Brookvale Green Development

Hydrogeological Assessment

July 2026

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1 Introduction

The Brookvale Green project is a proposed residential development on the former Te Mata Mushrooms Limited site at 174 and 176 Brookvale Road, Havelock North (the *site*). Application for the proposed development is currently proceeding under the Fast-track Approvals Act 2024.

LWP was originally commissioned to review the geology and hydrogeology of the site and provide recommendations to ensure works associated with a proposed stream diversion do not result in adverse effects on the underlying groundwater resource. After review of the application by the Hawkes Bay Regional Council (HBRC) and Hastings District Council (HDC), the scope of the assessment was extended to cover construction activities more generally across the proposed development.

This report incorporates data and findings from the recently completed Geotechnical Assessment (Hawke's Bay Geotech, 2026) appended to the substantive application, to provide an updated overview of the geology and hydrogeology of the site and associated risks to groundwater quality.

1.1 Background

Historically, the Hastings District Council (HDC) utilised three shallow wells located in road reserve along Brookvale Road as the primary source of municipal water supply for Havelock North. In August 2016, a major outbreak of gastroenteritis in Havelock North was traced to microbial contamination of the Brookvale Road supply wells.

While two of the three HDC Brookvale Road supply wells have been decommissioned following the 2016 gastroenteritis outbreak, HDC currently holds resource consent AUTH-132156-01 authorising abstraction from Well No. 4151 for '*Augmentation and Emergency Use Only*'. A significant portion of the proposed Brookvale Green development lies within the potential capture zone of this Well 4151. Consequently, land development activities on the Brookvale Green site have the potential to adversely affect underlying groundwater quality and potentially present an increased risk to water quality in the HDC supply.

1.2 Havelock North Enquiry

The *Government Inquiry into Havelock North Drinking Water*[1] canvassed a wider range of issues which potentially contributed to the August 2016 gastroenteritis outbreak.

Among issues identified by the Enquiry was insufficient recognition of the vulnerability of the Tukituki Aquifer to potential contamination resulting from overlying land use activities and the potential for this vulnerability to be increased as a result of activities which alter the natural integrity of lower permeability silt layers overlying the aquifer.

Part 2 of the Enquiry's report outlined six principles which "*….should imbue every aspect of the New Zealand approach to drinking water*". These principles include:

[1] https://www.dia.govt.nz/government-inquiry-into-havelock-north-drinking-water-report---part-1---overview

Principle 1: A high standard of care must be embraced

Unsafe drinking water can cause illness, injury or death on a large-scale. All those involved in supplying drinking water (from operators to politically elected representatives) must therefore embrace a high standard of care akin to that applied in the fields of medicine and aviation where the consequences of a failure are similarly detrimental to public health and safety. Vigilance, diligence and competence are minimum requirements and complacency has no place.

Principle 2: Protection of source water is of paramount importance

Protection of the source of drinking water provides the first, and most significant, barrier against drinking water contamination and illness. It is of paramount importance that risks to sources of drinking water are understood, managed and addressed appropriately. However, as pathogenic microorganisms are found everywhere, complete protection is impossible and further barriers against contamination are vital.

Principle 3: Maintain multiple barriers against contamination

Any drinking water system must have, and continuously maintain, robust multiple barriers against contamination appropriate to the level of potential contamination. This is because no single barrier is effective against all sources of contamination and any barrier can fail at any time. Barriers with appropriate capabilities are needed at each of the following levels: source protection; effective treatment; secure distribution; effective monitoring; and effective responses to adverse signals. A "source to tap" approach is required.

Principle 4: Change precedes contamination

Contamination is almost always preceded by some kind of change and change must never be ignored. Sudden or extreme changes in water quality, flow or environmental conditions (for example, heavy rainfall, flooding, earthquakes) should arouse particular suspicion that drinking water might become contaminated. Change of any kind (for example, personnel, governance, equipment) should be monitored and responded to with due diligence.

Principle 5: Suppliers must own the safety of drinking water

Drinking water suppliers must maintain a personal sense of responsibility and dedication to providing consumers with safe water. Knowledgeable, experienced, committed and responsive personnel provide the best assurance of safe drinking water. The personnel, and drinking water supply system, must be able to respond quickly and effectively to adverse monitoring signals. This requires commitment from the highest level of the organisation and accountability by all those with responsibility for drinking water.

Principle 6: Apply a preventive risk management approach

A preventive risk management approach provides the best protection against waterborne illness. Once contamination is detected, contaminated water may already have been consumed and illness may already have occurred. Accordingly, the focus must always be on preventing contamination. This requires systematic assessment of risks throughout a drinking water supply

from source to tap; identification of ways these risks can be managed; and control measures implemented to ensure that management is occurring properly. Adequate monitoring of the performance of each barrier is essential. Each supplier's risk management approach should be recorded in a living WSP which is utilised on a day to day basis.

These principles form the basis for managing effects of the proposed Brookvale Green development.

2 Site Description and Proposed Works

The Brookvale Green site is located on a flat-lying alluvial terrace extending northwards of a prominent terrace riser running approximately parallel to Arataki Road.

The subsurface geology of the site comprises a surficial layer of silty clay underlain by a thick sequence of alluvial sediments alternating layers of gravel, sand and silt. These alluvial sediments host a spatially extensive aquifer system in excess of 100 metres thick. Groundwater in this aquifer flows in a north-westerly direction, with significant discharge to the Mangaterere Stream observed in the reach immediately downstream of Brookvale Road.

S-Map[2] characterises soils on the site as including imperfectly to well-drained recent Hinds and Waimakariri soils which occupy the bulk of the site, along with an area of poorly drained Ruataniwha soils extending along the base of the alluvial terrace toward the south-eastern corner of the site.

The site is drained by un-named two surface watercourses which flow in a north-westerly direction into the downstream section of Mangateretere Stream via a culvert under Brookvale Road. These waterways are characterised as ephemeral, typically containing flowing water only in response to significant rainfall events.

Proposed works on site include:

- Cut and fill earthworks to form the final grade.
- Road subgrade excavations.
- Re-alignment of an approximately 360 metre section of the northern watercourse from its current position to more closely follow the northern site boundary.
- Installation of wastewater and stormwater infrastructure including:
  - A stormwater wetland.
  - Raingardens.
  - Stormwater detention and treatment devices.
  - Drainage and services trenches.
  - Drainage outlet structures

[2] https://smap.landcareresearch.co.nz/maps-and-tools/app

- Pump station works.

- Bore decommissioning
- Dewatering during construction

3 General Hydrogeological Setting

The Heretaunga Plains comprise a sequence of alluvial sediments deposited by the Tutaekuri, Ngaruroro and Tukituki rivers over the late Quaternary Period (last 250,000 years) which form highly permeable aquifers. These permeable layers are interspersed with finer-grained marine and estuarine sediments deposited during periods when sea levels were appreciably higher than the present day. In places, these fine-grained sediments separate the gravel aquifers forming aquitards which act to impede vertical groundwater flow. In general, aquifers on the Heretaunga Plain transition from unconfined in the west to relatively well confined in the east (exhibiting widespread artesian conditions), reflecting the presence of thicker and more laterally continuous aquitards near the present-day coast (Dravid and Brown, 1997[3]).

The Brookvale Road area is located in the Tukituki Aquifer, near the eastern margin of the Heretaunga Plains. This groundwater zone encompasses the area between the Tukituki River to the east and the Karamu Stream to the west, effectively forming a portion of the wider Heretaunga Plains groundwater system (HBRC, 2018[4]). The alluvial deposits in this area are characterised as coarse, open framework gravels which are highly permeable and which form high yielding aquifers. These gravel deposits are inferred to reflect Holocene gravel deposits accumulated on an alluvial fan formed by the Tukituki River which merge to the west and north with similar deposits associated with the Ngaruroro River.

The alluvial deposits are overlain by finer-grained sediments (silts and clays) of marine or estuarine origin which generally thicken to the west and north. In the past these fine-grained sediments were generally assumed to form a low permeability aquitard overlying a majority of the Tukituki Aquifer resulting in a transition from unconfined conditions near the Tukituki River to more well confined conditions to the west and north. This transition in aquifer confinement is reflected in groundwater levels which typically occur >4 metres below ground close to the Tukituki River but become artesian across the area west of Brookvale Road.

Recharge to the Tukituki Aquifer is inferred to be primarily derived from seepage losses from the Tukituki River, with a smaller component of recharge via land surface infiltration occurring where the surficial silts and clay deposits thin and become discontinuous closer to the Tukituki River. Groundwater flow is inferred to occur in a north-westerly direction, with appreciable discharge of throughflow occurring to the Mangateretere Stream immediately downstream of Brookvale Road where artesian head results in discharge of groundwater through areas where the surficial silt and clay later is thin or absent along the base of the channel.

Figure 2 shows a generalised gross section of the Tukituki Aquifer in the vicinity of Brookvale Road. The figure shows:

[3] Dravid, P.N., Brown, L.J., 1997; Heretaunga Plains Groundwater Study. HBRC and IGNS Publication, May 1997.

[4] HBRC, 2018; Heretaunga Plains Development Report. HBRC Report RM18-14, May 2018.

- The thickness of the surficial silty clay layer in the Brookvale Road area is limited. Bore logs in the Brookvale Road area typically indicate between 1 and 3 metres of fine-grained sediments overlying permeable alluvial deposits, reducing in thickness along the bed of stream channels crossing the area.
- Layers of coarse, poorly sorted alluvial gravels of the Tukituki fan interspersed with irregular and laterally discontinuous lenses of lower permeability clay, silt and 'clay-bound' gravels underlie the surficial silty clay later. These gravels typically exhibit high permeability, with aquifer transmissivity values in excess of 10,000 m^2/day commonly observed in aquifer tests.
- Tightly packed ('clay-bound') gravels, which are likely to retard vertical groundwater flow, underlie the upper gravel layer.

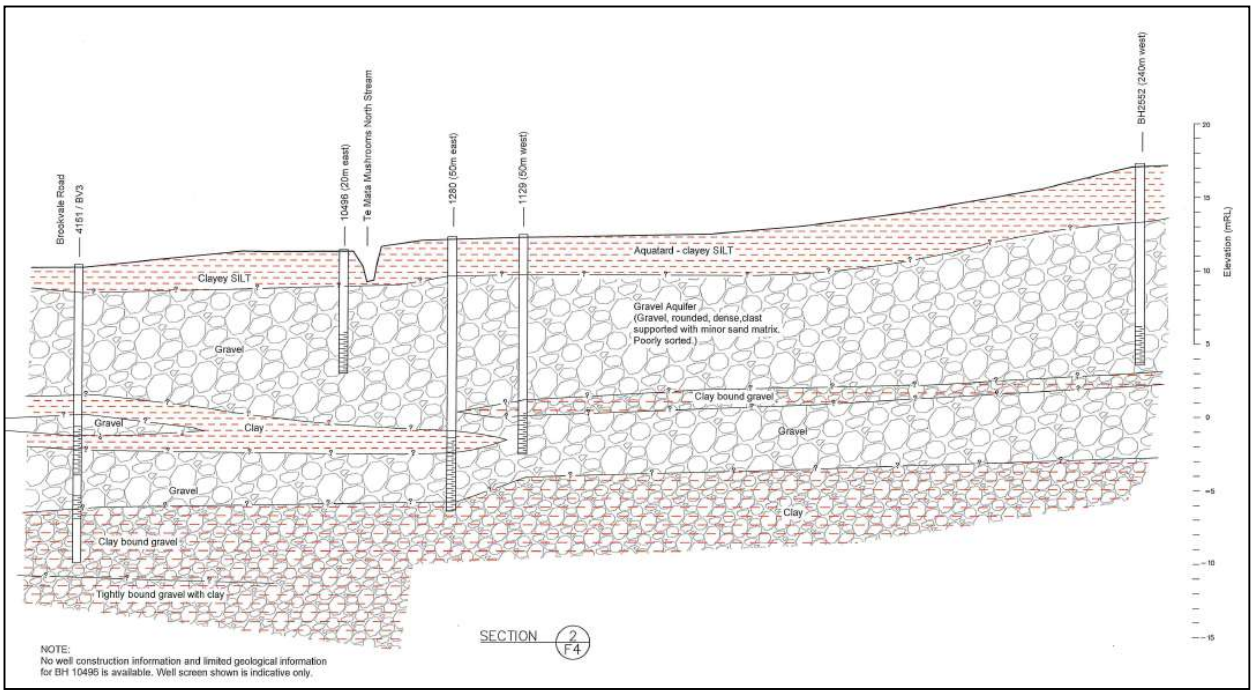

Figure 1. *Geological cross section running west to east from Brookvale Road (Tonkin and Tayler, 2016[5]).*

3.1 Local Hydrogeological Conditions

Historical assessments of subsurface geology and hydrogeology in the vicinity of Brookvale Road (e.g., MWH (2007)[6], Tonkin and Taylor (2016) and Lattey (2017)[7]) largely relied on geological logs recorded on the HBRC Wells database. While some of these logs were recorded as part of detailed geological investigations, a majority are based on generalised observations of subsurface geology

[5] Tonkin and Taylor, 2016; Bacteriological Contamination Investigation Brookvale Road Water Supply Bores, Havelock North. Report prepared for Hastings District Council, November 2016.

[6] MWH, 2007; Hastings District Council Brookvale Road Water Supply Bores Resource Consent Renewal, January 2017.

[7] Lattey, 2017; Geological Investigation. 174 Brookvale Road, Havelock North, Hawke's Bay. Report prepared for Te Mata Mushrooms Ltd, January 2017.

recorded by drillers. The spatial distribution of these logs is also limited, with a majority located along or west of Brookvale Road or across the central section of the Brookvale Green site.

The Hawke's Bay Geotech Geotechnical Assessment Report (2026)[8] combined existing geological data with the results of recently completed site investigations to develop a detailed geotechnical ground model of the Brookvale Green site. As illustrated on Figure 3, in addition to existing drillers logs, the model was developed using geological data recorded from 18 cone penetration tests (CPT), 6 scala penetration tests (SPT), 32 test pits and 20 hand augured holes distributed across the site.

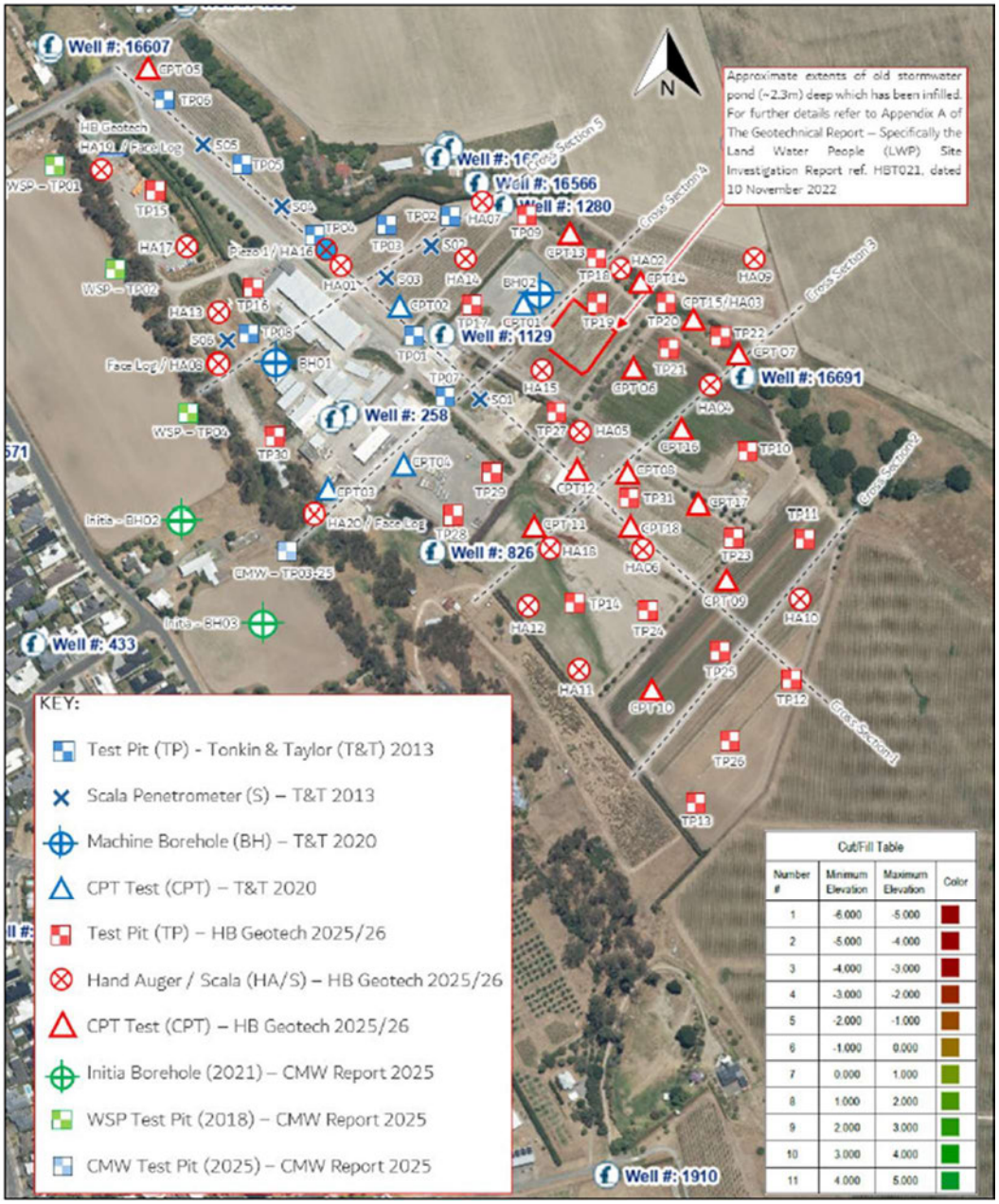

Figure 2. *Geological Investigations undertaken on the Brookvale Green site (reproduced from Hawke's Bay Geotech, 2026).*

[8] Subsequently referred to as the 'Geotechnical Report'

As detailed in Table 1, the model comprises seven individual geological units:

- Gravel fill: fill materials beneath existing roads and hardstand areas. Generally limited to a thickness of less than 0.5 metres.
- Weak and Organic Fill: fill placed into historical excavations or utilised to infill a previously re-aligned section of the northern drainage channel. Fill depth up to 3 metres in places.
- Natural organic soils: soils naturally developed in the base of existing drainage channels. Soil depth generally between 0.6 and 1.2 metres.
- Sandy silt to clayey silt: near surface deposits of fine-grained silt which are laterally continuous across the site, decreasing in thickness from ~4 metres toward Brookvale Road to less an 1 mete thick across south-eastern part of the site.
- Sandy Gravels: a thin (, laterally continuous layer of alluvium which merges into the thicker alluvial deposits to the west but which forms a near-surface parting within the silty clay deposits to the east.
- Deeper silts: Continuation of the near-surface silt deposits below the shallow gravel layer.
- Deeper gravel units: coarse-open framework gravels which host the Tukituki Aquifer.

Table 1. *Geotechnical ground model for the Brookvale Green site (modified from Hawke's Bay Geotech, 2026).*

Soil Unit(s)	**General Location**	**Indicative Depth to Top of Unit (m) min - max**	**Indicative Depth to Base of Unit (m) min-max**
Gravel Fill	Industrial areas, roads and carparks	Surface	0.3 - 0.5m
Weak and Organic Fill	Old channel infills and some fill earthworks in the north-west of the site. Potential for other localised areas on site	Below topsoil	1.0 - 3.0m
Natural organic and weak soils	Primarily within the base of the eastern ephemeral stream channel Likely within other stream channels	Below topsoil	0.6 - 1.2m
Sandy silt to clayey silt	Site wide (main unit encountered below topsoil or existing fill)	0.3 - 3.0m	0.8 - 4.0m
Sandy gravels	Site wide (main unit encountered below the sandy to clayey silts)	0.8 - 4.0m	2.5 - 10m
Deeper fine-grained units / Silts (clayey - sandy)	Site wide (main deeper unit along with sandy gravels - sometimes interbedded)	2.5 - 10m	9.0 - 10m
Deeper gravel units	Site wide (main deeper unit along with very stiff fine-grained units. Sometimes interbedded)	10 - >15m	Unknown

Figure 3 shows a geological cross section from the Geotechnical Report following a north-west to south-east orientation across the central portion of the Brookvale Green site. Four further cross sections orientated south-west to north-east (not reproduced in this report) are also provided in the Appendix C of the Geotechnical Report. These figures provide a detailed characterisation of the spatial variation in subsurface geology across the site. Key observations from these figures include:

- Surficial silt deposits are typically of the order of 3 to 4 metres thick across the north-western portion of the site (chainage 0 to ~400 m), reducing to less than 1 metre to the south-east (chainage 550 to 875 m).
- Across central and south-eastern portions of the site, the surficial silt deposits are underlain by a gravel layer generally ranging between 1.0 to 2.5 metres thick. This gravel layer forms a parting separating near-surface silt deposits from similar materials underlying the gravel layer. These deposits appear to be laterally continuous, coalescing with thicker alluvial deposits towards the eastern and western boundaries of the site.
- Deeper silt deposits effectively form a 'lens' of lower permeability material underlying the upper gravels across central and eastern portions of the site.
- Fill up to 2.4 metres deep, comprising a range of materials from dense gravel to organic silt with minor gravel and sand was observed at several locations across the site (refer Figure 7 of the Geotechnical Report). These materials reflect infilling of the previously re-aligned section of the northern watercourse and historical earthworks.
- Test pits (TP18, TP20, TP22) in the channel of the northern watercourse indicate between 0.6 and 1.2 metres of sandy silt with trace to minor clay overlying alluvial gravels. These observations are recorded in the section of the northern watercourse upstream of the section which was re-aligned in ~2016 so are presumed to reflect 'natural' conditions where the thickness of the surficial silt deposits had been reduced due to incision of the channel.

It is noted that although near-surface gravel deposits were identified in central and eastern portions of the site during previous investigations (e.g., Lattey (2017) observed a thin gravel layer exposed in the batters of the northern watercourse), these deposits were inferred to represent isolated gravel lenses occurring within the surficial silt deposits. Based on recent information, this shallow gravel layer appears to be laterally continuous across central and eastern areas of the site.

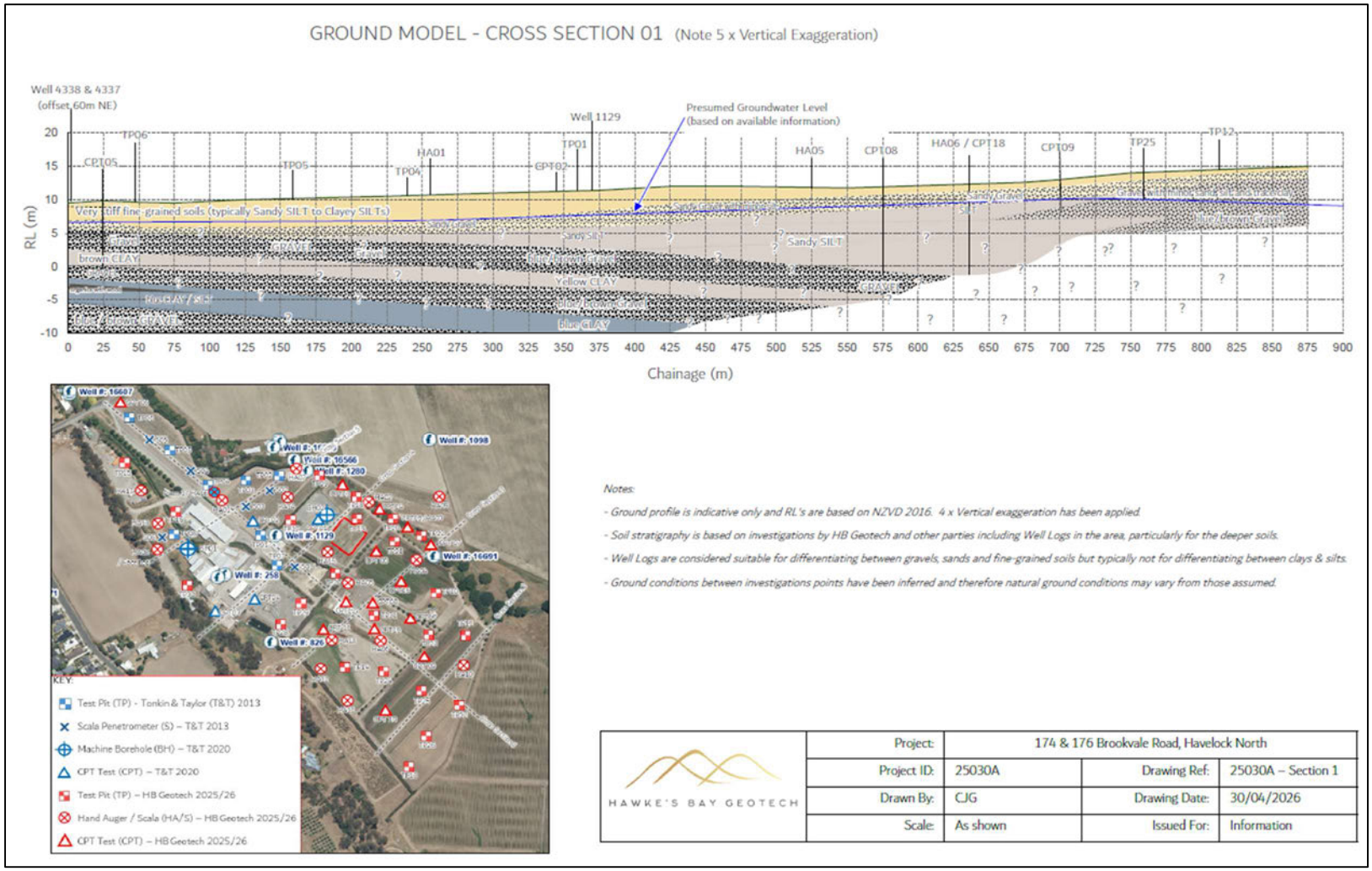

Figure 3. *Geological section across the Brookvale Green site orientated north-west to south-east (reproduced from Hawke's Bay Geotechnical, 2026 (Appendix C)).*

Figure 4 shows the spatial distribution of static groundwater levels recorded on the HBRC Wells database in the Brookvale Road area. The data shows static levels along Brookvale Road are relatively tightly constrained, ranging between -2.18m bgl and -2.54m bgl, with the limited range interpreted to reflect the hydraulic connection between shallow groundwater and the nearby Mangateretere Stream immediately downstream of Brookvale Road.

To the east of Brookvale Road, static water levels generally increase to between 4 to 5 metres bgl across the Brookvale Green site towards Te Mata Mangateretere Road. The Geotechnical Report records groundwater being encountered between 1 to 2 metres below the channel base in the northern watercourse (~3 to 4 metres below the surrounding ground level).

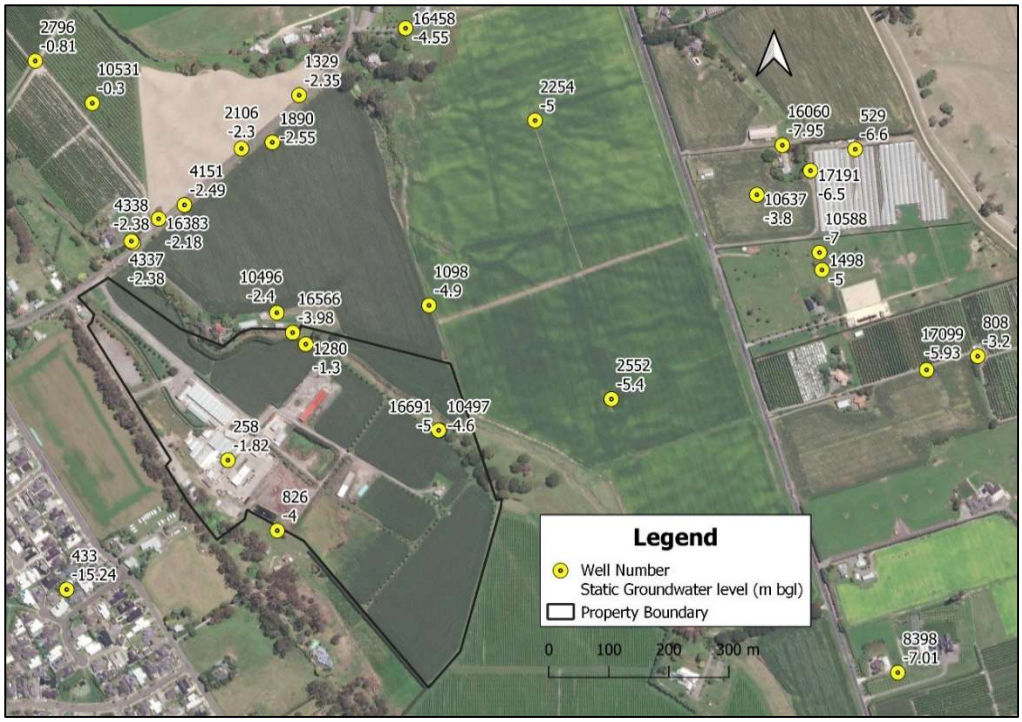

***Figure 4**. Static groundwater levels recorded in the Brookvale Road area (source HBRC).*

Groundwater inflow into the shallow gravel layer overlying the deeper silt deposits was observed in test pits across the eastern portion of the site (including test pits TP14, TP22, TP23, TP24 and TP31). at depths of between 1.0 to 2.0 m bgl. Given static water levels observed in surrounding wells, saturation within this unit may reflect perching of groundwater on the underlying silt deposits. Groundwater in the shallow gravel layer is likely to flow laterally to the west following the topographic gradient of the upper surface of the deeper silt unit and merge with the regional water table where the gravel deposits thicken toward the western portion of the site.

3.2 Hydrology

The watercourse traversing the northern portion of the site is characterised by a broad incised channel with grassy banks. Data available to characterise the hydrology of this waterway is limited to a series of observations undertaken over a period of a week in July 2022 as part of an investigation to characterise effects of unauthorised earthworks (construction of a stormwater pond) on the former Te Mata Mushrooms site (LWP, 2022). During this period significant rainfall

was recorded in the surrounding area (75mm between 10th and 15th June 2022, including 38mm on the 12th July) . A summary of these observations indicates:

- Semi-continuous discharge of the order of <1 L/s was observed following rainfall on the 12th July. This discharge largely ceased the following day.
- Areas of ponded water in the channel persisted for several days, gradually decreasing in extent indicating slow seepage into the stream bed (evaporation was inferred to be minimal during the observation period).
- Discharge of the order of 1 L/s from the southern branch into a pool situated immediately downstream of its confluence with the main branch. This discharge was sourced from a from spring located along the base of the elevated alluvial terrace to the south. Discharge from the pool was generally <1 L/s indicating seepage from the pool into the underlying ground.
- Infiltration in section of the stream which had been historically diverted (identified during the Havelock North enquiry) did not appear to occur any faster than observed in unmodified sections of the stream, with ponded water in this reach persisting for several days after rainfall.

Overall, these observations indicate the northern watercourse is ephemeral, only containing flowing water following significant rainfall (in excess of that recorded over the observation period). The slow reduction in the extent of ponded water and limited discharge from the pool downstream of the south branch confluence suggest that water from the stream does naturally infiltrate into the underlying aquifer, albeit at a low rate.

4 Brookvale Green Water Quality Risk

As outlined in Section 1, HDC currently hold resource consent AUTH-132156-01 authorising abstraction for '*Augmentation and Emergency Use Only*' from Well No. 4151 located adjacent to Brookvale Road. Due to the shallow water table, rapid permeability and variable thickness of low permeability silt material overlying the aquifer, groundwater quality in the vicinity of Well 4151 has the potential to be adversely affected by land use activities occurring across the up-gradient area.

The Brookvale Green site is located approximately 200 metres up-gradient of Well 4151. Activities associated with the proposed development have the potential to result in increased water quality risk down-gradient of the site due to:

- Disruption of near-surface low-permeability silt layers which naturally limit the infiltration of contaminants into underlying groundwater and/or exposure of permeable alluvial sediments.
- Development of infrastructure for stormwater and wastewater management which potentially contain elevated concentrations of microbial and chemical contaminants.
- Introduction of contaminants to groundwater during construction activities (e.g., spillage, adverse weather events).
- Mobilisation of contaminants during removal of undocumented fill identified in areas of the site.

The following section provides an assessment of water quality risks associated with the proposed Brookvale Green development following the Source - Pathway - Receptor model outlined in the *Technical Guidelines for Drinking Water Source Protection Zones* (PDP, 2018)[9]. These Guidelines are based on the well accepted method for evaluating contamination risks to drinking water sources, which involves assessing:

- the source of contamination
- the receptor that may be adversely affected by the contamination
- the pathway that allows the contaminant to reach the receptor.

A common method for managing risks to drinking water is to eliminate one of these three components, or to make the pathway between the source of contamination and receptor contain sufficient barriers (e.g. sufficient attenuation of contaminant concentrations), so that the risk of an adverse effect on the drinking water supply is acceptably low. As noted in Water Services Authority guidance on drinking water safety planning[10]:

> *Effective risk management is about identifying all potential hazards and hazardous events that could affect your drinking water supply, assessing the likelihood and consequences of these, and implementing suitable controls to reduce the risk of the unwanted event occurring*

For the proposed Brookvale Green development detailed identification of water quality risks and proposed risk mitigation will be documented in a Groundwater Protection Assessment and implemented through a Source Water Protection Plan developed as part of proposed consent conditions and subject to approval by HBRC and HDC prior to the commencement of works.

4.1 Source

Proposed works on site include which have the potential to alter water quality risk include:

- Cut and fill earthworks to form the final grade
- Road subgrade excavations
- Re-alignment of an approximately 360 metre section of the northern watercourse from its current position to more closely follow the northern site boundary
- Installation of wastewater and stormwater infrastructure including:
  - A stormwater wetland.
  - Raingardens.

[9] PDP, 2018; Technical Guidelines for Drinking Water Source Protection Zones. Report prepared for the Ministry for the Environment, June 2018.

[10] https://www.taumataarowai.govt.nz/drinking-water-suppliers-and-operators/for-drinking-water-suppliers/how-to-guidance/preparing-a-drinking-water-safety-plan/guidance-for-drinking-water-safety-planning#e643

- Stormwater detention and treatment devices.
- Drainage and services trenches.
- Drainage outlet structures
- Pump station works.

- Bore decommissioning
- Dewatering during construction

These activities have the potential to alter potential risks to groundwater quality down-gradient of the site due to:

- Disturbance of low permeability near-surface silt deposits
- Interception and/or disturbance of uncertified fill materials and organic soils
- Creation of preferential pathways for infiltration from the land surface
- Exposure or disturbance of permeable gravels
- Alteration to existing groundwater flow patterns.
- Introduction of contaminants during construction (including stormwater infiltration, spills and during extreme weather events)

Potential contaminants associated with these activities include:

Microbial

4.2 Receptor

For the purposes of this assessment, HDC Well 4151 is assumed to be the primary receptor located down-gradient of the Brookvale Green Development. This bore is located on road reserve adjacent to Brookvale Road approximately 100 metres north of the site entrance. Based on the inferred north-westerly groundwater flow direction, this bore is located approximately 200 metres directly down-gradient of the Brookvale Green site. However, as further discussed in the following section, alteration of the natural hydraulic gradient during pumping may induce groundwater flow from areas toward the western end of the site, potentially shortening this flow path.

Attachment 1 provides the bore log for Well 4151 recorded on the HBRC Wells database. It records Well 4151 was constructed using a 400 mm diameter steel casing drilled to a total depth of 35 metres bgl. The drillers log records subsurface geology as comprising a surficial layer of '*brown clay with silt*' between 0.05 and 2.0 metres bgl, underlain by an alternating sequence of sandy blue/brown gravel, brown gravel with clay and blue/brown clay. The primary water-bearing zones intercepted occur in sandy gravels between 15.2 to 20.0 and 22.6 to 26.5 metres bgl. The HBRC log records the well as being screened in the upper water-bearing gravel layer (15.2 to 20.0 metres bgl) although, as noted by Tonkin and Taylor (2016), alternative versions of the log appear to suggest the bore may have also been screened in the lower water-bearing gravel layer (22.6 to 26.5 metres bgl).

The HBRC log records results of an aquifer test conducted in September 2002 which yielded an estimated aquifer transmissivity value of 22,680 m^2/day and a storativity of 0.0016. The high aquifer

transmissivity is reflected in the estimated specific capacity of 42.4 L/s/m, both of which suggest that pumping of Well 4151 (even at its maximum consented rate of 90 L/s) is unlikely to induce significant drawdown radial drawdown in the surrounding aquifer. The log also records a static water level of -2.49 m, close to the base of the surficial silty clay layer.

It is noted that the HBRC Wells database also records a significant number of existing wells in the vicinity of the Brookvale Green site. The status of these bores is currently unknown. It is recommended that a survey of existing wells in the area is undertaken as part of the development of the Groundwater Protection Assessment.

4.2 Pathway

The potential pathway for movement of contaminants between the Brookvale Green site and down-gradient receptors involves infiltration of contaminants from the land surface to the underlying water table, followed by lateral transport through the underlying groundwater system.

Gyopari (2016)[11] documented the development of a steady-state groundwater model to simulate capture zones and estimate plausible groundwater travel times for the HDC Brookvale Road municipal supply in evidence presented to the Havelock North Enquiry. Figure 5 shows the results of a particle tracking simulation undertaken for a scenario simulating continuous abstraction from Well4151 at a rate of 90 L/s. The figure shows pathlines from Well 4151 extend in a south-easterly direction from Well 4151 crossing the northern portion of the Brookvale Green site (along and to the south of the northern watercourse). Estimated groundwater travel times range from <10-days near the northern watercourse close to Brookvale Road to 50-days across central areas of the Brookvale Green site, indicating a direct and relatively rapid connection between groundwater underlying the Brookvale Green site and Well 4151, when the well is being pumped at its maximum consented rate (90 L/s).

As discussed at some length in Part 1 of the Havelock North Enquiry, the Tukituki Aquifer was historically assumed to be confined due to the presence of a laterally continuous layer of silt which limited hydraulic connection between the land surface and underlying groundwater.

However, as documented in the Section 3, recent geological investigations indicate a limited thickness of surficial silt deposits overlying a shallow gravel layer (which is at least partially saturated) across central and south-eastern areas of the Brookvale Green site. The potential therefore exists for contaminants introduced at (or below) the land surface to infiltrate to this shallow gravel layer and be transported laterally to areas toward the western site of the site where this gravel layer merges with deeper gravel units hosting the regional water table.

[11] Gyopari, M.C., 2016; Statement of evidence by Dr Mark Christopher Gyopari on behalf of Hastings District Council to the Government Inquiry into Havelock North Drinking-Water. 22 December 2016.

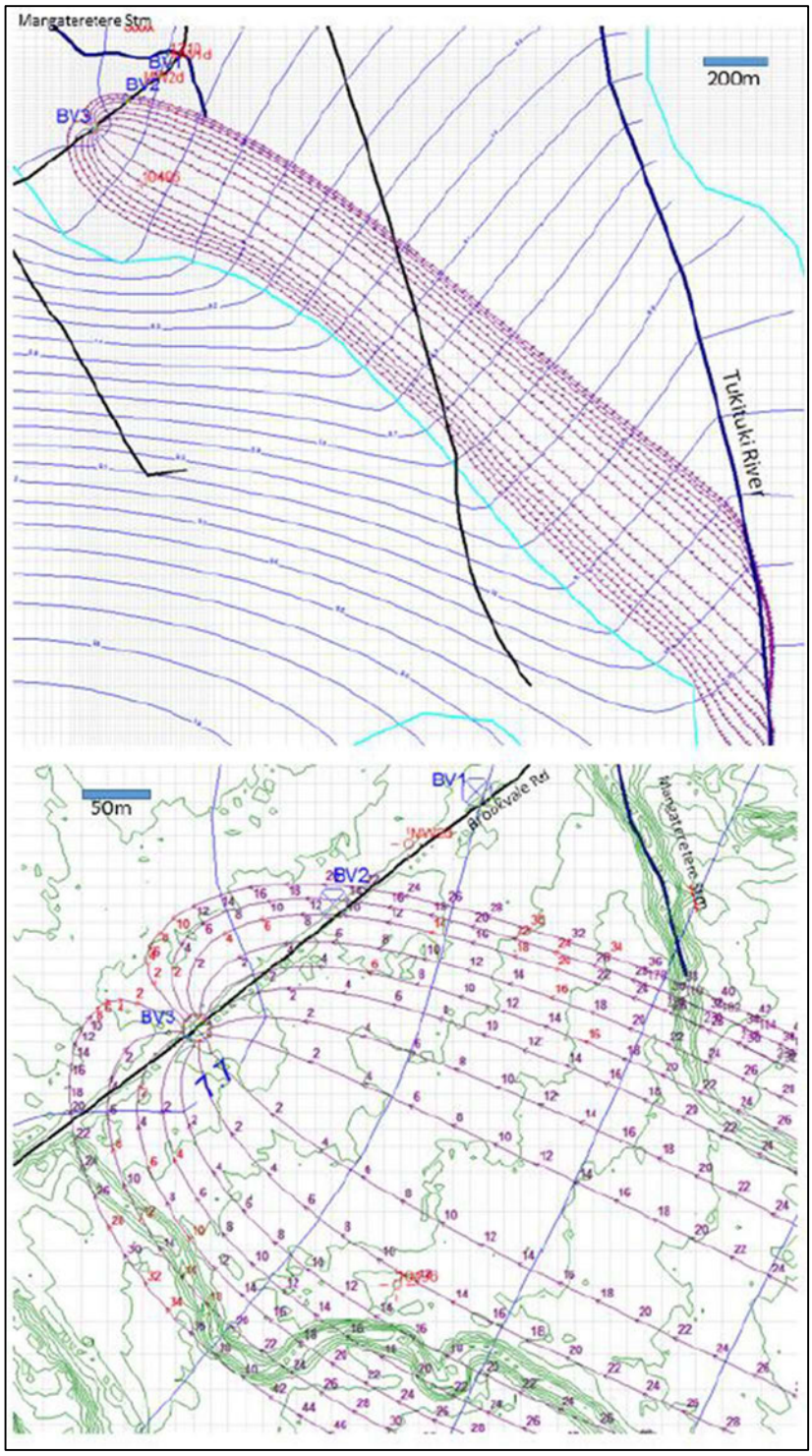

Figure 5. *Pathlines and estimated groundwater travel times (days) for Well 4151 (BV3) pumping at a continuous rate of 90 L/s (reproduced from Gyopari (2016)). Alignment of the northern watercourse on the Brookvale Green site identifiable on LIDAR topography shown on the lower panel (green contours).*

Figure 6 shows the interpreted depth below ground to alluvial gravel across the Brookvale Green site (based on the first recorded observation of gravel in individual test pit, borehole and hand auger logs). The figure shows a relatively consistent pattern with alluvial gravels underlying >2 metres of silt across the western half of the site but decreasing to less than 1 metre below the land surface to the south-east. The decreased thickness of the surficial silt deposits across central and south-eastern portions of the site is likely to provide a more direct pathway for contaminant losses to groundwater that exists to the west where the silt deposits are thicker.

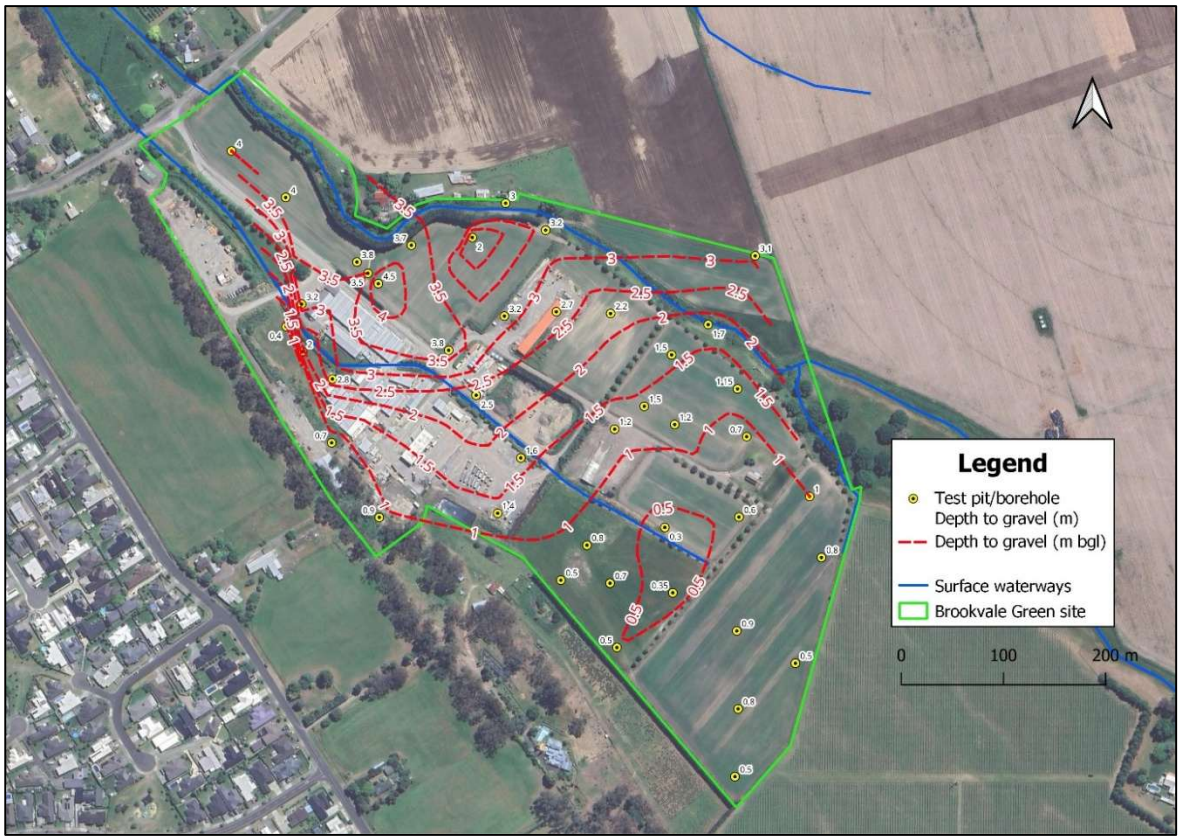

***Figure 6**. Depth to gravel (m bgl) recorded on borehole logs, test pits and hand augur holes on the Brookvale Green site.*

The potential for contaminant loss to groundwater is also likely to be elevated in areas where surficial silt materials have been removed during historical earthworks and replaced with un-documented fill. Such areas include the historically re-aligned section of the northern watercourse, infilled sections of the southern watercourse (particularly across eastern areas of the site) and the stormwater pond located in the central/northern section of the site. Removal of weak and organic soils within the section of the northern watercourse proposed to be re-aligned could also create a pathway for more direct infiltration of contaminants into underlying groundwater.

5 Discussion

Groundwater in the Brookvale Road area is vulnerable to contamination associated with overlying land use activities. This vulnerability is mitigated (at least in part) by the presence of a layer of silt overlying the aquifer which limits direct infiltration from the land surface to the underlying aquifer. However, as discussed at some length during the *Government Inquiry into Havelock North Drinking*

Water, areas where this silt layer is thin or absent present an elevated risk to down-gradient groundwater quality.

HDC currently hold resource consent AUTH-132156-01 authorising abstraction for '*Augmentation and Emergency Use Only*' from Well No. 4151 located adjacent to Brookvale Road. This well is screened between 15.2 to 20.0 metres bgl in a layer of highly permeable alluvium. While the high permeability of the alluvial materials (>20,000 m^2/day) limits drawdown in the surrounding aquifer, vertical flow induced by pumping has the potential to draw from near the water table surface (with higher potential to contain contaminants arising from overlying land use) into Well 4151.

Well 4151 is located down-gradient of the Brookvale Green site. Modelling undertaken for the Havelock North enquiry established the potential for direct and relatively rapid flow of groundwater from beneath the Brookvale Green site to Well 4151 (travel times >10 to 50-days depending on location). Consequently, changes to groundwater quality underlying the Brookvale Green site present a direct risk to water quality in Well 4151.

The thickness of the surficial silt layer is observed to vary across the Brookvale Green site. Central and western part of the site are typically underlain by >2 metres of silt which has the potential to significantly mitigate water quality risk. However, water quality risk increases across central and south-eastern areas of the site where the thickness of this silt layer decreases, and a relatively thin layer of gravel occurs at depths less than 2 metres bgl. This gravel layer appears to host shallow a shallow water table (at least in some areas) which is perched on underlying silt deposits. This unit therefore forms a potential pathway for contaminants infiltrating from the land to be flow laterally towards the western end of the site where it merges with thicker gravel deposits hosting the regional water table from which Well 4151 (and potentially other nearby wells) draw groundwater.

The proposed Brookvale Green development involves a wide range of activities, the effects of which have the potential to increase risks to down-gradient groundwater quality. These effects include:

- Disturbance of low permeability near-surface silt deposits.
- Creation of preferential pathways for infiltration from the land surface.
- Exposure or disturbance of permeable gravels.
- Interception and/or disturbance of uncertified fill materials and organic soils.
- Alteration to existing groundwater flow patterns.
- Introduction of contaminants during construction (including spills and during extreme weather events).
- Introduction of contaminants due to deterioration in the condition of infrastructure over time.

The extent to which proposed construction activities pose a risk to down-gradient groundwater quality will depend both on the nature of each specific activity (depth of excavation, extent of ground disturbance, potential contaminants present, impact on natural groundwater flow, potential for scour/erosion etc), as well as the specific location on the site where the activity occurs (e.g., depth

of surficial silt and underlying alluvium, presence of undocumented fill materials). Long-term management/mitigation of water quality risk will also require appropriate environmental monitoring and maintenance of infrastructure.

To ensure risks to groundwater quality are appropriately identified and managed, a Groundwater Protection Assessment will be prepared for the Brookvale Green development based on the finalised design. This assessment will include documentation of:

- Construction activities which may pose a risk to groundwater quality.
- Specification of engineering controls to mitigate potential infiltration and contaminant loss.
- Specification of management controls to mitigate risks to groundwater quality resulting from construction and long-term operation of the development.
- How the proposed engineering and management controls avoid creating or increasing risks to groundwater quality and down-gradient drinking-water supplies.

Recommendations of the Groundwater Protection Assessment will be operationalised through a Source Water Protection Plan which documents:

- Construction methodology
- Construction controls (including stop-work triggers)
- Supervision and inspection requirements during construction
- SQEP Hydrogeologist review
- Liner/barrier construction and QA
- Management of unexpected ground conditions
- Environmental controls
- Wet weather restrictions
- Monitoring locations, parameters, methodology, triggers for investigation and reporting requirements
- Management of dewatering (if required)
- Decommissioning of existing wells
- Notification requirements
- Verification and record keeping

In summary, subject to implementation of the controls identified in the Source Water Protection Plan, the proposed development is considered capable of being undertaken in a manner that appropriately manages risks to groundwater quality and downgradient drinking-water receptors. In particular, the Source Water Protection Plan will provide a construction-phase framework to ensure that higher-risk works are identified, appropriately supervised, and subject to site-specific controls, monitoring, and response procedures. This approach recognises the sensitivity of the Brookvale Road groundwater environment and provides a practical mechanism to ensure that groundwater

protection measures are confirmed and implemented as detailed design and construction methodologies are finalised.

Attachment 1. Well 4151 construction details and drillers log

HAWKES BAY REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

Well Number: 4151

IDENTIFICATION		WELL INFORMATION	
WQ Site		**Drill Date**	15/06/1998
NZTM Easting	1934988.979	**Driller**	Honnor Drilling Limited
NZTM Northing	5603185.138	**Casing Diameter (mm)**	400
Method	Differential GPS	**Bore Depth (m)**	35
Address	BROOKVALE ROAD, HAVELOCK NORTH	**Well Depth (m)**	28.5
		Screen top (m)	15.5
		Screen bottom (m)	20
		Open hole top (m)	
		Open hole bottom (m)	
		Water access	Unknown

Aquifer Information

Initial Water Level	-2.49
Initial Water Level Date	
Aquifer Lithology	Gravels
Aquifer Condition	Confined
Comments	Screen diameter is 340 mm o.d., slot size 0.110. Pumped for 24 hrs at 7200 l/m, drew down 2.3 m from -2.49m. TOC surveyed 2016 at 20.375m (HB Datum). MP at top of flange not standpipe.

Aquifer Test

Test Date	24-09-2002
Report Number	207
Maximum Pumping Rate (l/s)	89
Maximum DrawDown (m)	2.1
Duration (hours)	24
Number Of Pumping Steps	1

Aquifer Thickness (m)	9.3
Transmissivity (m^2/d)	22680
Storativity	0.0016
Hydralic Conductivity (m/d)	2438.7
Specific Capacity ((l/s)/m)	42.38

Bore Log

From Depth (m)	To Depth (m)	Lithology
0	0.05	FILL
0.05	2	brown CLAY with silt
2	10.5	brown GRAVEL
10.5	13	brown CLAY with gravel
13	14.3	brown CLAY
14.3	15.2	blue CLAY
15.2	20	brown GRAVEL (clean good and free)
20	22	brown GRAVEL with clay
22	22.6	CLAY (thin clay layer)
22.6	23.6	blue/brown GRAVEL with sand (water bearing)
23.6	26	blue GRAVEL with sand (pea gravel)
26	26.5	brown GRAVEL with clay (clay traces)
26.5	28	brown GRAVEL with clay (tight)
28	35	brown GRAVEL with clay (tight with very little water)