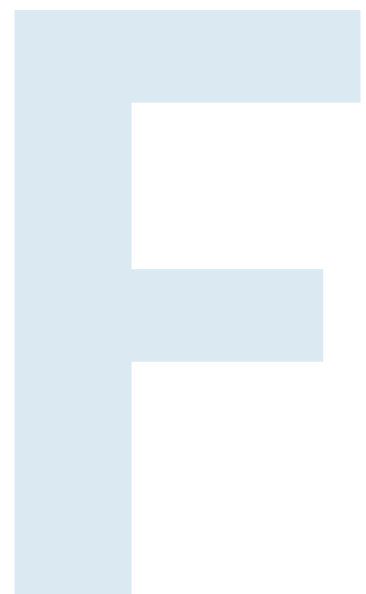


Technical Report F

Hydrogeology Assessment



Hydrogeological Assessment Report

Redvale Landfill Expansion

Prepared for: WM New Zealand

Prepared by: Tonkin & Taylor Ltd

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1 Introduction

1.1 General

Tonkin & Taylor Ltd (T+T) has been engaged by WM New Zealand (WMNZ) to provide technical assessments to understand the effects from a proposal to extend the use of Redvale Landfill, north of Auckland (the Project). This report forms part of a suite of technical reports prepared for WMNZ for inclusion in a substantive application for resource consent under the Fast-Track Approvals Act 2024.

This report assesses the actual and potential hydrogeological effects of the Project and is intended to support the Assessment of Environmental Effects (AEE).

1.2 Scope of work

The scope of this Hydrogeological Assessment includes the following:

- Describes the existing hydrogeological environment.
- Describes the actual and potential effects on groundwater expected to result from the construction and operation of the project.
- Recommends on-site measures to avoid, minimise or mitigate potential effects on groundwater, as appropriate.
- Outlines principles and general approach that will be followed to mitigate any residual adverse effects.

1.3 Site description

The Redvale Landfill is located in Dairy Flat, to the north of Auckland, approximately 9 km northwest of Albany and 1 km west of State Highway 1. Redvale Landfill, including the existing landfilling area and buffer zones, occupies approximately 88 ha in area. The landfill is divided into five main sub-areas for the purpose of describing the work within this application, known as the Northern, Eastern, Western, South-Western and South-Eastern Property.

The Landfill is accessed from the south-east along Landfill Access Road off Dairy Flat Highway, with Horseshoe Bush Road running along part of the northern boundary of the Landfill area. A tributary of the Rangitopuni Stream runs eastwards along the northern and eastern site boundaries towards the Dairy Flat Highway. A full description of the site is provided in the AEE prepared for the project.

1.4 Project description

Redvale Landfill is one of only two landfill sites in the Auckland region that can receive >350,000 tonnes or more of waste annually to service the approximately 1.5 million tonnes of waste that the Auckland Region produces each year. Redvale Landfill is currently scheduled to cease accepting waste in December 2028 and due to a delay in obtaining the resource consents required for the establishment and operation of the replacement Auckland Regional Landfill (ARL), WMNZ considers a transition plan is required. To address this potential gap in critical landfill infrastructure for residual waste disposal in the Auckland region, WMNZ is proposing to extend the operation of Redvale to the end of 2036 and develop 4.56 Mm³ of additional airspace at the existing facility. This includes 3.13 Mm³ in additional Class 1 Landfill expansion on top of the existing Class 1 refuse placement area and 1.43 Mm³ of Class 2 Landfill extension. The proposed works include the following:

- **Class 1 landfill expansion:** placement of waste within the existing landfill footprint, involving the removal of final cover and steepening of the final cap slope to accommodate additional waste.
- **Class 2 footprint extension:** extension of the existing landfill to the southwest to accommodate disposal of waste meeting Class 2 landfill waste acceptance criteria (WAC).
- **Relocation of ancillary activities:** the relocation of ancillary activities to allow for the placement of waste.
- **Sediment Retention Ponds:** The removal and filling in of Sediment Retention Pond 6 and the Office Pond while enlarging Pond 1 to capture and treat the stormwater from these catchments.

A full description of the proposal is included in the AEE prepared for the project.

1.5 Relevant site features

Prior to any development in the area, most of the site sloped gently down towards the north and east. Generally, the site is underlain by lower strength Northland Allochthon materials, but higher ground typically corresponds to relatively more competent Waitemata Group rocks. The Waitemata Group rocks are present over the south-western part of the site, rising to a ridge to the southwest and south of the landfill boundary. A tributary to the Rangitopuni Stream flows eastwards close to the northern site boundary, discharging into the Rangitopuni Stream to the northeast of the site. A small unnamed stream also originates to the south- west of the Class 2 footprint extension where it flows to the south and joins another tributary of the Rangitopuni Stream. The Rangitopuni Stream flows southwards close to the eastern boundary of the site.

The existing landfill is located on the site of a former limestone quarry and has been operating since 1993. The landfilling area is divided into a West Property and East Property, which are further split into a number of individual phases which have been progressively developed over the 30 years since construction began.

The original limestone (limerock) quarry was operated by the Redvale Lime Company Ltd, who excavated and crushed the limestone for use as aggregate and industrial lime. The quarry works were primarily in the central part of the overall landfill site with minor extraction from a smaller source in the western area. The landfill and quarrying operations co-existed from commencement of the landfill to when Redvale Lime Ltd vacated the site in 2004. At this time, excavation had reached depths of up to about 30 m below the original ground level, corresponding to base levels of about 30 m RL¹.

The East Property and West Property are shown on the Overall Site Layout & Extent of Works plan in Appendix B, Figure B1. The East Property is about 36 ha in area and the West Property about 23 ha in area. A sloping section of basegrade floor known as the Western Highwall marks the division between the East and West Properties. The floor of the West Property portion of the landfill is approximately 15 to 20 m higher in elevation than that of the East Property. The remainder of the area is accounted for by a paper road.

The landfill development has been carried out by progressive construction of individual landfill phases. The phase construction sequence and layout has been adjusted as the overall site development has progressed. The phase layout, for both completed and future phases, is shown in the Geotechnical Assessment Report, Appendix A, Figure A1. The original Phases 1 through 5 in the East Property were constructed with a remoulded local mudstone liner of varying thickness (300 mm to 900 mm). Subsequent phases were constructed with 900 mm thickness of clay.

¹ Level Datum: Auckland 1946.

1.5.1 Leachate collection and treatment

There are three longitudinal leachate collection pipes located on top of the liner in the East Property landfill which drain leachate from the northern end (44 m to 46 m RL) to 4 sumps at the southern end (38 m to 40 m RL). There is also a drain around the East Property perimeter which directs leachate to the sumps. See Leachate Collection Layout Plan in Appendix B, Figure B2. Each of the leachate collection sumps (LCS) and a number of the leachate collection risers (LCR) have continuous level monitoring. Leachate levels in the sumps indicate similar pressures over time, suggesting there is good hydraulic connection between them.

Leachate collection sump 1 (LCS1) is located in Phase 1. Leachate is collected periodically using trucks and delivered to an offsite Wastewater Treatment Plant (WWTP). Leachate is pumped from LCS3 and LCS4 directly to the leachate evaporation plant ('BeneVap') where the volume is measured. WMNZ budget to extract 260 m³ of leachate per day. Since late 2019, the rolling average of leachate treatment has ranged from about 25 m³ to 200 m³ per day.

LCS1 has been subject to overflow of leachate from other areas of the landfill in the past. In particular, a large rainfall event in August 2021 resulted in leachate from the West Property sump flowing to the East Property and collecting in LCS1.

1.5.2 Leachate monitoring wells

Leachate levels in phase 1 have been monitored by two leachate wells, LM1 and LM1A (refer to Figure 4.3). Leachate monitoring well LM1 was installed in 2016 between the longitudinal and perimeter leachate collection drains. Leachate monitoring well LM1A was installed in November 2019 between LM1 and the longitudinal leachate collection drain. During 2023 T+T provided further technical support through the design of a new vertical leachate extraction well (LM1B) with an adjacent three-level vibrating wire piezometer (VWP) assembly. Both the well and VWP assembly were installed within the Phase 1 cell, to the north of LM1 and LM1A (refer to Figure 4.3 for the location of the VWP).

The original resource consents for Redvale Landfill were granted in 1992 and renewed in 2016, at which time condition 108 was introduced requiring leachate levels in LM1 to be maintained at least 0.5 m below the groundwater level measured in WL3S (i.e., an inward hydraulic gradient) in Phase 1 of the landfill. Since then, the leachate level compliance point changed from LM1 to LM1A, after agreement between the PRP, Auckland Council and WMNZ, but has now reverted back LM1. The 2016 resource consents² also included a limit on leachate discharges to ground of 0.3 m³/day in condition 80, equivalent to 110 m³/year.

LM1 has had continuous leachate level monitoring since installation (apart from between 28 March and 16 July 2022 when leachate extraction from LM1 was undertaken), indicating levels exceeding condition 108 requirement of 48 m RL since May 2018. Over this period, WMNZ has proactively investigated and assessed the effects of the high leachate level, which has included leachate flux assessments (i.e., the rate of leachate that could seep through the liner in relation to leachate head), leachate extraction from LM1, managing leachate extraction from LCS1 and installation of a new leachate extraction well, LM1B. Leachate level management below 48 m RL in phase 1 has proven to be challenging, which has led WMNZ to submit a s127 application to vary the condition 108 leachate level requirement to 51 m RL. The technical assessment supporting the s127 application confirmed that increasing the leachate level requirement to 51 m RL would not materially affect environmental performance, with leachate discharges to ground predicted to remain below 0.3 m³/day.

LM1A has also had continuous leachate level monitoring since installation, except for periods between late 2021 to mid-2022 and some short periods during 2024 due to re-construction and

² Decision No: [2016] NZEnvC043. Final Decision on Appeals, 11 March 2016.

leachate extraction. Leachate level assessments in relation to the resource consent conditions are discussed further in Section 4.3.2.

2 Groundwater assessment

2.1 Methodology

The methodology used to assess the groundwater environment (hydrogeology) at, and surrounding Redvale Landfill, has been driven by the existing available data and reports, both historical and present-day, to build on the hydrogeological understanding of the site. The groundwater assessment methodology includes the following:

- Conducting a desk-based study to gain an initial understanding of the groundwater conditions at the site. This included a review of existing reports and hydrogeological assessments undertaken throughout the on-going development and operations of the existing landfill.
- Reviewing and analysing available monitoring and site investigation data relating to groundwater levels and quality, leachate levels and quality, geology and hydrogeology.
- Characterising the existing groundwater system(s) at the site (hydrogeological conceptual model). The hydrogeological conceptual model describes how groundwater currently moves through the wider site, recharge and discharge areas and existing groundwater quality.
- Assessing what changes may occur to the existing groundwater system(s) due to the proposed development, and estimation of the levels of risk to groundwater and nearby sensitive receptors, namely the Rangitopuni Stream (Sections 5 and 6).
- Recommendations for how the consequences of the groundwater risks, if any, can be mitigated in the proposed development (Section 7).

2.2 Previous groundwater assessments

A series of hydrogeological assessments have been undertaken throughout the ongoing development and operations of the landfill, as listed below:

- Redvale Landfill Consents Renewal Hydrogeology Report³.
- Redvale Landfill Consents Renewal Geotechnical Review Report⁴.
- Leachate Migration Modelling Redvale Landfill⁵.
- Leachate Mounding and Flux Assessment⁶.
- Addendum to Leachate Mounding and Flux Assessment Report⁷.
- DRAFT Leachate Mounding and Flux Assessment⁸.

These studies have focussed on developing the conceptual hydrogeological model for the site, fate and transport modelling, and more recently, assessing leachate mounding and flux concerns in Phase 1 of the landfill.

Relevant information from these assessments is summarised below:

- Groundwater flow in the area surrounding the landfill tends to follow topography, except in areas where landfill construction and operations result in temporary lowering of groundwater levels. Based on vertical hydraulic gradient data, there appears to be recharge from some of the surface ponds to groundwater.

³ T+T, 2013. Redvale Landfill Consents Renewal Hydrogeology Report. Ref: 29331.5000.

⁴ T+T, 2013. Redvale Landfill Consents Renewal Geotechnical Review Report. Ref: 29331.300.

⁵ T+T, 2017. Leachate Migration Modelling Redvale Landfill. Ref: 1003144.v3.

⁶ T+T, March 2022. Redvale Landfill – Leachate Mounding and Flux Assessment. Ref: 1004846.4003.v2.

⁷ T+T, October 2022. Redvale Landfill – Addendum to Leachate Mounding and Flux Assessment Report. Ref: 1004846.4003.

⁸ T+T, April 2025. DRAFT Redvale Landfill – Leachate Mounding and Flux Assessment. Ref: 1004846.004.v4.0.

- The permeability of the site geology is extremely low. Assumptions made during original design and consenting, that low permeability Northern Allochthon materials are present over most of the landfill footprint, have been confirmed. Permeability measurements and construction observations have established that the permeability of materials present beneath the landfill (liner and natural) is consistent with, or lower than, originally estimated.
- Changes in groundwater flow since the start of landfill operations have generally been limited. Temporary changes in flow close to the landfill occur, as a result of landfill void construction and operation, but recovery follows the completion of filling.
- Groundwater fate and transport modelling in 2013 indicated that, under the worst case observed conditions, contaminants from landfill leachate would take at least two centuries to reach the closest downgradient monitoring well on site (M8A), at that time, located 65 m from the edge of the landfill. This model was extremely conservative, and, on this basis, it was considered that the modelling indicated a negligible potential for adverse effects on groundwater quality beyond the site boundary.
- Ongoing groundwater quality assessments of the downgradient monitoring wells (including in early 2025) indicate that there has been no substantive change in groundwater quality at any of the monitored wells.
- Site operations generally maintain an inwards hydraulic gradient from natural geology towards the landfill, except at times in the south-eastern corner of the landfill footprint (Phase 1 area).
- The 2017 fate and transport modelling and assessment of effects review examined the potential for environmental effects should prolonged elevated leachate levels occur in the southeast corner of the landfill (i.e., Phase 1 area). The evaluation utilised maximum leachate levels, higher than present day. Modelling also assumed a consistent head of leachate on the liner. The assessment concluded that even with a continuous landfill leachate seepage over the course of thousands of years, the concentrations of contaminants in the Rangitopuni Stream would be well below ecological protection values and ANZECC trigger values for 90% protection of species, which were appropriate at the time.
- Mounding assessments in 2022 and 2025 have calculated low leachate fluxes in the southeast corner. These low fluxes, supported by present-day groundwater quality data and the 2017 fate and transport modelling, suggest that if leachate seepage through the liner does occur, the effects on the Rangitopuni Stream would be negligible.

3 Recent field investigations

T+T oversaw the installation of four machine drilled boreholes during October 2024. Detailed information about the field investigations is presented in the Geotechnical Assessment Report with some details provided in the following sub-sections.

Vibrating wire piezometers (VWPs) were installed in each borehole. Three of the boreholes were located along the western part of the Northern Boundary (W135, W136 and W137) and one was below the former Managed Fill area (W138). The primary purpose of the boreholes and VWPs was to clarify and confirm groundwater conditions along the western part of the landfill's northern boundary and within the managed fill extension.

A single VWP was installed in W135 and W137, with two VWPs (shallow and deep) installed in each of W136 and W138. The continuous groundwater level data from the VWPs have been downloaded regularly since being commissioned. Installation details of the VWPs are provided in the Geotechnical Assessment Report.

4 Existing groundwater conditions: hydrogeological conceptual model

4.1 Overview

This section provides a description of the hydrogeological conceptual model for the existing groundwater conditions in the vicinity of Redvale Landfill. It describes groundwater recharge, the predicted flow paths through the underlying geology and how groundwater is expected to move through the rock mass to areas of groundwater discharge. It also draws on information collected from the desktop review.

To provide a context to the following sub-sections, the summary has been provided immediately below rather than at the end of this section. Additional technical details about the conceptual model are provided in Appendix C.

4.2 Summary of hydrogeological conceptual model

Two schematic cross sections attached in Appendix B (Figure B3, Figures B4 and B5) and shown as Figure 4.1 and Figure 4.2 below, provide an overview of the hydrogeological conceptual model. It should be noted that these are 2-dimensional representations of a 3-dimensional groundwater flow regime.

The following is a summary of the hydrogeological conceptual model for the existing groundwater conditions in the vicinity of Redvale Landfill:

- Based on our understanding of the site-specific groundwater monitoring investigations, the geotechnical site investigations and previously published reports and maps of the area, we infer that the groundwater system beneath and surrounding the landfill is unconfined (i.e., groundwater table). In addition, we infer that groundwater within the Waitemata Group rocks and Northland Allochthon rocks are hydraulically connected and acting as one groundwater system, part of the regional Rangitopuni Waitemata sub-aquifer zone⁹. In this sub-aquifer zone, Auckland Council has calculated that there is groundwater available for allocation.
- Groundwater level contour maps of recently measured groundwater levels indicate that groundwater recharge in the immediate vicinity of the site occurs on the higher ground to the west-southwest of the existing landfill, likely through rainfall recharge. Groundwater discharge occurs through losses to the Rangitopuni Stream, which passes around the northwest-north and eastern boundaries of the landfill site. This is consistent with observations and conclusions made in previous assessments.
- An evaluation of the groundwater contour maps confirms that generally the local groundwater flow is controlled by topography, flowing predominantly from the higher ground in the west-southwest, beyond the existing landfill, towards the north (Phase 10 Bund), northeast and east-southeast beneath the landfill. Between summer and winter months, we observe an approximately 0.3 m to 1.1 m drop in groundwater levels in the summer, but not all monitoring wells record a change. Overall, the groundwater contours show minimal change in groundwater levels and flow directions between seasons.
- Based on the June 2021 contour map, adopted as the 'present-day' lateral hydraulic gradient beneath the landfill ranges between approximately 0.120 in the northerly groundwater flow direction and 0.058 in the east-southeasterly groundwater flow direction.
- Leachate and groundwater levels analysed for the Phase 1 area indicate that the lateral hydraulic gradient fluctuates in this area between inward into the landfill and outward. Based on median groundwater levels, leachate levels have remained at least 0.5 m below median

⁹ Auckland Council, Geomaps: <https://unitaryplanmaps.aucklandcouncil.govt.nz/upviewer/>. Accessed May 2025.

groundwater levels, indicating an inward hydraulic gradient is likely prevailing under median conditions.

- Generally, representative hydraulic conductivities of the rock mass beneath the existing landfill are low, particularly for the fine-grained material, as determined by laboratory tests and field tests (ranging between 3×10^{-8} m/s for limestone to $<5 \times 10^{-10}$ m/s for mudstone). Therefore, groundwater flow rates beneath the landfill are considered to be slow.
- Excavation for the proposed Class 2 footprint extension is inferred to extend predominantly into the Northland Allochthon mudstone, which is expected to have a representative hydraulic conductivity of approximately 5×10^{-10} m/s. In this area, groundwater generally flows from higher ground in the northwest toward the southeast and Sedimentation Pond 6.
- Recent water quality results (over the last 10 years) have been analysed to identify any changing trends in groundwater and leachate quality and to determine the 'present-day' groundwater quality surrounding the site. Overall, groundwater and leachate quality results show no evidence of significant change over time, and groundwater quality results show no evidence of leachate contamination. Leachate indicator parameter concentrations are typically higher within the leachate samples than groundwater by one or more orders of magnitude. In terms of the 'present day' groundwater quality, concentrations of leachate indicator parameters in downgradient groundwater are reported as follows (since 2015):
 - Ammoniacal nitrogen concentrations typically range between approximately 0.01 g/m³ and 4.4 g/m³.
 - Boron concentrations, typically range between approximately 7 g/m³ to less than 1 g/m³.
 - Chloride concentrations typically range between approximately 20 g/m³ and 370 g/m³.
 - COD concentrations¹⁰ typically range between <6 g/m³ and 64 g/m³.
 - In January 2025, the electrical conductivity ranged between 81.6 mS/m and 168.8 mS/m.
- There are no consented down-gradient groundwater takes within 2 km of the centre of the Redvale Landfill. The closest resource consent to take surface water (from a tributary of the Rangitopuni Stream) is approximately 800 m northwest of the centre of the landfill, and the closest consented bore, that has no associated water take consent or permitted activity, is approximately 680 m north-northeast of the centre of the landfill.

¹⁰ We note that for COD, the lab has not reported concentrations less than 6 g/m³. If concentrations are less than this, 6 g/m³ has been reported.

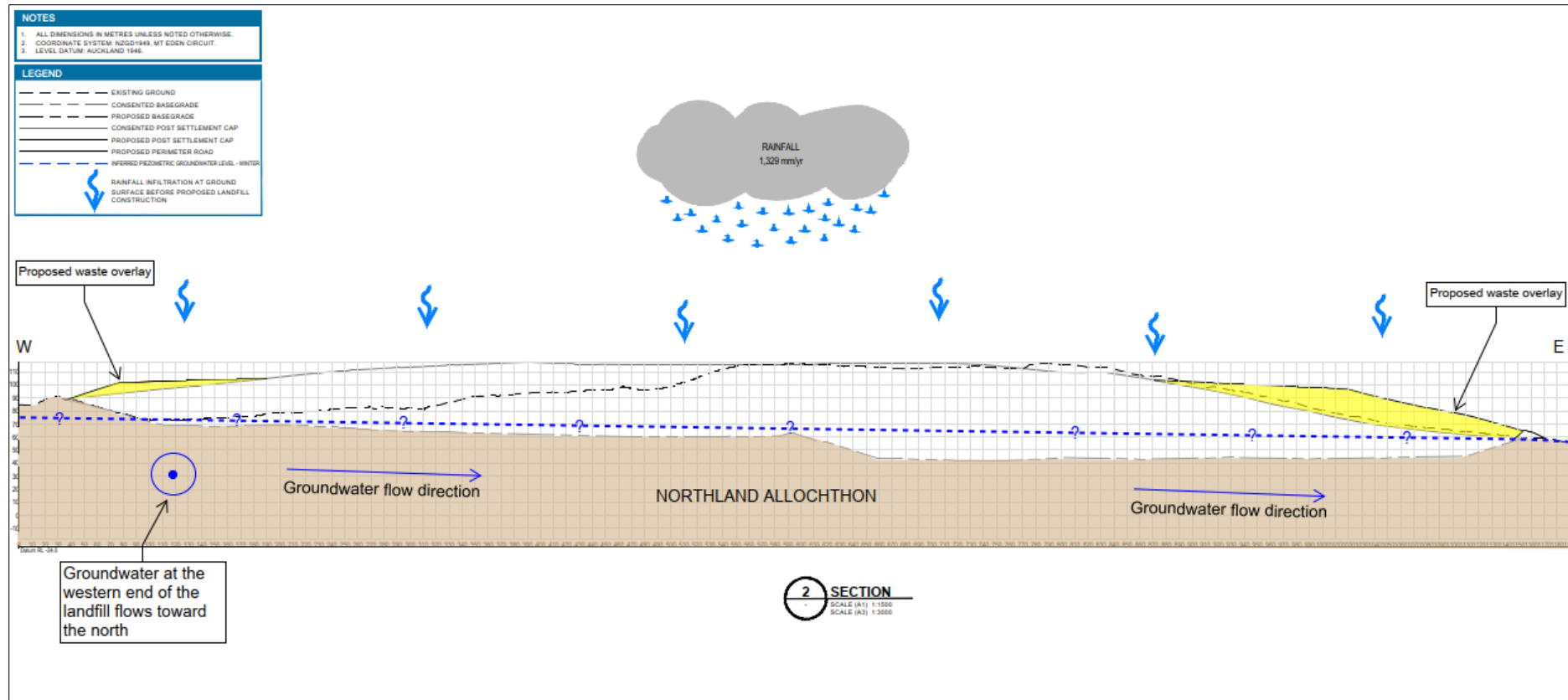


Figure 4.1: Conceptual hydrogeological cross section through the existing landfill from west to east.

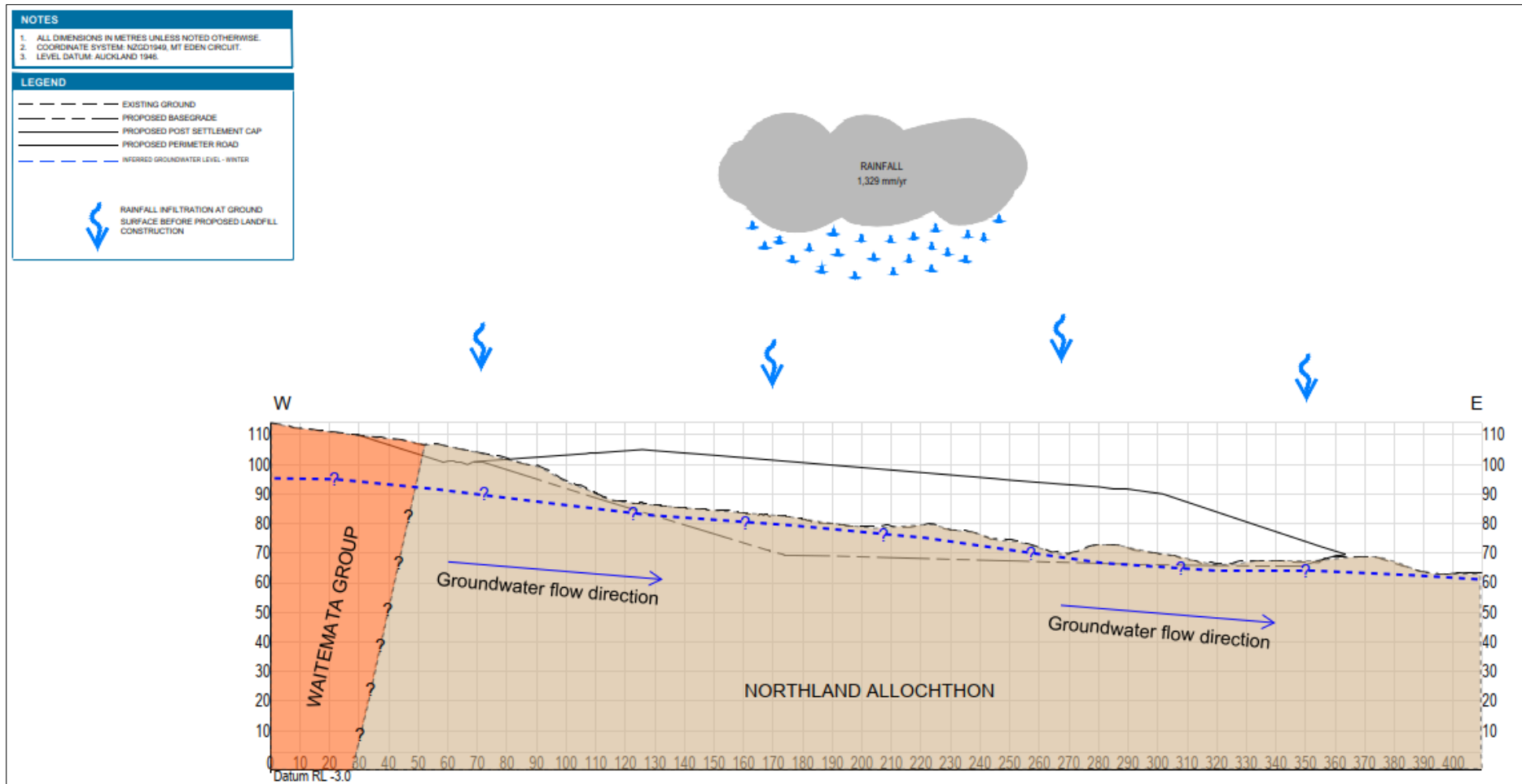


Figure 4.2: Conceptual hydrogeological cross section through the proposed Class 2 footprint extension from west to east: Pre-construction.

4.3 Groundwater levels and contours

4.3.1 Existing groundwater levels and contours for the wider site

Groundwater monitoring wells located around the perimeter of the landfill have been monitoring groundwater levels since at least 1998 until present time (Figure 4.3). Our assessment uses several recent time periods to develop representative groundwater contours, as described below. Generally, groundwater levels have remained stable, with expected seasonal and annual fluctuations based on seasonal and annual rainfall variations/trends (refer to Appendix C, Section C2 for time series plots of wells with ongoing groundwater level monitoring).

Groundwater flows from areas where the groundwater surface is at high elevations, towards areas where the groundwater surface is lower. Therefore, by creating groundwater surfaces and contours, we can determine the general groundwater flow direction and hydraulic gradient.

To understand the existing groundwater surface beneath the site, we have generated groundwater contours from recent time periods where the available data have the most complete groundwater level monitoring record. We have used June 2021 (45 wells) and March 2022 (57 wells) as representative time periods for winter and summer groundwater levels, respectively, to develop 'present-day' seasonal groundwater contours for the wider site. These contour maps are shown in Figure 4.4 and Figure 4.5 below, winter and summer respectively.

A detailed description of the contouring process is provided in Appendix C, Section C2.3 and larger contour maps are attached in Appendix B, Figures B6 to B8. The contours drawn across the existing landfill are piezometric contours, inferred from the groundwater level measurements in the monitoring wells finished in natural ground surrounding the landfill. The piezometric levels are the groundwater pressures that would be observed if a well was constructed in the geological formations beneath the basegrade of the landfill and the groundwater level measured there.

An evaluation of the groundwater contours confirms that generally, the local groundwater flow is controlled by topography, flowing predominantly from the higher ground in the west-southwest, beyond the landfill, generally towards the north (Phase 10 Bund), northeast and east-southeast beneath the landfill.

We have also generated groundwater contours for November 2024 (14 wells, including four wells drilled in October 2024 and installed with vibrating wire piezometers). Based on this contour surface, using more recent but limited groundwater level data, there has been no change in the predominant groundwater flow directions across the wider site (Figure 4.6).

From winter to summer, groundwater levels typically drop by about 0.3 to 1.1 m. However, not all monitoring wells show a significant change. Some show little seasonal variation, and a few even record rising water levels. Overall, the seasonal groundwater contours change very little.

Comparing winter 2021 to late winter 2024 (November 2024), we see notable differences at the eastern downgradient end of the landfill and along the southern boundary. At the far eastern end, groundwater levels were higher in late winter 2024 (by approximately 2.5 m at WL4S). In contrast, levels were deeper along the southern boundary, potentially by up to 6 m near W138S, compared with winter 2021. It is important to note that groundwater level data for the November 2024 contour map is relatively sparse, so the resulting contours carry greater uncertainty.

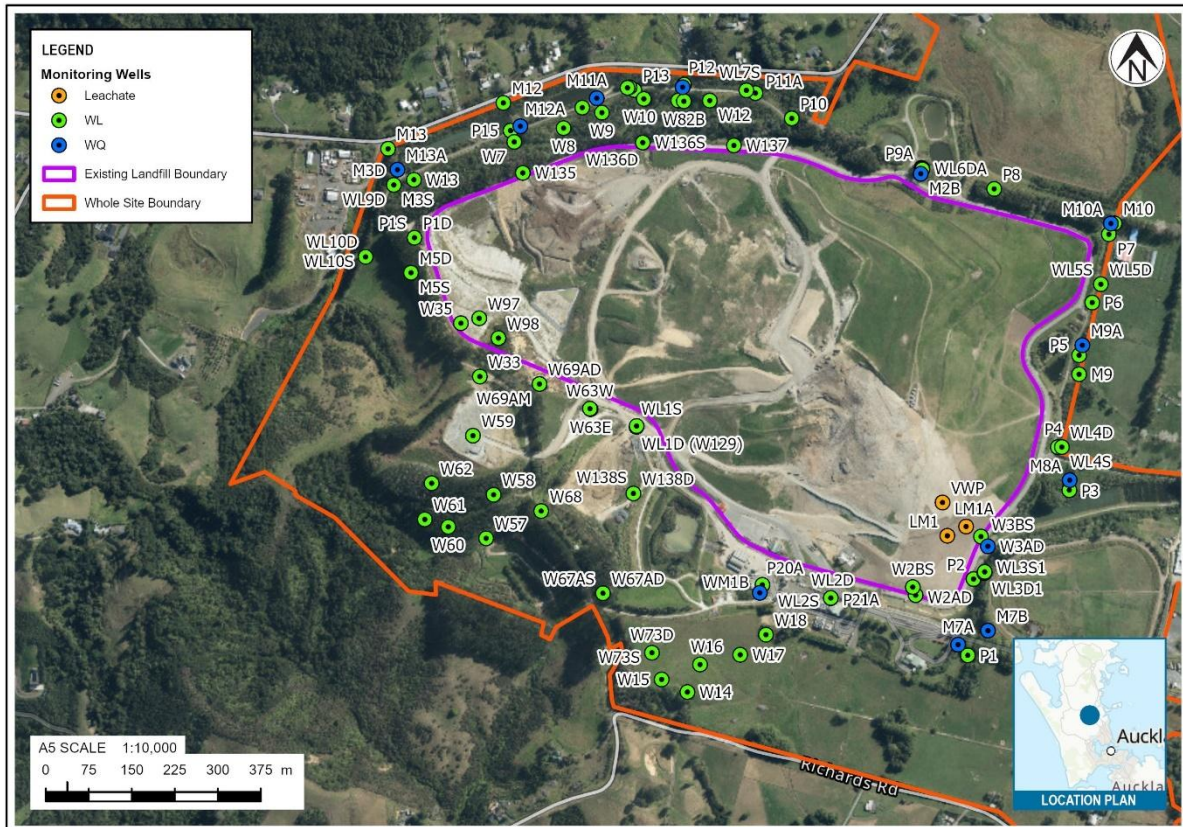


Figure 4.3: Location of monitoring wells surrounding the existing landfill – those with recent data. Wells monitoring leachate levels (Leachate) are shown as orange dots, wells monitoring groundwater levels (WL) are shown as green dots and wells monitoring groundwater quality (WQ) are shown as blue dots. Source: LINZ (cc-BY-4.0).

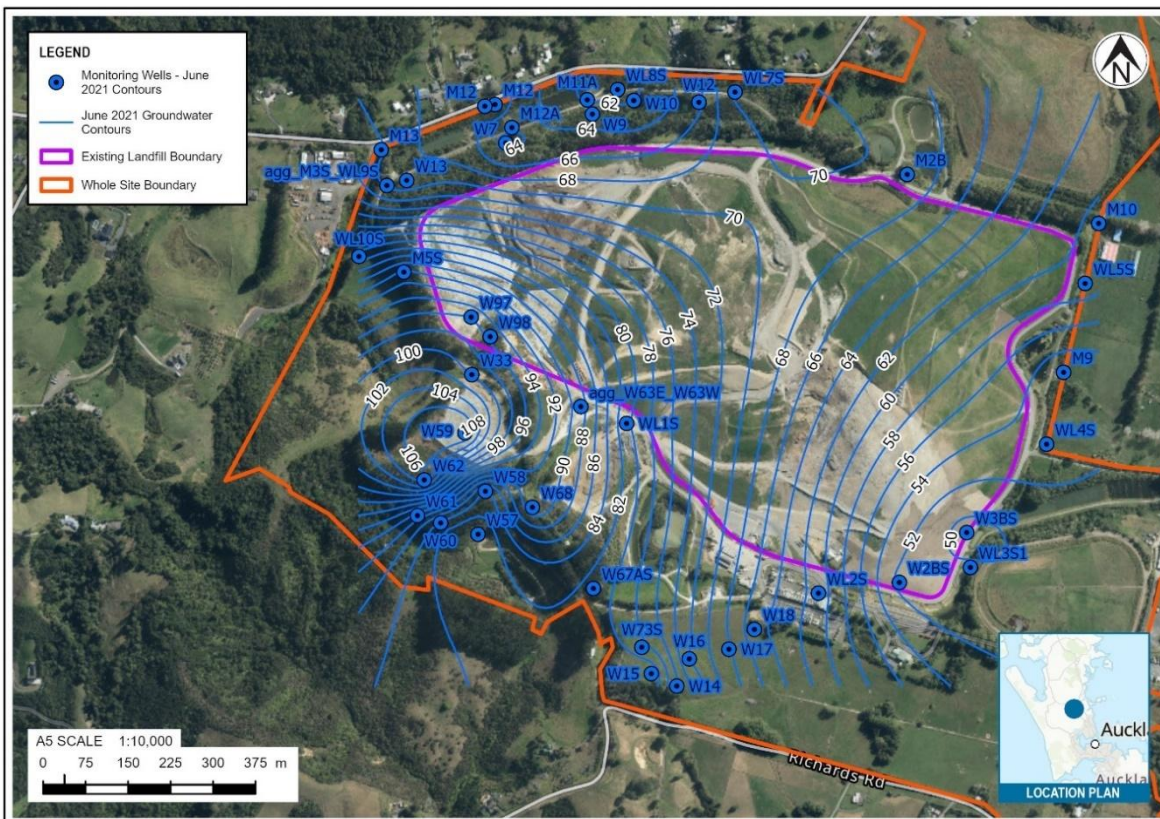


Figure 4.4: Groundwater contours for June 2021 (representative of winter conditions). Source: LINZ (cc-BY-4.0).

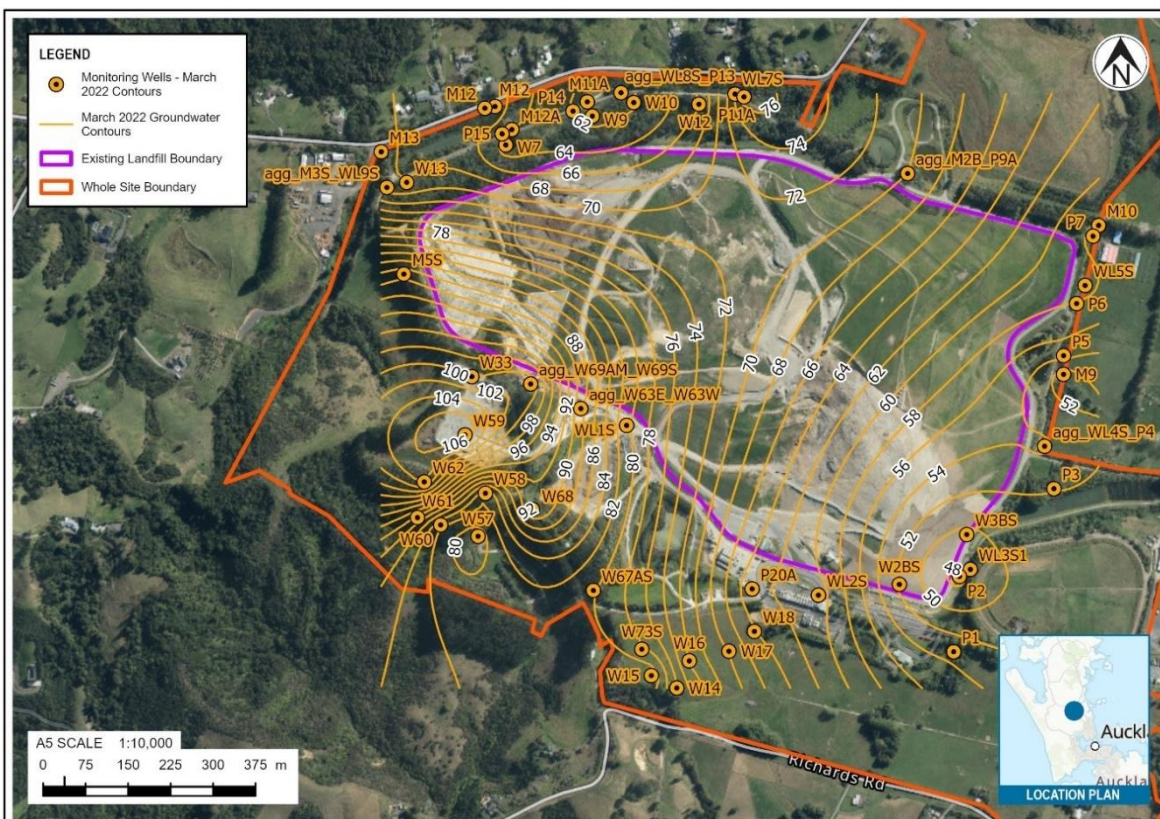


Figure 4.5: Groundwater contours for March 2022 (representative of summer conditions). Source: LINZ (cc-BY-4.0).

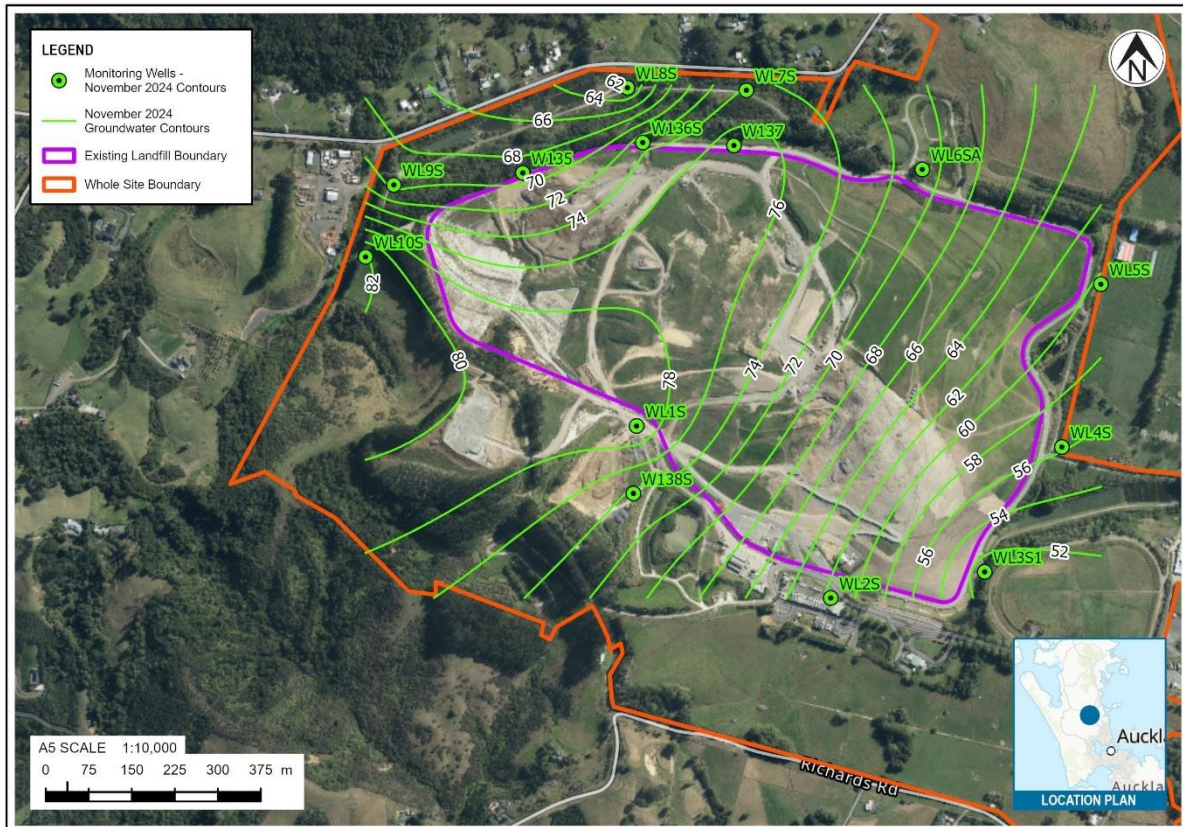


Figure 4.6: Groundwater contours for November 2024. Source: LINZ (cc-BY-4.0).

4.3.1.1 Areas of recharge and discharge

As part of the hydrogeological conceptual model, it is important to understand how groundwater is replenished (recharged) and where losses (discharges) occur. Based on the recent groundwater level contour maps, groundwater recharge in the immediate vicinity of the site occurs on the higher ground to the west-southwest of the landfill, likely through rainfall recharge. Groundwater discharge is inferred to mostly occur locally through losses to the Rangitopuni Stream, which passes around the northwest-north and eastern boundaries of the landfill site. This is consistent with observations and conclusions made in previous assessments.

4.3.1.2 Lateral hydraulic gradient

The groundwater contours from June 2021 and March 2022 have been used to determine the representative lateral hydraulic gradients of the shallow groundwater surface beneath the landfill. Given we observe minimal difference between seasonal groundwater levels based on the 2021 and 2022 groundwater contour maps, we have used the June 2021 contour map to calculate the 'present-day' horizontal hydraulic gradients beneath the landfill.

- For the northerly groundwater flow direction, the hydraulic gradient is approximately 0.12.
- For the north-easterly groundwater flow direction, the hydraulic gradient is approximately 0.073.
- For the east-southeasterly groundwater flow direction, the hydraulic gradient is approximately 0.058.

4.3.1.3 Vertical groundwater flow

Nested and paired groundwater monitoring wells located around the perimeter of the landfill have been used to determine the potential for vertical groundwater flow. In 2013, it was reported that vertical hydraulic gradients were generally upward except where recharge was occurring from unlined ponds.

Groundwater level data between approximately 2023 and the end of 2024/start of 2025 have been analysed to determine the 'present day' vertical groundwater flow regime surrounding the landfill. The following observations have been made:

- Northern boundary:
 - At monitoring wells WL6 (Pond 3), WL8 (Pond 4) and W136, the potential for vertical groundwater flow is assessed as downward, as observed in 2013.
- Eastern boundary:
 - At monitoring wells WL3, WL4 and WL5, the vertical groundwater flow gradient fluctuates from upward to downward and then back to upward. The fluctuations are likely due to shallow groundwater levels rising above the deeper monitored groundwater piezometric surface over the winter months and then decreasing again in the summer months when rainfall recharge is minimal.
- Southern boundary:
 - At monitoring well W138 (within the proposed Class 2 footprint extension), the potential for vertical groundwater flow is assessed as downward.
 - ☐ At this location, relative to the Class 1 landfill, leachate levels (based on median readings in Phase 1 -, refer to following sub-section, Figure 4.14), are lower than the groundwater level so an inward hydraulic gradient is expected to prevail.
- Western boundary:
 - At monitoring well WL9, the vertical groundwater flow is upward between November 2023 and March 2024, following which vertical flow is neutral.
 - At monitoring well WL10, the vertical groundwater flow is assessed as downward.

Previous studies have concluded that there is an inward hydraulic gradient, with groundwater levels outside of the landfill being higher than leachate levels. For this assessment, data is available for leachate levels in the southeast corner of the landfill (Phase 1). Inward gradients in the Phase 1 area of the existing landfill are discussed in the following sub-sections.

4.3.2 Existing leachate and groundwater levels and hydraulic gradients in Phase 1 area of existing landfill

Detailed assessments of leachate and groundwater levels and hydraulic gradients in the Phase 1 area have been undertaken by T+T in 2022^{6,7} and 2025⁸ to determine if leachate mounding within the waste mass is occurring in Phase 1 and to estimate the leachate flux out of the waste mass if outward gradients were to prevail. The following sub-sections summarise the findings of these assessments.

The data available for assessing the nature and extent of leachate mounding consists of:

- Leachate level data from leachate monitoring wells LM1 and LM1A, the VWP and from the leachate collection sump LCS1.
- Groundwater level data from nested wells WL2(S and D), WL3(S and D) and WL4(S and D), where S and D signify shallow and deep screens, respectively.

Locations of the wells, sump and leachate collection drains and the perimeter of the landfill liner are shown on Figure 4.7.

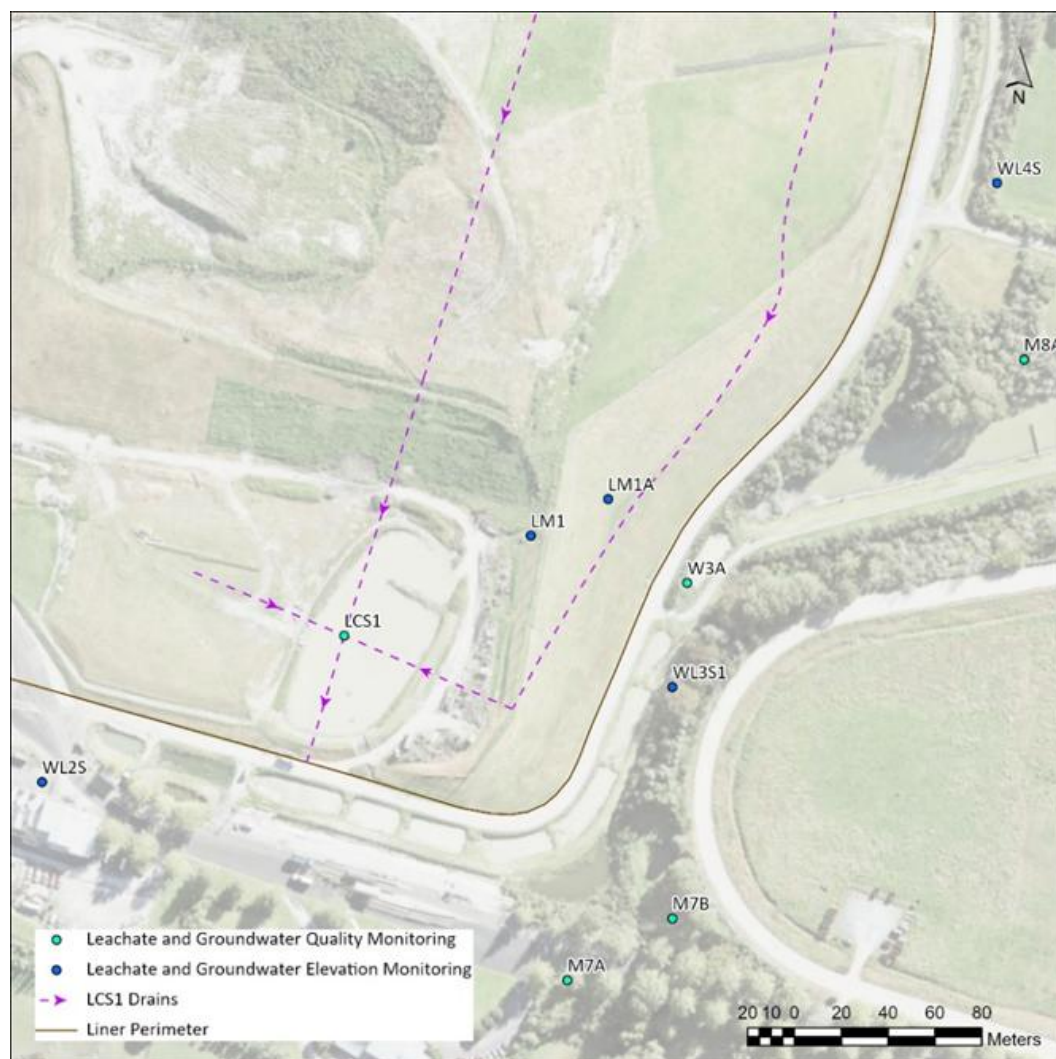


Figure 4.7: Redvale landfill south-eastern corner groundwater and leachate monitoring sites.

4.3.2.1 Lateral hydraulic gradients

Prior to 2019, leachate levels in LM1 and LM1A were lower than in groundwater monitoring well WL3S1, indicating an inward lateral gradient was prevailing (refer to Figure 4.8 and Figure 4.9, where a negative lateral hydraulic gradient corresponds to an inward gradient). Since early 2019, leachate levels in either LM1 or LM1A have fluctuated and have at times been higher than the groundwater level in WL3S1.

Specifically, leachate elevations recorded in LM1A indicate an outward gradient for about 50% of the time from late 2020 until September 2021 and an outward lateral gradient until early 2022. The lateral hydraulic gradient then reversed and from early 2022 until early 2024, an inward lateral hydraulic gradient likely prevailed between LM1A and WL3S1. For the majority of 2024, the data indicate an outward lateral hydraulic gradient again. However, near the end of 2024, this relationship changes and an inward lateral gradient has likely prevailed, up to at least early 2025.

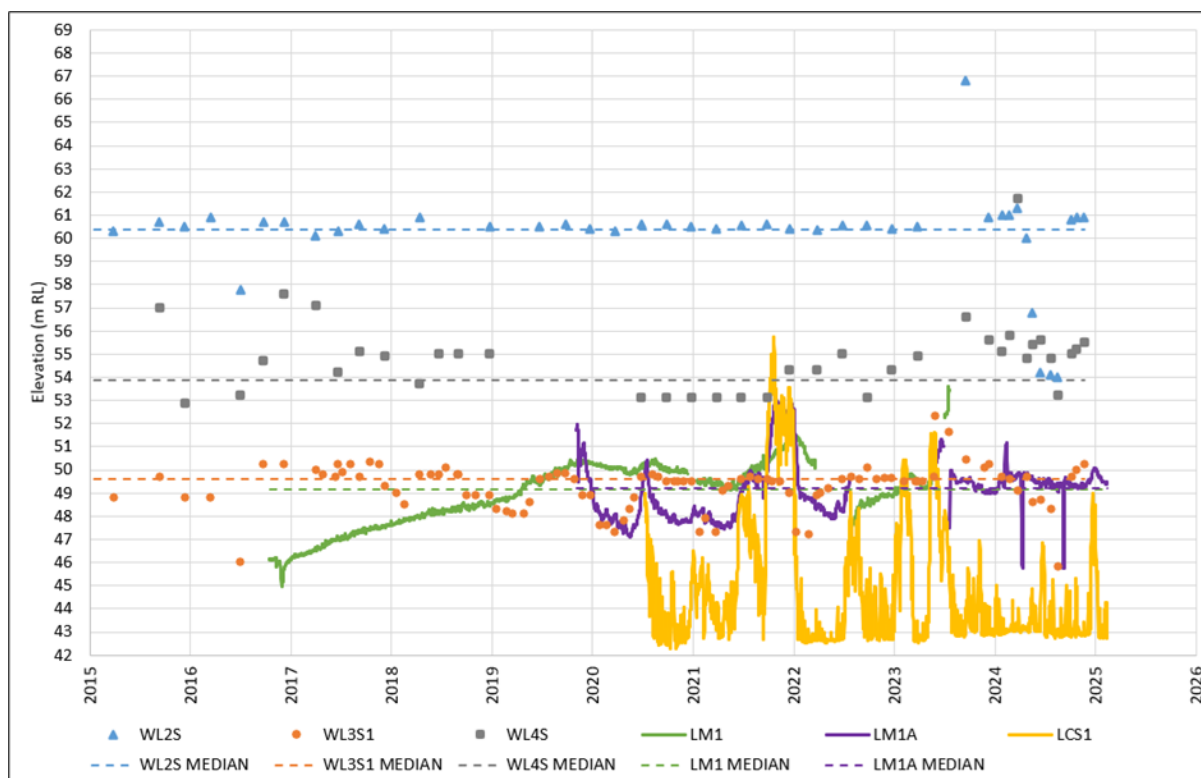


Figure 4.8: Leachate and groundwater elevation monitoring.

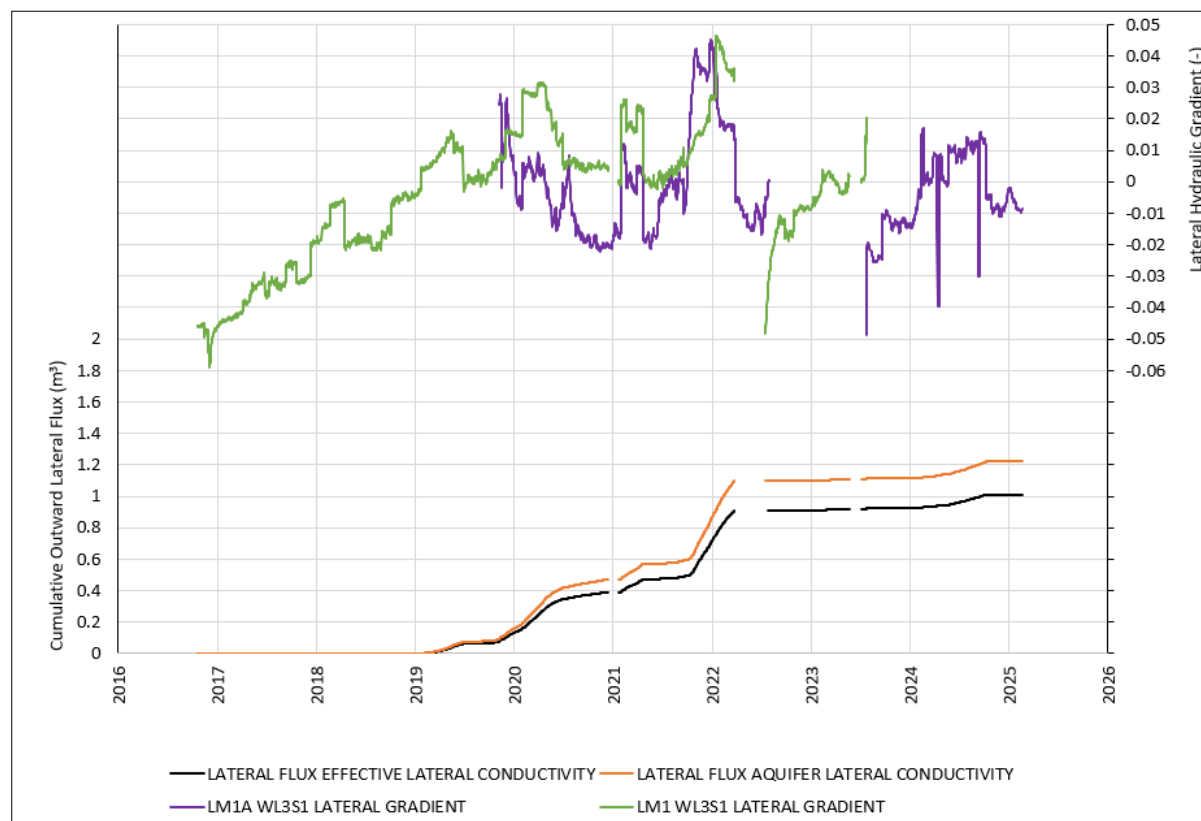


Figure 4.9: Calculated outward lateral gradients and estimated cumulative lateral leachate flux.

4.3.2.2 Vertical hydraulic gradients

Leachate levels in LM1 and LM1A were previously evaluated against groundwater levels in the deep monitoring well WL3D1. This location had a relatively consistent piezometric head between 50 and 51 m RL from 1998 to 2022. This consistency has continued since 2022, as indicated on Figure 4.10. Leachate levels were higher than groundwater levels in WL3D1 during late 2021 and also for a time in mid-2023. Following these times, leachate levels have generally been lower than the groundwater levels in WL3D1. For the periods when the groundwater in WL3D1 was above the leachate levels, an upward vertical gradient on the base of the landfill liner has prevailed.

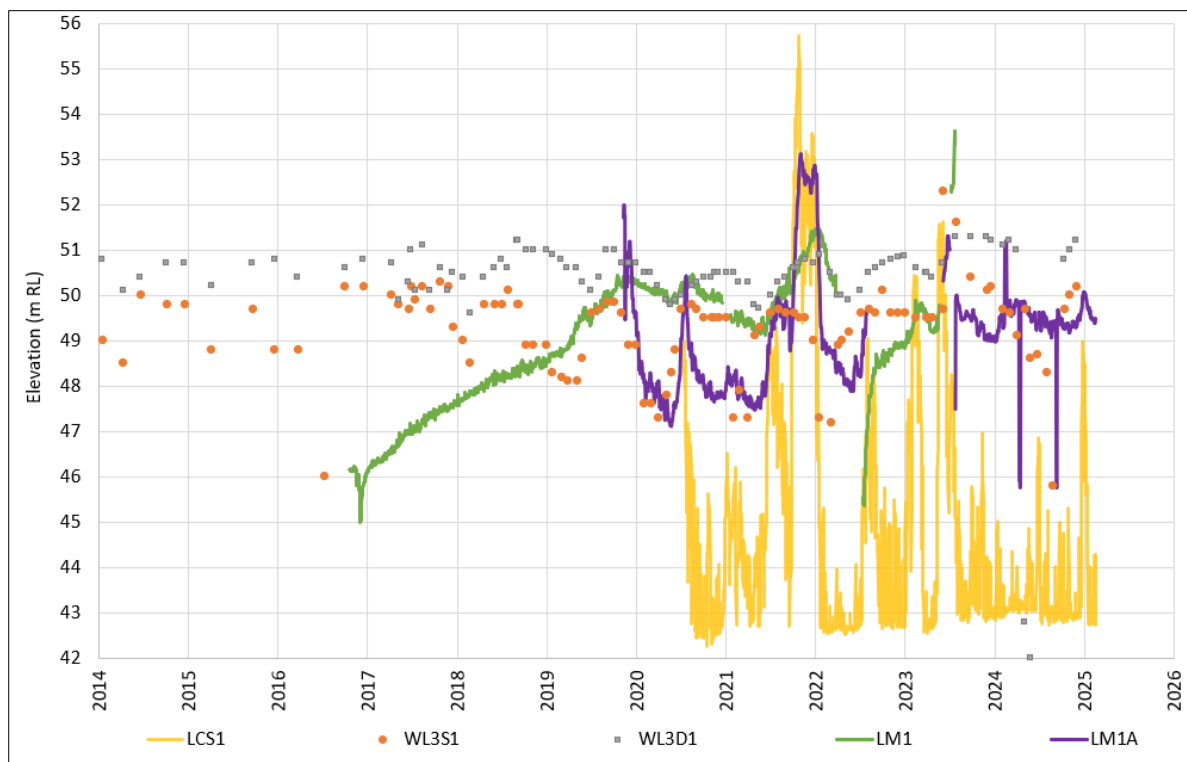


Figure 4.10: WL3D1 groundwater level record compared to shallow groundwater/leachate elevations.

The calculated vertical hydraulic gradients between LM1, LM1A and WL3D1 are illustrated on Figure 4.11, where the negative vertical gradients indicate an upward gradient.

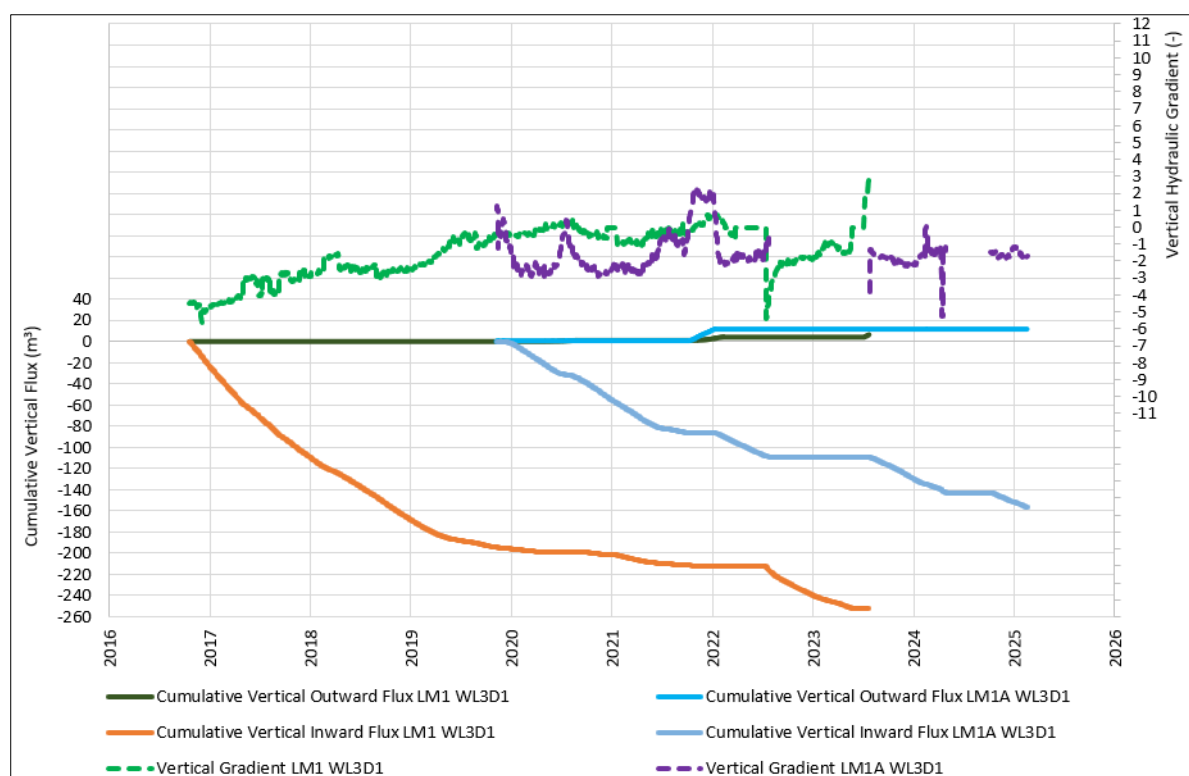


Figure 4.11: Calculated vertical outward gradients and estimated cumulative vertical leachate flux.

4.3.2.3 Summary

In summary, lateral and vertical hydraulic gradients have fluctuated between being inward or outward, and upward or downward, respectively, since approximately 2019 in the Phase 1 area. Median leachate levels suggest that leachate mounding is occurring in the Phase 1 area, with a relatively consistent leachate head, at approximately 8 m (Figure 4.12). Based on median groundwater levels, leachate levels have remained at least 0.5 m below median groundwater levels, indicating an inward hydraulic gradient likely prevails under median conditions (Figure 4.12).

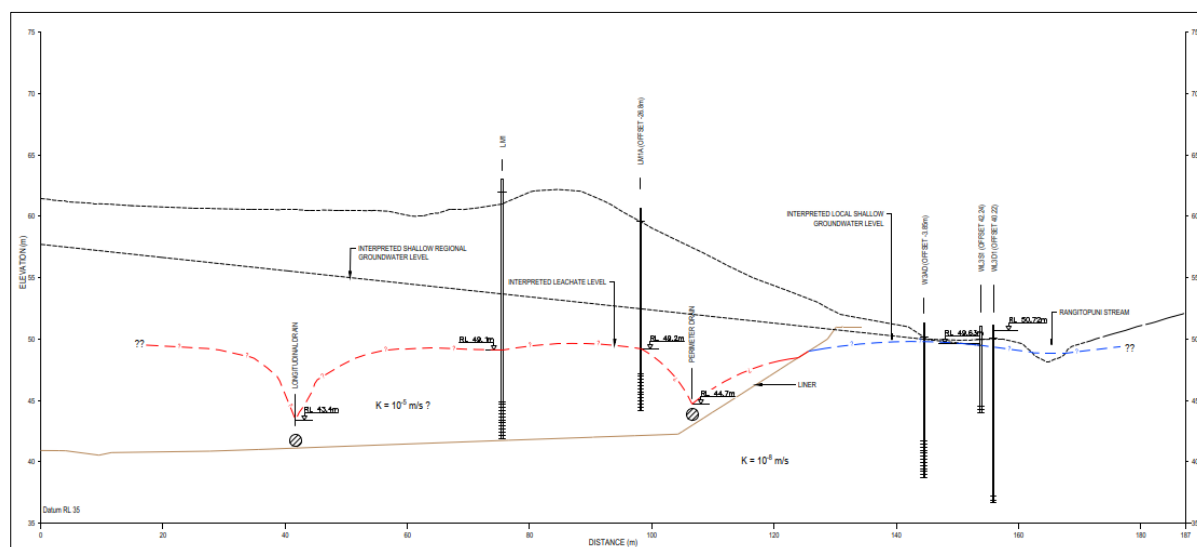


Figure 4.12: Conceptual model cross-section across Phase 1 using median levels between August 2021 and November 2024.

4.3.3 Existing groundwater levels in the proposed Class 2 footprint extension

Monitoring well W138 was drilled in October 2024 within the location of the proposed Class 2 footprint extension to monitor groundwater levels and confirm ground conditions in the area. Two VWP were installed in the well to monitor groundwater levels in the Pleistocene sediments (Tauranga Group) and underlying Northland Allochthon rocks (sheared mudstone). The shallow VWP was installed at a depth of approximately 7.1 m below ground level (bgl) and the deeper VWP was installed at a depth of approximately 15.1 m bgl.

A review of bore logs and available information from neighbouring wells (W129, W63E+W and W132 and W132A) indicates that the Tauranga Group sediments encountered in W138 are likely to be limited in aerial extent, potentially deposited by a historical stream before development at the site. Conservatively, we have assumed that groundwater in the Tauranga Group sediments encountered in W138 is hydraulically connected to groundwater in the surrounding and underlying Northland Allochthon rocks.

Recent groundwater levels in the proposed Class 2 footprint extension are reported in Table 4.1 and shown for W138 in Figure 4.13. Figure 4.14 further illustrates the current relationship between groundwater beneath the proposed Class 2 footprint extension and inferred leachate levels in the adjacent southern part of the Class 1 landfill, showing that groundwater levels are substantially higher at this location.

During the summer months, groundwater levels measured in W138 progressively deepen, as expected due to less rainfall recharge. To date, the shallowest groundwater level measured by W138S was in December 2024, at 4.69 m bgl (73.69 m RL). It is possible that groundwater levels could be shallower over the winter months in this area. The June 2021 groundwater level contour map indicates that groundwater levels could be close to ground level in this area over winter.

The existing ground profile generally falls south-eastwards, towards Sedimentation Pond 6 in this area and the recent groundwater contour maps indicate that the existing groundwater surface follows a similar profile, i.e. dipping down south-east towards the low ground corresponding to Sedimentation Pond 6 and the workshop area further to the east. Therefore, groundwater generally flows from higher ground in the northwest toward the southeast.

Table 4.1: Recent measured groundwater levels in the proposed Class 2 footprint extension

Date	W138S	W138D
	m bgl	
27/12/2019	-	-
27/3/2020	-	-
30/6/2020	-	-
30/9/2020	-	-
29/10/2024	-	-
5/11/2024	4.81	5.26
19/11/2024	4.90	5.45
25/11/2024	-	-
3/12/2024	4.69	5.62
17/12/2024	4.81	5.87
7/1/2025	5.15	6.04
21/1/2025	5.15	6.10

Date	W138S	W138D
	m bgl	
5/2/2025	5.25	6.10
18/2/2025	5.50	6.16
7/3/2025	5.45	6.11
18/3/2025	5.54	6.14
1/4/2025	5.64	6.07
14/4/2025	5.55	6.12
28/4/2025	5.41	6.17

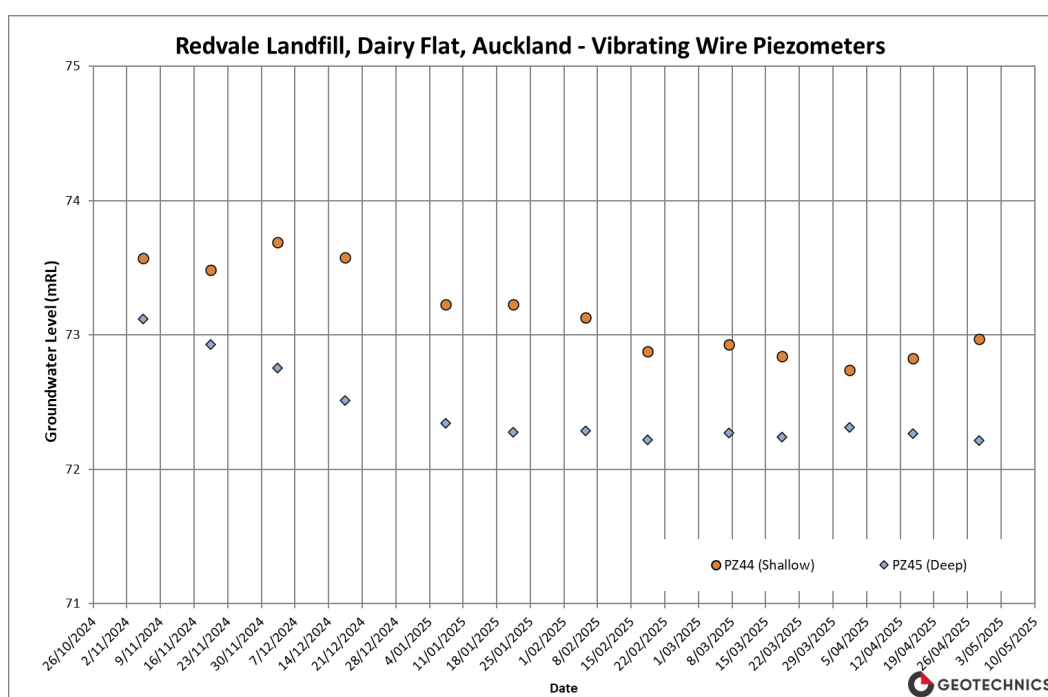


Figure 4.13: Fortnightly groundwater levels taken from the continuous data in well W138 (PZ44 and PZ45). Groundwater levels are reported as m RL. Refer to Figure Appendix C.5 for a larger version.

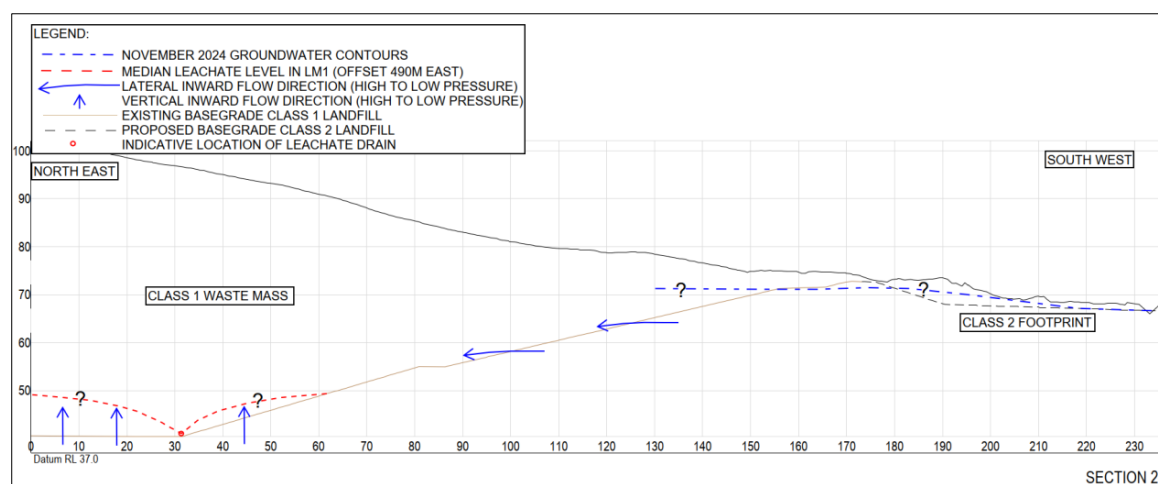


Figure 4.14: Current groundwater level cross-section adjacent to the proposed Class 2 footprint extension and southern part of the Class 1 landfill, showing groundwater in the Class 2 area above inferred leachate level in the Class 1 landfill. Extract from Section 2 line illustrated on Figure 6.1 in Section 6.2.

4.4 Hydrogeological parameters

4.4.1 Hydraulic conductivity across the wider site

The geological setting of the Redvale Landfill East Property, and eastern half of the West Property, essentially comprises two closely spaced north-south trending lens-shaped masses of easterly dipping Northland Allochthon limestone contained within sheared Northland Allochthon mudstones and siltstones. To the west of those units is a further zone of limestone, with Northland Allochthon Autoclastic Breccia mudstone/siltstone and Waitemata Group sandstones and siltstones along the Western Property's, and the wider landfill south-western boundary.

The hydraulic conductivity of the limestone rock mass encountered within the Redvale Landfill has been observed to be generally greater than for any adjacent finer grained materials such as mudstone or siltstone¹¹. The rock mass hydraulic conductivity is controlled by the defects within the rock mass, i.e. bedding and fractures (secondary porosity), and the effects are particularly pronounced where there has been relaxation of the rock mass as a result of stress relief following excavation/unloading. Limestone therefore tends to be the controlling lithology when considering groundwater behaviour within the overall rock mass. A consequence of the increased relative rock mass hydraulic conductivity is that slopes formed in limestone are usually better drained relative to those formed exclusively in finer grained materials, such as mudstone siltstone.

The 2013 Hydrogeology Report³ assessed the in-situ hydraulic conductivity of the limestone rock mass, determined by laboratory tests and field tests, to vary between about 1.1×10^{-5} m/s and 3×10^{-10} m/s. Such variability is not unexpected and was inferred to reflect factors such as:

- Smear on borehole/shaft walls affecting field test results.
- The variability of laboratory test samples.
- The relationship between vertical and horizontal hydraulic conductivity which will be linked to the limestone's sedimentary and tectonic structure.
- The overall inherent variability of the limestone materials, e.g. more marly or sandy horizons; and possible effects of stress relief.

The inferred representative hydraulic conductivity value of 3×10^{-8} m/s presented in the 2013 Hydrogeology Report³ is within the range of test values and is considered compatible with the construction observations of the limestone's field behaviour, particularly observations in the Western Property.

Table 4.2 presents the inferred representative hydraulic conductivity of the geological units mapped beneath the landfill as presented in the 2013 Hydrogeology Report. Generally, bulk permeabilities of the rocks beneath the landfill are low, particularly for the fine-grained material. Therefore, groundwater flow rates beneath the landfill are considered to be extremely low.

¹¹ T+T, November 2015. Redvale Landfill Phase 20A, Geotechnical Assessment Report. Job no: 30370.3000; T+T, November 2017. Redvale Landfill: Phase 20B, Geotechnical Assessment Report. Job no: 1002486.300.v1; T+T, July 2019. Redvale Landfill: Phase 21, Phase 22B and Phase 22C, Geotechnical Assessment Report.

Table 4.2: Summary of inferred representative hydraulic conductivity

Material type	Cross reference to geotechnical description	Inferred representative hydraulic conductivity (1990)	Inferred representative hydraulic conductivity (2013)	Comment
Northland Allochthon Marly Limestone	Unit N1	Undisturbed 1×10^{-9} m/s Remoulded $< 5 \times 10^{-10}$ m/s	Undisturbed 3×10^{-8} m/s Remoulded $< 5 \times 10^{-10}$ m/s	Undisturbed hydraulic conductivity based on flow and level changes measured at drains in Southern Highwall on Western Property
Northland Allochthon Sandy Limestone	Unit N1	Generally $< 1 \times 10^{-7}$ m/s	Generally $< 3 \times 10^{-8}$ m/s	As above
Northland Allochthon Mudstone	Units N2, N3, N4, N5, N6, N7, N8, Autoclastic Breccia	Undisturbed $< 5 \times 10^{-10}$ m/s Remoulded $< 1 \times 10^{-11}$ m/s	Undisturbed $< 5 \times 10^{-10}$ m/s Remoulded 6×10^{-11} m/s	Remoulded value is median of reported liner test results
Waitemata Group	Both pre- and post-emplacement of the Northland Allochthon	$< 5 \times 10^{-7}$ m/s	$< 5 \times 10^{-7}$ m/s	-
Pleistocene Materials		$< 5 \times 10^{-8}$ m/s	$< 5 \times 10^{-8}$ m/s	No specific tests

4.4.2 Hydraulic conductivity in the proposed Class 2 footprint extension

The geological map for the proposed Class 2 footprint extension indicates that it is predominantly underlain by sheared mudstone (Northland Allochthon), with a small area of pre-emplacement Waitemata Group sandstone along its western boundary. Fill and Tauranga Group sediments were encountered during drilling of W138, overlying Northland Allochthon mudstone.

Excavation for the Class 2 footprint extension is inferred¹² to extend predominantly into the Northland Allochthon mudstone, as illustrated on Figure 4.2. Based on Table 4.2, the Northland Allochthon mudstone is expected to have a representative hydraulic conductivity of approximately 5×10^{-10} m/s. In addition, Waitemata Group sandstone is expected to be encountered along the western boundary of the Class 2 footprint extension, which has a representative hydraulic conductivity of approximately 5×10^{-7} m/s.

4.4.3 Groundwater flux in Phase 1 area of existing landfill

Details of the leachate flux assessments can be found in the T+T 2022^{6,7} and 2025⁸ reports. In summary, if leachate seepage was to occur through the liner, the total outward flux has recently been estimated at approximately 1.5 m³/year. Therefore, the total cumulative leachate flux, if occurring, has remained well within the compliance limit of 0.3 m³/day (110 m³/year).

¹² Refer to the Geotechnical Assessment Report.

4.5 Groundwater and leachate quality

4.5.1 Monitoring method

Currently, groundwater samples are routinely collected from nine groundwater monitoring wells to monitor groundwater quality around the perimeter of the landfill, as listed in Table 4.3 and shown on Figure 4.3. In addition, leachate quality samples are taken from four leachate collection sumps (LCS) (Table 4.3 and refer to the Leachate Collection Layout Plan in Appendix B, Figure B2). Groundwater samples are tested for various suites of analytes as stipulated in Conditions 89, 90 and 91 on a quarterly and annual basis. There is no condition that requires leachate quality testing, but leachate sampling and quality testing is generally undertaken on a quarterly to annual basis depending on the analyte.

Given the groundwater flow directions beneath the landfill, the groundwater wells are suitably placed to monitor groundwater quality downgradient of the groundwater flow directions towards the north, northeast and east-southeast.

Table 4.3: Groundwater quality monitoring wells and leachate sample collection points – historical and current

Monitoring well/Leachate collection point	Groundwater/leachate	Landfill boundary	Well depth ² (m bgl)	Date of most recent water quality results provided to T+T
M1A	Groundwater	North	15	8 January 2025
M2B	Groundwater	Northeast	31.2	16 October 2024
M7A	Groundwater	Southeast	16.7	8 January 2025
M7B (historical)	Groundwater	Southeast	17 (screen interval 13.5 – 16.5)	30 September 2021
M8A	Groundwater	Southeast	16.8	8 January 2025
M9A	Groundwater	East	16.5	8 January 2025
M10A	Groundwater	Northeast	16.7	8 January 2025
M11A	Groundwater	North	15	8 January 2025
M12A	Groundwater	North	15	8 January 2025
M13A	Groundwater	North	12.5 (9.0 - 12.0)	8 January 2025
W2A ¹ (historical)	Groundwater	Southeast	11	30 September 2021
W3A ¹ (historical)	Groundwater	Southeast	12.7	30 September 2021 and one-off sample on 27 March 2025
LCS1	Leachate	Phase 1	-	14 January 2025
LCS2 (historical)	Leachate	Southern boundary, near southeast corner	-	12 June 2019
LCS3 (historical)	Leachate	Southern boundary, near southeast corner	-	4 September 2018

Monitoring well/Leachate collection point	Groundwater/leachate	Landfill boundary	Well depth ² (m bgl)	Date of most recent water quality results provided to T+T
LCS4	Leachate	Southern boundary, near southeast corner	-	9 October 2024

Notes:

1. We have assumed that these bores are W2AD and W3AD.
2. Redvale Landfill Management Plan 2022, Environmental Management Plan, Section 4.5 – Ground Water. Schedule 1 Monitoring Boreholes.

4.5.2 Groundwater quality results

Recent groundwater quality results (last 10 years) have been analysed to identify any changing trends in groundwater and to determine the ‘present-day’ groundwater quality surrounding the site. We have focused our assessment on the indicator parameters boron, chloride, chemical oxygen demand (COD), ammoniacal nitrogen, pH and electrical conductivity (EC) (in accordance with prior assessments of the site and the WasteMINZ Technical Guidelines for Disposal to Land Rev 3.1 (WasteMINZ Technical Guidelines)¹³. These parameters can provide an indication of leachate leakage through either a concentration gradient (such as ammonia and chloride) or because of their relative mobility in groundwater (such as boron).

We note that while pH is considered an indicator parameter, we observe that it is generally stable in all the groundwater monitoring wells and leachate samples, and there is no significant difference between leachate and groundwater pH. Therefore, we have not used pH as an indicator parameter for this assessment.

In order to understand how and/or if the landfill has affected groundwater quality downgradient of the site, we have grouped the monitoring bores according to their location with respect to the groundwater flow directions determined from the groundwater contours: north, northeast and east-southeast. We have not included M7B in our assessment, as the data we were provided with indicates that this bore was only sampled for eight rounds over a short sampling time period, between December 2019 to September 2021.

The following sections summarise the ‘present-day’ downgradient groundwater quality surrounding the site. Overall, groundwater quality results show no evidence of significant change over time, and no evidence of effects of leachate. Any apparent increasing trends in indicator parameter concentrations still remain within historically measured concentrations and there is no apparent difference in groundwater quality between the downgradient locations.

4.5.2.1 Northern boundary

The following wells monitor groundwater quality along the northern boundary of the landfill:

- M13A
- M12A
- M11A
- M1A

We have graphically analysed the groundwater quality results for these wells (refer to Appendix C, Section C3) and these graphs indicate the following:

¹³ Waste Management Institute New Zealand (WasteMINZ), September 2023. Technical Guidelines for Disposal to Land – Revision 3.1.

- Ammoniacal nitrogen concentrations in M12A and M11A have generally been decreasing, apart from an anomalous spike in December 2018 in M12A and a spike in June 2019 in M11A. Overall, groundwater sampled from M12A and M11A has generally had higher concentrations than in all the other groundwater monitoring wells surrounding the site over the period March 2013 to March 2020. Concentrations in M13A and M1A have remained relatively stable, apart from a spike in M1A in December 2018.
- Boron concentrations in all the wells, apart from M1A, have been decreasing (since 2020 in M12A). Concentrations in groundwater sampled at M1A have been increasing slightly since 2015, but concentrations have not been higher than historical results in this well.
- Chloride concentrations have been decreasing in M13A and M12A (since 2017), slightly increasing in M1A and have remained stable in M11A.
- COD concentrations have been decreasing in M12A and have remained generally stable in M11A, M13A and M1A (apart from a spike in M1A in December 2013 of 150 g/m³ (typical concentrations are between 6 g/m³ and 24 g/m³)).
- EC has remained stable in all wells, apart from in M12A, which indicates a generally decreasing trend (visually).

4.5.2.2 Northeast

The following wells monitor groundwater quality along the northeast boundary of the landfill:

- M2B
- M10A

We have graphically analysed the groundwater quality results for these wells (refer to Appendix C, Section C3) and these graphs indicate the following:

- Ammoniacal nitrogen concentrations in M10A have remained stable and there appears to have been a slight decrease in concentrations in M2B since January 2019.
- Boron concentrations in M10A have decreased and then stabilised for the last 10 years (<1 g/m³). Concentrations in M2B have increased since approximately the end of 2019, from generally around 3.5 g/m³ to 6.5 g/m³ in December 2023. Concentrations have since decreased to 4.8 g/m³ by October 2024. However, these concentrations are all still below concentrations measured pre-2012.
- Chloride concentrations have increased in M2B since 2013, from approximately 60 g/m³ up to 370 g/m³ in 2018. Concentrations have then decreased since June 2019, to approximately 130 g/m³ by Oct 2024. Concentrations in M10A have generally decreased.
- COD concentrations have remained stable in both monitoring wells.
- EC has generally decreased in M2B, since June 2018, and decreased slightly in M10A.

4.5.2.3 East-southeast

The following wells monitor groundwater quality along the east-southeast boundary/corner of the landfill:

- M9A
- M8A
- M7A
- W3A
- W2A

There is no recent data for W2A and W3A as monitoring at these locations has ceased (after September 2021). However, a sample was collected from W3A on 27 March 2025 to supplement the existing data and WMNZ has confirmed that quarterly monitoring of W3A has recommenced. We have graphically analysed the groundwater quality results for the wells (refer to Appendix C, Section C3) and these graphs indicate the following:

- Ammoniacal nitrogen concentrations have remained generally stable in all the wells, apart from in M7A. Concentrations in M7A appear to have been increasing since mid-2022.
- Boron concentrations have remained stable in all the wells, with a slight decreasing trend in M9A. Concentrations in M9A have been decreasing slightly over the last 10 years and have been visibly decreasing over the whole monitoring period.
- Chloride concentrations are generally stable in all the wells, with a slight decreasing trend in W3A.
- COD concentrations have remained stable in all the wells, with one high spike in W2A in December 2019.
- EC has generally remained stable in all the wells.

4.5.2.4 Groundwater quality relative to each monitoring well

In addition to analysing the groundwater quality data collected within specific areas surrounding the landfill, we have also compared the groundwater quality between all the monitoring wells, regardless of location, for the last 10 years of monitoring. The following is a summary of our observations:

- Out of all the groundwater monitoring wells, ammoniacal nitrogen concentrations are generally the highest in groundwater monitored by M12A and M11A. Typically, the concentration of ammoniacal nitrogen in these two wells ranges between 0.01 g/m³ and 4.4 g/m³ in M12A and 0.01 g/m³ and 3.4 g/m³ in M11A (ignoring the anomalous spikes). M13A generally has the lowest ammoniacal nitrogen concentrations out of all the groundwater wells, ranging between 0.01 g/m³ and 0.1 g/m³. When the groundwater quality results for all the wells are viewed together graphically, there is no apparent increasing trend in ammoniacal nitrogen concentrations in the groundwater sampled in the monitoring wells.
- Groundwater sampled in M2B typically has the highest boron concentration, ranging between approximately 2 g/m³ and 7 g/m³. Groundwater sampled by M7A and M13A has the lowest concentrations, at less than 1 g/m³. When all the wells are viewed together graphically, only groundwater sampled in M2B appears to have had a recent increase in boron concentration (however, recent concentrations in M2B remain below concentrations measured pre-2012).
- Chloride concentrations are typically highest in groundwater monitored by M2B, ranging between 80 g/m³ and 370 g/m³. Groundwater sampled at M11A and M1A has the lowest concentrations, ranging between approximately 20 g/m³ and 30 g/m³. When all the wells are viewed together graphically, there is no apparent increasing trend in chloride concentration in groundwater.
- M12A and M1A typically have the highest COD concentrations¹⁴. If the anomalous spikes in concentration are ignored, then concentrations have generally ranged between 6 g/m³ and 64 g/m³ in M12A and 6 g/m³ and 24 g/m³ in M1A. M9A has generally had the lowest COD concentrations, ranging between less than 6 g/m³ and 8 g/m³. There is no apparent increasing trend in COD in the groundwater sampled in the monitoring wells.

¹⁴ We note that for COD, the lab has not reported concentrations less than 6 g/m³. If concentrations are less than this, 6 g/m³ has been reported.

- Over the last 10 years, M2B has generally had the highest EC values, although since March 2022 EC has decreased in the sampled groundwater and is similar to the values in the other groundwater monitoring wells. Generally, M7A has recorded the lowest EC across all the groundwater monitoring wells. In January 2025, the EC in all the groundwater monitoring wells ranged between 81.6 mS/m in M11A and 168.8 mS/m in M8A. There is no apparent increasing trend in electrical conductivity in the groundwater sampled in the monitoring wells.

4.5.2.5 Trigger level exceedances

Trigger levels (trigger level 1 and trigger level 2) have been set for the monitored parameters in groundwater sampled at each of the monitoring wells. These were derived¹⁵ based on baseline monitoring results and the guideline values for the protection of 95% of the freshwater species (or any other standard guideline values approved by Auckland Council). W2A and W3A have no trigger levels.

We have analysed exceedances in the leachate indicator parameter concentrations in the groundwater monitoring wells since 2015 (refer to Table 4.4). Generally, exceedances of trigger levels have been irregular and show no trend, apart from in M2B and M7A. Chloride concentrations in both M2B and M7A routinely exceed TL2 and TL1 respectively, as has EC in M2B (TL2 until June 2022 and then TL1 until December 2023).

For groundwater sampled in M2B, these exceedances have been occurring since December 2013, with chloride concentrations and EC increasing up to the end of 2018 and then subsequently decreasing to the present day. For M7A, chloride concentrations in the sampled groundwater have exceeded TL1 since 2002. However, chloride concentrations have not increased above 100 g/m³ and TL2 is set at 400 g/m³. In contrast, chloride concentrations in leachate within LCS1 indicate an increasing trend from late 2019 to 2024.

Given that the other leachate indicator parameters tested in the sampled groundwater for these wells do not have sustained exceedances and there is no ongoing increasing trend in parameter concentrations in the groundwater, it is unlikely that leachate seepage through the lining system is the cause of these exceedances. This conclusion is consistent with those made in the 2016 and 2019 AECOM Redvale Landfill Groundwater Data Review reports¹⁶.

Table 4.4: Number of trigger level exceedances in leachate indicator parameter concentrations in groundwater since 2015 – grouped by downgradient location

Well	Downgradient location	Ammoniacal nitrogen	Boron	Chloride	COD	Electrical conductivity
M1A	North	Five above TL2	-	-	-	-
M11A	North	10 above TL2 and two above TL1	-	-	-	-
M12A	North	-	One above TL1	One above TL1	-	-
M13A	North	-	-	-	-	-
M2B	Northeast	-	-	Every sampling	-	All above TL2 until June 2022, then all above TL1

¹⁵ Waste Management, October 2022. Redvale Landfill Management Plan, Environment Management Plan. Section 4.5 - Ground Water. Edition 6.

¹⁶ AECOM, October 2016. Redvale Landfill Groundwater Data Review (May 2014 to June 2016). Doc No. R001. & AECOM, June 2019. Redvale Landfill Groundwater Data Review 2019. Job No. 60604705.

Well	Downgradient location	Ammoniacal nitrogen	Boron	Chloride	COD	Electrical conductivity
				round above TL2, apart from one		until Dec 2023, then below TLs apart from July 2024 (TL1)
M10A	Northeast	-	-	-	-	-
M7A	East-southeast	One above TL2		All above TL1 since 2002		Five above TL1 between Oct 2016 and Jan 2019
M8A	East-southeast	-	-	-	-	-
M9A	East-southeast	Two above TL1 between 2015 to 2016 and one above TL2 in Jun 2016	-	-	-	-

4.5.3 Leachate quality results

Leachate samples are collected from four leachate collection sumps located along the southern landfill boundary, toward the southeast corner (along the southern boundaries of Phase 15, 16 and 1; refer to Appendix B, Figure B2). Leachate samples have been routinely collected from LCS1 since monitoring began. Samples have not been taken from LCS2 since June 2019 and from LCS3 since September 2018. Results from sampling in LCS4 were provided from May 2021 to October 2024.

We have graphically analysed the leachate quality results from these collection points (refer to Appendix C, Section C3) and compared the leachate quality to the groundwater quality. These graphs indicate the following:

- Ammoniacal nitrogen concentrations in LCS1 have been decreasing over the last 10 years and recent concentrations in LSC1 are similar to those measured in LCS4. Ammonia concentrations are approximately two to three orders of magnitude higher than in the monitored groundwater.
- Boron concentrations in leachate have been stable and are generally an order of magnitude higher in concentration than in the groundwater.
- Chloride concentrations in the leachate have been stable and are generally one to two orders of magnitude higher than in groundwater.
- COD concentrations in the leachate have been stable. Recent concentrations have typically been between 1,000 g/m³ and 3,000 g/m³. Generally, COD concentrations in the leachate samples are two to three orders of magnitude higher than measured in groundwater.
- EC has been stable in the leachate and is generally one to two orders of magnitude higher than in groundwater.

5 Groundwater fate and transport modelling

5.1 General

Groundwater fate and transport modelling has been undertaken to assess the potential environmental effects of leachate seepage through the liner should that seepage occur. Fate and transport modelling was completed in 2013 and 2017 for the existing landfill to assess the nearest receiving environment, namely the Rangitopuni Stream. The assessment presented here builds on the 2013 and 2017 work.

Section 5.2 below sets out the methodology, analysis and results of the fate and transport modelling undertaken to reflect the proposed changes to the existing landfill.

The proposed construction of the Class 2 footprint extension has also been considered in terms of potential for leachate seepage as presented in Section 5.3.

5.2 Fate and transport modelling: existing landfill

5.2.1 Overview

The contaminant fate and transport modelling to consider the proposed changes to the existing landfill has been completed using analytical modelling based on the source, pathway and receptor relationships. It has been undertaken to assess the potential environmental effects should the seepage of leachate occur through the liner, particularly in respect of the proposed changes.

The assessment is based on the hydrogeological context provided in Section 4 of this report and is set out in the following sub-sections. The fate and transport modelling comprises the following steps:

- Identification of the changes that may be expected from increasing the capacity/thickness of the waste mass.
- Review of the existing leachate quality data to represent the source concentrations of fate and transport modelling.
- Contaminant exposure pathway assessment including a summary of valid pathways and receptors.
- Selection of appropriate environmental criteria to be protective of the identified receptors.
- Selection of model and modelling inputs to reflect the source, exposure pathways and points of exposure.
- Contaminant fate and transport modelling and comparison of results with environmental criteria.
- Sensitivity analysis.

5.2.2 Changes to the existing landfill

The existing landfill capacity is proposed to be increased by thickening the waste mass along the southern, eastern, and northern boundaries, as detailed in the Landfill Engineering Report¹⁷.

The following changes are considered relevant for the fate and transport modelling:

- Increased waste mass results in more leachate generation potential:

¹⁷ T+T June 2025. Landfill Engineering Report. Auckland Regional Council – Transition Project. Ref: 1092369.3000 v1.

- An increase in waste mass introduces more moisture-bearing materials and organic content, which can increase the volume of leachate generated¹⁸. However, the increase is not necessarily linear due to mitigating operational practices like daily capping and limited work faces.
- Importantly, the rate of leachate generation is influenced more so by rainfall infiltration than by waste volume alone.
- Steepened slopes may improve runoff:
 - Steeper side slopes can improve surface water runoff, reducing the infiltration of rainfall into the waste mass¹⁹, especially if surface water controls are well-designed.
- Daily capping and limited working faces are critical:
 - This practice minimises the exposed waste, reducing rainfall infiltration and leachate generation. The net increase in leachate may be moderate and not proportional to the waste mass volume increase.
- Hydraulic load on the liner may increase:
 - The added waste thickness around the perimeter of the landfill is likely to increase vertical stress, which could compress the leachate drainage layer, reducing operational permeability²⁰. This may lead to a higher leachate head on the liner, even if the leachate collection system is functioning.
- Leachate quality may change:
 - While the composition of leachate may not change dramatically, the concentration of contaminants could increase due to higher waste density and moisture content²¹.
 - The organic load may increase which can lead to higher BOD/COD.
 - Ammonia concentrations may increase. With more organic nitrogen in the waste, ammoniacal nitrogen levels in leachate may increase and persist longer.
 - The increase in waste mass may slightly elevate concentrations of heavy metals (e.g., copper, lead, zinc) and inorganics (e.g., chloride, sulphate), depending on the waste composition.
- Increased weight may reduce the permeability of the waste mass at the base of the landfill. It is possible that the increased overburden pressure could compress the drainage layer of the existing leachate collection system. However, the Redvale leachate collection system was designed for the existing maximum height of the landfill so the system will not be affected by the placement of additional waste¹⁷.

In light of the above, the modelling has accounted for the landfill changes as follows:

- The potential for additional leachate head on the liner has been accounted for in the modelling by assuming a continuous outward hydraulic gradient for the full period modelled.
- Potential changes in leachate quality have been accounted for by conservatively adopting the 95% upper confidence level (UCL) of the recent (last 10 years) or full leachate testing record reported for LCS1.

5.2.3 Potential sources and pathways

The potential source of contamination for this assessment is the leachate being generated by the existing and future landfill waste mass. Between 2022 to the present time, T+T has assessed

¹⁸ Adhikari et al. (2014), Factors Affecting the Composition of MSW Landfill Leachate, ResearchGate.

¹⁹ Huang & Fan (2016), Engineering geological analysis of MSW landfill stability, Springer.

²⁰ Geosynthetic Fundamentals in Landfill Design, Springer.

²¹ Adhikari et al. (2014), Factors Affecting the Composition of MSW Landfill Leachate, ResearchGate.

leachate mounding and leachate flux through an area on the south eastern corner (Phase 1) of the landfill^{6, 7}. The assessments have indicated that while the landfill liner and leachate collection system are all below the surrounding groundwater levels, there is a potential for outward leachate migration at times where the leachate levels in the monitoring wells (LM1 and LM1A) have risen above the surrounding groundwater level. When this occurs, there is the potential for leachate to seep from the south eastern corner of the landfill and follow the predominant groundwater flow direction to the east-southeast.

In addition to the infrequent potential for seepage in the south eastern corner of the landfill, our conceptual hydrogeological model indicates a component of groundwater flow trending northward (refer to Figure 4.4 to Figure 4.6). However, because the landfill liner and the leachate collection system in the area slopes southward, we consider leachate will not collect and mound in the area, and this pathway has not been considered any further.

5.2.4 Contaminants of concern

WMNZ has provided T+T with leachate testing data dating back to the late 1990's. The leachate has been collected from 4 collection sumps: LCS1, LCS2, LCS3 and LCS4. We have used the 95% upper confidence limit of the full dataset to provide representative source leachate concentrations for modelling. The exception is as follows:

- Zinc concentrations: Review of historical trends indicate that zinc concentrations decrease over time. On this basis, the 95% UCL from the last 10 years of leachate data was adopted for a source concentration.

The contaminants of concern selected are those documented in the WasteMINZ Technical Guidelines, Class 1 WAC. Where there is an absence of leachate source data for some contaminants of concern, we have adopted alternative source data as follows:

- The WAC TCLP limits for chlordane (gamma and alpha chlordane), toxaphene, 2,4 dichlorophenoxyacetic acid and pyridine have been adopted because these analytes are not included in the Redvale Landfill leachate data. These are extremely conservative as it effectively assumes that all waste in the landfill is discharging these contaminants at the maximum allowable concentration. This is unlikely to be the case.
- The maximum leachate concentration for beryllium from a previous report prepared on behalf of Waste Management Inc., dated 20 May 1997²².

5.2.5 Potential receptors

Our review of the existing environmental setting around the landfill and the updated conceptual hydrogeological model has identified the following potential receptors should leachate seepage into groundwater occur:

- Aquatic life in the Rangitopuni Stream to the south east of the landfill. This has been identified and assessed previously in historical fate and transport modelling.
- Surface water take from the Rangitopuni Stream for irrigation use of tomato plants (refer to Table Appendix C.2). This receptor has not been assessed previously in our fate and transport modelling.

5.2.6 Point of exposures guideline values

We have adopted the following guideline values for the contaminants of concern:

²² RUST, 20 May 1997. Leachate Report, Volume 1, Table A-3-2, MSW Leachate Characteristics, maximum value from literature data.

- ANZG (2018) default guideline values for the protection of 95% of freshwater species²³ for the assessment of effects to ecological receptors in the Rangitopuni Stream.
- ANZG (2023) water quality for irrigation and general water uses: guidelines for the assessment of effects for irrigation use²⁴.

In some cases guideline values do not exist for the contaminants of concern. Where this is the case, we have selected values from the following sources:

- Recreational water use guidelines and trigger values for freshwater protection as presented in ANZECC (2000) guidelines²⁵.
- Drinking Water Standards for New Zealand²⁶.

The adopted point of exposure guideline values are provided in the tables attached as Appendix D.

5.2.7 Fate and transport modelling methodology

The Groundwater Services Inc. RBCA²⁷ software package has been used to model the fate and transport of contaminants from the southern eastern part of the landfill to the downgradient surface water receptor, the Rangitopuni Stream.

Contaminant fate and transport in the saturated zone is modelled in RBCA using the Domenico analytical solution for multi-dimensional transport of contaminants undergoing attenuation and/or degradation²⁸. This solution accounts for advection, dispersion, adsorption of organic and inorganic contaminants, and includes natural attenuation of organic compounds. The RBCA model outputs comprise estimates of contaminant concentrations at specified distances from the source.

For surface water points of exposure, mixing of contaminants in groundwater entering surface water is accounted for based on groundwater discharges and surface water flow at the Rangitopuni Stream. Surface water flows incorporated into the modelling are based on the 1 in 5-year low flow sourced from NIWA²⁹.

5.2.8 RBCA site conceptual model and input parameters

Input values for the RBCA model to assess the potential effects on the receiving environment are set out in Table 5.1.

²³ ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

²⁴ ANZG (2023). Water Quality for Irrigation and General Water Uses: Guidelines. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand governments and Australian state and territory governments, Canberra.

²⁵ Australian and New Zealand Environment and Conservation Council (ANZECC) 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality

²⁶ Water Services (Drinking Water Standards for New Zealand) Regulations 2022.

²⁷ GSI Environmental Inc., 2011. Risk-Based Corrective Action Tool Kit for Chemical Releases (Version 2.6). <https://www.gsi-net.com/en/software/rbca-software-tool-kit-for-chemical-releases-version-2-6.html>

²⁸ Domenico, P. A. (1987). An analytical model for multidimensional transport of a decaying contaminant species. *Journal of Hydrology*, 91(1), 49–58.

²⁹ [NZ River Maps](https://shiny.niwa.co.nz/nzrivermaps/) (<https://shiny.niwa.co.nz/nzrivermaps/>)

Table 5.1: RBCA model groundwater parameters

Parameter	Value selected for model input	Source
Saturated hydraulic conductivity	1×10^{-8} m/s	Refer to Section 4.4.
Hydraulic gradient	0.058 – south east	Calculated from groundwater contours developed for the site.
Effective porosity	0.1	Reference value from literature ³⁰
Fraction of organic carbon, <i>foc</i>	0.003	Reference value from literature (low to be conservative). The <i>foc</i> value selected is the lowest of the soil types examined in the MfE guidelines ³¹
Landfill width (plume width at source)	150 m – south east	Measured based on the potential seepage zone in the south eastern corner of the landfill.
Dispersion for groundwater receptor	Receptor specific	Calculated from the distance to receptor based on the default calculation method employed in ASTM E-1739 ³²
pH of groundwater	7.4	Based on site-specific groundwater quality data. Refer to Section 4.5.
pH of leachate	7.4	Based on average of site-specific leachate quality data from LCS1.
Plume mixing depth at source	1 m	Mixing depth based on seasonal groundwater fluctuations.
Contaminant degradation	Contaminant-specific	RBCA default half-life values adopted for organic contaminants. Where RBCA has no default degradation values a half-life of $10e^{24}$ days was assumed (i.e., no degradation).

Table 5.2 lists the RBCA model parameters and the values specific to each receptor. The following assumptions were made:

- The stream dimensions are such that discharge from groundwater to the stream are fully mixed.
- Background contamination of groundwater and/or surface water, if any, was not considered.

³⁰ Domenico, P.A. and Schwartz, F.W., 1998. Physical and chemical hydrogeology.

³¹Ministry for the Environment, 1999, Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand.

³² ASTM E1739-95, 2002. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM International: West Conshohocken, PA. www.astm.org

Table 5.2: RBCA model site-specific parameters for the Rangitopuni Stream point of exposure

Parameter	Value selected for model input	Source
Distance to POE	480 m	Minimum distance of receptor stream to landfill footprint.
Length of groundwater – surface water interface l_{GWSW}	150 m	Estimated based on the intersection of the Rangitopuni Stream channel and the width of the landfill projected in the direction of groundwater flow.
Stream depth δ_{GWSW}	1 m	Assumed stream depth.
Surface water flow rate at POE	0.014 m ³ /s	1 in 5-year low flow. NIWA Rivermaps, Rangitopuni Stream catchment, NZ segment: 2035014

Fate and transport modelling also requires simplification of the hydrogeological conceptual site model. We have assumed that contaminant transport only occurs in the saturated Northland Allochthon soils. This is considered a conservative assumption as the closest receptor is located within the saturated Northland Allochthon soils.

5.2.9 Model conservatism

A number of conservative assumptions have been made during the modelling including no degradation of inorganic contaminants and modelling to steady state, i.e., maximum predicted concentrations. The RBCA model also has some internal inherent conservative assumptions. Important assumptions are listed in the following Table 5.3.

In reality, some attenuation of inorganic contaminants will occur, and steady-state conditions are likely to take many years to develop (in the order of one thousand years or more). Furthermore, leachate source concentrations will deplete over time due to dissolution and biodegradation, well before steady-state conditions can develop.

Table 5.3: Model conservatism

Item	Detail
Source concentrations	- Adopted the: 95% UCL leachate concentrations from LCS1, either over the full data record or the last 10 years of data, or - the waste acceptance criteria. - Inorganic source concentrations represent 'Total' concentrations and not the dissolved phase. It is the dissolved phase that will migrate in groundwater and this value is usually at least an order of magnitude less. - Assumed to be non-depleting over time. - No attenuation of contaminants during transport through liner. Modelling assumes contaminants are already present in groundwater at leachate concentrations beneath the existing clay liner.
Concentrations in groundwater	- No degradation occurs for the inorganic contaminants. - Continuous outward gradient occurs. In reality, the outward gradient only occurs infrequently.

Item	Detail
	Ground flows directly to the stream and enters at the closest point. In reality, groundwater is expected to have some southern flow component and would therefore travel further to reach the stream.
Receptor concentrations	- Maximum (i.e., steady state) concentrations are reached. - Low flow in the stream. In reality, the average stream flow would be more representative for determining receptor concentrations.

5.2.10 Existing landfill modelling results

The concentrations predicted by the RBCA model are summarised in Table 5.4. The RBCA input and results sheets are included in Appendix E, along with the sensitivity results referred to in the following section.

Table 5.4: Fate and transport modelling results

Point of exposure	Pathway and receptor	Contaminant concentration prediction	Results table reference
Rangitopuni Stream	<u>Pathway:</u> Groundwater within the Northland Allochthon and mixing with surface water. <u>Receptor type:</u> Ecological.	All contaminant concentrations in groundwater before discharging to the stream are predicted to be below the ANZG 95% default guideline values. All contaminant concentrations in the surface water receptor are predicted to be below the ANZG 95% default guideline values. Highly unlikely to pose a risk to ecological life within the stream.	Table Appendix D.3
	<u>Pathway:</u> Groundwater within the Northland Allochthon and mixing with surface water. <u>Receptor type:</u> Irrigation for tomato plants.	All contaminant concentrations in groundwater before discharging to the stream are predicted to be below the ANZG irrigation guideline values. All contaminant concentrations in the surface water receptor are predicted to be below the ANZG irrigation guideline values. Highly unlikely to pose a risk for use as an irrigation water take from the stream.	Table Appendix D.3

5.2.11 Model sensitivity

A sensitivity analysis has been undertaken to assist in quantifying the uncertainty in RBCA model predictions caused by model parameter uncertainty and conceptual model uncertainty. To assess uncertainty, the following parameters have been adjusted:

- Hydraulic conductivity: To evaluate the effects of increased or decreased groundwater flow velocity.
- Surface water flows: To evaluate the effects of over-estimation of surface water flows, i.e., lower flows.

The results of the sensitivity analysis are summarised in Table 5.5. The results generally indicate that there are no risks to the potential receptors if:

- Hydraulic conductivity is varied to account for a potential range of values in the underlying formation.
- Surface water flows are an order of magnitude lower than estimated.

Table 5.5: Summary of sensitivity analysis

Parameter	Sensitivity analysis result	Comment
Hydraulic conductivity <i>K</i> : Increase by one order of magnitude	No change at the receptor for non-degrading contaminants. Increased concentrations for degrading organic contaminants. All contaminant concentrations below the relevant guideline values.	Increased <i>K</i> reduces travel times (and therefore effect of degradation) in non-conservative contaminants.
Hydraulic conductivity <i>K</i> : Decrease by one order of magnitude	No change at the receptor for non-degrading contaminants. Reduced concentrations at receptor for degrading organic contaminants. All contaminant concentrations below the relevant guideline values.	Although lower <i>K</i> reduces throughflow, it also reduces inflow of groundwater into the surface water receptor and increases travel time/ degradation.
Surface water discharge: Decrease by an order of magnitude	No change in contaminant concentrations at the receptor. All contaminant concentrations below the relevant guideline values.	Decreasing surface water discharge results in lower dilution of leachate-affected groundwater by surface water.

5.3 Proposed Class 2 footprint extension

5.3.1 General

The Class 2 Waste Acceptance Criteria (WAC) set out in the WasteMINZ Technical Guidelines for Disposal to Land Rev 3.1³³ (WasteMINZ Technical Guidelines) are proposed for the Class 2 footprint extension at Redvale.

To support use of these WAC, the derivation set out in the WasteMINZ Technical Guidelines has been reviewed and compared against the site setting and exposure scenarios. The findings are set out in the following sub-sections.

5.3.2 Class 2 footprint extension exposure assessment

By definition, Class 2 landfills are designed for non-putrescible industrial and construction & demolition (C&D) wastes that may contain some contaminants but are not considered hazardous. They have limited biodegradable or hazardous content. A full list of contaminants of concern is presented in Appendix E of the WasteMINZ Technical Guidelines.

The proposed lining system is described in the Landfill Engineering Report³⁴. It has been designed in accordance with the WasteMINZ Technical Guidelines. The lining system will comprise a 900 mm thick compacted cohesive soil lining system with a maximum hydraulic conductivity of 1×10^{-8} m/s.

³³ WasteMINZ, September 2023. Technical Guidelines for Disposal to Land Rev 3.1.

³⁴ T+T June 2025. Landfill Engineering Report, Auckland Regional Landfill – Transition Project. Ref: 1092369.3000 v1.

The liner will minimise the potential for leachate seepage. The leachate drainage to be located above the liner will capture leachate for removal. The subsequent low leachate head on the liner and inferred inward hydraulic gradient assessed to occur given surrounding groundwater levels will act to reduce the impacts of leachate seepage through the liner, should this occur.

The primary exposure pathway is the potential seepage of leachate through the Class 2 footprint extension liner and into the formation directly beneath the landfill by diffuse flow. In the unlikely event that this occurs, and in the unlikely event that affected groundwater migrates from the landfill, there is a potential that contaminants could discharge to surface water features. If this occurred, discharge of contaminants to surface water features has the potential to impact ecological receptors within the surface water or water takes for irrigation.

The Rangitopuni Stream has previously been identified as the nearest downgradient surface water receptor (i.e., where groundwater is expected to discharge). This stream has also been considered as a potential receptor for leachate seepages from the Class 2 footprint extension. A small unnamed stream to the south-west of the Class 2 footprint extension flows into a tributary of the Rangitopuni Stream. However, this stream has been discounted as a groundwater receptor because groundwater flows away from the stream under both existing and post-construction conditions (i.e., it is hydraulically up-gradient).

5.3.3 Exposure assessment for Class 2 WAC

The WasteMINZ Technical Guidelines indicate that the Class 2 WAC have been derived using a structured risk-based approach and are based on the principle of protecting human health and the environment by limiting the concentration of contaminants in waste that could leach into soil, groundwater, or surface water. The Class 2 WAC have been derived assuming moderate environmental protection measures (e.g., engineered liners and leachate collection systems) which contribute to the level of containment, in particular for leachate seepages.

The WasteMINZ Technical Guidelines set out the basis for developing the WAC and present a conceptual site model along with an exposure assessment. Table 5.6 provides an assessment of the Class 2 footprint extension exposure assessment against the exposure assessment set out in the WasteMINZ Technical Guidelines. In summary, the two exposure assessments are consistent and so the assumptions used to derive the WAC are considered to fit those of the proposed Class 2 footprint extension.

Table 5.6: WAC derivation vs Redvale Class 2 model

Derivation assumption		Does the Redvale Class 2 conceptual model fit with WasteMINZ Technical Guidelines
Contaminant source or release:	The source of contamination is the Class 2 landfill waste mass.	Yes
Environmental fate and transport:	Once released to the environment, contaminants move through groundwater.	Yes
Exposure route:	Surface water.	Yes – Rangitopuni Stream
Exposed populations:	Ecological receptors.	Yes – in the Rangitopuni Stream

Derivation assumption		Does the Redvale Class 2 conceptual model fit with WasteMINZ Technical Guidelines
Leaching to groundwater or seepage	Pathway is mitigated by engineered controls including a lining system and leachate collection system to meet the requirements of the WasteMINZ Technical Guidelines. However, it is a primary pathway and has been used to derive WAC.	Yes

5.3.4 Development of the WAC

The WAC were based on the USEPA dilution and attenuation factor (DAF) approach¹³. A DAF of 20 was adopted to derive the WAC for inorganic contaminants and a DAF of 10 has been adopted to derive the WAC for organic contaminants.

The WAC are back-calculated based on receptor protection by applying the Drinking Water Standards for New Zealand³⁵ (for human health) and the Australia New Zealand Environment and Conservation Council ecological guidelines³⁶ (for ecological receptors). Multiple pathways were considered, including those relevant to the proposed Class 2 footprint extension. The limiting pathway that controls the WAC (i.e., resulting in the lowest WAC) have been adopted in the WasteMINZ Technical Guidelines.

5.3.5 Application of the WAC to the Class 2 footprint extension

We consider that it is not necessary to undertake fate and transport modelling for the proposed Class 2 footprint extension for the following reasons:

- The conceptual model and exposure assessment fits that of the proposed Class 2 footprint extension.
- The Rangitopuni Stream is the receiving environment, and the WAC are considered protective of ecological receptors because they have been derived using aquatic criteria.
- The WAC are also considered protective of the surface water take from the stream for irrigation of tomato plants because the aquatic criteria are predominantly more stringent than the irrigation guidelines²⁴. However, some exceptions are noted:
 - The irrigation guidelines for boron, fluoride and molybdenum are slightly lower than the aquatic criteria. These are minor differences, which coupled with the distance to the surface water take (i.e., approximately 850 m and the low hydraulic conductivity of the formation), the WAC for these contaminants are deemed to be protective.

³⁵ Water Services (Drinking Water Standards for New Zealand) Regulations 2022.

³⁶ ANZECC & ARMCANZ (2000) Water Quality Guidelines.

6 Assessment of effects on groundwater

6.1 Introduction

The effects of the revised final surface profile of Redvale Landfill (existing landfill), including the overlay with steepened side slopes and the proposed Class 2 footprint extension, on groundwater is largely anticipated to arise from:

- The excavation of Northland Allochthon mudstone and Waitemata Group sandstone to enable the construction of the Class 2 footprint extension and the storage of waste material resulting in the generation of leachate within the Class 2 footprint extension.
- The storage of waste material from the revised final surface profile of Redvale Landfill and prolonged leachate generation.

We have considered the following potential environmental effects on groundwater:

- Groundwater drawdown as a result of the excavation for the construction of the proposed Class 2 footprint extension.
- Effects on inward gradient of Class 1 landfill directly adjacent to the Class 2 footprint extension.
- Effects on regional groundwater resources, including neighbouring groundwater users.
- Surface water and stream depletion effects.
- Potential for saline intrusion.
- Potential discharge of contaminants into ground and groundwater as leachate seepage through the landfill lining system to account for landfilling operation of the revised final surface profile of the existing landfill.

The potential groundwater effects are outlined in the following sub-sections.

6.2 Groundwater take and diversion for dewatering during excavation of the Class 2 footprint extension

Based on the ground model detailed in the Geotechnical Assessment Report and the proposed excavation and construction design of the Class 2 footprint extension reported in the Landfill Engineering Report, the proposed Class 2 footprint extension will be excavated below the groundwater table (possibly up to 16 m below the groundwater table at the deepest point of the excavation if taking into account inferred seasonal high groundwater levels; refer to Table 6.1).

To control groundwater beneath the Class 2 footprint extension, it is likely that temporary subsoil drains will be constructed below the subgrade to drain groundwater away from the excavation and reduce uplift pressures on the liner. The subsoil drains will divert groundwater to the landfill stormwater management system. It is proposed that at any one time, only a third of the excavation will be open and lining will occur quickly. Therefore, total construction of the Class 2 footprint extension liner is expected to take up to six months.

The subsoil drains are proposed to be sealed up (grouted) after sufficient depth of waste has been placed over the liner to resist any uplift from groundwater pressures. However, while groundwater levels are expected to generally recover once the subsoil drains are grouted, theoretically there is potential for the shallow groundwater to migrate through the liner, once the subsoil drains have been grouted, and be permanently diverted by the leachate drainage blanket to the leachate collection system. The possibility that groundwater may migrate through the liner is due to the potential contrast between the hydraulic conductivity of the surrounding rock (i.e., 1×10^{-9} m/s) and the proposed lining system (i.e., 1×10^{-8} m/s).

Therefore, the purpose of this groundwater dewatering assessment is to estimate the dewatering inflow rates and the resultant drawdown (radius of influence) in the groundwater table due to the dewatering activities (temporary subsoil drains) and to consider the permanent effect on groundwater flows (diversion).

To assess the induced dewatering inflow rates and drawdown of the groundwater table, we have estimated groundwater inflow rates into the excavation using the Analytical Element Method (AEM). The three-dimensional groundwater flow modelling software Analytical Aquifer Simulator (AnAqSim) was used to generate a model of the excavation and simulate time-dependent (transient) groundwater drawdown and inflow rates due to the excavation. A technical memorandum outlining this assessment is attached as Appendix F.

6.2.1 Input parameters

The input parameters required for this dewatering and drawdown assessment are outlined in Table 6.1 and are based on the existing conceptual hydrogeological model for the Redvale Landfill and local area provided in Section 4. To capture the variability in the geology and hydrogeology, we have run several scenarios (Runs 1 and 3) which encompass the range in assessed hydraulic conductivity for the Rangitopuni Waitemata sub-aquifer zone (refer to Table 6.2). Additionally, we have used a conservative maximum initial groundwater level before excavation, based on the June 2021 groundwater contours, to account for seasonal changes in groundwater level (potential winter high)³⁷.

The hydraulic conductivity selected for the base case reflects the inference that the majority of the Class 2 footprint extension will be underlain by Northland Allochthon mudstone, with a small area underlain by Waitemata Group sandstone (refer to Section 4.4.2).

Table 6.1: Base case model input parameters

Layer ID	Excavation level (m RL)	Excavation area ¹ (m ²)	Initial water level ² (m RL)	Initial Groundwater flow direction	Hydraulic gradient	Isotropic hydraulic conductivity (m/day)	Specific yield
Layer1	66	28,990	82 m RL at approximate centre of excavation	102° east of north	0.058	3×10^{-4}	0.02

Notes:

1. The excavation area represents the area of the Class 2 footprint extension that is below the design groundwater level in the model (i.e., the head specified line boundary).
2. Based on the June 2021 groundwater contours. Specific yield is dimensionless.

Table 6.2: Sensitivity analysis input parameters

Run	K horizontal [m/s]	K horizontal [m/day]
Run1	1×10^{-8}	9×10^{-4}
Run2 – base case	3×10^{-9} (Geometric mean)	3×10^{-4}
Run3	1×10^{-9}	9×10^{-5}

³⁷ The groundwater level adopted for the take and divert assessment is different to the design groundwater level in the Geotechnical Assessment Report so that a conservative assessment of effects can be provided.

6.2.2 Results and discussion

The estimated time-dependent (transient) groundwater inflow rates into the excavation for the base case (Run 2) and sensitivity assessments (Runs 1 and 3) are reported in Table 6.3. Dewatering inflows will be higher at early times, as represented by the 30-day inflow estimates, and then reduce over time. Dewatering inflow rates at 180 days (approximately six months) are calculated to be in the range 11 m³/day to 35 m³/day, with the maximum estimated radius of influence (Run 1) extending to approximately 80 m from the edge of the floor of the excavation after 180 days (where dewatering of the excavation has no influence on the groundwater table) (Table 6.3). After 365 days, the radius of influence is predicted to extend to approximately 100 m from the edge of the floor of the excavation and this is considered steady state.

Drawdown effects on the groundwater table due to the dewatering activities will be confined to the WMNZ landholdings (refer Figure 6.1). Once the temporary subsoil drains have been grouted, groundwater levels surrounding the Class 2 footprint extension are expected to recover to approximate pre-excavation levels. Therefore, there is no potential for off-site adverse effects from the groundwater drawdown. An inward hydraulic gradient is likely to exist assuming leachate levels are maintained at levels below the level of the groundwater table surrounding the Class 2 footprint extension.

If groundwater migrates through the liner, drawdowns in the groundwater table are likely to be localised and confined to the Class 2 footprint extension footprint.

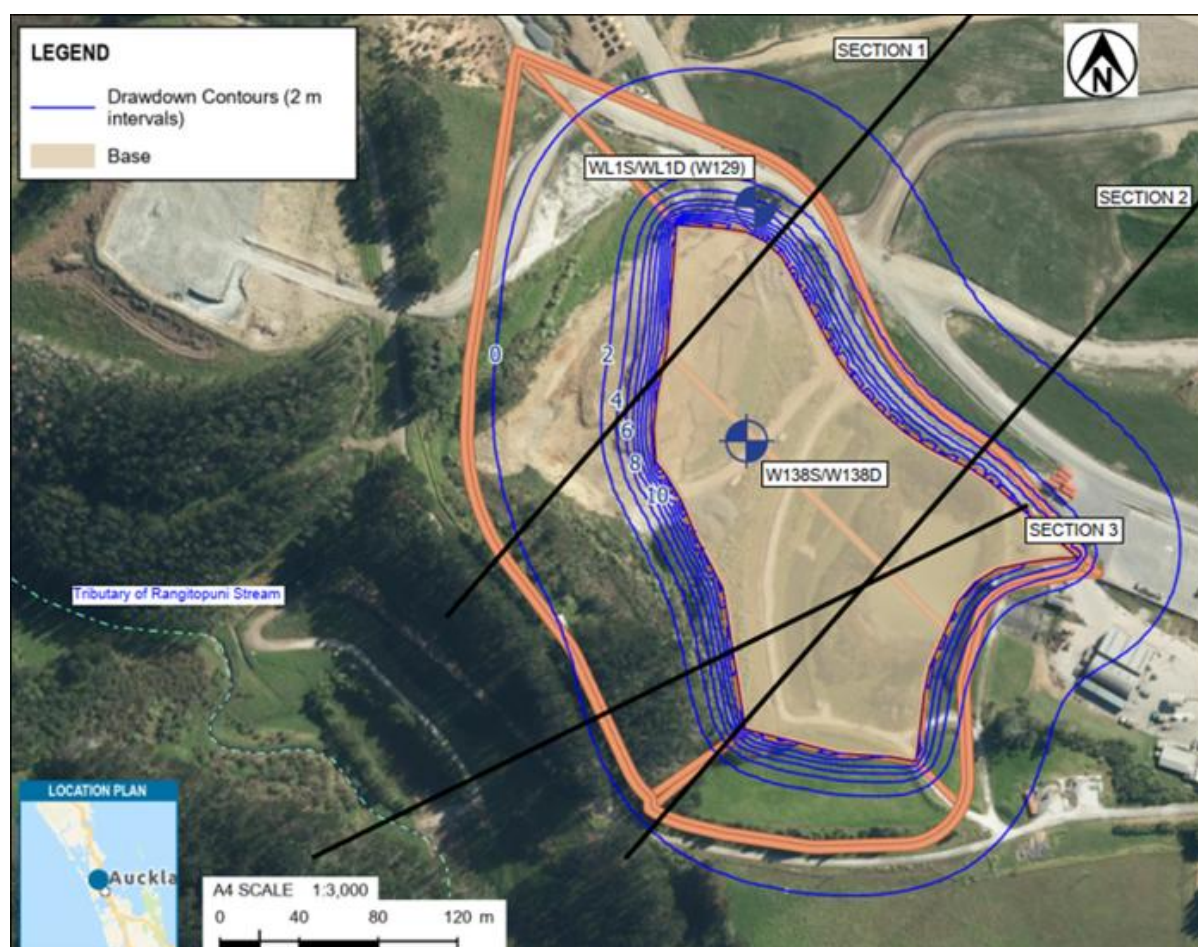


Figure 6.1: Predicted groundwater drawdown extents around the Class 2 Landfill extension during dewatering and lines of section referred to in Section 6.3.

Table 6.3: Estimated inflow rate(s) and radius of influence from the edge of the floor of the excavation

Sensitivity analysis Run	Inflow rate at 30-day timestep	Inflow rate at 180-day timestep	Approximate maximum radius of influence after 180 days	Inflow rate at 365-day timestep	Approximate maximum radius of influence after 365 days
Run1	102 m ³ /day	35 m ³ /day	80 m	19 m ³ /day	100 m
Run2 – base case	54 m ³ /day	21 m ³ /day	50 m	13 m ³ /day	60 m
Run3	26 m ³ /day	11 m ³ /day	20 m	7 m ³ /day	30 m

6.3 Effects on inward gradient of Class 1 landfill

Groundwater levels recorded in W138 indicate that, under current conditions, groundwater beneath the proposed Class 2 footprint extension is substantially higher than inferred leachate levels in the adjacent Class 1 landfill. The existing relationship is illustrated on Figure 6.2 (reproduced from Figure 4.14) and indicates that an inward hydraulic gradient currently prevails in this area.

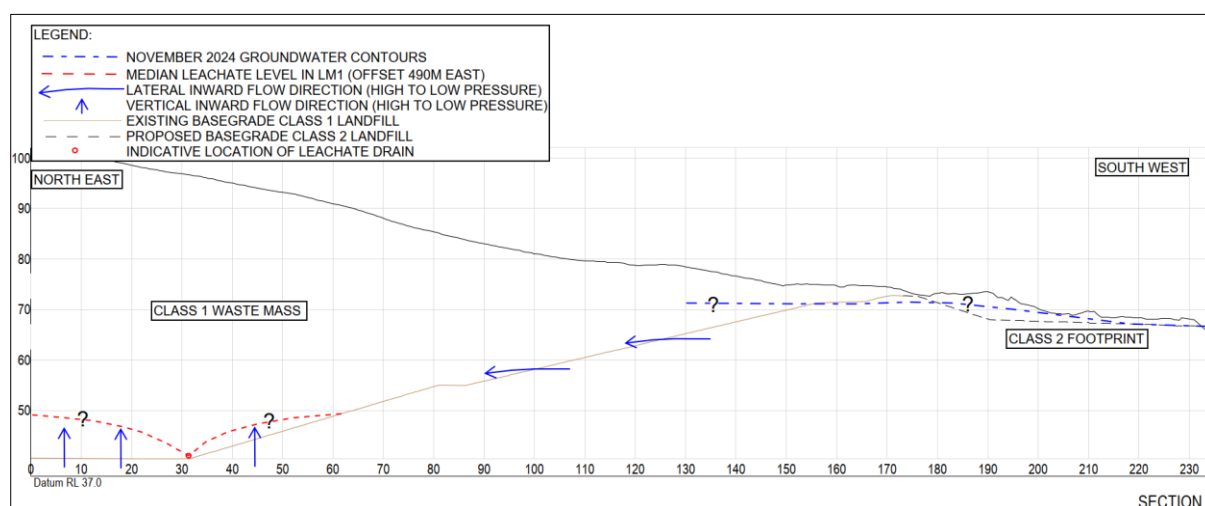


Figure 6.2: Existing hydraulic relationship between groundwater beneath the proposed Class 2 footprint extension and inferred leachate level in the adjacent Class 1 landfill (reproduced from Figure 4.14). Extract from Section 2 line illustrated on Figure 6.1 in Section 6.2.2.

Construction of the Class 2 footprint extension liner may reduce local groundwater recharge and cause some lowering of groundwater levels adjacent to the Class 1 landfill over the long term. Figure 6.3 (line of section 2) and Figure 6.4 (line of section 1) illustrate conservative post-construction conditions in which groundwater levels are reduced to the base of the Class 2 footprint extension.

Even under these conservative conditions, the groundwater level remains above the inferred leachate level in the adjacent Class 1 landfill. Accordingly, reversal of the inward hydraulic gradient is not expected, and the effect of the proposed Class 2 footprint extension on the prevailing inward gradient of the Class 1 landfill at this location is assessed to be negligible.

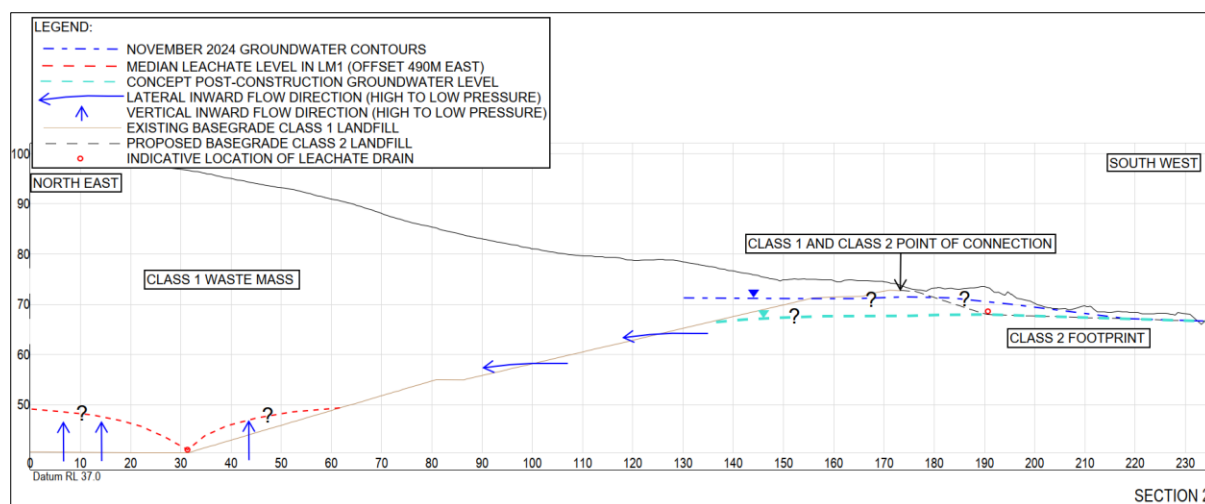


Figure 6.3: Conservative post-construction groundwater level condition adjacent to the Class 1/Class 2 boundary, showing groundwater levels remaining above inferred leachate level in the Class 1 landfill. Extract from Section 2 line illustrated on Figure 6.1 above.

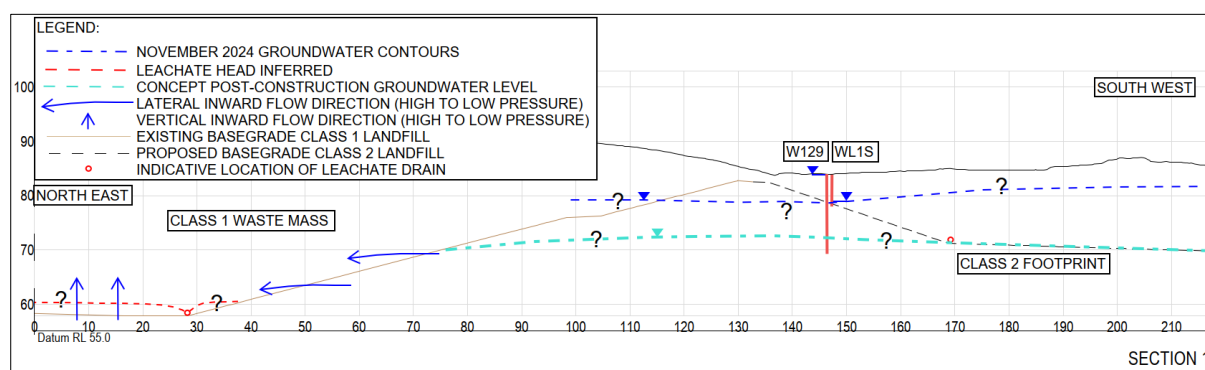


Figure 6.4: Conservative post-construction groundwater level condition adjacent to the Class 1/Class 2 boundary, showing groundwater levels remaining above inferred leachate level in the Class 1 landfill. Extract from Section 1 line illustrated on Figure 6.1 above.

6.4 Effects on regional groundwater resources and users

6.4.1 Effects on regional groundwater quantity

The inflow into the subsoil drains beneath the Class 2 footprint extension will be temporary, until the subsoil drains are grouted. However, there is the potential for longer-term migration of groundwater through the liner, which will be diverted by the leachate drainage blanket to the leachate collection system, if it occurs. Based on the conservative inflow rates estimated from Run 1, where the 30-day inflow rate reflects expected early time inflows, the 180-day rate reflects later time inflows and the 365-day rate reflects steady-state, the proposed groundwater take for the dewatering activities in the first year is approximately 11,900 m³/year (i.e., 30 days x 102 m³/day + 152.5 days x 35 m³/day + 182.5 days x 19 m³/day). This rate is estimated to reduce to 6,935 m³/year under steady-state conditions (365 days x 19 m³/day).

As discussed in Appendix C1.2.1, the proposed Class 2 footprint extension is located within the Rangitopuni Waitemata sub-aquifer zone. Table 6.4 summarises the available allocation³⁸ of

³⁸ Nicola Jones, Specialist, Coastal and Water Allocation Team, Auckland Council. pers. comm., email dated 26/11/2025. Subject: RE: Rangitopuni Waitemata sub-aquifer zone.

groundwater in the Rangitopuni Waitemata sub-aquifer zone and the impact on the allocation if WMNZ is consented to take the proposed maximum groundwater annual volume of approximately 11,900 m³.

Table 6.4: Groundwater allocation and availability for the Rangitopuni Waitemata sub-aquifer zone and the impact on allocation flow from the proposed take by the applicant

Management level (m ³ /year)	530,000
Percent allocated (%)	31
Groundwater available for allocation (m ³ /year)	365,927
Annual volume sought by WMNZ for dewatering activities (m ³ /year)	11,900
Remaining allocation (m ³ /year)	354,027

There is available allocation in terms of groundwater resources based on the proposed maximum annual volume of approximately 11,900 m³. On this basis, the proposed groundwater take will have negligible effect on the allocation of the regional groundwater resource.

6.4.2 Effects on neighbouring groundwater users

As reported in Appendix C, Section C1.2.2, at present there are no consented groundwater takes within 2 km from the approximate centre of the Redvale Landfill. At the time of our enquiry with Auckland Council, the closest drilled bore, which is not recorded as a monitoring or investigation bore, is located approximately 680 m north-northeast of the site. However, there is no groundwater take resource consent or permitted activity associated with this bore.

The drawdown results from the take and divert calculations provide a maximum radius of influence from the edge of the floor of the proposed Class 2 footprint extension of approximately 100 m. Given that the closest recorded bore is located more than 680 m from the proposed Class 2 footprint extension, there will be no adverse drawdown effects on neighbouring groundwater users associated with the proposed dewatering activities.

In addition, since the drawdown effects from the dewatering activities are confined to the WMNZ landholdings, there will be no instances of any unknown permitted activity bores having adverse interference effects.

6.5 Surface water and stream depletion effects

As discussed in Section 4.3.1.1, shallow groundwater in the area locally discharges to the Rangitopuni Stream. The take and divert calculations estimate that the radius of influence of the dewatering activities for the excavation and construction of the Class 2 footprint extension will only extend approximately 100 m from the edge of the floor of the excavation. Therefore, there will be no direct stream depletion effects on the Rangitopuni Stream due to the dewatering activities.

In addition, while the proposed Class 2 footprint extension will reduce the area over which rainfall can recharge the local groundwater catchment³⁹ to the Rangitopuni Stream, and potentially divert a small volume of groundwater, this reduction is estimated to be only 0.5%, which is considered negligible and is unlikely to have measurable effects on the groundwater baseflow to the Rangitopuni Stream.

³⁹ The Rangitopuni Stream surface water catchment was estimated to be 14 km² in footnote 5. We have assumed that the area of the surface water catchment reflects the local shallow groundwater catchment.

6.6 Potential for saline intrusion

Saline intrusion occurs when groundwater in an aquifer near the coast is replaced by seawater from the ocean. The Ghyben-Herzberg⁴⁰ relation predicts that the depth below sea level to the saline interface is approximately 40 times the height of the freshwater table above sea level. This height assumes that the density of freshwater is 1,000 kg/m³ and 1,025 kg/m³ for seawater.

Conservatively, the deepest groundwater elevation measured at the toe of the Redvale landfill is approximately 49 m RL (W3AD; March 2022). The closest coastline from the Class 2 footprint extension is approximately 7 km east, near Okura.

By applying the simplified Ghyben-Herzberg approximation: $z = 40 h$

Where z is the depth to the sea-water interface and h is the head of water above mean sea level (49 m in this case), we estimate the sea-water interface to be approximately 1,900 m below mean sea level. On this basis, saline intrusion at the Class 2 footprint extension cannot occur as a result of the dewatering activities.

6.7 Discharge of contaminants to ground and groundwater (fate and transport)

6.7.1 Existing landfill

The potential discharge of contaminants to the environment through the seepage of leachate through the landfill liner has been assessed using quantitative fate and transport modelling methods. This assessment is described in detail in Section 5.2. The assessment has considered one point of exposure which may potentially be affected by the seepage of leachate through the landfill liner:

- The Rangitopuni Stream to the south east of the existing landfill considering ecological effects and the irrigation of tomato plants.

The results of the fate and transport modelling (refer to Section 5) indicate that contaminant concentrations at the above receptors will not exceed the relevant guideline values. We therefore conclude that it is highly unlikely that the potential seepage of leachate through the landfill liner will have any adverse effects on the potential receptors.

6.7.2 Class 2 footprint extension

The WAC adopted for the Class 2 footprint extension are protective of aquatic life in the nearby Rangitopuni Stream. This means that if the seepage of leachate occurs through the Class 2 footprint extension liner adverse effects on the potential receptors are considered to be negligible.

⁴⁰ Hiscock, K.M., 2005. *Hydrogeology – Principles and Practice*. Blackwell Publishing, Malden, Oxford. 389 pp.

7 Mitigation and monitoring

7.1 Purpose and scope

This section sets out the groundwater and leachate monitoring, trigger levels, and response framework for the existing Class 1 landfill and the proposed Class 2 extension, ensuring continuity with the existing Landfill Management Plan (LMP) and associated resource consents. The framework uses the established monitoring network (with additions for the Class 2 footprint extension), well-specific trigger levels (TL1/TL2), and a tiered response linked to the LMP Groundwater Contingency Plan⁴¹.

Historical monitoring since 1993 has not confirmed leachate-related contamination of groundwater. While trigger level exceedances have occurred at times, Specialist Adviser reviews determined these were not due to leachate contamination. Fate and transport assessments indicate negligible potential for adverse effects on Rangitopuni Stream when the landfill operates per design.

7.2 Monitoring network

The existing monitoring bores will be updated, maintained and operated. Additional monitoring wells may be installed around the Class 2 footprint extension as required to ensure adequate upgradient, downgradient (near-toe and boundary), and cross-gradient coverage. Proposed wells for the Class 2 footprint extension include W69 (upgradient), WL2S/WL2D (downgradient near toe), M7A (downgradient near boundary), and W67AS (cross-gradient), subject to construction staging and accessibility.

New or replacement bores will be drilled and installed within one month of decommissioning or identified as being required. The LMP will be updated in accordance with existing consent requirements.

7.3 Baseline monitoring – Class 2 footprint extension

Baseline monitoring will establish an understanding of groundwater quality and levels prior to waste placement. This dataset will form the basis for comparing ongoing monitoring data during operation of the Class 2 footprint extension and for calculating statistically based trigger levels.

7.3.1 Monitoring locations

- Baseline monitoring will be undertaken at:
 - Existing upgradient and downgradient groundwater monitoring bores associated with the Class 2 footprint extension (refer to Figure 8.1 for well locations):
 - o Upgradient: W69.
 - o Downgradient close to toe: WL2S/WL2D.
 - o Downgradient close to boundary: M7A.
 - o Across gradient: W67AS, or replacement if decommissioned during construction.
 - New groundwater bores, if required, installed around the proposed Class 2 footprint extension to improve spatial coverage.

7.3.2 Parameters and frequency

Baseline monitoring will be based on the existing Class 1 baseline parameters as set out in proposed consent conditions and summarised as follows:

⁴¹ Redvale Landfill Extension Management Plan, Environmental Management Plan, Section 4.5 – Groundwater.

- Groundwater level: monthly.
- Field parameters: pH, electrical conductivity (EC), temperature.
- General chemistry: alkalinity, total hardness, sulphate.
- Indicator parameters: Total ammoniacal nitrogen, nitrate-nitrogen, chloride, EC.
- Metals: dissolved metals suite (arsenic, copper, lead, nickel, iron, manganese, magnesium, zinc) and total metals (boron, calcium, potassium, sodium).
- Organic indicators: chemical oxygen demand (COD).

Baseline sampling for the Class 2 footprint extension will be undertaken over at least ten monitoring rounds prior to waste placement, no less than monthly and no more than quarterly, to capture seasonal variability and provide sufficient data for statistical analysis.

7.4 Operational monitoring – Class 1 landfill and Class 2 footprint extension

Operational monitoring will ensure compliance with consent conditions and provide early detection of any change in groundwater quality potentially attributable to the landfills.

7.4.1 Monitoring network

The existing groundwater and leachate monitoring network for the Class 1 landfill will continue to operate.

For the Class 2 footprint extension, baseline monitoring wells will remain in service for operational monitoring. The combined network will provide:

- Upgradient control bores unaffected by landfill activities.
- Downgradient compliance bores screened across shallow and intermediate aquifer horizons.
- Across-gradient bores.

7.4.2 Sampling frequency and parameters

During operation of the Class 1 landfill and Class 2 footprint extension:

- Groundwater levels measured quarterly.
- Groundwater quality sampled quarterly.
- Leachate quality sampled annually (or consistent with current Class 1 monitoring).

The analytical suite will be consistent with the parameters set out in the consent conditions of the existing resource consent and be adaptive to any emerging contaminants identified through operational leachate quality monitoring data.

7.4.3 Data interpretation and reporting

Results will be:

- Evaluated against the baseline dataset and relevant guideline values.
- Assessed for spatial and temporal trends.
- Reviewed against TL1 and TL2 trigger levels.
- Summarised in annual monitoring reports, including interpretation and mitigation recommendations.

7.5 Trigger levels for Class 2 footprint extension (TL1 and TL2)

Trigger levels provide early warning and compliance thresholds for groundwater quality and groundwater levels. Existing trigger levels for Class 1 will continue to apply as set out in the LMP. New trigger levels for Class 2 footprint extension monitoring wells will be established from the baseline dataset and cross-checked against appropriate guideline values (e.g., ANZG 95% species protection) consistent with the LMP's historical approach.

7.5.1 Methods for deriving trigger levels

The derivation approach to trigger levels, consistent with the LMP, is described as follows:

- Well-specific statistics using recognised methods for groundwater datasets (e.g., mean/variance-based thresholds accounting for seasonal variability) using the Class 2 baseline series.
- Guideline check: Where appropriate, compare to guideline thresholds (e.g., where variability is small or background exceeds guidelines, adopt the more protective level consistent with the LMP practice).
- Review trigger levels annually and update as the dataset grows.

7.6 Response actions to trigger level exceedances

A tiered response framework will apply that is consistent with the LMP, set out in the following sub-sections.

7.6.1 TL1 exceedance – early warning response

The following actions are proposed if a TL1 is exceeded:

- Verification of sampling: check field procedures (purging, weather influences) and stability of field parameters prior to collecting the samples within four weeks.
- Trend assessment comparing recent and historical data.
- Prepare a brief investigation note with likely causes, pathways, and recommended next steps (e.g., increased frequency, confirmatory sampling, or additional bore(s) if warranted). Align with the LMP Contingency Plan flowchart (LMP Section 3.20 - Groundwater).

7.6.2 TL2 exceedance – management response

If TL2 is exceeded and verified, the following actions are proposed:

- Immediate notification to the Auckland Council and the Peer Review Panel and commence actions as set out in the LMP Contingency Plan flowchart.
- Consult the Specialist Adviser (LMP Section 3.20 - Groundwater) to determine whether a significant change attributable to leachate has occurred.
- Undertake targeted investigation (confirmatory sampling, conceptual model review, and source-control evaluation).
- Implement corrective actions as advised (e.g., increased leachate extraction, additional monitoring wells, cut-off measures, in-situ remediation, liner/drainage review) as required by proposed consent conditions, LMP Section 3.20 - Groundwater).

7.7 Reporting and record keeping

The following reporting and record keeping aligns with the LMP:

- Quarterly: Submit groundwater quality and level data to Auckland Council as required by the proposed consent conditions. The same quarterly data will also be incorporated into the independent monthly reports provided to the Peer Review Panel, consistent with LMP Section 3.20 – Groundwater.
- By 30 April each year: Submit all groundwater monitoring levels to Auckland Council for the year ending 31 March, consistent with proposed consent conditions. The information will include data recorded since installation of the monitoring point.
- Maintain electronic records (spreadsheets/database) for the life of the landfill as required in the LMP.

7.8 Summary

The combined monitoring, trigger level, and response framework is designed to maintain the protection of groundwater resources, provide confidence that the existing Class 1 landfill and proposed Class 2 footprint extension are operating without adverse effects, and enable early identification and mitigation of potential risks through a robust, evidence-based approach.

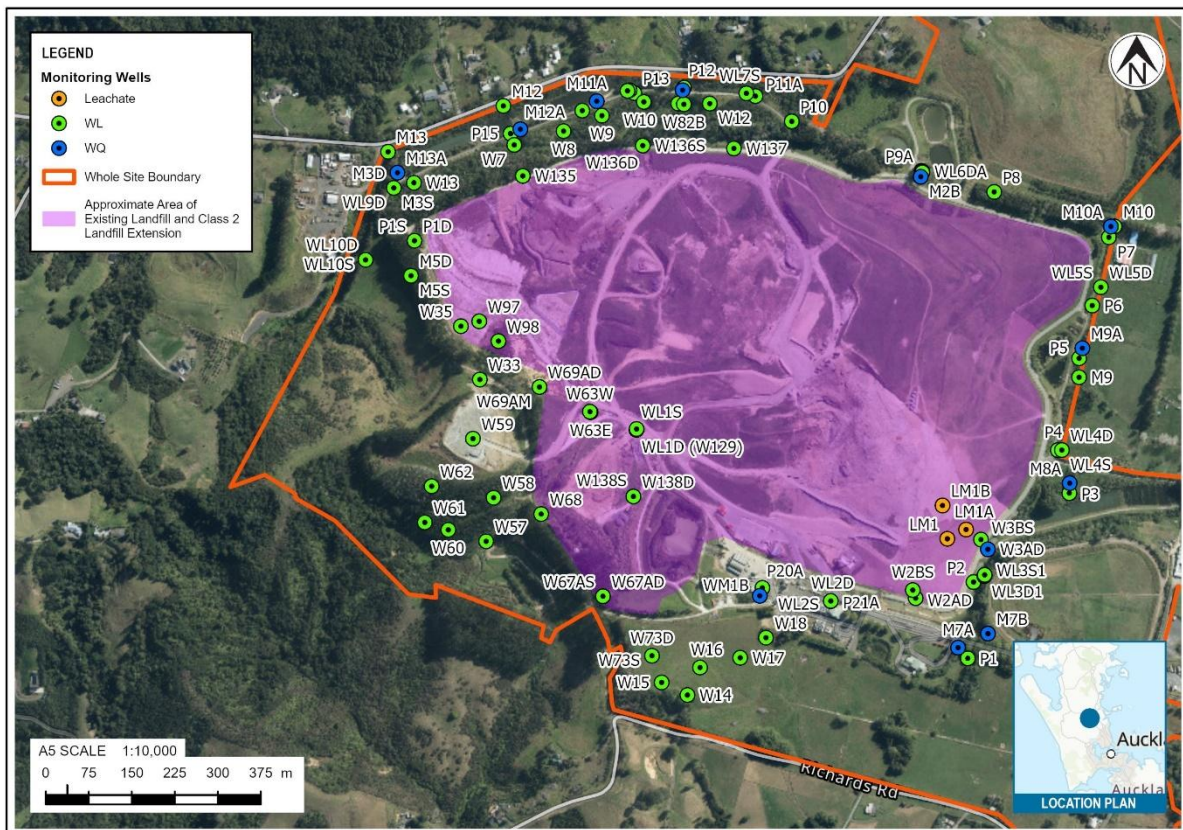


Figure 7.1: Existing monitoring well locations. Source: LINZ (cc-BY-4.0).

8 Summary and conclusions

T+T has been engaged by WMNZ to prepare a Groundwater Assessment to support a resource consent application for an extension to Redvale Landfill. This report evaluates the groundwater values and characteristics of the proposed landfill extension and assesses the effects on groundwater and the Rangitopuni Stream.

The proposed landfill extension aims to create additional airspace for waste placement. It includes two main components: steepening the existing landfill slopes and extending the landfill to the south-

west. The extension involves excavating and lining a new landfill cell to accommodate Class 2 waste (Class 2 footprint extension).

Groundwater beneath the landfill is part of the unconfined Rangitopuni Waitemata sub-aquifer zone. Based on an evaluation of groundwater monitoring data from wells surrounding the existing landfill, groundwater flows from higher ground in the west-southwest toward the north, northeast, and east-southeast. Leachate levels in the landfill are monitored to ensure compliance with regulatory requirements and to maintain an inward hydraulic gradient.

An assessment of current downgradient groundwater quality around the existing landfill indicates no significant changes over time and no evidence of leachate impact. Any apparent increasing trends in indicator parameter concentrations remain within historically measured concentrations. Additionally, there is no discernible difference in groundwater quality between downgradient monitoring locations.

Fate and transport modelling has been used to assess the potential environmental effects of leachate seepage through the landfill liner. Modelling results indicate that contaminant concentrations in groundwater and surface water after hundreds of years are predicted to be below guideline values, suggesting negligible potential for adverse effects on freshwater ecology in the Rangitopuni Stream plus the use of surface water for irrigation of tomato plants.

Effects of the proposed landfill extension on groundwater include minor dewatering associated with the Class 2 footprint extension, negligible effect on the prevailing inward gradient of the Class 1 landfill, negligible impact on regional groundwater resources, and no adverse effects on neighbouring groundwater users or stream depletion are anticipated. In addition, the fate and transport modelling indicate that there will be no adverse effects on the surface water quality of the Rangitopuni Stream through potential seepage through the landfill liner to ground and groundwater.

Mitigation measures comprise constructing a liner and leachate collection system for the Class 2 footprint extension and ongoing groundwater monitoring. Recommended monitoring parameters and frequency include background groundwater monitoring for the Class 2 footprint extension and continuing existing groundwater level and quality monitoring as set out in the proposed consent conditions and LMP.

This report concludes that the proposed landfill extension is unlikely to have adverse effects on groundwater quality and quantity or adverse effects on the Rangitopuni Stream. Recommended mitigation measures and monitoring will ensure the protection of groundwater resources and the surface water quality of the Rangitopuni Stream.

9 Applicability

This report has been prepared for the exclusive use of our client WMNZ, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application under the Fast-track Approvals Act 2024 and that an Expert Panel as the consenting authority will use this report for the purpose of assessing that application. We understand and agree that this report will be used by the Expert Panel in undertaking its regulatory functions.

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Appendix A Code of Conduct

Compliance with Environment Court Practice Note 2023

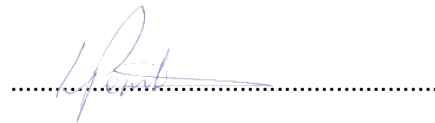
I confirm that, in my capacity as lead author of this report, I have read and abided by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses contained in the Practice Note 2023.

I am a Senior Hydrogeologist at Tonkin & Taylor Ltd (T+T), where I specialise in Hydrogeology. I have worked at T+T since 8 November 2005. Prior to joining T+T, I was an Environmental Geologist at the Defence Logistics Organisation, Bath, UK.

I have 20+ years' experience in environmental consultancy. I am a Member of the International Association of Hydrogeologists. I hold the following qualifications – BSc (Hons) Environmental Geoscience and MSc (Hons) Applied Environmental Geology.

Recent relevant projects and services that I have been involved with include:

- Closed Landfill Investigation Report, Pikes Point Closed Landfill, Auckland Council.
- Hydrogeological Assessment, Tirohia Landfill, WMNZ.
- Hydrogeological Assessment, Auckland Regional Landfill, WMNZ. Redvale Landfill, Leachate Assessment, WMNZ.



Leon Pemberton

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