FINAL REPORT

GEOTECHNICAL INVESTIGATION FOR THE PROPOSED WAIANIWANIWA WATER STORAGE DAM

Prepared for
Central Plains Water Enhancement Committee
Selwyn District Council and Christchurch City Council
c/- Private Bag 1
Leeston

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URS

Level 5, Landsborough House
287 Durham Street
PO Box 4479 Christchurch, New Zealand
www.urscorp.co.nz
Tel: +64 3 374 8500
Fax: +64 3 377 0655

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Prepared By	………………………………….. Tim McMorran Senior Engineering Geologist	URS New Zealand Limited Level 5, Landsborough House 287 Durham Street, Christchurch PO Box 4479, Christchurch New Zealand Tel: 64 3 374 8500
Reviewed By	………………………………….. Clive Anderson Principal	Fax: 64 3 377 0655

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	Cliff Tipler	Reference:	48685-002/2100/R1099c
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Introduction

Comprehensive feasibility level geotechnical investigations were carried out by URS New Zealand Limited for the Central Plains Water Enhancement Scheme during 2001 (URS, 2001). These investigations included a review of available literature including previous investigations (eg Paterson, 1987), geological mapping and new subsurface investigations.

Originally, subsurface investigations were undertaken at a proposed dam site in the Wairiri Valley. These investigations revealed that the site is underlain by up to about 25 m of weak fine-grained sediments (dominantly silt and sand) that would need to be removed prior to embankment construction. Also, the valley geometry (defined by a five metre contour survey) required saddle dams to be constructed at low points in the valley perimeter. Given the cost implications of these variations to the conceptual design for the scheme, additional investigations were proposed to evaluate an alternative water storage dam site in the Waianiwaniwa Valley.

The issues investigated as part of the Waianiwaniwa Valley study include:

- Foundation and reservoir geology;
- Availability of suitable construction materials;
- Presence of active faults beneath the dam footprint; and,
- Effect of historical underground coal mining on reservoir integrity.

The investigations carried out as part of this study included aerial photograph interpretation and geological mapping, excavation of test pits and trenches, and drilling of three cored drillholes. Six Cone Penetrometer Tests (CPTs) were also undertaken (URS, 2002). Eliot Sinclair & Partners Ltd has surveyed locations of all investigation points.

An aerial photograph based Digital Terrain Model (DTM) was produced by New Zealand Aerial Mapping to provide reliable geometric information on the reservoir. The DTM has a 5 m contour interval and is accurate to less than 1.6 metres (vertical height).

2.1 Site Description

The proposed Waianiwaniwa dam site is at the mouth of the Waianiwaniwa valley where the Waianiwaniwa River emerges from the Malvern Hills (Figure 1). The valley has a 1-km wide floor at approximately El 240 m in the vicinity of the proposed dam site. The Waianiwaniwa River follows a 6 km long valley starting near to where the Selwyn River emerges from its gorge upstream from Whitecliffs. Near its headwaters the Waianiwaniwa River flows east for about 3 km, then turns abruptly to flow south for a further 3 km down to the proposed dam site. It then flows across the Canterbury Plains to join the Selwyn River about 16 km to the southeast.

2.2 Regional Geology

Gregg (1964) and Wilson (1988) have undertaken regional geological studies presented as geological maps with scales of 1:250 000 and 1: 100 000 respectively. No detailed studies of the geology of the Malvern Hills have been carried out since Speight (1929). The geological setting for the proposed dam is presented in Figure 2.

The eastern Southern Alps largely consists of Torlesse rocks (greywacke sandstones and argillaceous mudstones) that locally form the basement. In Canterbury, these rocks are overlain by a sequence of terrestrial coal measures (Broken River Coal Measures), marine sandstones and mudstones (Eyre Group), and volcanigenic sediments and basalts (Burnt Hill Group) all of early to mid Tertiary age. In the Malvern Hills, Mount Somers Volcanics (rhyolite and andesite of Cretaceous age) occupy a stratigraphic position between the Torlesse and Tertiary rocks. Mount Somers Volcanics form Mount Misery to the south of the Selwyn River. The basal unit of the Broken River Coal Measures (the Monroe Conglomerate) mainly comprises gravel-sized fragments of the Mount Somers Volcanics.

Fluvioglacial gravels of Pleistocene age (Kowhai Formation) overlie the older rocks. Extensive outcrops of Hororata Formation, Woodlands Formation, Windwhistle Formation, Burnham Formation and Springston Formation underlie the proposed scheme corridor. The gravels generally become younger to the east.

2.3 Seismic Hazard

Recent studies by Stirling et al. (1999) and older studies by Smith and Berryman (1982) describe the regional seismic hazard in Canterbury. Stirling et al. (1999) use a Probabilistic Seismic Hazard Assessment method. Estimates of the level of shaking expected within the projected lifetime of an engineering structure arepresented in Table 1 for Rangiora, which is considered to most closely represent the foothills area. Using this data, we predict peak ground acceleration of about 0.31g for a 150 year return period and 0.47g for a 475 year return period for the scheme area.

Considerable research effort in New Zealand has been directed in the last decade to evaluating the hazard associated with geological structures capable of generating earthquakes (eg. Pettinga et al. 1998, Stirling et al., 1999, 2002). More than 20 active faults have been identified in Canterbury alone. Several of these structures pass within 30 km of the proposed dam site, as shown on Figure 2.

Table 1

Estimates of Peak Ground Acceleration for the CPWE area

Return Period (years)	Stirling et al. (1999) Pga (g)
50	0.20
150	0.31
475	0.47
1000	0.58

2.3.1 Porters Pass Fault

The Porters Pass Fault is the expression of the southwestern part of the Porters Pass-Amberley Fault Zone. It crosses the southeastern end of Lake Coleridge and strikes northeast to cross Lake Lyndon and Porters Pass. The fault is the most active structure known in the vicinity of the CPWE scheme. Recent research (Howard et al. in press) indicates that the Porters Pass Fault generates earthquakes of Magnitude M_w7.2+ every 2000 years. Associated with this earthquake is up to 8 m of lateral ground displacement. The Porters Pass Fault does not directly cross any part of the CPWE scheme, but passes approximately 27 km north of the proposed Waianiwaniwa dam site.

2.3.2 Springfield Fault

The newly discovered Springfield Fault strikes approximately northeast from the upper Selwyn River through Dalethorpe Station to Springfield (Jocelyn Campbell, University of Canterbury Department of Geological Sciences, personal communication, June 2001). This fault has experienced repeated movement during the last 10, 000 years and probably generates earthquakes of M_w7+ every few thousand years.

The Springfield fault does not cross any structure of the proposed scheme and passes approximately 14 km north of the proposed Waianiwaniwa dam site.

2.3.3 Hororata Fault

The Hororata Fault was discovered following recent seismic reflection surveys carried out for oil exploration. The fault passes within about 1 km of Hororata, and is thought to strike northeast and deforms young gravels at Racecourse Hill. Deformation of young gravels indicates that the fault may have experienced repeated movement during the last 10, 000 years. The Hororata fault probably generates earthquakes of M_w7+ every few thousand years.

The Hororata Fault passes about 3 km south of the proposed Waianiwaniwa dam site. The proposed distribution canal probably crosses the Hororata Fault about 5 km southwest of Hororata.

2.3.4 Other structures

The sequence of Cretaceous to Tertiary aged sediments described in Section 3 dip to the south east in the area of the proposed dam site as a result of tectonic uplift. During investigations for a proposed regional landfill 5 km north of the proposed dam site, a west dipping thrust fault (referred to as the Western Gully Fault) was found at the contact between Cretaceous coal measures and basement Torlesse sandstones (Mark Yetton, personal communication). East dipping reverse faults were also found outcropping south of the Western Gully Fault. These faults were inferred to be active on the basis of displaced Late Pleistocene and Holocene colluvium. Slickensided (sheared) joints were also found in drill core that was interpreted to represent small amounts of displacement along bedding within the Tertiary sediments.

Speight (1928) inferred an east-west striking fault at the contact between a small outcrop of Tertiary sediments in the upper Waianiwaniwa Valley and adjacent Torlesse greywacke outcrop. A similar sliver of Tertiary rocks exists northwest of Mount Misery and this may also be a result of down faulting of the Tertiary block. No comprehensive active faulting study has been completed in this area, but it is likely that these faults have been active during the recent geological past. If these faults are indeed active, their shaking hazard to the proposed dam is expected to be similar to, or lower than, the known active faults shown in Figure 2.

Section 3.5 presents evidence for and against active faulting in the dam footprint.

3.1 Site Investigations

Prior to undertaking the current study, a preliminary investigation (URS, 2002) was undertaken in the vicinity of the proposed site. The main objective of that study was to establish the depth of fine-grained sediments in the Waianiwaniwa Valley. A total of 6 Cone Penetrometer Test (CPT) probes were completed at two possible dam sites and the results of these tests are presented in Appendix A.

Subsequently, a total of 12 test pits and trenches were excavated to investigate the near surface geology. These were excavated using a 20 Tonne tracked excavator operated by W. A. Boyes Contracting Limited. All excavations were logged and representative samples taken by an engineering geologist, and the logs are presented in Appendix B. On completion of logging and sampling the excavations were backfilled.

Three exploratory drillholes were carried out along the proposed dam alignment. These were drilled using a UDR 650 drilling rig operated by McNeill Drilling. The holes were mainly advanced using PQ triple tube techniques, but non-cored "Tubex" techniques were used in some of the near surface gravels. The drill holes were logged and photographed by an engineering geologist, and these are presented in Appendix C.

The locations of all subsurface investigations are presented in Figure 5.

3.2 Geology of the Proposed Dam Footprint and Reservoir

3.2.1 Stratigraphic Sequence and Distribution

The geology of the reservoir is summarised in Figure 4. Cross sections of the reservoir and dam site are presented in Figures 6, 7 and 8.

Speight (1928), Gregg (1964) and Wilson (1988) show basement Torlesse rocks exposed in the upper part of the Waianiwaniwa catchment. An unconformable contact between the basement and the overlying Cretaceous and Tertiary sedimentary sequence strikes approximately northeast from Whitecliffs, passing east of Cairn Hill and Abners Head which are both basement outcrops.

Broken River Coal Measures outcrop to the east of the unconformity and coal has been won, particularly during the late 1800's and early 1900's. The coal measures include conglomerates at the base, sandstones and mudstones, coal seams and oyster beds and probably have a thickness of at least several hundred metres. Where the coal measures were observed in Bush Gully they dip about 45° to the southeast. An outcrop of intrusive dolerites of Paleocene age near to Glentunnel may indicate the easternmost outcrop of coal measures. The dolerite is interpreted to be part of the View Hill Volcanics on the basis of petrography.

Overlying the coal measures is a sequence of marine sandstones and mudstones of Tertiary age including many formational and group names (Conway Formation, Waipara Greensand, and Homebush Sandstone). Confusion regarding the usage of these terms, and the broadly similar sedimentological descriptions and engineering properties of the different units has led us to lump these units together as “Tertiary sediments”. These units are all silty fine to medium grained sandstones and up to 60% glauconitic. In terms of engineering properties, the Tertiary sediments are very weak to weak and joints are generally not present.

The Tertiary sedimentary rocks are overlain by a sequence of volcanic and volcanigenic rocks. Carlson and Rodgers (1975) describe the Burnt Hill Formation as sands, ash and breccia. These units outcrop in the Wairiri Valley and are inferred to underlie Homebush Ridge and outcrop on the west side of the ridge. Tuffs and Basalts of the Harper Hills Volcanics (Carlson and Rodgers 1975) outcrop along the crest of Homebush Ridge.

3.2.2 Cover Sequence

Pleistocene glacial outwash gravels form remnant aggradation[1] surfaces overlying the older rocks. Wilson (1988) has studied the glacial stratigraphy of the Canterbury Plains, and Rains (1966) has studied the glacial stratigraphy of the upper Selwyn River catchment.

Many of these outwash gravels have been grouped together as “Hororata Formation” (Wilson 1988) which includes a wide range of ages but is thought to have been deposited at least several hundred thousand years before present. The Hororata Formation includes a covering of up to 15 m thickness of loess that has accumulated since deposition of the gravels. The highest outwash surfaces, which are inferred to be Hororata Formation, are approximately 80 m above current Waianiwaniwa River level.

A prominent terrace at about RL 270 (about 30 m above valley floor level) is interpreted to be an aggradation surface formed by gravels of the Woodlands Formation. This terrace is at a similar elevation to Woodlands surfaces recognised by Wilson (1988), but has previously been mapped as Hororata Formation. Extensive terraces southeast of Homebush Ridge are also inferred to be Woodlands Formation aggradation surfaces.

The Waianiwaniwa valley contains sand and silt dominated alluvium. The valley floor grades toward a Burnham age aggradation surface of the Selwyn River at about RL 235. Colluvium and landslide deposits mantle the valley sides and fill tributary gullies. No peat deposits were encountered during investigations at the proposed damsite.

3.2.3 Drainage Pattern Changes

A complex history of river aggradation and downcutting, has resulted from distributary glaciers of the Rakaia Valley directing meltwater into the Selwyn River catchment (Rains, 1966). Drainage pattern changes have probably resulted from aggradation, downcutting and possibly tectonic adjustment, and we

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[1] Aggradation surfaces are extensive, nearly horizontal geomorphic surfaces built up by aggrading rivers as a result of excessive sediment supply, typically during periods of glacial advance.

infer that the Waianiwaniwa Valley may be an abandoned paleochannel of the Selwyn River. After abandoning its old channel and establishing the modern Selwyn River channel, aggradation during the last glacial advance appears to have blocked tributaries including the Waianiwaniwa Valley and the Wairiri Valley and resulted in accumulation of silt dominated lake sediments or sand dominated alluvium.

3.3 Damsite Geology

The proposed embankment alignment runs approximately east-west for most of its length and curves to the northeast at the left abutment end. The total length of the proposed dam is about 2000 m with a crest elevation of about 290 m, giving a maximum height of about 55 m above existing ground level. The dam footprint geology is described here in four distinct areas that are considered to have similar geological conditions:

- Left abutment;
- Valley mouth;
- 270 m terrace; and,
- Right abutment.

The **left abutment** is founded on the end of Homebush Ridge. The geological conditions underlying the left abutment are expected to comprise weak Tertiary sediments, and tuffs in a sequence dipping about 30° to the southeast (i.e. downstream). These rocks are expected to be overlain by a thin layer of colluvium including bouldery volcanic rocks and clay rich tuff derived material. A series of terraces are also evident on the end of Homebush ridge, the most prominent of which is at approximately RL270, the elevation of the terrace that occupies most of the dam footprint. The terraces are expected to be underlain by a small deposit of greywacke gravel with a loess cap up to about 10 m in thickness.

The **valley mouth** is approximately 300 m wide and has a flat floor at about RL 235 m. This elevation corresponds to a Burnham age aggradation terrace formed by the Selwyn River (Wilson, 1988). Test pits 5, 6 & 7, and drillhole WN3 were carried out in this area. The test pits investigated to a maximum depth of 6 m, and between 6 m and 70 m below ground level the geological materials have been described based on the results of WN3. Test pits 5 and 7 encountered interbedded gravels, sands and silts, containing mainly greywacke clasts with rare volcanics. Test pit 6 encountered greywacke gravels to a depth of 4 m.

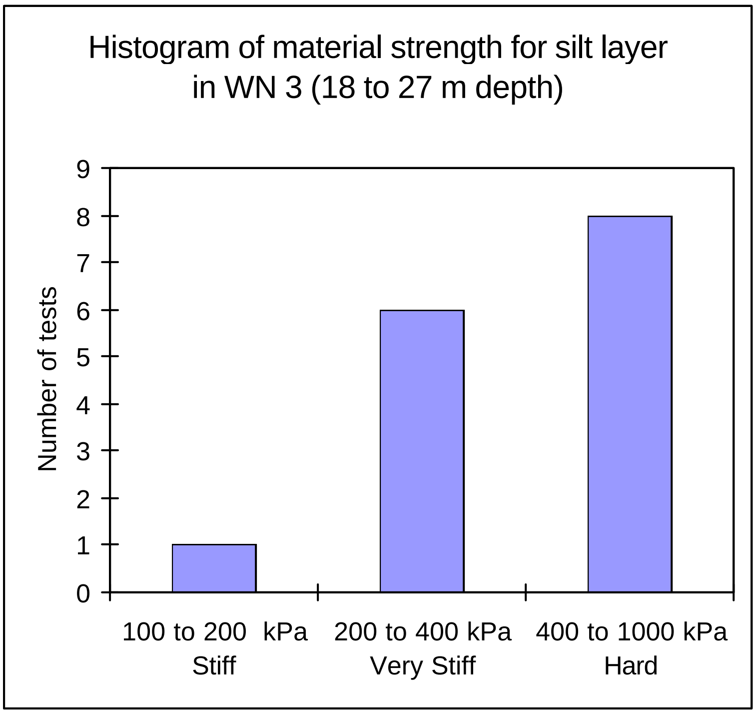
Drillhole WN3 encountered greywacke dominated gravels to a depth of 18 m. Gravel clasts were typically slightly weathered, brown or black stained on the outside. This sequence included a sandy silt layer at about 5.8 to 8 m depth (drillhole log is presented in Appendix C).

Between 17 and 18 m depth, volcanic clasts were noted within the gravels. Between 18 and 27 m depth grey very stiff silt and very fine sand was encountered. This was laminated in part with typical lamination thickness of less than a few mm. Pocket penetrometer strength measurements were undertaken with most results falling in the range of very stiff to hard (Figure 8). Between 27 m and 38 m depth further gravels were encountered. These were typically coarse greywacke gravels with a slightly cohesive silty sand matrix, and the clasts were typically relatively weathered. At the base of the gravel sequence an angular gravel layer of a few metres thickness directly overlies rock.

The statigraphic and depositional relationship between the different Quaternary units encountered during this investigation (such as the terrace gravels, valley infill and valley mouth infill) is unknown. We infer that the most likely geological scenario is that the lower part of the channel fill is relatively old (possibly Woodlands age), and that the upper channel fill is of relatively young Burnham age.

Figure 8

Pocket penetrometer results for silt layer in WN 3



Rock was encountered between 38 m and 70 m depth, giving a rockhead elevation of about RL200. The rock comprised very weak silty fine grained slightly glauconitic sandstones, greenish grey in colour. The bedding is typically dipping at about 15° but dip direction of bedding could not be measured as the core was not orientated. Joints were absent in the core, probably as a result of its relatively low strength, and the core was unweathered.

A **terrace** inferred to be a Woodlands Formation aggradational deposit occupies the majority of the dam footprint with a relatively level surface at about RL 270 m elevation. The terrace forms a spur protruding from the west side of the valley. The terrace is between about 200 and 400 m wide in a north-south direction. Malvern Hills Road follows a gully that crosses the terrace, falling to the northeast.

Test pits 1, 2, 3, 4, 8 and 9 and drillholes WN1 and WN2 fall within this area of the dam footprint. The top surface of the terrace is covered by about a 9 m thickness of loess. The loess comprises very stiff, light yellow fine sandy silt. WN1 is located below the proposed dam crest line approximately 400 m from the right abutment. Surface elevation at WN1 is about RL264 m and gravel was encountered to about 30 m depth underlain by Tertiary sediments (i.e. rockhead is at about 233 m elevation). WN2 is located on the north side of the terrace near the dam centreline, with a ground surface elevation of about RL232 m. In WN2, silt and gravel dominated colluvium and alluvium was encountered to a depth of 12 m, underlain by Tertiary sediments.

A gravel quarry at the eastern end of the terrace exposes brown silty gravel in an exposure about 10 m high. Approximately 1 m thickness of loess is exposed in the quarry, with the majority of the 9 m thickness apparently having been eroded off at that location.

The **right abutment** of the proposed dam will be formed against a terrace with a surface elevation of about RL320 m. Test pit 10 was excavated in the upper terrace surface and encountered 3 m of weathered very stiff to hard yellow brown sandy silty loess overlying highly weathered brown greywacke gravels. Test pit 11 was excavated on a spring line at about elevation RL280 m and it encountered gravelly colluvium and in situ weathered gravel to a depth of 2 m overlying very weak sandstone. Seepage was observed entering the pit at the base of the colluvium. The permeability contrast between outwash gravels and underlying Tertiary sediments is inferred to result in the spring line, which crosses the right abutment at about RL280 m.

3.4 Hydrogeology

Piezometers were installed in the three drillholes, and water level and permeability information is presented in Table 2. Groundwater was encountered in several of the test pits excavated in the valley floor. The Waianiwaniwa River water level at the time of the investigation was about 4 m below valley floor level. Water was encountered in test pits at shallower depths, particularly in the vicinity of TP1 and WN2 where standing water lies on the swampy paddocks.

Table 2

Depth to Groundwater and Mass Permeability Test Results

Borehole and Depth	Depth to Groundwater	Permeability range m/s	Material Description
WN1	>30 m	NA	Outwash Gravels
WN2	1.97 m	1×10^{-4} to 7×10^{-5}	Tertiary Sandstone
WN3	3.69	6×10^{-5} to 4×10^{-6}	Outwash Gravels

Note:
1. WN1 contained no standing water so couldn’t undertake rising and falling head tests
2. Depth to groundwater measured on 17 Sept 2002

The gravel dominated units within the dam footprint are expected to have variable mass permeability. The gravels that form the RL270 m outwash deposit are generally intermediate age greywacke gravels that are expected to have a mass permeability in the range 10^{-4} to 10^{-5} ms^{-1}. The valley fill alluvium encountered in WN3 (between ground surface and about 17 m depth) within the valley mouth includes Burnham age sandy gravels that are expected to be relatively permeable. Permeability tests were not carried out on these materials during this study but would be expected to be in the range of 10^{-3} to 10^{-4} ms^{-1}. The gravel encountered between 27 and 38 m depth is a relatively silty gravel with a relatively low permeability (see Table 2) as tested by rising and falling head tests.

The general permeability of the Tertiary sediments is expected to be in the range of 10^{-7} to 10^{-9} ms^{-1} based on previous permeability testing carried out in similar materials at the proposed Wairiri dam site (URS 2001) and elsewhere (Mark Yetton Geotech Consulting Ltd personal communication). Testing carried out in WN2 indicates a permeability of 1×10^{-4} ms^{-1}, which is much higher than expected in these materials. The higher permeability is expected to be due to a locally fractured zone or possibly a malfunctioning piezometer. More extensive permeability testing should be carried out at design stage to establish if any areas of the dam foundation require treatment such as grouting.

3.5 Evidence for Faulting Within the Dam Footprint

As described in Section 2.3.4 a linear topographic step crosses the downstream edge of the dam footprint. Trench TR1 was excavated on a steep south-facing slope west of Malvern Hills Road to look for evidence of fault-related deformation within the near surface materials. The location was chosen to avoid thick fan deposits which have formed at gully mouths along the terrace edge. Subhorizontal brown gravels were encountered in the trench underlying about 1.5 m thickness of loess and gravel colluvium. No evidence for faulting or tectonic deformation was found in TR1.

The RL270 m terrace shows a slight fall to the south which is consistent with the depositional dip of the fan surface, but could also be a tectonic tilt. Also the older Hororata age terraces show a general southeast tilt which may be tectonic or depositional. No evidence for faulting or folding of these surfaces was found during the investigation.

While no evidence was found for faults within the dam footprint, the possibility exists that faults may be found during design or construction. It is considered very unlikely that a fault could be found within the dam footprint that cannot be accommodated by a local change in embankment configuration, such that the embankment can handle the displacement expected to result from future movement.

3.6 Effect of Historical Underground Coal Mining

Coal mines were operated in the Malvern Hills throughout the late 1800’s and early 1900’s. The majority of mines were located in Bush Gully and in Surveyors Gully, though other mines were located where coal seams were found to outcrop. Figure 4 shows the locations of coal mines throughout the Waianiwaniwa Valley. The underground mining was extensive in places, particularly in the case of the Klondyke mine, which followed seams up to “1500 feet down dip” (approximately 300 m below ground level), and up to about 600 m along strike (personal communication, Ken Shearer, Canterbury Coal Ltd). Klondyke Mine was unusually extensive, and many mines were discontinued because they were overwhelmed by groundwater or because the coal seams were faulted out. In some circumstances the coal seam was found again, and mining continued. The faults responsible for displacing the coal do not have large throws as the coal seams generally follow a line of strike, that is not radically offset.

The proposed dam is outside the area of coal measures outcrop and it is therefore extremely unlikely that underground mining has been carried out in the dam footprint, however coal mining has been undertaken within the reservoir footprint.

There is not considered to be a significant likelihood of underground coal mines forming a continuous conduit out of the reservoir. The Homebush Mine is located in Surveyors Gully, west of the proposed reservoir. The entrance to this mine is at least 2 km from the nearest point in the reservoir and it is considered very unlikely that the Homebush mine reached to the proposed reservoir footprint. If records are found indicating that mining did reach the reservoir footprint, engineering works may need to be designed to address this. Such measures would probably involve blocking the mines with low permeability fill barriers and this could prove to be expensive.

4.1 Conceptual Embankment Design

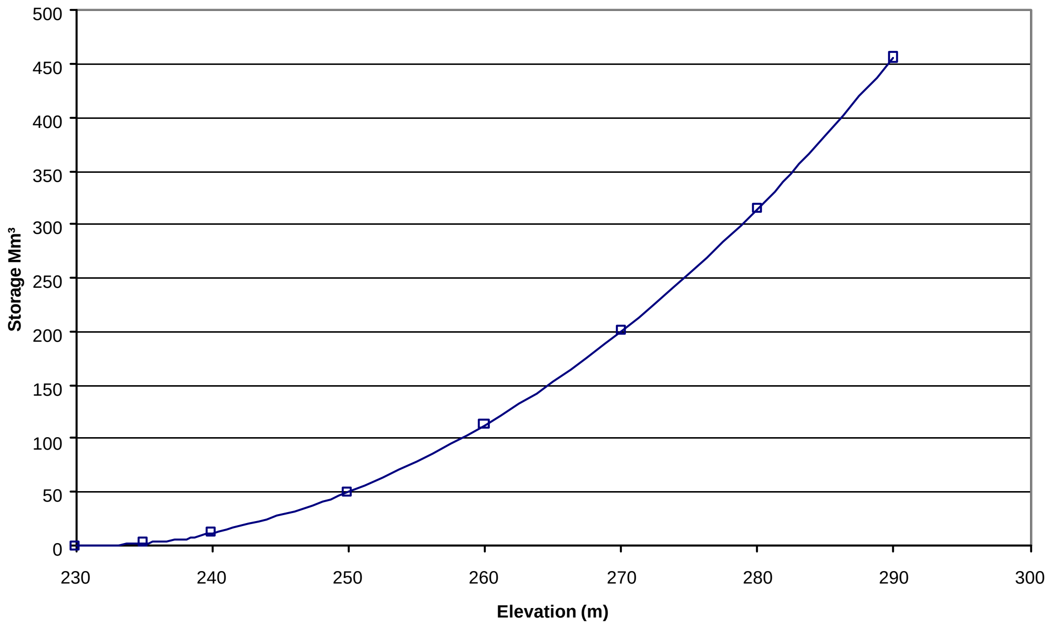
The proposed dam design incorporates a zoned earthfill embankment comprising locally borrowed gravel dominated materials. The core material comprises compacted weathered gravels of Hororata Formation with slopes of 0.5 horizontal to 1 vertical. A 3 m wide sand filter drain is required against the downstream face of the dam core to provide filter protection. Shoulder material could comprise younger greywacke-derived gravels with an outer construction slope of 2.5 horizontal to 1 vertical. A typical cross section of the conceptual embankment design is given in Figure 9.

The conceptual design requires that the loess cap is removed from the 270 m terrace (a depth of about 10 m). Elsewhere the design adopts a foundation level three metres below existing ground level. A cut off system has been included to prevent excessive flow through the gravels under the embankment. This cutoff incorporates a 5 m deep cutoff trench with a ten metre deep slurry trench constructed in the base of the core trench that extends to the Tertiary bedrock. At the valley mouth a deeper cutoff may be required if the lower gravels prove to be too permeable.

The reservoir volume has been calculated from the DTM and indicates that 290 M m³ of storage will require a maximum water level of RL280 m which is significantly less than RL 291 m previously estimated. The storage curve is presented in Figure 10, and Figure 11 indicates the shape of the proposed reservoir when full.

Figure 10

Storage Volume Curve for Proposed Reservoir



4.2 Foundation Suitability

Most of the embankment foundation footprint rests on weathered gravel of the 270 m terrace. The layer of loess that caps the terrace will probably need to be removed prior to embankment construction. Loess can suffer from collapse when saturated, can undergo piping failure under hydraulic gradients and could cause stability problems for the embankment. Additional investigations into the material properties and distribution of the loess will be needed during detailed design.

Springs on the right abutment at about RL280 (Section 3.3) will need to be controlled during construction. The springs indicate that there may be relatively permeable zones within the gravels that cap the abutment. Some form of seepage control will be required in this area to prevent leakage around the dam abutment. This will likely be a cutoff trench or upstream blanket.

The gravels form a suitable foundation for supporting the embankment. The permeability of the gravels is relatively high, and a cutoff beneath the embankment or a leakage reducing low permeability blanket will probably be required to limit leakage to an acceptable level. Where the embankment footprint sits on young valley fill sediments, further investigation will be required to ensure that weak materials are not present that could cause differential settlement. Removal of these materials may be required in some cases. It may also be possible to position the embankment so that a minimum amount of the dam footprint overlies the valley fill materials. Either of these options have implications for embankment volume, and needs to be assessed as part of the costing study for the dam.

Small terrace remnants are evident on the left abutment, which are interpreted to be outwash gravels. No subsurface investigations have yet been carried out on these terrace remnants, and local gravel deposits may need to be removed or treated. Subsurface investigations to map the extent of such deposits should be carried out in this area during the design phase.

4.3 Slope Instability

Existing slope instability has been observed in the reservoir. This includes mainly shallow slides and debris flows on the steep western slope of Homebush Ridge, slumping on dip slopes within the coal measures, and shallow failures of loess colluvium around the edges of the outwash terraces. No very large existing landslides have been observed that could generate significant waves in the reservoir.

Saturation of colluvium and existing landslide debris following lake filling will probably cause increased small scale landslide activity within the reservoir, particularly due to the fluctuation in water level caused by water demand. Increased landslide activity outside the reservoir is not expected due to the long flow paths for groundwater to reach out of the reservoir and the low permeability of the Tertiary sediments.

4.4 Construction Materials

4.4.1 Core Material

Weathered greywacke gravels with a relatively high clay content are likely to form a suitable core material. These materials could be borrowed from the terraces approximately 2 km upstream of the dam on the north side of the reservoir. Low permeability materials could also be borrowed from the underlying Tertiary sediments or from colluvial deposits on the northwest side of Homebush Ridge.

Investigations to confirm the available volumes and material properties (in particular grading variability and internal stability) of potential core materials need to be carried out prior to dam design.

4.4.2 Filter Zones

The near surface alluvium of the Waianiwaniwa River comprises gravelly sand, which can be processed to a suitable grading for filter zones. Selective quarrying of this material will require a resource volume investigation to map out the continuity of sand deposits. Testing to confirm the grading and physical properties of the sand will need to be carried out prior to dam design.

4.4.3 Shoulder Material

Strong, free draining greywacke gravels would be suitable shoulder materials for embankment construction. Possible sources could include the Burnham aged fan downstream of the dam site, selective removal of gravel dominated valley fill alluvium, and selective removal of less weathered gravel from the terraces 2 km northwest of the dam site. Internal transition zones could be constructed using gravels that have been weathered to an intermediate degree. Gravel-dominated materials could also be borrowed from some of the fans that have developed from erosion of the outwash gravel terraces.

Resource investigations and testing will be required to confirm the available quantities and mechanical properties of these materials prior to dam design. In particular, the shoulder material needs to be filter compatible with the filter sands.

Based on the results of this investigation we believe it would be possible to construct a dam in the Waianiwaniwa Valley with a storage volume of 290M m³. Maximum reservoir level to accommodate 290M m³ will be RL280 m. The proposed site at the mouth of the valley is considered to have suitable foundation conditions for construction of an earthfill embankment dam.

The dam would have a crest length of about 2000 m and a maximum height of about 55 m. Construction materials are available within a few kilometres of the dam site. Further assessment is required to evaluate the embankment volume, and to estimate the construction cost.

Other issues that need to be assessed as part of the dam design are spillway capacity and design, outlet works design, downstream hazard classification, and a review of possible alternative dam section configurations.

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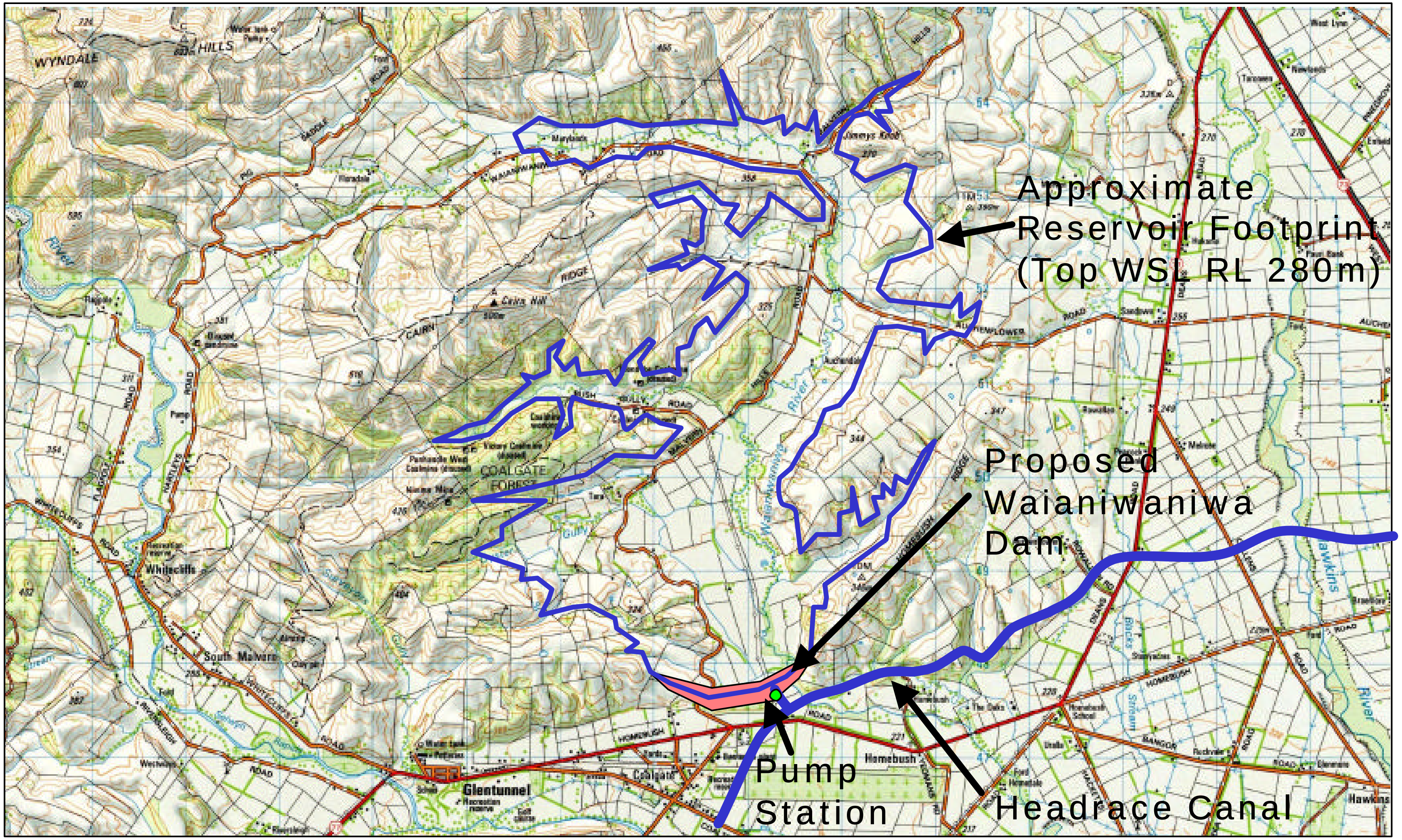
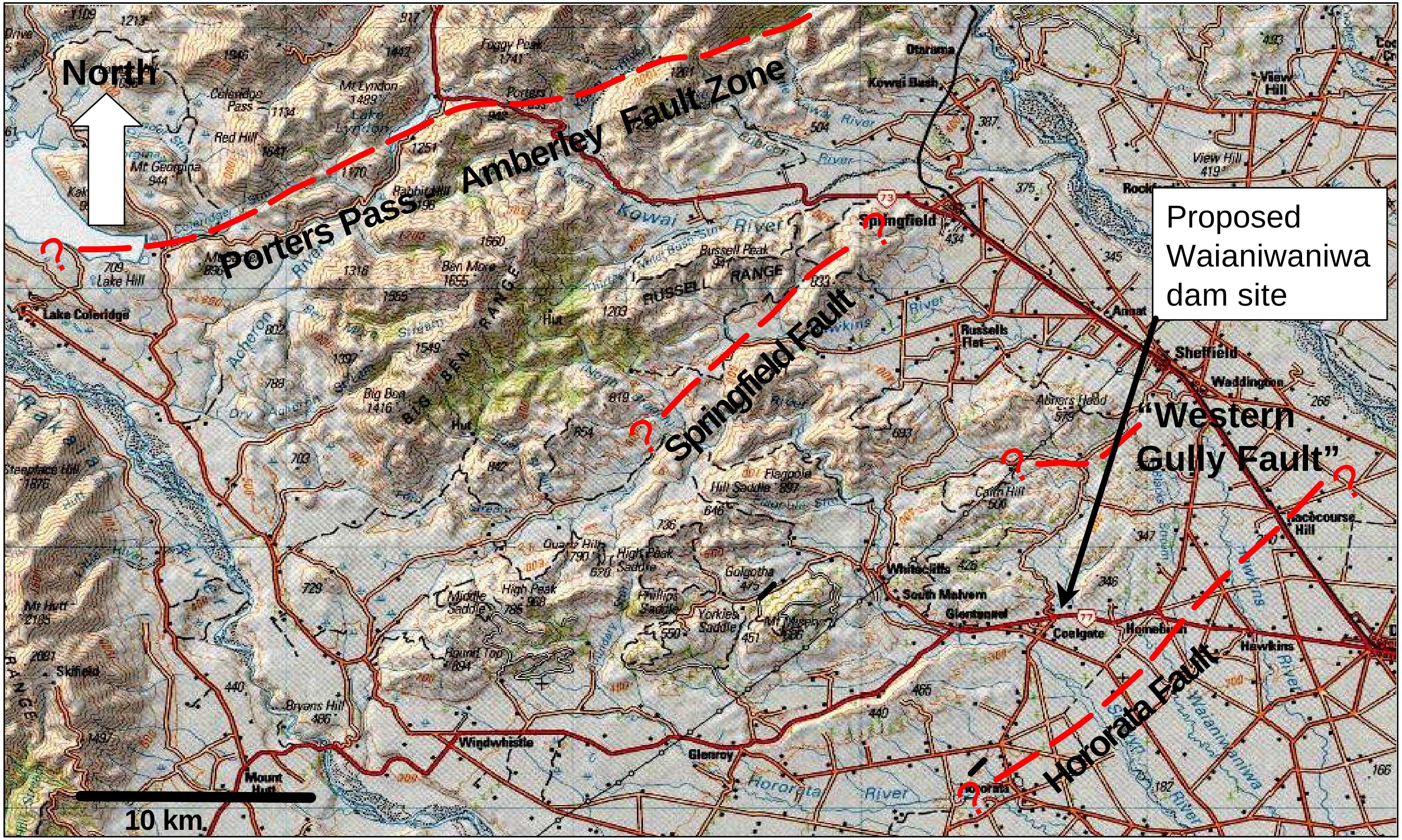


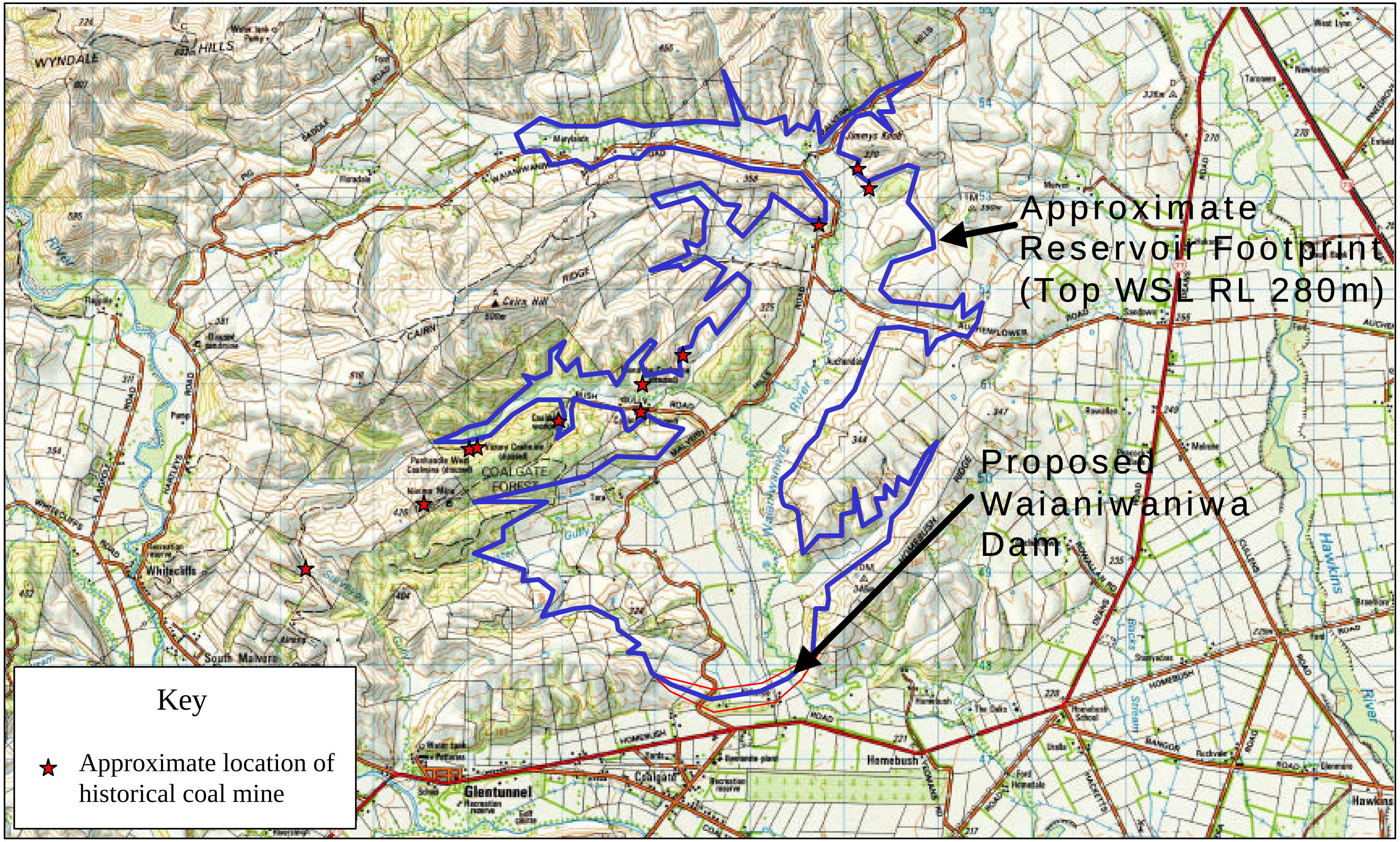
Layout of the proposed Waianiwaniwa storage dam, pump station and headrace canal

Figure 1



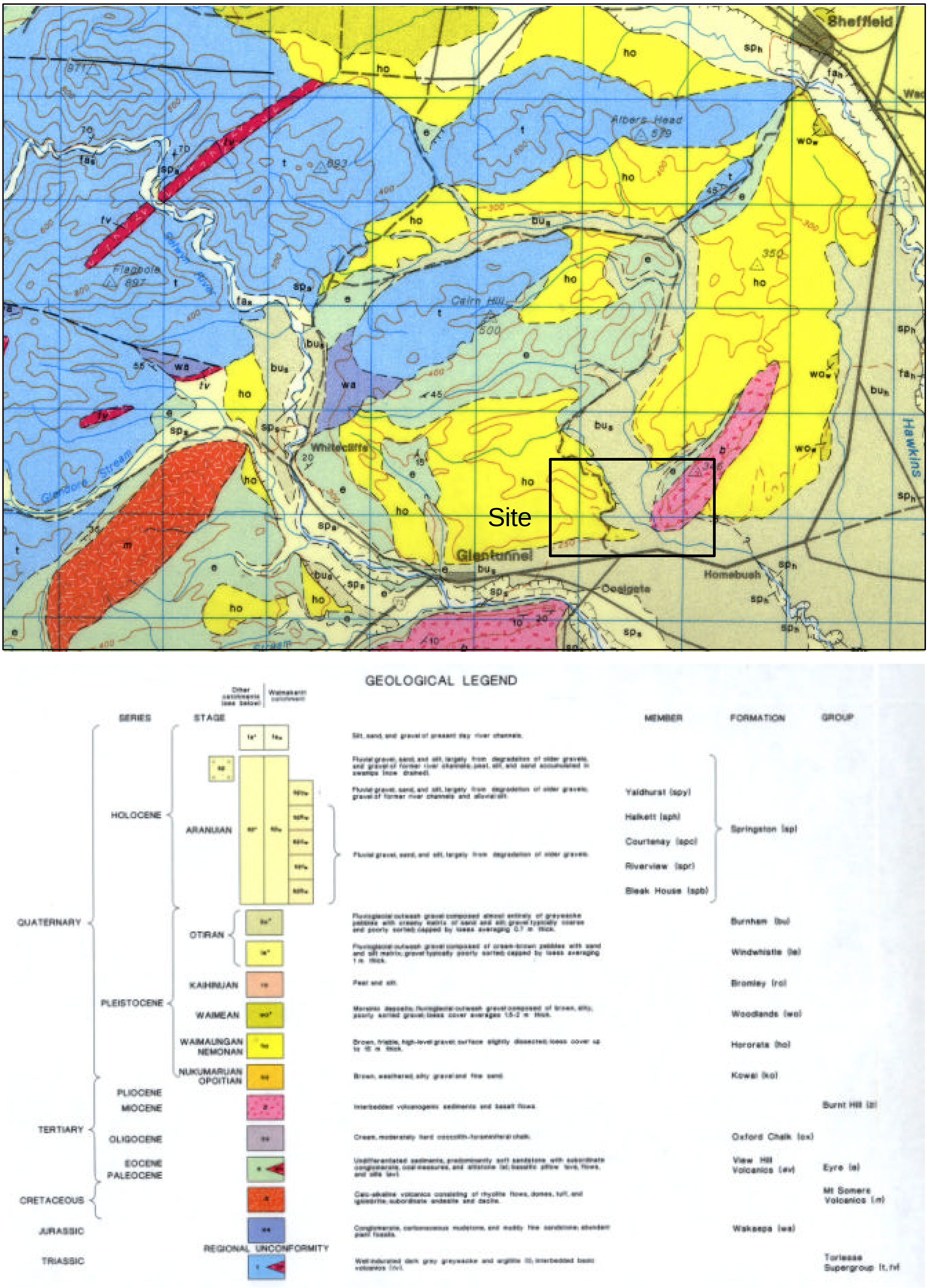
Map showing known active faults within 30 km of the proposed Waianiwaniwa dam site

Figure 2



Plan showing the locations of known underground coal mines in the Waianiwaniwa Valley

Figure 3



Geological map of Malvern Hills Area (after Wilson 1989)

Figure 4

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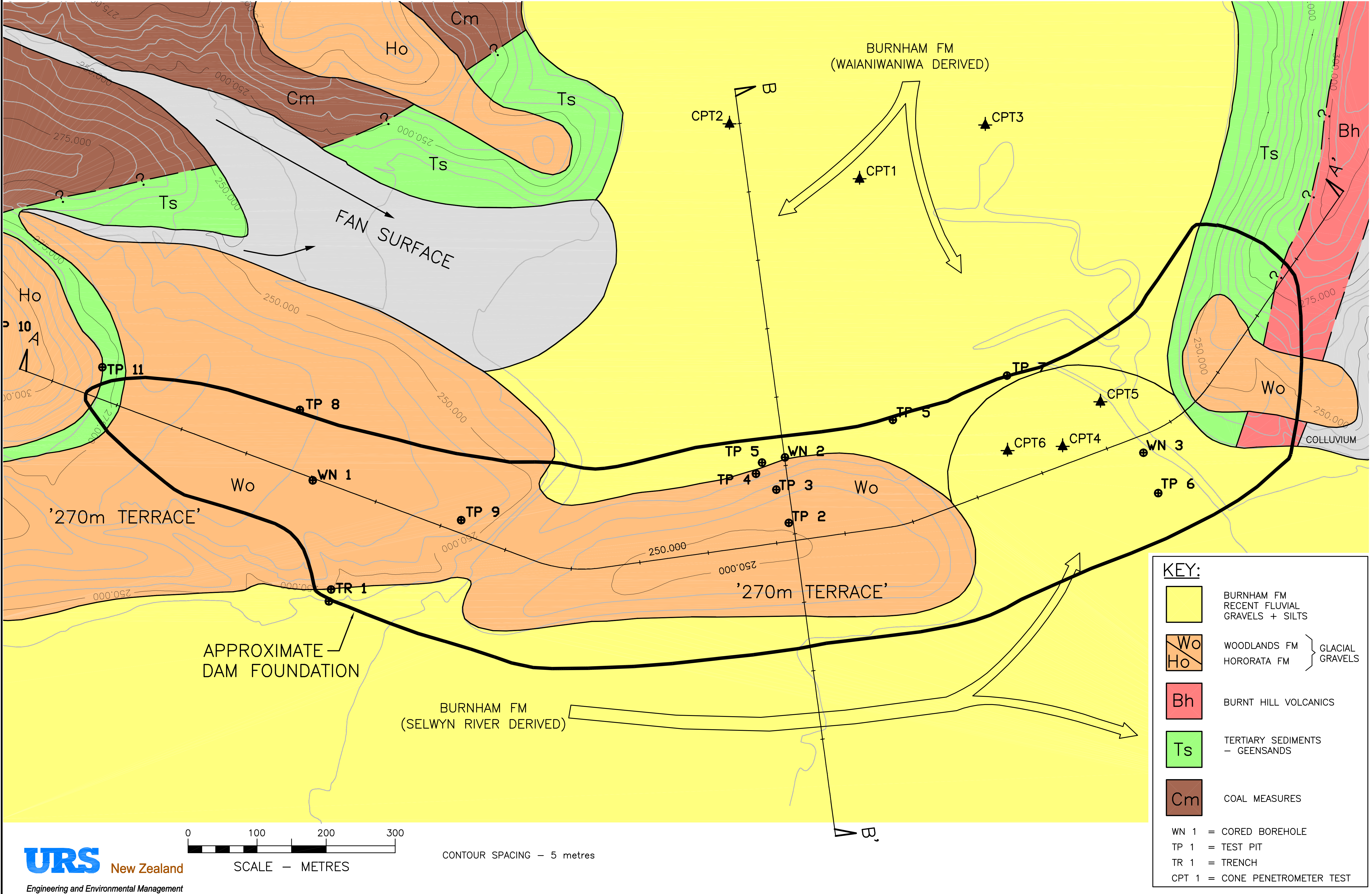
Rev A 19/9/02 STT



CONTOUR SPACING – 5 metres

URS New Zealand
Engineering and Environmental Management

INTERPRETED DAM SITE GEOLOGY AND LOCATION OF SUBSURFACE INVESTIGATIONS

Figure No. 5

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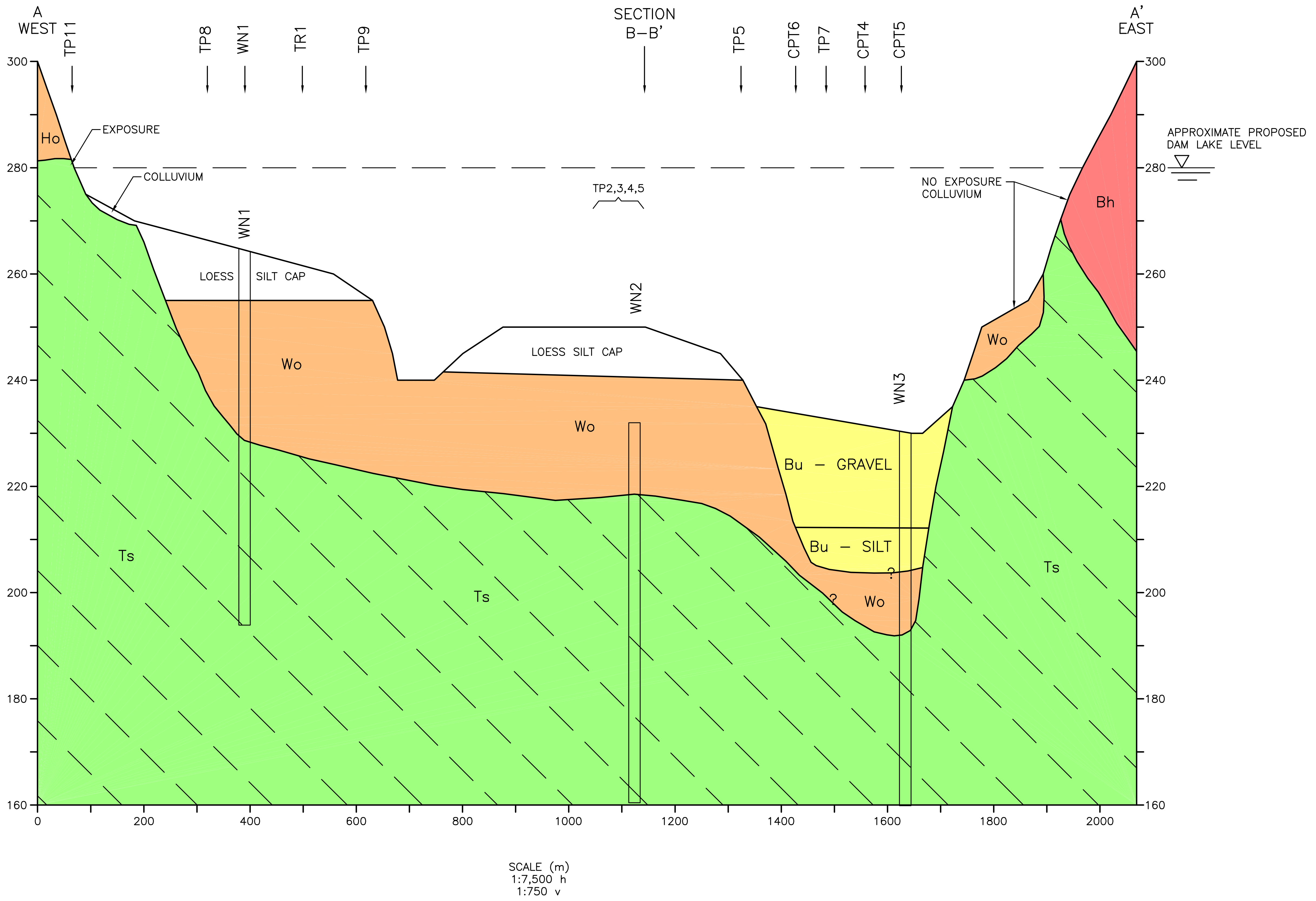
Rev A 20/9/02 STT



GEOLOGICAL CROSS SECTION ALONG THE PROPOSED EMBANKMENT

URS New Zealand
Engineering and Environmental Management

Figure No. **6**

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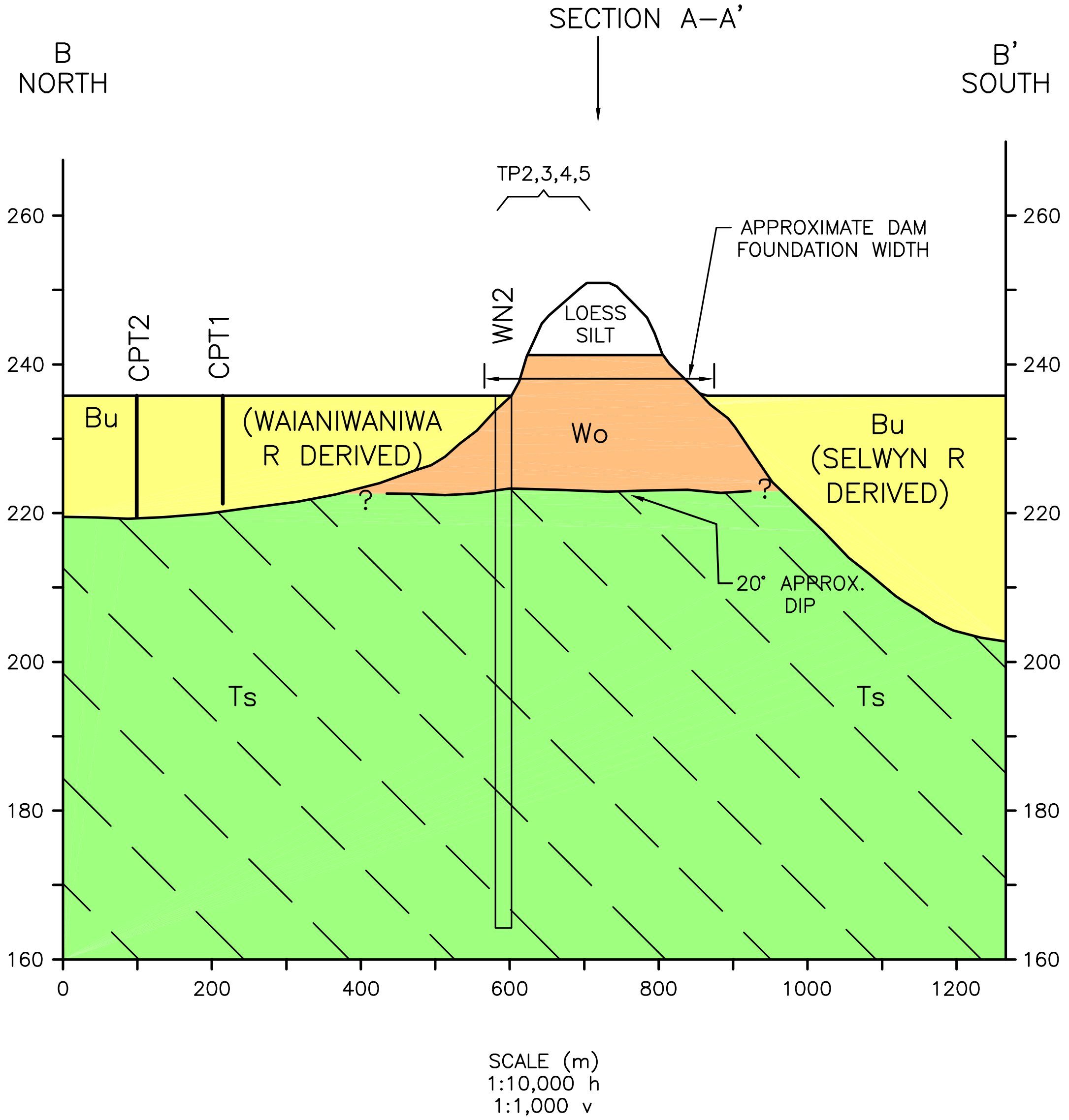
Rev A 20/9/02 STT



GEOLOGICAL CROSS SECTION ACROSS THE PROPOSED EMBANKMENT

URS New Zealand
Engineering and Environmental Management

Figure No. 7

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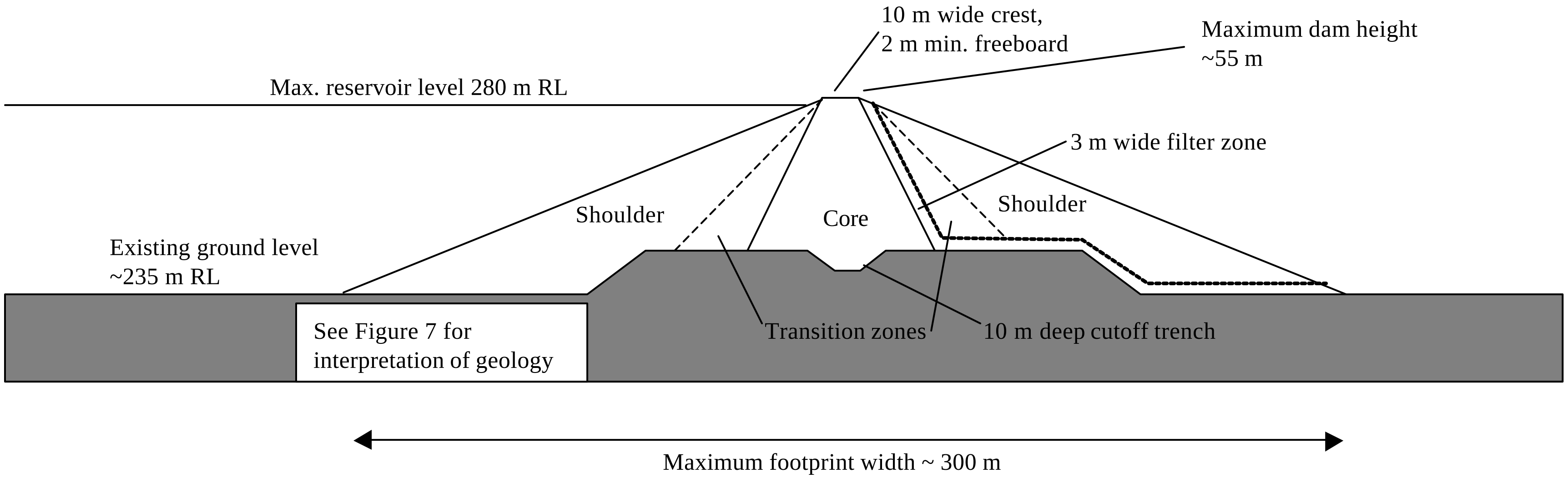

Conceptual embankment design for the proposed Waianiwaniwa storage dam

Figure 9

S:\JOBS\48685\002\2100\CE002G004
Rev A 20/9/02 GL

N

EXTENT OF RESERVOIR

0 1 2

SCALE (Km)

URS New Zealand

Engineering and Environmental Management

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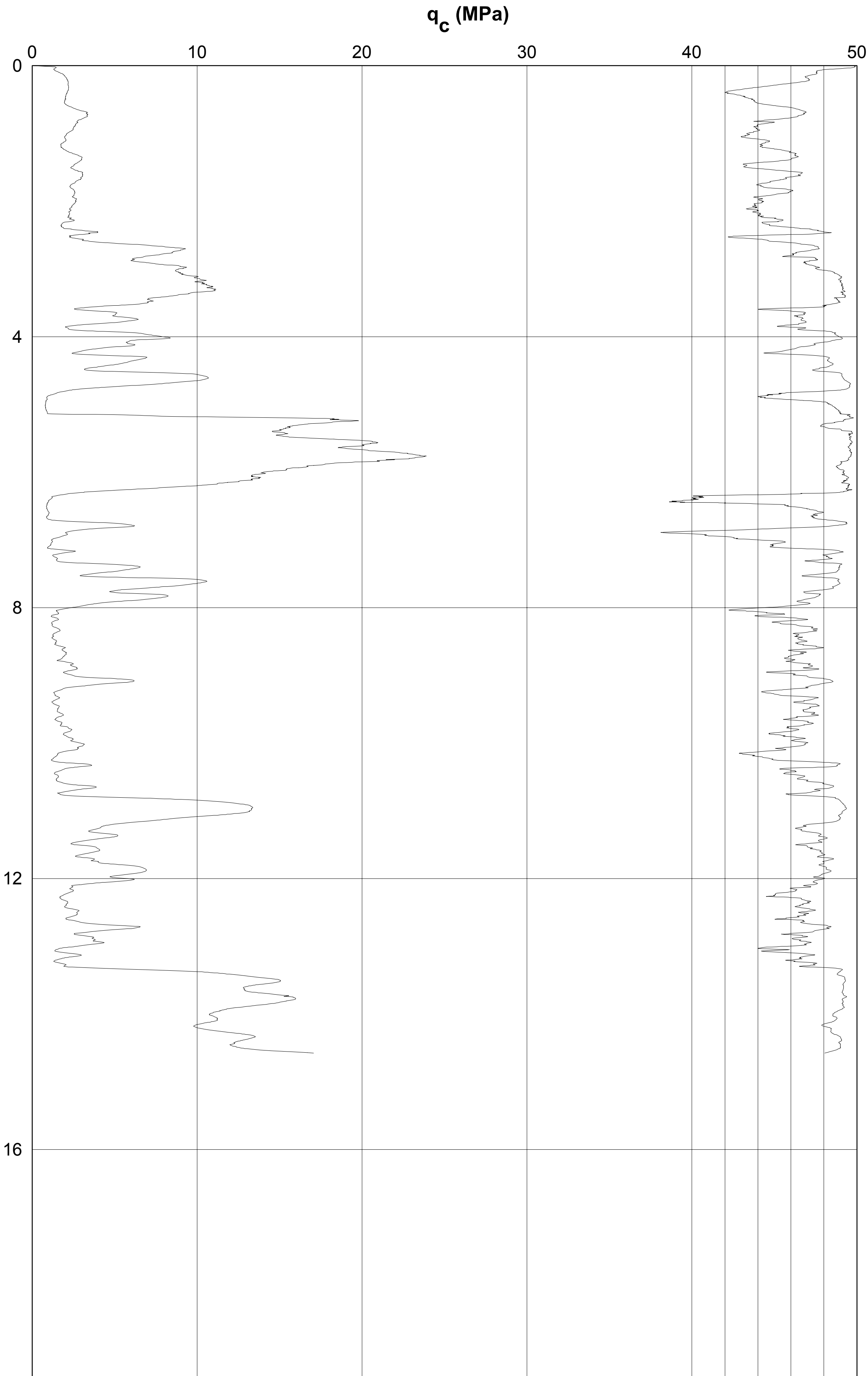
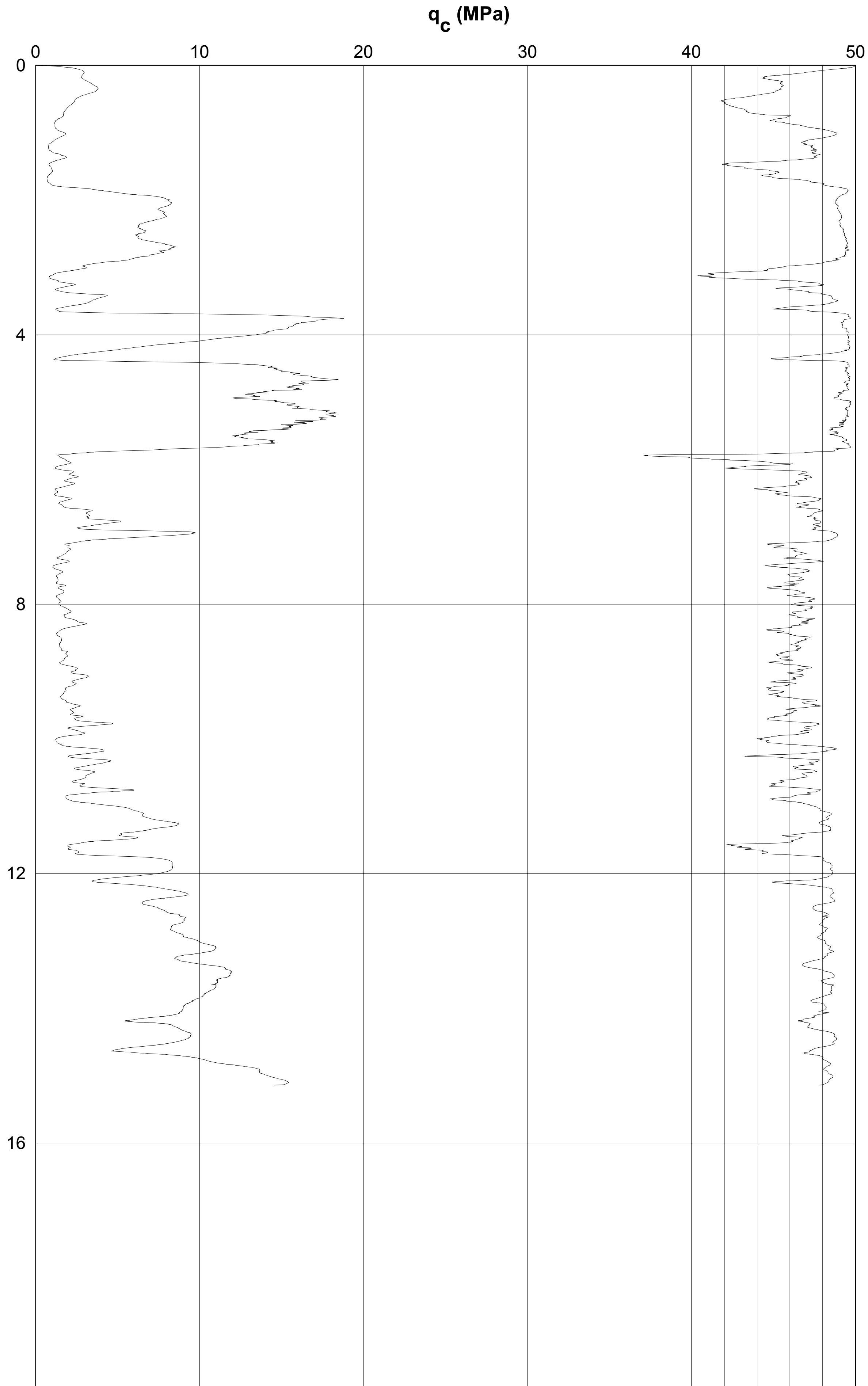
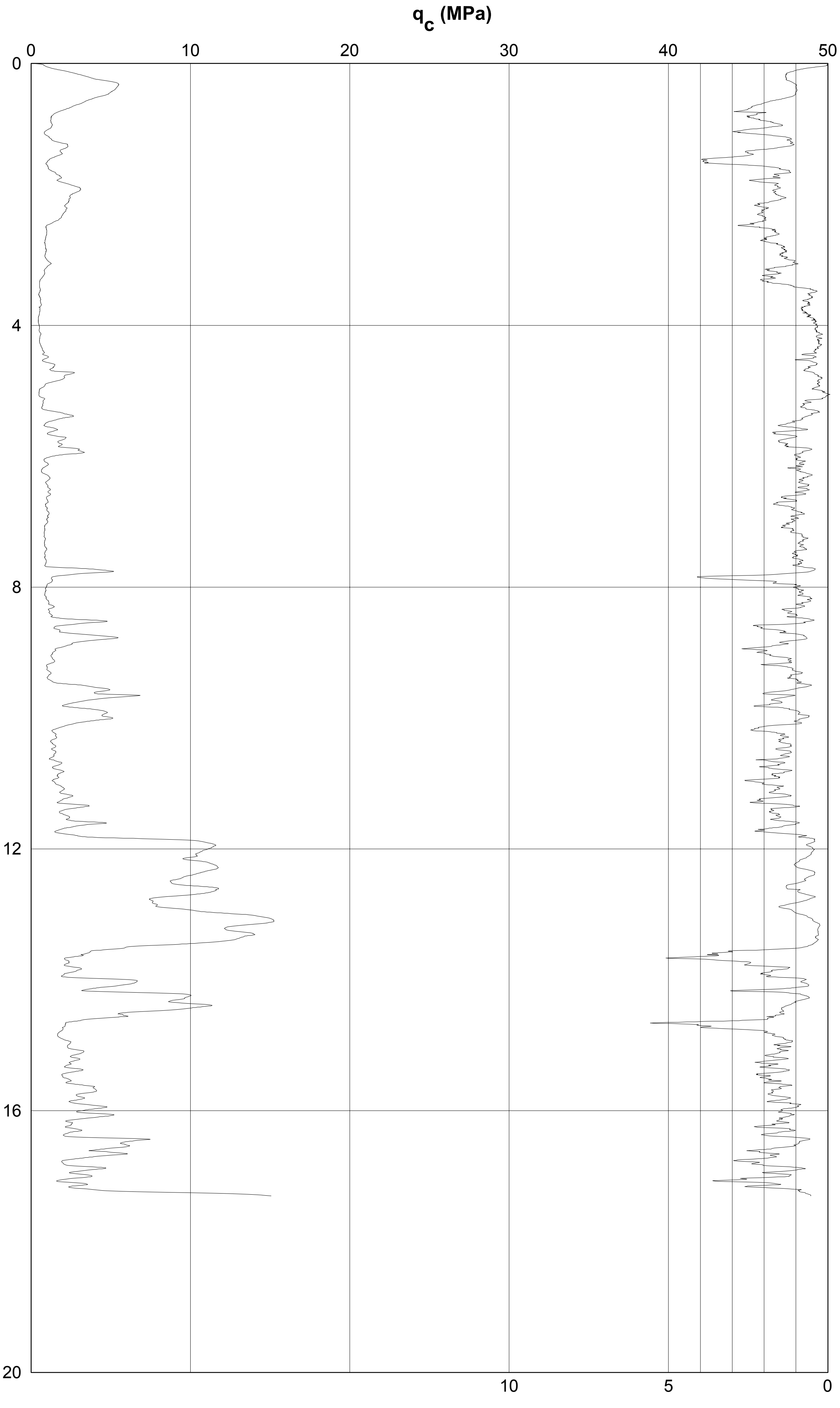
Figure No. **11**

Appendix A
CPT Test Results


q_c (MPa)
0
10
20
30
40
50
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

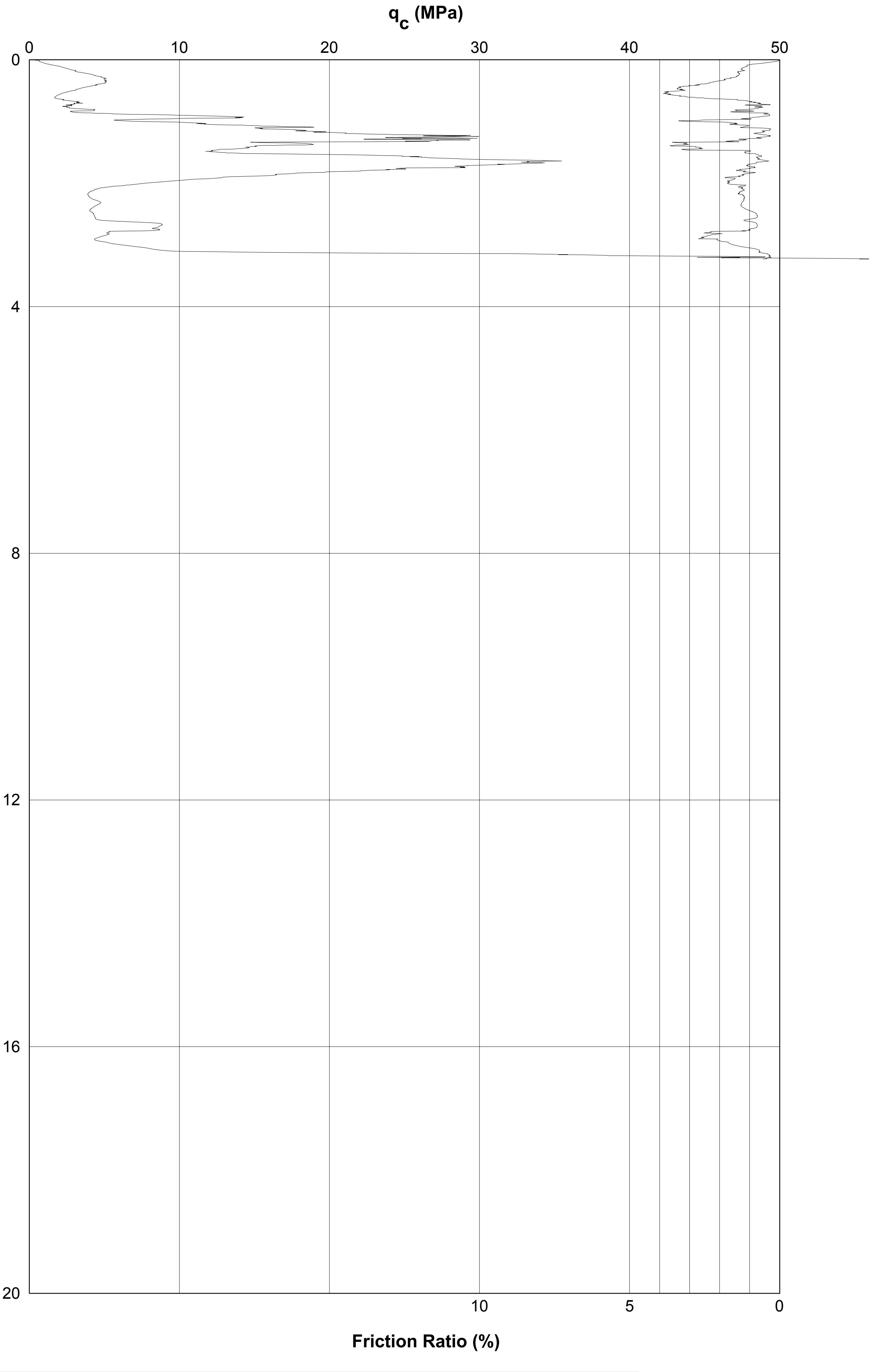
Wniwa 2



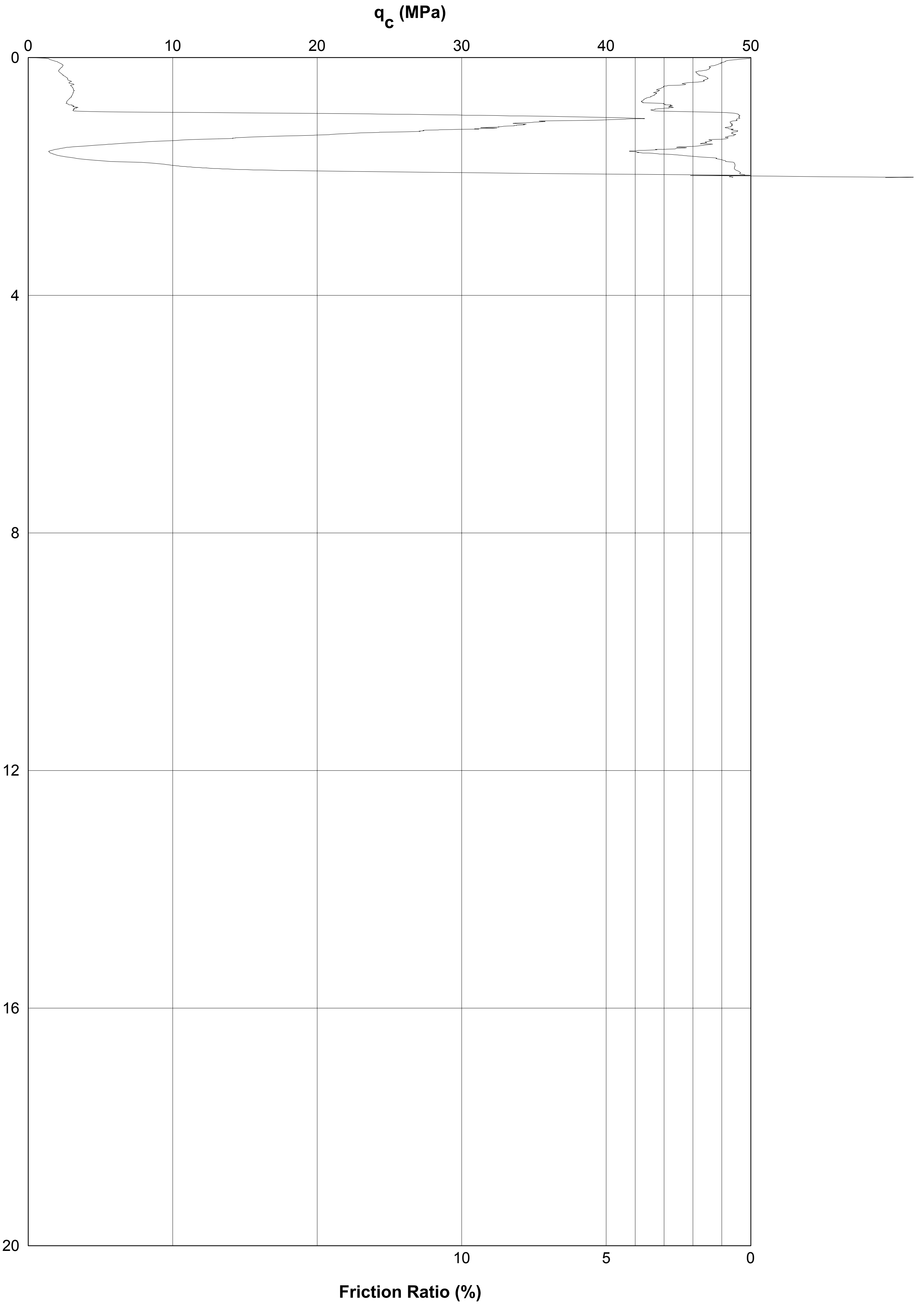


q_c (MPa)
0
10
20
30
40
50
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

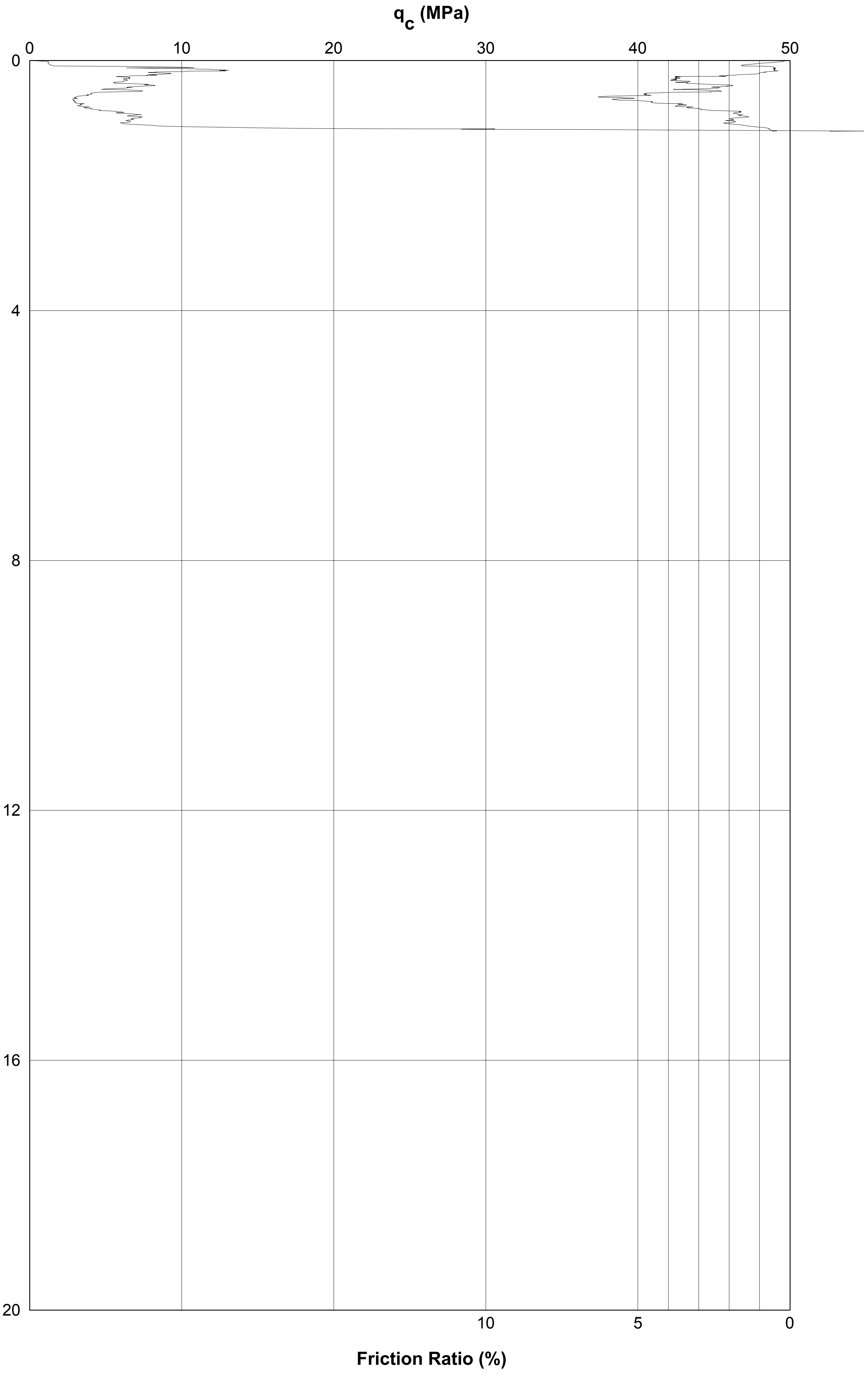
Wniwa 4



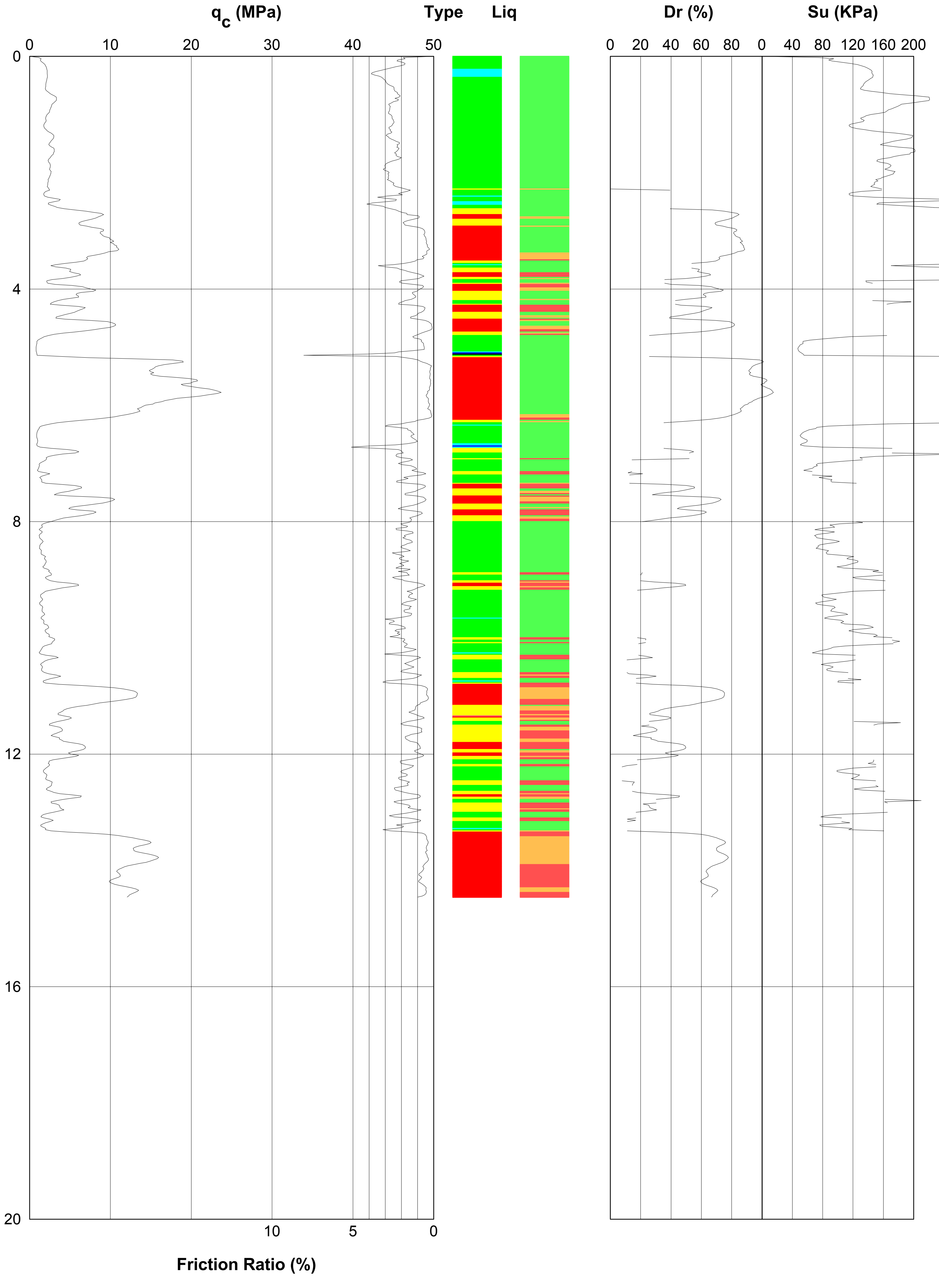
Wniwa 5



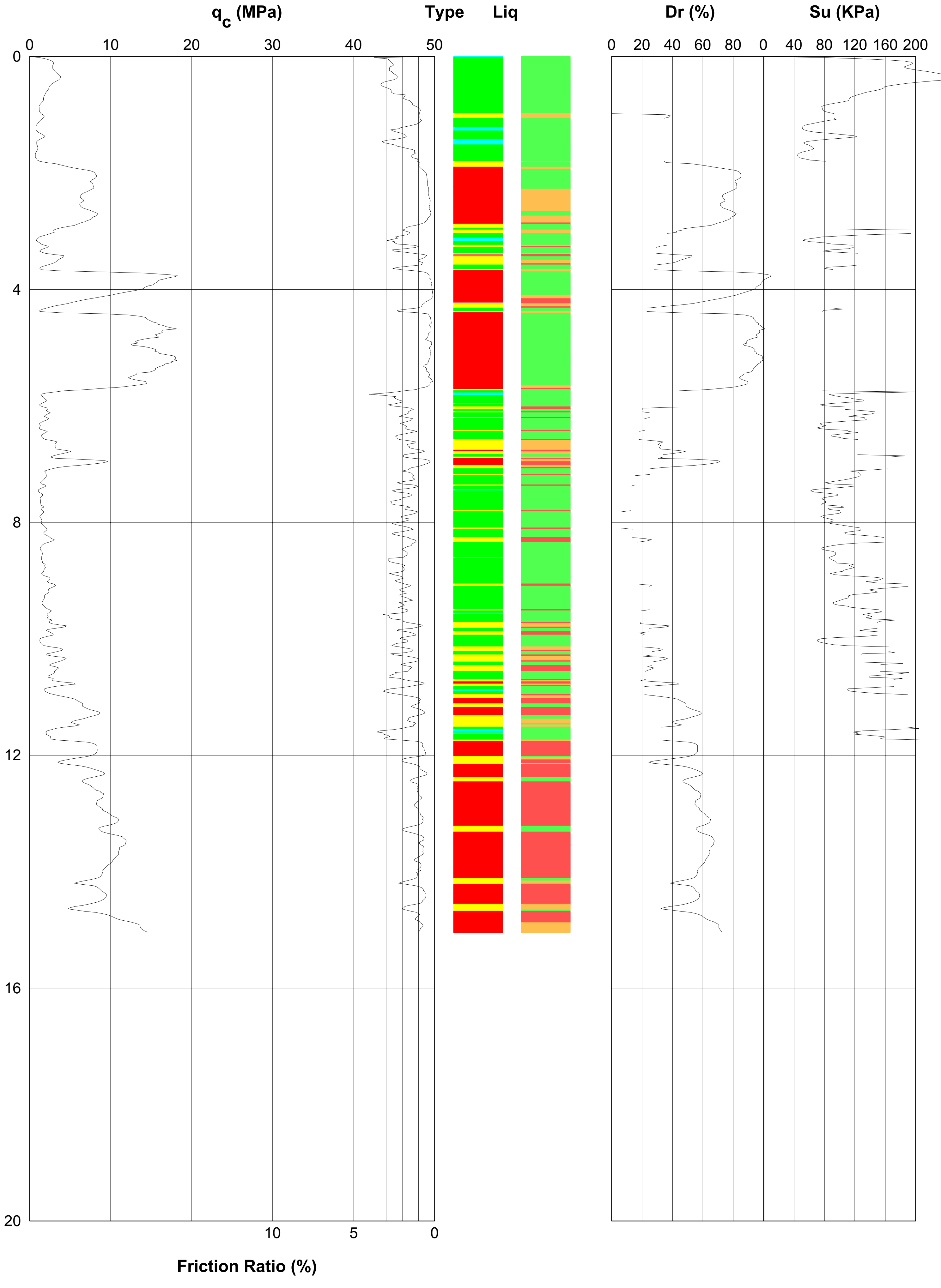
Wniwa 6



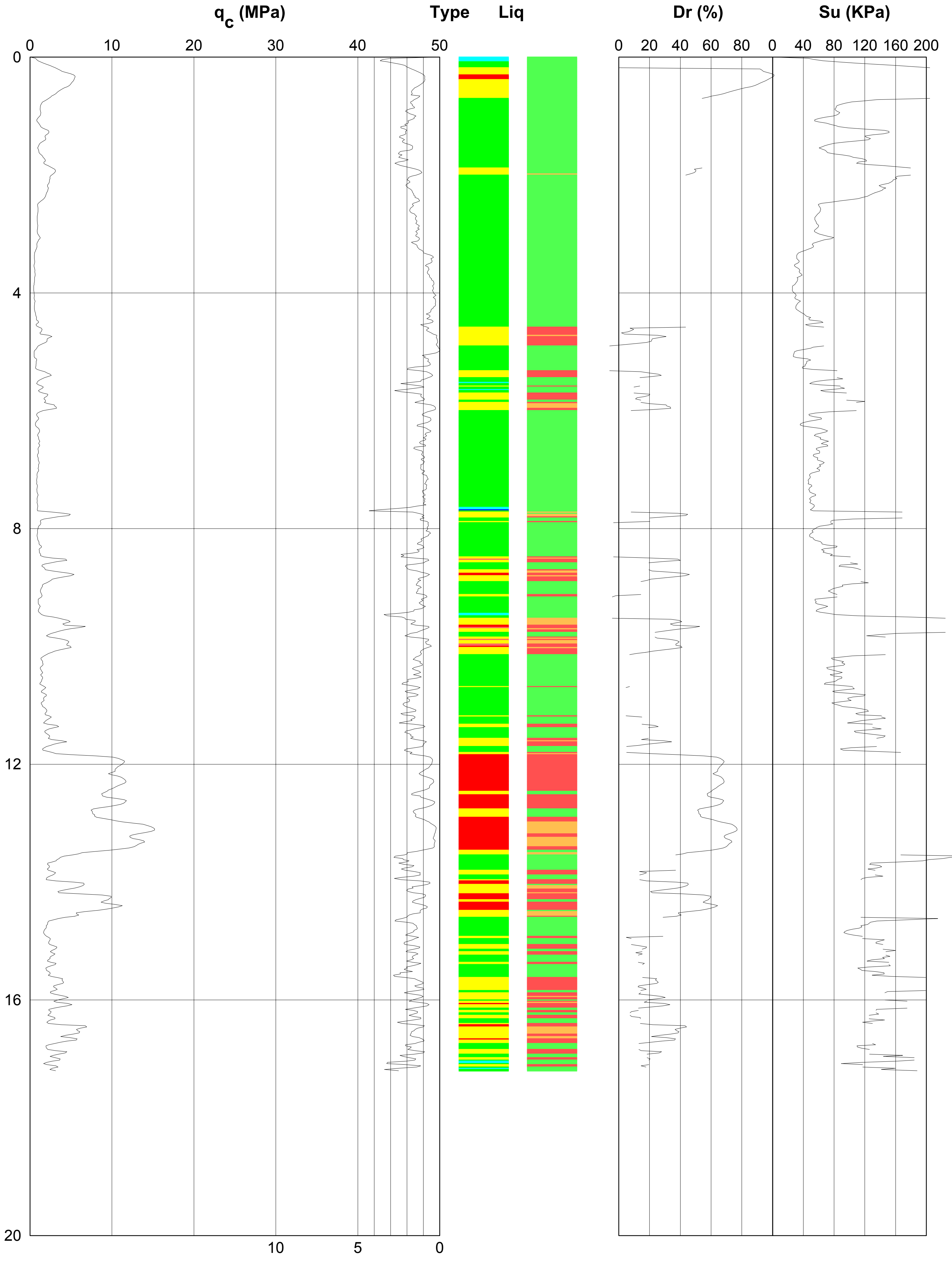
Wniwa 1


q_c (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
20
40
60
80
0
40
80
120
160
200
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

Wniwa 2

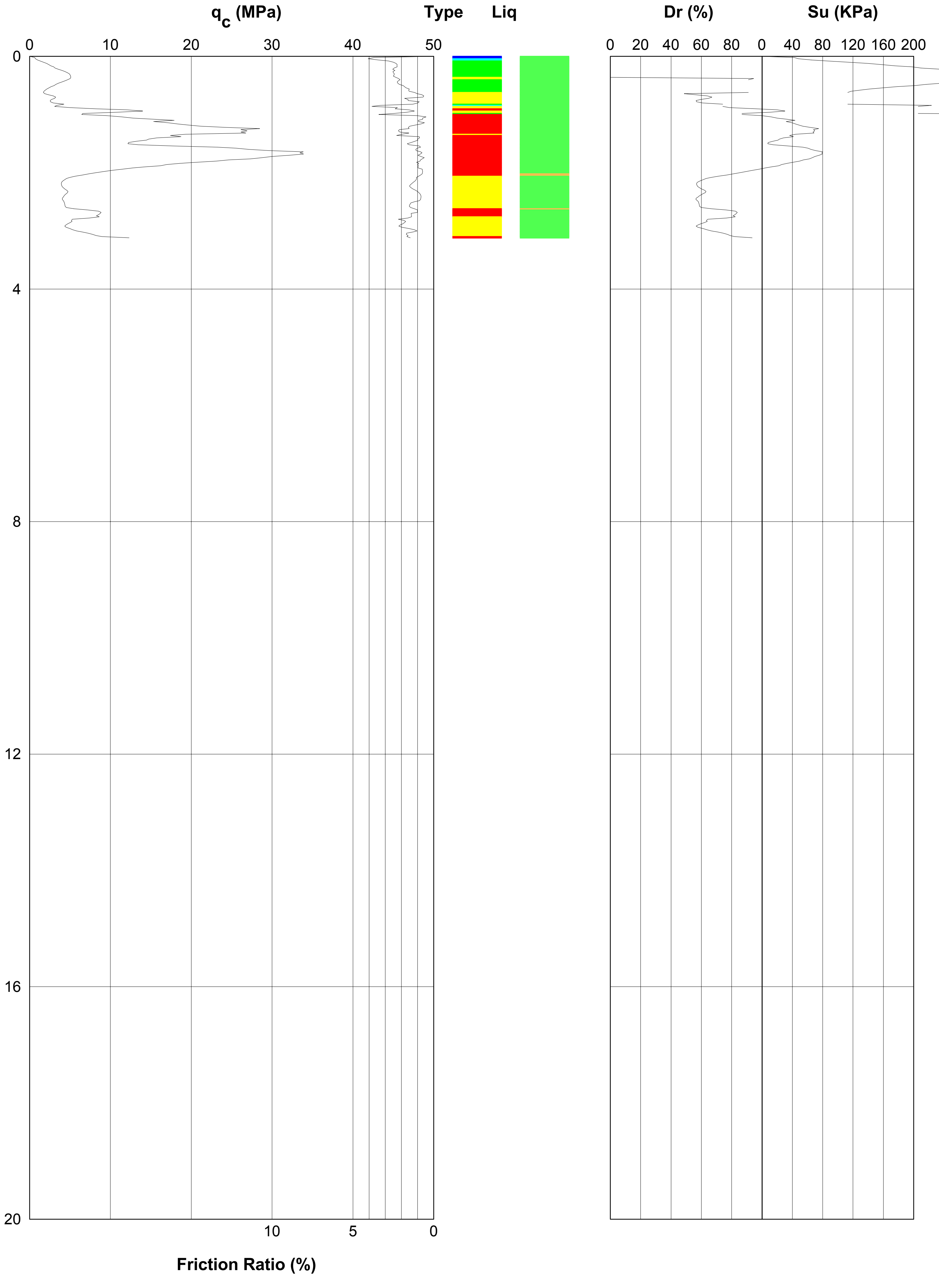

q_c (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
20
40
60
80
0
40
80
120
160
200
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

Wniwa 3

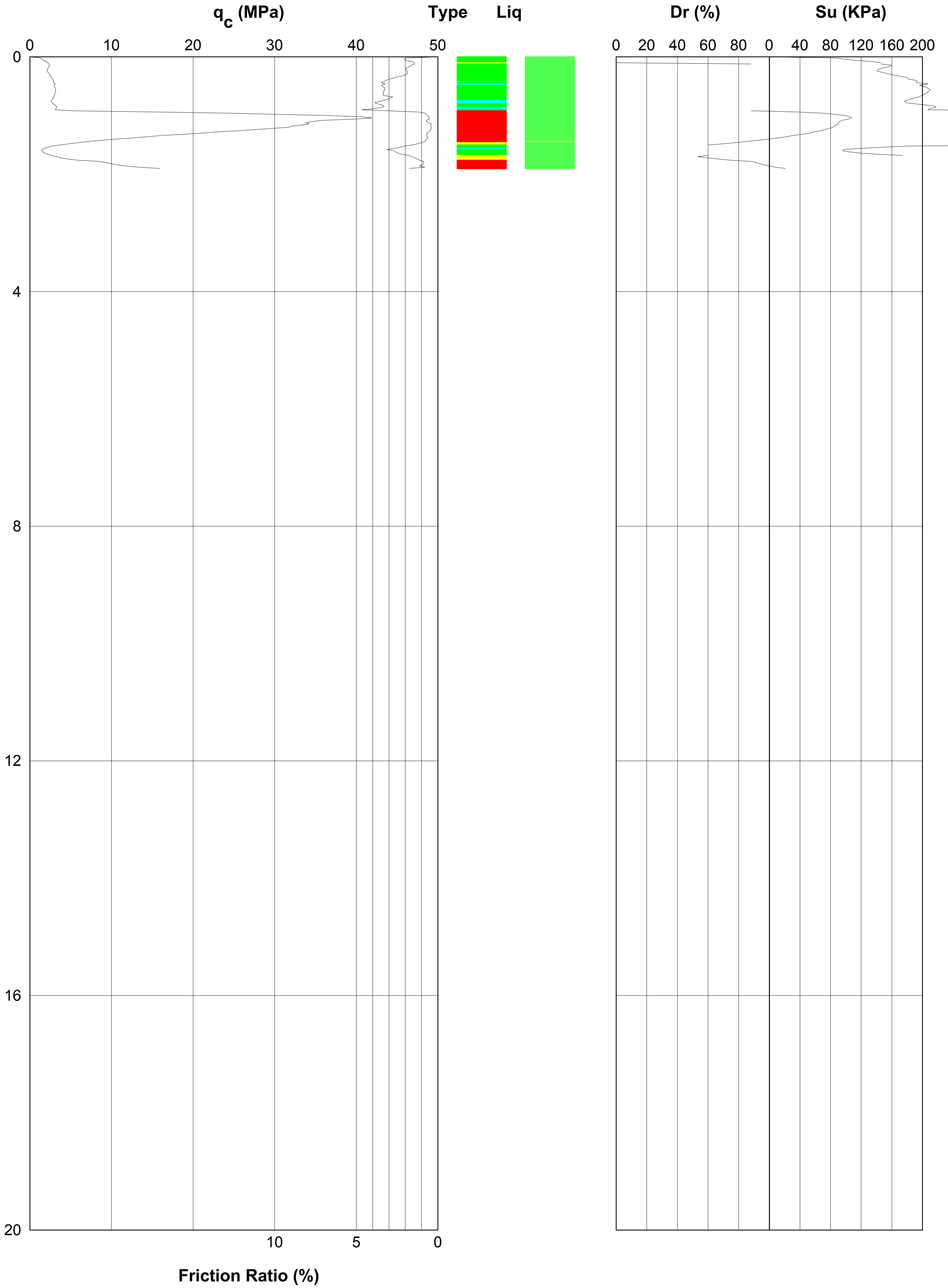


q_c (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
20
40
60
80
0
40
80
120
160
200
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

Wniwa 4

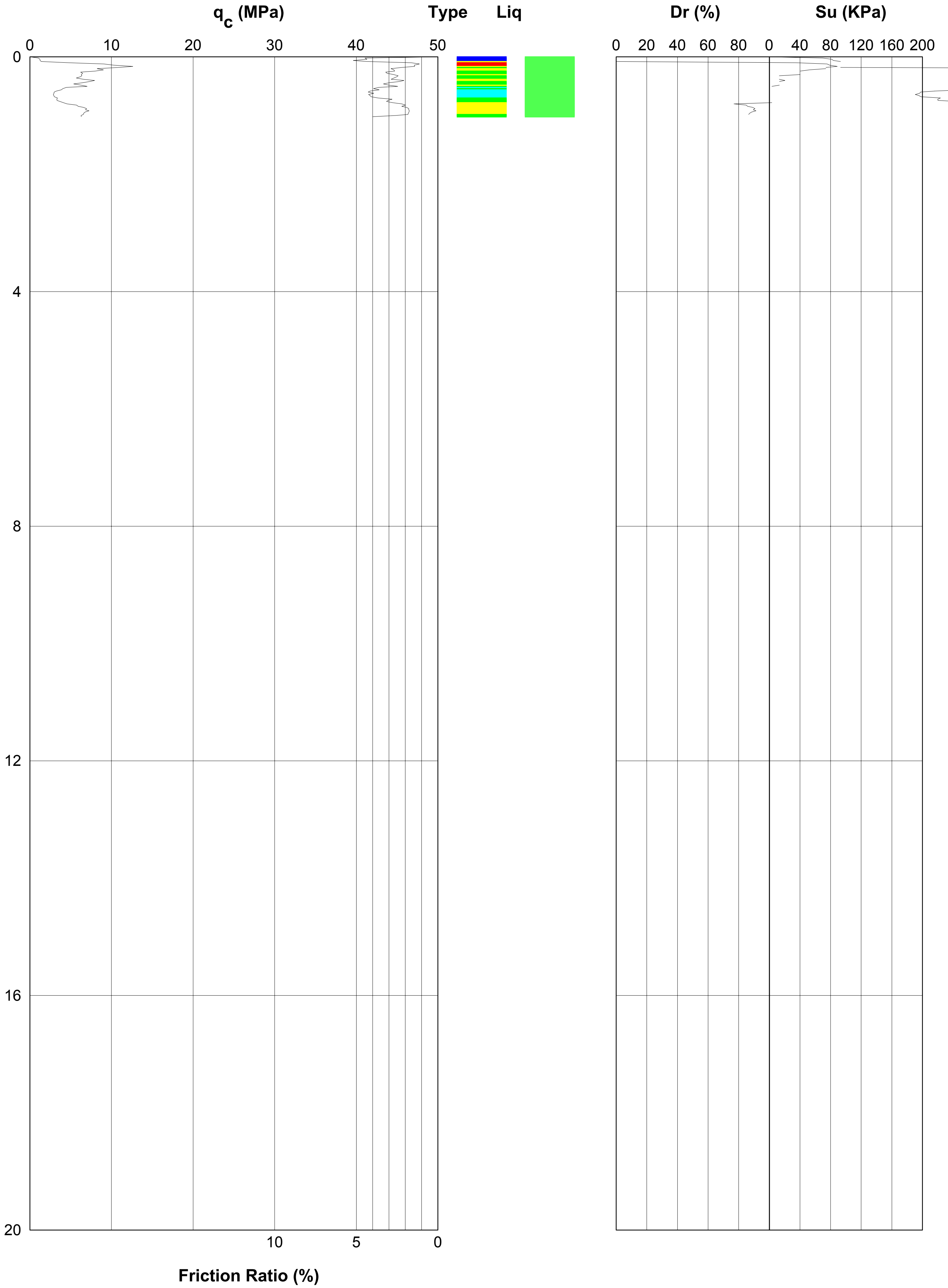

qc (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
4
8
12
16
20
10
5
0
Friction Ratio (%)
0
20
40
60
80
0
40
80
120
160
200

Wniwa 5



qc (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
20
40
60
80
0
40
80
120
160
200
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

Wniwa 6



q_c (MPa)
Type
Liq
Dr (%)
Su (KPa)
0
10
20
30
40
50
0
20
40
60
80
0
40
80
120
160
200
0
4
8
12
16
20
10
5
0
Friction Ratio (%)

CPT ANALYSIS NOTES

Soil Type

Interpretation using chart of Robertson & Campanella (1983). This is a simple but well proven interpretation using cone tip resistance and friction ratio only. No normalisation for overburden stress is applied.

🟥 sand (and gravel)
🟨 silt-sand
🟩 silt
🟦 clay-silt
🟦 clay
⬛ peat

Liquefaction Screening

The purpose of the screening is to highlight susceptible soils, that is sand and silt-sand in a relatively loose condition. This is not a full liquefaction risk assessment which requires knowledge of the particular earthquake risk at a site and additional analysis. The screening is based on the chart of Shibata and Teparaksa (1988)

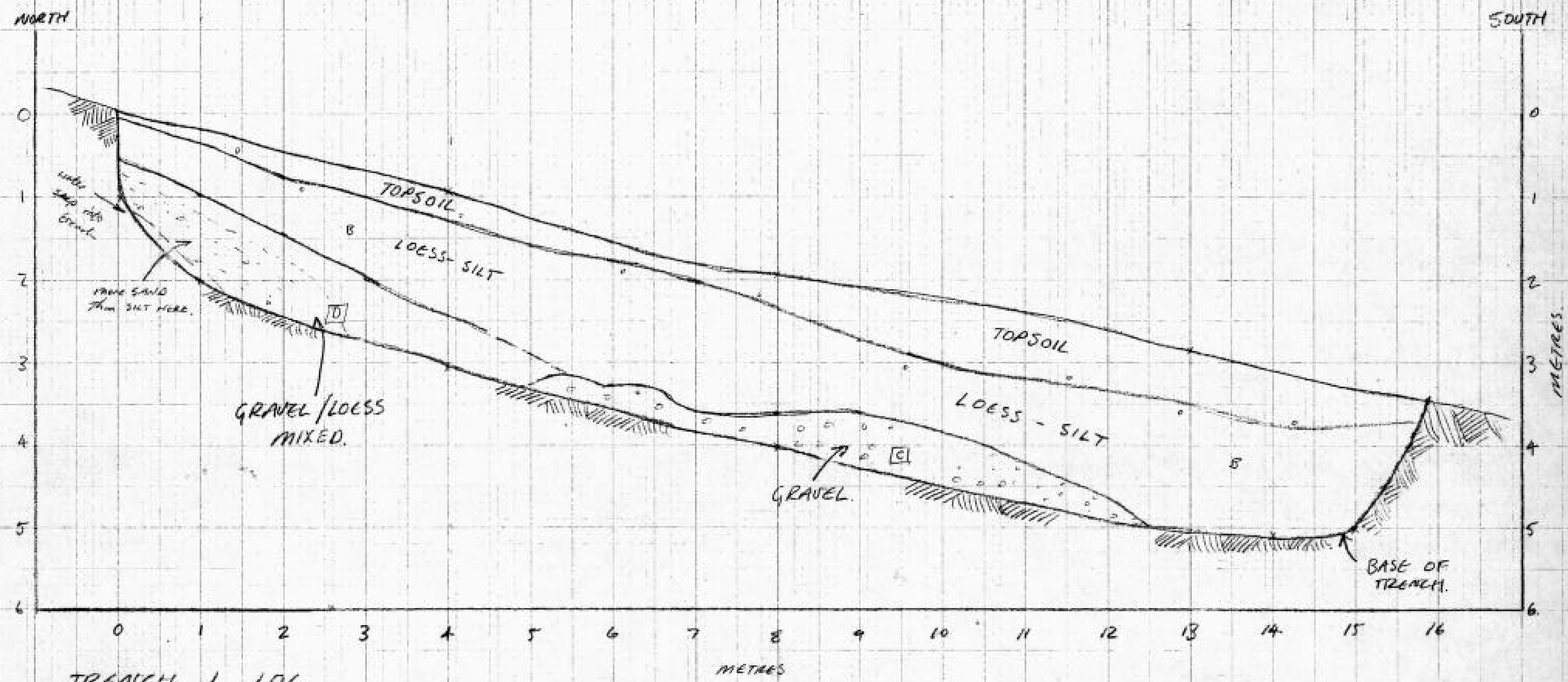
🟥 high susceptibility
🟧 medium susceptibility
🟩 low susceptibility

High risk is here defined as requiring a shear stress ratio of 0.4 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Medium risk is here defined as requiring a shear stress ratio of 0.2 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

SITE INVESTIGATION LTD

Appendix B
Test Pit Logs



TRENCH 1 LOG

DATE 29/8/02

LOCATION : 5747545mN 2426283mE
SOUTH SIDE OF TERRACE AT SLOPE BASE
WEST OF MALVERN HILLS RD

LOGGED BY MEH

CENTRAL PLAINS IRRIGATION SCHEME 48685 - 002 - Z100

Sheet 1 of 1

TEST PIT LOG TP 1

URS New Zealand Limited.
287 Durham Street, Christchurch
Phone (03) 374 8500
Fax (0) 377 0655

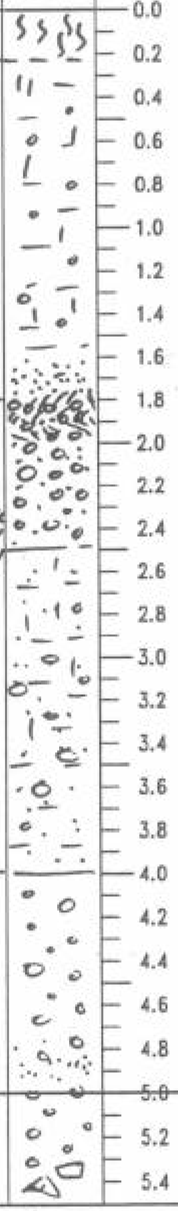
Project No.: 48685-002/2100
Project Reference: CPWE WAIANIWANIWA

Drilling Contractor: BOYES CONTRACTING

Excavation Method: Ex 200
Logged By: T McMorran
Checked By:
Date Started: 28/8/02
Date Finished:

Relative Level: mRL
Coordinates: mN
mE
Permit No:

Client: CENTRAL PLAINS WATER



DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam	Late Pleistocene and Holocene Alluvium				
SILT - yellow brown and light grey mottled silt with some sand and rare <50mm gravel clasts (mainly volcanic sourced) - sandy layer at 1.6-1.8m					
GRAVEL - blue grey sandy gravel. Maximum clast size 50mm. Volcanic and greywacke clasts. Strongly iron cemented between 1.8 and 2.0m.					
SILT - blue grey sandy silt with some rounded gravel clasts					
GRAVEL - blue grey sandy gravel with hard dark grey clasts, rounded to subrounded - greywacke? Some sandy layers and angular clasts dominant below 5.5m. Terminated at 6.0m.					

TEST PIT SECTION

TEST PIT TERMINATED AT:

Target Depth ☐
Refusal ☐
Flooding ☐
Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

Sheet 1 of 1

TEST PIT LOG TP 2

URS New Zealand Limited.
287 Durham Street, Christchurch
Phone (03) 374 8500
Fax (0) 377 0655

Project No.: 48685-002/2100

Project Reference: CPWE WAIANIWANIWA

Drilling Contractor: BOYES CONTRACTING

Excavation Method: Ex 200

Logged By: T McMorran
Checked By:
Date Started: 28/8/02
Date Finished:

Relative Level: mRL
Coordinates: mN
mE

Permit No:

Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0	Late Pleistocene to Holocene Loess				
SILT - light yellow brown silt with some clay [LOESS] - slight variability in clay and fine sand content with depth - mottled yellow brown and brown between 0.2 and 1.2m then mainly light yellow brown. - slight weathering around vertical sub-planar joints in soil - light grey colour - generally stiff to very stiff.		0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8					
Test pit continued to 6.0m (limit of reach)		5.0 5.2 5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

Target Depth ☐
Refusal ☐
Flooding ☐
Caving/collapse ☐

SAMPLE TYPE:

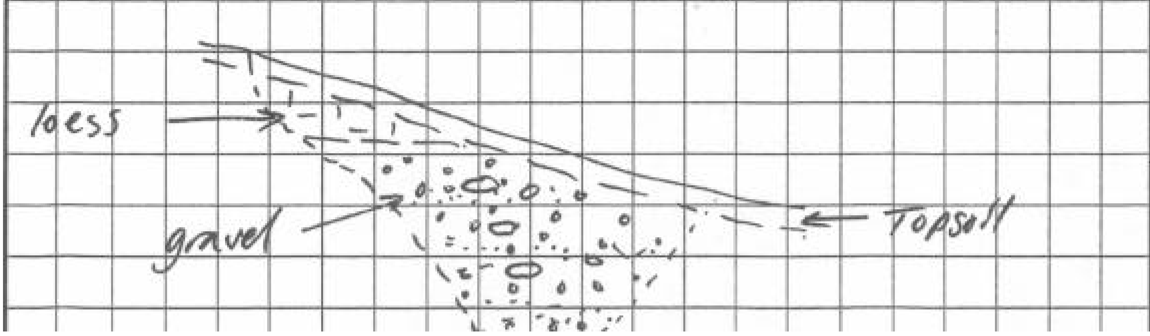
Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 3

URS New Zealand Limited. 287 Durham Street, Christchurch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.:	Project Reference:
Drilling Contractor: BOYES CONTRACTING		48685-002/2100	CPWE WAIANIWANIWA
Excavation Method: EX 200	Logged By: T McMorran Checked By: Date Started: 28/8/02 Date Finished:	Relative Level: mRL Coordinates: mN mE Permit No:	Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0					
SILT - yellow brown mottled brown silt with some clay (loess or loess colluvium)		0.2 0.4 0.6 0.8					
GRAVEL - dense brown clast supported gravel, heavily stained, slightly cemented. - clasts are greywacke, highly weathered to slightly weathered, subrounded and up to 200 mm max. dimension most clasts are less than 75 mm. - some crudely bedded layers - subhorizontal		1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8	Late Pleistocene Gravels				
Test pit continued to 5.8m		5.0 5.2 5.4					

TEST PIT SECTION



TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

SAMPLE TYPE:

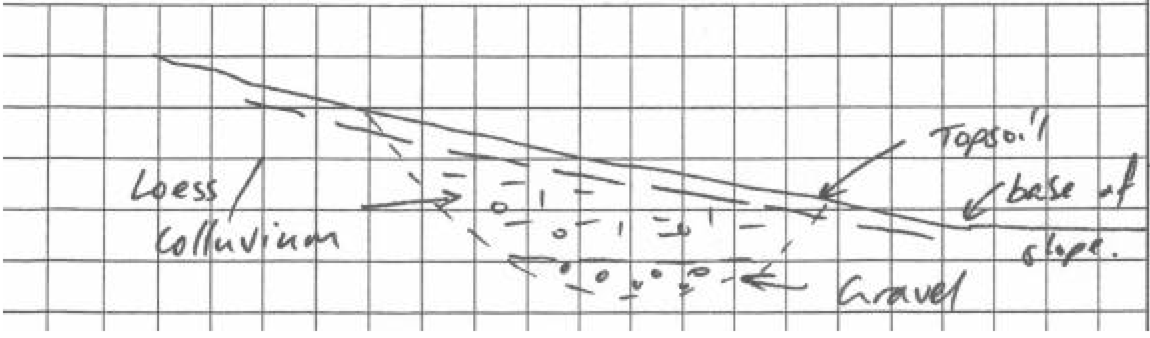
Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 4

URS New Zealand Limited. 287 Durham Street, Christchurch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.: 48685-002/2100	Project Reference: CPWE WAIANIWANIWA
Drilling Contractor: BOYES CONTRACTING			
Excavation Method:	Logged By: T McMorran Checked By: Date Started: Date Finished:	Relative Level: mRL Coordinates: mN mE Permit No:	Client: CENTAAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0 0.2	Late pleistocene and holocene deposits.				
SILT - mottled yellow brown and light grey silt with some clay. Contains rare highly weathered greywacke gravel clasts (rounded and up to 100mm) (loess and loess colluvium)		0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8					
GRAVEL - brown highly weathered greywacke gravel with clasts up to 200mm..		2.0 2.2 2.4					
Discontinued at 2.5m		2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8					
		5.0 5.2 5.4					

TEST PIT SECTION



TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

SAMPLE TYPE:

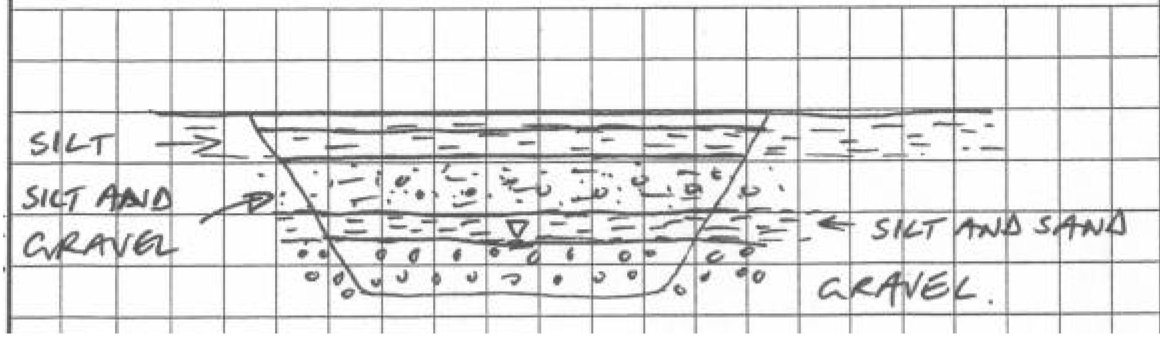
Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 5

URS New Zealand Limited. 287 Durham Street, Christchurch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.:	Project Reference:
Drilling Contractor: BOYES CONTRACTING		48685-002/2100	CPWE WAIANIWANIWA
Excavation Method: EX-200.	Logged By: T McMorran Checked By: Date Started: Date Finished:	Relative Level: mRL Coordinates: mN mE Permit No:	Client: CENTAAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0	LATE PLEISTOCENE (?) AND HOLOCENE SEDIMENTS				
SILT - stiff yellow brown silt		0.2 0.4 0.6					
SILT AND GRAVEL - mixed gravelly silt and fine gravell		0.8 1.0 1.2					
GRAVEL - fine pebbly gravel with mainly greywacke clasts some volcanics and clay clasts		1.4 1.6 1.8					
SILT AND SAND - interbedded clayey silt and sand		2.0 2.2 2.4					▽
GRAVEL - grey cobbly and pebbly gravel - sandy fine gravel matrix. Clasts are greywacke, rounded and up to 100mm.		2.6 2.8 3.0 3.2 3.4					
Discontinued at 3.5m due to collapse below water table.		3.6 3.8 4.0 4.2 4.4 4.6 4.8					
		5.0 5.2 5.4					

TEST PIT SECTION



TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

Sheet 1 of 1

TEST PIT LOG TP 6

URS New Zealand Limited,
287 Durham Street, Christchurch
Phone (03) 374 8500
Fax (0) 377 0655

Project No.: 48685-002/2100

Project Reference: CPWE WAIANIWANIWA

Drilling Contractor: BOYES CONTRACTING

Excavation Method: EX 200

Logged By: T McMorran
Checked By:
Date Started:
Date Finished:

Relative Level: mRL
Coordinates: mN
mE

Permit No:

Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - Brown gravelly silt		0.0					
GRAVEL - brown bouldery gravel crude horizontal stratification - rare thin horizons of sandy or silty gravel or pea gravel Gravel clasts are rounded or subrounded greywacke stained brown or black and up to ~150 mm -rarely up to 300 mm. - thin (50mm) yellow brown clayey layers at 1.6m and 2.2m. - heavy manganese (?) staining at 3.5m.		0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8	LATE PLEISTOCENE OUTWASH GRAVELS (BURNHAM FM)				▽
Discontinued at 4.0m due to groundwater		4.0 4.2 4.4 4.6 4.8					=
		5.0 5.2 5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

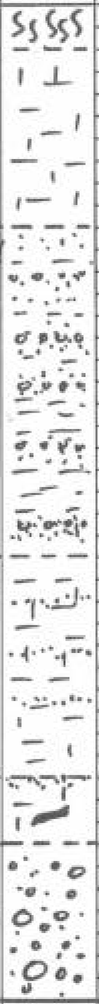
Target Depth ☐
Refusal ☐
Flooding ☐
Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 7

URS New Zealand Limited. 287 Durham Street, Christchurch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.: 48685-002/2100	Project Reference: CPWE WAIANIWANIWA
Drilling Contractor: BOYES CONTRACTING			
Excavation Method: EX200	Logged By: T McMorran Checked By: Date Started: Date Finished:	Relative Level: mRL Coordinates: mN mE Permit No:	Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0	LATE PLEISTOCENE(?) AND HOLOCENE SEDIMENTS				
SILT - yellow brown silt		0.2 0.4 0.6 0.8					
SILT, SAND AND GRAVEL - interbedded yellow brown silt, sand and fine gravel		1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4					
SILT AND CLAY - brown laminated clayey silt and sandy silt - strongly ironstained at 3.5m - blue silt and clay with wood		2.6 2.8 3.0 3.2 3.4 3.6					
GRAVEL - slightly sandy gravel with greywacke clasts to 50mm		3.8 4.0 4.2 4.4					▽ 4.0
DISCONTINUED AT 4.5m		4.6 4.8					
		5.0 5.2 5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

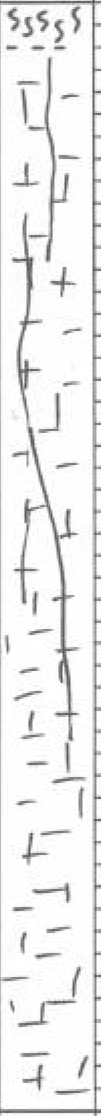
SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 8

URS New Zealand Limited.
287 Durham Street, Christchurch
Phone (03) 374 8500
Fax (0) 377 0655

Project No.: 48685-002/2100
Project Reference: CPWE WAIANIWANIWA
Drilling Contractor: BOYES CONTRACTING
Excavation Method: EX 200
Logged By: T McMorran
Checked By:
Date Started:
Date Finished:
Relative Level: mRL
Coordinates: mN
mE
Permit No:
Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0	LATE PLEISTOCENE AND HOLOCENE LOESS				
SILT - yellow brown silt [LOESS] - wet at surface - generally moist and stiff - light grey clayey veins to about 4m		0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8					
Discontinued at 6m (limit of reach)		5.0 5.2 5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

Target Depth	☐
Refusal	☐
Flooding	☐
Caving/collapse	☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 9

URS New Zealand Limited,
287 Durham Street, Christchurch
Phone (03) 374 8500
Fax (0) 377 0655

Drilling Contractor: BOYES CONTRACTING

Project No.: 48685-002/2100

Project Reference: CPWE WAIANIWANIWA

Excavation Method: EX200

Logged By: T McMorran
Checked By:
Date Started:
Date Finished:

Relative Level: mRL
Coordinates: mN
mE
Permit No:

Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0					
LOESS - SEE TP 8		0.2					
		0.4	LATE PLEISTOCENE AND HOLOCENE LOESS				
description		0.6					
		0.8					
		1.0					
		1.2					
		1.4					
		1.6					
		1.8					
		2.0					
		2.2					
-generally very stiff		2.4					
consistency		2.6					
		2.8					
		3.0					
		3.2					
		3.4					
		3.6					
		3.8					
		4.0					
		4.2					
		4.4					
		4.6					
		4.8					
Discontinued at 5.5m		5.0					
		5.2					
		5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

TEST PIT LOG TP 10

URS New Zealand Limited.
287 Durham Street, Christchurch

Phone (03) 374 8500
Fax (0) 377 0655

Project No.: 48685-002/2100

Project Reference: CPWE WAIANIWANIWA

Drilling Contractor: BOYES CONTRACTING

Excavation Method: EX 200

Logged By: T McMorran
Checked By:
Date Started:
Date Finished:

Relative Level: mRL
Coordinates: mN
mE
Permit No:

Client: CENTAAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0 0.2	LATE PLEISTOCENE AND/OR HOLOCENE LOESS				
SILT - light yellow brown and light grey mottled slightly clayey silt and fine sandy silt. slightly cemented, very stiff to hard. [weathered LOESS]		0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8					
GRAVEL - highly weathered yellow brown and black gravel. silty or clayey matrix clast are weak, highly weathered greywacke.		3.0 3.2 3.4 3.6 3.8	L. PLEISTOCENE GRAVEL				
Discontinued at 3.9m		4.0 4.2 4.4 4.6 4.8					
		5.0 5.2 5.4					

TEST PIT SECTION

TEST PIT TERMINATED AT:

Target Depth ☐
Refusal ☐
Flooding ☐
Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS
Disturbed Sample	DS

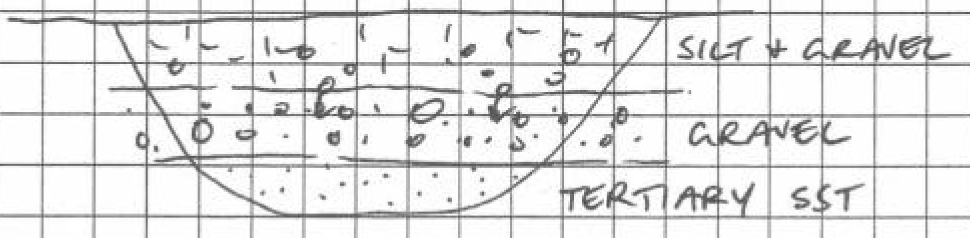
Sheet 1 of 1

TEST PIT LOG TP 11

URS New Zealand Limited. 287 Durham Street, Christchurch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.:	Project Reference:
Drilling Contractor: BOYES CONTRACTING		48685-002/2100	CPWE WAIANIWANIWA
Excavation Method: Ex 200	Logged By: T McMorran Checked By: Date Started: Date Finished:	Relative Level: mRL Coordinates: mN mE Permit No:	Client: CENTRAL PLAINS WATER

DESCRIPTION OF STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - dark brown silt loam		0.0	LATE PLEISTOCENE AND HOLOCENE GRAVEL ~~LOESS~~				
SILT - light grey wet silt		0.2 0.4					
GRAVEL - light grey silty gravel, wet. matrix supported. (slump material?)		0.6 0.8 1.0 1.2					
GRAVEL - brown cobbly gravel. silty matrix at 1.4m (supporting perched w.t.) -clasts are greywacke, rounded and highly weathered.		1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8					inflow at 1.4m.
SANDSTONE - very weak, light grey brown sandstone		3.0 3.2 3.4 3.6	TERTIARY ROCK				
Discontinued at 3-8m		3.8 4.0 4.2 4.4 4.6 4.8					
		5.0 5.2 5.4					

TEST PIT SECTION



TEST PIT TERMINATED AT:

- Target Depth ☐
- Refusal ☐
- Flooding ☐
- Caving/collapse ☐

SAMPLE TYPE:

Bulk Sample	BS
Tube Sample	TS

Appendix B
Test Pit Photographs

Test Pit 1 showing brown gravelly silt overlying saturated grey silts and gravels

Test Pit 2 showing yellow brown loess to full depth of excavation

Appendix B
Test Pit Photographs

Test Pit 3 showing yellow brown loess overlying grey brown gravels. Loess thickens upslope.

Test Pit 4 showing yellow brown loess colluvium containing rare gravel clasts overlying gravel.

Appendix B
Test Pit Photographs

Test Pit 5 showing interbedded sand, silt and pebbly gravel. Water table is at about 2 m depth.

Test Pit 6 showing yellow brown silty gravel. Water table is at about 4 m

Appendix B

Test Pit Photographs

Test Pit 7 showing interbedded sand, silt and pebbly gravel. Water table is at about 4 m depth.

Test Pit 8 showing yellow brown loess to the full excavation depth of about 6 m.

Appendix B
Test Pit Photographs

Test Pit 9 showing yellow brown loess to the full excavation depth of about 5.5 m.

Test Pit 10 showing yellow brown loess overlying weathered gravel at about 3 m depth.

Appendix B
Test Pit Photographs

Test Pit 11 showing yellow brown silty gravel colluvium overlying grey sandstone at about 3.0 m.

Appendix C
Drill Hole Logs

LOG OF DRILL HOLE

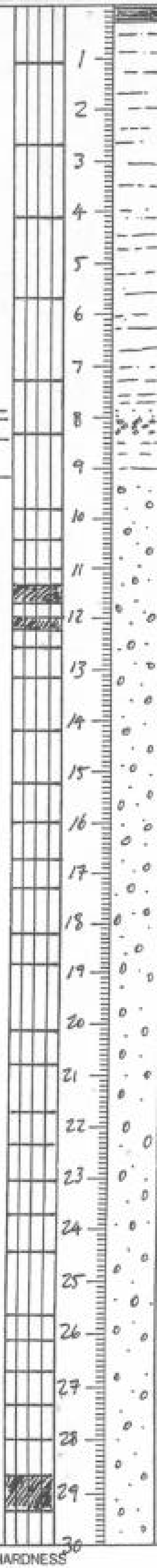
NO. WN 1

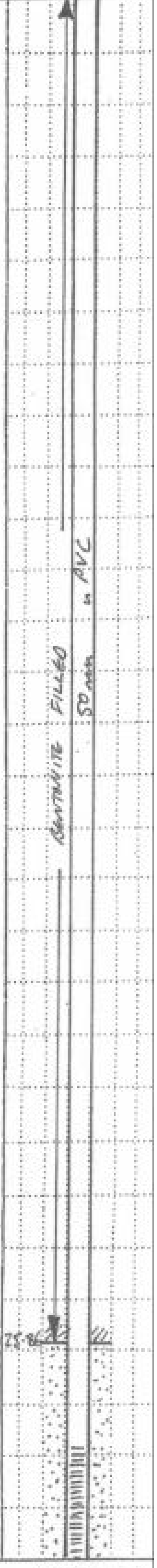
PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747723.85mN 2426260.22mE DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 263.67m H.A.D. COLLAR 263.67m

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING, LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/LIFT % 5 10 50	DEPTH H.A.D. Core size, casing	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (altitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.O.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁴cm 0·01 0·1 1 10 100 1000
TOPSOIL Brown Silt Loam SILT Yellow brown loess. Firm - very stiff								Top 0.20m Loess soft, moist. White coloured 'veins' throughout, 1cm wide.					
											2/9 3/9		
								7.14 - 7.24 dry, hard + brittle					
7.88 - 8.08m Sandy SILT Red brown (Iron stain). Grades from SILT above. 8.08 - 8.45m CONGLOMERATE Yellow brown, weak, unfractured. Gravel, sand + silt sized. 8.45 - 9.20m SILT Yellow brown Loess. Soft to stiff								Gravels in conglomerate <2cm diameter, rounded volcanic + Torlesse sandstone.					
9.20 - 31.46 Silty sandy GRAVELS Brown to red brown								~10% of gravel clasts between 5->20 cm diameter, mostly Torlesse sandstone. Some volcanics - basalt. ~50% of gravel clasts <5cm diameter					



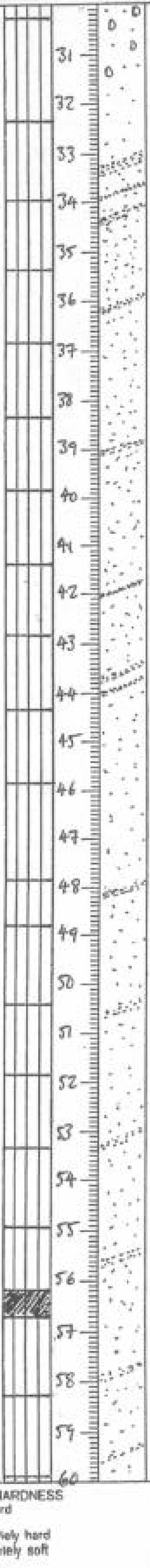


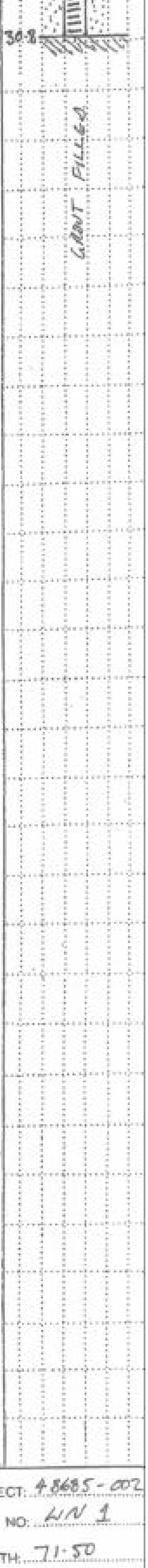
DRILLER: R HARREN	ROCK WEATHERING UW – Unweathered SW – Slightly weathered MW – Moderately weathered HW – Highly weathered CW – Completely weathered	ROCK HARDNESS VH – Very hard H – Hard MH – Moderately hard MS – Moderately soft S – Soft VS – Very soft	FRACTURE LOG (cms) 100 50 10 5 1 0.1 1 2 10 20 100 1000 Spacing of natural fractures Fractures/m of core	LOGGED: MGH DATE: 6/9/02 TRACED: CHECKED: ORIGINAL VERTICAL: SCALE: 1:100	PROJECT: 48685-002 HOLE NO: WN 1 LENGTH: 71.50 CORE BOXES:
STARTED: 2/9/02 FINISHED: 5/9/02 DRILL:	EXPLANATION				

NO.

LOG OF DRILL HOLE

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER
GRID REF. NZMG CO-ORD. 5747723.85mN 2426260.22mE DATUM LINZ (MSL)
ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 263.67m H.A.D. COLLAR 263.67m





DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING. LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/ LIFT % 5 10 50	DEPTH H.A.D. Core size casing	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 1 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁵cm/s .01 0.1 1 10 100 1000
Silty sandy GRAVELS continued.													
31.46 – 71.50 (EOH) SANDSTONE Weak to very weak, SW (Iron staining), Fine-coarse sand sized. Reddish grey to green								Glauconitic bands / quartz sand bands dipping at 10-15°					
								40.5 Slickensided clay band parallel to bedding					

DRILLER: R HARVEY
STARTED: 2/9/02
FINISHED: 5/9/02
DRILL:

ROCK WEATHERING
UW – Unweathered
SW – Slightly weathered
MW – Moderately weathered
HW – Highly weathered
CW – Completely weathered

ROCK HARDNESS
VH – Very hard
H – Hard
MH – Moderately hard
MS – Moderately soft
S – Soft
VS – Very soft

FRACTURE LOG
(cms) 100 50 10 5 1 0.1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MEH
DATE: 6/9/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:
SCALE: 1:100

PROJECT: 48685-002
HOLE NO: WN 1
LENGTH: 71.50
CORE BOXES:

LOG OF DRILL HOLE

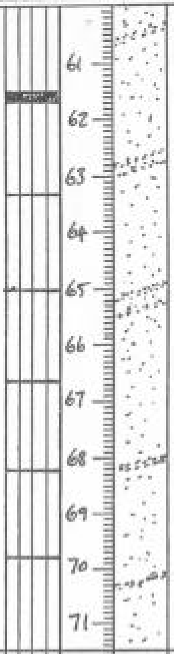
NO.

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747723·85 mN 2426260·22 mE DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION N/A H.A.D. GROUND 263·67m H.A.D. COLLAR 263·67m

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING, LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10 cm/s 01 1 10 100 1000
SANDSTONE weak to very weak, SW (iron staining), fine-coarse sand sized. Reddish grey to green CONTINUED.													
EOH 71·50m													



DRILLER: R HARZEN	
STARTED: 2/9/02	
FINISHED: 5/9/02	
DRILL:	

ROCK WEATHERING
UW – Unweathered
SW – Slightly weathered
MW – Moderately weathered
HW – Highly weathered
CW – Completely weathered

ROCK HARDNESS
VH – Very hard
H – Hard
MH – Moderately hard
MS – Moderately soft
S – Soft
VS – Very soft

FRACTURE LOG (cms)
100 50 10 5 1 0·1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MEH
DATE: 6/9/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:
SCALE: 1:100

PROJECT: 48685-002
HOLE NO: WN
LENGTH: 71·50
CORE BOXES:

NO. WN 2

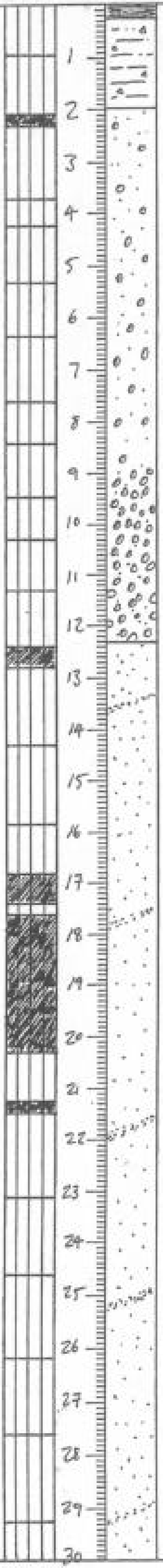
LOG OF DRILL HOLE

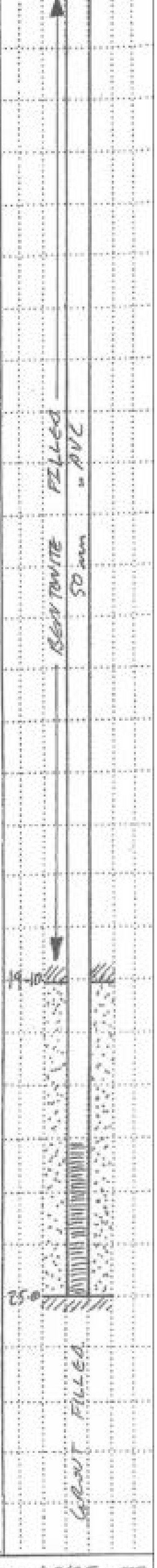
PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747757·03 mN 2426944·08 mE DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231·63 H.A.D. COLLAR 231·63

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING, LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/ LIFT %	DEPTH H.A.D. Core size, casing	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁵cm/s ·01 0·1 1 10 100 1000
TOPSOIL - Brown Silt Loam SILT - Light brown, hard. with some gravel								Silt. Top 0.2m light grey + iron stained. Colluvial deposit. Gravel angular			29/8 30/8		
1·98 - 12·30 Sandy GRAVEL with some silt. Weak Brown to red brown (iron stained)								Gravel clasts 10cm+ diameter of UW Torlesse sandstone, rounded. Upper 1m iron stained.					
Colour changes - blue grey. Fresh.													
								Clasts > 10cm diameter closely packed.					
12·30 → 71·45m (EOH) SANDSTONE Very weak to weak, fresh, unfractured, greenish-whiteish grey. Med-fine-coarse sand sized.								Top 0·5m loose sand Sand = quartz + glauconite Occasional clay bands generally dipping ~20°. Occasional glauconite laminations dipping ~20°					
								21·20 → 21·44 = Loose sand					
28·00 → 30·52 Iron staining of SANDSTONE (above)													





DRILLER: R HARVEY

STARTED: 28/8/02

FINISHED: 30/8/02

DRILL:

ROCK WEATHERING	ROCK HARDNESS
UW – Unweathered	VH – Very hard
SW – Slightly weathered	H – Hard
MW – Moderately weathered	MH – Moderately hard
HW – Highly weathered	MS – Moderately soft
CW – Completely weathered	S – Soft
	VS – Very soft

FRACTURE LOG (cms)
100 50 10 5 1 0·1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MEH
DATE: 30/8/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:
SCALE: 1:100

PROJECT: 48685-002
HOLE NO: WN 2
LENGTH: 71·45m
CORE BOXES:

NO.

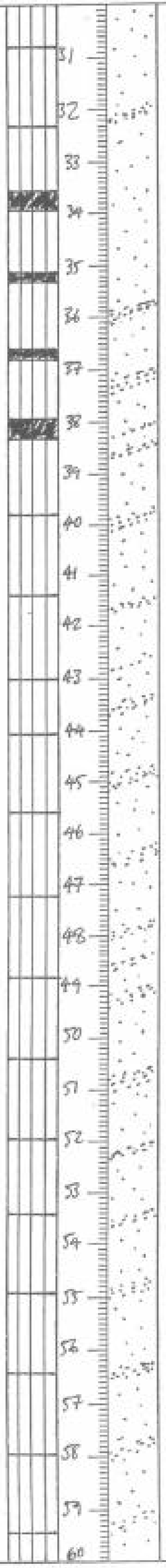
LOG OF DRILL HOLE

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747757 m N 2426944.03 m E. DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231.63 H.A.D. COLLAR 231.63

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING. LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/ LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁵cm/s .01 0.1 1 10 100 1000
SANDSTONE Very weak to weak, fresh, unfractured, greenish-whitish grey. Fine-med-coarse sand sized. CONTINUED.													
32.60 to 35.55 Iron staining of SANDSTONE (above)													
35.55 SANDSTONE (as above) blue-green grey								increase in glauconite content					
55.00 to 71.45m (EOH) SANDSTONE (as above) with some silt								strength increased by silt. Still weak. Glauconite cross bedding					



DRILLER: R HARVEY

STARTED: 28/8/02

FINISHED: 30/8/02

DRILL:

ROCK WEATHERING
- UW – Unweathered
- SW – Slightly weathered
- MW – Moderately weathered
- HW – Highly weathered
- CW – Completely weathered

ROCK HARDNESS
- VH – Very hard
- H – Hard
- MH – Moderately hard
- MS – Moderately soft
- S – Soft
- VS – Very soft

FRACTURE LOG (cms)

100 50 10 5 1 .01 Spacing of natural fractures

1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MEH

DATE: 30/8/02

TRACED:

CHECKED:

ORIGINAL VERTICAL:

SCALE: 1:100

PROJECT: 48685-002

HOLE NO. WN2

LENGTH: 71.45m

CORE BOXES:

NO. WN 2

LOG OF DRILL HOLE

PROJECT 48685 - 002 - 2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747757 m N 2426944·03 m E DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231·63 H.A.D. COLLAR 231·63

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING. LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁵cm/s .01 .1 1 10 100 1000
SANDSTONE weak, fresh, unfractured, blue-green grey. Fine-med-coarse sand sized. CONTINUED.					61–71								
EOH 71·45m													

DRILLER: R HARVEY

STARTED: 28/8/02

FINISHED: 30/8/02

DRILL:

ROCK WEATHERING
- UW – Unweathered
- SW – Slightly weathered
- MW – Moderately weathered
- HW – Highly weathered
- CW – Completely weathered

ROCK HARDNESS
- VH – Very hard
- H – Hard
- MH – Moderately hard
- MS – Moderately soft
- S – Soft
- VS – Very soft

FRACTURE LOG (cms)
100 50 10 5 1 0.1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MEM

DATE: 30/8/02

TRACED:

CHECKED:

ORIGINAL VERTICAL:

SCALE: 1:100

PROJECT: 48685 - 002

HOLE NO: WN2

LENGTH: 71·45m

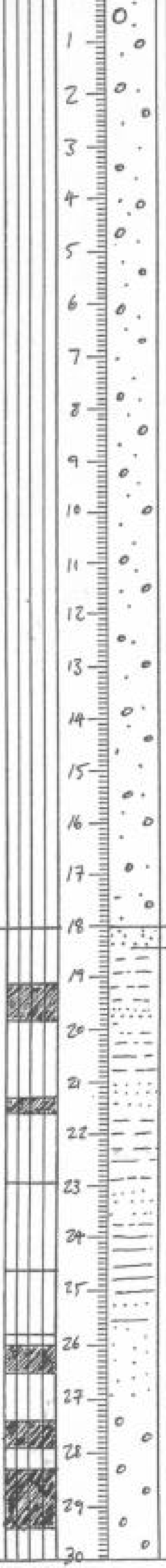
CORE BOXES:

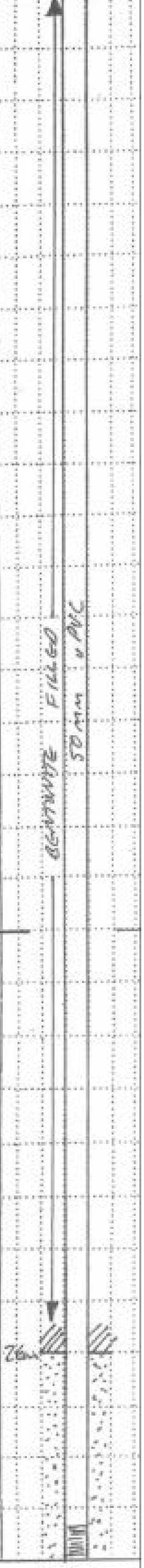
NO. WN 3

LOG OF DRILL HOLE

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER
GRID REF. NZMG CO-ORD. 5747763.73 mN 2427463.08 mE DATUM LINZ (MSL)
ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231.20m H.A.D. COLLAR 231.20m

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING. LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.O.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁵cm 01 0·1 1 10 100 1000
0 → 18.00m GRAVEL Sandy GRAVEL SAND UW - SW Brown to Grey Torlesse sandstone. Some volcanic clasts.								TUBEX 140			30/8 31/8 1/9		BENTONITE FILLED 50mm ⌀ PVC
18.00 → 18.43m SAND with trace of silt. Light brown, massive.								18.00m CORE RECOVERY COMMENCED. sand med-fine, quartz + volcanics.					
18.43 → 25.81m SILTSTONE Very weak to weak, UW, unfractured, dark grey, silt-sized. Interbedded / mixed with:- SANDSTONE Very weak, UW, unfractured, grey, fine sand sized.								SILTSTONE Top 0.30m greenish-grey & iron stained. SILT : SAND = 4:1 SANDSTONE beds continuous up to 0.4m. SILTSTONE beds continuous up to 0.9m					
25.81 → 27.20m SANDSTONE Very weak, UW, unfractured, grey, fine-coarse sized sand with some gravel.								27.40 carbon sample taken					26m
27.91 → 31.08 GRAVEL. Loose, clean, UW.								GRAVEL diameter <8cm, mostly <1cm. Torlesse sandstone. ~5% volcanics					





DRILLER: R HARRGN
STARTED: 30/8/02
FINISHED: 1/9/02
DRILL:

ROCK WEATHERING
UW – Unweathered
SW – Slightly weathered
MW – Moderately weathered
HW – Highly weathered
CW – Completely weathered

ROCK HARDNESS
VH – Very hard
H – Hard
MH – Moderately hard
MS – Moderately soft
S – Soft
VS – Very soft

FRACTURE LOG (cms)
100 50 10 5 1 0·1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MGH
DATE: 3/9/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:
SCALE: 1:100

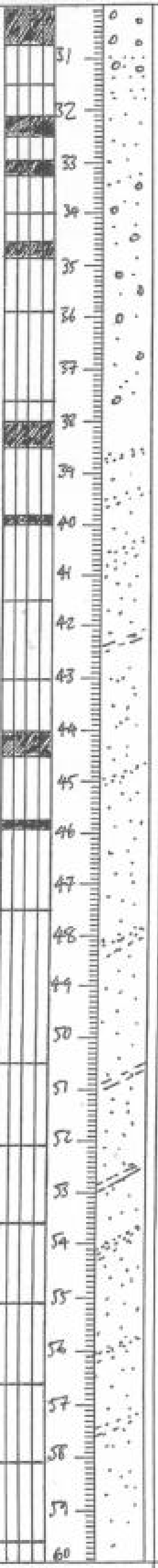
PROJECT: 48685-00
HOLE NO: WN 3
LENGTH: 70.08m
CORE BOXES:

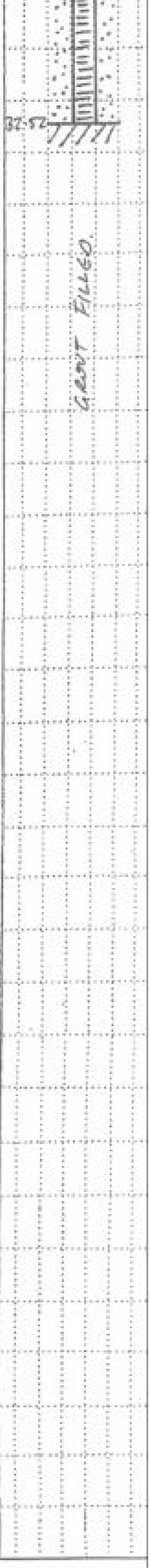
NO. WN 3

LOG OF DRILL HOLE

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER
GRID REF. NZMG CO-ORD. 5747763.73mN 2427468.08mE DATUM LINZ (MSL)
ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231.20m H.A.D. COLLAR 231.20m

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING, LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS, SHATTER, SHEAR AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compaciness, water content, group symbol etc.)	DATE/DEPTH	R.O.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0–100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY–10⁻⁵cm .01 .1 1 10 100 1000
GRAVEL. Loose, clean, UW continued.													
31.08 → 31.51m GRAVEL as above + course sand + trace silt. Firm													
31.51 → 31.80m SANDSTONE very weak, SW, unfractured greenish brown - greenish grey, med sand-sized													
31.80 - 37.92m Mix / interbedded GRAVEL + SANDSTONE (see above)													
37.91 - 70.08m (EOH) SANDSTONE weak, UW, unfractured, greenish grey sand sized.								Green = glauconite SILTSTONE bands < 3cm wide every ~ 0.1m - 0.5m Dip ~ 20° approx.					
								white sand lenses <0.5cm diameter. Bioturbation?					
								49.30 → 50.00 SANDSTONE only, no SILT.					





DRILLER: R HARRGN
STARTED: 30/8/02
FINISHED: 1/9/02
DRILL:

ROCK WEATHERING
UW. – Unweathered
SW – Slightly weathered
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HW – Highly weathered
CW – Completely weathered

ROCK HARDNESS
VH – Very hard
H – Hard
MH – Moderately hard
MS – Moderately soft
S – Soft
VS – Very soft

FRACTURE LOG (cms) 100 50 10 5 1 .01 Spacing of natural fractures
1 2 10 20 100 Fractures/m of core

EXPLANATION

LOGGED: MGH
DATE: 3/9/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:
SCALE: 1:100

PROJECT: 48685-002
HOLE NO: WN 3
LENGTH: 70.08m
CORE BOXES:

HOLE NO. WN 3

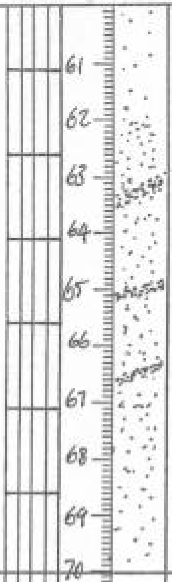
LOG OF DRILL HOLE

PROJECT 48685-002-2100 FEATURE WAIANIWANIWA DAM LOCATION CENTRAL PLAINS WATER

GRID REF. NZMG CO-ORD. 5747763.73 mN 2427463.08 mE DATUM LINZ (MSL)

ANGLE FROM HORIZONTAL VERTICAL DIRECTION NA H.A.D. GROUND 231.20m H.A.D. COLLAR 231.20m

DESCRIPTION OF CORE WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING. LITHOLOGICAL FEATURES (bedding, foliation, mineralogy, texture, cement, etc); STRATIGRAPHIC NAME	ROCK WEATHERING SW MW HW	ROCK HARDNESS H MH MS S	POINT LOAD TEST (MPa)	CORE LOSS/ LIFT % 5 10 50	DEPTH H.A.D. Core size, casing m	GRAPHIC LOG	FRACTURE LOG (Spacing of natural fractures) 50 10 5 cms	ROCK DEFECTS PROMINENT JOINTS, BEDDING, SEAMS, VEINS SHATTER, SHEAR, AND CRUSH ZONES, FOLIATION SCHISTOSITY (attitude, width, spacing, smoothness) (OR SOIL DESCRIPTION) (consistency, compactness, water content, group symbol etc.)	DATE/DEPTH	R.Q.D. %	WATER LEVEL Date	DRILL WATER LOSS % 0-100	WATER PRESSURE TESTS – Lugeons or PERMEABILITY-10⁻⁷cm .01 .1 1 10 100 1000
SANDSTONE weak, UW, unfractured, greenish grey sand sized 62.00 → 68.00m SANDSTONE (as above) dark green								higher concentration of glauconite					
EOH 70.08m													



DRILLER: R HARREY

STARTED: 30/8/02

FINISHED: 1/9/02

ROCK WEATHERING
UW – Unweathered
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ROCK HARDNESS
VH – Very hard
H – Hard
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MS – Moderately soft
S – Soft
VS – Very soft

FRACTURE LOG
(cms) 100 50 10 5 1 0.1 Spacing of natural fractures
1 2 10 20 100 1000 Fractures/m of core

EXPLANATION

LOGGED: MGM
DATE: 3/9/02
TRACED:
CHECKED:
ORIGINAL VERTICAL:

PROJECT: 48685-002
HOLE NO: WN 3
LENGTH: 70.08m
CORE BOXES:

Appendix C
Drill Core Photographs

WN 1 0 to 8.20 m

WN 1 8.20 to 16.82

Appendix C
Drill Core Photographs

WN 1 16.82 to 25.37

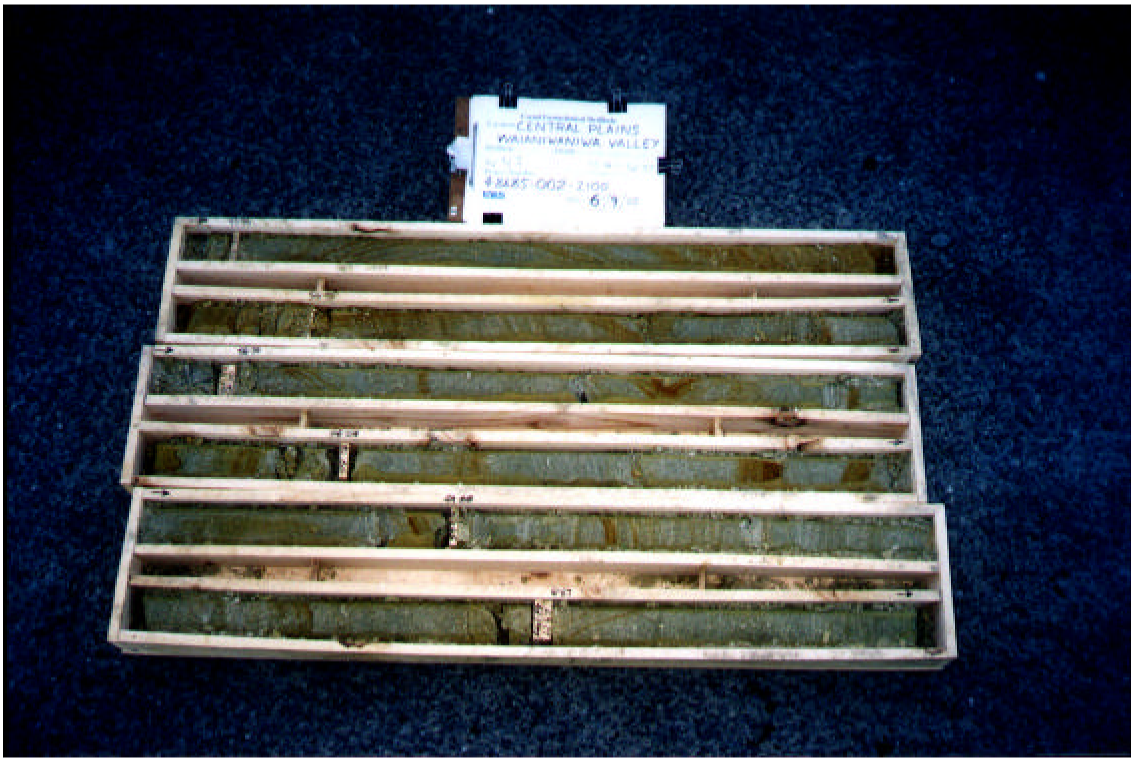
WN 1 25.87 to 34.45

Appendix C
Drill Core Photographs

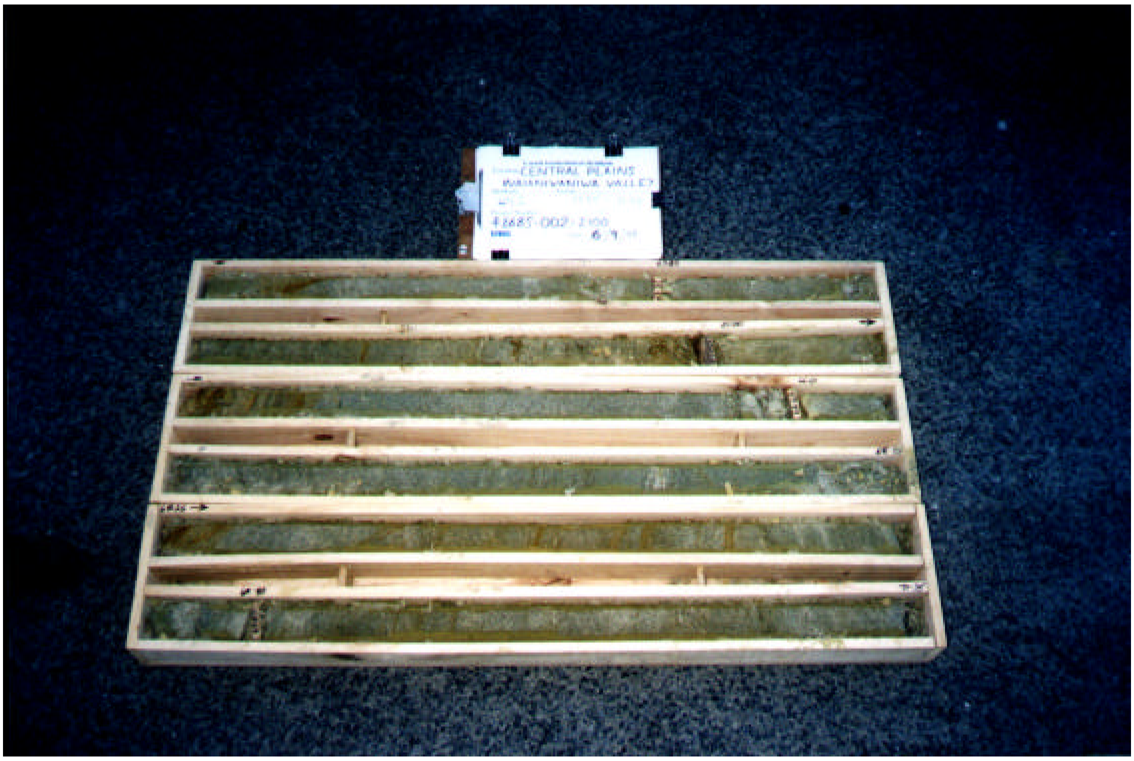
WN 1 34.45 to 43.10

WN 1 43.10 to 53.34

Appendix C
Drill Core Photographs



WN 1 53.34 to 62.35



WN 1 62.35 to 71.35

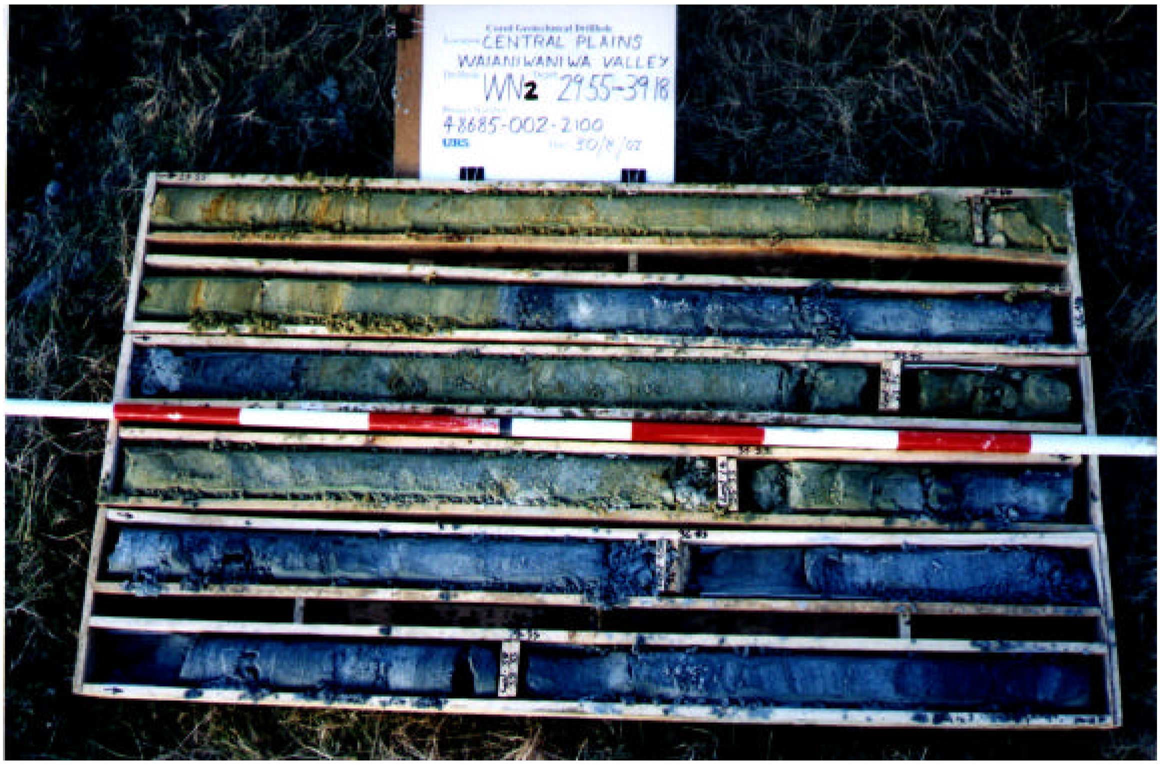
Appendix C
Drill Core Photographs

WN2 0 to 8.65 m

WN2 8.65 to 20.80

Appendix C
Drill Core Photographs

WN2 20.80 to 29.55



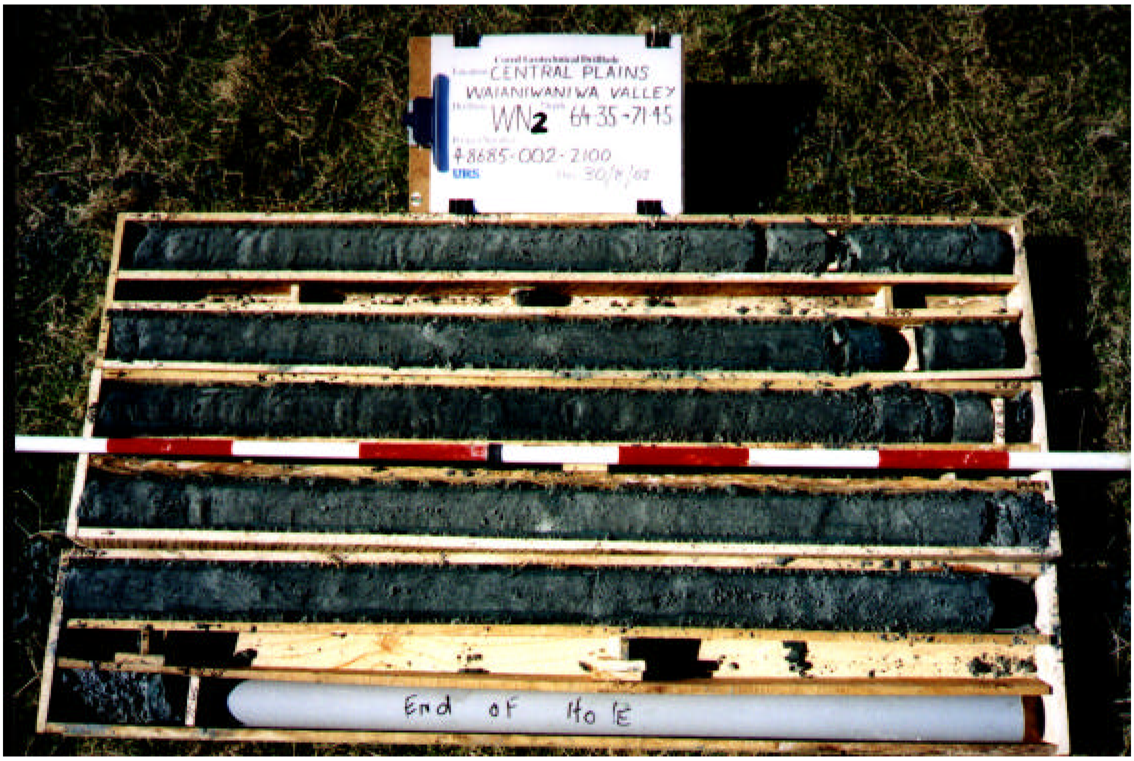
WN2 29.55 to 39.18

Appendix C
Drill Core Photographs

WN2 39.18 to 47.70

Appendix C
Drill Core Photographs

WN2 56.10 to 64.35



WN2 64.35 to 71.45

Appendix C
Drill Core Photographs

WN3 18.00 to 28.16

WN3 28.16 to 40.22

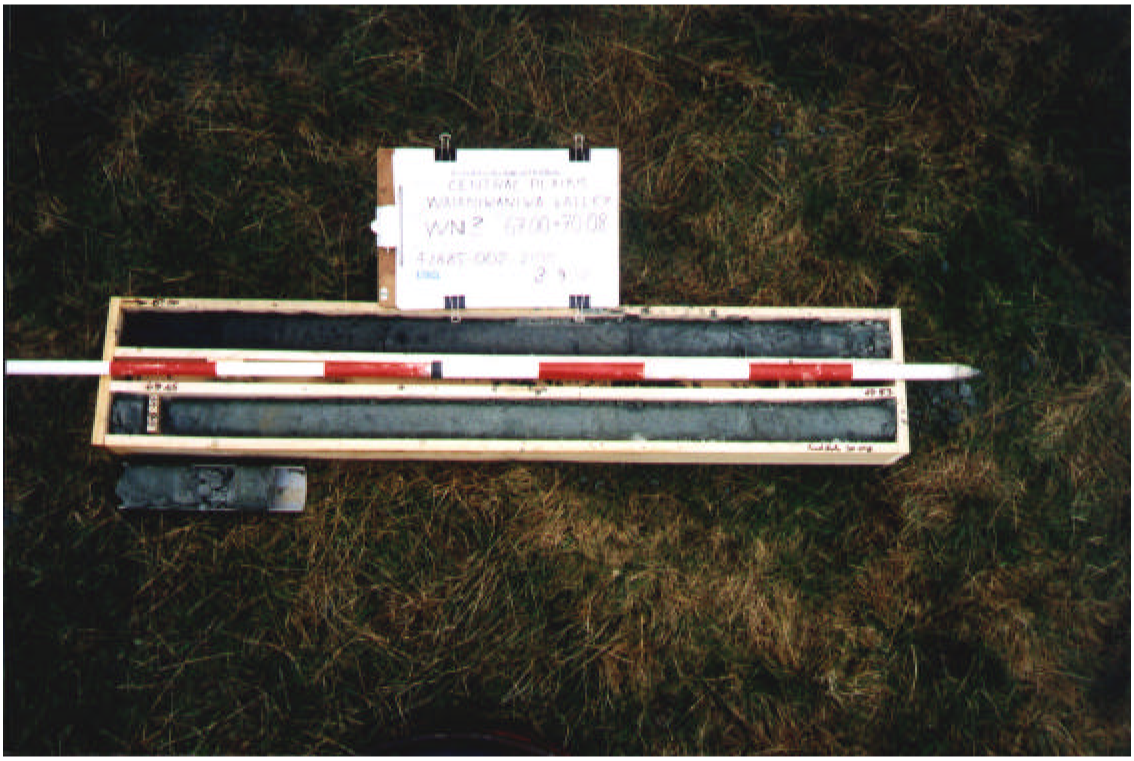
Appendix C
Drill Core Photographs

WN3 40.22 to 49.45

WN3 49.45 to 58.03

Appendix C
Drill Core Photographs

WN3 58.03 to 67.00



WN3 67.00 to 70.08