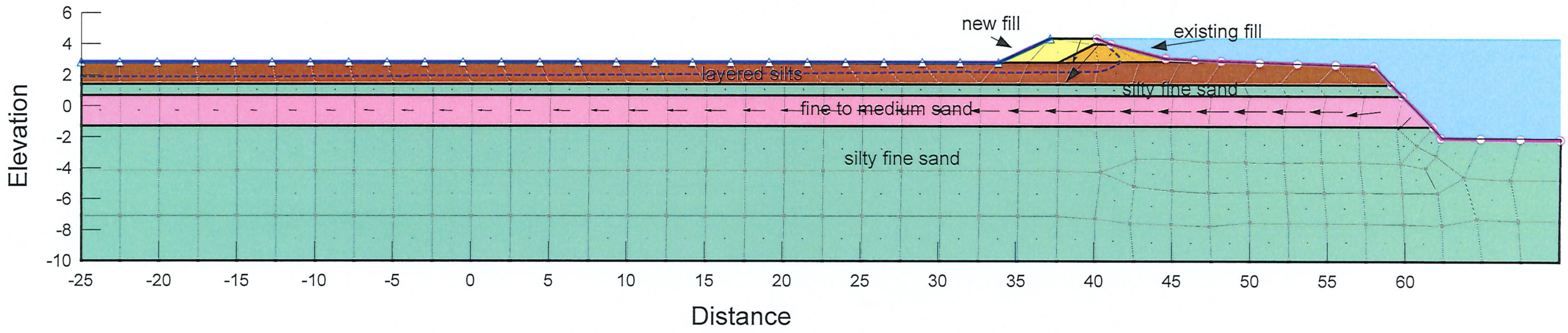
Website www.opus.co.nz

File Name: CS220 flood 50yr inland.gsz
Date: 14/11/2012 Time: 7:28:20 p.m.



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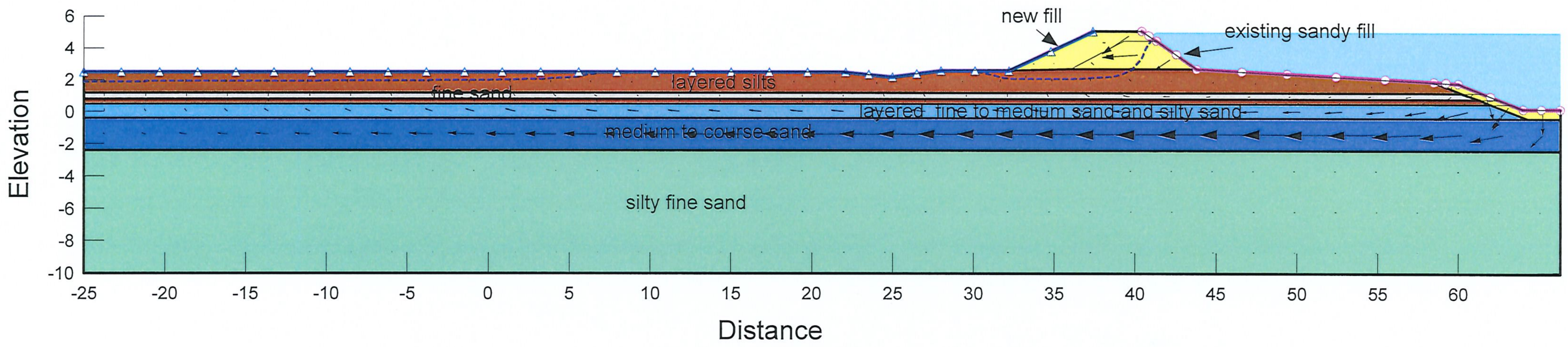
Date: 07/11/2012 Time: 4:17:25 p.m.



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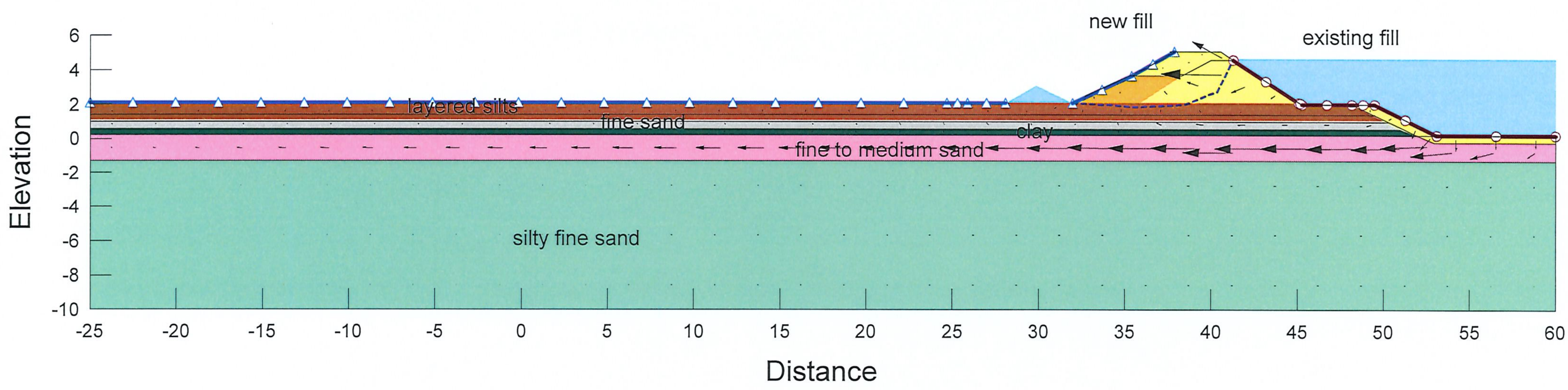

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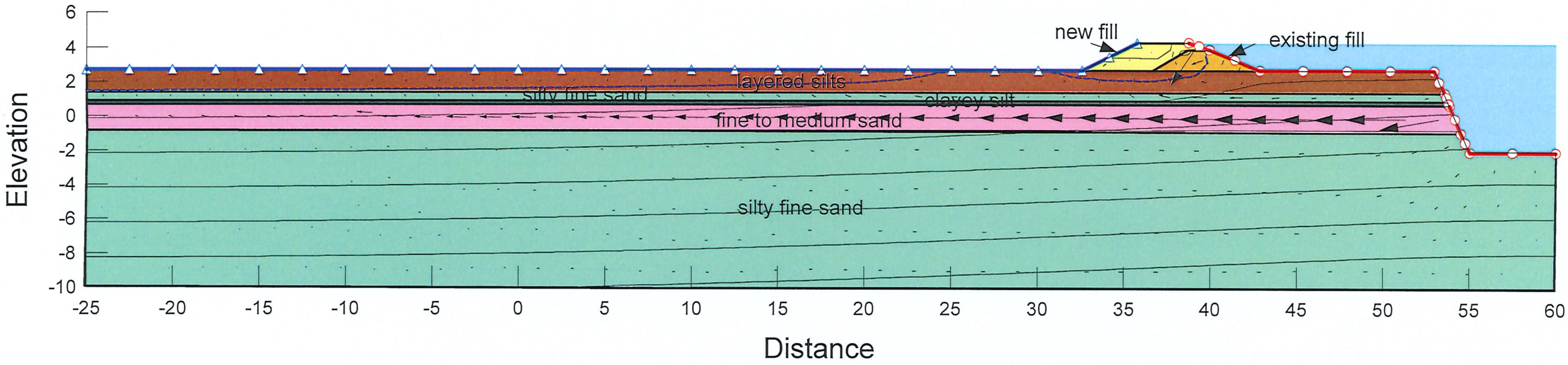
Date: 12/11/2012 Time: 9:38:16 a.m.



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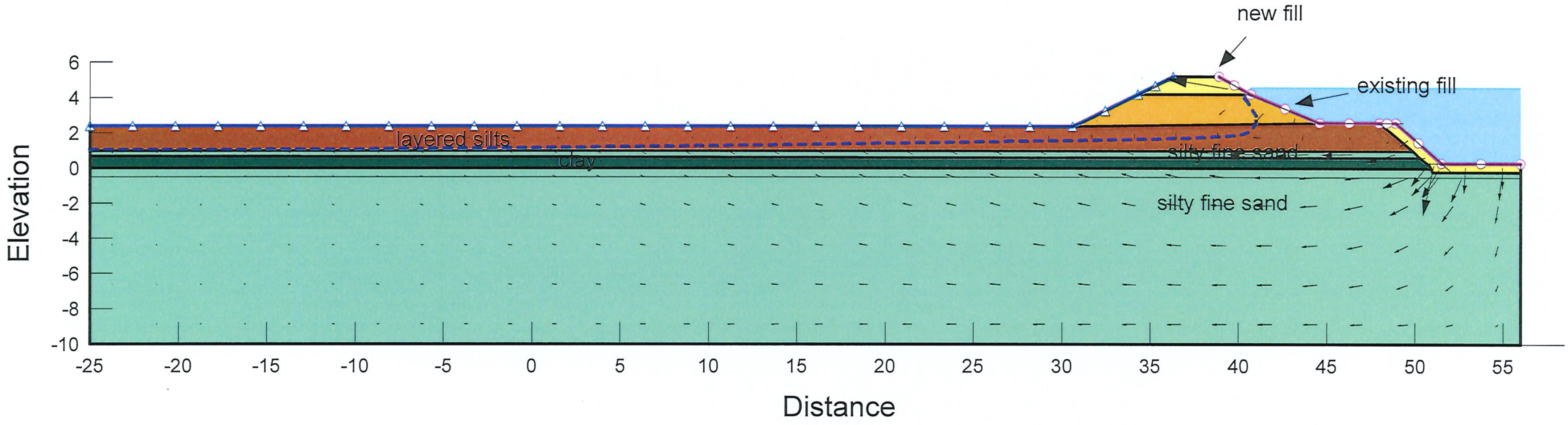
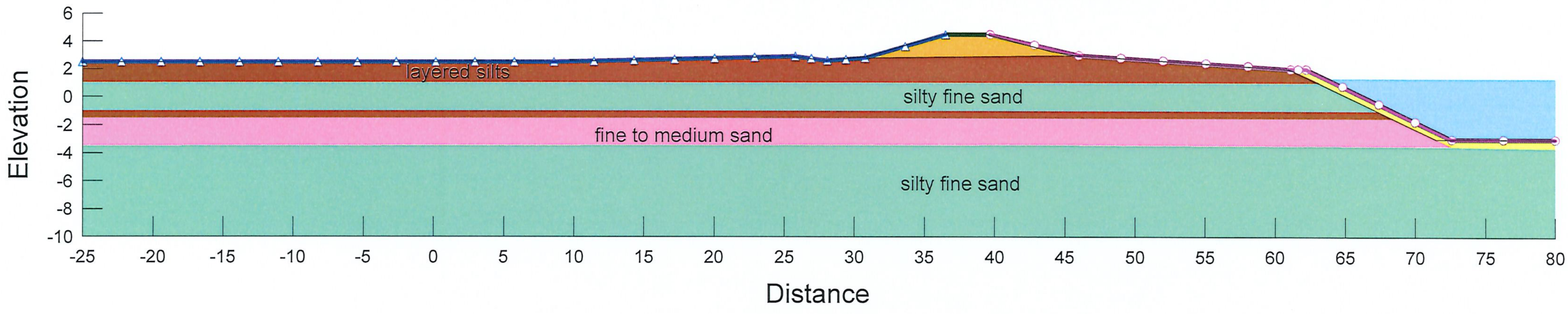
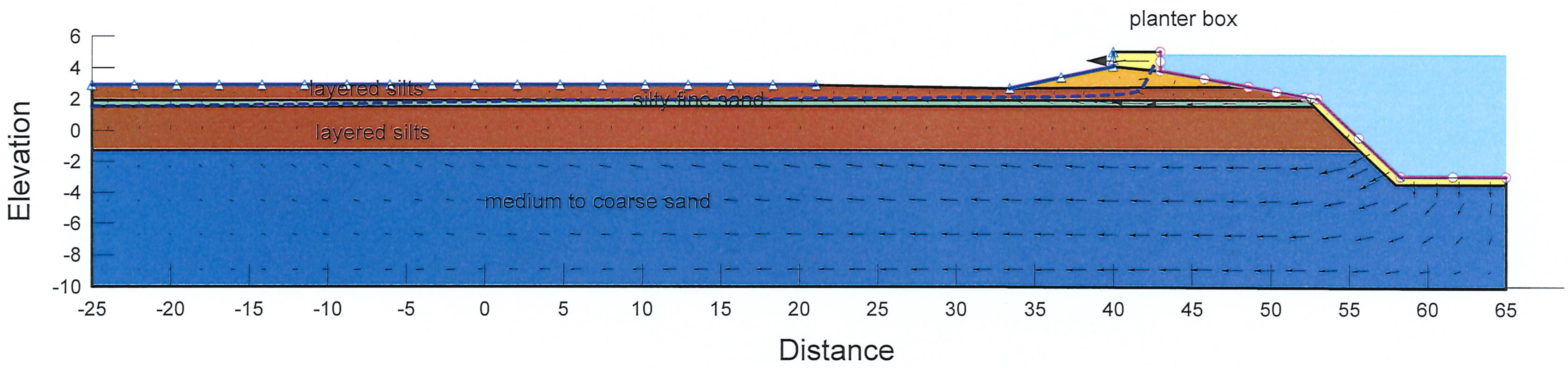
Date: 12/11/2012 Time: 10:01:45 p.m.



File Name: CS1437.gsz
Date: 09/11/2012 Time: 1:42:24 p.m.

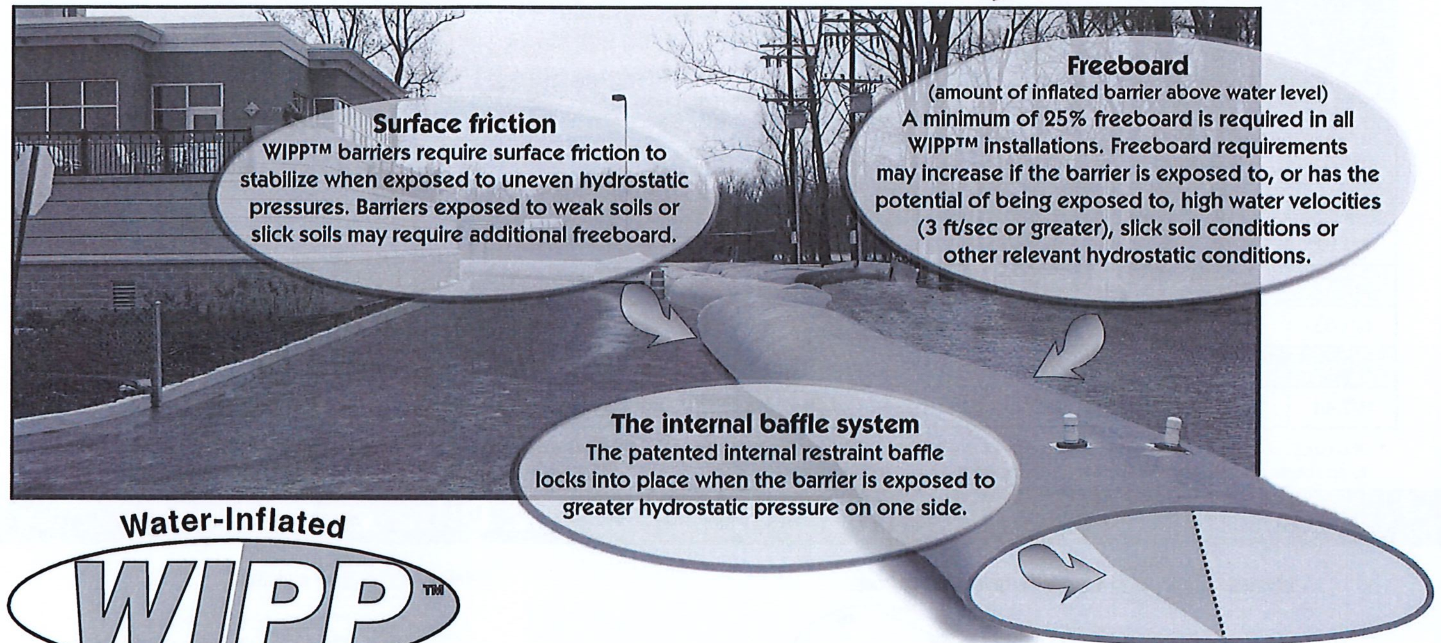


File Name: CS1815 50 year.gsz
Date: 09/11/2012 Time: 6:14:08 p.m.



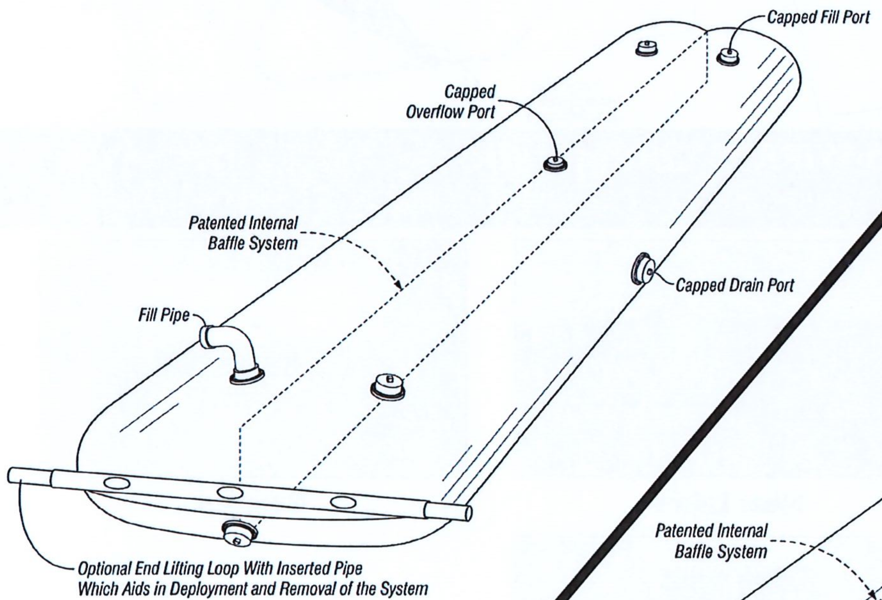
Commercial/Residential Applications

WIPP™ Stabilization Components



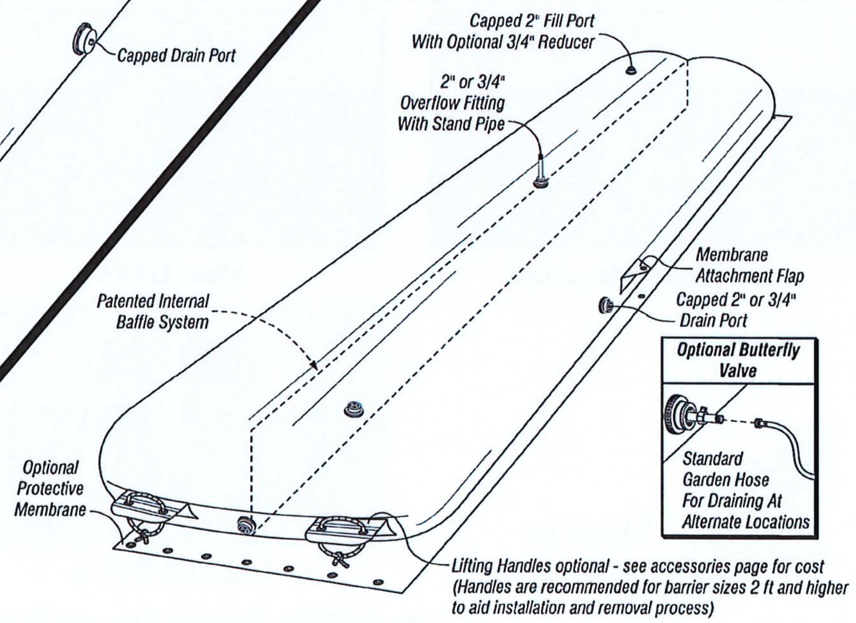
Water-Inflated WIPP™ Property Protector

WIPP™ Accessories:



Vinyl WIPP™
Industrial/Commercial

PE WIPP™
Light Commercial Residential



www.wippsystem.com

Call 800-245-0199 today for more information.

Hydro-Solutions, Inc.
Harnessing the Power of Water

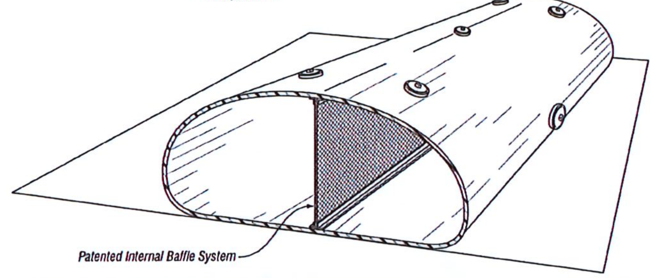
WIPP™ Standard Heights & Dimensions

Inflated Height (ft/m)	Maximum Controllable Water / Sediment Depth* (in/cm)	Inflated Volume (gal per linear ft/ liters per linear m)	Overlap Requirement (ft/m)	Inflated Width (ft/m)	SD - High Desity PE Weight per (lb per linear ft/ kg per linear m)	HD - 22 oz Vinyl Weight per (lb per linear ft/ kg per linear m)	MD - 30 oz Vinyl Weight per (lb per linear ft/ kg per linear m)
1/0.31	9/22.9	14/174	2.0/0.61	2.25/0.69	1.40/2.09	1.34/2.00	1.75/2.61
2/0.61	18/45.7	56/695	3.0/0.92	4.50/1.37	2.80/4.17	2.21/3.29	2.97/4.42
3/0.92	27/69.6	131/1627	4.5/1.37	7.00/2.14	4.20/6.26	3.38/5.04	4.60/6.85
4/1.22	36/91.4	225/2794	6.0/1.83	9.00/2.75	5.60/8.34	4.21/6.27	5.76/8.58
5/1.53	45/114.3	352/4371	7.5/2.29	11.25/3.43	9.60/14.30	N/A	8.32/12.39
6/1.83	54/137.2	506/6284	9.0/2.74	13.50/4.12	11.40/16.98	N/A	10.40/15.49
7/2.14	63/160.0	688/8544	10.5/3.20	15.75/4.81	N/A	N/A	12.00/17.87
8/2.44	72/183.0	901/11189	12.0/3.66	18.00/5.50	N/A	N/A	13.64/20.32

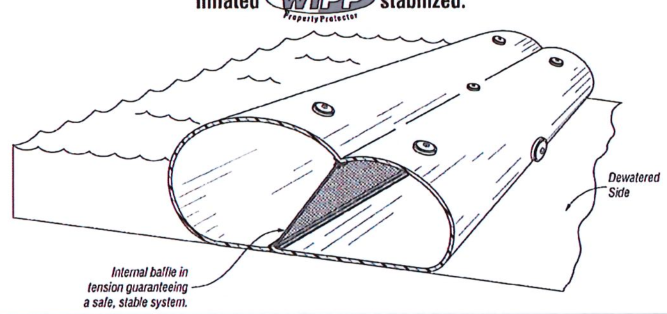
* This depth of water represents 75% of the height of a fully inflated WIPP™. It is <u>required</u> that a minimum 25% freeboard capacity be maintained during all phases of a project. Excess slope and grade, soil composition, moving water, and related hydrological criteria may increase or decrease the ability of an WIPP™ to perform as projected.

The Patented Baffle Makes the Difference

Inflated WIPP on dry surface prior to flood.

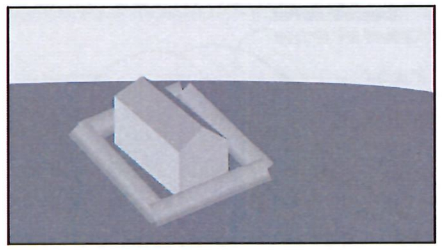


Inflated WIPP stabilized.

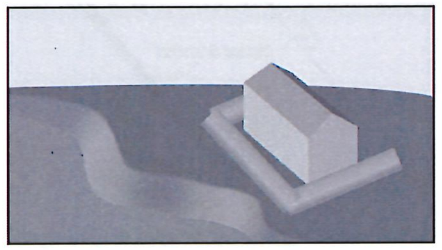


Standard WIPP™ Configurations

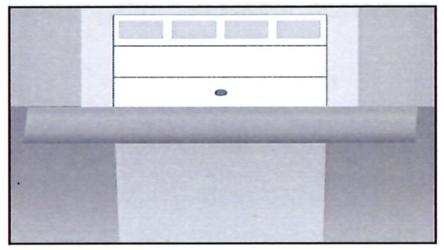
WIPP™ can be used in a variety of configurations to meet your specific flood protection needs.



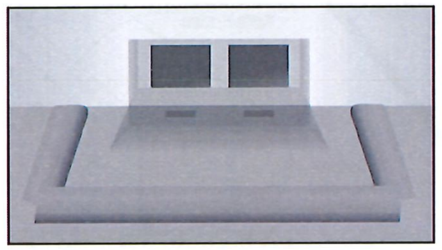
Complete Enclosure



Near Lakes



Garages



Loading Docks

Made in U.S.A.

Water-Inflated WIPP™ Property Protector

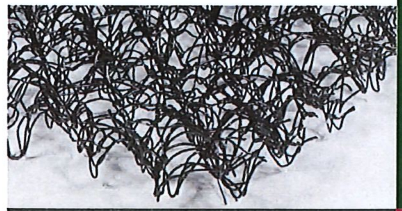
The WIPP™ System Release Statement

The WIPP System when properly used is a temporary barrier against surface water. Due to the unknown variables involved with the complex task of preventing floodwater from entering a facility, Hydro-Solutions, Inc. accepts no responsibility for floodwater infiltration under or around a properly inflated WIPP System. The WIPP System cannot prevent water from migrating underneath the system via cracks, crevices, pipes, etc., and/or porous soil conditions. Preparations should be made prior to a flood event and the installation of the WIPP System to insure that any area where water can infiltrate is properly sealed.

For more information, visit **www.wippsystem.com**

www.hydrologicalsolutions.com

*US Patent #5865564



Enkamat®

Permanent erosion prevention system

PRODUCT DATA			7010	7018	7020	7220
Product details						
Mass per unit area	(EN ISO 9864)	g/m²	260	290	400	400
Nominal thickness		mm	10	18	20	18
Tensile strength (md/cmd)[1]	(EN ISO 10319)	kN/m	2.0 / 1.4	2.0 / 1.2	2.2/ 1.6	2.0 / 2.2
Polymer 3-dimensional core			PA6			
Color			black			
Polymer density		kg/m³	1140			
Temperature resistance		°C	-40 to +80			
Inflammability	(DIN 4102)		B2			
Structure type			open	open	open	open, one side flat back
3 dimensional structure providing free volume		%	>95			
Soil retention factor		m/m²	1810	1290	1420	2980
Dimensions						
Length[2] x width of geocomposite		m	150 x 1.0	120 x 1.0	100 x 1.0	60 x 1.0
Length / diameter of roll		m	1.03/1.15	1.03/1.25	1.03/1.2	1.03/1.2
Gross weight [3]		kg	40	35	40	24.5

Prescription of installation

Ageing:	Good resistance to weathering and UV radiation.
Chemical resistance:	Resistant to all chemicals in concentrations which are normally contained in the earth and surface water.
Toxicity:	None; approved for use in potable water reservoirs; Enkamat is inert and not harmful to the environment.
Rodent damage:	No nutritive value; the tangled structure of the mat is unpleasant to burrowing animals and rodents.

[1] md = machine direction / cmd = cross machine direction.
[2] Standard width is 1.0 m; widths of 1.95 m and 3.85 m are available on request;
[3] Gross weight = matting + packaging, individual values may vary.

Colbond bv
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6800 TC Arnhem
The Netherlands

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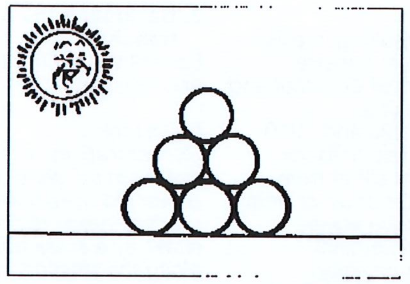
F: +31 85 744 1310
geosynthetics@colbond.com
www.colbond-geosynthetics.com
www.colbond.com

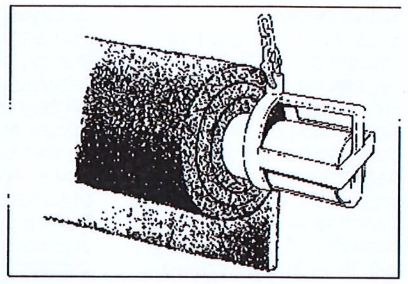
[redacted]

Storage, handling and laying guide Enkamat®; Enkamat® A20

Storage of Enkamat

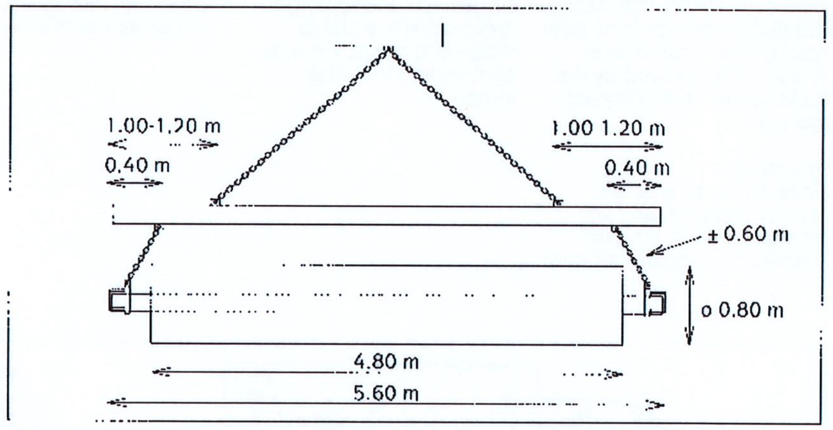
It is advisable to store Enkamat in its original wrapping; covering of any rolls remaining in the open for long periods is recommended.





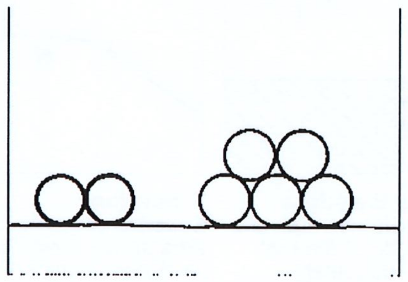
Handling Enkamat A20

To unload Enkamat A20 without damage the hood of the truck must be removed. For transportation on site and installation two endcaps and an extra steel pole are provided. The contractor shall alter the steel pole into a cross-bar as shown in the drawing. The user will need to provide chains and shackles to permit the safe handling of rolls weighing 2.5 tonnes. No other equipment should be substituted for the items provided. The empty poles and the remaining attributes are returnable after installation by Colbond Geosynthetics.



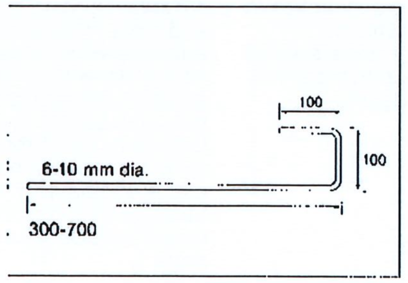
Storage of Enkamat A20

Enkamat A20 will be delivered on rolls with a diameter of approx. 0.80 m. The rolls should not be stacked more than two rolls high. During hot conditions rolls of Enkamat A20 should be covered to prevent softening of the bitumen.



Fixing pin details

The diameter and length of the fixing pins shall be chosen to suit the site and soil conditions; minimum dimensions are 6 mm diameter and 300 mm length for Enkamat, whereas Enkamat A20 requires minimum values of 8 mm diameter and 500 mm length. We advise to use ribbed mild steel.



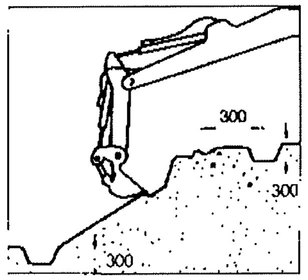
Note:

As vegetation is an integral part of the Enkamat erosion control system, the establishment of a vegetative cover is an important factor which should not be underestimated.
For this reason the following points should be considered:
a) Soil conditions under the Enkamat should be capable of supporting good growth.
b) Seed mixtures should be chosen to suit the particular soil and climatic conditions, as well as the land use.
c) The use of fertilisers and hydrophilic materials can prove beneficial in establishing vegetation.

A member of the ACORDIS group

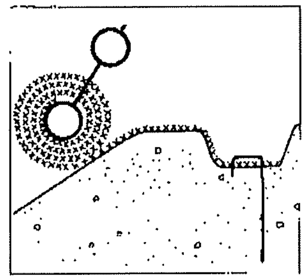
COLBOND
GEOSYNTHETICS

Laying guide Enkamat

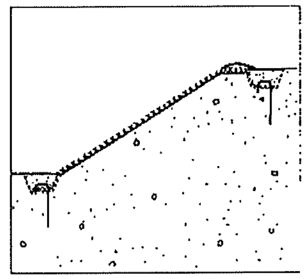


1. Excavation
Excavate the slope to a smooth profile, free from vegetation, roots, stones, etc., filling any voids. The slope must be stable and properly compacted, in particular in the backfilled areas. Excavate anchor trenches at the toe and shoulder of the bank not less than 300 mm deep (see overleaf for alternative details). If the soil is of poor quality, the surface layer should be improved by the inclusion of well compacted top soil.

Important:
Enkamat is an erosion control material, and will not increase the internal stability of unstable slopes.

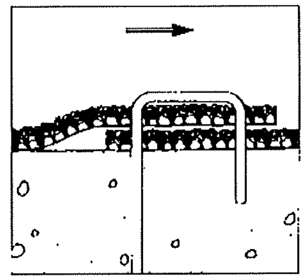


2. Laying
Place the matting in either trench, pin at 1 metre centres, unroll Enkamat and slightly tension.
Enkamat 7220 and 7210 should be laid flatback down. Work either from the shoulder down or from the toe up; we advise against longitudinal installation on steep slopes. Cut to the length required with a sharp blade and pin at 1 metre centres into the other trench.

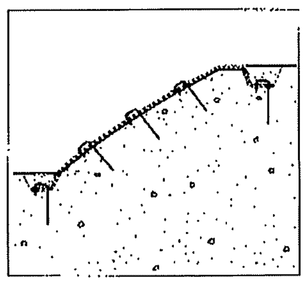


3. Backfilling the trenches
Backfill the anchor trenches and compact.

Important:
Concentrations of surface water run off should be prevented from flowing over the newly laid slope either by a small bund along the shoulder or diversion through gutters or pipes laid on the slope.

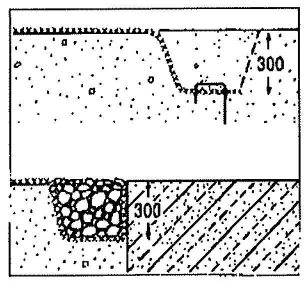


4. Securing of overlaps
In watercourses overlaps of 150 mm min. should be made with the upstream section laid over the downstream section. All overlaps should be pinned at max. 1 metre centres; in severe conditions additional pins at 500 mm centres are recommended. Particular attention should be paid to pinning at water level. On dry slopes overlaps of 100 mm are required.

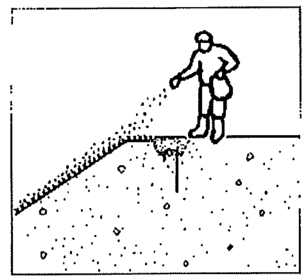


5. Intermediate pinning
It is essential to ensure total contact between Enkamat and the underlying soil. Intermediate pinning at regular intervals is required at high loadings. An ideal slope will be slightly convex. A concave slope should be pinned on a 1 m grid. Normal intermediate pinning would be at a rate of 1 pin every 2-3 m².

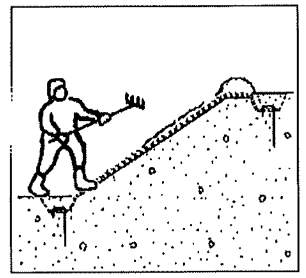
Important:
Intermediate pinning of the matting into any low spots should be carried out to ensure total contact between Enkamat and the soil below. However, it is best to backfill or reprofile all such low spots or voids.



6. Securing the edges
Free edges, for example the upstream side of the mat, should be adequately secured; the connection to hard revetments or structures requires special attention. See overleaf for alternative details.

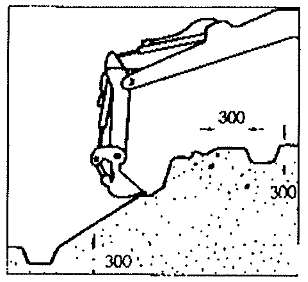


7. Seeding
Seed the empty Enkamat area above normal water level with 20 g/m² of suitable indigenous seed, and plant rhizomes or aquatic plants below normal water level (or spread some soil containing rhizomes prior to laying the Enkamat). 2/3 of the seed is to be placed into the open mat, the remaining 1/3 is to be sown on top of the finished profile. See note on page 1.

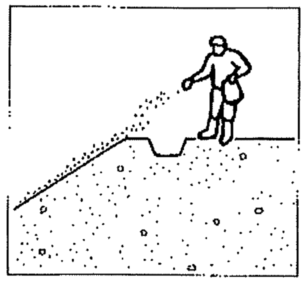


8. Topsoil filling
Rake in friable topsoil to give a cover of 10 mm to 20 mm over the Enkamat. Stone chippings should be considered where Enkamat is to be permanently submerged or subjected to high water velocities (approximately 15 kg/m² of 2-6 mm angular gravel to be raked in prior to topsoil filling of the upper section). The recommended soil cover results in optimum filling of the mat after natural compaction.

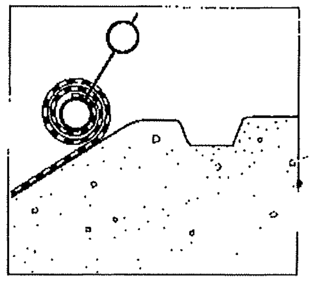
Laying guide Enkamat A20



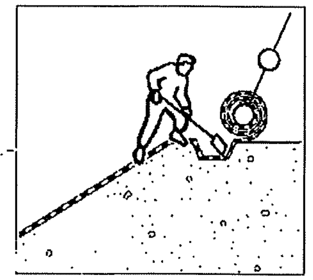
1. Excavation
Excavate the slope to a smooth profile, free from vegetation, roots, stones, etc., filling any voids. The slope must be stable and properly compacted, in particular in backfilled areas. Excavate anchor trenches at the toe and shoulder of the embankment not less than 300 mm deep. If the soil is of poor quality, the surface layer should be improved by including some topsoil.



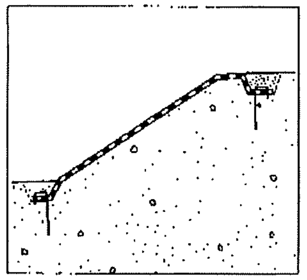
2. Seeding
Seed the area above normal water level with 30 gr/m² of suitable seed, and plant rhizomes or aquatic plants below normal water level (or spread some soil containing rhizomes prior to laying Enkamat A20). See note on page 1.



3. Laying
Place the matting in the trench, pin at 1 metre centres and unroll Enkamat A20. Work either from the toe up (recommended) or from the shoulder down; we advise against longitudinal installation. Keep the roll on or near the ground during installation to avoid unintentional unrolling. The installation of Enkamat A20 at temperatures below 5° C is not recommended.

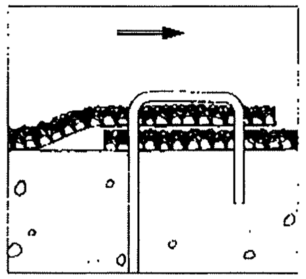


4. Cutting to length
Cut to the length required with a spade or disc cutter. If the roll has to rest on the slope or close to the brink of the bank it should be secured to prevent uncontrolled unrolling. People should not work or stand on the downhill side of the roll for safety reasons. Eye shields should be worn when using a disc cutter. Pin the Enkamat A20 at 1 m centres into the second trench.

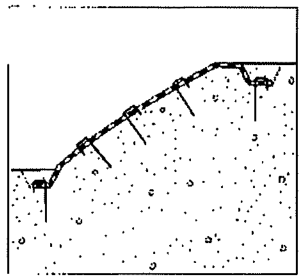


5. Backfilling to trenches
Backfill the anchor trenches and compact.

Important:
Concentrations of surface water run off should be prevented from flowing over the newly laid slope either by a small bund along the shoulder or diversion through gutters or pipes laid on the slope.

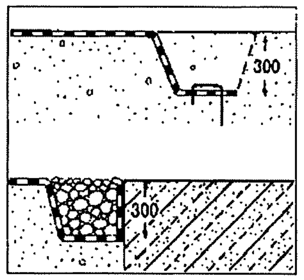


6. Securing of overlaps
Overlaps of 300 mm should be allowed for adjacent sections laid 'in-the-dry', 500 mm if laid 'in-the-wet'. All overlaps should be formed upstream over downstream and pinnend at 1 metre max. centres. In areas of turbulence or high velocities, pinning at 500 mm centres is recommended. Particular attention should be paid to pinning at water level and in the tidal zone.

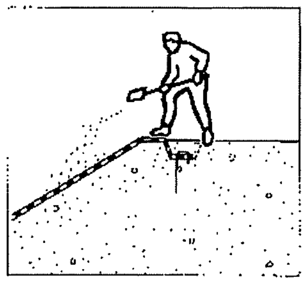


7. Intermediate pinning
In severe conditions we recommend the placing of intermediate pins at a rate of 1 pin every 3-4 m².

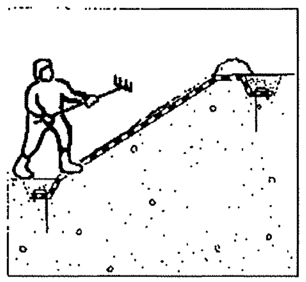
Important:
Intermediate pinning of the matting into any low spots should be carried out to ensure total contact between Enkamat A20 and the soil below. However, it is best to backfill or reprofile all such low spots or voids.



8. Securing the edges
Free edges should be adequately secured; the connection to hard revetments or structures requires special attention. See overleaf for alternative details.

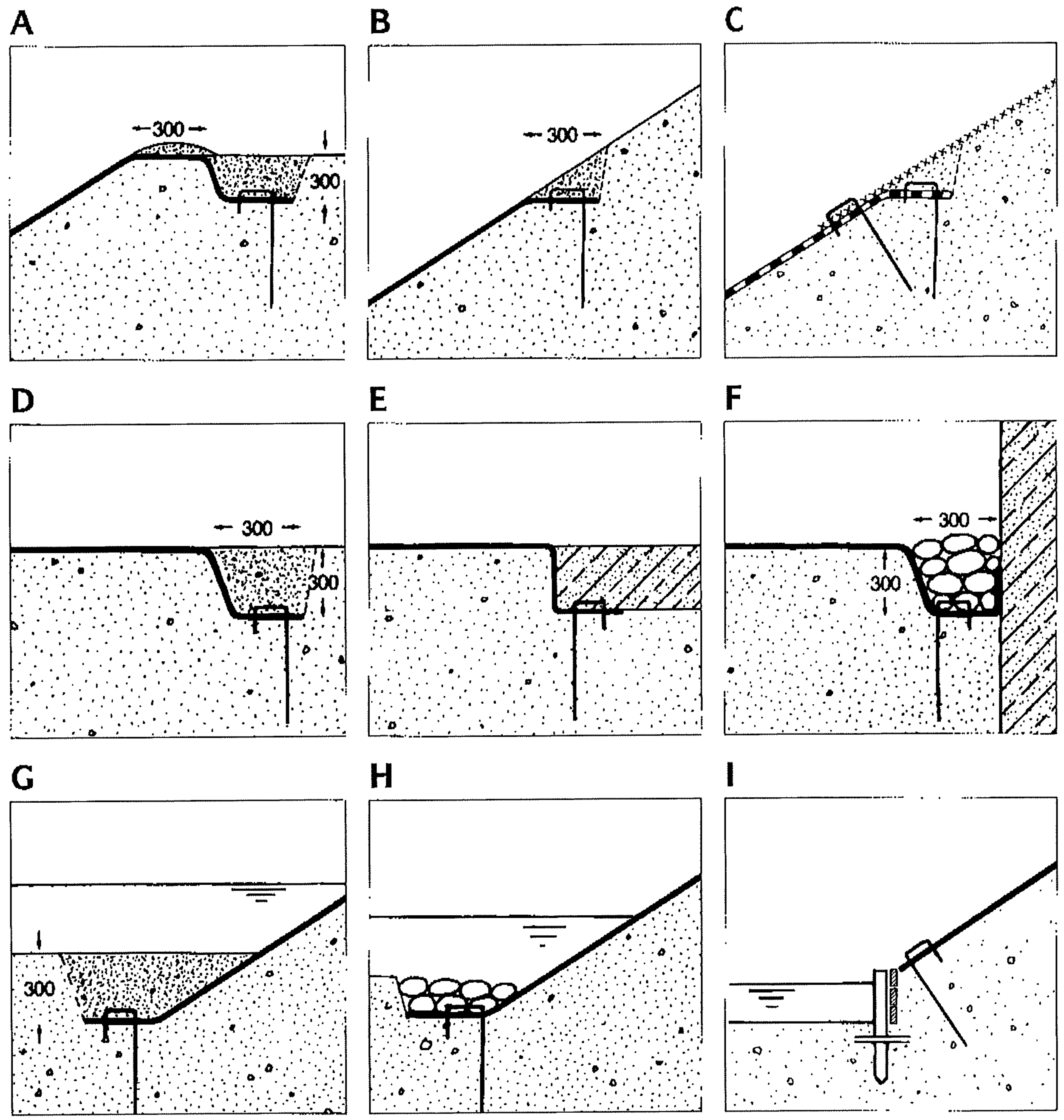


9. Blinding
If laid during the summer months, Enkamat A20 should be blinded with a thin layer of sand or friable topsoil to prevent any heat absorption from damaging the seed (not more than a few mm cover).



10. Enkamat A20 + Enkamat
When Enkamat A20 is used in combination with standard Enkamat, first install Enkamat A20, secure the top edge in a trench at least 500 mm above normal water level, fill and compact, as shown overleaf. Lay standard Enkamat to overlap the backfilled trench, secure with pins at 250 mm centres and rake in topsoil to give a covering of 10 mm to 20 mm over the Enkamat (detail C).

Principal anchoring details for Enkamat and Enkamat A20



Note:
All pins shall be placed parallel to the edges of the matting to assure optimum fixing efficiency (for clarity the pins have been shown above in the other direction).

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EM-23-GB-A-11/2002 Printed in the Netherlands

The Quality Management System of Colbond Geosynthetics, at Arnhem (development and sales) and Obernburg (production), has been approved by Lloyd's Register Quality Assurance Limited for the NEN-EN-ISO 9001: 2000 quality management system standard. (Certificate No. 935136)

Kowhai Park Stopbank - Wanganui					
Construction Cost Estimate (Rough)		Minimum Standard			
Item	**Description**	**Unit**	**Quantity**	**Rate**	**Value**
1	Establishment	LS	1	10,000	10,000
2	Surveying / As-builts	LS	1	10,000	10,000
3	Quality Control	LS	1	6,000	6,000
4	Health and Safety Plan	LS	1	1,000	1,000
5	Sediment and dust control	LS	1	8,000	8,000
6	Clear vegetation	LS	1	22,000	22,000
7	Strip and stockpile topsoil	m2	14,700	8	117,600
8	Remove and replace sand layers (Prov. Sum)	m3	400	40	16,000
9	Supply, place, compact and trim fill (solid)	m3	9,800	35	343,000
10	Supply and place 100mm topsoil	m2	14,700	7	95,550
11	Supply and apply seed and fertiliser	m2	14,700	3	44,100
12	Maintain grass for 3 months	LS	1	15,000	15,000
13	Form ends of stopbanks for flood barriers	no.	8	105	840
14	Supply and place planter box walls				
14a	500mm high with hand rails (Multi Sports)	m	24	790	18,960
14b	750mm high	m	50	620	31,000
14c	800mm high	m	53	655	34,715
15	Supply and construct 1.5m wide gravel path	m	1,376	88	121,088
16	Supply and construct 600mm high wing walls	LS	1	7,000	7,000
	to Anzac Parade Bridge				
17	Supply and construct 1.0m high floodwall	m	130	900	117,000
18	supply 1.2m dia. water filled barriers				
18a	Matarawa Stream bridge 30m	LS	1	18,000	18,000
18b	downstream end carpark 15m	LS	1	10,000	10,000
18c	upstream end carpark 10m	LS	1	7,000	7,000
18d	boat ramp 25m	LS	1	16,000	16,000
19	Extra work at skate board park	LS	1	10,000	10,000
20	Form gravel road over stopbank	LS	1	4,000	4,000
21	Extra work at Multi Sports Club	LS	1	3,000	3,000
22	Lift manholes	no.	5	250	1,250
23	Reinstate damaged areas	LS	1	10,000	10,000
	Contingencies				110,000
	Total cost to raise stopbank to 30 year return period plus 300mm freeboard le				**$1,208,103**

	Upgrade Options				
U1	Widen buttress section				
	strip topsoil	m2	740	8	5,920
	place fill	m3	200	35	7,000
	spread topsoil	m2	740	7	5,180
	grassing	m2	740	3	2,220
	Supply, construct 1.2m high timber retaining wall	m	30	655	19,650
U2	Widen path to 3m	m	1,376	22	30,272
	New 3m path in buttress section	m	184	108	19,872
U3	Place Enkamat along crest and beneath planters	m	2,023	165	333,795
	Total costs				**$1,632,012**

Kowhai Park Stopbank - Wanganui		Anzac Parade Option			
Construction Cost Estimate (Rough)		Minimum Standard			
Item	Description	Unit	Quantity	Rate	Value
1	Establishment	LS	1	10,000	10,000
2	Surveying / As-builts	LS	1	10,000	10,000
3	Quality Control	LS	1	6,000	6,000
4	Health and Safety Plan	LS	1	1,000	1,000
5	Sediment and dust control	LS	1	8,000	8,000
6	Clear vegetation	LS	1	22,000	22,000
7	Strip and stockpile topsoil	m2	11,100	8	88,800
8	Remove and replace sand layers (Prov. Sum)	m3	400	40	16,000
9	Supply, place, compact and trim fill (solid)	m3	7,800	35	273,000
10	Supply and place 100mm topsoil	m2	12,000	7	78,000
11	Supply and apply seed and fertiliser	m2	12,000	3	36,000
12	Maintain grass for 3 months	LS	1	15,000	15,000
13	Form ends of stopbanks for flood barriers	no.	8	105	840
14	Supply and place planter box walls				
14b	750mm high	m	50	620	31,000
15	Supply and construct 1.5m wide gravel path	m	524	88	46,112
16	Supply and construct 600mm high wing walls	LS	1	7,000	7,000
	to Anzac Parade Bridge				
17	Supply and construct 1.0m high floodwall	m	130	900	117,000
18	supply 1.2m dia. water filled barriers				
18a	Matarawa Stream bridge 30m	LS	1	18,000	18,000
18b	downstream end carpark 15m	LS	1	10,000	10,000
18c	upstream end carpark 10m	LS	1	7,000	7,000
19	Extra work at skate board park	LS	1	20,000	20,000
20	Form road over stopbank	ea.	2	3,300	6,600
21	N/A				0
22	Lift manholes	no.	2	250	500
23	Reinstate damaged areas	LS	1	10,000	10,000
	Contingencies				84,000
	Total cost to raise stopbank to 30 year return period plus 300mm freeboard le				**$921,852**
	Upgrade Options				
U1	Widen buttress section				
	strip topsoil	m2	740	8	5,920
	place fill	m3	200	35	7,000
	spread topsoil	m2	740	7	5,180
	grassing	m2	740	3	2,220
	Supply, construct 1.2m high timber retaining wall	m	30	655	19,650
U2	Widen path to 3m	m	524	22	11,528
	New 3m path in buttress section	m	184	108	19,872
U3	Place Enkamat along crest and beneath planters	m	1,750	165	288,750
	Total costs				**$1,281,972**

Kowhai Park Stopbank - Wanganui		Anzac Parade Option			
		Q30 design level			
Construction Cost Estimate (Rough)		Minimum Standard			
Item	Description	Unit	Quantity	Rate	Value
1	Establishment	LS	1	8,000	8,000
2	Surveying / As-builts	LS	1	8,000	8,000
3	Quality Control	LS	1	4,000	4,000
4	Health and Safety Plan	LS	1	1,000	1,000
5	Sediment and dust control	LS	1	7,000	7,000
6	Clear vegetation	LS	1	12,000	12,000
7	Strip and stockpile topsoil	m2	6,000	8	48,000
8	Remove and replace sand layers (Prov. Sum)	m3	400	40	16,000
9	Supply, place, compact and trim fill (solid)	m3	2,900	35	101,500
10	Supply and place 100mm topsoil	m2	7,800	7	50,700
11	Supply and apply seed and fertiliser	m2	7,800	3	23,400
12	Maintain grass for 3 months	LS	1	10,000	10,000
13	Form ends of stopbanks for flood barriers	no.	8	105	840
14	Supply and place planter box walls				
14b	450mm high	m	50	560	28,000
15	Supply and construct 1.5m wide gravel path	m	250	88	22,000
16	Supply and construct 600mm high wing walls	LS	1	6,500	6,500
	to Anzac Parade Bridge				
17	Supply and construct 0.7m high floodwall	m	130	850	110,500
18	supply 1.2m dia. water filled barriers				
18a	Matarawa Stream bridge 30m	LS	1	14,000	14,000
18b	downstream end carpark 15m	LS	1	7,000	7,000
18c	upstream end carpark 10m	LS	1	5,000	5,000
19	Extra work at skate board park	LS	1	20,000	20,000
20	Form road over stopbank	ea.	2	3,300	6,600
21	N/A				0
22	Lift manholes	no.	2	250	500
23	Reinstate damaged areas	LS	1	8,000	8,000
	Contingencies				52,000
	Total cost to raise stopbank to 30 year return period				**$570,540**
	Upgrade Options				
U1	N/A				
U2	N/A				
U3	Place Enkamat along crest and beneath planters	m	930	150	139,500
	(raised sections only)				
	Total costs				**$710,040**