Hydrogeological Review for Proposed Akaroa Wastewater Treatment and Disposal

Prepared for

Christchurch City Council

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Limitations:

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Executive Summary

A review of groundwater information in and around the Takamatua headland has been undertaken to provide information for the consideration of future treatment and disposal options for Akaroa Wastewater.

The Takamatua headland is formed by Akaroa volcanic rock overlain by variable thicknesses of loess (i.e. windblown silt from the Canterbury plains) and colluvium comprising a mixture of weathered volcanics and loess. These are generally low permeability materials due to the fine grained particles that make up the loess and the solid nature of the volcanic strata, with most groundwater movement occurring through joints and fractures in the volcanics, in coarser grained zones of colluvium or at the interface between these different strata. Groundwater feeds springs that emerge at discrete locations around Banks Peninsula.

Movement of groundwater through the loess can cause tunnel gullies to form and also contribute to land instability, as evidenced by the occurrence of historical landslide features on the southern side of the Takamatua headland. Therefore any wastewater treatment or disposal options involving the natural strata need to be carefully managed to avoid increased groundwater flow through the loess soils or along the interface between different strata types that could trigger land instability.

There is very limited information on groundwater levels in the area and high groundwater levels will have a bearing on the construction and operation of subsurface infiltration or wetland structures. Therefore groundwater level monitoring at any proposed treatment and disposal areas is recommended, to establish the range of groundwater level fluctuations that occur. It is also recommended that any concentrated subsurface infiltration or wetland structures should be lined to minimise infiltration losses of wastewater out into the surrounding strata.

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1.0 Introduction

Christchurch City Council (CCC) is proposing to construct a new Waste Water Treatment Plant (WWTP) north of Akaroa township on elevated sloping land adjacent to Old Coach Road. Options for the disposal of treated wastewater are being explored by CCC at present. The current options include irrigation to land and soakage to ground via infiltration basins or subsurface wetlands. The area of land being considered for disposal of wastewater is on the northern side of the Takamatua Headland situated directly west of the proposed WWTP.

This report provides a desktop review of the hydrogeological environment in the vicinity of the proposed WWTP and the adjacent headland between Akaroa and Takamatua. The review provides information on the following information for consideration of the suitability of disposal of treated wastewater to land:

- A description of the geological setting
- Groundwater use in the area
- Groundwater levels
- Groundwater flow conditions
- Potential groundwater issues relating to wastewater discharge options
- Recommendations to constrain current uncertainties

Figure 1, Appendix A shows the location of the proposed WWTP site and the Takamatua Headland to the west where disposal of wastewater is proposed.

2.0 Geological Setting

Banks Peninsula consists of the eroded remnants of two large, extinct stratovolcanoes, consisting of Lyttelton in the northwest and Akaroa in the southeast. The Miocene volcanic rocks of Banks Peninsula rest unconformably on a basement of Torlesse Terrane (Triassic), McQueens Volcanics (Cretaceous) and Charteris Bay Sandstone (Paleocene), which are exposed in Gebbies Pass at the head of Lyttelton Harbour.

The oldest and youngest Miocene volcanic rocks on the peninsula are associated with the Lyttelton Volcano and span from around 12 to 11 million years before present (Governors Bay Volcanics) through to around 7 to 5.8 million years before present (Stoddart Volcanics).

Activity associated with the Akaroa Volcano commenced around 9 million years before present, and over a period of around 1 million years a large composite cone of lava flows, pyroclastics (air fall deposits) and intrusive rocks was constructed.

Radial drainage patterns developed on Lyttelton and Akaroa volcanoes during their construction, and as activity waned, stream erosion became the dominant landscape process. The origin of Lyttelton and Akaroa Harbours is attributed to the preferential development of two major drainage channels further aided by influx of the sea.

In the last 2 million years, extensive glaciation of the Southern Alps has supplied very large volumes of sediment that has been carried by the major river systems and deposited to form the Canterbury Plains. It is thought that the former shallow seaway between Banks Peninsula and the mainland probably disappeared around 20,000 years ago as sea level fell.

Glacial activity during the Quaternary produced large quantities of silt-sized material that was transported by north-west winds and deposited as a blanket of loess on the eroded volcanic flanks, where it has become mixed to some extent with locally-derived volcanic material during slope movement processes to form colluvial deposits.

Sanders, 1986 and Bell and Trangmar, 1987 provide a general overview of the surficial soils of the harbour which overlie the volcanics as follows:

- Weathered volcanic bedrock (residual regolith), typically <1 m thick;
- Loess, wind deposited sand and silt, typically <16 m thick;
- Volcanic or Loess Colluvium, typically <1 m thick;
- Mixed Loess and Volcanic Colluvium, typically <20 m thick;

2.1 Local Geology

The geological map of banks peninsula (Sewell, Weaver, & Reay, 1992), indicates that the surface rocks (generally underlying thick loess) in the area of Takamatua Headland comprise blue-black, medium to fine grained lava flows, tuff agglomerate, radial dikes, endogenous domes and buried tuff cones. These deposits form the French Hill Formation of the Akaroa Volcanic Group and were deposited between approximately 9.1 and 8.3 million years before present. The slightly older cream to light grey Lushington Breccia is also exposed on the west of the headland underlying the French Hill Formation.

The valley floor of Takamatua Bay to the north and extending inland to the east along Takamatua Valley Road is mapped as being underlain by saline sand, silt and peat accumualtions of the Christchurch Formation deposited during the last 10,000 years.

ECan’s online GIS wells database identifies four boreholes (BY25/0001, BY25/0002, BY25/0003 and BY25/0004) on the subject property where the WWTP is proposed. These boreholes relate to a geotechnical investigation carried out by CH2M Beca (Beca) in January 2014. We have been provided with a report titled, Akaroa Wastewater Treatment Plant – Geotechnical Assessment Report (Beca, 2014), which gives details relevant to this investigation along with previous investigations carried out at the site. The report identifies a total of six boreholes (BH101 through BH106) that were drilled onsite in 2014, along with the excavation of six test pits (TP101 through TP106) and two trial trenches (TT101 and TT102).

In addition, previous onsite geotechnical investigations were carried out by Beca in 2012 (including two boreholes – BH1 and BH2) and 2013 (two boreholes – BH301 and BH302, two test pits – TP 301 and 302, and one trial trench – TT301) which are summarised in the report. Figure 2, Appendix A shows the location of the individual boreholes, test pit and trial trench excavations for all three of the onsite investigations.

Table 1 below provides details for the individual borehole/excavation investigations that have occurred at the site since November 2012.

Table 1: Intrusive Geotechnical Investigations carried out at site

Borehole/Excavation	Date	R.L. Ground (m)	Total Depth (m)
BH1	27-28 Nov 2012	118	22.55
BH2	29 Nov 2012	127	10.875
BH301	16-17 Dec 2013	120.3	18.95
BH302	18 Dec 2013	127.2	15.95
TP301	16 Dec 2013	123.5	4
TP302	16 Dec 2013	121	4.2
TT301	16 Dec 2013	131.8	3
BH101	21 Jan 2014	121.2	16.8
BH102	27-28 Jan 2014	126.3	15.3
BH103	28 Jan 2014	136.2	12.3
BH104	20 Jan 2014	122.5	21.65
BH105	24 Jan 2014	126.4	18.65
BH106	22 Jan 2014	139.7	12.32
TP101	27 Jan 2014	123.3	4.3
TP102	24 Jan 2014	121.5	4.2
TP103	27 Jan 2014	125.0	3.9

TP104	24 Jan 2014	122.7	4.3
TP105	24 Jan 2014	121.2	4
TP106	27 Jan 2014	124.0	4
TT101	27 Jan 2014	129.0	3.8
TT102	27 Jan 2014	125.0	2.7

Following drilling of boreholes BH101, BH102 and BH103 (2014), uPVC piezometers were installed in each of these three boreholes for the purpose of measuring groundwater levels.

Based on the results of the subsoil investigations carried out onsite, Beca summarise the natural subsurface profile as shown in Table 2 below:

Table 2: Intrusive Geotechnical Investigations carried out at site

Geology	Description	Depth to top of layer (m bgl)	Thickness (m)
Loess/Loess colluvium	Stiff SILT with some trace of clay and fine sand	0 to 1.1	0.7 to 8.3
Akaroa Volcanic Group – firm to very stiff soil	Interbedded completely weathered BASALT, completely weathered to moderately weathered basalt BRECCIA and tuff. Recovered as firm to very stiff soil	2.6 to 8.6	2.2 to 12.1
Akaroa Volcanic Group – hard soil to weak rock	Interbedded completely weathered to slightly weathered BASALT, completely weathered to slightly weathered basalt BRECCIA and tuff. Recovered as hard soil and extremely weak to weak rock.	0.7 to 19.5	>0.45 to >16.55

Overall the ground conditions appear to be broadly consistent with the published geological information for the area, comprising Quaternary loess overlying the Akaroa Volcanic Group. Beca also note the presence of non-engineered fill of variable thickness and composition at the site along the verge of Old Coach Road.

Figures 3a through 3c, Appendix A show cross sections through the site prepared by Beca based on the soils encountered during the subsoil investigations carried out at the site. The section lines for each individual cross section are shown in Figure 2. The variable thickness of each of the geological layers described in Table 2 is evident in these sections.

In addition to the onsite investigations, borelogs are available for an additional three bores (N36/0051, N36/0042 and N36/0245) situated on the Takamatua Headland in the vicinity of the WWTP site. The locations of these bores are shown in Figure 4, Appendix A and the individual borelogs are presented in Appendix B. Note that the three additional bores on this figure relate to ECan's records of the geotechnical boreholes drilled onsite by Beca.

The borelog for N36/0051 (23 m deep) describes brown clay from ground level to 4.5 m below ground level, underlain by rock to the base of the borehole. This is interpreted to represent loess to a depth of 4.5 m underlain by volcanics thereafter.

The borelogs for the more distant bores (N36/0042 and N36/0245) appear to indicate volcanics being present at shallow depths. The log for N36/0042 describes 2 m of earth (likely loess) underlain by dominantly blue, grey, red, orange or black rock (assumed to be volcanics) to the base of the borehole at 57 m below ground level. In between the rock layers there are some zones of clay described in this borelog which are assumed to be representative of weathered volcanics and/or explosive air fall deposits. The borelog for N34/0245 describes 3.4 m of loess from surface level underlain by volcanics to the base of the borehole at 5.4 m below ground level.

Overall, other than the onsite investigations there are very few bores drilled in the area and therefore only limited descriptions of the near surface strata are available. The available information indicates that the Quaternary loess cover (and colluvium) is very variable in thickness which is consistent with the published geological information.

3.0 Hydrogeology

3.1 Groundwater use and Yields

Groundwater will be present in both the surficial soils and within mainly fractures and joints in the underlying volcanics.

Figure 5, Appendix A shows all recorded bores in the area of Akaroa Harbour based on a search of ECan's database. In total 43 bores are identified in this figure and only 20 are recorded as being active. The recorded use for the active bores includes domestic and/or stock supply (8 bores), public water supply (7 bores - of which 5 are in Akaroa, 1 is in Wainui and 1 is situated in Takamatua), geotechnical (ECan's records for the onsite bores) and water level observation (2 bores).

Only six bores have yield information recorded on ECan's database. The highest recorded yields relate to the public supply bores (three of which have yield data), with the yields for these three bores ranging from 5.7 L/s (N36/0048 situated in Wainui) to 11.74 L/s (N37/0007 situated in Akaroa). Of the three other bores with recorded yield information, two (N36/0042 and N36/0051) are situated on the Takamatua Headland (see Figure 4), and one is situated at Wainui. Recorded yields for these three bores are low ranging from 0.6 L/s (N36/0042) to 1.9 L/s (N36/0051).

In summary yields appear to be low which is expected given the geology of the area and the general low number of bores and overall use of groundwater. In addition, all of the public supply bores in the area are drilled to relatively deep levels (between 41.2 m and 161.8 m) into volcanic strata and generally utilise very long screens to achieve their yield and/or require large drawdowns. For example N36/0048 located in Wainui (no screen information) requires 76.9 m of drawdown to achieve a 5.7 L/s yield and bore N37/0007 located in Akaroa is screened over an interval between 77.9 m and 137.9 m below ground level and draws down by 21.3 m for a yield of 11.74 m. The yields from the volcanic strata are expected to be reliant on intercepting interconnected fracture networks in the rocks and therefore it is likely that yields could vary between bores over short distances.

It is assumed that few (if any) abstraction bores are screened in surficial soils (above volcanics) as these deposits are expected to be of very low permeability.

3.2 Groundwater Levels

The limited number of bores in the area means there is a large amount of uncertainty with regard to groundwater levels in the vicinity of the proposed WWTP and Takamatua Headland.

As mentioned previously, Beca installed three piezometers at the site of the proposed WWTP in January 2014. The details for the piezometers are given in Table 3 below along with a summary of the groundwater level measurements made in the piezometers. In addition, groundwater levels were measured in three boreholes (no piezometers installed) during the same period and are also shown in the table.

Table 3: Details of Beca Piezometer Installations				
Borehole/ Piezometer	**Top of Screen (m bgl)**	**Bottom of Screen (m bgl)**	**Period of Groundwater measurements**	**Groundwater level variation (m bgl)**
BH101	9	12	22 Jan to 1 Feb 2014 (9 measurements)	7.98 to 8.03
BH102	8	11	28 Jan and 1 Feb 2014 (3 measurements)	9.21 to 9.25
BH103	9.5	11.5	28 Jan and 1 Feb 2014 (2 measurements)	9.12 to 9.8
BH104	-	-	21 and 22 Jan 2014 (2 measurements)	10.65 to 10.9
BH105	-	-	27 Jan 2014 (1 measurement)	10.05
BH106	-	-	23 and 24 Jan 2014 (2 measurements)	8.8 to 9.1

Overall groundwater levels were measured between 7.98 m and 10.9 m below ground level onsite. However, the maximum period over which measurements were taken was only 11 days and therefore it is not known how groundwater levels respond to rainfall recharge or the magnitude of variations that occur as a result of seasonal effects. Beca also note the potential effects that the drilling process may have had on the measured groundwater levels, including the effects of drilling muds or other fluids.

With respect to other available groundwater level records for the Takamatua Headland, the reported static water level in bore N36/0042 was measured at 41.2 m below ground level in October 1994 and the static water level in N36/0051 was recorded as 10.5 m below ground level in March 1999. Both of these bores appear to be screened in volcanic rocks are their locations have been given previously in Figure 4. The very deep measurement in N36/0042 is somewhat surprising and may possibly be indicative of a water level that had not recovered following drilling. Alternatively the low water level may mean that the strata intercepted by the well screen is overlain by perched layers with higher groundwater levels.

We are unaware of any other available groundwater level information for the Takamatua Headland area. Overall it is expected that groundwater levels may be highly variable over relatively short distances as a result of the variable topography in area. In addition, the relatively impermeable near surface soils can be expected to drain slowly and therefore during the winter months and following frequent heavy rainfall events it may be that shallow soils become saturated for prolonged periods in some areas. Considerable variations in soil properties are also expected over small distances and therefore the occurrence of locally perched groundwater is also likely following rainfall events.

3.3 Groundwater Flow

The pattern of groundwater flow can be expected to be highly variable. In general it is likely that the overall pattern of flow follows the topography of the land. Therefore a radial pattern of groundwater flow can be expected from the top of Takamatua Hill, however the direction of flow is likely to change markedly over short distances as a result of topographic features. Figure 6, Appendix A illustrates the expected high variability in flow direction based on the topography of the area. Based on this figure it can be seen that groundwater is expected to converge toward stream features in gullies and diverge on either side of a ridge.

The other likely significant influence on groundwater flow is the structure of the near surface soils together with the underlying volcanic rocks. The structure of each of these units can be expected to be complex and on a local scale there may be preferential pathways in both vertical and horizontal plains as a result of structural and textural changes in geology.

Figure 7, Appendix A shows an idealised representation of the surficial soils expected to be present in the area. The figure shows loess deposited on weathered volcanic rock overlain by loess colluvium and mixed loess and volcanic alluvium. While generally these materials can all be expected to be of low permeability, it likely there will be significant differences in relative permeability between the various units. Sanders, (1986) measured in situ permeability for these materials with the resulting values of conductivity given in Table 4 below.

Table 4: Insitu Hydraulic Conductivity of Surfical Soils

Surficial Unit	General Engineering Geological Description	In Situ Conductivity (m/s)
In Situ Loess	Unweathered to slightly weathered, yellowish brown (orange mottles formed where burrowing exists), massive CLAYEY SILT.	3.1×10^{-7}
Loess Colluvium	Slightly to moderately weathered, soft to stiff, mottled dark brown and light yellowish brown, massive SILT with some clay and rare fine gravel.	1.3×10^{-6}
Mixed Colluvium	Slightly to moderately weathered, soft to firm, dark yellowish brown, massive SILT with some fine to coarse gravel and clay, OR fine to coarse gravelly SILT with some sand and clay.	1.6×10^{-7} (10 % volcanics) 5.1×10^{-7} (20 % volcanics) 2.6×10^{-6} (35 % volcanics)
Volcanic Colluvium	Slightly to highly weathered, soft to hard, yellowish to reddish brown, SILTY FINE GRAVEL with some sand, OR fine to coarse GRAVEL with some silty and clay	1.1×10^{-5}

Notes: Adapted from Sanders 1986, Table 2.2

These measurements confirm the low hydraulic conductivity of the surficial soils and also demonstrate the relative differences in measured hydraulic conductivity with variations of around 2 orders of magnitude between the least permeable soils (loess and mixed colluvium containing a small proportion of volcanics) and the most permeable soils (volcanic colluvium). Therefore groundwater can be expected to find preferential pathways through colluvial materials with higher volcanics content as opposed to soils with greater concentrations of loess.

Field observations of water flow in loess is limited, but appears to commonly occur at the loess – bedrock interface and above the C fragipan (where this is developed). Layering in loess colluvium has a significant influence on water flow due to hydraulic conductivity and dispersive differences, and contacts between layers often provide discontinuities along which water movement and erosion tunnels can occur.

Tunnel gullying is an erosional feature caused by water flow within loess layers. Where the loess layers are thin or where the fragipan (often called C layer which represents a compacted layer in the loess profile with vertical joints) is poorly developed, gullying may occur directly over the volcanic bedrock and it is also possible that water within the volcanic joint system may provide the water source.

Groundwater seepage within mixed colluvium occurs throughout the individual deposits, sometimes creating small tunnels within the profile, or at the bedrock interface. Where underlying loess is firm water may perch above this. Infiltration through mixed colluvium is generally faster than through loess and is typically greater with increasing volcanic content.

Groundwater movement within volcanic colluvium is distributed throughout the colluvium profile but frequently occurs near the bedrock interface. The gravel texture generally means the permeability is greater than soils containing loess and infiltration rates will be greater.

Akaroa lava flows show extremely variable jointing over short distances. The jointing system is the primary factor determining whether the rocks will readily transfer and store water. Depending on the nature of jointing systems, the hydraulic conductivity of basalt lava flows can be expected to vary widely between 10^{-2} and 10^{-7} m/s (Freeze and Cherry, 1979).

Highly weathered lava flows can be expected to undergo significant reduction in permeability from the unweathered state. Brecciated lavas (that are also present in the general area and may constitute all or sections of a lava flow) are a common medium for lateral groundwater flow, although also may act as perching layers due to a lack of jointing.

Pyroclastic deposits including ash, tuff and bedded scoria are general of very low permeability and can be expected to act as effective barriers to groundwater flow.

Groundwater discharge in the Akaroa Harbour area occurs at springs whose form and distribution is geologically controlled. Discharge may occur directly from bedrock aquifers, but more commonly occurs through the extensive surficial cover.

Water is the dominant triggering mechanism for slope failures in the surficial cover in the area. Seeps and springs that serve as groundwater exits are indicators of internal water pressures, but they themselves are not necessarily the cause of mass movements. Springs uphill from a landslide can serve as sources of surface water that can infiltrate back into the slide material and contribute to renewed instability. If however they exit within the slide zone or downhill from it they can contribute to stability instead. Less pore pressure builds up when the groundwater is allowed to escape than when the groundwater exits are blocked.

Figure 8, Appendix A shows a conceptual representation of groundwater flow within the soils and underlying volcanic rocks in the area and illustrates that water may follow many pathways through the subsoil strata resulting in a very complex pattern of groundwater flow.

4.0 Potential Groundwater Effects on Wastewater Discharge Options

We understand that the current options for the disposal of wastewater from the proposed WWTP are as follows:

- Irrigation to land
- Discharge to subsurface wetlands
- Discharge to infiltration basins

The main groundwater issues associated with the disposal of the water from the WWTP are expected to be land stability, including tunnel gully erosion in loess soils, in addition to locally high groundwater levels affecting excavation depths.

Due to the general low permeability of the surficial soils in the area and the subsequent limited use of groundwater it is not expected that there will be any significant impacts of drinking water supplies as a result of the proposed discharge.

4.1 Land Stability

Information provided to PDP indicates that there is potential for the application of up to 900 mm per year of treated wastewater via irrigation to land. Based on average annual rainfall for Akaroa of 1,000 mm, the application of irrigation water could result in drainage similar to a doubling of the annual rainfall. Geotech Consulting (2010) has noted this issue previously and clearly indicated that the south facing slopes of Takamatua Peninsula would be unsuitable for irrigation of wastewater from a geotechnical perspective based on the presence of a highly visible large ancient landslide that includes actively growing areas of instability within its confines. The addition of significantly greater amounts of water infiltration to the soils has the potential to remobilise old failure surfaces and exacerbate active landslides.

Geotech Consulting (2010) identify an area of around 25 ha on the north slopes of the headland above Takamatua that could potentially be suitable for wastewater irrigation. However, conservative application loading is recommended in the first instance with careful monitoring of groundwater levels and slope stability over this time prior to any increase in application rates.

An additional stability issue is the potential for the formation of tunnel gully erosion. The loess soils on Banks Peninsula are typically highly dispersive (structurally unstable), with erosion and re-deposition having occurred since the original deposition. This erosion has been greatly increased as a result of deforestation.

Tunnel gullies are a specific type of gullying, where instead of eroding the soil surface (such as rill gullying), water seeps into the soil and forms underground cavities, which eventually collapse into open gullies (Figure 8). Tunnel gullies can be identified by the presence of water and sediment discharges from surface cracks or small holes (tunnel outlets), at changes in slope angle or cut faces; collapse holes aligned down slope; and open gullies up to 2 m deep filled with collapsed debris. Tunnel gullies often form where a soil is dry and desiccation cracks are present on the surface, providing a pathway for water to infiltrate into the soil.

Direct discharges of wastewater to ground are considered a high risk with respect to softening of loess soils and the potential development of tunnel gully erosion features. Direct discharges to ground should only occur to lined subsoil drains with sealed joints to ensure no direct access of water into the subsoil loess soils.

Any ponds or wetlands constructed in the area would also need to be lined and engineered to ensure that water cannot gain direct access into the underlying loess soils.

Irrigation to land has the potential to lead to significant loading of the underlying soils as a result of increasing groundwater levels and also provides a regular water source to access and soften the underlying soils. The best form of irrigation is considered to be trees as the canopy will intercept a significant proportion of rainfall and reduce rainfall infiltration.

4.2 High Groundwater Levels

The limited groundwater level information for the area, in addition to the topography of the headland and underlying geology suggests that groundwater levels are likely to be highly variable. Where groundwater levels are shallow, excavation depths for the installation of drainage or retention features will be limited. It will be important to obtain a greater understanding of groundwater levels over the area of any proposed excavation works prior to construction to ensure that localised shallow groundwater levels do not adversely affect the proposed development.

5.0 Recommendations

In summary there is a very limited amount of available groundwater information for the area. The main limitation in this regard is groundwater level data which is considered the most relevant information with respect to this proposal. It is recommended that a suite of groundwater level monitoring bores are installed over the area where any wastewater is proposed to be disposed of to ground, irrigated or stored prior to discharge.

In the first instance it is considered it would be beneficial to install up to six monitoring bores spaced over the northern region of the Takamatua Headland in the general area where wastewater would be discharged or stored. These bores should be installed at the earliest convenience to address the current uncertainty with respect to groundwater levels and confirm the viability of the various disposal options.

Groundwater levels in the monitoring bores would be best measured and recorded using pressure transducers so that short-term fluctuations and the response to rainfall recharge can be determined. Depending on availability it would also be beneficial to monitor a selection of existing bores in the area, such as the bores on the site of the proposed WWTP (if they are still present) and potentially bores N36/0042 and N36/0051 on the Takamatua Headland.

Once more detailed information is available with respect to the wastewater disposal option(s) that will be employed, including specific design details, then it may be necessary to install more groundwater level monitoring bores at targeted locations to confirm the feasibility of the proposal.

It would also be beneficial to carry out a survey of spring occurrence and distribution on the Takamatua Headland to determine natural groundwater discharge mechanisms and their proximity to waste water disposal features associated with the proposal. This would provide relevant information to better understand the implications of the various discharge options on the groundwater system.

6.0 References

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Appendix A: Figures

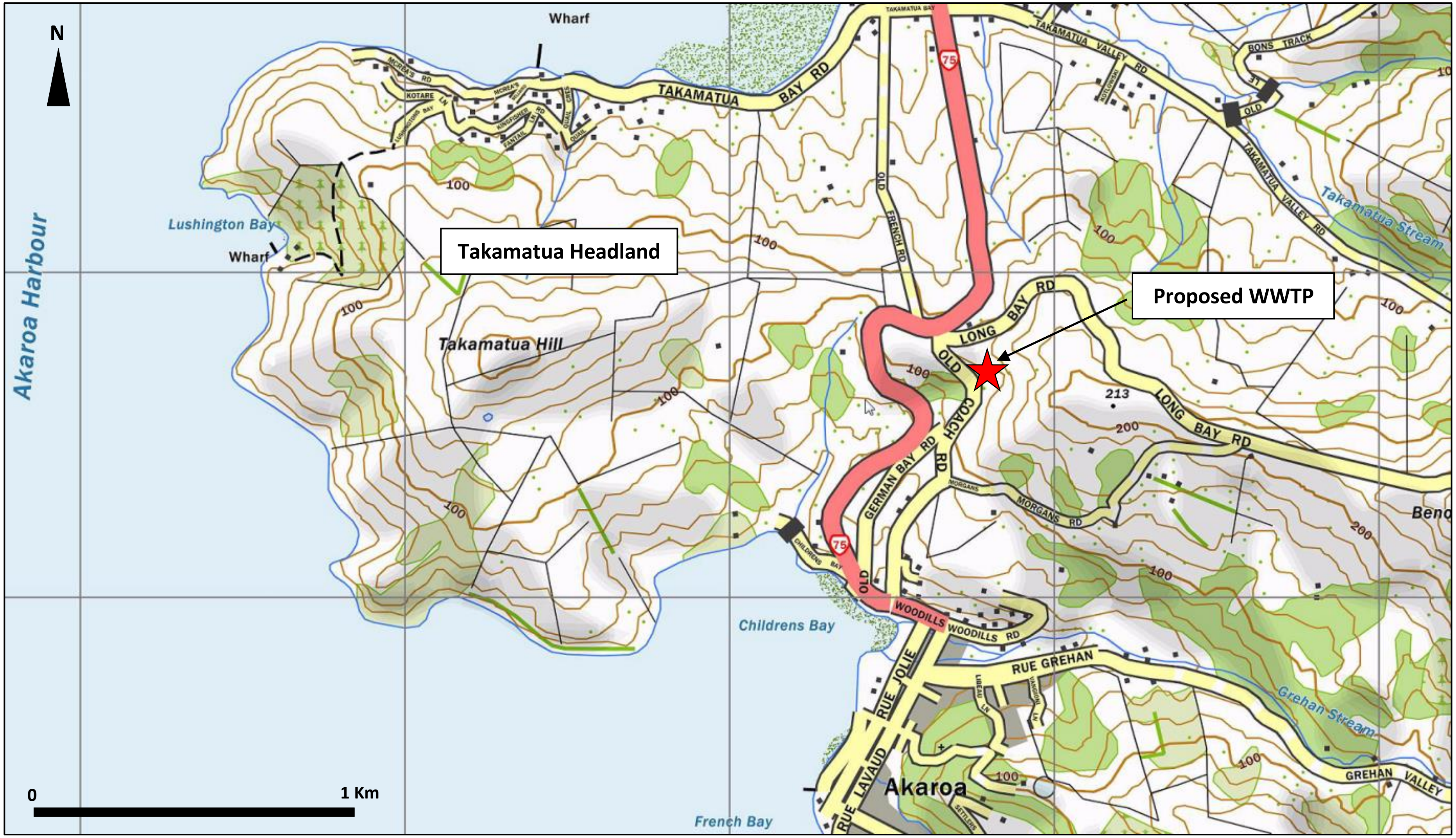

Figure 1: Location of Proposed Wastewater Treatment Plant and Takamatua Headland

(Source: Freshmap 1:20,000 NZTopo map)

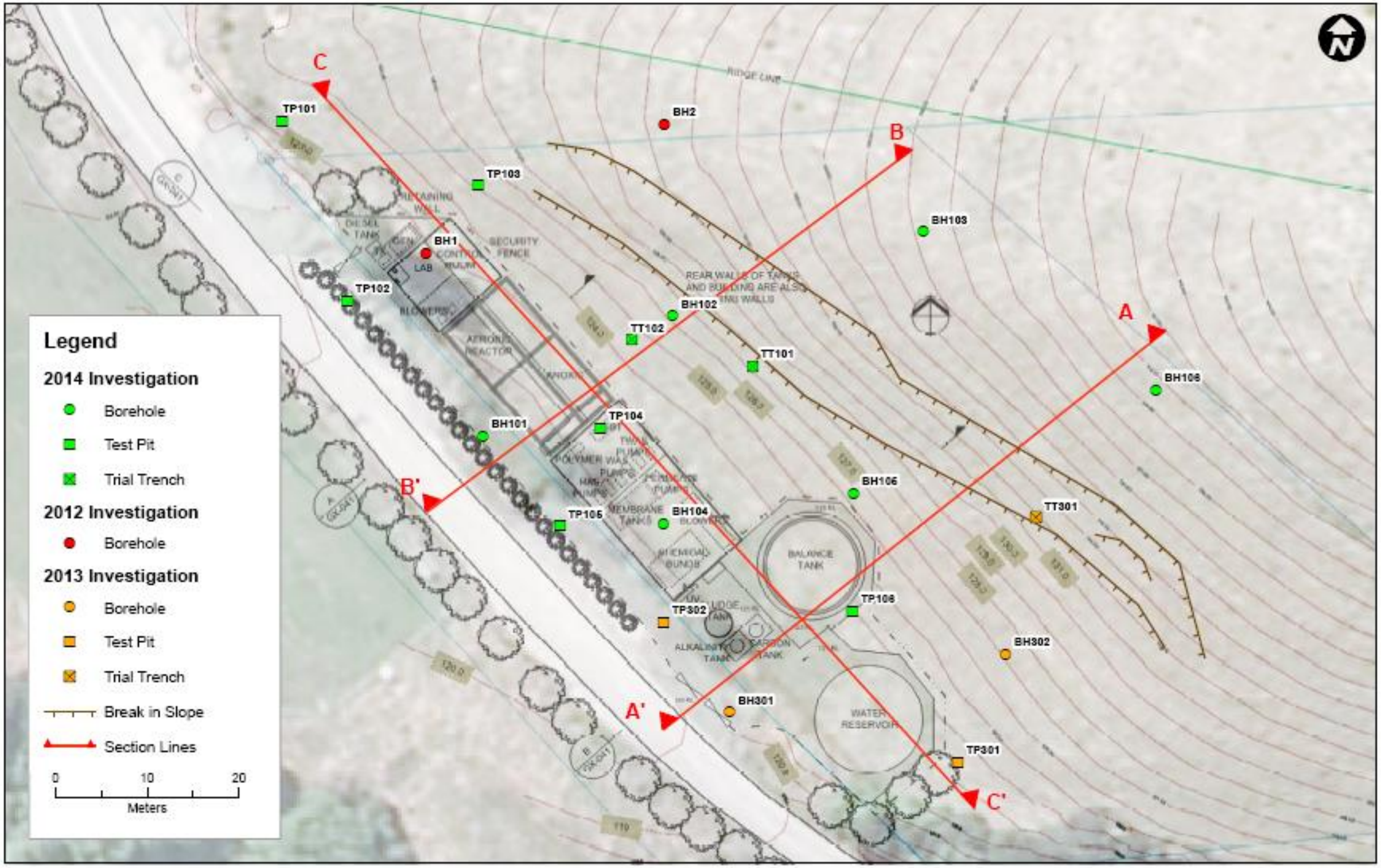

Figure 2: Locations of former Borehole, Test Pit and Trial Trench investigations carried out at the site of the proposed WWTP site by Beca

(Source: CHBeca, 2014)

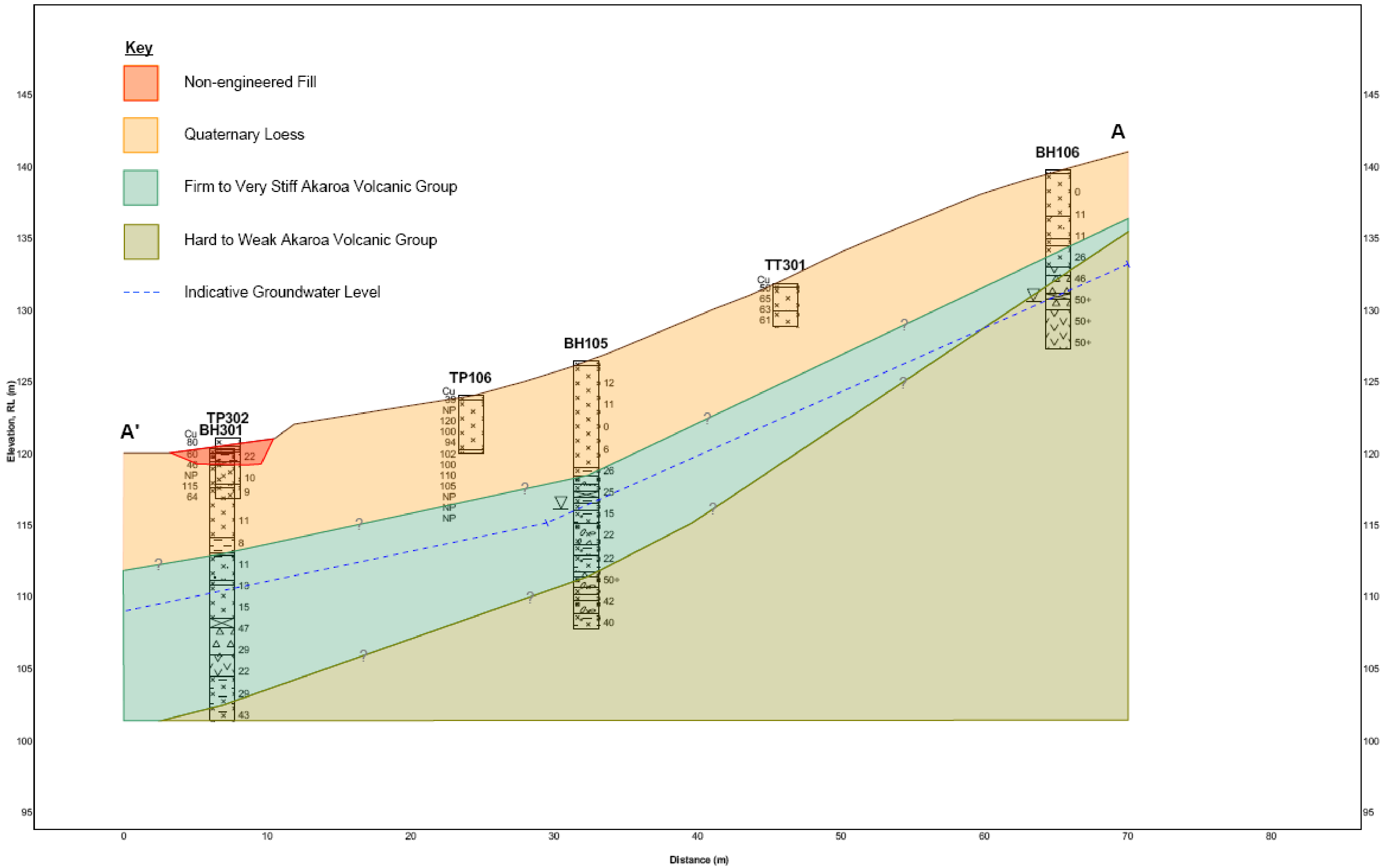

Figure 3a: Cross Section A-A'

(Source: CHBeca, 2014)

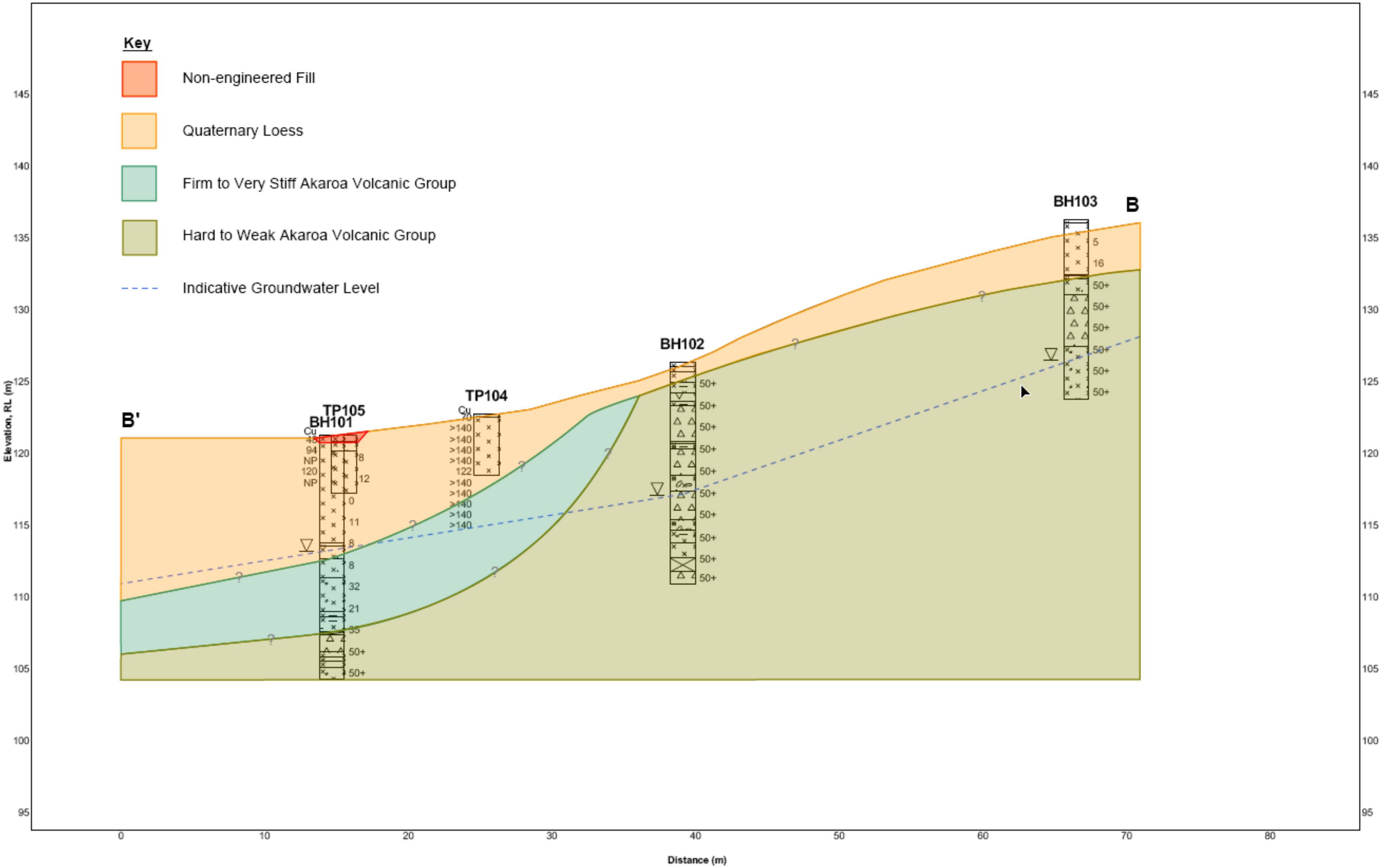

Figure 3b: Cross Section B-B'

(Source: CHBeca, 2014)

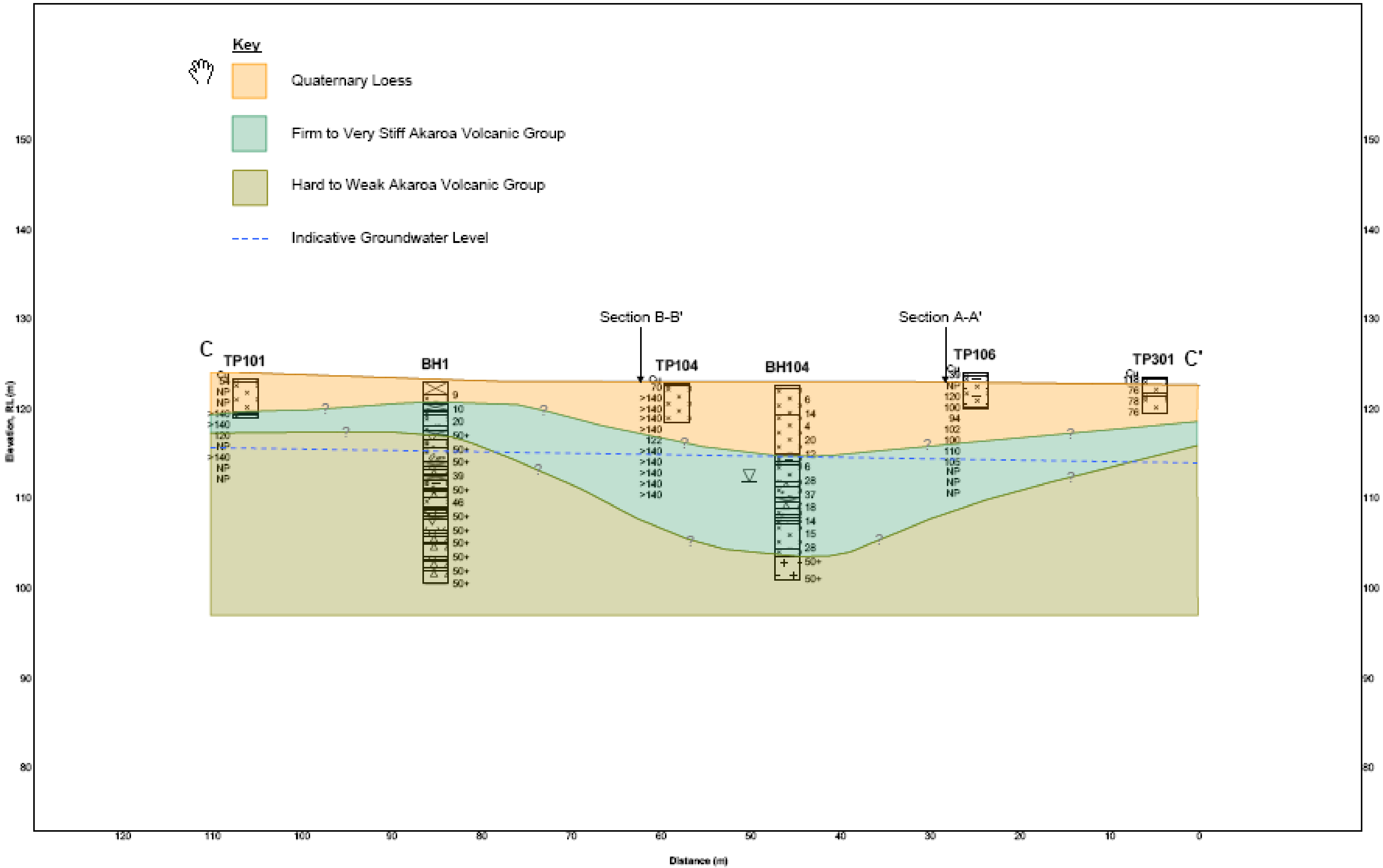

Figure 3c: Cross Section C-C'

(Source: CHBeca, 2014)

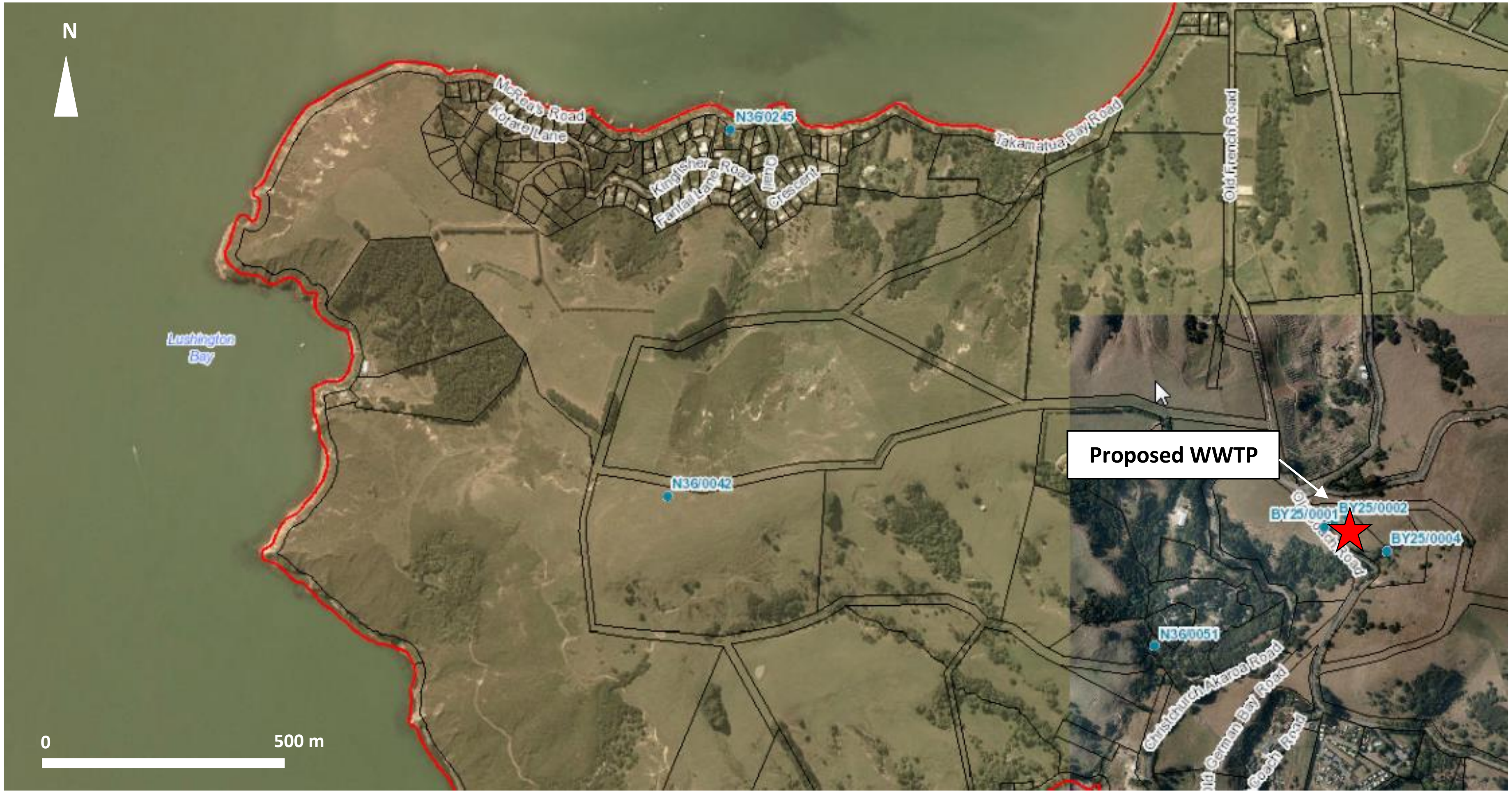

Figure 4: Location of other bores on Takamatua Headland with borelogs
(Source: ECan GIS wells database)

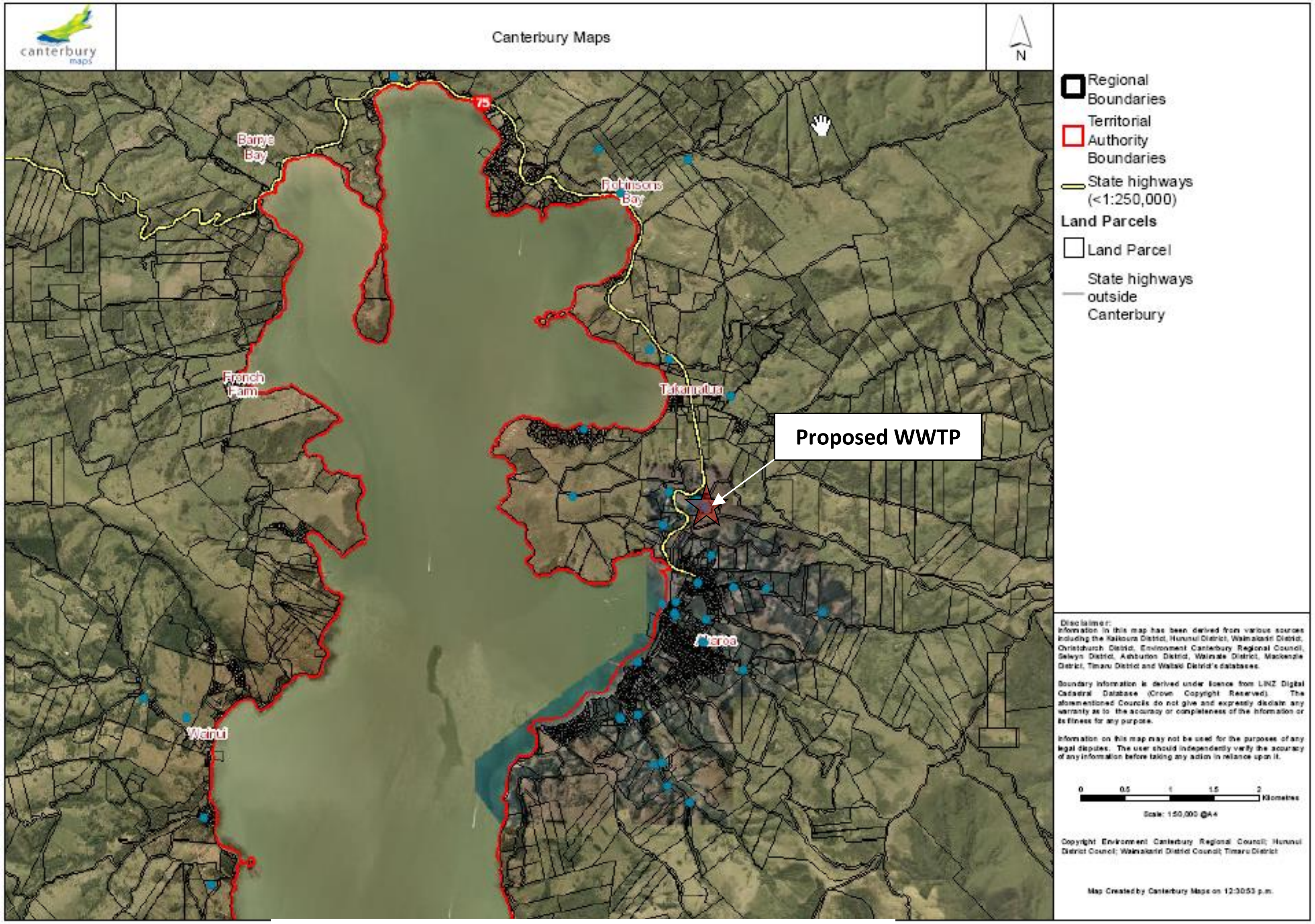

Figure 5: Bores located in vicinity of Akaroa Harbour

(Source: ECan GIS wells database)

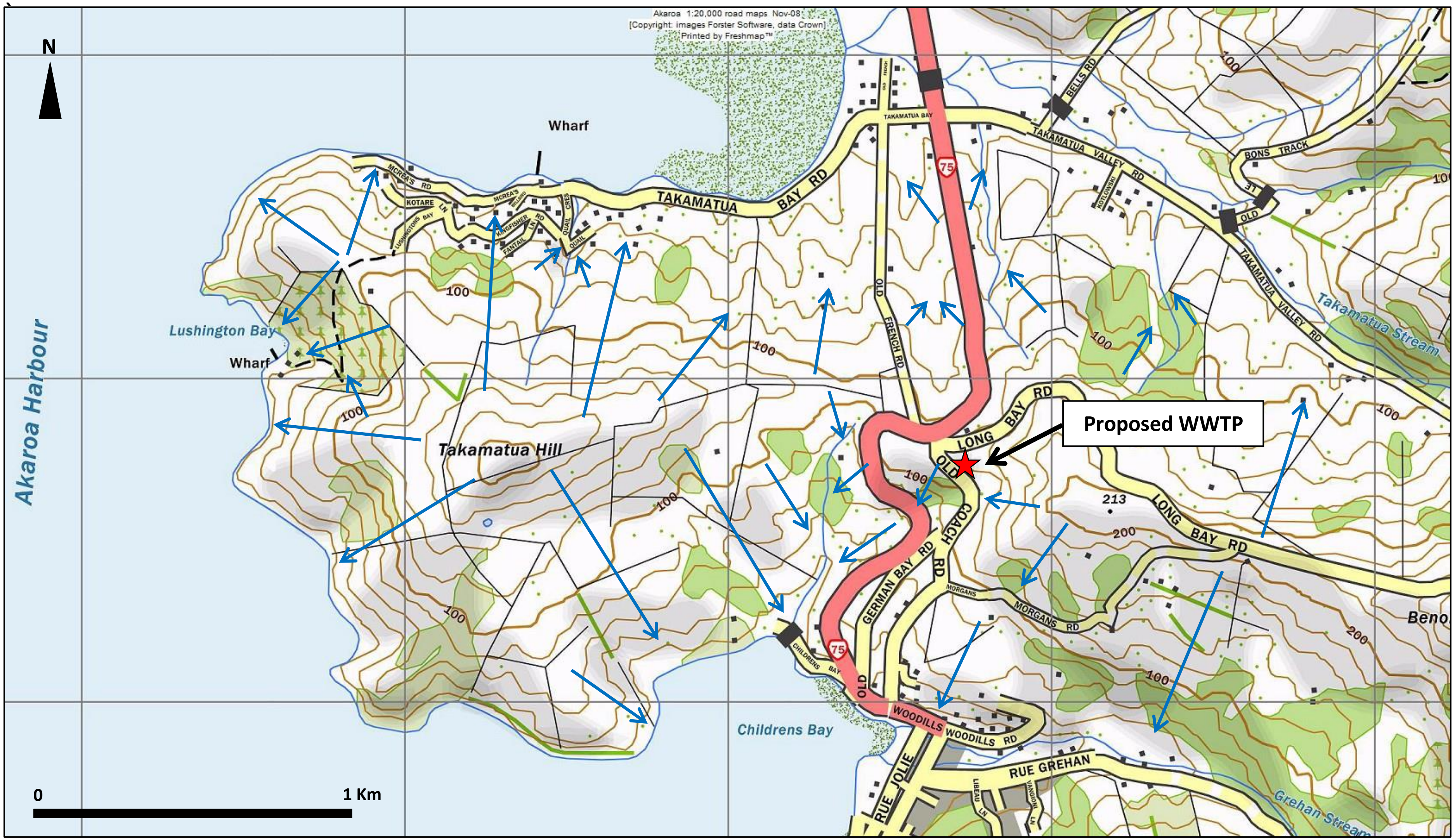

Figure 6: Expected pattern of shallow groundwater flow in vicinity of proposed WWTP

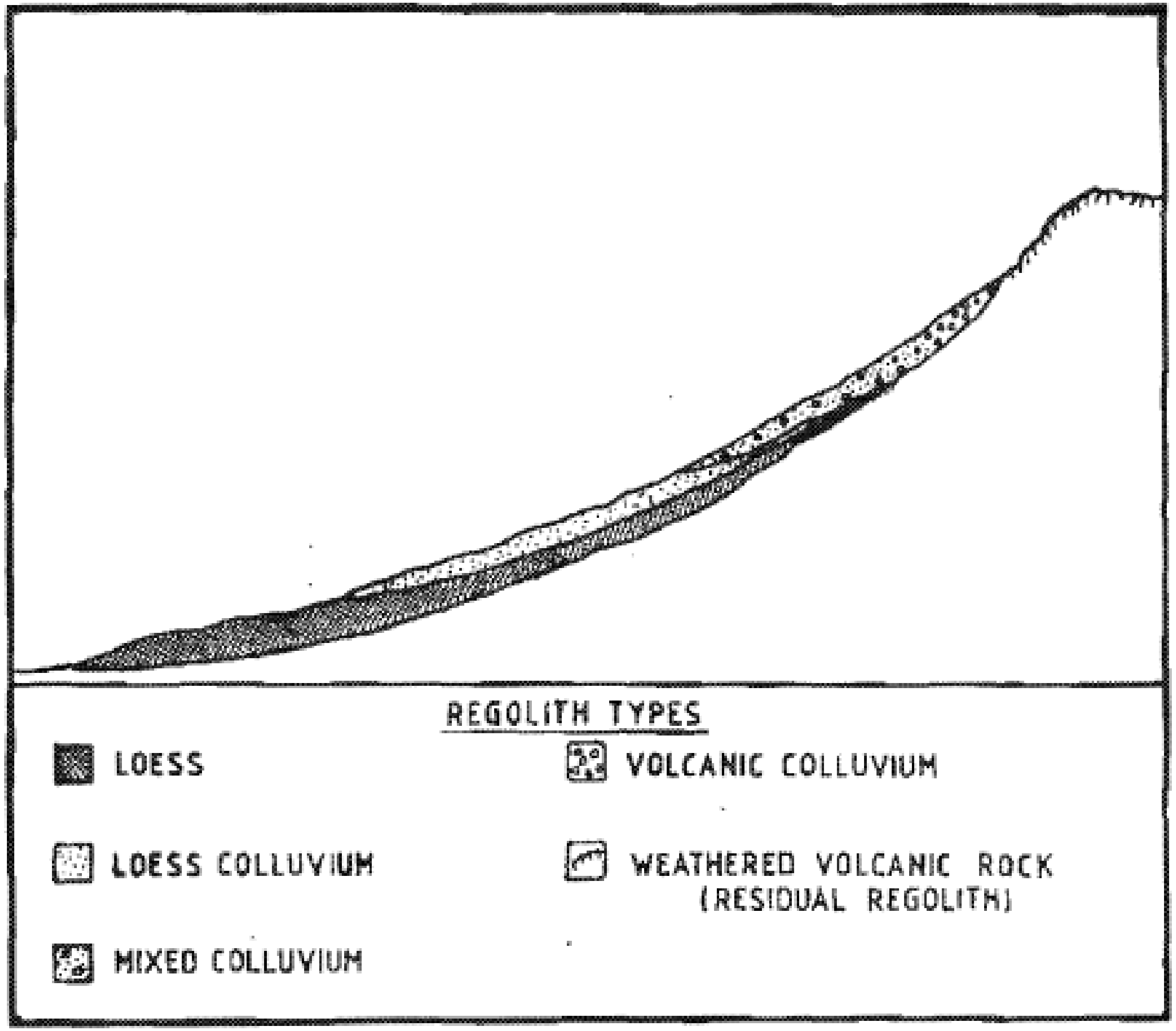

Figure 7: Typical surficial soils expected to be present in vicinity of Takamatua Headland

(Source: Sanders, 1986)

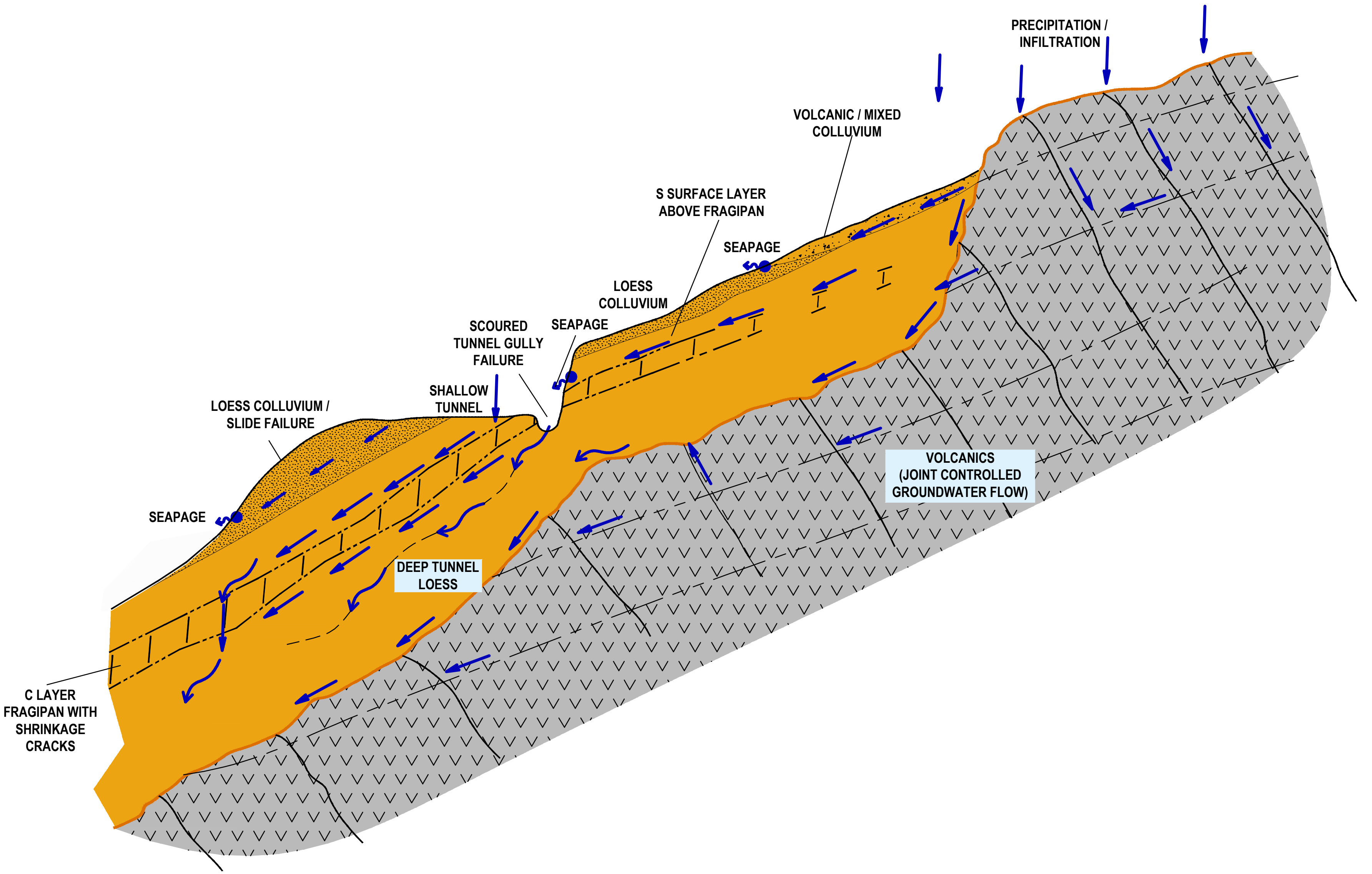

FIGURE 8 : CONCEPTUAL MODEL OF GROUNDWATER FLOW IN LOESS & VOLCANIC SOILS

Appendix B: Borelogs

Bore or Well No: N36/0051

Well Name:

Owner: KIGAN, DR & PF

Environment Canterbury
Your regional council

Street of Well: CHRISTCHURCH AKAROA ROAD

File No: CO6C/15448

Locality: AKAROA

Allocation Zone: Outside

NZTM Grid Reference: BY25:97299-50892 QAR 4

CWMS Zone: Banks Peninsula

NZTM X-Y: 1597299 - 5150892

Location Description:

Uses: Domestic and Stockwater

ECan Monitoring:

Well Status: Active (exist, present)

Drill Date: 09 Mar 1999

Water Level Count: 0

Well Depth: 23.00m -GL

Strata Layers: 4

Initial Water Depth: -10.50m -MP

Aquifer Tests: 0

Diameter: 150mm

Yield/Drawdown Tests: 1

Measuring Point Ait: 32.70m MSD QAR 4

Highest GW Level:

GL Around Well: 0.00m -MP

Lowest GW Level:

MP Description:

First Reading:

Last Reading:

Driller: McMillan Drilling Ltd

Calc. Min. (Below MP):

Drilling Method: Rotary/Percussion

Last Updated: 08 Nov 2013

Casing Material: STEEL

Last Field Check:

Pump Type:

Yield: 2 l/s

Aquifer Type: Joint/fractured rock

Drawdown: 10 m

Aquifer Name: Banks Peninsula Volcanics

Specific Capacity: 0.20 l/s/m

Screens:

Screen No.	Screen Type	Top (m)	Bottom (m)	Diameter (mm)	Leader Length (mm)	Slot Size (mm)	Slot Length (mm)
1	Stainless steel	21	23				

Step Tests:

Step Test Date	Step	Yield (l/s)	Drawdown	Duration (mins)
09 Mar 1999	1	1.9	9.6	1440

Date	Comments
07 Jul 1999	Drilled 200mm well casing to 7.5m. Open holed with 200mm bit to 23m. Installed 175mm screen (2.5mm slot size) & 150mm casing. Gravel packed screen & 150mm well casing. Well construction diagram on back of drillers log.

Aquifer test date(s) where this is the pump bore

Aquifer test date(s) where this is an observation bore

Borelog for well N36/0051

Grid Reference (NZTM): 1597299 mE, 5150892 mN
Location Accuracy: 50 - 300m
Ground Level Altitude: 32.7 m +MSD Accuracy: < 0.5 m
Driller: McMillan Drilling Ltd
Drill Method: Rotary/Percussion
Borelog Depth: 23.0 m Drill Date: 09-Mar-1999

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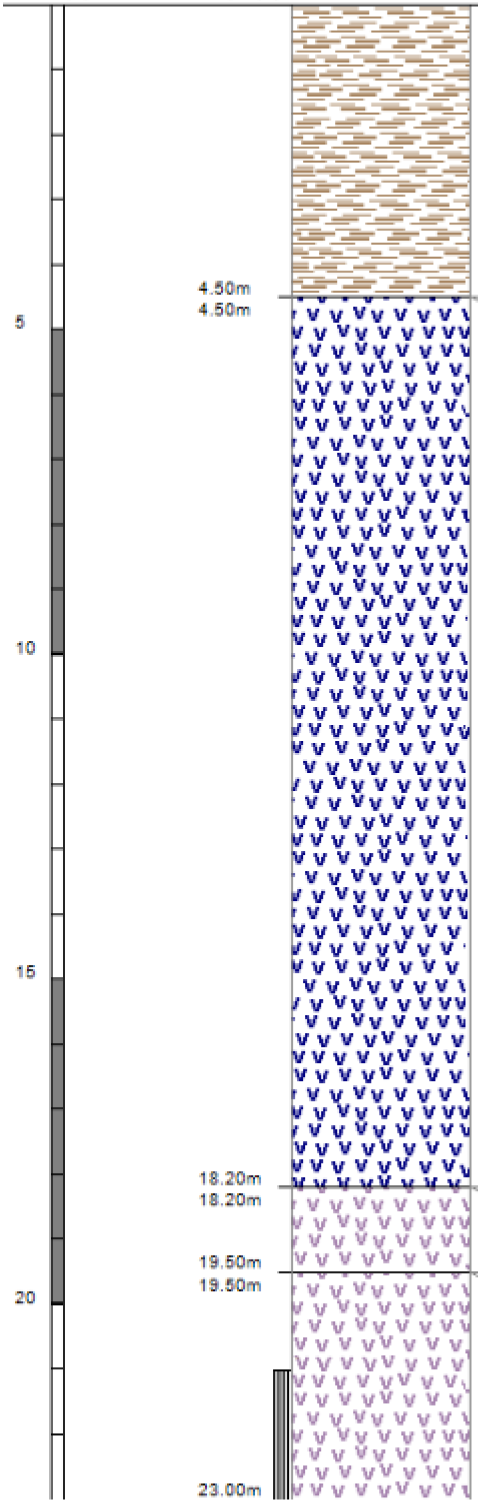


Depth(m)	Full Drillers Description	Formation Code
0 - 4.50m	Brown clay	
4.50m - 18.20m	Blueish/Grey rock - some broken	
18.20m - 19.50m	Broken stained Brown rock	
19.50m - 23.00m	Brown rock	

Bore or Well No: N36/0042
Well Name:
Owner: STUDER, A.

Environment Canterbury
Your regional council

Street of Well: MT DESMOND STATION
File No: CO6C/05114
Locality: TAKAMATUA BAY AKAROA
Allocation Zone: Outside
NZTM Grid Reference: BY25:96289-51201 QAR 4
CWMS Zone: Banks Peninsula
NZTM X-Y: 1596289 - 5151201
Location Description:
Uses: Stock Supply
ECan Monitoring:
Well Status: Active (exist, present)

Drill Date: 01 Oct 1994
Water Level Count: 0
Well Depth: 57.00m -GL
Strata Layers: 16
Initial Water Depth: -41.20m -MP
Aquifer Tests: 0
Diameter: 125mm
Yield/Drawdown Tests: 1

Measuring Point Ait: 198.34m MSD QAR 4
Highest GW Level:
GL Around Well: 0.00m -MP
Lowest GW Level:
MP Description:
First Reading:
Last Reading:
Driller: McMillan Drilling Ltd
Calc. Min. (Below MP):
Drilling Method: Unknown
Last Updated: 08 Nov 2013
Casing Material:
Last Field Check:
Pump Type: Unknown
Yield: 1 l/s
Aquifer Type: Unknown
Drawdown: 7 m
Aquifer Name:
Specific Capacity: 0.09 l/s/m

Screens:

Screen No.	Screen Type	Top (m)	Bottom (m)	Diameter (mm)	Leader Length (mm)	Slot Size (mm)	Slot Length (mm)
1	Slotted Casing	43	57				

Step Tests:

Step Test Date	Step	Yield (l/s)	Drawdown	Duration (mins)
01 Oct 1994	1	0.6	6.9	60

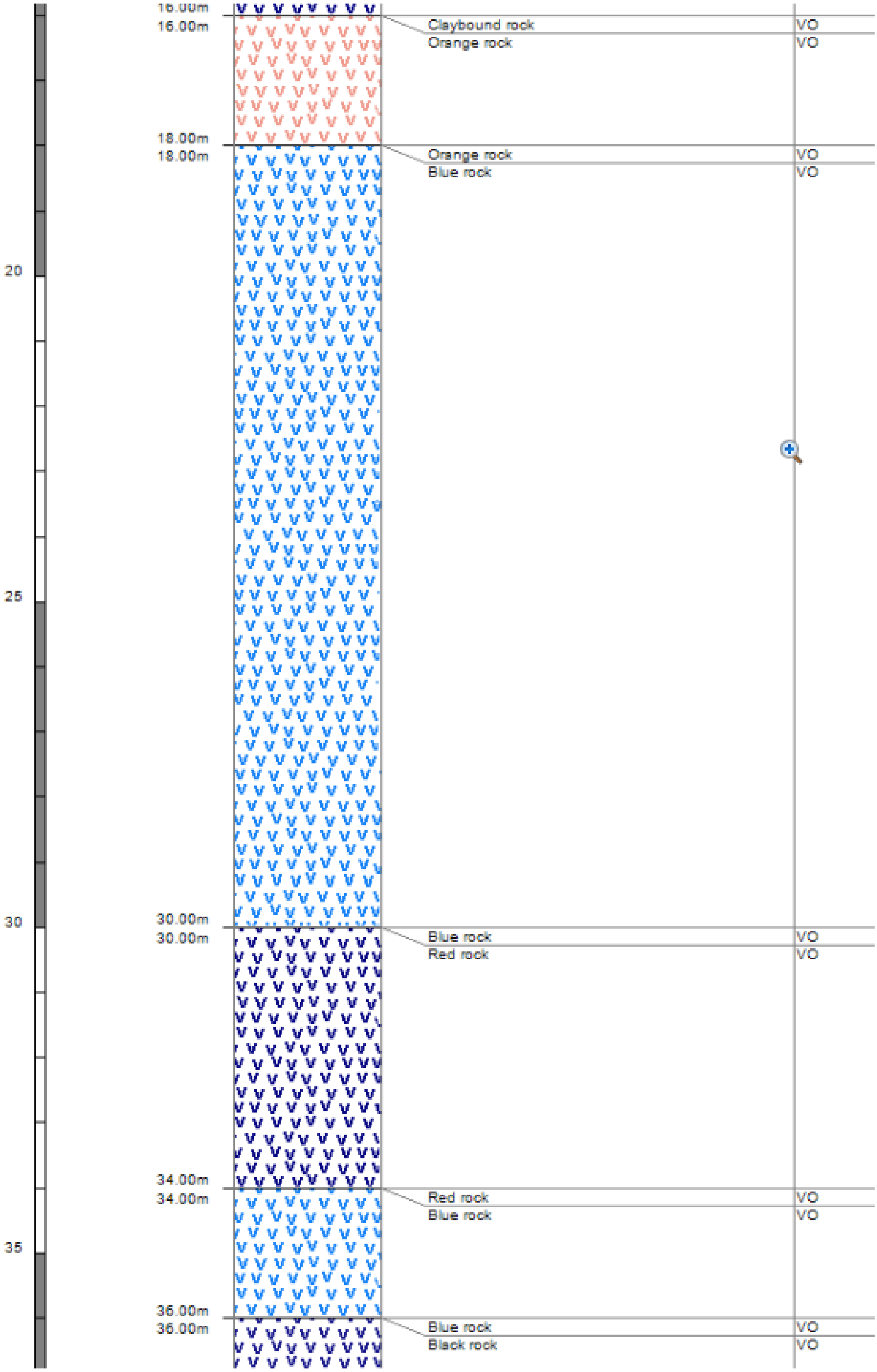
Aquifer test date(s) where this is an observation bore

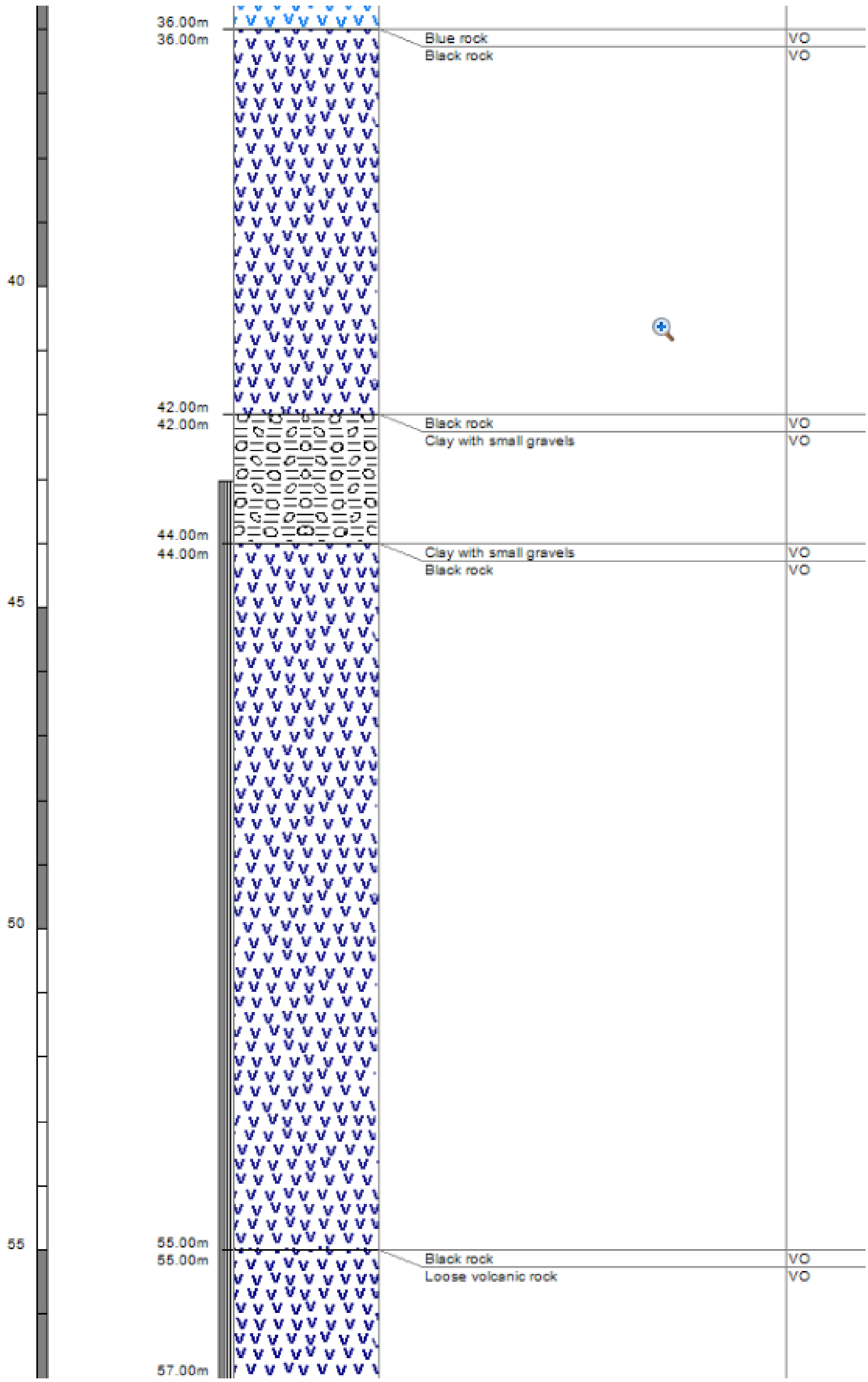
Borelog for well N36/0042

Grid Reference (NZTM): 1596290 mE, 5151202 mN
Location Accuracy: 50 - 300m
Ground Level Altitude: 198.3 m +MSD Accuracy: < 0.5 m
Driller: McMillan Drilling Ltd
Drill Method: Unknown
Borelog Depth: 57.0 m Drill Date: 01-Oct-1994

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
			Earth	VO
		2.00m		
		2.00m	Earth	VO
			Blue rock	VO
5				
		6.00m		
		6.00m	Blue rock	VO
		6.50m	Clay	VO
		6.50m	Clay	VO
		7.00m	Blue rock	VO
		7.00m	Blue rock	VO
			White clay	CO
		9.00m		
		9.00m	White clay	CO
			Grey rock	VO
10				
		11.00m		
		11.00m	Grey rock	VO
			Red rock	VO
		12.00m		
		12.00m	Red rock	VO
			Claybound rock	VO
15				
		16.00m		
		16.00m	Claybound rock	VO
			Orange rock	VO


16.00m
16.00m
Claybound rock
VO
Orange rock
VO
18.00m
18.00m
Orange rock
VO
Blue rock
VO
20
25
30
30.00m
30.00m
Blue rock
VO
Red rock
VO
34.00m
34.00m
Red rock
VO
Blue rock
VO
35
36.00m
36.00m
Blue rock
VO
Black rock
VO


36.00m
36.00m
Blue rock
VO
Black rock
VO
40
42.00m
42.00m
Black rock
VO
Clay with small gravels
VO
44.00m
44.00m
Clay with small gravels
VO
Black rock
VO
45
50
55
55.00m
55.00m
Black rock
VO
Loose volcanic rock
VO
57.00m

Bore or Well No: N36/0245

Well Name:

Owner: MR WESTON

Street of Well:	MC REA'S ROAD	**File No:**	CO9C/55
Locality:	TAKAMATUA	**Allocation Zone:**	Outside
NZTM Grid Reference:	BY25:96420-51962 QAR 4	**CWMS Zone:**	Banks Peninsula
NZTM X-Y:	1596420 - 5151962		
Location Description:		**Uses:**	Geotechnical / Geological Investigation
ECan Monitoring:			
Well Status:	Filled in		

Drill Date:	02 Oct 2008	**Water Level Count:**	0
Well Depth:	5.40m -GL	**Strata Layers:**	2
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:	70mm	**Yield/Drawdown Tests:**	0
Measuring Point Ait:	21.11m MSD QAR 4	**Highest GW Level:**	
GL Around Well:	0.00m -MP	**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:	McMillan Drilling Ltd	**Calc. Min. (Below MP):**	
Drilling Method:	Push Tube	**Last Updated:**	06 Nov 2008
Casing Material:	Not Lined	**Last Field Check:**	
Pump Type:			
Yield:		**Aquifer Type:**	
Drawdown:		**Aquifer Name:**	
Specific Capacity:			

Screens:

Screen No.	Screen Type	Top (m)	Bottom (m)	Diameter (mm)	Leader Length (mm)	Slot Size (mm)	Slot Length (mm)

Step Tests:

Step Test Date	Step	Yield (l/s)	Drawdown	Duration (mins)

Date	Comments
05 Nov 2008	Back filled with bentonite. For ground investigation purposes only. Permitted activity.

Aquifer test date(s) where this is the pump bore

Aquifer test date(s) where this is an observation bore

Borelog for well N36/0245

Grid Reference (NZTM): 1596421 mE, 5151963 mN
Location Accuracy: 50 - 300m
Ground Level Altitude: 21.1 m +MSD Accuracy: < 0.5 m
Driller: McMillan Drilling Ltd
Drill Method: Push Tube
Borelog Depth: 5.4 m   Drill Date: 02-Oct-2008

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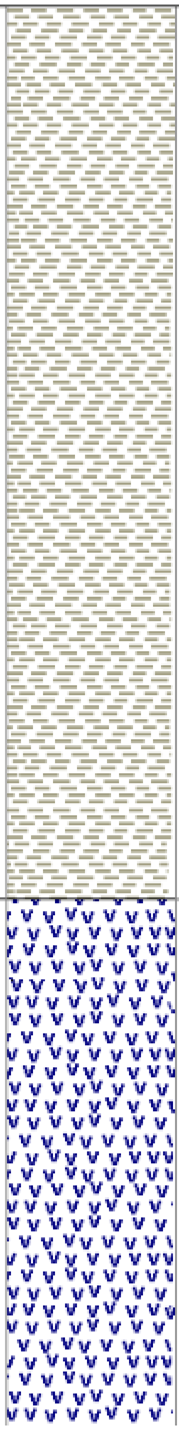

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
			Brown silt (loess)	
1				
2				
3				
		3.40m	Brown silt (loess)	
		3.40m	Residual/high weathered volcanic rock some fragments of moderately weathered rock	
4				
5				
		5.40m		