REPORT

TAURANGA CITY COUNCIL

Study into the Decommissioning of Soak-holes in the Otumoetai Area

Report prepared for:

TAURANGA CITY COUNCIL

Report prepared by:

TONKIN & TAYLOR LTD

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July 2006

Job no: 23064

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Executive summary

Tonkin & Taylor Ltd was commissioned by the Tauranga City Council (TCC) to carry out a study into the effect of soak-holes on the stability of slopes in the Bellevue, Brookfield, Judea and Otumoetai areas of Tauranga following the 18 May 2005 rainstorm event. The intent of this study is to define and prioritise areas in which soak-holes should be decommissioned to enhance the stability of adjacent slopes.

The stability of the slopes in the area is mostly controlled by their height and gradient. The shallow geology tends to follow the topography and any water supplied to them is likely to flow sub parallel to surface water. Slopes that are greater than 5 m high with gradients greater than 25 degrees have been classified as slopes vulnerable to landslipping. The vulnerable slopes have been further subdivided into major (greater than or equal to 15 m) and minor (less than 15 m) slopes.

Although not the primary cause of landslipping in and around Otumoetai, the soak-holes in the area still have a detrimental effect on slope stability. Zones where decommissioning of soak-holes is recommended include any areas that direct water toward vulnerable slopes. For major slopes these zones extend to the catchment boundaries behind the slope crests, and for minor slopes they extend behind the crest for three times the slope height. These zones have been categorised into three levels of priority to aid Tauranga City Council (TCC) resourcing the decommissioning process. Soak-holes should be set back from slope crests in any case, including areas where soak-hole decommissioning has not been specifically recommended. We suggest that soak-holes should not be drilled closer than 15 m to the crest of any slope, embankment or cutting that is greater than 5 m high or steeper than 20 degrees.

No new soak-holes should be drilled in areas where their decommissioning is recommended. In other areas specific designs for individual soak-holes should be submitted to TCC for their approval prior to excavation. These designs should take into account the outlet points of the seepage and should be in accordance with TCC regulations. We understand that these regulations currently require that soak-holes are sufficient to cope with water supplied to them during 1 in 10 year 10 minute storms.

1 Introduction

Tonkin & Taylor Ltd was commissioned by the Tauranga City Council (TCC) to carry out a study into the effect of soak-holes on the stability of slopes in the Bellevue, Brookfield, Judea and Otumoetai areas of Tauranga following the 18 May 2005 rainstorm event. The event led to widespread landslippage throughout Tauranga City, but particularly in the areas mentioned and also Maungatapu and Welcome Bay[1].

A previous study into soak-holes in Tauranga was carried out in 1992[2]. This subdivided Tauranga into areas where soak-holes were generally suitable, areas where specific investigations should be carried out prior to their excavation and areas that were generally unsuitable for soak-holes. The 1992 study classified most of the elevated areas in Otumoetai and those areas proximal to steep slopes as generally unsuitable for soak-holes.

The field area for the current study is shown in Figure 1 and includes the area bounded by Waihi Road in the South and Ngatai Road in the north. Previous studies into slope stability in the Otumoetai area indicate that major landslippage was generally isolated to steep slopes and that it occurred during intense rainfall events that were preceded by periods of high rainfall or relatively recent storm events[1]. Many of the slips in Otumoetai occurred close to or within overland flow paths of water and, although many were small shallow failures, there were a number of failures of substantial volume including those at Vale Street, Lemon Grove, Milton Road, Pillans Road and Grange Road.

The primary cause of the landslips has been determined as substantial infiltration of water into the ground caused by rainfall [1]. It was also noted that soak-holes may be detrimental to slope stability, albeit to a lesser extent, by concentrating water and creating local areas of high pore water pressure. They may also supply water to the fissured surface of the Hamilton Ash allowing deeper permeation of the water than would naturally occur which would clearly have adverse effects, particularly when the soak-holes are present close to the crests of steep slopes[1]. With this in mind we have been asked to demarcate areas where soak-holes should be prohibited in order to minimise their effect on slopes in the area. The aim of this project is, therefore, to produce a map with a line or lines around vulnerable slopes to demarcate areas where soak-holes should be decommissioned and prohibited to minimise their effect on slope stability.

2 Methodology

Our methodology has been to:

i. Research relevant documents that pertain to landslipping in Tauranga.
ii. Map soil in new exposures and head scarps created by recent landslips in the area and format the new information for addition to the TCC GIS database.
iii. Drill window sample holes along three lines across the peninsula to broadly examine the variability of the shallow geology and enable drafting of geological cross sections.
iv. Analyse the geomorphology.
v. Determine slopes that are vulnerable to landslipping and define catchment boundaries for those slopes.
vi. Estimate the capacity of the Rotoehu Ash to cope with soak-hole discharge during major storm events, to assist in determining areas where soak-holes should be decommissioned and prohibited from future developments based on (iv) and (v) above.

It is our understanding that contractors excavating soak-holes usually drill until they reach the Hamilton Ash, i.e. through the Rotoehu Ash[3]. The Rotoehu Ash is generally a silty fine to medium sand that is porous and permeable and the water being supplied to the soak-holes drains away through this layer. Although we believe this to be the most common practice, it does not always occur. In areas where the Rotoehu Ash is not present contractors are likely to keep excavating the holes until they reach a porous and permeable layer. Such layers are also present at various levels in the Matua Subgroup but at depths where they are unlikely to greatly affect the stability of the slopes. This being the case we have concentrated our investigations on the Rotoehu Ash and have mapped its distribution, thickness and depth at various locations around the peninsula. Our approach to examining the geology and geomorphology has been to try and determine broad variations over the peninsula. This approach allows us to interpret general controls on slope stability rather than analyse individual slopes in detail. A detailed study into the factors controlling the locations of certain eroded gullies, gully heads and individual landslips would require a much more intensive drilling programme which is outside the scope of this report.

We have also estimated the capacity of the Rotoehu Ash to cope with the discharge from soak-holes, examining both the storage capacity of the layer, and the rate at which water can flow into and out of the layer. This governs the influence that the water entering the soak-holes has on groundwater regime. The results have assisted in determining areas around Otumoetai where the decommissioning of soak-holes is recommended. To aid TCC in the allocation resources to the decommissioning process we have further refined these areas assigning three levels of priority. Areas in which we believe soak-hole decommissioning should take place first are assigned priority level 1.

3 Geology and Geomorphology

3.1 Introduction

The geological map of the Tauranga Area, (1:50,000 scale)[4] shows the field area to be underlain by Te Ranga Ignimbrite, with overlying fluviatile terrace sequences of the Matua Subgroup volcanic ash deposits. The volcanic ash deposits overlying the Matua Subgroup are further subdivided into the Younger Ash, Rotoehu Ash and Hamilton Ash.

3.2 Geomorphology

The Otumoetai/Brookfield/Bellevue/Judea peninsula comprises an upstanding area of land that reaches 56 metres above sea level. This is bounded by steep sea cliffs and is dissected by deep gullies that have eroded inland from the sea cliffs. The gullies sometimes have active streams at their bases and usually have rounded head scarps.

The slopes in the field area have been classified according to their gradients using ArcInfo GIS software based on topographic information provided by the TCC. The results of this slope gradient classification are shown in Figures 2 and 3. These show that the slopes vary in steepness with many slopes greater than 35 degrees. The head scarps of new landslips visited during the course of this study are shown in Figures 4 and 5. Comparison of these figures with Figures 2 and 3 indicates that locations of many of the landslips that occurred during 18 May 2005 were coincident with the steepest slopes and, for the purposes of this study, slopes with gradients greater than 25 degrees (or approximately 1 m vertical: 2 m horizontal) have been considered as potentially susceptible to landslipping. Major landslides such as those at Pillans Road, Lemon Grove and Vale Street also occurred where the slopes where relatively high, so the overall stability of slopes in the area is also partly controlled by their height.

3.3 Geology

The landslipping that occurred in the area was almost entirely within the Matua Subgroup and overlying ash deposits that outcrop in the sides of the steep gullies and sea cliffs[1]. To determine any geological controls on slope stability the geological variation of the area was examined by field mapping and window sampling. The field mapping was undertaken in February and March 2006 and the window sampling carried out during March and April 2006, with the data being compiled onto Figures 4 and 5. This information was augmented using existing borehole data and allowed the drafting of a number of cross sections across the peninsula (Figures 6, 7, 8 and 9).

3.3.1 Window Sample Holes

The window sample holes were drilled at positions shown in Figures 4 and 5 to analyse the variation in the shallow geology along three lines that run approximately east-west across the peninsula. It is understood that it is common practice when drilling soak-holes for contractors to drill until they hit 'chocolate' (Hamilton Ash)[3]. The layer above this is the porous and permeable Rotoehu Ash and it is this layer into which the soak-holes usually drain. This being the case it was decided to target the Rotoehu Ash and terminate the window samples when its base was observed. The logs of the window sample holes are given in Appendix C.

The general geological sequence described in section 3.1 was confirmed in the window sample holes and various shallow layers are described below.

3.3.2 Younger Ashes

Younger ashes were observed in all of the window sample holes and were generally slightly clayey, slightly sandy SILT, orangish yellow, moist, low plasticity and low sensitivity, becoming sandy to very sandy SILT towards their base. This material was often friable and sometimes crumbled on remoulding.

3.3.3 Rotoehu Ash

The Rotoehu Ash mainly comprised silty, fine to medium SAND that was light greyish white and finely bedded. It was loosely packed, crystal-rich, pumiceous, moist, well graded with two fine clayey silt beds 0.2 to 0.4m thick above its base. The Rotoehu Ash was seen in all of the window samples drilled and its thickness varied between 0.4 and 1.3 m, but it was usually between 0.8 and 1.0 m thick. The top of the Rotoehu Ash was between 0.6 and 3.4 metres below ground level (mbgl) although it was usually encountered between 1.5 and 2.5 mbgl.

3.3.4 Hamilton Ash

Most of the window sample holes were terminated in the Hamilton Ash. It was observed in all of the window samples with the exception of WS27 adjacent to Otumoetai Road. It was clayey SILT, dark brown (becoming orange brown with depth), moist, moderately plastic, moderately sensitive. The Hamilton Ash has been described as blocky in Reference 1. This blocky nature is imparted by numerous fissures that seem to penetrate this unit and are likely to have the effect of allowing water to permeate to the deeper layers of the Matua Subgroup. The exact cause of the fissuring is unknown, but it is thought to be related to stress relief adjacent to slopes.

3.3.5 Matua Subgroup

The Matua Subgroup is described in Reference 2 as comprising silts sands and gravels, lacustrine and estuarine muds, low grade coal and peat, interbedded with tephras and distal ignimbrites. It also contains the Pahoia Tephras which are very sensitive, rhyolitic clay. The Matua Subgroup was observed in only one window sample hole (WS27), but was seen in many of the outcrops visited and in the boreholes drilled as part of other investigations which confirmed the above description.

3.3.6 Groundwater

Standpipes were installed in eight window sample holes (WS3, WS7, WS12, WS17, WS19, WS21, WS25 and WS30). Where possible these standpipes were installed adjacent to vulnerable slopes or in positions where effects of the soak-hole decommissioning may be observed. Groundwater measurements were taken on 26 April 2006 and the results are given in Appendix B. The readings were taken the day after a reasonably heavy rainfall event and most of the wells were dry with only one reliable reading taken from WS25 where groundwater was 4.1 metres below ground level.

3.4 Types of Slope Failure Observed

Previous studies into the slope stability of the Tauranga area include References 1, 5, 6 and 7. A number of types of slope failure have been observed in Tauranga. These include[1,5]:

- Large scale block failures
- Piping-triggered block failure
- Wave erosion triggered block failure
- Colluvium/Topsoil failure

Many of these failures occurred on steep sea cliffs during periods of intense rainfall as was experienced in March 1979 at Maungatapu, and in August 1979 at Omokoroa[6] although along the shoreline there is probably also undercutting of the cliff caused by marine erosion[5] that is not necessarily coincident with storm events. It has also been noted that storms which resulted in numerous slope failures were preceded by periods of high rainfall. The 18 May 2005 event was preceded by another storm event on 3 May 2005.

Most of the slips caused by the 18 May 2005 event involved shallow block failure of the upper half of a slope with the slip material mixing with water and becoming small mudflows[1]. Large landslides such as Vale Street were large block slides that involved the whole slope[1]. Both of these types of failure would have involved a number of the ashes and fluviatile sediments described above. The initial stages of piping failure were also noted in the Rotoehu Ash during this study. In the head scarp of the Vale Street landslip the Rotoehu Ash had begun to erode away from around water seepages. Although this kind of erosion is unlikely to lead to the larger landslides observed, it may lead to shallow failures involving the upper few metres of the ground where the Rotoehu Ash is exposed, e.g. the steep sea cliffs adjacent to shorelines in the area.

3.5 Discussion

The dip of the Rotoehu Ash across the field area is shown in Figures 4 and 5 and the shallow geology along the various sections across the peninsula is shown in Figures 6, 7, 8 and 9.

The dip of the Rotoehu Ash was measured during field mapping and calculated from the window sample holes and boreholes. The dip of the ash mostly appears to follow the topography i.e. where the topography flat, the dip of the ash is very shallow and vice versa. The steepest dips were seen in the areas with the steepest slopes e.g. Lemon Grove.

The cross sections show that there is generally no great variation in geology across the peninsula. The geology described earlier in this section was almost always encountered where we drilled and mapped albeit at varying depths and the Younger, Rotoehu and Hamilton ashes appear to follow the topographic variation dipping subparallel to slope directions suggesting that the gullies are at least older than that Hamilton Ash and the shallow geology is only exposed where active erosion has taken place e.g. sea cliffs, steeper gully sides that have experienced recent slope failure or adjacent to incised streams. The mapping and cross sections indicate that there is nothing in a broad geological sense that makes some slopes more susceptible to failure than others and landslips appear to occur through the volcanic ashes and Matua Subgroup by similar mechanisms irrespective of the dips of the individual strata. There may be local geological controls on the positions of certain landslips, gullies and gully heads, but it is likely that the general stability of any given slope in the area is more dependent on its morphology. The dependence on the slope morphology is further evidenced by the locations of the slips themselves, with the larger slope failures e.g. Pillans Road, Vale Street and Lemon Grove all occurring in areas that are relatively high and steep.

It is understood that most soak-holes utilise the porosity of the Rotoehu Ash to dispose of storm water. If the interpretation of the dip directions and cross sections is correct then any water supplied to the Rotoehu Ash from the soak-holes will essentially flow parallel to the topography away from catchment boundaries (see Figures 4 and 5) following the surface water flow paths. In most cases in the Otumoetai area, this means towards the gullies and sea cliffs which is not desirable in the case of vulnerable slopes.

A further effect of the soak-holes is the rapid supply of water to deeper soil levels than it would otherwise reach. The Hamilton Ash underlying the Rotoehu Ash has a fissured surface allowing water to permeate the Matua Subgroup, particularly in the proximity of slopes. This would result in significant lateral disturbing forces in the slope in addition to the reduction in effective stress of the soils. The Matua Subgroup contains a number of sensitive ash layers (Pahoia Tephras) that may be affected by significant influx of water into overlying layers. The water supplied to the Rotoehu Ash may lead to a significant increase the pore water pressure at depth and thereby contribute to the instability of the slope, particularly where sensitive layers such as the Pahoia Tephras are present.

At the head of the Vale Street slip the initial stages of piping failure were observed in an outcrop of Rotoehu Ash. If left unchecked piping can decrease the stability of a slope. In the Otumoetai Area the zone affected by piping is generally shallow, but its extent may be reduced by minimising the amount of water flow into the Rotoehu Ash.

4 Analysis of Water Flow in Soak-holes

4.1 Introduction

This section analyses the volume of water supplied to soak-holes during storm events and the subsequent infiltration of water into the Rotoehu Ash. It examines the storage capacity and permeability of Rotoehu Ash and its probable behaviour during the 18 May 2005 storm event. It also describes the reasons for the decommissioning of soak-holes by providing criteria for the delineation of zones in the Otumoetai area in which they should be removed.

4.2 Criteria for Removal of the Soak-holes

Our starting point for establishing zones for the removal of soak-holes was to identify the slopes most vulnerable to instability in the event of major storms similar to the one of 18 May 2005. Excluding effects from rainfall, the most significant factors influencing the stability of the slopes are their shape and their geological structure. The detailed geological investigation described in Section 3, has shown that the basic geology of all the slopes is very similar. The same sequence of ash layers is generally found right across the study area, with the shallower layers closely following the topography of the ground. It is only at the cliff lines themselves, which have been formed by sea erosion and slipping, that the surface topography cuts across the ash layers. There are thus no geological features (such as dip/strike angles, or weaker layers at particular sites) that may make some slopes more likely to slip than others.

The most vulnerable slopes have therefore been identified primarily on the basis of their surface shape, in particular their inclination and height. Based on past experience and observations, especially those arising from the 18 May 2005 event, a definition of vulnerable slopes would be those with portions that are steeper than 2H:1V (or approximately 25 degrees) and of reasonable height (in this case greater than or equal to 5 m). These slopes have been first identified on a broad basis using the 1:5000 topographical maps and subdivided into major and minor slopes with major slopes comprising those that are greater than or equal to 15 m high and minor slopes less than 15 m high. They have then been further refined to some extent by visual site inspections, and by consideration of any other factors that may possibly influence their stability. Apart from height and inclination, a further factor that influences stability is the shape of the cliff line in plan. Where the cliff line is concave, especially where it forms deep horse-shoe shaped gullies, the likelihood of slips is significantly higher than where it is convex. This is because both surface run-off and groundwater seepage tend to become concentrated in the concave areas. However, the convex and concave areas are so closely interconnected in the Otumoetai area that it is not considered practical to separate them for the purposes of establishing the soak-hole zones.

Having established the vulnerable slopes, the next step was to determine the extent of soak-hole removal from the residential areas above the slopes. As mentioned above, the geological investigation has established that the ash layers quite closely follow the ground topography. The Rotoehu Ash layer, which is the permeable layer that the soak-holes are designed to discharge into, generally follows the ground shape at a depth of 2 m to 3 m so that any water discharged into this layer from sites up-hill of vulnerable slopes flows towards these slopes. Ideally, therefore it is desirable to remove and ban all such soak-holes. Establishing the "up-hill" areas is fairly straightforward; it simply involves determining the flow direction of surface water, i.e. the "catchment" of the vulnerable slopes. This can generally be done with sufficient accuracy from the 1:5000 contour plans.

The above procedure means that in general the maximum distance from the top of the slopes requiring soak-hole removal will be about 100 to 150m. This limiting distance comes about because the width of the plateau areas between cliff lines is generally less than 300m. This is reasonable for the major slopes in view of their height. The zone of greatest direct influence in terms of rainfall effects would be about three times the height of the slope; in many cases the steep portions of these slopes are about 30m to 40m high giving set back distances of at least 100m. However, for the minor slopes, including the entire catchment area above the slopes would result in excessively large set back distances, so for the minor slopes a set back distance of three times the slope height has been adopted.

As an aid to further refining the above procedure, an attempt has been made to determine analytically the way in which the soak-holes and the Rotoehu Ash (the "aquifer") actually handle the discharge during major storms. The detailed calculations are set out in Appendix D and approximate the ability of the Rotoehu Ash to take up water supplied to it during heavy rainfall. A summary of what they show is described in Sections 4.2.1 and 4.2.2.

4.2.1 Capacity of the aquifer to receive water from the soak-holes

If the aquifer is essentially "dry", it could accept 80 to 160 m^3 of water from a single house. In other words this is the storage capacity of the aquifer beneath the area of an average house site. The volume of water coming from a house during the 18 May 2005 storm was about 17 m^3 in the first hour of the storm and about 67 m^3 in the 24 hour period. Thus, from a volume point of view the aquifer should be able to take the flow, provided it was "empty" i.e. "dry" at the start of the storm.

However, it is not just the volume that governs the capacity of the aquifer. It is also the rate at which water can flow into it from a soak-hole. Calculations suggest that the rate of flow into the aquifer is unlikely to exceed about 2.5 m^3/hour unless pressure builds up within the soak-hole. This flow rate is too slow to handle the storm discharge and therefore the soak-hole is likely to "fill up" with water and provide a pressure head forcing the water to flow into the aquifer at a faster rate. However, even with the increased flow coming from this effect, it is probable that not all the discharge from the house roof will go into the aquifer. The soak-hole will fill up and overflow with water then discharging onto the ground.

The implication from the above calculation is that water pressure is likely to build up in the aquifer, with the result that water is more likely to be "forced" into the deeper layers, especially the brown Hamilton Ash immediately below the Rotoehu Ash. The presence of the soak-holes, with their discharge into the Rotoehu Ash, clearly means that water can more rapidly enter the slopes, especially the deeper layers and thus reduce the overall stability of the slope.

The calculation is approximate because exact values of the soil properties use are not known. Assumed values have been used. The calculation is also approximate because it fails to take account of direct infiltration into the aquifer from the ground surface. Some of the upper layers are of moderate permeability and some water will enter the aquifer directly, in which case it may fill up with water more rapidly than the above estimates suggest.

4.2.2 Rate at which water will flow out of the aquifer once the rainfall has stopped

It is generally the case that the distance from which water will flow towards any particular slope varies from about 50m to 150m or in some cases more than 200m. If we take a mean figure of 100 m, then the time needed for the aquifer to drain completely could be as short as about 5 days, but is more likely to be approximately 120 days i.e. almost 4 months.

The first implication from this calculation is that the aquifer would only become "dry" after a reasonably long dry period. The term "dry" is used here to mean that all the water that can drain out of the aquifer under the influence of gravity has drained out of it. It does not mean that it is bone dry. Surface tension effects mean that significant water is still present. Thus at the end of a reasonable summer the aquifer could well be "dry" and have the capacity to take up inflow from a reasonable storm without becoming pressurised, i.e. without significant head building up within the soak-hole or the aquifer. The second implication is that if a storm event follows fairly soon after another storm, or after a prolonged period of intermittent rain, then the consequences are likely to be much more severe than if it occurs after a relatively long dry period.

4.3 Discussion

The calculations summarised above generally confirm what was believed to be the case from the observed behaviour of the soils during the 18 May 2005 event. They do not provide any justification for taking out fewer soak-holes than those identified by the method described at the beginning of Section 4.2. Areas where soak-holes should be decommissioned are shown in Figures 4 and 5 with the set back for these areas following the criteria of three times the slope height for minor slopes and to the nearest catchment boundary for major slopes. A certain amount of judgement was necessary in applying the above criteria, especially where the steepness or height of the relic cliff lines change rapidly, or where the cliffs fade out altogether. A certain degree of judgement in situations such as this is inevitable.

Further to the above criteria we have classified areas for the removal of soak-holes as Priority 1, 2, or 3. These priorities have been assigned to assist the TCC in allocating resources to the soak-hole decommissioning process. They are not meant for any other purpose. These classifications are applied to vulnerable slopes and are based on the following:

- Priority 1 – Catchments of major slopes where extensive landslipping occurred during the 18 May 2005 storm event.
- Priority 2 – All other major slopes and minor slopes that experienced stability problems in the 18 May 2005 storm event.
- Priority 3 – All other minor slopes.

No new soak-holes should be permitted in any of the areas shaded in Figures 4 and 5 regardless of their priority.

The removal of soak-holes from all areas above slopes would be advantageous to slope stability. In areas that have not been classified as priority 1 to 3, caution should be exercised during soak-hole design. No soak-holes should be drilled within 15 m of the crest of a slope, embankment or cutting that are greater than 5 m high and steeper than 20 degrees. Where they are permitted the design of individual soak-holes should be submitted to TCC for approval. These designs should take into account the exit point of the seepage and they should be carried out according to TCC regulations. We understand that these regulations currently require that the soak-holes are sufficient to receive water from 1 in 10 year ten minute storms without overflowing. For storms of greater intensity the soak-holes are likely to overflow. In these cases the overland flow paths should be considered for storm water management purposes. A full appreciation of local overland flow paths is beyond the scope of this report but, where possible, directing overland flow away from appurtenant structures on neighbouring properties should be given consideration in the planning of any proposed future developments.

5 Conclusions

The soak-holes in the Otumoetai area were identified as having a detrimental effect on slope stability in the Otumoetai area[1]. With this in mind a study was initiated to determine where decommissioning of the soak-holes would have the greatest effect in enhancing the stability of slopes in the area. This study looked at the geology and geomorphology of the area to determine any possible controls they have on the stability of the slope. It then determined slopes vulnerable to landslipping and produced a set of criteria to determine areas in which soak-holes should be decommissioned from the said slopes. The set back distances of soak-holes from the slope crests was quantified using assumed soil parameters, and property and roof areas. The following conclusions have been reached:

- The stability of any given slope is mostly controlled by its morphology and vulnerable slopes are those that are greater than or equal to 25 degrees and greater than or equal to 5 m high;
- Slopes have been further subdivided into minor slopes (less than 15 m high) and major slopes (greater than or equal to 15 m high);
- In most places the shallow geology is subparallel to the surface topography, and there are thus no apparent geological controls on a large scale that make some slopes more susceptible to slope failure than others;
- Water supplied to the Rotoehu Ash will generally flow subparallel to the surface water flow paths;
- Water supplied to the soak-holes may also gain access to deeper sensitive layers in the Matua Subgroup faster than it would under natural conditions;
- The initial stages of piping erosion were observed in the Rotoehu Ash and this may contribute to shallow failures where the unit outcrops, e.g. the steep and high sea cliffs. Restricting the infiltration of water into the Rotoehu Ash would minimise the effect of piping erosion on slope stability;
- Areas where it is recommended that soak-holes be decommissioned are shown on Figures 4 and 5. The areas of soak-hole decommissioning are based on the criteria of removing the soak-holes completely in areas where the water will flow towards the major slopes (i.e. to the nearest catchment boundary behind the slope crest), and within three times the slope height for minor slopes;
- In areas where decommissioning has not been prioritised they should not be drilled closer than 15 m to the crest of a slope, embankment or cutting;
- Where soak-holes are permitted their designs should take into account the exit points for the seepage and they should be designed according to TCC regulations. We understand that these regulations currently require that soak-holes are able to receive water from a 1 in 10 year ten minute storm without overflowing.

6 Applicability

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

TONKIN & TAYLOR LTD
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor by:

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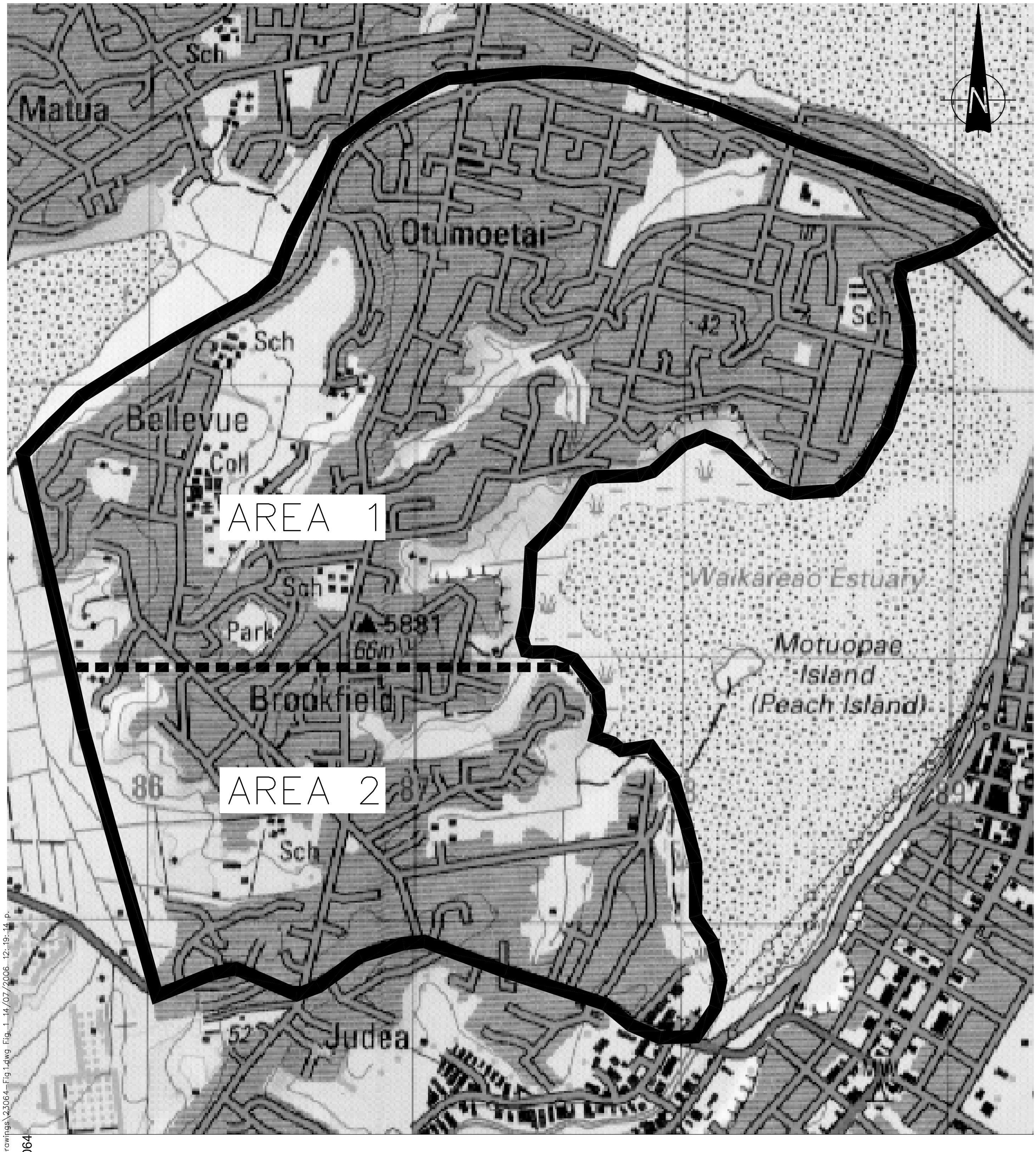
Appendix A: Figures



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SCALES (AT A4 SIZE) NOT TO SCALE

PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Field Area

FIG. No. Figure 1

REV. 0

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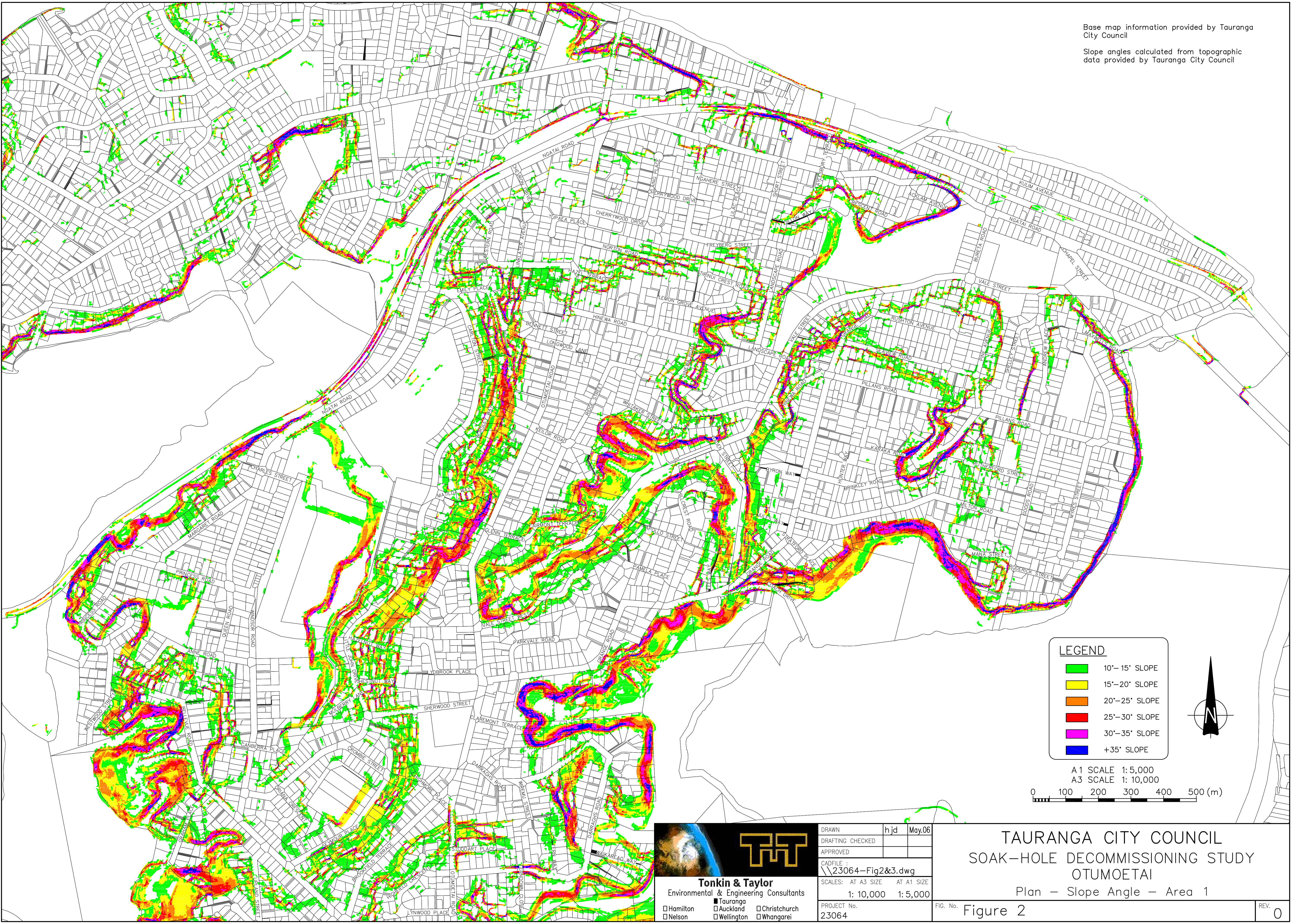

Base map information provided by Tauranga City Council

Slope angles calculated from topographic data provided by Tauranga City Council

LEGEND

🟩 10°– 15° SLOPE
🟨 15°–20° SLOPE
🟧 20°–25° SLOPE
🟥 25°–30° SLOPE
🟪 30°–35° SLOPE
🟦 +35° SLOPE

A1 SCALE 1: 5,000
A3 SCALE 1: 10,000

0 100 200 300 400 500 (m)

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DRAWN	hjd	May.06
DRAFTING CHECKED		
APPROVED		
CADFILE : \\23064–Fig2&3.dwg		
SCALES: AT A3 SIZE 1: 10,000	AT A1 SIZE 1: 5,000	
PROJECT No. 23064		

TAURANGA CITY COUNCIL
SOAK–HOLE DECOMMISSIONING STUDY
OTUMOETAI
Plan – Slope Angle – Area 1

FIG. No. Figure 2

REV. 0

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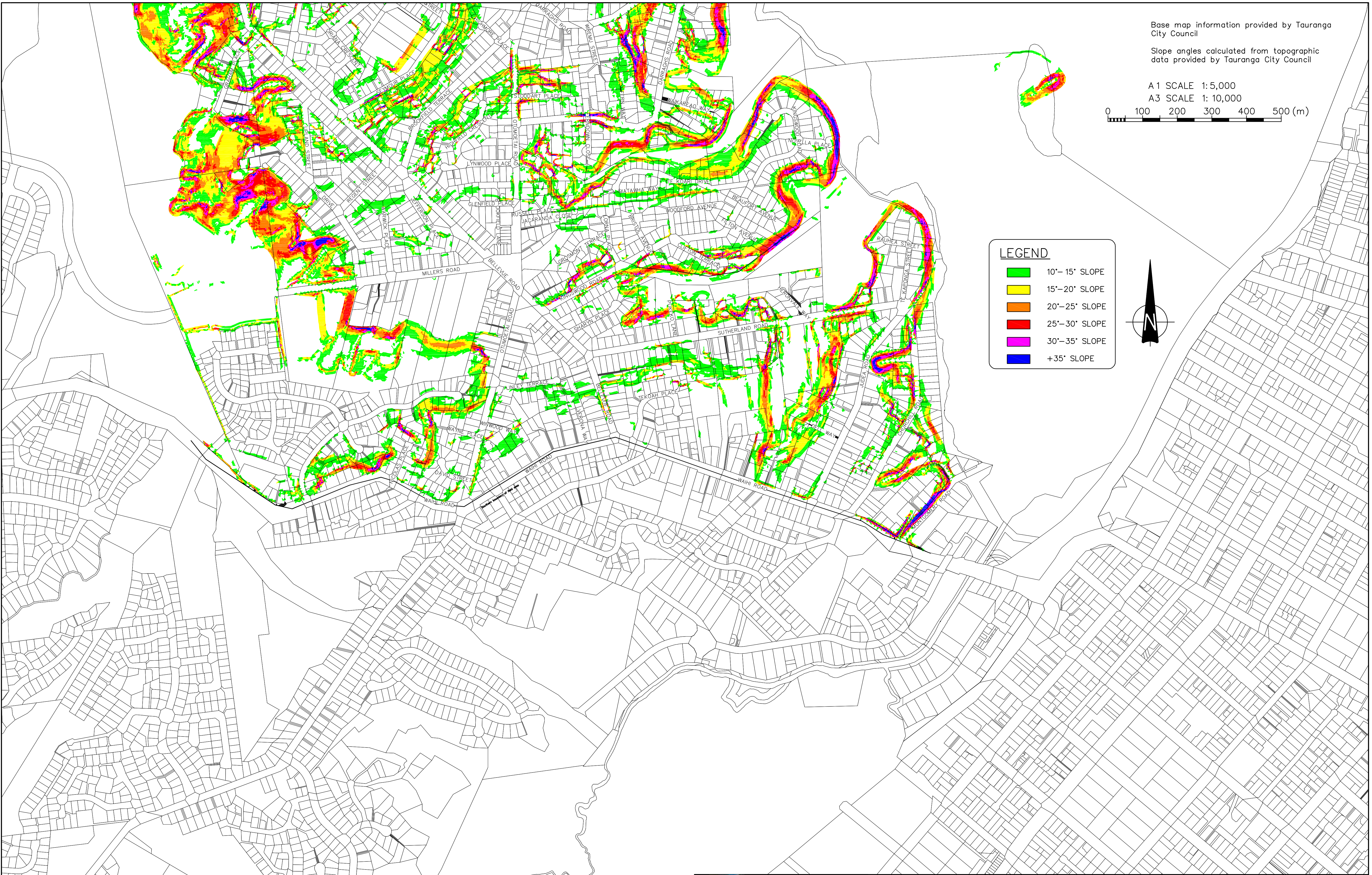

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APPROVED		

CADFILE : \\23064–Fig2&3.dwg

SCALES: AT A3 SIZE 1: 10,000 AT A1 SIZE 1:5,000

PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK–HOLE DECOMMISSIONING STUDY
OTUMOETAI
Plan – Slope Angle – Area 2

FIG. No. Figure 3

REV. 0

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Topographic base map information provided by Tauranga City Council

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APPROVED		

CADFILE : \\23064-Fig4&5.dwg

SCALES: AT A3 SIZE 1: 10,000 AT A1 SIZE 1: 5,000

PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Areas Recommended for Soak-hole Decommissioning

FIG. No. Figure 4

REV. 0

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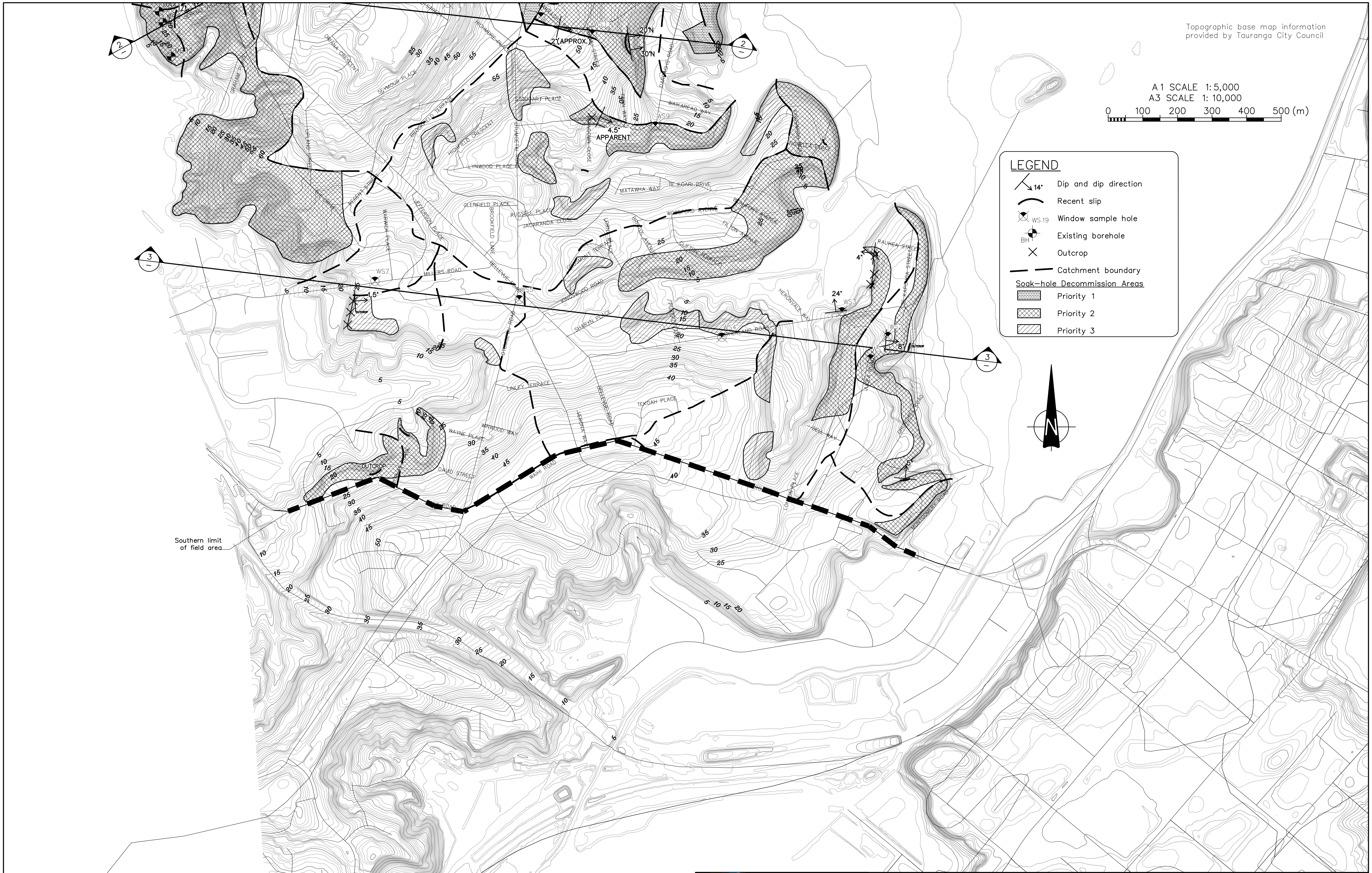

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DRAFTING CHECKED		
APPROVED		

CADFILE : \\23064-Fig4&5.dwg

SCALES: AT A3 SIZE 1: 10,000 AT A1 SIZE 1: 5,000

PROJECT No. 23064

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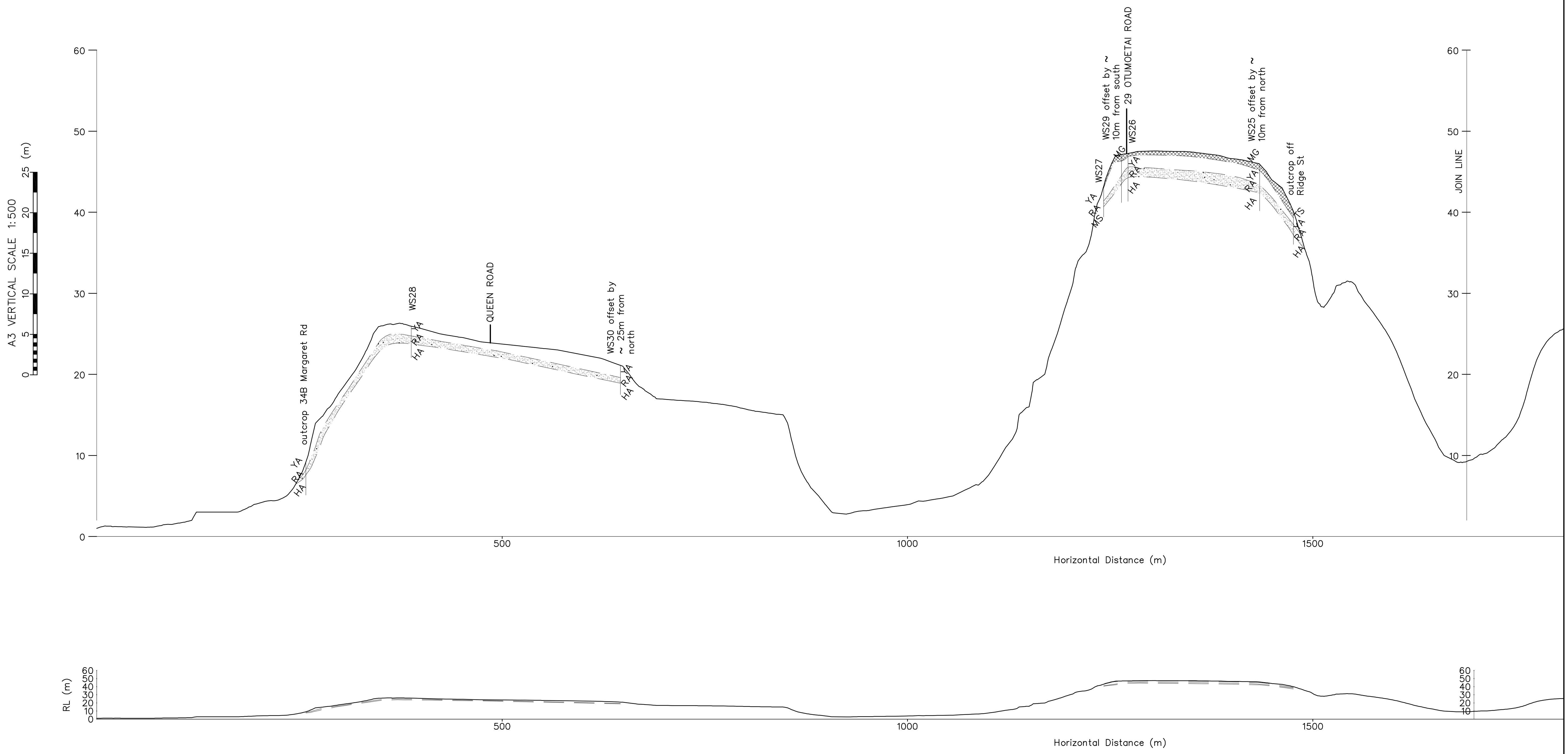
TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Areas Recommended for Soak-hole Decommissioning

FIG. No. Figure 5

REV. 0

Topography created from data provided
by Tauranga City Council



SECTION 1 (CONTINUED ON SHEET 2)

A3 SCALE 1:5000
0 50 100 150 200 250 (m)

LEGEND

MG ▨	MADE GROUND/FILL
YA	YOUNGER ASHES
RA ░	ROTOEHU ASH
HA	HAMILTON ASH
MS	MATUA SUBGROUP

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☐ Nelson ☐ Wellington ☐ Whangarei

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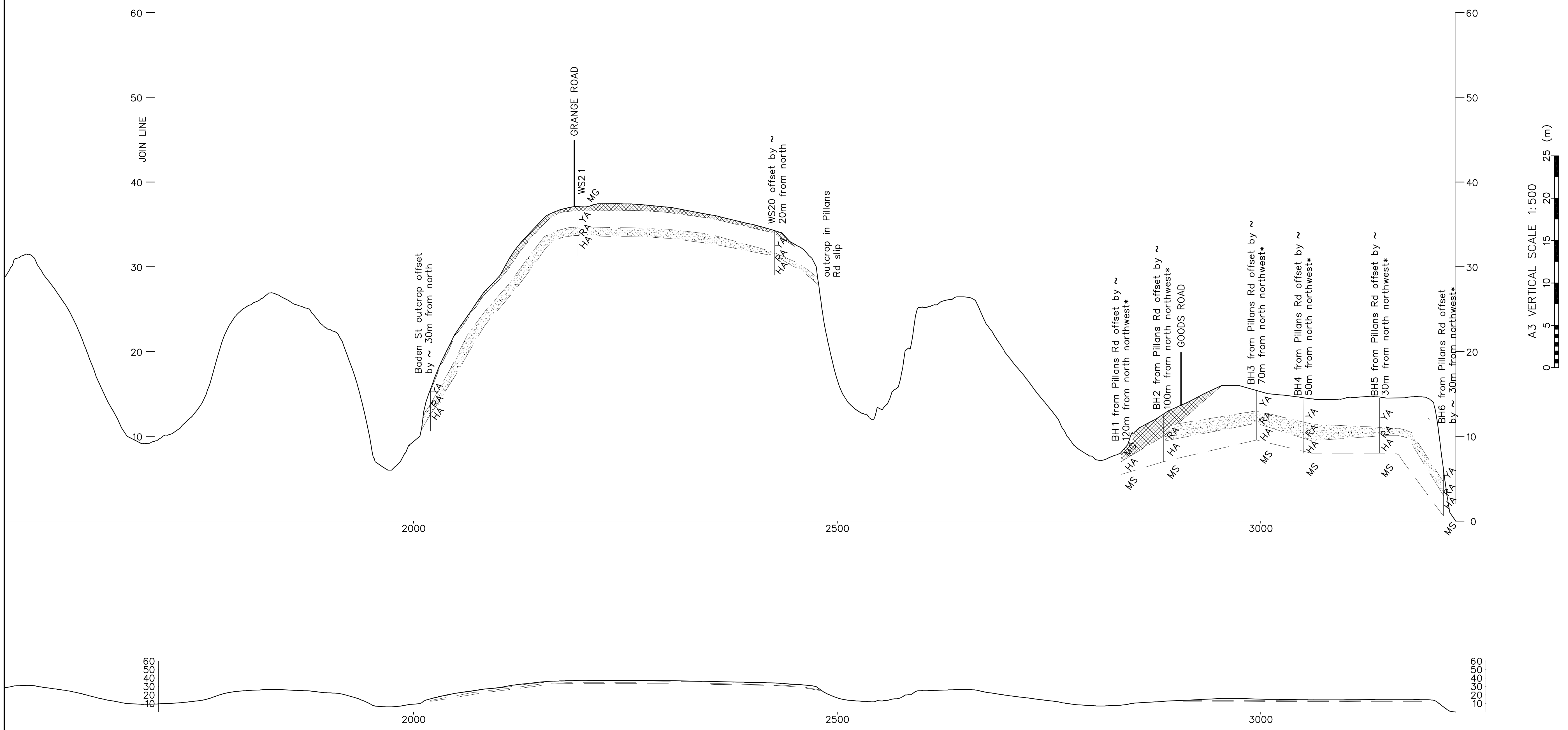
APPROVED		
CADFILE : \\23064-Fig6-s1.dwg		
SCALES (AT A3 SIZE) AS SHOWN		
PROJECT No. 23064		

TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Section 1 – Sheet 1 of 2

FIG. No. Figure 6

REV. 0

Topography created from data provided by Tauranga City Council



SECTION 1 (CONTINUED FROM SHEET 1)

A3 HORIZONTAL SCALE 1:5000
0 50 100 150 200 250 (m)

LEGEND

MG	▨	MADE GROUND/FILL
YA		YOUNGER ASHES
RA	░	ROTOEHU ASH
HA		HAMILTON ASH
MS		MATUA SUBGROUP

* Borehole data from Reference 9

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APPROVED		

CADFILE : \\23064–Fig6–s2.dwg
SCALES (AT A3 SIZE) AS SHOWN
PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK–HOLE DECOMMISSIONING STUDY OTUMOETAI
Section 1 – Sheet 2 of 2

FIG. No. Figure 6
REV. 0

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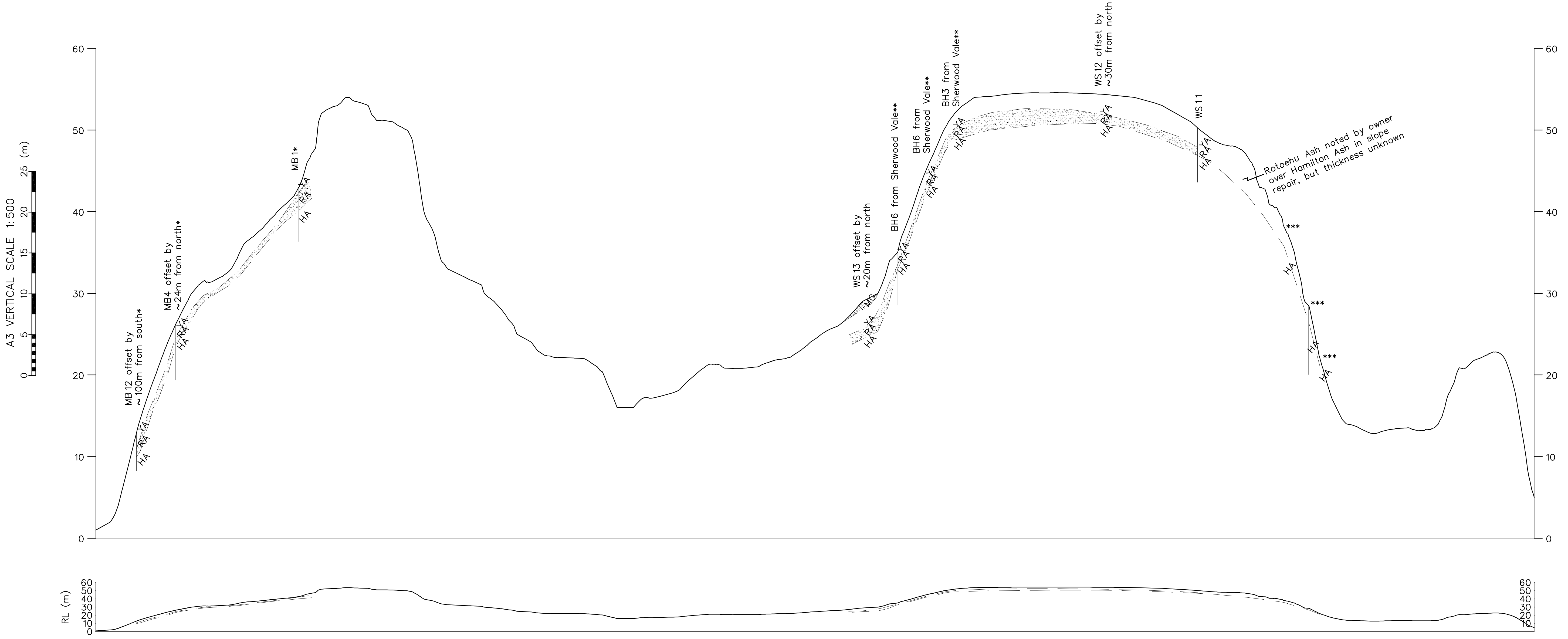
Topography created from data provided by Tauranga City Council



SECTION 2

A3 SCALE 1:5000
0 50 100 150 200 250 (m)

LEGEND

MG	▨	MADE GROUND/FILL
YA		YOUNGER ASHES
RA	░	ROTOEHU ASH
HA		HAMILTON ASH
MS		MATUA SUBGROUP

* MB boreholes from reference 8
** Sherwood Vale boreholes provided by Shrimpton & Lipinski
*** Trial pits carried out by Shrimpton & Lipinski. Logs provided by owner of 49 Darraghs Rd

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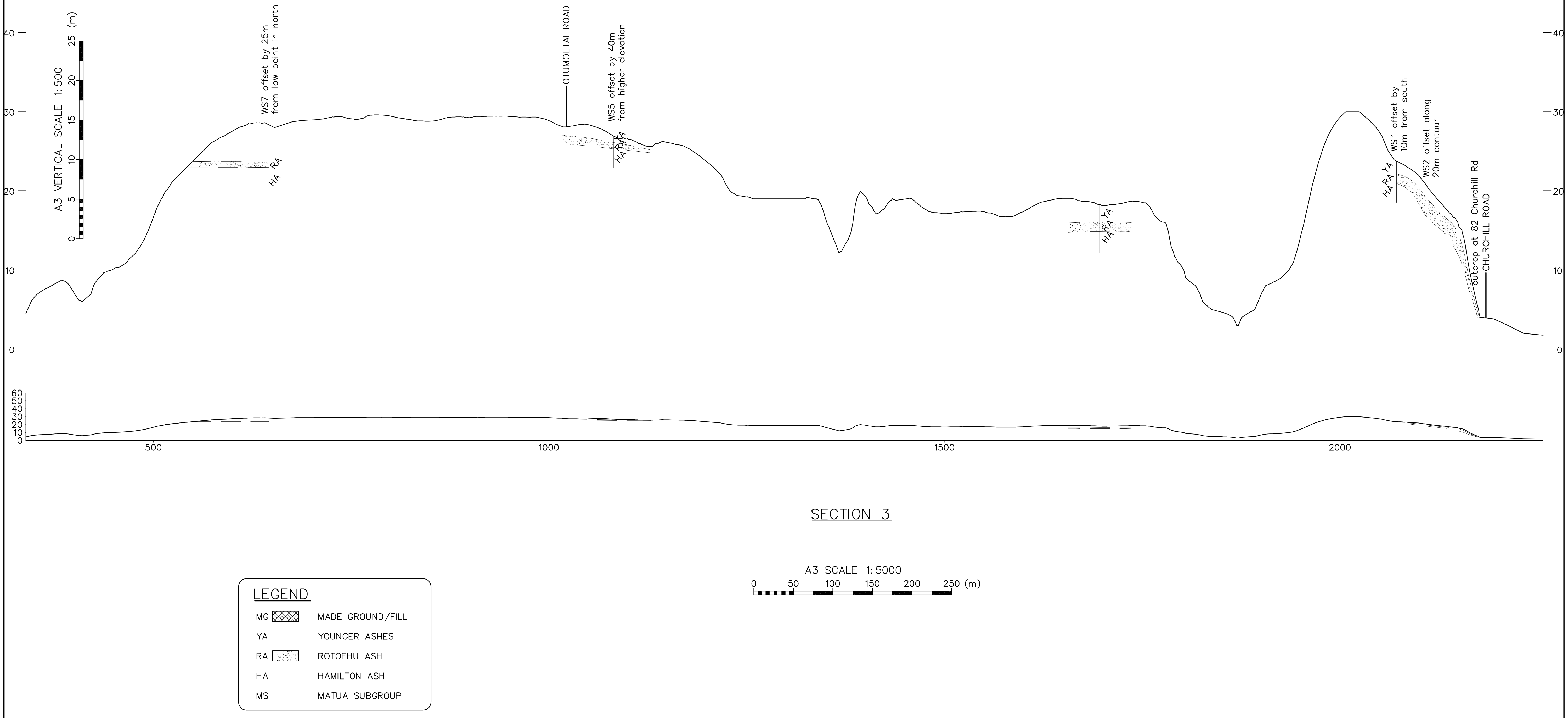
DRAFTING CHECKED		
APPROVED		

CADFILE : \\23064-Fig7.dwg
SCALES (AT A3 SIZE) AS SHOWN
PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Section 2

FIG. No. Figure 7
REV. 0

Topography created from data provided by Tauranga City Council



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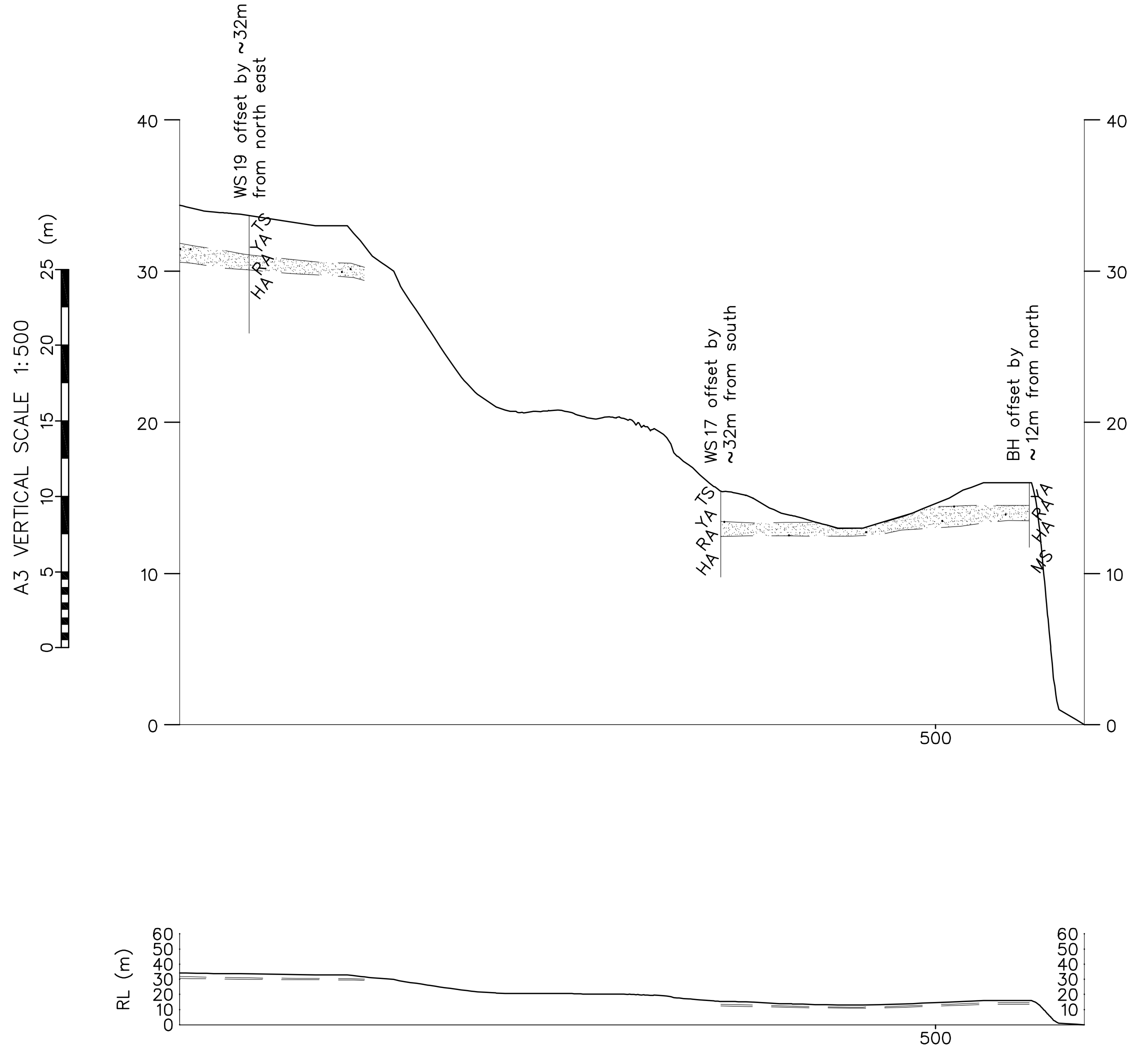
DRAWN hjd May.06
DRAFTING CHECKED
APPROVED
CADFILE : \\23064-Fig8.dwg
SCALES (AT A3 SIZE) AS SHOWN
PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK-HOLE DECOMMISSIONING STUDY
OTUMOETAI
Section 3

FIG. No. Figure 8
REV. 0

P:\23064-Soakpits\Working material\CAD\Drawings\23064-Fig9.dwg, Fig 9, 6/07/2006 12:40:17 p., smbj

Topography created from data provided
by Tauranga City Council



SECTION 4

A3 SCALE 1: 5000
0 50 100 150 200 250 (m)

LEGEND

MG	▨	MADE GROUND/FILL
YA		YOUNGER ASHES
RA	▒	ROTOEHU ASH
HA		HAMILTON ASH
MS		MATUA SUBGROUP

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DRAWN	hjd	May.06
DRAFTING CHECKED		
APPROVED		

CADFILE : \\23064–Fig9.dwg
SCALES (AT A3 SIZE) AS SHOWN
PROJECT No. 23064

TAURANGA CITY COUNCIL
SOAK–HOLE DECOMMISSIONING STUDY
OTUMOETAI
Section 4

FIG. No. Figure 9
REV. 0

Appendix B: Site Investigation Information

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS1
Hole Location: Judea Rd by Churchill Park
SHEET 1 OF 1

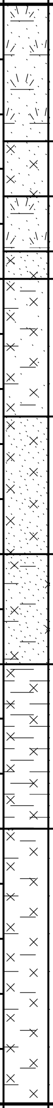
PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6385180.00 mN
2787756.00 mE
R.L. m
DATUM
DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:
HOLE STARTED: 21/03/06
HOLE FINISHED: 21/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL	ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
FILL	SILT, dark brown, organic
YOUNGER ASH	sandy SILT, light yellowish brown, loose, medium dense, with occasional rootlets
	sandy SILT, brown, loose
	silty fine SAND, orangish yellow, with small crystals of quartz, magnetite, occasional pryoxene
	clayey, sandy SILT, yellowish brown becoming greyer with depth
ROTOEHU ASH	silty SAND, pale brownish grey, pumiceous and crystal rich, loose
	silty, clayey SAND, greyish white with manganese staining, moist, holds together when moulded, crystals of quartz and feldspar - becomes fine SAND, crystal rich and pumiceous
HAMILTON ASH	silty CLAY, brown to dark brown, moist, moderately sensitive
	clayey SILT, orange brown, firm, moist - becomes pale pink orange, slightly sensitive
	END OF BOREHOLE AT 4.0m

Column headings: FLUID LOSS, WATER, CORE RECOVERY, METHOD, CASING, TESTS, SAMPLES, R.L. (m), DEPTH (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, MOISTURE CONDITION / WEATHERING, STRENGTH/DENSITY CLASSIFICATION, SHEAR STRENGTH (kPa) 10 25 50 100 200, COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250, DEFECT SPACING (mm) 50 250 1000 2000

DEPTH (m): 1, 2, 3, 4, 5, 6



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS2
Hole Location: 67 Judea Rd

SHEET……1……. OF ……1…….

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6385268.00 mN
2787829.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

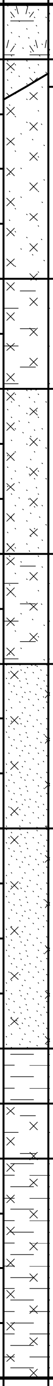
HOLE STARTED: 21/03/06
HOLE FINISHED: 21/03/06
DRILLED BY: jbb
LOGGED BY: dmmm CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	DEPTH (m)	SOIL DESCRIPTION
TOPSOIL		sandy SILT, dark brown
		sandy SILT, brown, loose, dry
YOUNGER ASH		slightly sandy SILT, light brownish orange, loose, dry, sand is very fine and contains crystals
	1	clayey SILT, light brown, firm to stiff, dry, insensitive - becomes slightly sandy
		very sandy SILT, loose to medium dense, friable, dry
	2	clayey, slightly sandy SILT, light brown, moist, slightly sensitive, very greasy and probably contains allophanes
ROTOEHU ASH		slightly silty, fine to medium SAND, whitish grey, loose, medium dense, sand contains small pumice fragments, quartz and feldspar, also other ferromagnesian minerals
	3	slightly silty, fine to coarse SAND, whitish grey - two fine silty bands at 3.2m and 3.5m, fine sand coarsening to medium sand at base
		CLAY, dark brown, soft, firm, paleosol
HAMILTON ASH	4	clayey SILT, dark brown, stiff, paleosol
		silty CLAY, light yellow brown, stiff, moist, plastic, moderately sensitive
	5	**END OF BOREHOLE AT 5.0m**
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS3
Hole Location: 19 Sutherland Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT	LOCATION: OTUMOETAI	JOB No: 23064	
CO-ORDINATES 6385310.00 mN 2787733.00 mE	DRILL TYPE: Window Sampler	HOLE STARTED: 21/03/06	
	DRILL METHOD:	HOLE FINISHED: 21/03/06	
R.L. m		DRILLED BY: jbb	
DATUM	DRILL FLUID:	LOGGED BY: dmmm	CHECKED:

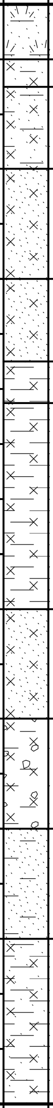
GEOLOGICAL — GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m)

ENGINEERING DESCRIPTION — GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 500 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL	DEPTH (m)	ENGINEERING DESCRIPTION
TOPSOIL / FILL		clayey, sandy SILT, brown, loose, slightly moist, some roots, one large rhyolite cobble at base - probably made ground
		sandy, clayey SILT, yellowish orange to brown, with large rhyolite fragments, moist
		slightly clayey, sandy SILT, orange brown, sand is small crystals, ferromags, quartz and feldspar
ROTOEHU ASH		silty SAND, grey white, moist, sand is crystals and pumice, crystals are feldspar, quartz and ferromags
	1	- clay rich sensitive band at 1.0m
		silty, fine to coarse SAND, greyish white, mostly dry with moist clay rich band, sensitive
		- thin clay rich band at 1.15m
HAMILTON ASH		silty CLAY, brown, firm, paleosol, moderately sensitive
		silty CLAY, orange brown, firm, paleosol, moderately sensitive, contains allophane (is greasy on remoulding)
	2	
		silty, fine SAND, orangish brown
MATUA SUBGROUP		clayey, slightly sandy SILT, pink grey, moist
	3	clayey, fine SAND, orangish yellow, loose to medium dense
		silty, slightly sandy CLAY, brownish grey, soft, moist to wet, moderately sensitive
	4	**END OF BOREHOLE AT 4.0m** - 19mm standpipe installed
	5	
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS4
Hole Location: 71 Sutherland Rd

SHEET ..1.. OF ..1..

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6385253.00 mN
2787366.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 11/04/06
HOLE FINISHED: 11/04/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

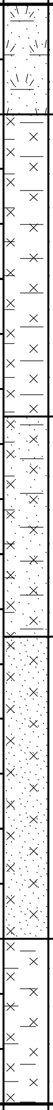
GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL UNIT	DEPTH (m)	ENGINEERING DESCRIPTION
TOPSOIL		SILT, dark brown, organic
YOUNGER ASH		slightly clayey SILT, brown, moist, non plastic, non sensitive - becomes light grey brown 0.8 - 1.0m
	1	slightly sandy clayey SILT, orangish yellow, moist, plastic, moderately sensitive - becomes light grey brown clayey SILT, moist to wet
ROTOEHU ASH	2	silty fine to coarse SAND, light pinkish grey, moist, well graded - 3.0-3.1m becomes light grey sandy SILT - at 3.2m becomes orangish brown, non plastic, non sensitive
HAMILTON ASH	3	clayey SILT, dark brown, moist, plastic, moderately sensitive
	4	**END OF BOREHOLE AT 4.0m**
	5	
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS5
Hole Location: Lees Park, Otumoetai Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6385303.00 mN
2786724.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 24/03/06
HOLE FINISHED: 24/03/06
DRILLED BY: mhh
LOGGED BY: dmmm
CHECKED:

GEOLOGICAL										ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown, moist, non plastic, non sensitive, sand is very fine
YOUNGER ASH									1								slightly sandy SILT, brownish orange, moist, non plastic, non sensitive, sand is fine
																	sandy, clayey SILT, orangish yellow, moist, slightly plastic
									2								clayey SILT, light brown, moist, plastic, sensitive
ROTOEHU ASH																	silty, fine to coarse SAND, light whitish yellow, loose to medium dense, moist
									3								clayey SILT, greyish white, moist to wet, plastic, sensitive
																	silty, fine to coarse SAND, white, loose to medium dense, moist to wet
HAMILTON ASH																	clayey SILT, dark brown, moist to wet, moderately plastic, moderately sensitive
									4								**END OF BOREHOLE AT 4.0m**
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS7
Hole Location: 45 Miller Rd

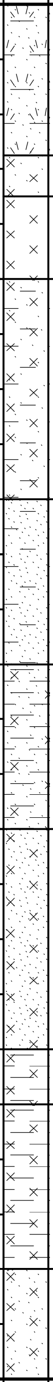
SHEET ...1..... OF ...1.....

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6385391.00 mN
2786311.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 21/03/06
HOLE FINISHED: 21/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:



GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL / FILL																	sandy SILT, dark brown, contains glass etc.
																	slightly sandy SILT, brown, loose, friable, non sensitive (old soil)
YOUNGER ASH																	SILT, orangish brown, friable, dry
									1								clayey, slightly sandy SILT, light pink orange, firm, moist, slightly sensitive, contains allophane
									2								clayey, fine to medium SAND, loose to medium dense, moist, poorly graded
																	sandy, silty CLAY, grey, moist to wet, firm, moderately sensitive
ROTOEHU ASH									3								silty, fine to coarse SAND, light whitish grey, loose to medium dense, sand is pumiceous and crystal rich containing poorly graded sub horizontal beds of whitish grey silt
HAMILTON ASH																	silty CLAY, dark brown
									4								silty CLAY, dark brown, firm, moist, moderately sensitive
																	sandy SILT, orangish brown, soft, moderately plastic, sensitive
									5								**END OF BOREHOLE AT 5.0m** - 19mm standpipe installed
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS8
Hole Location: 172 Darraghs Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT	LOCATION: OTUMOETAI	JOB No: 23064	
CO-ORDINATES 6388583.00 mN 2787125.00 mE	DRILL TYPE: Window Sampler	HOLE STARTED: 22/03/06	
		HOLE FINISHED: 22/03/06	
R.L. m	DRILL METHOD:	DRILLED BY: jbb	
DATUM	DRILL FLUID:	LOGGED BY: dmmm	CHECKED:

GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
FILL																	very gravelly SILT, brown, dry
YOUNGER ASH																	sandy, very gravelly SILT, light brown, loose to medium dense, dry, non plastic, non sensitive
																	sandy fine SILT, light yellow to yellow brown, dense, dry, non plastic, non sensitive, sand is small crystals
ROTOEHU ASH									1								silty very fine SAND, light whitish yellow, dry, pumiceous with crystals of quartz and feldspar
																	silty fine SAND, light greyish white, dense, dry, pumiceous with crystals of quartz and feldspar
HAMILTON ASH									2								slightly silty CLAY, dark brown, firm, moist, slightly plastic, sensitive - becomes less sensitive - becomes orangish brown, firm to stiff, moist, low plasticity - becomes light orangish brown
									3								**END OF BOREHOLE AT 3.0m**
									4								
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS10
Hole Location: 43 Darraghs Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386136.00 mN
2787010.00 mE
R.L. m
DATUM
DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:
HOLE STARTED: 22/03/06
HOLE FINISHED: 22/03/06
DRILLED BY: jbb
LOGGED BY: dmmm CHECKED:

GEOLOGICAL										ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
FILL										▨							FILL, with sand and gravel
									1								**END OF BOREHOLE AT 0.75m -** borehole terminated due to mixed fill including concrete, and proximity to services
									2								
									3								
									4								
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS11
Hole Location: 2 Wiremu St

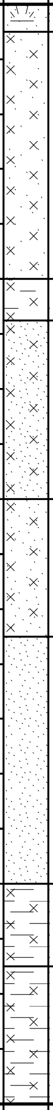
SHEET……1….. OF ……1…..

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386093.00 mN
2786951.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 22/03/06
HOLE FINISHED: 22/03/06
DRILLED BY: jbb
LOGGED BY: dmmm CHECKED:



GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown, organic
																	slightly sandy SILT, brown, friable, loose to medium dense, dry, non plastic, non sensitive
									1								clayey SILT, brownish grey
YOUNGER ASH																	very silty SAND, orangish yellow, loose to medium dense, dry, coarse ash
									2								sandy SILT, with minor clay, greyish brown, firm, low plasticity, sand is fine crystals
ROTOEHU ASH									3								fine to coarse SAND, light greyish white, bedded, well graded, sand comprises pumice, lithics and crystals, loose to medium dense with bands of fine ash
HAMILTON ASH																	silty CLAY, with minor sand, dark brown, moist, slightly sensitive, paleosol
																	firm to stiff CLAY / SILT, dark orange brown, moist, moderately sensitive
									4								**END OF BOREHOLE AT 4.0m**
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

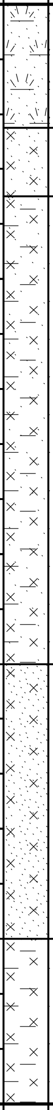
BOREHOLE No: WS12
Hole Location: 1 Darraghs Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386160.00 mN
2786808.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 11/04/06
HOLE FINISHED: 11/04/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown, organic, moist, non plastic, non sensitive
YOUNGER ASH																	sandy SILT, brown, moist, non plastic, non sensitive - becomes very sandy with clasts of Rotoehu Ash
																	slightly sandy, clayey SILT, brown, moist, low plasticity, low sensitivity
									1								- becomes grey
																	- becomes brownish yellow, sandy (sand is mafic crystals)
									2								- becomes light grey slightly sandy SILT, moist, plastic, moderately sensitive
ROTOEHU ASH																	silty fine to coarse SAND, light greyish white, pumiceous with mafic and felsic crystals
									3								- becomes light grey, slightly sandy SILT - becomes light greyish white fine to medium SAND
HAMILTON ASH																	clayey SILT, light brown with dark brown mottling, moderately plastic, moderately sensitive - becomes low plasticity, low to non sensitive, clayey SILT
									4								**END OF BOREHOLE AT 4.0m** - 19mm standpipe installed to base of hole
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS13
Hole Location: 66 Seymour Pl

SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386203.00 mN
2786527.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 22/03/06
HOLE FINISHED: 22/03/06
DRILLED BY: jbb
LOGGED BY: dmmm
CHECKED:

GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown, organic
FILL																	layers sequence of slightly clayey SILT, orange brown, very stiff, dry, non plastic, non sensitive with slightly clayey, slightly sandy SILT, brown
									1								CLAY, brown, moist, low to moderate plasticity, moderately sensitive, with clumps of white sand
YOUNGER ASH																	slightly clayey, slightly sandy SILT, brown, moist, low plasticity, non sensitive, old natural soil
																	CLAY, with minor sand and silt, brown, moist, low plasticity, moderately sensitive, sand is small crystals of quartz or feldspar, manganese staining smears when sample extracted
									2								CLAY, with minor sand, light brown, moist, moderately plastic, moderately sensitive
																	very sandy CLAY, orange yellow, moist to wet, low plasticity, low sensitivity, sand is mostly crystals of quartz, feldspar and ferromags
									3								clayey SILT, with minor sand, light grey, moist to wet, low plasticity, low sensitivity
ROTOEHU ASH																	silty fine SAND, greyish white, thinly bedded, some dark bands and iron staining (unusual)
									4								fine to coarse SAND, greyish white, moist to wet
HAMILTON ASH																	silty CLAY, dark brown, moist, moderately plastic, moderately sensitive, paleosol
									5								**END OF BOREHOLE AT 5.0m**
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS17
Hole Location: Goods Rd/ Roderick St intersection
SHEET 1 OF 1

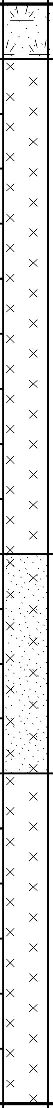
PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES mN
mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown
YOUNGER ASH																	SILT, brown with black speckling, firm, moist, plastic - becomes orange brown with black speckling, traces of fine sand, friable
									1								- becomes brown, plastic - becomes light brown, sandy, friable
ROTOEHU ASH									2								silty, fine to medium SAND, light grey, moist - band of light whitish grey sandy silt (50mm) - becomes light grey, traces of silty, fine to medium
HAMILTON ASH																	SILT, dark brown, very stiff, friable, moist
									3								- becomes light brown
									4								**END OF BOREHOLE AT 4.0m** - 19mm standpipe installed to 4.0m
									5								
									6								



TONKIN & TAYLOR LTD

BOREHOLE LOG

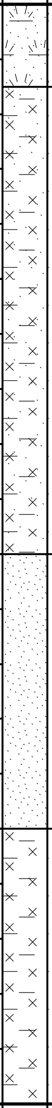
BOREHOLE No: WS19
Hole Location: 49 Milton Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES mN
mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 11/04/06
HOLE FINISHED: 11/04/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:



GEOLOGICAL GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	ENGINEERING DESCRIPTION SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	SILT, dark brown, organic
YOUNGER ASH																	slightly sandy, clayey SILT, dark brown, moist, moderately plastic, low sensitivity
																	- becomes light brown grey
									1								
																	- becomes brown yellow, very sandy
																	- becomes light brown slightly sandy SILT
ROTOEHU ASH									2								SAND, greyish white
HAMILTON ASH									3								clayey SILT, dark brown
									4								**END OF BOREHOLE AT 4.0m** - 19mm standpipe installed to 4.0m
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS20
Hole Location: end of Karaka St

SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT	LOCATION: OTUMOETAI	JOB No: 23064	
CO-ORDINATES: 6387131.00 mN 2788097.00 mE	DRILL TYPE: Window Sampler	HOLE STARTED: 24/03/06	
	DRILL METHOD:	HOLE FINISHED: 24/03/06	
R.L. m		DRILLED BY: mhh	
DATUM	DRILL FLUID:	LOGGED BY: mhh	CHECKED:

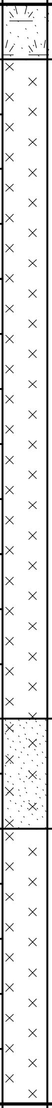
GEOLOGICAL: GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

Columns: FLUID LOSS, WATER, CORE RECOVERY, METHOD, CASING, TESTS, SAMPLES, R.L. (m), DEPTH (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, MOISTURE CONDITION / WEATHERING, STRENGTH/DENSITY CLASSIFICATION, SHEAR STRENGTH (kPa) 10 25 50 100 200, COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250, DEFECT SPACING (mm) 50 250 1000 2000

ENGINEERING DESCRIPTION

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL	DEPTH (m)	ENGINEERING DESCRIPTION
TOPSOIL	0	sandy SILT, dark brown, organic
YOUNGER ASH		SILT, with traces of fine sand, friable, stiff, moist, organic rootlets present
	1	
		- become orange brown, sandy at 1.6m
	2	- becomes brown, traces of fine sand at 2.0m
ROTOEHU ASH		silty, fine to medium SAND, light brown with black and white speckling, moist
		- band of soft SILT, traces of fine sand, sensitive
HAMILTON ASH	3	SILT, dark brown, hard, friable, moist
		- becomes orange brown, slightly sandy
	4	**END OF BOREHOLE AT 4.0m**
	5	
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS21
Hole Location: corner Brinkley Rd & Grange Rd
SHEET …1…. OF …1….

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6387073.00 mN
2787822.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL

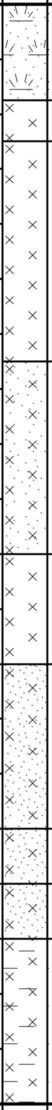
ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



Geological unit	Depth (m)	Description
TOPSOIL / FILL		SILT, with minor sand, dark brown, soft, loose, moist
FILL		SILT with minor sand, dark brown with orange mottling, soft, moist to wet
YOUNGER ASH		SILT with minor sand, light brown, loose, moist, non plastic, non sensitive, sand is very fine mafic and felsic crystals, firm
	1	
		sandy SILT, with minor clay, orangish yellow, medium dense, loose, moist, non plastic, slightly sensitive, sand is fine to medium with crystals of quartz, feldspar and mafics
	2	SILT, with minor sand, grey, soft, loose, moist, non plastic, non sensitive
ROTOEHU ASH		silty, fine to coarse SAND, light grey to greyish white, loose, moist, moderately graded, pumiceous with crystals of quartz, feldspar, mica and fine mafics
	3	silty, very fine SAND, light grey, loose, moist to wet, well graded
		silty, fine to medium SAND, loose, moist to wet, moderately graded, pumiceous with mafic and felsic crystals
HAMILTON ASH		clayey SILT, dark brown, moist to wet, low plasticity, non to moderately sensitive, paleosol - becomes orange brown
	4	**END OF BOREHOLE AT 4.0m** - 19mm standpipe installed to 4.0m
	5	
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS22
Hole Location: 96 Grange Rd

SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386988.00 mN
2787791.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 11/04/06
HOLE FINISHED: 11/04/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL										ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown
YOUNGER ASH																	SILT, with traces of sand, brown, firm, moist
									1								
																	- becomes light brown, slightly plastic, black staining and speckling
																	- becomes sensitive, non plastic
									2								- becomes sandy
ROTOEHU ASH																	fine to coarse SAND, with minor silt, light brown with black and white speckling, moist
																	- 50mm band of sandy silt, cream, sensitive
HAMILTON ASH									3								SILT, dark brown, stiff, moist
																	- becomes dark orange brown, very stiff
									4								**END OF BOREHOLE AT 4.0m**
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS24
Hole Location: Ridge/Keilor
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6387174.00 mN
2787063.00 mE
R.L. m
DATUM
DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:
HOLE STARTED: 11/04/06
HOLE FINISHED: 11/04/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL — GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

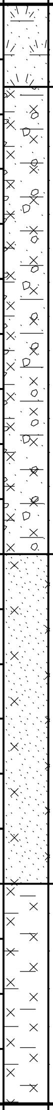
FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m)

ENGINEERING DESCRIPTION

GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL	DEPTH (m)	SOIL DESCRIPTION
TOPSOIL		SILT, dark brown, organic
YOUNGER ASH		slightly sandy, slightly clayey SILT, orangish brown, moist, low plasticity, non sensitive - becomes light greyish brown
	1	- becomes moist, moderately plastic, moderately sensitive - becomes very sandy SILT, orangish yellow, moist, non plastic, non sensitive - becomes grey SILT, wet
ROTOEHU ASH	2	slightly silty, fine to coarse SAND, light yellowish grey, moist, well graded
	3	- becomes fine light grey sandy SILT - becomes light greyish white silty fine SAND
HAMILTON ASH		clayey SILT, dary brown, moist, plastic, moderately sensitive - becomes orangish brown clayey SILT, low plasticity, moderately sensitive
	4	**END OF BOREHOLE AT 4.0m**
	5	
	6	

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS25
Hole Location: 96 Ridge St

SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6387038.00 mN
2787031.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

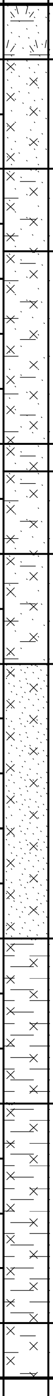
HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY:
LOGGED BY: dmmm CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	DEPTH (m)	SOIL DESCRIPTION
TOPSOIL		sandy SILT, dark brown, firm, moist, non plastic, non sensitive
FILL		sandy SILT, brown, loose, moist, mottled with pieces of soil
YOUNGER ASHES		clayey, slightly sandy SILT, orangish brown, loose, moist, non plastic, non sensitive
	1	clayey, slightly sandy SILT, light orangish brown, moist, non plastic, non sensitive, sand is small crystals of pyroxene, hornblende, feldspar and quartz
		very sandy, clayey SILT, orange brown, poorly graded, plastic, moderately sensitive, sand is hornblende, quartz and feldspar
	2	sandy, very clayey SILT, greyish brown, soft, moderately plastic, moderately sensitive, sand is hornblende, feldspar and quartz
		slightly sandy, clayey SILT, light brownish grey, moist, moderately plasticity, moderate sensitivity, sand is crystals of mica, ferromags, quartz and feldspar
ROTOEHU ASH	3	silty, fine to coarse SAND, grey to greyish white, loose, poorly graded, moist, some crude subhorizontal bedding, pumiceous with crystals of mica, quartz, feldspar and pyroxene - becomes soft, wet, clayey SILT with minor fine sand, moist to wet, moderately plastic, moderately sensitive - becomes fine sand at 3.4m
HAMILTON ASH		CLAY / SILT, soft to firm, dark brown, moist, moderate to high plasticity, moderately sensitive - becomes orange brown at 3.7m
	4	CLAY / SILT, firm to stiff, orangish brown, moist, low plasticity, low to non sensitive
	5	SILT / CLAY, firm, light orange brown, moist, moderately plasticity, moderately sensitive
	6	**END OF BOREHOLE AT 5.0m** - 19mm standpipe installed to 4.0m

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS26
Hole Location: 342c Otumoetai Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6387034.00 mN
2786880.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

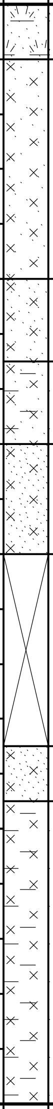
GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT,
GENERIC NAME,
ORIGIN,
MINERAL COMPOSITION.

FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



Geological unit	Soil description
TOPSOIL	slightly sandy SILT, dark brown, moist, low plasticity, low sensitivity
YOUNGER ASH	slightly sandy SILT, dark brown but becomes light brown, moist, not plastic, not sensitive, sand is crystals of feldsic and mafic minerals
	sandy SILT, orange yellow, moist, non plastic, non sensitive, sand is fine to medium grained with crystals of pryoxene, quartz and feldspar
	slightly sandy, clayey SILT, light brown grey, moist, low plasticity, moderate sensitivity, sand is crystals of mafic and felsic minerals including muscavite and also small pumice clasts
ROTOEHU ASH	silty, fine to coarse SAND, light grey becoming greyish white, loose, moist, poorly graded, pumiceous with crystals of quartz, feldspar, pryoxene, hornblende and biotite
	NO RECOVERY
	silty, fine to medium SAND, light greyish white, moist, poorly graded, but fines upwards to fine sand, pumiceous with crystals of quartz, feldspar, pryoxene, hornblende and biotite
HAMILTON ASH	clayey SILT, dark brown, soft, wet, moderate plasticity, moderate sensitivity - becomes light orange brown, firm, moist, moderate to low sensitivity

END OF BOREHOLE AT 4.0m

DEPTH (m): 1, 2, 3, 4, 5, 6

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS27
Hole Location: 342c Otumoetai Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6387059.00 mN
2786827.00 mE
R.L. m
DATUM
DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:
HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY: mhh
LOGGED BY: dmmm
CHECKED:

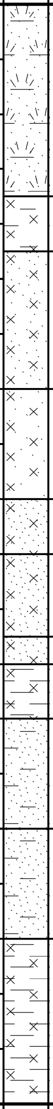
GEOLOGICAL — GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

Columns: FLUID LOSS, WATER, CORE RECOVERY, METHOD, CASING, TESTS, SAMPLES, R.L. (m), DEPTH (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, MOISTURE CONDITION / WEATHERING, STRENGTH/DENSITY CLASSIFICATION, SHEAR STRENGTH (kPa) 10 25 50 100 200, COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250, DEFECT SPACING (mm) 50 250 1000 2000

ENGINEERING DESCRIPTION

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



Depth (m): 1, 2, 3, 4, 5, 6

GEOLOGICAL UNIT	ENGINEERING DESCRIPTION
TOPSOIL	clayey SILT, dark brown, soft, moist, moderate plasticity, moderate sensitivity
YOUNGER ASH	clayey SILT, with minor very fine sand, brown, soft, moist, low plasticity, moderate sensitivity - becomes soft to very soft, moderate to high plasticity, moderate to high sensitivity
	sandy SILT, light grey brown, moist, low plasticity, not sensitive, sand is fine to medium with mafic and felsic crystals, friable and loose - becomes pinkish grey
	slightly sandy SILT, light brown, moist, not plastic, not sensitive, sand is small fragments of pumice, crystals of pryoxene and mica obvious, behaves in a granular fashion
ROTOEHU ASH	silty, fine to medium SAND, light pinkish grey, loose, moist, poorly graded, pumiceous, fine sand-sizd crystals of pryoxene, quartz and mica
MATUA SUBGROUP	silty, fine SAND, grey, loose, wet, poorly graded, pumiceous (very small clasts)
	silty, very fine SAND, light grey brown, medium dense, moist to wet, poorly graded
	CLAY / SILT, light grey, stiff, moist to dry, low plasticity, low sensitivity
	clayey, fine to medium SAND, loose to medium dense, moist, poorly graded
	clayey SAND, orange yellow, moist to wet, poorly graded, full of allophane, very greasy
	CLAY / SILT, brownish grey, wet, high plasticity, high sensitivity
	END OF BOREHOLE AT 4.0m

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS28
Hole Location: 34 Margaret Rd

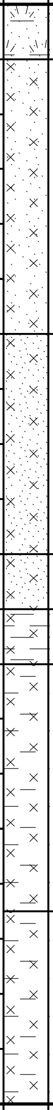
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386928.00 mN
2785990.00 mE
R.L. m
DATUM

DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 24/03/06
HOLE FINISHED: 24/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL									ENGINEERING DESCRIPTION								
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	sandy SILT, dark brown, organic, moist
YOUNGER ASH									1								very sandy SILT, brown, friable, loose, dry, sand is very fine
ROTOEHU ASH																	silty, fine to coarse SAND, very light yellowish white to greyish white, friable, moist, pumiceous with numerous crystals
									2								silty fine SAND, grey, loose to medium dense
HAMILTON ASH																	silty CLAY / very clayey SILT, dark brown, moist to wet, plastic, sensitive
									3								clayey SILT, orange brown, firm, moist, low plasticity, moderately sensitive
																	clayey SILT, brown to grey, soft, moist to wet, plastic, sensitive
									4								**END OF BOREHOLE AT 4.0M**
									5								
									6								

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: WS29
Hole Location: 342c Otumoetai Rd

SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT
LOCATION: OTUMOETAI
JOB No: 23064

CO-ORDINATES 6386998.00 mN
2786868.00 mE
R.L. m
DATUM

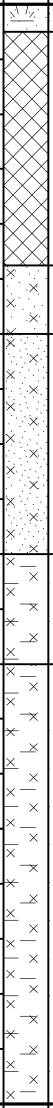
DRILL TYPE: Window Sampler
DRILL METHOD:
DRILL FLUID:

HOLE STARTED: 29/03/06
HOLE FINISHED: 29/03/06
DRILLED BY: mhh
LOGGED BY: dmmm CHECKED:

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION. | FLUID LOSS | WATER | CORE RECOVERY | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 2000

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL	ENGINEERING DESCRIPTION
TOPSOIL	sandy SILT, dark brown
FILL	sandy SILT, with clasts of soil, beds of greyish white sand, variable dark brown - light orange brown mottled, moist, non plastic, non sensitive
YOUNGER ASH	sandy SILT, light brown, moist, low plasticity, low sensitivity, sand is small mafic and felsic crystals
ROTOEHU ASH	silty, fine to coarse SAND, light pinkish brown, loose, moist, poorly graded, crystals of quartz, biotite, feldspar and pryoxene (possible also hornblende)
HAMILTON ASH	clayey SILT, dark brown, firm, moist to wet, plastic, moderately sensitive
	clayey SILT, orangish brown, firm, moist, low plasticity, moderately sensitive
HAMILTON ASH / MATUA SUBGROUP	- becomes light orangish brown, moist to wet, sensitive
	END OF BOREHOLE AT 4.0m

TONKIN & TAYLOR LTD

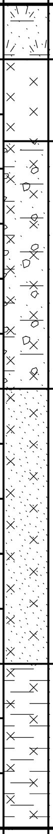
BOREHOLE LOG

BOREHOLE No: WS30
Hole Location: 162 Windsor Rd
SHEET 1 OF 1

PROJECT: SOAKPITS PROJECT	LOCATION: OTUMOETAI	JOB No: 23064	
CO-ORDINATES 6387015.00 mN 2786242.00 mE	DRILL TYPE: Window Sampler	HOLE STARTED: 11/04/06	
	DRILL METHOD:	HOLE FINISHED: 11/04/06	
R.L. m		DRILLED BY: mhh	
DATUM	DRILL FLUID:	LOGGED BY: dmmm	CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																	SILT, dark brown, organic
YOUNGER ASH																	SILT, light brown, moist, low plasticity, moderate sensitivity
									1								slightly sandy, slightly clayey SILT, orangish yellow, moist, low plasticity, low to moderate sensitivity - becomes moderately plastic, moderately sensitive - becomes light grey clayey SILT, moist, moderately plastic
ROTOEHU ASH									2								silty fine to medium SAND, pumiceous, moist, sand mostly comprises quartz and feldspar with some mafics - becomes grey sandy SILT, wet, plastic, sensitive - becomes light greyish white fine to medium SAND
HAMILTON ASH																	CLAY/SILT, dark brown, moist to wet, plastic, sensitive - becomes orangish brown clayey SILT, low plasticity, moderately sensitive
									3 4 5 6								**END OF BOREHOLE AT 3.0m** - 19mm standpipe installed to 3.0m



Job Name: TONTJUDEARDSITE	Job No: 650035.029	Test: Ground water monitoring.	Date: 26/04/06

Goods Rd and Roderick St	No Water
49 Milton Rd	No Water
Brinkley St and Grange Rd	No Water
Ridge St	4.1m
162 Windsor Rd	2.9m
Millars Rd	No Water
Darraghs Rd	4m (Bottom of hole)

GEOTECHNICS LTD.
Tauranga Laboratory
56 10th Ave, Tauranga
Tel: 07 571 0280 Fax: 07 571 0282

LAB. REF.: 052/06

FILE:
650035.029

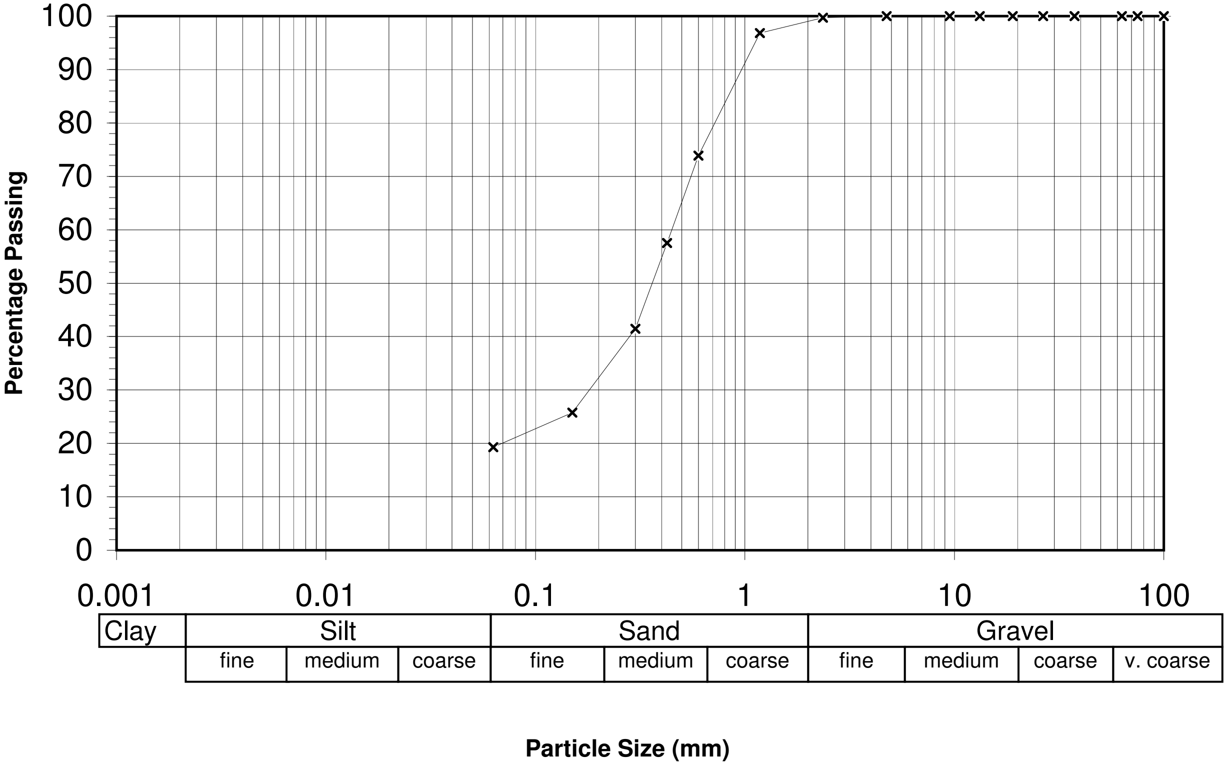
Sheet of

Location: JUDEA RD TAURANGA		Job Name:	TONTJUDEASITE
Material: SEE BELOW		Job Number:	650035.029
Sample Number:	JUDEARD/110406/PSD/WS12	Depth:	-

Sample History: Natural/~~Air-dried/Oven Dried/Unknown.~~ Whole Soil/~~Fraction passing..........mm sieve~~

PARTICLE SIZE DISTRIBUTION

NZS 4402:1986 TEST 2.8.1 ~~& 2.8.2~~



Sieve Aperture (mm)	Cumulative % Passing
200.0	100
150.0	100
100.0	100
75.0	100
63.0	100
37.5	100
26.5	100
19.0	100
13.2	100

Sieve Aperture (mm)	Cumulative % Passing
9.5	100
4.75	100
2.36	100
1.18	97
0.60	74
0.425	58
0.30	41
0.15	26
0.063	19

Note: For Wet Sieve, the percentage passing the < 0.063mm was obtained by Difference ~~/ Weight~~.

Tested:	KHC	Date:	13/4/06
Calculated:	EEK	Date:	26/4/06
Checked:		Date:	

Pumice SAND, fine to medium round/subround, possible traces of silt, light to medium grey-brown, moist

GEOTECHNICS LTD.
Tauranga Laboratory
56 10th Ave, Tauranga
Tel: 07 571 0280 Fax: 07 571 0282

LAB. REF.: 052/06

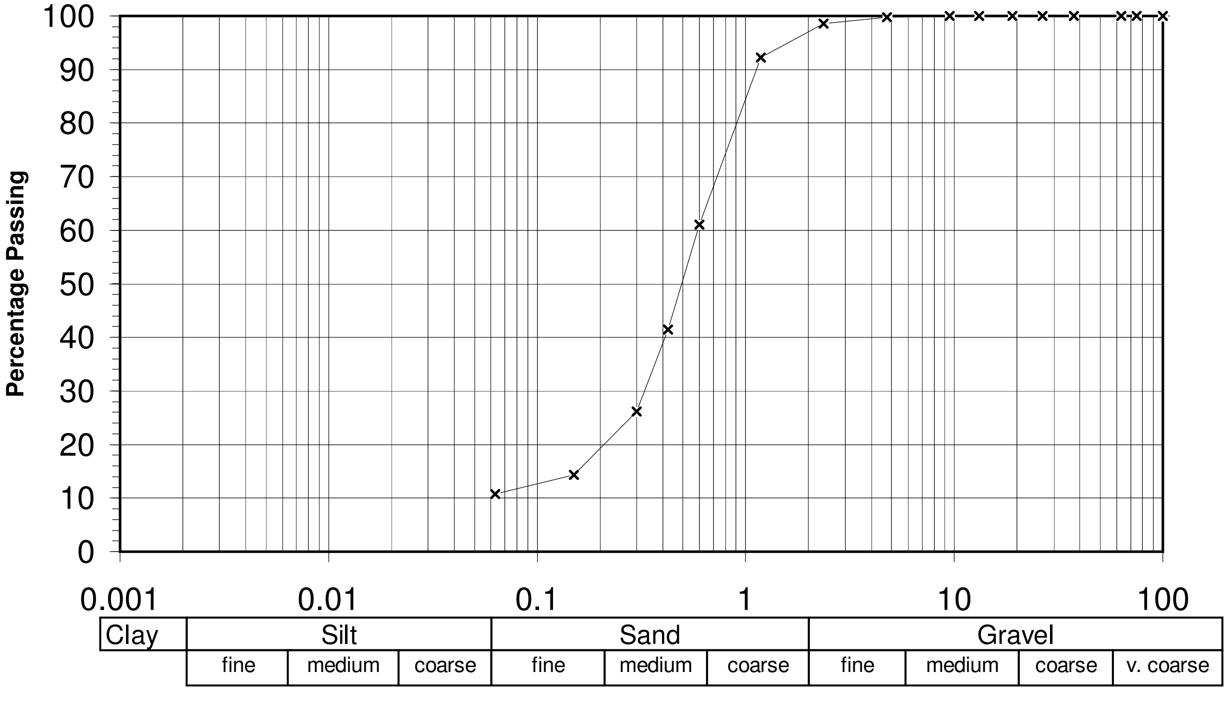
FILE:
650035.029
Sheet of

Location:	OTUMOETAI	Job Name:	TONTJUDEASITE
Material:	SEE BELOW	Job Number:	650035.029
Sample Number:	JUDEARD/110406/PSD/WS24	Depth:	-

Sample History: Natural/~~Air-dried/Oven Dried/Unknown.~~ Whole Soil/~~Fraction passing..........mm sieve~~

PARTICLE SIZE DISTRIBUTION

NZS 4402:1986 TEST 2.8.1 ~~& 2.8.2~~



Particle Size (mm)

Sieve Aperture (mm)	Cumulative % Passing
200.0	100
150.0	100
100.0	100
75.0	100
63.0	100
37.5	100
26.5	100
19.0	100
13.2	100

Sieve Aperture (mm)	Cumulative % Passing
9.5	100
4.75	100
2.36	99
1.18	92
0.60	61
0.425	41
0.30	26
0.15	14
0.063	11

Note: For Wet Sieve, the percentage passing the < 0.063mm was obtained by Difference ~~/ Weight.~~

Tested:	KHC	Date:	13/4/06
Calculated:	EEK	Date:	13/4/06
Checked:		Date:	

Pumice SAND, f-m round-subround, traces fine gravel, l-m grey-brown, creamy gravel, moist

Appendix C: Calculations on the Performance of Soak-holes

These calculations are fairly approximate, but we believe they provide a reliable indication of the way the soak-holes are most likely to behave during major storm events.

Assumptions:

1. Soak-holes have a diameter of 0.2m and discharge into the Rotoehu ash layer (referred to as the "aquifer"). For simplicity, one soak-hole per site was assumed.
2. The Rotoehu ash layer is 1m thick
3. The coefficient of permeability of the Rotoehu ash is 10^{-3} m/sec (most probable value), and the porosity is 0.3. The available porosity (the porosity which water actually flows in and out of) is 0.1 to 0.2.
4. Depth of soil above the Rotoehu ash is 2.5m (average).
5. Average size of a house section is 20m by 40m ($800m^2$) and the average roof area of each house is $250m^2$.
6. The inclination of the ground towards the top of the cliffs is between 1/50 to 1/20.
7. Rainfall figures for the May 2005 event are 67mm in the first hour, 112 mm in the second hour and 265mm in 24 hours.

Estimation of the volume capacity of the aquifer

The storage capacity of the aquifer = 800 x 1 x (0.1 to 0.2) = 80 to $160m^3$.
Volume coming from a house in the first hour = 0.067 x 250 = 16.8 m^3/hour
Volume coming from a house in 24 hours = 0.265 x 250 = 66.7 m^3.

Estimation of the rate at which water will flow from soak-holes into the aquifer

For simplicity, consider a flat site, and use the Dupuit assumption and formula for flow towards a well. A soak-hole will act as a reverse well so that the same assumptions and formula can be applied to the soak-hole. For this estimate, it is assumed that the discharge from each house is taken up by the aquifer area immediately beneath the section the house occupies. In other words the discharge goes into an aquifer area of $800m^2$. In practice each house may have more than one soak-hole but for simplicity the assumption is made that there is only one soak-hole
Initially, assuming the aquifer is dry, flow will be unconfined, and given by the formula

$$Q = \frac{\pi k \left(h_2^2 - h_1^2\right)}{\log_e \frac{R}{r}}$$

This expression is for a well, which is circular; it can be used approximately for a rectangular area by using a circle of the same area. The equivalent radius, R, is therefore = $\sqrt{}$ 800/π = 16m.
Taking $h_2 = 0$, $h_1 = 1$m, r = 0.1m
Putting these figures into the above formula gives Q = 0.62k m^3/sec = 2,230k m^3/hour.
For k = 10^{-3} m/s this gives Q = 2.23 m^3/hour

This figure can now be compared with the flow rate into the soak-hole coming from the storm.
Volume to be discharged in the first hour = 0.067 x 250 = 16.8 m^3/hour
Volume to be discharged in 24 hours = 0.267 x 250 = 66.7 m^3.

This shows that the soak-hole will rapidly fill up with water and the flow rate will immediately increase because of the "driving force" coming from the head of water in the aquifer. The value of h_2 increases to 3.5m and this gives Q = 7.58k m^3/sec = 27,300k m^3/hour. For k = 10^{-3} m/s this gives Q = 27.3 m^3/hour. This is adequate to accept the discharge into the soak-hole, but for only a very short period of time. Once the aquifer becomes full, or approaches full, the flow will become confined, and the flow will also reach the boundaries of the site and meet with flow coming from neighbouring properties.

For confined flow, the Dupuit formula is: $Q = \dfrac{2\pi kH\left(h_2 - h_1\right)}{\log_e \dfrac{R}{r}}$

where H is the thickness of the aquifer.

This formula give Q = 3.10k m^3/sec, = 11,160k m^3/hour, which for k = 10^{-3}m/sec gives Q = 11.2 m^3/hour. This is an absolute maximum and would apply for only a very short period, before the aquifer starts to fill with water and the flow comes up against flow from soak-holes on neighbouring properties. These figures suggest that the capacity of the aquifer to take in the storm-water discharge is inadequate until the head (water level) builds up in the soak-hole. This means that the aquifer is almost certainly "pressurised" during storms such as the May 2005 event.

Calculation of the rate at which water will drain out of the aquifer

Use Darcy's Law Q = kiA:
For i = 1/20 and k = 10^{-3}m/sec Q = 0.5 x 10^{-4} m^3/sec/m = 0.18 m^3/hour/m
This is a peak rate, and the average rate over which drainage occurs would be about half this rate, = 0.09 m^3/hour/m
If the aquifer is fully saturated, volume of water free to drain out (assuming the distance over which water will drain out is 100m) = n(porosity) x 100 x 1 x 1 = 100n m^3 per m width along the slope. For n = 0.1 Vol = 10m^3 and for 0.2 Vol = 20m^3.
The time for water to drain out therefore = 10/0.09 = 111 hours = 4.6 days

With the lower gradient (1/50) and possibly lower permeability
Flow rate Q = 7.2 x 10^{-3} m^3/hour/m
Time = 10/7.2 x 10^{-3} = 2778 hours = 116 days (= 4 months).