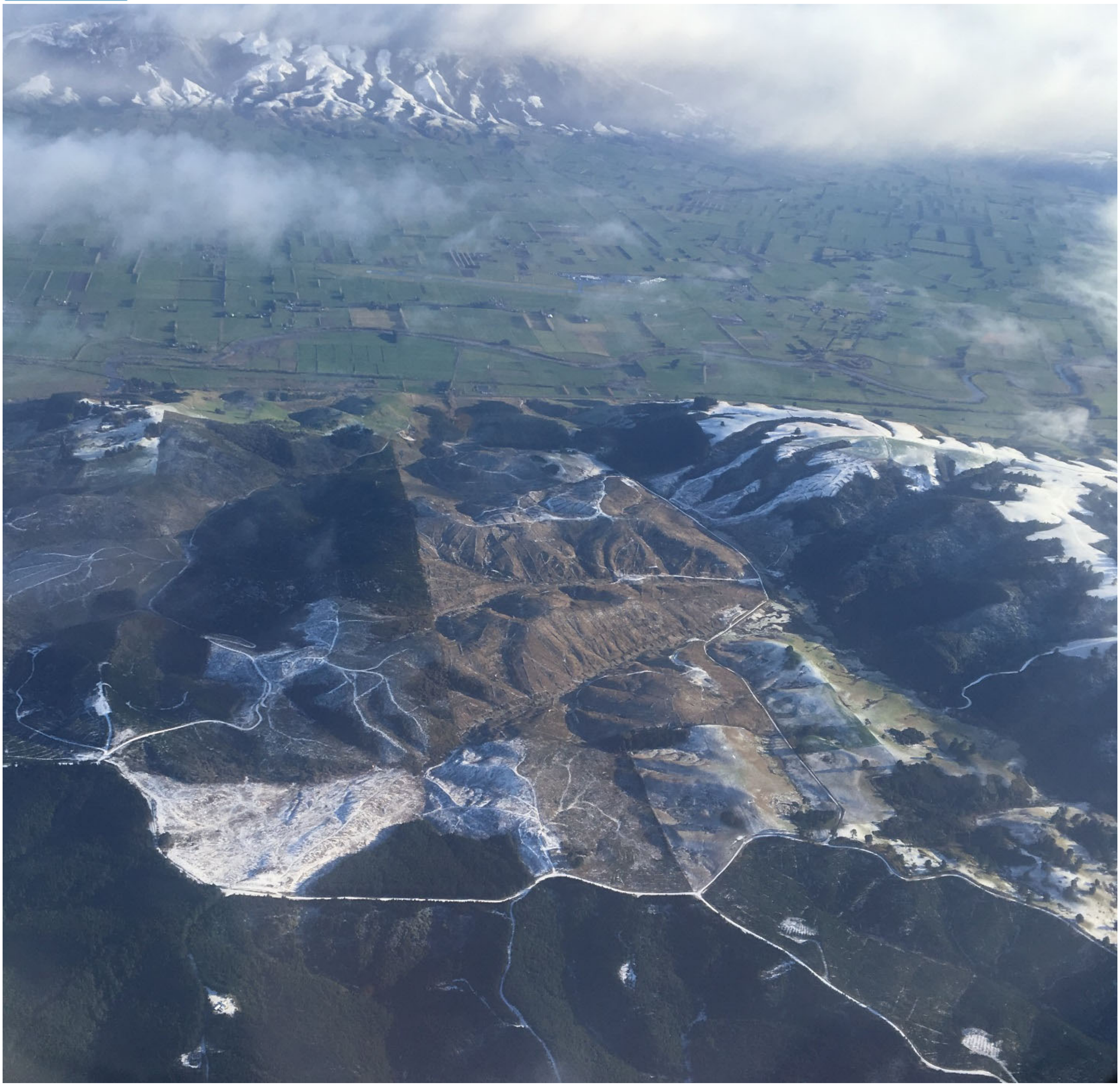
Appendix 8: Groundwater Report



Dunedin City Council

Waste Futures Phase 2 - Work Stream 3. Smooth Hill Landfill Assessment of Effects to Groundwater

August 2020 (Updated May 2021)

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1. Introduction

1.1 Project Background

The Dunedin City Council (Council) collects residential waste and manages the disposal of both residential and most commercial waste generated from the Dunedin City area, and environs. The Council has embarked on the Waste Futures Project to develop an improved comprehensive waste management and diverted material system for Dunedin, including future kerbside collection and waste disposal options. As part of the project, the Council has confirmed the need to develop a new landfill to replace the Council's current Green Island Landfill which is envisaged to reach full capacity in the next few years. Final closure could be around 2028 depending on the closure strategy adopted by the Council. likely to come to the end of its functional life sometime between 2023 and 2028

The Council commenced siting studies for a new landfill location in the late 1980's and early 1990 and selected the Smooth Hill site in south west Dunedin, shown in Figure 1 below, as the preferred locationoption. At that time the site was designated in the Dunedin District Plan, signalling and enabling its future use as a landfill site. The Council also secured an agreement with the thencurrent landowner, Fulton Hogan Ltd, to purchase the land and the Council took ownership of the land in September 2020. Since the 1990's the Council extended the life of Green Island Landfill and further development of the Smooth Hill site has been on hold.

Over the following period the Council extended the life of Green Island Landfill and further development of the Smooth Hill site has been on holAs part of the Waste Future's Project, the Council has reconfirmed the technical suitability of Smooth Hill for the disposal of waste, and has developed a concept design for the landfill and associated road upgrades. The concept design for the landfill has been developed by GHD with technical input from Boffa Miskell, and represents contemporary good practice landfill design that meets adopted New Zealand landfill design standards. The Council is now applying for the remaining RMA authorisations required to enable the construction, operation, and aftercare of the landfill, and construction of the associated roading upgrades.

The Council lodged applications for resource consents for Smooth Hill landfill with both the Otago Regional Council and Dunedin City Council in August 2020. The applications included an earlier version of this report. This report has now been updated to reflect both the changes in the design and in response to s92 questions.

While being similar in many ways to the previous design, the key changes are summarised as follows:

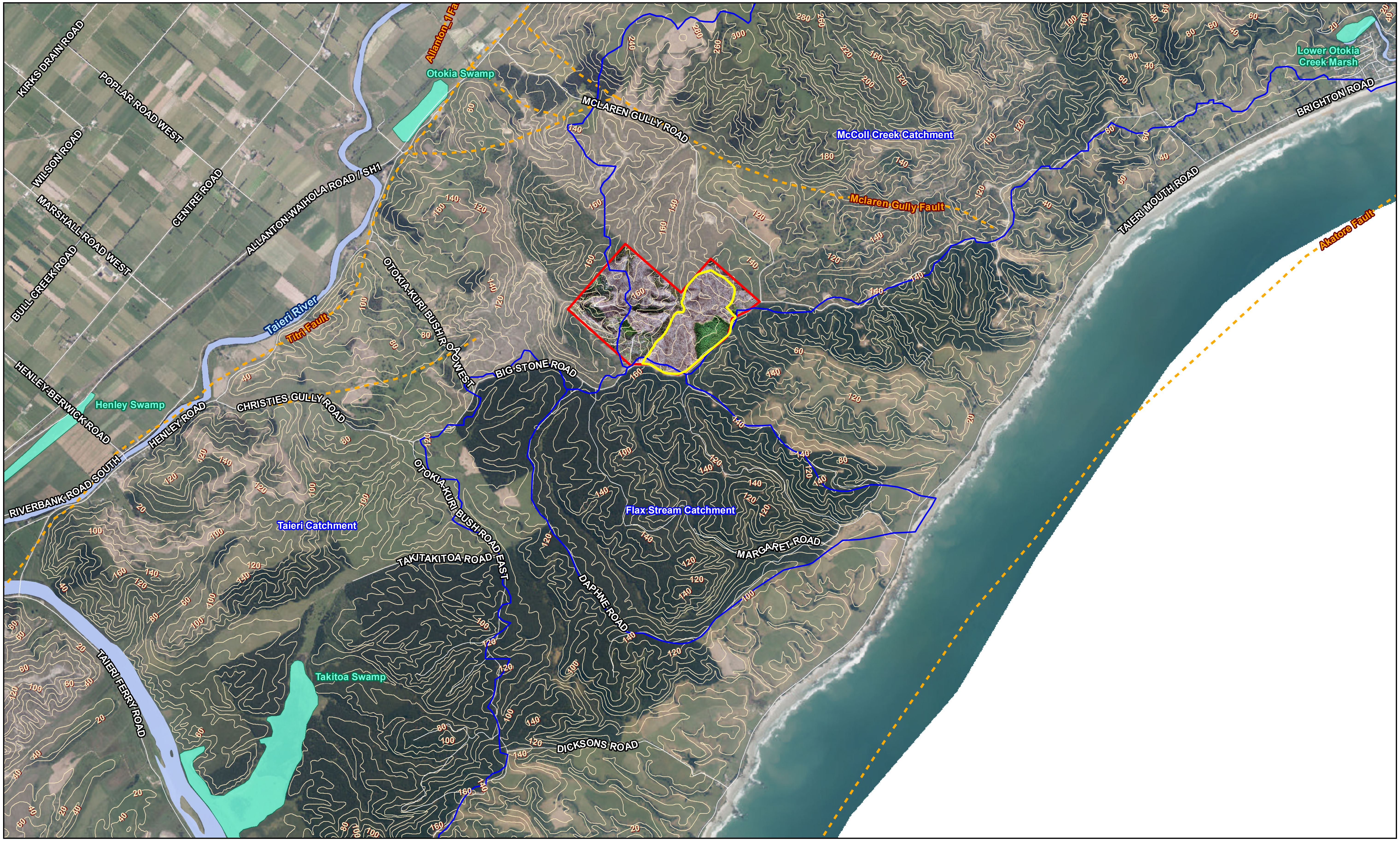
- The landfill size has been reduced. The revised landfill lies within the footprint of Stage 1 and Stage 2 of the original design, with the western Stages 3, 4 and 5 no longer included (for comparison see Drawings C102 and C104. In overall terms:
  - the footprint of the landfill is reduced from 44.5 ha to 18.6 ha
  - landfill (gross) capacity is reduced from approximately 7.9-million m^3 to 3.3-million m^3
  - net waste capacity is reduced from 6.2-million m^3 to 2.9-million m^3
  - the predicted landfill life has reduced from 55-years to 40-years
- Practical adjustments to the general construction of the landfill, including:
  - Landfill staging and construction sequencing, to a more typical 'bottom-up' filling methodology, which improves the intermediate and overall landform stability of the new design (Drawing C210 to C214).

- Leachate containment and collection systems adjusted to reflect the revised construction sequencing.
- Construction phase systems for stormwater diversion, treatment and control.
- Relocation of the attenuation basin to the west of the revised landfill footprint rather than immediately downstream of the landfill toe.

1.2 Project Overview

The proposal includes the following key components:

- ~~The staged construction, operation, and closure of a class 1 landfill within the existing designated site to accept municipal solid waste. The landfill will have a capacity of approximately 6 million cubic metres (equivalent to approximately 5 million tonnes), and expected life at current Dunedin disposal rates of approximately 55 years.~~ The landfill will receive waste only from commercial waste companies or bulk loads.
- Infrastructure to safely contain, collect, manage, and dispose of leachate, landfill gas, groundwater, and stormwater so as to avoid consequential adverse effects on the receiving environment.
- Facilities supporting the operation of the landfill, including staff and maintenance facilities.
- Environmental monitoring systems.
- Landscape and ecological mitigation, including planting.
- Upgrades to McLaren Gully Road (including its intersection with State Highway 1) and Big Stone Road, to facilitate vehicle access to the site.
- The proposed Smooth Hill Landfill site is located approximately 28 km southwest of Dunedin City. The boundary of the proposed site is shown in Figure 1. The waste facility itself will operate within these boundaries.



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- Site boundary
- Landfill operational extent
- Regional catchment boundary
- Significant wetlands
- Major waterways
- Fault
- Contours (20m)

Dunedin City Council
Smooth Hill

Job Number	12506381
Revision	C
Date	19 May 2021

Smooth Hill Site Location

Figure 1

N:\NZ\Christchurch\Projects\51\12506381\GIS\Maps\Deliverables\Hydro\12506381_Z001_Hydro_SiteLocation.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence); General topo - LINZ 2019; Regional catchments and significant wetlands - ORC 2019; Faults - GNS. Created by:jrprice

~~1.2~~1.3 Purpose of this Report

The proposed Smooth Hill Landfill requires resource consents from Otago Regional Council for:

- The ~~taking and~~ diversion of surface water for land drainage of the site, and discharge of stormwater and contaminants to the Otokia Creek (McColl Creek catchment)~~, and Open Stream (Flax Stream catchment)~~.
- Taking of groundwater from the landfill groundwater collection system and use for non-potable water supply.
- ~~The taking of groundwater and leachate from landfill leachate collection system.~~
- Discharge of leachate onto land that may result in contaminants entering groundwater.

This report provides technical assessment of the potential effects on groundwater and connected surface water flows, and the effects of leachate leakage on groundwater quality. It is provided to Otago Regional Council as a supporting document to the application for resource consents for the purpose of assisting Council in decision-making.

Note the potential effects of site stormwater on downstream surface water flows and quality are discussed in the Surface Water Report (GHD 2021d~~0~~) and referenced in this report.

~~1.3~~1.4 Scope of Assessment

GHD carried out site investigation work at the site between May 2019 and ~~November 2019~~March 2021. These works provided information to refine the understanding of geological and hydrogeological conditions in the vicinity of the proposed landfill. The information obtained from the site investigation was also used to carry out an assessment of potential impacts to groundwater and surface water, associated with construction, operation, and aftercare of the proposed landfill at Smooth Hill, Dunedin.

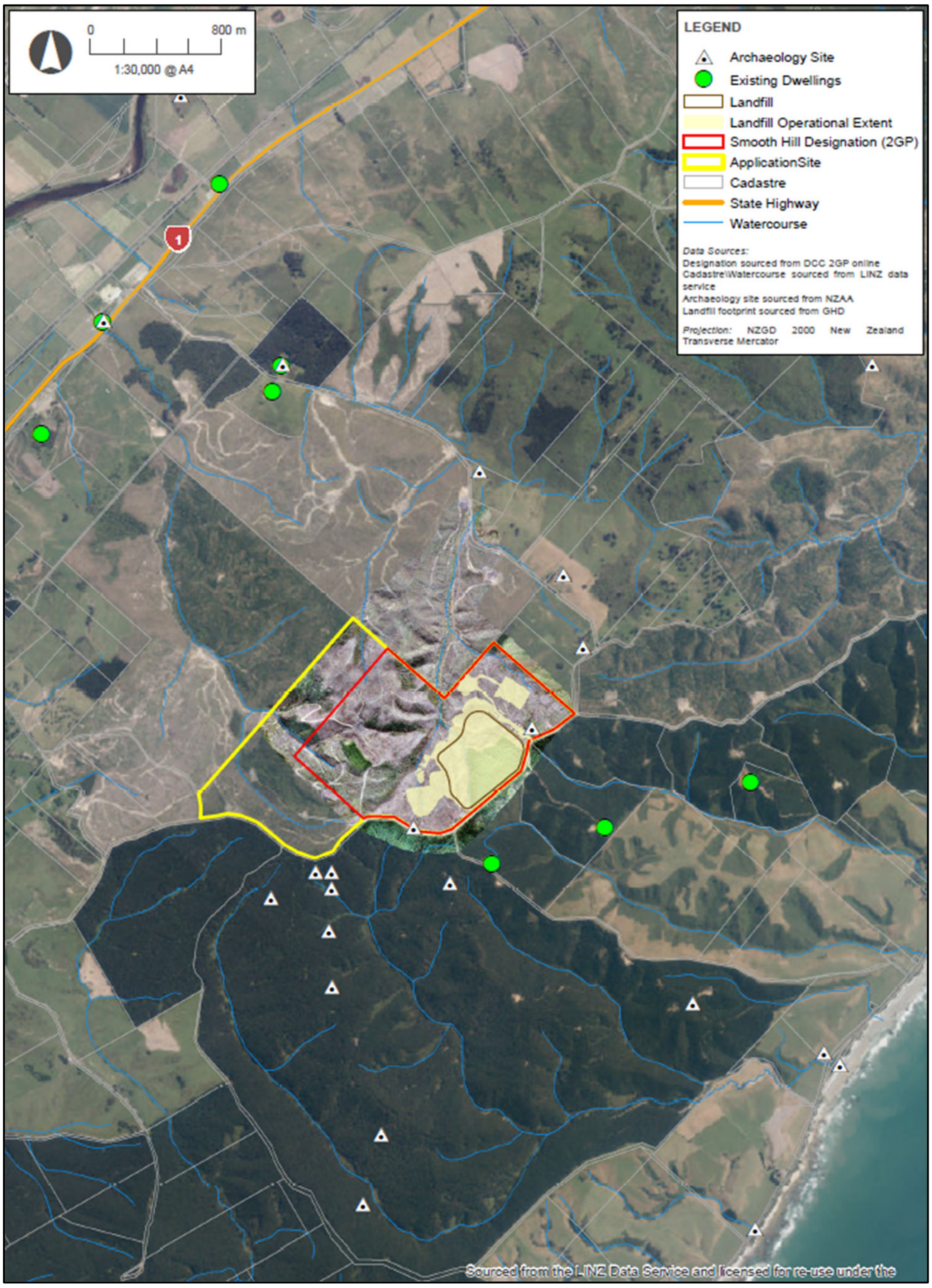
This report outlines the investigation that has been carried out and its findings and provides an assessment of the potential influences of the proposed landfill on groundwater and surface water levels, flow and quality.

2. Environmental Setting

2.1 Site Description

The proposed Smooth Hill landfill site is bordered by Big Stone Road along its southern boundary. Access from State Highway 1 (SH1) is typically via McLaren Gully Road. The site is bounded to the north and west by forestry land and to the northeast by pastoral farmland

Figure 2: Site Layout (Updated May 2021)



The proposed site is located within the range of hills that bounds the Taieri Basin on its eastern extent and separate it from the coast. The site extends across two valleys trending approximately south to north, which are connected to smaller valleys from the east and west. The slopes around the southern half of the site form a natural “amphitheatre” shape, which is bisected by a larger central ridge and a smaller ridge in the south western corner – both trending approximately south to north.

The majority of the site was until recently covered by a Radiata Pine plantation, which following harvesting now comprises a mixture of scrub, bare earth and forestry waste, and newly planted pine seedlings. ~~Approximately 8 ha of Macrocarpa plantation remains in the south eastern section of the site, and A~~areas of remnant native vegetation are present in the bottom of the valleys. A number of existing forestry tracks provide access around the site.

Most of the site and the upper reaches of the gullies are generally dry with ephemeral stream flows during periods of rainfall. Towards the base of the gullies in the northern parts of the site the ground is typically wet and boggy where standing or flowing water has been observed associated with diffuse seepage.

2.2 Geology

A review of the available geological maps (Bishop [1994], and Bishop and Turnbull [1996]) covering the site shows that the main lithology is the Henley Breccia unit (Figure 3). The basement rock in the proposed site area is expected to be Caples Terrane schist (map symbol *IIIA*). The schist basement is overlain unconformably by the Upper Cretaceous Henley Breccia (map symbol *he*), which comprises a terrestrial sequence of piedmont breccias and conglomerates up to 1000 m thick. ~~Taratu Formation (map symbol *ta*) is mapped as outcropping along the tops of several ridgelines to the south and east of the site. Taratu Formation unconformably overlies the Henley Breccia.~~

The Titri Fault is located approximately 3 km north west of the site, which strikes in a north east south west direction. This fault separates the elevated topography in the vicinity of the site from the Lower Taieri Basin, a tectonic depression resting between two major faults, which has been infilled with approximately 300 m of Tertiary and Quaternary alluvial deposits (Rekker and Houlbrooke, 2010) (Figure 1).

Although not shown on the geological map, the Henley Breccia unit is overlain by several metres of loess deposits, and locally by alluvium and colluvium (slip debris). A description of loess soils in Otago is provided in Bishop & Turnbull (1996): *"In the Dunedin map area, such unmapped surficial materials are dominated by loess which, where remobilised, grades into loess colluvium. Loess forms a widespread blanket across most of eastern Otago, particularly near the coast. Loess typically forms a yellow-brown, massive layer or series of layers, mixed at the base with weathered bedrock and overlain by darker organic-rich soil. Columnar jointing and shrinkage cracks are common. Where loess mantles slopes, down-slope creep and alluvial processes have incorporated clasts of weathered underlying material, upslope material, and organic matter to form 'loess colluvium'."*

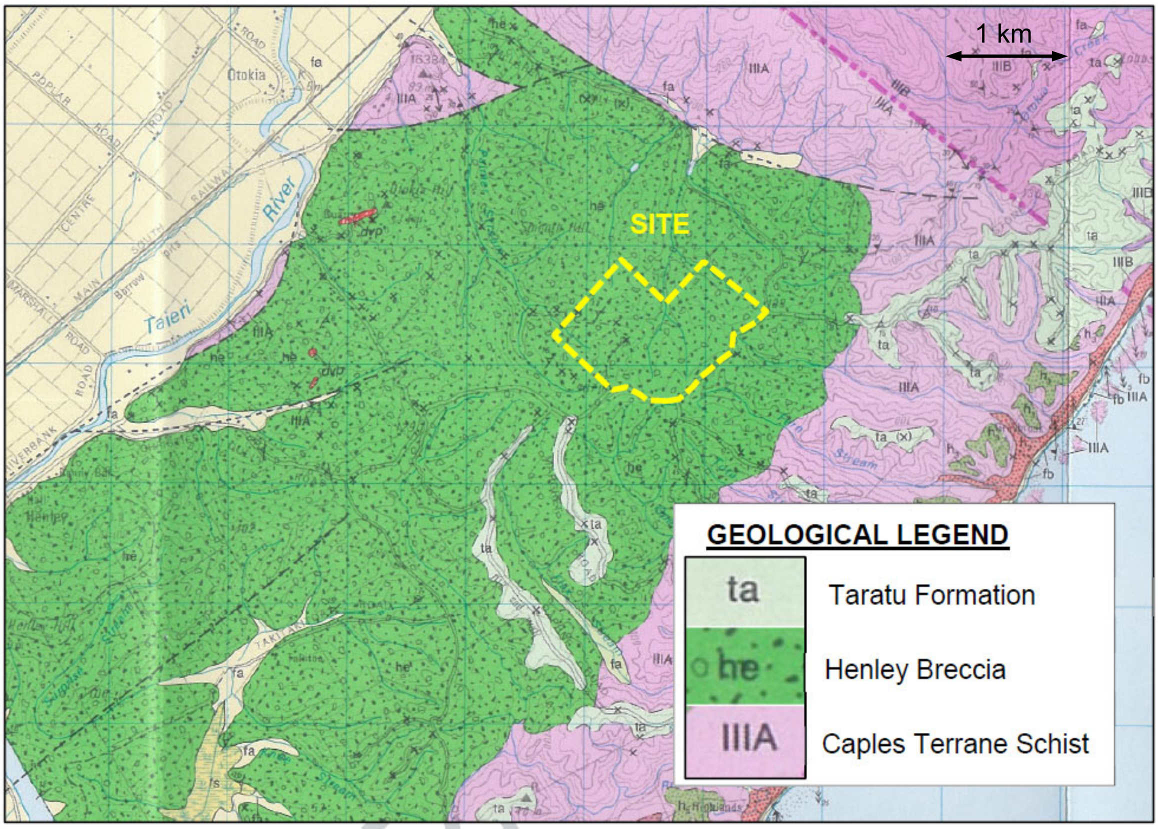


Figure 3: Excerpt from 1:50,000 Geology of the Milton Area (Bishop, 1994)

2.3 Hydrogeology and Hydrology

Otago Regional Council (ORC) designate water allocation regions by surface water catchment and/or aquifer. Due to the limited groundwater resource at the location of the Smooth Hill site, the proposed ~~landfill footprint~~site forms part of the "McColl Creek" surface water allocation catchment (Figure 1 and Figure 4) rather than a defined aquifer system. The catchment has an available allocation of 0.93 L/s and has no recorded active consents (including surface water or groundwater takes) (ORC, 2019). Bounded by Big Stone Road to the south east and by the elevated ridge on the north west, the catchment is approximately 2700 hectares (ha) in area. McColl Creek discharges to the Pacific Ocean at Brighton, with the main tributary referred to as Otokia Creek.

While small sections of the Smooth Hill designation extend into surrounding surface water catchments, the landfill footprint and associated infrastructure will be fully located within the upper reaches of the Otokia Creek catchment~~The proposed Smooth Hill Landfill footprint is located within the upper reaches of the Otokia Creek~~ (Figure 1 and Figure 4). The catchment area for Otokia Creek, immediately downstream of the landfill, ~~the Otokia Creek at the site~~ is approximately 69.2 ha. This ~~, which~~ encompasses the catchments of ~~the two~~ three first order streams, including that located in the landfill footprint~~.~~ ~~whose confluence is located approximately 100 m south of where the stream crosses the northern site boundary~~ (Figure 1 and Figure 4).

~~While almost all of the landfill footprint and related structures/activities will be located within the Otokia Catchment, a small area (approximately 9,000 m^2) of landfill embankment on the southern edge of the landfill is part of the Open Stream surface water catchment located to the south of the site (see Drawing 51-12506381-C303). The Open Stream catchment forms part of the "Flax Stream" surface water allocation catchment (Figure 1 and Figure 4) which is approximately 612 ha in area, and discharges to the Pacific Ocean south east of the Site. The Flax Stream surface water catchment has an available allocation of 0.22 L/s and has no~~

~~recorded active consents (including surface water or groundwater takes) (ORC, 2019). The embankment proposed to be constructed within the Open Stream catchment will comprise clean engineered fill. Waste is not proposed to be placed in this area.~~

The catchment of the deep groundwater system is not considered to be constrained to the topographically defined surface water catchments. Instead, the deep groundwater system likely forms part of a larger, currently undefined, unit within the Henley Breccia in the elevated coastal range between the Taieri Basin and the coast.

The nearest allocation catchment designated for groundwater is the Taieri Catchment, located in the Taieri Basin west of the Titri Fault. This aquifer comprises Quaternary and Tertiary alluvium deposits (ORC, 2019). The closest active groundwater consent is approximately 5.7 km from the site in the Taieri Catchment, at the Dunedin International Airport (Figure 5). This groundwater take is for operation of a ground source heat pump (Consent number RM11.369.01). The Taieri Basin itself is predominantly recharged from three rivers, the Taieri, Silver Stream and Waipori (Rekker and Houlbrouke, 2010). The Henley Breccia was not included in the Otago Regional Council Lower Taieri Basin groundwater allocation study (Rekker and Houlbrouke, 2010) as the impermeable basement rock was not considered to have much potential for significant hydraulic connection.

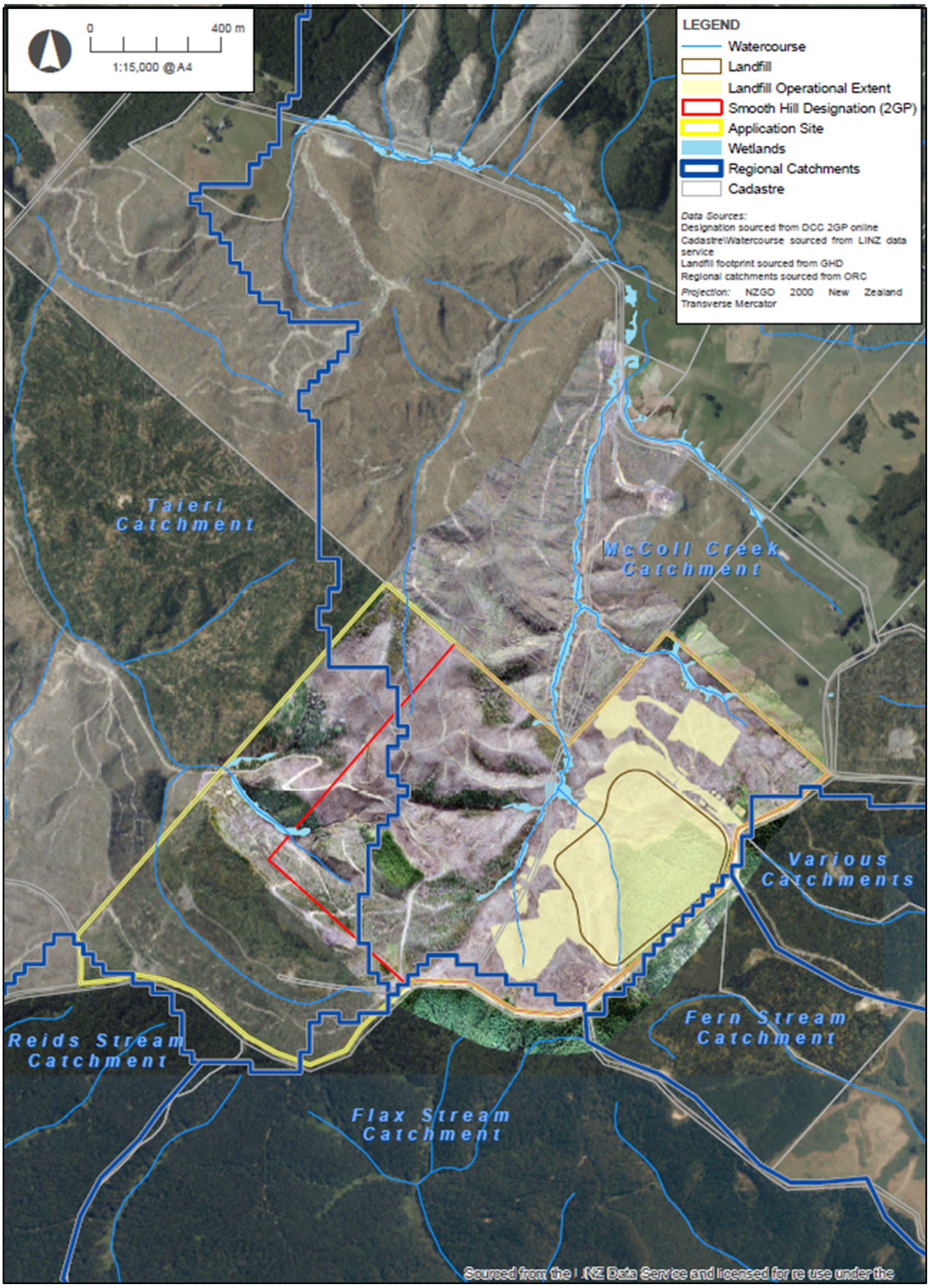
Excluding the Otokia Creek, the nearest surface water features are the Palmer Stream, whose catchment is immediately west of the site, the Taieri River approximately 3.4 km northwest of the site, and the Pacific Ocean approximately 3 km south east of the site.

There are two regionally significant wetlands within the vicinity of the site designated on the ORC mapping tool (2019); Otokia Swamp, located approximately 3.4 km north west of the site adjacent to the Taieri River, and Lower Otokia Creek Marsh, adjacent to McColl Creek approximately 7.6 km north east of the site at Brighton (Figure 4).

Rainfall varies across the region. Annual average rainfall (measured over the period 1981 – 2010) is 652 mm at Dunedin International Airport, approximately 6 km north west of the site, 738 mm at Musselburgh, Dunedin, approximately 23 km north east of the site, and 968 mm at the Botanical Gardens, Dunedin, approximately 25 km north east of the site (NIWA, 2015). It is likely that rainfall at the Smooth Hill site will be greater than the rainfall recorded at the airport due to its elevated coastal location. An on-site meteorological station has been established and has been collecting data since mid-2020. However, at the time of reporting insufficient data has been collected to allow a meaningful analysis of site data and how it may compare to the local established stations described above. Data collected to the time of reporting is presented in Appendix A.

Mean potential evapotranspiration is 856 mm/year at Musselburgh, Dunedin (1981 – 2010), calculated using the Penman method (NIWA, 2015) with this considered indicative of conditions at the site.

Figure 4: Surface Water Catchments **(Updated May 2021)**



Paper Size A3

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- Site boundary
- Landfill operational extent
- Regional catchment boundary
- Registered bores
- Groundwater Take Permit

Dunedin City Council
Smooth Hill

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Bores and Consents

Figure 5

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community); General topo - LINZ 2019; Regional catchments, significant wetlands, wells and consents - ORC 2019. Created by:jrprice

3. Investigation Findings and Interpretation

3.1 Investigation Findings

Two phases of intrusive site investigation were undertaken in 2019, with ten boreholes and eleven test pits advanced between May and June, and an additional five boreholes and 15 bulk samples collected from a number of shallow test pits between October and November 2019. Thirteen of the boreholes were installed as monitoring wells, with ten of these comprising two nested wells. A number of shear vane tests were undertaken in the test pits and samples were collected for geotechnical laboratory analysis. A full summary of the site investigation works is provided in the GHD Geotechnical Factual Report (GHD, 2021a).

Following development, hydraulic conductivity testing was undertaken in all monitoring wells. Due to low groundwater recharge rates and associated issues with collecting representative samples, groundwater quality sampling was only undertaken in a few select monitoring wells in 2019. Continuous monitoring of groundwater levels was undertaken during November 2019, in all monitoring wells which had encountered groundwater for a period of 16 days. Additional continuous groundwater monitoring was undertaken in a select number of monitoring wells between January and July 2020. Manual groundwater dips were also collected during a site visit in March 2021. A summary of the hydrogeological field work undertaken is presented in Appendix A. Bore logs are presented in Appendix B. The boreholes installed as monitoring wells, and an existing monitoring well at the site, that were used for hydrogeological site investigation are presented in Figure 6.

3.2 Geology

A detailed description of the geological investigations undertaken at the site and the interpreted findings are presented in the GHD geotechnical reports (GHD, 20210a; 202001b).

The site investigation findings confirmed the presence of Henley Breccia overlain by surficial loess across the majority of the site and by Taratu formation along elevated ridgelines (Section 2.2). The Henley Breccia is comprised of Upper Cretaceous terrestrial materials deposited during periods of uplift and erosion of a schist block west of the Titri Fault, caused by movement of the associated fault zone. In more recent times this fault has reversed with uplift of the Henley Breccia, resulting in the present coastal range.

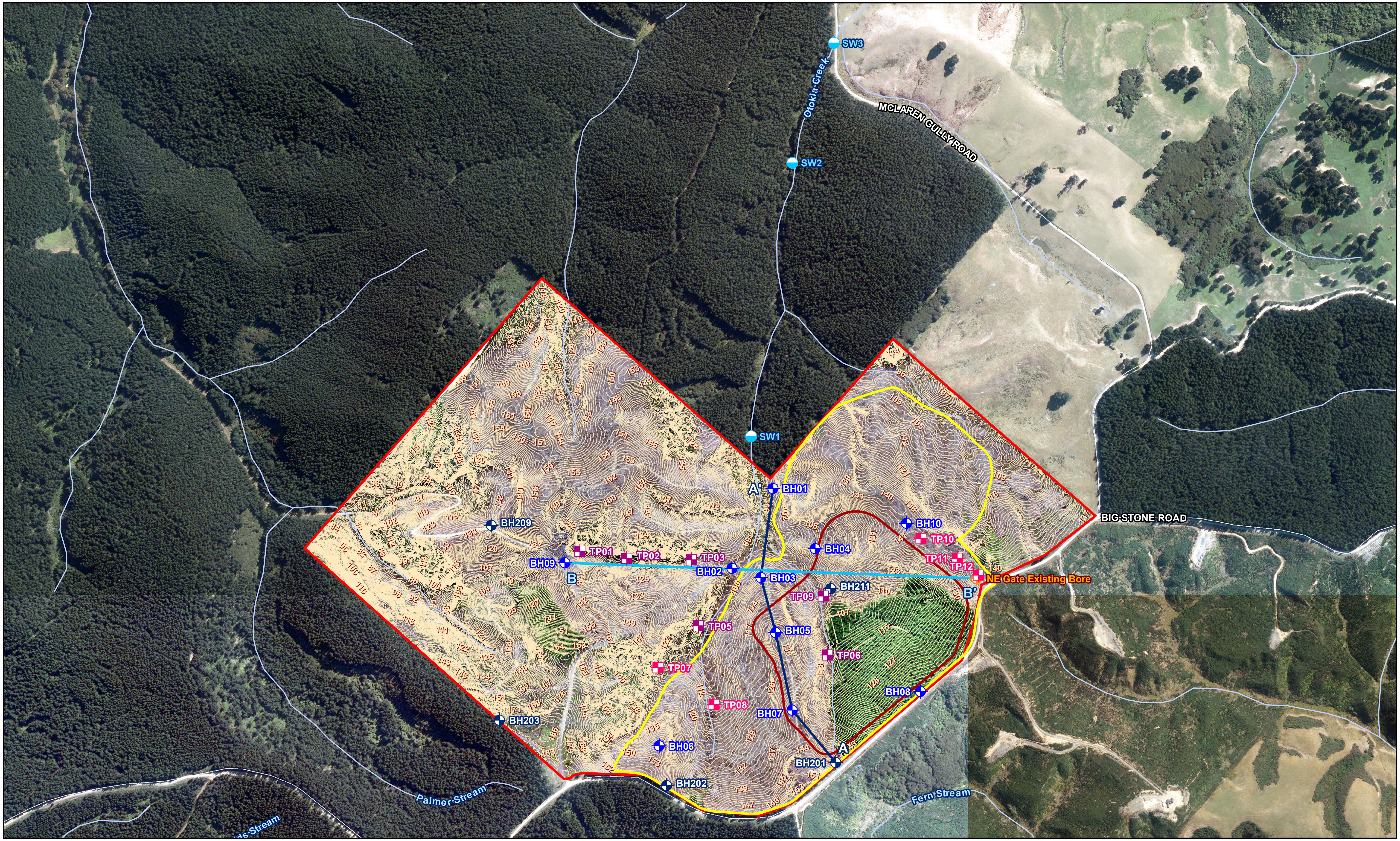
Conceptual geological cross sections from approximately south to north and west to east across the proposed landfill site are presented in Figure 7 and Figure 8, respectively (note that these sections exclude top soil and fill materials). The cross-section locations are shown in plan view in Figure 6.

In summary, a thin veneer of topsoil was found across the majority of the site, comprising silt with trace to minor clay, and occasional trace to minor fine sand, roots and organic matter. The topsoil is predominantly underlain by loess soils on the ridges and upper sections of the valleys. The loess generally comprised silt, non-plastic to low plasticity, with varying amounts of clay, sand and fine gravel. The loess has largely been eroded away in the valley bottoms, with colluvium and alluvium deposits instead located in these topographical low points (Figure 9). The colluvium is made up of reworked loess with gravel and organics, with the silt, sand and gravel alluvium derived from the easily remobilised loess and weathered Henley Breccia.

The underlying Henley Breccia has been encountered as sandstone, siltstone, conglomerate and breccia. Completely weathered to highly weathered Henley Breccia is evident at shallow depths, however with increasing depth it was recorded as unweathered to slightly weathered breccia with few defects. ~~Taratu Formation, comprising weakly cemented, slightly to highly weathered sandstone, siltstone and conglomerate, was encountered overlying the Henley Breccia investigation locations on elevated ridge locations (BH09, BH10, BH203 and BH209).~~

Fill material was identified at the surface at a number of site locations, where it is typically utilised for 'skidder pads' and track formation associated with the recent forestry land use. Shallow slip debris (colluvium) was also located at the surface intermittently around the site. In these locations buried topsoil was encountered, to a maximum depth of 4.4 m below ground level (bgl), beneath the slip debris, and overlying alluvium or loess.

A layer of fine-grained, low permeability material noted for its distinctive reddish brown and brown coloration ~~siltstone layer, possibly a historic lake deposit,~~ was also recorded intermittently across the site in a number of bores within the Henley Breccia~~,~~ at elevations between approximately 95 m RL and 103 m RL (BH03, BH04, BH05 and BH211). A reddish-brown layer was also observed during wash drilling of BH201, however no approximate depth for this layer was recorded. The elevation of ~~the siltstone~~ this low permeability layer indicates that it is likely to have been eroded away at BH01 and BH02 and is therefore not anticipated to be consistent across the whole site.



Paper Size A3

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Metres

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Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Site boundary
- Landfill operational extent
- Landfill liner extent
- Cross section A-A'
- Cross section B-B'
- Phase 1 investigation borehole
- Phase 1 investigation test pit
- Phase 1 trial pit investigation
- Phase 2 investigation borehole
- Surface water sampling locations
- Unknown previous investigation groundwater monitoring well
- Waterways
- Contours (1m)

Dunedin City Council
Smooth Hill

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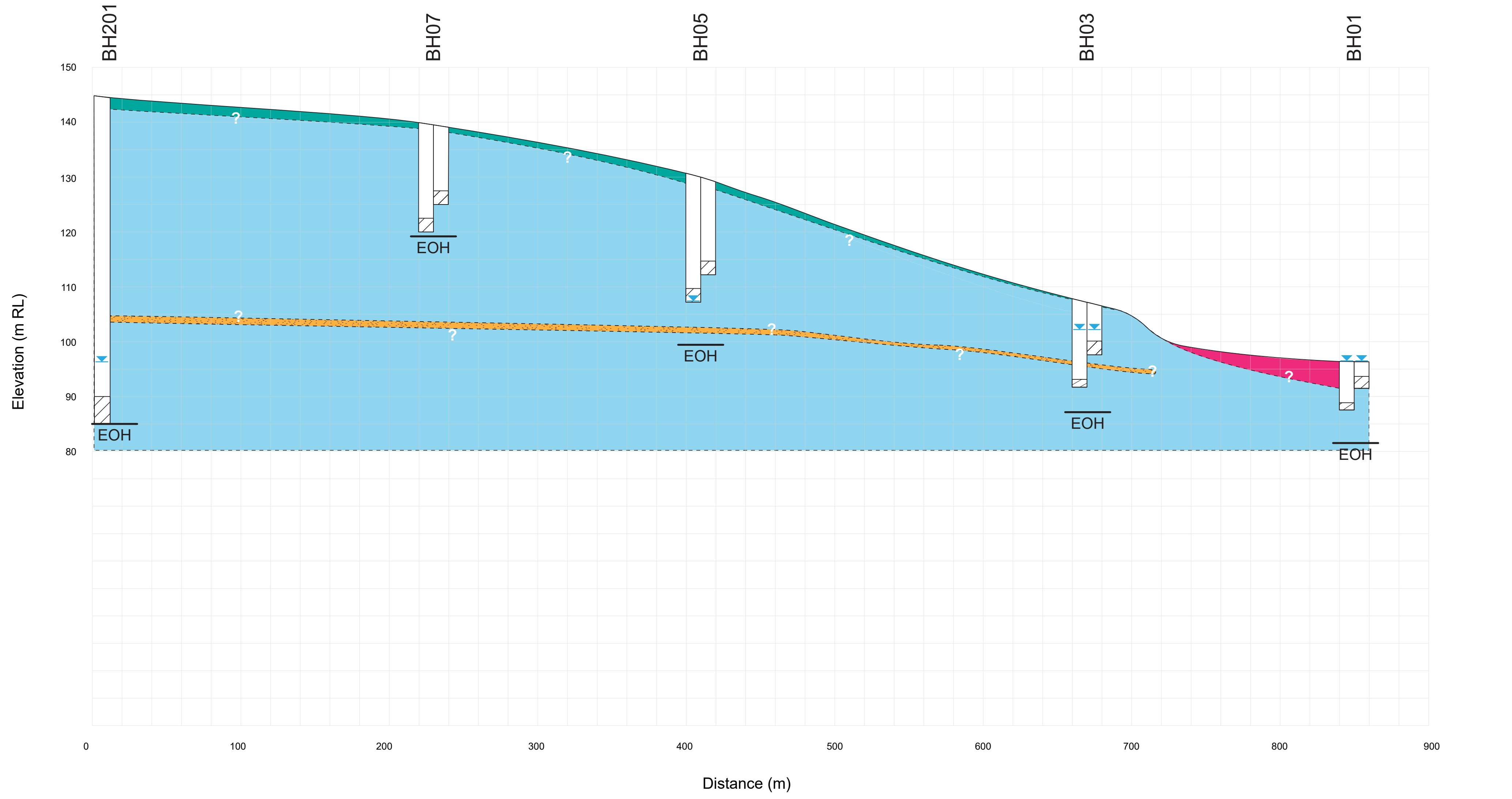
Investigation Location Plan

Figure 6

N:\NZ\Christchurch\Projects\51\12506381\GIS\Maps\Deliverables\Hydro\12506381_Z003_Hydro_InvestigationLocations.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (); General topo - LINZ 2019; Contours - Stantec Created by:jrprice



DRAWING NOT TO SCALE

LEGEND

Loess

Alluvium / Colluvium

Fine-grained Low Permeability Layer

Henley Breccia

Groundwater Level

Borehole

Monitoring Well Screen

Dunedin City Council
Smooth Hill

Job Number 12506381
Revision A
Date 18 May 2021

Cross Section A-A'

Figure 7

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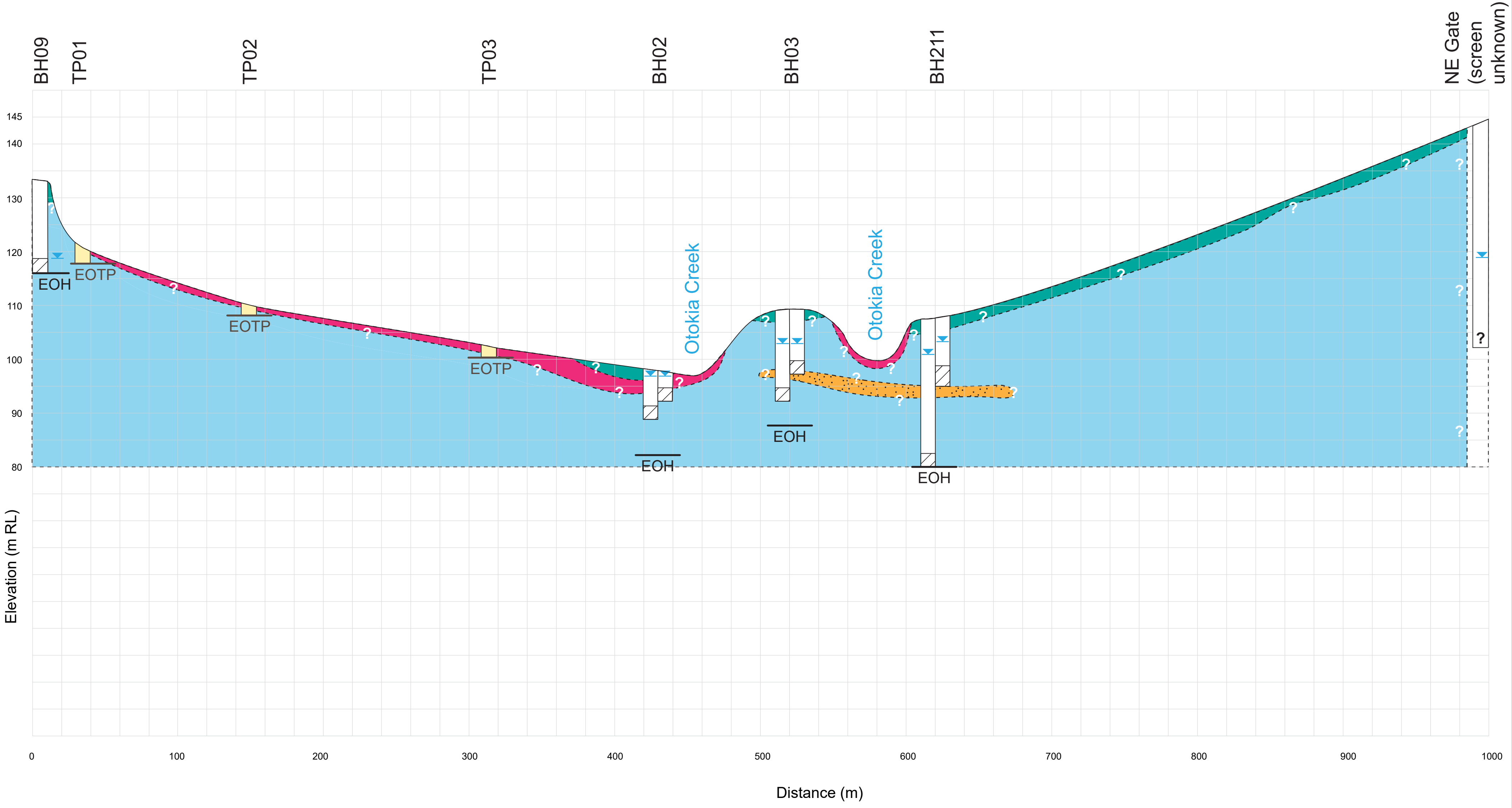
Data source: GHD. Created by:jrprice



DRAWING NOT TO SCALE

LEGEND

- Loess
- Alluvium / Colluvium
- Fine-grained Low Permeability Layer
- Henley Breccia
- Monitoring Well Screen
- Groundwater Level
- Test Pit
- Borehole

Dunedin City Council
Smooth Hill

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Date	18 May 2021

Cross Section B-B'

Figure 8

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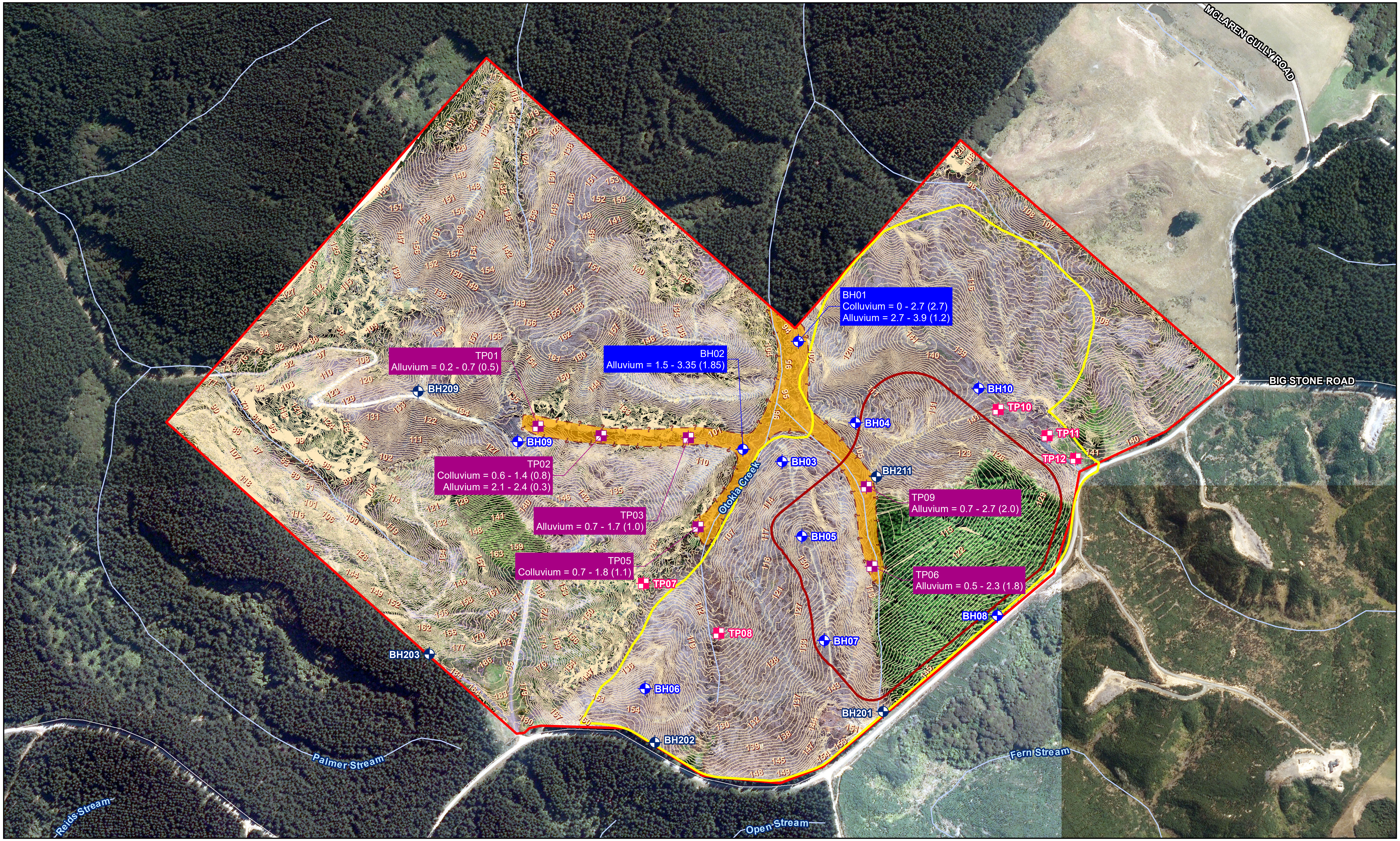
Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com

Data source: GHD. Created by:jrprice



Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Site boundary
- Landfill operational extent
- Landfill liner extent
- Inferred colluvium / alluvium extent
- Phase 1 investigation borehole
- Phase 1 investigation test pit
- Phase 1 trial pit investigation
- Phase 2 investigation borehole
- Waterways
- Contours (1m)

Depth recorded (mbgl)

Colluvium/Alluvium = 0.5 - 1.0 (0.5)

Thickness (m)

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Colluvium / Alluvium Extent

Figure 9

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (); General topo - LINZ 2019; Contours - Stantec Created by:jrprice

3.3 Hydrogeology

3.3.1 Hydraulic Conductivity

Hydraulic conductivity estimates of the differing geological units at the site, determined from hydraulic testing during the site investigation (Appendix A) are presented in Table 1.

Table 1: Estimated Geological Unit Hydraulic Conductivity Ranges

Geological Unit	Hydraulic Conductivity Range (m/s)	Reference/Justification
Alluvium	1.3×10^{-5}	BH01a permeability testing
Loess	$5.3 \times 10^{-10} – 3.2 \times 10^{-8}$	Constant head permeability test in a triaxial cell (Laboratory testing (GHD, 2021~~0~~a))
Henley Breccia	$3 \times 10^{-9} – 3 \times 10^{-6}$	Permeability testing

Testing has suggested a large range of hydraulic conductivity for the Henley Breccia, with a general trend of decreasing hydraulic conductivity with increasing depth evident. Higher permeability results were generally recorded in gravelly or sandstone layers, likely to be the result of weathering and relaxation in the upper materials resulting in greater jointing and fracturing (increased secondary porosity). Lower permeability results were generally recorded in the unweathered breccia (Table A 3 in Appendix A).

3.3.2 Hydraulic Gradients, Groundwater Recharge and Flow

Groundwater Levels and Hydraulic Gradients

Groundwater level monitoring at the site has indicated differing seasonal and rainfall response between shallow and deep monitoring wells. Continuous monitoring results presented in Figure A 3 (Appendix A) demonstrate~~s~~ greater response to rainfall within the shallower BH02A compared to deeper BH02B, resulting in occasional reversal of vertical hydraulic gradients. Recent drought conditions have been recorded at the site, within only 35.4 mm of rainfall occurring between 1 December 2020 – 20 March 2021 (Appendix A). This has correlated with a long term decline in shallow groundwater levels over this period. The greatest groundwater level fluctuation has been recorded in BH03~~a~~A, where the March 2021 level was 1.79 m lower than that recorded in November 2019. Conversely, groundwater levels in deeper monitoring wells have generally recorded more subdued fluctuations. Additionally, groundwater levels in the majority of deeper monitoring wells are recorded to have increased between July 2020 and March 2021. This may be due to a lag time in recovery from more severe drought conditions in early 2020.

As displayed on Figure 7 and Figure 8, the highest static groundwater levels at the site were recorded in BH10B (121.54 m RL), BH09 (120.13 m RL) and the existing monitoring well (NE Gate) (~~118.93~~117.70 m RL)~~ and BH09 (118.22 m RL)~~ located on~~ the~~ elevated ridges (ground level 133 – 145 m RL) in the eastern and western extents of the site~~, respectively~~. These bores are screened at approximate elevations between 103 m RL and 119 mRL, respectively. BH201, although located at similar ground elevation (144 m RL) to the NE Gate bore (145 m RL), is screened at a lower elevation of 90 m RL. The groundwater level recorded within BH201 is approximately~~was~~ 97.12~~5~~ m RL, with the apparent differences in groundwater elevation between wells indicating that downward vertical hydraulic gradients are typically present within the Henley Breccia. This is consistent with the topographical setting, where slow percolation to a deep groundwater system is expected in areas elevated above the broader regional setting.

Groundwater levels in the alluvium at BH01A and Henley Breccia at BH01B were recorded to be very similar to one another and at ground level;, potentially under slightly artesian conditions in November 2019 (Table 2). Vertical hydraulic gradients appear to be changeable at BH02 as groundwater within the nested monitoring wells respond differently to rainfall recharge (Figure A 3). Very minor downward vertical gradients have been consistently recorded within the nested monitoring well installed in the shallow Henley Breccia at BH03. Nested monitoring wells in boreholes BH04 and BH211 have also consistently recorded downward vertical hydraulic gradients (Table 2), with the brown siltstonefine-grained, low permeability reddish brown layer identified in this area, separating the nested -monitoring well screens in boreholes BH03, BH04 and BH211, and likely increasing the vertical gradients at these locations.

The- reddish brown low permeability layerbrown siltstone layer, and decreasing permeability of Henley Breccia with depth, is interpreted as retarding percolation of groundwater. This has resulted in the formation of a localised shallow groundwater system within the alluvium (BH01A and evidenced in the moist to saturated conditions in a number of the test pits included on Figure 9 and the surrounding shallow Henley Breccia above the brown siltstonelow permeability layer (BH02A, BH02B, BH03A, BH04A and BH211A).

Table 2: Vertical Hydraulic Groundwater Gradients (Updated May 2021)

Monitoring Well	Date	Shallow Monitoring Well Groundwater Level (m RL)	Deep Monitoring Well Groundwater Level (m RL)	Screen separation (m)	Downwards Vertical Hydraulic Gradient
BH01	25/11/19	95.96 (BH01A)	95.99 (BH01B)	6.0	- 0.005
BH02	13/7/20	97.47 (BH02A)	96.67 (BH02B)	4.0	0.2
	24/03/21	96.18 (BH02A)	97.12 (BH02B)		- 0.24
BH03	13/7/20	102.71 (BH03A)	102.45 (BH03B)	2.5	0.1
BH04	25/11/20	106.36 (BH04A)	103.54 (BH04B)	5.5	0.51
BH211	28/01/20	104.55 (BH211A)	101.12 (BH211B)	10.5	0.33

Downward vertical gradients are expected to dominate the deeper groundwater system but differences in permeability and dipping of layers of the Henley Breccia is expected to promote some horizontal groundwater movement. Comparison of groundwater levels in screens of similar elevation in the deep groundwater system (BH201, BH202, BH211B), suggest a horizontal hydraulic gradient for the deeper groundwater in approximately a south east direction towards the Pacific Ocean.

Horizontal hydraulic gradients in the localised shallow groundwater system are expected to be more influential and are interpreted to be towards the northwest, following topography towards Otokia Creek. Minor artesian groundwater conditions occasionally recorded at BH01A, BH01B and BH02A, and groundwater seeps observed towards the bottom of the valley during site visits, indicate that the shallow groundwater system discharges to the Otokia Creek. The alluvium and colluvium itself is likely to be recharged from rainfall, run off and groundwater recharge from the shallow Henley Breccia towards the base of the valleys.

Groundwater Recharge and Flow

Groundwater is expected to be recharged at different rates across the site due to the different properties of the surficial materials. Low groundwater recharge rates are anticipated to occur through the low permeability loess materials located on the ridges and valley slopes. Instead, the loess soils are interpreted to promote run-off of excess water generating flow to the base of the valleys, where alluvium and colluvium materials have been deposited. The alluvium and colluvium is inferred to have much higher permeability than the loess and is expected to receive greater recharge directly from rainfall. Runoff generated across the loess soils is also expected to provide additional groundwater recharge through these units.

Groundwater flow from the localised shallow groundwater system within the 69.2 ha local Otokia Creek catchment (approximately at the location of BH01) is calculated using Darcy's Law to be approximately ~~3,600~~3,000 m^3/year (Table 3). Approximately 800 m^3/year of this is considered to be contributed from the valley where the proposed Smooth Hill landfill will be located (Table 3).

Total rainfall across the 69.2 ha catchment ~~area~~ is predicted to be approximately 560,200 m^3/year, when based on an annual average of 809 mm (calculated by the weather generator model (WGEN) in HELP (Appendix C)). This indicates that horizontal flow through the shallow groundwater system is less than 1% of the total rainfall over the catchment area.

Recharge to the deeper groundwater is constrained by the low permeability loess, with the muted groundwater response in deeper monitoring wells to seasonal changes in rainfall, supporting the inference of limited percolation from the shallow groundwater. Given that horizontal flow from the permeable shallow groundwater system is predicted to be less than 1% of total rainfall, recharge to the deep system is considered likely to be no greater than this. As such, ~~Allowing a component of loss to the deeper groundwater system of less than that flowing to the shallow system (given significantly lower permeability and muted response to seasonal changes in rainfall),~~ total recharge of groundwater across the site is expected to be less than 2% of total rainfall.

The catchment of the deep groundwater system is not constrained to the topographically defined Otokia Creek surface water and shallow groundwater system catchments. Instead, the deep groundwater system forms part of a larger, currently undefined, unit within the Henley Breccia in the elevated coastal range between the Taieri Basin and the coast.

Flow has not been estimated within the deep groundwater system as discharge to the Pacific Ocean is considered to be negligible (Rekker and Houlbrooke, 2010).

Table 3: Estimated Groundwater Flow in Shallow Groundwater System (Updated May 2021)

Parameter	Adopted Value	Justification
69.2 ha Otokia Creek catchment		
Area (A)	650 m^2	Saturated aquifer thickness = 6.5 m (Difference between groundwater level (103.3 m RL) and top of fine grained low permeability layer at BH03 (96.8 m RL))
		Aquifer width = 100 m (Approximate width of valley at location of BH01 where alluvium is anticipated)
Hydraulic Conductivity (K)	6.6 x 10^{-6} m/s	Average based on maximum recorded Henley Breccia permeability (BH02A) and alluvium permeability (BH01A) during hydraulic testing.
Hydraulic Gradient (i)	0.022	Average change in head = 4.4 m (Head difference between BH01 and BH02 = 1.5 m. Head difference between BH01 and BH03 = 7.3 m)
		Distance = 200 m (Approximate distance between BH01 and BH02/BH03)
Discharge (Q)	2,976 m^3/year	$Q = AKi$ Darcy's Law
Proposed Smooth Hill Landfill sub-catchment		
Area (A)	96 m^2	Saturated aquifer thickness = 3.0 m (Estimated based on groundwater levels at BH02A, BH01A and TP09, and top of fine-grained low permeability layer)
		Aquifer width = 32 m (Approximate width of valley at toe of proposed landfill where alluvium is anticipated)
Hydraulic Conductivity (K)	1.3 x 10^{-5} m/s	Hydraulic testing of alluvium (BH01A)
Hydraulic Gradient (i)	0.02	Change in head = 4.0 m (Estimated head difference between toe of landfill and BH01)
		Distance = 193 m (Approximate distance between toe of landfill and BH01)
Discharge (Q)	787 m^3/year	$Q = AKi$ Darcy's Law

3.3.3 Groundwater and Surface Water Quality

Groundwater quality sampling was undertaken at the site ~~between 6 and 25~~in November 2019 and March 2021. Surface water quality sampling was undertaken in July 2020. Surface water sampling was also scheduled to be undertaken in March 2021 however samples were not collected as -the majority of the stream was dry during this time, with only stagnant isolated pools of water present. The groundwater and surface water results are compared against the ANZG (2018) 95% freshwater protection criteria and the Otago Regional Plan Discharge Threshold (2016) for nutrients as presented in Table A 5 in Appendix A. Nitrate-N concentrations at BH01A (10.8 - 26.7 mg/L), BH03A (4.32 mg/L), BH03B (4.35 mg/L) and BH201 (3.37 mg/L) were recorded to exceed the Otago threshold of 1.0 mg/L. All other bores recorded nitrate-N at concentrations less than 0.~~1~~6 mg/L. The ammonia as N concentrations were also recorded to exceed the Otago Regional Plan threshold of 0.2 mg/L at BH02B (0.27 mg/L), BH03B (0.36 mg/L), BH04B (0.28 - 0.37 mg/L), BH201 (1.61 – 2.59 mg/L), BH209 (0.3 mg/L) and BH211B (0.36 mg/L).

Davis (2014) reported that application of fertiliser at a forestry plantation in Ashley, Canterbury, increased nitrate-N concentrations to a maximum recorded concentration of 39.3 mg/L in the root-zone soil drainage water. However, it should be noted that this concentration was recorded prior to any dilution in groundwater. The Ashley plantation site had pallic soils, which are typically derived from loess. David (2014) also reported that harvesting, as has occurred recently at the Smooth Hill site, can lead to a short-lived increase in leaching loss of nitrate-N.

It is interpreted that the greatest concentrations of nitrate-N, recorded within BH01A, have resulted from runoff from the site recharging into the shallow alluvium. The elevated ammoniacal-N concentrations in BH201, where groundwater is 46.45 mbgl, indicates that the influence of inorganic nitrogen has been present at the site for an extended period of time, given the low permeability and low percolation rates within the Henley Breccia.

Anaerobic groundwater conditions are inferred in the monitoring wells installed in borehole BH02, as indicated by elevated concentrations of iron and low concentrations of sulphate. Dissolved oxygen (DO) concentrations and the oxidation reduction potential (ORP) were also low in BH02 during monitoring, with DO ~~recorded between~~as low as ~~1.86 and 2.51~~0.58 mg/L, and ORP ~~between +59.2 and~~as low as -23.3 mV (Table A 4 Appendix A). This has likely resulted in elevated ammoniacal-N relative to other inorganic nitrogen, with ~~-~~any nitrate-N in groundwater at the location being preferentially used by microbes under the reducing conditions. Reducing conditions are also inferred to be present in monitoring wells BH201 and BH04B given the low concentrations of sulphate, and the presence of ammoniacal-N.

Trace metals in groundwater were measured at concentrations above the ANZG water quality criteria in seven locations for copper, five locations for nickel, eight locations for zinc and one location for cadmium. The elevated concentrations of soluble trace metals is interpreted to be a function of the reducing conditions apparent in groundwater across much of the site.

The relatively consistent water chemistry in the nested monitoring wells at boreholes BH02 and BH03 support inference of downward percolation of water in the Henley Breccia. Likewise, the differences in key parameter concentrations measured at the monitoring wells in boreholes BH04 and BH211 suggests the fine-grained low permeability ~~brown siltstone~~ layer located between these two screens retards downward percolation to some extent, despite the downward vertical hydraulic gradient.

The difference in parameter concentrations at monitoring wells BH01A and BH01B, with higher concentrations of nitrate-N in BH01A, are expected to reflect the lack of downward water movement in the valley floor.

No exceedances of the adopted water quality criteria were recorded within surface water samples at SW1 and SW2. Surface water sampled at SW3 recorded one exceedance of the ANZG criteria for copper (Table A 5 in Appendix A). It is noted that approximately 40 mm of rainfall was recorded in Musselburgh, Dunedin (Agent 15752) over the 7 days prior to the samples being collected on 6 July 2020 (NIWA, 2021). It is considered likely that the surface water samples are not representative of groundwater baseflow to the Otokia Creek and mostly comprise stormwater runoff and interflow.

3.4 Surface Water Interactions

An upper branch of the Otokia Creek originates within the site boundary at Smooth Hill. This stream was observed to be flowing during a number of site visits in winter and spring 2019, and winter 2020, however was not flowingconfirmed as ephemeral in the vicinity of the proposed Smooth Hill landfill footprint during site visits in January 2020 and March 2021 as far north as the culvert beneath McLaren Gully Road. Site observations in spring 2019 during the summer months indicate that when the stream is flowingstream flow through the culvert underadjacent to McLaren Gully Road the flow is less than 10 litres/second.

Minor artesian groundwater levels were recorded during November 2019 at the base of the valley in the alluvium at BH01A and in the Henley Breccia at BH01B and BH02A, indicating that Otokia Creek baseflow is in part contributed to from groundwater derived from the site. During rainfall events, the low permeability of the loess is expected to result in relatively high runoff, flowing directly to the Otokia Creek, or recharging the relatively permeable alluvium at the base of the valley either as interflow or groundwater proper. The high runoff, and recent harvesting of forestry at the site, is also likely to result in high sediment loading within the runoff, some of which is expected to be discharged to the Otokia Creek.

During dry conditions (observed in January 2020 and March 2021), shallow groundwater levels drop below the Otokia Creek stream bed in the base of the valley near the site, with perennial baseflow not present until much further downstream (beyond the McLaren Gully road culvert).

~~As discussed in Section 2.3, a small section of the site (approximately 9,000 m^2) lies within the Open Stream surface water catchment south of the site. Construction of an embankment comprised of engineered clean fill will be undertaken in this area, with no placement of waste proposed. A catchpit at the edge of the landfill boundary with Big Stone Road will convey runoff from this area through a culvert which will discharge to the Open Stream catchment (see Drawing 51-12506381-C302).~~

3.5 Conceptual Hydrological and Hydrogeological Model

The current understanding of the groundwater and surface water at the proposed Smooth Hill landfill site is that a localised shallow groundwater system is present as a function of the distribution of permeable alluvium and weathered Henley Breccia within the topographical lows of the valleys. This shallow system supports groundwater levels near the surface in the valley floor and contributes baseflow to the downstream perennial sections of the Otokia Creek. Low rates of infiltration through the loess and seepage from the shallow system to the deeper low permeability unweathered Henley Breccia occurs, with this slow downward percolation constituting the deeper groundwater system.

3.5.1 Deep Groundwater System

Groundwater within the Henley Breccia is subject to vertical downwards hydraulic gradients with minor rainfall recharge occurring through the low permeability loess materials that overlie the breccia across the majority of the site.

It is not known where the groundwater divide occurs in the elevated coastal region between the Titri Fault and the coastline, however if this follows topography it is expected the divide is located along the north south trending ridgeline in the western portion of the site designation between Big Stone Road and McLaren Gully Road. Under this assumption groundwater within the deep system to the east of this ridgeline would flow to the south east and discharge towards the coast. ~~It is anticipated that groundwater recharge at the small section of site that lies within the Open Stream surface water catchment forms part of the deep groundwater system south of Big Stone Road that flows south east towards the coast.~~

Groundwater quality of the deep groundwater system ~~is represented by samples from BH03B, BH04B and BH201.~~includes elevated concentrations of nitrate-N (BH03B and BH201), and ammoniacal-N (BH03B, BH04B, BH201, BH209 and BH211B), which together with the downward vertical hydraulic gradients measured in nested monitoring wells~~ across the siltstone layer~~, ~~infer~~supports inferences that some recharge from the shallow groundwater system is occurring. These elevated concentrations of inorganic nitrogen are likely to have been derived from forestry operations. Nitrate is anticipated to have undergone both denitrification and dissimilatory nitrate reduction to ammonium (DNRA) under reducing conditions. Elevated concentrations of ~~nickel and zin~~soluble trace metals~~c~~ are also likely to result from the reducing groundwater conditions and enabling leaching from minerals in the breccia material.

The deep groundwater system within the Henley Breccia is not considered as a viable groundwater resource in the Otago Regional Council Lower Taieri Groundwater Allocation Study (Rekker and Houlbrooke, 2010), given the low permeability and minimal potential yields. There are no recorded active groundwater takes from the Henley Breccia. The nearest recorded borehole is greater than 1.5 km west of the site (I45/0001), and no recorded bores or consents are located south east of the site (Figure 5).

While groundwater in this deep unit is considered to flow towards the Pacific Ocean, meaningful discharge is not anticipated to be occurring. In addition, there are no environmental receptors within 2 km of the site that are likely to be impacted by the deep groundwater system. It is noted that regardless of deep groundwater flow direction, the rates of deep groundwater flow are so low that potential impacts to receptors would be negligible.

3.5.2 Shallow Groundwater and Surface Water System

A localised shallow groundwater system is considered to have formed in the base of the valley at the site. The deposition of relatively permeable alluvium and colluvium in the topographical lows has formed a shallow unit which receives recharge directly from rainfall, as well as from runoff over the low permeability loess soils and groundwater from the shallow Henley Breccia.

The shallow Henley Breccia underlying the alluvium and colluvium typically has a greater permeability than the low permeability breccia that hosts the deep groundwater system, due to the presence of gravel and sandstone layers and due to relaxation of the rock mass and weathering. Groundwater from the shallow Henley Breccia is inferred to discharge into the alluvium and colluvium unit, with water levels in BH01A and BH01B demonstrating an upward vertical hydraulic gradient. Horizontal groundwater flow directions in the shallow Henley Breccia also suggests groundwater flow follows topography towards Otokia Creek. This shallow groundwater system is anticipated to be the source of baseflow for the Otokia Creek, which is currently understood to be ephemeral up-stream of BH01 and becoming perennial a short distance downstream of BH01 (although periods of no flow have been observed in 2020/2021 following low rainfall). Otokia Creek is also likely to receive runoff during rainfall events, which has the potential to transport a substantial sediment load given the steep topography and recent deforestation at the site. This is discussed further in the landfill design report (GHD, 2021~~0~~c).

A discontinuous fine-grained brown siltstonelow permeability layer within the Henley Breccia, distinct in its colouration, possibly a historic lake deposit, underlies the shallow breccia in a number of locations. This layer is interpreted as providing a degree of separation between the localised shallow groundwater system and the deep groundwater system, with recharge from the shallow to deep units impeded by this layer. The approximate elevation of the fine-grained siltstone low permeability layer indicates that it may have been eroded at the locations of BH01 and BH02.

Groundwater quality in the shallow groundwater system is considered to reflect the recent land use at the site, with fertiliser applied to the local forestry and recent disturbance likely to have resulted in elevated nitrate-N concentrations in the alluvium and shallow breccia at BH01A and BH03A, respectively. The site has been used for forestry for over 20 years and no other notable source of nitrate has been identified at the site.

Given the absence of groundwater use, the assessment of effects to groundwater and surface water focuses on the impact of landfill development on runoff and groundwater discharge to Otokia Creek. There are no recorded active surface water takes from Otokia or McColl Creeks, therefore risks will be assessed for environmental receptors only.

An assessment of the effects to the Open Stream surface water catchment has been excluded from this report, as placement of clean engineered fill is the only proposed activity in this area. A catchpit and culvert will convey rainfall run off to the Open Stream catchment (see Drawing 51-12506381-C302), therefore the proposed activities in this area are considered to have a very low potential effects and unlikely to significantly impact surface water or groundwater flow and quality within the Open Stream catchment. Furthermore, groundwater recharge is also considered unlikely to be impacted as the landfill waste will not overlie this section of the Open Stream catchment.

4. Assessment of Effects

The proposed landfill at the Smooth Hill site has the potential to influence groundwater and surface water levels, flow and quality in the vicinity of the site. To assess the potential impacts to groundwater and surface water, the landfill activity has been considered in the context of the conceptual hydrological and hydrogeological model, with water balance and analytical models developed to represent key processes and support analysis of potential effects.

The following sections outline the assessment and the predicted effects on groundwater and surface water.

4.1 Landfill Activity

4.1.1 Potential Adverse Effects

Placement of the proposed landfill has the potential to impact surface water and groundwater levels due to a reduction in recharge through the loss of infiltration area, runoff interception and removal of groundwater via subsurface drainage. The proposed landfill also has the potential to influence groundwater and surface water quality in the vicinity of the site in the event leakage of leachate were to occur through the landfill liner into the groundwater system.

4.1.2 Landfill Design

The proposed Smooth Hill landfill comprises a capacity of approximately 3~~6~~ Mm^3 to provide for the safe disposal of municipal solid waste for a period in excess of 35 years, and will occupy a footprint of approximately 18.6~~44.5~~ Ha of the 87 Ha designated for the landfill.

Construction of the landfill ~~each stage~~ will involve removal of un-consolidated surficial materials, followed by creation of planar surfaces for the placement of the landfill liner. Depth of excavation will typically be between two and 10 metres and include removal of all loess and some of the underlying weathered and unweathered rock. Most excavated materials (excluding those that are unsuitable) will then be used to form the landfill profile, liner and capping. Excavated weathered rock will be used for engineered fill.

Following excavation and filling, a 200 mm layer of selected soils will be placed where necessary to provide a construction base for the compacted clay layer of the landfill liner. A 10 m high toe bund will be constructed at the northern low point of the landfill to facilitate placement of waste and contain leachate.

The landfill ~~has been designed to include five stages, which~~ will be constructed and receive waste in a consecutive manner, with filling commencing within the central northern sections (Stage 1) and then progressing clockwise around the remainder of the footprint from the northeast (Stage 2, Stage 3 and Stage 4 – see Drawings C210 to C214). ~~Stages 1 and 2 will be in the north eastern portion of the landfill footprint, separated by the natural ridge from Stages 3, 4 and 5 in the south western portion.~~ Each stage will be developed sequentially in a number of sub-stages. Each sub-stage will progress through; exposed liner, open waste, daily cover, intermediate cover and final cap.

The Design Report (GHD 2021c~~0~~) specifies that any liner system must comply with either a Type 1 or Type 2 liner system as set out in WasteMINZ. In the Design Report, and for the purpose of this assessment, it has been assumed that a Type 2 liner will be utilised. This comprises 600 mm compacted clay base layer with a permeability of 1×10^{-8} m/s or less, overlain by a 5 mm geosynthetic clay liner (GCL) and 1.5 mm HDPE flexible membrane liner (FML). A 300 mm leachate drainage layer and overlying geotextile will be placed on top of the liner. If a

Type 1 liner system was considered the findings from this assessment would be approximately the same with respect to leachate leakage, as the 600 mm compacted clay layer in a Type 1 system requires a permeability of 1×10^{-9} m/s or less which is an order of magnitude lower than for a Type 2 liner system.

The leachate collection system will comprise the 300 mm drainage layer and perforated pipework in the drainage media to transfer leachate to the leachate sumps at the low point of the landfill liner. Two separate systems will be installed to collect leachate from Stages 1 and 2, and Stages 3, 4 and 5. Leachate pumps and risers will convey the leachate to storage tanks, from where it will be transported to the Dunedin City Waste Water Treatment Plant (WWTP). Leachate generation will be minimised by reducing the exposure of waste. Daily cover materials will generally be won from earthworks at the site. The low permeability loess from the site is considered viable for use as intermediate (300 mm) and final cap (600 mm) material.

During the operational phase of the landfill, any stormwater that comes into contact with waste will be treated as leachate. However, diversion of clean stormwater will be undertaken to separate it from waste where possible, and directed to a sediment retention pond (SRP) and a flow attenuation basin (see Drawing C303). SRPs will also be used for stormwater from stockpile 1 and the workshop area. After passing through an SRP, stormwater will generally be diverted to the attenuation basin before discharge to the Otokia Creek, except during development of Stage 1 of the landfill. Due to elevation constraints during Stage 1, after treatment through an SRP stormwater will be discharged via a pipe through the toe bund to Otokia Creek. Once Stage 1 is complete the pipe will be sealed and all stormwater directed via the perimeter swale to the attenuation basin (Design Report 2021a)..

All runoff from the completed landfill surface will be directed to thean attenuation basin which will discharge to the Otokia Creek catchment. The catchment area of the attenuation basin will be 69.2 ha, which is larger than the landfill footprint (44.5 ha) as natural runoff flow paths for the valley immediately north-west of the proposed landfill (where BH09 and BH02 are situated (Figure 5)) will also be intercepted along with other stormwater from the facilities area.

The attenuation basin and all SRPs- will comprise an upstream forebay area to provide initial treatment and downstream pond where water will be retained (see Surface Water Report, 2021 GHDd). Water within the attenuation basin will either soak to ground or discharge via low-level pipe or over the spillway to the Otokia Creek.

The attenuation basin consists of an upstream forebay area and a downstream area separated by a gabion basket (see Drawings 51-12506381-C306 and C307). The forebay will be excavated approximately 1.5 m (to approximately 95.5 m RL) into the existing ground surface and provide capacity for 700 m^3. The unlined forebay provides initial treatment and soakage for stormwater and groundwater collected from a subsoil drainage network. During periods of higher rainfall, water will overflow from the forebay and through a gabion basket, reducing potential velocities, into the unlined downstream area. Water in this area is retained by a small dam and will either soak into the underlying ground or discharge via a low level pipe or spillway to the Otokia Creek tributary downstream. This area may be planted with wetland type flora.

To control groundwater beneath the landfill, a network of subsoil drains will be constructed beneath the lining system. These will provide groundwater drainage under all stages of the landfill development, directing drainage to an access manhole immediately before either discharging to the attenuation basin or being directed to storage for use on site as non-potable waterthe Otokia Creek catchment. The manhole facilitates monitoring for leachate impact on groundwater quality, in the event that leachate seeps through the landfill liner. Where monitoring of groundwater indicates unacceptable changes in groundwater quality, the groundwater will be intercepted and treated as leachate. The perforated HDPE pipes of groundwater drainage system will be installed to a minimum elevation of 99.5 m RL along the northern low point of the landfill (Drawing C308). Existing ground level at the minimum elevation of the subsoil drains ranges between approximately 100 and 107 m RL.

4.1.3 Landfill Closure and Aftercare

Placement of the final cap after completion of the landfill will include an upper topsoil and / or growth layer, and surface vegetation, likely grass, will be established. Surface contour drains to manage stormwater that falls on the cap will also be connected to the perimeter drainage system that reports to the attenuation basin. Stockpile sites will be graded to conform to the adjacent topography and vegetated.

Post-closure aftercare activities will include operation and maintenance of:

- Landfill gas extraction, treatment and destruction system.
- Leachate collection system.
- Stormwater systems.
- Landfill cap, including fill in locations of differential settlement, repair of surface erosion and vegetation maintenance.
- Remaining site infrastructure.
- Ongoing environmental monitoring.

4.1.4 Leachate Management

Landfill leachate will be produced where rainfall percolates through waste and due to decomposition of the waste. Rates of generation ~~are expected to be at their highest~~will peak during operation of the landfill as more waste is placed. However, this is mitigated as much as possible through careful management of the active landfill face including the use of daily and intermediate cover. Rainfall that falls on the exposed liner prior to placement of waste ~~Where it cannot be directed to the surface water system, rainfall that falls on the exposed liner prior to placement of waste~~ will also report to the leachate collection system. Placement of the final cap is designed to minimise leachate generation, however leachate will continue to be generated and report to the collection system after landfill closure.

The landfill liner is designed to minimise leakage of leachate and will be designed to meet the landfill guideline specifications for either a Type 1 or Type 2 liner (WasteMINZ, 2018). The primary containment layer is the HDPE geomembrane. This is used in both the Type 1 and Type 2 liner systems. ~~For the Type 2 liner system this leakage is mitigated through intimate contact with the underlying GCL or for Type 1 by the compacted clay layer.~~ Individual sheets of HDPE are welded together and all welds tested for potential leaks. The HDPE geomembrane is practically impermeable and strict quality control measures are used to promote liner integrity during placement. However, for the purposes of assessing environmental effects a minimum level of leakage through the membrane is assumed based on the assumption that multiple imperfections in liner installation could occur. Leachate leakage is also minimised to the extent practicable by use of an underlying compacted clay layer, as for a Type 1 liner, and through intimate contact of the HDPE with the underlying GCL for a Type 2 liner.

~~For the Type 2 liner system this leakage is mitigated through intimate contact with the underlying GCL or for Type 1 by the compacted clay layer.~~ The rate of leachate leakage is largely controlled by the head of leachate on top of the liner. The minimum leachate collection system requirement in the WasteMINZ (2018) technical guidelines states that the leachate head is not to exceed 300 mm above the liner.

Monitoring of the following will be undertaken during operation and after closure to assess whether significant leachate leakage is occurring:

- Groundwater collected in the subsoil drainage system prior to discharge to the Otokia Creek catchment.
- The attenuation basin, comprising stormwater runoff and groundwater, prior to discharge to the Otokia Creek catchment.
- Down hydraulic gradient groundwater monitoring wells to provide advance warning of potential impacts to surface water quality through seepage of groundwater to the surface water system.~~.~~

A landfill management plan is being developed to define monitoring requirements for the site. Appendix D provides recommendations with respect to monitoring.

4.2 Landfill Water Balance and Leachate

4.2.1 Assessment Methodology

To inform the assessment of potential effects to surface water and groundwater the Hydrologic Evaluation of Landfill Performance (HELP) software was used to predict average run-off, evapotranspiration, leachate generation and leakage during different phases of construction and after closure. The HELP model provides analytical estimation of water movement and prediction of a water balance for the landfill. Landfill design, material properties and location specific weather data are used in developing the model. Appendix C presents the full methodology and results for the leachate generation, reporting times and leakage assessment.

4.2.2 Landfill Runoff

The rainfall runoff predicted to report to the attenuation basin during operation and after closure of the landfill is presented in Table 4. During landfill operation, the worst-case scenario for runoff will occur after the landfill footprint is fully occupied, but sections of exposed liner and open waste are still present in the final stage of development which report all runoff to the leachate collection system. After placement of ~~the intermediate and~~ final capping layer, and the majority of the intermediate capping layers, (which will occur progressively as the landfill is developed)~~,~~ ~~all~~ rainfall runoff will be directed to the attenuation basin before discharge.

During landfill operation, ~~a minimum of~~ approximately 12~~.7~~% of rainfall runoff is predicted to report to the attenuation basin, with the remainder either infiltrating into the landfill or undergoing evapotranspiration. After landfill closure, the percentage of rainfall that reports to the attenuation basin increases to approximately ~~13.8~~14%. This equates to between approximately ~~45,000~~18,000 m^3/year to ~~49,000~~21,000 m^3/year of runoff from the ~~44.5~~18.6 ha landfill area before and after closure, respectively.

Table 4: Rainfall runoff predicted to report to the attenuation basin (Updated May 2021)

Landfill Phase	Worst case area during operation (m^2)	Runoff to attenuation basin (m^3/year)	Percentage of total Rainfall (%)*
Exposed Liner	10,000	0	
Open Waste	2,500	0	
Open Waste with Daily Cover	11,500	0	

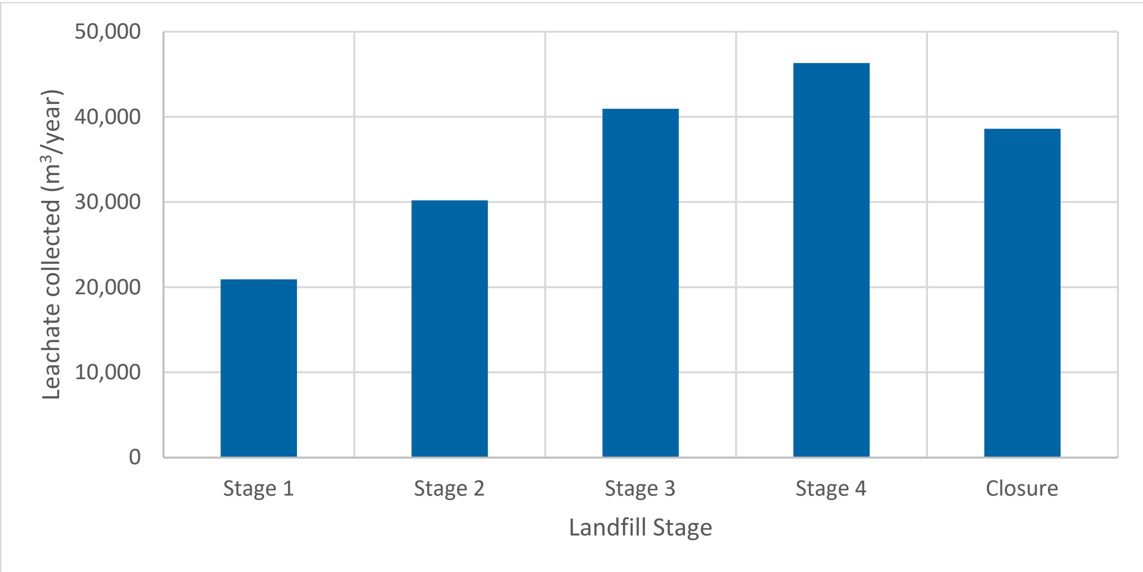
Intermediate Cap	3,000	264	
Final Cap	159,000	18,067	
Total	**186,000**	**18,330**	**12 %**
Landfill Phase	Area after closure (m^2)	Runoff to attenuation basin (m^3/year)	Percentage of rainfall over landfill (%)*
Final Cap	**186,000**	**21,135**	**14 %**

* Assuming annual average of 809.5 mm over ~~44.5~~18.6 ha

4.2.3 Leachate Generation and Leakage

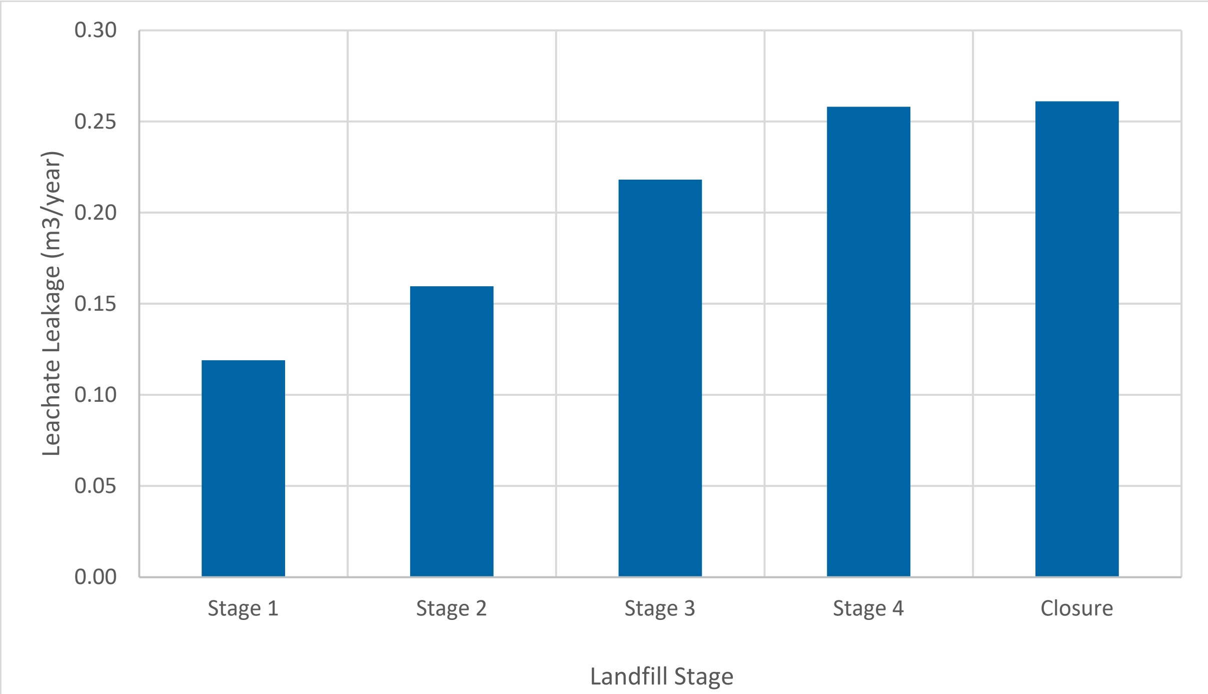
Figure 10 presents a summary of the landfill leachate predicted to be collected in the leachate collection system~~s~~ during operation and after ~~stage~~ closure. ~~There are two drainage collection systems for the proposed landfill, which separate the leachate collection in Stages 1 and 2 from leachate collection in Stages 3, 4 and 5. The predicted leachate volumes reported to the collection systems during operation will not occur concurrently as each landfill stage will be closed before the next one is opened.~~ The largest leachate ~~volumes are~~collection volumes are likely to occur during operation of stage 4~~5~~, with a total predicted leachate volume of approximately ~~99,000~~46,310 m^3/year ~~for the whole landfill (worst case for stages 3, 4 and 5 combined with closed stages 1 and 2)~~. After complete landfill closure, the total leachate predicted to be collected ~~from all five stages~~ is approximately 38,584~~90,000~~ m^3/year.

Figure 10: HELP Model landfill leachate to collection system (Updated May 2021)



A summary of the predicted leachate leakage through the landfill liner during operation and after stage closure is presented in Figure 11. ~~As with leachate generation, the leachate leakage during landfill operation will not occur concurrently due to sequential stage construction.~~ The maximum leachate leakage is likely to occur during operation of stage 4 and after landfill closure~~5~~, with a predicted leakage rate of 0.26~~3.0~~ m^3/year. ~~(generated from operational stage 5 and closed stages 1, 2, 3 and 4). The predicted total leachate leakage from all stages after landfill closure is approximately 1.9 m^3/year.~~

Figure 11: HELP Model leachate leakage through the landfill liner (Updated May 2021)



4.2.4 Leachate Quality

Leachate from a Class 1 (municipal) landfill is generated due to the interaction of waste with infiltrating water and the release of liquids directly from the waste. Leachate can have varying quality, dependent upon the relative proportion of different waste types, landfill design, age of the landfill and local environmental setting. Typically, contaminant concentrations in leachate are highest when waste is exposed during operation, and decrease with closure and as the landfill ages. Decomposition of putrescible material and the transition of the landfill waste over time from an aerobic to anaerobic state, and the generation of organic acids, also plays a key role in determining leachate quality, influencing microbial reactions, solubility and physiochemical reactions of leachate constituents.

Decomposition of putrescible waste and the leachate generating environment is often defined to occur in three stages:

1. Aerobic degradation, generating heat and producing organic compounds and carbon dioxide.
2. Anaerobic degradation where large organic molecules are broken down into simple compounds such as hydrogen, ammonia, water, carbon dioxide and organic acids.
3. Methanogenic degradation where organic acids break down to form methane gas and other products.

Table 5 outlines an upper quartile for the highest leachate constituent concentrations of eight New Zealand landfills, provided in the Centre for Advanced Engineering Landfill Guidelines (CAE, 2000).

Table 5: Upper quartile of the highest leachate constituent concentrations

Parameter	Upper Quartile Concentration – Class 1 Landfills (mg/L excluding pH)(1)
Aluminium	7.9
Ammoniacal Nitrogen	705
Arsenic	0.17
Boron	12.3
Cadmium	0.0063
Calcium	378
Chloride	1730
Chromium	0.17
Dissolved Reactive Phosphorus	3.4
Iron	183
Lead	0.13
Magnesium	193
Manganese	5.4
Nickel	0.19
Nitrate Nitrogen	0.86
pH	8.1 pH Units
Potassium	630
Silica	36
Sodium	1165
Sulphate	292
Total Kjeldahl Nitrogen	1220
Zinc	1.2
Total VOC	6.5
Total SVOC	4.4

1) Upper quartile of the highest leachate concentrations recorded in eight consented municipal solid waste (MSW) Class 1 Landfills in New Zealand (CAA, 2000[1]). Note some landfills did not provide concentrations for all parameters.

[1] The more recently published guidance (WasteMINZ, 2018) make use of the same data from eight New Zealand Class 1 landfills. Data from this more recent document has not been used owing to inaccuracies in the presented leachate chemistry.

4.3 Catchment Water Balance

Table 6 presents the water balance comparison of the existing environment with the worst-case operational landfill scenario and after landfill closure within the 69.2 ha Otokia Creek catchment area.

Total rainfall over the Otokia Creek proposed landfill attenuation basin catchment area (69.2 ha) is predicted to be approximately 560,200 m^3/year (based on annual average of 809.5 mm). Actual evapotranspiration and runoff for the existing environment has been predicted using the weather generator model (WGEN) in HELP (Appendix C) to be approximately 218,300218,400 m^3/year and 334,600335,900 m^3/year, respectively. As discussed in Section 3.3.2, groundwater recharge for the existing environment is anticipated to comprise less than 2 % of total rainfall.

With the landfill proposed to occupy 18.644.5 ha of the catchment, the remaining 24.750.6 ha will continue to contribute runoff at the same rate as under the existing environment. The ongoing contribution from the landfill footprint area to the catchment is dependent upon the stage of development. Table 4 outlines the worst case for the reduced net runoff to the catchment.

The changes to the shallow groundwater system have assumed that no further shallow groundwater will be contributed from the landfill sub-catchment (Table 3), which will reduce the existing flow from approximately 3,000 m^3/year to 2,200 m^3/year. The changes to the deep groundwater system assume an even distribution of recharge across the 69.2 ha Otokia Creek catchment. With loss of recharge across the 18.6 ha landfill footprint this would reduce recharge to the deep groundwater system by approximately 27 %, from approximately 3,000 m^3/day to 2,200 m^3/day.

Table 6: Catchment Water Balance (69.2 ha) (Updated May 2021)

	Existing Environment	Worst Case During Landfill Operation	Landfill Closure
Inputs (m^3/year)			
Rainfall	560,200		
Outputs (m^3/year)			
Evapotranspiration	218,300	241,200	246,100
Runoff	335,900	268,300	271,100
Shallow Groundwater System	3,000	2,200	2,200
Deep Groundwater System	3,000	2,200	2,200
Leachate Collection System	-	46,300	38,600
Leachate Leakage	-	0.26	0.26

The combined runoff to the catchment from both the landfill (Table 4) and the intercepted valley to the north-west is likely to be a minimum ofremaining 50.6 ha is estimated at approximately 173,600268,300 m^3/year during the worst case operational scenario(Table 6). This is a reduction of nearly 50approximately 20% compared to the existing environment. After closure, the entire landfill will contribute runoff, which is predicted to increase to 271,100 m^3/year.

An increase in evapotranspiration is predicted to occur during landfill operation and closure in comparison to the existing environment due to a relative increase in water infiltration and soil moisture retention within the surface landfill capping soils compared to the existing environment, as well as a 'good grass' cover for the final cap, which allows for increased evapotranspiration. The existing scenario is considered to have 'poor grass' cover due to onsite forestry operations and the presence of scrub vegetation.

In terms of groundwater impacts from landfill construction two aspects are considered:

- Table 6 indicates a reduction in recharge to both the shallow and deep groundwater systems beneath the landfill footprint.
- In addition, a groundwater discharge rate of up to 87 m^3/day is predicted from sub-surface drains beneath the landfill following drain installation. This water will be stored and used on site as part of a non-potable water supply or allowed to discharge to Otokia Creek catchment (further discussed in 4.4.1 below). The value of 87 m^3/day is an increase from values previously reported. The increase relates primarily to the assumed inclusion of a groundwater drain along the up gradient base of the toe bund (see C308).

This reduction in recharge to groundwater during the course of landfill operation and post-closure, will likely result in downward adjustment of groundwater levels to a new steady state reflecting the loss of recharge. This is predicated to eventually reduce below the level of the sub-surface drains. In the long-term, groundwater diversion through the sub-surface drains is expected to be negligible.

4.4 Effects to Shallow Groundwater and Surface Water

4.4.1 Assessment Methodology

Estimates of groundwater recharge and discharge for the existing environment, described in Section 3.3.2, provide the basis for assessing the potential impacts to shallow groundwater. A water balance approach has been used in combination with simplistic analytical groundwater flow equations (Darcy's Law) to predict changes to the shallow groundwater system and subsequently surface water.

Assessment considers the potential adverse effects of the following scenarios:

1. Predicted effects excluding the potential mitigation measures of soakage of stormwater to ground down gradient of the landfill, representing an upper bound for potential impacts or a sensitivity scenario.
2. Predicted effects including the mitigating influence of stormwater soakage to ground down gradient of the landfill, representing the expected outcome.

Of these scenarios, Scenario 2, which considers the normal operation of the landfill and current climatic conditions, is considered appropriate for the purpose of assessing effects to the environment associated with the landfill. Scenario 1 is provided for context to the sensitivity of the predicted effects.

4.4.2 Scenario 1 - Potential Upper Bound for Effects to Shallow Groundwater

Groundwater Recharge and Flow

After the placement of the 44.518.6 ha landfill footprint, there will be no further recharge to the shallow groundwater system from rainfall infiltration over the area of the landfill. Assuming an even distribution of recharge across the entire 69.2 hano further contribution to the Otokia Creek catchment from the landfill sub-catchment this ~~would reduce~~is anticipated to ~~recharge to the shallow groundwater system by approximately 67 % and~~ reduce shallow groundwater flow at the site from approximately 3,~~6~~000 m^3/year to approximately ~~1,200~~2,200 m^3/year. This reflects the upper bound for potential influence on groundwater recharge and flow, assuming no soakage of stormwater to ground.

Groundwater Levels and Gradients

Groundwater flow in the shallow groundwater system at the site is predicted to reduce from approximately 3,0~~6~~00 m^3/year to 2,200 ~~1,200~~ m^3/year~~, where loss of recharge across the landfill footprint is considered in isolation.~~. ~~Assuming this scenario,~~ Using Darcy's Law to back calculate the discharge (by reducing saturated aquifer thickness and change in groundwater head in Table 3 by the same factor), groundwater levels in the shallow groundwater system are predicted to reduce by ~~approximately~~ less than ~~2 – 3~~1 m ~~in the immediate vicinity of the landfill~~. The implications of this are threefold:

- A reduction in groundwater discharge to the Otokia Creek.
- A potential shift downstream where the stream transitions from ephemeral to perennial stream flow.
- A potential impact on water levels in any wetlands located immediately downstream of the landfill.

The less than 1~~2-3~~ m change in shallow groundwater levels and the potential effects described above will be confined to the immediate downstream vicinity of the landfill. With increased distance downstream, the impact on groundwater levels will diminish as the contribution of groundwater from the wider catchment increases and the proportional contribution from the ~~44.5~~18.6 ha associated with the landfill decreases. This is further discussed in Section 4.4.4.

Placement of sub-surface drainage to ensure dewatered conditions beneath the landfill are not expected to intercept groundwater in the southern extent of the footprint, where groundwater has been encountered at relatively deep levels. However, in the northern section of the landfill footprint, near the toe of the landfill, there is potential for interception of groundwater within the shallow groundwater system. The sub-surface drainage in this area will be installed to a minimum elevation of 99.5 m RL across an area where existing ground levels range between approximately 100 – 107 m RL. Groundwater levels recorded in the shallow groundwater system in nearby monitoring wells have been recorded to maximum levels of ~~97.5 m RL (BH02A),~~ 103.3 m RL (BH03A), 104.55 mRL (BH211A) and 106.4 m RL (BH04A), where ground levels are 107.5 mRL, 107.0 mRL and 108.2 mRL, respectively. Groundwater levels recorded above the minimum elevation of the sub-surface drainage (99.5 m RL) are generally in monitoring wells located in elevated areas along the valley sides, ~~(BH03A and BH04A),~~ whereas the drains are proposed to be located within the existing valley bottoms where groundwater levels are lower. This inference is supported by ~~(BH02A).~~ trial pit TP09, located approximately 25 m south east of the proposed minimum elevation of sub-surface drainage, which was excavated from ground level (101 mRL) to an elevation of 98 mRL with no groundwater encountered (Figure 6).

Although sub-surface drainage may provide initial lowering of groundwater levels within the localised shallow groundwater system, it is anticipated that this will be for a relatively short period of time as groundwater levels are expected to be reduced below the elevation of the drains due to loss of recharge with placement of the landfill liner (Section 4.3). Significant volumes of groundwater are therefore not anticipated to be abstracted through the subsoil drainage system over the life of the landfill, with the maximum estimated discharge in the order of 87 m^3/day (Table 7). It is noted that this water will be abstracted and used as part of the non-potable water supply for the site or discharged to Otokia Creek catchment.

Table 7: Estimated groundwater discharge from sub-soil drains (Updated May 2021)

Parameter	Adopted value	Justification
Initial saturated aquifer thickness (H)	9.55 m	Difference between maximum recorded groundwater level at BH211A (104.55 mRL) and approximate elevation of siltstone layer in BH211 (95 mRL)
Saturated aquifer thickness after drawdown (h)	4.5 m	Difference between minimum elevation of sub-soil drainage (99.5 mRL) and approximate elevation of siltstone layer in BH211 (95 mRL)
Hydraulic conductivity (K)	3.2×10^{-6} m/s	Maximum Henley Breccia permeability recorded during hydraulic testing (BH02A)
Radius of influence (R_0)	27.1 m	$R_0 = 3000\,(H-h)\sqrt{K}$ Sichart & Kryieleis (note *H* - *h* is in feet and *K* is in m/s) (Jacob, 1950)
Distance to the line source (L)	13.5 m	$R_0 = 2L$ (Powers et. al, 2007)
Unit length of trench (x)	120 m	Length of sub-soil drainage at minimum elevation of 99.5 mRL
Sub-soil drains discharge (Q)	87 m^3/day	$\frac{Q}{x} = \frac{K(H^2-h^2)}{2L}$ Flow to a drainage trench in an unconfined aquifer (Powers et. al, 2007)

4.4.3 Scenario 2 – Predicted Effects to Shallow Groundwater

The attenuation basin and SRPs are designed to provide additional water quality polishing with respect to sediment and are also designed to moderate stormwater runoff originating across the ~~flows downstream of the~~ landfill and associated facility areas. The ~~two sections of th~~attenuation basin has no proposed lining in the base, which will allow infiltration of stormwater to the underlying groundwater system while stormwater is ponded prior to discharge. This recharge is anticipated to provide sufficient soakage to greatly mitigate the loss of groundwater recharge and the associated effects described in 4.4.2. In addition, while some of the groundwater abstracted from the sub-soil drainage may be directed for non-potable use some will also be allowed to discharge to the Otokia Creek~~system~~ catchment and further supplement the surface water system. However, this has not been assumed when evaluating the predicated effects as the rate of groundwater collected is likely to reduce significantly with time from an initial rate in the order of 87 m^3/day.

The current groundwater conditions down gradient of the landfill, where groundwater levels ~~are~~ have previously been recorded near surface, provide limited opportunity for stormwater to soak to ground as there is no storage capacity within the shallow aquifer. With the proposed landfill development and loss of recharge across the landfill footprint, the lowering of groundwater levels will provide capacity for soakage of stormwater from the attenuation basin. Alluvium and colluvium in the ~~gully~~ valley floor~~, and the excavation of the unlined forebay into these materials,~~ is expected to promote soakage, such that at times when stormwater is generated it is expected that soakage to ground downstream of the landfill will occur. The ~~forebay capacity (designed to hold 1% AEP~~attenuation basin capacity provides~~s~~ the means to capture a significantly greater volume of stormwater for soakage than is estimated to presently recharge the shallow groundwater system (approximately 3,~~6~~000 m^3/year), with this expected to greatly mitigate loss of groundwater flow through the valley floor.

So while the catchment is expected to see changes in where groundwater recharge occurs, the influence of the landfill on groundwater levels and flow in the shallow aquifer is expected to be less than minor.

4.4.4 Effects to Surface Water Level Flow

Assessment of potential effects to surface water flow considers the two scenarios above.

Under the upper bound for effects scenario (Scenario 1), which excludes soakage of stormwater from the landfill attenuation basin, a decrease in groundwater flow by approximately ~~2,400~~800 m^3/year (equivalent of 0.03~~8~~ litres/second) and decrease in groundwater levels by up to ~~3~~ 1 m down gradient of the landfill is predicted. This would result in decreased baseflow in Otokia Creek and subsequent potential movement of the semi~~-~~perennial flow transition to further downstream. The distance between the proposed landfill and McLaren Gully Road, ~~where~~ beyond which the Otokia Creek tributary has ~~is confirmed as having~~ perennial flow, is approximately 1 km. Ground elevation reduces by approximately 20 m over this distance. Assuming a linear surface gradient, the predicted reduction in groundwater levels due to landfill placement is anticipated to move the transition location for semi~~-~~perennial stream flow up to ~~50~~ 3645 m further downstream from its current location, although this will also be mitigated by the contribution of groundwater from the wider catchment.

Under Scenario 2, with ~~clean~~ stormwater diverted ~~from the landfill~~ to the attenuation basin, moderation of stormwater runoff and soakage of stormwater to ground is expected to mitigate the predicted loss of baseflow and subsequent transition of perennial stream flow. With a high capacity to attenuate stormwater discharge from the site, the volume of stormwater soaking to ground is likely to be greater than that presently being recharged to the catchment and greatly mitigate loss of stream baseflow.

4.5 Effects to Deep Groundwater

Any change in groundwater levels due to reduced recharge will have a negligible impact on the deep groundwater system, which does not support any registered groundwater takes and is not considered to provide baseflow to any streams. All valleys in the vicinity of the site that host ephemeral streams are anticipated to have their own localised shallow system similar to that encountered and described at Smooth Hill.

With an estimated average horizontal permeability of $1x10^{-8}$ m/s in the deep groundwater system of the Henley Breccia, and a distance of approximately 2.6 km from the south eastern edge of the site, it would take groundwater an average of 8,245 years to reach the Pacific Ocean along a direct flow path. The deep groundwater system is therefore considered to contribute negligible discharge to the Pacific Ocean.

4.6 Effects to Water Quality

4.6.1 Assessment Methodology

Existing contaminant flux from the shallow groundwater system towards the Otokia Creek has been estimated using concentrations recorded in groundwater samples collected at the site

(Appendix A Table A5), as well as estimated rates of shallow groundwater discharge (Section 3.3.2).

The leachate contaminant flux for leakage from the proposed landfill has been predicted using concentrations from Class 1 landfills across New Zealand (CAE, 2000), as presented in Table 5 (Section 4.2.4). The modelled rate of leachate leakage reflects the closed landfill scenario outlined in Section 4.2.3. A comparison of the contaminant flux has been undertaken between the shallow groundwater in the existing environment and the maximum rate of leachate leakage under the(observed during Stage 4 and after closure of the landfill closed landfill scenarios,) to provide an indication of the potential for long-term adverse influence on groundwater and surface water. The closed landfill scenario is considered an appropriate comparison for the existing situation, owing to the significant time involved with broad scale catchment water mixing compared to the temporary nature of the operational scenarios, and because it reflects the maximum landfill footprint and predicted leachate leakage.

4.6.2 Predicted Changes in Contaminant Flux

Table 8 presents the estimated contaminant flux in the shallow groundwater system under existing conditions for both the landfill sub-catchment and the full 69.2 ha sub catchment of the Otokia creek, and also resulting from the maximum predicted rate of leachate leakage and following mixing of leachate with the shallow groundwater system downgradient of the landfill for the closed landfill scenario. The results indicate that for the majority of parameters contaminant flux is predicted to reduce significantly following construction of the landfill. This is the result of the reduction in the existing groundwater flows described in Section 4.3 and the small amount of leachate leakage anticipated. Increases in contaminant flux are, however, predicted for iron, lead, dissolved reactive phosphorus (DRP) and ammoniacal-N following construction of the landfill. The predicted flux for a number of key parameters has been converted to concentration within the shallow groundwater system down-gradient of the landfill within Table 9, and compared against adopted water quality -criteria. The indicated concentrations are considered conservative in that geochemical equilibrium reactions, microbial reactions and adsorption have not been considered. Such reactions remove contaminant mass through precipitation of minerals and binding to aquifer materials respectively.

Table 8: Predicted Changes in Flux in Shallow Groundwater (Updated May 2021)

Parameter	Flux (kg/year excluding pH)			
	Existing shallow groundwater system in landfill sub-catchment (800 m^3/year)	Existing shallow groundwater system (69.2 ha Otokia Creek catchment – 3,000 m^3/year)	Leachate leakage (closed landfill – 0.26 m^3/year)	Predicted shallow groundwater system down-gradient of landfill (2,200 m^3/year)
Aluminium	-	-	0.0021	-
Arsenic	0.00025	0.00092	0.000045	0.00072
Boron	-	-	0.0032	-
Cadmium	0.000035	0.00013	0.0000016	0.000098

Parameter	Flux (kg/year excluding pH)			
	Existing shallow groundwater system in landfill sub-catchment (800 m^3/year)	Existing shallow groundwater system (69.2 ha Otokia Creek catchment – 3,000 m^3/year)	Leachate leakage (closed landfill – 0.26 m^3/year)	Predicted shallow groundwater system down-gradient of landfill (2,200 m^3/year)
Calcium	111.5	422.6	0.10	311.2
Chloride	94.0	355.9	0.45	262.3
Chromium	0.00008	0.00032	0.000046	0.00028
Iron	0.026	0.097	0.048	0.12
Lead	0.000021	0.000080	0.000034	0.000093
Magnesium	36.3	137.6	0.051	101.4
Manganese	0.25	0.94	0.0014	0.69
Nickel	0.0038	0.014	0.000050	0.011
Potassium	4.6	17.2	0.16	12.8
Silica	-	-	0.0094	-
Sodium	66.0	249.3	0.30	183.6
Sulphate	128.6	488.4	0.076	359.9
Zinc	0.0046	0.018	0.00032	0.013
Total VOC	-	-	0.0017	-
Total SVOC	-	-	0.0012	-
Total Kjeldahl Nitrogen	0.35	1.3	0.32	1.3
Dissolved Reactive Phosphorus	0.00088	0.0033	0.00090	0.0033
Ammoniacal Nitrogen	0.012	0.045	0.18	0.22
Nitrate Nitrogen	11.3	43.0	0.00022	31.7
Total Inorganic Nitrogen	11.3	43.0	0.18	31.9

Table 9: Predicted contaminant concentration within shallow groundwater system down gradient of landfill

Parameter	Water Quality Criteria (mg/L)	Predicted concentration (mg/L)	Predicted increase/decrease in shallow groundwater flux
Iron	-	0.054	Increase
Lead	0.0034 (1)	0.000042	Increase
Cadmium	0.0002 (1)	0.000045	Decrease
Chromium	0.001 (1)	0.00013	Decrease
Nickel	0.011 (1)	0.0049	Decrease
Zinc	0.008 (1)	0.0061	Decrease
Dissolved reactive phosphorus	0.035 (2)	0.0015	Increase
Nitrate	1.0 (2)	14.5	Decrease
Ammoniacal Nitrogen	0.2 (2)	0.10	Increase

1) ANZG (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Default criteria values for freshwater – protection: 95% of species.

2) ORC (2016). Otago Regional Council. Regional Plan: Water for Otago. Schedule 16A: Discharge Thresholds for Discharge Threshold Area 2.

The flux of lead, DRP, ammoniacal-N and iron are predicted to increase following construction of the landfill. However, the predicted concentrations of lead, DRP and ammoniacal nitrogen within the shallow groundwater system down gradient of the landfill are not anticipated to exceed the adopted water quality criteria presented in Table 9. No applicable criteria is available for iron, however, this parameter is not considered to be of concern given concentrations greater than the predicted concentration were recorded in nine of the 14 samples collected from the shallow groundwater system, to a maximum of 4.69 mg/L (BH02A) (Appendix A – Table A5).

Nutrient transformation between nitrogen species, nitrate and ammoniacal nitrogen, is dependent upon a variety of environmental conditions, therefore total inorganic nitrogen is considered to represent a better measure for comparing nitrogen flux for the existing and landfill scenarios. This indicates that following placement of the landfill, total inorganic nitrogen (comprising both ammoniacal nitrogen and nitrate nitrogen) is estimated to reduce within the shallow groundwater system from approximately 43 kg/year to 32 kg/year.

4.6.3 Effects to Groundwater and Surface Water Quality

Under the existing environment, the influence of current and historical site activities is reflected in the quality of the shallow and deep groundwater, particularly in the form of nutrients, which are readily leached from soils.

Placement of the proposed Smooth Hill landfill is inferred to preclude recharge from rainfall/runoff to the shallow groundwater system beneath the landfill footprint. Predicted long term leachate leakage through the liner of ~~1.9~~0.26 m^3/year (14~~43~~ L/ha/year) is expected to reflect the only recharge to groundwater across the landfill footprint area, with this decrease in infiltration predicted to locally lower groundwater levels (refer Sections 4.4.2 and 4.4.3). Widely distributed infiltration, low leakage rates and a significant thickness of unsaturated material below the liner is expected to significantly retard the rate of leachate percolation to groundwater, providing the opportunity for significant attenuation of contaminants.

On reaching and mixing with shallow groundwater, migration of leachate constituents will occur with groundwater flow. The rate of groundwater flow through the shallow aquifer is expected to be low, as a function of moderate permeability and a loss of driving head (a function of reduced groundwater recharge). Travel times for migration of groundwater ~~through the shallow aquifer to the toe of the landfill~~ are correspondingly expected to be protracted and potential for further attenuation of contaminant concentrations exists prior to influenced groundwater moving beyond the landfill designation.

The impacts of leachate leakage on groundwater quality down gradient of the landfill are expected to be limited in the context of the existing groundwater quality, with mixing with groundwater ~~beneath the~~down gradient of the landfill footprint alone expected to provide greater than 1000-fold dilution. In addition, ~~significant~~ dilution is expected to occur as the catchment stormwater is preferentially enabled to soak to ground from the attenuation basin, which is expected to mitigate loss of flow to the shallow groundwater system to some extent. Soakage from the attenuation basin will further dilute groundwater with any residual landfill leachate influence ~~by approximately three fold~~. Greater dilution is expected owing to the significant average volumes of stormwater (~~173,600~~268,000 m^3/year) predicted to discharge ~~through the attenuation basin~~to the 69.2 ha Otokia Creek catchment and the ability to moderate flows and temporarily retain stormwater in the SRPs and the attenuation basin ~~in the forebay~~, promoting soakage to ground from the latter (Section 4.3).

Considering the reduction in contaminant flux and the levels of dilution predicted, the effects to groundwater quality in the immediate vicinity of the site are expected to be negligible.

As discussed in section 4.4.4 of this report, the tributary to Otokia Creek downstream of the landfill transitions from ephemeral to permanent flow prior to the Maclaren Gully Road culvert. This permanent flow will be supported by shallow groundwater discharge including a contribution from the groundwater discharge from beneath the landfill (although permanent flow has been observed to cease after extended periods of low rainfall). However, given the anticipated impact on groundwater quality is anticipated to be negligible immediately downstream of the landfill, the impact on the surface water quality in the stream is anticipated to be less as the landfill groundwater will be further diluted by groundwater seepage from the wider catchment in the surface water flow.

~~4.6.4 Surface water Quality Limits – Regional Plan~~

~~Schedule 15.2.2 of the regional plan establishes water quality limits for surface water. The relevant limits are:~~

~~Nitrate –nitrite~~	~~0.075 mg/l~~
~~Dissolved Reactive Phosphorus (DRP)~~	~~0.01 mg/l~~
~~Ammoniacal nitrogen~~	~~0.1 mg/l~~
~~E Coli~~	~~260 cfu/100ml~~
~~Turbidity~~	~~5 NTU~~

~~As described in Section 4.6.2 the total flux contribution for DRP and total nitrogen~~ is~~are expected to decrease in comparison to current shallow groundwater discharges from beneath~~

the landfill footprint. Therefore, on the assumption that shallow groundwater eventually discharges to the surface water system downstream from the landfill, no significant impact is anticipated on these parameters in surface waters.

As discussed in 4.6.2 a small increases in the total annual flux of ammoniacal nitrogen and DRP is expected in the shallow groundwater seepage but the associated seepage rate is very small (1,200 m^3/year or less than 0.04 l/second). Furthermore, however, as discussed in 4.6.2 the predicted concentrations of these parameters are expected to be less than groundwater guideline criteria. Additionally, t the flux of total inorganic nitrogen is estimated to reduce from approximately 4373 kg/year to less than 233 kg/year, and considering nutrient transformations between nitrogen species, the impact to groundwater and surface water quality is considered to be less than minor.

E.Coli is not anticipated to be a contaminant of concern associated with the groundwater system and turbidity is a storm water issue and discussed in the Sediment and Erosion Assessment Report (GHD 2020).

5. Summary and Conclusions

5.1 Effects to Shallow Groundwater and Surface Water Levels and Flow

Placement of the landfill is likely to reduce groundwater recharge within the 69.2 ha ~~landfill attenuation basin catchment area~~Otokia Creek catchment by approximately 2~~6~~7 %, with groundwater levels in the down gradient shallow groundwater system ~~beneath the landfill~~ predicted to reduce by ~~approximately 2 – 3~~less than 1 m. Under a scenario which assumes no soakage of stormwater to ground (Scenario 1 Section 4.4.2), this would result in reduced discharge to the Otokia Creek, and the location where the stream transitions from ephemeral to perennial moving up to ~~50~~ 45 m further downstream.

When moderation of stormwater flows and soakage of stormwater to ground from the attenuation basin is considered~~within the forebay and downstream wetland section of the~~ (Scenario 2 Section 4.4.3), this is likely to mitigate the reduced groundwater recharge beneath the landfill footprint. This is expected to be predominantly mitigated by the discharge of stormwater from the attenuation basin, providing a source of recharge to the shallow groundwater system, and subsequently, baseflow for the Otokia Creek.

Although changes in groundwater recharge are expected at the site due to placement of the landfill, the influence on shallow groundwater and surface water levels~~,~~ and flow are expected to be less than minor with respect to Otokia Creek baseflow.

5.2 Effects to Deep Groundwater System

The deep groundwater system is not considered to currently provide baseflow to any streams~~,~~ and does not support any registered groundwater takes. The very low estimated hydraulic conductivity of the unit (less than 1x10^{-8} m/s), indicates that the deep groundwater system contributes negligible discharge to the Pacific Ocean. The reduction in recharge due to placement of the landfill is therefore likely to have a less than minor impact to the deep groundwater system.

5.3 Effects to Groundwater and Surface Water Quality

A comparison of the leachate contaminant flux for leakage from the proposed landfill to the groundwater in the existing environment indicates that contaminant flux is predicted to reduce significantly following construction of the landfill for the majority of parameters. The exception to this is lead, iron, DRP and ammoniacal nitrogen. As discussed in Section 4.6.2, lead, DRP and ammoniacal nitrogen are not predicted to exceed relevant groundwater quality criteria within the downgradient shallow groundwater system and iron is not considered to be at a concentration of concern. Additionally, with respect to ammoniacal nitrogen, the flux of total inorganic nitrogen is considered to be a more appropriate measure considering nutrient transformations between nitrogen species. Given the inferred use of fertilisers during current site conditions, total inorganic nitrogen is estimated to reduce from approximately 43 ~~73~~ kg/year to 32~~less than 2~~ kg/year. The impact to groundwater from construction of the landfill is therefore considered to be less than minor.

5.4 Monitoring Recommendations

Monitoring of groundwater, discharge from sub-surface drainage and surface water is recommended to be undertaken before, during and after operation of the landfill. This will enable the existing environment to be further characterised, and for potential impacts from the landfill to be monitored during operation and after closure. Monitoring is described in Appendix D.

6. Limitations

This report: has been prepared by GHD for Dunedin City Council and may only be used and relied on by Dunedin City Council for the purpose agreed between GHD and the Dunedin City Council as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than the Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Smooth Hill Landfill Project arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Dunedin City Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of vegetation and topography. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

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Appendices

Appendix A – Hydrogeology Site Investigation

A.1 Introduction

Two phases of intrusive site investigation were undertaken at the site to characterise the geological and hydrogeological conditions, and provide sufficient information to assess effects to groundwater and surface water that may be associated with the proposed activity. Conditions assessed included local geology, groundwater levels and hydraulic properties that may influence drainage and flow of groundwater within the vicinity of the proposed landfill.

This appendix provides details of the following site works:

- **Appendix A.2** Geology and Elevation Survey
- **Appendix A.3** Water Level Monitoring
- **Appendix A.4** Hydraulic Testing (permeability analysis)
- **Appendix A.5** Groundwater Quality (Groundwater Sample Analysis)
- **Appendix A.6** Rainfall

The sections below outline the methodologies used; the data outputs are provided in the following pages.

A.2 Geology

Ten boreholes were drilled at the site between 27 May and 17 June 2019 during the phase 1 site investigation (BH01 – BH10) by McNeil Drilling. The boreholes were drilled at PQ size (122 mm outer diameter) using rotary drilling methodology and a truck mounted UDR600 rig. An additional five boreholes were drilled at site between 24 October and 7 November 2019 during the phase 2 site investigation (BH201, BH202, BH203, BH209 and BH211) by Speights Drilling using a tracked, Maruka-mounted rig. BH201 and BH202 were cored to approximately 10 m bgl followed by wash drilling to termination depth. All other phase 2 investigation bores were advanced using rotary drilling methodology. All bores were drilled at PQ size.

Table A 1 below presents all site investigation bores, plus one borehole found to already be installed at the site from an unknown previous site investigation (adjacent to the north eastern site gate). All bore logs from the GHD investigations are presented in Appendix B.

The phase 1 bores (BH01-BH10) were surveyed by Woods Surveying in North Taieri Circuit (2000) projection and New Zealand Vertical Datum (2016). Coordinates and ground elevation for the phase 2 bores and the NE Gate existing bore were not surveyed, and were therefore estimated from Google Earth and a Stantec contour map (Stantec, *undated*).

Table A 1: Boreholes and Monitoring Wells

Bore ID	Coordinates North Taieri Circuit (2000)		Ground Elevation (m RL) NZVD (2016)	Monitoring Well Screen (mbgl)
	Easting	Northing		
BH01	396465.5	788214.5	96.01	2 – 4 (BH01A) 8 – 9 (BH01B)
BH02	396358.6	788022.9	97.41	3 – 5 (BH02A) 7 – 9 (BH02B)
BH03	396428.4	787998.3	107.48	8.5 – 10.5 (BH03A) 13 – 15 (BH03B)
BH04	396563.6	788063.8	108.15	4.5 – 6.5 (BH04A) 12 – 15 (BH04B)
BH05	396459.8	787862.1	129.5	15 – 17 20 – 23
BH06	396168.3	787594	149.75	Not Installed
BH07	396493.7	787671.9	139.73	12 – 15 (BH07A) 16.8 – 19.8 (BH07B)
BH08	396809.7	787700.7	143.89	Not Installed
BH09	395951.8	788050.4	132.8	14.5 – 16.5
BH10	396788.3	788118.5	139.07	13.5 – 15.5 (BH10A) 18 – 20 (BH10B)
BH201	396593	787538	144	54 – 60
BH202	396181	787498	144	54 – 60
BH203	395779	787672	182	Not Installed
BH209	395775	788148	132	Not Installed
BH211	396592	787977	107	8.5 – 11.5 (BH211A) 22 – 25 (BH211B)
Existing Bore (NE Gate)	396955	787978	145	Unknown (Max bore depth 42.5)

A.3 Groundwater Level Monitoring

Groundwater levels recorded by manual dip on 25 November 2019, and 13 July 2020 and 24 March 2021 are presented in Table A 2.

Groundwater levels were also recorded using Solinst pressure transducers (level loggers). These were installed within all monitoring wells at the site (excluding the existing bore and monitoring wells which were dry) to record groundwater levels between 9 November 2019 and 25 November 2019 (Figure A 1 and Figure A 2). Unfortunately, data was not able to be retrieved from the pressure transducer installed in BH02B in 2019. Pressure transducers were also installed within BH01B, BH02A, BH02B, BH03A and BH03B between 28 January 2020 and 13 July 2020 (Figure A 3). Groundwater levels were also collected using a dip meter during installation and retrieval to enable the data collected by the pressure transducers to be calibrated to relative levels.

The loggers were set to record at 15 - -minute intervals. A baro-logger was also installed in the air column in BH07 upstand for the duration of the monitoring period to record barometric pressure changes; this allowed compensation for atmospheric pressure changes in the recorded pressure head from each of the level loggers to be undertaken.

Table A 2: Manual Groundwater Levels (updated May 2021)

Monitoring Well	25/11/2019		28/01/2020		13/07/2020		24/03/2021	
	mbtoc	m RL	mbtoc	m RL	mbtoc	m RL	mbtoc	m RL
BH01A	0.05	95.96	*No reading possible*		*No reading possible*		0.90	95.66
BH01B	0.57	95.99	0.65	95.91	0.91	95.65	1.37*	95.20*
BH02A	0.82	97.47	1.22	97.07	0.94	97.35	2.11	96.18
BH02B	1.6	96.67	1.19	97.08	1.05	97.215	1.15	97.12
BH03A	4.55	103.29	5.05	102.79	5.13	102.71	6.34	101.51
BH03B	4.34	103.24	4.82	102.76	5.13	102.45	6.12	101.47
BH04A	2.3	106.36	2.6	106.06	2.63	106.03	3.56	105.11
BH04B	5.19	103.54	4.71	104.02	4.53	104.2	4.4	104.33
BH05A	Dry		Dry	Dry	Dry		Dry	
BH05B	Dry		Dry	Dry	22.85	107.25	21.39	108.71
BH07A	Dry		Dry	Dry	Dry		Dry	
BH07B	Dry		Dry	Dry	Dry		Dry	
BH09	15.27	118.22	Not measured		14.03	119.46	13.37	120.13
BH10A	Dry		Dry		Dry		Dry	
BH10B	Dry		Dry		19.29	120.32	18.08	121.54
BH201	47.06	97.55	Not measured		47.27	97.34	47.49	97.12
BH202	*48.15**	*96.45**	Not measured		41.9	102.7	41.67	102.94
BH211A	3.23	104.19	2.87	104.55	3.48	103.94	3.12	104.30
BH211B	*13.45**	*94.0**	6.33	101.12	5.86	101.59	5.29	102.16
Existing bore (NE Gate)	26.37	118.93	27.26	118.04	27.93	117.37	27.6	117.70

** Groundwater levels impacted by well development or groundwater sampling.*

Figure A 1: Groundwater levels (excluding BH02B, BH202, BH211A & BH211B)

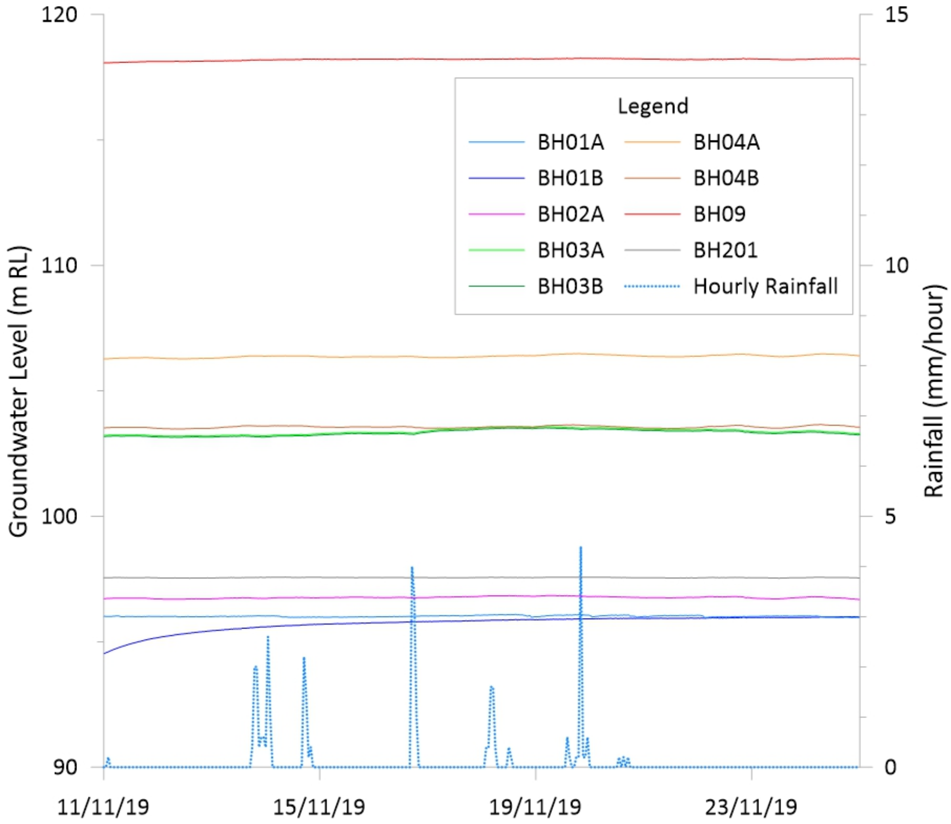


Figure A 2: Groundwater levels in locations where groundwater was still recovering following well development

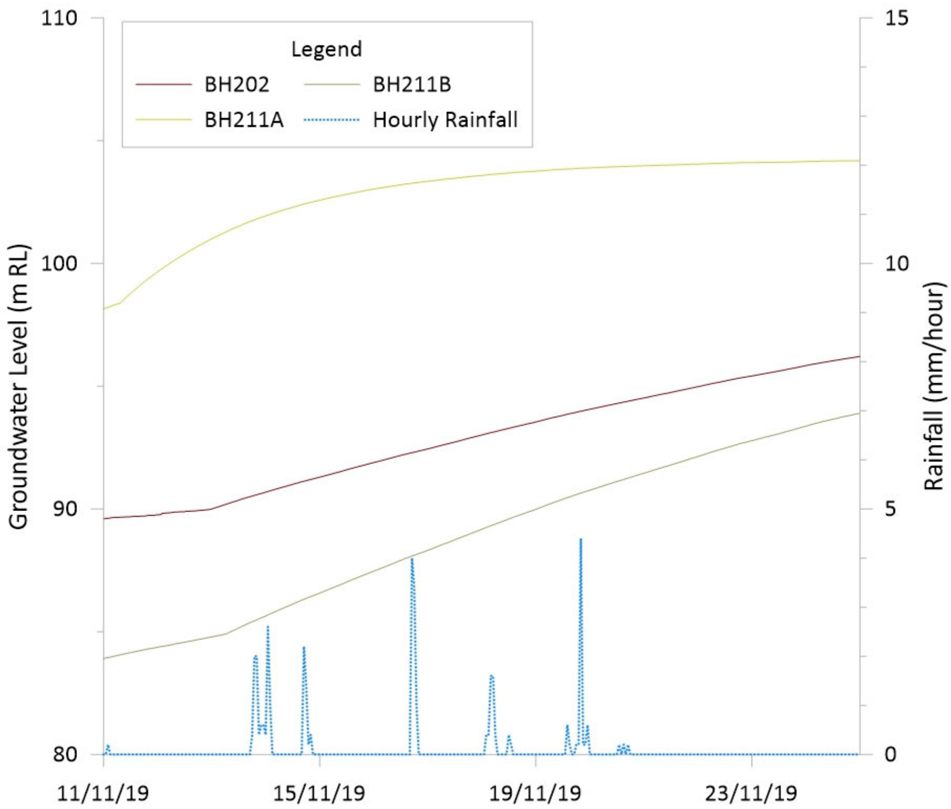
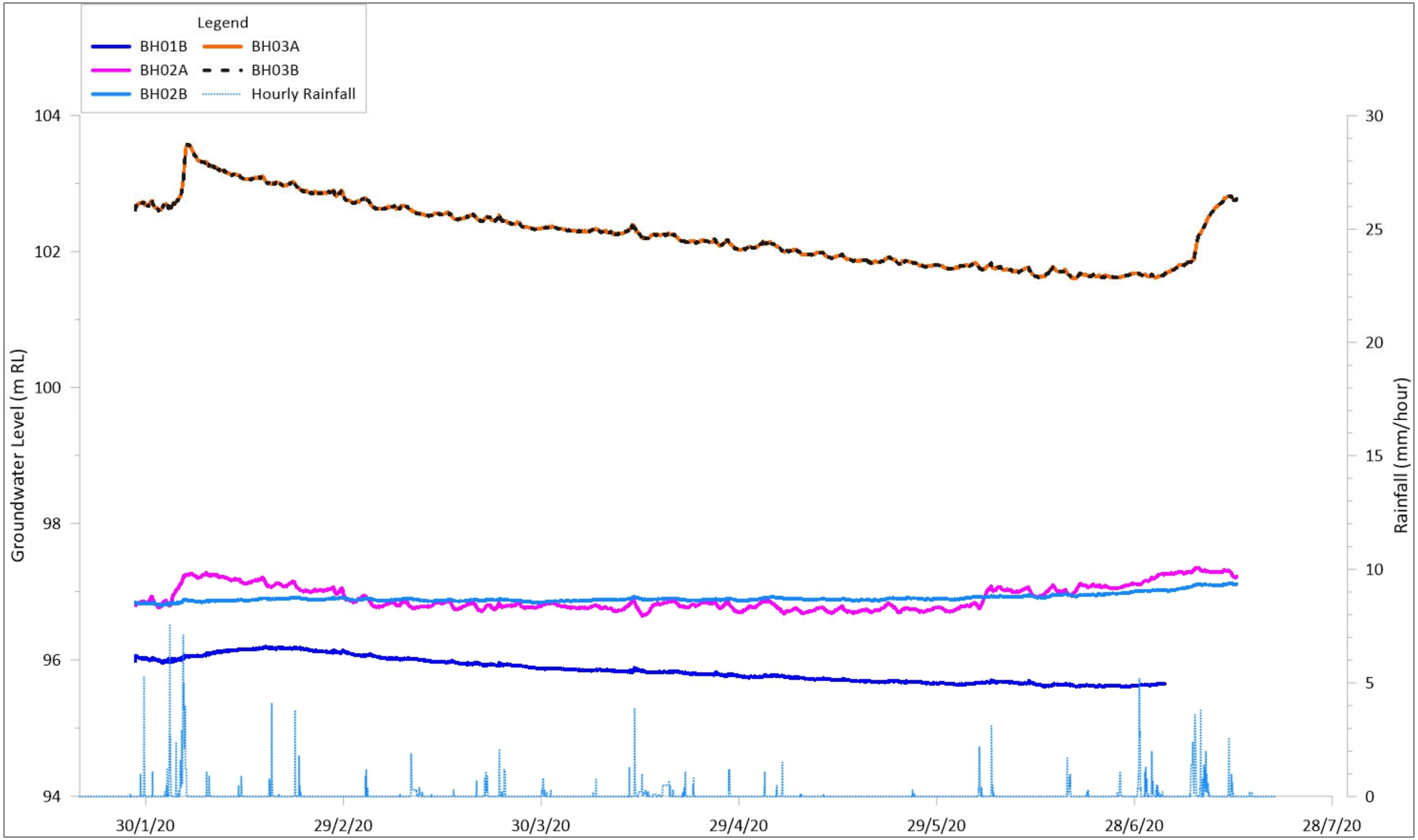


Figure A 3: 2020 groundwater levels



A.4 Hydraulic Testing

Hydraulic permeability testing was undertaken at all boreholes installed at the site. Due to very slow recharge at the majority of monitoring wells, two methods of hydraulic testing were undertaken to obtain as much information as possible from the site.

The first method involved recording the groundwater recovery following removal of water during well development. The second method of hydraulic testing was undertaken using a solid displacement slug was also undertaken at a number of the bores. Results are presented in Table A 3.

The results from the recovery tests following development represent a minimum value of permeability due to non-instantaneous displacement which is likely to have impacted surrounding groundwater levels. Where hydraulic testing was undertaken with a displacement slug, comparison between the two methods was able to be undertaken. The comparison indicated that the rising head tests following well development underestimated permeability by between approximately half an order of magnitude (BH201) to over two orders of magnitude (BH02A). The discrepancy generally increases with increasing permeability, as development is likely to have had a greater impact to the surrounding groundwater where permeability is higher.

A.5 Groundwater and Surface Water Quality

Groundwater samples were collected from a number of monitoring wells ~~between 6 and 25~~in November 2019 and March 2021, and surface water samples were collected from Otokia Creek in July 2020. No surface water samples were able to be collected in March 2021 as the Otokia Creek was observed to be dry between the site and McClaren Gully Road.

During the November 2019 monitoring round groundwater was purged from wells BH01 – BH04 until they either went dry or a minimum of three well volumes was removed. BH201 was not able to be purged as the depth to groundwater was a significant constraint. After groundwater had recharged a grab sample was collected from each monitoring well using dedicated water bailers. A water quality reading was also obtained from BH01 – BH04 at this time (Table A 4). The samples were kept cool in a chilly bin, then couriered to Analytica Laboratories for analysis. The analytical results are presented in Table A 5.

During the March 2021 monitoring round, low flow groundwater monitoring was undertaken in BH01, BH02, BH03, BH04 and BH211. Grab samples were collected from all other monitoring wells due to the significant constraints of low permeability and depth to groundwater. Water quality readings were obtained from all sampled monitoring wells (Table A 4). The samples were kept cool in a chilly bin, then couriered to Analytica Laboratories for analysis. The analytical results are presented in Table A 5.

A.6 Rainfall

An on-site meteorological station was established in July 2020 and has been collecting rainfall data since installation. The data is presented in Figure A-4.

Table A 3: Hydraulic Testing Results

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH01A	Alluvium / Colluvium	FHT1	B&R	1.1×10^{-5}	1.3×10^{-5}	Geomean of displacement hydraulic testing
			Hvorslev	9.2×10^{-6}		
		FHT2	B&R	8.0×10^{-6}		
			Hvorslev	7.9×10^{-6}		
		FHT3	B&R	2.1×10^{-5}		
			Hvorslev	2.3×10^{-5}		
		RHT1	B&R	2.5×10^{-5}		
			Hvorslev	3.2×10^{-5}		
		RHT2	B&R	8.6×10^{-6}		
			Hvorslev	6.7×10^{-6}		
BH01B	Gravel (Henley Breccia)	Rising head test following well development	B&R	5.3×10^{-9}	5×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	5.3×10^{-9}		
BH02A	Gravel (Henley Breccia)	Rising head test following well development	B&R	1.8×10^{-8}	3.2×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	1.3×10^{-8}		
		FHT1	B&R	3.5×10^{-6}		
			Hvorslev	3.5×10^{-6}		
		RHT1	B&R	2.9×10^{-6}		
			Hvorslev	2.9×10^{-6}		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH02B	Unweathered Henley Breccia	Rising head test following well development	B&R	1.7×10^{-9}	2×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	1.5×10^{-9}		
BH03A	Sandstone / siltstone (Henley Breccia)	Rising head test following well development	B&R	3.8×10^{-7}	1.6×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	4.3×10^{-7}		
		FHT1	B&R	1.5×10^{-6}		
			Hvorslev	1.9×10^{-6}		
		RHT1	B&R	1.4×10^{-6}		
			Hvorslev	1.5×10^{-6}		
BH03B	Unweathered Henley Breccia	Rising head test following well development	B&R	6.1×10^{-7}	1.6×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	4.3×10^{-7}		
		FHT1	B&R	1.7E x 10^{-6}		
			Hvorslev	1.7×10^{-6}		
		RHT1	B&R	1.6×10^{-6}		
			Hvorslev	1.6×10^{-6}		
BH04A	Conglomerate / sandstone (Henley Breccia)	Rising head test following well development	B&R	5.2×10^{-9}	-	Low permeability potentially due to insufficient well development.
			Hvorslev	7.9×10^{-9}		
		FHT1	Did not reach 70% recovery	$< 5.2 \times 10^{-9}$		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH04B	Slightly weathered Henley Breccia	Rising head test following well development	B&R	3.4×10^{-8}	1.9×10^{-7}	Geomean of displacement hydraulic testing
			Hvorslev	2.7×10^{-8}		
		FHT1	B&R	2.2×10^{-7}		
			Hvorslev	2.1×10^{-7}		
		RHT1	B&R	1.9×10^{-7}		
			Hvorslev	1.6×10^{-7}		
BH09	Henley Breccia	Rising head test following well development	B&R	4.1×10^{-9}	6×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	8.0×10^{-9}		
BH201	Henley Breccia	Rising head test following well development	B&R	1.4×10^{-8}	6.2×10^{-8}	Geomean of displacement hydraulic testing
			Hvorslev	1.6×10^{-8}		
		FHT1	B&R	8.9×10^{-8}		
			Hvorslev	9.4×10^{-8}		
		RHT1	B&R	4.4×10^{-8}		
			Hvorslev	3.9×10^{-8}		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH202	Henley Breccia	Rising head test following well development	B&R	2.5×10^{-10}	$< 3 \times 10^{-9}$	1 order of magnitude greater than hydraulic testing following development. Static groundwater level has not yet been determined as bore recovery was still occurring during 25/11/2019 site visit.
			Hvorslev	3.8×10^{-10}		
BH211A	Henley Breccia	Rising head test following well development	B&R	7.5×10^{-10}	8×10^{-9}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	9.3×10^{-10}		
BH211B	Henley Breccia	Rising head test following well development	B&R	5.6×10^{-10}	$< 6 \times 10^{-9}$	1 order of magnitude greater than hydraulic testing following development. Static groundwater level has not yet been determined as bore recovery was still occurring during 25/11/2019 site visit.
			Hvorslev	7.6×10^{-10}		

* FHT/RHT = Falling/Rising Head Test undertaken using displacement slug

Table A 4: Groundwater Quality Sample Parameters

Monitoring Well	Sample Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (us/cm)	ORP (mV)
BH01A	6/11/19	14.3	6.5	2.43	1189	196.4
	24/03/21	13.0	6.57	0.76	1158	159.3
BH01B	9/11/19	12.3	7.08	4.81	578	176.9
	24/03/21	13.7	7.32	1.66	617	148.3
BH02A	9/11/19	12.6	6.55	1.86	337.9	59.2
	25/03/21	14.1	6.85	0.58	625	1.2
BH02B	9/11/19	12.3	6.12	2.51	575	-23.3
	25/03/21	13.5	8.22	4.8	1008	41.3
BH03A	9/11/19	12.4	6.6	4.24	886	206.1
	25/03/21	13.2	6.59	0.80	1259	81.6
BH03B	9/11/19	12.3	6.81	7.07	923	196.5
	25/03/21	13.1	6.78	0.89	1309	83.1
BH04A	9/11/19	12.8	6.75	7.14	1145	161.6
	26/03/21	18.2	6.81	1.88	1766	42.2
BH04B	9/11/19	14.0	6.7	6.31	610	30.2
	23/03/21	12.5	6.96	0.49	1500	86.1
BH05B	24/03/21	12.8	6.99	4.74	1008	-1.4
BH09	24/03/21	10.9	7.2	5.89	790	82.4
BH10B	26/03/21	10.5	7.45	7.99	470.2	27.7
BH201	25/11/19	Not measured				
	24/03/21	13.3	7.56	5.71	757	78.0

Monitoring Well	Sample Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (us/cm)	ORP (mV)
BH202	24/03/21	12.2	7.67	7.65	811	71.1
BH211A	26/03/21	16.6	7.54	0.72	889	28.7
BH211B	26/03/21	14.0	8.18	0.58	652	40.6
Existing bore (NE Gate)	24/03/21	11.8	7.08	6.14	522.8	66.4

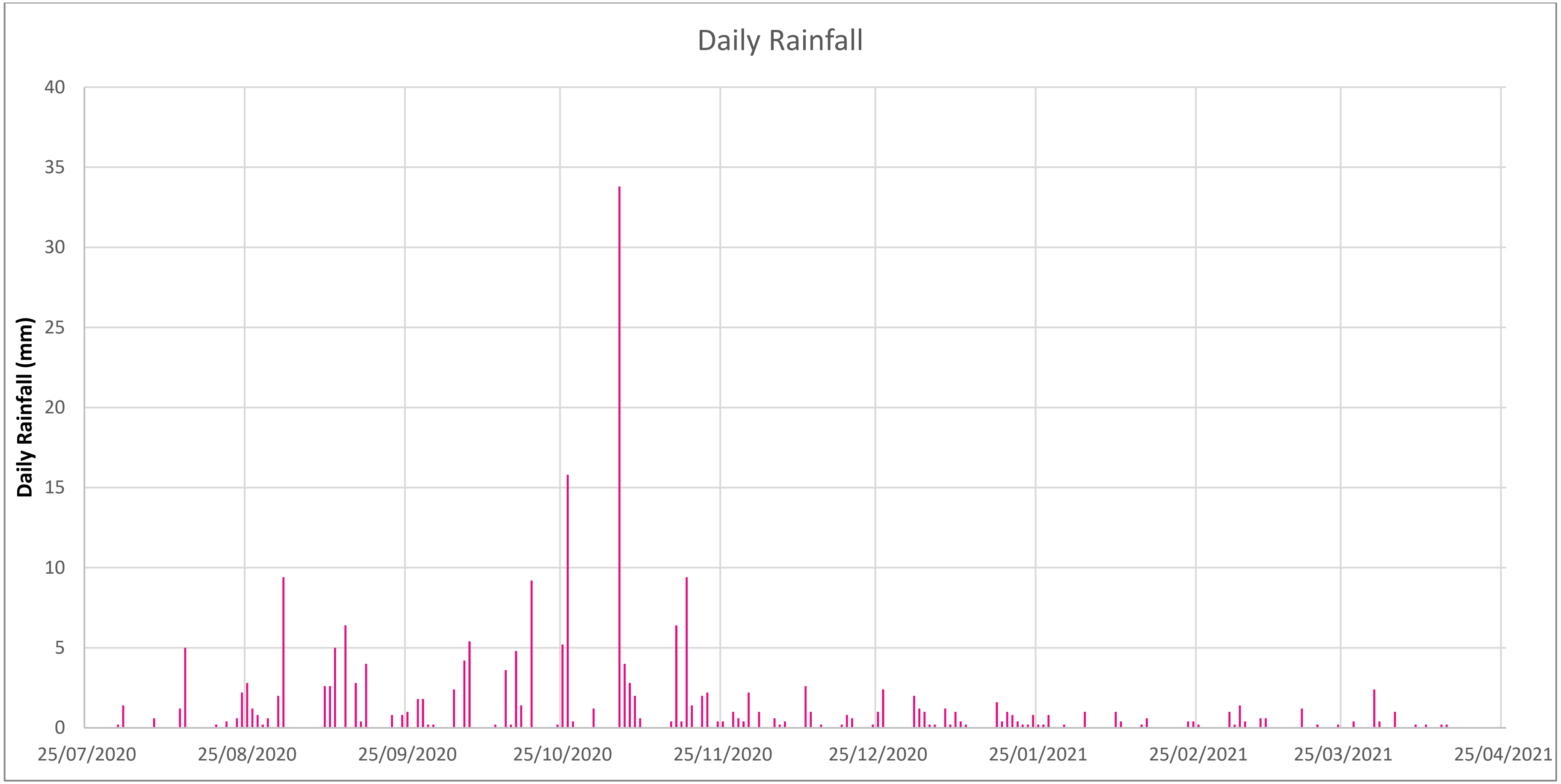
Sample Name	Date	Laboratory Number	Total Alkalinity (CaCO3)	Electrical Conductivity	pH	Chloride	Ammonia as N	Nitrite-N (NO2-N)	Nitrate-N (NO3-N)	Total Kjeldahl Nitrogen	Total Nitrogen	Sulphate	Dissolved Reactive Phosphorus	Total Phosphorus	Carbonate/ Bicarbonate/ CO2/ Hydroxide: Bicarbonate Alkalinity	Carbonate Alkalinity	Hydroxide Alkalinity	Free Carbon Dioxide
			mg/L	µS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Criteria			-	-	-	-	**0.2**	**1.0**	**1.0**	-	-	-	**0.035**	-	-	-	-	-
BH01A	6/11/19	19-40125-1	324	1610	7.3	145	0.03	0.05	**26.7**	0.81	28	182	-	-	-	-	-	-
BH01A	23/03/21	21-12139	437	1480	7.4	108	<0.005	0.058	**10.8**	0.18	11	202	<0.002	0.022	436	<1	<1	36.5
BH01B	9/11/19	19-40125-2	277	876	7.8	76.9	0.15	0.0056	0.0591	0.7	0.76	59.7	-	-	-	-	-	-
BH01B	23/03/21	21-12139	290	748	8.3	63.1	0.02	<0.001	0.227	0.22	0.45	17.6	<0.002	0.03	285	4.9	<1	3.1
BH02A	9/11/19	19-40125-3	238	538	7.2	39.3	0.11	0.0013	0.0919	0.57	0.66	0.68	-	-	-	-	-	-
BH02A	25/03/21	21-14269	233	530	7.5	37	0.15	<0.001	0.0223	1.5	1.5	0.55	<0.002	0.14	233	<1	<1	15.3
BH02A Duplicate	25/03/21	21-14269	229	530	7.7	37	0.15	<0.001	0.0242	1.1	1.1	0.57	<0.002	0.12	228	1.2	<1	8.4
BH02B	9/11/19	19-40125-4	275	772	8	89.3	0.14	<0.0010	<0.0020	1.65	1.7	4.91	-	-	-	-	-	-
BH02B	25/03/21	21-14269	366	943	8.4	101	**0.27**	<0.001	0.0246	3.4	3.4	0.7	<0.002	0.096	357	8.7	<1	2.8
BH03A	9/11/19	19-40125-5	461	1800	7.4	109	<0.005	0.0193	**4.32**	0.53	4.9	57.8	-	-	-	-	-	-
BH03A	25/03/21	21-14269	551	1300	7.4	85.4	0.04	0.0056	0.233	1.2	1.4	68.6	<0.002	0.006	550	1.4	<1	42
BH03B	9/11/19	19-40125-6	497	1310	7.5	106	0.07	0.0194	**4.35**	0.69	5.1	59.8	-	-	-	-	-	-
BH03B	25/03/21	21-14269	601	1330	7.6	86.9	**0.36**	<0.001	0.0948	<0.8	<0.1	62.3	0.004	0.01	599	2.4	<1	27.7
BH04A	9/11/19	19-40125-7	248	1430	7.2	301	0.03	0.0163	0.0672	0.45	0.54	9.28	-	-	-	-	-	-
BH04A	25/03/21	21-14269	455	1650	7.5	274	0.05	0.001	0.0173	<0.8	<0.1	5.01	0.032	0.017	454	1.3	<1	28.9
BH04B	9/11/19	19-40125-8	1088	2060	7.2	80.3	**0.28**	0.0061	0.029	0.93	0.96	44.9	-	-	-	-	-	-
BH04B	23/03/21	21-12139	1169	2030	7.8	55.7	**0.37**	<0.001	0.0024	0.56	0.56	15.6	<0.002	0.032	1161	7.2	<1	35
BH05B	25/03/21	21-14269	429	992	7.9	49.5	<0.005	<0.001	0.589	<0.8	0.59	45.9	<0.002	0.84	426	3.1	<1	11.1
BH10B	26/03/21	21-14269	403	812	8	28.9	0.02	0.0017	0.0898	<0.8	<0.1	35.3	<0.002	0.2	398	4.2	<1	7.2
BH201	25/11/19	19-41653	267	754	8.1	66.4	**2.59**	0.0068	0.0379	3.75	3.8	17.8	-	-	264	2.8	<1.0	4.7
BH201	24/03/21	21-12139	284	791	8.3	91.1	**1.61**	0.0039	**3.37**	2.2	5.6	15.6	<0.002	0.31	279	4.7	<1	3.1
BH202	24/03/21	21-12139	285	749	8	70	0.14	<0.001	0.0082	0.9	0.91	26.4	<0.002	0.41	283	2.8	<1	5.3
BH209	24/03/21	21-12139	229	666	7.7	31.2	**0.3**	0.0044	0.139	<0.8	0.14	67.2	<0.002	0.94	228	<1	<1	9.9
BH211A	26/03/21	21-14269	371	843	8.2	50.3	0.03	0.0066	0.464	1.3	1.8	16.8	<0.002	0.024	365	5.7	<1	4.4
BH211B	26/03/21	21-14269	274	640	8.4	46	**0.36**	<0.001	0.0026	1.1	1.1	1.27	0.005	0.015	268	6.1	<1	2.2
Existing Well	24/03/21	21-12139	343	881	7.6	76.8	0.11	<0.001	<0.002	<0.8	<0.1	29.2	<0.002	0.79	341	1.2	<1	17.9
SW1	6/07/20	20-24885-1	-	325	6.7	-	0.05	0.0045	0.322	1.49	1.8	33.2	-	-	-	-	-	-
SW2	6/07/20	20-24885-2	-	340	6.7	-	0.03	0.003	0.0245	1.45	1.5	32.3	-	-	-	-	-	-
SW3	6/07/20	20-24885-3	-	331	6.7	-	0.02	0.0014	0.0506	1.03	1.1	29.7	-	-	-	-	-	-

Sample Name	Date	Laboratory Number	Soluble Trace Elements: Arsenic[1]	Cadmium[2]	Chromium	Copper	Lead	Nickel	Zinc	Magnesium	Calcium	Sodium	Potassium	Iron	Manganese	Total Recoverable: Magnesium	Calcium	Iron	Manganese
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Water Quality Criteria			**0.013**	**0.0002**	**0.001**	**0.0014**	**0.0034**	**0.011**	**0.008**	-	-	-	-	-	**1.9**	-	-	-	**1.9**
BH01A	6/11/19	19-40125-1	<0.00050	0.000026	<0.00020	**0.0025**	<0.000050	0.0061	0.0078	44.6	138	79.9	5.41	0.12	0.159	-	-	-	-
BH01A	23/03/21	21-12139	<0.0005	0.000086	<0.0002	0.00063	<0.00005	0.0036	0.0048	58.9	178	84.5	6.32	<0.005	0.376	-	-	-	-
BH01B	9/11/19	19-40125-2	0.00088	0.000023	0.00023	0.001	0.00013	0.005	0.0068	18.3	69.9	67.8	6.3	0.021	1.66	-	-	-	-
BH01B	23/03/21	21-12139	<0.0005	<0.00002	<0.0002	**0.0028**	<0.00005	0.0027	0.0041	18.4	68.5	68	5.14	0.06	1.41	-	-	-	-
BH02A	9/11/19	19-40125-3	0.0092	<0.000010	0.00024	0.00052	0.000052	0.0032	**0.0091**	12.2	36.3	56.9	2	3.4	1.05	-	-	-	-
BH02A	25/03/21	21-14269	0.00093	<0.00002	<0.0002	0.00041	<0.00005	0.0017	0.0025	12.7	38.6	59.7	1.8	4.69	1.06	-	-	-	-
BH02A Duplicate	25/03/21	21-14269	0.001	<0.00002	<0.0002	0.00043	<0.00005	0.0018	0.0038	12.7	38.4	59.5	1.8	4.6	1.07	-	-	-	-
BH02B	9/11/19	19-40125-4	0.0012	0.00013	0.00054	**0.0033**	0.00023	**0.0238**	0.0018	8.26	25.7	120	8.72	0.24	0.141	-	-	-	-
BH02B	25/03/21	21-14269	0.0011	0.00006	<0.0002	<0.0002	<0.00005	0.0063	<0.001	10.9	31.6	172	4.8	0.25	0.435	-	-	-	-
BH03A	9/11/19	19-40125-5	<0.00050	0.000039	<0.00020	0.00097	<0.000050	0.0054	0.0063	34.1	135	53.3	14.1	0.018	0.909	-	-	-	-
BH03A	25/03/21	21-14269	<0.0005	0.000059	<0.0002	0.0012	<0.00005	0.0055	0.0045	42.7	170	52.4	16.3	0.057	1.09	-	-	-	-
BH03B	9/11/19	19-40125-6	<0.00050	<0.000010	0.00021	0.0011	<0.000050	0.0056	**0.0097**	38	144	65.2	13.5	<0.0050	1.45	-	-	-	-
BH03B	25/03/21	21-14269	<0.0005	<0.00002	<0.0002	0.00072	<0.00005	**0.0247**	0.0033	49.1	171	70.6	11.2	0.015	1.42	-	-	-	-
BH04A	9/11/19	19-40125-7	<0.00050	0.00019	0.00023	**0.0016**	<0.000050	**0.0344**	**0.027**	24.5	63	161	4.6	0.36	1.68	-	-	-	-
BH04A	25/03/21	21-14269	<0.0005	<0.00002	<0.0002	0.0009	<0.00005	0.0044	0.0014	28.5	86.9	222	5.16	<0.005	0.649	-	-	-	-
BH04B	9/11/19	19-40125-8	0.00086	0.000032	<0.00020	0.00047	<0.000050	**0.0268**	**0.0095**	57.3	169	202	9.08	0.879	1.32	-	-	-	-
BH04B	23/03/21	21-12139	0.0024	<0.00002	0.00048	<0.0002	<0.00005	0.0029	<0.001	56.7	137	301	8.43	7.11	0.71	-	-	-	-
BH05B	25/03/21	21-14269	<0.0005	<0.00002	<0.0002	**0.0051**	0.00016	0.0072	**0.0096**	25.1	116	68.4	10.6	0.013	0.326	-	-	-	-
BH10B	26/03/21	21-14269	0.00069	0.000066	<0.0002	**0.0025**	0.000088	0.0046	**0.058**	23.3	104	43.3	6.74	0.013	0.346	-	-	-	-
BH201	25/11/19	19-41653	0.0028	0.000061	0.0003	0.0011	<0.000050	**0.013**	**0.01**	-	-	-	-	-	-	-	-	-	-
BH201	24/03/21	21-12139	0.0056	<0.00002	<0.0002	0.00028	<0.00005	0.0014	0.0053	23.9	57.3	86.1	12.4	0.846	0.124	-	-	-	-
BH202	24/03/21	21-12139	0.0038	0.00003	<0.0002	<0.0002	<0.00005	0.00092	<0.001	35.2	88.2	87.9	11.4	2.46	0.448	-	-	-	-
BH209	24/03/21	21-12139	0.0036	**0.00447**	<0.0002	0.00054	0.000082	0.0052	**0.0083**	10.2	16.5	105	19.3	0.32	0.27	-	-	-	-
BH211A	26/03/21	21-14269	0.00089	<0.00002	<0.0002	**0.0017**	<0.00005	0.0037	0.0044	12.5	40	137	5.03	0.065	0.176	-	-	-	-
BH211B	26/03/21	21-14269	0.0006	0.000035	<0.0002	<0.0002	<0.00005	0.00031	<0.001	7.42	22.7	107	7.27	0.083	0.177	-	-	-	-
Existing Well	24/03/21	21-12139	0.00089	<0.00002	0.00034	<0.0002	0.000099	0.00091	0.0025	25.1	95.6	65.6	6.06	2.24	0.376	-	-	-	-
SW1	6/07/20	20-24885-1	<0.00050	<0.000020	<0.00020	0.00072	<0.000050	0.0013	0.0048	-	-	-	-	-	-	8.77	15.6	4.48	0.957
SW2	6/07/20	20-24885-2	<0.00050	<0.000020	<0.00020	0.00028	<0.000050	0.0007	0.0024	-	-	-	-	-	-	9.02	16.3	9.07	0.651
SW3	6/07/20	20-24885-3	<0.00050	<0.000020	<0.00020	**0.012**	0.00057	0.00083	0.0028	-	-	-	-	-	-	9.04	16.1	7.45	0.812

Notes:
Shaded and **bolded** values exceed the corresponding water quality criteria.

Water Quality Criteria References
ORC (2016). Otago Regional Council. Regional Plan: Water for Otago. Schedule 16A: Discharge Thresholds for Discharge Threshold Area 2
ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Default guideline values for freshwater - protection: 95% of of species.
bold and shaded indicates exceedance over screening values, - no screening value available in Otago Regional Plan or ANZG (2018)
1 - Value for Arsenic (AsV) used
2 - Value for Chromium (CrVI)

Figure A 4: Daily rainfall at onsite meteorological station (Updated May 2021)



Appendix B – Borelogs

Project : Smooth Hill Landfill Consenting	**Hole No. : BH01**
Client : Dunedin City Council	Sheet : 1 of 2
Site : Smooth Hill Dam foundation	Hole Length : 15.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 6/06/2019 Completed: 6/06/2019	Logged : MF
Easting: 396465.49 Northing: 788214.52 System: TAIETM2000	Processed : HB
RL: 96.01 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
0.00 - 1.20	Fine to medium gravelly SILT, trace fine to coarse sand, trace clay; light yellow brown & orange brown. Stiff, moist, low plasticity. (COLLUVIUM?). Gravel clasts comprise quartz and schist, sub angular to sub rounded.	COLLUVIUM	M	St	PQTT		77
1.20 - 2.70	Inferred CORELOSS. Possible slip base & stream alluvium lost? Driller said it "was so soft, it was like drilling nothing". Tried pushing down with no water or rotation, but still could not retrieve core. Same for next coreloss zone at 3.0 m to 3.9 m.	ALLUVIUM		"	PQTT		20
2.70 - 2.90	Silty CLAY, trace fine sand; grey & orange brown. Soft to firm, moist, high plasticity. (ALLUVIUM?).	ALLUVIUM	M	S-F			
2.90 - 3.00	Silty fine to coarse SAND, trace organics; grey. Poorly graded. (ALLUVIUM?). Note no moisture condition or density determined and logged.	ALLUVIUM		"	PQTT		0
3.00 - 3.90	Inferred CORELOSS. Possible alluvium loss?	ALLUVIUM					
3.90 - 4.40	Slightly weathered, light grey fine to coarse SANDSTONE; moderately strong to strong; well indurated, no defects. (HENLEY BRECCIA).	HENLEY BRECCIA			PQTT	SW	100 22
4.40 - 4.80	Slightly weathered, grey SILTSTONE; very weak to weak; poorly indurated, no defects.	HENLEY BRECCIA				SW	
4.80 - 5.28	Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; poorly indurated, no defects. 5.28 - 5.38 From 5.28 m, becomes moderately strong to strong, well indurated. 5.38 - 6.00 From 5.38 m, becomes very weak to weak, poorly indurated. 6.00 - 6.25 From 6.00 m, becomes moderately strong to strong, well indurated. 6.25 - 6.80 From 6.25 m, becomes very weak to weak, poorly indurated.	HENLEY BRECCIA			PQTT	SW	98 80
6.80 - 7.80	Slightly weathered, light yellow brown & reddish brown SILTSTONE; very weak to weak; poorly indurated, no defects. From 6.9 m, becomes light grey & reddish brown. From 7.05m, becomes light grey with purple-brown layers. From 7.3 m to 7.4 m, becomes fin	HENLEY BRECCIA			PQTT	SW	100 97
7.80 - 8.30	Slightly weathered, light grey with purple-brown layers fine to medium SANDSTONE; very weak to weak; poorly indurated, no defects.	HENLEY BRECCIA			PQTT	SW	53 53
8.30 - 9.00	Inferred CORELOSS in gravel layer. Gravel present on ends of core abutting this zone. Fine to medium gravel, quartz and schist clasts, sub angular to sub rounded.	HENLEY BRECCIA		"			
9.00 - 9.50	Slightly weathered, grey and brown SILTSTONE; very weak to weak; poorly indurated, no defects.	HENLEY BRECCIA			PQTT	SW	100 100
9.50 - 11.30	Slightly weathered, light grey with purple-brown layers fine to medium SANDSTONE; very weak to weak; poorly indurated, no defects.	HENLEY BRECCIA				SW	

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Looks like drill pad on slip debris pile. Scarp above (east) of pad.
Ground stripped ~0.6 m, including all topsoil.
Piezo installed 10/06/2019.
As of end of 07/06/2019, driller has been unable to recover core from last run. keeps slipping out of barrel. Will try again before piezo install on 10/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNiells

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH01
Client : Dunedin City Council	Sheet : 2 of 2
Site : Smooth Hill Dam foundation	Hole Length : 15.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 6/06/2019 Completed: 6/06/2019	Logged : MF
Easting: 396465.49 Northing: 788214.52 System: TAIETM2000	Processed : HB
RL: 96.01 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR SCR RQD (%)	Casing
10.5–11.3	From 10.5 m: 10 mm thick bedding visible.	HENLEY BRECCIA	PQTT	SW	100 / 100	
11.3	11.30 - 13.10 Unweathered, grey BRECCIA; moderately strong to strong; fine to medium gravel size clasts, coarse sand matrix, matrix supported, well indurated, no defects. Clasts are quartz and schist, angular to sub rounded, 300-600 mm bedding. From 11.7 m: very few		PQTT	UW	97 / 97	
12.2, 12.8			PQTT		100 / 100	
13.1	13.10 - 15.00 From 13.1 m, becomes weak to moderately strong, fine to coarse gravel clasts, clast supported, moderate to well indurated. Note - As of end of 07/06/2019, driller has been unable to recover core from last run. keeps slipping out of barrel. Will try aga		PQTT	UW		122mm
15	End of Hole @ 15.00m,Target Depth.					

Columns also present: RL (m), Graphic, Moisture condition, Consistancy / Relative density, Sample (Number / Type, Result), Flush Return (%), Estimated Strength (MPa), Defect Spacing (mm), Instrumentation Installation, Water level.

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Looks like drill pad on slip debris pile. Scarp above (east) of pad.
Ground stripped ~0.6 m, including all topsoil.
Piezo installed 10/06/2019.
As of end of 07/06/2019, driller has been unable to recover core from last run. keeps slipping out of barrel. Will try again before piezo install on 10/06/2019.

Refer to explanation sheets for abbreviation and symbols

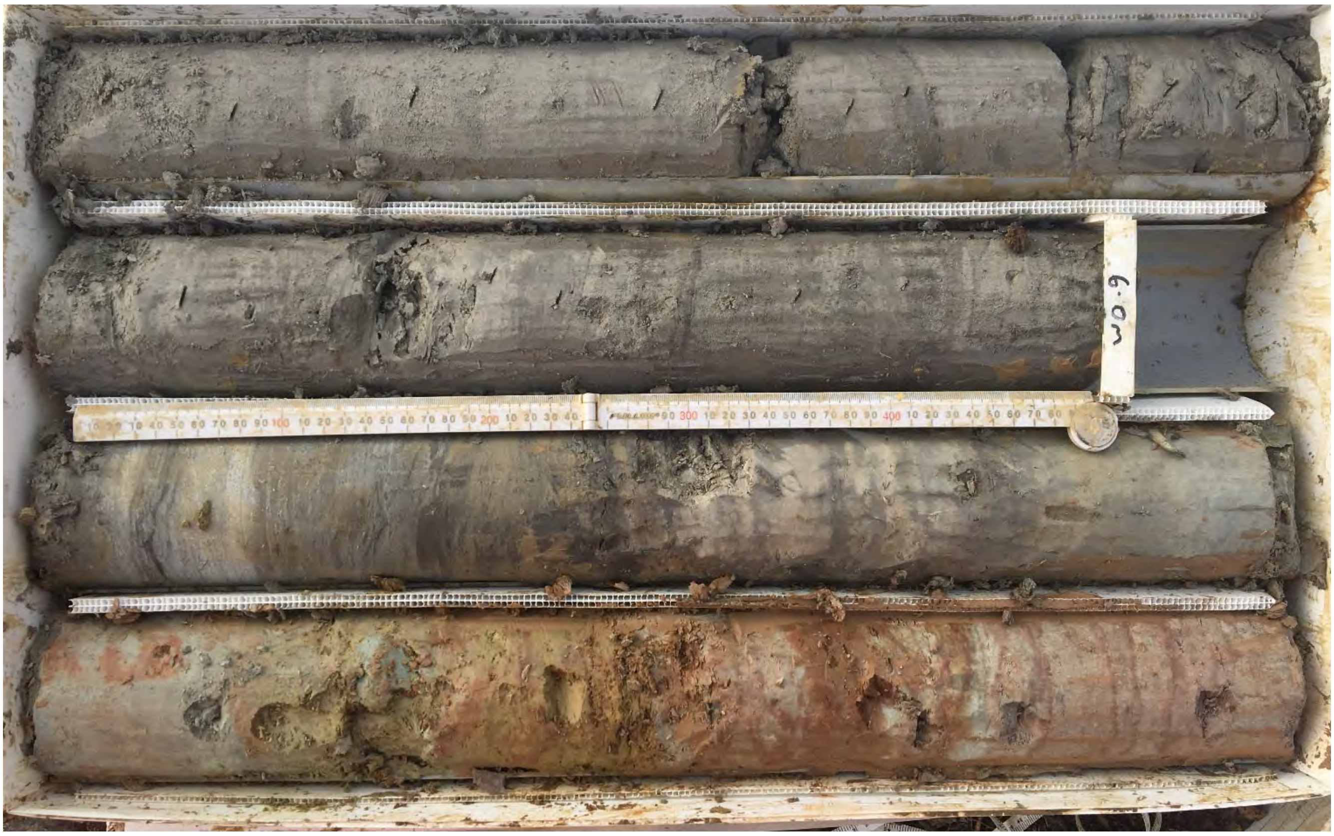
Inclination: Vertical
Orientation:
Contractor: McNiells
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH01	

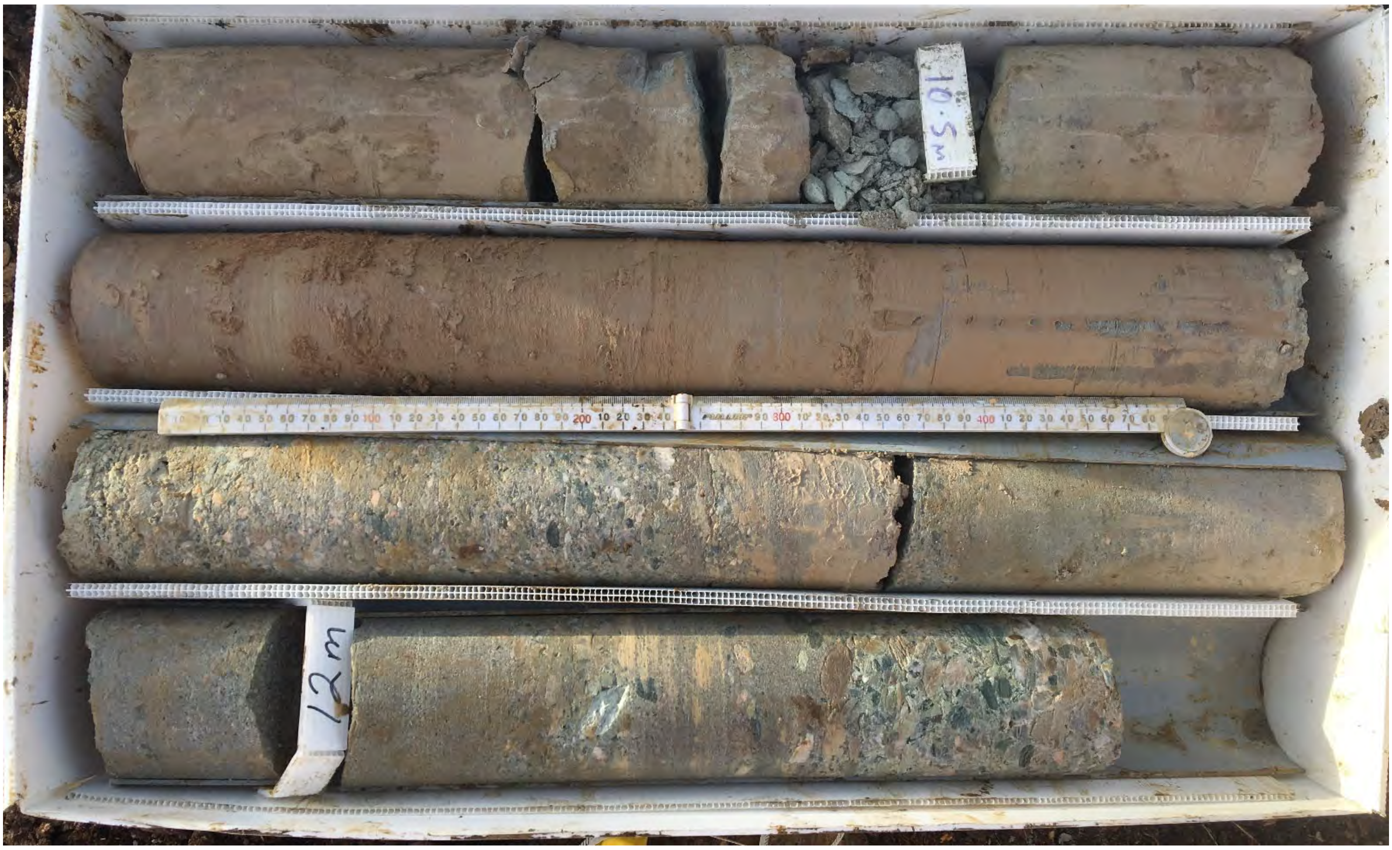
Box 1 of 5: 0.00 m to 4.80 m



Box 2 of 5: 4.80 m to 7.20 m

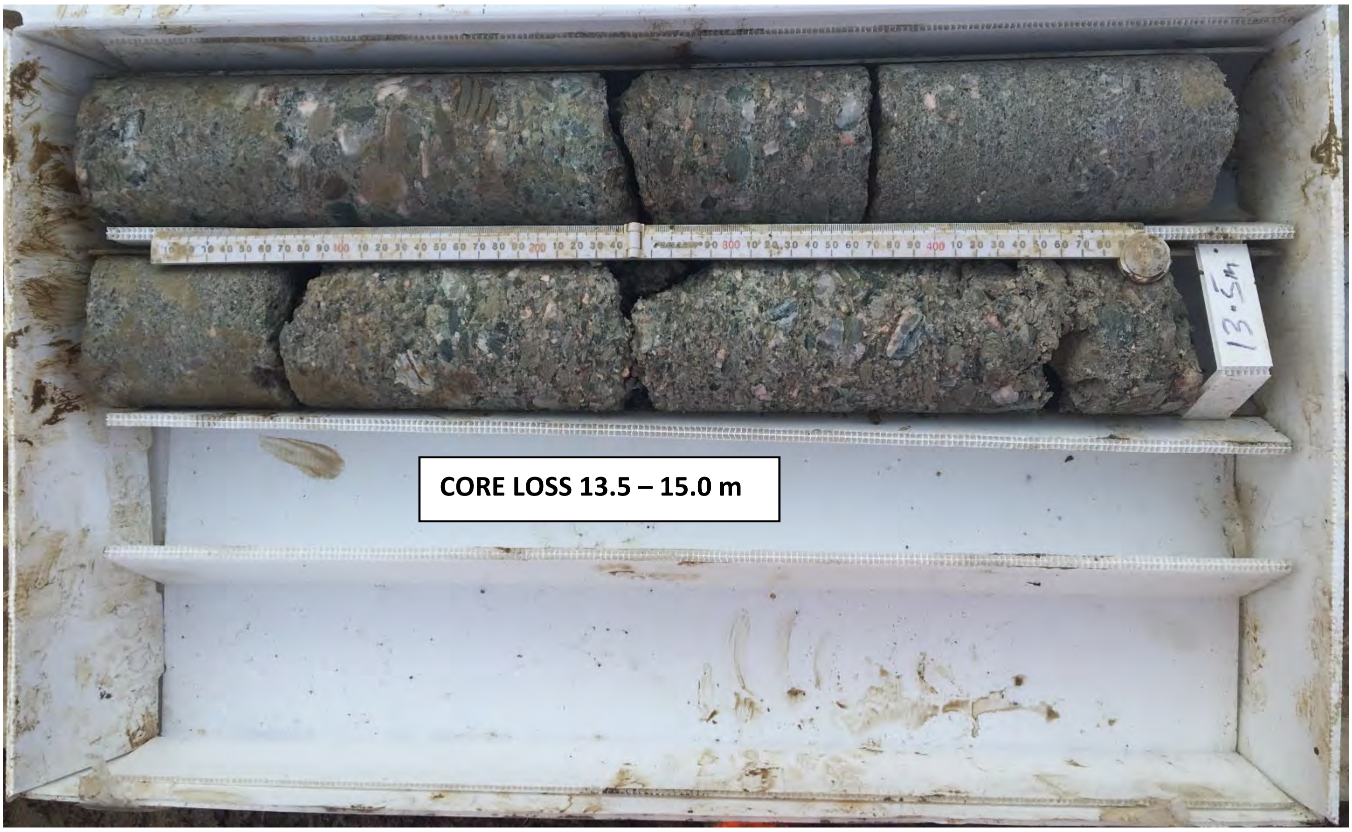
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 3
Borehole ID	BH01	

Box 3 of 5: 8.20 m to 10 .20 m



Box 4 of 5: 10.20 m to 12.40 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 3
Borehole ID	BH01	



Box 5 of 5: 12.40 m to 15.00 m (EOH)

Project	: Smooth Hill Landfill Consenting
Client	: Dunedin City Council
Site	: Smooth Hill Toe bund
Job Number	: 12506381
Commenced	: 27/05/2019
Completed	: 28/05/2019

Hole No. : BH02

Sheet	: 1 of 2
Hole Length	: 15.00m
Scale @ A4	: 1:50
Logged	: MF
Processed	: HB
Checked	: JS

Easting: 396358.59 Northing: 788022.89 System: TAIETM2000

RL: 97.41 Datum: NZVD2016

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Result	Method	TCR / SCR / RQD (%)	Weathering
0 – 0.5	0.00 - 0.50 Inferred CORELOSS			"				
0.5 – 1.5	0.50 - 1.50 SILT, minor clay, trace to minor fine sand; light grey & brown. Stiff to very stiff, moist, non plastic. Contains Fe weathered spots & small (<50mm) lenses of Fe staining. (LOESS)	LOESS	M	St-VSt	SV@1.5m 42/5	PQTT	67	
1.5 – 2.15	1.50 - 2.15 Inferred CORELOSS	HISTORIC [PRE GLACIAL] ALLUVIUM		"		PQTT	50	
2.15 – 2.45	2.15 - 2.45 Fine sandy SILT, trace clay; light grey. Firm, moist, non plastic (transitions into)	HISTORIC [PRE GLACIAL] ALLUVIUM	M	F				
2.45 – 2.6	2.45 - 2.60 Silty fine SAND; grey. 'Very loose to loose', saturated, poorly graded (ALLUVIUM?). Moisture content may be influenced by drilling fluid in loose materials.	HISTORIC [PRE GLACIAL] ALLUVIUM	S	VL-L				
2.6 – 2.9	2.60 - 2.90 Fine sandy SILT; grey. Firm, moist, non plastic. Rootball at 2.8-2.9 m	HISTORIC [PRE GLACIAL] ALLUVIUM	M	F	SV@2.8m /	PQTT		
2.9 – 3.35	2.90 - 3.35 Inferred CORELOSS (Likely gravel that got washed away)	HISTORIC [PRE GLACIAL] ALLUVIUM		"			70 / 63	
3.35 – 3.7	3.35 - 3.70 GRAVEL; light grey. 'Very loose to loose', saturated, gravel is fine, angular to subangular quartz & schist. Fines matrix washed away. Moisture content may be influenced by drilling fluid in loose materials. (ALLUVIUM? TOP OF BRECCIA?) End of day 27/05/19.		S	VL-L				
3.7 – 3.95	3.70 - 3.95 Fine to coarse SAND, minor to some fine gravel; grey. 'Very dense' soil or extremely weathered to very weathered rock (BRECCIA), dry, non plastic; gravel is fine quartz & schist, angular to subangular.	HENLEY BRECCIA	D	VD				CW-RS
3.95 – 5.3	3.95 - 5.30 Unweathered, bedded, alternating grey fine SANDSTONE & SILTSTONE; very weak; bedding 300 to 500 mm thick, uniform grainsize within layers. Quartz vein noted at 4.6 m at 60 degrees to core axis, (bedding horizontal?).	HENLEY BRECCIA			SV@4.3m UTP	PQTT	109 / 100	UW
5.3 – 5.7	5.30 - 5.70 Unweathered, grey SANDSTONE (BOULDER); strong; lithified fine angular gravel layers, no defects (BRECCIA).	HENLEY BRECCIA						UW
5.7 – 5.9	5.70 - 5.90 Silty CLAY; dark grey. Firm to stiff, moist, high plasticity (not lithified).	HENLEY BRECCIA	M	F-St				
5.9 – 6.4	5.90 - 6.40 Unweathered, bedded, alternating grey fine SANDSTONE & SILTSTONE; very weak; bedding 300 to 500 mm thick, uniform grainsize within layers. 10 mm coal lense at 6.11 - 6.12 m.	HENLEY BRECCIA				PQTT	100 / 100	UW
6.4 – 6.55	6.40 - 6.55 Unweathered, grey silty fine SANDSTONE; weak to moderately strong.	HENLEY BRECCIA						UW
6.55 – 9.1	6.55 - 9.10 Unweathered, grey BRECCIA; weak to moderately strong; semi distinct bedding, no defects. Clasts are quartz & schist, fine to medium gravel size, angular to subrounded. Coarse SAND matrix.	HENLEY BRECCIA				PQTT	100 / 100	UW
9.1 – 9.2	9.10 - 9.20 SILT; grey. Very stiff to hard, dry, non plastic (not lithified).		D	VSt-H		PQTT	96 / 96	UW
9.2 – 9.8	9.20 - 9.80 Unweathered, grey BRECCIA; weak to moderately strong; semi distinct bedding, no defects. Clasts are quartz & schist, fine to medium gravel size, angular to subrounded. Coarse SAND matrix. Lithified solid.							UW

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Groundwater SWL at 0.23 mbgl (31/05/2019).

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH02
Client : Dunedin City Council	Sheet : 2 of 2
Site : Smooth Hill Toe bund	Hole Length : 15.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 27/05/2019 Completed: 28/05/2019	Logged : MF
Easting: 396358.59 Northing: 788022.89 System: TAIETM2000	Processed : HB
RL: 97.41 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR SCR RQD (%)	Casing
9.80 - 11.00	9.80 - 11.00 From 9.8 m: clast size increased to coarse breccia.	HENLEY BRECCIA	PQTT	UW		
11.00 - 11.80	11.00 - 11.80 From 11.0m: less lithified, weak to moderately strong	HENLEY BRECCIA	PQTT	UW	100 100	
11.80 - 12.40	11.80 - 12.40 Clast size changes back to fine to medium gravel, more matrix dominaed, moderately strong to strong. From 12.35 m: matric changes from coarse sand to SILT, minor to some clay (looks like fine powder of crushed rock). Clast size increases again, moderatel	HENLEY BRECCIA	PQTT	UW	100 100	
12.40 - 13.50	12.40 - 13.50 From 12.4 m: becomes weak to moderately strong.	HENLEY BRECCIA	PQTT	UW		
13.50 - 15.00	13.50 - 15.00 From: 13.35 m: matrix changes to coarse sand/silt mix, harder lithification,, moderately strong to strong.	HENLEY BRECCIA	PQTT	UW	100 100	122mm
15.00	End of Hole @ 15.00m,Target Depth.					

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Groundwater SWL at 0.23 mbgl (31/05/2019).

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

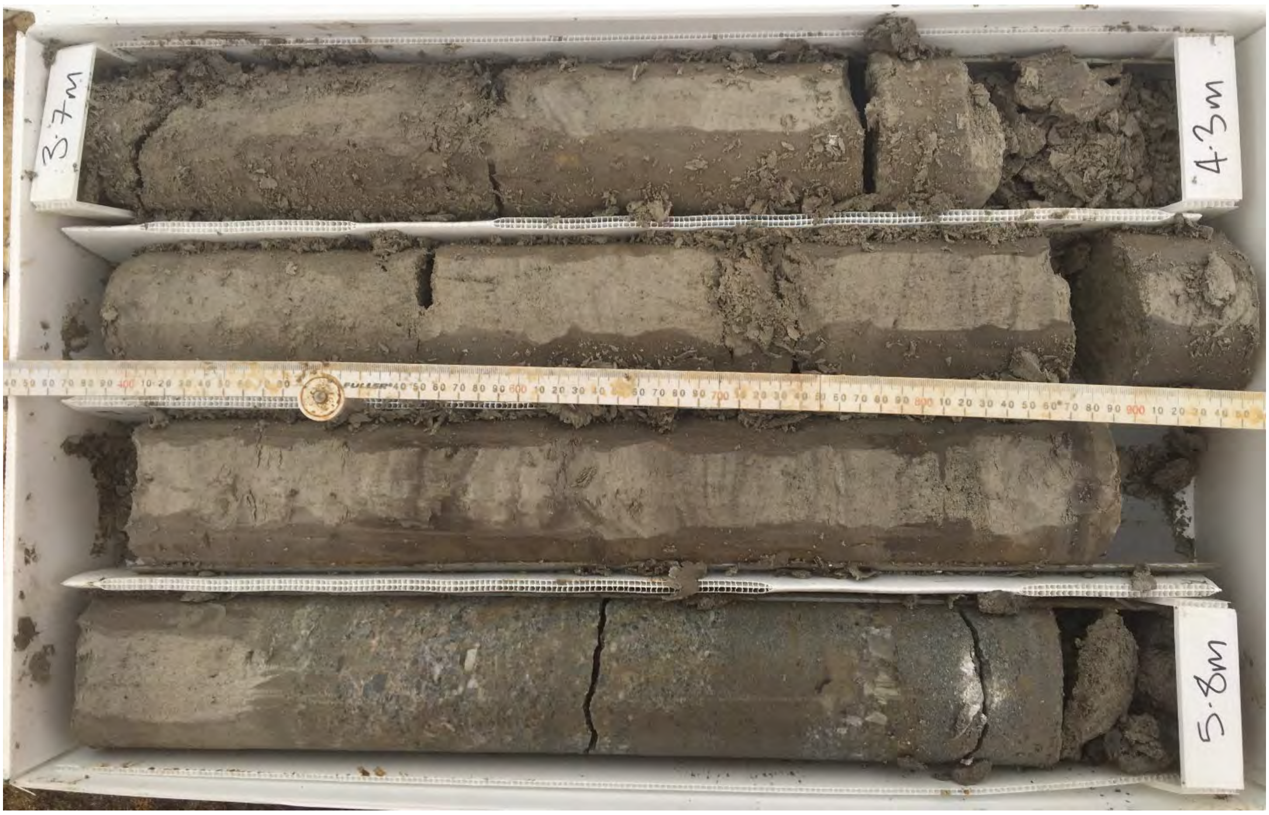
Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
27/05/19	00:00		15

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH02	

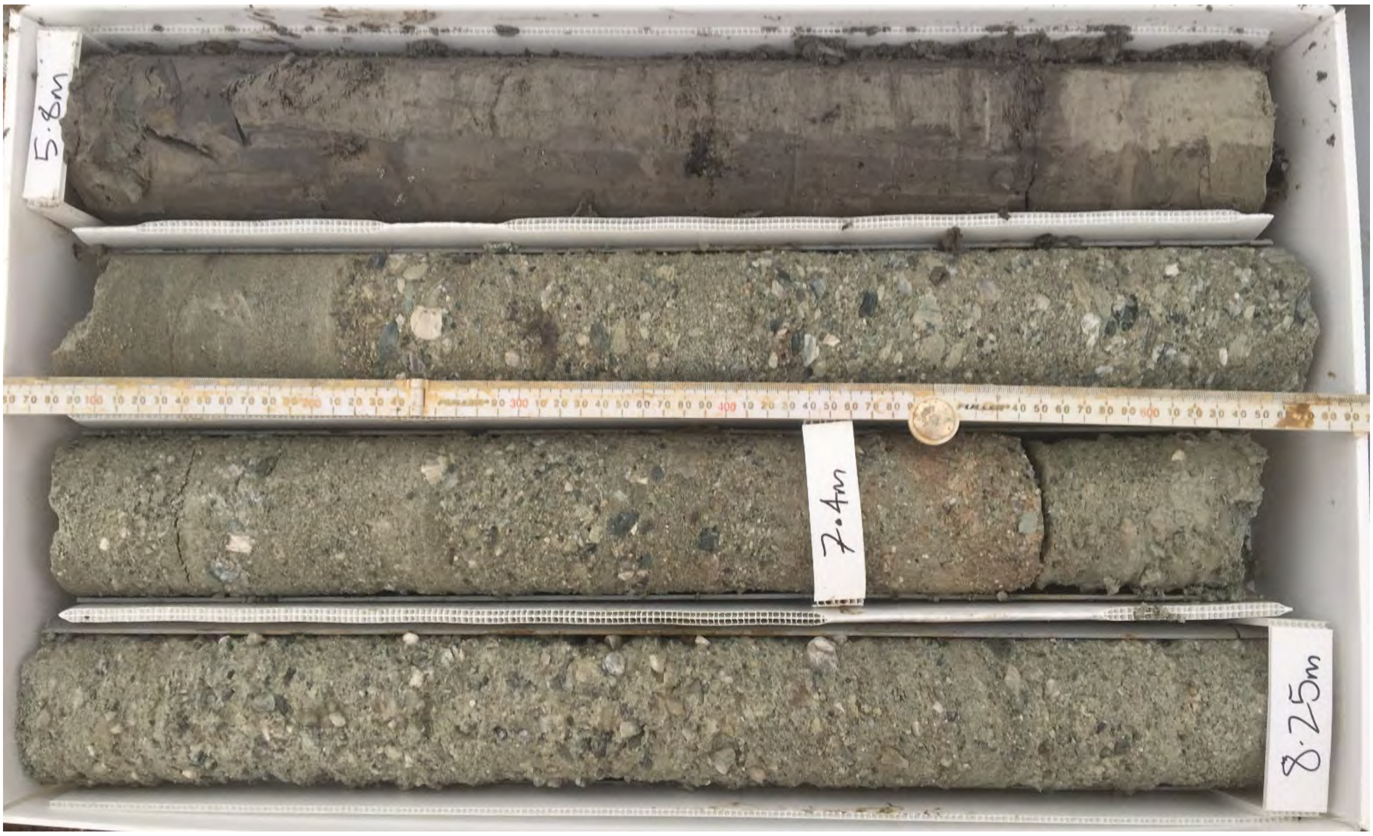
Box 1 of 6: 0.0 m to 3.7 m



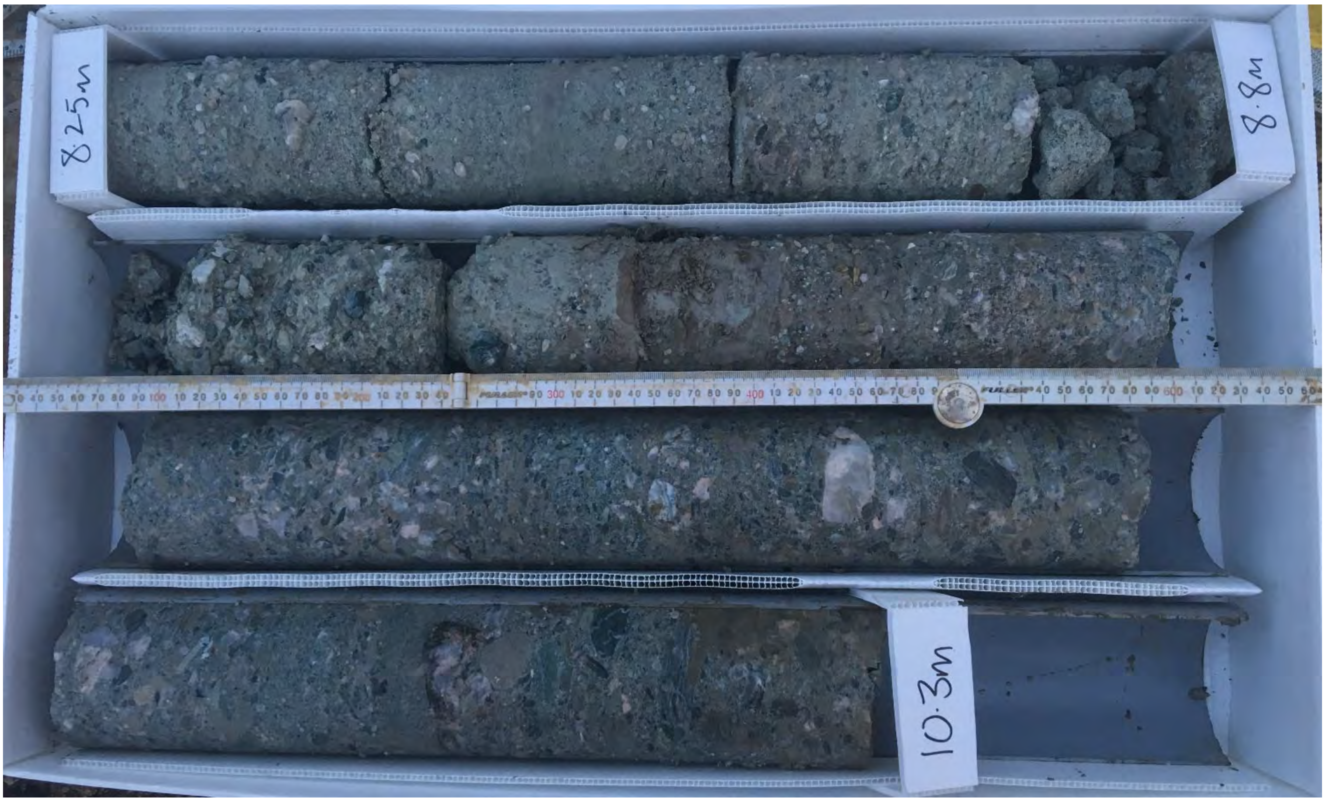
Box 2 of 6: 3.7 m to 5.8 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 3
Borehole ID	BH02	

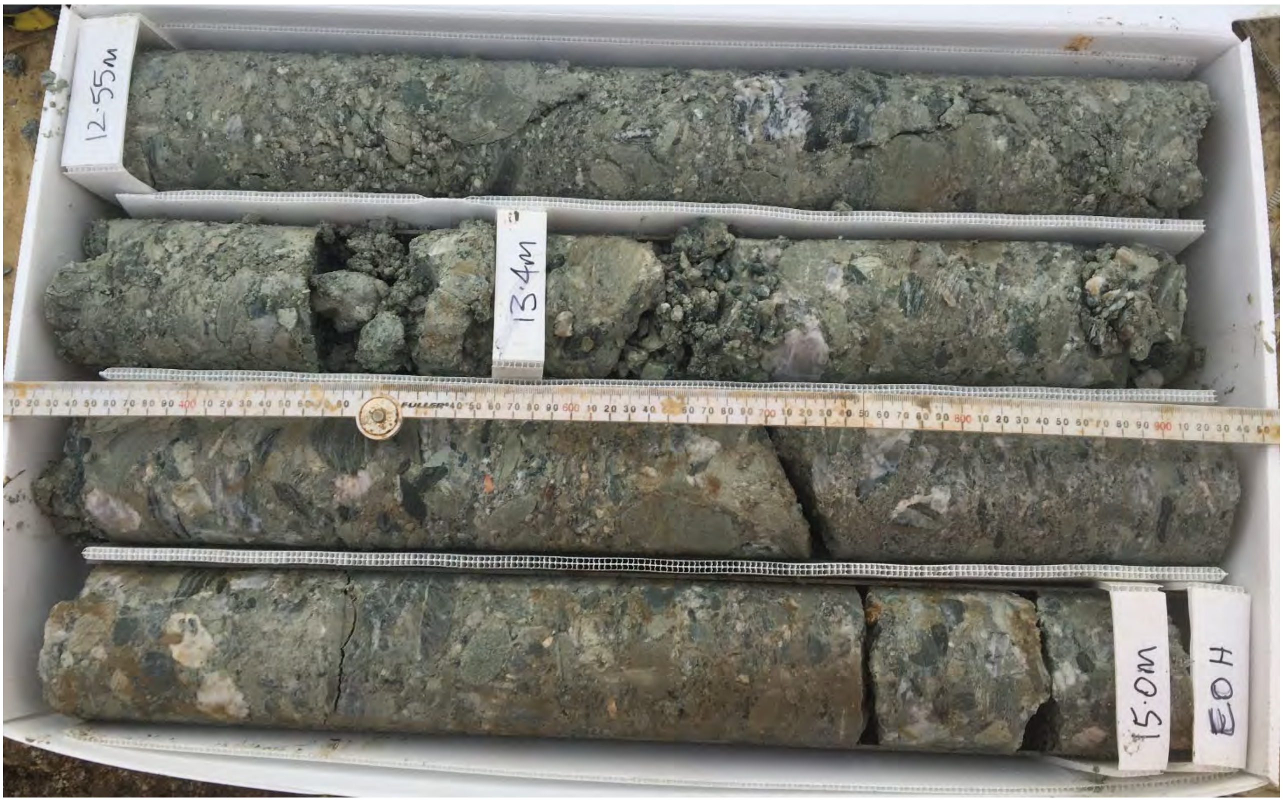


Box 3 of 6: 5.8 m to 8.25 m



Box 4 of 6: 8.25 m to 10.3 m

Box 5 of 6: 10.3 m to 12.55 m



Box 6 of 6: 12.55 m to 15.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH03
Client : Dunedin City Council	Sheet : 1 of 2
Site : Smooth Hill Toe bund/central ridge	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 28/05/2019 Completed: 29/05/2019	Logged : MF
Easting: 396428.38 Northing: 787998.34 System: TAIETM2000	Processed : HB
RL: 107.48 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Result	Method	TCR SCR RQD (%)	Weathering
0 – 0.2	0.00 - 0.20 TOPSOIL SILT, minor clay; light brown & grey. Very stiff, moist, low plasticity; organics mixed in soil.	TOPSOIL	M	VSt		PQTT	73	
0.2 – 1.9	0.20 - 1.90 Clayey SILT, trace fine sand, trace fine gravel; yellow brown & light grey. Very stiff to hard, moist, high plasticity. (LOESS).	LOESS	M	VSt-H	SV@1.5m 140/			
1.9	1.90 - 2.30 SILT, minor clay, minor fine sand; ligt grey & light orange brown. Very stiff to hard, dry to moist, low plasticity.		D-M	VSt-H		PQTT	100	
2.6	2.30 - 2.60 SILT, minor fine sand, trace clay; light grey and orange brown. Hard, dry, non plastic. Variable Fe staining throughout core.		D	'H'				
3.2	2.60 - 3.20 Inferred CORELOSS			"				
3.65	3.20 - 3.65 Silty, coarse sandy GRAVEL; brown. 'Very loose to loose', moist, well graded (completely weathered rock? never lithified?), clasts angular to sub angular; quartz & schist. Moisture content may be influenced by drilling fluid in loose materials.	HENLEY BRECCIA	M	VL-L		PQTT	60	
5.7	3.65 - 5.70 Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. 'Dense', dry, well graded (highy weathered rock?), sub angular to angular clasts; quartz & schist. End of shift 28/05/19 at 17:16.		D	D		PQTT	27	
6.05	5.70 - 6.05 Highly weathered, reddish grey BRECCIA Boulder; strength undetermined.					PQTT	100	HW
6.2	6.05 - 6.20 Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. 'Dense', dry, well graded (highy weathered rock?), sub angular to angular clasts; quartz & schist.		D	D				
6.6	6.20 - 6.60 SILT, minor fine to medium sand, trave to minor fine gravel; grey & yellow brown. Very stiff, moist, non plastic.		M	VSt				
7.5	6.60 - 7.50 (800 mm coreloss assumed this unit) Fine to medium GRAVEL; white &grey. ' Very loose to loose', moist, well graded. Clasts are angular to sub angular quartz & schist. Any matrix has been washed away. Moisture content may be influenced by drilling fluid in loose materials.		M	'VL-L'		PQTT	38	
7.9	7.50 - 7.90 SILT, trace fine gravel; brown, grey, light purple. Hard, dry, non plastic. (Transitions from hard silt to siltstone).		D	H		PQTT	100	
8.45	7.90 - 8.45 Unweathered, dark grey SILTSTONE; weak to moderately strong; no obvious small scale bedding, no defects.			"			100	UW
8.9	8.45 - 8.90 Unweathered, grey fine SANDSTONE; weak to moderately strong; no obvious small scale bedding, no defects.							UW
9.2	8.90 - 9.20 Inferred CORELOSS (loose sand layer washed away?).					PQTT	73	
	9.20 - 10.10 Unweathered, bedded, alternating dark grey & grey SILTSTONE & SANDSTONE; weak to moderately strong, no obvious small scale bedding, no defects. ~300-400 mm alternating SILTS.						69	UW

Water level: Groundwater level at the end of drilling 29-05-2019 (~3.9 m)

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

Groundwater SWL at 3.9 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id: GEO1826

Ground Water Level			
Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Smooth Hill Toe bund/central ridge
Job Number: 12506381
Commenced: 28/05/2019 Completed: 29/05/2019

Hole No. : BH03
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JS

Easting: 396428.38 Northing: 787998.34 System: TAIETM2000
RL: 107.48 Datum: NZVD2016

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR / SCR / RQD (%)
10.1	10.10 - 10.70 Unweathered, grey fine to medium SANDSTONE; very weak to weak; no defects.	HENLEY BRECCIA			PQTT	UW	123 / 100
10.7	10.70 - 10.90 SILT, minor clay; brown. Very stiff to hard, dry to moist, non plastic; looks organic in origin. (Buried topsoil?).		D-M	VSt-H		UW	
10.9	10.90 - 11.05 Unweathered, light grey SILTSTONE; very weak to weak; no defects.					UW	
11.05	11.05 - 13.65 Unweathered, light grey & white BRECCIA; moderately strong to strong; Clasts; quartz & schist, fine to medium gravel size, angular to sub angular. Matrix supported, coarse sand matrix.				PQTT	UW	100 / 100
13.65	13.65 - 14.20 Unweathered, light grey fine SANDSTONE; moderately strong to strong; no defects. From 13.79 to 13.82 m: thin SILT layer, stiff.				PQTT	UW	94 / 94
14.2	14.20 - 17.20 Unweathered, light grey & white BRECCIA; moderately strong to strong; Clasts; quartz & schist, fine to medium gravel size, angular to sub angular. Matrix supported, coarse sand matrix. Distict beds of fine & coarse clasts. 200 mm thick beds for both grain sizes.				PQTT	UW	107 / 100
					PQTT		93 / 93
17.2	17.20 - 17.60 Fine to medium SAND; grey. 'Dense', dry to moist, poorly graded, non lithified. (SANDSTONE. Extremely weak to very weak, completely weathered to residual soil).		D-M	D		CW-RS	
17.6	17.60 - 18.25 Unweathered, light grey fine SANDSTONE; moderately strong to strong; no defects.				PQTT	UW	107 / 100
18.25	18.25 - 19.25 Unweathered, grey BRECCIA; moderately strong to strong; no bedding evident, quartz & schist clast supported matrix, angular to sub angular up to 80 mm in size.					UW	
19.25	19.25 - 20.00 Unweathered, light grey fine SANDSTONE; moderately strong to strong; One defect: Joint at 19.4 m, Very steeply inclined (75 degrees to core axis), stepped to planar, rough, tight, Fe staining.				PQTT	UW	100 / 100

Casing: 122mm

End of Hole @ 20.00m,Target Depth.

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater SWL at 3.9 mbgl during piezo install.
Refer to explanation sheets for abbreviation and symbols

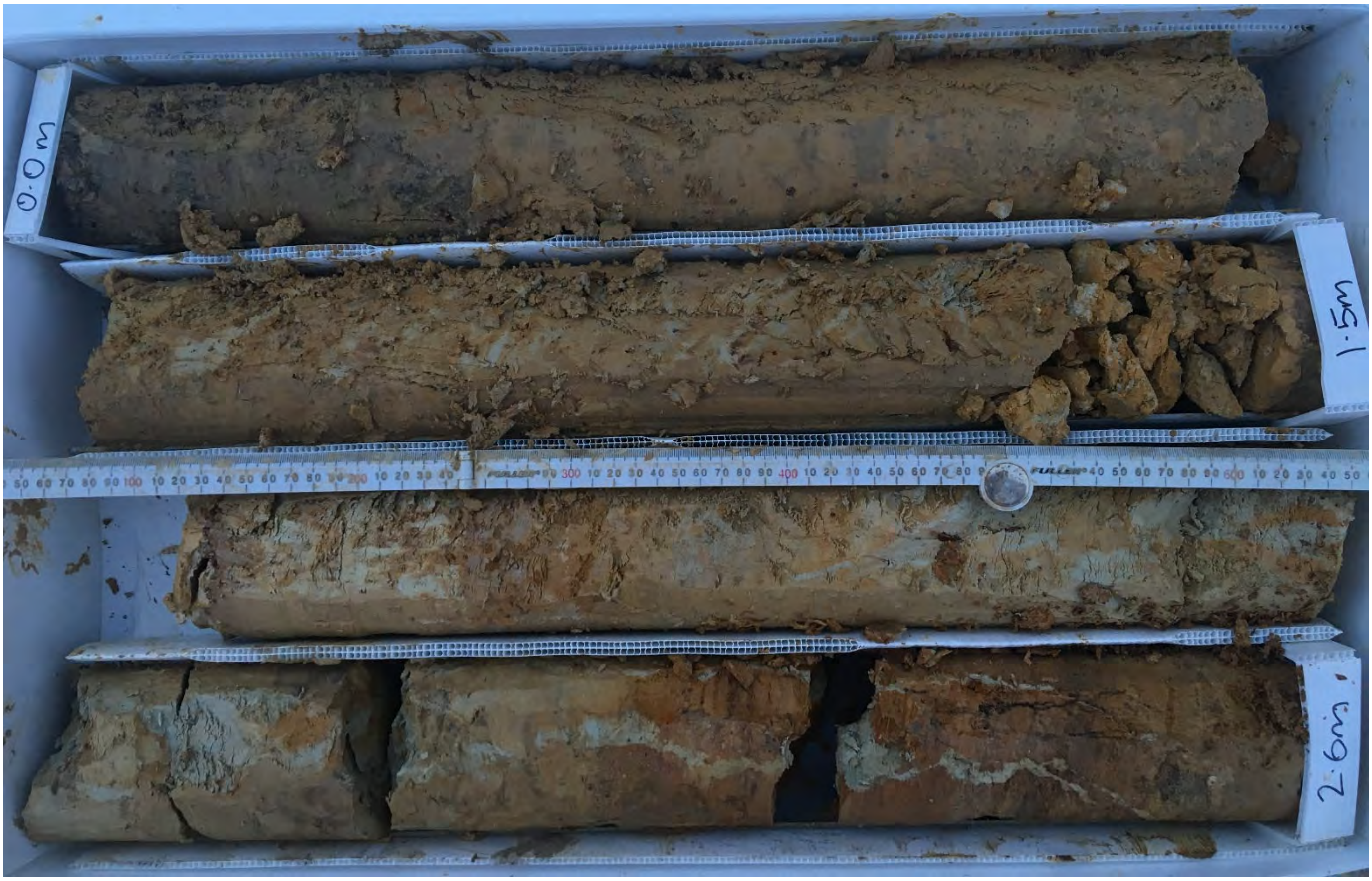
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
29/05/19	00:00	3.9	20

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH03	



Box 1 of 8: 0.0 m to 2.6 m

Box 2 of 8: 2.6 m to 6.25 m

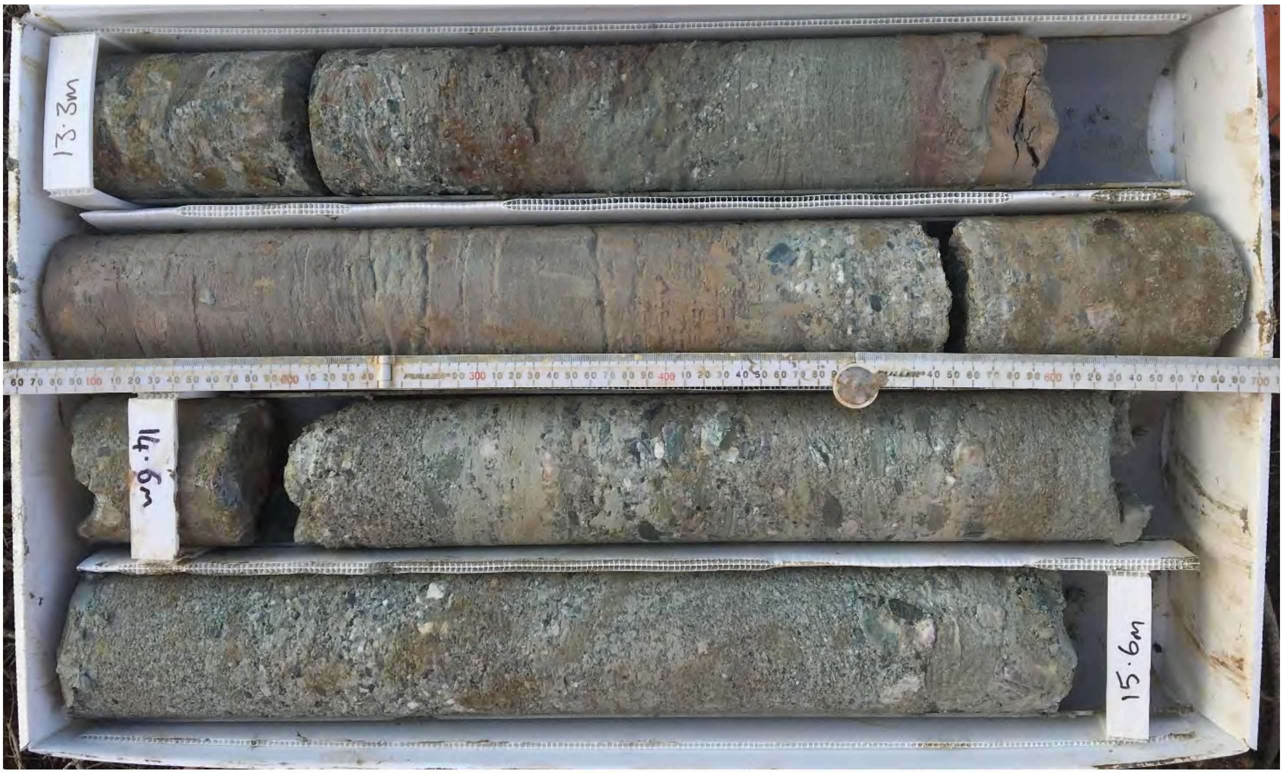
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 4
Borehole ID	BH03	

Box 3 of 8: 6.25 m to 9.25 m

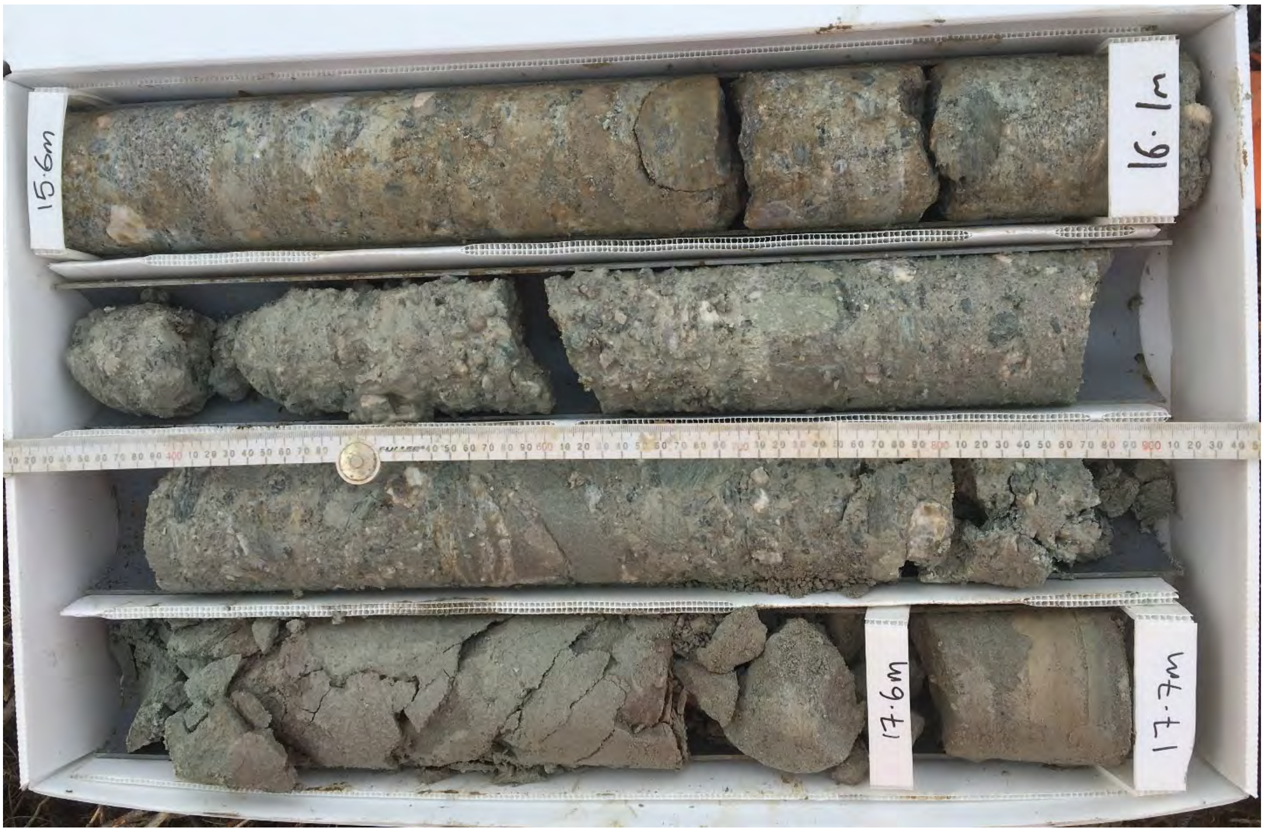
Box 4 of 8: 9.25 m to 11.05 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 4
Borehole ID	BH03	

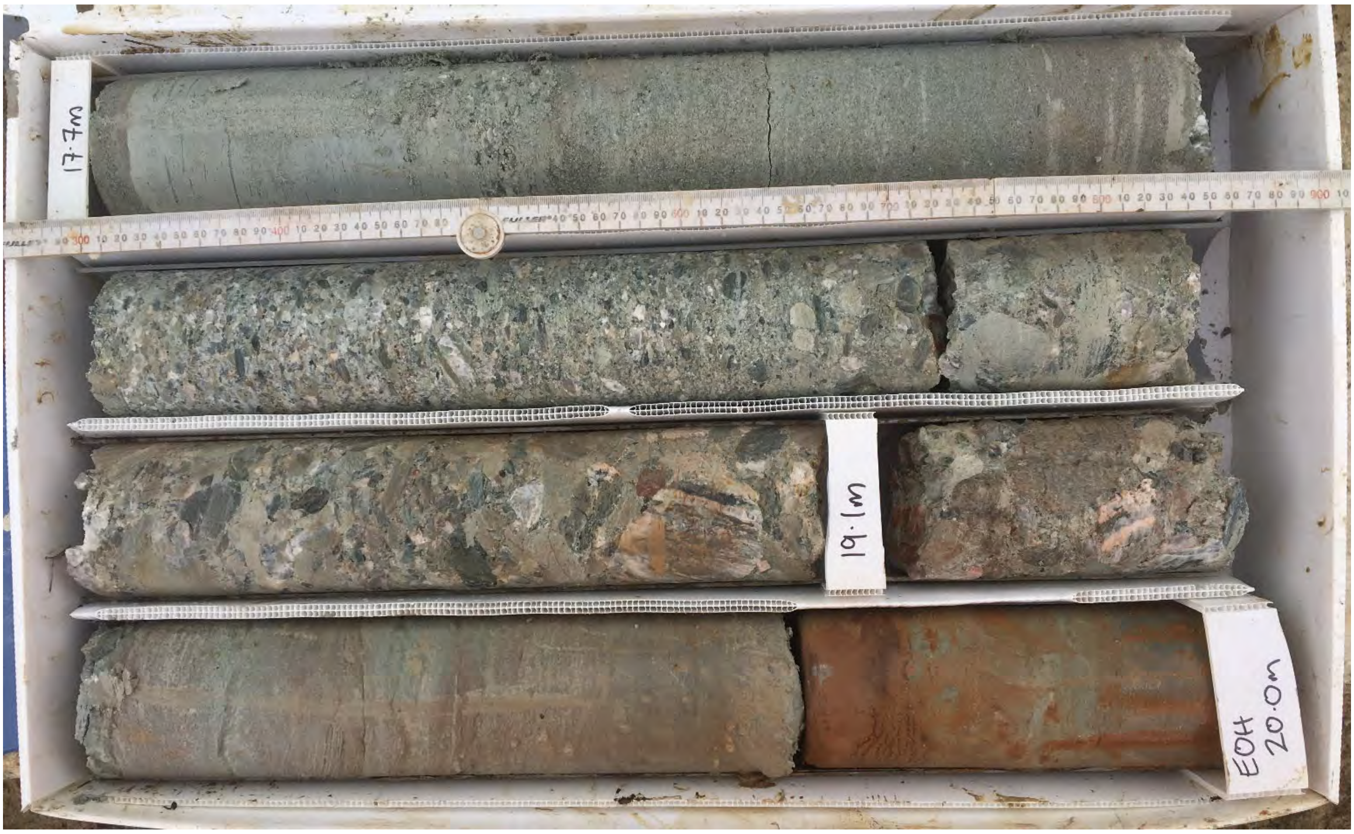
Box 5 of 8: 11.05 m to 13.3 m



Box 6 of 8: 13.3 m to 15.6 m



Box 7 of 8: 15.6 m to 17.7 m



Box 8 of 8: 17.7 m to 20.0 m (EOH)

Hole No. : BH04

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Smooth Hill Toe bund foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 7/06/2019

Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JS

Easting: 396563.6 Northing: 788063.75 System: TAIETM2000
RL: 108.15 Datum: NZVD2016

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR / SCR / RQD (%)
0–0.25	0.00 - 0.25 SILT, minor clay; dark grey. Firm, moist, low plasticity. (TOPSOIL/FILL). From 0.2 m: some intermixing with underlying soil.	TOPSOIL FILL	M	F	PQTT		100
0.25–0.9	0.25 - 0.60 SILT, minor clay, trace fine sand, trace organics (roots); orange brown. Stiff, moist, low plasticity. (LOESS). 0.60 - 0.90 From 0.6m, becomes light grey with orange-brown streaks, stiff to very stiff.	LOESS	M	St			
			M	St-VSt			
0.9–1.4	0.90 - 1.40 Silty fine to medium SAND; grey with orange streaks. Density undetermined, moist, poorly graded. from 1.1 m, becomes trace fine gravek, sub angular to sub rounded quartz and schist.	TOPSOIL	M				
1.4–1.5	1.40 - 1.50 (BURIED TOPSOIL) SILT with roots; grey. Stiff to very stiff, moist, non plastic.	BURIED TOPSOIL	M	St-VSt	PQTT	HW	73
1.5–2.45	1.50 - 2.45 Silty, fine to coarse sandy, fine to medium GRAVEL; orange brown. Density undetermined, moisture content undetermined, well graded, quartz and schist clasts, sub angular to sub rounded. (Heavily weathered rock?).						
2.45–2.8	2.45 - 2.80 Inferred CORELOSS.			"			
2.8–4.4	2.80 - 4.40 Moderately weathered, light grey & orange brown fine to medium SANDSTONE; very weak to weak; poorly indurated, no defects. Fe banding throughout. Fe bands change angle downhole from sub horiztontal to sub vertical & back & back. Bedding 1-20 mm thick. (HENLEY BRECCIA).	HENLEY BRECCIA			PQTT	MW	100 / 100
4.4–4.7	4.40 - 4.70 Moderately weathered, CONGLOMERATE; extremely weak to very weak; poorly indurated, well graded, fine to coarse quartz and schist clasts, sub angular to rounded, silt matrix, matrix supported.			"	PQTT	MW	20 / 0
4.7–5.9	4.70 - 5.90 Inferred CORELOSS from this run.						
5.9–6.4	5.90 - 6.40 Inferred CORELOSS from this run.			"			
6.4–8.7	6.40 - 7.00 Slightly weathered, grey with purple-brown layers fine to medium SANDSTONE; very weak to weak; poorly indurated, poorly graded.				PQTT	SW	69 / 69
	7.00 - 7.40 From 7.0 m, becomes moderately strong to strong, well indurated.					SW	
	7.40 - 8.40 From 7.4 m, becomes very weak to weak, poorly indurated.				PQTT	SW	100 / 75
	8.40 - 8.70 From 8.40 m, becomes moderately strong to strong, well indurated.					SW	
8.7–8.85	8.70 - 8.85 Slightly weathered, BRECCIA; moderately strong to strong; fine to medium gravel clasts, fine to coarse sand matrix.					SW	
8.85–	8.85 - 9.60 Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; poorly indurated, poorly graded, no defects.				PQTT	SW	83 / 63
	9.60 - 10.10 From 9.6 m, becomes moderately strong to strong, well indurated.					SW	

Water level: 7-06-2019 (at approx. 2 m)

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Groundwater at 2.52 mbtoc (TOC 0.53 m agl) - corrected groundwater at 1.99 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNiells

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Smooth Hill Toe bund foundation
Job Number: 12506381

Commenced: 6/06/2019 | Completed: 7/06/2019

Easting: 396563.6 | Northing: 788063.75 | System: TAIETM2000
RL: 108.15 | Datum: NZVD2016

Hole No. : BH04
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	10.1		10.10 - 10.60 Slightly weathered, grey BRECCIA; moderately strong to strong; well indurated, fine to medium gravel clasts, fine to coarse sand matrix, matrix supported. Clasts are quartz & schist, sub rounded to angular. Very wide spaced defects.	HENLEY BRECCIA						PQTT		SW		83 63			
	10.6		10.60 - 10.80 Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; poorly indurated, no defects.									SW SW					
	10.8		10.80 - 11.10 Slightly weathered, brown SILTSTONE; very weak to weak; poorly indurated, no defects. From 11.0 m, becomes light grey.							PQTT		SW		97 97			
	11.1		11.10 - 11.50 Slightly weathered, light grey & pinkish grey BRECCIA; weak to moderately strong; moderate to well indurated, no defects, fine to coarse gravel clasts, fine to coarse sand matrix, clast supported. Clasts are quartz and schist sub angular to angular. Note: clast size dcreases with depth. 11.50 - 12.20 From 11.5 m, becomes moderately strong to strong, well indurated, fine to medium gravel clasts. 12.20 - 15.00 From 12.2 m, becomes weak to moderately strong, moderate to well indurated, fine to coarse gravel clasts. From 13.9sm: clasts mostly medium to coarse gravel.							PQTT PQTT		SW SW		88 56 100 73			
	15		End of Hole @ 15.00m,Target Depth.														

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Groundwater at 2.52 mbtoc (TOC 0.53 m agl) - corrected groundwater at 1.99 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

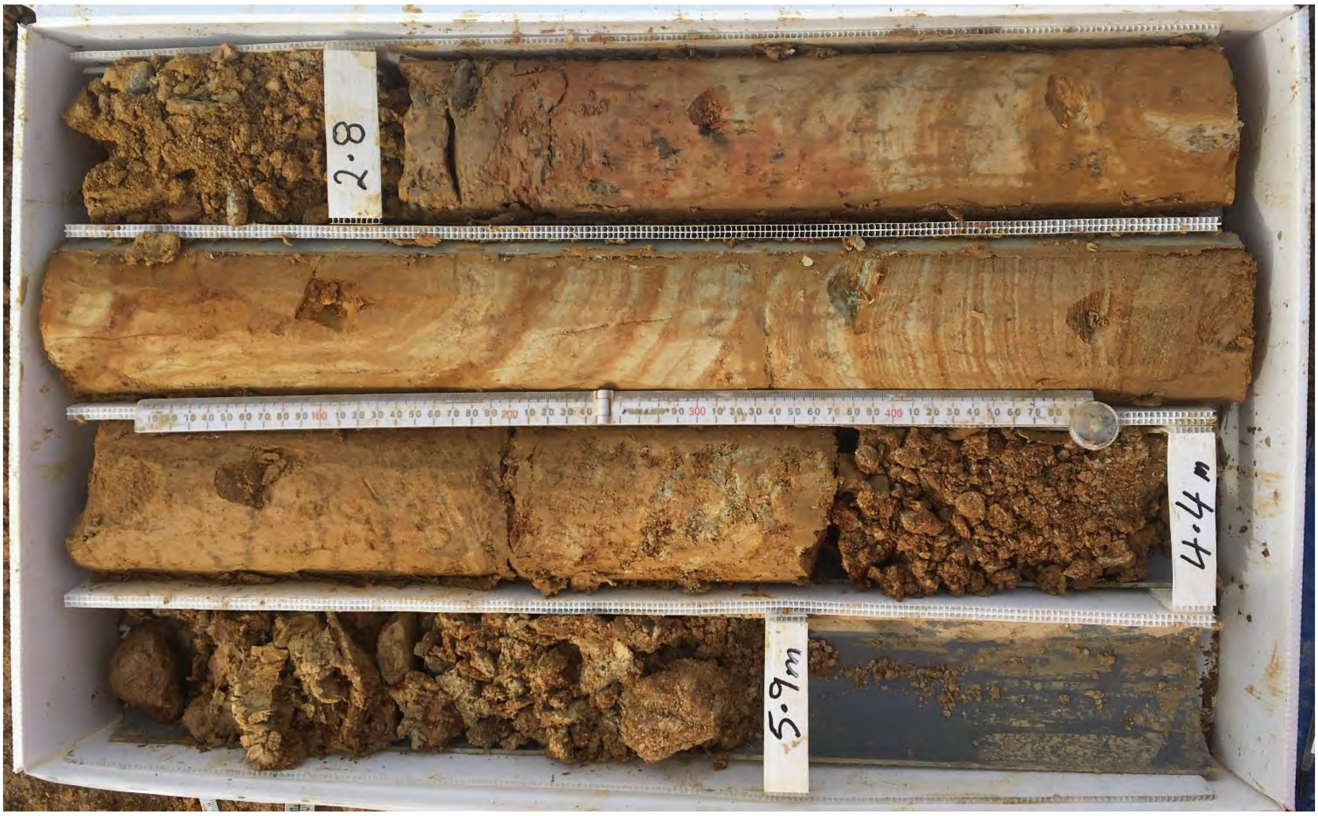
Inclination: Vertical
Orientation:
Contractor: McNiells
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	1.99	15

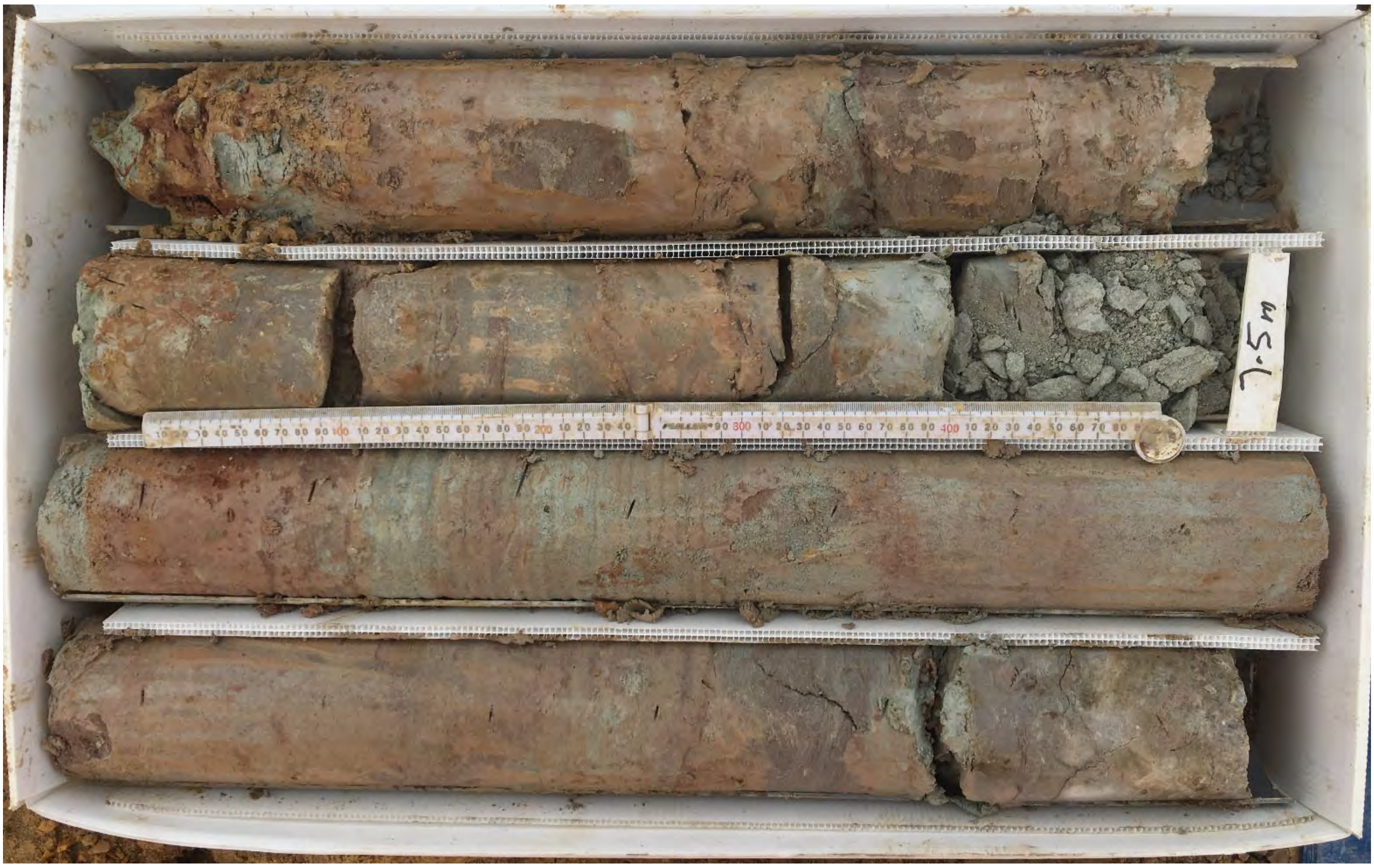
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH04	

Box 1 of 6: 0.0 m to 2.7 m



Box 2 of 6: 2.7 m to 5.9 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 3
Borehole ID	BH04	

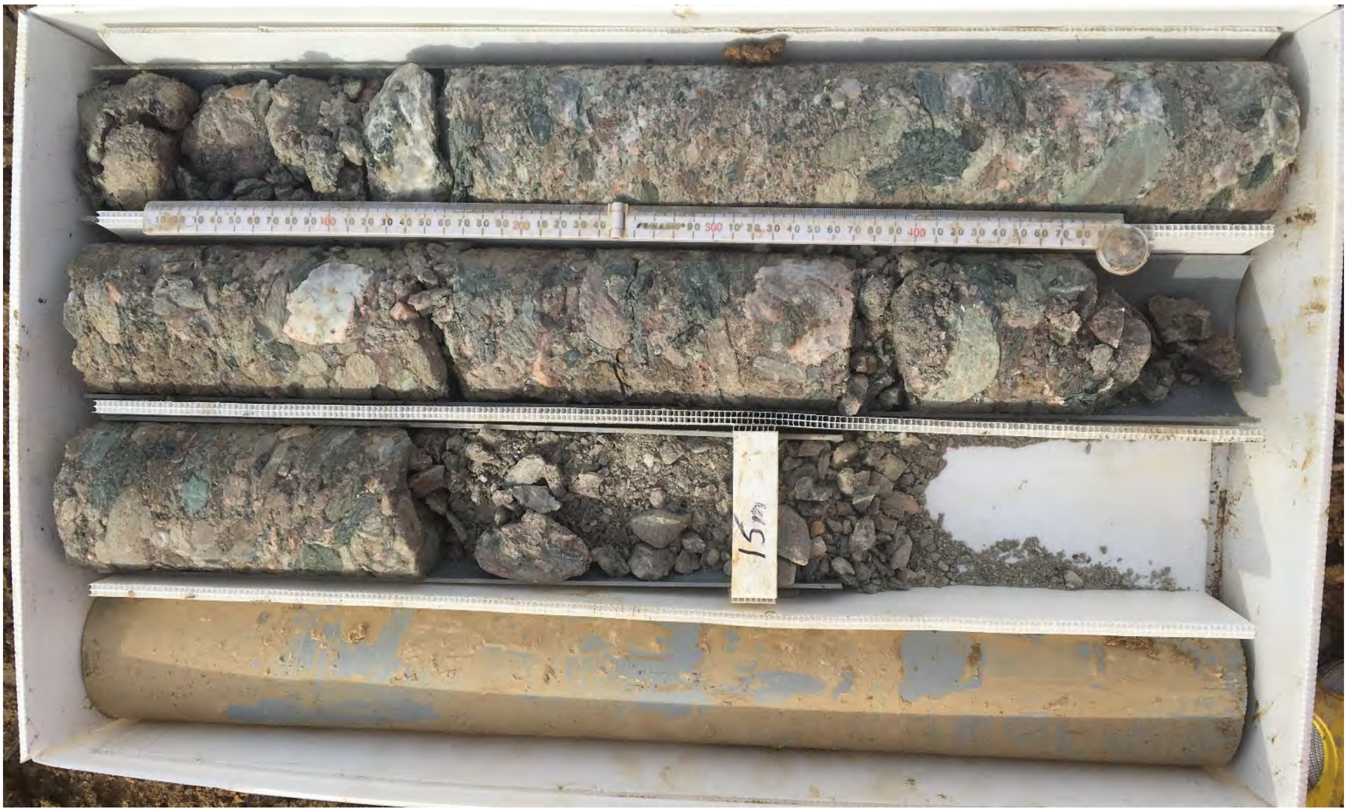


Box 3 of 6: 5.9 m to 8.7 m

Box 4 of 6: 8.7 m to 11.1 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 3
Borehole ID	BH04	

Box 5 of 6: 11.1 m to 13.5 m



Box 6 of 6: 13.5 m to 15.0 m (EOH)

Project	: Smooth Hill Landfill Consenting
Client	: Dunedin City Council
Site	: Smooth Hill Central ridge
Job Number	: 12506381
Commenced: 29/05/2019	Completed: 30/05/2019

Hole No.	**: BH05**
Sheet	: 1 of 3
Hole Length	: 30.00m
Scale @ A4	: 1:50
Logged	: MF
Processed	: HB
Checked	: JS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000

RL: 129.5 Datum: NZVD2016

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative density	Sample Result	Method	Weathering	TCR SCR RQD (%)
0.00 - 0.80	Clayey SILT; grey & dark orange brown. Very stiff, moist, high plasticity. (LOESS).	LOESS	M	VSt		PQTT		100
0.80 - 1.00	SILT, minor clay, trace fine sand; orange brown with some grey. Very stiff, moist, low plasticity.		M	VSt				
1.00 - 1.50	Fine to medium gravelly SILT, trace clay; orange brown & white. Very stiff, moist, low plasticity.		M	VSt	SV@1.5m UTP			
1.50 - 2.70	Inferred CORELOSS Catcher did not grip sample. Note: No shear vane undertaken at 2.7 m due to no core.			"		PQTT		0
2.70 - 2.80	Fine to medium gravelly SILT, trace clay; orange brown & white. Very stiff, moist, low plasticity.		M	VSt		PQTT		53
2.80 - 3.50	Inferred CORELOSS (Washed away?).			"				
3.50 - 3.70	Fine to medium GRAVEL; creamy white. Undetermined density, undetermined moisture condition, well graded, quartz & schist gravel, angular to sub angular.							
3.70 - 3.80	Fine to medium gravelly SILT, trace clay; orange brown & white. Very stiff, moist, low plasticity. Fe staining on upper contact.		M	VSt				
3.80 - 4.00	SILT, trace organics; light grey. Hard, dry to moist, non plastic.		D-M	H				
4.00 - 4.45	Fine gravelly SILT, trace clay, trace organics; orange brown & light grey. Very stiff, moist, non plastic. Note no shear vane at 4.2 m due to material being too gravelly.		M	VSt				
4.45 - 5.70	SILT, trace clay, trace organics; light grey with orange brown streaks. Hard, dry to moist, non plastic. From 5.1 m, becomes orange brown with some light grey. From 5.35 m, 2-3 mm Fe "gravel" beds. From 5.6 m, becomes very thinly laminated (2-3mm).		D-M	H		PQTT		103
5.70 - 5.90	Silty CLAY, trace fine sand, trace organics; brown to grey. Stiff to very stiff, moist, high plasticity.		M	St-VSt	SV@5.7m UTP			
5.90 - 6.50	SILT, trace clay, trace organics; light grey with black flecks. Hard, moist, non plastic, Fe staining. Note: Fe stained contact at 6.50 m.		M	H		PQTT		100
6.50 - 6.80	SILT, trace medium gravel (schist), brown to grey. Hard, moist, non plastic. Note: dark orange brown Fe stained contact at 6.80 m.		M	H				
6.80 - 7.20	SILT, trace organics; light grey & orange brown, with black flecks. Hard, dry, non plastic, thin (<1mm) 'rusty' laminations.		D	H				
7.20 - 7.75	Moderately weathered, dark grey with black streaks SILTSTONE; very weak to weak; thinly beded, contains organic rich layers, defects 500-1000 mm spacing.					PQTT	MW	100 87
7.75 - 7.80	Moderately weathered, grey SANDSTONE; very weak; 50 mm bedded layer within siltstone.						MW	
7.80 - 8.50	Moderately weathered, dark grey with black streaks SILTSTONE; very weak to weak; thinly beded, contains organic rich layers, defects 500-1000 mm spacing. From, 7.9 m: 2-5 mm thick lignite layers. At 8.2 m: 20 mm lignite layer. At 8.32 m to 8.37 m: 50 mm lignite layer. At 8.42 m to 8.44 m: 20 mm lignite layer.						MW / SW	
8.50 - 8.70	From 8.5 m, becomes slightly weathered, lignite					PQTT	SW	93 93

Notes and Comments:

End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project	: Smooth Hill Landfill Consenting
Client	: Dunedin City Council
Site	: Smooth Hill Central ridge
Job Number: 12506381	
Commenced: 29/05/2019	Completed: 30/05/2019
Easting: 396459.76	Northing: 787862.12
System: TAIETM2000	
RL: 129.5	Datum: NZVD2016

Hole No.	**: BH05**
Sheet	: 2 of 3
Hole Length	: 30.00m
Scale @ A4	: 1:50
Logged	: MF
Processed	: HB
Checked	: JS

Depth (m)	Material Description	Geological Unit	Consistancy / Relative density
	layers gone but occassional organic rich layers remain.	LOESS	
	8.70 - 9.10 From 8.7 m. becomes weak to moderately strong.	LOESS	
	9.10 - 9.60 Slightly weathered, grey SANDSTONE; weak to moderately strong; fine sand to coarse gravel size grains, wide spaced defects, no organic content.	LOESS	
	9.60 - 9.77 Slightly weathered, grey SILTSTONE; weak to moderately strong; bedded siltstone layer in sandstone.	LOESS	
	9.77 - 13.20 Slightly weathered, grey SANDSTONE; weak to moderately strong; fine sand to coarse gravel size grains, wide spaced defects, no organic content. From 10.2 m, becomes fine grained. At 10.25 m to 10.27 m: 20 mm lignite layer. From 10.9 m, becomes fine to coarse sand, trace fine gravel (quartz & schist) grainsize. From 11. 4 m, becomes fine sand grainsize, occassional organic layers (thin), occassional defects (~ 1/m), black staining. From 12.69 m to 12.73 m, organic rich 2 mm lignite layer at each end.	LOESS	
	13.20 - 14.10 From 13.20 m, becomes moderately strong to strong.	LOESS	
14.1	14.10 - 14.60 Unweathered, massive, grey & white BRECCIA; moderately strong to strong; fine to coarse gravel size clasts, coarse sand matrix. Matrix supported. Clasts are angular to sub angular quartz and schist, some clasts up to 100 mm in grainsize.	HENLEY BRECCIA	
	14.60 - 15.60 From 14.6 m, becomes weak to moderately strong. Softer matrix.	HENLEY BRECCIA	
	15.60 - 16.20 From 15.6 m, becomes moderately strong to strong. Matrix more lithified.	HENLEY BRECCIA	
	16.20 - 16.60 From 16.20 m, becomes weak to moderately strong. Matrix less lithified.	HENLEY BRECCIA	
	16.60 - 17.10 From 16.60 m, becomes moderately strong to strong. Matrix more lithified.	HENLEY BRECCIA	
	17.10 - 17.70 From 17.1 m, becomes weak to moderately strong. Matrix less lithified.	HENLEY BRECCIA	
17.7	17.70 - 18.10 Inferred CORELOSS (weaker rock matrix?).	HENLEY BRECCIA	"
18.1	18.10 - 18.50 Unweathered, massive, grey & white BRECCIA; very weak to weak; fine to coarse gravel size clasts. Clast supported. Clasts are angular to sub angular quartz and schist, some clasts up to 100 mm in grainsize. Weaker matrix resulted in lots of rock breakup during drilling/extraction from tube. Note: do not think it is defect controlled or open in ground. From 18.3 m, becomes coarse gravel dominated.	HENLEY BRECCIA	
	18.50 - 19.20 From 18.50 m, becomes moderately strong to strong. Matrix more lithified.	HENLEY BRECCIA	
19.2	19.20 - 20.00 Slightly weathered, grey fine SANDSTONE; very weak to weak; orange Fe stained layer every ~ 300 mm.		

Depth (approx., m)	Method	Weathering	TCR / SCR / RQD (%)
10.2 - 11.7	PQTT	SW	97 / 97
11.7 - 13.2	PQTT	SW	100 / 100
13.2 - 14.7	PQTT	SW / UW	100 / 100
14.7 - 16.2	PQTT	UW	100 / 93
16.2 - 17.7	PQTT	UW	87 / 67
17.7 - 19.2	PQTT	UW	100 / 93
19.2 - 20.0	PQTT	SW	100 / 94

Notes and Comments:

End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical
Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH05
Client : Dunedin City Council	Sheet : 3 of 3
Site : Smooth Hill Central ridge	Hole Length : 30.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/05/2019 Completed: 30/05/2019	Logged : MF
Easting: 396459.76 Northing: 787862.12 System: TAIETM2000	Processed : HB
RL: 129.5 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Casing	Method	Weathering	TCR SCR RQD (%)
20	Core breaks on Fe stained layers but unlikely layers are open in ground. The weakest plane is what breaks during handling. The Fe stained layers probably indicate time gaps in depositional history.					PQTT	SW	100 / 94
	20.00 - 20.55 From 20.0 m, very weak to weak, occassional slightly weathered, grey siltstone layers (bedding) up to 50 mm. 20.55 - 20.65 From 20.55 m, becomes moderately strong to strong. 20.65 - 21.80 From 20.65 m, becomes very weak to weak.					PQTT	SW	103 / 100
21.95	21.80 - 21.95 From 21.8 m, becomes weak to moderately strong.						SW	
22.4	21.95 - 22.00 At 21.9 m: slightly weathered, grey SILTSTONE (20 mm bedded layer). 22.00 - 22.40 From 22.0 m, becomes moderately strong to strong						SW	
	22.40 - 24.10 Slightly weathered, grey pinkish white BRECCIA; moderately strong to strong; clast supported, fine to coarse gravel size clasts, angular to sub angular quartz and schist clasts. From 23.8 m, becomes fine gravel size clasts with occassional coarse gravel clasts.	HENLEY BRECCIA				PQTT	SW	87 / 87
	24.10 - 24.30 From 24.1 m, becomes very weak to weak. Soft matrix. 24.30 - 24.65 From 24.3 m, becomes moderately strong to strong. 24.65 - 24.75 From 24.65 m, becomes very weak to weak. Soft matrix. 24.75 - 26.65 From 24.75 m, becomes moderately strong to strong. Hard matrix (well indurated). Note: from 25.3 m to 26.65 m, clast size increasing.					PQTT / PQTT	SW / SW / SW / SW	100 / 87
26.65	26.65 - 26.80 SILT; brown. Hard, dry, non plastic. Breaks down from completely weathered to residual, brown SILTSTONE; extremely weak to very weak.		D / D	H / VD			CW-RS	
27.3	26.80 - 27.20 Silty SAND; light grey. 'Very dense', dry, moderately graded. 27.20 - 27.30 From 27.2 m, becomes SILT brown. Hard, dry, non plastic.		D / D	H / D		PQTT	CW-RS	
27.8	27.30 - 27.80 From 27.3 m, becomes fine to medium SAND; brown. 'Dense', dry, poorly graded. Breaks down from completely weathered to residual, brown fine to medium SANDSTONE; very weak.						CW-RS	
	27.80 - 28.40 Slightly weathered, light brown, grey, white BRECCIA; weak to moderately strong; clast supported, fine to coarse gravel size quartz and schist clasts, angular to sub angular.						SW	
	28.40 - 30.00 From 28.4 m, becomes unweathered, moderately strong to strong, clast size increases.				122mm	PQTT	UW	
30	End of Hole @ 30.00m,Target Depth.							

Notes and Comments:

End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

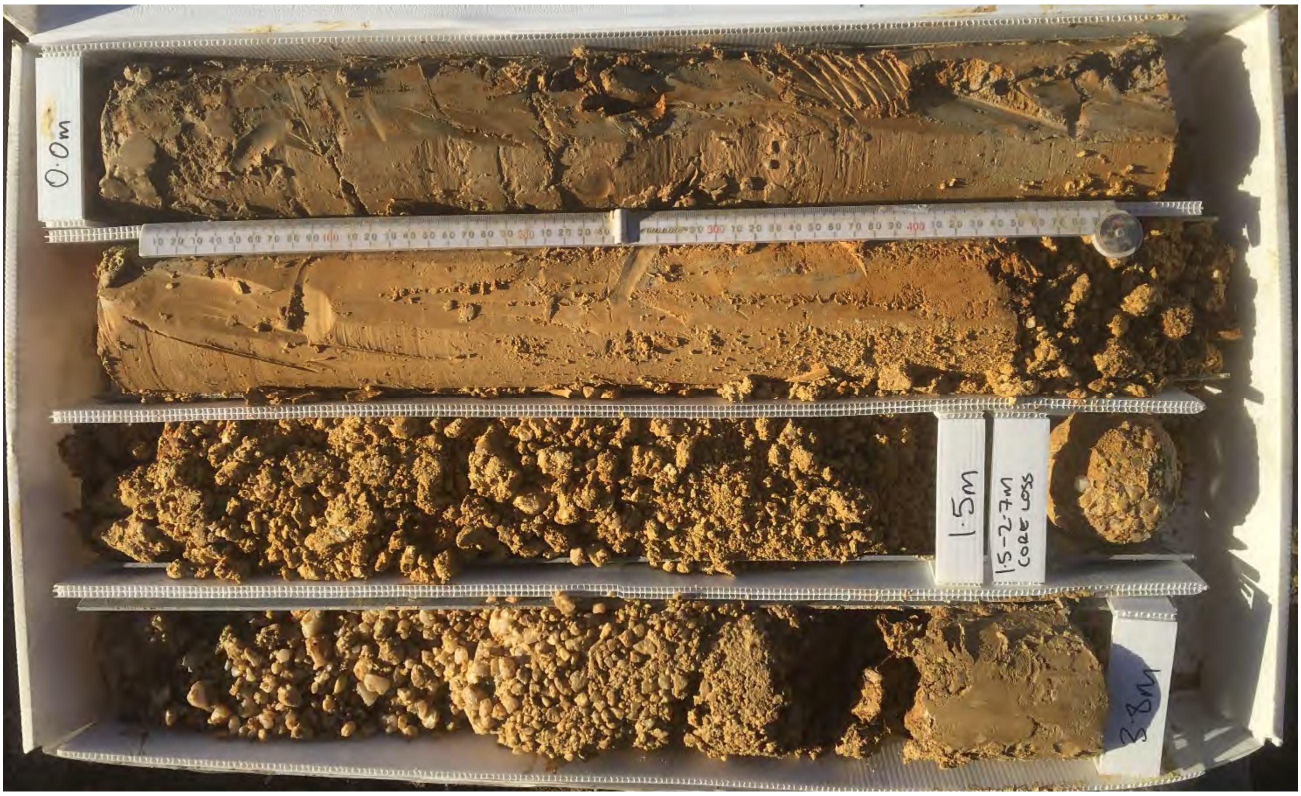
Shear Vane Id: GEO1826

Ground Water Level

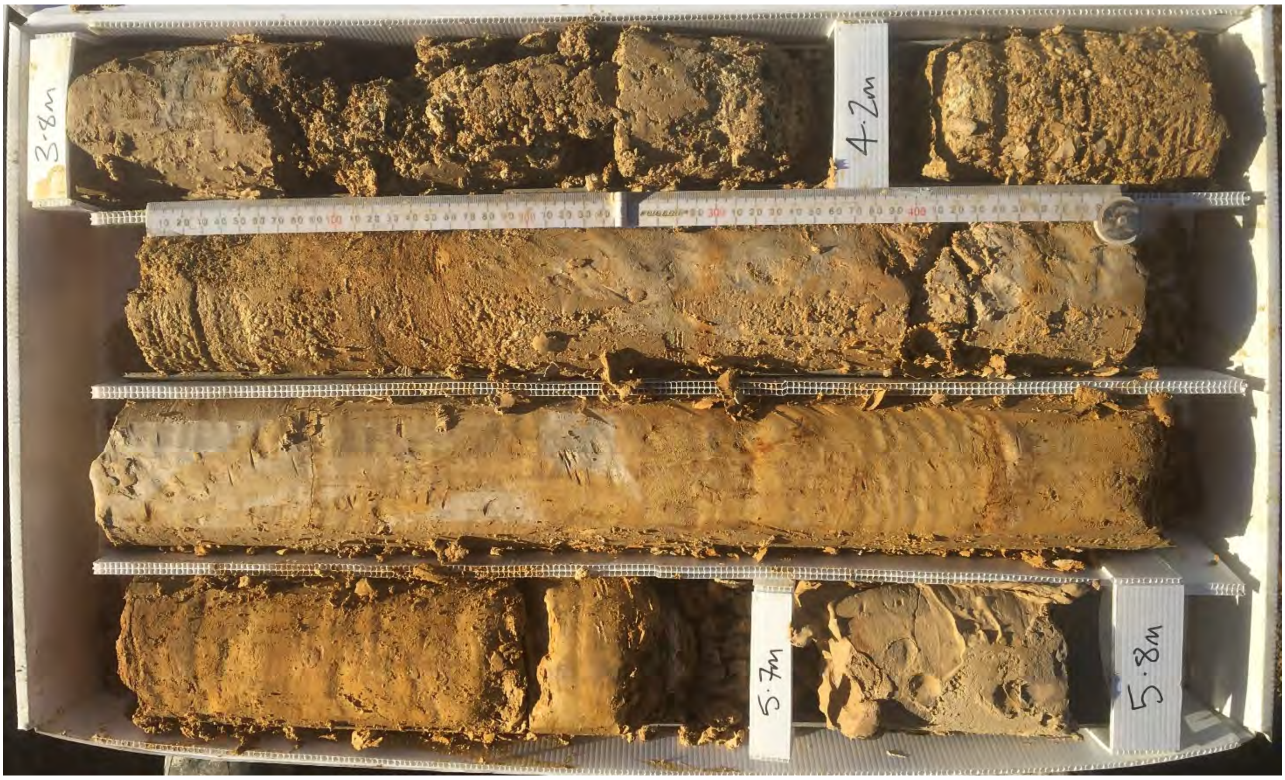
Date	Time	Reading (mbgl)	Hole depth (mbgl)
30/05/19	00:00		30

CLIENTS | PEOPLE | PERFORMANCE

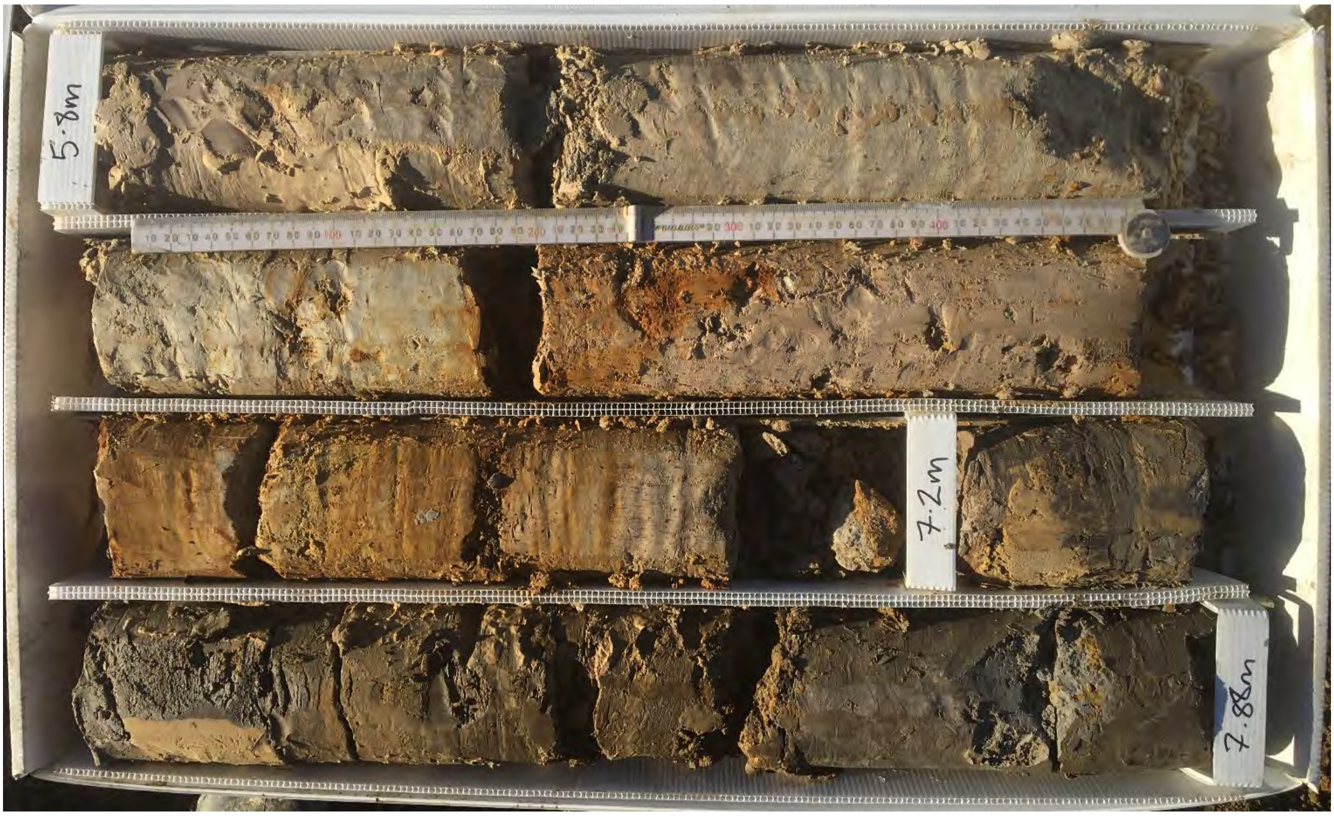
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 7
Borehole ID	BH05	



Box 1 of 14: 0.0 m to 3.8 m



Box 2 of 14: 3.8 m to 5.8 m



Box 3 of 14: 5.8 m to 7.88 m

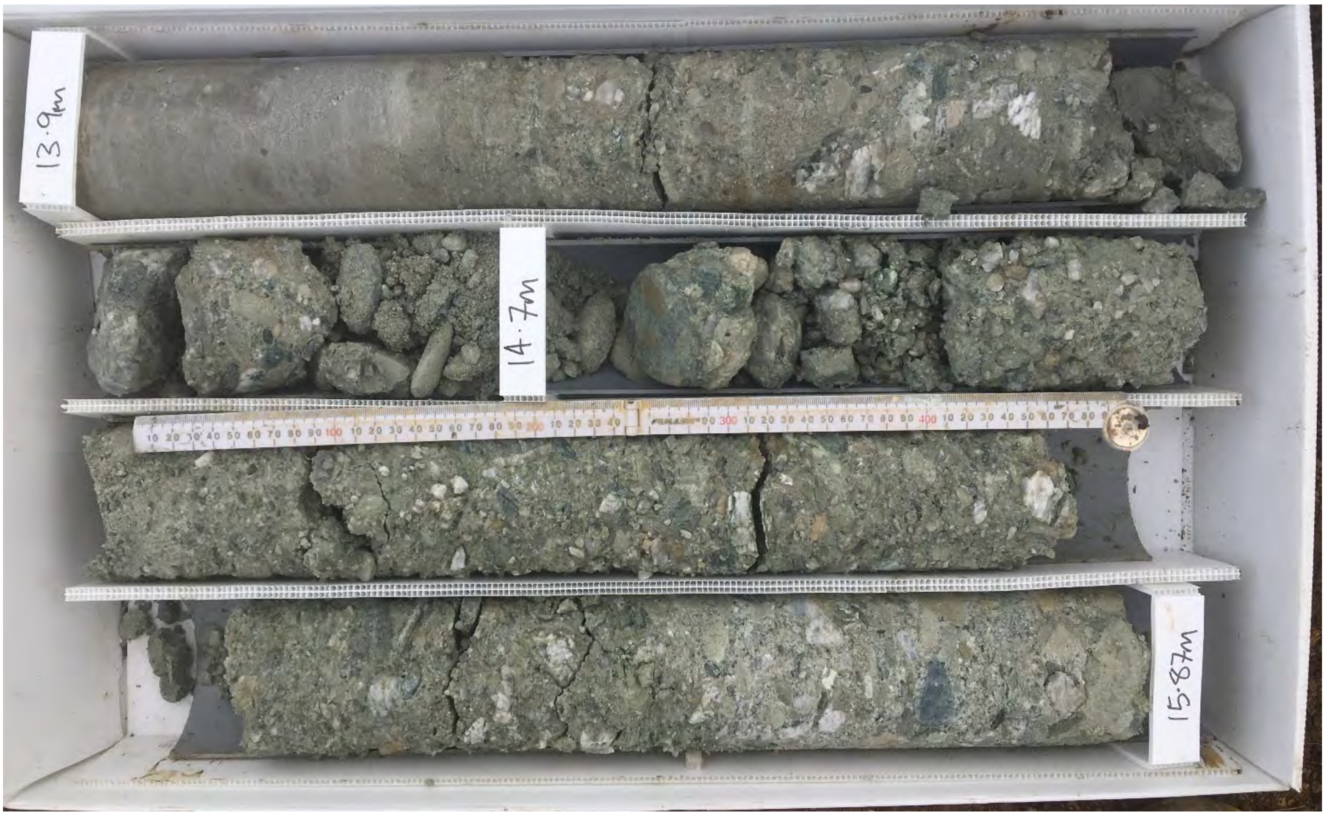
Box 4 of 14: 7.88 m to 9.93 m

Box 5 of 14: 9.93 m to 11.87 m

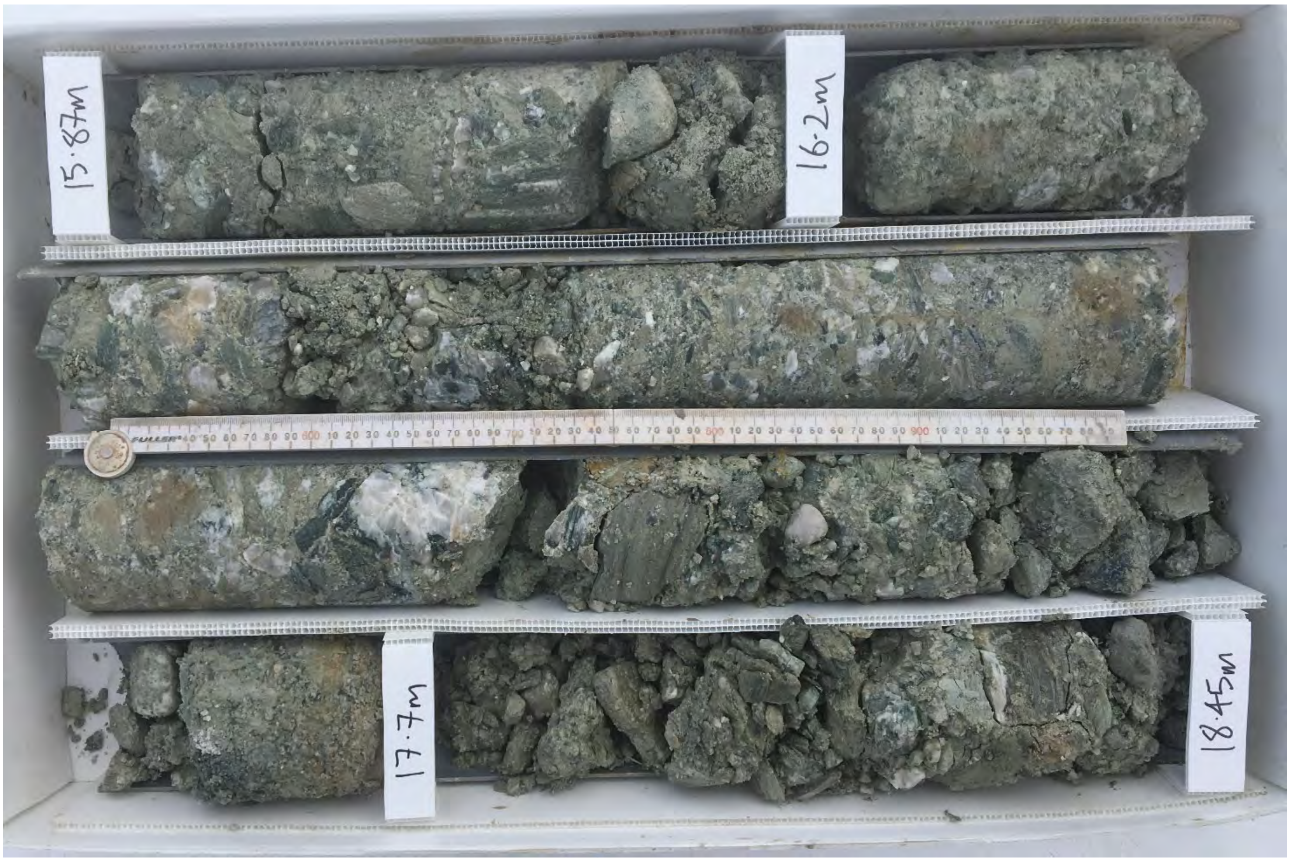
Box 6 of 14: 11.87 m to 13.9 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 4 of 7
Borehole ID	BH05	



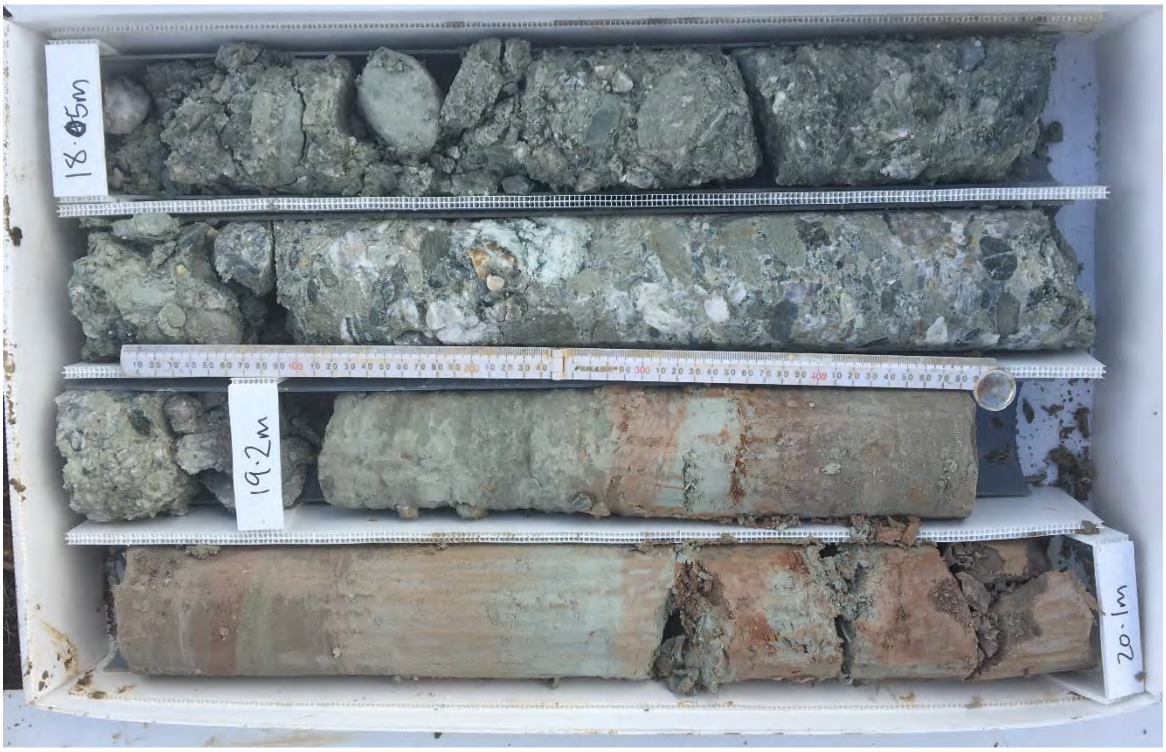
Box 7 of 14: 13.9 m to 15.87 m



Box 8 of 14: 15.87 m to 18.45 m

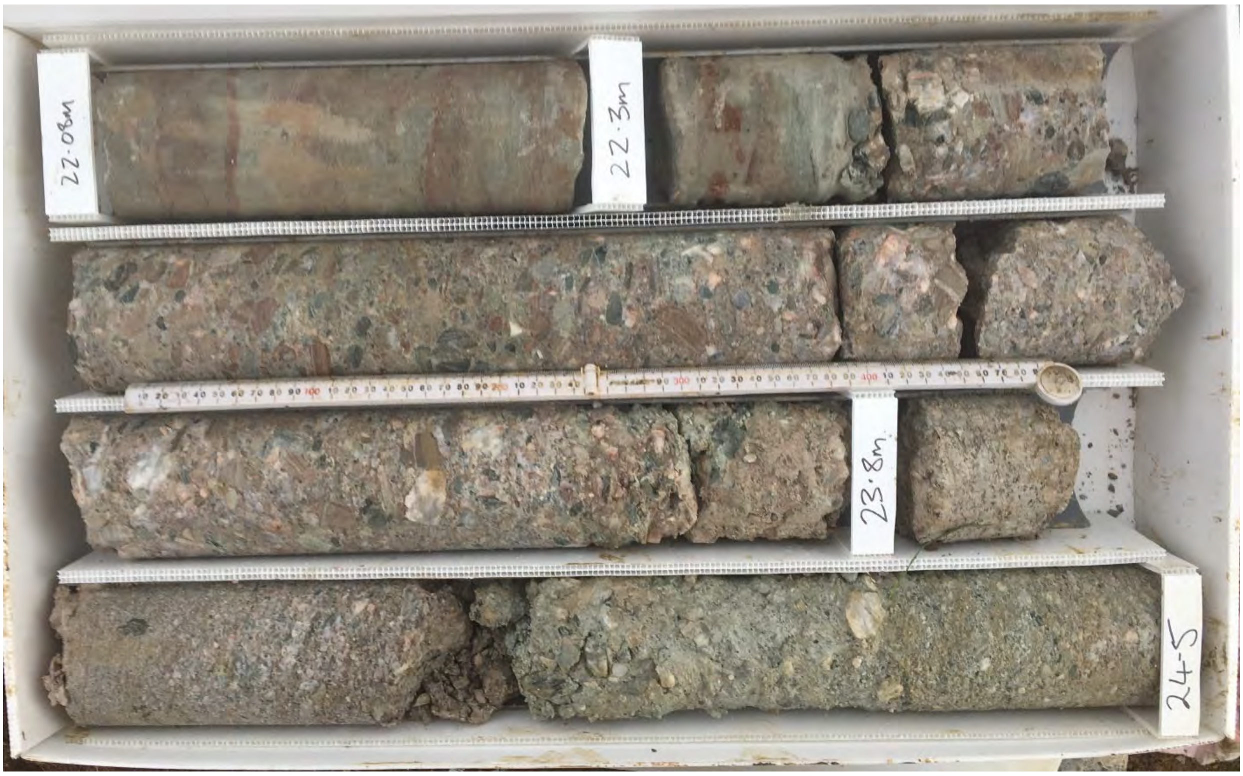
CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	
Borehole ID	BH05	

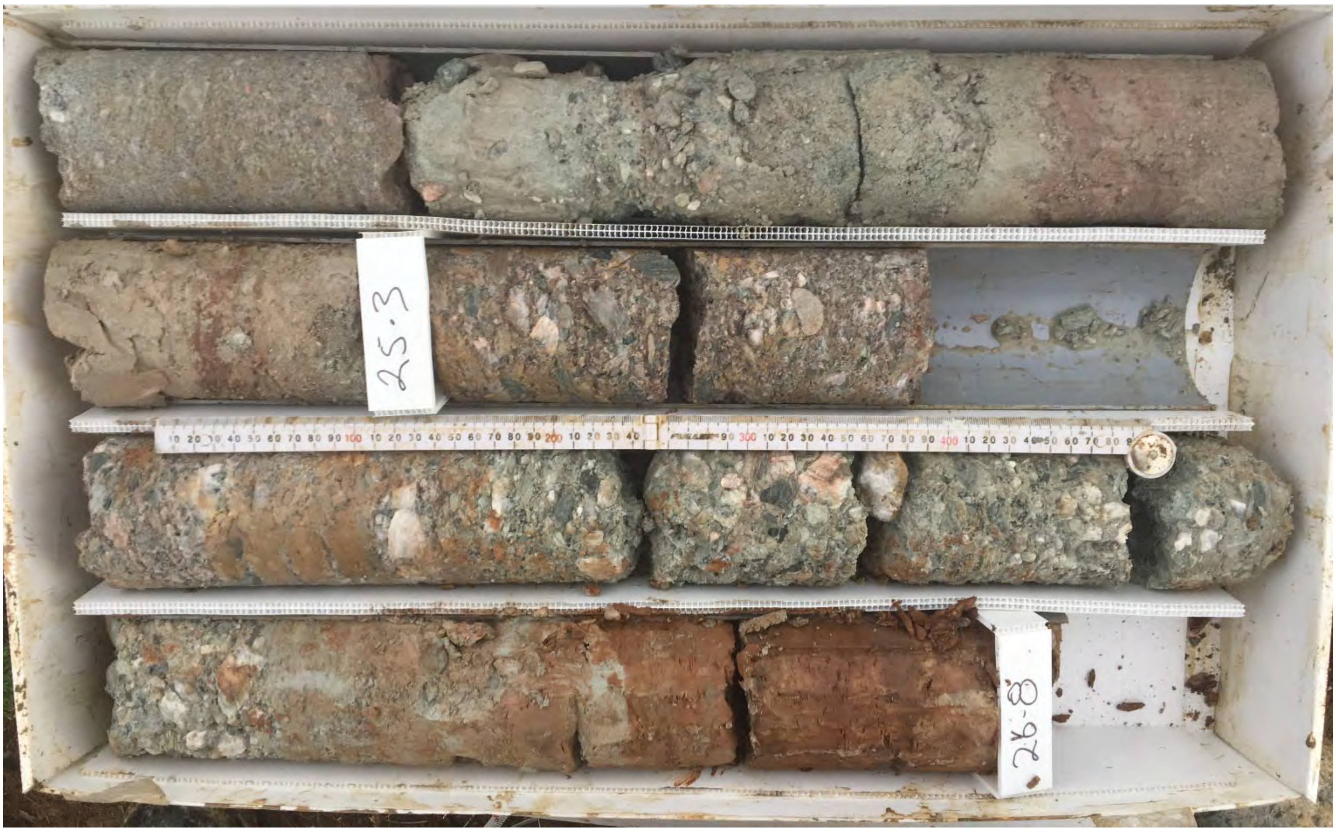


Box 9 of 14: 18.45 m to 20.1 m

Box 10 of 14: 20.1 m to 22.08 m

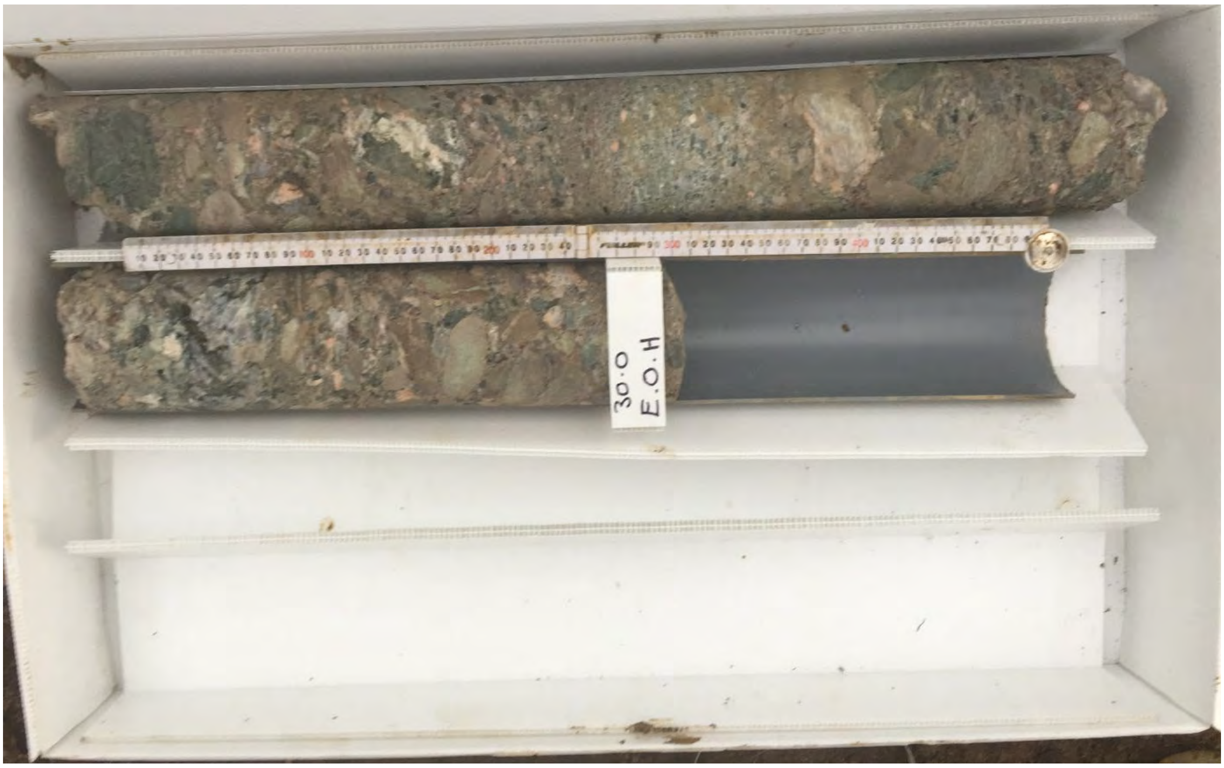


Box 11 of 14: 22.08 m to 24.5 m



Box 12 of 14: 24.5 m to 26.8 m

Box 13 of 14: 26.8 m to 29.0 m



Box 14 of 14: 29.0 m to 30.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH06
Client : Dunedin City Council	Sheet : 1 of 3
Site : Southwest Ridge	Hole Length : 30.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 13/06/2019 Completed: 14/06/2019	Logged : MF
Easting: 396168.25 Northing: 787593.98 System: TAIETM2000	Processed : HB
RL: 149.75 Datum: NZVD2016	Checked : JHS

Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR / SCR / RQD (%)
0 – 0.25		Top 250 mm dug out for drill pad (TOPSOIL)	TS					
0.25 – 1.25		SILT, trace to minor clay, trace fine to medium sand, trace fine gravel; grey and orange-brown. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt	PQTT		83 / 17
1.25 – 1.5		Highly weathered, yellow-brown SILTSTONE; extremely weak; no defects (HENLEY BRECCIA)	HENLEY BRECCIA					
1.5 – 7.2		Highly weathered, thinly bedded, yellow-brown silty fine SANDSTONE; extremely weak; no defects; iron-staining in layers and spots; trace organics throughout; 2.70 m: 170 mm layer gravelly SANDSTONE 4.90 m: 200mm loose sand/pebbly layer; likely coreloss depth 5.50 - 5.70 m: Fine gravel (quartz and schist, angular to sub-angular) layer 6.70 - 7.20 m: moderately weathered, very weak to weak	HENLEY BRECCIA			PQTT	HW	100 / 89; 93 / 75 / 75; 78 / 78 / 78; 100 / 100 / 100
7.2 – 8.18		Moderately weathered, yellow-brown SILTSTONE; very weak to weak; very widely spaced defects 7.30 - 7.75 m: light grey with black flecks 7.75 m: orange-brown with black streaks; break on bedding plane, dark iron-staining on face	HENLEY BRECCIA			PQTT		60 / 60 / 60
8.18 – 8.7		Moderately weathered, grey, fine to coarse SANDSTONE; extremely weak to very weak 8.10 - 8.70 m: CORELOSS	HENLEY BRECCIA			PQTT	MW	
8.7 – 10		Moderately weathered, fine to medium SANDSTONE; very weak to weak; widely spaced defects 9.25 m: tight break, iron-stained face, staining decreases for 50 mm above and below break 9.72 m: 15-20 mm dark brown layer	HENLEY BRECCIA			PQTT		100 / 87 / 87

Other columns: Sample (Number / Type, Result), Casing, Flush Return (%), Estimated Strength (MPa), Defect Spacing (mm), Instrumentation Installation, Water level.

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level			
Date	Time	Reading (mbgl)	Hole depth (mbgl)

GHD	Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Southwest Ridge Job Number: 12506381	Hole No. : BH06 Sheet : 2 of 3 Hole Length : 30.00m Scale @ A4 : 1:50
	Commenced: 13/06/2019 — Completed: 14/06/2019	Logged : MF
Easting: 396168.25	Northing: 787593.98 — System: TAIETM2000	Processed : HB
RL: 149.75	Datum: NZVD2016	Checked : JHS

Columns: RL (m) | Depth (m) | Graphic | Material Description | Geological Unit | Moisture condition | Consistancy / Relative density | Sample: Number / Type, Result | Casing | Method | Flush Return (%) | Weathering | Estimated Strength (MPa) | TCR SCR RQD (%) | Defect Spacing (mm) | Instrumentation Installation | Water level

Material Description

Depth (m)	Material Description
9.75 – 10.2	9.75 m: tight break, iron stained face; core stained below break, but not above 10.00 - 10.20 m: with some fine rounded gravel
10.2 – 10.45	10.20 - 10.45 m: CORELOSS
10.45 – 12.45	Moderately weathered, laminated to moderately thickly bedded, light grey and orange-brown SANDSTONE; extremely to very weak; poorly indurated; very widely spaced defects 10.75 m: 100 mm SILTSTONE, black basal contact 10.85 m: 60 mm light grey with black flecks, minor organic inclusions 11.00 m: yellow-brown and orange-brown 11.10 m: 2-3 mm iron stained 'rusty' layer 11.55 m: 70 mm light grey interbed *12.00* JT, 45°, pl, r, CLAY, Iron stained clay infill. 12.25 m: 100 mm minor organics, orange-brown and black layer
12.45 – 12.54	Moderately weathered grey and white CONGLOMERATE; very weak to weak; clasts, fine to medium, rounded to sub-rounded, quartz and schist
12.54 – 13.40	12.54 - 13.40 m: CORELOSS
13.40 – 13.54	Moderately weathered grey and white CONGLOMERATE; very weak to weak; clasts, fine to medium, rounded to sub-rounded, quartz and schist
13.54 – 15.4	Slightly weathered, grey with occasional black, fine to medium SANDSTONE; very weak to weak; poorly indurated, no defects. Closely to very closely spaced laminations of lignite
15.4 – 16	Slightly weathered, grey with occasional black SILTSTONE; very weak to weak; no defects; occasional lignite 15.60 m: 100 mm SANDSTONE
16 – 17.6	Slightly weathered, grey with occasional black, fine to medium SANDSTONE; very weak to weak; no defects; occasional lignite 16.40 - 16.60 m: minor fine gravel (quartz and schist) 'pebbly conglomerate' 17.05 - 17.25 m: SILTSTONE
17.6 – 18	Slightly weathered, light grey BRECCIA; extremely weak to weak; no defects; clasts: quartz and schist, fine to medium gravel size, angular to sub-rounded; matrix supported; matrix: fine to coarse sand
18 – 18.2	18.00 - 18.20 m: CORELOSS
18.2 – 19.4	Slightly weathered, light grey BRECCIA; extremely weak to weak; no defects; clasts: quartz and schist, fine to medium gravel size, angular to sub-rounded; matrix supported; matrix: fine to coarse sand 19.10 - 19.20 m: unweathered, weak to moderately strong 19.20 - 19.40 m: moderately strong to strong, well indurated
19.4 – 20	Unweathered, light grey and black fine to medium SANDSTONE; very weak to weak; very widely spaced defects; with moderately widely spaced laminated very thin to thin beds

Geological Unit: HENLEY BRECCIA

Weathering: MW (to approx. 13.4 m); SW (approx. 13.4 – 19.4 m); UW (below 19.4 m)

Core Runs

Method	TCR / SCR / RQD (%)
PQTT	83 / 83 / 83
PQTT	56 / 56 / 56
PQTT	87 / 87 / 87
PQTT	100 / 100 / 100
PQTT	100 / 100 / 87
PQTT	87 / 63 / 63
PQTT	93 / 65 / 47

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical — Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Ridge
Job Number: 12506381
Commenced: 13/06/2019 Completed: 14/06/2019

Hole No. : BH06
Sheet : 3 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396168.25 Northing: 787593.98 System: TAIETM2000
RL: 149.75 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Weathering	Method	TCR / SCR / RQD (%)
129	20–21	of lignite and widely spaced moderately thin siltstone beds Unweathered, light grey and black fine to medium SANDSTONE; very weak to weak; very widely spaced defects; with moderately widely spaced laminated very thin to thin beds of lignite and widely spaced moderately thin siltstone beds *(continued from layer starting at 19.4m)* 20.20 m: fine to coarse sand 20.70 m: fine to medium sand	HENLEY BRECCIA	UW	PQTT	93 / 65 / 47
128	21–22	21.06 m: 230 mm siltstone interbed 21.70 m: very thinly bedded (2-10 mm)			PQTT	100 / 100 / 100
127	22–23	22.20 m: moderately thickly bedded (~ 300 mm) 22.40 m: 150 mm siltstone interbed 22.75 m: laminated (2-10 mm)			PQTT	87 / 87 / 87
126	23–24				PQTT	100 / 100 / 100
125	24–25					
124	25–26				PQTT	88 / 88 / 88
123	26–27					
122	27–28	27.50 - 28.50 m: very closey spaced fractures, possibly drilling induced			PQTT	100 / 32 / 32
121	28–29	28.40 - 28.50 m: dark grey-brown for 100 mm 28.70 - 28.80 m: dark brown layer - looks like lithified topsoil				
120	28.8–30	Unweathered, light grey BRECCIA; weak to moderately strong; no defects; moderately well indurated; clasts: quartz and schist, fine gravel size, sub-angular to sub-rounded; matrix supported; matrix: fine to coarse sand			PQTT	76 / 76 / 76

End of Hole @ 30.00m,Target Depth.

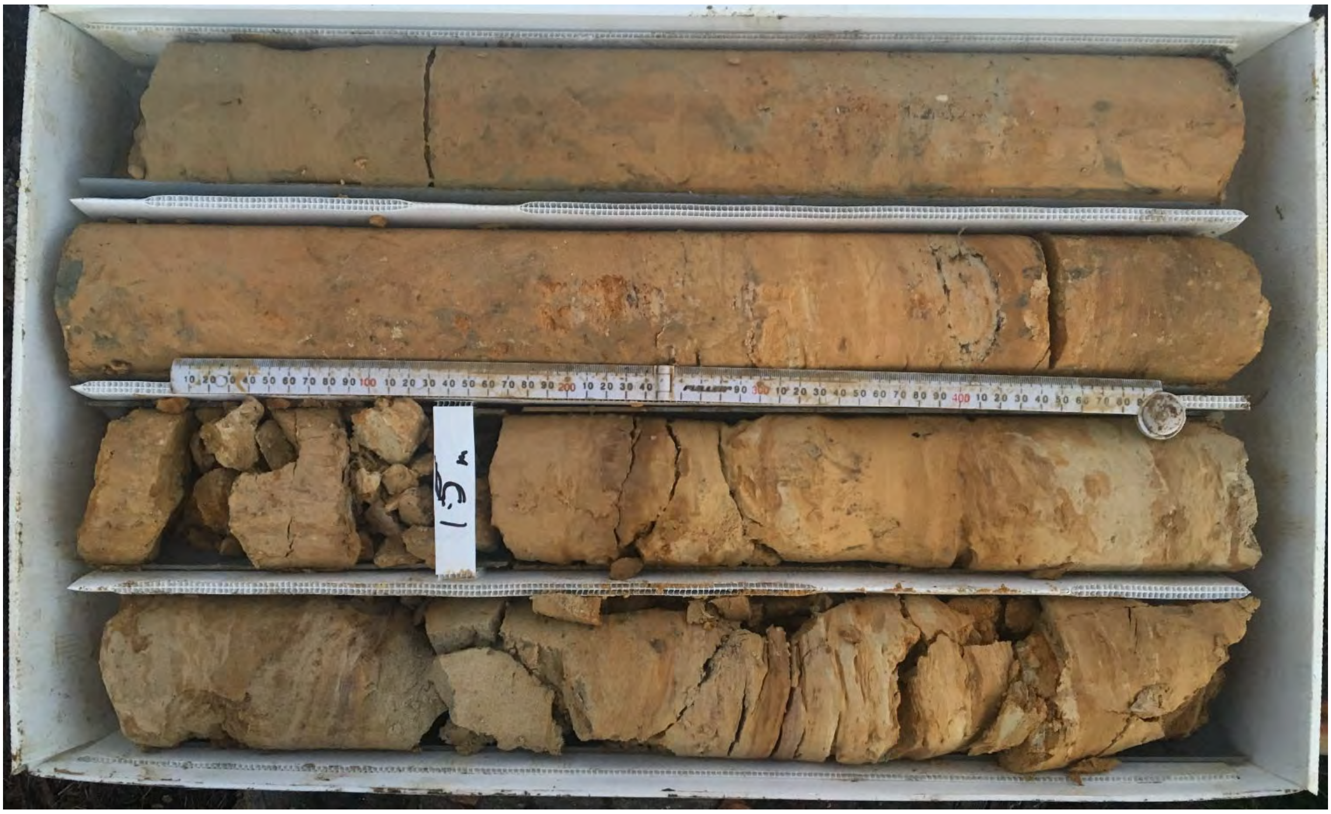
Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
14/06/19	00:00		30

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 7
Borehole ID	BH06	



Box 1 of 13: 0.0 m to 2.4 m

Box 2 of 13: 2.4 m to 4.6 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 7
Borehole ID	BH06	

Box 3 of 13: 4.6 m to 7.2 m

Box 4 of 13: 7.2 m to 10.0 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 7
Borehole ID	BH06	

Box 5 of 13: 10.0 m to 13.2 m

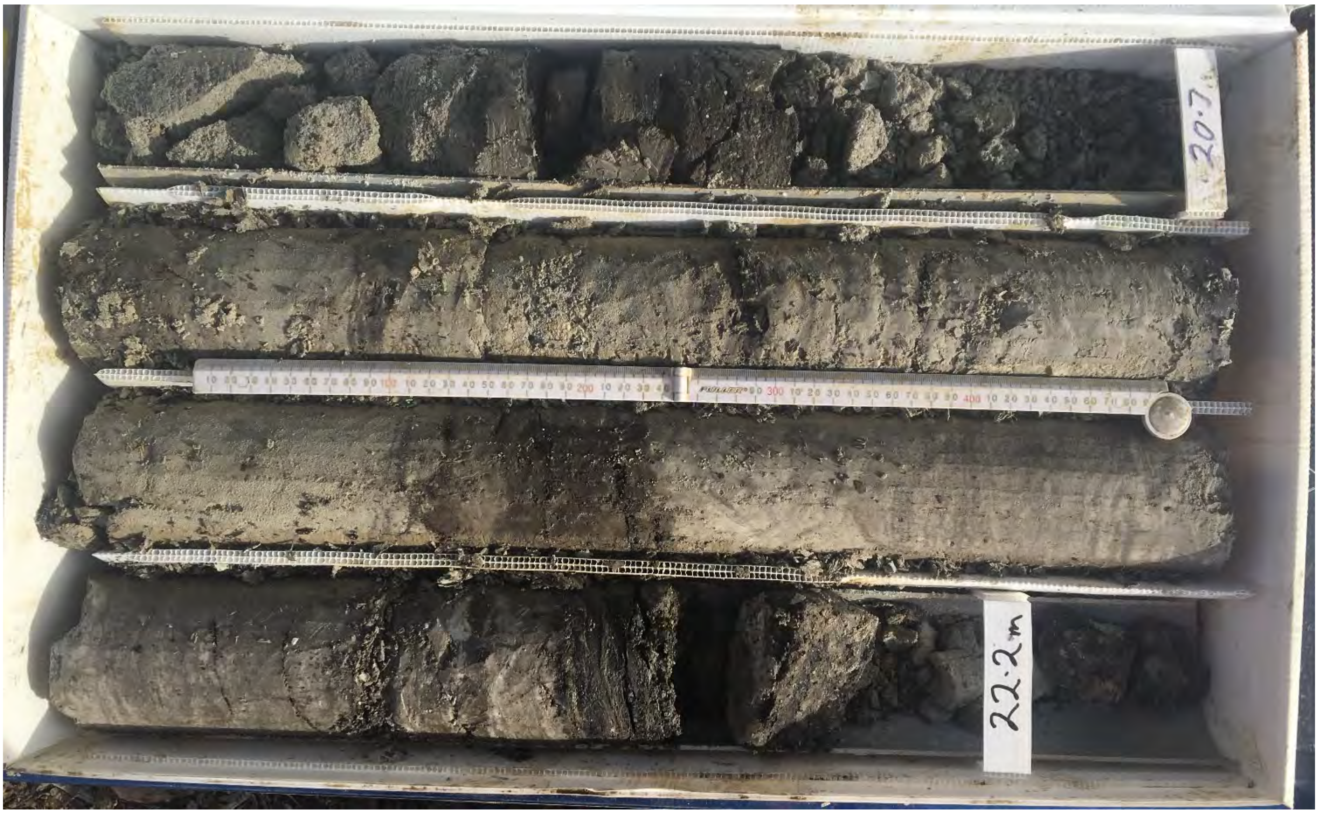
Box 6 of 13: 13.2 m to 15.6 m

Box 7 of 13: 15.6 m to 17.7 m

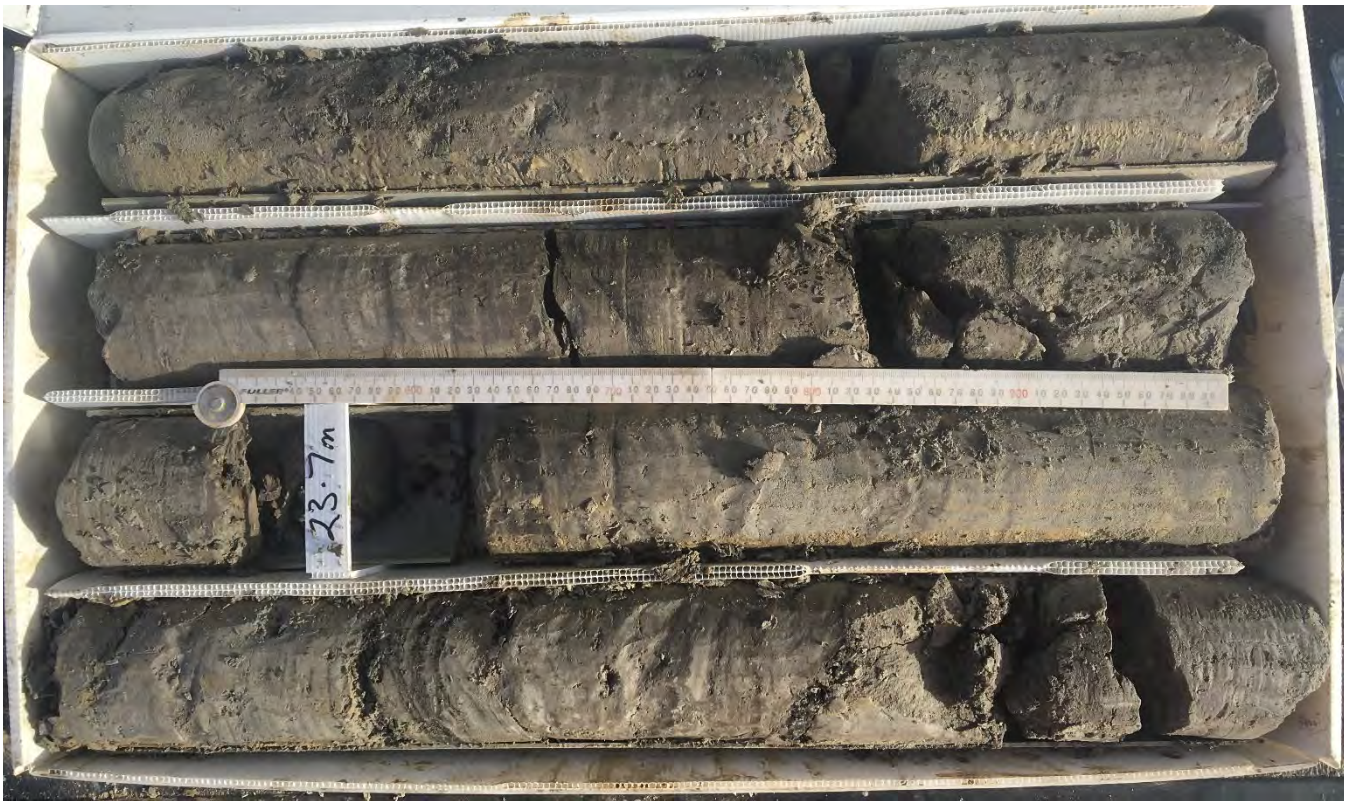
Box 8 of 13: 17.7 m to 20.2 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 5 of 7
Borehole ID	BH06	

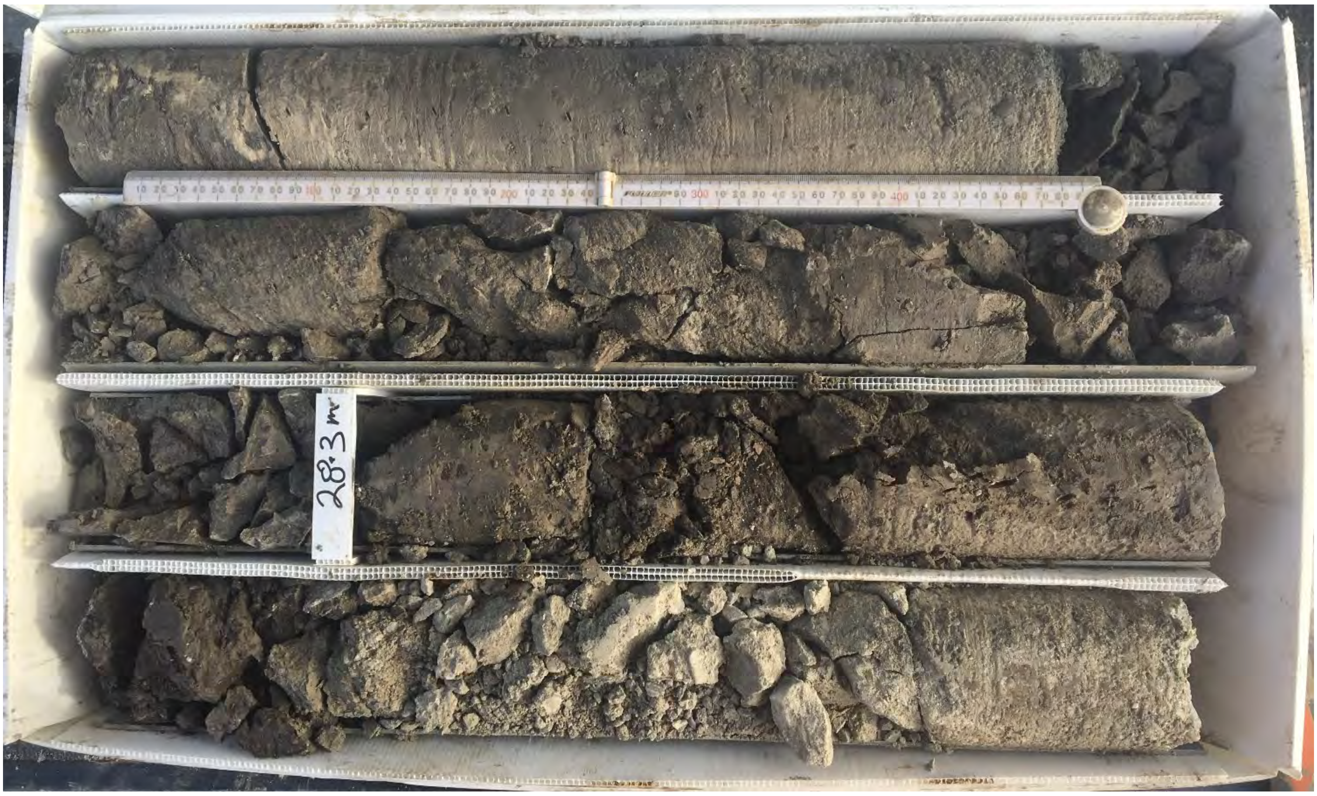


Box 9 of 13: 20.2 m to 22.2 m



Box 10 of 13: 22.2 m to 24.7 m

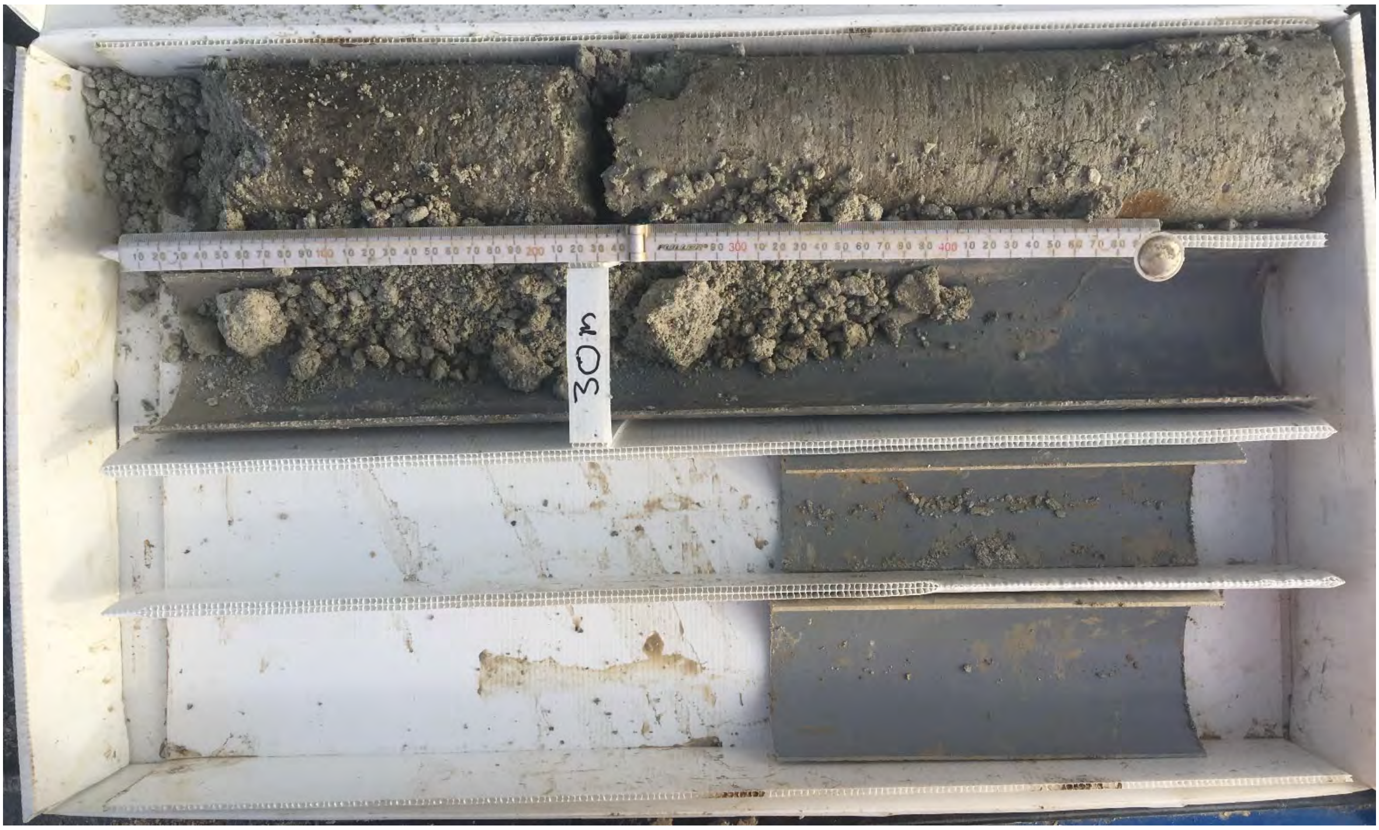
Box 11 of 13: 24.7 m to 27.0 m



Box 12 of 13: 27.0 m to 29.3 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 7 of 7
Borehole ID	BH06	



Box 13 of 13: 29.3 m to 30.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH07
Client : Dunedin City Council	Sheet : 1 of 2
Site : Smooth Hill Central ridge	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 30/05/2019 Completed: 4/06/2019	Logged : MF
Easting: 396493.65 Northing: 787671.87 System: TAIETM2000	Processed : HB
RL: 139.73 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
0 – 1.4	0.00 - 1.40 SILT, minor clay, trace fine sand, trace organics; light grey & orange brown. Very stiff, moist, low plasticity. (LOESS). From 1.25 m to 1.30 m, 50 mm layer with minor to some Fe "rusty" inclusions (red to brown).	LOESS	M	St	PQTT		84
1.4	1.40 - 2.05 Fine sandy SILT, minor fine gravel; yellow brown. Hard, dry, non plastic. (Inferred CORELOSS 1.4-1.6 m).	LOESS	D	'H'	PQTT		85
	2.05 - 2.80 From 2.05 m, Fe staining in layers for 250 mm.	LOESS	D	H			
	2.80 - 3.40 From 2.8 m, no gravel, Fe stained layers common.	LOESS	D	H	PQTT		100
3.4	3.40 - 3.75 SILT, some clay; light grey & yellow brown with orange brown layers. Hard, dry, non plastic. Fe stained layers throughout.	LOESS	D	H			
3.75	3.75 - 3.90 Clayey SILT, trace fine sand, trace organics; grey to brown. Stiff to very stiff, moist, high plasticity. Possibly organic origin.	LOESS	M	St-VSt			
3.9	3.90 - 4.10 SILT, some clay; light grey & yellow brown with orange brown layers. Hard, dry, non plastic. Fe stained layers throughout.	LOESS	D	H			
4.1	4.10 - 4.80 Grades into: Moderately weathered, thinly layered, ight grey & yellow brown SILTSTONE; very weak; widely spaced defects. (HENLEY BRECCIA).	HENLEY BRECCIA			PQTT	MW	100 / 100
4.8	4.80 - 5.95 From 4.8 m, becomes moderately weathered, alternating bedded SILTSTONE & fine SANDSTONE; very weak to weak; bedding 200-400 mm thick. Note at 5.17m: 2 x 5-8 mm organic rich layers.	HENLEY BRECCIA				MW	
5.95	5.95 - 7.20 Slightly weathered to moderately weathered, light grey & yellow brown BRECCIA; weak to moderately strong; coarse sand matrix, matrix supported. Clasts are fine to coarse gravel quartz and schist, angular to sub rounded.	HENLEY BRECCIA			PQTT	SW-MW	100 / 100
	7.20 - 8.10 From 7.2 m, becomes very weak to moderately strong. Matric less indurated.	HENLEY BRECCIA			PQTT	SW-MW	100 / 93
8.1	8.10 - 8.80 Slightly weathered to moderately weathered, light grey & brown silty fine SANDSTONE; very weak to moderately strong.	HENLEY BRECCIA				SW-MW	
8.8	8.80 - 9.33 Slightly weathered to moderately weathered, light grey & yellow brown BRECCIA; weak to moderately strong; coarse sand matrix, matrix supported. Clasts are fine to medium gravel quartz and schist, angular to sub rounded. Note: less indurated matrix.	HENLEY BRECCIA			PQTT	SW-MW	100 / 97
	9.33 - 9.40 From 9.33 m, becomes extremely weak, non indurated silty GRAVEL (some components as breccia).	HENLEY BRECCIA				SW-MW	
	9.40 - 9.70 From 9.4 m, becomes weak to moderately strong.	HENLEY BRECCIA				SW-MW	

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH07
Client : Dunedin City Council	Sheet : 2 of 2
Site : Smooth Hill Central ridge	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 30/05/2019 Completed: 4/06/2019	Logged : MF
Easting: 396493.65 Northing: 787671.87 System: TAIETM2000	Processed : HB
RL: 139.73 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Consistancy / Relative density	Method	Weathering	TCR / RQD (%)
	matrix more indurated, fine to coarse gravel clasts.					
10.0	9.70 - 10.00 From 9.7 m, becomes fine to medium gravel size clasts.					
10.25	10.00 - 10.10 Slightly weathered to moderately weathered, grey SILTSTONE; very weak to weak.				SW-MW	
	10.10 - 10.25 Slightly weathered to moderately weathered, grey SANDSTONE; very weak to weak.				SW-MW	
10.65	10.25 - 10.65 Slightly weathered to moderately weathered, fine to medium grained, grey BRECCIA; very weak to weak. Note at 10.60 m: minor break on bedding plane, Fe staining. *10.60 - 10.80* BP, 70°, pl, r, VN, CLAY, Fe staining			PQTT	SW-MW	100 / 100
	10.65 - 11.00 Slightly weathered, dark grey fine sandy SILTSTONE; very weak to weak; occassional organic layers up to 10 mm thick.				SW	
13	11.00 - 13.00 From 11.0 m, becomes unweathered. Note at 11.7 m: End of shift 30/05/2019.			PQTT	UW	100 / 100
13.3	13.00 - 13.30 Unweathered, CONGLOMERATE; weak to moderately strong; fine gravel to coarse sand.				UW	
14.7	13.30 - 14.70 Unweathered, light grey & white fine to coarse BRECCIA; very weak to weak; no defects. Clasts quartz and schist, sub angular to sub rounded, matrix supported, medium to coarse sand matrix, weakly indurated.			PQTT	UW	83 / 78
15.1	14.70 - 15.10 Unweathered, grey SILTSTONE; very weak to weak; no defects.	HENLEY BRECCIA			UW	
15.5	15.10 - 15.50 Unweathered, grey fine to medium SANDSTONE; very weak to weak; no defects.			PQTT	UW	92 / 92
15.8	15.50 - 15.80 Unweathered, grey SILTSTONE; very weak to weak; no defects.				UW	
17.3	15.80 - 17.30 Unweathered, light grey fine gravelly fine to coarse SANDSTONE; very weak to weak; no defects. No obvious bedding. Note inferred boundary at at approximately 17.3 m - unsure of coreloss location.		"	PQTT	UW	40 / 33
19.5	17.30 - 19.50 Unweathered, brown SILTSTONE; very weak to weak; no defects. From 17.65 m, becomes dark grey. From 17.85 m, becomes grey.			PQTT	UW	47 / 27
20	19.50 - 20.00 Unweathered; light grey, white & purple BRECCIA; weak to moderately strong; no defects. Coarse sand matrix, matrix supported, medium to well indurated.			PQTT	UW	78 / 78
	End of Hole @ 20.00m,Target Depth.					

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
04/06/19	00:00		20

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH07	

Box 1 of 8: 0.0 m to 2.7 m

Box 2 of 8: 2.7 m to 4.8 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 4
Borehole ID	BH07	

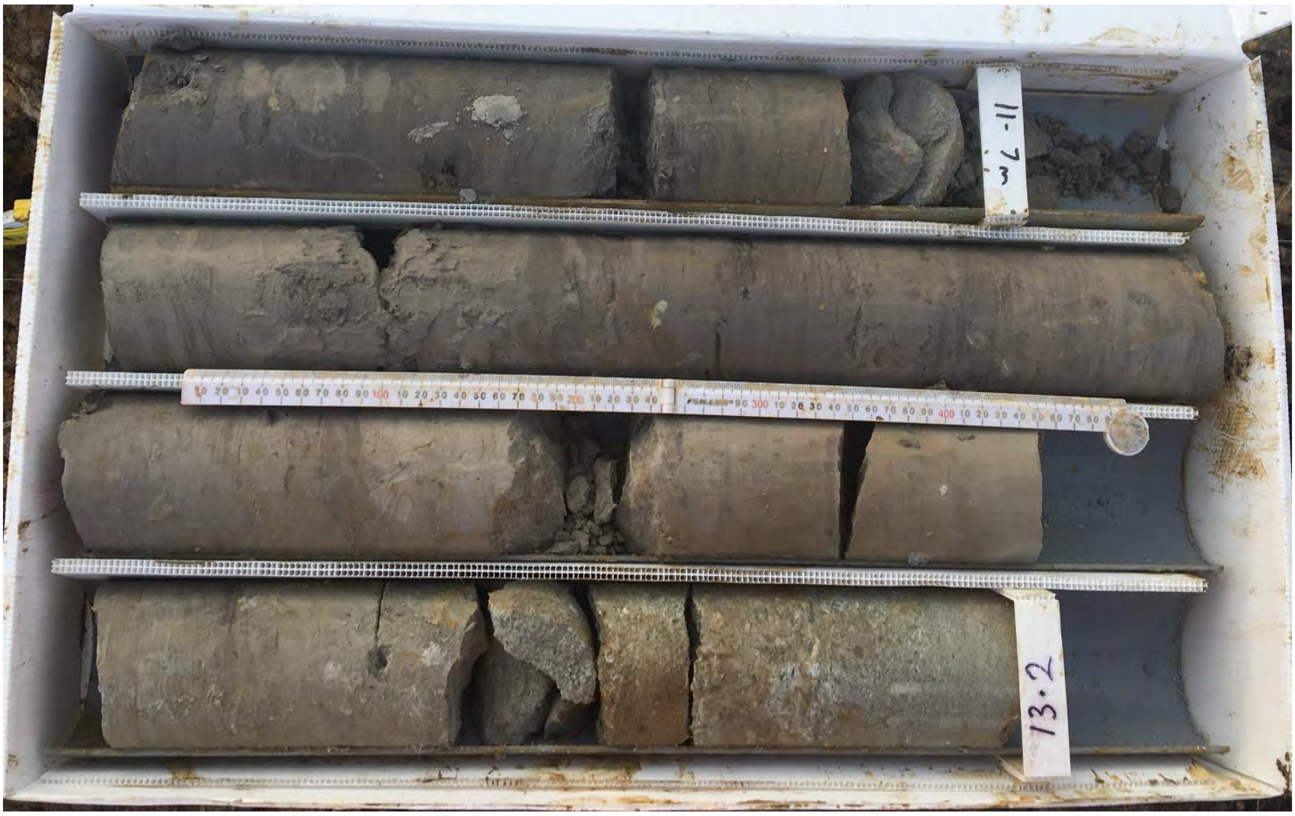
Box 3 of 8: 4.8 m to 7.0 m

Box 4 of 8: 7.0 m to 9.1 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 4
Borehole ID	BH07	

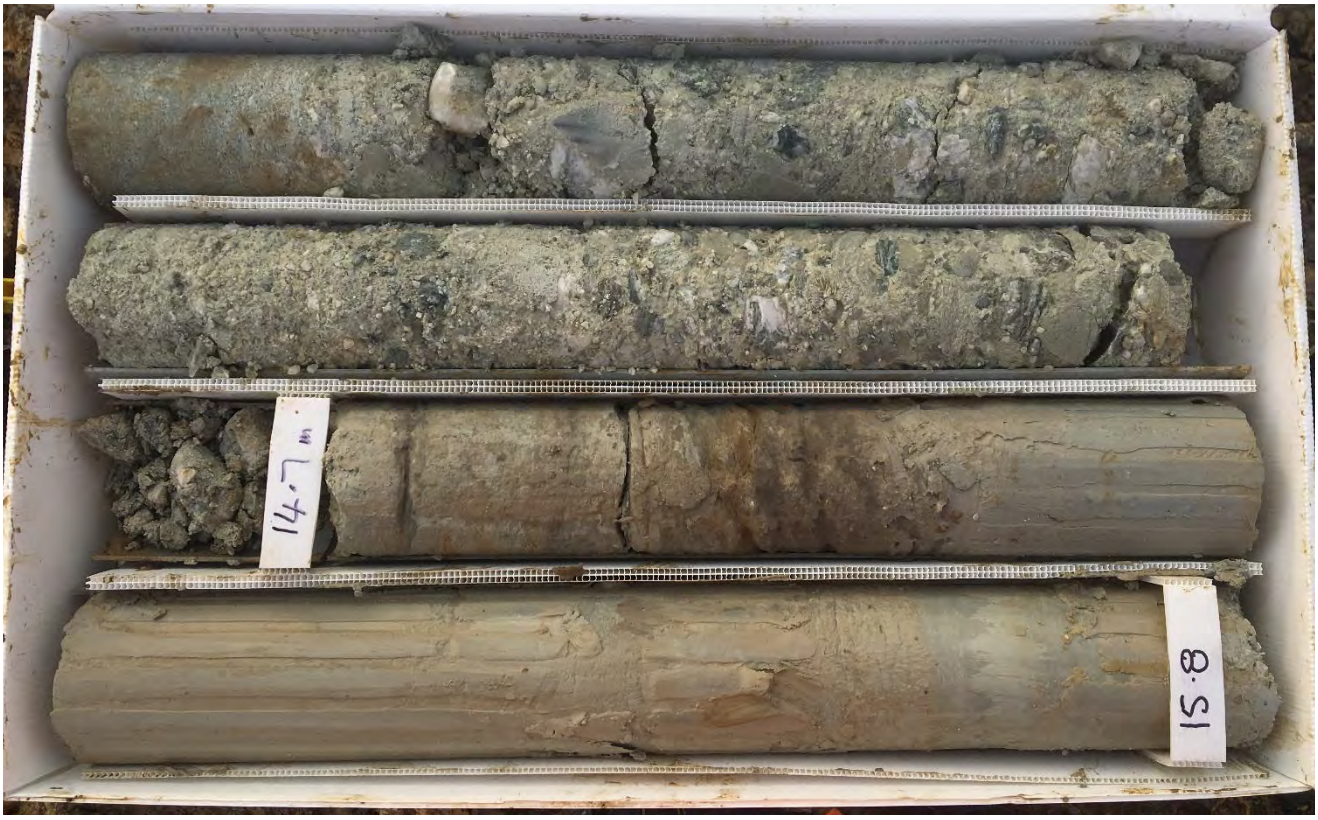
Box 5 of 8: 9.1 m to 11.2 m



Box 6 of 8: 11.2 m to 13.2 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 4 of 4
Borehole ID	BH07	



Box 7 of 8: 13.2 m to 15.8 m

Box 8 of 8: 15.8 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH08
Client : Dunedin City Council	Sheet : 1 of 2
Site : Big Stone Road	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 11/06/2019 Completed: 11/06/2019	Logged : MF
Easting: 396809.71 Northing: 787700.67 System: TAIETM2000	Processed : HB
RL: 143.89 Datum: NZVD2016	Checked : JHS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Result	Method	Weathering	TCR SCR RQD (%)
0–0.25	TOPSOIL; silt, trace to minor clay, trace fine sand; dark grey and yellow-brown. Very stiff, moist, low plasticity; trace roots	TS	M	VSt		PQTT		68
0.25–1.84	SILT, trace clay, trace fine sand; grey mottled orange-brown. Very stiff, moist, low plasticity (LOESS) 0.60 m: more orange-brown mottled grey 1.50 m: grey and brown mottled orange iron stained inclusions	LOESS	M	VSt		PQTT		
1.84–2.86	1.84 - 2.86 m: CORE LOSS	LOESS				PQTT		23
2.86–3.75	Fine sandy SILT, trace clay; light grey-brown. Very stiff, dry, low plasticity 3.00 m: light grey and orange; iron stained laminations	LOESS	D	VSt	SV@3m 194 kPa SV@3.5m UTP	PQTT		100
3.75–4.1	SILT, trace to minor clay, trace coarse sand (rusty); light grey and orange-brown. Very stiff to hard, moist, low plasticity	LOESS	M	VSt-H		PQTT		90
4.1–4.4	SILT, minor to some clay; brown with black flecks and streaks. Very stiff to hard, dry to moist, high plasticity; trace to minor organics (BURIED TOPSOIL)	BTS	D-M	VSt-H				
4.4–5.0	Highly weathered, grey, orange-brown and yellow-brown BRECCIA; very weak to weak; no defects; clasts: quartz and schist, sub-angular to sub-rounded, fine gravel size; matrix: fine to coarse sand; matrix supported	HENLEY BRECCIA				PQTT	HW	100 100 100
5.0–5.2	Highly weathered, grey and orange-brown SILTSTONE; extremely weak to very weak; no defects	HENLEY BRECCIA				PQTT	HW	
5.2–6.2	Highly weathered, grey, orange-brown and yellow-brown BRECCIA; very weak to weak; no defects; clasts: quartz and schist, sub-angular to sub-rounded, fine to medium gravel, matrix: fine to coarse sand; matrix supported	HENLEY BRECCIA				PQTT	HW	
6.2–6.9	6.20 - 6.90 m: CORELOSS (inferred silty GRAVEL)	HENLEY BRECCIA				PQTT		53 40 33
6.9–7.4	Fine to medium GRAVEL; orange-brown, white, yellow-brown and grey. Poorly graded; inferred silt matrix from minimal matrix recovery; gravel, quartz and schist, angular to sub-rounded.	HENLEY BRECCIA				PQTT	MW	
7.4–8.1	Moderately weathered, grey, orange-brown and white BRECCIA; weak; gravel quartz and schist, angular to sub-rounded, fine to medium gravel; matrix: fine to coarse sand; matrix supported	HENLEY BRECCIA				PQTT	MW	100 100 100
8.1	Slightly weathered, light grey SILTSTONE; very weak to weak; no defects (grades into next unit)	HENLEY BRECCIA				PQTT	SW	
	Slighty weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects	HENLEY BRECCIA				PQTT	SW	
	Slightly weathered, light grey and grey BRECCIA; weak to moderately strong; no defects; no visible bedding; matrix: fine to coarse sand, matrix supported; clasts: quartz and schist, sub-rounded to angular, fine to medium gravel size 9.00 - 14.10 m: unweathered, fine to coarse gravel size clasts, clast supported	HENLEY BRECCIA				PQTT	UW	93 93 93

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

Groundwater not encountered. No piezos were installed.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: UDR600 (truck mounted)

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH08
Client : Dunedin City Council	Sheet : 2 of 2
Site : Big Stone Road	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 11/06/2019 Completed: 11/06/2019	Logged : MF
Easting: 396809.71 Northing: 787700.67 System: TAIETM2000	Processed : HB
RL: 143.89 Datum: NZVD2016	Checked : JHS

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR / SCR / RQD (%)
10.0 – 14.1	Slightly weathered, light grey and grey BRECCIA; weak to moderately strong; no defects; no visible bedding; matrix: fine to coarse sand, matrix supported; clasts: quartz and schist, sub-rounded to angular, fine to medium gravel size *(continued from layer starting at 8.1m)* 11.20 m: fine to medium gravel sized clasts, moderately strong to strong 11.60 m: fine to coarse gravel clasts, weak to moderately strong	HENLEY BRECCIA	PQTT	UW	93 / 93 / 93; 100 / 100 / 100; 97 / 97 / 97
14.1 – 14.6	14.10 - 14.60 m: CORELOSS	HENLEY BRECCIA	PQTT		69 / 67 / 43
14.6 – 16.75	Unweathered, grey silty fine to medium SANDSTONE; very weak to weak; no defects; no visible bedding 16.40 m: 100 mm breccia interbed	HENLEY BRECCIA	PQTT	UW	100 / 100 / 100
16.75 – 17.95	Fine to coarse grained SANDSTONE, moderately strong to strong, with very closely spaced very thin interbeded of gravelly sandstone; fine gravel. 17.50 m: weak to moderately strong, moderately well indurated		PQTT	UW	100 / 100 / 100
17.95 – 19.5	Unweathered, light grey, grey and white BRECCIA; moderately strong to strong; no defects; no visible bedding; matrix: fine to coarse sand; clasts: schist and quartz, angular to sub-rounded, fine to coarse gravel size; clast supported 19.20 m: clasts predominantly medium to coarse gravel sized		PQTT	UW	100 / 100 / 100
19.5 – 20.0	Unweathered, light grey fine to coarse SANDSTONE; moderately strong to strong; no defects; well indurated; no visible bedding		PQTT	UW	100 / 100 / 100

End of Hole @ 20.00m,Target Depth.

Columns also present (no entries): Moisture condition; Consistancy / Relative density; Sample: Number / Type, Result; Casing; Flush Return (%); Estimated Strength (MPa); Defect Spacing (mm); Instrumentation Installation; Water level.

RL (m): 133, 132, 131, 130, 129, 128, 127, 126, 125, 124

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

Groundwater not encountered. No piezos were installed.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: UDR600 (truck mounted)

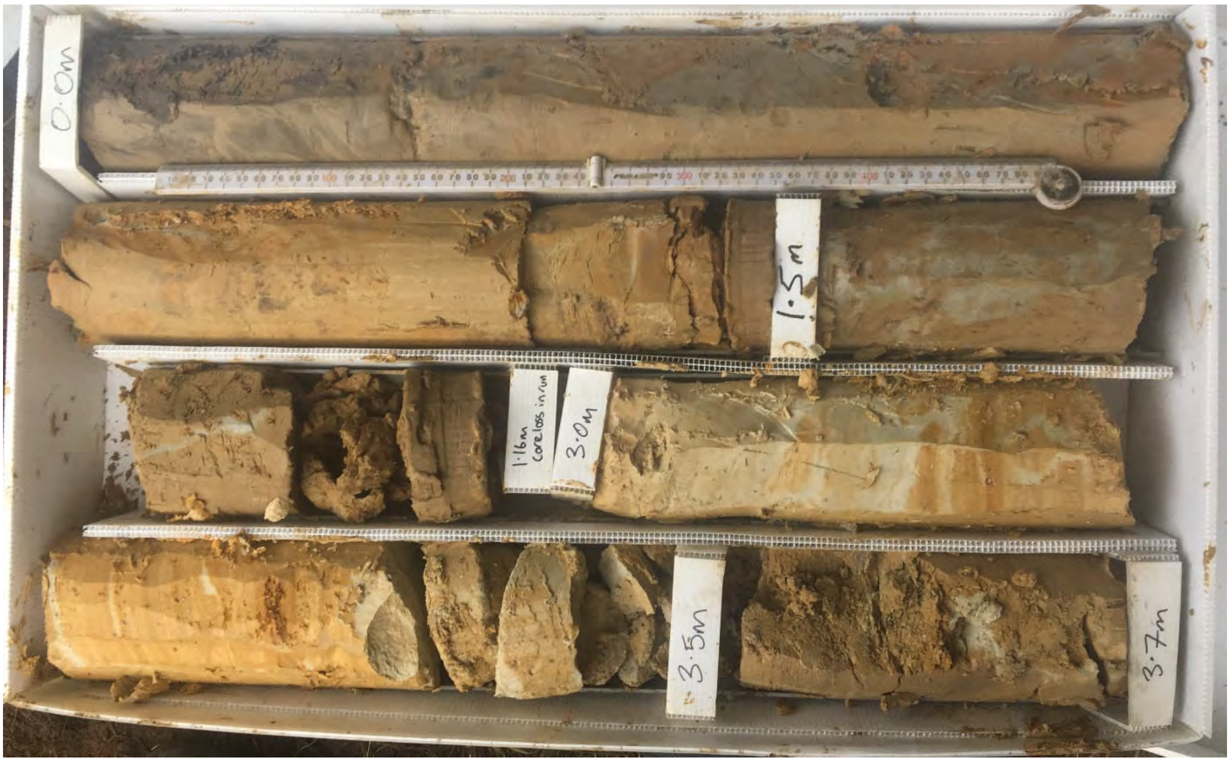
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
11/06/19	00:00		20

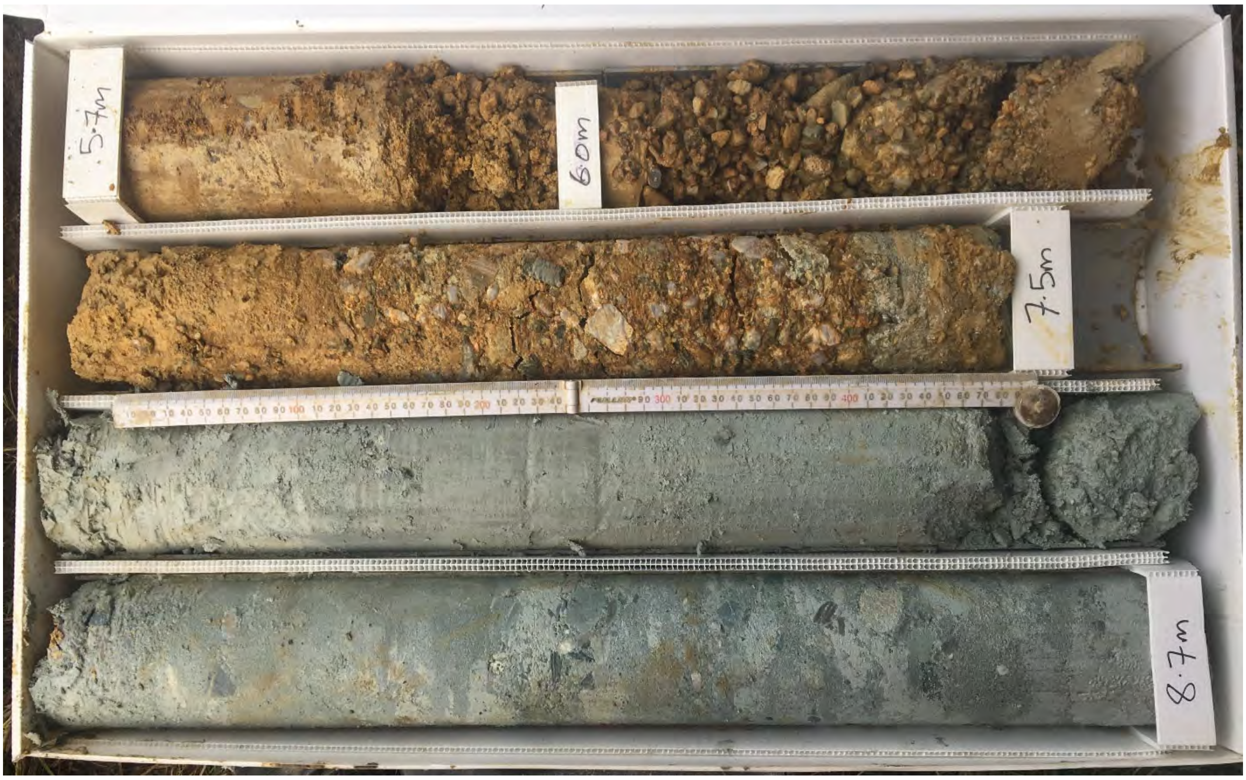
CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH08	

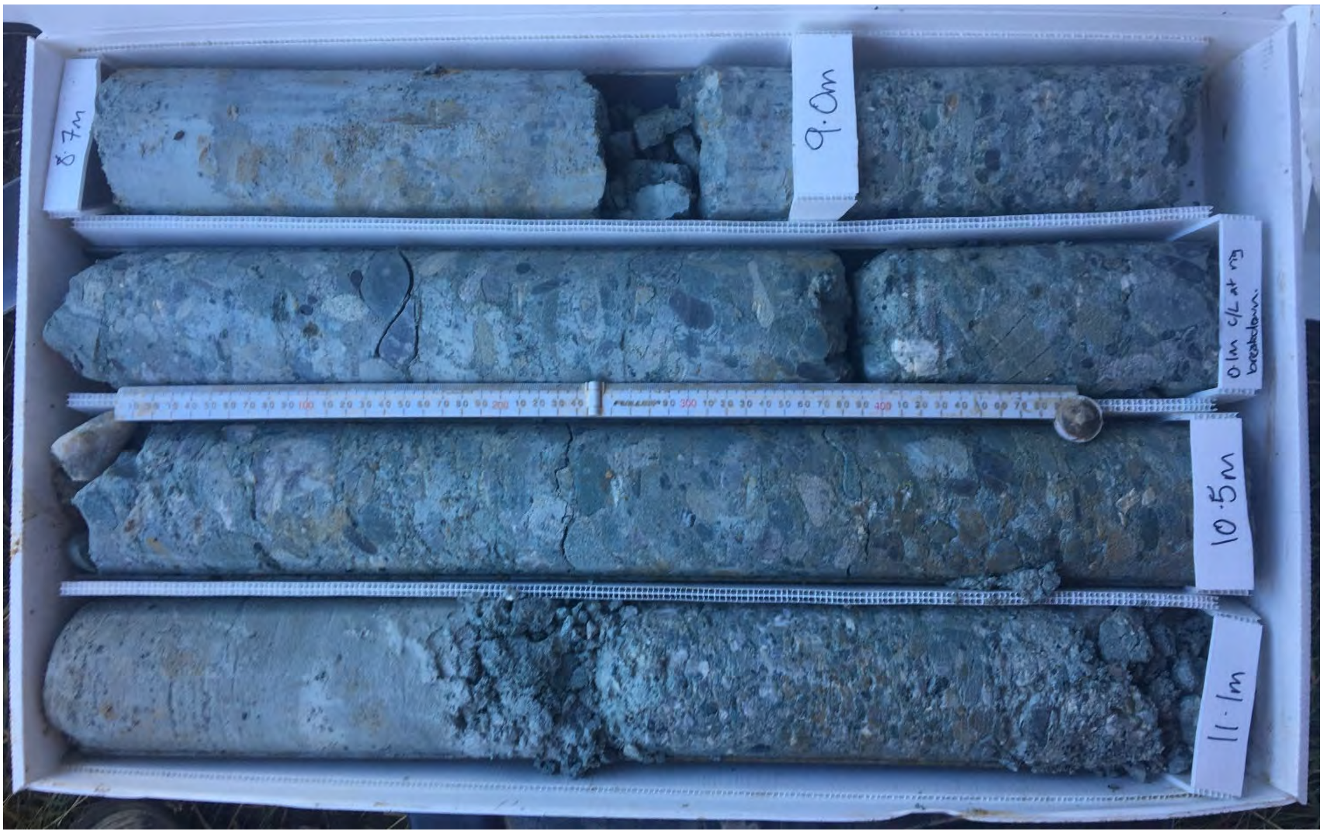


Box 1 of 8: 0.0 m to 3.7 m

Box 2 of 8: 3.7 m to 5.7 m



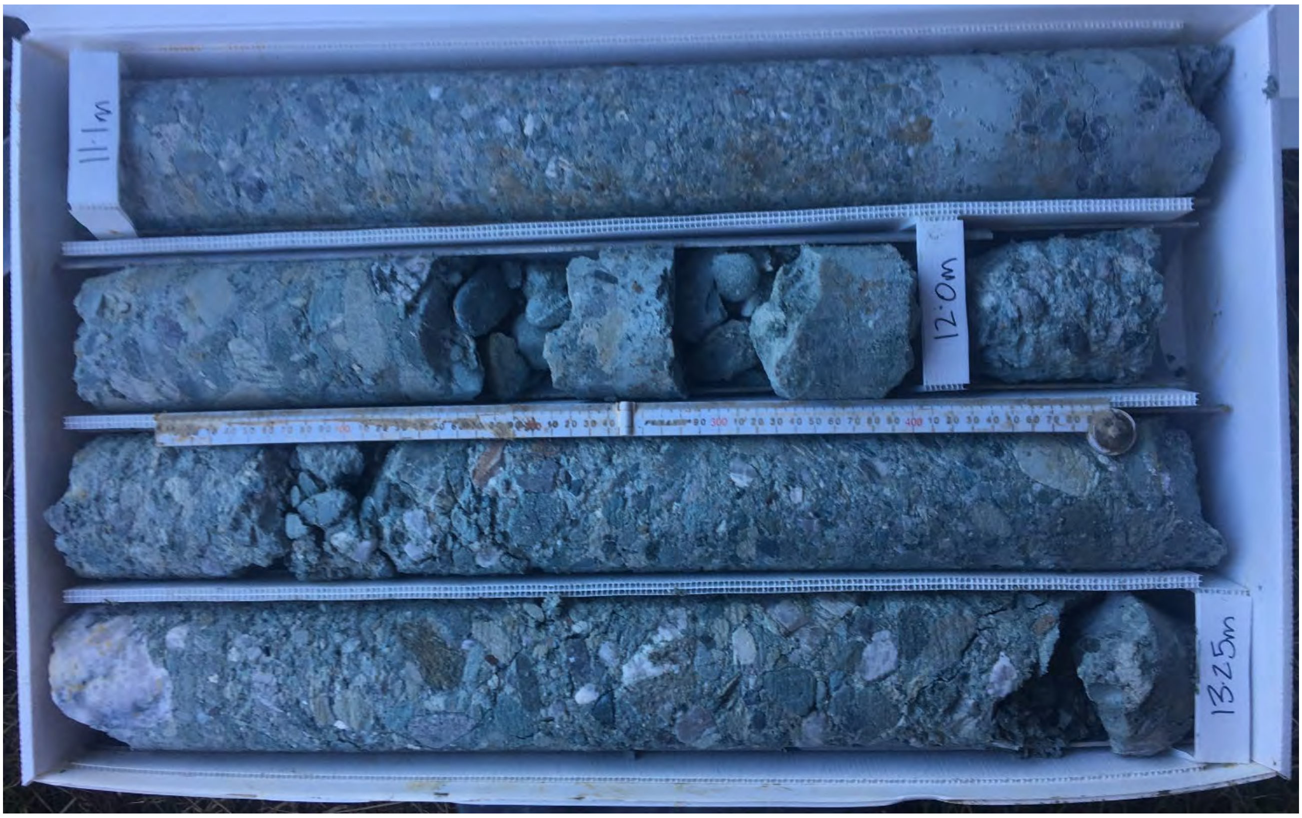
Box 3 of 8: 5.7 m to 8.7 m



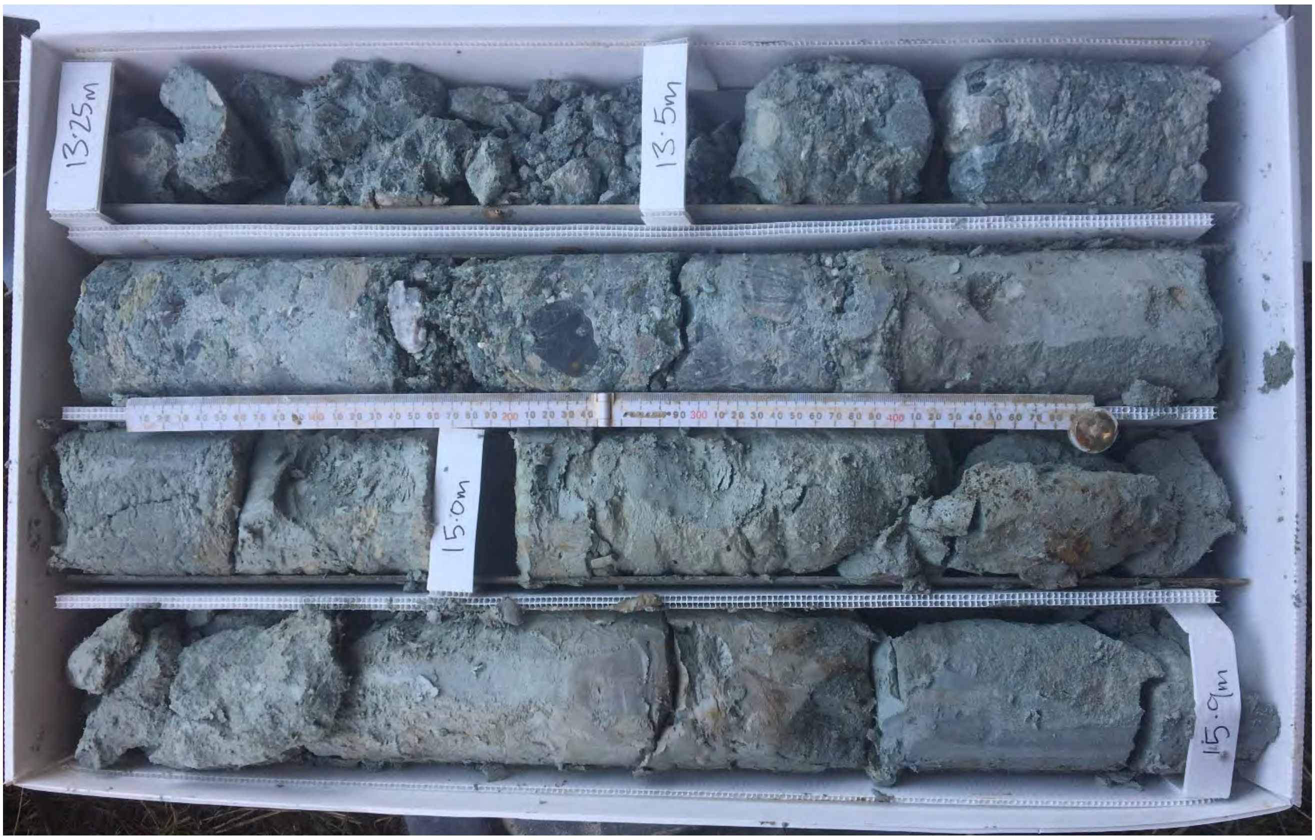
Box 4 of 8: 8.7 m to 11.1 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 4
Borehole ID	BH08	

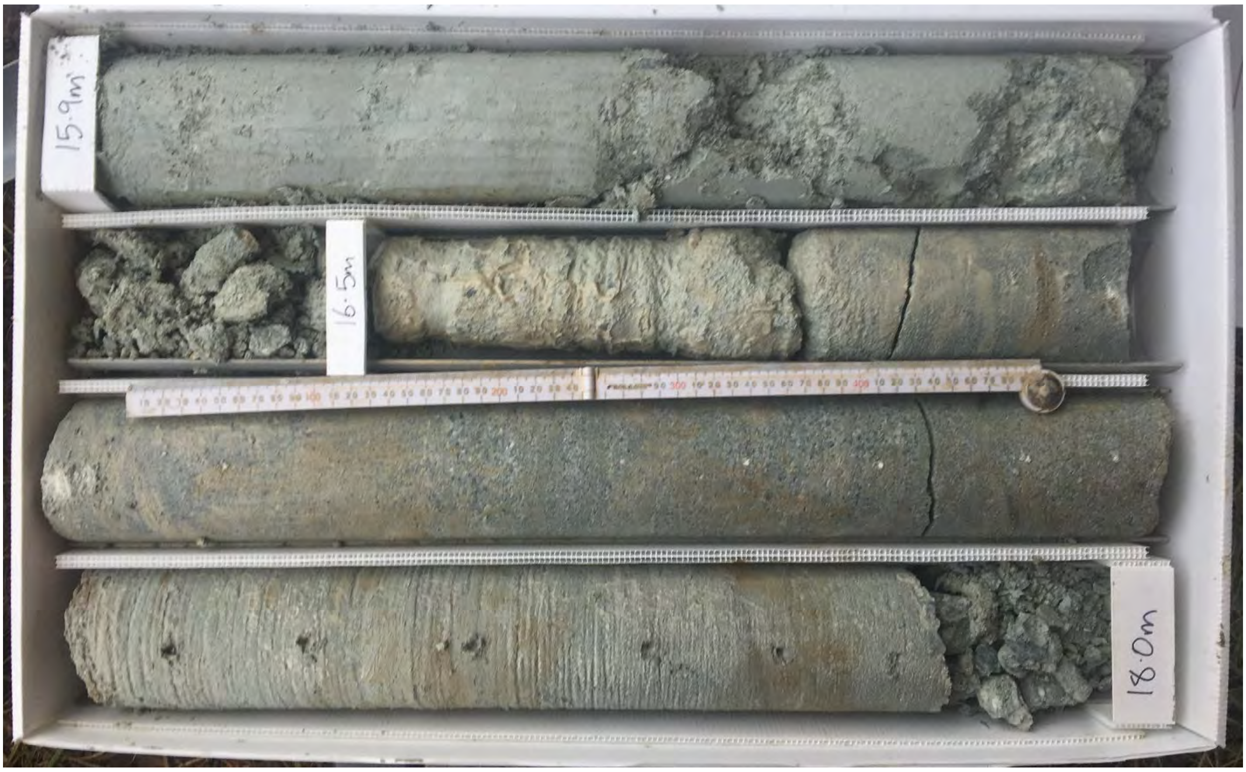


Box 5 of 8: 11.1 m to 13.25 m



Box 6 of 8: 13.25 m to 15.9 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 4 of 4
Borehole ID	BH08	



Box 7 of 8: 15.9 m to 18.0 m

Box 8 of 8: 18.0 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH09
Client : Dunedin City Council	Sheet : 1 of 2
Site : Western Boundary	Hole Length : 16.50m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 12/06/2019 Completed: 12/06/2019	Logged : MF
Easting: 395951.84 Northing: 788050.36 System: TAIETM2000	Processed : HB
RL: 132.8 Datum: NZVD2016	Checked : JHS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
0 – 0.5	0.00 - 0.50 m: CORELOSS (FILL: reworked Loess)	FILL						PQTT				67			
0.5 – 1.1	SILT, trace to minor clay, trace fine to coarse sand, trace fine gravel; grey and orange-brown. Very stiff, moist, low plasticity; gravel: angular, iron stained (LOESS) 0.90 m: brown	LOESS	M	VSt											
1.1 – 1.5	Fine gravelly SILT, trace clay; yellow-brown and orange-brown. Stiff to very stiff, moist, low plasticity	LOESS	M	St-VSt											
1.5 – 2.4	1.50 - 2.40 m: CORELOSS *inferred Henley Breccia from minimal recovery	HENLEY BRECCIA						PQTT				40			
2.4 – 2.6	Gravelly medium to coarse SAND; yellow-brown. Poorly graded; gravel: fine, quartz and schist, sub-angular to rounded.	HENLEY BRECCIA													
2.6 – 3.0	Sandy SILT, minor gravel, trace clay; yellow-brown, orange-brown and grey. Firm, moist, low plasticity. Gravel: fine to medium, quartz and schist, angular to rounded. Sand: fine to medium	HENLEY BRECCIA	M	F				PQTT				0			
3.0 – 9.1	3.00 - 9.10 m: CORELOSS *inferred gravelly sand (Henley Breccia) from minimal recovery	HENLEY BRECCIA						PQTT / PQTT / PQTT / PQTT				0 / 0 / 0 / 0			
9.1 –	Slightly weathered, thinly laminated, grey silty fine SANDSTONE; very weak; very wide spaced defects							PQTT		SW		100 / 93			

RL (m): 132, 131, 130, 129, 128, 127, 126, 125, 124, 123

Notes and Comments:	Inclination: Vertical Orientation:	Ground Water Level			
End of Hole @ 16.50m, Target Depth.	Contractor: McNeills	Date	Time	Reading (mbgl)	Hole depth (mbgl)
	Equipment: UDR600 (truck mounted)				
Refer to explanation sheets for abbreviation and symbols	Shear Vane Id:				

Project : Smooth Hill Landfill Consenting	Hole No. : BH09
Client : Dunedin City Council	Sheet : 2 of 2
Site : Western Boundary	Hole Length : 16.50m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 12/06/2019 Completed: 12/06/2019	Logged : MF
Easting: 395951.84 Northing: 788050.36 System: TAIETM2000	Processed : HB
RL: 132.8 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR / SCR / RQD (%)
	10.0	Slightly weathered, thinly laminated, grey silty fine SANDSTONE; very weak; very wide spaced defects *(continued from layer starting at 9.1m)*	HENLEY BRECCIA	PQTT	SW	100 / 93
	10.8	10.80 m: very weak to weak		PQTT		100 / 100 / 100
	11.9	11.90 m: extremely to very weak; trace to minor fine gravel: quartz and schist, angular to sub-angular		PQTT		
	12.4	12.40 - 16.50 m: CORELOSS *minimal silty fine sand and angular to sub-rounded, quartz and schist gravel recovered (Inferred weathered breccia)				27 / 20 / 16
				PQTT		15 / 0 / 0
				PQTT		0 / 0 / 0
	16.5	End of Hole @ 16.50m,Target Depth.				

Water level: 12-06-2019 Groundwater at 13.93 mbgl

Notes and Comments:
End of Hole @ 16.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

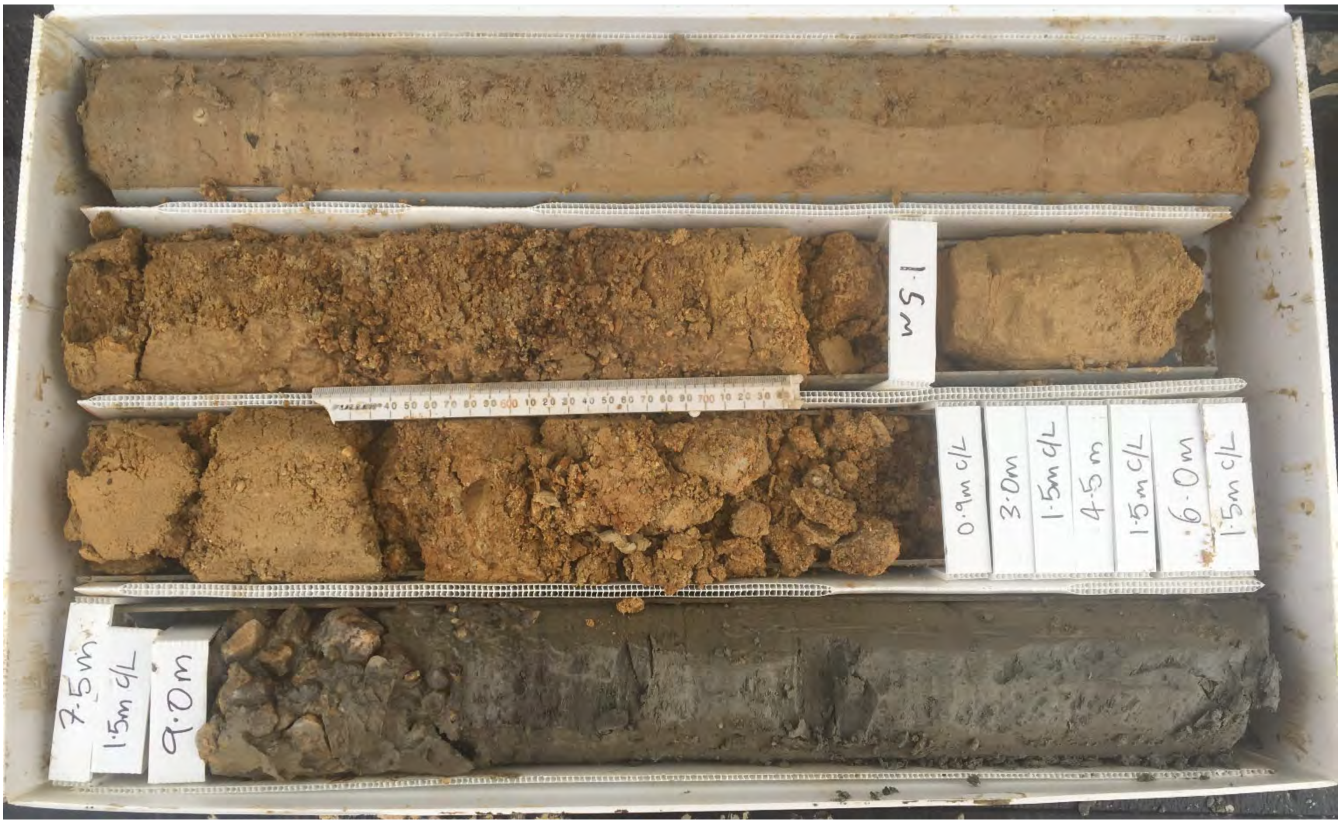
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

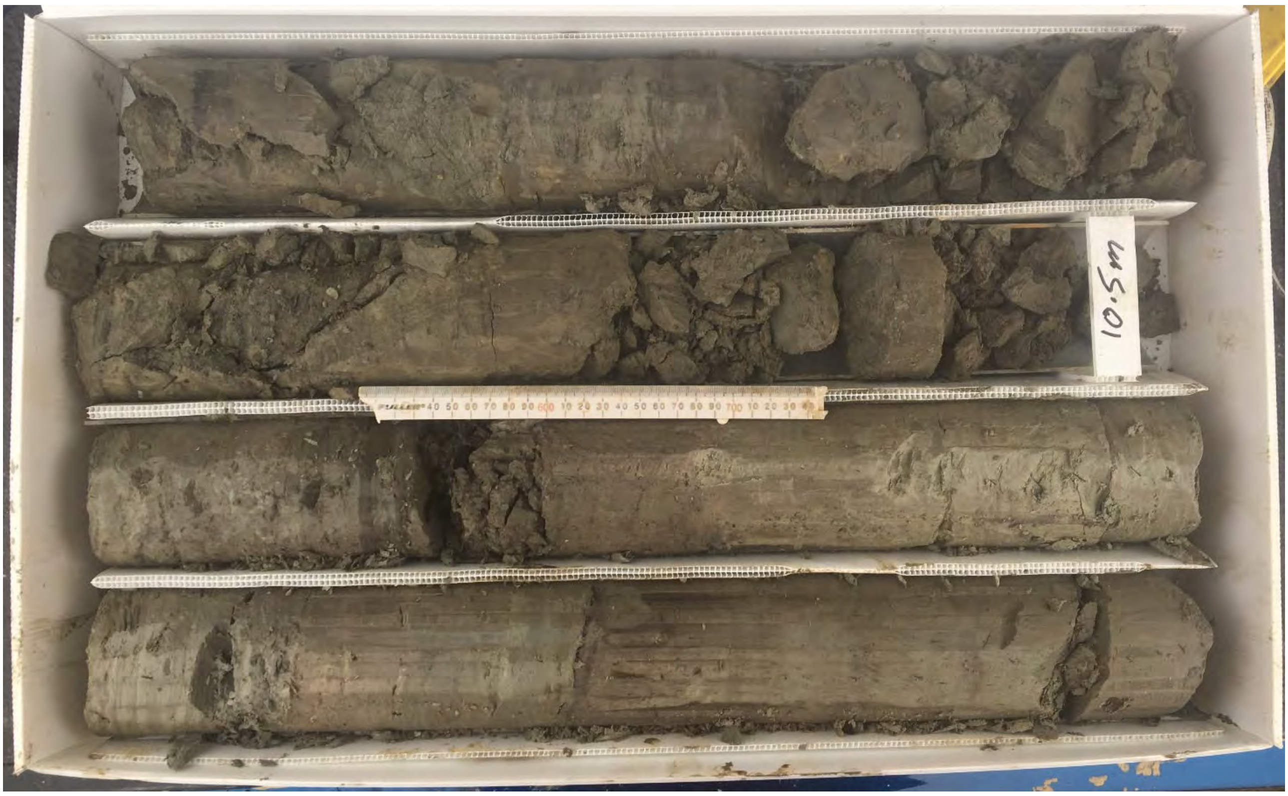
Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	13.93	16.5

GHD CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 2
Borehole ID	BH09	



Box 1 of 3: 0.0 m to 9.6 m



Box 2 of 3: 9.6 m to 11.7 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 2
Borehole ID	BH09	

Box 3 of 3: 11.7 m to 16.5 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH10
Client : Dunedin City Council	Sheet : 1 of 3
Site : Smooth Hill Eastern ridge	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 4/06/2019 Completed: 5/06/2019	Logged : MF
Easting: 396788.26 Northing: 788118.5 System: TAIETM2000	Processed : HB
RL: 139.07 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
0 – 0.25	0.00 - 0.25 SILT, trace fine sand, trace clay; brown. Firm to stiff, moist, low plasticity. (TOPSOIL).	TOPSOIL	M	F-St	PQTT		12
0.25 – 1.6	0.25 - 1.60 CORELOSS			"			
1.6 – 2.4	1.60 - 2.40 Fine sandy SILT; light greyb& yellow brown. Stiff, moist, low plasticity.	LOESS	M	St	PQTT		136
2.4 – 2.6	2.40 - 2.60 Completely weathered to residual soil, fine to coarse SAND, minor silt; colour unspecified. Density unspecified, moist, poorly graded. (HENLEY BRECCIA).	LOESS	M			CW-RS	
2.6 – 3.3	2.60 - 3.30 High weathered, pebbly coarse SAND; colour unspecified. Density unspecified, moist, poorly graded. (Heavily weathered, very weak to weak rock?).		M		PQTT	HW	93 93
3.3 – 4.9	3.30 - 4.90 Moderately weathered, grey, orange brown & yellow brown SILTSTONE; very weak to weak, no defects. (HENLEY BRECCIA). At 4.3 m, 300 mm SANDSTONE layer.	Henley Breccia				MW	
4.9 – 6.6	4.90 - 6.60 Moderately weathered, light grey & organge brown fine SANDSTONE; very weak to weak; no defects. Occasional lignite inclusions. At 5.5 m: 140 mm SILTSTONE layer.	Henley Breccia			PQTT	MW	86 86
6.6 – 7.05	6.60 - 7.05 Moderately weathered, orange brown, white & grey, fine to medium pebbly CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts are quartz & schist, sub angular to rounded.	Henley Breccia			PQTT	MW	93 93
7.05 – 7.6	7.05 - 7.60 Moderately weathered, light grey & orange brown SILTSTONE; very weak to weak; no defects noted.	Henley Breccia				MW	
7.6 – 7.72	7.60 - 7.72 Moderately weathered, orange brown, white & grey, fine to medium pebbly CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts are quartz & schist, sub angular to rounded.	Henley Breccia			PQTT	MW	28 28
7.72 – 8.8	7.72 - 8.80 Inferred CORELOSS. Offisiders dropped rod & bent end & it did not pick up core.			"			
8.8 – 9.1	8.80 - 9.10 Inferred CORELOSS depth.			"			
9.1 – 9.55	9.10 - 9.55 Moderately weathered, orange brown, white & grey, fine to medium pebbly CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts are quartz & schist, sub angular to rounded.	Henley Breccia			PQTT	MW	75 75
9.55 –	9.55 - 11.40 Slightly weathered, grey SANDSTONE; very weak	Henley Breccia				SW	

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 10.17 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH10
Client : Dunedin City Council	Sheet : 2 of 3
Site : Smooth Hill Eastern ridge	Hole Length : 20.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 4/06/2019 Completed: 5/06/2019	Logged : MF
Easting: 396788.26 Northing: 788118.5 System:	Processed : HB
RL: 139.07 Datum: NZVD2016	Checked : JS

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR SCR RQD (%)
10.0	to weak; thinly bedded (1-10 mm). Only artificial breaks. Occasional lignite.	Henley Breccia			
10.4	From 10.4 m, becomes yellow brown, fine to coarse SANDSTONE.		PQTT	SW	106 / 81
11.40 - 11.60	From 11.4 m, becomes weak to moderately strong.				
11.60 - 17.40	From 11.6 m, becomes very weak to weak.		PQTT		114 / 96
	Note: From 15.5 m: lignite content increases. From 15.6 m: 40 mm lignite. From 15.8 m: 100 mm lignite rich layer.		PQTT		92 / 92
			PQTT		89 / 89
			PQTT		103 / 100
17.40 - 17.65	From 17.4 m, becomes moderately strong to strong, well indurated.				
17.65 - 19.20	From 17.65 m, becomes very weak to weak, poorly indurated.		PQTT		100 / 100
19.20 - 19.80	From 19.2 m, becomes weak to moderately strong, moderate to well indurated.		PQTT		100 / 100
19.80 - 20.00	From 19.8 m, becomes moderately strong to				

Water level: 7-06-2019 (at approx. 10.17 m)

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Hole extended to find groundwater.
Groundwater at 10.17 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	10.17	20

Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Smooth Hill Eastern ridge Job Number: 12506381	Hole No. : BH10 Sheet : 3 of 3 Hole Length : 20.00m Scale @ A4 : 1:50
Commenced: 4/06/2019 Completed: 5/06/2019	Logged : MF
Easting: 396788.26 Northing: 788118.5 System:	Processed : HB
RL: 139.07 Datum: NZVD2016	Checked : JS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	20		strong, well indurated.														
			End of Hole @ 20.00m,Target Depth.														
	21																
	22																
	23																
	24																
	25																
	26																
	27																
	28																
	29																
	30																

Notes and Comments:

End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 10.17 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

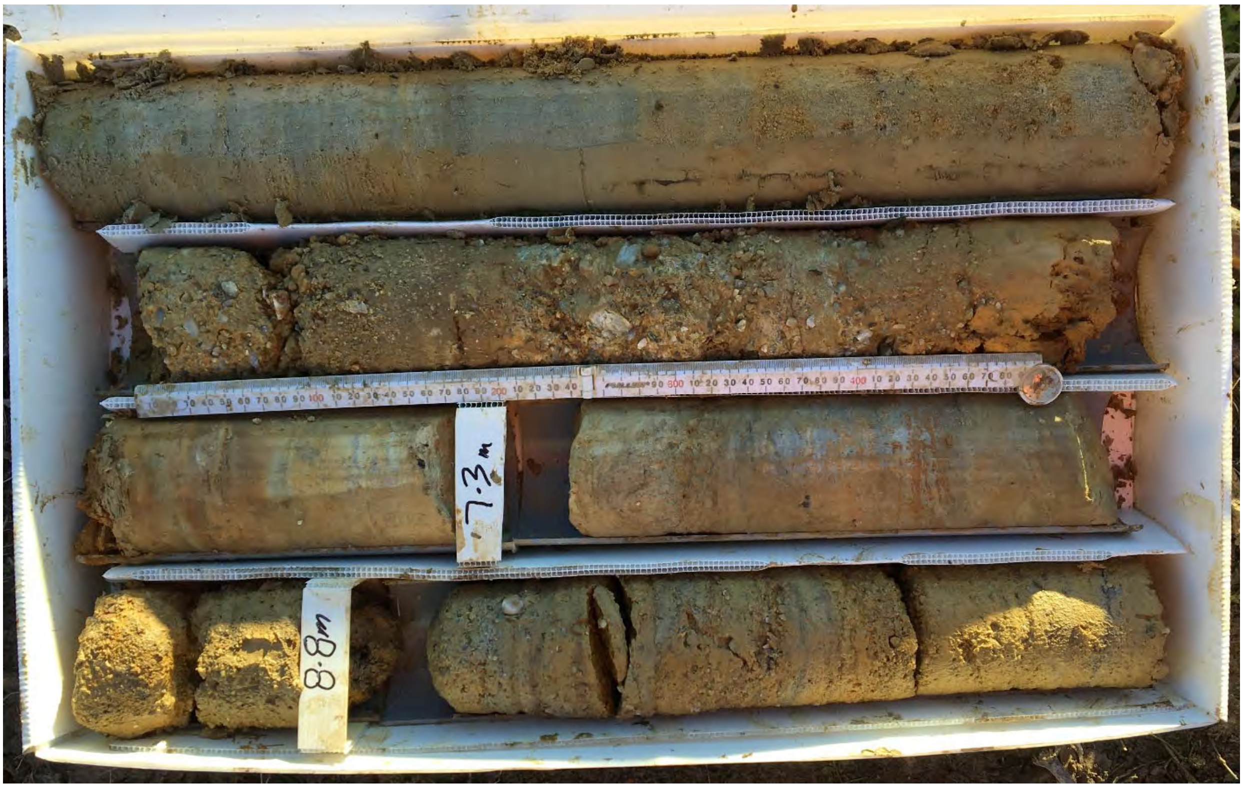
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH10	

Box 1 of 8: 0.0 m to 3.2 m

Box 2 of 8: 3.2 m to 5.8 m

CLIENTS | PEOPLE | PERFORMANCE

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 4
Borehole ID	BH10	



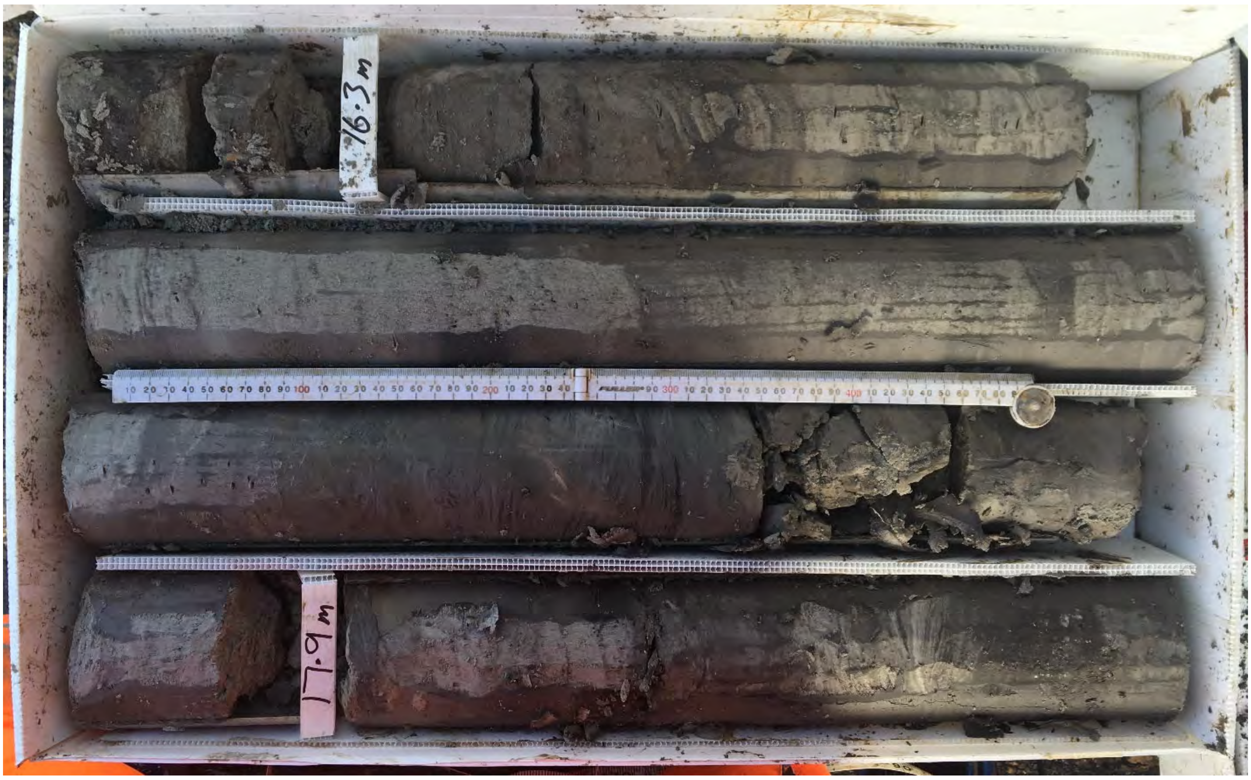
Box 3 of 8: 5.8 m to 9.2 m

Box 4 of 8: 9.2 m to 11.6 m

Box 5 of 8: 11.6 m to 13.8 m

Box 6 of 8: 13.8 m to 16.0 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 4 of 4
Borehole ID	BH10	



Box 7 of 8: 16.0 m to 18.4 m

Box 8 of 8: 18.4 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : TP01
Client : Dunedin City Council	Sheet : 1 of 1
Site : Manuka Gully (Stockpile Area)	Hole Length : 2.50m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 12/06/2019 Completed: 12/06/2019	Logged : MF
Easting: 395988.85 Northing: 788077.23 System: TAIETM2000	Processed : HB
RL: 121.2 Datum: NZVD2016	Checked : MF

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
121	0 – 0.2		SILT, trace to minor clay; dark grey-brown. Firm, wet, low plasticity; minor to some organics/roots (TOPSOIL)	TS	W	F											
	0.2 – 0.7		SILT, trace clay, trace fine to medium sand; light grey with orange streaks. Stiff to very stiff, moist, low plasticity; iron-stained organics throughout (ALLUVIUM)	ALLUVIUM	M	St-VSt											
120	0.7 – 1.9		Gravelly SILT, minor clay, minor fine to coarse sand; orange-brown. Very stiff, moist to wet, low plasticity; gravel: fine to medium, quartz and schist, sub-angular to rounded; highly weathered rock (HENLEY BRECCIA) 1.10 m: grey with some orange-brown	HENLEY BRECCIA	M-W	VSt						HW					
119	1.9 – 2.5		Slightly weathered, grey with black streaks SILTSTONE; very weak; ripped easily with toothed excavator bucket									SW					
	2.5		End of Hole @ 2.50m,Target Depth.														

Notes and Comments:

End of Hole @ 2.50m, Target Depth.

Soils too gravelly for shear vane.
Groundwater seepage into test pit at 1.0 mbgl

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator - toothed bucket

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Manuka Gully (Stockpile Area) Job Number: 12506381	Hole No. : TP02 Sheet : 1 of 1 Hole Length : 2.60m Scale @ A4 : 1:25
Commenced: 12/06/2019 Completed: 12/06/2019	Logged : MF
Easting: 396103.5 Northing: 788056.91 System: TAIETM2000	Processed : HB
RL: 110.4 Datum: NZVD2016	Checked : MF

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Result	Weathering	Water level
0 – 0.6	SILT, trace to minor fine sand, trace to minor clay; brown. Firm, moist, low plasticity; minor organics/roots (TOPSOIL)	TOPSOIL	M	F	SV@0.3m 65/17 kPa		12-06-2019 Groundwater seepage into test pit at 0.4 mbgl
0.6 – 1.4	Silty SAND, trace clay; light grey with orange-brown streaks. 'Loose to medium dense', poorly graded; sand: fine (COLLUVIUM)	COLLUVIUM		'L-MD'			
1.4 – 2.1	SILT, minor clay, trace to minor fine sand; brown. Firm, moist, low plasticity; wood fragments throughout layer, most at top (BURIED TOPSOIL)	BURIED TOPSOIL	M	F	SV@1.8m 90/33 kPa		
2.1 – 2.4	Gravelly SILT; grey. Wet, well graded; gravel: fine to coarse (ALLUVIUM)	ALLUVIUM	W				
2.4 – 2.6	Slightly weathered, grey SILTSTONE; ripped easily with toothed bucket (HENLEY BRECCIA)	HB				SW	
	End of Hole @ 2.60m,Target Depth.						

Other columns (all empty): RL (m), Graphic, Sample Number / Type, Casing, Method, Flush Return (%), Estimated Strength (MPa), TCR SCR RQD (%), Defect Spacing (mm), Instrumentation Installation.

Notes and Comments:

End of Hole @ 2.60m, Target Depth.

Groundwater seepage into test pit at 0.4 mbgl.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator - toothed bucket

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	0.4	2.6

Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Manuka Gully (Stockpile Area) Job Number: 12506381 Commenced: 12/06/2019 Completed: 12/06/2019	Hole No. : TP03 Sheet : 1 of 1 Hole Length : 2.00m Scale @ A4 : 1:25 Logged : MF Processed : HB Checked : MF

Easting: 396262.16 Northing: 788048.16 System: TAIETM2000
RL: 102.61 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
102	0	SILT, trace to minor fine sand, trace to minor clay; brown. Soft, moist to wet, low plasticity; minor organics/roots (TOPSOIL)	TOPSOIL	M-W	S											
	0.7	Silty SAND, trace clay; light grey with brown streaks. Moist, poorly graded; sand is fine (ALLUVIUM)	ALLUVIUM	M												
101	1.2	Gravelly SILT; grey. Wet to saturated, well graded; gravel: fine to coarse	ALLUVIUM	W - S												12-06-2019 Groundwater encountered at 1.2 mbgl
	1.7	Slightly weathered, grey SILTSTONE; extremely to very weak; no defects - ripped easily (HENLEY BRECCIA)	HB								SW					
	2	End of Hole @ 2.00m,Target Depth.														

Notes and Comments:

End of Hole @ 2.00m, Target Depth.

Test pit sides too soft to get shear vane readings.
Groundwater encountered at 1.2 mbgl.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator - toothed bucket

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	1.2	2

Project : Smooth Hill Landfill Consenting	Hole No. : TP05
Client : Dunedin City Council	Sheet : 1 of 1
Site : Southwest Gully Base	Hole Length : 3.30m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 13/06/2019 Completed: 13/06/2019	Logged : MF
Easting: 396281 Northing: 787868 System: TAIETM2000	Processed : HB
RL: 125 Datum: NZVD2016	Checked : MF

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Weathering	Water level
125	0	SILT, minor clay; brown. Soft, wet to saturated, low plasticity; minor organics throughout (TOPSOIL)	TOPSOIL	W-S	S		
	0.7	Silty fine to medium SAND; grey and yellow-brown. 'Loose', wet, poorly graded (COLLUVIUM)	COLLUVIUM	W	'L'		
124	1	Fine to coarse SAND, minor to some silt; grey with black streaks. 'Loose', saturated, poorly graded; organics throughout	COLLUVIUM	S	'L'		
	1.4	Tree trunks and branches with some gravel. Groundwater outflow from base of layer	COLLUVIUM				
123	1.8	SILT, minor clay, trace fine sand; grey with yellow-brown streaks. Stiff, moist, low plasticity; highly weathered rock (HENLEY BRECCIA)	HENLEY BRECCIA	M	St	HW	13-06-2019 Groundwater flowing into pit
122	2.8	Slightly weathered, SILTSTONE; ripped easily	HENLEY BRECCIA			SW	
	3.3	End of Hole @ 3.30m,Target Depth.					

Other columns: Sample (Number / Type, Result), Casing, Method, Flush Return (%), Estimated Strength (MPa), TCR SCR RQD (%), Defect Spacing (mm), Instrumentation Installation — no entries.

Notes and Comments:
End of Hole @ 3.30m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
13/06/19	00:00	1.9	3.3

Project : Smooth Hill Landfill Consenting	Hole No. : TP06
Client : Dunedin City Council	Sheet : 1 of 1
Site : Gully East of Central Ridge	Hole Length : 2.50m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 13/06/2019 Completed: 13/06/2019	Logged : MF
Easting: 396585.7 Northing: 787800.45 System: TAIETM2000	Processed : HB
RL: 108.24 Datum: NZVD2016	Checked : MF

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density
0 – 0.5	Organic SILT, minor clay; dark brown-grey. Firm, moist, low plasticity; minor to some roots (TOPSOIL)	TOPSOIL	M	F
0.5 – 2.3	SILT, minor clay, light grey with orange-brown streaks. Stiff, moist, low plasticity; minor organic inclusions (ALLUVIUM)	ALLUVIUM	M	St
2.3 – 2.5	SILTSTONE; difficult to rip (HENLEY BRECCIA)	HB		
	End of Hole @ 2.50m,Target Depth.			

Other columns: RL (m), Graphic, Sample (Number / Type, Result), Casing, Method, Flush Return (%), Weathering, Estimated Strength (MPa), TCR SCR RQD (%), Defect Spacing (mm), Instrumentation Installation, Water level — no entries.

Notes and Comments:
End of Hole @ 2.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator - toothed bucket

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
13/06/19	00:00		2.5

GHD	Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Southwest Gully Base Job Number: 12506381 Commenced: 28/05/2019 Completed: 28/05/2019	Hole No. : TP07 Sheet : 1 of 1 Hole Length : 2.50m Scale @ A4 : 1:25 Logged : MF

Easting: 396182 | Northing: 787790 | System: TAIETM2000 | Processed : HB
RL: 120 | Datum: NZVD2016 | Checked : MF

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
120	0		SILT/organic matter, brown. Soft, moist to saturated, fibrous, non plastic (TOPSOIL)	TOPSOIL	M-W	S				TP							
	0.5		SILT, minor clay, trace fine sand; light grey and yellow-brown. Stiff to very stiff, moist, low plasticity (LOESS)	LOESS	M	St-VSt				TP							
119	1																
	1.4		Slightly weathered, grey SILTSTONE; weak to moderately strong; no defects (HENLEY BRECCIA)	HENLEY BRECCIA						TP		SW					28-05-2019 Water perched on SILTSTONE (1.4)
118	2																
	2.4		BRECCIA														
	2.5		End of Hole @ 2.50m,Target Depth.														
117	3																
116	4																
115	5																

Notes and Comments:
End of Hole @ 2.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical
Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - smooth bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00	1.4	2.5

Project : Smooth Hill Landfill Consenting	Hole No. : TP08
Client : Dunedin City Council	Sheet : 1 of 1
Site : Gully Between Southern Ridges	Hole Length : 4.50m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 28/05/2019 Completed: 28/05/2019	Logged : MF
Easting: 396303 Northing: 787682 System: TAIETM2000	Processed : HB
RL: 115 Datum: NZVD2016	Checked : MF

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	0	SILT, minor clay, trace fine sand; dark grey. Firm to stiff, moist, low plasticity;, minor organic matter (FILL)	FILL	M	F-St											
		0.50 m: grass and trees - buried surface, saturated		S												
	0.6	SILT, minor clay, trace fine sand; dark grey. Firm to stiff, wet, low plasticity; trace to minor organics (BURIED TOPSOIL)	BURIED TOPSOIL	W	F-St											
114	1															
	1.2	SILT, minor to some clay, trace fine sand; light grey and yellow-brown. Stiff to very stiff, moist, low plasticity; trace organics (LOESS)	LOESS	M	St-VSt											
113	2															
112	3															
	3.5	SILT, some coarse sand, minor fine gravel; light grey. Stiff to very stiff, moist, non-plastic; gravel comprises quartz and schist; highly weathered rock (HENLEY BRECCIA)	HENLEY BRECCIA	M	St-VSt						HW					
111	4															
	4.5	End of Hole @ 4.50m,End of Reach.														
110	5															

Notes and Comments:

End of Hole @ 4.50m, End of Reach.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator - smooth bucket

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00		4.5

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : South East Gully Outflow
Job Number: 12506381
Commenced: 13/06/2019 Completed: 13/06/2019

Hole No. : TP09
Sheet : 1 of 1
Hole Length : 3.00m
Scale @ A4 : 1:25
Logged : MF
Processed : MF
Checked : MF

Easting: 396577.97 Northing: 787947.86 System: TAIETM2000
RL: 101.04 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
101	0	SILT, minor fine to coarse gravel; yellow-brown and grey. Stiff, moist, low plasticity; minor organic content (SLIP DEBRIS)	SLIP DEBRIS	M	St											
	0.4	Branches and grass (BURIED VEGETATION)														
	0.5	SILT, minor clay; brown. Firm to stiff, moist, low plasticity (BURIED TOPSOIL)	BTS	M	F-St											
	0.7	Gravelly silty SAND; orange-brown. Moist, poorly graded; gravel is fine; sand is fine to coarse (ALLUVIUM) 1.00 m: light grey and orange-brown 1.30 m: light grey with orange-brown streaks	ALLUVIUM	M												
	2.7	Fine SANDSTONE; easily ripped (HENLEY BRECCIA)	HB													
98	3	End of Hole @ 3.00m,Target Depth.														

Depth scale: 0, 1, 2, 3, 4, 5. RL scale: 101, 100, 99, 98, 97.

Notes and Comments:
End of Hole @ 3.00m, Target Depth.
Test pit dug to side of gully base - too boggy in gully base to excavate

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor:
Equipment: 22t Excavator
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : TP10
Client : Dunedin City Council	Sheet : 1 of 1
Site : Future Laydown Area	Hole Length : 3.60m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 10/06/2019 Completed: 10/06/2019	Logged : MF
Easting: 396820.11 Northing: 788079.25 System: TAIETM2000	Processed : HB
RL: 140.74 Datum: NZVD2016	Checked : MF

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Weathering
0 – 0.4	SILT, trace to minor clay, trace fine sand; dark grey. Very stiff, moist, low plasticity; tree roots throughout (TOPSOIL)	TOPSOIL	M	VSt			
0.4 – 1.2	SILT, minor clay; light grey and yellow-brown. Very stiff, moist, low plasticity; root webs throughout (LOESS)	LOESS	M	VSt		SV@0.5m 136/62 kPa; SV@1m 194 kPa	
1.2 – 2	SILT, minor fine sand, trace clay; orange-brown and light grey. Very stiff, dry, low plasticity	LOESS	D	VSt		SV@1.5m 194 kPa	
2 – 2.2	SILT, minor fine sand, trace clay; orange-brown. Very stiff, dry, low plasticity; iron-stained horizon	LOESS	D	VSt		SV@2m 194 kPa	
2.2 – 3	SILT; orange-brown and grey alternating. Very stiff, dry, non-plastic	LOESS	D	VSt	2.20	SV@2.5m UTP	
3 – 3.6	Highly weathered SILTSTONE (HENLEY BRECCIA) 3.00 - 3.60 m: hard, root webs visible in places	HENLEY BRECCIA		H	3.60	SV@3m UTP; SV@3.5m UTP	HW
	End of Hole @ 3.60m,Target Depth.						

RL (m): 140, 139, 138, 137, 136

Other columns: Casing, Method, Flush Return (%), Estimated Strength (MPa), TCR SCR RQD (%), Defect Spacing (mm), Instrumentation Installation, Water level

Notes and Comments:

End of Hole @ 3.60m, Target Depth.

EOH at 3.6 mbgl, too hard to dig/end of reach.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : TP11
Client : Dunedin City Council	Sheet : 1 of 1
Site : Future Laydown Area	Hole Length : 3.80m
Job Number: 12506381	Scale @ A4 : 1:25
Commenced: 10/06/2019 Completed: 10/06/2019	Logged : MF
Easting: 396907.03 Northing: 788032.98 System: TAIETM2000	Processed : HB
RL: 141.24 Datum: NZVD2016	Checked : MF

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Weathering
0–0.5	SILT, trace to minor clay, trace fine sand; dark grey and orange-brown. Very stiff, moist, low plasticity; tree roots extend to approximately 1.2 m bgl (TOPSOIL)	TOPSOIL	M	VSt			
0.5–1.3	SILT, trace to minor clay; grey with orange-brown streaks. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt		SV@0.5m 140/36 kPa; SV@1m 194 kPa	
1.3–2.6	SILT, trace clay; light grey/white and orange-brown. Very stiff, dry, low plasticity; powdery when crumbled, iron-staining throughout; strength increases with depth 1.80 m: 50-100 mm iron-stained layer. 2.00 m: 50-100 mm iron-stained layer.	LOESS	D	VSt	1.50–3.50	SV@1.5m 194 kPa; SV@2m UTP	
2.6–3.8	Highly weathered, orange-brown SILTSTONE (HENLEY BRECCIA) 2.70 m: light grey and orange-brown 3.00 m: grey and orange-brown.	HENLEY BRECCIA				SV@2.8m UTP; SV@3.7m UTP	HW
3.8	End of Hole @ 3.80m,Target Depth.						

Notes and Comments:

End of Hole @ 3.80m, Target Depth.

EOH at 3.08 mbgl, too hard to excavate.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
10/06/19	00:00		3.8

Project	: Smooth Hill Landfill Consenting
Client	: Dunedin City Council
Site	: Future Laydown Area
Job Number	: 12506381
Commenced	: 10/06/2019
Completed	: 10/06/2019
Easting	: 396596.93
Northing	: 787986.46
System	: TAIETM2000
RL	: 142.28
Datum	: NZVD2016

Hole No. : TP12

Sheet	: 1 of 1
Hole Length	: 4.40m
Scale @ A4	: 1:25
Logged	: MF
Processed	: HB
Checked	: MF

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Weathering
0	SILT, minor clay, trace fine sand, dark grey and brown. Stiff to very stiff, moist, low plasticity. Trace to minor roots (FILL)	FILL	M	St-VSt		SV@0.4m 139/44 kPa	
0.7	Sandy SILT, grey. Very stiff, dry, non-plastic; some large roots extend to approximately 1.2 m bgl; trace organics; sand is fine (BURIED TOPSOIL).	BTS	D	VSt	1.00		
1	Sandy SILT; light grey, light yellow-brown and orange-brown. Very stiff, dry, non-plastic; sand is fine; occasional roots to 1.2 m bgl; strength increases with depth (LOESS) 2.50 m: 50-100 mm iron-stained layer 3.60 m: 50-100 mm iron-stained layer	LOESS	D	VSt		SV@1m UTP SV@2m UTP SV@2.9m UTP	
4	Highly weathered, SILTSTONE (HENLEY BRECCIA)	HB				SV@4.4m UTP	HW
4.4	End of Hole @ 4.40m,Target Depth.						

Notes and Comments:

End of Hole @ 4.40m, Target Depth.

EOH at 4.4 mbgl, deepest excavator could excavate soil.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical

Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
10/06/19	00:00		4.4

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 1 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Weathering
144	0 – 0.35	Clayey SILT, trace fine sand; dark grey. Soft, moist to wet, high plasticity; minor to some organic matter, reducing with depth (TOPSOIL)	TS	M-W	S	
	0.35 – 1.9	SILT, minor clay, trace fine sand; grey and orange-brown. Very stiff, moist, low plasticity (LOESS) 1.00 - 1.90 m: grey and brown	LOESS	M	VSt	
	1.9 – 2.65	SILT, trace clay; light grey with orange-brown streaks. Very stiff, moist, non-plastic; completely weathered (HENLEY BRECCIA)	HENLEY BRECCIA	M	VSt	CW
	2.65 – 3	SILT, some clay to clayey; red-brown, orange-brown and grey. Firm to stiff, moist, high plasticity; minor rock fragments; completely weathered	HENLEY BRECCIA	M	F-St	CW
	3 – 3.4	SILT, trace to minor clay; red-brown. Very stiff to hard, moist, low plasticity; completely weathered	HENLEY BRECCIA	M	VSt-H	CW
	3.4 – 5	Moderately weathered, grey and yellow-brown, moderately thickly bedded, fine to medium grained SANDSTONE; very weak; very widely spaced defects 4.20 - 5.00 m: fine to coarse sand *4.60* BP, 10°, pl, r, Fe-stained, black 4.90 - 5.00 m: grades into breccia	HENLEY BRECCIA			MW
	5 – 6.45	Moderately weathered, brown, grey, orange-brown and red-brown BRECCIA; extremely to very weak; very widely spaced defects; matrix supported; fine sandy silt matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel. Soil description: fine to coarse gravelly, fine sandy silt *6.12* JT, 15°, pl, r, clean *6.15* JT, 85°, pl, r, clean *6.17* JT, 20°, pl, r, clean 6.30 - 6.45 m: transition from moderately to slightly weathered	HENLEY BRECCIA			MW
	6.45 – 7.9	Slightly weathered, grey and light grey BRECCIA; very weak to weak; no defects; matrix supported; fine sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel 7.00 - 7.90 m: weak to moderately strong 7.20 - 7.90 m: clast supported 7.50 - 7.90 m: medium to coarse gravel	HENLEY BRECCIA			SW
	7.9 – 8.6	Slightly weathered, grey and light grey BRECCIA; extremely to very weak; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel. Soil description: fine to coarse gravelly, fine sandy silt	HENLEY BRECCIA			SW
134	8.6 – 10	Slightly weathered, grey and light grey BRECCIA; weak to moderately strong; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel 9.10 - 9.35 m: 250 mm light grey, fine grained SANDSTONE	HENLEY BRECCIA			SW

Method	TCR (%)	SCR / RQD (%)
PQTT	100	
PQTT	96	
PQTT	100	62
PQTT	88	34
PQTT	100	70
PQTT	100	48
PQTT	100	29

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 2 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	10 – 10.8		Slightly weathered, grey and light grey BRECCIA; weak to moderately strong; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel *(continued from layer starting at 8.6m)*							PQTT		SW		100 29			
133 – 124	10.8 – 20		10.8 m to 61.0 m: Wash drilling							Wash drilled							

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. RL scale: 133, 132, 131, 130, 129, 128, 127, 126, 125, 124.

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 3 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
124–114	20–30		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Southern Boundary Job Number: 12506381	Hole No. : BH201 Sheet : 4 of 7 Hole Length : 61.00m Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	30		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*														
113	31																
112	32																
111	33																
110	34																
109	35									Wash drilled							
108	36																
107	37																
106	38																
105	39																
104	40																

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 5 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	40		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
103	41																
102	42																
101	43																
100	44																
99	45																
98	46																
97	47																
96	48																
95	49																
94	50																

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 6 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	50		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
93	51																
92	52																
91	53																
90	54																
89	55																
88	56																
87	57																
86	58																
85	59																
84	60																

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH201
Client : Dunedin City Council	Sheet : 7 of 7
Site : Southern Boundary	Hole Length : 61.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 29/10/2019 Completed: 1/11/2019	Logged : MF
Easting: 396596 Northing: 787540 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
84–83	60–61		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
83	61		End of Hole @ 61.00m,Target Depth.														

RL scale: 83, 82, 81, 80, 79, 78, 77, 76, 75, 74. Depth scale: 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70.

Notes and Comments:

End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track Mounted Rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 1 of 5: 0.00 m to 2.30 m

Box 2 of 5: 2.30 m to 4.50 m

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 3 of 5: 4.50 m to 6.80 m

Box 4 of 5: 6.80 m to 9.00 m

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 5 of 5: 9.00 m to 10.80 m

10.80 m to 61.00 m (EOH) – Wash drilled, no core recovered

Project : Smooth Hill Landfill Consenting	Hole No.	: BH202
Client : Dunedin City Council	Sheet	: 1 of 7
Site : Southern Boundary	Hole Length	: 60.60m
Job Number: 12506381	Scale @ A4	: 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged	: MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed	: MF
RL: 144 Datum: NZVD2016	Checked	: JHS

Depth (m)	Graphic depth	Material Description	Geological Unit	Moisture condition	Consistency / Relative density
0 – 1.6	0	SILT, trace to minor clay; grey and orange-brown. Firm to stiff, moist, low plasticity (FILL/COLLUVIUM?) 0.30 - 0.80 m: brown and grey, very stiff 0.80 - 0.90 m: trace clay, grey, stiff, minor to some organic matter (roots) 0.90 - 1.20 m: grey and brown, very stiff, trace iron-oxide nodules, "chaotic" texture 1.20 - 1.60 m minor iron-oxide nodules	FILL/COLLUVIUM?	M	F-St / VSt / St / VSt
1.6	1.6 1.5	SILT, trace to minor clay; dark brown. Very stiff, moist, low plasticity; small branches (BURIED TOPSOIL)	T	M	VSt-H
– 3.5		SILT, trace clay; orange-brown and grey; Very stiff to hard, moist, non-plastic; trace iron-oxide nodules; completely weathered (HENLEY BRECCIA) 2.60 - 2.80 m: minor to some iron-oxide nodules - increases with depth	HENLEY BRECCIA		
3.5 – 4.1	3.5	Gravelly, sandy SILT; orange-brown, brown and grey; Very stiff to hard, moist, non-plastic; sand is medium to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	VSt-H
4.1 – 4.5	4.1	4.10 - 4.50 m: CORE LOSS			
4.5 – 5.7	4.5	4.50 - 5.70 m: CORE LOSS			
5.7 – 5.9	5.7	Gravelly, sandy SILT; orange-brown, brown and grey; Very stiff to hard, moist, non-plastic; sand is medium to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	VSt-H
5.9 – 6.3	5.9	SILT, trace to minor clay; grey and brown. Very stiff to hard, moist, non-plastic; completely weathered		M	VSt-H
6.3 – 6.75	6.3	Gravelly, silty SAND; orange-brown. Moist; well sorted; sand is fine to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	
6.75 – 7.4	6.75	Gravelly, sandy SILT; orange-brown and grey. Firm, moist, non-plastic; sand is fine to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	F
7.4 – 7.8	7.4	Highly weathered, light brown, thinly to moderately thickly bedded SILTSTONE; extremely weak; no defects. Soil description: SILT, minor clay; hard			
7.8 – 8.0	7.8	Moderately weathered, dark grey, thinly bedded SILTSTONE; extremely to very weak; no defects; trace to minor lignite			
8.0 – 8.2	8	Moderately weathered, light grey, fine to coarse grained SANDSTONE; very weak; no defects			
8.2 – 8.5	8.2	Moderately weathered, black, LIGNITE; very weak, no defects			
8.5 –	8.5	Slightly weathered, light grey and grey, thinly to moderately thickly bedded, fine to medium grained SANDSTONE; very weak; no defects; occasional lignite layers 8.60 - 8.85 m: fine to coarse sand 8.99 - 9.02 m: 30 mm lignite			

Method	TCR (%)	Weathering
PQTT	100	
PQTT	100	
PQTT	94	
PQTT	0	CW
PQTT	0	
PQTT	100	
PQTT	95	
PQTT	100 83	HW MW
PQTT	100 90	SW

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 2 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	10.6		9.84 - 9.89 m: 50 mm lignite Slightly weathered, light grey and grey, thinly to moderately thickly bedded, fine to medium grained SANDSTONE; very weak; no defects; occasional lignite layers *(continued from layer starting at 8.5m)* 10.30 - 10.45 m: 150 mm lignite							PQTT		SW		100 90			
133	11		10.60 m to 60.60 m: Wash drilled	HENLEY BRECCIA						Wash drilling							
132	12																
131	13																
130	14																
129	15																
128	16																
127	17																
126	18																
125	19																
124	20																

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 3 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
123	21		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
122	22																
121	23																
120	24																
119	25																
118	26																
117	27																
116	28																
115	29																
114																	

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 4 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
113–104	30–40		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							

Depth scale: 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40. RL scale: 113, 112, 111, 110, 109, 108, 107, 106, 105, 104.

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 5 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
103–94	40–50		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 6 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
93	51		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
92	52																
91	53																
90	54																
89	55																
88	56																
87	57																
86	58																
85	59																
84																	

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH202
Client : Dunedin City Council	Sheet : 7 of 7
Site : Southern Boundary	Hole Length : 60.60m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 2/11/2019 Completed: 4/11/2019	Logged : MF
Easting: 396181 Northing: 787498 System: TAIETM2000	Processed : MF
RL: 144 Datum: NZVD2016	Checked : JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	60		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*														
	60.6		End of Hole @ 60.60m,Target Depth.														
83	61																
82	62																
81	63																
80	64																
79	65																
78	66																
77	67																
76	68																
75	69																
74	70																

Notes and Comments:

End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

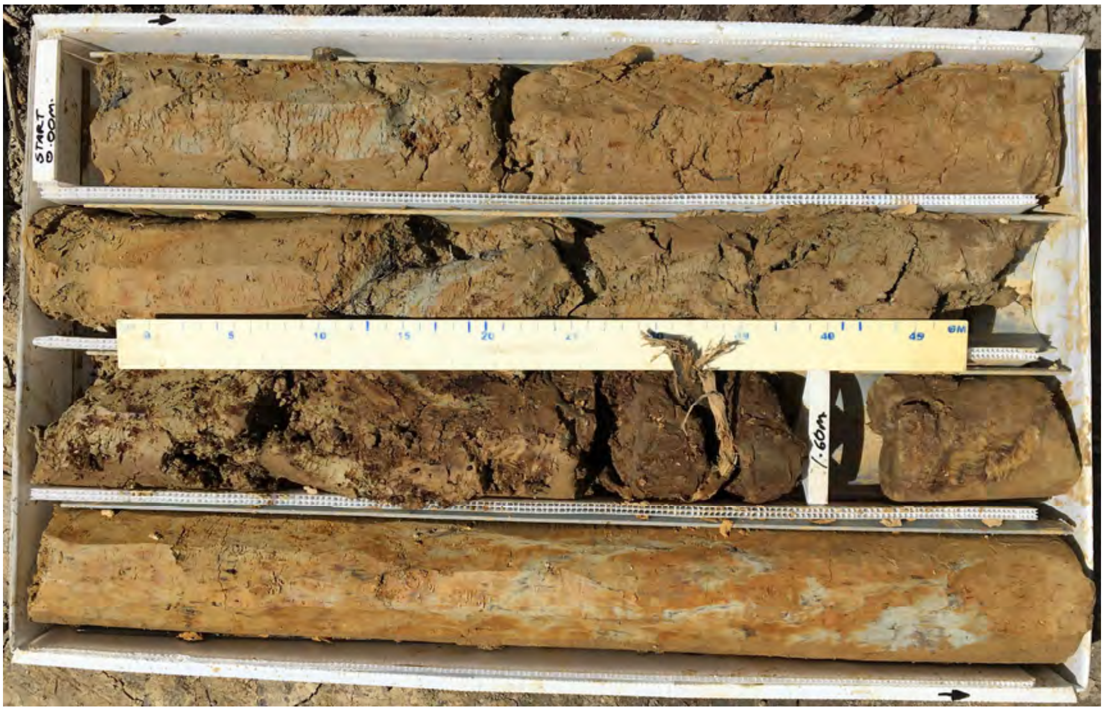
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

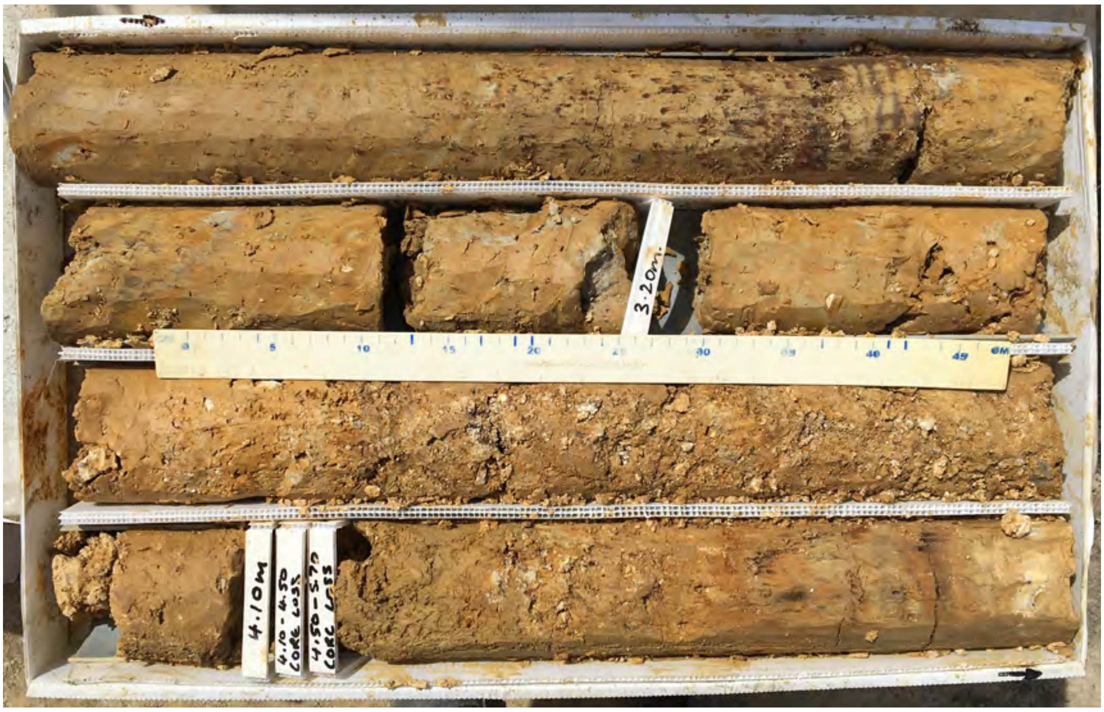
Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		



Box 1 of 4: 0.00 m to 2.30 m



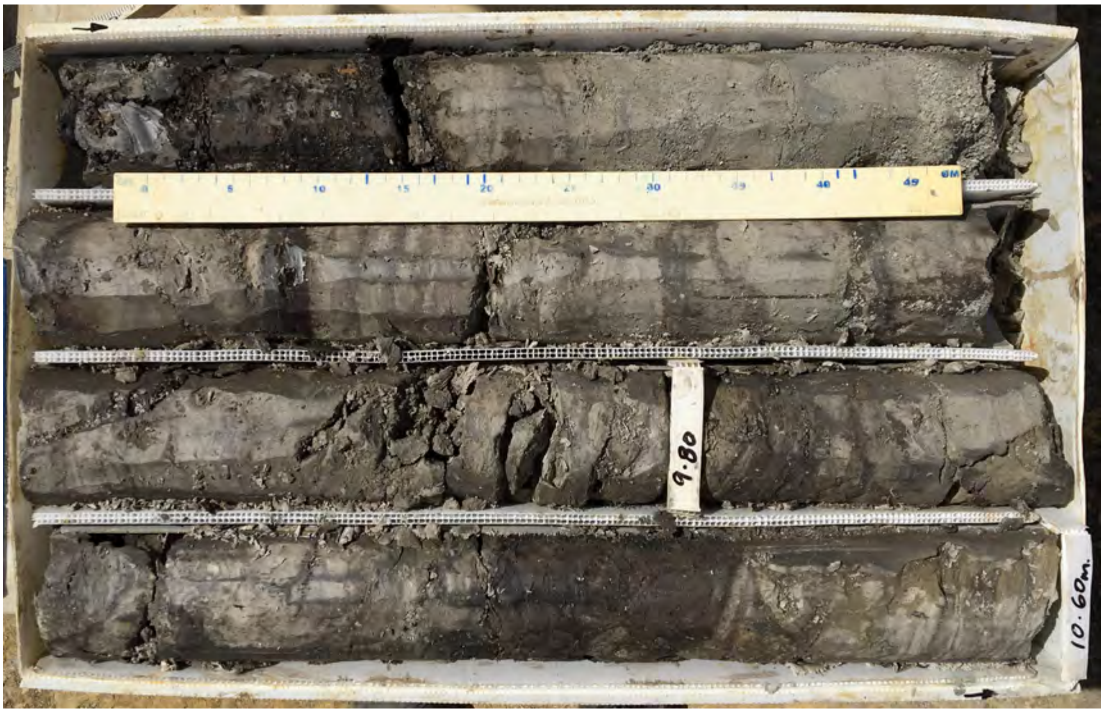
Box 2 of 4: 2.30 m to 6.10 m

Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		

Box 3 of 4: 6.10 m to 8.30 m



Box 4 of 4: 8.30 m to 10.60 m

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Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		

10.60 m to 60.60 m (EOH) - Wash drilled, no core recovered

Project : Smooth Hill Landfill Consenting Client : Dunedin City Council Site : Southwest Boundary Job Number: 12506381	Hole No. : BH203 Sheet : 1 of 2 Hole Length : 19.70m Scale @ A4 : 1:50
Commenced: 7/11/2019 Completed: 7/11/2019	Logged : MF
Easting: 395779 Northing: 787672 System: TAIETM2000	Processed : MF
RL: 182 Datum: NZVD2009	Checked : JHS

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR / SCR (%)
0 – 1.1	Highly weathered, cream, orange-brown and yellow-brown, CONGLOMERATE; extremely weak; no defects; matrix supported; matrix is fine to coarse sandy silt; clasts are fine, rounded to subrounded, quartz and schist gravel. Soil description: gravelly sandy silt (Henley Breccia)	HENLEY BRECCIA	PQTT	HW	96 / 85
1.1 – 2.1	Highly weathered, orange-brown and grey, laminated to moderately thickly bedded SILTSTONE; extremely weak; no defects. Soil description: Silt, minor fine to medium sand, hard 1.90 - 2.10 m: moderately weathered, grey with occasional orange-brown	HENLEY BRECCIA	PQTT	HW	97 / 76
2.1 – 2.9	Grades into: moderately weathered, grey with occasional orange-brown, laminated to moderately thickly bedded, silty fine grained SANDSTONE; extremely weak; no defects. Soil description: silty fine sand	HENLEY BRECCIA	PQTT	MW	
2.9 – 4.8	Moderately weathered, brown and grey, moderately thickly bedded CONGLOMERATE; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine, rounded to subangular, quartz and schist gravel	HENLEY BRECCIA	PQTT	MW	100 / 66
4.8 – 5.8	Moderately weathered, brown and grey, BRECCIA; very weak; no defects; matrix supported; matrix is silty fine sand; clasts are fine to medium, angular to subrounded, quartz and schist gravel (HENLEY BRECCIA)	HENLEY BRECCIA	PQTT	MW	98 / 58
5.8 – 6.0	5.80 - 6.00 m: CORE LOSS				
6.0 – 7.5	BRECCIA (continued from 4.8 m) 6.10 - 6.40 m: iron staining, orange-brown	HENLEY BRECCIA	PQTT	MW	82 / 28
7.5 – 10+	Moderately weathered, orange-brown, very thinly to moderately thickly bedded SILTSTONE; very weak; no defects; moderately widely spaced lignite layers 5-20 mm thick 7.90 - 11.15 m: slightly weathered, grey	HENLEY BRECCIA	PQTT	SW	100 / 89; 100 / 87

RL (m): 181 at 1 m, 180 at 2 m, 179 at 3 m, 178 at 4 m, 177 at 5 m, 176 at 6 m, 175 at 7 m, 174 at 8 m, 173 at 9 m, 172 at 10 m.

Notes and Comments:
End of Hole @ 19.70m, Target Depth.
Groundwater not encountered
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting		Hole No.	: BH203
Client : Dunedin City Council		Sheet	: 2 of 2
Site : Southwest Boundary		Hole Length	: 19.70m
Job Number: 12506381		Scale @ A4	: 1:50
Commenced: 7/11/2019	Completed: 7/11/2019	Logged	: MF
Easting: 395779	Northing: 787672	System: TAIETM2000	Processed : MF
RL: 182	Datum: NZVD2009		Checked : JHS

RL (m)	Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR / SCR / RQD (%)
	10–11.15	Moderately weathered, orange-brown, very thinly to moderately thickly bedded SILTSTONE; very weak; no defects; moderately widely spaced lignite layers 5-20 mm thick *(continued from layer starting at 7.5m)* 10.00 - 10.10 m: fine SANDSTONE	HENLEY BRECCIA	PQTT	SW	100 / 87
171	11.15–14.55	Unweathered, light grey, laminated to moderately thickly bedded, fine grained SANDSTONE; very weak; no defects; moderately widely spaced lignite layers 5-30 mm thick 14.45 - 14.55 m: grades into BRECCIA		PQTT	UW	100 / 53
170–168				PQTT		100 / 100
	14.55–15.4	Unweathered, light grey, BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine, quartz and schist, angular to subangular gravel		PQTT		100 / 81
167–165	15.4–17.6	Unweathered, light grey, laminated to moderately thickly bedded, fine grained SANDSTONE; very weak to weak; no defects 16.00 - 16.15 m: moderately strong 17.30 - 17.60 m: grades into BRECCIA		PQTT		100 / 92
				PQTT		97 / 75
164–163	17.6–19.70	Slightly weathered, light grey and white, BRECCIA; moderately strong to strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel		PQTT	SW	83 / 19
162	19.70	End of Hole @ 19.70m,Target Depth.				

Columns also present (no entries): Graphic, Moisture condition, Consistancy / Relative density, Sample (Number / Type, Result), Casing, Flush Return (%), Estimated Strength (MPa), Defect Spacing (mm), Instrumentation Installation, Water level.

Notes and Comments:

End of Hole @ 19.70m, Target Depth.

Groundwater not encountered

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical   Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 19.7 m		

0.00 m to 2.30 m

2.30 m to 4.60 m

Report of Photographs
Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		

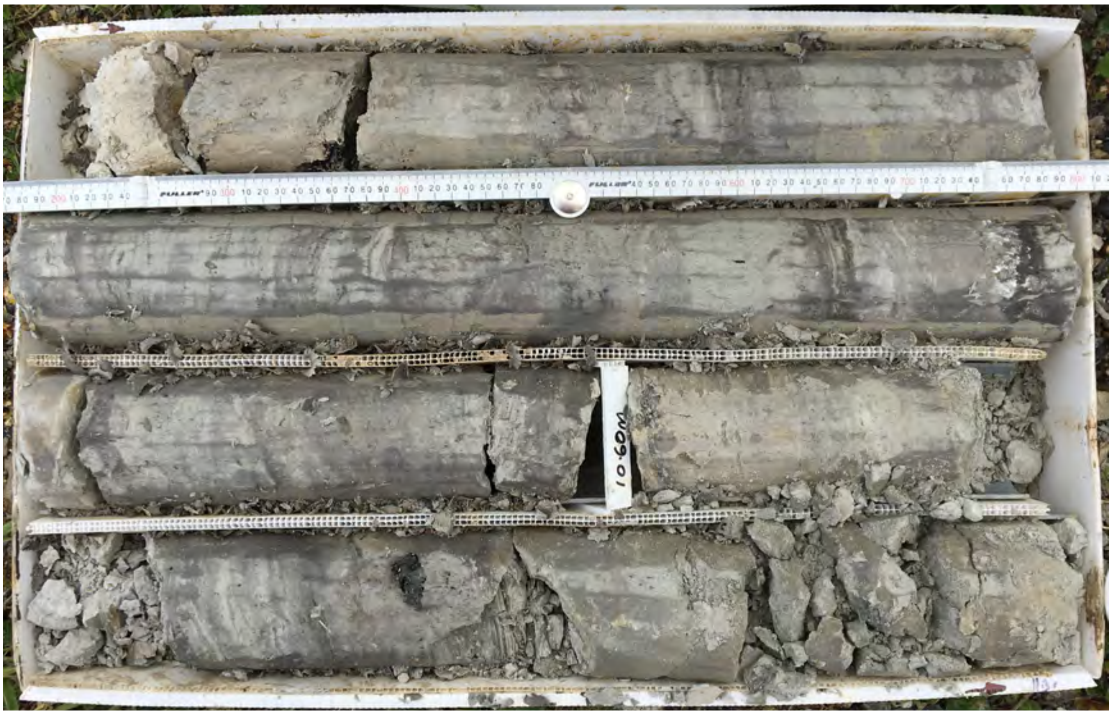
4.60 m to 6.90 m

6.90 m to 9.20 m

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		



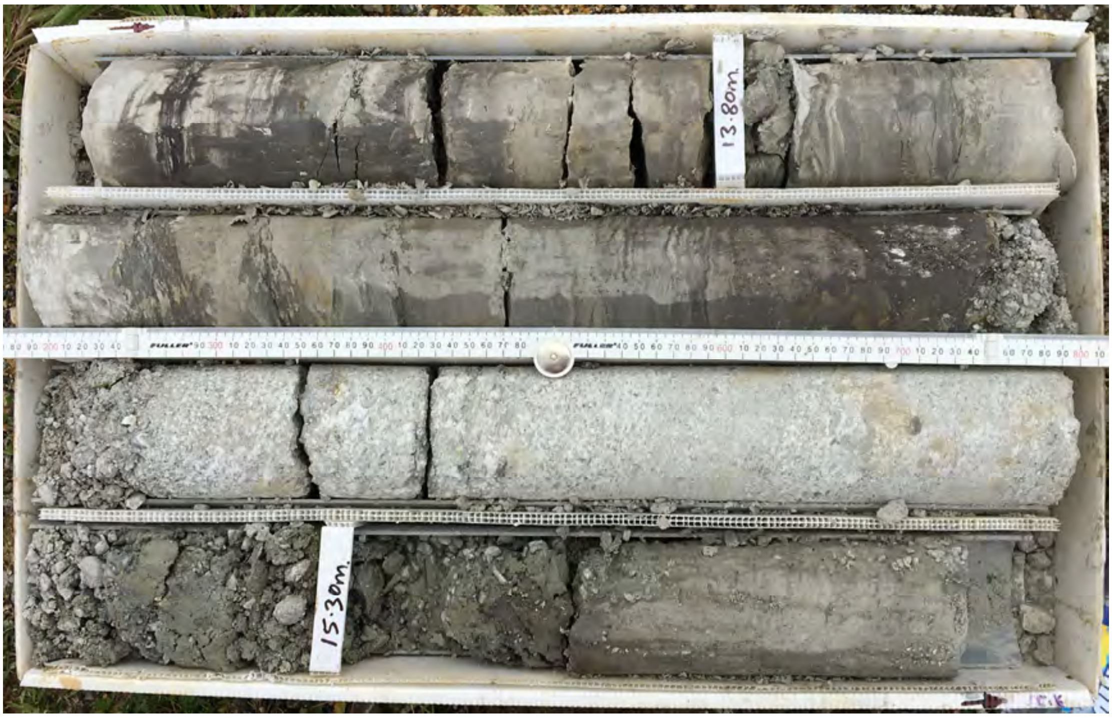
9.20 m to 11.30 m

11.30 m to 13.40 m

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		



13.40 m to 15.60 m

15.60 m to 17.90 m

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		

17.90 m to 19.70 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH209
Client : Dunedin City Council	Sheet : 1 of 1
Site : Western Boundary	Hole Length : 10.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 24/10/2019 Completed: 24/10/2019	Logged : MF
Easting: 395775 Northing: 788148 System:	Processed : MF
RL: 132 Datum:	Checked : JHS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
0 – 0.6	Intermixed: clayey SILT, sandy SILT, and SILT with minor clay; grey and brown. Soft to firm, moist to wet, low to high plasticity; wood fragments throughout (FILL)	FILL	M-W	S-F	PQTT		92
0.6 – 3.15	SILT, minor clay, trace find sand; light grey and orange-brown. Very stiff, moist, low plasticity; trace fine gravel sized iron oxide nodules (LOESS) 0.80 - 3.15 m: grey-brown and orange-brown	LOESS	M	VSt	PQTT		100
3.15 – 3.6	Gravelly SILT; grey, cream and brown. Very stiff to hard, dry to moist, non-plastic; gravel is fine to medium, rounded to subangular quartz and schist; highly weathered (Henley Breccia)	HENLEY BRECCIA	D-M	VSt-H	PQTT	HW	96
3.6 – 4	SILT, minor to some clay; grey with orange-brown streaks. Firm to stiff, moist, high plasticity	HENLEY BRECCIA	M	F-St		HW	
4 – 5.3	Moderately weathered, orange-brown, very thinly to moderately thickly bedded fine-grained SANDSTONE; very weak; no defects 4.80 - 5.30 m: light grey	HENLEY BRECCIA			PQTT	MW	100 / 86
5.3 – 5.9	Moderately weathered, brown and orange-brown CONGLOMERATE; extremely weak; no defects; matrix supported; clasts are fine to medium, rounded to subangular, quartz and schist gravel; silty sand matrix. Soil description: gravelly silty sand	HENLEY BRECCIA			PQTT	MW	100 / 60
5.9 – 6.65	Moderately weathered, orange-brown, very thinly to moderately thickly bedded fine-grained SANDSTONE; very weak; no defects	HENLEY BRECCIA				MW	
6.65 – 7.3	Slightly weathered, grey, laminated to moderately thinly bedded fine-grained SANDSTONE; very weak; no defects	HENLEY BRECCIA			PQTT	SW	100 / 100
7.3 – 7.8	Slightly weathered, brown with occasional orange-brown and white, moderately thinly to moderately thickly bedded, fine to medium-grained SANDSTONE; very weak; no defects; minor fine quartz and schist gravel	HENLEY BRECCIA				SW	
7.8 – 10	Slightly weathered, brown and orange-brown CONGLOMERATE; extremely weak; no defects; clast supported; silty sand matrix; clasts are fine to coarse, rounded to subangular, quartz and schist gravel. Soil description: silty, sandy, fine to coarse gravel	HENLEY BRECCIA			PQTT	SW	100 / 0
					PQTT		94 / 0
10	End of Hole @ 10.00m,Target Depth.						

Notes and Comments:

End of Hole @ 10.00m, Target Depth.

Groundwater not encountered

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Tracked Rig

Shear Vane Id:

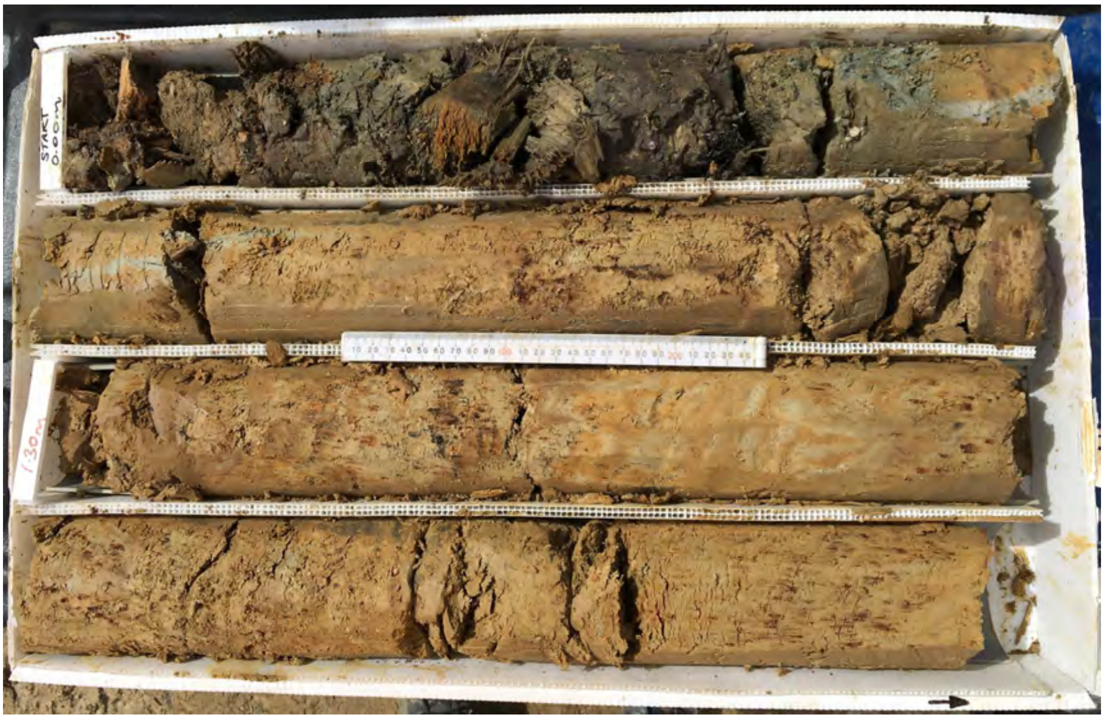
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Western Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		



Box 1 of 5: 0.00 m to 2.40 m

Box 2 of 5: 2.40 m to 4.70 m

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Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		

Box 3 of 5: 4.70 m to 7.15 m

Box 4 of 5: 7.15 m to 9.20 m

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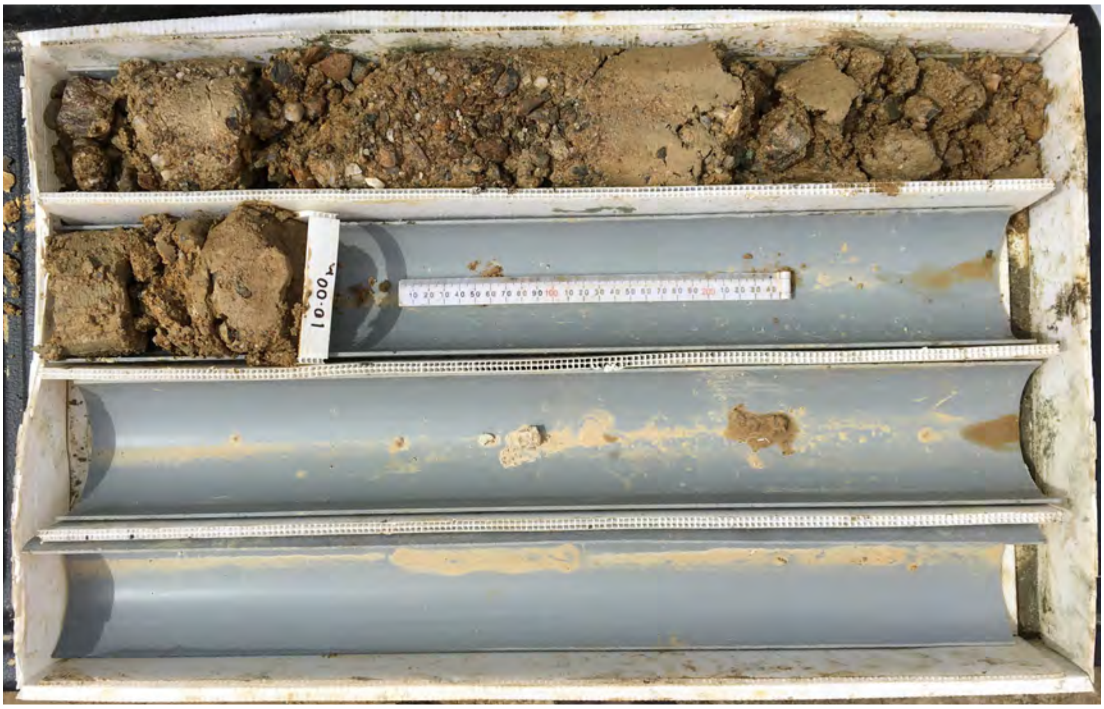
Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		



Box 5 of 5: 9.20 m to 10.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH211
Client : Dunedin City Council	Sheet : 1 of 3
Site : Eastern gully base	Hole Length : 25.20m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 4/11/2019 Completed: 6/11/2019	Logged : MF
Easting: 396598 Northing: 787965 System: TAIETM2000	Processed : MF
RL: 107 Datum: NZVD2009	Checked : JHS

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
	0 – 0.35	0.00 - 0.35 m: CORE LOSS (inferred at top of run)				PQTT		78
	0.35 – 0.7	SILT, minor fine to medium sand, trace clay; grey, orange-brown and dark grey intermixed. Stiff to very stiff, moist, low plasticity (FILL)	FILL	M	St-VSt			
106	0.7 – 1.6	SILT, trace to minor fine to medium sand; grey and orange-brown. Very stiff, moist, low plasticity; trace to minor iron-oxide nodules (LOESS)	LOESS	M	VSt			
	1.6 – 1.8	1.60 - 1.80 m: CORE LOSS (inferred depth)						
105	1.8 – 1.95	SILT (continued from 0.7 m)				PQTT		75
104	1.95 – 3.2	Sandy SILT, minor fine gravel; orange-brown and grey. Very stiff to hard, moist, non-plastic; sand is fine to medium; gravel is angular to rounded quartz and schist; completely weathered breccia (HENLEY BRECCIA) 2.40 - 2.80 m: firm to stiff 2.80 - 3.20 m: very stiff	HENLEY BRECCIA	M	VSt-H F-St VSt	PQTT	CW	62
	3.2 – 3.7	3.20 - 3.70 m: CORE LOSS						
103	3.7 – 4.2	SILT; dark grey. Firm to stiff, moist, low plasticity; completely weathered siltstone		M	F-St	PQTT		100
	4.2 – 4.6	Gravelly SAND; grey. Moist; sand is fine to coarse; gravel is fine, angular to subrounded, quartz and schist; completely weathered breccia		M	VSt-H			
102	4.6 – 5.2	4.60 - 5.20 m: CORE LOSS						
	5.2 – 5.4	Gravelly SAND (continued from 4.2 m)		M	VSt-H	PQTT		59 25
101	5.4 – 6.2	Highly weathered, orange-brown and grey, moderately thickly bedded BRECCIA; extremely weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to rounded, quartz and schist gravel. Soil description: gravelly sand					HW	
	6.2 – 6.75	Slightly weathered, light grey and white, moderately thickly bedded SILTSTONE; very weak to weak; no defects						
100	6.75 –	Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel				PQTT	SW	100 93
99						PQTT		100 70
98		8.80 - 9.90 m: very weak to weak				PQTT		100 79
97								

Sample: Number / Type; Result. Casing. Flush Return (%) 25 50 75. Estimated Strength (MPa) EW VW W MS S VS ES. Defect Spacing (mm) 20 60 200 600 2000. Instrumentation Installation. Water level.

Notes and Comments:

End of Hole @ 25.20m, Target Depth.

Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211
Sheet : 2 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

Depth (m)	Material Description	Geological Unit	Method	Weathering	TCR / SCR RQD (%)
9.90–11.80	9.90 - 11.80 m: weak to moderately strong Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 6.8m)*	HENLEY BRECCIA	PQTT; PQTT	SW	100 / 92; 100 / 60
11.8–12.0	Slightly weathered, grey SILTSTONE; very weak; no defects; trace to minor fine gravel, content decreases with depth	HENLEY BRECCIA	PQTT	SW	97 / 90
12.0–13.65	Slightly weathered, brown, SILTSTONE; very weak; no defects; possible lithified topsoil 13.50 - 13.65 m: grey	HENLEY BRECCIA	PQTT	SW	100 / 87
13.65–14.0	Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak to weak; no defects	HENLEY BRECCIA		SW	
14.0–16.1	Slightly weathered, grey and white BRECCIA; weak to moderately strong; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel	HENLEY BRECCIA	PQTT; PQTT	SW	100 / 46; 100 / 35
16.1–16.6	Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak; no defects	HENLEY BRECCIA	PQTT	SW	100 / 84
16.6–17.6	Slightly weathered, grey and white BRECCIA; very weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to subrounded, quartz and schist gravel	HENLEY BRECCIA		SW	
17.6–18.3	Slightly weathered, grey, fine to medium grained SANDSTONE; very weak; no defects	HENLEY BRECCIA	PQTT	SW	100 / 86
18.3–19.1	Slightly weathered, grey and white BRECCIA; moderately strong to strong; no defects; clast supported; fine to coarse sand matrix; clasts are fine to medium, angular to subrounded, quartz and schist gravel	HENLEY BRECCIA		SW	
19.1–20.0	Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel	HENLEY BRECCIA	PQTT	SW	100 / 71

Column headings: RL (m), Depth (m), Graphic, Material Description, Geological Unit, Moisture condition, Consistancy / Relative density, Sample (Number / Type, Result), Casing, Method, Flush Return (%), Weathering, Estimated Strength (MPa), TCR SCR RQD (%), Defect Spacing (mm), Instrumentation Installation, Water level

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting	Hole No. : BH211
Client : Dunedin City Council	Sheet : 3 of 3
Site : Eastern gully base	Hole Length : 25.20m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 4/11/2019 Completed: 6/11/2019	Logged : MF
Easting: 396598 Northing: 787965 System: TAIETM2000	Processed : MF
RL: 107 Datum: NZVD2009	Checked : JHS

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	20	Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 19.1m)*	HENLEY BRECCIA								SW					
86	21	21.00 - 25.20 m: occasional cobble-sized clast							PQTT				96 / 51			
85	22	22.00 - 25.20 m: clast supported							PQTT				100 / 63			
84	23	22.65 - 23.00 m: moderately strong to strong							PQTT				100 / 36			
83	24	24.00 - 24.40 m: moderately strong to strong							PQTT				92 / 68			
82	25	End of Hole @ 25.20m,Target Depth.														
81	26															
80	27															
79	28															
78	29															
77	30															

Notes and Comments:

End of Hole @ 25.20m, Target Depth.

Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: Track mounted rig

Shear Vane Id:

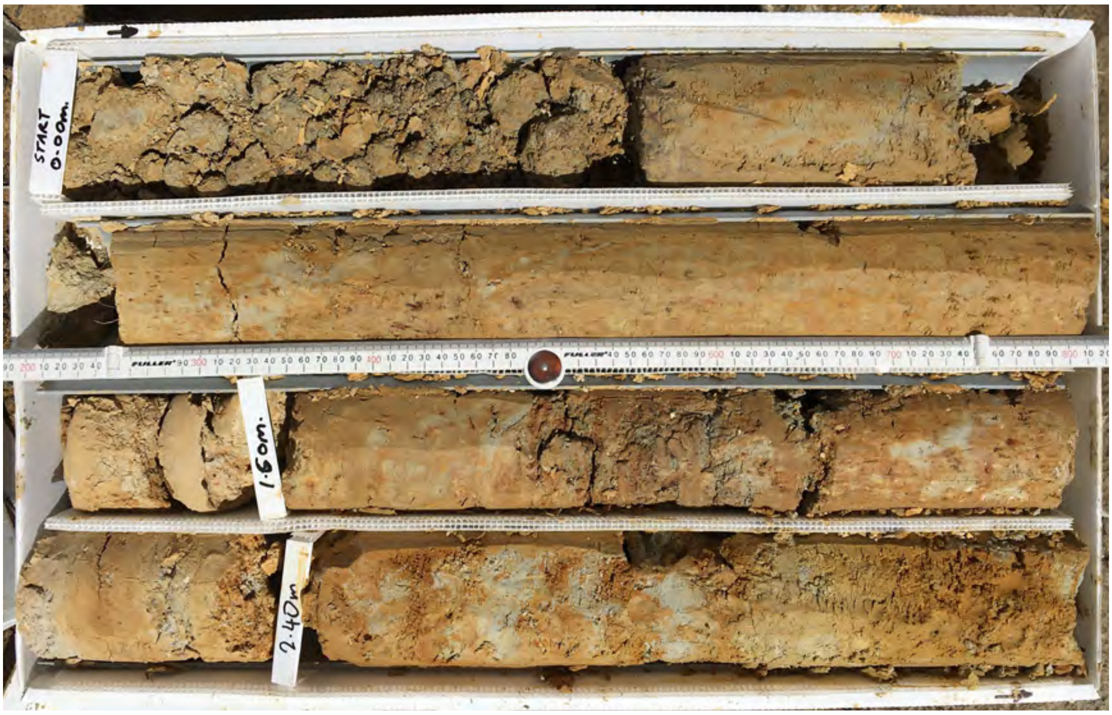
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

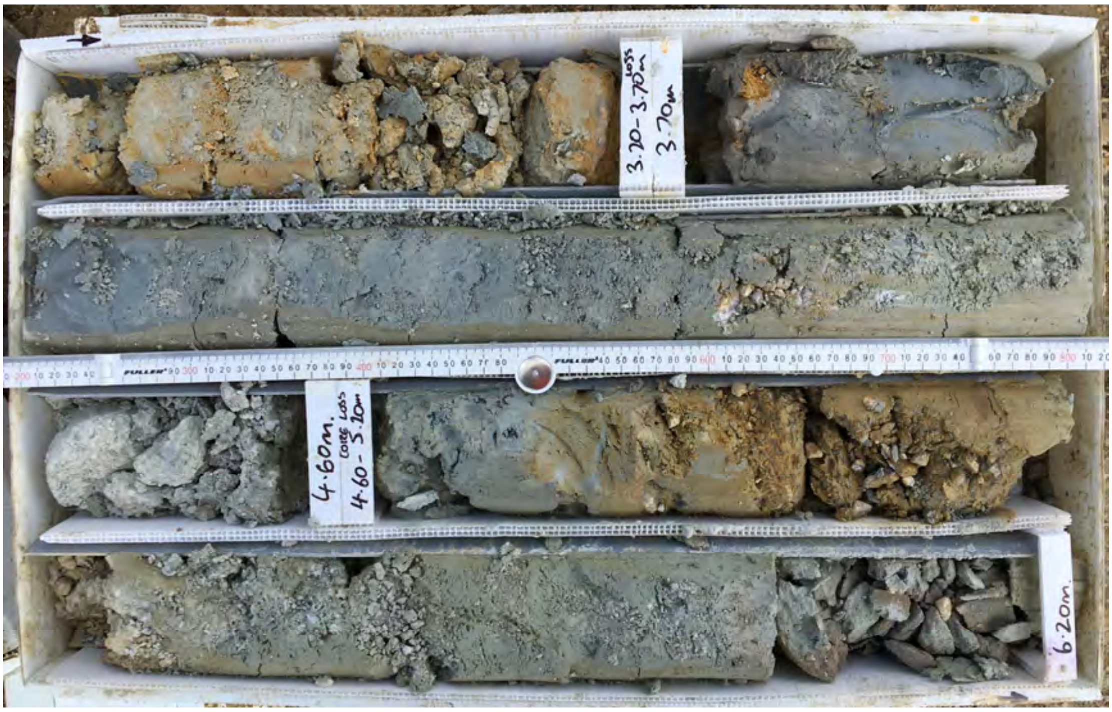
Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019 **Completed** 06/11/2019
Site	Smooth Hill	**Logged By**	MF
Job #	12506381	**Checked By**	
Client	Dunedin City Council	**Core Depth**	0.0 m – 25.2 m



0.00 m to 2.80 m



2.80 m to 6.20 m

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		

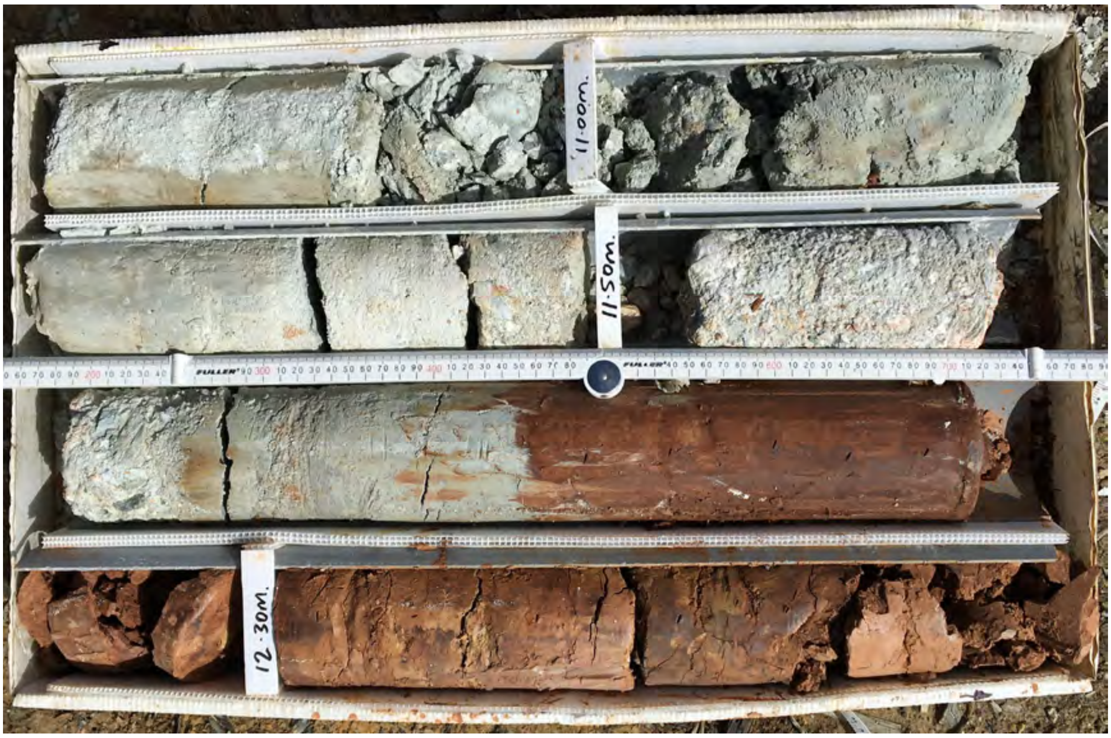
6.20 m to 8.50 m

8.50 m to 10.70 m

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



10.70 m to 12.80 m

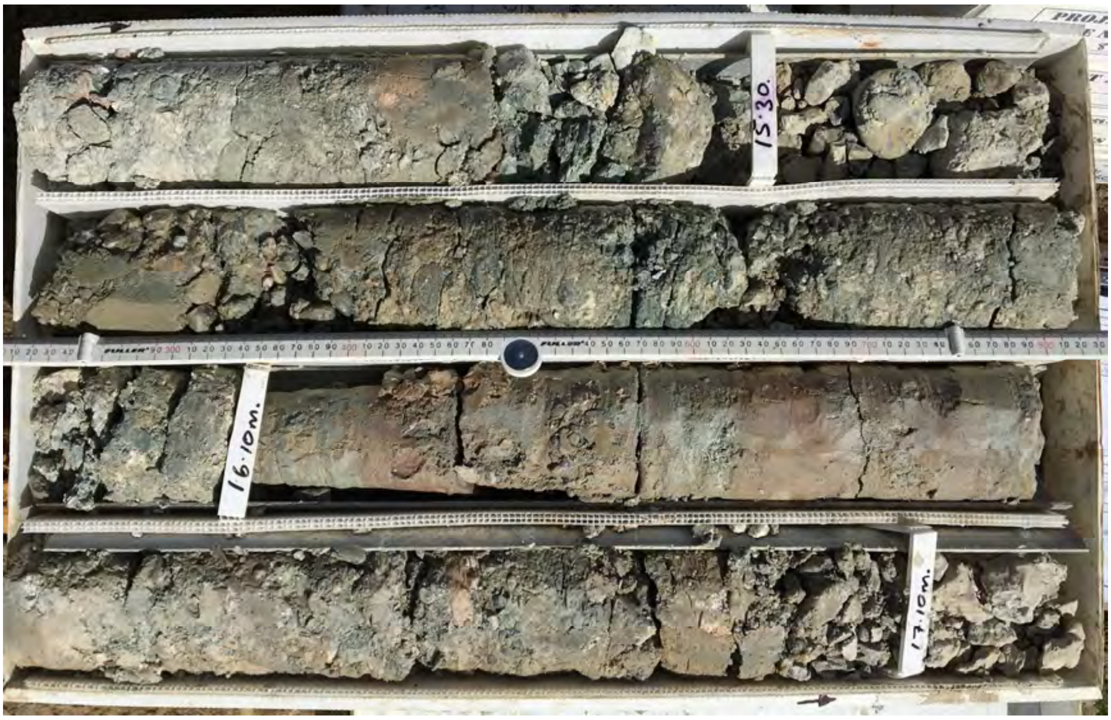
12.80 m to 14.90 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



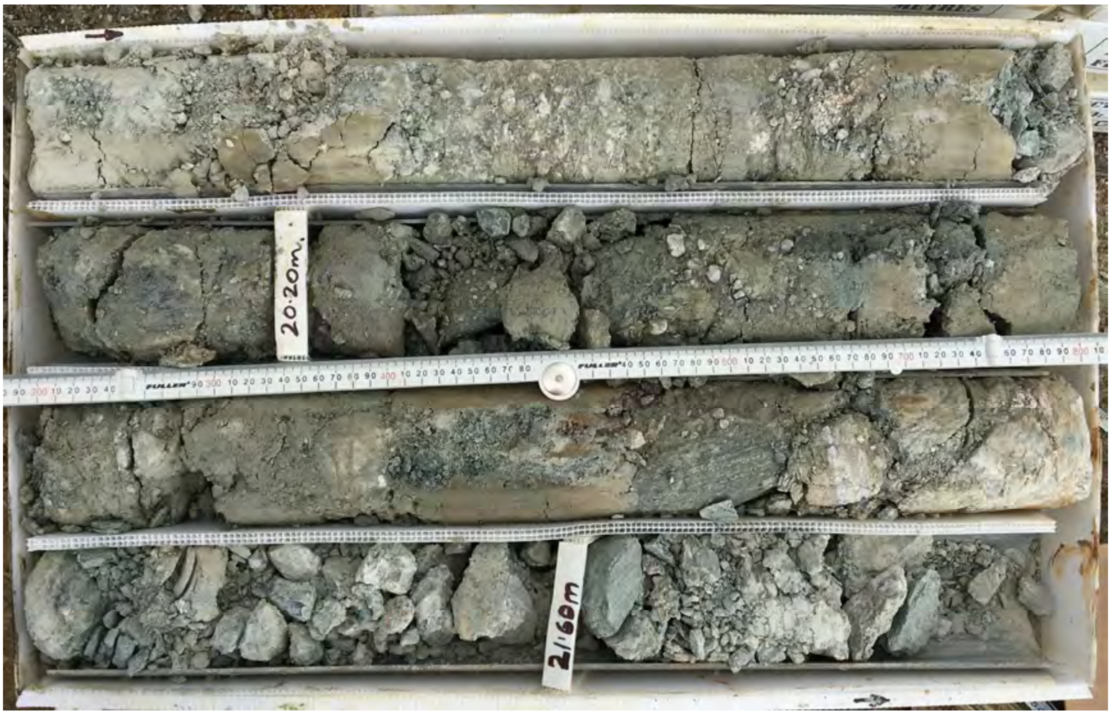
14.90 m to 17.20 m

17.20 m to 19.50 m

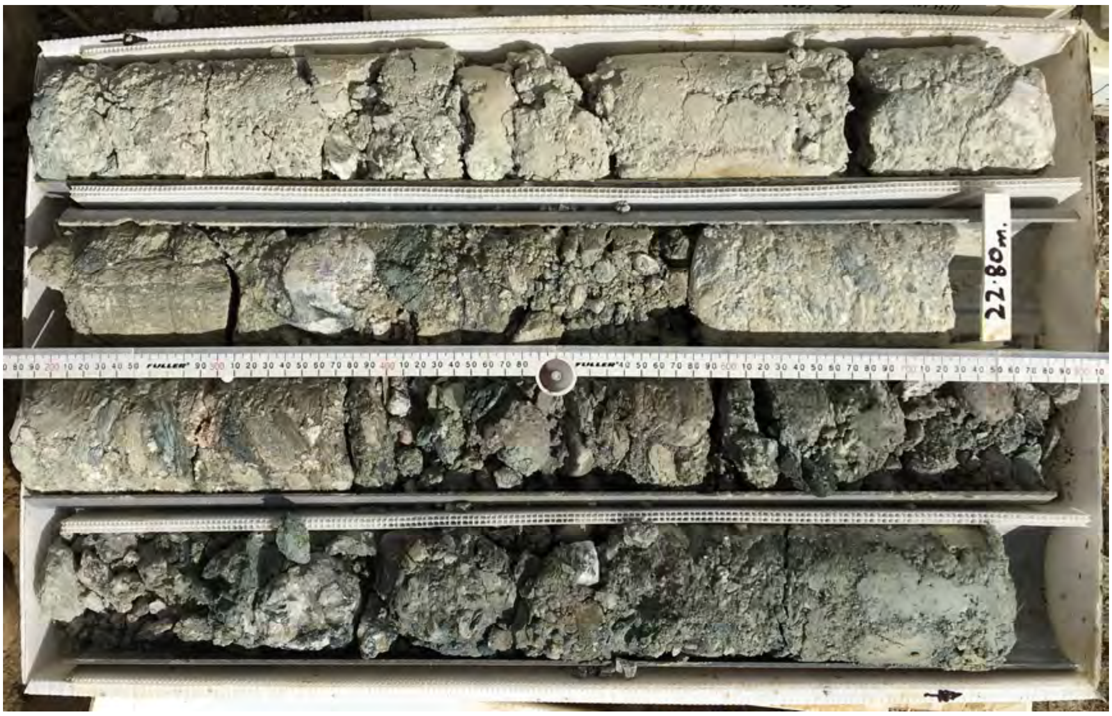
Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



19.50 m to 21.70 m



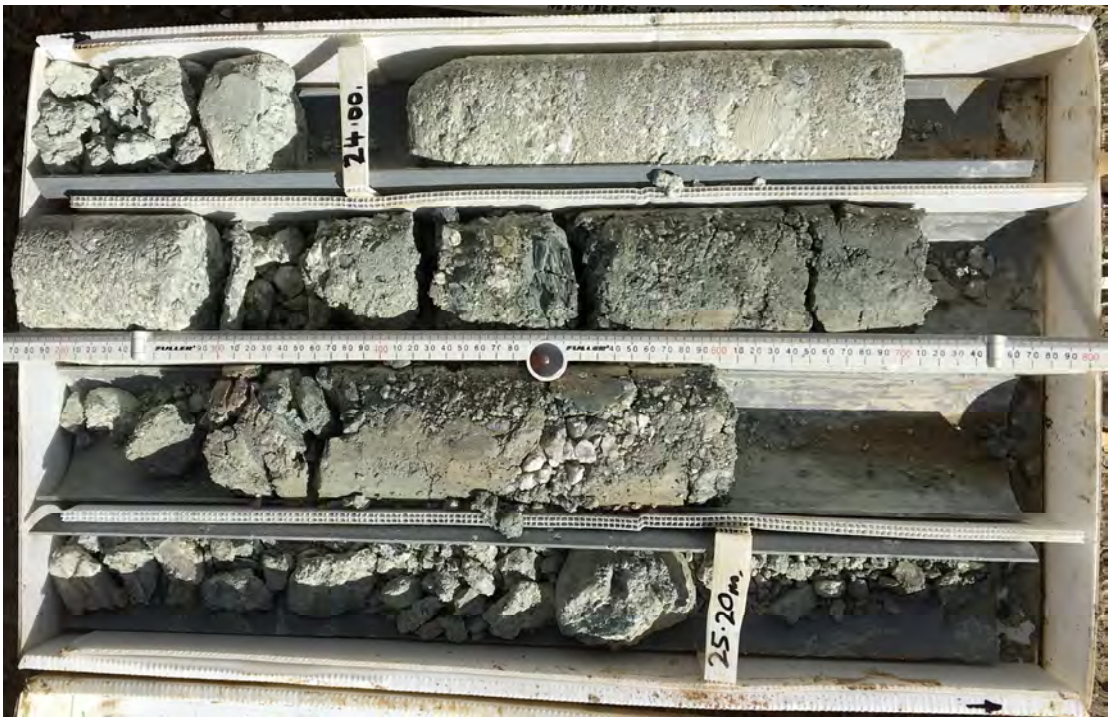
21.70 m to 23.90 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



23.90 m to 25.20 m (EOH)

Appendix C – Technical Appendix

Technical Appendix

1. Introduction

This technical appendix outlines the assessment of leachate generation and leakage for the proposed Smooth Hill landfill, and has been prepared to support both the landfill design and an assessment of environmental effects (AEE), as presented in the following reports:

- GHD, 2021~~0~~. Waste Futures – Smooth Hill Landfill. Concept Design Report.
- GHD, 2021~~0~~. Waste Futures – Smooth Hill Landfill. Assessment of Effects to Groundwater.

1.1 Landfill Design

The flow balancing of the landfill leachate collection system requires that the following hydraulic aspects are considered in the design of the proposed Smooth Hill landfill:

- Flow capacity of the leachate drainage pipework.
- In-landfill storage basin capacity.
- Leachate pump station capacity and rising main size.
- Leachate above ground storage (prior to discharging off site).

Additionally, restricting the maximum leachate head to less than 300 mm is a minimum requirement for leachate collection systems within the WasteMINZ technical guidelines for disposal to land (WasteMINZ, 2018).

To inform the hydraulic design, leachate generation and reporting times to the leachate collection system have been estimated for storm events of varying rainfall intensity.

1.2 Assessment of Environmental Effects

The following aspects of the proposed Smooth Hill Landfill are required to be understood to inform assessment of potential environmental effects:

- Likely volume of leachate leaking to ground, as a function of landfill area, stages of development and expected liner performance.
- The landfill water balance during construction and after closure, including runoff, evapotranspiration and leachate generation.

2. Leachate Assessment Methodology

2.1 Introduction

The leachate assessment comprised analysis of the following:

1. Seasonal and average leachate generation and leakage, to support landfill cover design and assessment of environmental effects (AEE), with this analysis described in Section 2.2.
2. Storm event leachate generation and flow to the leachate collection system to support hydraulic design of the collection system, with this analysis described in Section 2.3.

2.2 HELP Modelling and Landfill Leachate Balance

Leachate generation, leakage to ground and leachate head above the liner was assessed using the Hydrologic Evaluation of Landfill Performance (HELP) software (Berger and Schroeder, 2013). HELP 3.95D is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills and cover systems. The model utilises weather, soil and design data to account for the effects of surface storage, runoff, infiltration, evapotranspiration, soil moisture, lateral subsurface drainage, vertical drainage and leakage through soil and geo-membrane liners.

Four different landfill profiles were modelled to assess leachate generation and leakage. The water balance estimated for each were applied for ~~the five~~the four stages of landfill~~ stages~~ development to provide the whole of landfill water balance at different times through the landfill operational lifecycle.

The results of this assessment provide information to support landfill capping design, and assessment of environmental effects.

2.2.1 Landfill Profile and Cover

Four landfill profiles, in different phases of landfill development, were considered in predicting the landfill water balance:

- Open waste.
- Daily cover.
- Intermediate cover.
- Final cap.

Additionally, a profile was modelled to represent existing conditions at the site to assess changes to the water balance and quantify potential effects to groundwater.

A liner only profile (prior to placement of waste) was not modelled with HELP, as all rainfall is assumed to report to the leachate collection system. Average annual rainfall of 809.5 mm was adopted for this profile from the results of the weather generator model (discussed further in Section 2.2.3).

All landfill profiles comprised a landfill liner, discussed further in Section 2.2.2, overlain by a 30~~0~~ c~~m~~m gravel drainage layer and municipal waste. A municipal waste thickness of 100 c~~m~~m was adopted for open waste, daily cover and intermediate cover landfill phases. A municipal waste thickness of 1,400 c~~m~~m was adopted for the final cap phase, to represent the final average waste thickness across the landfill. The profile characteristics adopted are presented in attached Table A 1. Soil values of total pore volume, field capacity and wilting point were adopted from published USDA soil textures (Schroeder et al., 1994), however saturated hydraulic conductivity was modified for a number of the soil units. Justification for the adopted soil textures and saturated hydraulic conductivity is presented in Table 1.

Table 1: Justification for adopted soil texture and saturated hydraulic conductivity

Profile	Soil Unit	Adopted USDA Soil Texture[1]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
Existing Environment	Silt loam	23 – Silt Loam (moderately compacted)	$9x10^{-6}$	$1x10^{-5}$	On site top soil described as silt with trace to minor clay. Hydraulic conductivity higher than triaxial permeability test results (ranging from $5.3x10^{-8}$ cm/s – $3.2x10^{-6}$ cm/s) to account for macro pores.
Landfill Open Waste	Upper Municipal Waste Layer (Layer 1)	21 - Gravel	$3x10^{-1}$	$3x10^{-3}$	Poor soil moisture retention expected due to high heterogeneity and poor compaction. Plastics in the waste are also likely to channel the drainage, limit the spreading of infiltration, and restrict the wetting of the waste[2]. Adopted. saturated hydraulic conductivity therefore similar, but slightly greater than, that of municipal waste.
Landfill Daily Cover	Daily Cover (Layer 1)	9 – Silt Loam (slightly compacted)	$1.9x10^{-4}$	$1x10^{-3}$	On site top soil described as silt with trace to minor clay, however lower soil moisture retention characteristics and increased saturated hydraulic conductivity adopted as site won material will have significant open macro-pores allowing water transmission. Slight compaction.
Landfill Intermediate Cover	Intermediate Cover (Layer 1)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Minor compaction and contouring.

Profile	Soil Unit	Adopted USDA Soil Texture[1]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
Landfill Final Cap	Topsoil (Layer 1 & 2)	28 – Silty Clay (moderately compacted)	1.2×10^{-6}	1×10^{-4}	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Minor compaction and contouring.
	Barrier Clay (Layer 3)	28 – Silty Clay (moderately compacted)	1.2×10^{-6}	5×10^{-6}	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Moderate compaction.
	Soil (Layer 4)	28 – Silty Clay (moderately compacted)	1.2×10^{-6}	1×10^{-4}	Represents layer 1 of intermediate cover which will be present before placement of final cap.
All Landfill Profiles (Landfill Waste and Liner)	Municipal Waste	18 - Municipal Waste (312 kg/m³)	1×10^{-3}		No changes to USDA soil texture characteristics.
	Drainage Layer	21 – Gravel	3×10^{-1}		No changes to USDA soil texture characteristics.
	FML Geomembrane	35 – High Density Polyethylene (HDPE)	2×10^{-13}		No changes to USDA soil texture characteristics.
	GCL	17 – Bentonite Mat	3×10^{-9}	5×10^{-9}	Adopted saturated hydraulic conductivity increased slightly to match GRI-GCL3 requirement for a typical GCL.
	Clay	28 – Silty Clay (moderately compacted)	1.2×10^{-6}	1×10^{-6}	On site loess largely described as silt with trace to some clay to silty clay. Adopted saturated hydraulic conductivity anticipated to be achieved using site won loess materials.

1) Schroeder et al., 1994.

2) Berger and Schroeder, 2013.

2.2.2 Landfill Liner and Slope

The landfill liner, as presented in the profiles in attached Table A 1, is proposed to comprise a 600 mm clay base layer, overlain by a 5 mm geosynthetic clay liner (GCL) and 1.5 mm flexible membrane liner (FML).

The following landfill liner defects and condition, were adopted within the HELP model with regards to the FML:

- FML comprised a high density polyethylene.
- Pinhole density: 2 / hectare.
- Installation defects: 25 / hectare.
- Installation quality: Poor.

Two liner slope scenarios were modelled for each ~~landfill profile~~stage of the landfill (Table 2), which reflect different liner slopes between ~~benched~~ the ~~(~~low gradient~~)~~ base and battered ~~(~~high gradient~~)~~ areas of the landfill. For each slope scenario, the average distance to the leachate drain was adopted. The areas assessed during each ~~For each~~ stage of the landfill development are also provided in Table 2. ~~, it was assumed that at any given point in time the bench to batter ratio would be approximately 3:7, with this being generally consistent with the whole of landfill distribution of liner slopes~~.

Table 2: Landfill Stage

Stage	Slope Type	Liner Slope	Average Flow Path Distance to Leachate Drain (m)	Area (m^2)
All stages	Base	4%	~~270~~50	~~32,600~~44,000
1	Batter	~~25~~20%	~~1~~50	~~70,542~~17,000
2	Batter	20%~~25%~~	~~140~~75	~~66,788~~61,000
3	Batter	20%~~25%~~	~~160~~90	~~50,276~~113,000
4	Batter	20%~~25%~~	100~~150~~	~~55,123~~142,000

2.2.3 Weather and Rainfall Runoff

Synthetic weather files were generated for a 50 year period using a weather generator model (WGEN), a stochastic model used to generate daily weather variables. Taulis and Milke (2005) from the University of Canterbury developed climate parameters for Dunedin, Otago, which were used within the Weather Generator to generate inputs for:

- Evapotranspiration
- Precipitation
- Air Temperature
- Solar Radiation

In developing the HELP climate data, the following user defined parameters and values were also included:

- Maximum leaf area index:
  - 3.5 was adopted for all landfill phases
- Evaporative zone depth:
  - 1 cm was adopted for open waste
  - 15 cm was adopted for daily cover, intermediate cover and final cap

The evaporative zone depth was reduced for the open waste profile to account for rapid infiltration of rainfall through the shallow layers of municipal waste, which is expected to be very heterogeneous and poorly compacted, resulting in poor soil moisture retention. Plastics in the waste are also likely to channel the drainage, limit the spreading of infiltration, and restrict the wetting of the waste (Berger and Schroeder, 2013). For the same reason, a 10 cm thick drainage layer was specified as layer 1 of the open waste soil profile (attached Table A 1).

Rainfall runoff within the HELP model is determined through application of a runoff curve number. The parameters utilised for determination of the curve number include soil texture, surface slope, compaction, surface vegetation and average surface flow path length. The adopted criteria for each landfill phase and stage are presented in attached Table A 2 and Table A 3, respectively. Sensitivity analysis was undertaken to assess whether changes in surface slope of the intermediate and final cap profiles influenced the HELP model water balance. The analysis indicated that there was very little difference in water balance with slope changes between a 5% and 33% slope. A 33% slope was therefore adopted for all intermediate and final cap landfill profiles (attached Table A 2). A 0.1% slope was adopted for open waste and waste with daily cover to simulate an approximately flat surface (attached Table A 2).

2.2.4 Landfill Development Stages and Landfill Leachate Balance

Water balances for the four~~five~~ stages of landfill development (Drawing No. 51-12506381-01-C201) were determined, considering progressive development from Stage 1 to Stage 4~~5~~. For each stage of the landfill development, with the exception of the completed and closed landfill, a worst case scenario of open landfill area is assumed, with the operational areas of the landfill comprising the following:

- 10,000 m^2 of exposed liner.
- 2,500 m^2 of exposed landfill waste with no cover.
- 11,500 m^2 of exposed landfill waste with daily cover.
- Intermediate and final cap areas varying depending on the total footprint each stage of landfill development.

2.3 Storm Event Leachate Reporting Times

The time for leachate to report to the leachate drainage system was modelled using Geostudio 2018 SEEP/W finite element numerical modelling software. This allowed for analysis of rainfall infiltration through open (un-covered) waste material, and estimation of the time for leachate to reach the drainage layer.

Model set up is described in Table 3.

Table 3: Model Set Up

Parameter	Adopted Value	Justification
Model dimensions	0.1 m wide x 14 m thick	Width chosen to ensure sufficient mesh density Average thickness of waste layer in landfill
Waste Hydraulic Conductivity	2.15×10^{-3} m/s	High permeability of recently placed waste (Uniform Sand - SEEP/W Database)
Waste Volumetric Water Content Function	Uniform Sand Function (SEEP/W Database)	Low residual water content
Drainage Layer Hydraulic Conductivity	3×10^{-3} m/s	Particle size density (PSD) hydraulic conductivity analysis of drainage layer aggregate.
Drainage Layer Volumetric Water Content Function	Uniform Sand (SEEP/W Database)	Low residual water content
Rainfall Boundary Condition	Water rate for each rainfall event (detailed in Table 4)	HIRDS* rainfall intensity data
Drainage Layer Boundary Condition	0 m water pressure head	Simulates leachate removal from the drainage layer

* High Intensity Rainfall Design System (HIRDS) v4 Depth Duration Frequency (DDF) for site coordinates.

Table 4: Rainfall rate from HIRDSv4 DDF rainfall depths

10 Year Annual Recurrence Interval (ARI)	Rainfall depth (mm)
2 Hour	27.5
12 Hour	65.1
48 Hour	115

The following assumptions were adopted for the model:

- No evaporation or runoff was allowed for (100% of rainfall was assumed to infiltrate into the waste).
- The average final landfill waste thickness was adopted (14 m).
- The model assumes the waste is homogeneous.

3. Results

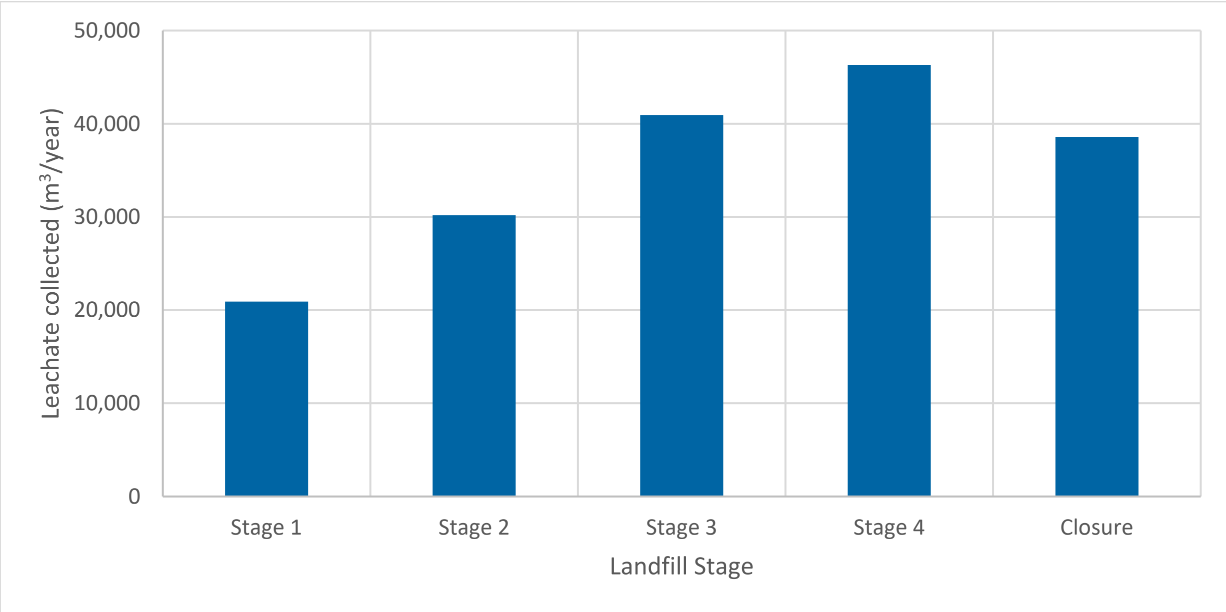
3.1 HELP Modelling

HELP model outputs from each model profile and stage are detailed in attached Table A 4 and Table A 5, and are further discussed in the sections below.

3.1.1 Leachate Generation

Attached Table A 6 presents the HELP model results of leachate collected through the drainage layer for both the final closed landfill, and the worst case landfill state, which comprises a combination of landfill profiles including exposed liner, open waste, intermediate waste and final cap.~~ Attached Table A 7 presents the HELP model results for leachate collection for closed landfill stages modelled using final cap profile only~~. A summary of the leachate predicted to be collected during operation and after ~~stage~~ closure is presented in Figure 1. ~~There are two drainage collection systems for the proposed landfill, which separate the leachate collection in Stages 1 and 2 from leachate collection in Stages 3, 4 and 5.~~

Figure 1: HELP Model landfill leachate collection (Updated May 2021)



The predicted leachate volumes reported to the collection systems will occur sequentially ~~during operation will not occur concurrently as each landfill stage will be closed before the next one is opened (ie. when stage 2 is operational, stage 1 will be closed and covered with final cap)~~. The largest leachate volumes are likely to occur during operation of stage ~~5~~4, with a total predicted leachate volume of approximately ~~98,525~~46,310 m^3/year~~ for the whole landfill~~.~~ Approximately 57,699 m^3/year of this will be generated from operational stage 5 and closed stages 3 and 4. The remaining leachate of approximately 40,826 m^3/year will be generated from closed stages 1 and 2.~~

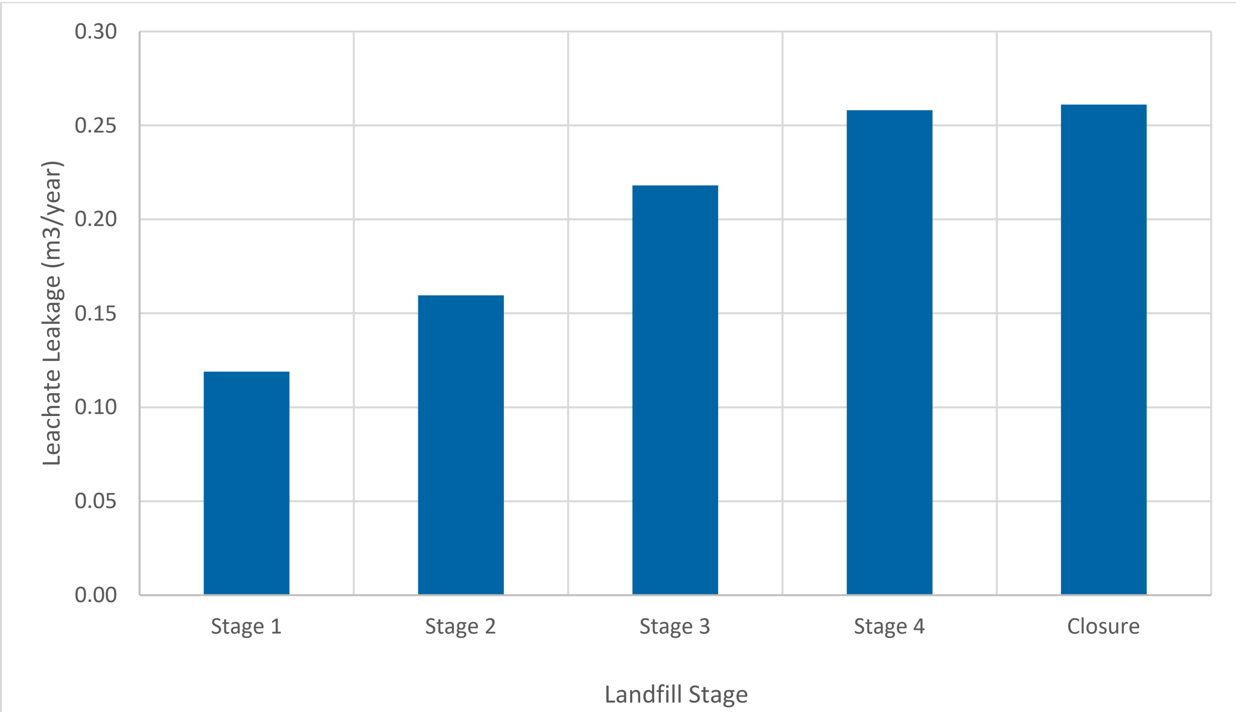
After ~~complete~~ landfill closure, the total leachate predicted ~~from all five stages~~to report to the collection system is approximately ~~89,588~~38,584 m^3/year.~~, with around 40,826 m^3/year reporting to the drainage system for stages 1 and 2, and around 48,762 m^3/year reporting to the drainage system for stages 3, 4 and 5.~~

3.1.2 Leachate Leakage

Attached Table A 7 presents the ~~areas considered for leachate generation, and the~~ results of leachate leakage through the landfill liner, respectively, comprising a combination of landfill profiles including exposed liner, open waste, intermediate waste and final cap. A summary of the predicted leachate leakage through the liner during development of the landfill and after closure is presented in Figure 2.

The maximum leachate leakage is predicted to occur ~~during operation of stage 5~~after closure, with an estimated leakage rate of ~~2,950~~261 litres/year (~~3.0~~0.26 m^3/year)~~ (generated from operational stage 5 and closed stages 1, 2, 3 and 4)~~. ~~The predicted total leachate leakage from all stages after landfill closure is approximately 1,884 litres/year (1.9 m^3/year).~~

Figure 2: HELP Model leachate leakage through the landfill liner (Updated May 2021)



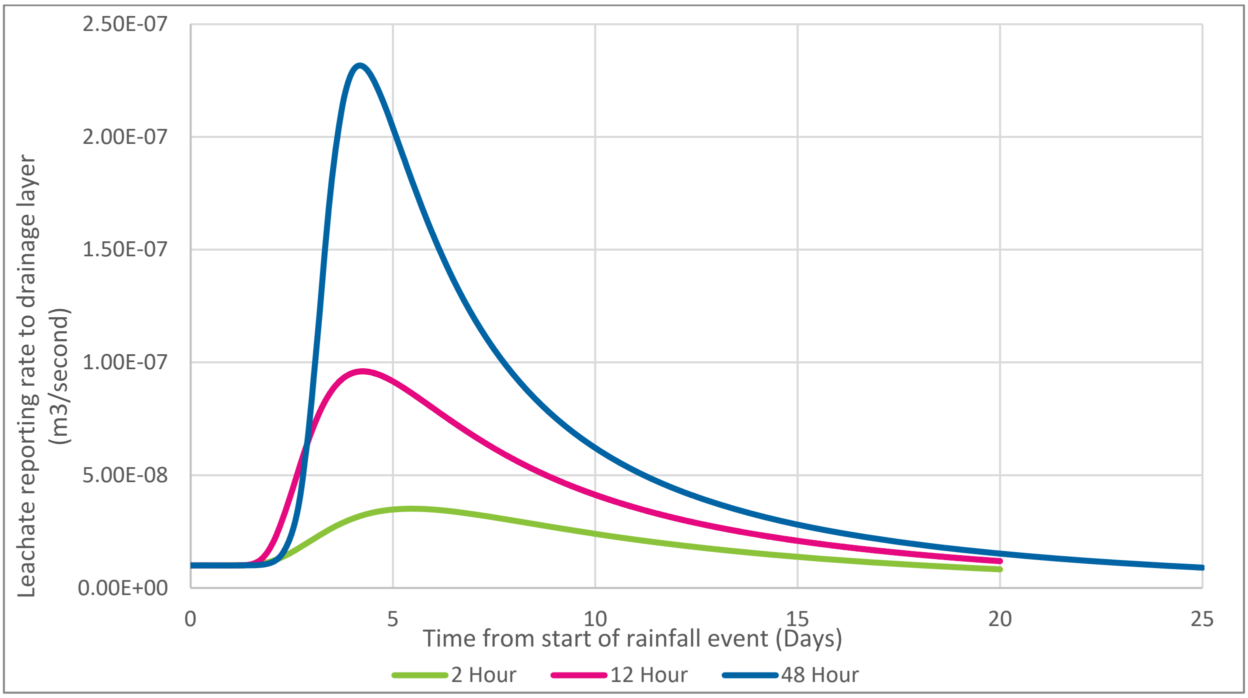
3.1.3 Leachate Head above the Liner

The minimum leachate collection system requirement in the WasteMINZ (2018) technical guidelines states that the leachate head not to exceed 300 mm. The maximum head recorded through the full 50 year HELP model was 52.1 mm under the slope scenario 1 open waste landfill profile ~~in~~during ~~both~~ stage~~s~~ 1~~ and 2~~. The HELP model results in attached Table A 4 indicate that the average predicted head above the liner is ~~19.2~~3.6 mm for the open waste landfill profile. This reduces to average predicted head above the liner of approximately ~~9.9~~1.8 mm, ~~8.3~~1.5 mm and ~~7.4~~1.4 mm for daily cover, intermediate cap and final cap landfill profiles, respectively.

3.2 Storm Event Leachate Reporting Times

The results of the SEEP/W leachate modelling is presented in Figure 3, with Table 5 presenting the percentage of total rainfall reporting to the drainage layer for each of the ARI events. The results indicate that peak leachate reporting rates through 14 m of landfill waste occur approximately 4 to 5 days after the start of each rainfall event for the three ARI events modelled. It is anticipated that rainfall events with varying intensity would also respond within this approximate timeframe for the same thickness of waste. Reporting times would be expected to be faster for a smaller waste layer, and greater for a larger waste layer, due to the respective reduced and increased flow path lengths.

Figure 3: Leachate reporting rate to drainage layer following 10 Year ARI rainfall event



The results also demonstrate that increasing the length of the rainfall event corresponds with increasing reporting rates during peak flow. Infiltration resulting from the two and twelve hour events appears to travel through the waste within approximately 20 days, while infiltration from the 48 hour event took approximately 25 days. Rainfall events that last longer than 48 hours are therefore anticipated to take longer than 25 days to report to the landfill drainage system for a similar waste thickness as that modelled.

Table 5: Percentage of total rainfall reporting to leachate drainage layer through 14 m of waste

10 Year Annual Recurrence Interval (ARI)	Time since commencement of rainfall event											
	1 Hour	4 Hours	12 Hours	1 Day	2 Days	3 Days	4 Days	5 Days	10 Days	15 Days	20 Days	25 Days
2 Hour	0.1 %	0.4 %	1.7 %	2.5 %	5.2 %	9.3 %	16 %	24 %	63 %	86 %	100%	-
12 Hour	0.05 %	0.2 %	0.63 %	1.3 %	2.8 %	8.2 %	19 %	31 %	71 %	90 %	100 %	-
48 Hour	0.03 %	0.1 %	0.36 %	0.7 %	1.4 %	3.9 %	16 %	32 %	73 %	88 %	96 %	100 %

4. References

Berger, K. and Schroeder, P.R. 2013. The Hydrologic Evaluation of Landfill Performance (HELP) Model. User's Guide for HELP-D (Version 3.95D). 6th revised edition for version HELP 3.95D.

Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J.W., and Peyton, R. L. (1994). "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3," EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.Taulis, M.E. and Milke, M.W. Estimation of WGEN weather generation parameters in arid climates. Ecological Modelling 184: 177-191

Waste Management Institute New Zealand (WasteMINZ), 2018. Technical guidelines for disposal to land. August 2018.

Attachments

Table A 1: HELP Model Soil Profiles

Scenario	Layer No.	Layer Description	Soil Texture Description*	Layer Type**	Layer Thickness (cm)	Saturated Hydraulic Conductivity (cm/s)	Total Pore Volume (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)
Existing Environment	1	Top soil / loess	Silt Loam – moderately compacted	VPL	100	1.0E-05	0.461	0.360	0.203
Landfill Open Waste	1	Municipal Waste	Gravel	VPL	10	3.0E-03	0.397	0.032	0.013
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	90	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Landfill Daily Cover	1	Daily Cover	Silt Loam – slightly compacted	VPL	15	1.0E-03	0.501	0.284	0.135
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	100	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Landfill Intermediate Cover	1	Intermediate Cover	Silty Clay – moderately compacted	VPL	30	1.0E-04	0.452	0.411	0.311
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	100	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Landfill Final Cap	1	Topsoil	Silty Clay Loam – moderately compacted	VPL	10	1.0E-05	0.445	0.393	0.277
	2	Topsoil	Silty Clay Loam – moderately compacted	LDL	5	1.0E-05	0.445	0.393	0.277
	3	Clay cap	Silty Clay – moderately compacted	BSL	60	5.0E-06	0.452	0.411	0.311
	4	Soil	Silty Clay – moderately compacted	VPL	50	1.0E-04	0.452	0.411	0.311
	5	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	1400	1.0E-03	0.671	0.292	0.077
	6	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	7	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	8	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	9	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).[1]

** VPL = Vertical Percolation Layer. LDL = Lateral Drainage Layer. GML = Geomembrane. BSL = Barrier Soil Layer.

[1] Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J.W., and Peyton, R. L. (1994). "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3," EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Table A 2: Parameters for determination of runoff curve number for each landfill phase

Scenario	Soil Texture	Surface slope	Surface Vegetation
Existing Environment	**Silt loam**	**10%**	**Poor Grass**
Landfill Open Waste	Municipal Waste	0.1%	Bare Soil
Landfill Daily Cover	Slightly compacted silt loam	0.1%	Bare Soil
Landfill Intermediate Cover	Moderately compacted silty clay	33%	Poor Grass
Landfill Final Cap	Moderately compacted silty clay loam	33%	Good Grass

Table A 3: Parameters for determination of runoff curve number for existing environment and each landfill stage

~~Stage~~Scenario	Average Surface Flow Path Length (m)
Existing Environment	500
Landfill Stage 1	150
Landfill Stage 2	200~~50~~
Landfill Stage 3	200~~100~~
Landfill Stage 4	300
~~5~~	~~400~~

Table A 4: HELP Model Leachate Results (Updated May 2021)

			OW	DC	IC	FC	OW	DC	IC	FC	OW	DC	IC	FC
Stage	**Liner Slope**	**Average Distance to Drain (m)**	**Average Annual Total Leachate Leakage (mm/year) /m²**				**Average Annual Total Leachate Collected from Drainage Layer (mm/year) / m²**				**Average Head on top of FML (mm)**			
All stages	4%	50	0.006	0.00327	0.00273	0.00246	538.800	275.662	229.513	207.203	3.562	1.816	1.513	1.364
1	20%	50	0.00143	0.00073	0.0006	0.00056	541.354	276.624	229.524	207.202	0.743	0.378	0.32	0.287
2	20%	75	0.00206	0.00106	0.00089	0.00081	538.85	276.465	231.338	207.292	1.11	0.567	0.475	0.425
3	20%	90	0.00245	0.00126	0.00106	0.00096	538.85	276.465	231.337	207.291	1.331	0.681	0.57	0.51
4	20%	100	0.00271	0.0014	0.00119	0.00107	538.916	277.541	233.654	207.517	1.48	0.759	0.64	0.568

* OW = Open Waste. DC = Daily Cover. IC = Intermediate Cover. FC = Final Cap.

Table A 5: HELP Model Runoff and Evapotranspiration Results (Updated May 2021)

Stage	Open Waste	Daily Cover	Intermediate Cover	Final Cap	Open Waste	Daily Cover	Intermediate Cover	Final Cap
	Average Annual Total Runoff (mm/year) / m^2				Average Annual Actual Evapotranspiration (mm/year) / m^2			
1	0.649	20.919	92.297	113.975	270.158	512.902	478.663	488.504
2	0.600	20.073	90.362	113.9	270.158	512.947	487.784	488.21
3	0.600	20.073	90.362	113.9	270.158	512.947	487.784	488.21
4	0.537	18.922	87.876	113.628	270.158	513.021	487.954	488.276

Table A 6: Predicted leachate collected through the drainage layer under worst case operational landfill phases (Updated May 2021)

Landfill Stage	Exposed liner*		Open Waste		Daily Cover		Intermediate Cover		Final Cap		Total Leachate Collected	
	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	(L/Yr)	(m^3/Yr)
1	10,000	8,095,000	2,500	1,348,788	11,500	3,173,214	28,000	6,426,446	9,000	1,864,825	20,908,272	20,908
2	10,000	8,095,000	2,500	1,347,073	11,500	3,175,468	33,000	7,608,848	48,000	9,948,205	30,174,594	30,175
3	10,000	8,095,000	2,500	1,347,090	11,500	3,176,759	32,000	7,386,447	101,000	20,933,922	40,939,218	40,939
4	10,000	8,095,000	2,500	1,347,222	11,500	3,186,537	3,000	697,979	159,000	32,983,269	46,310,008	46,310
Closure	-								186,000	38,580,691	38,580,691	38,581

*100% of rainfall assumed to report from exposed liner. Annual average rainfall of 809.5 mm adopted.

Table A 7: Predicted leachate leakage through landfill liner during landfill development and after closure (updated May 2021)

Landfill Stage	Exposed waste		Exposed waste with Daily Cover		Intermediate Cap		Final Cap		Total	
	Area (m^2)	Leachate Leakage (l/Yr)	Area (m^2)	Leachate Leakage (L/Yr)	Area (m^2)	Leachate Leakage (L/Yr)	Area (m^2)	Leachate Leakage (L/Yr)	(Litres/year)	(m^3/Yr)
1	2,500	15	11,500	29	28,000	60	9,000	17	119	0.12
2	2,500	11	11,500	23	33,000	55	48,000	72	160	0.16
3	2,500	10	11,500	21	32,000	49	101,000	139	218	0.22
4	2,500	10	11,500	21	3,000	5	159,000	223	258	0.26
Closure	-						186,000	261	261	0.26

Appendix D – Monitoring Plan

Monitoring of surface water and groundwater is proposed to be undertaken during pre-construction, construction, operation and after landfill closure at the locations and frequency proposed in Table D 1. The location of the groundwater monitoring wells and surface water monitoring points are presented in Drawing 51-12506381-C309. The parameters proposed to be analysed in the water samples are presented in Table 5 in Section 4.2.4 of the main report. Establishment of baseline data will be required for at least 18 months prior to construction commencing. The data collected as part of this study will be included as part of the baseline monitoring database and samples will continue to be collected and analysed on a quarterly basis.

Table D 1: Water Monitoring Locations and Frequency

Monitoring Point	Frequency
Groundwater sample from subsoil drainage system prior to discharge to wetlands or pumped for non-potable use (GW7)attenuation basin.	Continuous monitoring of pH, EC and Ammonia for duration of consent once subsoil underdrains established Monthly monitoring of full set of parameters for the duration of the consent
Groundwater monitoring wells (2) (GW1 – GW6, and BH202 on Drawing 51-12506381-C309)	Quarterly monitoring for the duration of the consent
Surface water monitoring (3) (SW1 – SW67 on Drawing 51-12506381-C309)	Continuoues monitoring of pH, EC and Ammonia for stormwater discharge from Stage 1 of the landfill – when flows occur (SW2) Monthly monitoring for the duration of the consent (when flows occur) for all locations
Wetland monitoring - Monitoring of wetland features downstream of the landfill (within 100m of the attenuation basintoe bund) to identify any long term changes in water levels associated with landfill development	Continuous monitoring – data loggers

1) Groundwater monitoring wells to be sampled either by low flow, or purge 3 well volumes followed by a grab sample

2) Sample flowing water only (not stagnant), ensure sample from centre of water column to avoid bottom or surface sediment/debris. See Surface Water report for further background

Parameter trigger levels, and contingency actions should trigger levels be exceeded, will be detailed in the landfill management plan (LMP).

This report has been prepared by Zoë Pattinson, a hydrogeologist with GHD Ltd, under the direction and supervision of Anthony Kirk. Zoe has 8 years' experience in consulting and the following qualifications and institutional memberships: BSc Environmental Geoscience. MSc Hydrogeology. Fellow of the Geological Society of London (FGS). International Association of Hydrogeologists (IAH). Anthony is a Principal and Technical Director with GHD Ltd, who has over 20 years' experience in environmental consulting, and has the following qualifications and institutional memberships: BSc Chemistry and Earth Science. MSc Chemistry. NZ Hydrological Society. International Association of Hydrogeologists (IAH).

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