Report

Assessment of Groundwater Pollution Plume Mobility and Remediation Plan

Levin Landfill, Hōkio Beach Road, Levin

Prepared for Horowhenua District Council

Prepared by Earthtech Consulting Limited

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Levin Landfill, Hōkio Beach Road, Levin

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Executive Summary

This report provides a hydrogeological assessment of the extent of an existing groundwater plume containing solutes of particular concern, emanating from the unlined "Old Landfill[1]" areas of the Levin Landfill site. This assessment is aimed at understanding the migration of solutes that can be specifically linked to typical landfill leachate emissions, such as ammoniacal-nitrogen (ammoniacal-N), boron, chloride and electrical conductivity (EC), with the intent of mitigating these emissions through a Best Practicable Option (BPO) plan. The findings of this assessment have enabled a preliminary engineering design for the BPO which is additionally provided in this report.

An Environmental Court of New Zealand Consent Order (19 December 2019) was issued following a matter presented between the Hōkio Environmental Kaitiaki Alliance (HEKA) and Horizons Regional Council (HRC) and Horowhenua District Council (HDC), ruling that the Levin Landfill Consent Conditions be amended. The Horizons Regional Council has issued several (a suite of) consents in relation to the operation of the Levin Landfill which are detailed in HDC's Annual Compliance Audit Report for July 2021 to June 2022 (HDC, December 2022). This latter compliance audit rated the Levin Landfill as moderately non-compliant. Consent condition 2A of ATH-2002003983.02 (6010) requires that the selected leachate remediation option (the BPO) is fully implemented by June 2023.

A BPO has been put into action by HDC, following a decision made by Council on 14 December 2022 for a series of works aimed at the remediation of environmental areas affected by historical pollution plumes. A key component of this BPO is the confirmation of possible high levels of concentration of solutes to the north of the landfill around the vicinity of borehole (BH) C2 (i.e. BHC2). A key concern of the migration of solutes from the Levin Landfill (Old Landfill areas) is the potential influence on the Hōkio Stream.

The Court Order further details HDC's consent conditions providing monitoring conditions and trigger values (Table C1) for sampling locations within the Hōkio Stream, namely locations HS1A, HS2 and HS3. Specifically, at the downstream location of HS3, maximum and average ammoniacal-N trigger value concentrations of 2.1mg/ℓ and 0.4mg/ℓ respectively, are stated.

There is much available data over some 30 years of monitoring the Levin site, from the boreholes located across the landfill property. This assessment has demonstrated there to be a passing of peak concentrations followed by declining trends due to landfill source depletion, evident to the north of the Old Landfill. BHC2, specifically, shows an increase in concentrations of ammoniacal-nitrogen (at approximately 170mg/ℓ) and increasing boron concentrations. The increasing trend in BHC2 shows to be dissimilar to the trend at BHB2 and BHB3 which show an apparent source depletion effect with the passing of peak concentrations associated with the pollution plume. Thus, there are two effects. First is the apparent fractionation of the plume with chloride following advective flow followed by other solutes in order of mobility. Then second,

[1] Also referred to as the "Old Dump" of the Levin Landfill Site

the passing of peak concentrations followed by declining trends due to landfill source depletion. This mobility has been diagrammatically illustrated in the several figures attached to this report.

The recent increasing trend of ammoniacal-N in the Hōkio Stream at sampling location HS2, noted in Stantec's Annual Compliance Report (Stantec, September 2022), is now understood to be attributed to the outer reaches of the migrating front (as shown in Figure 10 attached). Whilst the finding of this assessment is that it is unlikely ammoniacal-N will exceed the ANZECC (95%ile) DGV of 2.1*mg/ℓ* at the HS3 location, it will progressively exceed the consent average trigger value of 0.4*mg/ℓ* over time.

This assessment is conclusive in determining the migration of solutes contributing to increases in concentrations in the Hōkio Stream (in particular ammoniacal-N). Additionally, this assessment has enabled good accuracy for the location, requirements, and magnitude of the BPO (engineering) plan. Thus, the BPO detailed in this report is recommended to be implemented within the next 12 months, focusing on reducing or removing ammoniacal-N from the receiving (and received) environment.

Further groundwater investigations are required to confirm the above analytical assessment and aquifer conditions for detailed remedial works design. The recommended groundwater investigations are as follows:

1. Boreholes at three locations on Tatana Flats and within sand dunes to confirm aquifer extent and leachate plume indicators both spatially and with depth. Groundwater level monitoring and permeability testing.

2. Eleven CPT (Dutch Cone Penetrometer) soundings on three cross-section locations across Tatana Flats (including Section A-A).

3. Groundwater flow and transport modelling to determine pumping volumes required to reduce contaminant effects on the Hōkio Stream as required by the BPO. Modelling of the preferred mitigation option (shallow drains or groundwater bores) to be completed.

4. Hōkio Stream flow gauging at HS1A, HS2 and HS3 under summer low flow conditions for two rounds at least two weeks apart. Flow gauging of the Northern Farm Drain outlet to the Hōkio Stream at the same time.

Input from Phil Landmark of Stantec and David McMillan of HDC has played a significant role in shaping this assessment's analysis. We thank them for their input – ngā mihi nui.

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1. Introduction

Earthtech Consulting Limited (Earthtech) has been appointed by the Horowhenua District Council (HDC) to carry out a hydrogeological assessment of the extent of an existing groundwater plume containing solutes of particular concern, emanating from the unlined "Old Landfill" areas of the Levin Landfill site. This assessment is aimed at identifying the migration of solutes that can be specifically linked to typical landfill leachate emissions, such as ammoniacal-nitrogen (ammoniacal-N), boron, chloride and electrical conductivity (EC), with the intent of mitigating these emissions through an overall remediation plan or Best Practicable Option (BPO) plan.

A BPO has been put into action by HDC, following a decision made by Council on 14 December 2022 for a series of works aimed at the remediation of environmental areas affected by historical pollution plumes. A key component of this BPO is the confirmation of possible high levels of concentration of solutes to the north of the landfill around the vicinity of borehole (BH) C2 (i.e. BHC2), and the provision of a works scope required for remediation. A key concern of the migration of solutes from the Levin Landfill (Old Landfill areas) is the potential influence on the Hōkio Stream. Therefore, understanding both the present (status quo) circumstances of the groundwater regimes is equally important to the prediction of future effects. The engineering of a proposed mitigation measure (or measures) is thus reliant on the extent of remedial action required to ensure that the concentration of contaminants migrating from the landfill does not exceed consented surface water limits within the Hōkio Stream.

Consent conditions are covered by compliance authorisations issued by the Horizons Regional Council (HRC) and, additionally, by an Environmental Court decision (Consent Order) dated 19 December 2019. Crucial to consent conditions is that should any of the trigger values be exceeded at the downstream monitoring site HS3, the consent holder (HDC) shall propose a statistical analysis approach to the Regional Council (HRC) for certification. This analysis is to be run for the parameter(s) exceeding the relevant trigger value, on the last 24 consecutive samples, to determine if there are any significant increases in concentrations between upstream and downstream.

Stantec's Annual Report for 2021 to 2022 (Stantec, 2021-2022) noted that at the HS2 location (slightly upstream of HS3 "*the maximum result for total ammoniacal-N was over three times greater than the trigger value*". HS2 concentration was 7.7*mg/ℓ* and at HS3 was 1.4*mg/ℓ*; however, the upstream concentration was tested at 1.8*mg/ℓ*.

Earthtech's approach is to carry out a detailed review of available geohydrological data from many years of ongoing monitoring and provide a "full picture" of the current migration of solutes from the Old Landfill. Solutes that are typically directly linked to landfill leachate effects are ammoniacal-nitrogen (NH_4-N or ammoniacal-N), boron (B), chloride (Cl) and electrical conductivity (EC). These are "conservative" leachate indicators due to high relative mobility in groundwater. Other key parameters that are useful in the understanding of potential contamination by such solutes are alkalinity (Alk), sulphate (SO4), chemical oxygen demand (COD), sodium (Na) and pH. This assessment has concentrated on the former mentioned four (4) solutes. The mobility of these solutes has been determined in this assessment report showing plume location, migration velocities and migration predictions (of solute mass fluxes).

Based on the findings of this assessment, a BPO plan is provided in this report, recommending action that can be taken to suitably abate and significantly reduce the environmental impacts of leachate (solutes) from the Levin Landfill site. Some further groundwater investigations are required for detailed remedial works design.

Input from Phil Landmark of Stantec and David McMillan of HDC has played a significant role in shaping this assessment's analysis. We thank them for their input – ngā mihi nui.

2. Background

2.1 Site Overview and Description

The Levin Landfill, located on Hōkio Beach Road, had operated for over 50 years until it closed in November 2021, whilst the future of the landfill decision is undertaken. Located on the property are, in effect, two general waste type landfills, i.e. an old closed landfill which is unlined (also referred to as the Old Landfill) and an engineered lined landfill facility, lined to Class 1[2] standards. The Old Landfill, which closed in 2004, is an unlined landfill located on sand dunes, and comprises two areas separated by an access road, referred to as Areas 1 and 2, as shown in Figure 2.

The site area of some 72*ha* is bounded forest to the west, east and south and established vegetation and dense tree growth along the northern boundary. The site is situated on historical dune sands and underlying gravels at depth, as depicted in Figure 5. The Tatana property borders the site to the north, and the ground is flat with a series of constructed watercourses. Groundwater is close to the surface at approximately 0.5*m* to 1*m* below ground level across this northern land strip. A constructed drain, termed the Northern Farm Drain (previously referred to as "Tatana Drain"), runs along the northern boundary fence immediately outside the property, as shown in Figures 2 and 3. An established cleanfill type landfill is located on the Tatana property. The Hōkio Stream is situated some 300*m* to the north of the Levin Landfill, flowing in a westerly direction to Hōkio Beach, out-letting to the sea. The areas of the closed landfill are of primary pertinence to this assessment report.

[2] For Class 1 type specification refer to WasteMINZ Technical Guidelines for Disposal to Land, Rev. 3, updated 2022

2.2 Legal Context

The Horizons Regional Council has issued several (a suite of) consents in relation to the operation of the Levin Landfill which are detailed in HDC's Annual Compliance Audit Report for July 2021 to June 2022 (HDC, December 2022). This latter compliance audit rated the Levin Landfill as moderately non-compliant. Consent condition 2A of ATH-2002003983.02 (6010) requires that the selected leachate remediation option (the BPO) is fully implemented by June 2023.

An Environmental Court of New Zealand Consent Order (19 December 2019) was issued following a matter presented between the Hōkio Environmental Kaitiaki Alliance (HEKA) and Horizons Regional Council (HRC) and Horowhenua District Council (HDC), ruling that the Levin Landfill Consent Conditions be amended. Accordingly, the General Consent Conditions on discharge of leachate to ground notes, under Discharge Permit 6010 section 2A, that by the end of April 2021, the Permit Holder must complete an assessment of leachate remediation options (and a BPO) to:

a) *cease, or if cessation is not feasible, materially reduce the discharge of leachate to the Tatana Drain and Hōkio Stream; or*

b) *if neither of the options in (a) are feasible then options to offset effects within the Hōkio catchment and if that is not feasible or possible options to compensate effects within the Hōkio catchment or outside of it (either option through an ecological package).*

The order further states that the Permit Holder (HDC) shall decide on a BPO that is feasible to implement, applying the hierarchy under a) and b) above from the assessment. HDC must notify the Regulatory Manager of HRC which BPO it selects and provide a copy of the final assessment. The selected leachate remediation option must be fully implemented by June 2023.

The Court Order further details HDC's consent conditions in Section 3, providing monitoring conditions and trigger values (Table C1) for sampling locations within the Hōkio Stream, namely locations HS1A, HS2 and HS3. Specifically, at the downstream location of HS3, maximum and average ammoniacal-N trigger value concentrations of 2.1mg/ℓ and 0.4mg/ℓ respectively, are stated.

2.3 Best Practicable Option

A BPO is being put into action by the HDC, addressing a series of works aimed at the remediation of environmental areas affected by historical pollution plumes. A key component of this BPO is the confirmation of contamination in the gully area around the vicinity of borehole BHC2, and the provision of a works scope required for the remediation of contaminated land and for undertaking remediation.

Council resolved in a meeting on 23 November 2022 (resolution no. CO/2022/141) to make a decision about the future of the Levin Landfill as an amendment to the 2021 Long Term Plan, enabling a decision on the future of the Levin Landfill to be made in June 2023. This timing thus synchronises with the Consent Authorisation ATH-2002003983.02 (6010 – discharge of landfill leachate onto and into land) for a BPO to be implemented by June 2023. In a report submitted to Council on 14 December 2022, the details of a proposed BPO were presented to Council. The proposed BPO package decision, shown in Table 1 below, was passed and adopted by Council.

This assessment report provides a recommended BPO scope addressing point 3 in Table 1, with estimated budgetary figures for achieving this. This report enables guidance into point 4 of the BPO, offering answers on what is to be mitigated, how mitigation can be appropriately carried out, what effect action taken will have against predictions on the mobility of solutes, and how the mitigation can be suitably monitored to determine the rate of success, i.e. the monitoring of betterment over time.

Table 1: BPO for the Remediation of the Old Landfill

	Timing	BPO Element	Estimated Cost
1	Do now (annual)	Maintenance contractor company to monitor the landfill cap and repair as needed (includes repairing seeps if seen).	$130,000.00 pa
2	Do now (by June 2023)	Import clay soil, shape the top of the Old Landfill to stop water ponding, cease ingress and direct flows. Re-establish vegetation.	$220,000.00
3	Do now (by June 2023)	Confirm contamination in gully area (BHC2), scope required remediation of contaminated land, and undertake remediation.	$300,000.00
4	Start now (1-5 years)	Assess targeted restoration of Northern Farm Drain and Hōkio Stream, working with a local iwi and willing landowners. Develop a restoration programme, secure funding and proceed with restoration project.	$300,000.00 seed funding request
5	Do next (2-5 years)	Add additional capping to the top and sides of the Old Landfill as suitable soil becomes available, prioritising areas identified by maintenance contractor, and ensuring suitable drainage constructed as capping applied. Continue until at least 700*mm* capping applied. Re-establish vegetation.	$0 to $4M depending on soil availability

2.4 Monitoring Regime

Monitoring bores have been installed across the Levin Landfill property, as shown in Figure 2, to monitor groundwater in various aquifers, i.e. the shallow and deep aquifers. Certain bores have been installed with the aim of providing specific monitoring information, i.e. background, leachate irrigation and early detection. Additionally, there are several locations where surface water monitoring is carried out (refer: Figure 2). There are several bores located north of the Old Landfill which are shown as Areas 1 and 2 in Figures 2 and 3. Additionally, several surface water monitoring points are shown in Figure 3, particularly in the Northern Farm Drain (TD1) and the Hōkio Stream (HS1A, HS1, HS2 and HS3).

Monthly monitoring of surface water in the Hōkio Stream is required at HS1, HS1A, HS2 and HS3 (in accordance with Table C of General Conditions applicable to Discharge Permit 6010). The trigger values (Table C1) for ammoniacal-N are 2.1*mg/ℓ* and 0.4*mg/ℓ* for maximum and average concentrations at location HS3 respectively. The approach in this report has focussed on position HS2, situated slightly further upstream (~50*m*) of HS3, since this is in close proximity to the entrant point of the Northern Farm Drain, and since analytical results at the HS2 location have shown to be comparatively *generally marginal* to HS3 (noted in the Quarterly Groundwater, Surface Water and Leachate Monitoring Report) (Stantec, February 2023).

Whilst several boreholes have shown probable signs of attenuation of a pollution plume, BHC2 is demonstrating an increase in concentrations of contamination, i.e. in ammoniacal-nitrogen concentrations (at approximately 170*mg/ℓ*) and increasing boron concentrations. The trend in BHC2 shows to be increasing, dissimilar to the trend at BHB2 and BHB3 which show an apparent source depletion effect with the passing of the pollution plume. Additionally, ammoniacal-N concentration has recently increased at location HS2 (Hōkio Stream). Thus, there are two effects. First is the apparent fractionation of the plume with chloride following advective flow followed by other solutes in order of mobility. Then second, the passing of peak concentrations followed by declining trends due to landfill source depletion. These are broadly illustrated in the graph extracts from the Annual Compliance Report (Stantec, Sept. 2022) in Figure A.

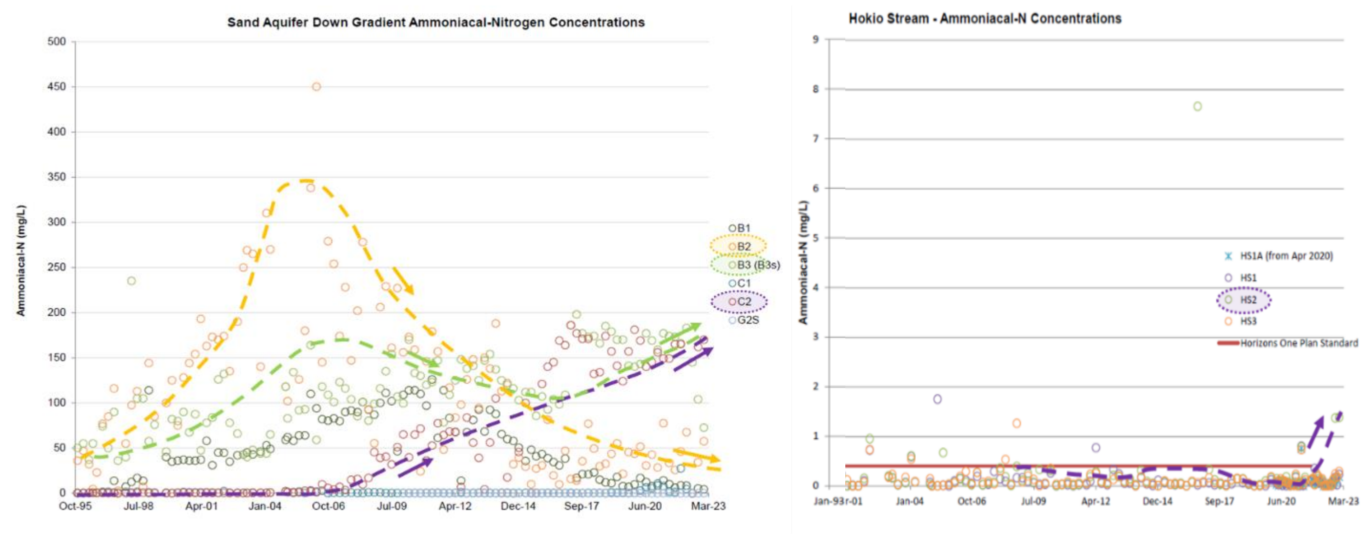


Figure A: Trends for ammoniacal-N concentrations at borehole locations and the Hōkio Stream, shown on graph extracts from the Annual Compliance Report (Stantec, September 2022).

The quality data of raw leachate from the lined Levin Landfill (Class 1) facility can be regarded as indicative of the quality of source leachate from the closed landfill at the time of closure (circa 2004). Leachate characteristics are shown in Table 2 below, sourced from Stantec's Annual Report for 2021 to 2022 (Stantec, 2021-2022). Source depletion of leachate typically occurs over time resulting in reducing trends of leachate concentrations in the landfill. Leachate from the lined Levin Landfill is currently pumped to the Levin wastewater treatment plant (WWTP).

Table 2: Leachate quality characteristics from the existing Levin Class 1 Lined Landfill

Parameter	Unit	Concentration
Ammoniacal-N	*mg/ℓ*	1,360
Alkalinity	*mg/ℓ*	6,630
Boron	*mg/ℓ*	6.24
Chloride	*mg/ℓ*	1,090
Electrical Conductivity	*mS/m*	1,485
Chemical Oxygen Demand (COD)	*mg/ℓ*	4,290

2.5 Current Remedial Works

Further to the BPO works scope described in 2.3 above, construction of the capping was underway during March to April 2023, as shown in Figure B. A recent news post (*Three options on the table as future of Levin Landfill still up in the air*, 29 April 2023)[3] noted the following:

- The HDC notes that no leachate from the new landfill is going into the waterways, but is working with a team to understand what is happening with the Old Landfill.
- The Council is monitoring the Old Landfill and looking at options for remediating some loadings that are found to be higher than allowed.
- *We're trying to put a picture together to figure out the best strategy going forward to manage any adverse effects* (David McMillan, HDC).
- The Council is also investigating building a wetland at the site to help mitigate the environmental effects of anything seeping out of the old landfill.

[3] Three options on the table as future of Levin Landfill still up in the air | Stuff.co.nz

Figure B: The new landfill, left, has a temporary cover while a decision on its future is made, and a permanent cover is being put on the Old Landfill, right

3. Geology

3.1 Previous Investigations

A previous geological assessment of the Levin Landfill was presented in September 2019 by Tonkin and Taylor. Their work provided a vertical cross-section from the south through Area 1 of the landfill and to the Hōkio Stream up north (Tonkin and Taylor, 2019).

This figure (Figure 14) presented on-site geology as follows:

- Recent dune sands from RL0*m* up to RL30*m*.
- Silts and clay for a 2*m* thick layer from approximately RL0*m* to RL-2*m*.
- Gravels from RL-2*m* to RL-10*m*.

The associated hydrogeology interpretation describes a shallow unconfined aquifer within the dune sand formation, 10*m* to 5*m* thick near the Hōkio Stream, and a deep confined aquifer within the deeper gravel layer underneath. The aquifers are described as being separated by the 2*m* thick aquitard. The shallow unconfined aquifer has a groundwater table which generally follows the ground surface and is connected to the Northern Farm Drain. The deep confined aquifer is reported as being artesian.

3.2 Geology and Groundwater Systems

The three different landforms on site (Figure 1) are as follows:

- Undulating sand dunes south of the Northern Farm Drain from RL12*m* to RL40*m*.
- Dune terraces of RL9*m* to RL12*m* between the dunes and the eastern part of the Northern Farm Drain.
- Stream flats of RL6*m* to RL8*m* between the Northern Farm Drain and the Hōkio Stream.

A vertical cross-section of the site (Figure 5) has been constructed from BH XS1 to BH D3r, and the Northern Farm Drain and Hōkio Stream up north. It is based on the information of the following drillers logs provided by Stantec: BHXS1, BHC2DD, BHC2DS, BHC2, BHD3rd, BHD3rs.

The implied geology from the drillers bore logs obtained consists of:

- Sand formation from ground level to RL-5*m* to RL-7*m*
- Sandy silt with gravels underneath the sand formation.

The current drillers logs did allow the differentiation of geology associated with the landforms described above.

The hydrogeological interpretation is as follows:

- Upper unconfined aquifer within the sand formation.
- Lower aquifer within the sandy silt with gravels layer underneath the sand formation.
- Absence of separating aquitard.

The unconfined aquifer has groundwater levels between RL12.4*m* to RL5.6*m*, with a flow direction towards the north to discharge to the Northern Farm Drain and Hōkio Stream (which is at about RL5*m*).Groundwater levels from both shallow and deep bores do not show any artesian conditions. Where shallow and deep bores are located in close proximity, the shallow water level is usually higher than the deep level. On some occasions, the reverse occurs. The groundwater table plot for January 2023 is presented in Figure 11.

4. Groundwater Quality

4.1 Groundwater Chemistry and Solute Flow Paths

A series of monitoring bores is located on site, upgradient and downgradient of the different landfill areas. Their locations are presented in Figure 2.

The water quality data from these bores from February 1994 to January 2023 has been studied. The evolution of four specific solutes has been assessed and plotted (see Appendix 1). The four solutes used as early leachate indicators are the following:

- Electrical Conductivity (EC) in *mS/m*
- Chloride (Cl) in g/m^3
- Boron (B) in g/m^3
- Ammoniacal-Nitrogen (NH_4N) in g/m^3

Figure 4 presents the concentration values for these four solutes in January 2023 in the main observation bores. This has allowed us to assess the flow path of their concentration plume with time and their up-to-date location in the area.

Figure 4 shows the majority of bores immediately south and upgradient of the unlined landfill areas to have background groundwater concentrations of:

- Electrical Conductivity (EC) at < 35 *mS/m*
- Chloride (Cl) at 15 to 35g/m^3
- Boron (B) at < 0.05g/m^3
- Ammoniacal-Nitrogen (NH_4N) at 0.01g/m^3 to 0.2g/m^3

The concentration contour lines for January 2023 are presented in Figures 7 to 10. The low concentrations of solutes in BHC2D(s and d) compared to the shallower BHC2 shows evidence of the plume being limited to the upper part of the shallow unconfined aquifer. Further CPT investigations are proposed to investigate geological controls on groundwater further.

From the water quality data and these maps, the following observations have been made:

- EC highest concentration in January 2023 is 284*mS/m* in BHC2, located at the eastern end of the Northern Farm Drain. It is also >200 *mS/m* in BHB1 and BHG2, northeast and southeast of the Northern Farm Drain.
- EC value is rising in BHC2, the other monitoring bores show a decrease or stability in the values.

- Chloride highest concentration in January 2023 is 585g/m^3 in BHG2. Its concentration plume is located northeast of the Northern Farm Drain, next to Hōkio Beach Road.
- Chloride concentration is rising in BHG2, the other monitoring bores show a decrease or stability.

- Boron highest concentration in January 2023 is 2.16g/m^3 in BHB2, southeast of Northern Farm Drain.
- Boron concentration is rising in BHB2, the other monitoring bores show a decrease or stability.

- Ammoniacal-N highest concentration in January 2023 is 170 g/m^3 in BHC2, located at the eastern end of the Northern Farm Drain.

- Ammoniacal-N concentration is rising in BHC2, the other monitoring bores show a decrease or stability.

From this first assessment, the borehole BHC2 shows the highest concentration of ammoniacal nitrogen on site and shows a rise in its level (Figure C below). This indicates that the highest concentration plume must be located in this vicinity.

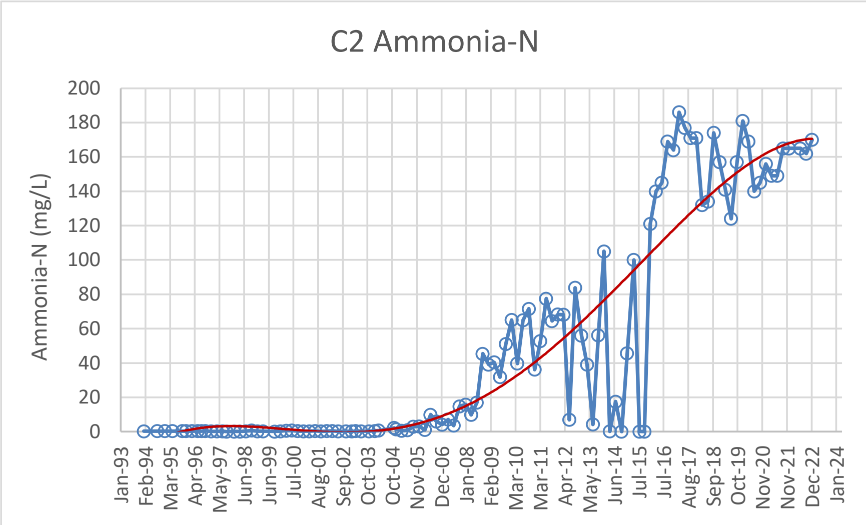


Figure C: Ammoniacal-N concentration over time in the groundwater monitoring borehole BHC2

4.2 Velocities

For all four solutes, their masses are expected to travel within the groundwater, following groundwater flow from the south to the north of the area. The four leachate indicators are expected to have different behaviours in terms of travel time, as all chemical components have different retardation factors. Chloride usually travels faster than boron and ammoniacal-N; therefore, its concentration plume is expected to be located further north than the other solutes plumes.

The peak concentrations of each solute have been studied over time, which allowed the estimation of groundwater velocities of the four leachate indicators, as presented in Table 3. An estimation of the time needed for the peak concentrations of the solutes in groundwater to reach Hōkio Stream has been calculated as shown in Figure D below.

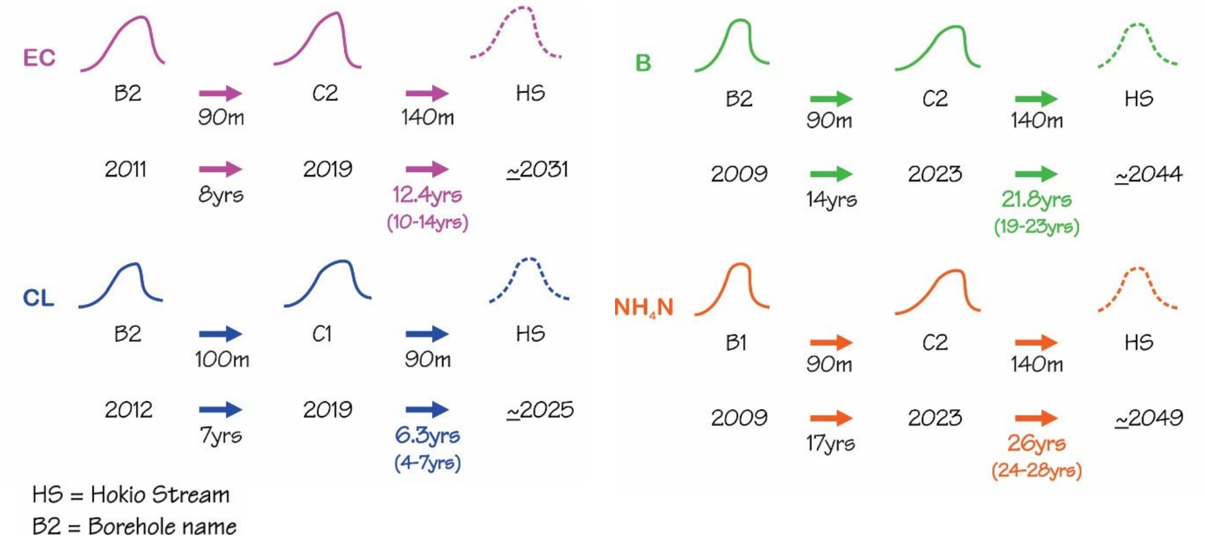


Figure D: Concentration plume peaks travel time

Table 3: Velocities of solutes

Solute	Electrical Conductivity	Chloride	Boron	Ammoniacal-N
Velocity (m/yr)	11.3	14.3	6.4	5.3

Chloride presents the fastest velocity, as this solute represents advective flow. It is followed by boron and then ammoniacal-N.

4.3 Permeabilities

Permeability testing carried out in July 2012 has been provided. Test results (Table 4) present a large range of permeability values, ranging from 0.59*m/d* to 498*m/d*. This range includes high 100*m/d* to 500*m/d* permeability conditions outside of that expected for sands, and therefore this test data has low reliability and has been disregarded.

Permeability values from the Tonkin and Taylor assessment modelled a value of $1.0e^{-5}$*m/s*, 0.9*m/d* for the sand aquifer which is within the expected range of value for this type of formation (Tonkin and Taylor, 2019).

Field permeabilities (k_h) has also been back-analysed by Earthtech for chloride using its observed velocity of 14.3*m/yr* (Table 3). The method of calculation is as follows:

- $k_h = (v * ne) / i$
- v = plume velocity
- ne = effective porosity of 0.15 (ø)
- i = hydraulic gradient (ø) = Δh / distance = (water level BHB2 Jan 23 – water level BHXS1 Jan 23) / perpendicular down gradient distance BHB2-BHXS1

The field permeability calculated with this method is typical for sand. All permeability values are presented in the table below for information.

Table 4: Permeabilities of solutes

Earthtech (2023)		Tonkin and Taylor (2019)		Levin Landfill (2012)	
Solute	**Field Permeability**	**Aquifer**	**Permeability**	**Borehole**	**Permeability**
	m/d		m/d		m/d
Chloride	0.39	Sand aquifer	0.9	BH C2	0.59
				BH B2	142.3
				BH G2s	398.4
				BH D3r	498.0

The solute plumes have been observed spatially both horizontally (Figure 4) and vertically (Figure 6). Cross-section A-A' shows the leachate indicator concentrations in two monitoring bores that have both a shallow and a deep intake zone. Figure 6 does not show significant contamination of the deeper groundwater system for leachate indicators in BHC2.

5. Groundwater and Surface Water Interaction

The upper unconfined aquifer discharges to the Hōkio Stream, which runs from east to west at the northern end of the site. Four surface monitoring points are located at the Hōkio Stream: HS2 and HS3 on the western side, HS1 and HS1A on the eastern side. Their surface water quality data from February 1994 to February 2023 has been obtained.

Darcy flow equations and mass balance calculations have been used to provide a preliminary assessment of groundwater effects on the Hōkio Stream.

5.1 Groundwater and Surface Water Flows

For this assessment, we focused on ammoniacal-N concentrations, as this parameter is the most critical. The groundwater flow has been calculated with Darcy equations as follows:

- Darcy equation: $Q = K * A * i$

- $K = 0.39 m/d$ – Aquifer Permeability (Section 4.3)
- $i = 0.015$ – Hydraulic gradient (From Cross section AA')
- $A = 3{,}250 m^2$ – Area for a 13m thick aquifer and a 250m wide section (corresponding to the estimated width of the concentration plume for ammoniacal N > 10g/m^3 from Figure 10).

- Groundwater flow: $Q = 19m^3/d$

The surface flow in the Hōkio Stream is described in the Horizons Council publication (NIWA, 2011) as ranging between 0.3m^3/s and 2m^3/s. To make the dilution assessment conservative, the minimum value has been chosen.

- Surface flow in Hōkio Stream: = 0.3m^3/s
  = **25,920m^3/d,** say 25,900m^3/d

From Horizons online environmental data, a hydrograph of Hōkio Stream level over the last 12 months at its source, Lake Horowhenua weir, has been observed (Figure E). It shows general low flow conditions occurring from October 2022 to April 2023.

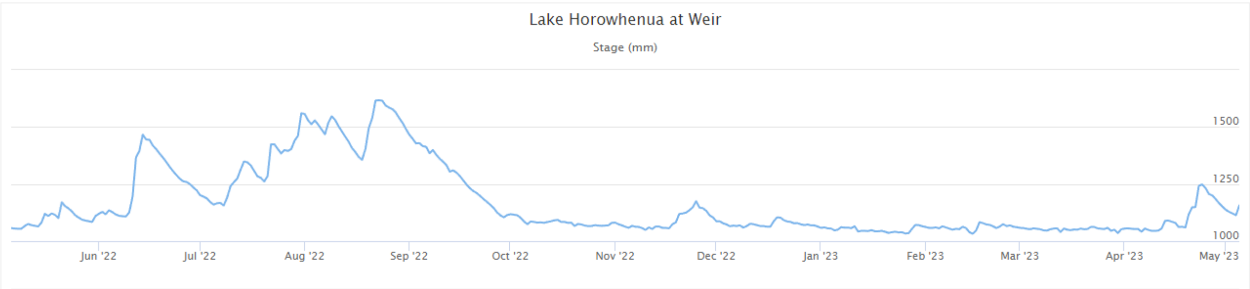


Figure E: Hydrograph of the weir at Lake Horowhenua
Horizons Regional Council Environmental data

The mass balance assessment is based on the following model in Figure F below:

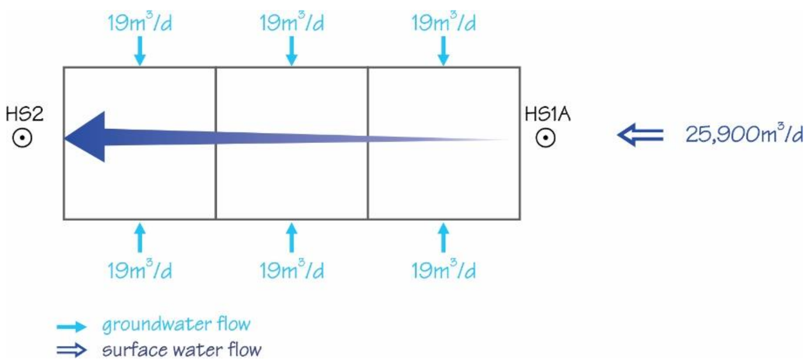


Figure F: Groundwater and surface water model in the Hōkio Stream

This model was built from six 250m sections, corresponding to the ammoniacal-N > 50g/m^3 plume width (from Figure 10), which is in the middle, south of Hōkio Stream. Therefore, the total groundwater flow into the stream is 6 * 19 = 114m^3/d.

From this model, the total flow arriving at HS2 is the following:

- Total surface flow at HS2: 25,900 + 114 = **26,014m^3/d**

5.2 Groundwater and Surface Water Ammoniacal-N Concentrations

Based on the January 2023 ammoniacal-N contour map (Figure 10), the average groundwater concentration is estimated to be <5g/m^3 at Hōkio Stream for January 2023. A value of 0.2g/m^3 is assumed to be the ammoniacal-N groundwater background level, outside of the concentration plume.

The following ammoniacal-N concentrations were measured in the surface water monitoring sites of the Hōkio Stream:

- In HS1A: 0.1g/m^3 Average January 2022 – January 2023
  0.2g/m^3 Maximum values for January 2022 – January 2023 (occurring in January 2023)

- In HS2: **0.5g/m^3** Average January 2022 – January 2023 (above 0.4g/m^3 consented limit at HS3)
  1.4g/m^3 Maximum values for January 2022 – January 2023 (occurring in January 2023)

Specifically, the following ammoniacal-N levels have been measured in the Hōkio Stream up and downgradient of the Figure 10 plume during early 2023. High values of ammoniacal-N occurred in the last summer period in the downgradient monitoring site HS2 as shown in Table 5.

Table 5: Ammoniacal-N concentration in surface monitoring points for early 2023

	Ammoniacal-N Concentration			
	Upgradient surface water monitoring point		Downgradient surface water monitoring point	
	HS1A	HS1	HS2	HS3
	(g/m^3)	(g/m^3)	(g/m^3)	(g/m^3)
Nov-22	0.16	0.17	**1.37**	0.24
Dec-22	0.09	0.02	0.17	0.18
Jan-23	0.18	0.23	**1.38**	0.29
Feb-23	0.02	0.04	**1.23**	0.14

Table 5 shows the groundwater plume affecting the Hōkio Stream with increases in ammoniacal-N between the upgradient and downgradient surface water sampling locations. Typically, the current increase in ammoniacal-N is from 0.2g/m^3 to 1.4g/m^3. This effect occurred in November 2022, plus January and February 2023.

The consented ammoniacal-N trigger limits in surface water are 2.1*g/m*^{3} maximum and 0.4*g/m*^{3} average in HS3. We are currently above this limit in HS2, as the average ammoniacal-N for the period February 2022 – February 2023 is 0.47*g/m*^{3}. HS2 is located approximately 150*m* upgradient of HS3, and ammoniacal-N concentrations are expected to increase as the groundwater concentration plume moves up north, and its peak concentration has not reached Hōkio Stream yet. Therefore, there is a potential risk for HS3 ammoniacal-N concentration exceeding the consented limit.

5.3 Increase of Ammoniacal-N Concentrations in Hōkio Stream Over Time

Under current conditions, the average ammoniacal-N concentration of groundwater discharging to the Hōkio Stream is <5*g/m*^{3}. Figure 10 shows that ammoniacal-N discharge from the groundwater plume is expected to increase.

The compliance level for ammoniacal-N concentration in Hōkio Stream is 2.1*g/m*^{3} and the highest value monitored so far in the western end of the site of the Hōkio Stream in January 2023 is 1.4*g/m*^{3}.

To increase ammoniacal-N from the current level of 1.4*g/m*^{3} to the consented limit of 2.1*g/m*^{3} in HS2, an increase of NH_4N concentration of 0.7*g/m*^{3} would need to occur. With the total surface water plus groundwater flow at HS2 of 26,140*m*^{3}*/d*, this would require an increase of 320*g/m*^{3} of NH_4N coming from the concentration plume on the southern side (over its total 750*m* length) calculated as follows:

- NH_4N flux = 0.7 * 26,014 = 18,210*g/d*
- NH_4N concentration = 18,210 / (3*19) = **320*g/m*^{3}**

The current maximum ammoniacal-N concentration observed on site is 170*g/m*^{3} (occurring in BHC2 in January 2023).

These calculations show that Hōkio Stream has the ability to dissimilate ammoniacal-N concentration to under the maximum consented limit, as a concentration of 320*g/m*^{3} across the total aquifer width of 750*m* is conservative. However, the average ammoniacal-N concentration is already above 0.4*g/m*^{3} at HS2, and is expected to increase to above average trigger limits at HS3 as well. Therefore, remediation is required.

6. Best Practicable Option Approach

6.1 Remediation Approach and Considerations

The treatment objective is to remove the mass flux of solutes of concern from the environment, that are laying cause to a pollution plume of landfill leachate contaminants from the Levin Landfill. The mobility of solutes within this plume has been described in this report, and illustrated in Figures 6 through 10. These solutes flow with the groundwater and will increasingly affect surface water quality in the Northern Farm Drain and Hōkio Stream. The velocities and mass fluxes of these solutes vary, and to a degree, the directions of flow vary, but the highest concentrations of the plumes have moved from the original source (the Old Landfill) and are now (by 2023) located in the received environment. This environmental location is the "pathway" en route to the "receptor" being the Hōkio Stream, as illustrated in the sketch of Figure G below. Further shown in the sketch below is the approach to this BPO whereby zones for possible treatment action between the source and the receptor can be used to mitigate to mass flow of solutes, or potential contaminants.

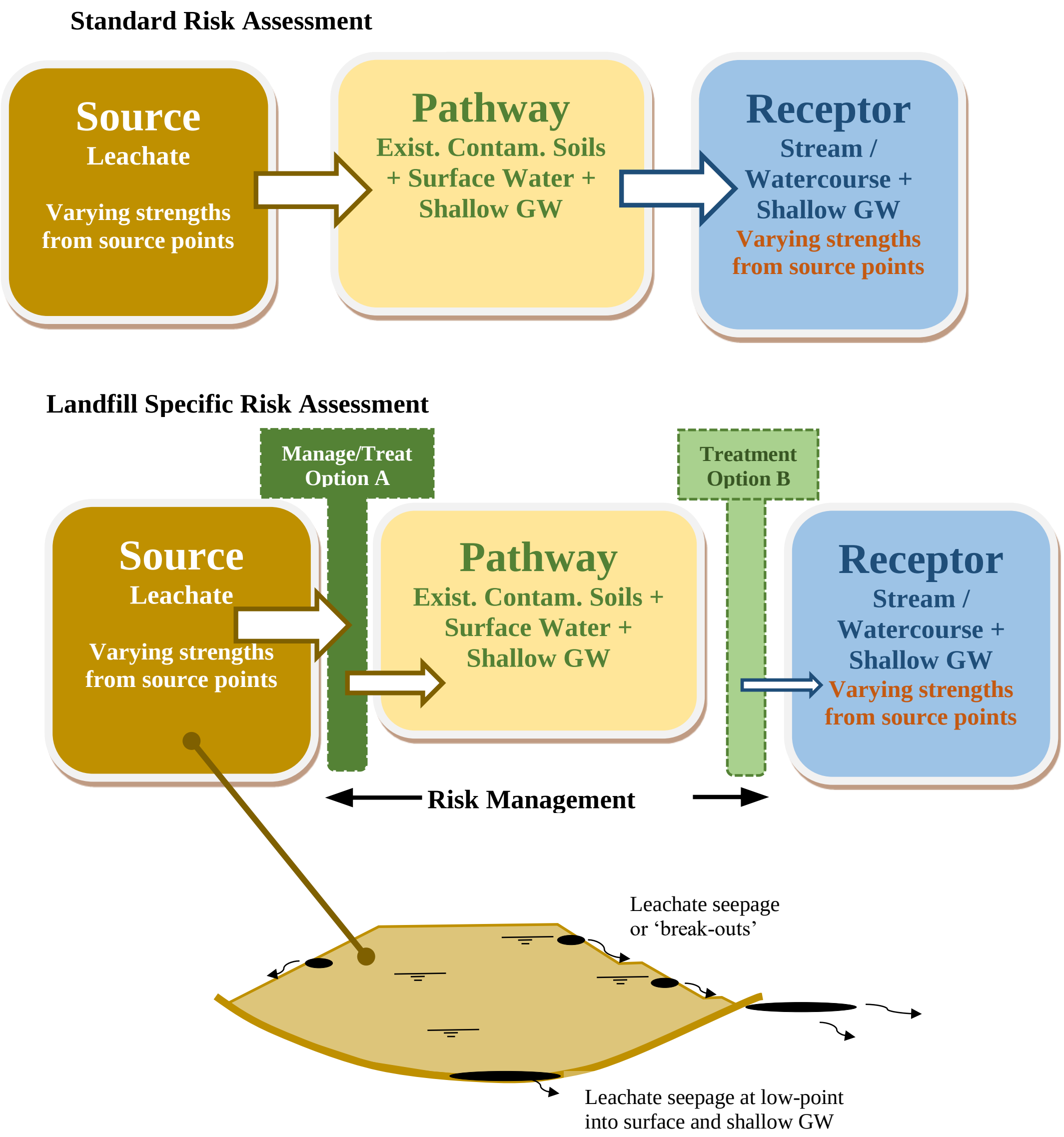


Figure G: Illustration of the BPO approach and a Landfill vs. a Standard Risk Assessment approach. Note: whilst in effect the same, the modelling of the mass flux flows of solutes and pathways is crucial.

The understanding of the "source" is understandably the point of generation, and "leachate generation" is not necessarily "leachate production". The generation of leachate in a model is applicable when leachate is set to flow from the source, and not when the source gains more input. The input into a landfill is often termed leachate production and can be equal to generation for engineered landfills, but often this leachate can seep out laterally, flowing out the side slopes or other locations where preferential flow paths emanate, as shown in the landfill insert sketch in Figure G. Whilst it is common to assess leachate flow from a landfill to effectively be equal to ingress, the "field capacity" and landfill degradation processes are significant and must be considered. Storage of liquid in a landfill (i.e. landfill leachate) often comprises a series of trapped pockets or water tables within the landfill, as shown in the sketch. This field capacity, or ability of a landfill to store liquid can be likened to a wet sponge where no liquid necessarily "flows" from the sponge since driving pressure head is very low or zero.

The BPO should address (and has addressed) the source, by constructing a 700*mm* clay-soil capping over the closed landfill and by land-forming a graded surface to ensure rainfall flows off the capping to designated flow areas off the landfill. Thus, the potential for ingress of rainwater into the landfill has been minimised as well as the potential to cause pressure heads to build up within the waste body.

Our approach, with the leadership of HDC's Solid Waste Advisor, is to suitably abate and significantly reduce the environmental impacts of leachate (solutes) from the Levin Landfill site, as a three-phased plan as follows:

- Phase 1: Hydrogeological Assessment of BHC2 Contamination Plume (and affected flanking areas), i.e. this report with BPO plan.
- Phase 2: Mitigation, i.e. detailed design, construction of physical works and implementation.
- Phase 3: Monitoring, i.e. of removal of environmental mass loadings and environmental betterment.

6.2 Treatment Options

6.2.1. Extraction

The location of the solute plumes of EC, B, Cl and NH4-N all require extraction of solute mass to be carried out. The *epicentre* of highest concentrations of chloride (i.e. chloride plume) is predicted to reach the Hōkio Stream by 2025. However, ammoniacal-N is arguably the most significant since current concentrations at the plume *epicentre* are some 150*mg/ℓ* to 180*mg/ℓ* and levels of 10*mg/ℓ* will soon reach the Hōkio Stream, as shown in Figure 10. Ammoniacal-N is potentially toxic to plants at 50*mg/ℓ* to 150*mg/ℓ* and fish life at levels of approximately 2*mg/ℓ*. Thus, this BPO concentrates on the reduction or removal of ammoniacal-N from the receiving (and received) environment.

The extraction BPO project is described as follows:

- Location:

  Required extraction is to be immediately north of BHC2. The exact location could be either within the property boundary or alternatively within the Northern Farm Drain, as shown in Figure H below. Permission would be required from the owners of the Tatana property.

- Extraction System:

  - OPTION 1: 200*m* subsoil drain, pumping chamber, storage tank and on-site disposal
  - OPTION 2: Three extraction wells with pumps, storage tank and on-site disposal

  Note: Both options have disposal to wastewater or on-site treatment and discharge to reedbed alternatives.

- Conceptual Design Parameters:

Design Extraction Flow Requirement	100	m^3/day
allowance for\in-drain storage:	1.5	days
thus:	150	m^3
Subsoil Drain:		
depth (D):	2.3	*m*
width (W):	1	*m*
length (L):	200	*m*
voids:	33%	
subsoil pipe min dia:	100	*mm*
pipe vol:	0.016	per *m*
total pipe vol:	3.1	m^3
vol drainage stone:	0.743	per *m*
vol drainage stone:	0.743	per *m*
total vol drainage stone:	148.7	m^3
total vol provided:	151.8	m^3

- Figure 12 provides a concept layout design plan for OPTION 1 (subsoil extraction system).

- Figure 13 provides a concept layout design plan for OPTION 2 (extraction wells system).

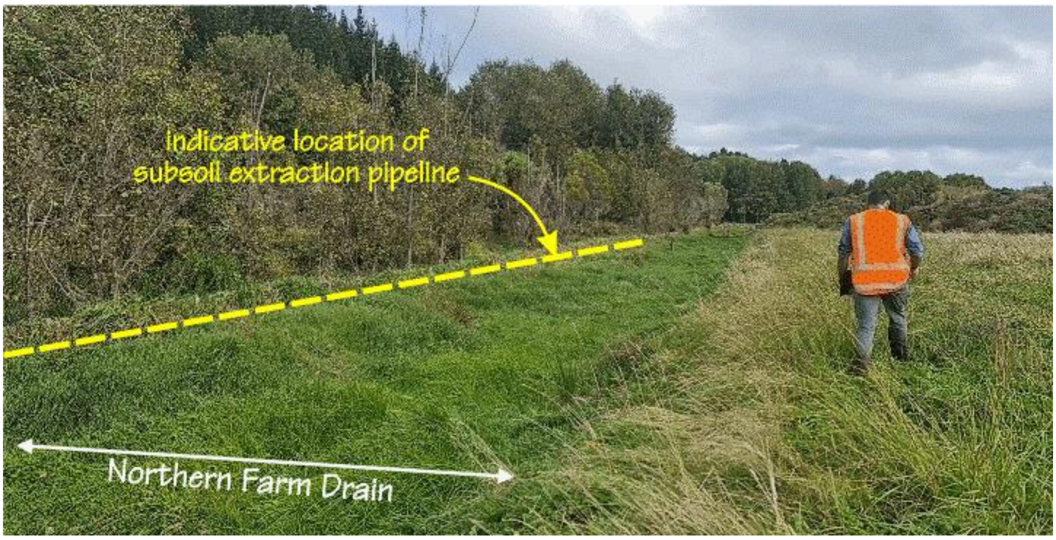


Figure H: The Northern Farm Drain located along the property boundary immediately north of the Levin Landfill site. The required extraction system is to be within the Levin Landfill property boundary or the Northern Farm Drain itself

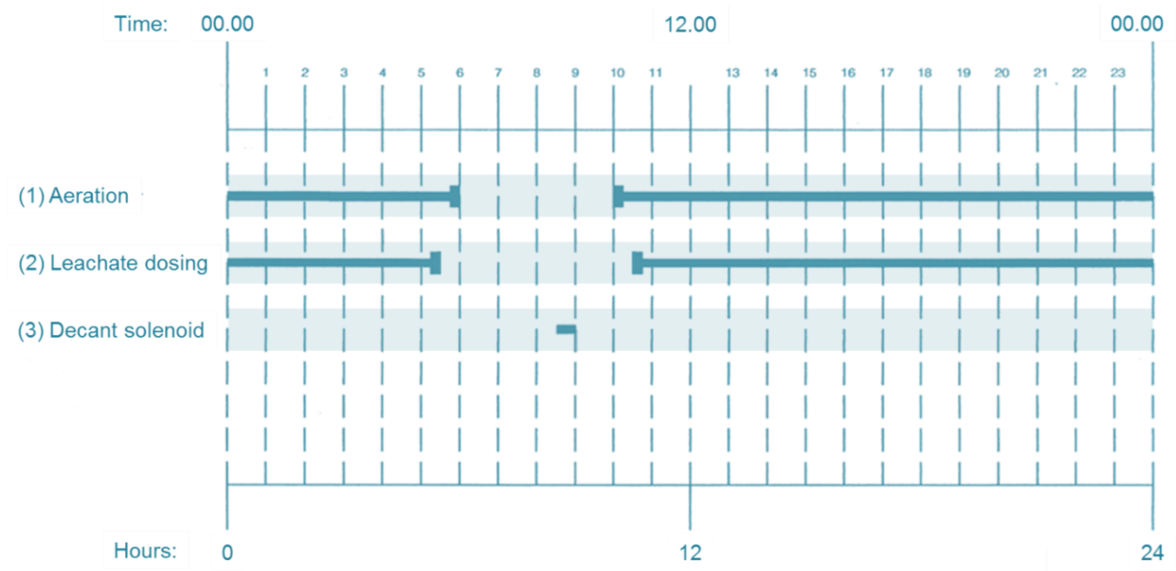
6.2.2. On-Site Treatment

A proposed on-site treatment system is to entail natural treatment processes, i.e. biological treatment and constructed reedbeds. The proposed treatment plant is to comprise an aeration lagoon or tank, i.e. a Sequencing Batch Reactor (SBR) for primary treatment and constructed reedbeds for polishing treatment. Concept design parameters are provided as follows:

- Biological nitrification and denitrification process design parameters (preliminary design for treatment of 50m^3/*day* and remainder discharged to WWTP via leachate pumping station):
  - Aeration system: SBR – est. 250m^3
  - O_2 requirement (proposed use of external mounted venturi type aerators):

Parameter	Concentration	Units
COD	200	*mg/ℓ*
NH_4N	180	*mg/ℓ*
COD	200	*ℓ/day*
NH_4	9,000	*g/day*
COD	10,000	*g/day*
O_2 Requirement	55	*kg* O_2/*day*
O_2 Requirement @ 20*hrs*	2.75	*kg* O_2/*hr*
two aerators:	1.4	*kg* O_2/*hr*
aerator kW	1.4	kW
Use 2 x 1.4kW ABS type aerators or similar		

– An indicative treatment process is shown below:



(1) Aeration on from 10.00 to 06.00 (20 hours per day).

(2) Leachate dosing on within period (1) above, on 4 occasions every hour, for 1 minute each, at variable rates, to achieve desired daily amounts treated.

(3) Solenoid valve energised (open for effluent release) from 08.30 to 09.00.

- pH Control:

  – Est. 265*mg*/*ℓ* alk. deficit, i.e. 13*kg*/*day*
  – i.e. 0.6630*kg* NaOH per m^3 (assume 45% NaOH)
  – i.e. 33.15*kg*/*day* nitrification and
  – i.e. est. 8.3*kg*/*day* for combined nitrification and denitrification
  – Note: carbon source, e.g. methanol or glycerol to be determined by treatment trials.

- Constructed Wetlands / Reedbeds

  – Only very low levels of ammoniacal-N (<2*mg*/*ℓ*) may be discharged to the proposed reedbed systems as there is risk of rendering a wetland toxic over time. Treated effluent with elevated nitrate-N (post-biological nitrification) may be discharged directly to the reedbeds.
  – Hydraulic Retention Time (HRT) = three to five days
  – Allow reedbed treatment up to 5*g*N/m^2/*day*.

Treatment alternatives for the removal of solutes, primarily ammoniacal-N, from the proposed extraction areas shown in Figures 12 and 13 are:

- on-site treatment, or
- disposal to the Levin WWTP, via the existing leachate pump station on site.

Disposal to the WWTP will require checking with HDC's wastewater team to ensure that up to an additional 100m^3 per day (allowing initially for no on-site treatment) may be disposed to the pipeline. Since January 2012, all leachate (about 50m^3 per day) has been pumped to the Levin WWTP (Stantec's Annual Compliance Report, July 2021 – June 2022, Sept. 2022).

Modifications made to the leachate pumping system allow leachate from the leachate pond to be pumped to a manhole located next to the leachate pond, from where it is pumped to the Levin WWTP. This allows leachate pumping to occur without having to fill up the leachate pond (Stantec, Sept. 2022). If required, discharge to the wastewater line from the proposed new extraction system could be time and/or flow controlled to ensure this additional volume is suitably managed.

This decision can be expected to be primarily a financial one. From an environmental standpoint, however, the introduction of constructed wetlands (reedbeds) would appropriately supplement on-site treatment for the removal of residual nitrogen. Discharge of groundwater containing elevated levels of ammoniacal-N into any wetland system would pose the risk of rendering these systems toxic to aquatic species and vegetation. This assessment has demonstrated the mobility of the ammoniacal-N plume with concentration levels of up to 180mg/ℓ at the *epicentre* of the plume. As previously mentioned, ammoniacal-N is potentially toxic to plants at 50mg/ℓ to 150mg/ℓ and fish life at levels of approximately 2mg/ℓ. Potentially contaminated ground and surface waters extracted from the areas to the north of the existing Levin Landfill will contain elevated levels of ammoniacal-N. Therefore, without treatment for the removal of ammoniacal-N, the introduction of standalone wetlands is not recommended. Specialist site-specific investigation will need to be carried out prior to the introduction of constructed wetlands.

6.2.3. Estimated Cost of Extraction

Cost estimation for either extraction option would require detailed scoping and quantification, which would form part of the next phase of work. *Broad-brush* estimated costs, based on conceptual design, are provided as follows to allow for early budgeting:

The cost for implementation of an extraction system comprising the well points, i.e. Option 2, is expected to be lower than Option 1.

Option 1 Scope	High Level Estimated Cost
Extraction trench as per details in Figure 12, including 100$k\ell$ balance tank.	$105,000.00
Pumping main to on-site wastewater connection at leachate pump station.	$80,000.00
Indicative cost (excluding GST)	$185,000.00

Note: costs exclude power supply, pumps and controls, P&Gs and establishment charges.

Importantly is the decision to carry out on-site treatment or disposal to the available wastewater via the existing leachate pump station on site. The analysis provided below provides a comparison between costs for HDC trade waste charges (for disposal to the available wastewater line), versus estimated costs for an on-site treatment plant. The costs for constructed wetlands/reedbeds is excluded from the calculation below.

Leachate quality parameters from BHC2, i.e. from newly proposed subsoil drain or extraction wells		
Est. Flow (Q) *m^3/day*	**100**	***m^3/day***
Suspended Solids (SS)		
Est. SS	400	*mg/ℓ*
	40	*kg/day*
SS Unit charge	$1.09	$/*kg*
SS charge	$43.60	$/*day*
SS charge	$15,924.90	$ *pa*
Chemical Oxygen Demand (COD)		
Est. COD	200	*mg/ℓ*
	20	*kg/day*
COD Unit charge	$0.48	$/*kg*
COD charge	$9.60	$/*day*
COD charge	$3,506.40	$ *pa*
Total Kjeldahl Nitrogen (TKN)*		
Est. TKN	200	*mg/ℓ*
	20	*kg/day*
TKN Unit charge	$1.71	$/*kg*
TKN charge	$34.20	$/*day*
TKN charge	$12,491.55	$ *pa*
Summary		
Total estimated charge for proposed discharge to available sewer line from Levin Landfill:	$87.40	*per day*
	$31,922.85	*pa*
Thus, est. cost per m^3 (treated at Wastewater Treatment Plant):	$0.87	$/$m^3$
Estimated cost for on-site DN+N treatment**:	$3.91	$/$m^3$
	4.5	times more for on-site treatment cost

*total N in ammoniacal taken, as TKN analytical testing not currently carried out
(required $N_{org}+NH_4+NH_3$ for TKN)

The operational cost for on-site treatment is some 4.5 times higher than disposal to the available wastewater line (i.e. existing leachate pumping chamber) on site. More accurate costs for an on-site treatment solution are to be determined in the next phase.

7. Conclusions and Recommendations

The following conclusions and recommendations are noted from the findings of this assessment:

1. The presence of a pollution plume emanating from the closed landfill (Old Landfill) of the Levin Landfill site has been determined previously by others, namely Stantec and Tonkin and Taylor. A recent finding of significance, however, has been the increasing trend of elevated levels of ammoniacal-N (~170*mg/ℓ*) and Boron at BHC2 and flanking areas, i.e. BHB3. Levels at other borehole locations have demonstrated that the peak concentrations have passed through and levels are decreasing, or attenuating.

2. Solutes that are typically directly linked to landfill geochemical activity have been focussed upon in this assessment, these being ammoniacal-nitrogen (NH_4-N), boron (B), chloride (Cl) and electrical conductivity (EC). A key finding of this assessment is that the areas where the highest concentrations of the plumes of these solutes are situated, are all beyond (outside of) the original source of the closed landfill. This mobility has been diagrammatically illustrated in Figures 7 to 10 of this report.

3. The recent increasing trend of ammoniacal-N in the Hōkio Stream at sampling location HS2, noted in Stantec's Annual Compliance Report (Stantec, September 2022) is now understood to be attributed to the outer reaches of the migrating front (as shown in Figure 10).

4. This assessment has established that whilst it is unlikely ammoniacal-N will exceed the ANZECC (95%ile) DGV of 2.1mg/ℓ at the HS3 location, it will progressively exceed the consent average trigger value of 0.4mg/ℓ over time.

   To this regard, calculations show that the Hōkio Stream has the ability to dissimilate ammoniacal-N concentration to under the maximum consented limit, as a concentration of 320g/m^3 across the total aquifer width of 750*m* is conservative. However, the ammoniacal-N concentration is already above the average trigger limit of 0.4*mg/ℓ* at HS2, and is expected to increase to above average trigger limits at HS3 as well. Thus, remediation is required.

5. Future assessment of the Northern Farm Drain contribution to Hōkio Stream surface water is required and a weir development will be needed to obtain the drain flow.

6. Much required geological information has been found to be unavailable to allow for a higher accuracy of determining groundwater flow location (with depth), subterranean soil permeabilities and flow velocities. Notwithstanding this challenge, this assessment has provided key findings through a back-analysis approach using the abundance of available monitoring data. The HDC and Stantec are commended for the amount of data that has been made available, enabling a good degree of accuracy to the answers provided in this report.

   It is recommended that exploratory investigations be carried out to accurately determine the geological regime and location of the gravels, which are indicatively shown in Figure 5. A series of cone penetrometer tests would suffice for this aim.

7. The location of the solute plumes of electrical conductivity (EC), boron (B), chloride (Cl) and ammoniacal-nitrogen (NH_4-N) all require extraction of solute mass to be carried out. The *epicentre* of highest concentrations of chloride (i.e. chloride plume) is predicted to reach the Hōkio Stream by 2025. However, ammoniacal-N is arguably the most significant since current concentrations at the plume *epicentre* are some 150*mg/ℓ* to 170*mg/ℓ* and levels of 10*mg/ℓ* will soon reach the Hōkio Stream, as shown in Figure 10. It is likely that the front of the plume, i.e. at 10*mg/ℓ* concentration, has already reached the Hōkio Stream. Ammoniacal-N is potentially toxic to plants at 50*mg/ℓ* to 150*mg/ℓ* and fish life at levels of approximately 2*mg/ℓ*.

8. Further groundwater investigations are required to confirm the above analytical assessment and aquifer conditions for remedial works design. Recommended groundwater investigations are as follows:

   i) Boreholes at three locations on Tatana Flats and within sand dunes to confirm aquifer extent and leachate plume indicators both spatially and with depth. Groundwater level monitoring and permeability testing.

   ii) Eleven CPT (Dutch Cone Penetrometer) soundings on three cross-section locations across Tatana Flats (including Section A-A).

   iii) Groundwater flow and transport modelling to determine pumping volumes required to reduce contaminant effects on the Hōkio Stream as required by the BPO. Modelling of the preferred mitigation option (shallow drains or groundwater bores) to be completed.

   iv) Hōkio Stream flow gauging at HS1A, HS2 and HS3 under summer low flow conditions for two rounds at least two weeks apart. Flow gauging of the Northern Farm Drain outlet to the Hōkio Stream at the same time.

9. The BPO engineering provided in this report is recommended to be implemented within the next 12 months, focussed on the reduction or removal of ammoniacal-N from the receiving (and received) environment. Thus, it is recommended that detailed engineering design be progressed for the BPO.

10. If on-site treatment is preferred, with discharge of treated water to wetland systems (reedbeds), a pilot plant treatability trial is recommended to verify treatment efficiency and full-scale requirements.

8. Next Steps

The next steps will become more focussed on the BPO implementation within the soonest time possible. These steps we see would include:

- Confirming a decision on the implementation approach for a BPO addressing the findings of this assessment and recommended BPO action. This work package of the overall BPO could be phased to ensure that the mass fluxes (migration of solutes) of the ammoniacal-N plume are sufficiently reduced to ensure low or no effects on the Hōkio Stream.

- Groundwater investigations as outlined above.

- Selection of a BPO extraction option, i.e. either Option 1 or Option 2 entailing extraction by subsoil drain or by extraction wells, respectively.

- Informing the Horizons Regional Council (HRC) of the findings of this report and the BPO approach to be considered.

- The alternatives for on-site treatment or discharge to WWTP via the available leachate pumping station on site is to be considered and decided upon. A request or permission is to be sought on the acceptance of a flow volume of up to some $100m^3/day$ from HDC's wastewater team.

- Detailed design of the proposed BPO is to be carried out as part of a follow-on phase of this assessment. Quotes from suppliers and contractors can then be obtained, budget approved and physical works progressed.

- Discussions with Regional Council regarding resource consent requirements.

- Timing of the above-mentioned steps needs to be with immediacy to meet the consent condition of the BPO being fully implemented by June 2023. This date is arguably impractical. We suggest a rapid programme response to achieve the earliest possible BPO.

9. References

Horizons Regional Council (2022) Annual Compliance Audit Report Horowhenua District Council Levin Landfill, Reporting Period July 2021 – June 2022, December 2022.

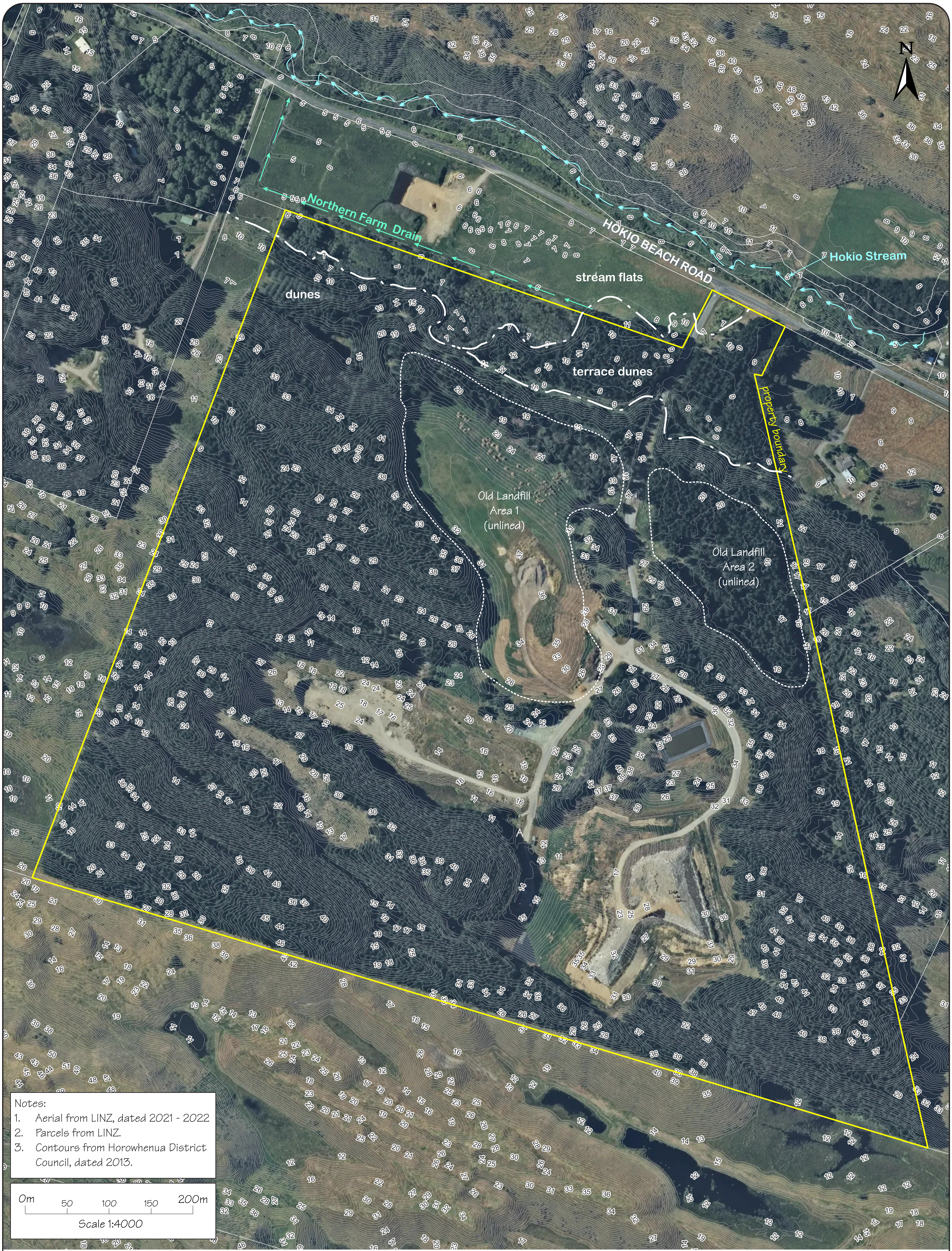
NIWA (2011) *Lake Horowhenua Review – Assessment of opportunities to address water quality issues in Lake Horowhenua*. Prepared for Horizons Regional Council. Retrieved from All Publications - Horizons Regional Council.

Stantec (2022) Levin Landfill Annual Compliance Report July 2021 – June 2022 (as required by Resource Consents DP6009, DP6010, DP6011 and DP102259), prepared for Horowhenua District Council, September 2022.

Stantec (2022) Levin Landfill October 2022 Quarterly Groundwater, Surface Water and Leachate Monitoring Report, prepared for Horowhenua District Council, November 2022

Stantec (2023) Levin Landfill January 2023 Quarterly Groundwater, Surface Water and Leachate Monitoring Report, prepared for Horowhenua District Council, February 2023

Tonkin and Taylor (2019) *Levin Landfill – Summary of leachate option assessment*. (Ref 1011583).



Notes:
1. Aerial from LINZ, dated 2021 - 2022
2. Parcels from LINZ.
3. Contours from Horowhenua District Council, dated 2013.

NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

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LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

Site Location Plan

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	L.S	S.SW	

DRAWING NO.: FIG. 1
REF: 10009-R1
SCALE: 1:4000
CRS: NZTM
DATUM:

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LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

Site Bore Location Plan

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	L.S	S.SW	

DRAWING NO.: FIG. 2
REF: 10009-R1
SCALE: 1:4000
CRS: NZTM
DATUM:

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Note: All drawings are to be approved (initialled) before final issue.

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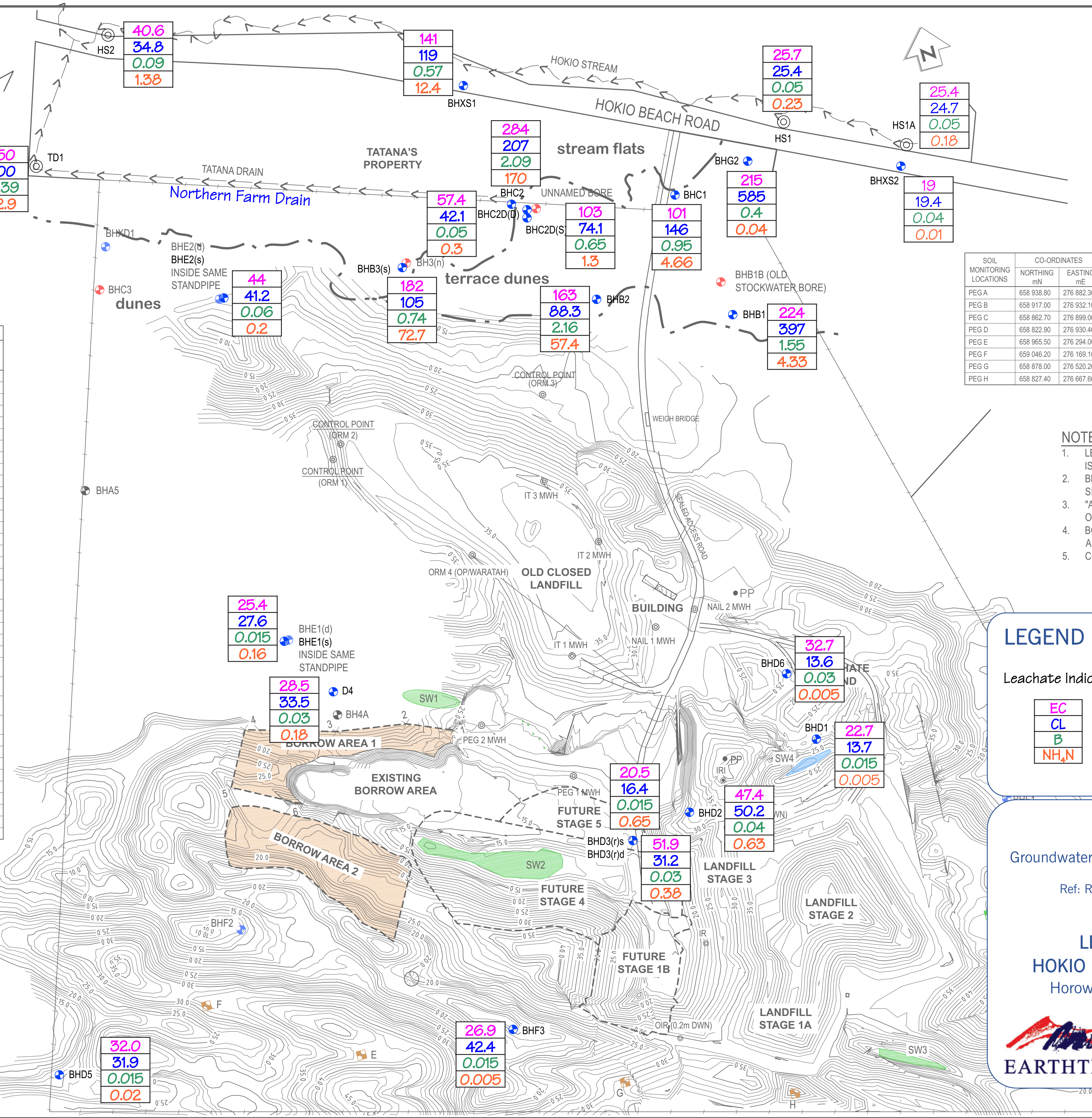
LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Monitoring Points North of Old Landfill

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	P.K	S.SW	

DRAWING NO.: FIG. 3
REF: 10009-R1
SCALE: 1:2000
CRS: NZTM
DATUM:



COORDINATES OF SURVEY CONTROL MARKS			
PT	NORTHING mN	EASTING mE	RL
ORM 1	659 498.38	276 412.21	38.94
ORM 2	659 510.09	276 422.72	34.98
ORM 3	659 505.14	276 612.86	21.10
ORM 4(OP/W)	659 380.16	276 511.94	30.92
MWH NAIL 1	659 272.67	276 656.87	27.61
MWH NAIL 2	659 278.98	276 695.22	28.40
MWH IT 1	659 267.33	276 576.02	30.03
MWH IT 2	659 361.94	276 627.00	33.70
MWH IT 3	659 428.24	276 593.00	32.74
MWH PEG 1	659 160.94	276 548.30	32.99
MWH PEG 2	659 227.86	276 479.35	30.49
IRII	659 075.85	276 698.70	30.04
OIR	658 903.62	276 579.37	30.35
IRI	659 121.09	276 679.47	40.00
IR	276 625.10	658 981.29	21.30
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT			

SOIL MONITORING LOCATIONS	CO-ORDINATES		LEVEL (m)
	NORTHING mN	EASTING mE	
PEG A	658 938.80	276 882.30	39.2
PEG B	658 917.00	276 932.10	39.5
PEG C	658 862.70	276 899.00	46.1
PEG D	658 822.90	276 930.40	40.4
PEG E	658 965.50	276 294.00	36.6
PEG F	659 046.20	276 169.10	32.9
PEG G	658 878.00	276 520.20	32.6
PEG H	658 827.40	276 667.60	23.5

BORROW AREA 1 SET-OUT COORDINATES		
POINT NO.	NORTHINGS mN	EASTINGS mE
1	659 230.38	276 453.28
2	659 247.32	276 413.49
3	659 257.33	276 349.62
4	659 280.93	276 269.42
5	659 233.27	276 243.39
6	659 201.34	276 302.68

NOTES:

1. LEVELS ARE TOP OF STANDPIPE. WHERE THERE IS NO STANDPIPE, LEVELS ARE TOP OF PVC PIPE.
2. BHA2, BHA3 AND BHD3 HAVE BEEN LOST DUE TO SITE WORKS.
3. "A" SERIES BORE HOLES ARE AUGER HOLES ONLY AND MAY NOT BE ABLE TO BE LOCATED.
4. BORES INSTALLED IN AUG 2009. DETAILS ARE APPROXIMATE.
5. CONTOUR INTERVALS: 5m MAJOR, 1m MINOR

BORE LOCATIONS AND DETAILS						
BORE HOLE NO	NORTHING mN	EASTING mE	R.L. (m)	DEPTH OF WELL (m)	PIEZOMETER DIAMETER (mm)	FUNCTION
A1	659 060.15	276 944.89	12.95			SHALLOW AQUIFER
A2 (DESTROYED)						SHALLOW AQUIFER
A3 (DESTROYED)						SHALLOW AQUIFER
A4	659 271.67	276 354.72	10.10			SHALLOW AQUIFER
A5	659 530.47	276 185.91	9.62			SHALLOW AQUIFER
B1	659 561.81	276 797.35	9.04	4.3	40	SHALLOW AQUIFER
B1B (STOCK BORE)	659 530.08	276 799.91	9.28	10		
B2	659 576.32	276 683.50	9.42	3.5	50	SHALLOW AQUIFER
B3(s)	659 651.19	276 519.52	7.76	2.83	50	SHALLOW AQUIFER
B3(n)	659 654.26	276 524.38	7.49	2.33	32	DEEP AQUIFER
C1	659 649.64	276 777.83	7.47	3.60	50	SHALLOW AQUIFER
C2	659 680.80	276 631.22	7.50	2.81	32	SHALLOW AQUIFER
C2D(s)	659 671.19	276 641.63	10.13	12.88	32	SHALLOW AQUIFER
C2D(d)	659 671.19	276 641.63	10.11	18.85	32	DEEP AQUIFER
C3	659 704.29	276.246.89	7.22	2.8	32	SHALLOW AQUIFER
D1	659 134.97	276 771.65	27.46	23.69	50	EARLY DETECTION
D2	659 101.02	276 642.06	32.12	29.46	50	EARLY DETECTION
D4	659 293.20	276 356.60	17.97	17.0		SHALLOW AQUIFER
D5	659 020.80	276 022.40	20.65	18		SHALLOW AQUIFER BACKGROUND
D6	659 200.31	276 761.08	26.41	16.07	50	EARLY DETECTION
E1(d)	659 349.54	276 329.48	20.91	37.80	32	SHALLOW AQUIFER
E1(s)	659 349.54	276 329.48	20.91	20.05	32	DEEP AQUIFER
E2(s)	659 667.30	276 354.69	13.15	15.24	32	SHALLOW AQUIFER
E2(d)	659 667.30	276 354.69	13.15	28.66	32	DEEP AQUIFER
F1	659 037.10	276 925.50	18.90	15.0	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F2	659 105.00	276 218.00	13.50	10.2	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F3	658 951.70	276 434.00	16.70	10.5	50	SHALLOW AQUIFER LEACHATE IRRIGATION
G1(s) 4	658 786.00	277 046.00	24	15	50	SHALLOW AQUIFER BACKGROUND
G1(d) 4	658 786.00	277 046.00	24	31.5	50	DEEP AQUIFER BACKGROUND
G2 4	659 673.00	276 835.00	8	4	50	SHALLOW AQUIFER
COORDINATES FOR BORE HOLES BELOW ARE APPROXIMATE ONLY						
D3(r) s	659 089.60	276 585.30	18	10	50	EARLY DETECTION
D3(r) d	659 089.60	276 585.30	18	32	50	EARLY DETECTION
BHXS1	659 797.20	276 617.30	-	4	50	SHALLOW AQUIFER
BHXS2	659 620.80	276 984.30	-	4	50	SHALLOW AQUIFER
BHXD1	659 741.00	276 262.60	-	35	50	DEEP AQUIFER
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT						

LEGEND

- MONITORING SAMPLING LOCATION
- MONITOR BORES CURRENTLY SAMPLED (FROM JAN 2010)
- BORES NOT SAMPLED
- SHALLOW HANDAUGER STANDPIPES NOT ABLE TO BE LOCATED
- SOIL SAMPLING LOCATION PEG - MONITORED
- SOIL SAMPLING LOCATION PEG - NOT MONITORED
- EXISTING STORMWATER SOAKAGE AREA
- PROPOSED STORMWATER SOAKAGE AREA
- PROPOSED BORROW AREAS

LEGEND

Leachate Indicators January 2023

EC	Electrical Conductivity
CL	Chloride
B	Boron
NH_4N	Ammoniacal-Nitrogen

FIGURE 4

Groundwater and Surface Monitoring Plan

Ref: R10009-1 dated 10/05/23

Project:

LEVIN LANDFILL

HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

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NOT FOR CONSTRUCTION

REV	REVISIONS	DRN	CHK	APP	DATE
E	FOR INFORMATION - BHD3(r)s AND BHD3(r)d ADDED, AND CONTOURS UPDATED FROM JULY 2021 SURVEY	BCJ	PSL	PSL	24.09.21
D	FOR INFORMATION - BORROW AREA 2 RELOCATED, DEFINED AREAS OF FUTURE STAGES 1B, 4 AND 5	BCJ	PSL	PSL	01.06.21
C	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES AND BORE HOLES AND SAMPLING LOCATIONS ADDED FOR HOKIO STREAM AND TATANA DRAIN	BCJ	PSL	PSL	24.03.21
B	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES	BCJ	PSL	PSL	22.09.20
A	FOR INFORMATION	BCJ	PSL	PSL	26.08.19

SURVEYED	MWH	
DESIGNED	N/A	-
DRAWN	Brent James	08.2019
CAD REVIEW	Brent James	23.09.21
APPROVED	Phil Landmark	23.09.21
PROF REGISTRATION:		

Stantec

Client:

HOROWHENUA DISTRICT COUNCIL
LEVIN LANDFILL

MONITORING BORES, SOIL SAMPLING LOCATIONS & BORROW AREAS
SITE PLAN, LOCATION AND DETAILS

Status Stamp: FOR INFORMATION ONLY

Date Stamp: 24.09.21

Scales: 1:2000 (A1) 1:4000 (A3)

Drawing No.: 310101088-19-001-G001

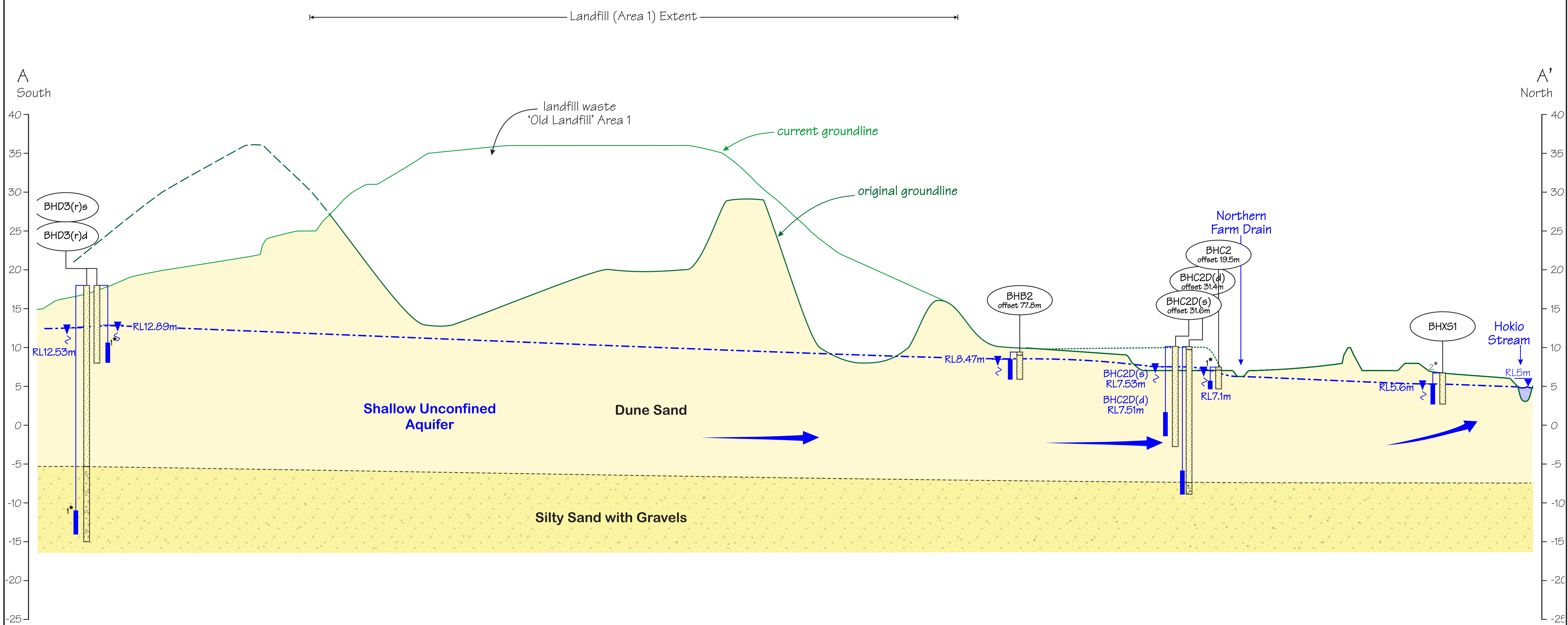
Rev.: E

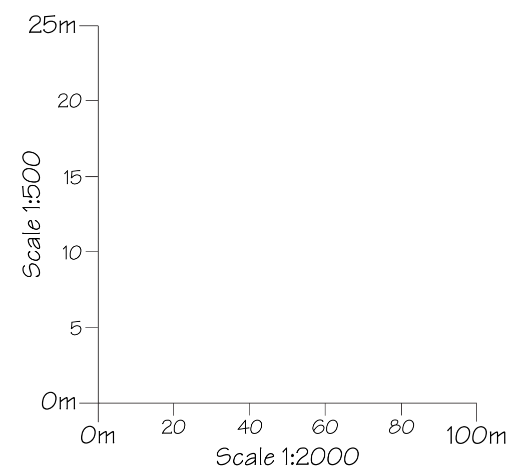
26/08/2019 9:35 a.m.

ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK

pw:\\stantec-ap-pw.bentley.com:stantec-ap-pw-01\Documents\New Zealand Clients\Horowhenua District Council\80500724 (310101088) - Levin Landfill Volumes\2019\General\310101088-19-001-G001





Notes:

1. Original groundline from original site topography and aerial photography from N.Z Aerial mapping, dated 27 April 1981.
2. Current groundline from Stantec drawing 310101088-19-001-G001 Rev E ' Monitoring bores, Soil Sampling Locations & Borrow Areas Site Plan, Location and Details', dated 24 September 2021.
3. 1* Intake details inferred.
4. 2* RL ground level estimated.
5. Water level (RL) from January 2023.

NOT FOR CONSTRUCTION

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LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Cross-Section A-A'

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	P.K	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	P.K	P.K	S.SW	

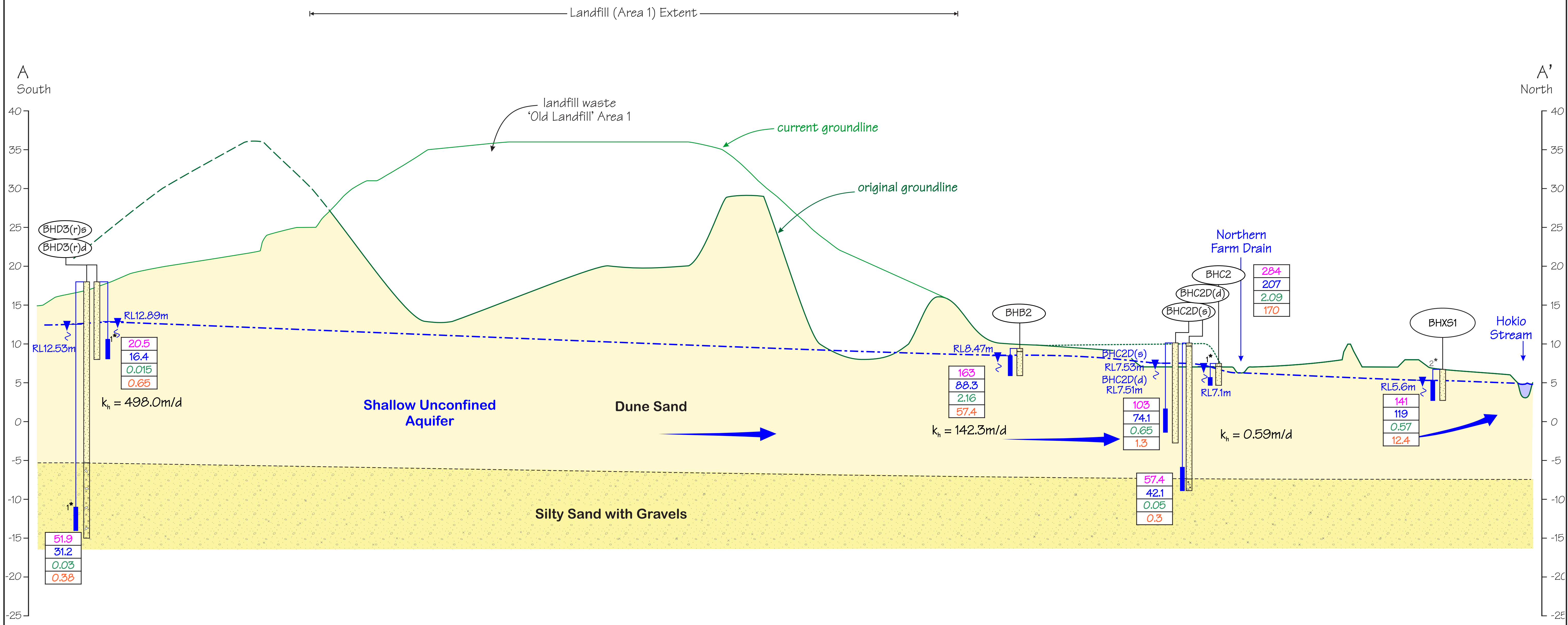
DRAWING NO.: FIG. 5

REF: 10009

SCALE: 1:2000(h) 1:500(v)

CRS: Wanganui 1949

DATUM:

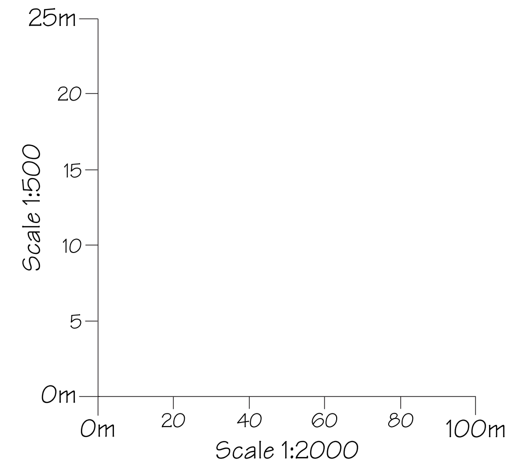


Notes:

1. Original groundline from original site topography and aerial photography from N.Z Aerial mapping, dated 27 April 1981.
2. Current groundline from Stantec drawing 310101088-19-001-G001 Rev E ' Monitoring bores, Soil Sampling Locations & Borrow Areas Site Plan, Location and Details', dated 24 September 2021.
3. 1* Intake details inferred.
4. 2* RL ground level estimated.
5. Water level (RL) from January 2023.

LEGEND

EC CL B NH_4N	Leachate indicators January 2023
k_h = 142.3m/d	Permeability testing July 2012



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Horowhenua District Council

Cross-Section A-A' with Leachate Level Indicators

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	P.K	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	P.K	P.K	S.SW	

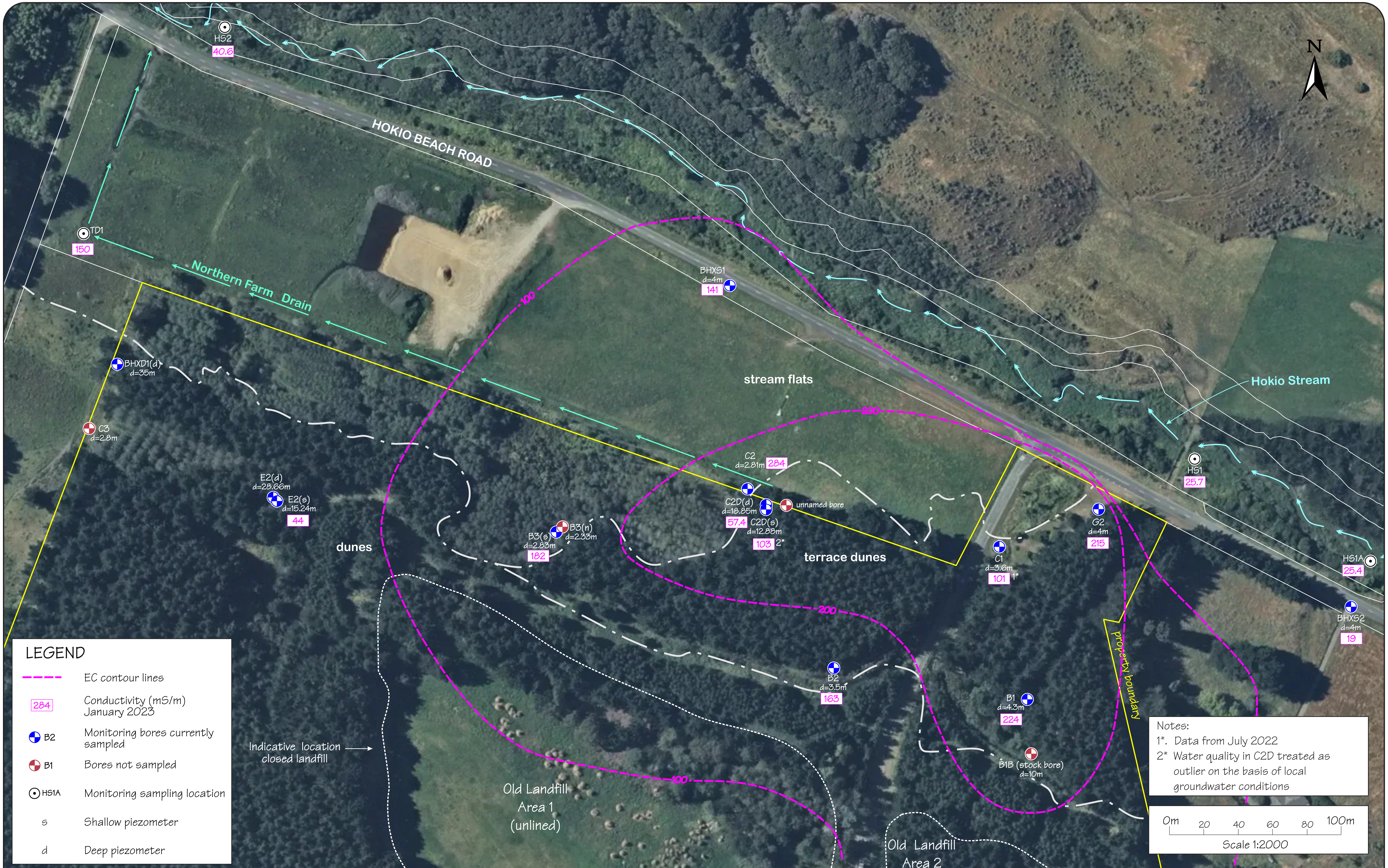
DRAWING NO.: FIG. 6

REF: 10009

SCALE: 1:2000(h) 1:500(v)

CRS: Wanganui 1949

DATUM:



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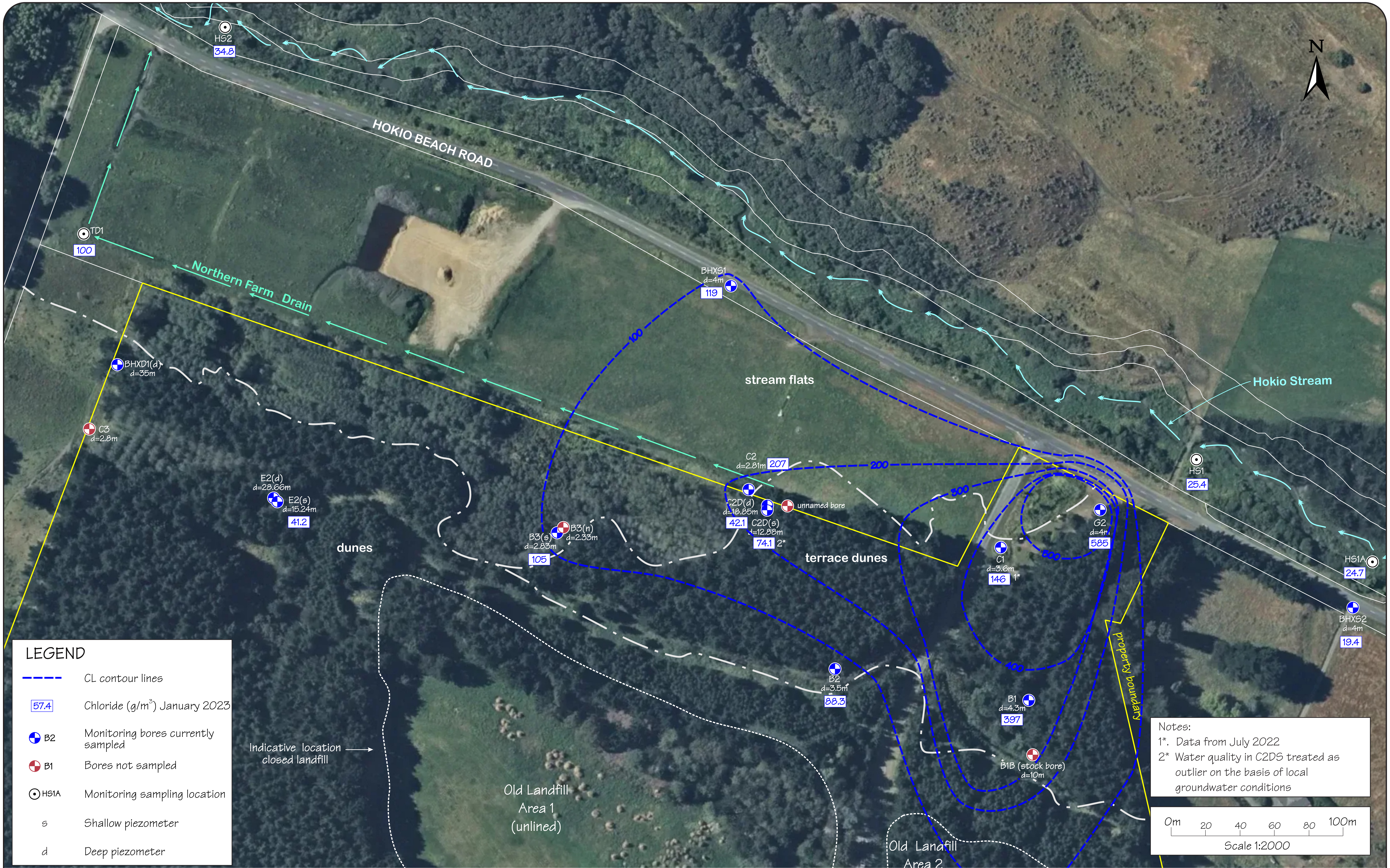
LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Electrical Conductivity Plume - January 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	M.F	P.K	S.SW	

DRAWING NO.: FIG. 7
REF: 10009-R1
SCALE: 1:2000
CRS: NZTM
DATUM:



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Horowhenua District Council

Chloride Plume - January 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	M.F	P.K	S.SW	

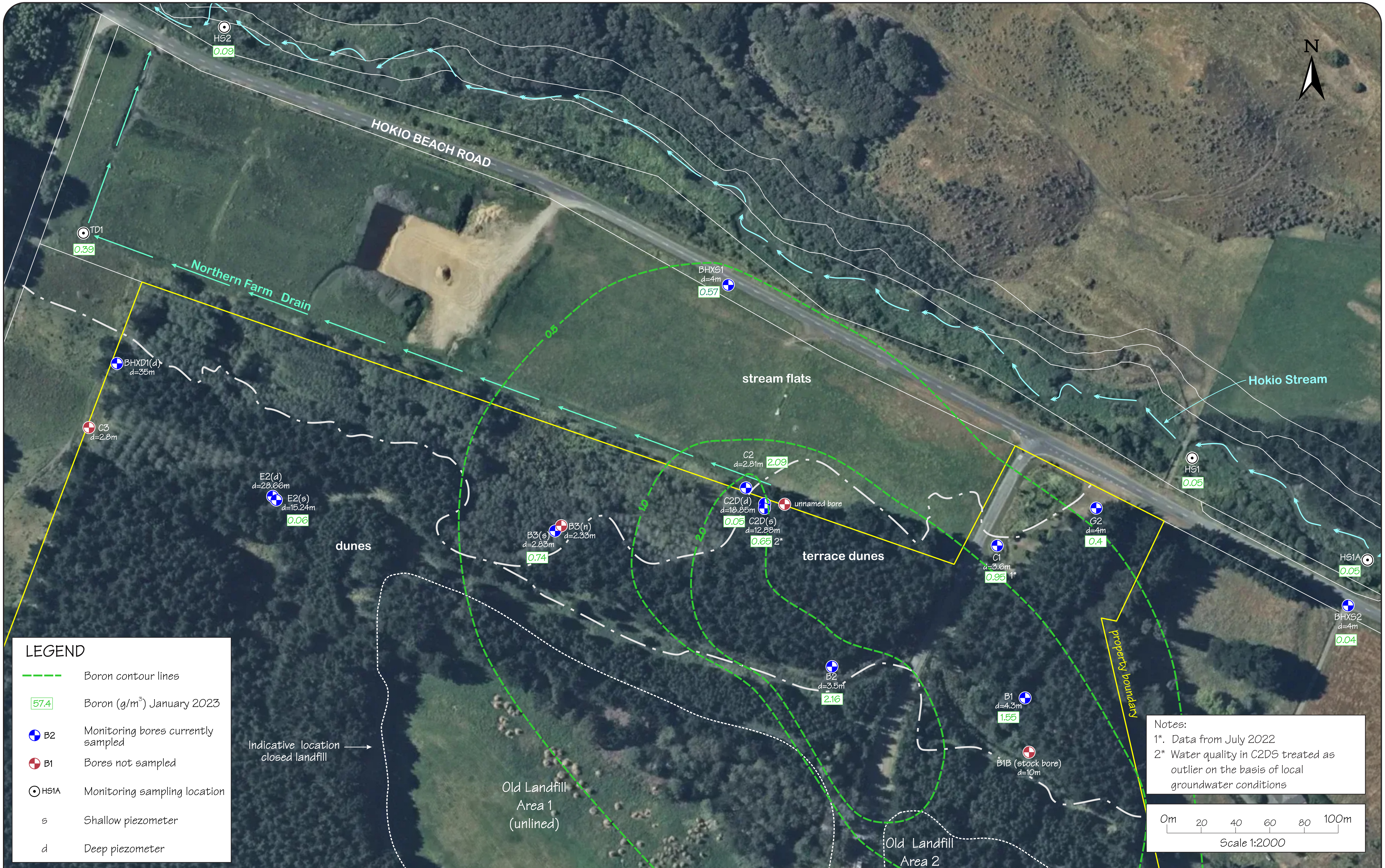
DRAWING NO.: FIG. 8

REF: 10009-R1

SCALE: 1:2000

CRS: NZTM

DATUM:



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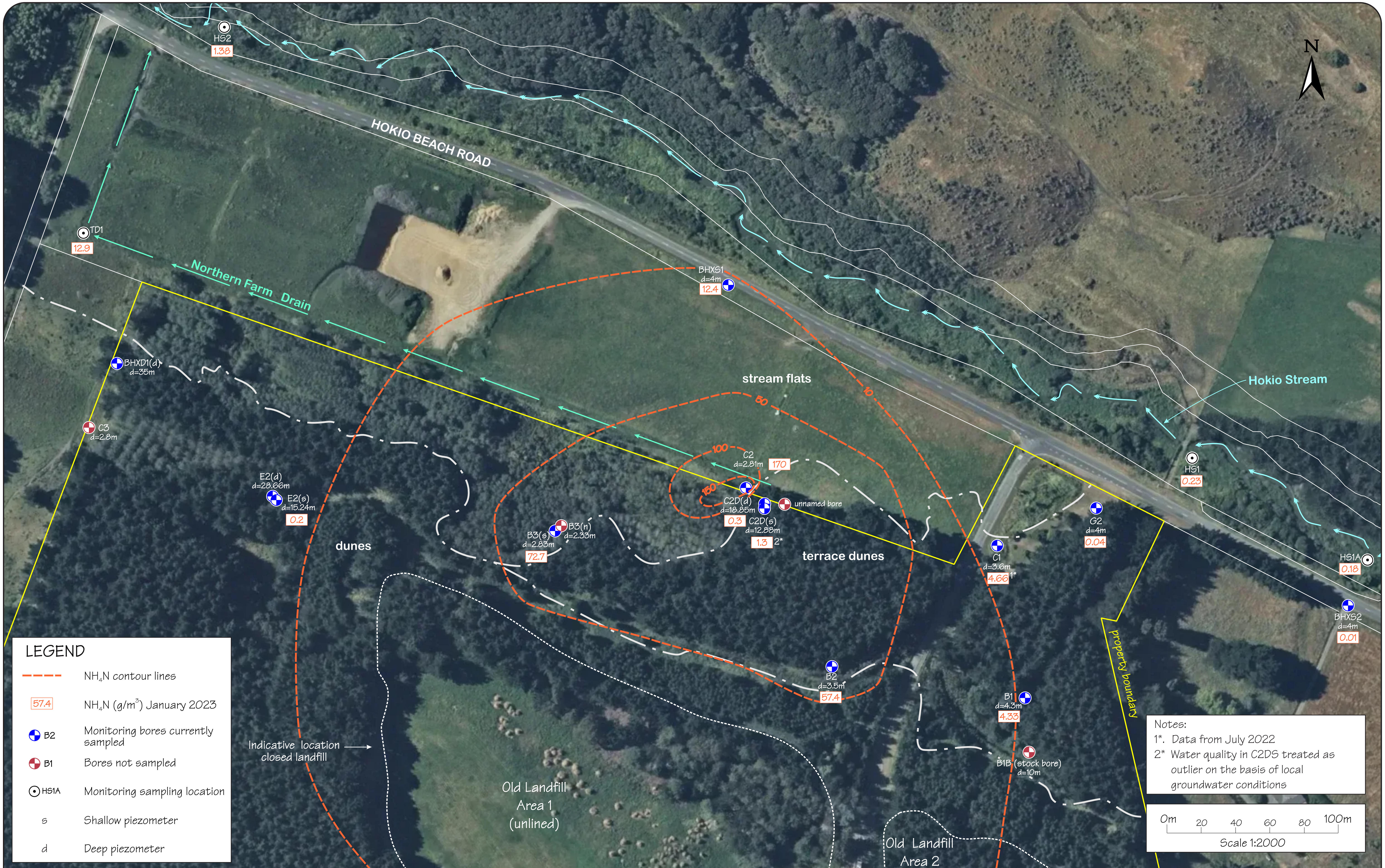
LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

Boron Plume - January 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	M.F	P.K	S.SW	

DRAWING NO.: FIG. 9
REF: 10009-R1
SCALE: 1:2000
CRS: NZTM
DATUM:



NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

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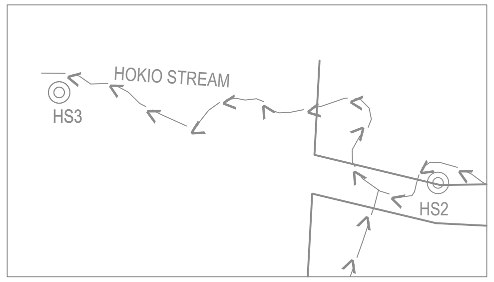
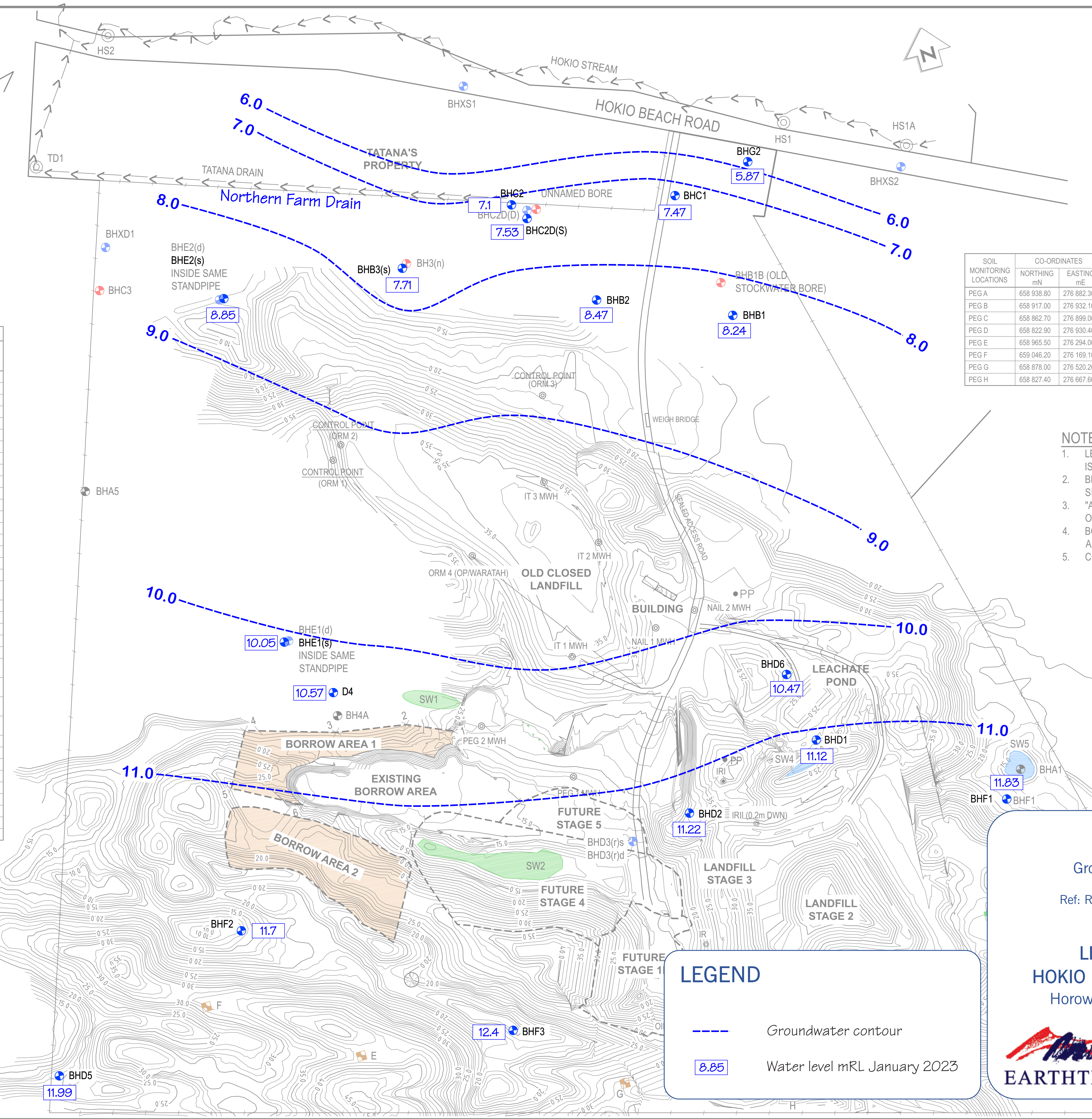
Horowhenua District Council

Ammoniacal Nitrogen Plume - January 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	M.F	P.K	S.SW	

DRAWING NO.: FIG. 10
REF: 10009-R1
SCALE: 1:2000
CRS: NZTM
DATUM:





BORE LOCATIONS AND DETAILS						
BORE HOLE NO	NORTHING mN	EASTING mE	R.L. (m)	DEPTH OF WELL (m)	PIEZOMETER DIAMETER (mm)	FUNCTION
A1	659 060.15	276 944.89	12.95			SHALLOW AQUIFER
A2 (DESTROYED)						SHALLOW AQUIFER
A3 (DESTROYED)						SHALLOW AQUIFER
A4	659 271.67	276 354.72	10.10			SHALLOW AQUIFER
A5	659 530.47	276 185.91	9.62			SHALLOW AQUIFER
B1	659 561.81	276 797.35	9.04	4.3	40	SHALLOW AQUIFER
B1B (STOCK BORE)	659 530.08	276 799.91	9.28	10		
B2	659 576.32	276 683.50	9.42	3.5	50	SHALLOW AQUIFER
B3(s)	659 651.19	276 519.52	7.76	2.83	50	SHALLOW AQUIFER
B3(n)	659 654.26	276 524.38	7.49	2.33	32	DEEP AQUIFER
C1	659 649.64	276 777.83	7.47	3.60	50	SHALLOW AQUIFER
C2	659 680.80	276 631.22	7.50	2.81	32	SHALLOW AQUIFER
C2D(s)	659 671.19	276 641.63	10.13	12.88	32	SHALLOW AQUIFER
C2D(d)	659 671.19	276 641.63	10.11	18.85	32	DEEP AQUIFER
C3	659 704.29	276.246.89	7.22	2.8	32	SHALLOW AQUIFER
D1	659 134.97	276 771.65	27.46	23.69	50	EARLY DETECTION
D2	659 101.02	276 642.06	32.12	29.46	50	EARLY DETECTION
D4	659 293.20	276 356.60	17.97	17.0		SHALLOW AQUIFER
D5	659 020.80	276 022.40	20.65	18		SHALLOW AQUIFER BACKGROUND
D6	659 200.31	276 761.08	26.41	16.07	50	EARLY DETECTION
E1(d)	659 349.54	276 329.48	20.91	37.80	32	SHALLOW AQUIFER
E1(s)	659 349.54	276 329.48	20.91	20.05	32	DEEP AQUIFER
E2(s)	659 667.30	276 354.69	13.15	15.24	32	SHALLOW AQUIFER
E2(d)	659 667.30	276 354.69	13.15	28.66	32	DEEP AQUIFER
F1	659 037.10	276 925.50	18.90	15.0	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F2	659 105.00	276 218.00	13.50	10.2	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F3	658 951.70	276 434.00	16.70	10.5	50	SHALLOW AQUIFER LEACHATE IRRIGATION
G1(s) 4	658 786.00	277 046.00	24	15	50	SHALLOW AQUIFER BACKGROUND
G1(d) 4	658 786.00	277 046.00	24	31.5	50	DEEP AQUIFER BACKGROUND
G2 4	659 673.00	276 835.00	8	4	50	SHALLOW AQUIFER
COORDINATES FOR BORE HOLES BELOW ARE APPROXIMATE ONLY						
D3(r) s	659 089.60	276 585.30	18	10	50	EARLY DETECTION
D3(r) d	659 089.60	276 585.30	18	32	50	EARLY DETECTION
BHXS1	659 797.20	276 617.30	-	4	50	SHALLOW AQUIFER
BHXS2	659 620.80	276 984.30	-	4	50	SHALLOW AQUIFER
BHXD1	659 741.00	276 262.60	-	35	50	DEEP AQUIFER
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT						

LEGEND

- MONITORING SAMPLING LOCATION
- MONITOR BORES CURRENTLY SAMPLED (FROM JAN 2010)
- BORES NOT SAMPLED
- SHALLOW HANDAUGER STANDPIPES NOT ABLE TO BE LOCATED
- SOIL SAMPLING LOCATION PEG - MONITORED
- SOIL SAMPLING LOCATION PEG - NOT MONITORED
- EXISTING STORMWATER SOAKAGE AREA
- PROPOSED STORMWATER SOAKAGE AREA
- PROPOSED BORROW AREAS

COORDINATES OF SURVEY CONTROL MARKS			
PT	NORTHING mN	EASTING mE	RL
ORM 1	659 498.38	276 412.21	38.94
ORM 2	659 510.09	276 422.72	34.98
ORM 3	659 505.14	276 612.86	21.10
ORM 4(OP/W)	659 380.16	276 511.94	30.92
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MWH NAIL 2	659 278.98	276 695.22	28.40
MWH IT 1	659 267.33	276 576.02	30.03
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MWH IT 3	659 428.24	276 593.00	32.74
MWH PEG 1	659 160.94	276 548.30	32.99
MWH PEG 2	659 227.86	276 479.35	30.49
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OIR	658 903.62	276 579.37	30.35
IRI	659 121.09	276 679.47	40.00
IR	276 625.10	658 981.29	21.30
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT			

SOIL MONITORING LOCATIONS	CO-ORDINATES		LEVEL (m)
	NORTHING mN	EASTING mE	
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PEG B	658 917.00	276 932.10	39.5
PEG C	658 862.70	276 899.00	46.1
PEG D	658 822.90	276 930.40	40.4
PEG E	658 965.50	276 294.00	36.6
PEG F	659 046.20	276 169.10	32.9
PEG G	658 878.00	276 520.20	32.6
PEG H	658 827.40	276 667.60	23.5

BORROW AREA 1 SET-OUT COORDINATES		
POINT NO.	NORTHINGS mN	EASTINGS mE
1	659 230.38	276 453.28
2	659 247.32	276 413.49
3	659 257.33	276 349.62
4	659 280.93	276 269.42
5	659 233.27	276 243.39
6	659 201.34	276 302.68

NOTES:

1. LEVELS ARE TOP OF STANDPIPE. WHERE THERE IS NO STANDPIPE, LEVELS ARE TOP OF PVC PIPE.
2. BHA2, BHA3 AND BHD3 HAVE BEEN LOST DUE TO SITE WORKS.
3. "A" SERIES BORE HOLES ARE AUGER HOLES ONLY AND MAY NOT BE ABLE TO BE LOCATED.
4. BORES INSTALLED IN AUG 2009. DETAILS ARE APPROXIMATE.
5. CONTOUR INTERVALS: 5m MAJOR, 1m MINOR

LEGEND

- - - - Groundwater contour

8.85 Water level mRL January 2023

FIGURE 11

Groundwater Contours

Ref: R10009-1 dated 10/05/23

Project:
LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

EARTHTECH
Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

NOT FOR CONSTRUCTION

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

REV	REVISIONS	DRN	CHK	APP	DATE
E	FOR INFORMATION - BHD3(r)s AND BHD3(r)d ADDED, AND CONTOURS UPDATED FROM JULY 2021 SURVEY	BCJ	PSL	PSL	24.09.21
D	FOR INFORMATION - BORROW AREA 2 RELOCATED, DEFINED AREAS OF FUTURE STAGES 1B, 4 AND 5	BCJ	PSL	PSL	01.06.21
C	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES AND BORE HOLES AND SAMPLING LOCATIONS ADDED FOR HOKIO STREAM AND TATANA DRAIN	BCJ	PSL	PSL	24.03.21
B	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES	BCJ	PSL	PSL	22.09.20
A	FOR INFORMATION	BCJ	PSL	PSL	26.08.19

SURVEYED	MWH	
DESIGNED	N/A	-
DRAWN	Brent James	08.2019
CAD REVIEW	Brent James	23.09.21
APPROVED	Phil Landmark	23.09.21
PROF REGISTRATION:		

Stantec

Client:

HOROWHENUA DISTRICT COUNCIL
LEVIN LANDFILL

MONITORING BORES, SOIL SAMPLING LOCATIONS & BORROW AREAS
SITE PLAN, LOCATION AND DETAILS

Status Stamp: FOR INFORMATION ONLY

Date Stamp: 24.09.21

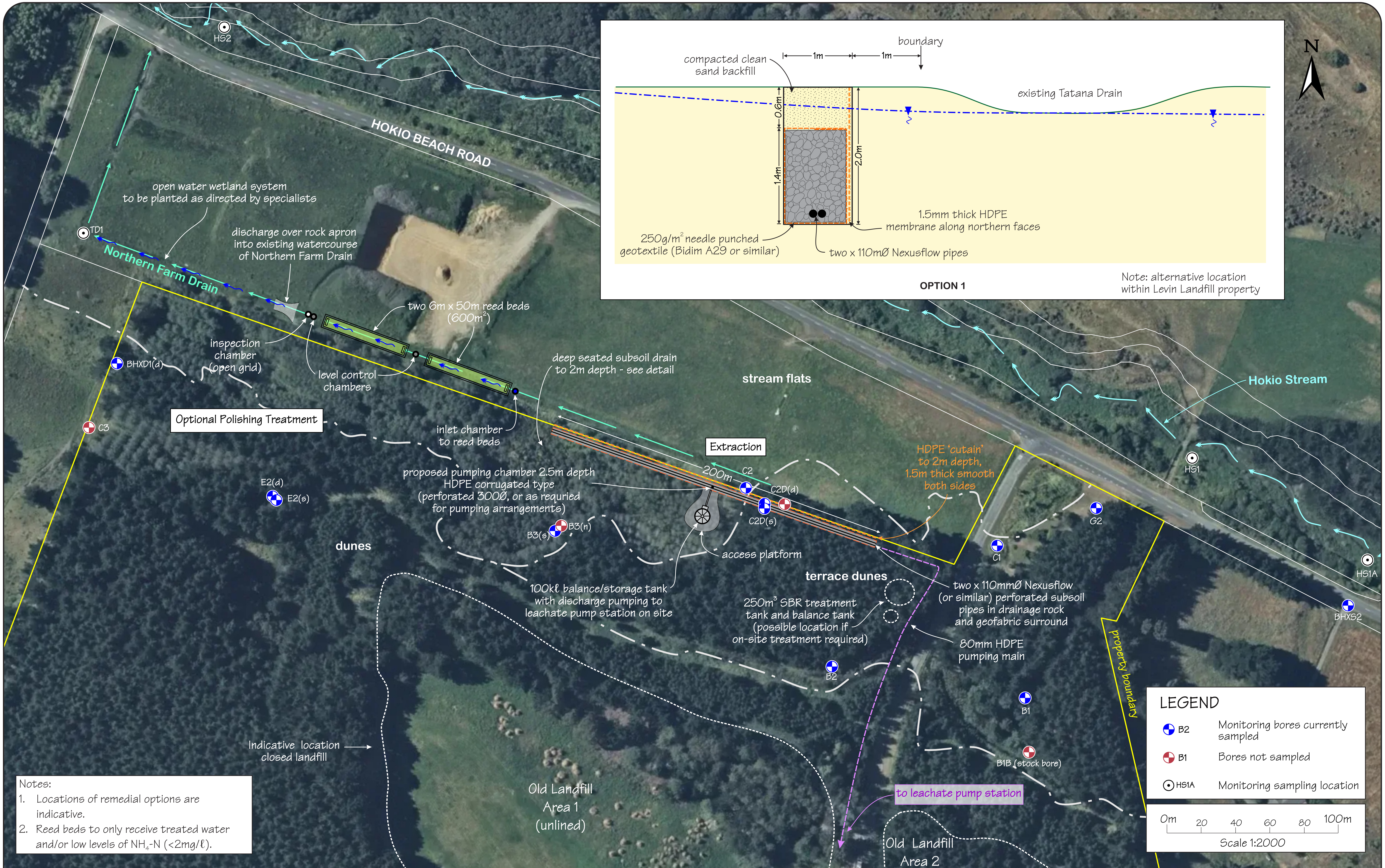
Scales: 1:2000 (A1) 1:4000 (A3)

Drawing No.: 310101088-19-001-G001

Rev.: E

26/08/2019 9:35 a.m.

pw:\\stantec-ap-pw.bentley.com:stantec-ap-pw-01\Documents\New Zealand Clients\Horowhenua District Council\80500724 (310101088) - Levin Landfill Volumes\2019\General\310101088-19-001-G001



Notes:
1. Locations of remedial options are indicative.
2. Reed beds to only receive treated water and/or low levels of NH_4-N (<2mg/ℓ).

NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.
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Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

BPO Groundwater Trench Option

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	L.S	S.SW	

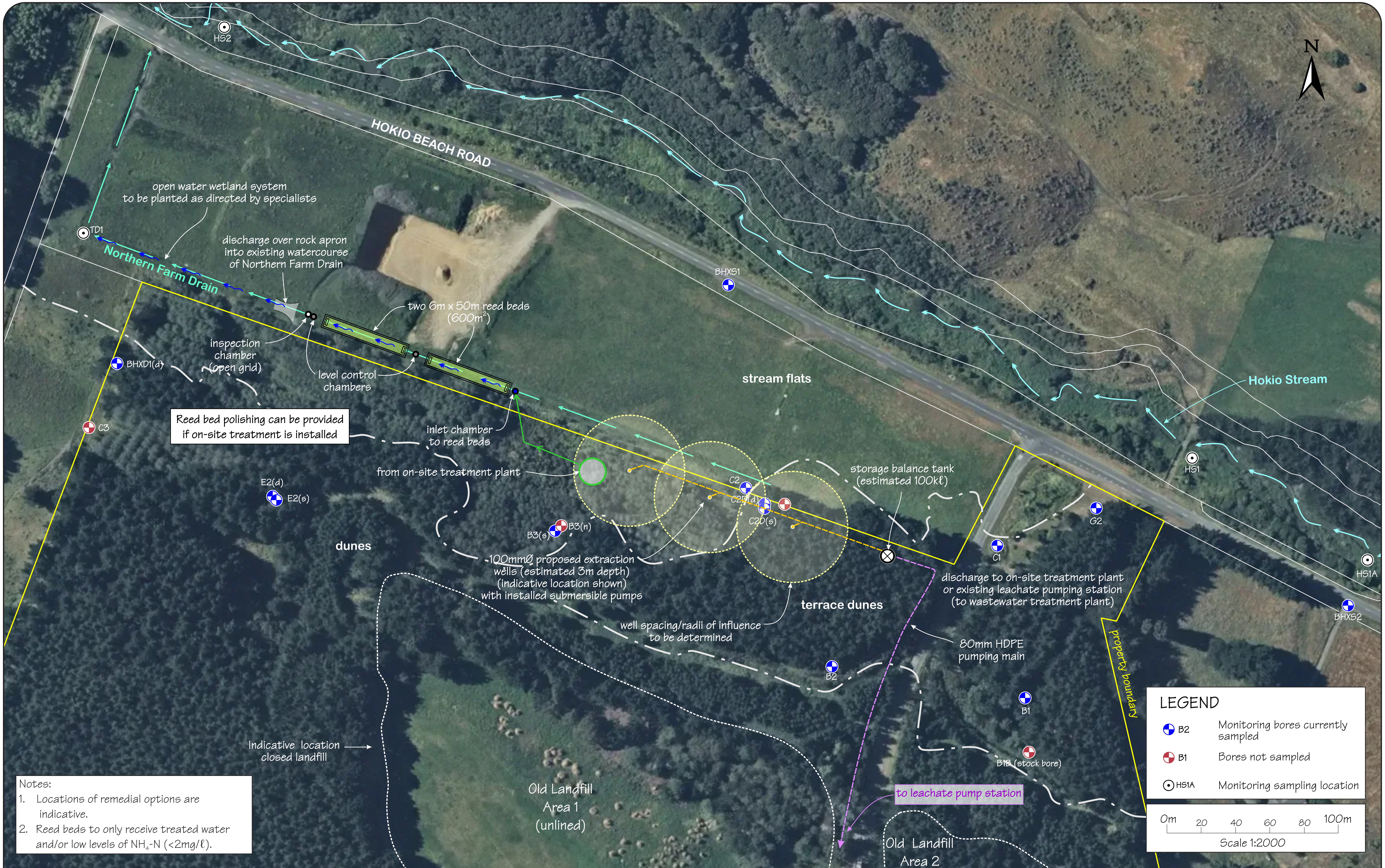
DRAWING NO.: FIG. 12

REF: 10009-R1

SCALE: 1:2000

CRS: NZTM

DATUM:



NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.

P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

BPO Extraction Wells Option

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	L.S	S.SW	

DRAWING NO.: FIG. 13

REF: 10009-R1

SCALE: 1:2000

CRS: NZTM

DATUM:

FIGURE 14

Tonkin and Taylor Cross-Section

Ref: R10009-1 dated 10/05/23

Project:

LEVIN LANDFILL

HOKIO BEACH ROAD, LEVIN

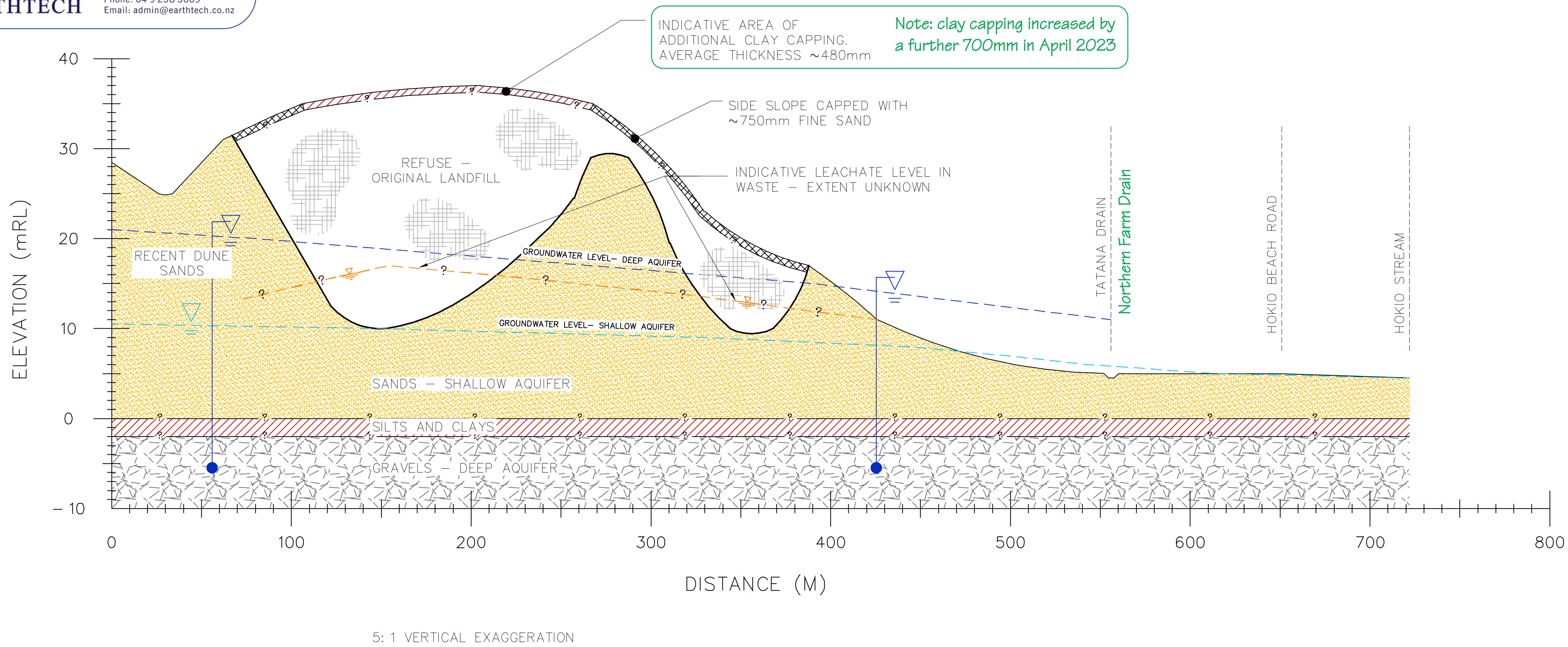
Horowhenua District Council

Earthtech markups in green.

EARTHTECH

Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

NOTES:
1. LOCATIONS ARE BASED ON REVIEW OF EXISTING INFORMATION AND ARE APPROXIMATELY. LAYOUT PROVIDED AS CONCEPT SITE MODEL ONLY.
2. EXISTING TOPOGRAPHY IS BASED ON: STANTEC, 2018: "LEVIN LANDFILL ANNUAL COMPLIANCE REPORT JULY 2017 - JUNE 2018", DATED SEPTEMBER 2018.
2. ORIGINAL SITE TOPOGRAPHY AND AERIAL PHOTOGRAPHY FROM N.Z. AERIAL MAPPING, DATED 27 APRIL 1981.
3. SHALLOW GROUNDWATER LEVELS BASED ON INTERPRETATION PROVIDED BY STEPHEN DOUGLASS, DATED OCTOBER 2018.



SCALE 1: 4000 (H)

0 40 80 120 160 200 (m)

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

0	DRAFT FOR DISCUSSION	DAUM	SEPT 2019

PROJECT No.		
DESIGNED	DAUM	SEPT 19
DRAWN		
CHECKED		
APPROVED	DATE	

CLIENT	HOROWHENUA DISTRICT COUNCIL
PROJECT	LEVIN LANDFILL
TITLE	LEACHATE BEST PRACTICABLE OPTION ASSESSMENT CONCEPT CROSS SECTION
SCALE (A3)	1:4000(H) 1:800(V) FIG No. 1011583-002 REV 0

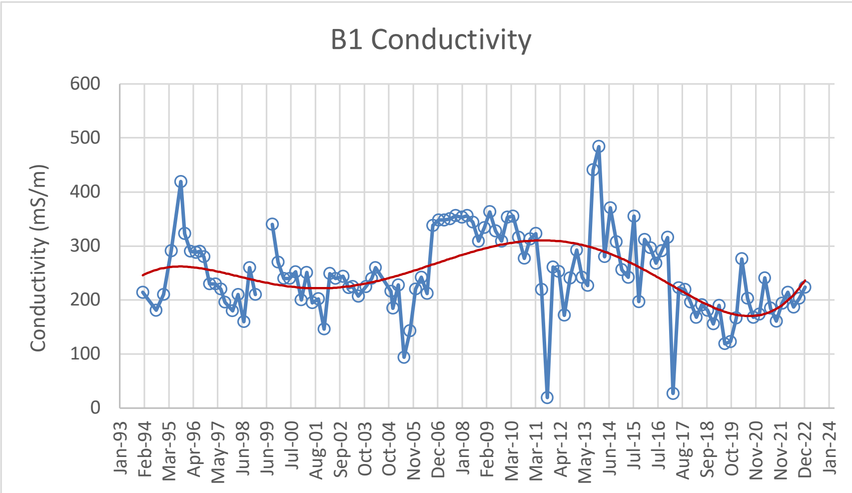
UNDER REVISION

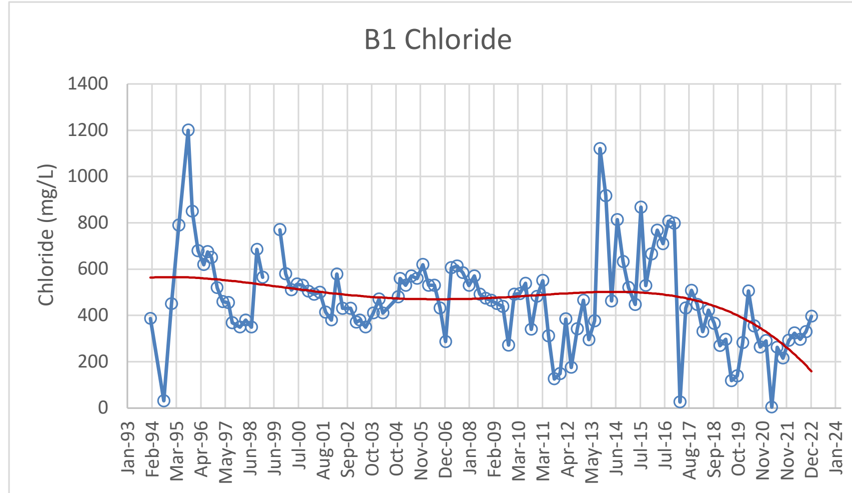
Assessment of Groundwater Pollution Plume Mobility and Remediation Plan

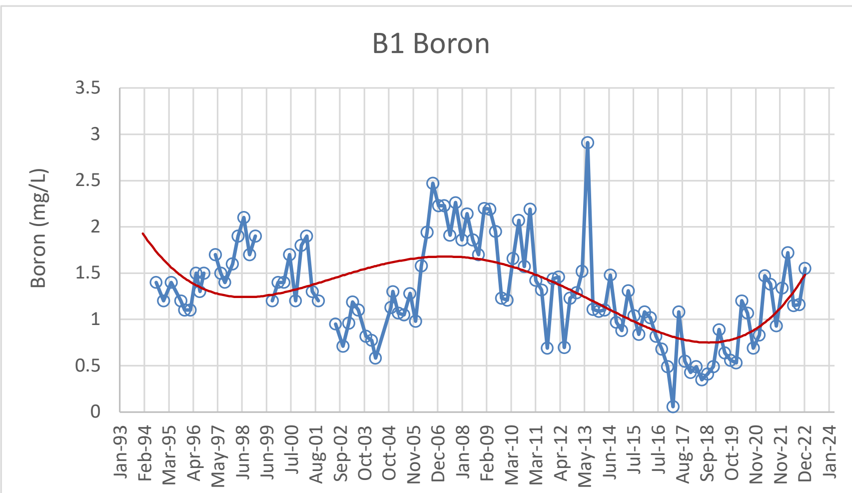
Levin Landfill, Hōkio Beach Road, Levin

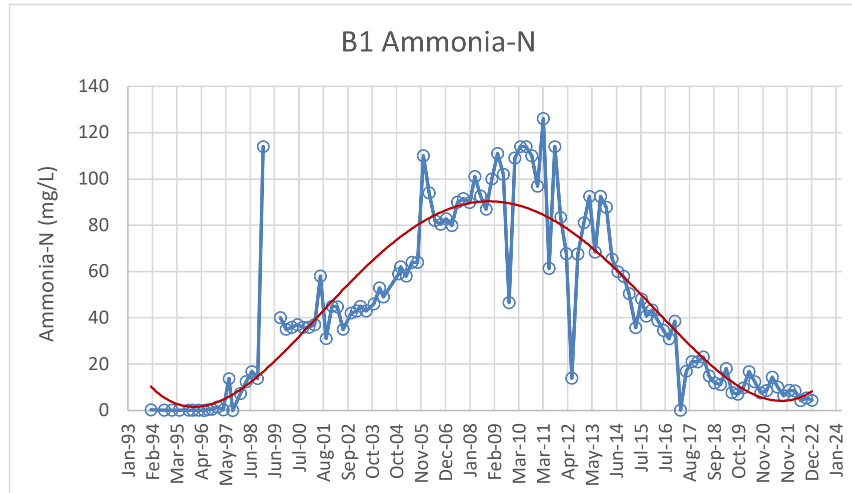
Appendix A

Groundwater Chemistry Plots


B1 Conductivity
Conductivity (mS/m)
600
500
400
300
200
100
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


B1 Chloride
Chloride (mg/L)
1400
1200
1000
800
600
400
200
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


B1 Boron
Boron (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


B1 Ammonia-N
Ammonia-N (mg/L)
140
120
100
80
60
40
20
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

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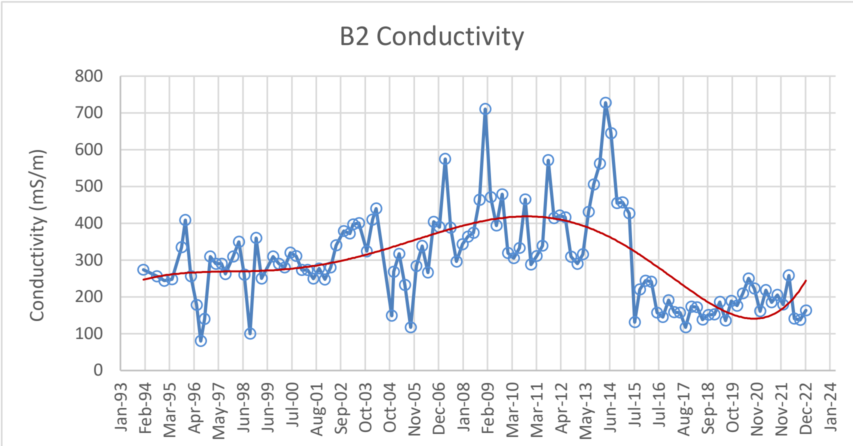
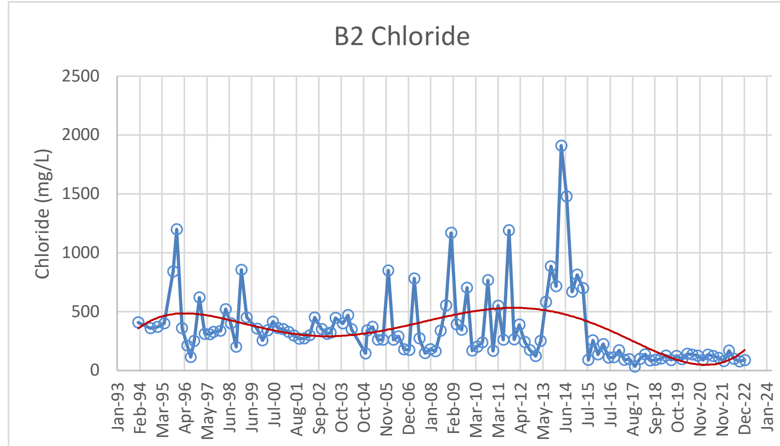
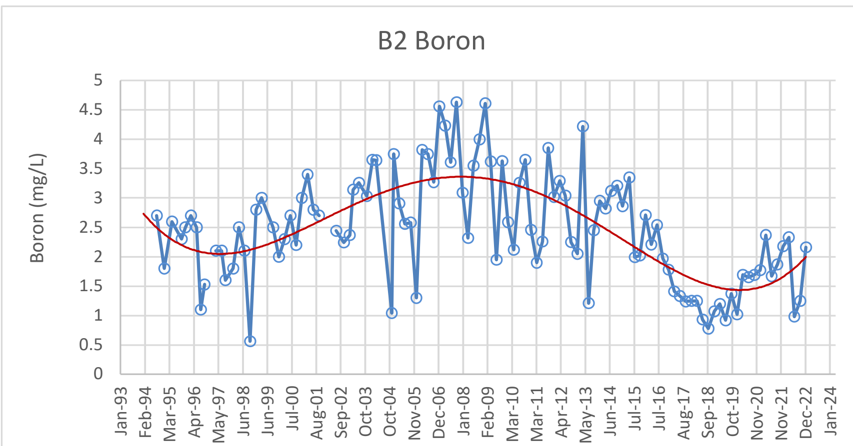
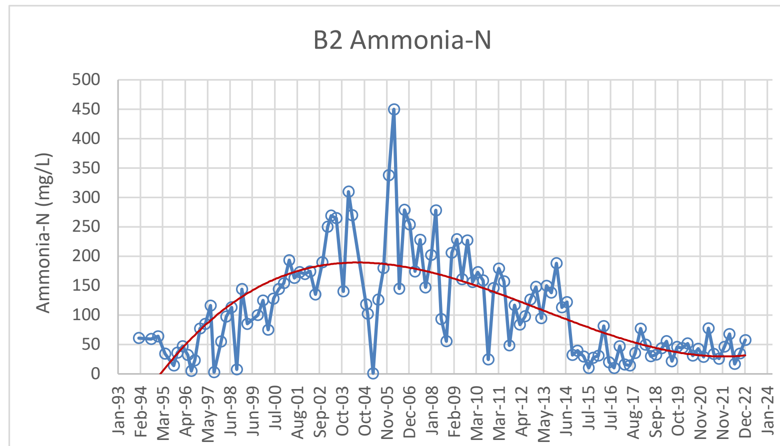

B2 Conductivity
Conductivity (mS/m)
800
700
600
500
400
300
200
100
0
Jan-93 Feb-94 Mar-95 Apr-96 May-97 Jun-98 Jun-99 Jul-00 Aug-01 Sep-02 Oct-03 Oct-04 Nov-05 Dec-06 Jan-08 Feb-09 Mar-10 Mar-11 Apr-12 May-13 Jun-14 Jul-15 Jul-16 Aug-17 Sep-18 Oct-19 Nov-20 Nov-21 Dec-22 Jan-24


B2 Chloride
Chloride (mg/L)
2500
2000
1500
1000
500
0
Jan-93 Feb-94 Mar-95 Apr-96 May-97 Jun-98 Jun-99 Jul-00 Aug-01 Sep-02 Oct-03 Oct-04 Nov-05 Dec-06 Jan-08 Feb-09 Mar-10 Mar-11 Apr-12 May-13 Jun-14 Jul-15 Jul-16 Aug-17 Sep-18 Oct-19 Nov-20 Nov-21 Dec-22 Jan-24


B2 Boron
Boron (mg/L)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-93 Feb-94 Mar-95 Apr-96 May-97 Jun-98 Jun-99 Jul-00 Aug-01 Sep-02 Oct-03 Oct-04 Nov-05 Dec-06 Jan-08 Feb-09 Mar-10 Mar-11 Apr-12 May-13 Jun-14 Jul-15 Jul-16 Aug-17 Sep-18 Oct-19 Nov-20 Nov-21 Dec-22 Jan-24


B2 Ammonia-N
Ammonia-N (mg/L)
500
450
400
350
300
250
200
150
100
50
0
Jan-93 Feb-94 Mar-95 Apr-96 May-97 Jun-98 Jun-99 Jul-00 Aug-01 Sep-02 Oct-03 Oct-04 Nov-05 Dec-06 Jan-08 Feb-09 Mar-10 Mar-11 Apr-12 May-13 Jun-14 Jul-15 Jul-16 Aug-17 Sep-18 Oct-19 Nov-20 Nov-21 Dec-22 Jan-24

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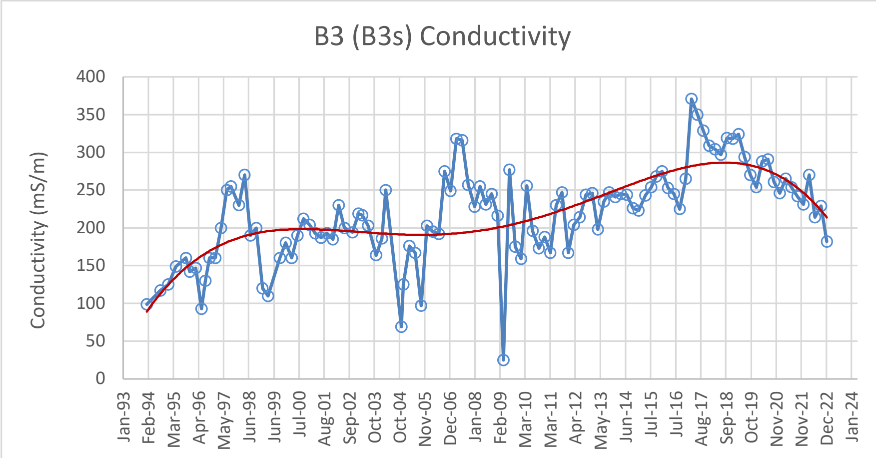
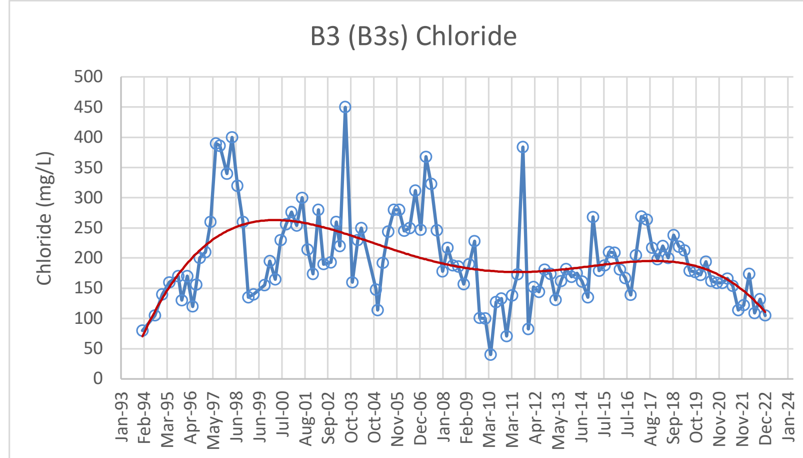
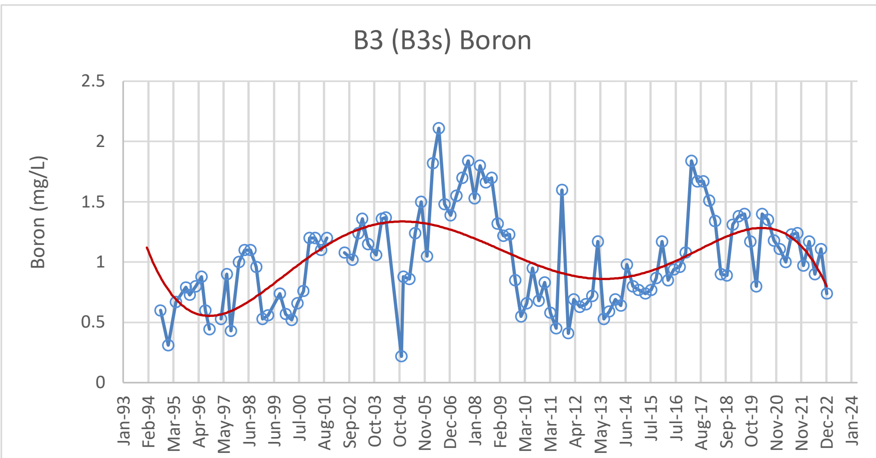
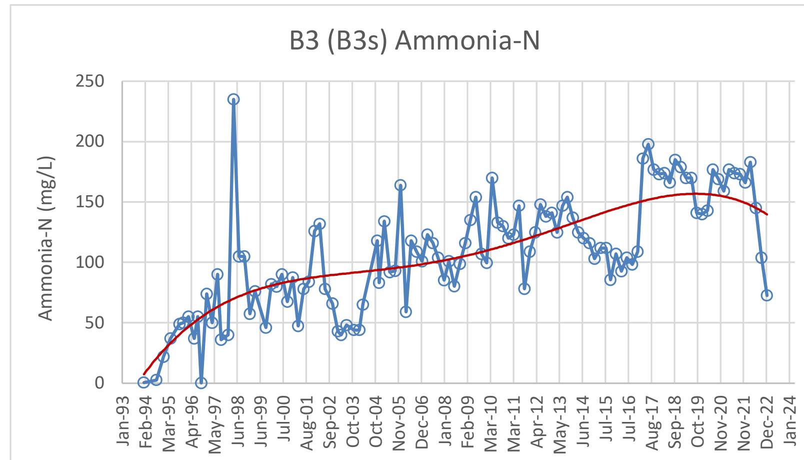
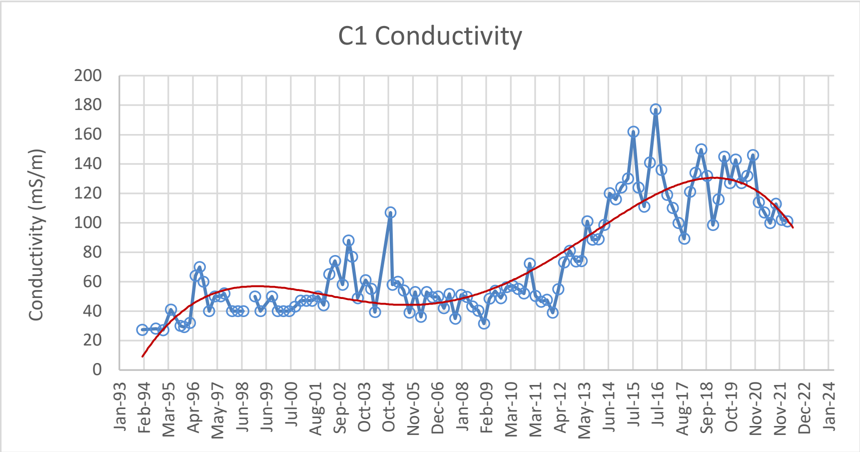

B3 (B3s) Conductivity
Conductivity (mS/m)
0
50
100
150
200
250
300
350
400
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

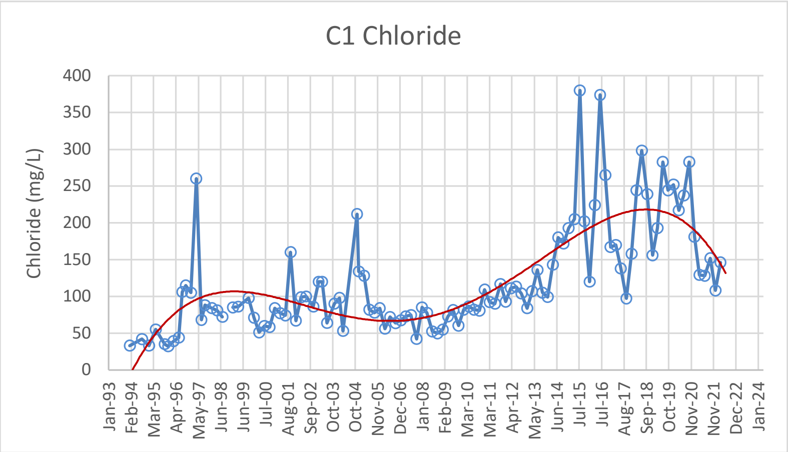

B3 (B3s) Chloride
Chloride (mg/L)
0
50
100
150
200
250
300
350
400
450
500
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

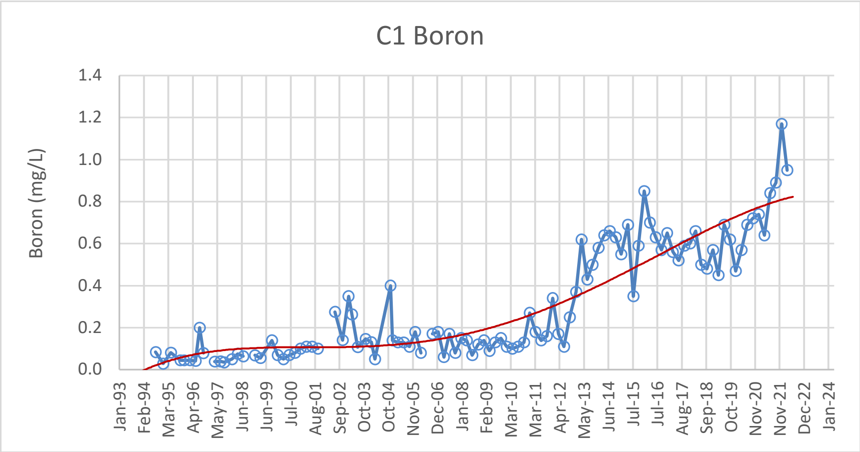

B3 (B3s) Boron
Boron (mg/L)
0
0.5
1
1.5
2
2.5
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

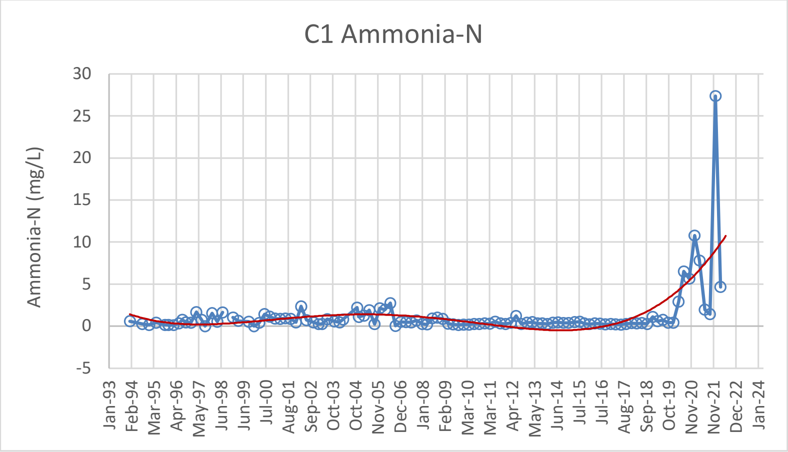

B3 (B3s) Ammonia-N
Ammonia-N (mg/L)
0
50
100
150
200
250
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

EARTHTECH

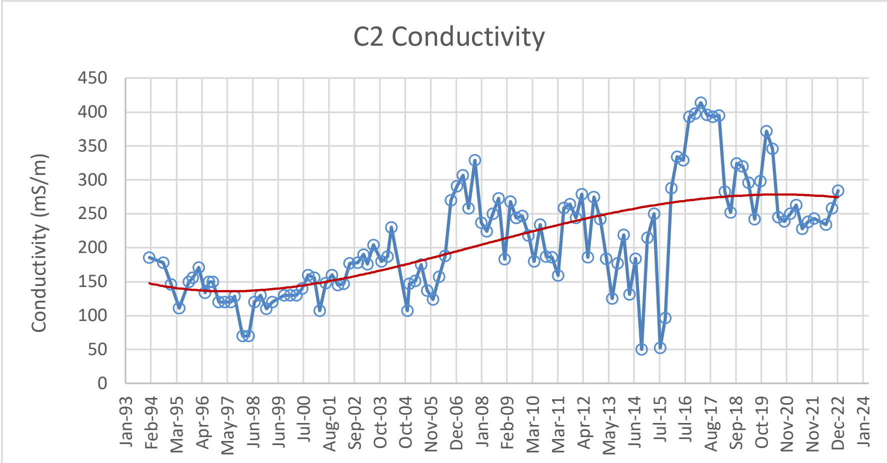

C1 Conductivity
Conductivity (mS/m)

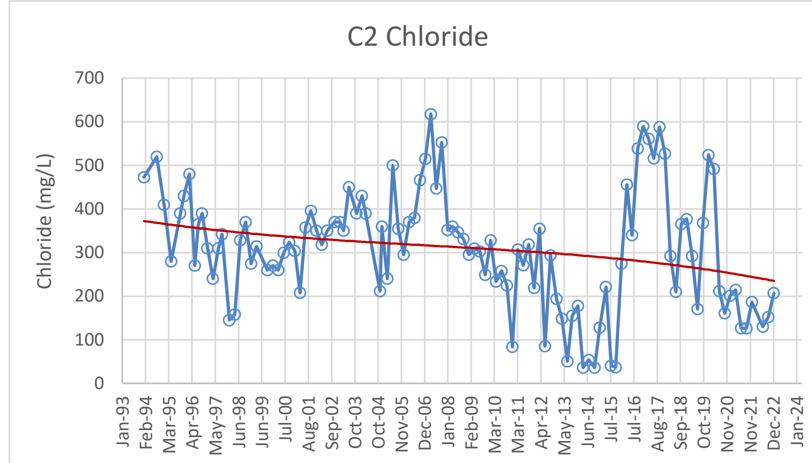

C1 Chloride
Chloride (mg/L)


C1 Boron
Boron (mg/L)


C1 Ammonia-N
Ammonia-N (mg/L)

EARTHTECH


C2 Conductivity
Conductivity (mS/m)
0
50
100
150
200
250
300
350
400
450
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


C2 Chloride
Chloride (mg/L)
0
100
200
300
400
500
600
700
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
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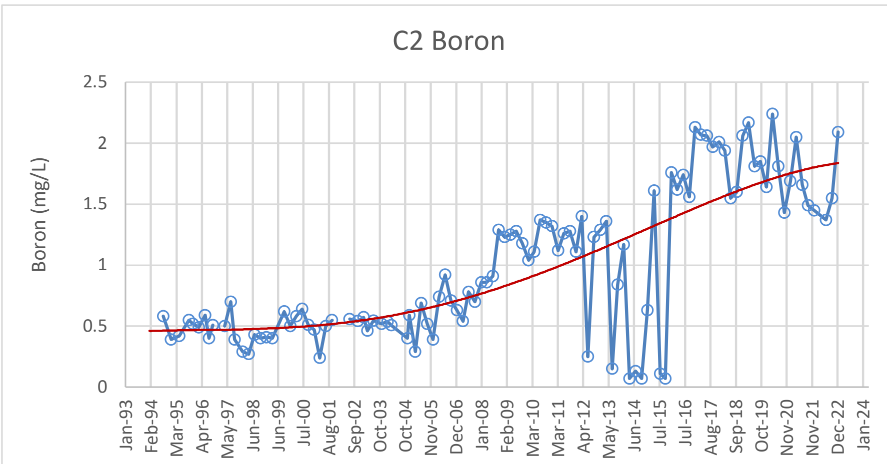
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


C2 Boron
Boron (mg/L)
0
0.5
1
1.5
2
2.5
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
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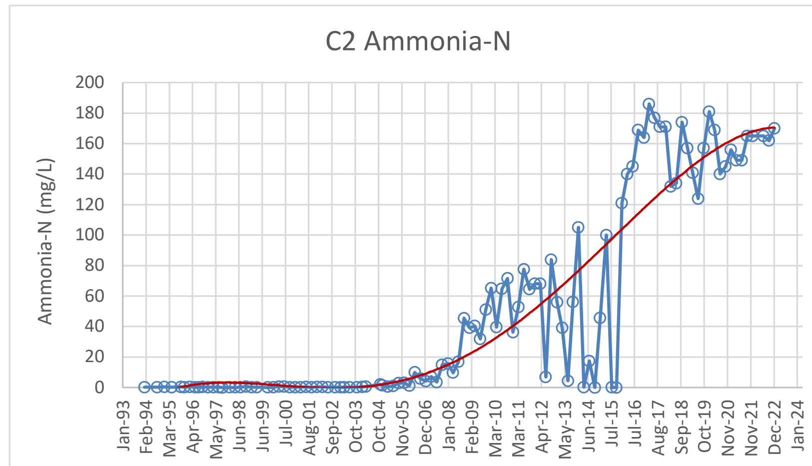
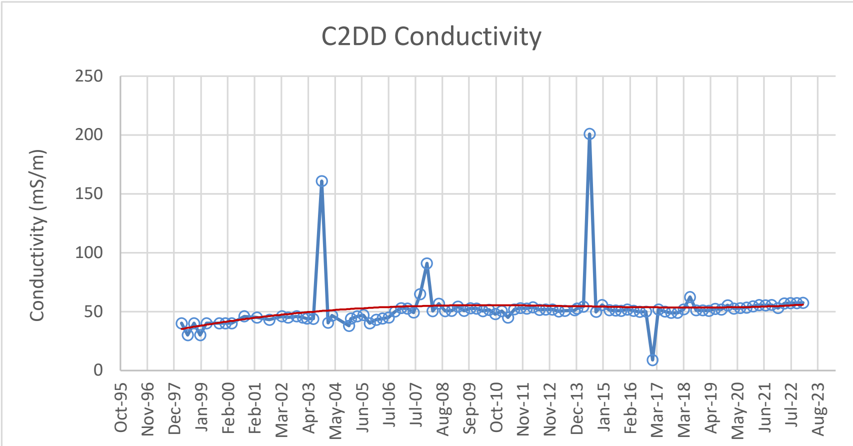
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


C2 Ammonia-N
Ammonia-N (mg/L)
0
20
40
60
80
100
120
140
160
180
200
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

EARTHTECH


C2DD Conductivity
Conductivity (mS/m)
250
200
150
100
50
0
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Feb-01
Mar-02
Apr-03
May-04
Jun-05
Jul-06
Jul-07
Aug-08
Sep-09
Oct-10
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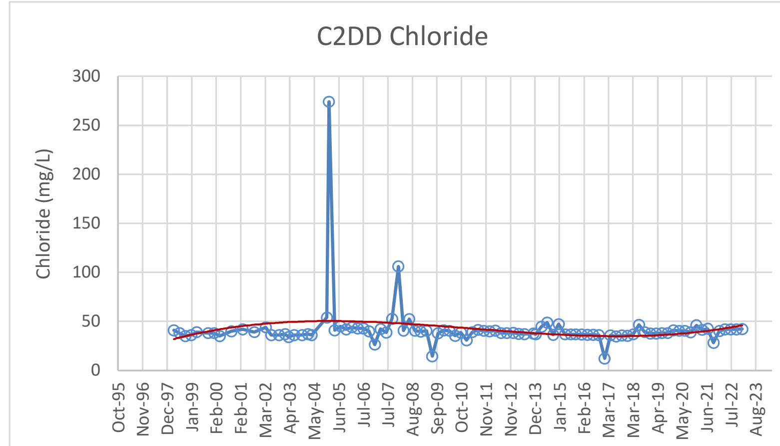
Jun-21
Jul-22
Aug-23


C2DD Chloride
Chloride (mg/L)
300
250
200
150
100
50
0
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Feb-01
Mar-02
Apr-03
May-04
Jun-05
Jul-06
Jul-07
Aug-08
Sep-09
Oct-10
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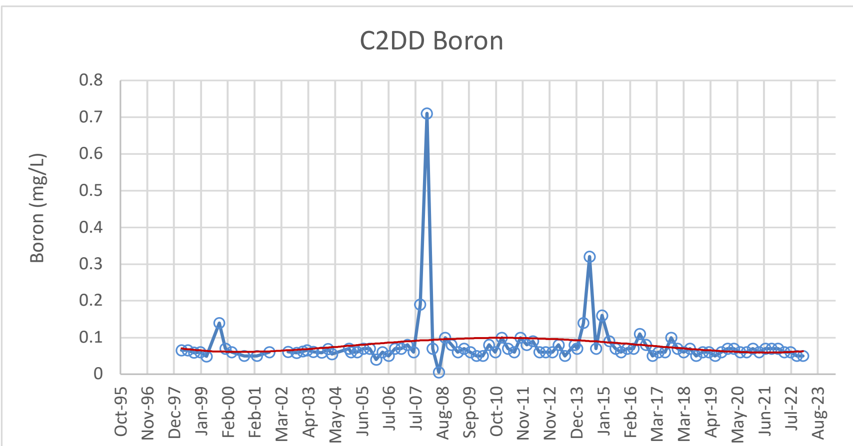
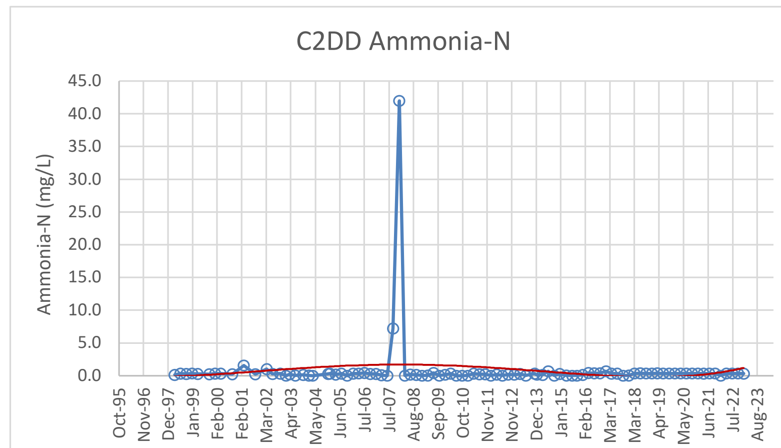
Jun-21
Jul-22
Aug-23


C2DD Boron
Boron (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Feb-01
Mar-02
Apr-03
May-04
Jun-05
Jul-06
Jul-07
Aug-08
Sep-09
Oct-10
Nov-11
Nov-12
Dec-13
Jan-15
Feb-16
Mar-17
Mar-18
Apr-19
May-20
Jun-21
Jul-22
Aug-23


C2DD Ammonia-N
Ammonia-N (mg/L)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Feb-01
Mar-02
Apr-03
May-04
Jun-05
Jul-06
Jul-07
Aug-08
Sep-09
Oct-10
Nov-11
Nov-12
Dec-13
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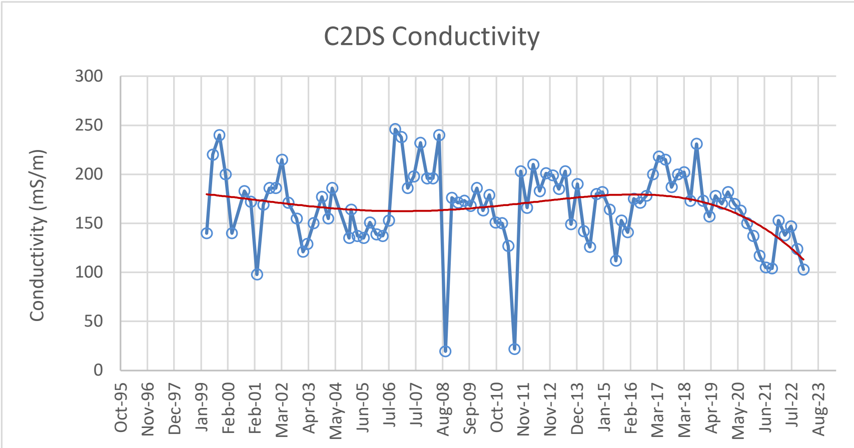
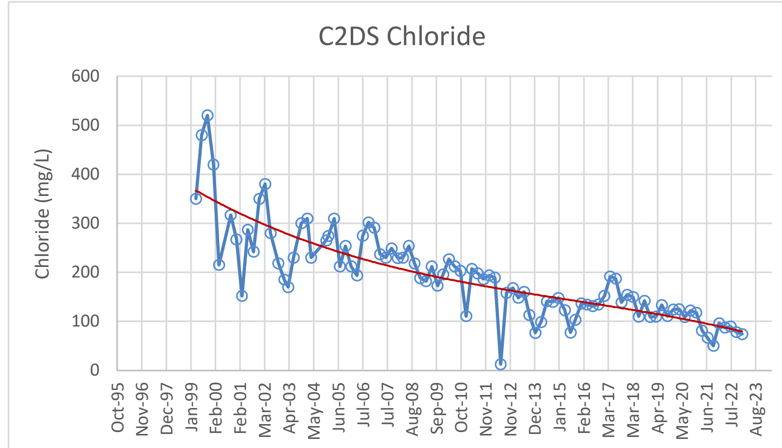
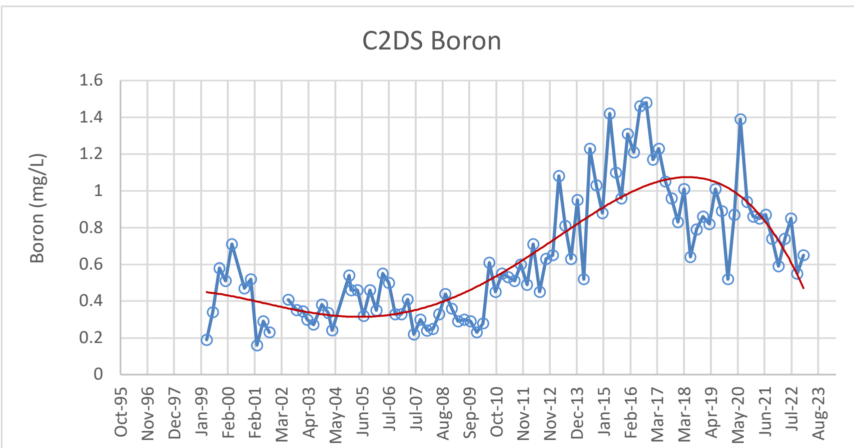
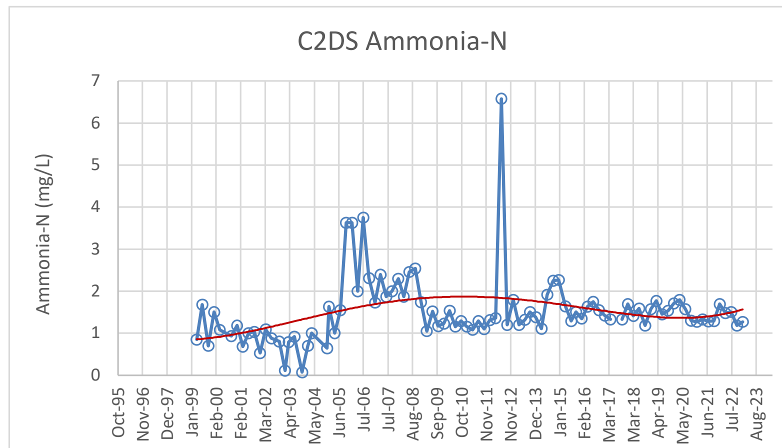
Feb-16
Mar-17
Mar-18
Apr-19
May-20
Jun-21
Jul-22
Aug-23

EARTHTECH

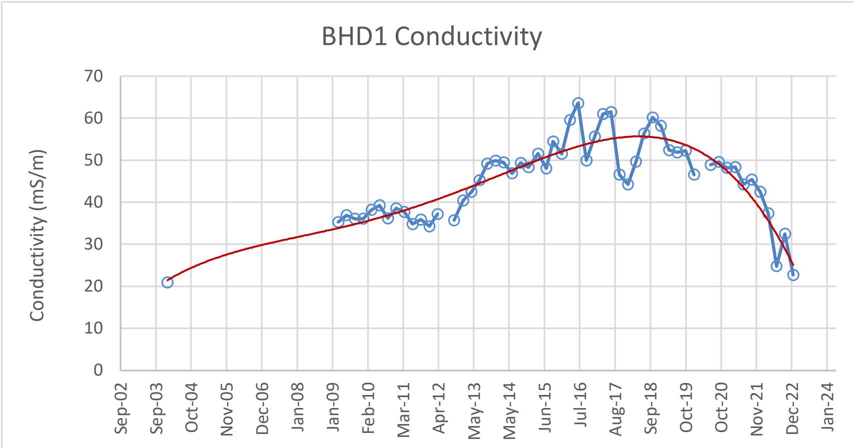

C2DS Conductivity
Conductivity (mS/m)
0
50
100
150
200
250
300
Oct-95 Nov-96 Dec-97 Jan-99 Feb-00 Feb-01 Mar-02 Apr-03 May-04 Jun-05 Jul-06 Jul-07 Aug-08 Sep-09 Oct-10 Nov-11 Nov-12 Dec-13 Jan-15 Feb-16 Mar-17 Mar-18 Apr-19 May-20 Jun-21 Jul-22 Aug-23

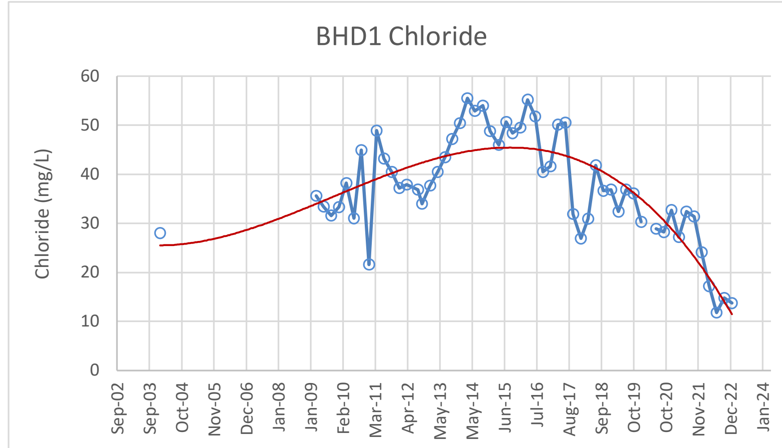

C2DS Chloride
Chloride (mg/L)
0
100
200
300
400
500
600
Oct-95 Nov-96 Dec-97 Jan-99 Feb-00 Feb-01 Mar-02 Apr-03 May-04 Jun-05 Jul-06 Jul-07 Aug-08 Sep-09 Oct-10 Nov-11 Nov-12 Dec-13 Jan-15 Feb-16 Mar-17 Mar-18 Apr-19 May-20 Jun-21 Jul-22 Aug-23

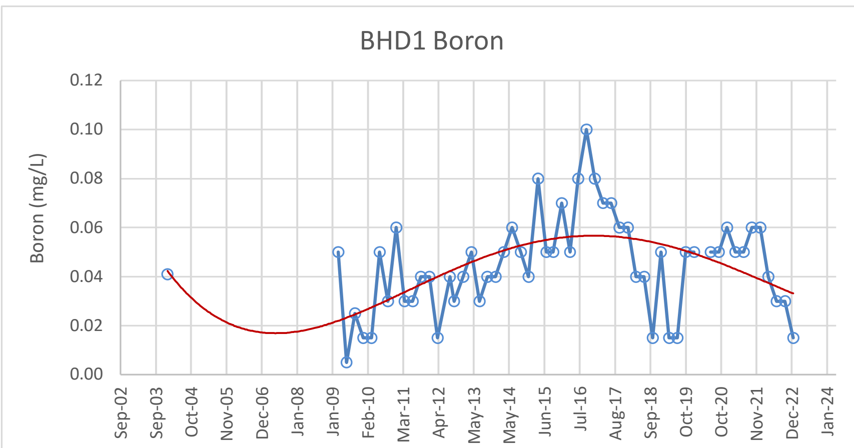

C2DS Boron
Boron (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Oct-95 Nov-96 Dec-97 Jan-99 Feb-00 Feb-01 Mar-02 Apr-03 May-04 Jun-05 Jul-06 Jul-07 Aug-08 Sep-09 Oct-10 Nov-11 Nov-12 Dec-13 Jan-15 Feb-16 Mar-17 Mar-18 Apr-19 May-20 Jun-21 Jul-22 Aug-23

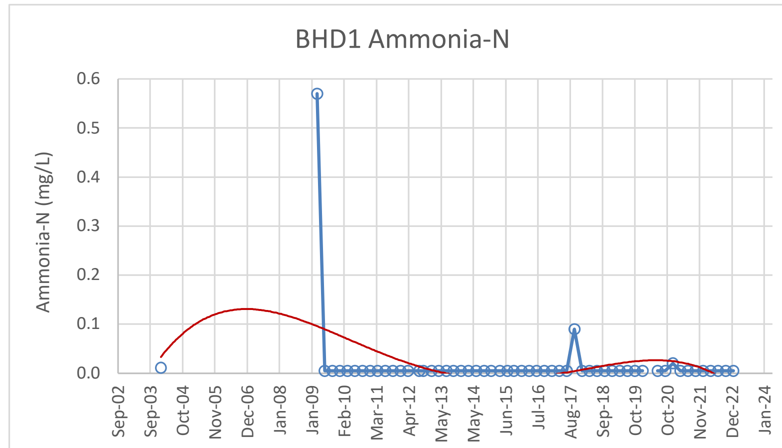

C2DS Ammonia-N
Ammonia-N (mg/L)
0
1
2
3
4
5
6
7
Oct-95 Nov-96 Dec-97 Jan-99 Feb-00 Feb-01 Mar-02 Apr-03 May-04 Jun-05 Jul-06 Jul-07 Aug-08 Sep-09 Oct-10 Nov-11 Nov-12 Dec-13 Jan-15 Feb-16 Mar-17 Mar-18 Apr-19 May-20 Jun-21 Jul-22 Aug-23

EARTHTECH

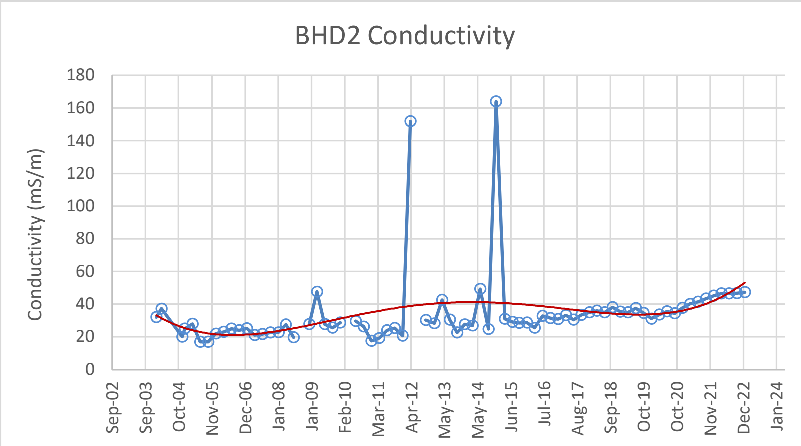

BHD1 Conductivity
Conductivity (mS/m)
0
10
20
30
40
50
60
70
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

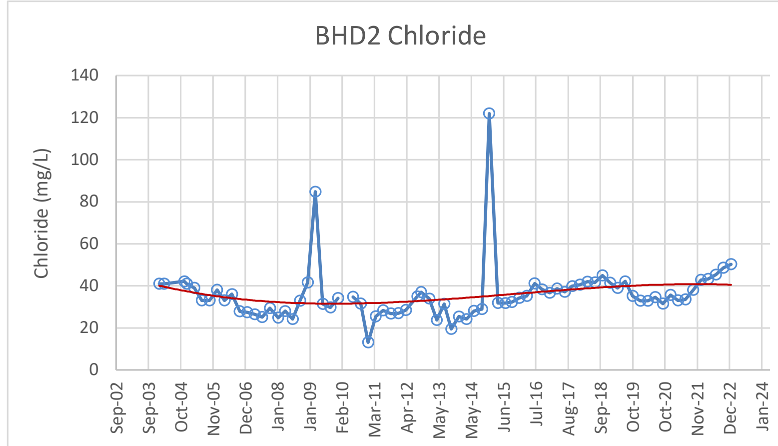

BHD1 Chloride
Chloride (mg/L)
0
10
20
30
40
50
60
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

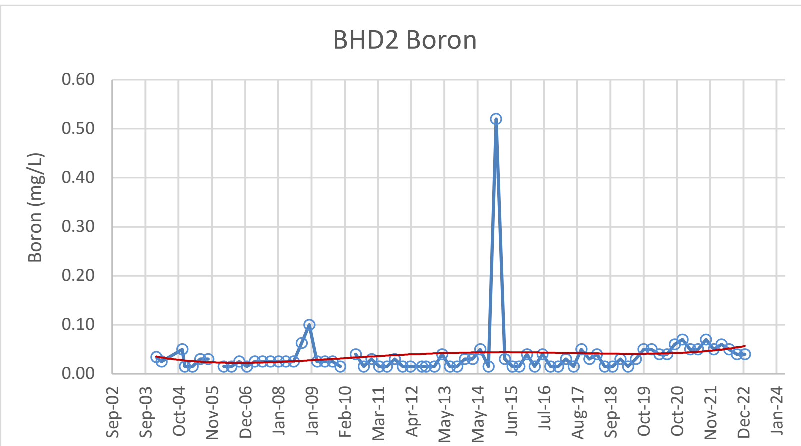

BHD1 Boron
Boron (mg/L)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

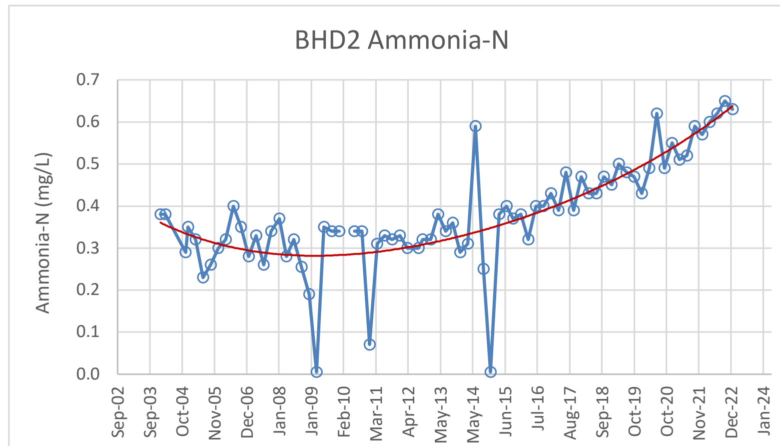

BHD1 Ammonia-N
Ammonia-N (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

EARTHTECH


BHD2 Conductivity
Conductivity (mS/m)
0
20
40
60
80
100
120
140
160
180
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


BHD2 Chloride
Chloride (mg/L)
0
20
40
60
80
100
120
140
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


BHD2 Boron
Boron (mg/L)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


BHD2 Ammonia-N
Ammonia-N (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

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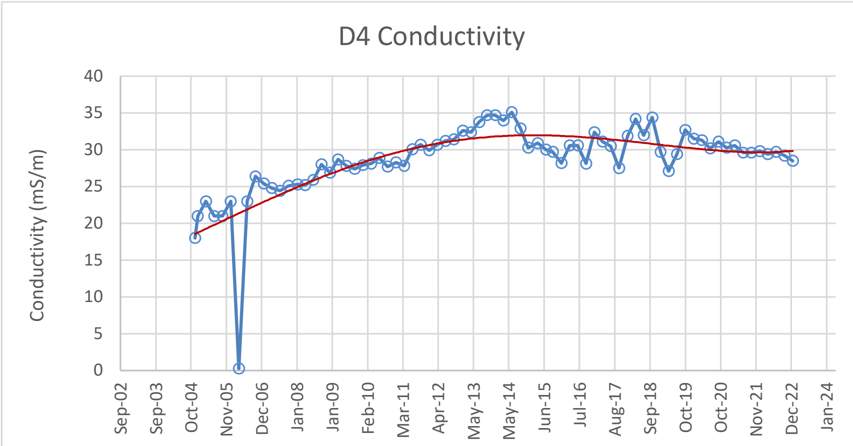
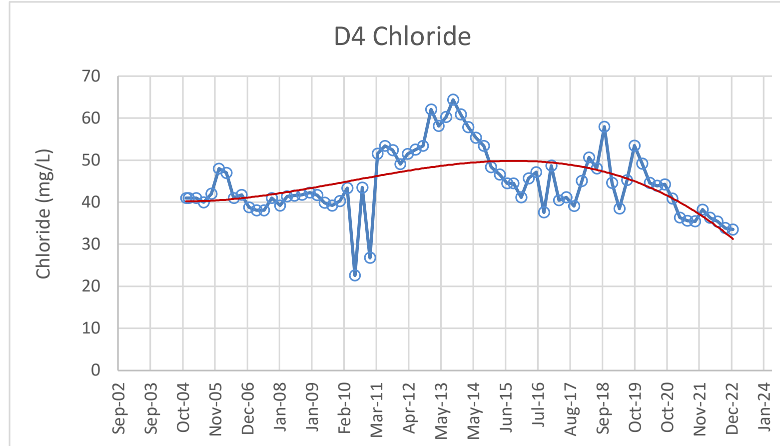
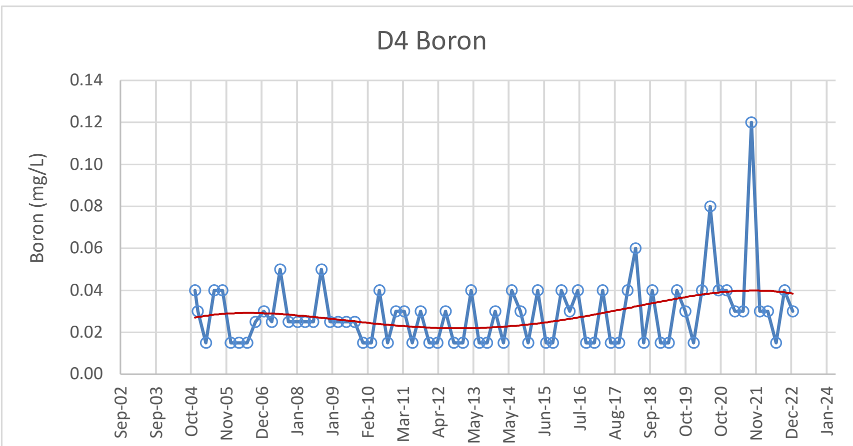
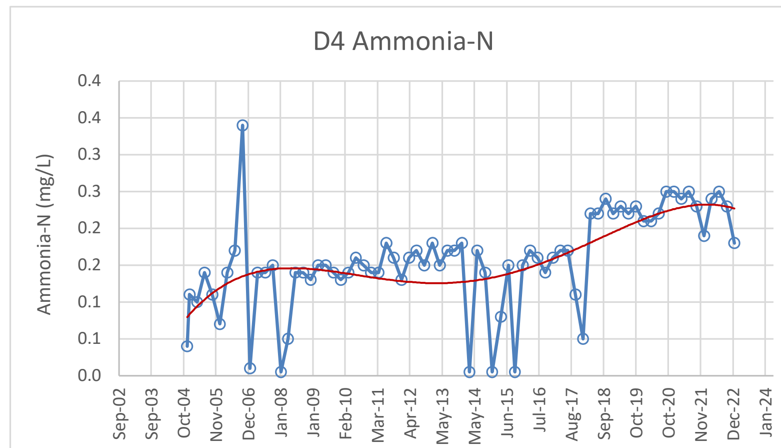

D4 Conductivity
Conductivity (mS/m)
40
35
30
25
20
15
10
5
0
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


D4 Chloride
Chloride (mg/L)
70
60
50
40
30
20
10
0
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


D4 Boron
Boron (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24


D4 Ammonia-N
Ammonia-N (mg/L)
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
Sep-02
Sep-03
Oct-04
Nov-05
Dec-06
Jan-08
Jan-09
Feb-10
Mar-11
Apr-12
May-13
May-14
Jun-15
Jul-16
Aug-17
Sep-18
Oct-19
Oct-20
Nov-21
Dec-22
Jan-24

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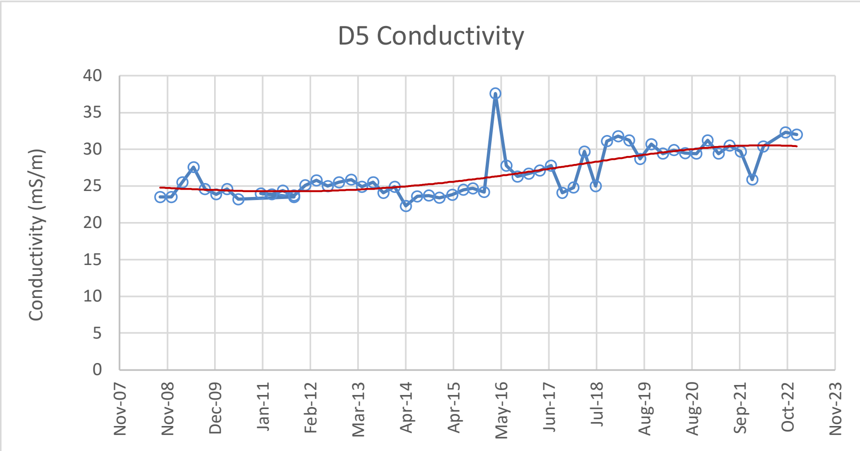
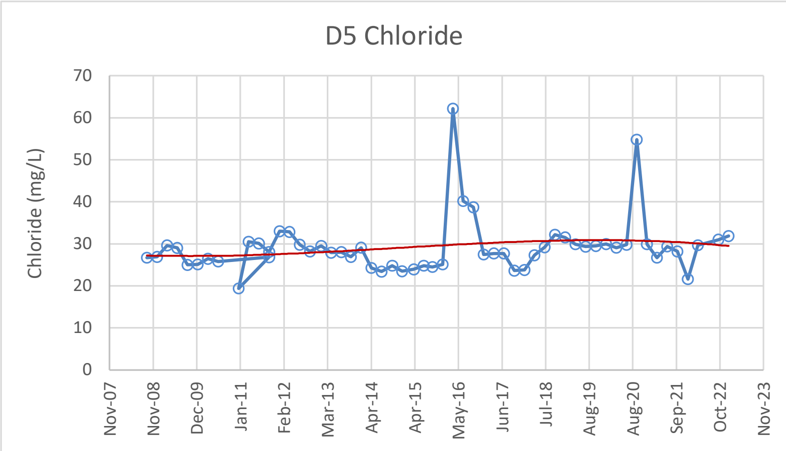
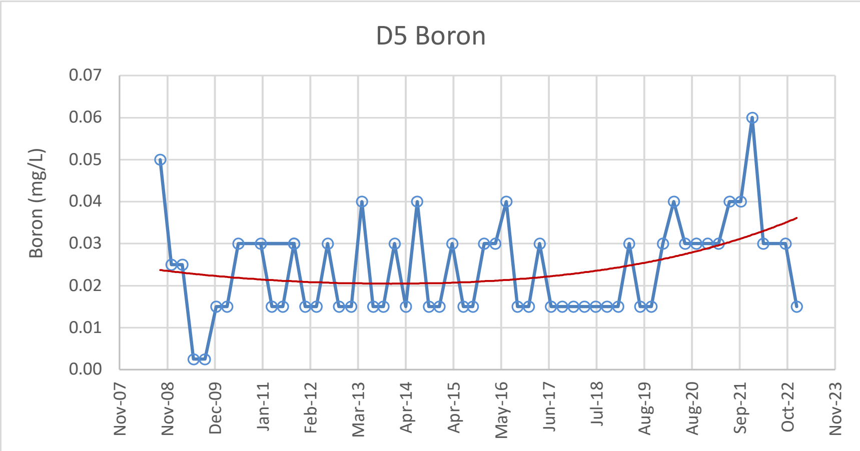
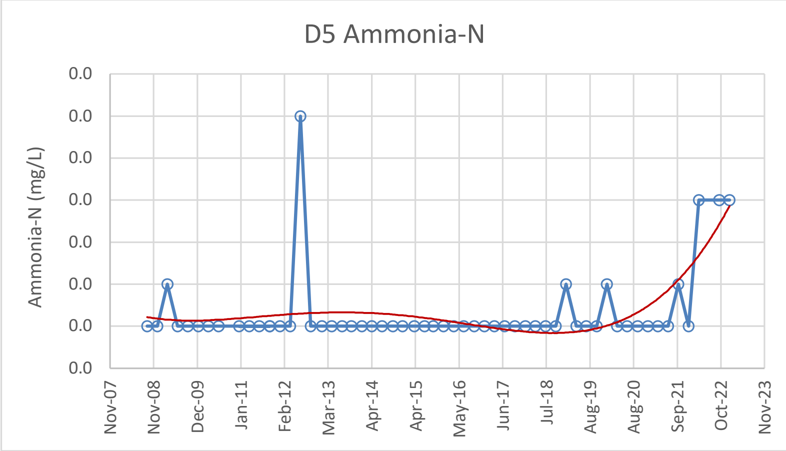

D5 Conductivity
Conductivity (mS/m)
40
35
30
25
20
15
10
5
0
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


D5 Chloride
Chloride (mg/L)
70
60
50
40
30
20
10
0
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


D5 Boron
Boron (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


D5 Ammonia-N
Ammonia-N (mg/L)
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23

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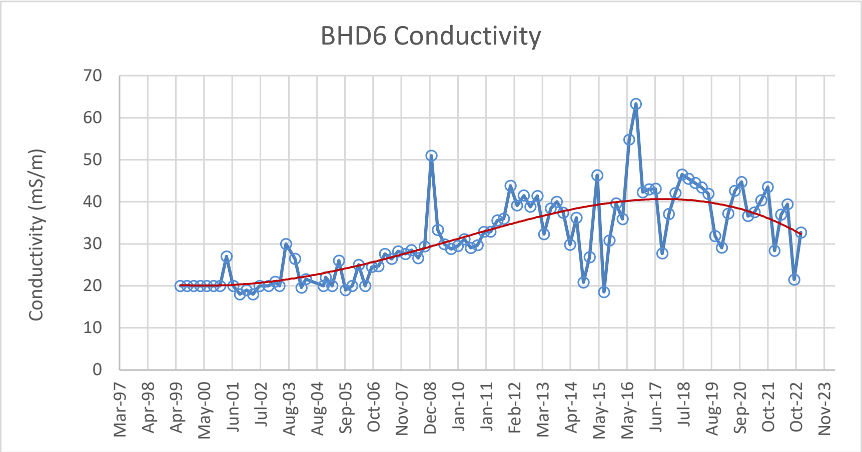
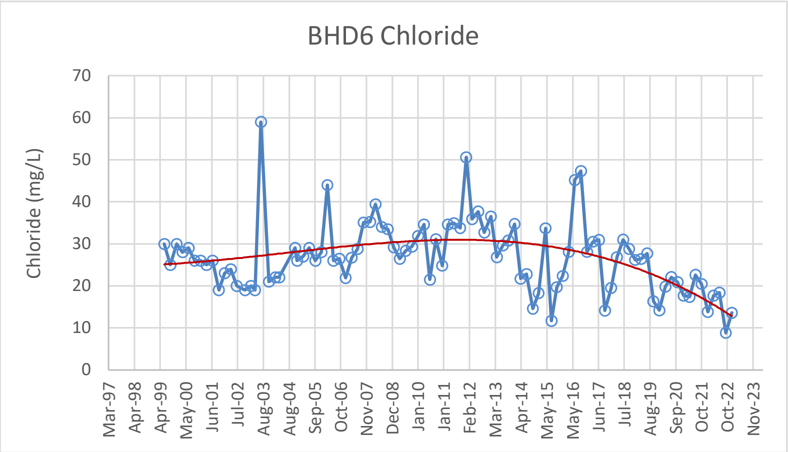
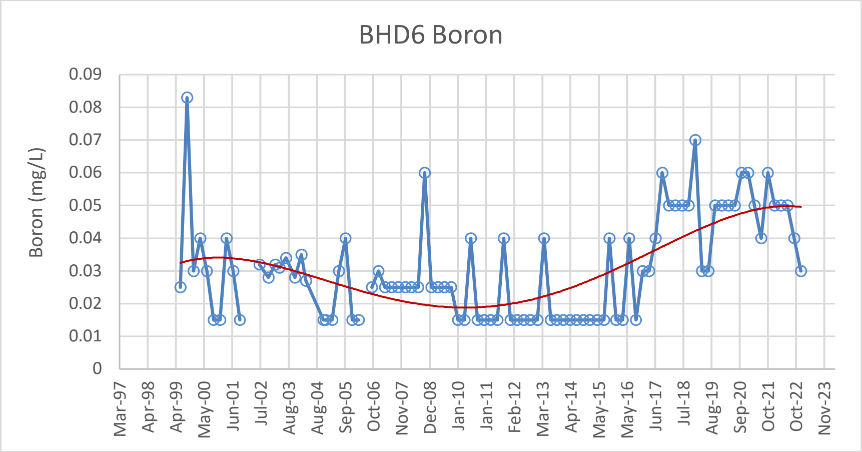
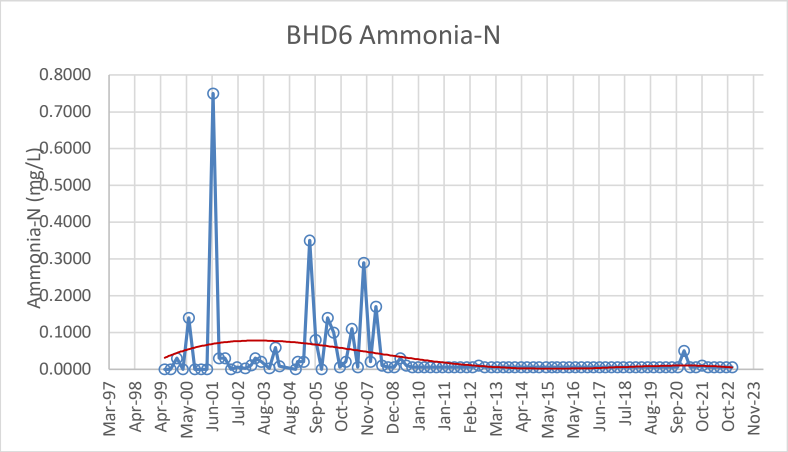

BHD6 Conductivity
Conductivity (mS/m)


BHD6 Chloride
Chloride (mg/L)


BHD6 Boron
Boron (mg/L)


BHD6 Ammonia-N
Ammonia-N (mg/L)

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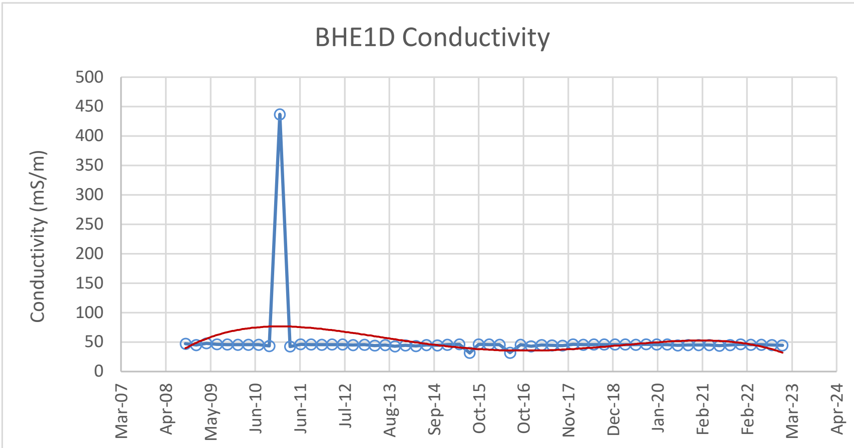
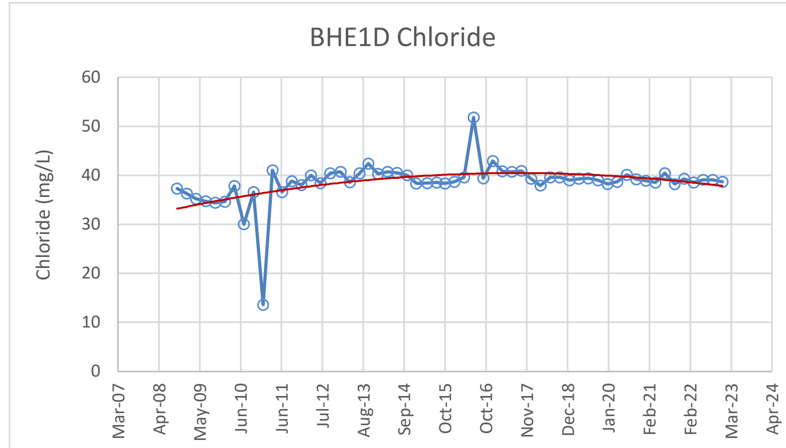
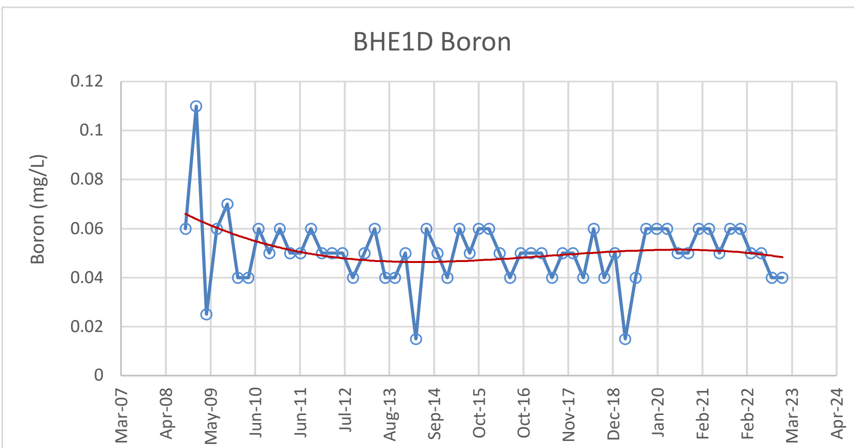
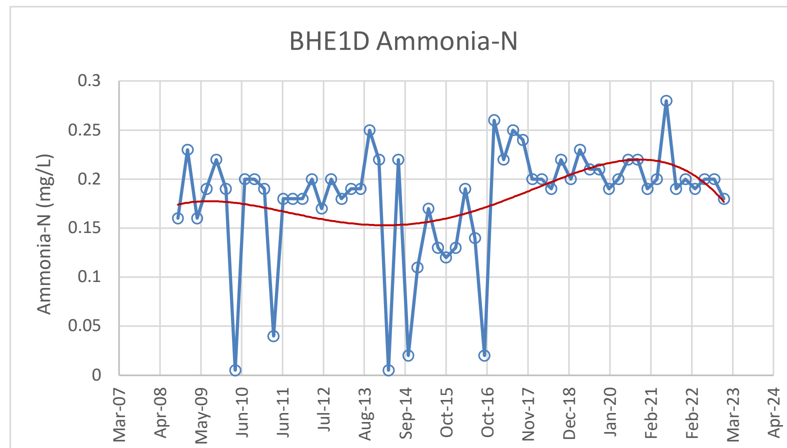
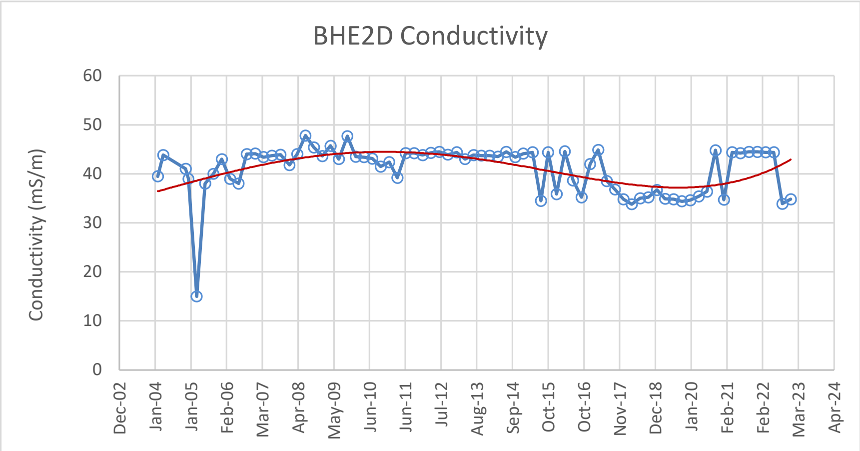

BHE1D Conductivity
Conductivity (mS/m)
500
450
400
350
300
250
200
150
100
50
0
Mar-07
Apr-08
May-09
Jun-10
Jun-11
Jul-12
Aug-13
Sep-14
Oct-15
Oct-16
Nov-17
Dec-18
Jan-20
Feb-21
Feb-22
Mar-23
Apr-24

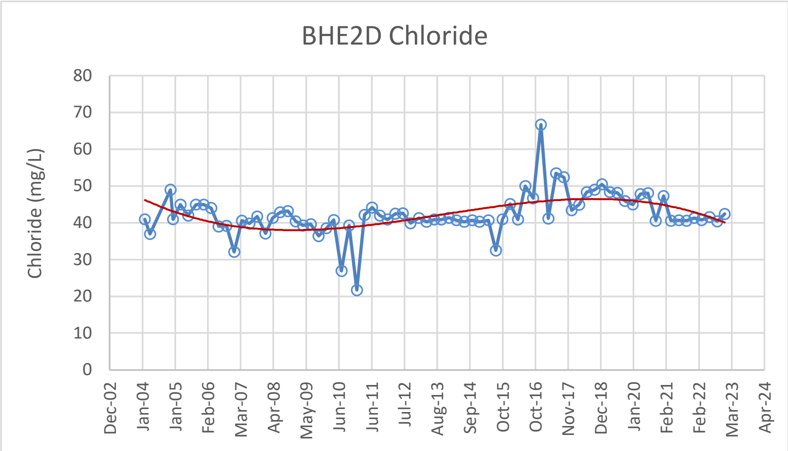

BHE1D Chloride
Chloride (mg/L)
60
50
40
30
20
10
0
Mar-07
Apr-08
May-09
Jun-10
Jun-11
Jul-12
Aug-13
Sep-14
Oct-15
Oct-16
Nov-17
Dec-18
Jan-20
Feb-21
Feb-22
Mar-23
Apr-24

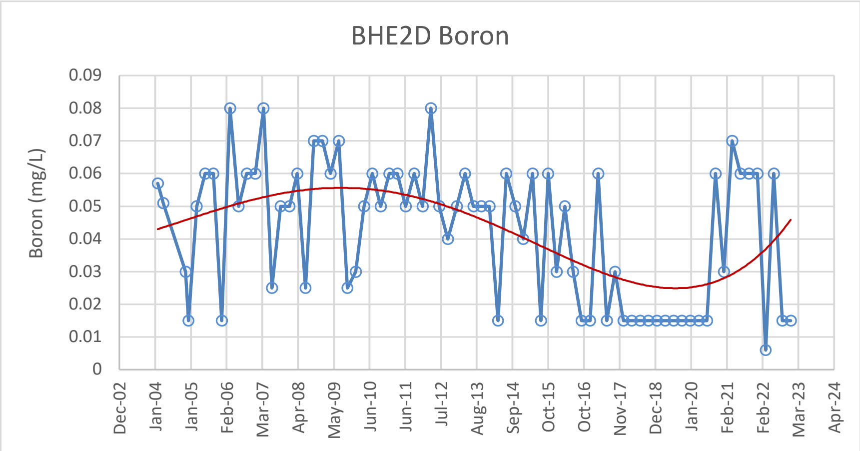

BHE1D Boron
Boron (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Mar-07
Apr-08
May-09
Jun-10
Jun-11
Jul-12
Aug-13
Sep-14
Oct-15
Oct-16
Nov-17
Dec-18
Jan-20
Feb-21
Feb-22
Mar-23
Apr-24

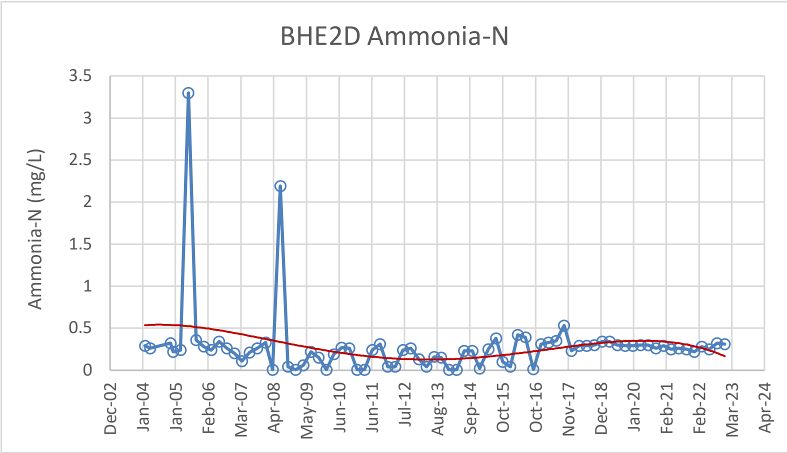

BHE1D Ammonia-N
Ammonia-N (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Mar-07
Apr-08
May-09
Jun-10
Jun-11
Jul-12
Aug-13
Sep-14
Oct-15
Oct-16
Nov-17
Dec-18
Jan-20
Feb-21
Feb-22
Mar-23
Apr-24

EARTHTECH

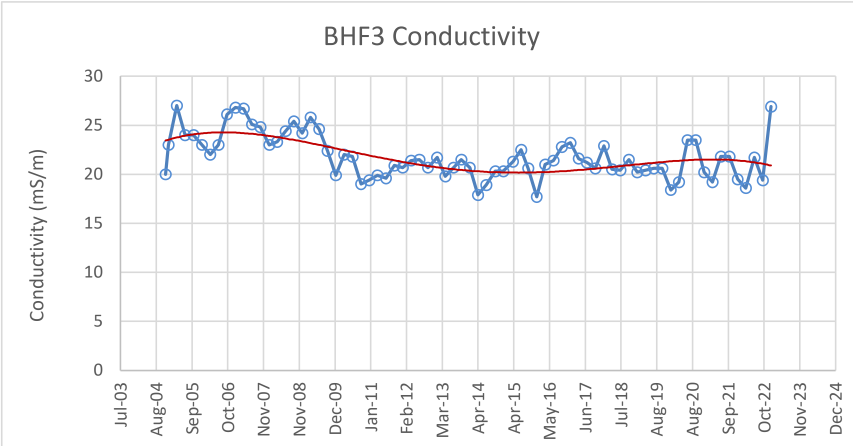

BHE2D Conductivity
Conductivity (mS/m)


BHE2D Chloride
Chloride (mg/L)


BHE2D Boron
Boron (mg/L)


BHE2D Ammonia-N
Ammonia-N (mg/L)

EARTHTECH


BHF3 Conductivity
Conductivity (mS/m)
30
25
20
15
10
5
0
Jul-03
Aug-04
Sep-05
Oct-06
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
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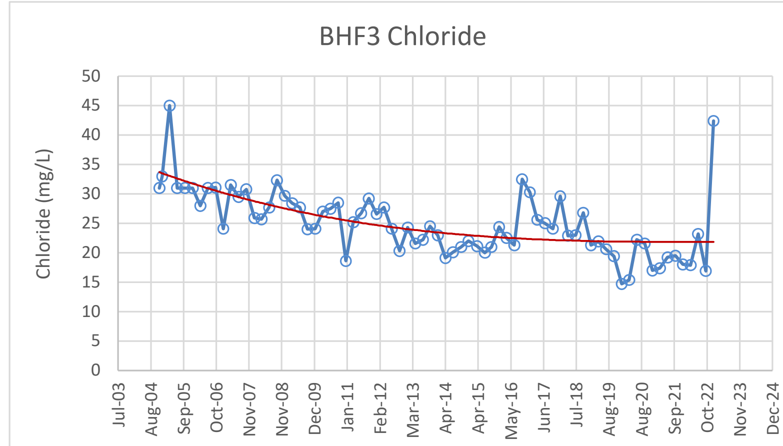
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23
Dec-24


BHF3 Chloride
Chloride (mg/L)
50
45
40
35
30
25
20
15
10
5
0
Jul-03
Aug-04
Sep-05
Oct-06
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
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Jul-18
Aug-19
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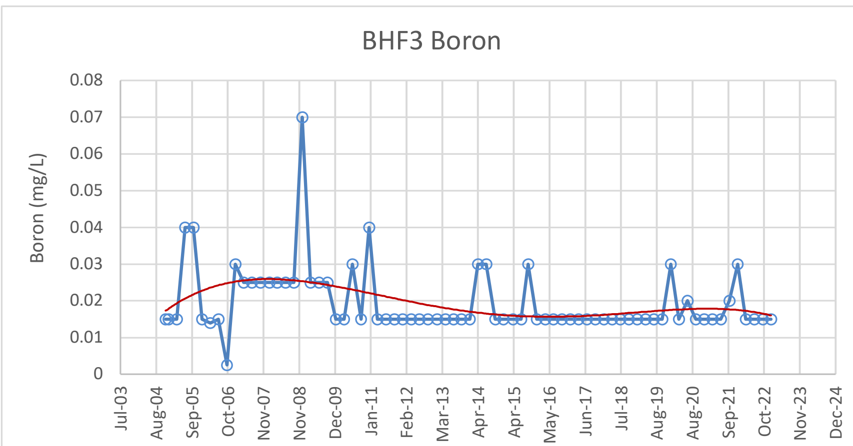
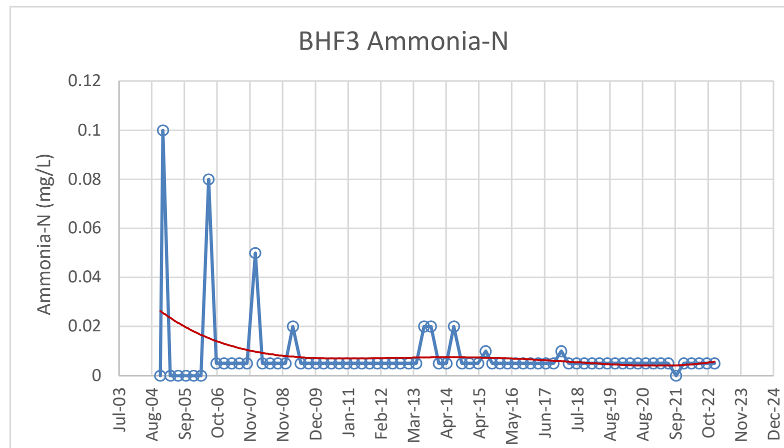
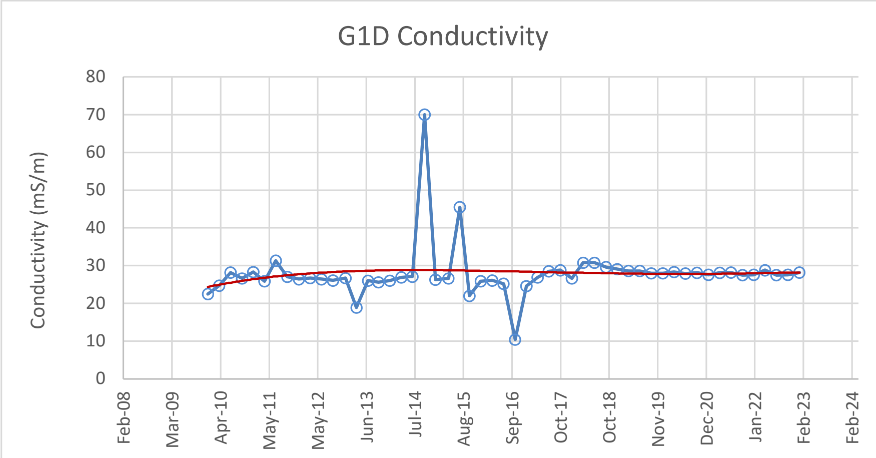
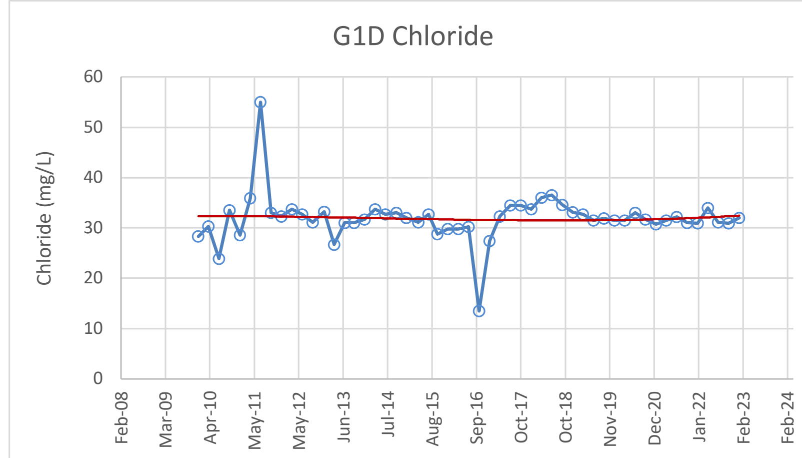
Sep-21
Oct-22
Nov-23
Dec-24

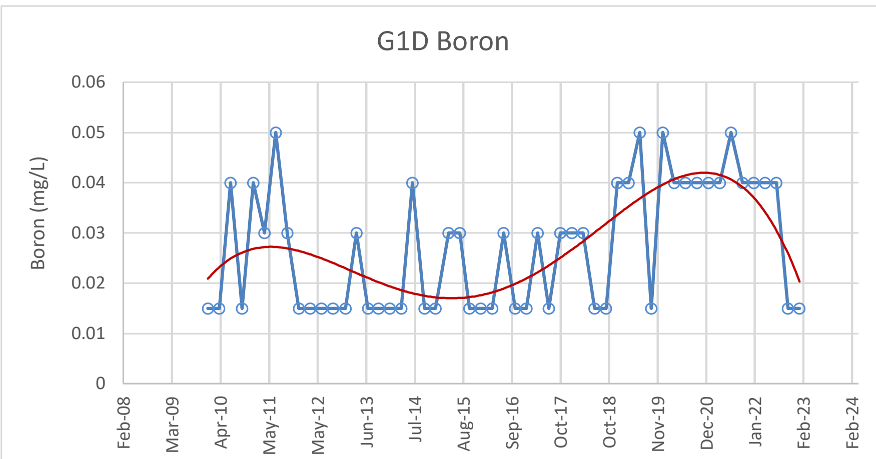

BHF3 Boron
Boron (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Jul-03
Aug-04
Sep-05
Oct-06
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23
Dec-24

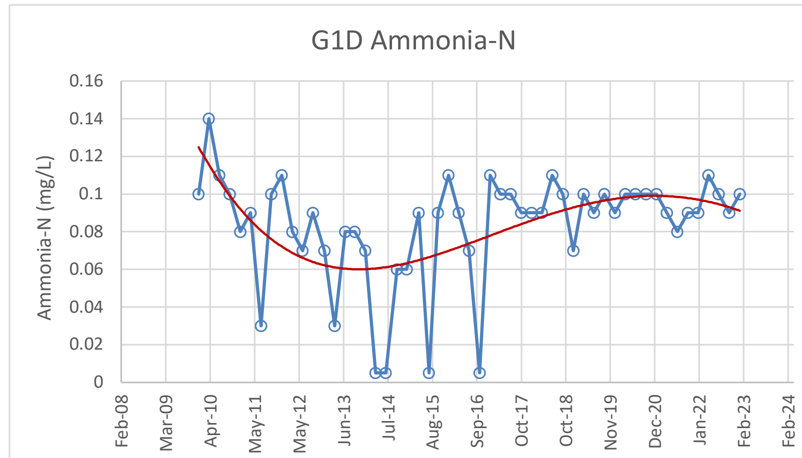

BHF3 Ammonia-N
Ammonia-N (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul-03
Aug-04
Sep-05
Oct-06
Nov-07
Nov-08
Dec-09
Jan-11
Feb-12
Mar-13
Apr-14
Apr-15
May-16
Jun-17
Jul-18
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23
Dec-24

EARTHTECH

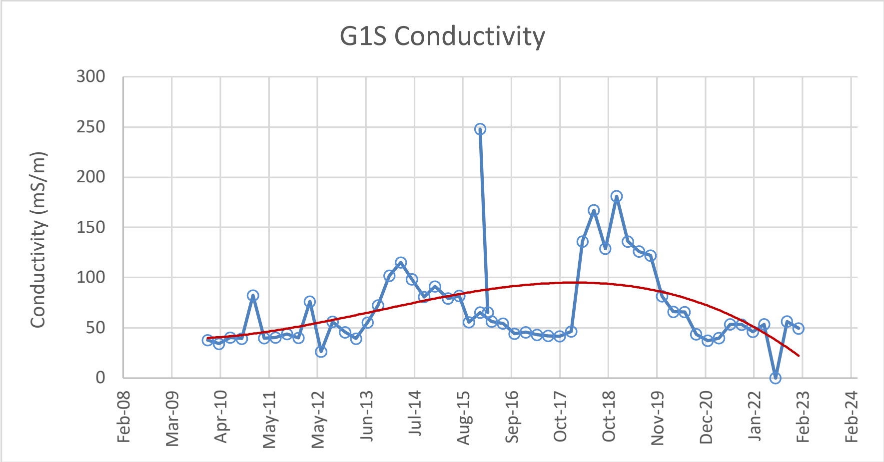

G1D Conductivity
Conductivity (mS/m)
80
70
60
50
40
30
20
10
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

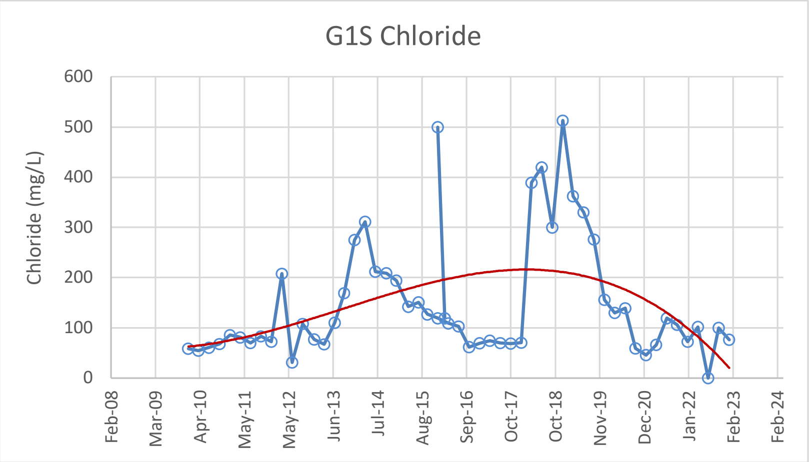

G1D Chloride
Chloride (mg/L)
60
50
40
30
20
10
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G1D Boron
Boron (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G1D Ammonia-N
Ammonia-N (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

EARTHTECH


G1S Conductivity
Conductivity (mS/m)
300
250
200
150
100
50
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G1S Chloride
Chloride (mg/L)
600
500
400
300
200
100
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
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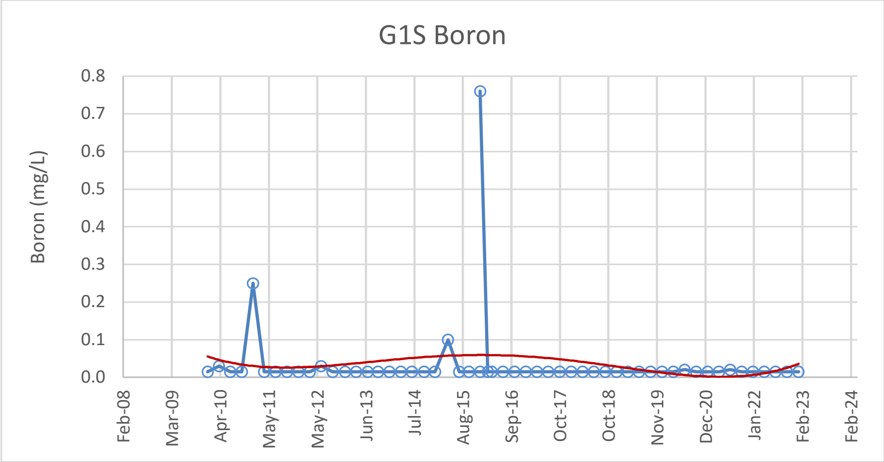
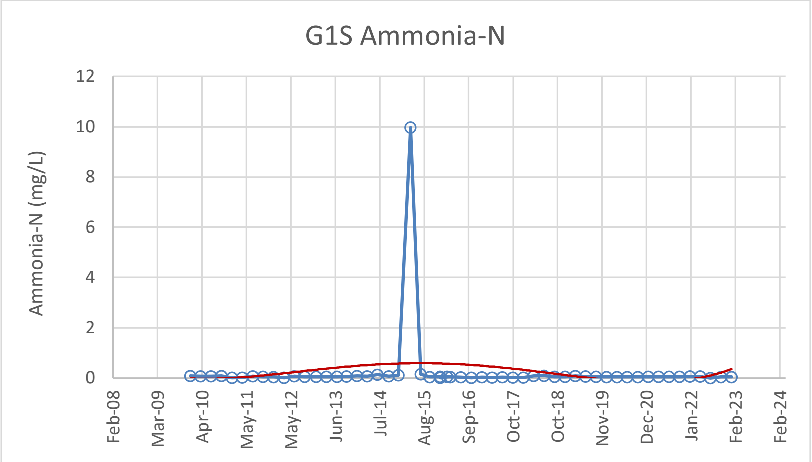
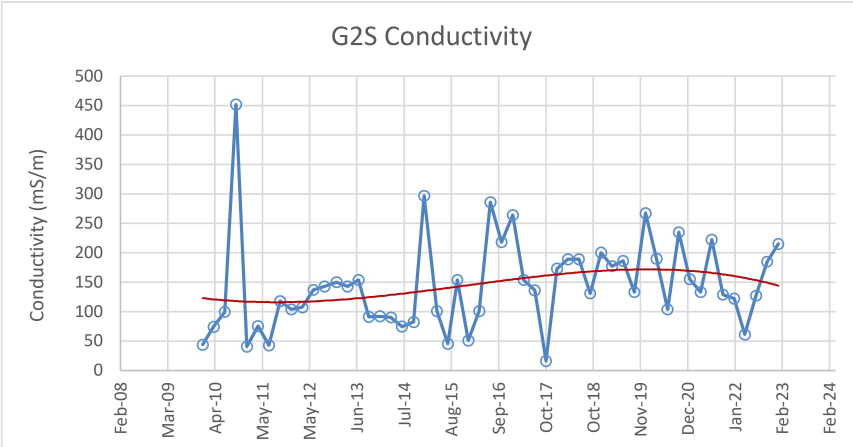
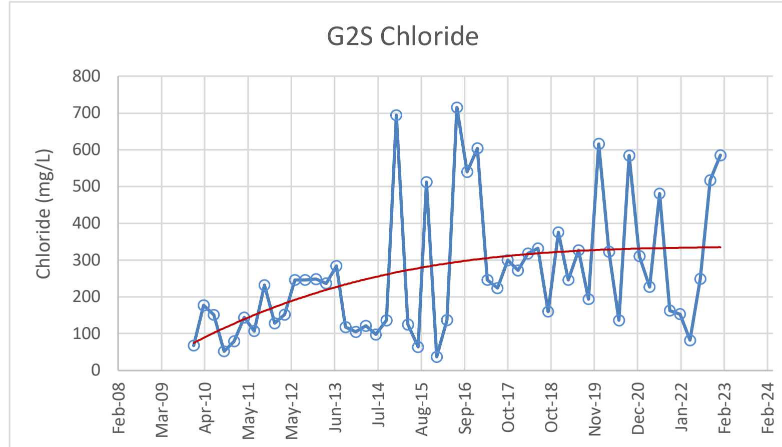
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

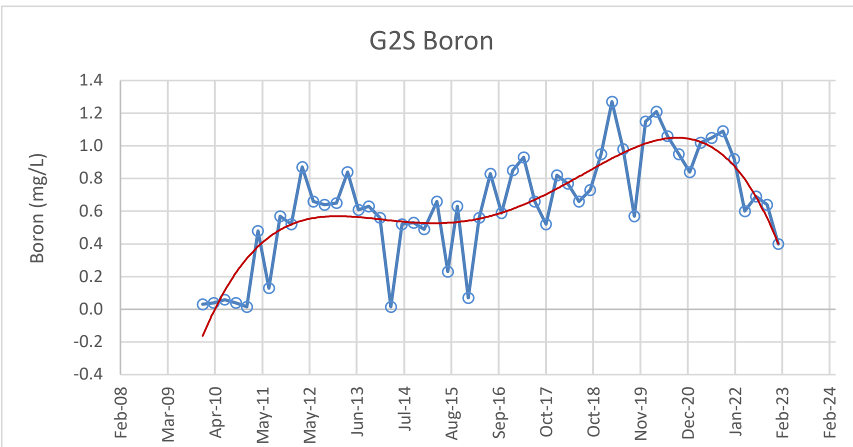

G1S Boron
Boron (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

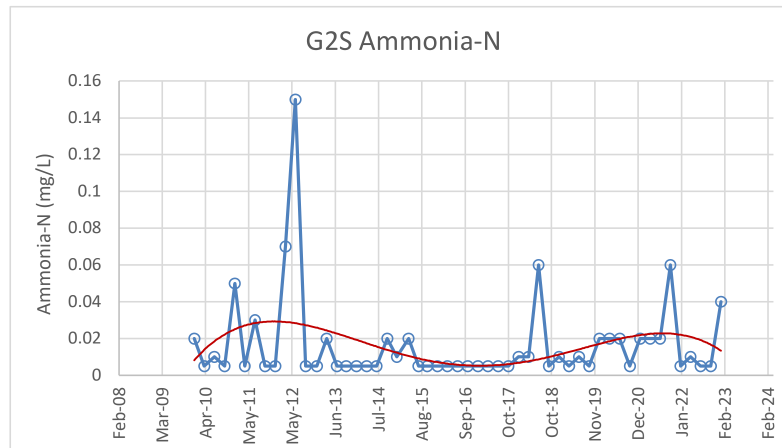

G1S Ammonia-N
Ammonia-N (mg/L)
12
10
8
6
4
2
0
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

EARTHTECH


G2S Conductivity
Conductivity (mS/m)
0
50
100
150
200
250
300
350
400
450
500
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G2S Chloride
Chloride (mg/L)
0
100
200
300
400
500
600
700
800
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G2S Boron
Boron (mg/L)
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24


G2S Ammonia-N
Ammonia-N (mg/L)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Feb-08
Mar-09
Apr-10
May-11
May-12
Jun-13
Jul-14
Aug-15
Sep-16
Oct-17
Oct-18
Nov-19
Dec-20
Jan-22
Feb-23
Feb-24

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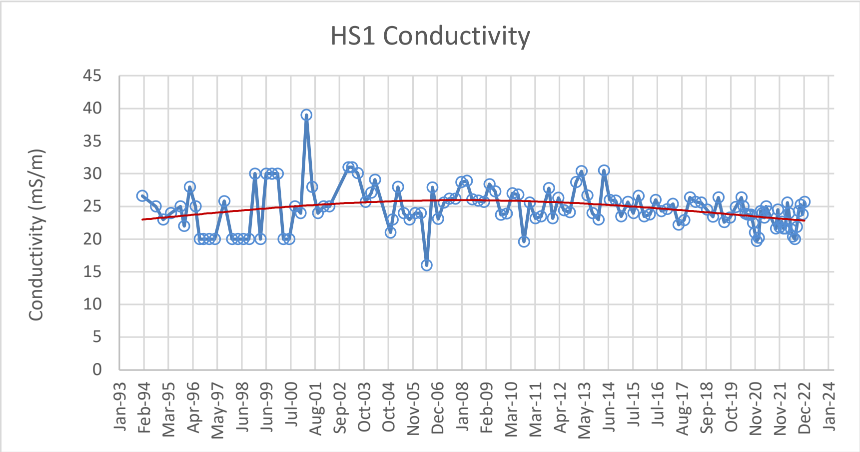
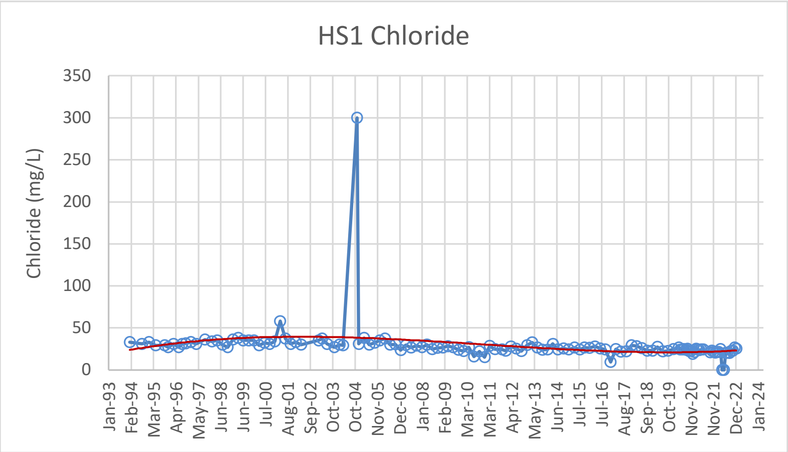
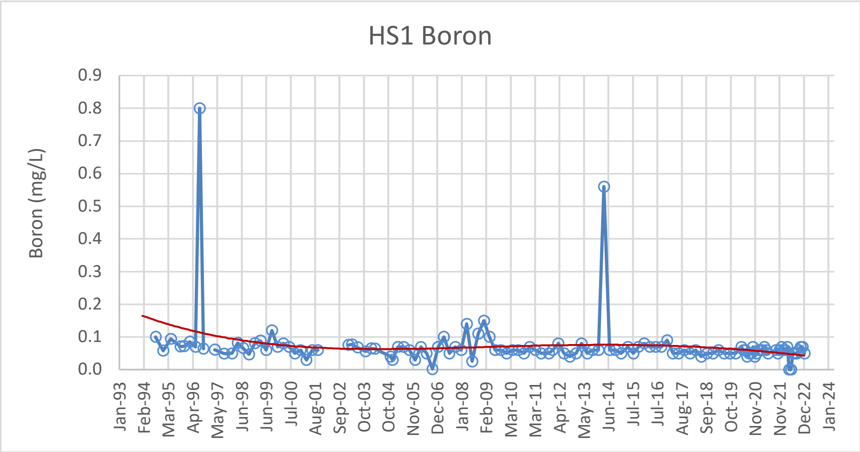
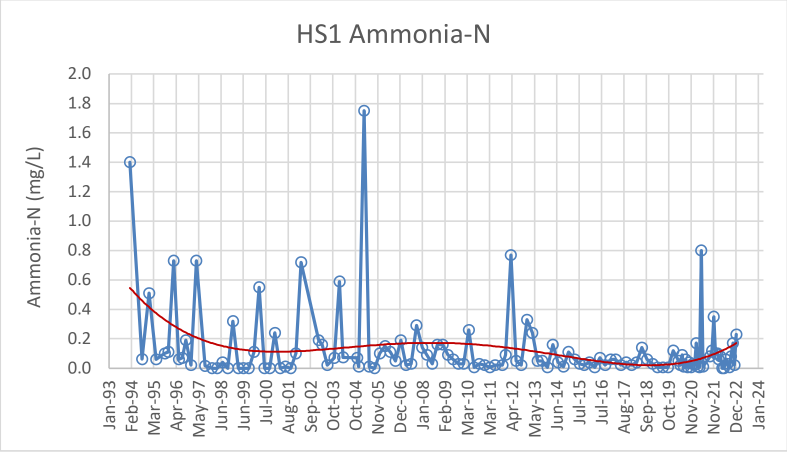
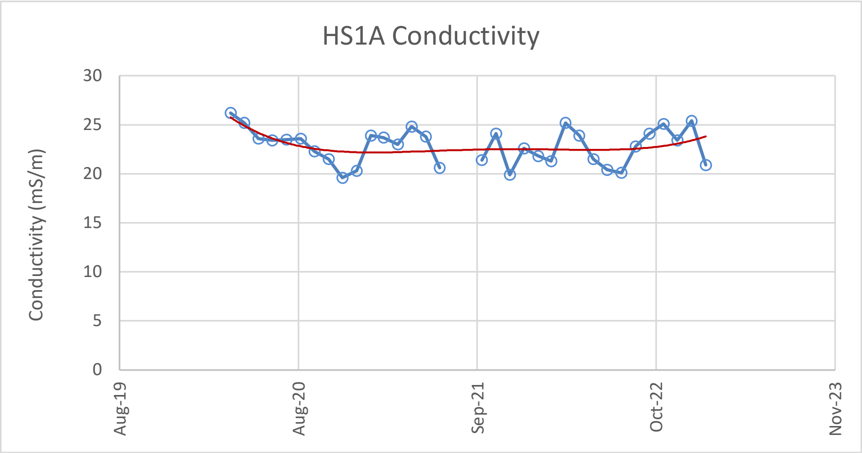

HS1 Conductivity
Conductivity (mS/m)
45
40
35
30
25
20
15
10
5
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

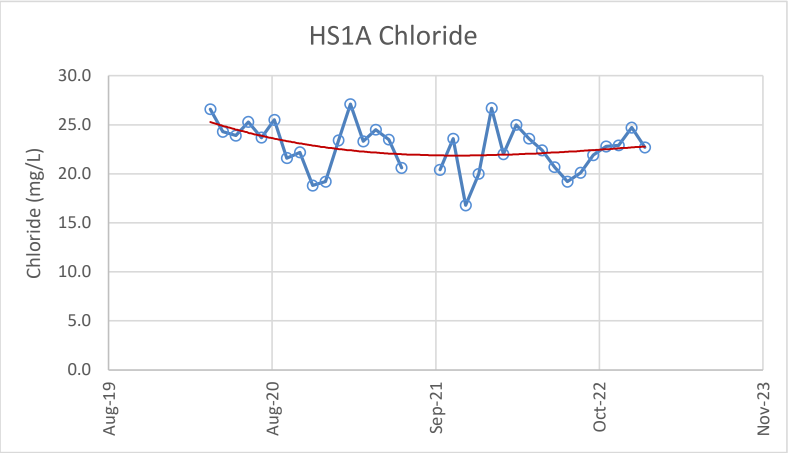

HS1 Chloride
Chloride (mg/L)
350
300
250
200
150
100
50
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

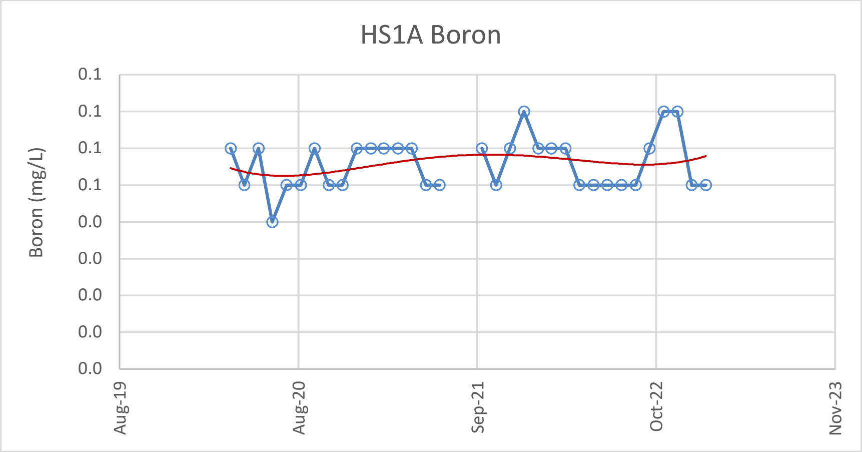

HS1 Boron
Boron (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

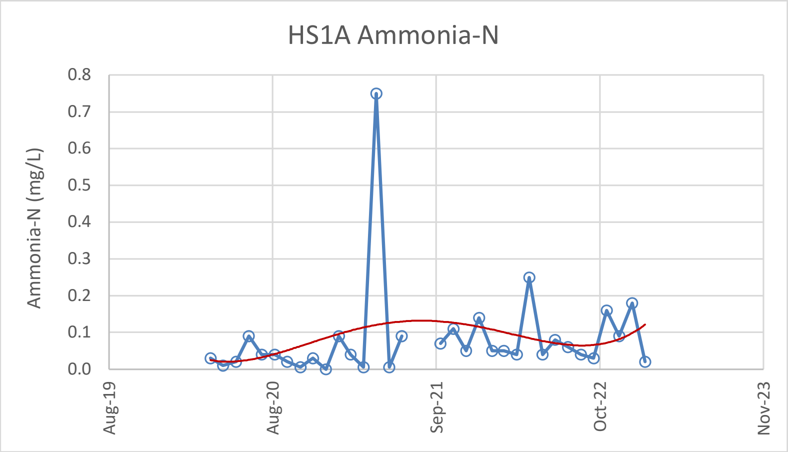

HS1 Ammonia-N
Ammonia-N (mg/L)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

EARTHTECH


HS1A Conductivity
Conductivity (mS/m)
30
25
20
15
10
5
0
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


HS1A Chloride
Chloride (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


HS1A Boron
Boron (mg/L)
0.1
0.1
0.1
0.1
0.0
0.0
0.0
0.0
0.0
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23


HS1A Ammonia-N
Ammonia-N (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Aug-19
Aug-20
Sep-21
Oct-22
Nov-23

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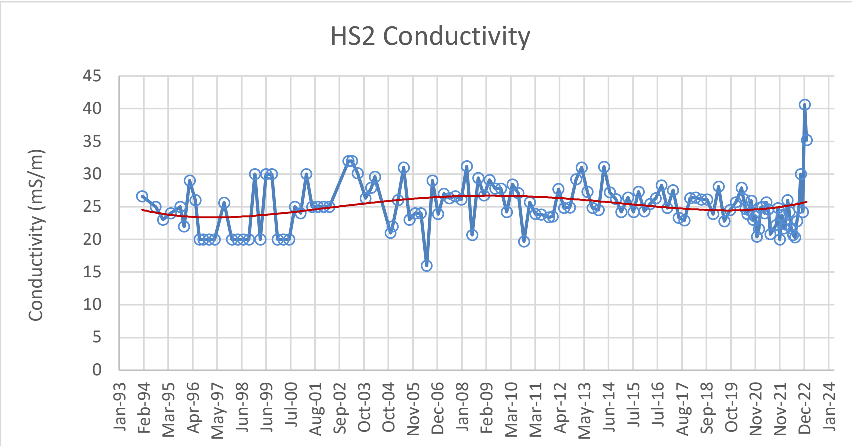
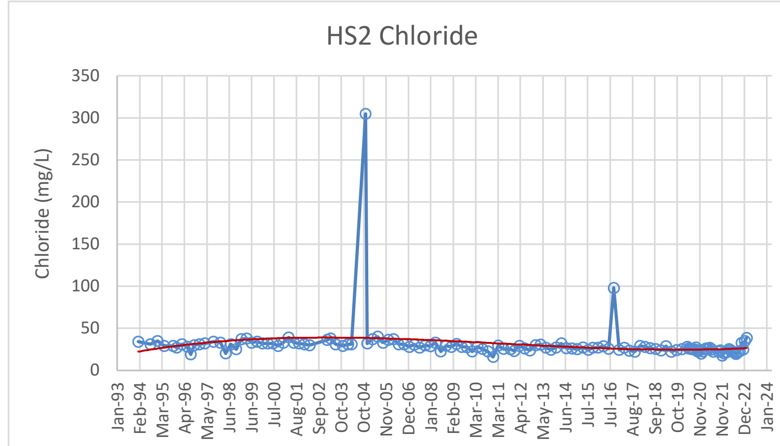
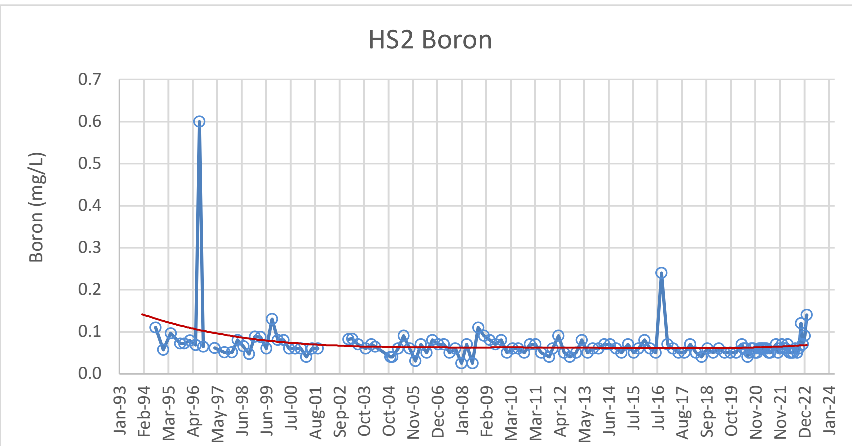
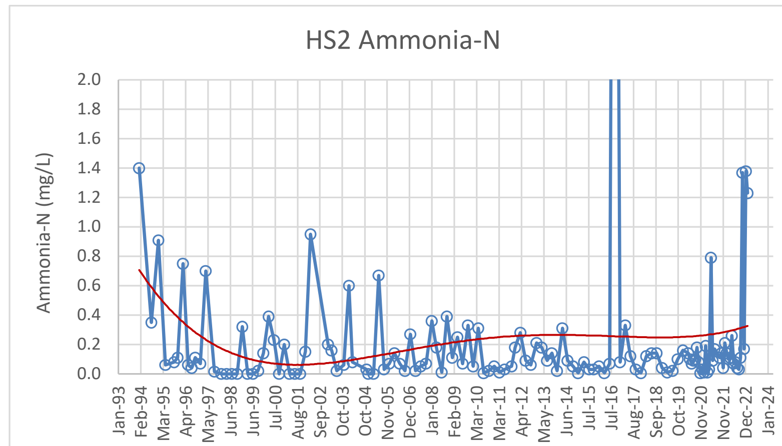

HS2 Conductivity
Conductivity (mS/m)
0
5
10
15
20
25
30
35
40
45
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


HS2 Chloride
Chloride (mg/L)
0
50
100
150
200
250
300
350
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


HS2 Boron
Boron (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24


HS2 Ammonia-N
Ammonia-N (mg/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

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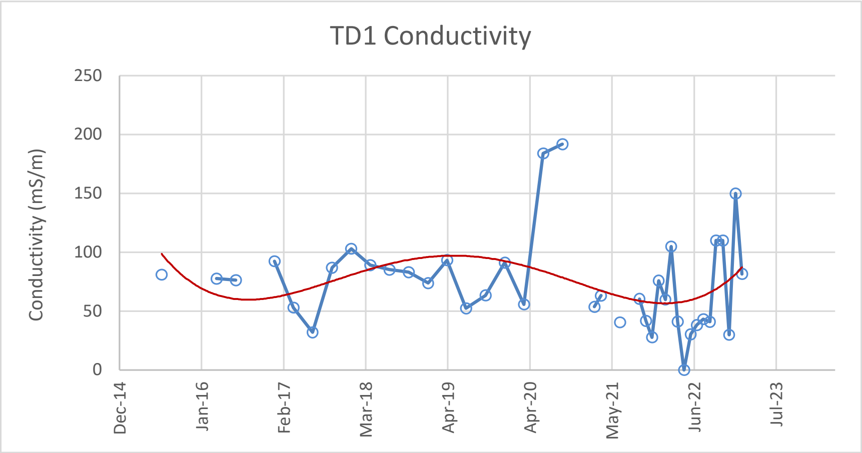
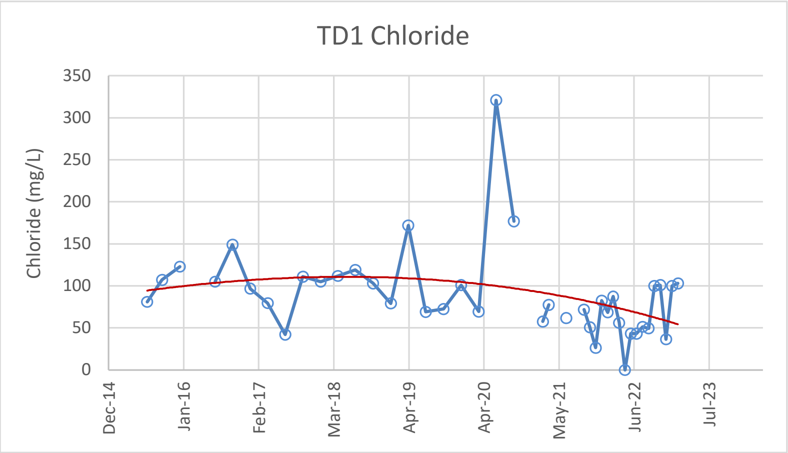
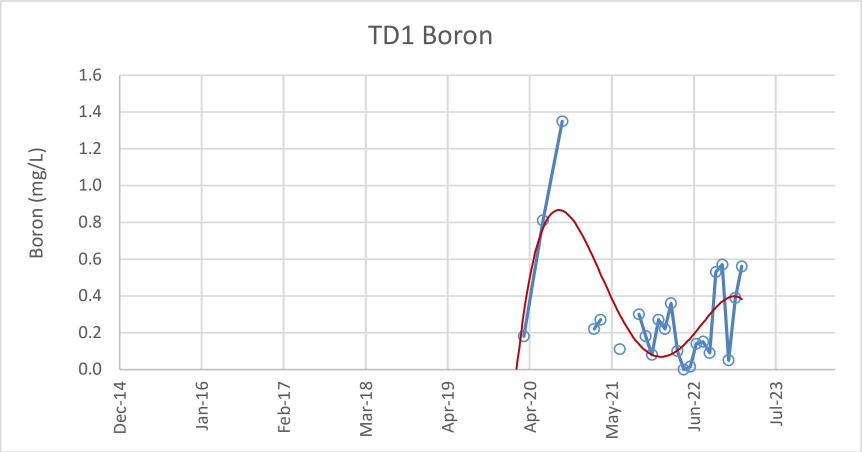
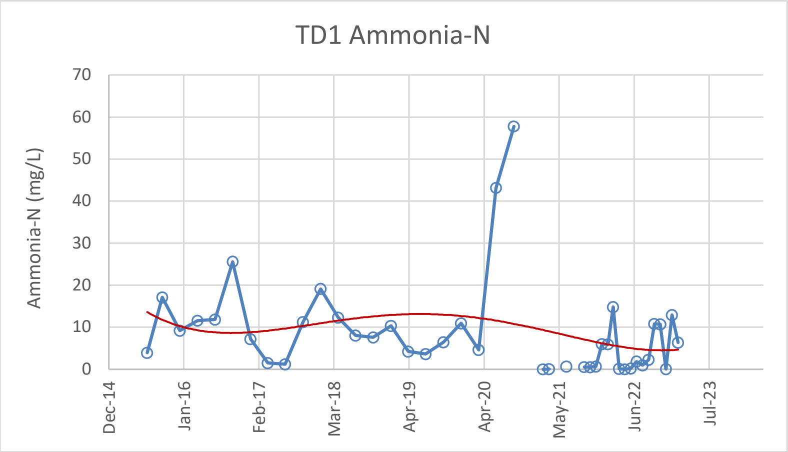

TD1 Conductivity
Conductivity (mS/m)
250
200
150
100
50
0
Dec-14
Jan-16
Feb-17
Mar-18
Apr-19
Apr-20
May-21
Jun-22
Jul-23


TD1 Chloride
Chloride (mg/L)
350
300
250
200
150
100
50
0
Dec-14
Jan-16
Feb-17
Mar-18
Apr-19
Apr-20
May-21
Jun-22
Jul-23


TD1 Boron
Boron (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Dec-14
Jan-16
Feb-17
Mar-18
Apr-19
Apr-20
May-21
Jun-22
Jul-23


TD1 Ammonia-N
Ammonia-N (mg/L)
70
60
50
40
30
20
10
0
Dec-14
Jan-16
Feb-17
Mar-18
Apr-19
Apr-20
May-21
Jun-22
Jul-23

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Assessment of Groundwater Pollution Plume Mobility and Remediation Plan

Levin Landfill, Hōkio Beach Road, Levin

Appendix B

Nitrification and Denitrification Treatment of Leachate

Nitrification of Ammoniacal Nitrogen

Nitrification is the biological oxidation of ammoniacal-N to nitrate nitrogen by autotrophic bacteria, which derive energy from the oxidation reaction, and utilise inorganic carbon as their principal food source. The nitrification reaction is a two-stage oxidation, each stage being performed by a distinct group of bacteria. The first stage, oxidation of ammoniacal-N to nitrite nitrogen, is performed by bacteria of the genus Nitrosomonas. The second stage, where this nitrite nitrogen is further oxidised to nitrate nitrogen, is performed by species of Nitrobacter. The reactions are shown empirically below:

1st Stage

$$55\ NH_4^+ + 76\ O_2 + 5\ CO_2 \rightarrow 54\ NO_2^- + 109\ H^+ + 52\ H_2O + C_5H_7O_2N \quad (a)$$

2nd Stage

$$115\ NO_2^- + 52.5\ O_2 + 5\ CO_2 + NH_4^+ + H_2O \rightarrow C_5H_7O_2N + H^+ + 115\ NO_3^- \quad (b)$$

From the above empirical reactions, it can be calculated that for one kilogram of ammoniacal-N that is nitrified:

- 4.27*kg* of dissolved molecular oxygen are used,
- 7.14*kg* of alkalinity, as $CaCO_3$, are destroyed,
- 0.22*kg* of new cells are synthesised.

Both groups of bacteria are relatively sensitive (compared with those groups which oxidise organic substrates) to environmental conditions, and either one or both stages can be easily inhibited by:

- Low pH-values (below about 6.5);
- Insufficient dissolved oxygen (below about 2*mg/ℓ*);
- Low temperatures;
- Toxic inhibition.

A wide range of chemicals are known to inhibit nitrification by toxic effects, although enough work has now been carried out on nitrification in leachate to show that such inhibition is rare, and treatment can be readily achieved, particularly in methanogenic leachate. However, the range of toxic chemicals includes both ammoniacal-N itself, and the intermediate oxidation product, nitrite nitrogen, both of which can potentially inhibit the second stage of the reaction, leading to a build-up of nitrite nitrogen in effluent.

The optimum pH-value for biological nitrification is typically between 7.5 and 8.0 (often quoted as 8.4), and nitrification rates decrease very sharply at pH values below 5.5. Nitrifying bacteria can, however, sometimes adapt to acidic environments, but rarely operate efficiently within them. Therefore, unless the wastewater being treated contains sufficient alkalinity, the nitrification reaction will ultimately prove to be self-inhibitory as it releases hydrogen ions and depresses pH-values. This process, together with maintenance of insufficient concentrations of dissolved oxygen, is the most common cause of failure in full-scale treatment plants trying to accomplish nitrification.

Operation at ambient temperatures could provide some constraints for nitrification within leachate treatment at the Levin Landfill site, (although successful treatment has been maintained through winter months at many UK landfills in simple aerated lagoons. Nevertheless, design of a full-scale plant based on use of a tank, with submersible venturi aerators (as opposed to external mounted), can ensure that temperatures within the treatment reactor will remain at optimum values for nitrification at all times. In a well-run plant, alkalinity and dissolved oxygen levels would not pose any threats to treatment efficiency. It is anticipated that no particular toxic substances have specifically been identified in the proposed (contaminated) groundwater influent. There is, therefore, no theoretical reason to suppose that nitrification of ammoniacal-N cannot readily be accomplished. It is recommended that measures are undertaken at detailed design stage, to maintain temperatures at between 20°C and 35°C at all times, and thereby maximise treatment rates.

Denitrification

Biological denitrification is the reduction of nitrate nitrogen to nitrogen gas by facultative heterotrophic organisms that use organic carbon for energy and as a carbon source. These organisms can use molecular oxygen as the electron acceptor under aerobic conditions, but use nitrate nitrogen as the electron acceptor under anoxic conditions. An anoxic stage is a zone where chemically combined oxygen is available, and can be used by bacteria, in the form of nitrate nitrogen and nitrite nitrogen. It should not be confused with "anaerobic", which describes conditions where a complete absence of available oxygen exists.

Denitrification of nitrate nitrogen to nitrogen gas occurs in many wastewater treatment plants, and has become the most widely-used nitrogen removal process in municipal wastewater treatment. A large number of bacterial species which occur naturally in the activated sludge process, or in extended aeration treatment systems, are capable of denitrification, making use of the oxygen contained in the nitrate ion. These organisms are termed heterotrophic bacteria, and are capable of using either molecular oxygen, or nitrate nitrogen and nitrite nitrogen oxygen, when they oxidise organic compounds. Under anoxic conditions, in the absence of available molecular oxygen, nitrate nitrogen dissimulation occurs through a complex series of reactions catalysed by enzymes. Facultative bacteria which are oxidising organic carbon compounds in a single sludge process are therefore able to switch easily from oxygen to nitrate nitrogen for respiration.

In a treatment plant where nitrification is the main process being achieved, it is generally necessary to add an organic substrate to allow denitrification to proceed. In the absence of a source, a variety of organic substrates are suitable. Methanol (CH_3OH) is widely used, although in several more recent full-scale leachate treatment plants which incorporate denitrification the cheaper and safer waste product, glycerol (generated as a by-product in biodiesel production), has been substituted. The overall detailed reaction for methanol, including cell synthesis, may be expressed by the following equation:

(a) $NO_3^- + 1.08\ CH_3OH + 0.24\ H_2CO_3 \rightarrow 0.06\ C_5H_7O_2N + 0.47\ N_2 + 1.68\ H_2O + HCO_3^-$

The N_2 gas is released to air. From this empirical reaction it may be calculated that for one kilogram of nitrate nitrogen that is denitrified:

At least 2.47*kg* of methanol are used;
0.45*kg* of new cells are synthesised;
3.57*kg* of alkalinity are formed.

The presence of dissolved oxygen inhibits the denitrification process, and concentrations of more than 0.2*mg/ℓ* to 0.5*mg/ℓ* have been shown to significantly reduce denitrification activity and efficiency.

Denitrification activity is reduced at low temperatures and enhanced by an increase in temperature up to an optimum of 40°C. Temperatures above this level do, however, prevent denitrification.

As alkalinity is formed during denitrification, the addition of an acid such as hydrochloric acid may be needed to maintain the pH-value within a narrow optimal range of 7 to 7.5. It has been shown that for pH-values less than 6.0, or greater than 8.0, there is a rapid decrease in denitrification activity.

Heavy metals may have a minor inhibitory effect on denitrification, but certain organic substances have potential to be extremely toxic. However, nitrifiers are much more sensitive to inhibitory substances, and normally nitrification ceases before any inhibition of denitrification is detected.