7.0 SOILS, GEOLOGY AND HYDROGEOLOGY

7.1 INTRODUCTION

This Chapter 7 presents the assessment of likely significant effects of the Proposed Development with regard to peat, geology and hydrogeology during Construction, Operational and Post-Closure Phases. It also presents potential cumulative effects in relation to known other projects in and near the Drehid Waste Management Facility (WMF) site. This Chapter 7 specifically incorporates the description of:

- The assessment methodology that was followed.
- The baseline environmental conditions that served as the basis for assessment of likely significant effects.
- Suitable mitigation measures to reduce or eliminate likely significant effects.

In this Chapter 7, both *potential effects* (pre-mitigation) and *residual effects* (post-mitigation) are addressed. Associated mitigation measures are of two types: *mitigation by avoidance* and *mitigation by design*.

Consistent with existing EIA directives and guidance, a 'Do Nothing' scenario is included and cumulative effects are considered.

This Chapter 7 should be read in conjunction with:

- Chapter 2: Description of the Existing Infrastructure and Proposed Development
- Chapter 6: Biodiversity
- Chapter 8: Water

7.2 CONTEXT AND OBJECTIVES

This Chapter 7 directly addresses the refusal points that were cited by An Bord Pleanála (ABP) in November 2020[1]:

- Mainly that the information presented in the previous EIAR (TCE, 2017) was insufficient to demonstrate that the subsurface geology of the site is suitable for the then proposed hazardous waste cell, referring to the site's high groundwater levels and outstanding questions around the permeability of the subsurface geology.
- That the hydrological and hydrogeological investigations presented in the previous EIAR were insufficient to conclude that the Proposed Development will not give rise to significant negative effects on groundwater and surface water receptors, with particular concerns about ammonia.

In relation to the first bullet, this Chapter 7 has taken regard of the decision by BnM to abandon the hazardous waste element of the planning application. As described in Chapter 2, only non-hazardous waste will be landfilled.

With regard to the second point, this Chapter 7 presents an assessment of likely significant effects which:

- Is based on a more detailed description of baseline conditions, supported by expanded site investigation and monitoring activity as described herein.

[1] Planning Board's decision dated 11 November 2020.

- Proposes mitigation measures that are informed by the updated description and understanding of baseline conditions, including the permeability characteristics of the subsurface geology.

The assessment of likely significant effects considers:

- The influence of ammonia leaching in the bog on groundwater quality.
- Groundwater-surface water interactions.
- The scale and influence of groundwater baseflow on the Cushaling River.
- The long-term monitoring of water quality that is necessary to continue to describe the existing environment, check compliance, identify effects, and judge the effectiveness of mitigation measures, during all phases of the Proposed Development.

In describing likely significant effects, this Chapter 7 has also taken regard of the Timahoe South Bog Decommissioning and Rehabilitation Plan[2] which was prepared by Bord na Móna (BnM, 2022) in connection with the Peatlands Climate Action Scheme (PCAS)[3], and which is regulated by the National Parks and Wildlife Services (NPWS) on behalf of the Department of Housing, Local Government & Heritage.

The TSB Decommissioning and Rehabilitation Plan has undergone a public consultation process. A Natura Impact Statement (NIS) was submitted to NPWS in June 2022 in accordance with Habitats Regulations. Observation received from NPWS in August 2022 were accounted for in the final NIS. It is noted that the Decommissioning and Rehabilitation Plan is not a subject of this planning application. Its implementation covers areas of TSB that are outside the redline boundary of the Proposed Development, as presented in Chapter 8.

7.3 METHODOLOGY

7.3.1 Regulatory Requirements and Guidance

This Chapter 7 has been prepared based on the following relevant directives, regulations and guidance:

Directives:

- Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU).
- European Union (2000/60/EC) Water Framework Directive
- European Union (2006/188/EC) Groundwater Directive
- European Union (1992/43/EEC) Habitats Directive

National Legislation:

- S.I. No. 191/2020, European Union (Environmental Impact Assessment) (Environmental Protection Agency Act 1992) (Amendment) Regulations 2020.
- S.I. No. 349 of 1989, European Communities (Environmental Impact Assessment) Regulations, with amendments.
- S.I. No. 722 of 2003, European Communities (Water Policy) Regulations.
- S.I. No. 9 of 2010, European Communities Environmental Objectives (Groundwater) Regulations, as amended (S.I. No. 366 of 2016).

[2] Publicly available at: Timahoe-South-Rehab-Plan-_Final-v5.pdf (bnmpcas.ie)
[3] Bord na Móna Peatlands Climate Action Scheme (bnmpcas.ie)

- S.I. No 272 of 2009, European Communities Environmental Objectives (Surface Waters) Regulations, as amended (S.I. No. 386 of 2015 and S.I. No. 77 of 2019).

Guidance:

- EPA (2022): Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (May 2022).
- Department of Housing, Planning and Local Government (2018): Guidelines for Planning Authorities and An Bord Pleanála on carrying out Environmental Impact Assessment (August 2018).
- Institute of Geologists of Ireland (IGI) (2013): Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements.
- National Roads Authority (NRA) (2009): Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes.
- EPA (2003): Towards Setting Guideline Values for the Protection of Groundwater in Ireland.

7.3.2 Appraisal Methodology

The appraisal methodology considers the source-pathway-receptor model of environmental risk assessment. For potential effects to occur or be realised, there must be a source or cause of effect, a pathway that connects the source with a receptor, and a receptor which can be affected.

The assessment of likely significant effects in this Chapter uses the criteria shown in Table 7-1 which are taken from EPA's "*Effect Classification Terminology*" (EPA, 2022). Effects are considered in terms of their quality, significance, extent, probability, duration, and type.

Table 7-1 Effect Classification Terminology (EPA, 2022)

Impact Characteristic	Term	Description
Quality	Positive	A change which improves the quality of the environment
	Neutral	No effects or effects that are imperceptible, within normal bounds of variation or within the margin of forecasting error.
	Negative	A change which reduces the quality of the environment.
Significance	Imperceptible	An effect capable of measurement but without significant consequences.
	Not significant	An effect which causes noticeable changes in the character of the environment but without significant consequences
	Slight	An effect which causes noticeable changes in the character of the environment without affecting its sensitivities
	Moderate	An effect that alters the character of the environment in a manner consistent with existing and emerging baseline trends
	Significant	An effect, which by its character, magnitude, duration or intensity alters a sensitive aspect of the environment
	Very significant	An effect which, by its character, magnitude, duration or intensity significantly alters most of a sensitive aspect of the environment
	Profound	An effect which obliterates sensitive characteristics

Impact Characteristic	Term	Description
Extent and Context	Extent	Describe the size of the area, number of sites and the proportion of a population affected by an effect
	Context	Describe whether the extent, duration, or frequency will conform or contrast with established (baseline) conditions
Probability	Likely	Effects that can reasonably be expected to occur because of the planned project if all mitigation measures are properly implemented
	Unlikely	Effects that can reasonably be expected not to occur because of the planned project if all mitigation measures are properly implemented
Duration and Frequency	Momentary	Effects lasting from seconds to minutes
	Brief	Effects lasting less than one day
	Temporary	Effects lasting less than one year
	Short-term	Effects lasting 1-7 years
	Medium-term	Effects lasting 7-15 years
	Long-term	Effects lasting 15-60 years
	Permanent	Effects lasting over 60 years
	Reversible	Effects that can be undone, for example through remediation or restoration
	Frequency	Describe how often the effect will occur (once, rarely, occasionally, frequently, constantly – or hourly, daily, weekly, monthly, annually)
Types	Indirect	Effect on the environment, which are not a direct result of the project, often produced away from the project site or because of a complex pathway
	Cumulative	The addition of many minor or insignificant effects, including effects of other projects, to create larger, more significant effects.
	'Do Nothing'	The environment as it would be in the future should the subject project not be carried out
	'Worst Case'	The effects arising from a project in the case where mitigation measures substantially fail
	Indeterminable	When the full consequences of a change in the environment cannot be described.
	Irreversible	When the character, distinctiveness, diversity or reproductive capacity of an environment is permanently lost
	Residual	The degree of environmental change that will occur after the proposed mitigation measures have taken effect
	Synergistic	Where the resultant effect is of greater significance than the sum of its constituents

7.3.2.1 Importance/Sensitivity of the Existing Environment

Descriptors of likely significant effects are contextualised with regard to the importance or sensitivity of the receiving environment and criteria used for rating their attributes. The attributes that were considered are presented in Table 8-2. Receiving environments that are designated sites or protected areas are intrinsically more sensitive to potential effects compared to environments that are not designated or otherwise protected, or of local importance only. This principle is reflected in the attributes that were considered.

To judge the attributes of receiving water bodies, publicly available information were researched and used, such as NPWS' mapping of designated and protected sites (available from Maps and Data | National Parks & Wildlife Service (npws.ie)) and EPA's assigned WFD status of water bodies (available at EPA Maps).

Table 7-2 Criteria for Rating Attributes of Soil, Geology and Hydrogeology

Importance/ Sensitivity	Criteria	Effects on Attributes Considered
Very High	Important at a national or international scale with no/little potential for replacement or substitution	**Peat:** Intact; (Part of) a designated site. **Geology:** Rare and of high European or national geological/ geomorphological importance; Resources are economically significant; No to very limited potential for replacement or substitution. **Hydrogeology:** Receiving groundwater environment: • Provides baseflow or other environmental supporting conditions for a designated site. • Is (part of) a protected area. • Is a classified regionally important karstified aquifer (Rkc/Rkd). Groundwater vulnerability is Extreme or High; Project is located within an Inner groundwater source protection zone (SPZ) of a public water supply.
High	Important at a national scale with limited potential for replacement or substitution	**Peat:** Exploited, but restorable; Part of or incorporates a groundwater dependent terrestrial ecosystem. **Geology:** Site of high national geological/ geomorphological importance; Resources are economically important; Limited potential for replacement of substitution. **Hydrogeology:** Receiving groundwater environment: • Provides baseflow or other environmental supporting conditions for protected area streams or lakes, or a wetland. • Is a classified regionally important aquifer (Rg/Rf). Groundwater vulnerability rating of High; Project is located within an Outer groundwater SPZ of a public water supply.
Medium	Important at a local scale with some potential for replacement or substitution	**Peat:** Partially degraded, but restorable. **Geology:** Resources are of some economic importance; Some potential for replacement/substitution. **Hydrogeology:** Receiving groundwater environment: • Provides environmental supporting conditions for streams, lakes or wetlands. • Is a locally important, moderately productive (Lg/Lk/Lm) aquifer. Groundwater vulnerability rating is High or Moderate.

Importance/ Sensitivity	Criteria	Effects on Attributes Considered
		Project is located outside a groundwater SPZ of public water supply, but groundwater is sourced locally for private water supply.
Low	Important at a local scale with potential for replacement or substitution	**Peat:** Significantly degraded, but restorable. **Geology:** Local geological/ geomorphological importance; Resources not economically important; Some potential for replacement/substitution. **Hydrogeology:** Receiving groundwater environment: • Provides limited environmental supporting conditions for streams, lakes or wetlands. • Is a poorly productive important aquifer. Groundwater vulnerability rating is Low or Moderate. Project site is located outside a groundwater SPZ of public water supply, but groundwater is sourced locally for private water supply.
Negligible	Low quality and/or common with potential for replacement or substitution	**Peat:** Severely degraded, not restorable. **Geology:** Disturbed lands of low quality (and/or contaminated). Resources not economically important. No geological/ geomorphological importance Potential for replacement/substitution. **Hydrogeology:** Groundwater receiving environment: • Does not provide environmental supporting conditions for streams, lakes or wetlands. • Is a poorly productive aquifer. Groundwater vulnerability rating of Low. Project site is located outside groundwater SPZ of public water supply, but groundwater is sourced locally for private water supply.

7.3.2.2 Magnitude of Effects

The magnitude of effects were assigned from Table 7-3 based on the attributes that were assigned. Effects can be negative, neutral, or positive, as well as major, moderate, minor or imperceptible.

Table 7-3 Criteria for Estimating Magnitude of Effects on Receiving Environment Attributes

Magnitude of Effects	Criteria	Attributes Considered
Major Negative`	**Adverse:** Results in loss of attribute and/or quality and integrity of attribute	**Peat:** Permanent loss of peat Effects cannot be mitigated. **Geology:** Loss or significant damage to areas designated as being of national or regional geological interest. Loss of resource and/or quality and integrity of resource. Severe damage to characteristics, features or elements. Effects cannot be mitigated. **Hydrogeology:**

Magnitude of Effects	Criteria	Attributes Considered
		Loss of or extensive, non-reversible damage to part of an aquifer, designated site, or protected area. Predicted significant effect on the groundwater supporting conditions to streams, lakes or wetlands. Will directly impact a groundwater-sourced public or private water supply intended for human consumption. Effects cannot be mitigated.
Moderate Negative	**Adverse:** Results in effect on integrity of attribute or loss of part of attribute	**Peat:** Partial loss of peat. Effects can be mitigated. **Geology:** Loss of geological resources but no adverse effect on quality or integrity of resources. Partial loss / damage to key characteristics, feature or elements, but not result in the loss of or damage to areas designated as being of regional or national geological interest. Effects can be mitigated. **Hydrogeology:** Potential loss or damage to a groundwater resource (quality and quantity). Predicted potential effect on the groundwater supporting conditions to streams, lakes, or wetlands. Potential effect on groundwater-sourced public or private water supplies intended for human consumption or other purpose. Will affect a groundwater-sourced private water supply not intended for human consumption. Effects can be mitigated.
Minor Negative	**Adverse:** Results in a manageable effect on integrity of attribute or loss of part of attribute	**Peat:** Temporary loss of peat. Effects can be mitigated. **Geology:** Some measurable change in soil or geological attributes, quality or integrity. Minor loss or alteration to characteristics, feature or elements. Project will not affect areas of national or regional geological resources or localities of interest, but may result in loss or damage to areas of geological interest locally. Effects can be mitigated. **Hydrogeology:** Small measurable and acceptable loss of groundwater resources. Small measurable and acceptable effect on the groundwater supporting conditions to streams, lakes, or wetlands. Low-risk potential effect on groundwater-sourced public or private water supplies intended for human consumption or other purpose. Effects can be mitigated.
Neutral	Imperceptible alteration to one or more characteristics,	**Peat:** Project does not affect or cause a loss of peat. **Geology:**

Magnitude of Effects	Criteria	Attributes Considered
	features or elements of attribute	Project will cause non-measurable change in soil or geological attributes, quality or integrity. Non-measurable loss or alteration to characteristics, feature or elements. Project will not affect any areas of soil/ geological resources or localities of interest. **Hydrogeology:** Project will not affect groundwater resources, groundwater supporting function to streams, lakes, or wetlands, or the groundwater receiving environment. Project will not affect any public or private water supplies intended for human consumption or other purpose.
Minor Positive	**Beneficial:** Results in some positive effect on attribute or a reduced risk of negative effect occurring	**Peat:** Project contributes to bog restoration locally. **Soils and Geology:** Project may result in the preservation of geological attributes or qualities that are of local or academic interest. Project may result in the discovery of geological attributes or qualities that may become of local or academic interest. **Hydrogeology:** Minor potential for measurable enhancement of local groundwater resources and/or groundwater supporting conditions to streams, lakes or wetlands.
Moderate Positive	**Beneficial:** Results in moderate improvement in attribute quality and integrity	**Peat:** Project contributes to bog preservation and restoration in an expanded area. **Geology:** Project is beneficial to geological understanding. Project identifies geological attributes or qualities that are of local or national academic interest. Project results in some improvement to geological/geomorphological attribute quality and integrity. **Hydrogeology:** Project results in some measurable enhancement of local groundwater resources and/or groundwater supporting conditions to streams, lakes or wetlands. Project has the potential to help achieve environmental requirements and conservation objectives in protected areas or designates sites.
Major Positive	**Beneficial:** Results in major improvement in quality and integrity of attribute	**Peat:** Project results in preservation of existing high-grade peat and restoration of degraded peat across the bog. **Geology:** Project directly benefits geological understanding which is of academic, economic and national interest. Project results in major improvement to geological/geomorphological attribute quality and integrity. **Hydrogeology:**

Magnitude of Effects	Criteria	Attributes Considered
		Project will result in considerable enhancement of local groundwater resources and/or the groundwater supporting conditions to streams, lakes or wetlands. Project will help to achieve environmental requirements and conservation objectives in protected areas or designates sites.

With reference to Tables 7-2 and 7-3, designated sites and protected areas are:

- Special Areas of Conservation (SACs) and Special Protected Areas (SPAs) which are managed by NPWS and which are commonly referred to as 'European sites' or 'Natura 2000 sites'.
- Natural Heritage Areas (NHAs), which are areas "considered important for the habitats present or which holds species of plants and animals whose habitat needs protection".[4] The Geological Survey of Ireland (GSI) has compiled a national list of geological/geomorphological sites in need of protection through NHA designation.

- Drinking Water Protected Areas, which are designated by EPA.

Designated sites and protected areas have environmental requirements which are stipulated in the following main legislation:

- Birds and Natural Habitats Regulations, S.I. No. 477 of 2011, as amended.
- Urban Wastewater Treatment Regulations, S.I. No. 208/1999, as amended.
- Drinking Water (No. 2) Regulations, S.I. No. 278 of 2007, as amended.
- Groundwater Regulations, S.I. No 366 of 2016, as amended.

Some SACs have groundwater dependencies as qualifying interests, and such SACs are termed 'groundwater dependent terrestrial ecosystems' (GWTDEs). In such settings, groundwater provides the principal environmental supporting conditions for the SAC (Kilroy *et al.,* 2008).

7.3.3 Desk Study

A comprehensive desk study was undertaken as part of the characterisation of baseline conditions. This involved a review of past reports related to the site (including TCE, 2017, with appendices), scientific journal articles that are relevant to the scientific topics involved, and publicly available information which is listed in Appendix D of the IGI guidance for the preparation of the soils, geology and hydrogeology chapters of EIARs (IGI, 2013).

Specific reports from the site which are of immediate relevance to this Chapter 7 are:

- Tobin Consulting Engineers (2018). Drehid Waste Management Facility, IED Application, Operational Report, December 2018, Revision A
- Tobin Consulting Engineers (2017). Proposed Development at Drehid Waste Management Facility. Environmental Impact Assessment Report (EIAR), main report and appendices.
- Tobin Consulting Engineers (2008). Drehid Waste Management Facility. Environmental Impact Statement Report, with appendices.
- O'Callaghan & Moran (2015). Hydrogeology Review/Technical Assessment Report.
- O'Callaghan & Moran (2018). Addendum Report.

[4] https://www.npws.ie/protected-sites/nha

- Annual Environmental Reports for Leachate, Groundwater, and Surface Water, prepared by BnM in compliance with Industrial Emission Discharge (IED) license conditions for the current WMF (W0201-03).

The publications and materials used are referenced throughout Chapter 7, as appropriate.

BnM also produces water quality monitoring data under their current IED license. These data are presented and referenced throughout Chapter 7.

Geographic Information System (GIS) files and other monitoring data generated by public bodies like EPA, OPW, and GSI are also referenced and used throughout Chapter 7.

7.3.4 Site Investigation and Monitoring Conducted for this EIAR

A site investigation (SI) and monitoring programme was undertaken across TSB between July 2020 and July 2022 in support of the current EIAR, with a focus on the Proposed Development area.

The SI is presented as a Factual Report in Appendix 7-1 (CDM Smith, 2022). The information that was obtained from the SI builds on the significant volume of geological and hydrogeological data and information that were presented in past EIA reports (TCE, 2008; TCE, 2017).

As mentioned in Section 7.2, the ABP refusal of November 2020 considered that the EIAR submitted in 2017 was not sufficient to conclude that the Proposed Development will not give rise to significant negative effects on groundwater and surface water receptors. Accordingly, the scoping of the new SI considered ABP's points of refusal carefully in order to address queries and associated data gaps. Related content, materials and findings are presented in detail in subsequent sections of Chapter 7.

The scoping for the new SI, and the field implementation of the SI, was led by the authors of this Chapter 7.

7.3.4.1 Drilling of Boreholes

A total of 54 no. boreholes were drilled at 36 no. locations across TSB, including 24 no. boreholes in or near the landfill expansion area. Some of the boreholes were drilled at the same location to different depths in order to accommodate monitoring well installation in different hydrogeological units (Section 7.3.4.2).

Within and near the landfill expansion area, emphasis was placed on lithological characterisation (Sections 7.4.2 through 7.4.5) and documenting the permeability of the different geological media (Section 7.4.15).

The new borehole locations are shown in Figure 7-1 and the boreholes are summarized in Table 7-4. Geological logs are presented in Appendix 7-1.

The new boreholes supplement 32 boreholes and more than 130 no. trial pits that were drilled and excavated within TSB in past site investigations (TCE, 2008;, OCM, 2014, TCE, 2017). The information obtained supplements geological interpretations presented in past geophysical survey reports (Apex, 2002 and 2016).

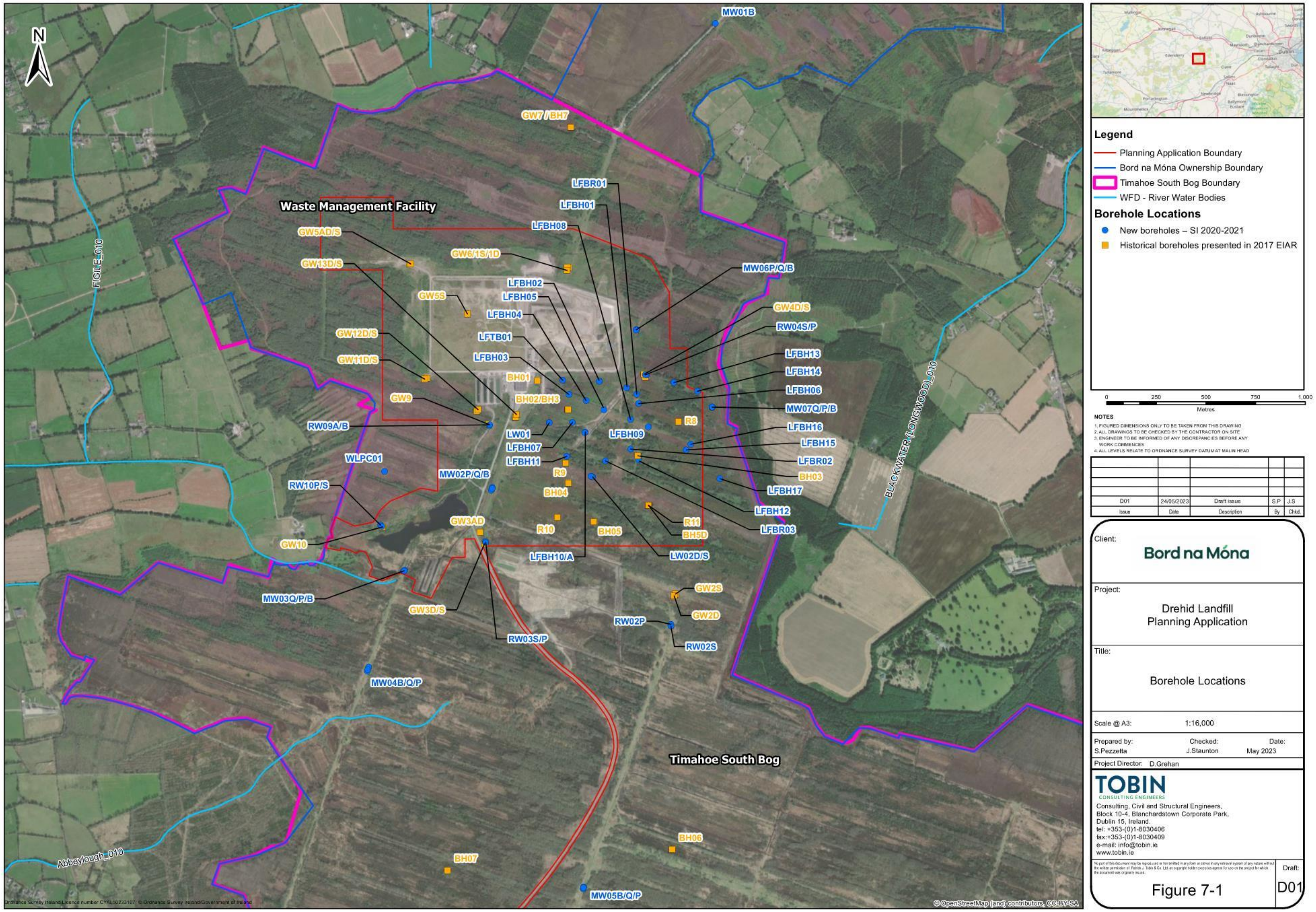

Figure 7-1 Locations of Boreholes Drilled For the Updated SI (2020-2021)

Table 7-4 Summary of Boreholes Drilled For the Updated SI (2020-2021)

Borehole ID	Peg ID	Easting (ITM)	Northing (ITM)	Ground Level (m OD)	Total Depth (TD)	PSD[1] Test	Triaxial Test
LFBH01	LFBH01	674863.16	731746.89	83.250	10.00	Yes	-
LFBH02	LFBH02	674999.32	731715.05	83.002	7.00	-	-
LFBH03	LFBH03	674709.35	731680.95	82.278	7.00	Yes	-
LFBH04	LFBH04	674796.81	731650.00	83.818	14.50	-	-
LFBH05	LFBH05	674885.47	731603.23	84.507	7.00	-	-
LFBH06	LFBH06	675060.95	731634.31	83.961	7.50	-	-
LFBH07	LFBH07	674727.17	731540.43	83.959	8.50	-	-
LFBH08	LFBH08	675020.45	731554.60	84.557	10.00	-	-
LFBH09	LFBH09	675108.70	731516.64	84.510	10.50	-	Yes
LFBH10	LFBH10	674791.96	731490.87	84.512	2.30	-	-
LFBH10A[2]	LFBH10	674789.67	731488.17	84.736	8.80	-	Yes
LFBH11	LFBH11	674698.29	731368.60	84.249	6.00	Yes	-
LFBH12	LFBH12	675060.26	731353.28	85.782	7.00	Yes	-
LFBH13	LFBH13	675238.07	731741.02	84.185	7.00	-	-
LFBH14	LFBH14	675357.48	731697.23	85.130	8.50	Yes	-
LFBH15	LFBH15	675300.18	731401.22	85.282	8.50	-	-
LFBH16	LFBH16	675323.47	731430.02	85.712	12.40	-	Yes
LFBH17	LFBH17	675469.34	731257.12	86.119	17.50	Yes	-
LFBR01	LFBR01	675051.57	731682.63	83.898	18.00	-	Yes
LFBR02	LFBR02	675020.00	731405.41	85.361	25.70	-	Yes
LFBR03	LFBR03	674893.24	731346.47	84.873	21.50	-	Yes
LFTB01	LFTB01	674677.79	731752.04	83.012	12.50	-	-
LW01	LFMW01	674610.18	731538.91	83.379	10.00	Yes	-
LW02D	LFMW02	674829.34	731265.87	84.853	13.00	Yes	-
LW02S	LFMW02B	674820.57	731269.13	84.760	7.00	-	-
MW01B	WLMW01W	675446.45	733547.55	85.300	25.50	-	-
MW02B	WLMW02W	674319.35	731198.76	84.674	37.50	Yes	Yes
MW02P	WLMW02P	674322.87	731213.62	84.743	3.00	-	-
MW02Q	WLMW02Q	674323.89	731207.44	84.854	20.00	-	-
MW03B	WLMW03W	673882.75	730795.54	84.060	19.50	-	Yes
MW03P	WLMW03P	673878.04	730791.82	84.294	4.50	-	-
MW03Q	WLMW03Q	673880.75	730793.72	84.150	9.00	-	-
MW04B	WLMW04W	673695.13	730288.39	84.426	24.10	-	-
MW04P	WLMW04P	673701.44	730308.42	84.423	4.50	-	-
MW04Q	WLMW04Q	673697.44	730296.25	84.505	11.50	-	-
MW05B	WLMW05W	674783.81	729202.74	85.665	27.00	Yes	Yes
MW05P	WLMW05P	674781.19	729193.69	85.875	4.50	-	-
MW05Q	WLMW05Q	674782.55	729198.25	85.588	13.80	Yes	-
MW06B	WLMW06W	675049.20	732007.37	82.695	21.00	-	Yes
MW06P	WLMW06P	675048.86	732006.48	82.681	3.00	-	-
MW06Q	WLMW06Q	675047.90	732004.36	82.740	11.70	Yes	-
MW07B	WLMW07W	675430.17	731615.73	86.592	18.00	-	Yes

Borehole ID	Peg ID	Easting (ITM)	Northing (ITM)	Ground Level (m OD)	Total Depth (TD)	PSD[1] Test	Triaxial Test
MW07P	WLMW07P	675430.19	731619.17	86.556	1.50	-	-
MW07Q	WLMW07Q	675430.19	731617.00	86.548	6.00	Yes	-
RW02P	RWGW02S	675222.79	730523.61	84.346	1.00	-	-
RW02S	RWGW02D	675222.54	730513.98	84.340	13.00	Yes	-
RW03P	RWGW03S	674288.38	730940.10	84.001	2.20	-	-
RW03S	RWGW03D	674291.35	730936.25	83.959	10.00	-	-
RW04P	RWGW04S	675099.16	731778.68	84.268	3.30	-	-
RW04S	RWGW04D	675094.24	731780.42	84.339	13.00	Yes	-
RW09A	RWGW09S	674309.21	731523.24	83.076	4.00	Yes	-
RW09B	RWGW09D	674311.37	731527.80	83.003	10.00	Yes	-
RW10P	RWGW10S	673760.86	731024.30	83.713	2.80	-	-
RW10S	RWGW10D	673768.50	731016.43	83.759	7.00	Yes	-
WLPC01	WLPC01	673781.25	731292.73	83.297	16.00	-	-

Note: [1] PSD = particle size distribution (grain size) analysis; [2]re-drill of LFBH10

In Table 7-4, the boreholes that have a prefix 'LF' were drilled within or near the landfill expansion footprint. The boreholes were drilled at multiple locations to obtain a good spatial representation of subsurface data. Actual drilling locations were where ground conditions allowed, taking advantage of existing tracks with the bog, thus tend to form two transects oriented roughly NE-SW and NW-SE.

All boreholes were drilled with either air rotary or sonic drilling methods. The sonic drilling method was applied for coring purposes, both through subsoils and into bedrock.

All drilling works were supervised by qualified geologists. Samples collected during air-rotary drilling were described in the field. Cores retrieved with the sonic method were boxed and geologically logged by the drilling Contractor in their warehouse facility. Quality control (visual inspections of cores and review of logs) was carried out by the authors of this Chapter 7, including a field supervisor of drilling works. All of the cores are kept in the drilling Contractor's warehouse facility until the planning application is concluded.

As indicated in Table 7-4, a subset of subsoil samples were collected for grain size analysis by an accredited geotechnical laboratory, focussing on poorly sorted sand and gravel type sediments. Undisturbed samples were also tested for vertical permeability by an accredited geotechnical laboratory, focussing on clay/silt units. Further details are provided in Sections 7.4.3 and 7.4.15.

Outside the landfill expansion footprint, boreholes were drilled for geological information and to install new or replacement monitoring wells. The purpose of the new monitoring wells was to be able to document key aspects of this Chapter 7, including groundwater-surface water interactions and the position of a groundwater divide south of the landfill expansion area. This is described in detail in subsequent sections of this Chapter 7.

One specific borehole was drilled to the northwest of the Borrow Pit near the western margin of the BnM landholding to verify the nature of an apparent north-south trending low-resistivity anomaly which was flagged during geophysical surveys in the past (Apex 2016).

7.3.4.2 Installation of Monitoring Wells

At the 54 no. drilled locations, a total of 41 no. monitoring wells were installed, as summarised in Table 7-5, at the locations shown in Figure 7-2. To address ABP's refusal points on site characterisation and to expand on the hydrogeological characterisation that was presented in the 2017 EIAR, the new monitoring wells were installed to document:

- Groundwater levels and flow gradients across the Proposed Development area.
- Groundwater quality in the Proposed Development area.
- Groundwater-surface water interactions in TSB, including the Cushaling River.
- The position of a potential groundwater divide between the subcatchments of the Cushaling and Abbeylough Rivers within TSB (see Chapter 8).
- Hydraulic properties of subsoils in the Proposed Development area, in different hydrogeological units.

Monitoring wells were installed in each of three main hydrogeological units that define the Proposed Development area: peat, Quaternary sediments (glacial tills, mainly), and limestone bedrock. The monitoring wells were installed under supervision, and well screens were installed carefully such that 'response zones' (screen intervals) of individual wells only extend across one hydrogeological unit. This was done purposefully to be able to assign individual wells to individual units, such that data associated with a given well are representative of only unit only. The was deemed necessary to be able to investigate and document hydrogeological differences between units, notably groundwater levels, flow patterns, and gradients, and groundwater quality.

Table 7-5 Summary of Monitoring Wells Installed for the Updated SI (2020-2021)

Borehole ID	Monitoring Well ID	Easting (ITM)	Northing (ITM)	Ground Level (m OD)	Total Depth (TD)	Top of Casing Elevation (m OD)	Response Zone Top (m bToC)[1]	Response Zone Bottom (m bToC)
LFBH01	LFBH01	674863.16	731746.89	83.250	10.00	83.424	6.00	7.50
LFBH02	-	674999.32	731715.05	83.002	7.00	-	-	-
LFBH03	-	674709.35	731680.95	82.278	7.00	-	-	-
LFBH04	LFBH04	674796.81	731650.00	83.818	14.50	83.929	6.00	7.50
LFBH05	LFBH05	674885.47	731603.23	84.507	7.00	84.715	5.00	7.00
LFBH06	-	675060.95	731634.31	83.961	7.50	-	-	-
LFBH07	-	674727.17	731540.43	83.959	8.50	-	-	-
LFBH08	-	675020.45	731554.60	84.557	10.00	-	-	-
LFBH09	-	675108.70	731516.64	84.510	10.50	-	-	-
LFBH10	-	674791.96	731490.87	84.512	2.30	-	-	-
LFBH10A	LFBH10A	674789.67	731488.17	84.736	8.80	84.873	6.00	7.60
LFBH11	-	674698.29	731368.60	84.249	6.00	-	-	-
LFBH12	LFBH12	675060.26	731353.28	85.782	7.00	86.198	3.00	3.50
LFBH13	LFBH13	675238.07	731741.02	84.185	7.00	84.341	2.00	3.50
LFBH14	LFBH14	675357.48	731697.23	85.130	8.50	85.542	6.00	8.50
LFBH15	-	675300.18	731401.22	85.282	8.50	-	-	-
LFBH16	LFBH16	675323.47	731430.02	85.712	12.40	85.832	2.60	3.00
LFBH17	-	675469.34	731257.12	86.119	17.50	-	-	-
LFBR01	-	675051.57	731682.63	83.898	18.00	-	-	-
LFBR02	-	675020.00	731405.41	85.361	25.70	-	-	-
LFBR03	LFBR03	674893.24	731346.47	84.873	21.50	85.253	6.50	8.40

Borehole ID	Monitoring Well ID	Easting (ITM)	Northing (ITM)	Ground Level (m OD)	Total Depth (TD)	Top of Casing Elevation (m OD)	Response Zone Top (m bToC)[1]	Response Zone Bottom (m bToC)
LFTB01	-	674677.79	731752.04	83.012	12.50	-	-	-
LW01	LW01	674610.18	731538.91	83.379	10.00	83.561	7.00	10.00
LW02D	LW02D	674829.34	731265.87	84.853	13.00	84.917	8.60	10.60
LW02S	LW02S	674820.57	731269.13	84.760	7.00	84.849	5.00	6.20
MW01B	MW01B	675446.45	733547.55	85.300	25.50	85.719	21.50	25.50
MW02B	MW02B	674319.35	731198.76	84.674	37.50	85.119	32.50	37.50
MW02P	MW02P	674322.87	731213.62	84.743	3.00	85.097	0.50	3.00
MW02Q	MW02Q	674323.89	731207.44	84.854	20.00	85.170	3.50	4.50
MW03B	MW03B	673882.75	730795.54	84.060	19.50	84.312	14.50	19.50
MW03P	MW03P	673878.04	730791.82	84.294	4.50	84.560	1.00	3.55
MW03Q	MW03Q	673880.75	730793.72	84.150	9.00	84.478	4.30	7.80
MW04B	MW04B	673695.13	730288.39	84.426	24.10	84.717	19.10	24.10
MW04P	MW04P	673701.44	730308.42	84.423	4.50	84.753	1.00	3.40
MW04Q	MW04Q	673697.44	730296.25	84.505	11.50	84.767	9.00	10.80
MW05B	MW05B	674783.81	729202.74	85.665	27.00	85.754	17.70	26.70
MW05P	MW05P	674781.19	729193.69	85.875	4.50	86.000	1.50	3.00
MW05Q	MW05Q	674782.55	729198.25	85.588	13.80	85.721	7.50	10.40
MW06B	MW06B	675049.20	732007.37	82.695	21.00	83.083	17.00	21.00
MW06P	MW06P	675048.86	732006.48	82.681	3.00	83.157	1.00	2.90
MW06Q	MW06Q	675047.90	732004.36	82.740	11.70	83.129	9.00	11.40
MW07B	MW07B	675430.17	731615.73	86.592	18.00	86.788	13.90	17.90
MW07P	MW07P	675430.19	731619.17	86.556	1.50	86.830	0.50	1.50
MW07Q	MW07Q	675430.19	731617.00	86.548	6.00	86.742	4.50	5.90
RW02P	RW02P	675222.79	730523.61	84.346	1.00	87.241	0.35	0.85
RW02S	RW02S	675222.54	730513.98	84.340	13.00	87.077	8.00	11.00
RW03P	RW03P	674288.38	730940.10	84.001	2.20	84.354	0.50	2.20
RW03S	RW03S	674291.35	730936.25	83.959	10.00	84.210	8.50	9.50
RW04P	RW04P	675099.16	731778.68	84.268	3.30	84.480	1.50	3.30
RW04S	RW04S	675094.24	731780.42	84.339	13.00	84.652	7.30	10.30
RW09A	RW09A	674309.21	731523.24	83.076	4.00	83.292	2.00	4.00
RW09B	RW09B	674311.37	731527.80	83.003	10.00	83.063	8.00	10.00
RW10P	RW10P	673760.86	731024.30	83.713	2.80	83.963	0.50	2.60
RW10S	RW10S	673768.50	731016.43	83.759	7.00	83.889	3.00	4.50

Notes: [1] m bTofC = metres below top of casing

In Table 7-5, the wells that are highlighted in grey colour represent wells with response zones in peat only. Those highlighted in the tan colour were installed with response zones in the Quaternary unit only. Those highlighted in light blue were installed with response zones in bedrock only.

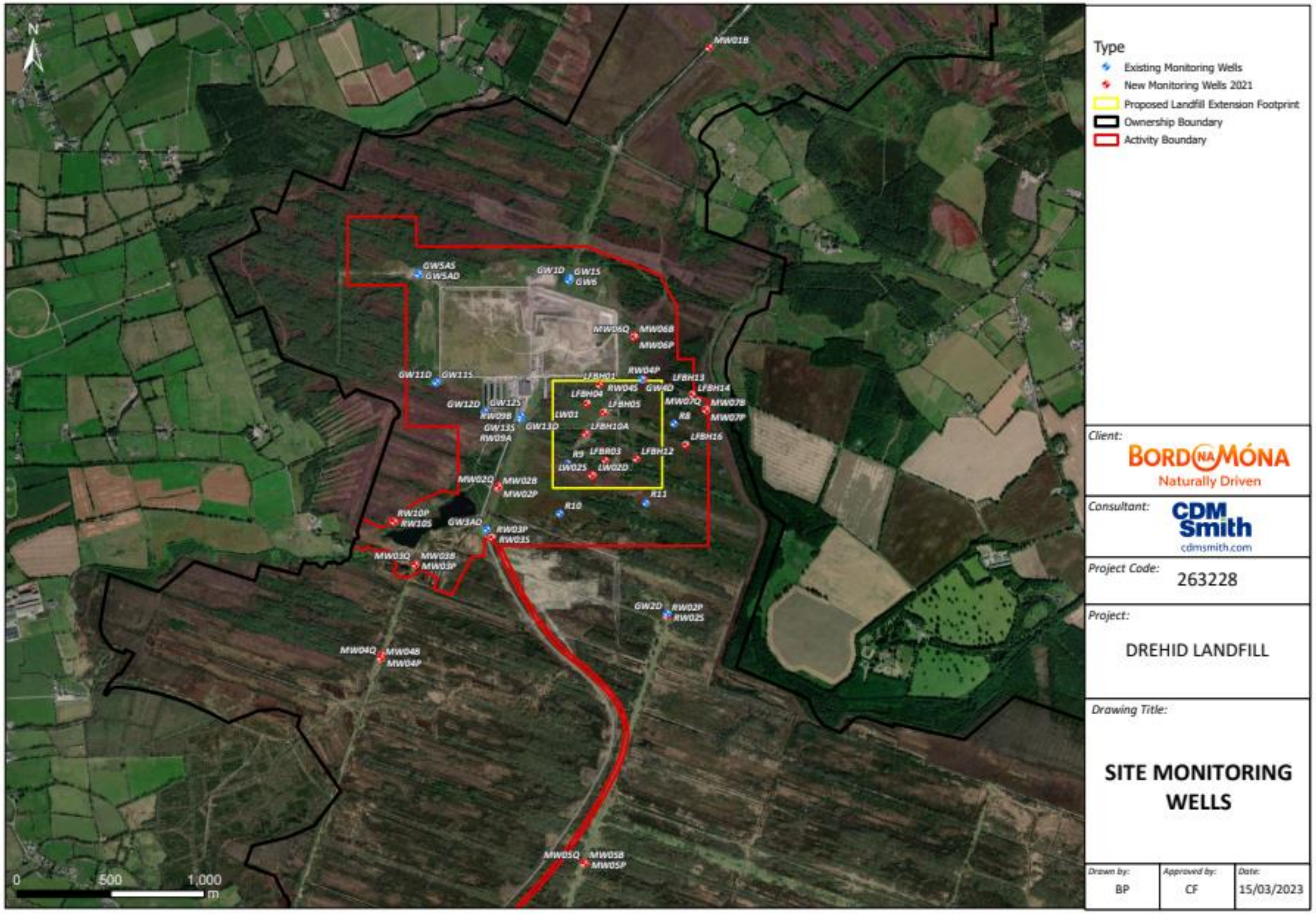

Figure 7-2 Locations of Piezometers/Monitoring Wells Installed for the Updated SI (2020-2021)

The new monitoring wells in Table 7-5 supplement the existing monitoring wells that were installed in the past (TCE, 2008; OCM, 2014; TCE, 2017). Most of the existing wells are usable and relevant to this EIAR. Data from usable existing wells were incorporated in this EIAR. Where existing wells were noted to have deteriorated or their construction details were unclear based on technical review and physical inspection, those wells were not used in the current EIAR. Accordingly, some of the new monitoring wells serve as replacement wells, whereby the intent was to upgrade or rehabilitate the existing groundwater monitoring network within TSB. These are identified by the prefix 'RW' in Table 7-5.

Nested wells covering two or more units at the same location were installed at 6 no. new and 5 no. existing well locations, the latter representing replacement wells. Nested wells were installed as separate wells, adjacent to each other (*i.e.,* not within the same borehole).

All new monitoring wells were installed with 50 mm diameter unplasticized vinyl chloride (uPVC) casing and screen materials. Response zones were gravel packed. Annular spaces above response zones were filled with hydrating bentonite pellets to hydraulically isolate the response zones from overlying units. The purpose of this was to assure that groundwater level and quality data in respective wells are representative of single hydrogeological units.

7.3.4.3 Groundwater Level Monitoring

Manual water level measurements were taken from existing and new monitoring wells on a monthly basis between September 2021 and July 2022, on dates when the same monitoring wells were sampled for groundwater quality analyses. An additional round of manual measurements was carried out in bedrock wells in July 2022 to address a data gap of summer groundwater levels in bedrock. The manually measured data are included in Appendix 7-1.

Monitoring wells in both Quaternary subsoils and bedrock were also equipped with pressure transducers for automatic recording of water levels in the period between August 2021 and June 2022. This included paired wells with response zones in different hydrogeological units. Wells that were prioritised or pressure transducer installations were those:

- Closest to the planned expansion area, in order to characterise groundwater level fluctuations near the landfill and a seasonally high water level elevation.
- At the outflow location to the Cushaling River, in order to characterise and quantify groundwater-surface water interactions.
- An outlying area in the southern part of TSB, as a means of comparing groundwater-bog interaction at this location with wells closer to the landfill.

The available transducers were purposefully moved between wells to be able to examine groundwater level responses across TSB. The longest time-series belongs to well MW02B (a bedrock well, from October 2021 through June 2022) and GW5AS (a Quaternary well, from August 2021 into April 2022). Details and findings are presented in Section 7.4.13.

7.3.4.4 Hydraulic Testing

The completed new monitoring wells in the Quaternary unit and bedrock were hydraulically tested to derive estimates of hydraulic conductivity (permeability). As presented in Appendix 7-1, testing consisted of up to 3 falling and rising head tests in each well. The testing resulted in a broader set of permeability values across the Proposed Development area, which responds to ABP's refusal of November 2020 (where questions about the permeability of the subsurface geology had been raised). Details and findings are presented in Section 7.4.15.

7.3.4.5 Groundwater Sampling

Existing and new monitoring wells were sampled on a routine basis for groundwater quality characterisation of the peat, Quaternary and bedrock hydrogeological units. Samples were analysed for physico-chemical parameters, leachate indicators, and nutrient constituents (including total ammonia) on a mostly monthly basis between August 2021 or September 2021 (depending on well) and May 2022. Sampling and laboratory analysis for a wider suite of metals was conducted in December 2021 and May 2022.

The sampling was carried out by BnM's long-term environmental monitoring contractor, which assured consistency in procedures and methods based on BnM's routine monitoring programme over many years. The laboratory analysis was conducted by an external, accredited laboratory which has an equally long track-record working with BnM.

Further details and findings are presented in Sections 7.4.19 through 7.4.23.

7.3.4.6 Surface Water Monitoring

Surface water monitoring was carried out, as follows:

- Streamflow measurements were taken on seven occasions between October 2021 and April 2022 at three outflow stations; one from Timahoe North Bog (TNB) and two from TSB. The details of the surface water monitoring are provided in Chapter 8 but relevant findings are also referenced in this Chapter 7.
- Pressure transducers were installed at the same outflow locations to record water levels continuously between August 2021 and June 2022 in order to document how stream water levels (hence also flow, qualitatively) responded across a winter season. Details are provided in Chapter 8, and findings from Chapter 8 are used to the hydrogeological characterisation in this Chapter 7.

An expanded set of surface water locations was also sampled by BnM on a regular weekly to bi-weekly basis at the existing WMF and across TSB between August or September 2021 (depending on location) and December 2022. This sampling complements BnM's ongoing surface water compliance monitoring (under license), as presented in Chapter 8. The purpose of the added monitoring was to add spatial and temporal resolution for analysis of key water quality parameters, with the goal of describing patterns and trends, and relative load contributions from different sources, within TSB. Details are provided in Chapter 8.

7.3.5 Difficulties Encountered in Compiling Information

One monitoring well in TNB, which was installed to serve as a control point for groundwater levels in bedrock to the north of the existing WMF, was damaged shortly after it was installed. Its destruction meant that groundwater levels could not be measured as intended. TSB and TNB are divided by a slight topographic high (see Chapter 8), and conceptually, TNB is in a different groundwater catchment from TSB, since groundwater flow gradients are influenced by topography.

As described in Section 7.4.13, the groundwater level data from other wells are sufficient to conclude that a groundwater divide exists between TNB and TSB. Hence, the absence of the data point in TNB does not materially affect the presentation in this Chapter 7.

No other significant constraints were encountered during the compilation of this Chapter. A robust evaluation of likely significant effects on soils, geology and hydrogeology has, therefore, been possible.

7.4 BASELINE ENVIRONMENT

7.4.1 Physiography and Topography

The Proposed Development area (red boundary outline in Figure 7-3) is situated entirely within TSB (purple outline boundary in Figure 7-3). TSB covers a total area of approximately 17.07 km^2 (BnM, 2022) and ranges in elevation between approximately 80 and 90 mOD. The site topography is generally flat, and based on detail LiDAR digital terrain model data, the ground profile slopes at angle of less than 1°.

TSB is surrounded by gentle hills that reach maximum elevations of 116 mOD in the townland of Hodgestown to the east and 142 mOD in Carbury to the west.

TSB is crossed by a network of artificial drains which in the past served to facilitate BnM's peat extraction activity. The drains can be up to 4 m deep and 4 m wide, extending through both peat and subsoils. The landfill expansion area currently forms a drained mosaic of young pine and scrub woodland with dry heath. (Photo 1).

Photo 1 Landfill Expansion Area Viewed From the Existing WMF (Looking South, August 2020)

TSB is surrounded by agricultural lands to the west, south and east, with a scattered rural pattern of farms and residential dwellings along local roads. TSB transitions north across a gentle topographic saddle where the bog becomes referred to as TNB (see Figure 7-3).

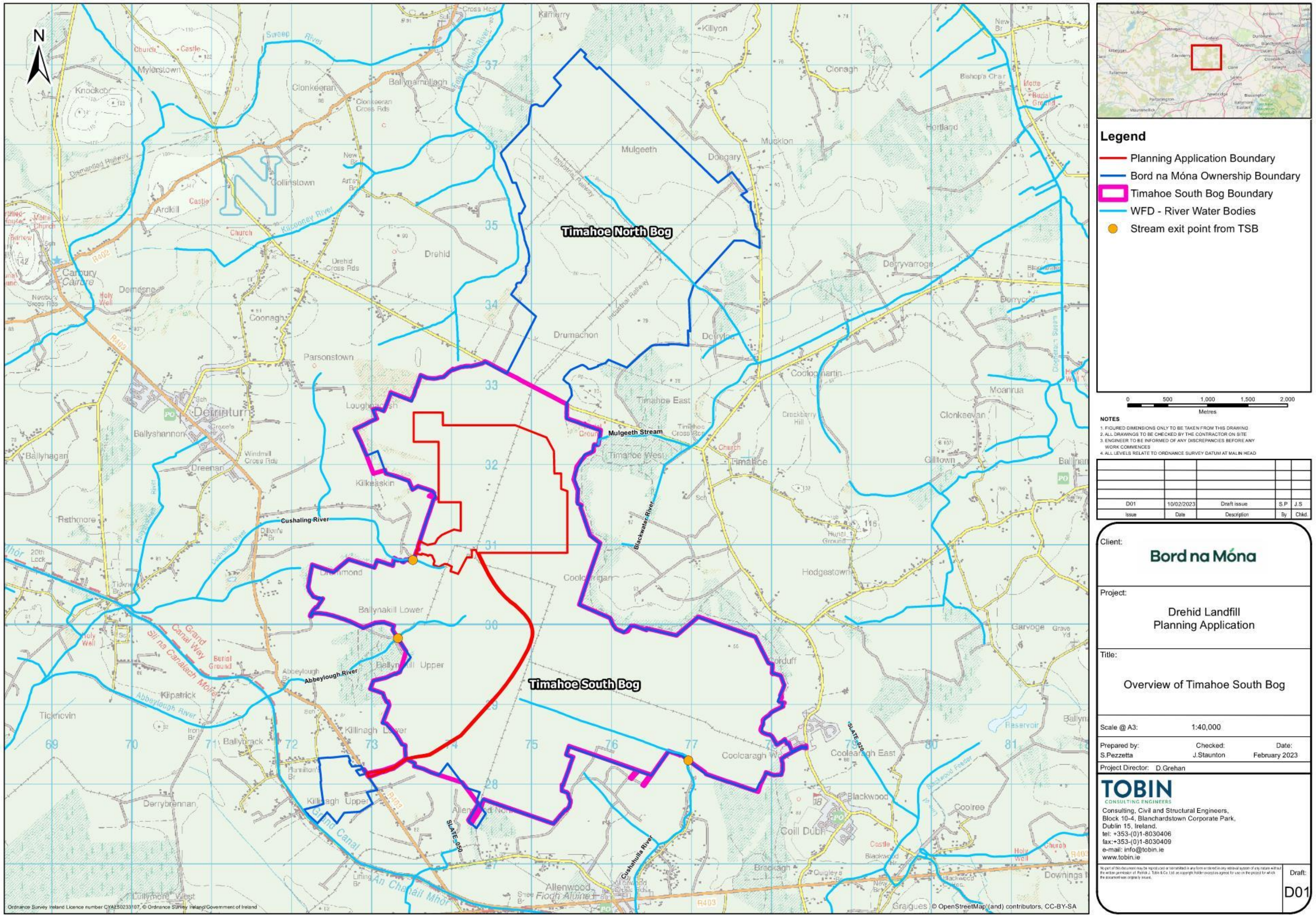

Figure 7-3 Overview of TSB and Proposed Development Boundary

7.4.2 Soils

Soils within TSB and the landfill expansion area consist entirely of cutover peat (Figure 7-4). TSB is bordered by mineral poorly drained soils to the west and south, and mainly by mineral well drained soils to the east. Alluvial sediments are mapped by GSI in a narrow band along the Cushaling River where the river exits the BnM landholding to the west.

The residual peat with TSB, which is exposed along drains (Photo 2) and along margins of stripped peat areas, is soft, dark orange/brown to black, and fibrous with many rootlets.

Photo 2 Exposed Peat Along Drain Near the Landfill Expansion Area

Based on data presented in the 2017 EIAR, the thickness of residual peat across TSB ranges from zero (stripped peat) to 7.7 m. Based on the additional information from newly drilled boreholes in and around the landfill expansion area, recorded thicknesses range from zero (where peat is stripped) to 3.5 m (borehole LFTB01 in the northwest corner of the landfill expansion footprint).

7.4.3 Subsoils

Subsoils across TSB (at ground level) are mapped by GSI as 'cutover raised peat' (Figure 7-5). To the west, south and east of TSB, subsoils are mapped as glacial till derived from limestones ('TLs' in Figure 7-5). Quaternary age gravel bodies are also mapped near Cushaling River just west of the Borrow Pit at the western margin of the BnM landholding (indicated by green polygons in Figure 7-5). The Borrow Pit is a former sand quarry pit which now forms a small lake.

The new boreholes drilled within the Proposed Development area generally encountered peat, glacial till ('boulder clay'), and limestone bedrock. The till is predominantly a CLAY with variable composition of silt, sand, gravel, pebbles and cobbles. The CLAY can be significantly silty, sandy and gravelly (Photo 3). The CLAY matrix ranges from soft to stiff, and plasticity ranges from low to high. An illustrative example of the clay/silt-dominated till is shown in Photo 4.

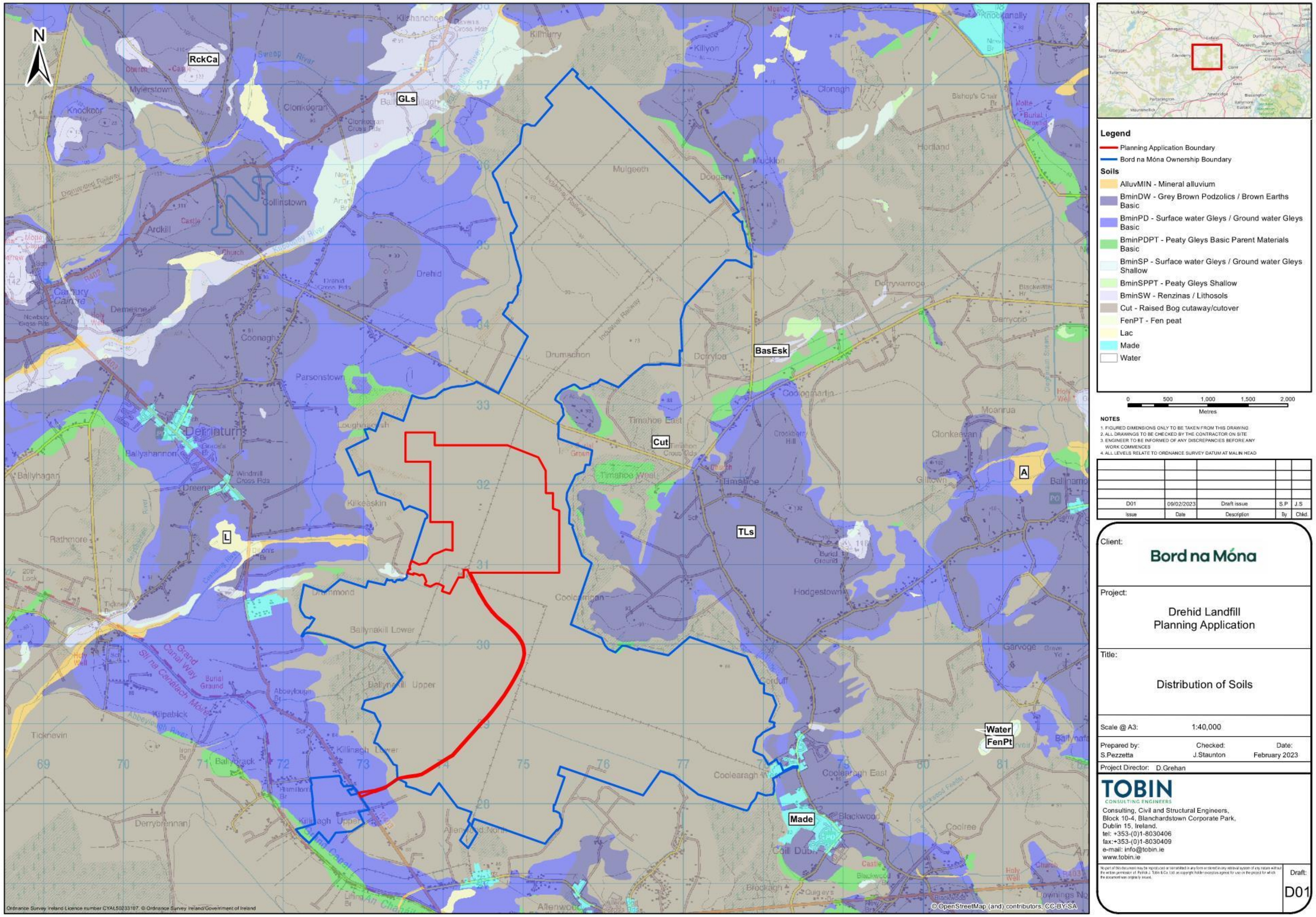

Figure 7-4 Distribution of Soils

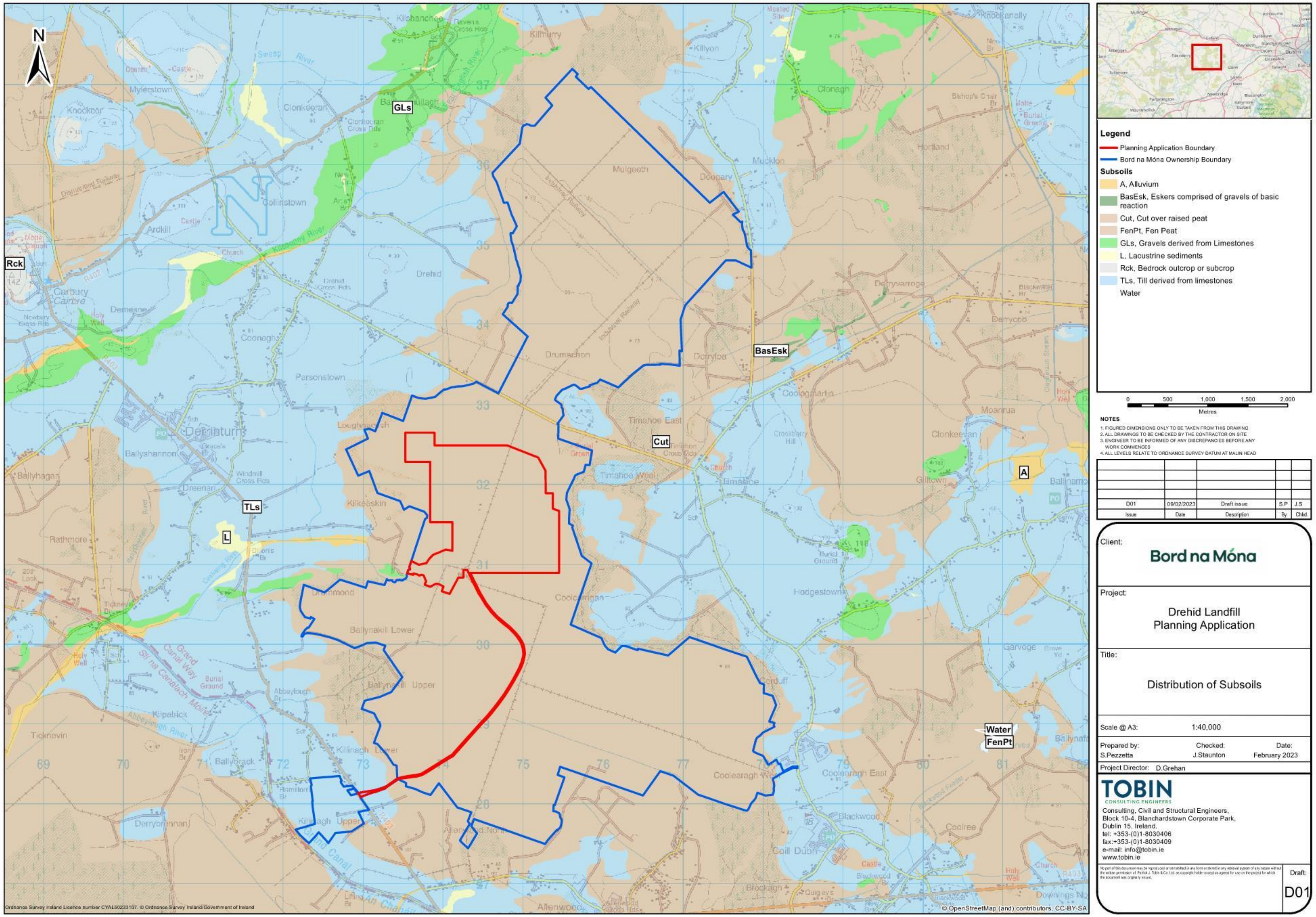

Figure 7-5 Distribution of Subsoils

Photo 3 Exposed Subsoils Beneath Stripped Peat Near the Landfill Expansion Area

Photo 4 Glacial Till Core, Borehole MW02B (Peg ID: WLMW02W), 22.5-24.0 m Depth

Sand- and gravel-grade sediments are also present within the till. These occur at different depths within and between boreholes. As such, they appear as lenses, but in three dimensions they may be interconnected in which case they will form a network of sand and gravel channels. Due to the observed variability between boreholes, the geometry or extent to which the sands and gravels are contiguous at depth cannot be ascertained with certainty.

In individual boreholes, recorded sand and gravel intervals range in thickness from <0.3 to 7.5 m. The latter was recorded between 3.5 and 11 m depth in borehole LFTB01 at the northern end of the landfill expansion area, and directly above bedrock (See Section 7.4.5).

During the recent SI, 11 no. sand/gravel samples were selected for particle size distribution analyses. Laboratory data sheets are provided in Appendix 7-1 and results are summarized in Table 7-6. All 11 samples can be characterised as poorly sorted sediments with variable silt fractions and with less than 10% percent passing of clay. These findings are consistent with geological information provided in the previous EIAR (TCE 2017), which is included as Appendix 7-2 (TCE, 2017).

In the most recent SI boreholes that were cored through the Quaternary sediments, the sand and gravel dominated intervals are manifested by poor core recovery (Section 7.4.5). The coarser-grained nature of these sediments is hydrogeologically significant, as they are more permeable than surrounding clays and silt. This is also acknowledged and reflected in the 2017 EIAR (TCE, 2017).

Two other boreholes slightly to the west of LFTB01, namely GW-13D (OCM, 2014) and BH01 (Causeway, 2016) recorded the presence of sand and gravel sediments at depth, and the driller's log from GW-13D included a note of "*large volume of water in gravel*" between 4.5 and 11.5 m depths (OCM, 2014).

7.4.4 Bedrock

Bedrock across TSB is mapped by GSI mainly as 'Waulsortian Limestone', with the Lucan Formation present to the northwest, the Allenwood Formation present to the east, and the Boston Hill Formation present to the south (Figure 7-6). The Waulsortian Limestone is a massively bedded, pale to dark grey limestone which incorporates skeletal debris and dark grey carbonate mud (McConnel and Philcox, 1994). The Lucan Formation, also referred to as the 'Calp' limestone, comprises interbedded dark grey, argillaceous limestone and black shales. The Allenwood Formation is a pale to dark grey limestone with minor shales. Finally, the Boston Hill Formation comprises muddy limestones and shale (McConnell and Philcox 1994).

The dominant structural geological trend is northeast-southwest (McConnell and Philcox, 1994), with both faulting (thick black lines in Figure 7-6) and folding orientated along this axis. Conjugate sets of northwest-southeast trending faults are also mapped by GSI. A northwest-southeast trending fault is interpreted by GSI through the southern part of TSB (Figure 7-6). This fault juxtaposes the geologically older Waulsortian Limestones against the geologically younger Boston Hill Formation, which means the fault is interpreted by GSI to be a 'normal fault' with the downthrown block to the northeast.

Table 7-6 Summary of Grain Size Distribution Analysis

Borehole ID	Peg ID	Top Sample (mbgl)	Bottom Sample (mbgl)	Field Description of Unit From Which Sample Was Taken	Gravel (% dry mass)	Sand (% dry mass)	Silt (% dry mass)	Clay (% dry mass)	Uniformity Coefficient
LFBH01	LFBH01	7.50	8.50	Grey slightly sandy slightly gravelly CLAY	42.8	26.3	23.5	7.4	830
LFBH03	LFBH03	2.50	3.50	Dark grey slightly gravelly silty CLAY with medium boulder content	24.5	31.6	39.3	4.6	86
LFBH11	LFBH11	3.00	4.00	Dark grey slightly gravelly silty CLAY with medium boulder content	34.6	24.8	33.4	7.2	370
LFBH12	LFBH12	3.00	3.50	Grey clayey sandy GRAVEL	66.5	18.6	11.9	3.0	480
LFBH14	LFBH14	6.00	8.50	Grey/pale grey clayey very gravelly SAND[1]	51.0	33.5	11.4	4.1	580
LFBH17	LFBH17	4.50	5.50	Dark grey slightly gravelly silty CLAY with medium boulder content	18.4	18.3	57.6	5.7	19
LFBH17	LFBH17	7.00	8.00	Dark grey slightly gravelly silty CLAY with medium boulder content	48.2	21.7	25.5	4.6	920
LW01	LFMW01	5.00	6.00	Dark grey gravelly CLAY with low boulder content[2]	41.7	21.8	28.5	8.0	780
LW01	LFMW01	8.00	10.00	Pale grey slightly clayey sandy GRAVEL	47.4	45.7	7.0	-	15
LW02D	LFMW02	7.00	8.00	Grey slightly clayey sandy GRAVEL	49.8	30.9	16.1	3.2	250
LW02D	LFMW02	10.00	11.00	Grey SAND & GRAVEL	15.7	77.0	7.0	-	3.1
MW02B	WLMW02W	3.85	4.85	Light grey/brown slightly clayey SAND & GRAVEL	71.8	20.6	8.0	-	73
MW05B	WLWM05W	7.50	9.00	Grey clayey very gravelly SAND with low cobble content	73.7	20.8	6.0	-	57
MW05Q	WLMW05Q	7.50	10.40	Brownish grey slightly clayey very sandy GRAVEL	49.9	33.2	16.2	0.7	170
MW06Q	WLMW06Q	9.00	11.40	Grey gravelly sandy CLAY with high cobble content	21.5	28.5	39.4	10.6	88
MW07Q	WLMW07Q	4.95	6.00	Pale grey slightly gravelly slightly sandy CLAY	32.3	25.4	32.3	10.1	280
RW02S	RWGW02D	4.00	10.00	Grey slightly silty sandy GRAVEL	44.6	26.6	22.8	6.0	640
RW04S	RWGW04D	3.50	5.50	Grey/pale grey slightly sandy gravelly CLAY[2]	42.3	23.0	27.7	7.0	810
RW04S	RWGW04D	8.00	10.00	Grey slightly sandy clayey GRAVEL	67.5	15.6	12.6	4.3	700
RW09A	RWGW09S	2.00	4.00	Grey slightly clayey very sandy GRAVEL	84.3	14.9	1.0	-	3.5
RW09B	RWGW09D	8.00	10.00	Dark grey slightly clayey sandy GRAVEL	47.0	30.1	17.2	5.7	620
RW10S	RWGW10D	3.00	4.50	Grey gravelly SAND	69.8	26.1	4.0	-	17

Note: [1]gravel content higher than sand in results; [2]whole unit (not descriptive of sample result)

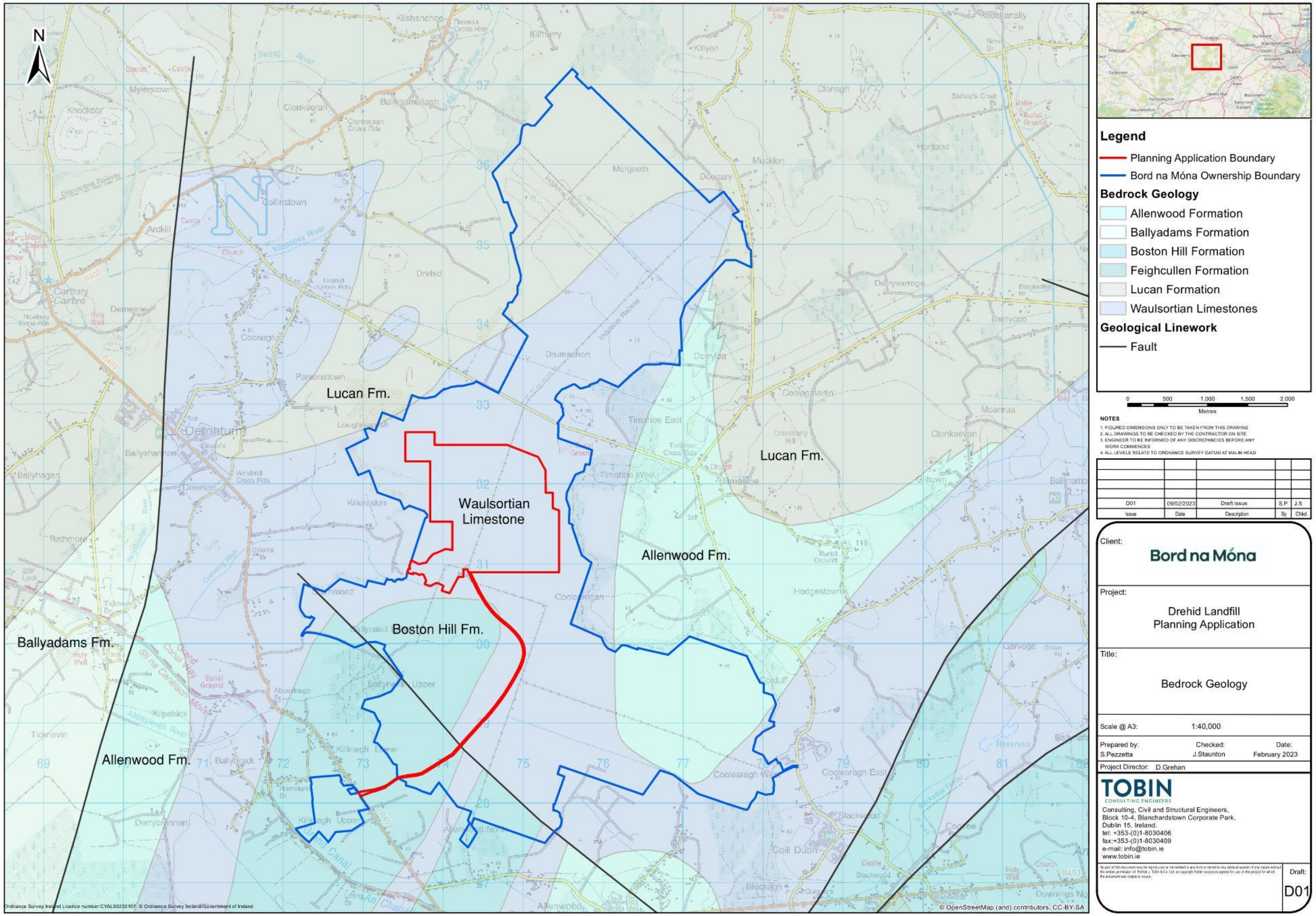

Figure 7-6 Bedrock Geology Map

Eleven of the new SI boreholes were cored in bedrock. The cores are mainly described as massive pale grey to greyish-black limestone with prevalent calcite veining. The bedrock is extensively jointed and fractured, and partially to extensively weathered (Photo 5).

Photo 5 Bedrock Core, Borehole MW02B (Peg ID: WLMW02W), 36.0-37.5 m Depth

Fractures are infilled with sediments, mainly clays, that range in colour from predominantly light brown to brown, and blueish grey. Orange-brown staining is also visible along fracture surfaces.

The bedrock surface beneath the Proposed Development area is well defined based on confirmatory data from drilling. As documented in Table 7-7, the confirmed (drilled) depth to bedrock across the landfill expansion area ranges from 11.00 to 21.80 metres below ground level (mbgl). This is consistent with past geophysical survey results (Apex, 2016) which had indicated (without the benefits of drilling) that the thickness of overlying till ("overburden") would range from approximately 9 to 25 m.

Table 7-7 Confirmed Depths To Bedrock From Borehole Logs

ID	X (ITM)	Y (ITM)	Depth to Bedrock (mbgl)	Bedrock Elevation (mOD)
GW1D	674702.468	732320.952	12.00	72.678
GW2D	675222.810	730529.793	15.00	72.181
GW3aD	674263.304	730979.641	28.10	56.508
GW4D	675087.817	731782.171	14.00	70.578
GW5aD	673898.862	732340.921	7.20	79.279
GW6	674699.823	732303.991	24.00	60.854
GW11D	673992.506	731764.156	21.80	62.918
GW12D	674251.971	731604.858	19.70	63.353
GW13D	674445.034	731580.463	16.60	67.566
LFBH04	674796.811	731649.998	13.00	70.818
LFBH16	675323.466	731430.022	11.25	74.462
LFBR01	675051.573	731682.629	14.75	69.148
LFBR02	675020.003	731405.406	21.80	63.561
LFBR03	674893.240	731346.472	20.50	64.373
LFTB01	674677.786	731752.035	11.00	72.012
MW01B	675446.666	733547.562	16.05	69.250
MW02B	674319.353	731198.759	31.20	53.474
MW03B	673882.752	730795.538	9.00	75.060
MW04B	673695.130	730288.387	12.85	71.576
MW05B	674783.814	729202.735	12.90	72.765
MW06B	675049.201	732007.368	13.00	69.695
MW07B	675430.174	731615.734	7.50	79.092
WLPC01	673781.255	731292.732	14.50	68.797

ID	X (ITM)	Y (ITM)	Depth to Bedrock (mbgl)	Bedrock Elevation (mOD)
R8	675260.700	731544.100	12.30	73.400
R9	674692.800	731335.200	14.50	69.730
R11	675110.700	731123.200	10.90	75.850
GW7	674718.470	733025.761	123.80	-28.700

Across TSB, the depth range is much broader, from 7.2 to 123.8 mbgl. The latter refers to a borehole (BH7/GW7) which was drilled at the northern TSB boundary in 2003. The great depth was ascribed to the presence of a deep Tertiary age erosional channel through bedrock which has been filled in with Tertiary age clays and glacial till (TCE, 2008, TCE 2017).

Converted to mOD, the reported, confirmed bedrock surface elevations are depicted in Figure 7-7. The bedrock surface is uneven. Although there is a general deepening of the surface from (north)east to (south)west across the landfill expansion area, there is no clear trajectory of the Tertiary erosional channel across TSB.

7.4.5 Lithological Detail of the Landfill Expansion Area

Three of the new SI boreholes in the planned expansion area (LFBR01, LFBR02, and LFBR03) were cored through subsoils and into bedrock. These boreholes provide details of the complete lithological succession in the planned expansion area. A photographic log of each borehole is presented in Appendix 7-3.

Peat in the landfill expansion area was penetrated by several boreholes and the recorded thicknesses ranged from 0.0 to 3.5 m.

The dominant subsoil lithology is silty, sandy and gravelly CLAY with variable content of cobbles and pebbles (of limestone). The CLAY is significantly silty, sandy or gravelly, and in certain instances the definition of what constitutes a sandy/gravelly CLAY or a clayey SAND or GRAVEL is at the geologist's discretion.

In LFBR01, sand and gravel-grade sediments (with silt and clay) were described from the following depth intervals: 6.80-7.05, 10.50-11.30 (left side of Photo 5), and 13.50-14.75 m, the latter resting directly on bedrock. These intervals correspond to elevations of 77.10-76.85, 73.40-72.60, and 70.40-69.15 mOD, respectively.

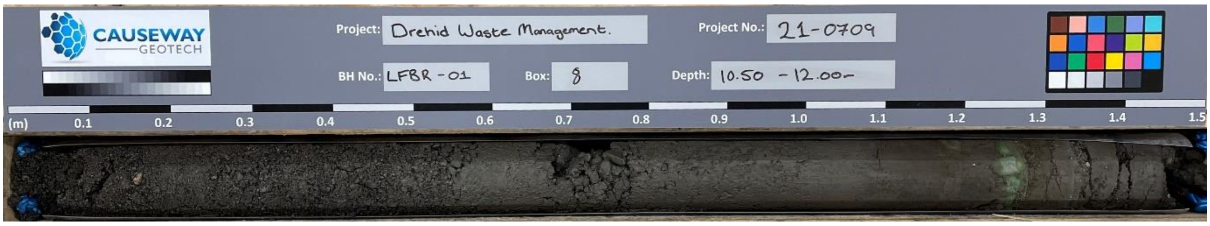

Photo 6 Predominantly Sand, 10.50-11.30 m Depth, in Borehole LFBR01

In LFBR02, predominantly sand and gravel-grade sediments (with silt and clay) were described from the following depth intervals: 6.00-6.95, 9.90-10.70, 11.90-12.50, and 19.50-21.80 m, the latter also resting directly on bedrock. These intervals correspond to elevations of 79.36-78.41, 75.46-74.66, 73.46-72.86, and 64.26-63.56 mOD, respectively.

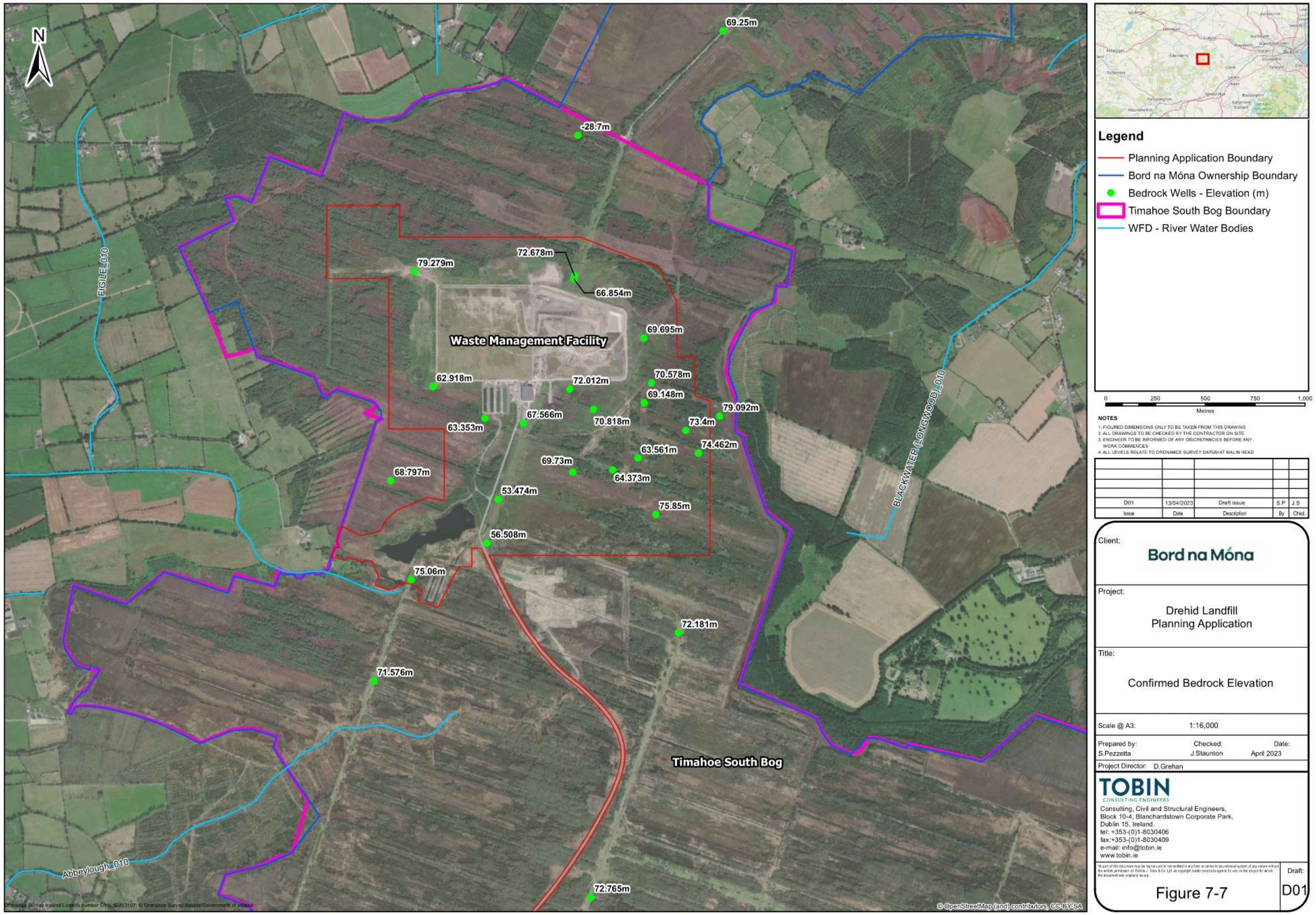

Figure 7-7 Confirmed Bedrock Surface Elevations (mOD)

In LFBR03, predominantly sand and gravel-grade sediments (with silt and clay) were encountered at the following depth intervals: 6.00-7.65, 10.40-11.95, and 13.80-20.50 m, the latter resting on bedrock as well. These intervals correspond to elevations of 78.87-77.22, 74.47-72.92, and 71.07-64.37 mOD, respectively. An interval from 18.15-20.50 m (or 66.72-64.37 mOD) consisted mainly of cobbles and pebbles, and a high cobble content was also recorded from 13.80 m depth, as shown in Photo 7, which is also characterised by poor core recovery.

Photo 7 Core, Borehole LFBR03, 13.50-15.00 m Depth

In borehole LFBR01, bedrock was encountered 14.75 mbgl (69.15 mOD). The borehole was cored 3.25 m into bedrock. The core log is described as a massive, grey limestone with calcite veining (up to 15 mm thick) and weathered, sediment (mainly clay)-filled joints and fractures (Photo 8).

Photo 8 Core, Borehole LFBR01, 15.00-16.50 m Depth

In borehole LFBR02, bedrock was encountered 21.80 mbgl (63.56 mOD). The borehole was cored 4.10 m into bedrock. The core log is described as a massive, grey limestone with calcite veining (up to 25 mm thick), and is partially weathered with orange-brown stained joint surfaces and clay-infilled fractures (20-80 mm thick).

In borehole LFBR03, bedrock was encountered 20.50 mbgl (64.37 mOD). The borehole was cored 1 m into bedrock, with a similar description as LFBR02.

Other boreholes in the landfill expansion area did not fully penetrate the till, but also recorded predominantly sand and gravel-grade materials, as follows:

- LFBH01: 78.25-75.75 mOD
- LFBH07: 81.46-79.96, 77.97-<75.46 mOD
- LFBH09: 78.81-78.44, 75.51-75.01 mOD
- LFBH10A: 83.29-81.59 mOD
- LFBH17: 80.12-79.62 mOD

Based on these data, and with consideration of past boreholes drilled in the same or surrounding area (TCE, 2008; OCM, 2015; Causeway, 2016; and TC, 2017), interpreted geological cross-sections across the landfill expansion area are presented as indicated in Figure 7-8 (cross-section line locations), with one oriented NE-SW (Figure 7-9) and two oriented N-S (Figures 7-10 and 7-11).

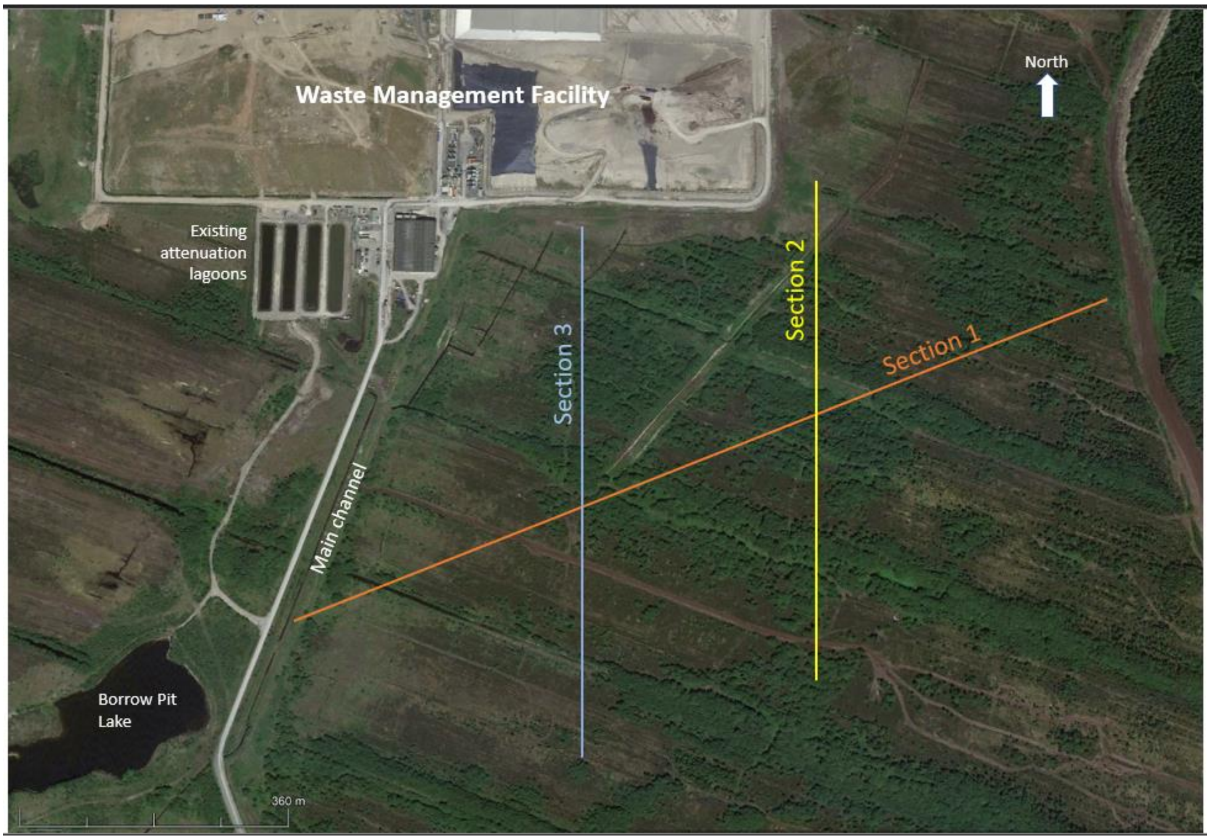

Figure 7-8 Geological Cross-Sections Location Map

7.4.6 Geological Resources

Commercial peat extraction by BnM ceased in the late 1980s. The remaining peat is significantly degraded and drained. Residents around TSB still extract peat along the margins of the bog, but not within the redline boundary.

The planned landfill expansion area has not been assigned a granular aggregate potential by GSI. The nearest mapped aggregate potential is noted where "gravel bodies" are marked on the Quaternary map cover (Section 7.4.3). Here, the GSI's 'granular aggregate potential' is mapped as "Low" [5]. As stated above, a former sand and gravel quarry, which is now referred to as the Borrow Pit, forms a small lake in the same general vicinity.

GSI's 'crushed rock aggregate potential' (of bedrock) within TSB is mapped as "Low" and "Moderate", depending on location. There are no bedrock outcrops within TSB.

7.4.7 Geological Heritage

There are no recorded or GSI-mapped Geological Heritage sites, mineral deposit sites or mining sites (current or historic) within TSB. The nearest such site is in Carbury where the Calp limestone is exposed in a disused quarry (county side code KE011), approximately 6 km to the northwest of the existing WMF.

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[5] https://www.gsi.ie/en-ie/data-and-maps/Pages/default.aspx

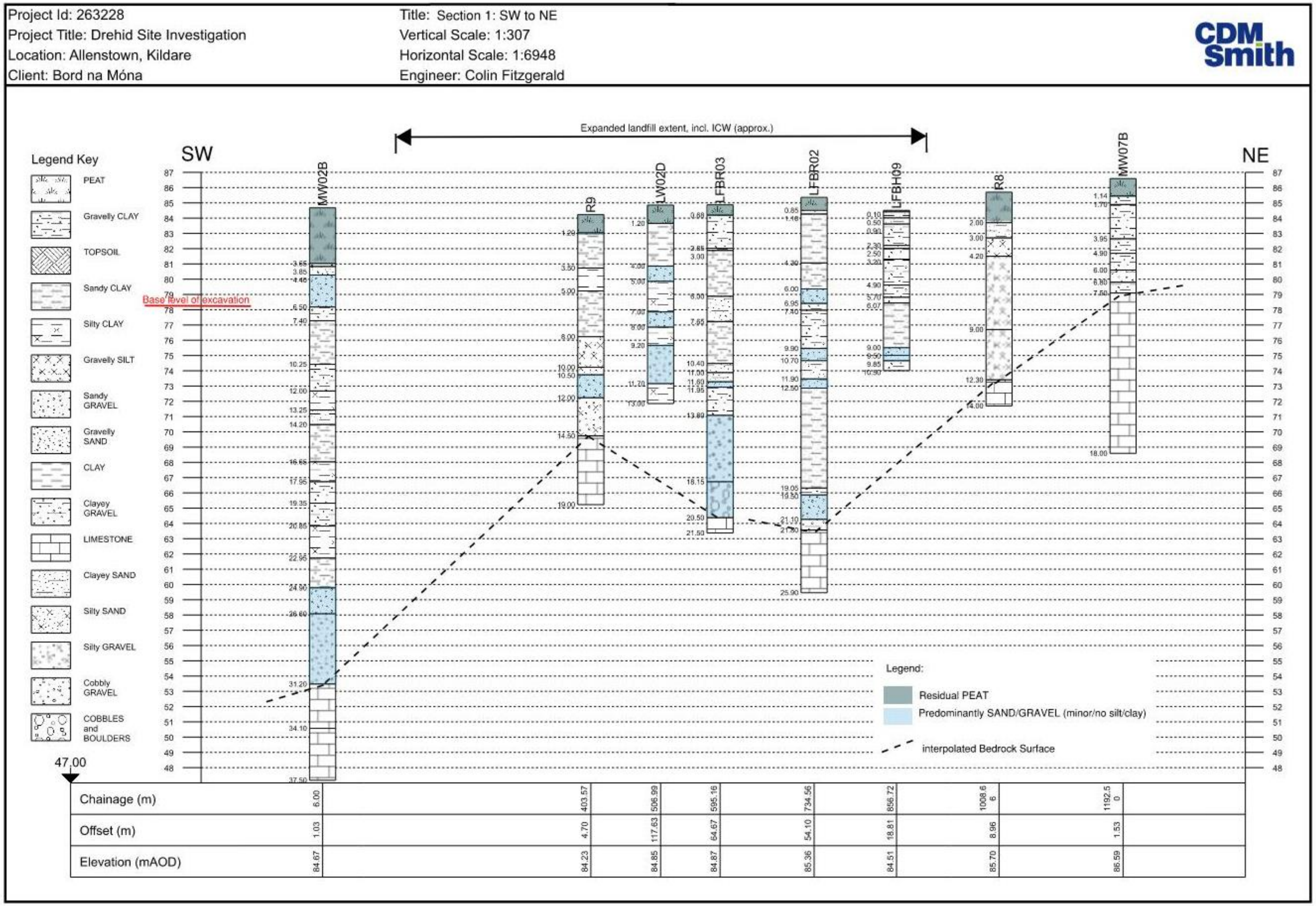

Figure 7-9 Geological Cross-Section 1: NE-SW Across the Landfill Expansion Area

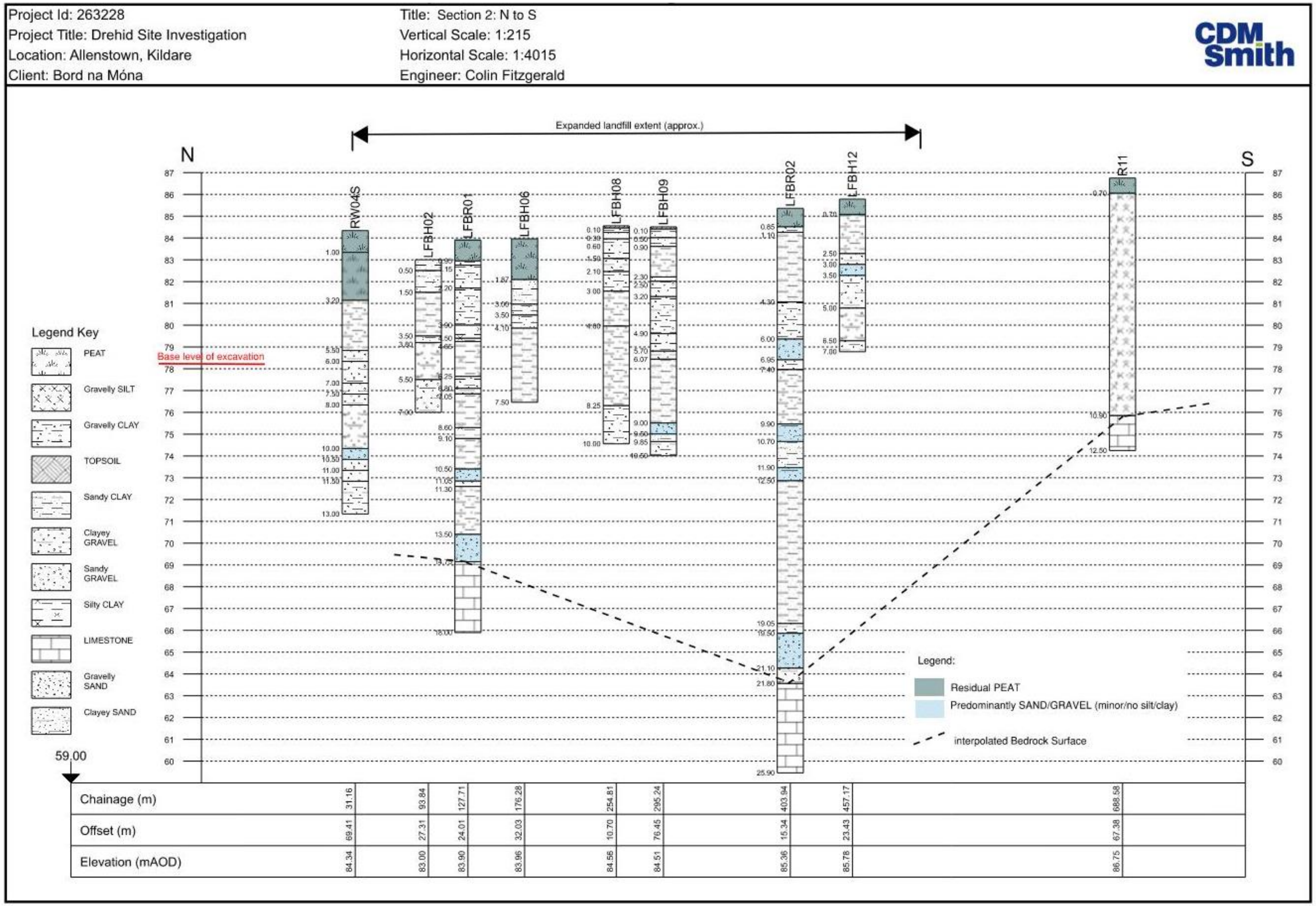

Figure 7-10 Geological Cross-Section 2: N-S Across the Landfill Expansion Area

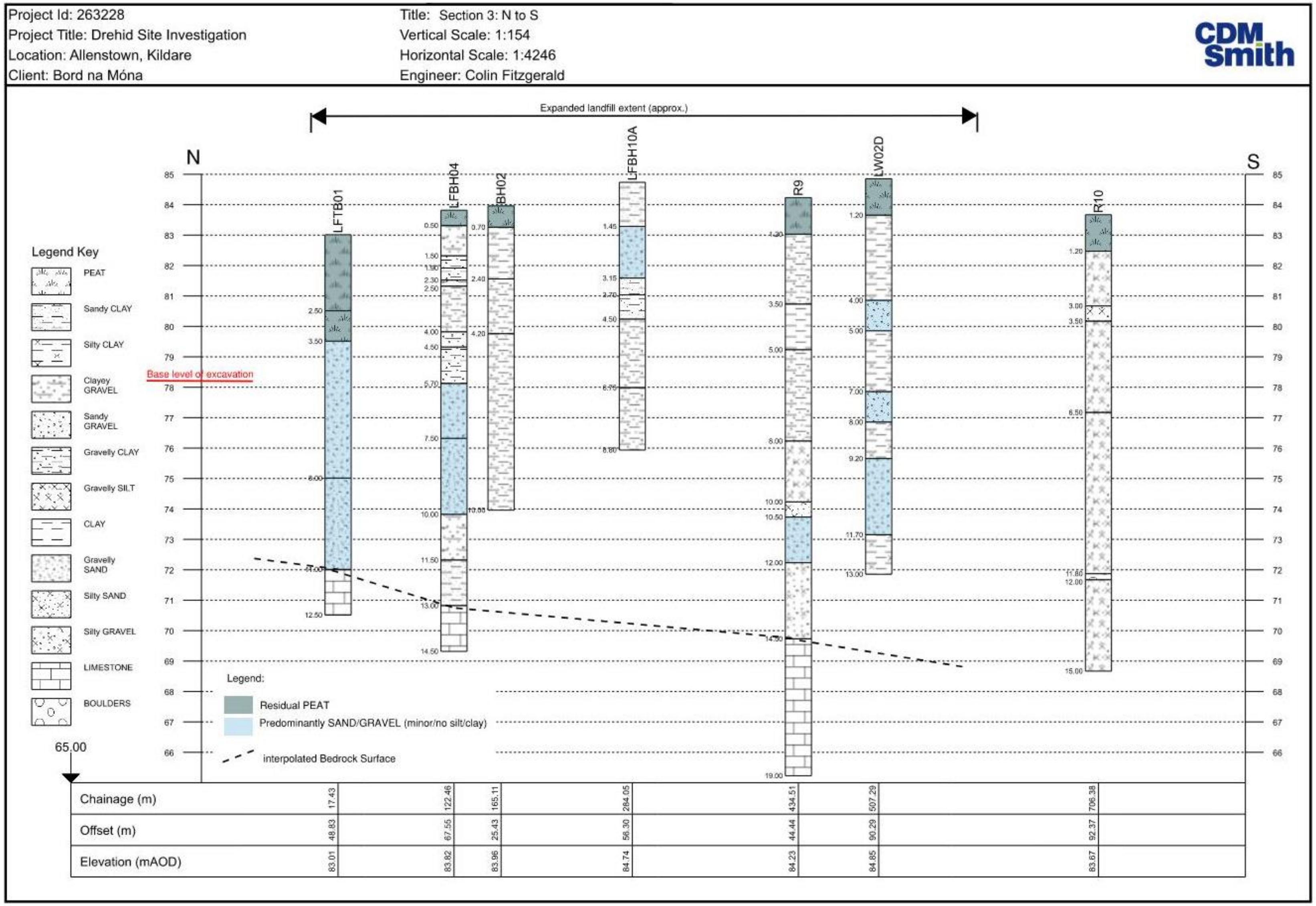

Figure 7-11 Geological Cross-Section 3: N-S Across the Landfill Expansion Area

7.4.8 Geohazards

Landslide susceptibility in TSB is mapped by GSI as "Low" across TSB. The mapping considers topographic slope, soil type and concentration/dispersion of overland flow. Peat can be mobilized when disturbed, but given the flat topography, there are no identified, specific geohazards within the planned expansion area (Appendix 7-6). There are also no incidents of peat slides within Timahoe Bog in the past.

7.4.9 Aquifer Classification

Based on regional information, the GSI considers the Waulsortian Limestone across TSB to be an 'Ll' aquifer (Figure 7-12), which is defined as a "*Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones*". The Allenwood Formation to the east of TSB is mapped as an 'Lk' aquifer, or "*Locally Important Aquifer – Karstified*".

Aquifer type designations are based on regional interpretations by GSI. The different categories refer to groundwater resource potentials. Locally important aquifers can be developed for water supply purposes, but they are less significant (mainly as a resource for water supply) compared to regionally important aquifers in the GSI classification scheme.

The differentiation between 'Ll' and 'Lk' aquifer categories is the nature of the bedrock aquifer itself. The 'k' in 'Lk' refers to 'karstified'. It means the bedrock has been subject to a process of 'karstification', which mainly occurs in limestones, and which is manifested by solutionally enlarged fractures or conduits (such as the Burren of Co. Clare). Solution conduits can be of considerable hydrogeological significance as groundwater and associated pollutants can travel far (over several kms) in short periods of time (hours, days). The presence of karst means there is an inherently greater risk of pollution impact at greater distances from a given site.

There are no recorded karst features in GSI's national karst feature database in or around TSB. This does not necessarily mean they are absent, However, neither open nor sediment-filled karst conduits were encountered or noted in any of the boreholes that were drilled onsite to date, neither in the past SIs nor during the most recent SI. Nevertheless, the presence of buried karst in the Waulsortian Limestone is known from literature elsewhere in Ireland (e.g., Murray and Henry 2018), hence the potential for presence of (buried) karst beneath the glacial till cannot be ruled out, even if conduits are likely clay-infilled (as indicated by clay-infilled fractures in bedrock cores).

7.4.10 Public and Private Water Supply

The nearest public water supplies (PWSs) are the Johnstown PWS and Robertstown PWS to the northeast and southeast of the landfill expansion area, respectively (Figure 7-13). Both abstract groundwater. The Johnstown PWS abstracts groundwater from the bedrock aquifer while Robertstown PWS is mainly sourced from wells installed in gravels above bedrock. Both PWSs have defined source protection zones (SPZs) but these do not extend to TSB. The shortest distance from the landfill expansion area to respective Outer SPZs are approximately 4.8 and 7.1 km, respectively.

The nearest PWS that is sourced from surface water in a downstream direction from TSB is in Athy, on the River Barrow, more than 30 km (straight-line distance) from the BnM landholding.

With regard to private wells, there are dwellings and farms in all directions around TSB. The nearest dwellings are more than 1 km from the existing WMF and landfill expansion area.

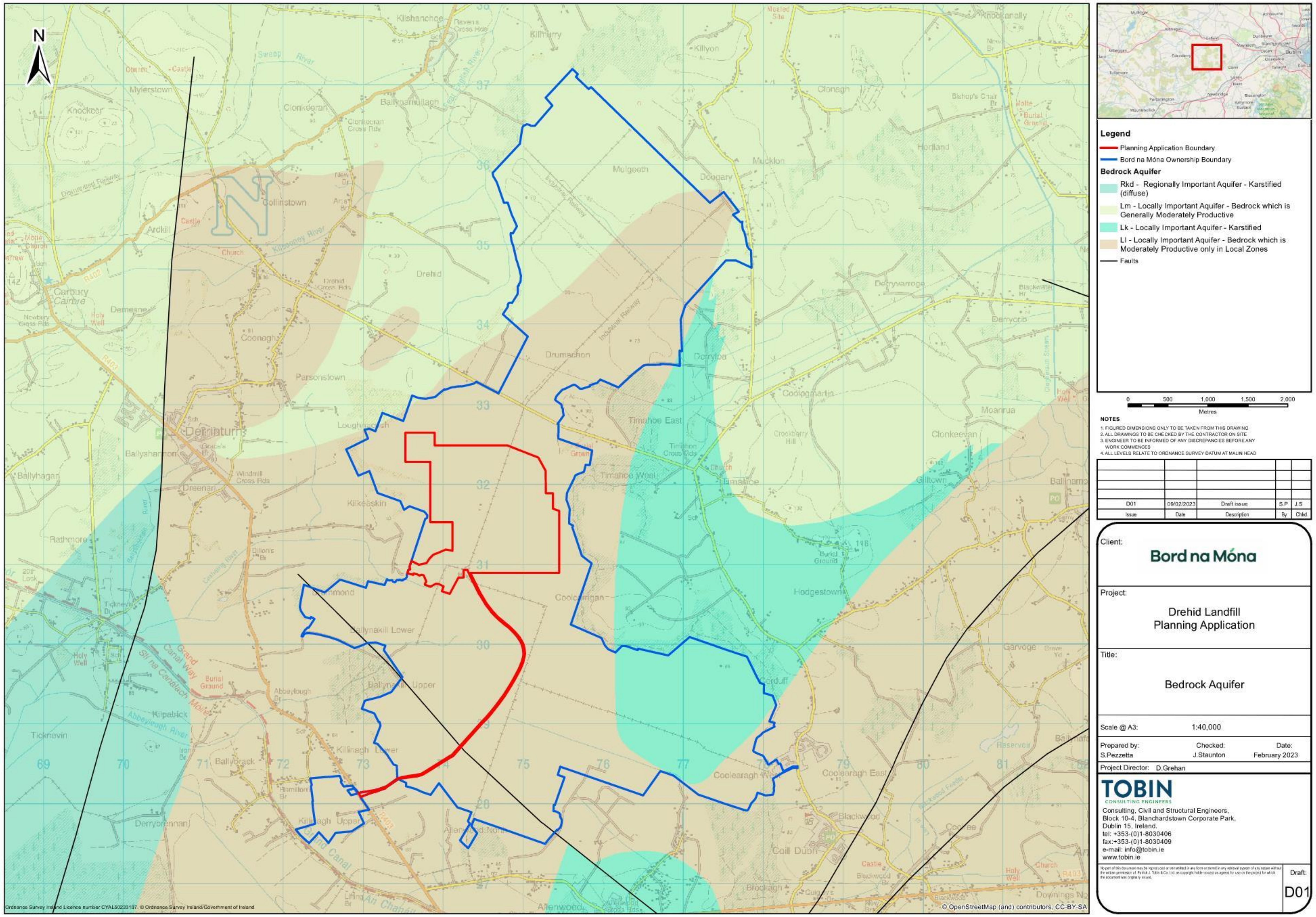

Figure 7-12 Bedrock Aquifer Classification Map

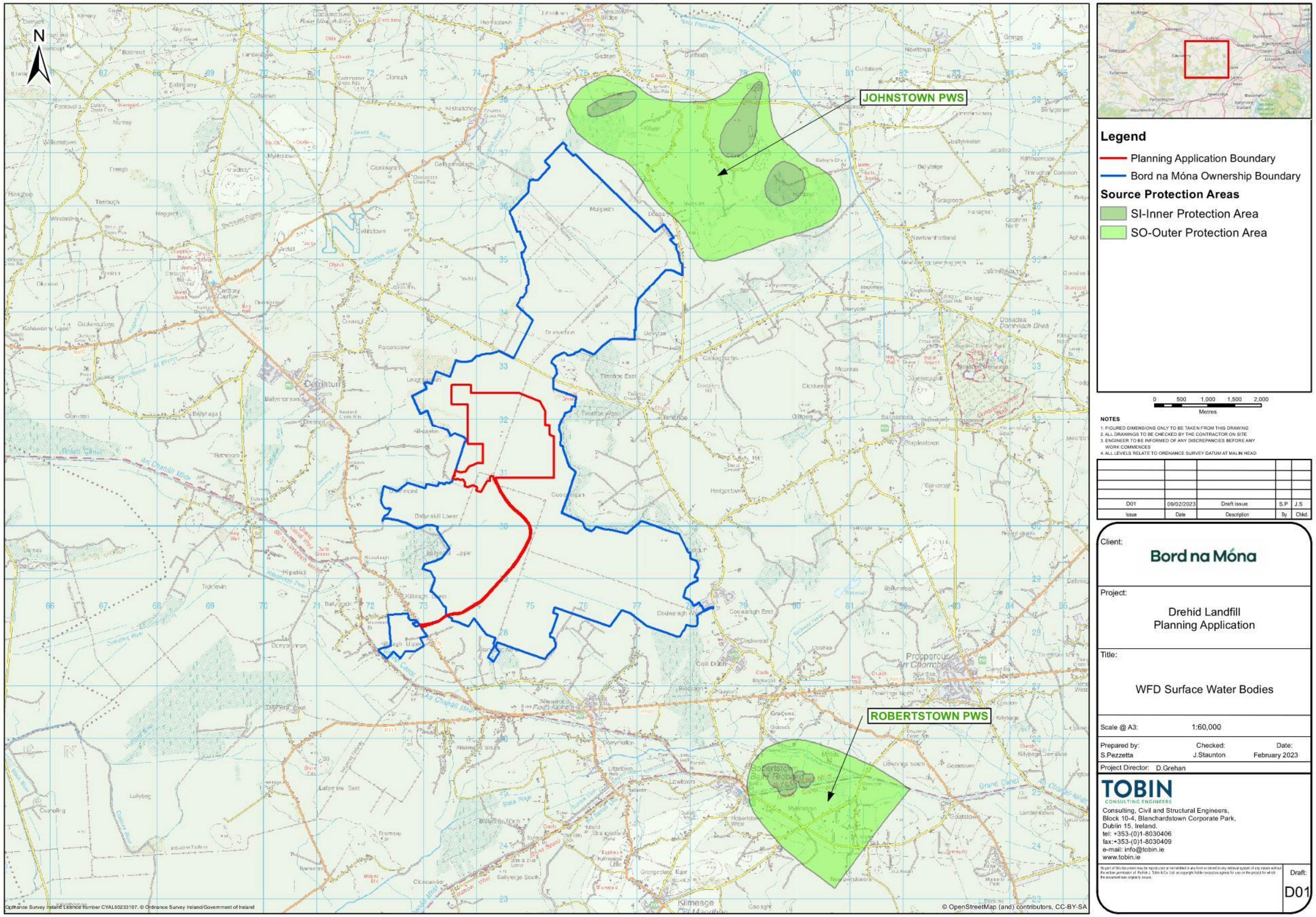

Figure 7-13 Source Protection Zones of Groundwater-Sourced PWS in Relation to Proposed Development Area

Dwellings are connected to public water supply but some dwellings, and farms especially, may retain use of private wells. The nearest private well in a downstream direction from the landfill expansion area is just west of the BnM landholding boundary, and this well regularly sampled by BnM (Section 7.4.18). There are no private wells directly between the WMF or landfill expansion area and the Cushaling River.

7.4.11 Groundwater Vulnerability

The GSI has mapped groundwater vulnerability, which applies to the bedrock aquifer, as 'Low' across TSB. This is based on the combined consideration of 'Low' permeability subsoils (i.e. clays/silt) and large depth to bedrock (>10 m). The new site-specific subsoil information from boreholes drilled within the landfill expansion area confirms the 'Low' groundwater vulnerability classification.

Nevertheless, groundwater in the Quaternary sediments is relevant in the vulnerability context, for two reasons:

- It is part of the environmental supporting conditions of the bog, which is described further in Section 7.4.14.
- It can serve as a pathway of contaminants to the Cushaling River, which is described further in the assessment of likely significant effects of the Proposed Development in Section 7.5.

7.4.12 Groundwater Response Matrix

As noted previously, the landfill expansion area is underlain by an 'LI' bedrock aquifer in a 'Low' groundwater vulnerability setting. Based on GSI's 'Response Matrix' for siting of landfills[6], the relevant protection response category is 'R1' which considers the "*risk to groundwater contamination*" that is "*Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence*".

Because the glacial till that overlies the 'LI' bedrock aquifer incorporates lenses or channels of sand- and gravel-grade sediments, it is considered prudent to adjust the response matrix category for TSB to 'R2[1]', as these can provide localised groundwater pathways to drains and the Cushaling River. The 'R2[1]' category is subject to the same "*Acceptable subject to…..*" definition presented above, but with the following added qualifier (DELG/EPA/GSI 1999):

> *"Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down-gradient of the site and to the projected future development of the aquifer".*

In the case of TSB, the relevant "*high permeability zones*" would be the sand and gravel intervals documented in the Quaternary unit. As described in Chapter 2, the expanded landfill will accept non-hazardous waste only, hence the risk of leachate contamination is significantly mitigated by the planned landfill design as well as the mitigation measures which are described in Section 7.5. For these reasons, the Proposed Development site can be considered as potentially suitable for landfill expansion purposes, subject to the assessment of likely significant effects presented herein.

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[6] Available at: https://www.gsi.ie/documents/Groundwater_Response_Matrix_for_Landfills.pdf

7.4.13 Groundwater Level Interpretations

Past investigations (TCE, 2017; OCM, 2015) and regular annual environmental monitoring conducted by BnM (e.g. Marron, 2023) have documented groundwater flow towards the Cushaling River from the existing WMF and landfill expansion area.

An expanded set of monitoring wells was installed in and around the landfill expansion area to verify flow directions in a broader geographic context within TSB and to provide more detailed information on water level fluctuations seasonally, as described below, partly to help quantify the interaction between groundwater and the Cushaling River.

7.4.13.1 Groundwater Flow Patterns

Updated monitoring data, which includes the new monitoring wells, confirms the general groundwater flow direction towards the Cushaling River from the WMF and landfill expansion area, both in the Quaternary and bedrock units, as presented below.

Figure 7-14 shows manually measured groundwater levels and interpreted groundwater contours based on wells with response zones in the Quaternary unit on 6-8 September 2011 (left panel) and 26-28 April 2022 (right panel), reflecting end of summer and end of winter seasons, respectively. Groundwater flow directions are indicated by the blue arrows (perpendicular to contours) and flow is convergent on the main channel between the WMF and old settlement ponds, and to Cushaling River further downstream. As such, the main channel appears to act as a groundwater sink in addition to being a conveyance channel for surface water (Chapter 8). The convergent groundwater flow is likely also influenced by the higher permeability of the sand and gravel sediments that are documented at depth near the main channel and northwestern part of the landfill expansion area, as described in Section 7.4.3.

Within the landfill expansion area, flow is towards the west and northwest, depending on location. The northwesterly flow component is influenced by the under-cell drainage system which lowers groundwater levels beneath the WMF, presently in the eastern part of the WMF where cells are presently, actively being filled. The purpose of the groundwater lowering is to counteract potential hydraulic 'heave' of the landfill liner, which can damage the liner. As described in Chapter 8, the shallow groundwater captured by the under-cell drainage system is discharged to the attenuation lagoon and ICW south of the WMF, from where water is led via the main channel to Cushaling River.

Based on Figure 7-14, the lateral flow gradient also varies by location, but the average gradient across the landfill expansion area is approximately 0.005 (reflected by a ~2 m head change over a ~1 km distance). It is noted that flow gradients across TSB can only ever be presented in general ways. This is because the flow system and flow directions are influenced locally by the drainage network, whereby shallow groundwater will also discharge into drains where and when groundwater levels are higher than water levels in drains. In many places, the drains penetrate both the peat and subsoils (Photo 9). It should be noted that drain water can also recharge groundwater, depending on the relative water levels between the drains and the shallow groundwater flow system.

As such, there is a level of complexity to localised flow paths which is not represented by the existing monitoring network, and which is constrained by the spatial distribution and spacing of wells across TSB. This does not affect the interpretations of water levels presented here, as the overall drainage and flow direction within the Proposed Development area is conclusively towards the Cushaling River.

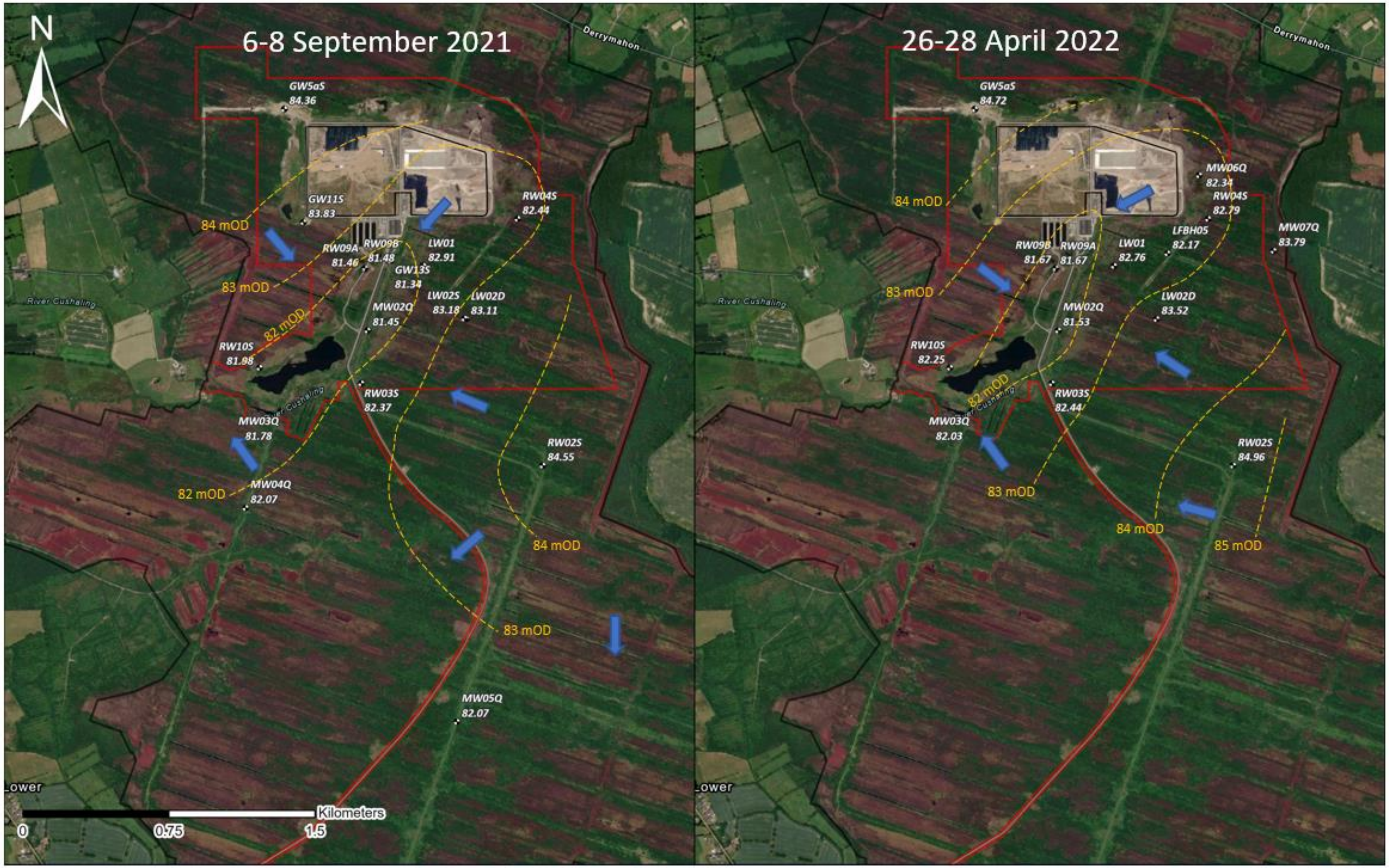


Figure 7-14 Interpreted Groundwater Flow, Quaternary Unit, September 2021 and April 2022

Photo 9 Drain Extending into Subsoils and With Adjacent Peat Stripped

Figure 7-15 shows groundwater levels and interpreted flow directions in bedrock wells on 6-8 September 2021 and 28 July 2022. Flow patterns in bedrock are similar to flow patterns in the Quaternary unit, and similarly drain and discharge towards the Cushaling River.

Groundwater levels in bedrock also appear to be influenced by the lowering of shallow groundwater levels in the eastern section of the WMF. The approximate lateral flow gradient across the landfill expansion area is approximately 0.001 (~1 m head difference over ~1 km distance).

The groundwater flow system, as a whole, in the Proposed Development area is interpreted from the groundwater contours to be topographically controlled north of the WMF, whereby a groundwater divide between TSB and TNB exists which is roughly coincident with the topographic saddle that was referred to in Section 7.4.1. This was also documented in the previous EIAR (TCE, 2017).

7.4.13.2 Groundwater Level Fluctuations

Water levels in peat wells that had measurable water levels across the winter season of 2021-2022 are depicted in Figure 7-16. They all show rising and falling water levels on either side of a seasonal high in February 2022. Depth to water in the measured peat wells is significantly deep, >0.5 m, showing the effects of bog drainage. Some peat wells were dry throughout the monitoring period (e.g. MW02P), or had measurable water levels only in February and March 2022 (e.g., MW05P).

Figure 7-15 Interpreted Groundwater Flow, Bedrock, September 2021, July 2022

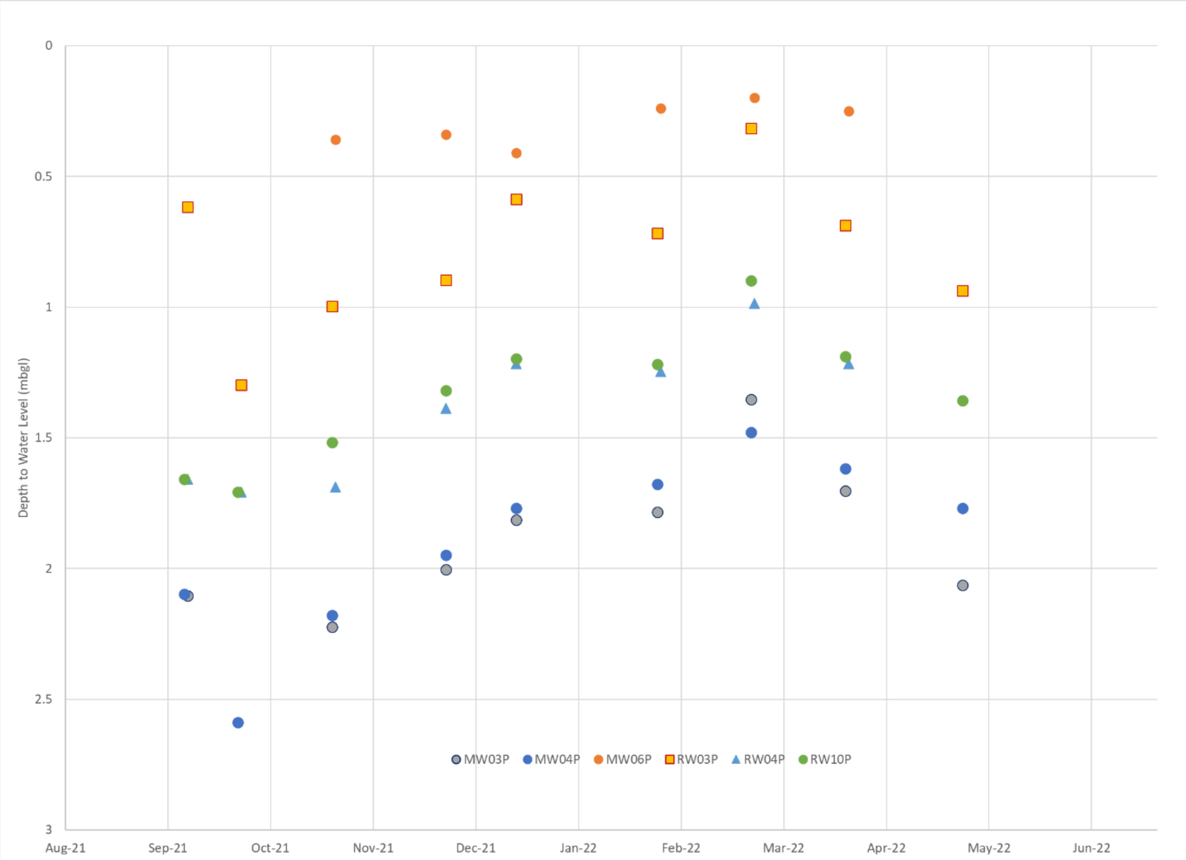


Figure 7-16 Measured Water Levels, Peat Wells, September 2021 through April 2022

Groundwater level fluctuations in Quaternary and bedrock wells are depicted in Figure 7-17 and 7-18, respectively. Both sets of time-series data depict seasonal changes, whereby:

- Maximum water level fluctuations were generally less than 1 m between September 2021 and April 2022.
- Quaternary and bedrock wells both show a seasonal high in late February 2022.
- Quaternary and bedrock wells both respond to rainfall events (the latter being marked by the sudden jumps in the black cumulative rainfall graph).

Not all wells respond identically. This reflects local hydrogeological differences, including well positions relative to features that influence groundwater levels (drains and the WMF).

The water levels in Figures 7-17 and 7-18 are referenced to mOD as all new monitoring wells and their reference points (top of casing) were surveyed to mOD. Manual measurements of depth to groundwater levels were converted to elevations in order to interpret flow directions. The transducer data, which measure a height of water above the transducer, were also referenced to mOD based on the depth of transducer installations below the surveyed reference point. In most instances, the manual and transducer data agree and can be correlated across the hydrographs. However, manual measurements at the start of transducer time series are off by a fixed depth of 0.15 m on 6 of 59 measurement occasions (e.g. well GW4D in mid-August 2021). This is likely due to an instrument or measurement error. However, as shown on Figures 7-17 and 7-18, the manual measurements are in good agreement with the transducer data on 53 of 59 occasions, which serve to validate the transducer data conversion to mOD.

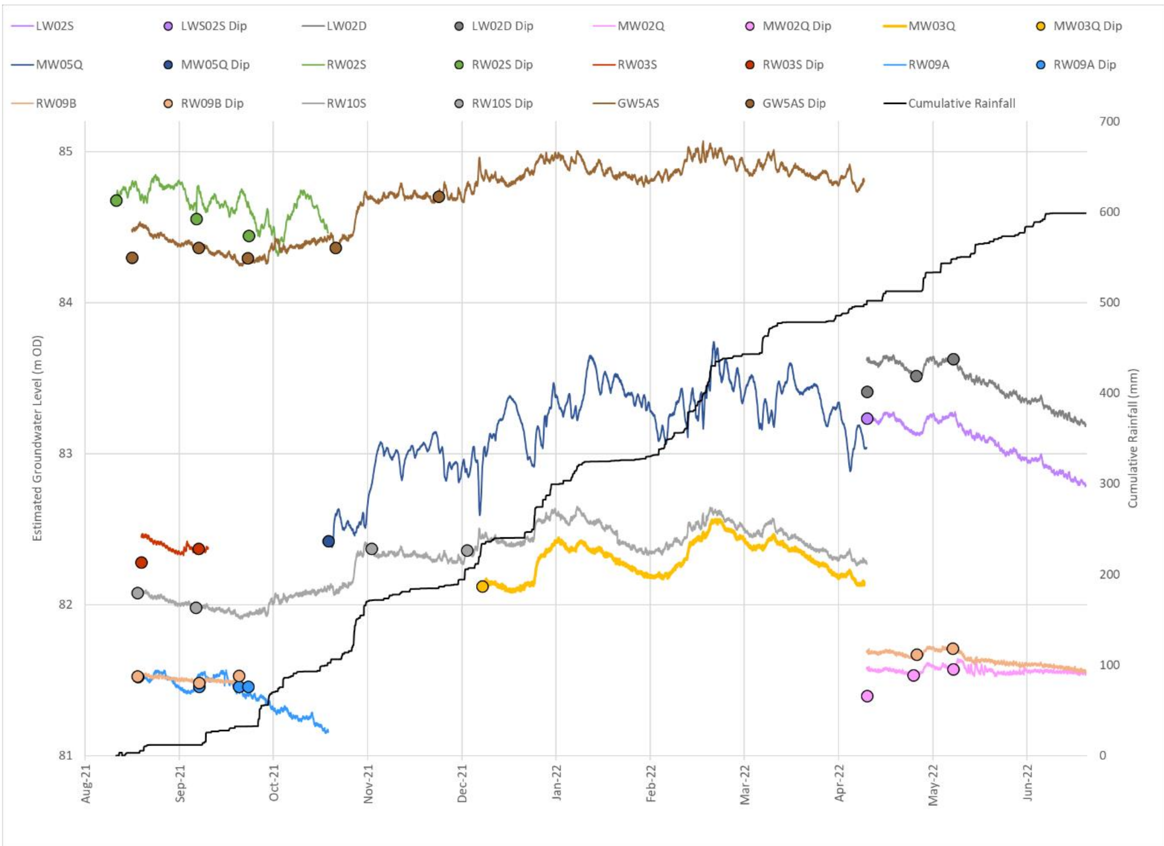


Figure 7-17 Estimated Groundwater Levels, Quaternary Wells, August 2021-June 2022

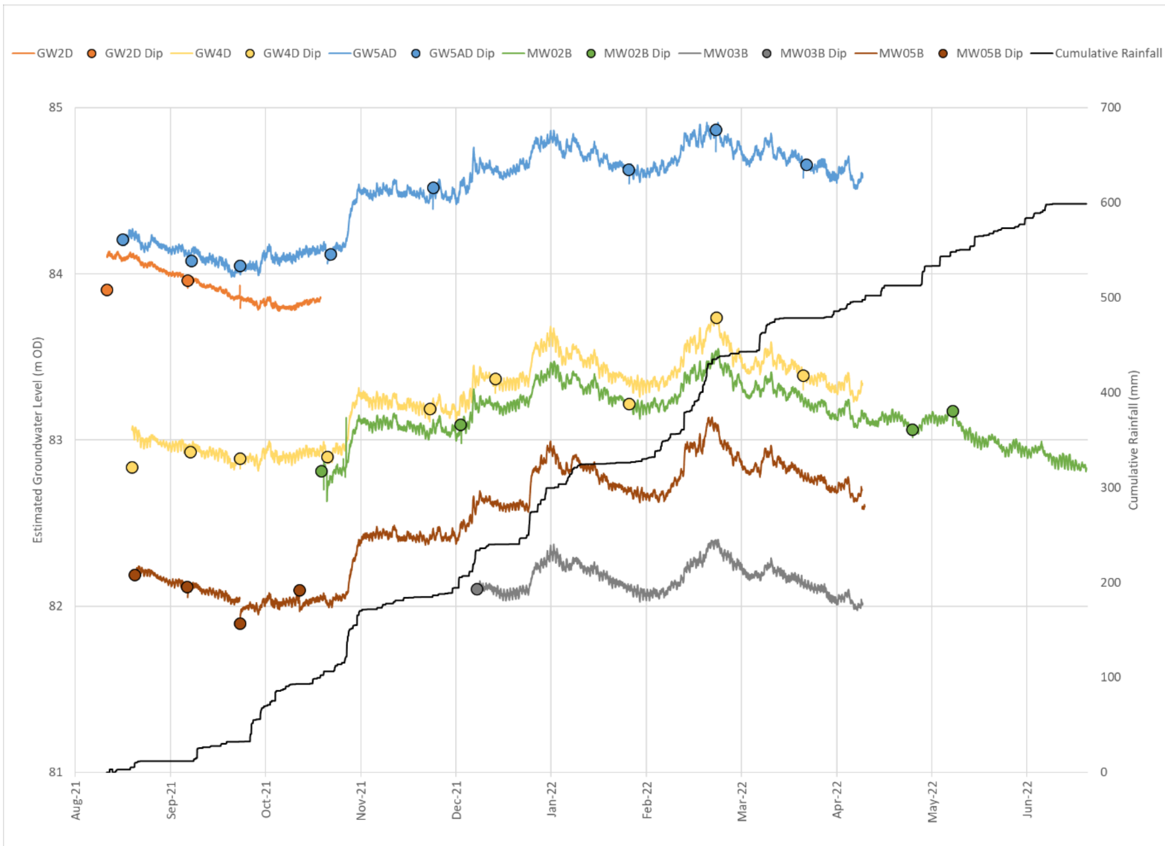


Figure 7-18 Estimated Groundwater Levels, Bedrock Wells, April 2021-June 2022

7.4.13.3 Vertical Hydraulic Gradients

Based on the manual groundwater level measurements, calculated vertical head gradients in paired Quaternary/bedrock wells are presented in Table 7-8. The vertical head gradients were established by dividing the measured head difference in paired wells with the vertical separation distance of the mid-points of the response zones in respective wells.

Table 7-8 Calculated Vertical Head Gradients in Nested/Paired Monitoring Wells

Date	ID	Distance Between Mid-points of Response Zones (m)	WL m (OD)	Head Difference (m)	Vertical Gradient Calculated
07-09-21	GW1S	16.15	83.085	0.779	0.048
	GW1D		82.306		
23-09-21	GW1S		82.965	0.599	0.037
	GW1D		82.366		
21-10-21	GW1S		83.005	0.589	0.036
	GW1D		82.416		
24-11-21	GW1S		83.235	0.589	0.036
	GW1D		82.646		
14-12-21	GW1S		83.335	0.579	0.036
	GW1D		82.756		
26-01-22	GW1S		83.125	0.469	0.029
	GW1D		82.656		
23-02-22	GW1S		83.605	0.519	0.032
	GW1D		83.086		
23-03-22	GW1S		83.385	0.569	0.035
	GW1D		82.816		
27-04-22	GW1S		83.235	0.579	0.036
	GW1D		82.656		
16-08-21	GW5AS	13.90	84.298	0.089	0.006
	GW5AD		84.209		
07-09-21	GW5AS		84.364	0.285	0.021
	GW5AD		84.079		
23-09-21	GW5AS		84.294	0.245	0.018
	GW5AD		84.049		
21-10-21	GW5AS		84.364	0.245	0.018
	GW5AD		84.119		
24-11-21	GW5AS		84.704	0.185	0.013
	GW5AD		84.519		
26-01-22	GW5AS		84.834	0.205	0.015
	GW5AD		84.629		
23-02-22	GW5AS		85.024	0.155	0.011
	GW5AD		84.869		
23-03-22	GW5AS		84.874	0.215	0.015
	GW5AD		84.659		
27-04-22	GW5AS		84.724	0.245	0.018
	GW5AD		84.479		

Date	ID	Distance Between Mid-points of Response Zones (m)	WL m (OD)	Head Difference (m)	Vertical Gradient Calculated
08-09-21	GW11S	19.00	83.833	0.738	0.039
	GW11D		83.095		
24-11-21	GW11S		84.073	0.288	0.015
	GW11D		83.785		
08-09-21	GW12S	17.50	83.101	0.179	0.010
	GW12D		82.922		
24-11-21	GW12S		83.341	-0.021	-0.001
	GW12D		83.362		
24-11-21	GW13S	19.80	81.276	-1.194	-0.060
	GW13D		82.47		
21-09-21	MW02Q	31.00	81.453	-0.251	-0.008
	MW02B		81.704		
03-12-21	MW02Q		81.683	-1.411	-0.046
	MW02B		83.094		
27-04-22	MW02Q		81.533	-1.531	-0.049
	MW02B		83.064		
10-05-22	MW02Q		81.573	-1.601	-0.052
	MW02B		83.174		
07-09-21	MW03Q	10.95	81.780	-0.09	-0.008
	MW03B		81.870		
22-09-21	MW03Q		82.378	0.678	0.062
	MW03B		81.700		
02-11-21	MW03Q		81.948	0.218	0.020
	MW03B		81.730		
03-11-21	MW03Q		82.098	0.726	0.066
	MW03B		81.372		
03-12-21	MW03Q		82.010	-0.03	-0.003
	MW03B		82.040		
08-12-21	MW03Q		82.122	0.017	0.002
	MW03B		82.105		
26-04-22	MW03Q		82.030	0.06	0.005
	MW03B		81.970		
10-05-22	MW03Q		82.070	0.03	0.003
	MW03B		82.040		
06-09-21	MW04Q	11.70	82.074	-0.116	-0.010
	MW04B		82.19		
22-09-21	MW04Q		82.774	0.364	0.031
	MW04B		82.41		
03-11-21	MW04Q		82.387	0.797	0.068
	MW04B		81.59		
04-11-21	MW04Q		82.337	0.72	0.062
	MW04B		81.617		

Date	ID	Distance Between Mid-points of Response Zones (m)	WL m (OD)	Head Difference (m)	Vertical Gradient Calculated
06-09-21	MW05Q	13.25	82.069	-0.047	-0.004
	MW05B		82.116		
23-09-21	MW05Q		81.789	-0.107	-0.008
	MW05B		81.896		
12-10-21	MW05Q		82.025	-0.074	-0.006
	MW05B		82.099		
27-09-21	MW06Q	8.80	82.151	-0.379	-0.043
	MW06B		82.53		
03-12-21	MW06Q		83.251	-0.009	-0.001
	MW06B		83.26		
27-04-22	MW06Q		82.341	-0.459	-0.052
	MW06B		82.8		
11-05-22	MW06Q		82.401	-0.479	-0.054
	MW06B		82.88		
27-09-21	MW07Q	10.70	84.645	1.283	0.120
	MW07B		83.362		
22-10-21	MW07Q		83.832	1.01	0.094
	MW07B		82.822		
06-12-21	MW07Q		84.315	0.743	0.069
	MW07B		83.572		
27-04-22	MW07Q		83.785	0.253	0.024
	MW07B		83.532		
11-05-22	MW07Q		84.265	0.633	0.059
	MW07B		83.632		
11-08-21	RW02S	13.00	84.677	0.771	0.059
	GW2D		83.906		
06-09-21	RW02S		84.554	0.593	0.046
	GW2D		83.961		
26-04-22	RW02S		84.964	0.613	0.047
	GW2D		84.351		
07-09-21	RW03S	19.50	82.370	-0.387	-0.020
	GW3AD		82.757		
26-04-22	RW03S		82.440	-0.517	-0.027
	GW3AD		82.957		
07-09-21	RW04S	16.30	82.437	-0.491	-0.030
	GW4D		82.928		
27-04-22	RW04S		82.787	-0.491	-0.030
	GW4D		83.278		

Vertical head gradients across TSB are generally downward (represented by positive values). However, upward gradients are noted in wells located close to the eastern part of the WMF (wells MW06P/Q) where groundwater levels are being lowered by the under-cell drainage system in the Quaternary unit, and in wells located immediately adjacent to the main channel (e.g., RW04S/GW4D), noting that groundwater flow converges on the main channel, which acts as a hydraulic sink.

A slight vertical upward gradient is documented in well pair MW05Q/B in September and early October 2021, but this gradient was reversed in winter 2022 when water levels in the bog rose. This is illustrated in Figure 7-19 which shows hydrographs of two Quaternary/bedrock paired wells, MW05Q/MW05B and GW5AS/GW5AD. The former is located more than 1 km south of the landfill expansion area. The latter is located northwest of the existing WMF.

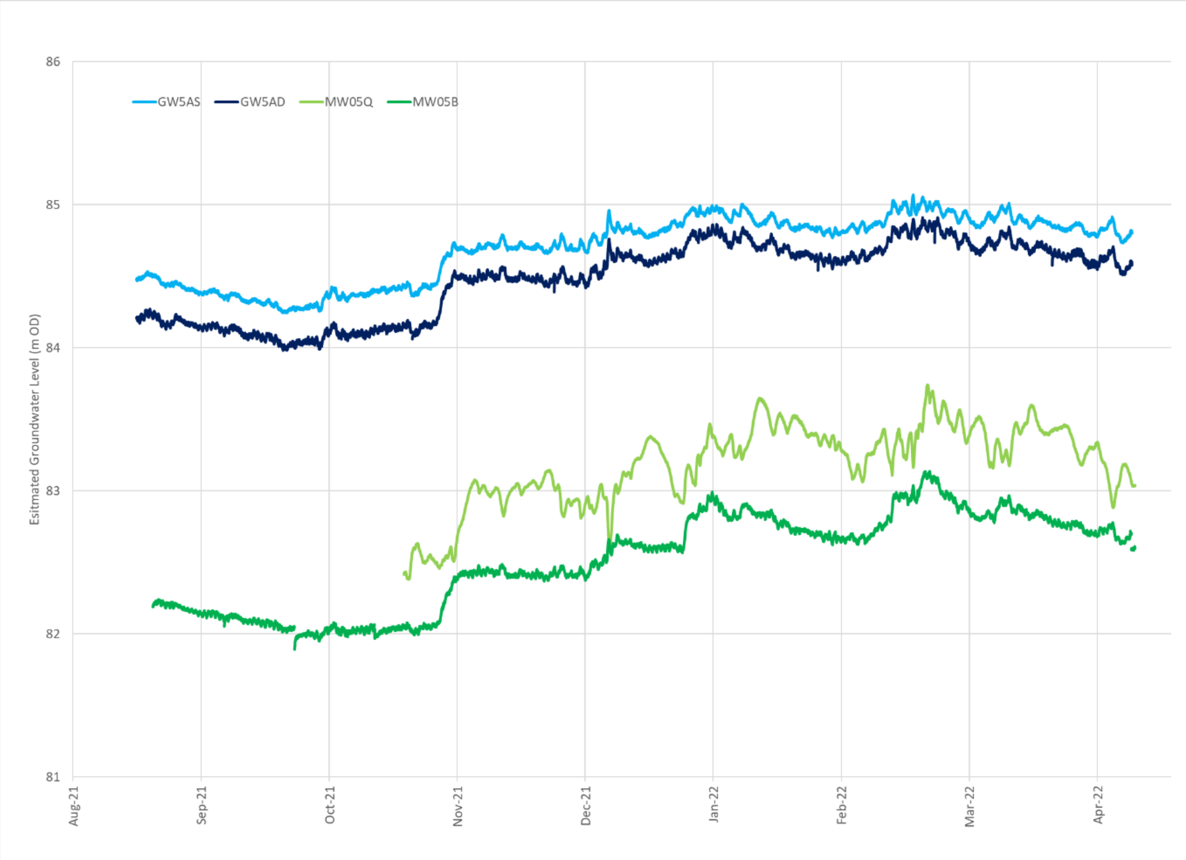


Figure 7-19 Groundwater Levels in Two Paired Quaternary/Bedrock Wells

The downward gradient was maintained at both well pairs across the winter season. The expected gradient in the landfill expansion area is, therefore, downward under natural conditions.

7.4.14 Groundwater-Surface Water Interaction

Groundwater levels respond similarly to surface water levels, which means that groundwater and surface water are hydraulically connected. This is illustrated in Figure 7-20 which shows the measured water level responses between December 2021 and April 2022 at:

- The headwater of the Cushaling River at measurement station 'RS02' immediately west of the BnM landholding boundary (see Chapter 8).
- The Borrow Pit lake, whereby the water levels reflects groundwater in the Quaternary unit.
- Quaternary monitoring well MW3Q nearby.

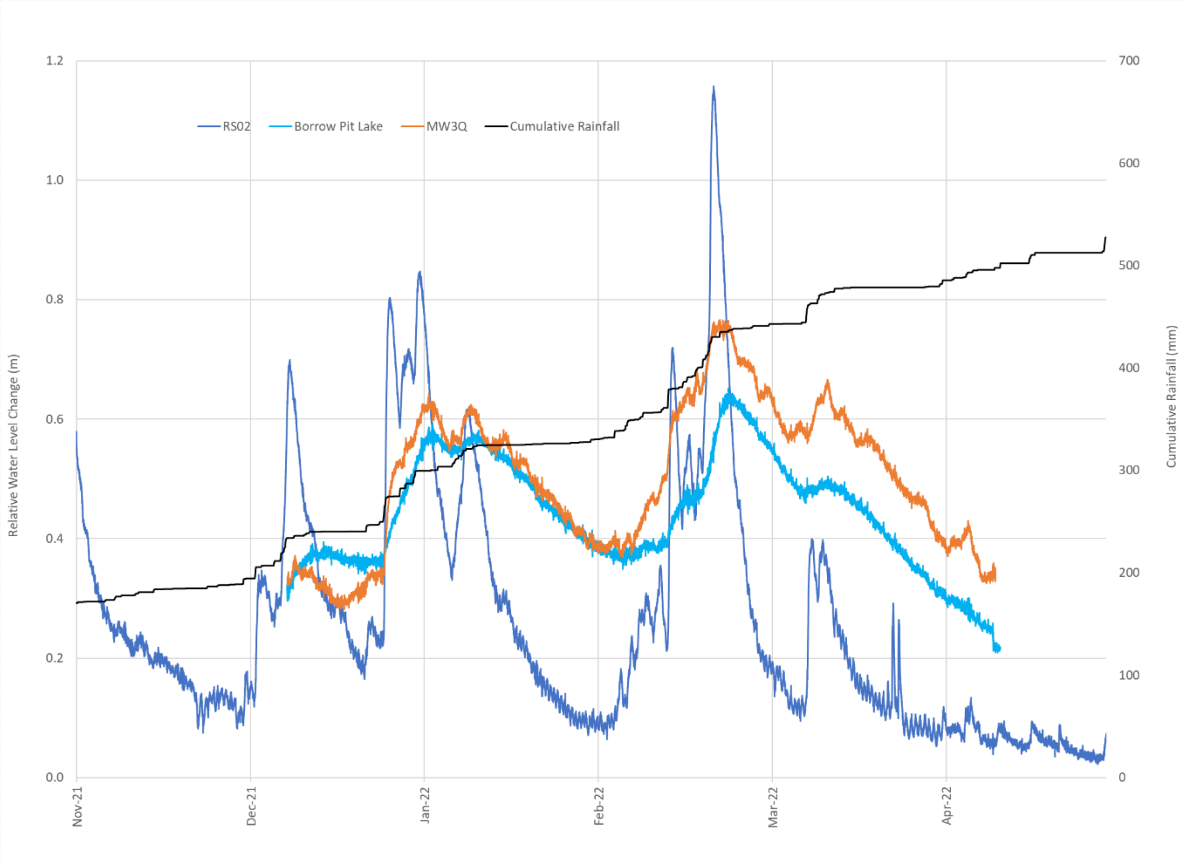


Figure 7-20 Relative Water Level Changes in Quaternary Well MW3Q, Borrow Pit Lake, and Nearby Cushaling River

The observed response in RS02 is 'flashy', with water levels rising and falling quickly during and after two large rainfall events. The equivalent responses in the Borrow Pit lake and MW3Q are slower and more muted, reflecting the contributions of storage in the system to the respective responses (specifically storage in the lake and storage in the Quaternary hydrogeological unit). The synchronised responses demonstrate the hydraulic interconnection between groundwater and surface water at the site.

7.4.15 Hydraulic Properties

Falling and rising head tests (FHT and RHT) were conducted in 21 no. new monitoring wells as part of the most recent SI, with an emphasis on wells in and near the landfill expansion area. The raw data and analyses are presented in Appendix 7-1. The tests were conducted in both Quaternary and bedrock wells. In the Quaternary wells, the tests were prioritized in wells that have response zones in sand and gravel lenses (reflecting potential shallow groundwater pathways).

Findings are summarized in Table 7-9. Estimated hydraulic conductivity values in all tests range from 6.47×10^{-7} to 2.32×10^{-4} m/s in Quaternary wells and from 9.03×10^{-8} to 1.82×10^{-5} m/s in bedrock wells.

Table 7-9 Summary of Estimated Permeability from Rising and Falling Head Tests

Monitoring Well ID	Response Zone	Hydrogeological Unit	FHT (m/s)	RHT (m/s)	Average (m/s)
LFBH04	Sand & Gravel	Quaternary	6.74E-05	5.72E-05	6.23E-05
LFBH05	Sand & Gravel	Quaternary	2.59E-05	2.25E-05	2.42E-05

Monitoring Well ID	Response Zone	Hydrogeological Unit	FHT (m/s)	RHT (m/s)	Average (m/s)
LFBH10A	Clay/silt	Quaternary	6.47E-07	3.77E-07	5.12E-07
LFBH13	Clay/silt	Quaternary	2.04E-06	4.43E-06	3.24E-06
LFBH14	Sand	Quaternary	4.61E-06	3.71E-06	4.16E-06
LW01	Gravel	Quaternary	3.17E-05	4.94E-05	4.05E-05
LW02S	Clay/silt	Quaternary	1.15E-05	1.16E-06	6.32E-06
LW02D	Clay, Sand & Gravel	Quaternary	4.05E-05	4.19E-05	4.12E-05
MW02Q	Sand & Gravel	Quaternary	6.00E-05	4.99E-05	5.60E-05
MW03Q	Gravel & Sand	Quaternary	5.30E-06	3.99E-06	4.64E-06
MW04Q	Sand & Gravel	Quaternary	7.96E-06	8.63E-06	8.29E-06
MW05Q	Gravel	Quaternary	6.75E-05	5.50E-05	6.13E-05
RW03S	Gravel	Quaternary	1.11E-05	9.44E-06	1.03E-05
RW09B	Gravel	Quaternary	2.32E-04	-	2.32E-04
RW10S	Gravel & Sand	Quaternary	7.21E-05	8.53E-05	7.87E-05
MW02B	Limestone	Bedrock	1.82E-05	2.39E-06	1.03E-05
MW03B	Limestone	Bedrock	6.87E-07	4.17E-07	5.52E-07
MW04B	Limestone	Bedrock	-	9.03E-08	9.03E-08
MW05B	Limestone	Bedrock	1.37E-06	4.34E-07	9.04E-07
MW06B	Limestone	Bedrock	9.89E-06	1.29E-05	1.14E-05
MW07B	Limestone	Bedrock	2.97E-07	3.94E-07	3.45E-07

The geometric mean of all RHT and FHT in the monitoring wells with response zones in the Quaternary unit is 1.47×10^{-5} m/s. In bedrock, the geometric mean is 1.23×10^{-6} m/s. This means that the permeability of sand and gravel units is higher than the bedrock, by one order of magnitude, in the tested wells. Being illustrative values of site-specific conditions, the information is used for groundwater flux calculations later in this Chapter 7.

A total of 17 no. undisturbed clay/silt samples were also selected for laboratory testing of vertical hydraulic conductivity, mainly from boreholes in and downgradient of the landfill expansion area. Vertical hydraulic conductivity is of interest as it provides a relative measure of how permeable or impermeable a geological material is in the vertical direction. Clays impede vertical migration, which is significant for contaminant transport. Hence, vertical permeability values are relevant to interpretations of vertical hydraulic gradients, flow rates, and contaminant transport.

Laboratory results are presented in Appendix 7-1 and summarized in Table 7-10. The obtained values range from 1.5×10^{-10} m/s to 1.0×10^{-8} (geometric mean of 6.5×10^{-10} m/s), attesting to the low vertical permeability characteristics of the clayey till. The range of values and geometric mean are consistent with reported values previously from laboratory tests of ten clay samples closer to the existing WMF, specifically an average value of 6.78×10^{-10} m/s (TCE, 2008).

Table 7-10 Summary of Estimated Vertical Hydraulic Conductivity from Triaxial Laboratory Tests

Borehole ID	Sample Interval Top (m mBGL)	Length of Sample (mm)	Vertical Permeability K_v (m/s)	Description of Sample
LFBH09	4.50	100.20	8.90E-10	Greyish brown very gravelly sandy silty CLAY
LFBH10A	6.00	99.99	4.80E-09	Greyish brown very gravelly sandy SILT
LFBH16	4.50	101.18	2.30E-10	Brownish grey slightly gravelly sandy slightly clayey SILT

Borehole ID	Sample Interval Top (m mBGL)	Length of Sample (mm)	Vertical Permeability K_v (m/s)	Description of Sample
LFBR01	4.00	101.47	4.10E-10	Brownish grey very gravelly slightly sandy SILT
LFBR01	4.25	101.27	5.10E-10	Brownish grey very gravelly slightly sandy SILT
LFBR01	8.05	99.19	3.40E-10	Greyish brown very gravelly slightly sandy silty CALY
LFBR02	13.50	99.01	3.20E-10	Greyish brown very gravelly sandy clayey SILT
LFBR02	16.50	101.19	2.00E-10	Brown vey gravelly sandy silty CLAY
LFBR03	9.00	101.22	5.50E-09	Greyish brown very gravelly very sandy SILT
LFBR03	10.50	99.28	1.00E-08	Greyish brown very gravelly very sandy CLAY
MW02B	7.00	101.20	1.50E-10	Greyish brown gravelly SILT
MW02B	9.95	99.44	3.80E-10	Greyish brown very gravelly sandy slightly clayey SILT
MW03B	7.00	101.17	1.70E-09	Greyish brown very gravelly sandy SILT
MW05B	3.00	101.40	4.90E-10	Brownish grey very gravelly sandy CLAY
MW06B	7.25	99.99	1.80E-10	Greyish brown very gravelly sandy very silty CLAY
MW06B	8.75	100.65	2.10E-10	Brown gravelly slightly sandy silty CLAY
MW07B	4.30	101.73	1.50E-09	Greyish brown very gravelly slightly sandy clayey SILT

As reported by TCE (2008, 2017), test pumping of an existing bedrock well (GW6 near the existing WMF) yielded estimates of bedrock aquifer transmissivity of <1-18 m^2/d depending on the analytical method applied. In an Irish hydrogeological context, such values are indicative of low-permeability characteristics, and are consistent with "*best estimates*" of transmissivity for 'locally important' bedrock aquifers (Kelly et al, 2015) and "productivity classes" IV /V (poorly productive) per GSI's "*productivity index*" (Wright, 1997).

7.4.15.1 Groundwater Flow Velocity

To examine potential groundwater travel times in the Quaternary unit, the groundwater flow velocity was calculated from the equation:

$$v = [K \times i]/n_e$$

where,

- v = velocity (m/d)
- K = 1.47×10^{-5} m/s, or 1.27 m/d, conservatively as a geometric mean for the more permeable fractions of the Quaternary sediments (from Section 7.4.15).
- i = 0.005, as an average hydraulic gradient across the landfill expansion area (from Section 7.4.13.1)
- n_e = effective porosity of the Quaternary sediments, conservatively taken to be 0.15 (Tedd et al., 2015).

Hence, the calculated velocity is 0.04 m/d, which equates to 15 m/year within the Quaternary unit, and which indicates that groundwater travels 1 km in approximately 68 years.

7.4.16 Groundwater Baseflow to Cushaling River

Because groundwater and surface water levels are interconnected, the groundwater levels in the Quaternary unit are influenced by the artificial drainage network in TSB, and vice versa, Conceptually, groundwater discharges into or is recharged by the drains depending on the relative water levels between the two. Groundwater that discharges to drains is carried as surface water towards the Cushaling River.

Groundwater that is not captured by drains discharges into the main channel that runs between the WMF and Cushaling River, and the Cushaling River directly. As such, groundwater provides baseflow to the river via groundwater pathways.

The magnitude of direct groundwater discharges to Cushaling River was calculated from Darcy's Law of groundwater flow, which is defined by the equation:

$$Q = K \times i \times A$$

and where,

- Q = discharge rate (m^3/s)
- K = hydraulic conductivity (m/s)
- i = hydraulic gradient (m/m)
- A = cross-sectional area of groundwater discharge (m^2), i.e. the depth of groundwater flow multiplied by length of contribution along a channel or stream.

Darcy's law was applied to estimate both the discharge of groundwater from the Quaternary unit and bedrock aquifer into the main channel and Cushaling River between the existing ICW and the western BnM landholding boundary, a lateral distance of approximately 1,500 m.

For the Quaternary unit, input values are:

- K = 1.47×10^{-5} m/s, conservatively as a geometric mean for the more permeable fractions of the Quaternary sediments (from Section 7.4.15).
- i = 0.005, as an average hydraulic gradient across the landfill expansion area (from Section 7.4.13.1)
- A = 30,000 m^2 (groundwater flow along 1,500 m and assumed depth of flow of 20 m, reflecting the thickness of the Quaternary unit).

For the bedrock aquifer, input values are:

- K = 1.23×10^{-6} m/s, as a geometric mean (from Section 7.4.15)
- i = 0.001, as an average hydraulic gradient across the landfill expansion area (from Section 7.4.13.1)
- A = 30,000 m^2 (groundwater flow along 1,500 m and assumed depth of flow of 20 m at the top of bedrock)

Based on these inputs:

- Q (discharge from Quaternary unit) = 0.0022 m^3/s.
- Q (discharge from bedrock) = 3.69×10^{-6} m^3/s.

The total calculated discharge is, therefore, 0.00224 m^3/s. However, the groundwater discharge into the main channel and Cushaling River takes place from both sides, hence the estimated discharge is doubled for a total of 0.0045 m^3/s, or 389 m^3/d. This is a small value, but is consistent with the baseflow estimate presented in Chapter 8 using EPA Qube model metrics and measured streamflow data.

7.4.17 WFD Groundwater Body Status and Risk

A WFD compliance assessment is presented in Chapter 8, addressing both WFD reportable surface water and groundwater bodies.

The existing WMF and planned landfill expansion areas are located within the Kildare groundwater body (GWB) (WFD reporting code IE_SE_G_077), near the boundary with the Trim GWB (IE_EA_G_002) to the north and east.

According to EPA's latest available WFD status classification for the period 2016-2021[7] both the Kildare and Trim GWBs are at "Good" qualitative (chemical) status and "Good" quantitative status (i.e., not overexploited), and thus at "Good" status overall, meeting WFD "Good status" objectives.

According to the 3rd cycle river basin management plan (RBMP) for Ireland, covering the period 2022-2027 (EPA, 2021), the Kildare GWB is "Not At Risk" of failing to achieve WFD "Good" status objectives in 2027. However, the Trim GWB to the north and east is considered to be "At Risk", with domestic wastewater identified as the significant pressure in the GWB (EPA, 2021). These pressures are not relevant to groundwater conditions within TSB. Domestic wastewater is not being discharged within the bog and is not planned as part of the Proposed Development (see Section 7.5).

7.4.18 Receptor Importance and Sensitivity

With regard to soils, geology and hydrogeology, the potential environmental receptors are the peat of TSB, the subsoils beneath the peat, and groundwater, mainly in the Quaternary unit.

With reference to Table 7-2, which presents attributes that were considered to determine the importance/ environmental sensitivity of the receiving environment:

- The residual peat in the Proposed Development area is significantly exploited and degraded, but is partially restorable outside the Proposed Development boundaries. The importance/sensitivity of the peat in the Proposed Development area is considered to be Low.
- The subsoils in the Proposed Development area are not economically important and do not have other geological or geomorphological attributes that are of significance. Hence, the importance/sensitivity of the geological environment is considered to be Low.
- The shallow groundwater flow system in the Quaternary unit supports the environmental conditions of TSB and provides limited baseflow to Cushaling River and other streams that exit TSB. The underlying bedrock aquifer is 'poorly productive' and unlikely to be used for public water supply within TSB. For these reasons, the importance/sensitivity of the groundwater environment is considered to be Medium.

7.4.19 Groundwater Quality – Overview and Screening

Groundwater quality in TSB was initially tested in 2003, 2006 and 2007 in a small set of wells, as follows: GW-1S/D, GW2-S/D, GW-3S/D, GW-4S/D, GW-5AS/D, GW-6. These wells had been installed and sampled for baseline characterisation purposes as part of the initial EIA for the WMF (TCE, 2008). The associated data are reproduced in Appendix 7-4 and referenced below.

Routine sampling has been undertaken since 2014 in a broader set of wells, as follows: GW-1S/D, GW2-S/D, GW-3S/D, GW-4S/D, GW-5AS/D, GW-6, GW-9, GW-10, GW-11S/D, GW-12S/D, and GW-13S/D. The additional wells were installed in 2014 (OCM, 2014) and the data are reproduced below, in three groupings:

- Wells located immediately around the perimeter of the WMF.

[7] EPA Maps

- Wells located hydraulically downgradient of the WMF, mainly south of the existing attenuation lagoon and ICW system.
- Wells located distant from the WMF, outside any potential influence of the WMF.

The routine samples were historically analysed for:

- General physico-chemical parameters, major ions and nutrients – e.g., total ammonia, pH, chloride, and SEC.
- Metals (dissolved).
- Organic compounds – e.g., volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), as well as pesticides.

In preparation of the current EIAR, additional groundwater sampling beyond BnM's routine monitoring programme was undertaken in the new, additional monitoring wells that were installed in 2020-2021. The data, which cover the period September 2021 through May 2022, provide continuity of historical records in some wells and new data for enhanced baseline characterisation of groundwater quality in and near the proposed landfill expansion area. The samples were collected from peat, Quaternary, and bedrock wells, and were analysed for key leachate indicators. Dissolved metals were also included in two sampling rounds, in December 2021 and May 2022.

The expanded 2021 and 2022 data are presented in Table 7-11 for peat wells, Table 7-12 for Quaternary wells, and Table 7-13 for bedrock wells. The dataset is referenced as the '2021-2022' data in subsequent sections of this Chapter 7. In each table, mean concentrations were calculated using half the limit of detection (LOD) when the reported data were below the LOD, and mean concentrations were not calculated when all results were below LOD or where only one sample was collected or analysed.

The available groundwater quality data (historical and recent) were screened against threshold values, as follows:

- Those listed in Schedule 5 of the European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016 (S.I. No. 366/2016), specifically:
    - Column 2 – *"assessment of adverse impacts of chemical inputs from groundwater on associated surface water bodies."*
    - Column 4 – *"assessment of the general quality of groundwater in a groundwater body in terms of whether its ability to support human uses has been significantly impaired by pollution."*
- Those listed in EPA's report "*Towards Setting Guidance Values for the Protection of Groundwater in Ireland*" (EPA, 2003). Commonly referred to as "interim guidance values" (IGV), these apply mainly for parameters that are not specifically included in the Groundwater Regulations. As a 2003 publication, the IGVs tend to represent drinking water standards, GSI 'trigger values', or environmental quality standards for surface waters in 2003. In screening terms, IGVs were considered but were given less weight than threshold values published subsequently in the Groundwater Regulations.

The screening criteria (threshold values) are summarised in Table 7-14.

Table 7-11 Indicator Parameters, Peat Wells, 2021-2022 Data

Well	Item	Count	Total Ammonia mg/L as NH_3-N	Ammonium mg/L as NH_4	Nitrate mg/L as NO_3	TON mg/L-N	Ortho-P mg/L as P	TP mg/L as P	SEC µS/cm	Chloride mg/L	pH --
RW03P	Mean	9	0.38	0.46	--	--	--	2.084	447	16.69	6.52
	Min		0.19	0.24	<4	<1	<0.03	<0.05	365	11.30	6.40
	Max		0.67	0.87	<4	<1	<0.03	9.500	524	22.30	6.70
RW04P	Mean	8	3.05	3.85	--	--	0.027	2.664	399	10.94	6.58
	Min		1.70	2.20	<4	<1	0.014	<0.05	238	9.70	6.30
	Max		4.90	6.30	<4	<1	0.110	7.800	673	15.60	7.10
MW02P	Mean	1	0.32	0.41	--	--	--	--	789	15.30	6.70
	Min		0.32	0.41	<4	<1	<0.03	0.050	789	15.30	6.70
	Max		0.32	0.41	<4	<1	<0.03	0.050	789	15.30	6.70
MW03P	Mean	9	1.52	1.82	--	--	0.068	2.306	330	12.28	6.10
	Min		0.78	1.01	<4	<1	<0.03	<0.05	234	7.60	6.00
	Max		2.40	2.70	<4	<1	0.230	9.700	470	17.70	6.30
MW04P	Mean	9	3.48	4.07	3.44	0.82	1.282	2.050	550	18.64	6.39
	Min		1.60	2.10	<4	<1	0.110	0.200	334	13.20	6.10
	Max		7.70	6.40	15.00	3.40	0	6.000	755	28.60	6.70
MW06P	Mean	6	10.70	13.68	--	--	--	1.187	1,505	18.73	6.53
	Min		6.60	8.00	<4	<1	<0.03	0.320	1,308	16.90	6.50
	Max		12.70	16.30	<4	<1	<0.03	2.500	1,564	23.60	6.60
MW07P	Mean	2	0.62	0.77	--	--	0.065	2.775	145	12.65	6.05
	Min		0.60	0.73	<4	<1	0.060	2.750	141	12.40	6.00
	Max		0.63	0.81	<4	<1	0.070	2.800	148	12.90	6.10
RW10P	Mean	9	1.66	1.99	--	--	--	4.217	337	10.87	6.16
	Min		1.10	1.50	<4	<1	<0.03	0.400	200	9.50	5.80
	Max		2.30	2.80	<4	<1	<0.03	14.750	509	13.10	6.50

Table 7-12 Indicator Parameters, Quaternary Wells, 2021-2022 Data

Well	Item	Count	Total Ammonia	Ammonium	Nitrate	TON	Ortho-P	TP	SEC	Chloride	pH
			mg/L as NH_3-N	mg/L as NH_4	mg/L as NO_3	mg/L-N	mg/L as P	mg/L as P	µS/cm	mg/L	--
MW02Q	Mean	3	3.19	4.11	--	--	0.090	0.285	679	17.90	6.97
	Min		2.80	3.60	<0.2	<0.02	0.040	0.250	598	14.10	6.80
	Max		3.40	4.40	<4	<1	0.150	0.320	796	21.70	7.30
MW03Q	Mean	3	4.50	5.81	--	--	--	1.275	810	26.20	7.04
	Min		3.50	4.50	<0.2	<0.2	<0.03	1.250	760	25.60	6.80
	Max		5.00	6.50	<4	<1	<0.06	1.300	903	26.80	7.52
MW04Q	Mean	1	--	--	--	--	--	--	--	--	--
	Min		10.00	12.90	<4	<1	<0.03	10.00	545	17.20	7.20
	Max		10.00	12.90	<4	<1	<0.03	10.00	545	17.20	7.20
MW05Q	Mean	1	--	--	--	--	--	--	--	--	--
	Min		3.20	4.10	<4	<1	<0.03	0.120	762	17.10	6.90
	Max		3.20	4.10	<4	<1	<0.03	0.120	762	17.10	6.90
MW06Q	Mean	2	3.82	4.95	--	--	--	--	380	--	7.37
	Min		3.73	4.80	<0.2	<0.2	<0.03	0.50*	368	13.40*	7.10
	Max		3.90	5.10	<4	<1	<0.06	0.50*	392	13.40*	7.64
MW07Q	Mean	2	4.16	5.31	--	--	--	--	593	--	7.18
	Min		4.10	5.20	<0.2	<0.2	<0.03	1.90*	580	8.00*	6.90
	Max		4.21	5.42	<4	<1	<0.06	1.90*	606	8.00*	7.46
LFBH05	Mean	2	4.76	6.18	--	--	--	0.590	682	--	7.38
	Min		4.62	5.95	<0.2	<0.2	<0.03	0.430	662	11.50*	7.00
	Max		4.90	6.40	<4	<1	<0.06	0.739	701	11.50*	7.76
LW01	Mean	3	4.64	5.96	--	--	--	0.088	586	15.10	7.33
	Min		4.10	5.20	<0.2	<0.2	<0.03	0.075	547	14.70	7.10
	Max		5.72	7.37	<4	<1	<0.06	0.100	619	15.50	7.68
LW02D	Mean	3	6.84	8.60	--	--	--	0.546	722	10.39	6.96
	Min		6.20	8.00	<0.2	<0.2	<0.03	0.330	711	9.28	6.80
	Max		7.21	9.20	<4	<1	<0.06	0.830	743	11.20	7.27

Well	Item	Count	Total Ammonia mg/L as NH_3-N	Ammonium mg/L as NH_4	Nitrate mg/L as NO_3	TON mg/L-N	Ortho-P mg/L as P	TP mg/L as P	SEC µS/cm	Chloride mg/L	pH --
LW02S	Mean	1	--	--	--	--	--	--	--	--	6--
	Min		3.80	4.90	<4	<1	0.060	4.650	706	9.80	6.70
	Max		3.80	4.90	<4	<1	0.060	4.650	706	9.80	6.70
RW02S	Mean	3	3.59	4.69	2.10	0.40	--	1.300	734	14.60	7.29
	Min		3.30	4.30	<0.2	0.20	<0.03	1.200*	727	13.60	7.10
	Max		4.08	5.26	4.20	<1	<0.06	1.400*	740	15.60	7.68
RW03S	Mean	3	7.39	9.52	--	--	--	2.125	613	15.40	7.29
	Min		5.60	7.20	<0.2	<0.2	<0.030	1.400	589	14.50	7.10
	Max		8.36	10.76	<4	<1	<0.060	2.850	629	16.30	7.56
RW04S	Mean	3	8.68	11.19	--	--	--	1.117	683	14.30	7.15
	Min		7.30	9.40	<0.2	<0.2	<0.030	0.860	676	13.60	6.90
	Max		9.45	12.17	<4	<1	<0.060	1.991	696	15.00	7.54
RW09A	Mean	9	0.74	0.88	3.33	0.79	0.054	0.154	484	14.29	7.16
	Min		0.05	0.06	<0.2	<0.2	<0.030	0.060	372	9.10	6.70
	Max		1.60	2.10	8.70	2.00	0.120	0.400	620	19.50	7.65
RW09B	Mean	3	1.24	1.59	--	--	0.055	0.218	299	10.40	7.69
	Min		1.20	1.50	<0.2	<0.2	0.040	0.125	295	10.30	7.50
	Max		1.30	1.70	<4	<1	0.070	0.310	303	10.50	7.97
RW10S	Mean	3	4.25	5.50	--	--	0.042	0.191	584	12.15	7.18
	Min		4.00	5.20	<0.2	<0.2	<0.03	0.112	559	11.50	7.00
	Max		4.40	5.70	<4	<1	0.080	0.270	612	12.80	7.53
GW1S[1]	Mean	12	5.42	7.02	--	--	0.178	0.418	1,002	15.04	6.73
	Min		4.65	5.98	<0.2	<1	<0.03	0.270	963	12.50	6.60
	Max		6.30	8.20	<4	<1	0.800	0.660	1,057	16.40	7.16
GW2S[1]	Mean	4	1.41	1.80	--	0.40	--	5.680	755	11.37	7.27
	Min		0.75	0.96	<0.2	0.20	<0.03	1.189	729	11.00	6.80
	Max		1.72	2.20	<4	<1	<0.06	13.75	784	12.00	8.07
GW3S[1]	Mean	18	0.42	0.55	--	--	0.086	0.200	294	12.86	7.78

Well	Item	Count	Total Ammonia	Ammonium	Nitrate	TON	Ortho-P	TP	SEC	Chloride	pH
			mg/L as NH_3-N	mg/L as NH_4	mg/L as NO_3	mg/L-N	mg/L as P	mg/L as P	µS/cm	mg/L	--
	Min		0.39	0.50	<0.2	<0.2	<0.03	0.140	286	11.60	7.29
	Max		0.51	0.64	<4	<1	0.160	0.300	326	13.60	8.30
GW4S[1]	Mean	18	6.31	7.81	1.37	0.42	--	1.640	657	14.55	7.39
	Min		0.65	3.70	<0.2	<0.2	<0.03	0.450	433	10.40	6.70
	Max		7.50	9.04	<4	<1	<0.06	4.850	698	17.00	8.07
GW5S	Mean	16	6.01	7.62	2.64	0.63	0.027	0.488	990	12.71	6.80
	Min		5.40	7.00	<4	<1	<0.03	0.360	930	10.20	6.50
	Max		6.60	8.30	4.70	1.00	0.060	0.620	1,103	14.10	7.60
GW9	Mean	19	2.30	2.02	1.80	0.52	0.123	0.173	518	18.94	7.48
	Min		0.32	0.41	<0.2	<0.2	<0.06	0.090	321	10.30	6.80
	Max		5.40	4.40	4.40	1.00	0.280	0.400	636	31.10	8.30
GW10	Mean	18	3.50	4.31	--	--	0.063	0.144	589	10.83	7.35
	Min		2.60	3.30	<0.2	<0.2	<0.06	0.052	503	8.90	6.80
	Max		4.80	4.80	<4	<1	0.120	0.300	643	15.60	8.27
GW11S	Mean	2	9.28	11.95	--	--	0.465	--	771	12.55	7.39
	Min		9.15	11.80	<0.2	<1	<0.06	0.540*	755	11.70	6.80
	Max		9.40	12.10	<4	<1	0.900	0.540*	787	13.40	7.98
GW12S	Mean	2	5.80	7.45	--	--	0.150	--	363	10.45	7.84
	Min		5.60	7.20	<0.2	<1	<0.06	0.410*	346	9.80	7.50
	Max		5.99	7.70	<4	<1	0.270	0.410*	380	11.10	8.17
GW13S	Mean	2	0.80	1.03	--	--	0.105	--	570	--	7.69
	Min		0.74	0.95	<0.2	<1	0.100	0.130*	538	17.40*	7.10
	Max		0.85	1.10	<4	<1	0.110	0.130*	602	17.40*	8.28
R9[2]	Mean	2	3.90	5.08	--	--	--	0.084	454	--	7.67
	Min		3.80	5.00	<0.2	<0.2	<0.03	0.037	448	17.40*	7.30
	Max		4.00	5.15	<4	<1	<0.06	0.130	460	17.40*	8.03
R10	Mean	2	5.84	7.55	--	--	--	4.226	611	--	7.29
	Min		5.30	6.90	<0.2	<0.2	<0.03	2.752	572	15.00*	7.10

Well	Item	Count	Total Ammonia	Ammonium	Nitrate	TON	Ortho-P	TP	SEC	Chloride	pH
			mg/L as NH_3-N	mg/L as NH_4	mg/L as NO_3	mg/L-N	mg/L as P	mg/L as P	µS/cm	mg/L	--
	Max		6.37	8.20	<4	<1	<0.06	5.700	650	15.00*	7.47

Note:
[1] response zones are mainly in the Quaternary but also straddle peat.
[2] response zone is in the Quaternary but the borehole was drilled into bedrock and the borehole was filled with cuttings, which means there is a potential pathway from bedrock to the response zone.

Table 7-13 Indicator Parameters, Bedrock Wells, 2021-2022 Data

Well	Item	Count	Total Ammonia	Ammonium	Nitrate	TON	Ortho-P	TP	SEC	Chloride	pH
			mg/L as NH_3-N	mg/L as NH_4	mg/L as NO_3	mg/L-N	mg/L as P	mg/L as P	µS/cm	mg/L	--
	Mean		0.93	1.20	--	--	0.060	--	294	--	7.90
MW02B	Min	2	0.90	1.16	<0.2	<0.2	<0.06	0.110*	280	11.50*	7.70
	Max		0.96	1.23	<4	<1	0.090	0.110*	307	11.50*	8.10
	Mean		7.61	9.82	--	--	--	0.160	473	39.15	7.80
MW03B	Min	3	1.00	1.30	<0.2	<0.2	<0.03	0.070	395	13.60	7.50
	Max		20.70	26.70	<4	<1	<0.06	<0.5	625	64.70	8.10
	Mean		11.00	14.20	--	--	--	0.300	532	41.50	7.70
MW04B	Min	1	11.00	14.20	<4	<1	<0.03	0.300	532	41.50	7.70
	Max		11.00	14.20	<4	<1	<0.03	0.300	532	41.50	7.70
	Mean		12.00	15.50	--	--	--	0.210	489	64.10	7.90
MW05B	Min	1	12.00	15.50	<4	<1	<0.03	0.210	489	64.10	7.90
	Max		12.00	15.50	<4	<1	<0.03	0.210	489	64.10	7.90
	Mean		4.09	5.28	--	--	--	--	371	--	7.43
MW06B	Min	2	4.08	5.26	<0.2	<0.2	<0.03	0.420*	355	13.30*	7.20
	Max		4.10	5.30	<2	<1	<0.06	0.420*	386	13.30*	7.66
	Mean		2.54	3.26	--	--	--	--	595	--	7.29
MW07B	Min	2	<0.02	<0.03	<0.2	<0.2	<0.03	0.150*	570	8.70*	6.90
	Max		5.06	6.51	<4	<1	<0.06	0.150*	620	8.70*	7.67
	Mean		6.61	9.00	--	--	0.089	0.475	764	14.45	7.18
GW1D	Min	17	4.30	7.00	<0.2	<1	<0.03	0.340	649	12.60	7.00
	Max		7.63	9.80	<4	<1	0.370	0.720	827	16.30	7.60
	Mean		1.82	2.37	3.77	1.35	--	0.275	632	15.10	7.43
GW2D	Min	3	1.50	1.90	<0.2	<1	<0.03	0.220	607	14.30	7.10
	Max		2.07	2.70	9.20	2.20	<0.06	0.330	672	16.30	8.08
	Mean		0.65	0.80	2.08	--	0.076	0.228	295	12.92	7.73
GW3D	Min	17	0.60	0.77	<0.2	<1	<0.03	0.130	285	11.80	7.50
	Max		0.80	0.81	4.30	<1	0.160	0.380	328	13.50	8.24
GW4D	Mean	17	3.71	4.32	--	--	--	0.310	527	14.38	7.42

Well	Item	Count	Total Ammonia	Ammonium	Nitrate	TON	Ortho-P	TP	SEC	Chloride	pH
			mg/L as NH_3-N	mg/L as NH_4	mg/L as NO_3	mg/L-N	mg/L as P	mg/L as P	µS/cm	mg/L	--
	Min		3.10	4.00	<0.2	<1	<0.03	0.230	481	12.30	7.10
	Max		4.40	4.60	<4	<1	<0.06	0.430	645	17.00	8.21
GW5D	Mean	16	7.55	9.40	--	--	0.052	0.328	690	12.12	7.18
	Min		6.30	8.10	<0.2	<1	<0.03	0.240	657	10.40	6.90
	Max		8.30	10.00	<4	<1	0.170	0.440	761	13.90	8.01
GW6	Mean	17	5.47	6.88	--	--	--	0.305	449	13.30	7.55
	Min		4.70	6.10	<0.2	<1	<0.03	0.260	434	11.50	7.30
	Max		6.00	7.30	<4	<1	<0.06	0.360	477	15.10	8.23
GW11D	Mean	2	8.22	10.60	--	--	0.465	--	702	12.65	7.53
	Min		8.20	10.60	<0.2	<1	<0.06	0.360*	698	11.90	7.00
	Max		8.23	10.60	<4	<1	0.900	0.360*	706	13.40	8.05
GW12D	Mean	2	1.98	2.55	--	--	0.080	--	279	10.30	8.00
	Min		1.96	2.50	<0.2	<1	<0.06	0.140*	270	9.70	7.70
	Max		2.00	2.60	<4	<1	0.130	0.140*	287	10.90	8.29
GW13D	Mean	2	0.59	0.76	--	--	--	--	232	12.20	8.00
	Min		0.56	0.72	<0.2	<1	<0.03	<0.05	216	11.30	7.80
	Max		0.62	0.80	<4	<1	<0.06	<0.05	247	13.10	8.20
R8[2]	Mean	2	8.82	11.33	--	--	--	3.996	756	--	7.08
	Min		8.50	10.90	<0.2	<0.2	<0.03	2.792	749	13.00*	6.90
	Max		9.13	11.76	<4	<4	<0.06	5.200	762	13.00*	7.26
R11[2]	Mean	2	3.38	4.36	--	--	--	0.412	786	--	7.06
	Min		3.35	4.32	<0.2	<0.2	<0.03	0.253	772	12.10*	6.80
	Max		3.40	4.40	<4	<4	<0.06	0.570	800	12.10*	7.31

Note:
[1] response zone is mainly in bedrock but also straddles overlying silts.

Table 7-14 Groundwater Threshold Values Used for Screening of Indicator Parameters

Parameter	Unit	Groundwater Regulations Column 2	Groundwater Regulations Column 4	IGV
SEC	µS/cm	--	1,875	--
Chloride	mg/L	--	187.5	30[1]
Ammonium	mg/L-N	0.065	0.175	0.15[1]
Nitrate	mg/L-NO_3	--	37.5	25[1]
Orthophosphate	mg/L-P	0.035	--	0.03[1]
Total chromium	µg/L	--	37.5	30[2]
Arsenic	µg/L	--	7.5	10[3]
Lead	µg/L	--	7.5	--
Mercury	µg/L	--	0.75	1[3]
Aluminium	µg/L	--	150	200[3]
Zinc	µg/L	--	75	100[2]
Barium	µg/L	--	--	100[3]
Cadmium	µg/L	--	--	5[1,3]
Copper	µg/L	--	--	30[3]
Iron	µg/L	--	--	200[2]
Manganese	µg/L	--	--	25[1]
Nickel	µg/L	--	--	20[2]
Potassium	mg/L	--	--	5[1]
Sodium	mg/L	--	--	150[3]
Sulphate	mg/L	--	--	200[2]

Notes:
[1]GSI 'trigger value'; [2]EQS for surface waters; [3]Drinking Water Standard

The presentation of groundwater quality data covers:

- Key leachate indicators, including ammonia and chloride.
- Nutrients.
- Trace metals.
- Organic compounds.

The presentation is preceded by a summary of leachate quality, based on BnM's monitoring of leachates under existing license conditions.

7.4.19.1 Summary of Leachate Quality

BnM collects leachate samples annually (in Q3 or Q4) from leachate collection storage tanks at the existing WMF. Results for physico-chemical parameters, nutrients and (dissolved) metals between 2008 and 2022 are summarised in Table 7-15.

Table 7-15 Summary of Annual Leachate Data, 2008-2022

Parameter	Unit	Tank LT-1 2008-2015	Tank TK-2 2015-2022
pH	--	6.7-7.9	7.1-8.1
Electrical Conductivity	µS/cm	6,700-33,600	16,260-40,100
Chloride	mg/L	18-3,481	1,894-4,963
Biological Oxygen Demand	mg/L-O_2	32-12,625	325-2,500
Chemical Oxygen Demand	mg/L-O_2	93-18,575	5,140-11,570
Total Ammonia	mg/L[1]	2.3-2,818	0.16-1,927
Total Oxidisable Nitrogen	mg/L-N	<0.2-0.41	<0.2-<10

Parameter	Unit	Tank LT-1 2008-2015	Tank TK-2 2015-2022
Total Phosphorus	mg/L-P	2.25-21	5.99-25
Fluoride	mg/L	<0.2-97.65	<0.5-55.5
Sulphate	mg/L	8.86-112	112-1,833
Calcium	mg/L	57-482	46-480
Sodium	mg/L	207-2,461	535-3,490
Magnesium	mg/L	63-188	0.344-304
Potassium	mg/L	553-1,964	402-2,140
Arsenic	µg/L	<2-345	381.4-1,080[2]
Aluminium	µg/L	168-2,307	2,160-2,940[2]
Barium	µg/L	24-806	330-370[2]
Boron	µg/L	116-56,840	4,650-31,840
Cadmium	µg/L	<0.2-<20	<0.5-2.67
Chromium (total)	µg/L	38-683	273-2,280
Cobalt	µg/L	15-33	20-28
Copper	µg/L	3-228	5.49-17.5
Cyanide	µg/L	--	0.08[2]
Iron	µg/L	<1-19,000	<1-1,490
Lead	µg/L	6-64	6.99-11.6
Manganese	µg/L	289-11,586	266-952
Mercury	µg/L	<1-<10	<0.02-440
Nickel	µg/L	3-438	86-378
Selenium	µg/L	3-36	<10[3]
Silver	µg/L	<2-<20	<2-1,060
Tin	µg/L	9-23	25-282
Zinc	µg/L	<20-1,307	<20-2,900

Notes:
[1]total ammonia is laboratory returns are reported either as NH_3-N or NH_4-N;
[2]reported in 2022
[3] three results in total over the period of record

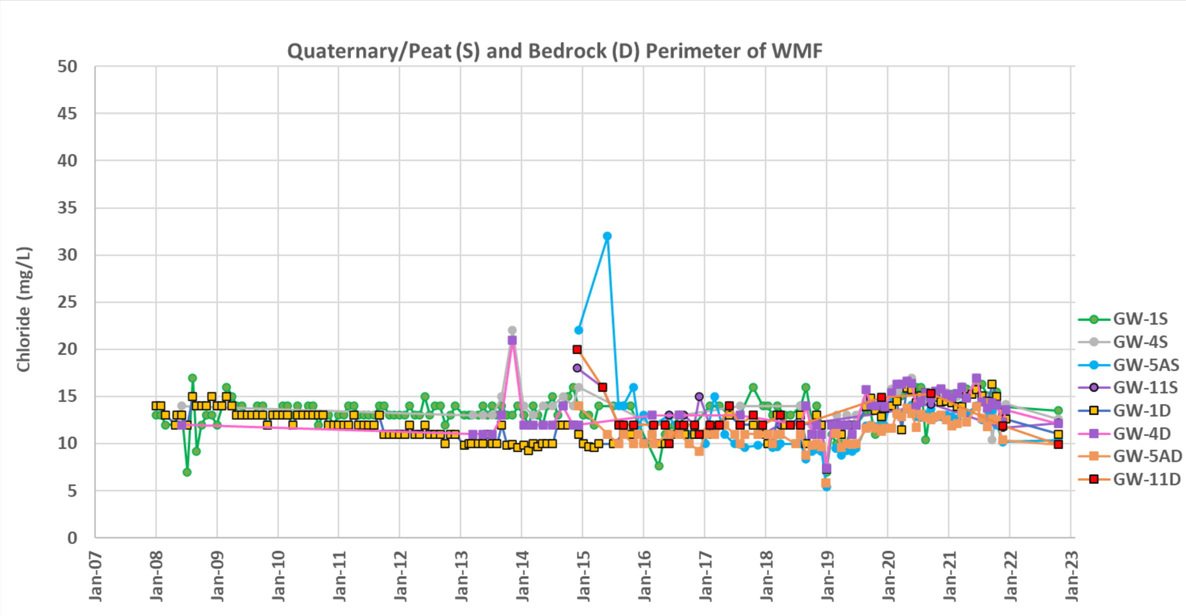
VOCs, SVOCs and PAHs are also historically detected in the leachate. In 2021, eleven VOC compounds were detected, including BTEX constituents. The highest concentration of an individual constituent was 'm,p-xylene' at 29 µg/L. In 2022, fewer detections and lower concentrations were recorded. SVOCs and pesticides have historically been non-detect, *i.e.,* below respective LODs.

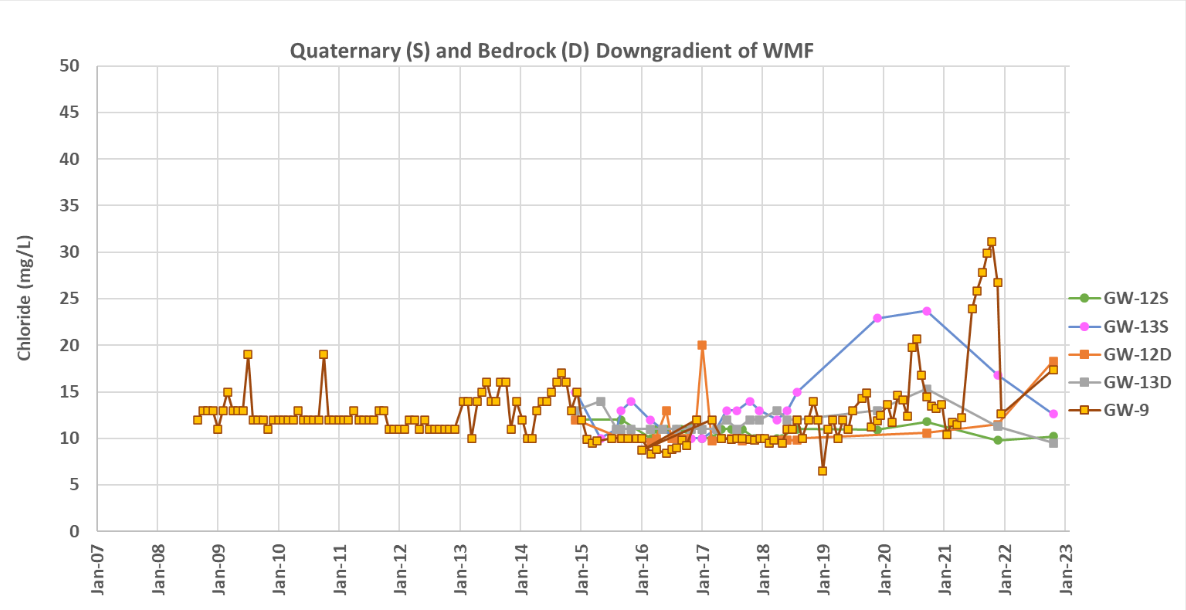
In a national study on leachate led by EPA, leachate samples collected from the Drehid WMF (AECOM, 2021) showed the presence of VOCs and phenolic compounds, as well as per- and poly-fluoroalkyl substances (PFAS) and brominated flame retardants (BFRs).

7.4.20 Groundwater Quality – Leachate Indicators

7.4.20.1 Chloride

Chloride is a useful tracer as it is not affected by bio-geochemical attenuation processes in the groundwater environment (Hendry et al, 2000; Mazurek et al., 2011). Despite the recorded chloride concentrations in the thousands of mg/L in leachate, chloride concentrations in groundwater near the WMF, and within TSB generally, are lower than 20 mg/L (Figure 7-21).





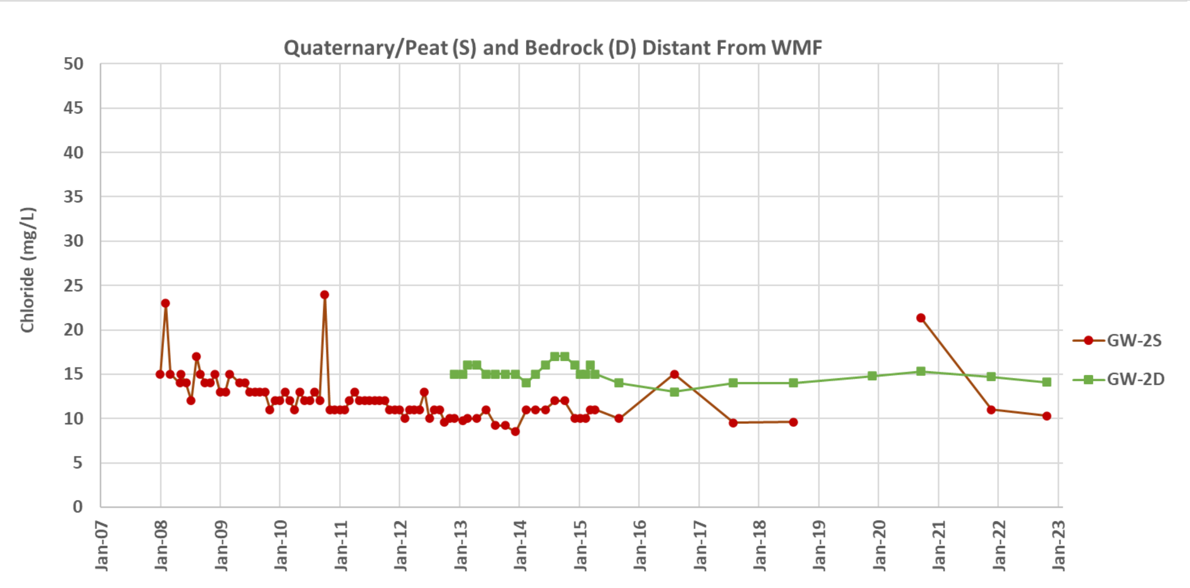


Figure 7-21 Chloride in Groundwater, Historical Data

Wells that are both near and far from the WMF show similar responses with time, and only the magnitude of responses are different. Wells immediately south of the WMF show greater variability (to a maximum of 32 mg/L).

In February 2003, i.e. pre-WMF, samples taken from wells installed at the time (GW-1S/1D; GW-2S; GW-3S/D; GW-4S/D; GW-5S/D) show chloride concentrations in the range 21-44 mg/L (TCE, 2008), with the highest concentration in well GW-2S, approximately 1.5 km south/southwest of the WMF. In 2006 and 2007, also pre-WMF, concentrations were consistently below 20 mg/L (TCE, 2008).

In the expanded 2021-2022 dataset, chloride concentrations ranged as follows:

- Peat wells: from 7.6 mg/L in MW03P to 28.6 mg/L in MW04P.
- Quaternary wells: from 8 mg/L in MW07Q to 26.7 mg/L in MW03Q.
- Bedrock wells: from 8.7 mg/L in MW07B to 64 mg/L in MW05B.

With the exception of the sample from MW05B, none of the concentrations exceeded groundwater screening values. Well MW05B is located in the southern part of TSB, in a separate groundwater catchment and outside any influence from the WMF.

7.4.20.2 Specific Electrical Conductivity

In the historical dataset, SEC values range from 200 to 1,200 µS/cm, depending on well (Figure 7-22). Well GW1S adjacent to the WMF shows the highest values and may be influenced by the perimeter swale which collects stormwater from the WMF. The deeper paired well GW1D has lower SEC values, around 700-800 µS/cm. A leachate influence is not inferred due to the low concentrations of chloride, which are within naturally occurring ranges.

SEC values in wells near the attenuation lagoons south of WMF (GW12 and GW13 clusters) are lower than 500 µS/cm. This implies that water discharged from the lagoons (which receive stormwater runoff) may influence groundwater chemistry locally. In the 2021-2022 dataset, SEC ranged as follows:

- Peat wells: between 141 µS/cm in MW7P to 1,564 µS/cm in MW6P.
- Quaternary wells: between 286 µS/cm in GW3S and 1,103 µS/cm in GW5S.
- Bedrock wells: between 216 µS/cm in GW13D and 827 µS/cm in GW1D.

None of the samples exceeded the groundwater screening value of 1,875 µS/cm (Table 7-14).

7.4.20.3 Sodium

As indicated by Figure 7-23, sodium concentrations in groundwater near the WMF and within TSB are generally less than 20 mg/L and steady. Wells downgradient and far from the WMF show similar concentration level and responses as wells near the WMF.

Baseline concentrations of sodium ranged from 9.2 to 64 mg/L in 2003 and from <2 to 39.5 mg/L in 2006 (TCE, 2008). Current (2021-2022) concentrations are similar. None of the recorded concentrations to date have exceeded the groundwater screening value of 150 mg/L (Table 7-14).

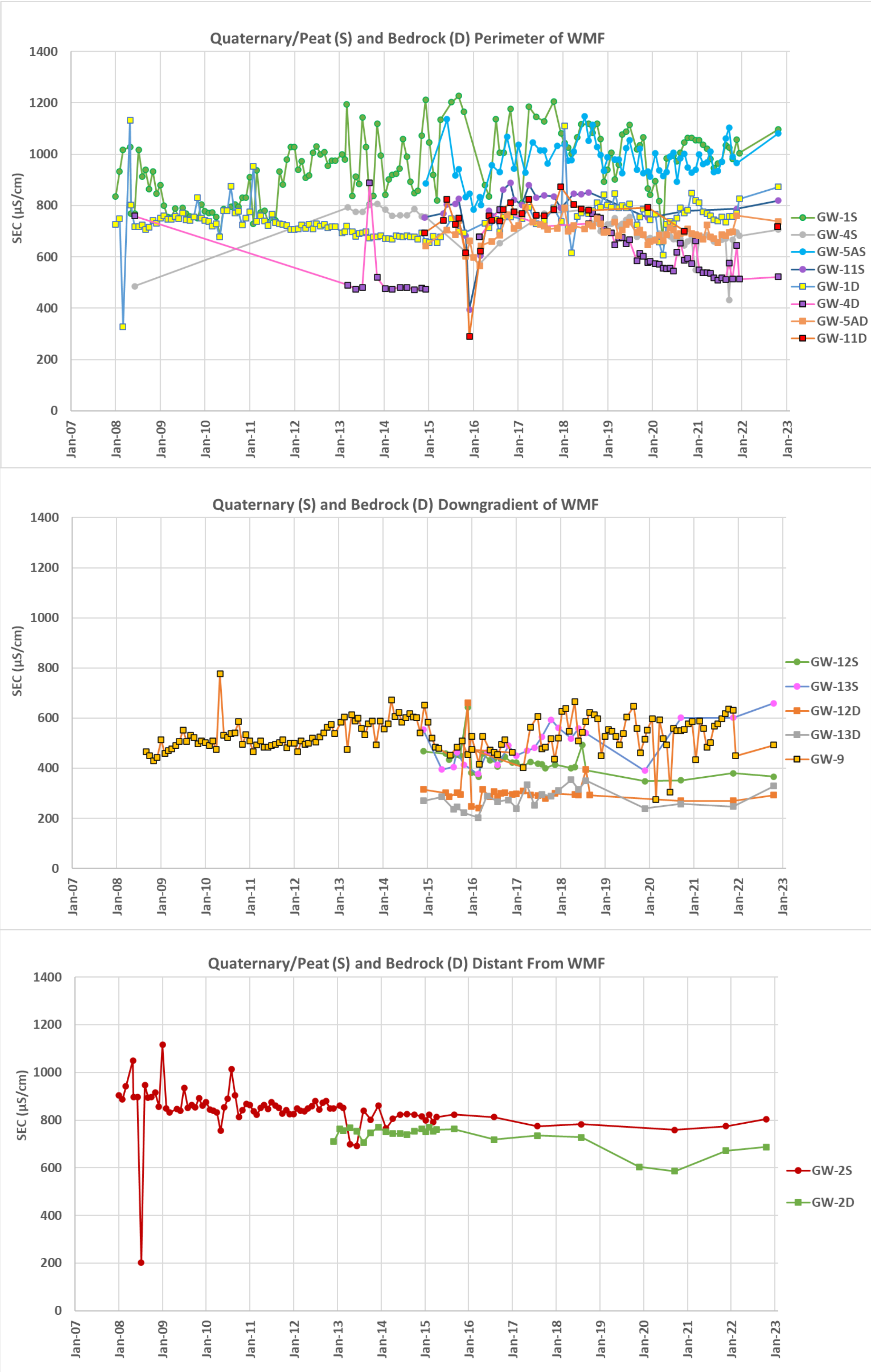


Figure 7-22 SEC Concentrations, Historical Data

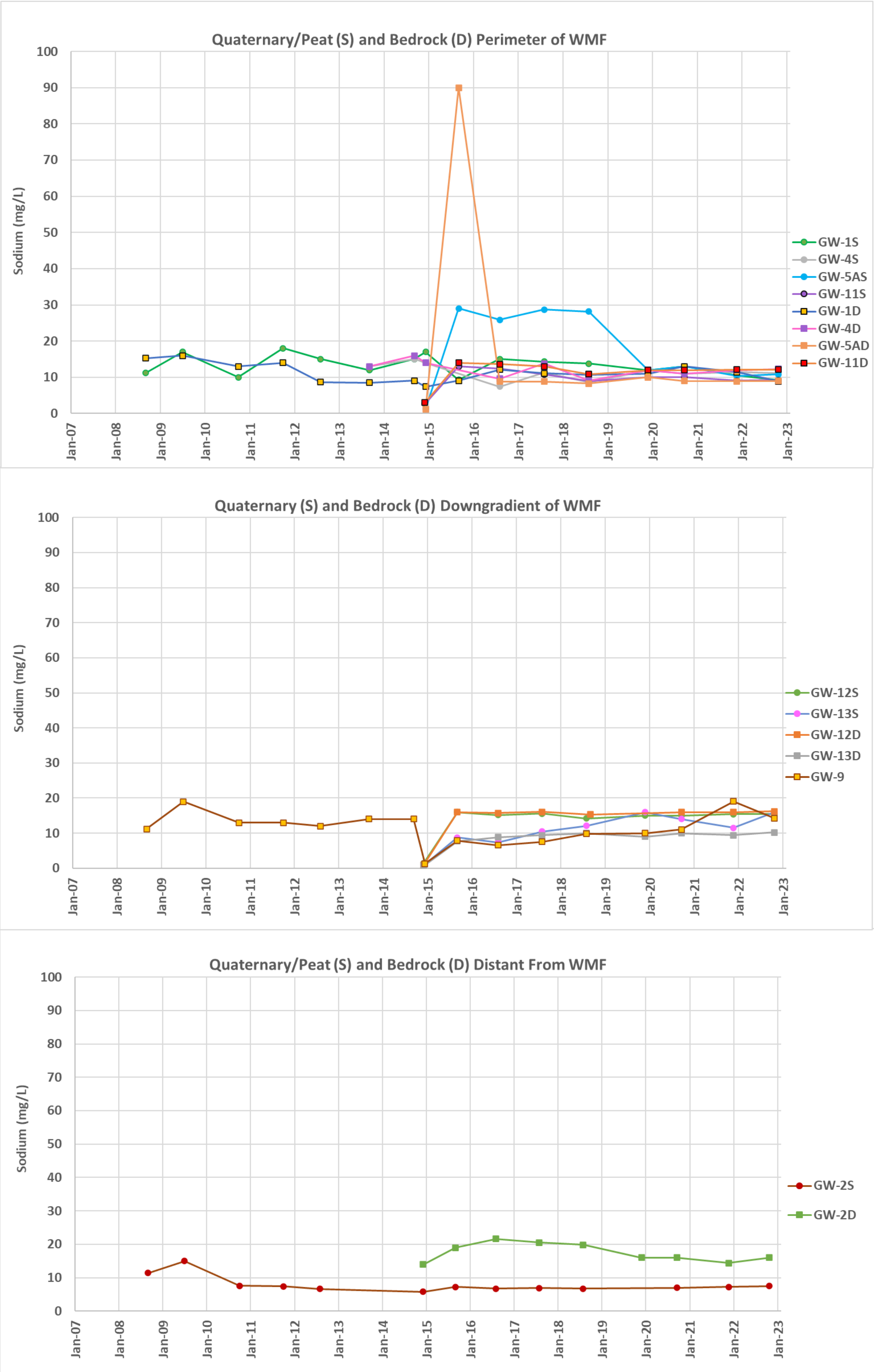


Figure 7-23 Sodium in Groundwater, Historical Data

7.4.20.4 Potassium

As indicated by Figure 7-24, potassium concentrations in groundwater near the WMF and within TSB are generally less than 5 mg/L (which is also the IGV in Table 7-14) and relatively steady (referring to the high initial concentrations in 2014 for wells installed in 2014). Wells downgradient and far from the WMF show similar concentration level and responses as the wells near the WMF perimeter.

Baseline concentrations of potassium ranged from 0.8 to 3.2 mg/L in 2003 and from 0.6 to 1.9 mg/L in 2006 (TCE, 2008). Like sodium, current (2021-2022) concentrations are similar.

7.4.20.5 Ammonia/Ammonium

Total ammonia concentrations are elevated across TSB, and includes remote areas of the bog, away from the WMF. This applied to groundwater and surface water (see Chapter 8 for surface water results).

Reported baseline concentrations of total ammonia (as NH_4) ranged from 0.5 to 8 mg/L in 2003 (TCE, 2008). Baseline concentrations in 2006 (NH_3-N) ranged from 0.41 to 8.7 mg/L (TCE, 2008). Monthly samples in 2007 in the same pre-WMF set of wells ranged from 0.4 to 8.7 mg/L, with consistently highest concentrations in well GW-1D (TCE, 2008).

Concentrations in the remote well pair GW-2S/2D (Quaternary/bedrock) are consistently elevated, both pre- and post-WMF, as shown in Figure 7-25. These wells are located approximately 1.5 km south/southeast of the WMF and are hydraulically side gradient of the WMF. The observed elevated concentrations in these wells, along with elevated pre-WMF concentrations in other parts of TSB attest to a natural influence of ammonia leaching in TSB (See also Chapter 8).

As illustrated by Figure 7-25, there has been little or no change in reported concentrations over time and current concentrations are consistent with pre-WMF (2003 and 2006) concentrations.

Historical total ammonia (NH_3-N) data from other monitoring wells are shown in Figure 7-26, as reported by BnM's external laboratory. Concentrations generally range from <1 to 10 mg/L.

For the expanded dataset in 2021-2022, ammonia concentrations (as ammonium, NH_4) ranged as follows:

- Peat wells: from 0.24 mg/L in RW03P to 16.3 mg/L in MW06P, noting that MW06P is an order of magnitude higher than all other results. The well is located east and upgradient of the existing WMF.
- Quaternary wells: from 0.06 mg/L in RW09A to 12.9 mg/L in MW04Q. The latter well is located in the topographic and groundwater subcatchment of TSB which drains to the Abbeylough River.
- Bedrock wells: from <0.03 mg/L in MW07B to 26.7 mg/L in MW03B. Concentrations in the dataset are generally less than 10 mg/L.

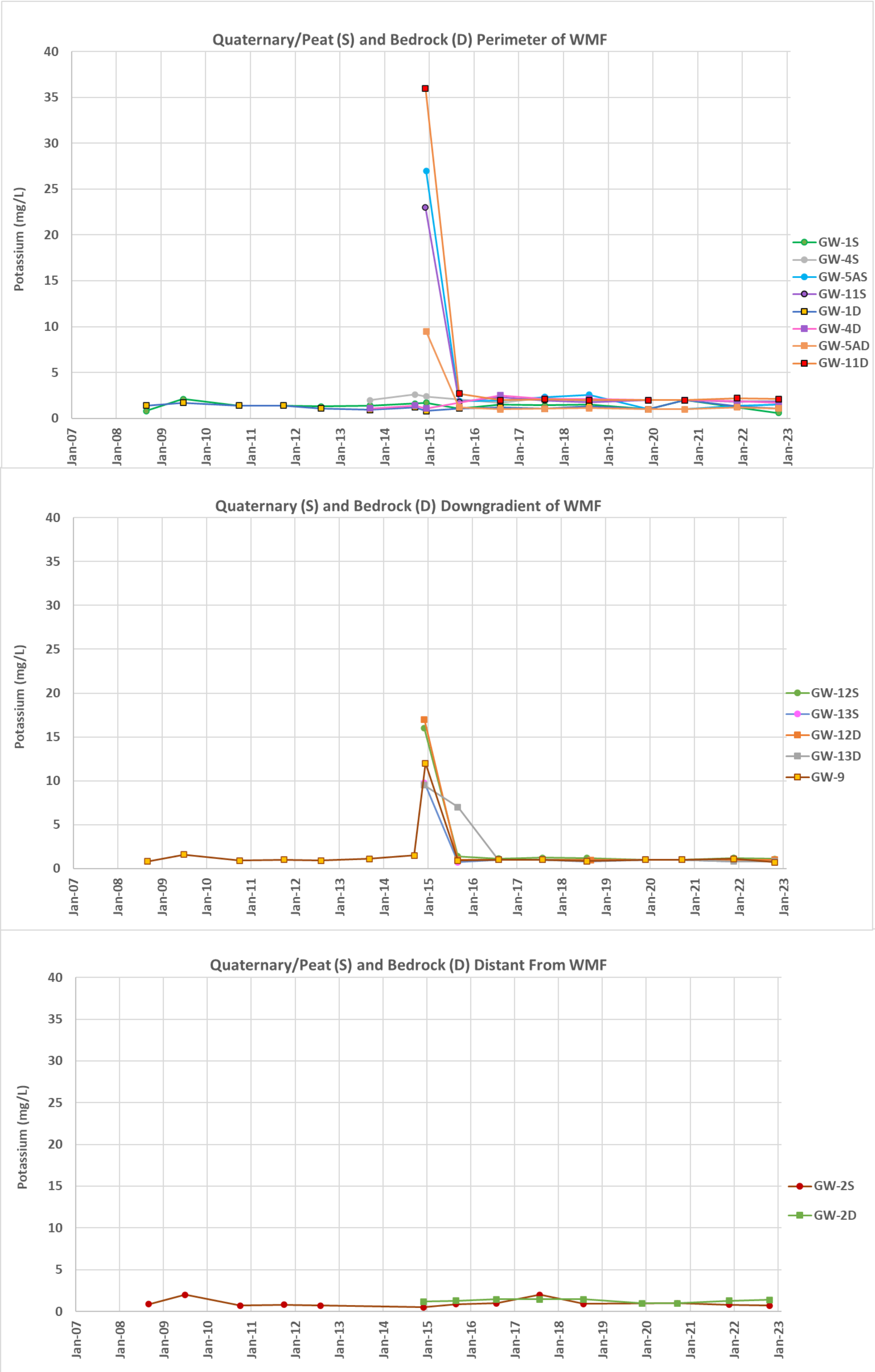


Figure 7-24 Potassium in Groundwater, Historical Data

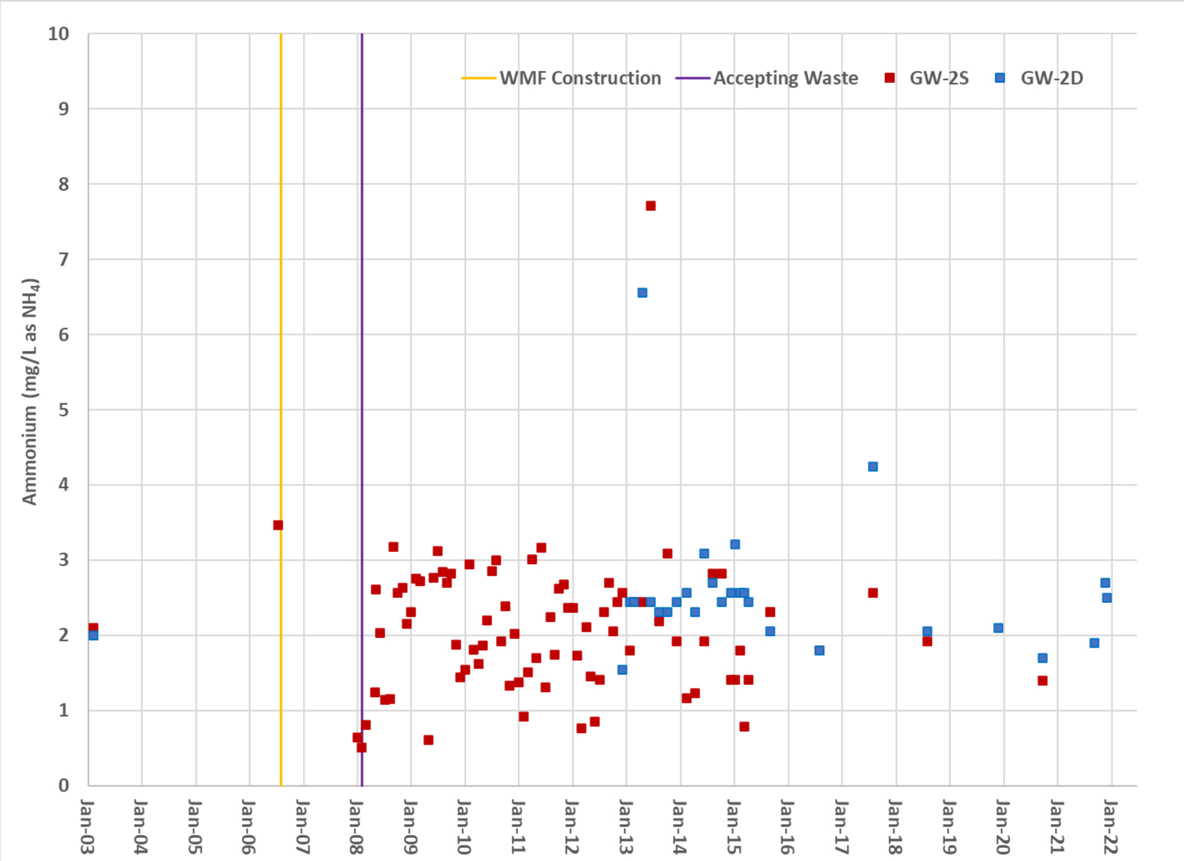


Figure 7-25 Ammonium (NH_4^+) Concentrations, GW-2S and GW-2D, 2003-2022

7.4.20.6 Other Nutrients

In the historical data, there are few detections of nitrate above the LOD (0.04, 0.05, 0.2, 0.3 and 4 mg/L as NO_3, depending on sampling round). Nitrate (as NO_3) in the 2003 pre-WMF dataset were mostly at or below the LOD of 0.03 mg/L, with one value of 25.6 mg/L in remote well GW-2S, noting that a nitrite (NO_2) concentration of 0.68 mg/L was recorded in the same sample (TCE, 2008).

In the 2006 dataset, recorded nitrate concentrations (as N) ranged from <0.05 to 0.21 mg/L, with only a single detection in well GW-2S (TCE, 2008). In BnM's dataset from 2014-2022, there are few detections above LODs, the maximum being 8.5 mg/L (as NO_3) in GW-1S.

The expanded 2021-2022 dataset included nitrate analysis in 54 sampled wells. Nitrate was generally reported below LODs (0.2 and 4.0 mg/L as NO_3, depending on round). The recorded nitrate detections can be summarised as follows:

- Peat wells: detected in 1 of 8 sampled wells only - MW04P near the old settlement ponds. Concentrations ranged from <4 to 15 mg/L (as NO_3), with a mean of 3.44 mg/L from 9 samples in MW04P.
- Quaternary wells: detected in 6 of 28 sampled wells. The highest concentration was 8.7 mg/L (as NO_3) in RW09A, located south of the existing WMF.
- Bedrock wells: detected in 2 of 17 sampled wells. The highest concentration was 9.2 mg/L (as NO_3) in GW-2D which is approximately 1.5 km south/southwest of the WMF (no detections in paired well GW-2S).

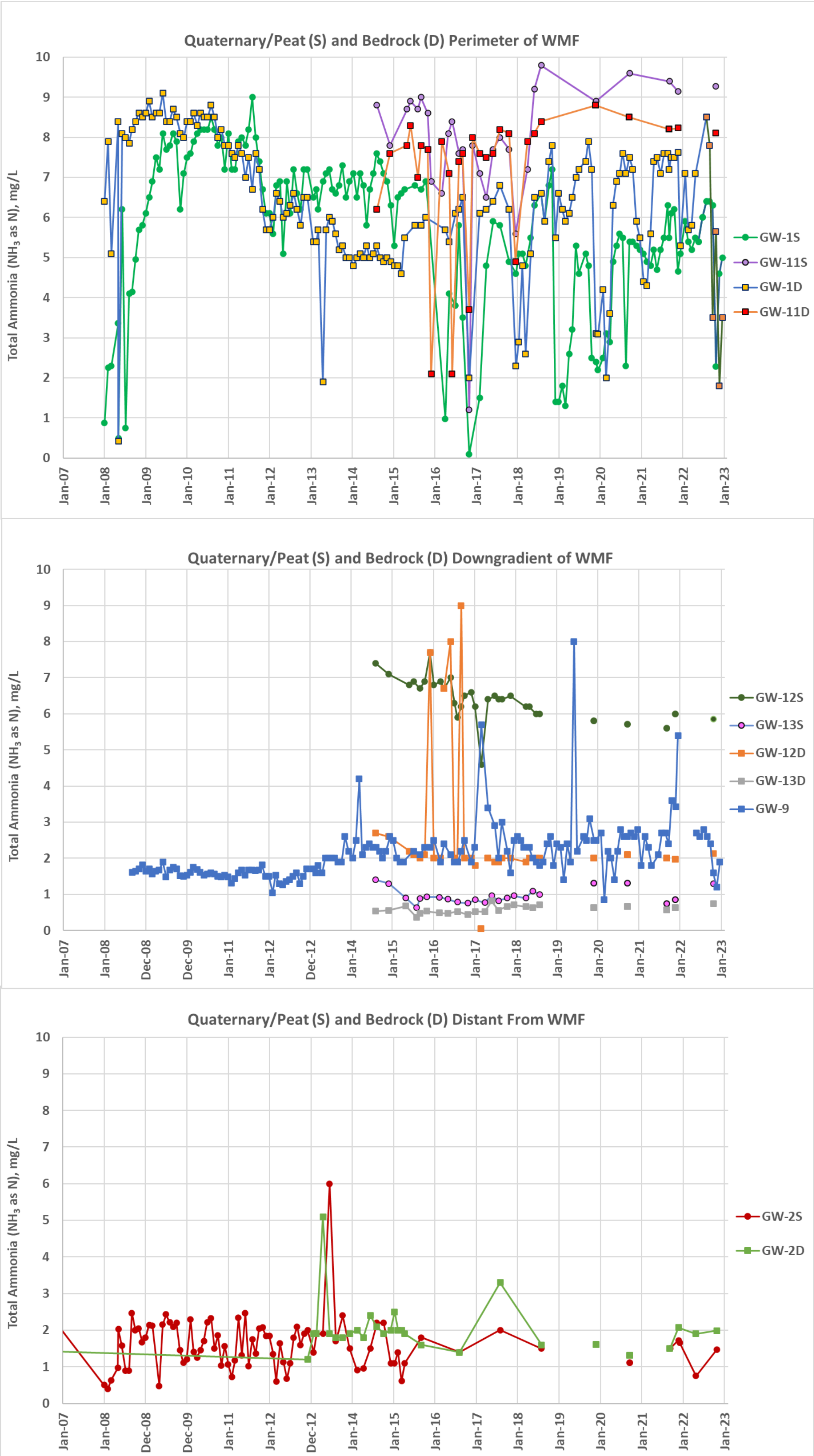


Figure 7-26 Total Ammonia (NH_3-N) in Groundwater, Historical Data

In comparison, ortho-P, the biologically available form of phosphorus (P), was detected sporadically in wells across TSB. With an LOD of 0.01 and 0.06 mg/L-P in the 2020-2021 dataset, recorded detections ranged as follows:

- Peat wells: from 0.04 mg/L-P to 0.57 mg/L-P, the latter being reported in well MW04P.
- Quaternary wells: from 0.04 to 0.9 mg/L-P, the latter being reported in well GW11S.
- Bedrock wells: from 0.052 to 0.9 mg/L-P, the latter being reported in well GW11D.

Based on the historical data shown in Figure 7-27, the highest and, in some cases, increasing concentrations of ortho-P all occur in wells downgradient of the attenuation lagoons and ICW system. Wells along the WMF perimeter generally show concentrations which are below the reported LODs.

7.4.20.7 pH

pH is an important baseline parameter as it influences the hydrochemical processes that take place in groundwater and controls (with temperature) the form of ammonia that is present, as described in Chapter 8. Recorded historical data are presented in Figure 7-28. Some of the wells nearest the WMF show an apparent decreasing trend, which is described further in Section 7.4.19. Remote wells do not show a similar trend. pH values are marginally higher downgradient of the WMF compared to upgradient, as exemplified by MW13S/D and MW1S/D.

In the expanded 2021-2022 dataset, pH ranged across TSB as follows:

- Peat wells: From 5.8 in RW10P to 7.1 in RW04P, but mostly below 6.5.
- Quaternary wells: From 6.5 in GW5S to 8.3 in GW3S and GW9.
- Bedrock wells: From 6.8 in R11 to 8.29 in GW12D.

The mean pH value for 17 bedrock wells was 7.53, which is higher than the mean for 28 Quaternary wells of 7.25, which in turn is higher than the mean for 8 peat wells of 6.38. This is consistent with the naturally lower pH environment of peat, and the influence decreases with depth (through the Quaternary and into bedrock).

As described in chapter 8, because the pH is mostly less than 8, the ammonia is present in groundwater mainly as ammonium (NH_4^+, the ionized form of ammonia).

7.4.20.8 Sulphate

Sulphate is not represented in the 2021-2022 dataset, but recorded historical data for sulphate are shown in Figure 7-29. The majority of results are lower than the LOD of 0.5 or 5 mg/L (depending on sampling round and laboratory used), with non-detections indicated as zero values in Figure 7-29.

All recorded sulphate (as SO_4) concentrations to date above LODs are below the IGV of 200 mg/L, and the majority of detections are observed in well pairs GW-1S/1D and GW-2S/2D. These are in very different settings, the former being at the WMF perimeter and the latter being more than 1.5 km away from the WMF.

Pre-WMF, sulphate concentrations ranged from <0.5 to 14.9 mg/L in the 2006 dataset, the latter being recorded in remote well GW-2S. In 2003, recorded concentrations ranged from <3 to 59 mg/L, the latter being recorded in well GW-1D. The concentration in GW-2S in 2003 was 45 mg/L (TCE, 2008).

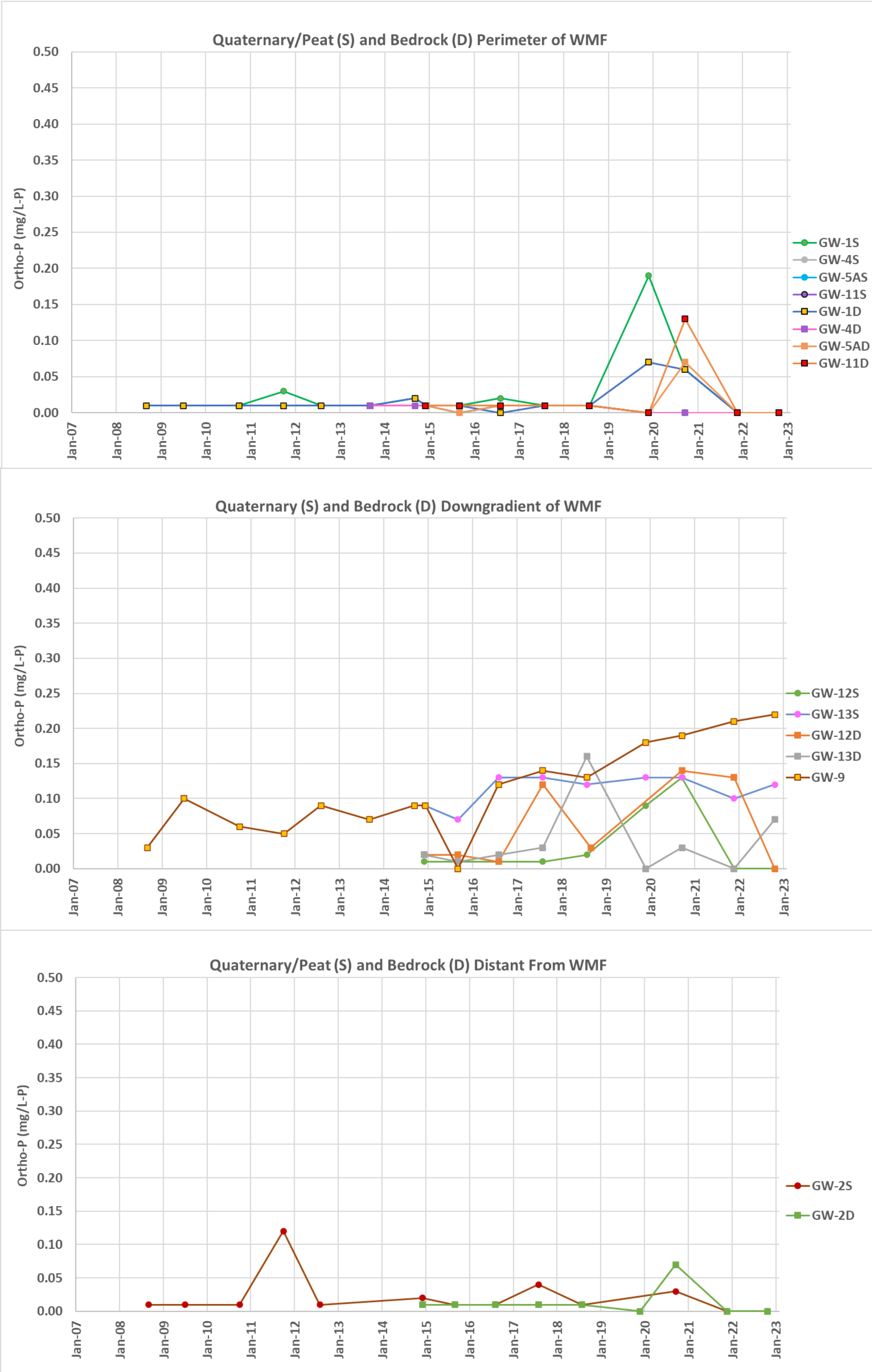
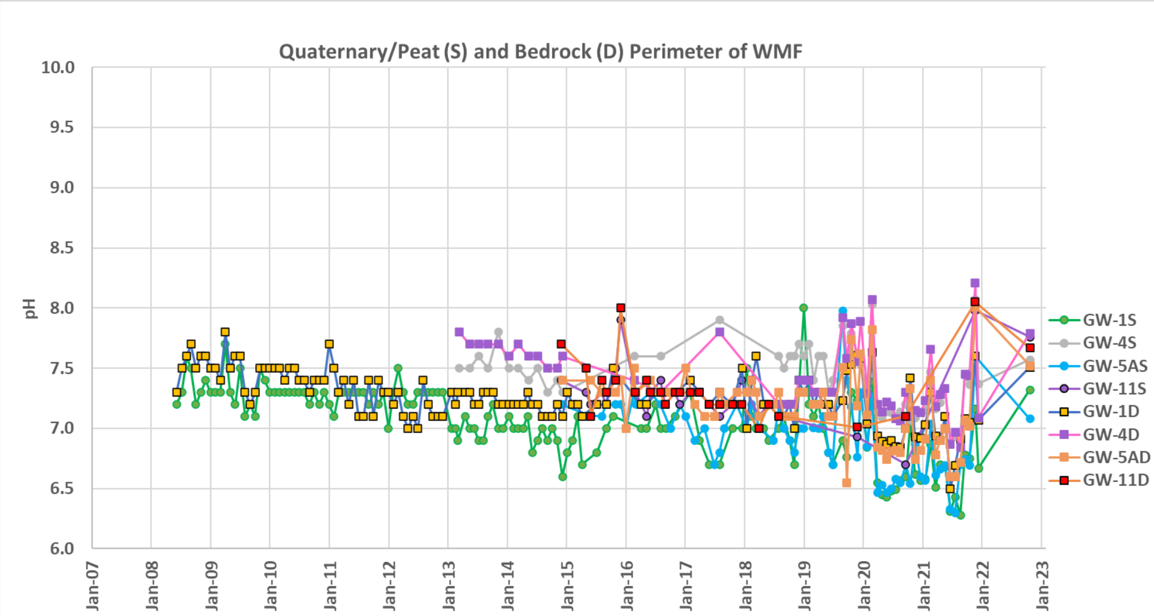
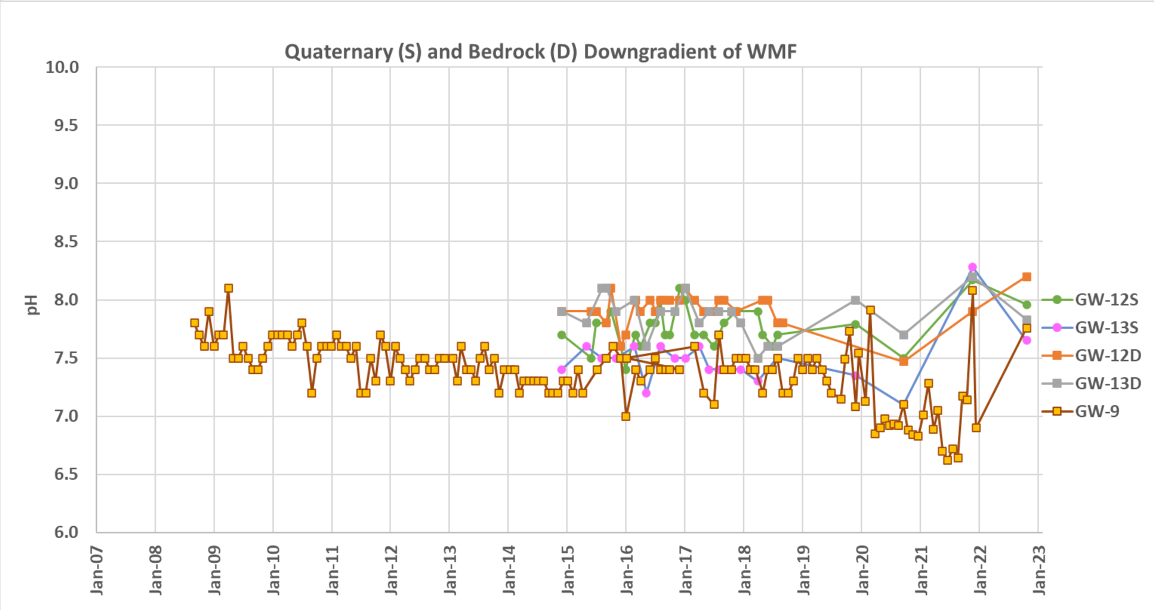


Figure 7-27 Ortho-P (as P) in Groundwater, Historical Data





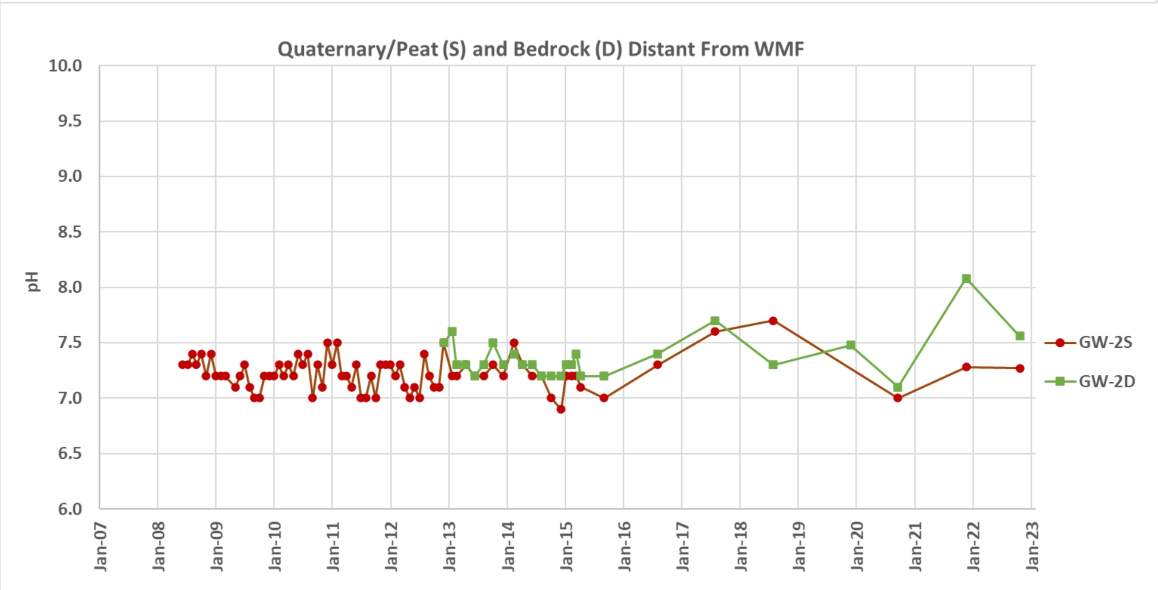


Figure 7-28 pH of Groundwater, Historical Data

7.4.21 Groundwater Quality – Trace Metals

Arsenic (As), barium (Ba), iron (Fe), manganese (Mn) and nickel (Ni) have been flagged at elevated concentrations in the past in both Quaternary and bedrock wells within TSB (TCE, 2017; Marron, 2020; Marron, 2023). The vast majority of screening criteria exceedances are represented by As, Ba, Fe, Mn, and Ni. Bedrock wells also have a small number of recorded exceedances of copper (Cu), cadmium (Cd) and mercury (Hg). Details are presented and discussed below.

Historical records for As, Ba, Mn, and Ni are shown in Figures 7-30 through 7-33. Arsenic concentrations show variability in all wells across the available time series. Most sample results exceed the 7.5 µg/L threshold value (Table 7-14), including results from wells that are distant from the WMF (GW-2S/2D). The highest recorded concentrations are observed both in Quaternary and bedrock wells near the WMF. However, elevated concentrations of arsenic were already recorded pre-WMF. In the 2003 dataset, arsenic concentrations ranged from <5 to 22 µg/L, the higher value being associated with wells GW-1D and GW-3D (both bedrock).

In the 2006 and 2007 datasets, values range from 3 to 142 µg/L, with the highest value recorded in bedrock well GW-1D. Several concentrations exceeded the threshold value of 7.5 µg/L, as follows: GW-1S (15-25 µg/L), GW-1D (125-142 µg/L), GW-3D (24 µg/L), GW-4D (15 µg/L) and GW6 (27 µg/L) (TCE, 2008).

Barium concentrations (Figure 7-31) range from <100 to approximately 900 µg/L, with the highest concentrations assigned to wells near the WMF and well pair GW-2S/2D which is remote and outside the hydrogeological influence of the WMF. Most detections exceed the 100 µg/L IGV. In 2003 and 2006/2007, i.e., pre-WMF, elevated detections above the IGV were recorded in most of the sampled wells, e.g., GW-1S (259-343 µg/L), GW-1D (251-327 µg/L) and GW-6 (123 µg/L) (TCE, 2008). Concentrations in remote well GW-2S/2D were 521 and 452 µg/L, and 270 µg/L, respectively.

Manganese concentrations range from non-detect (LOD 5 µg/L, shown as zero values in Figure 7-32) to 2,200 µg/L, although the majority of recorded concentration are less than 500 µg/L. Hence, the majority of samples exceed the IGV of 50 µg/L. In 2003, pre-WMF, reported manganese detections ranged from 6 µg/L in GW-1D to 409 µg/L in GW-2S (TCE, 2008). In 2006/2007, detections ranged from 55 µg/L in GW-1D to 330 µg/L in GW-4S. Concentrations in remote well GW-2S were 307 and 262 µg/L in 2006 and 2007, respectively.

Nickel concentrations range from non-detect (LOD 0.4 and 4 µg/L, depending on sampling round, zero values in Figure 7-33) to 69 µg/L. The highest concentrations occur near the WMF in bedrock wells, and most IGV exceedances occur in the same wells. Concentrations in remote well pair GW-2S/2D also periodically exceeds the IGV of 20 µg/L. In 2006/2007, pre-WMF, elevated detections above the 20 µg/L IGV were recorded in GW-1S (19-27 µg/L) and GW-1D (27-33 µg/L) (TCE, 2008). Concentration exceedances also occurred in remote well GW-2S were 30 and 24 µg/L in 2006 and 2007, respectively.

The new monitoring wells, including replacement wells, that were installed in 2020-2021 were analysed for dissolved metals in December 2021 and May 2022. The data for As, Ba, Fe, Mn and Ni are summarised in Table 7-16 with exceedances of screening thresholds (from Table 7-14) shown in bold font. Overall, results are consistent with historical data, confirming that trace metals are present at concentrations above screening criteria in both Quaternary and bedrock across TSB. This includes the landfill expansion footprint, which is represented by wells LW01, LW02D, and LFBH05.

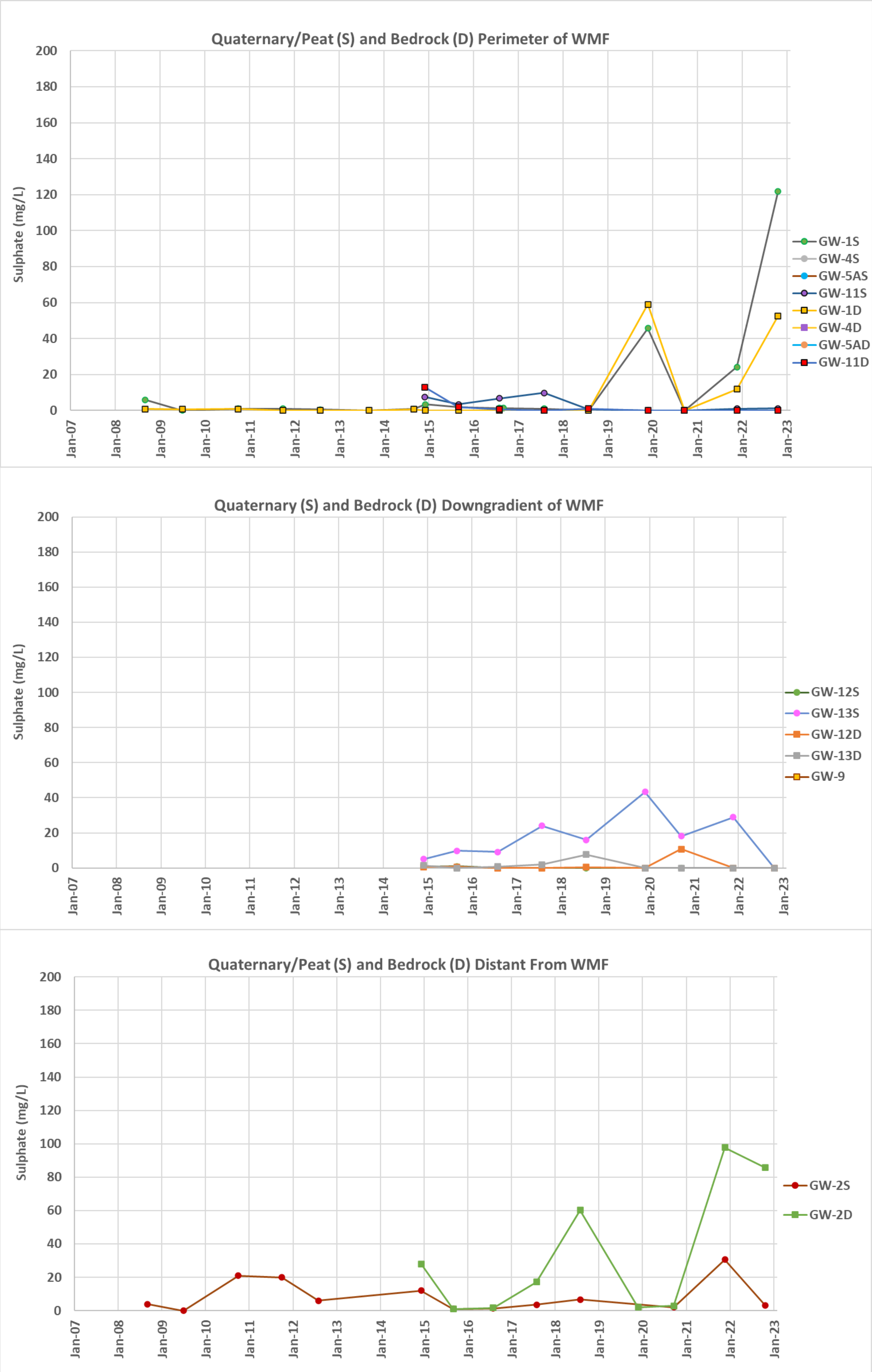


Figure 7-29 Sulphate in Groundwater, Historical Data

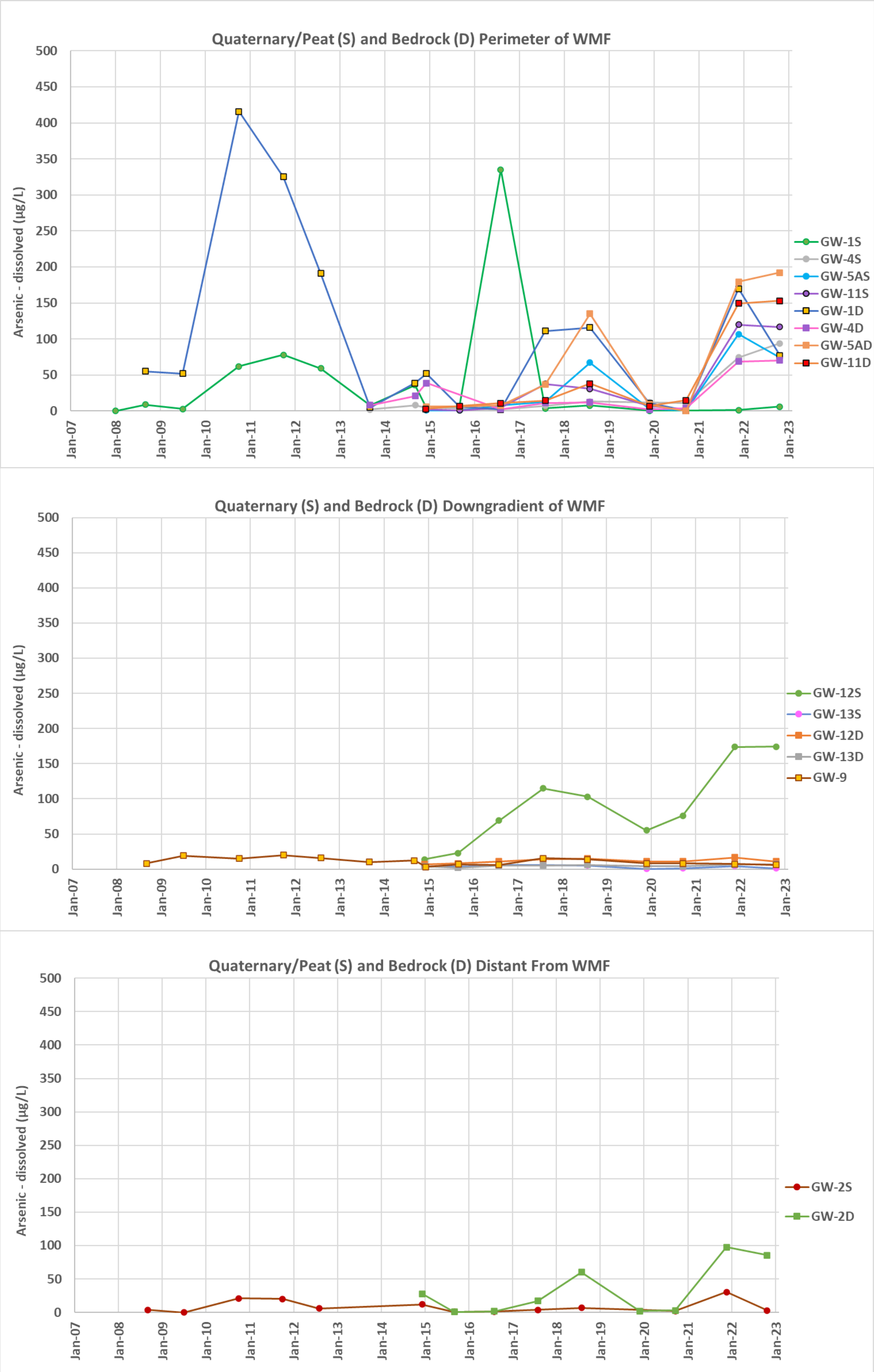


Figure 7-30 Arsenic (Dissolved) in Groundwater, Historical Data

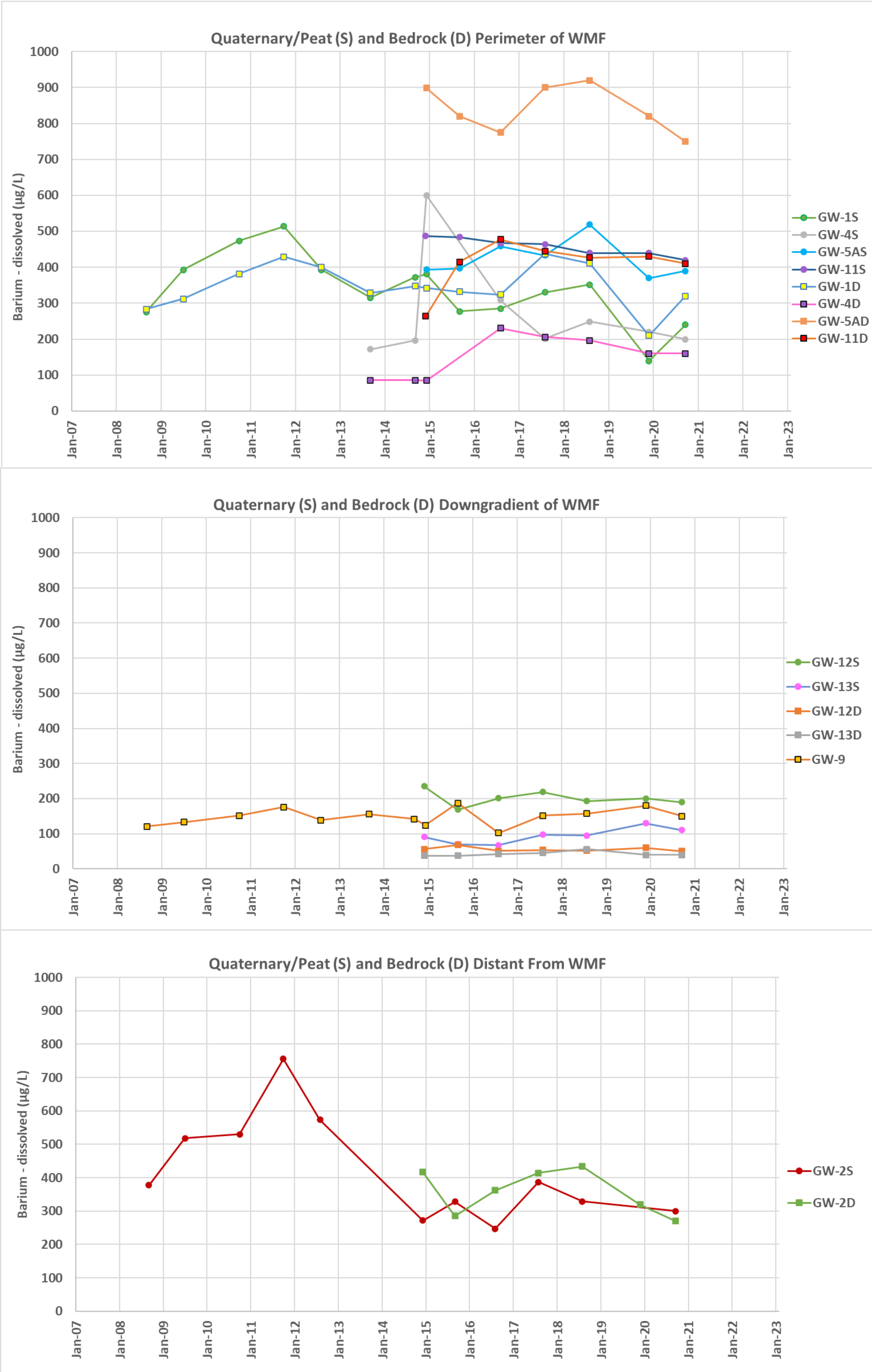


Figure 7-31 Barium (Dissolved) in Groundwater, Historical Data

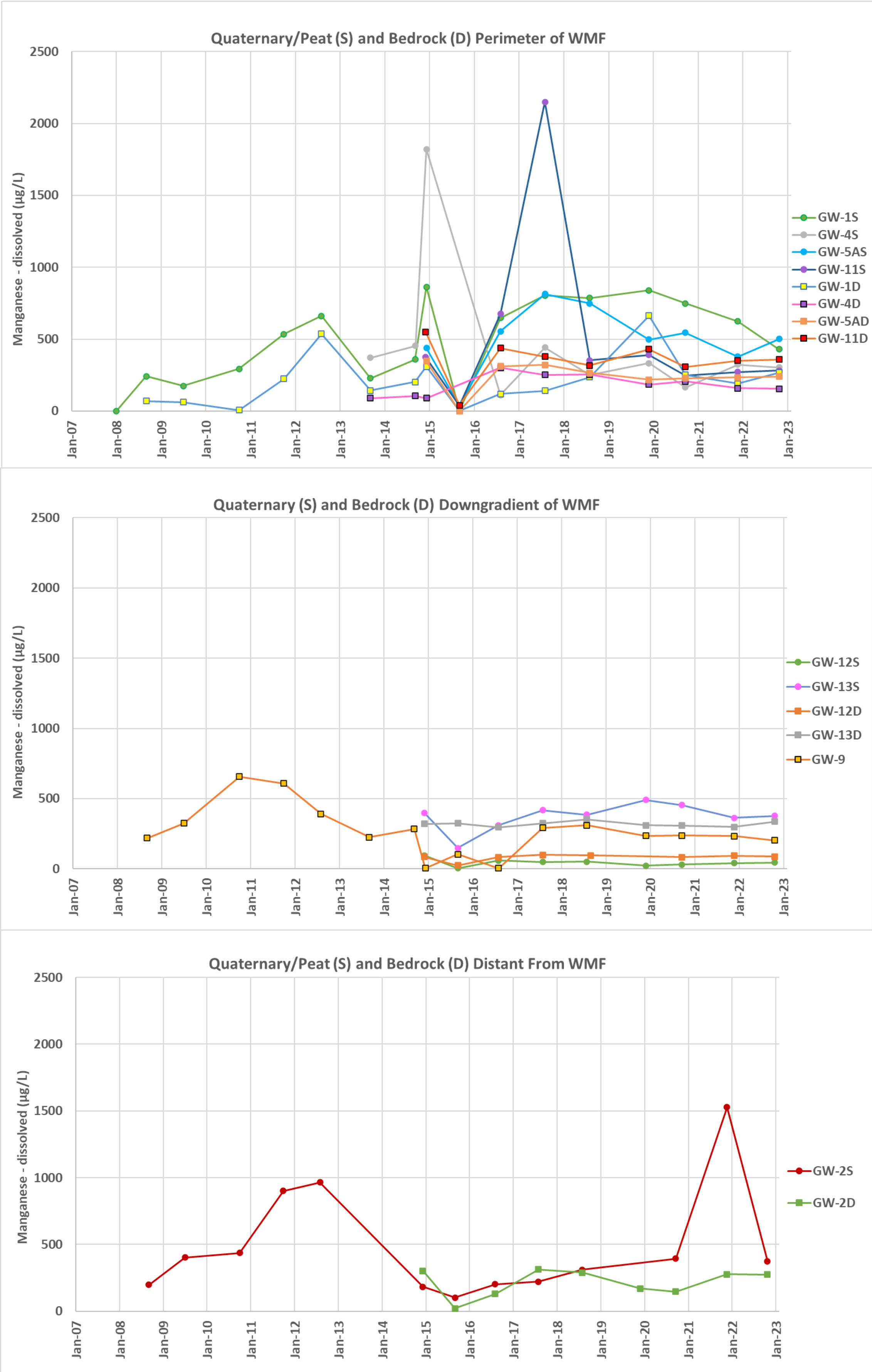


Figure 7-32 Manganese (Dissolved) in Groundwater, Historical Data

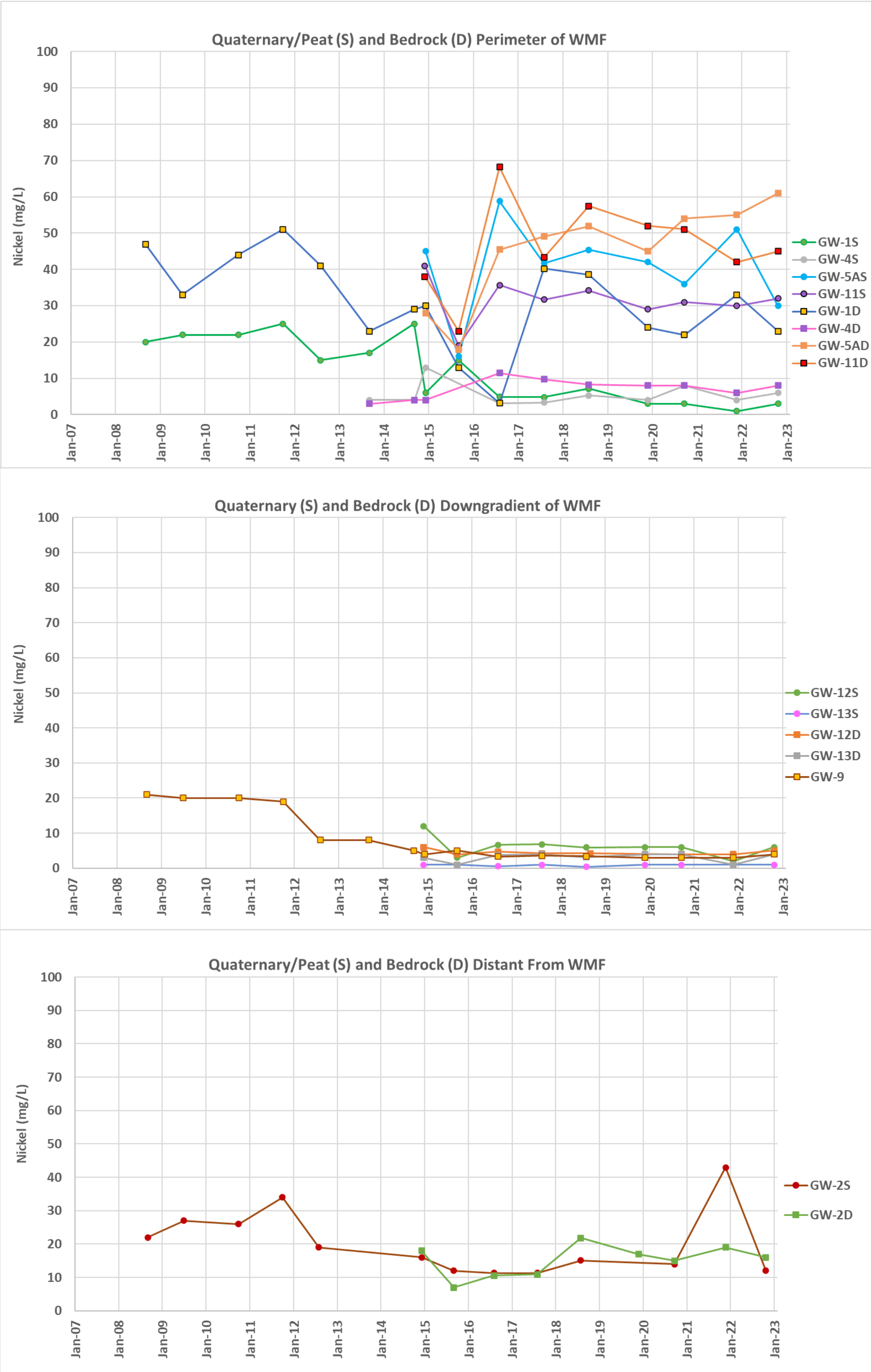


Figure 7-33 Nickel (Dissolved) in Groundwater, Historical Data

Table 7-16 Concentrations of As, Ba, Fe Mn and Ni in Groundwater Samples, 2021-2022

	Dec-21	May-22	Dec-21	May-22	Dec-21	May-22	Dec-21	May-22	Dec-21	May-22
Well	As (µg/L)	As (µg/L)	Ba (µg/L)	Ba (µg/L)	Fe (µg/L)	Fe (µg/L)	Mn (µg/L)	Mn (µg/L)	Ni (µg/L)	Ni (µg/L)
RW02S	**21.20**	**17.90**	**470**	**451**	**4,702**	**3,506**	**853**	**591**	7	6
RW03S	**172.30**	**177.30**	**416**	**420**	**3,664**	**4,677**	**358**	**411**	12	11
RW04S	<2.5	**57.20**	**220**	**237**	<20	**13,758**	**480**	**335**	5	6
RW09A	5.80	6.20	40	40	**667**	**1,688**	**763**	**475**	12	6
RW09B	**10.30**	**17.60**	64	80	**1,157**	**1,947**	**225**	**154**	<2	<2
RW10S	**16.50**	**15.30**	**145**	**132**	**3,685**	**4,658**	**226**	**228**	7	5
MW02Q	**9.40**	<2.5	**215**	**198**	**6,878**	**122**	**619**	**407**	<2	5
MW02B	**20.40**	**17.20**	76	81	**1,197**	**1,390**	**279**	**316**	<2	<2
MW03Q	**22.60**	**16.00**	**741**	**522**	**6,686**	**6,685**	**1,503**	**993**	**23**	18
MW03B	<2.5	<2.5	68	72	**840**	**831**	**517**	**557**	2	3
MW06B	**101.40**	**89.40**	95	95	**4,873**	**4,079**	**133**	**126**	12	12
MW06Q	**62.70**	**46.10**	61	87	**2,063**	**5,220**	**159**	**282**	7	3
MW07Q	<2.5	<2.5	**153**	**136**	119	<20	**894**	**386**	15	**20**
MW07B	**30.40**	**74.20**	**161**	**173**	**3,572**	**6,559**	**1,811**	**1,563**	13	**23**
LW01	**68.70**	**77.80**	**397**	**342**	**6,048**	**6,542**	**146**	**165**	5	7
LW02D	**68.00**	**76.50**	**325**	**304**	**16,349**	**16,377**	**263**	**223**	19	19
LFBH05	**138.90**	**148.90**	**290**	**289**	**7,423**	**8,885**	**116**	**99**	12	14

7.4.22 Groundwater Quality – Organic Compounds

Since the WMF became operational in 2008, there have been no detections of VOCs or pesticides above LODs (mostly 0.5 to 4 µg/L for individual constituents) in groundwater. All SVOCs, including phenols and PAHs, have also been reported below LODs (mostly 0.5 to 1 µg/L for individual constituents) with the exception of phenol (5 µg/L) and 4-methylphenol (27 µg/l) recorded at GW-3S in 2022.

Pre-WMF, there were no VOCs, SVOCs, or pesticides detected in the 2006 sampling round. Diesel range organics, mineral oil and PAHs were detected in groundwater samples in 2003, and this was ascribed to lubricant oil used in the drilling process at the time (TCE, 2017).

7.4.23 Groundwater Quality - Private Well Near Western Landholding Boundary

A private well located immediately west of the landholding and near the Cushaling River adjoining the bog is sampled by BnM annually (usually in Q3 or Q4). The recorded data are presented in Table 7-17. Numbers in bold represent exceedances of screening criteria.

Table 7-17 Recorded Groundwater Quality – Private Well West of Landholding

Parameter	Units	Dec-12	Dec-13	Oct-14	Dec-15	Aug-16	Nov-19	Sep-20	Dec-21
pH	--	7.8	7.8	7.4	7.7	7.6	7.59	7.8	7.99
Conductivity	µS/cm	438	440	417	416	408	389	373	444
Chloride	mg/L	9.2	8.7	11	9.9	9.6	10	10.5	9.4
Total Ammonia (NH_3-N)	mg/L	1.3	1.4	1.4	1.5	1.1	1.3	1.2	1.23
Ammonium (NH_4)[1]	mg/L	**1.7**	**1.8**	**1.8**	**1.9**	**1.4**	**1.7**	**1.5**	**1.6**
Sulphate	mg/L	1.7	2	2.4	1.8	6	<5	<5	1
Nitrate as NO_3	mg/L	<0.04	<0.2	<0.04	<0.04	<0.2	<4	<4	0.3

Parameter	Units	Dec-12	Dec-13	Oct-14	Dec-15	Aug-16	Nov-19	Sep-20	Dec-21
Ortho-P (as PO_4)	mg/L	<0.16	<0.01	<0.16	<0.16	<0.01	**0.5**	**0.04**	<0.06
Total P (as PO_4)	mg/L	<0.05	<0.05	<0.05	0.08	<0.05	--	--	0.116
Dissolved Metals									
Calcium	mg/L	58	70	52.6	52.3	52.8	63	63	-
Magnesium	mg/L	15	17	14.4	13.7	15	16	16	-
Potassium	mg/L	1.4	1.2	<1	1.7	<1	<1	<1	-
Sodium	mg/L	9	10	9.31	8.75	9.26	9	9	-
Iron	mg/L	<0.1	<0.1	<0.019	0.037	0.112	0.04	<0.01	-
Boron	µg/L	11	12	22	0	3.4	<10	10	<12
Arsenic	µg/L	3	3	3.06	0	**11.1**	3	2	-
Barium	µg/L	**268**	**335**	**276**	**283**	**256**	**270**	**220**	**-**
Cadmium	µg/L	<2	<2	<0.1	0.135	<0.08	0.2	0.17	<0.5
Cobalt	µg/L	<2	<2	0.884	1.87	<0.15	1	1	-
Chromium	µg/L	<2	<2	1.99	2.38	0	<1	<1	<1.5
Copper	µg/L	<2	<2	<0.85	2.22	1.32	<1	1	<7
Mercury	µg/L	<1	<1	<0.01	0.0149	<0.01	<0.03	<0.03	<1
Manganese	µg/L	**292**	**391**	**300**	**360**	0.964	**333**	**309**	-
Beryllium	µg/L	<2	<2	<0.07	<0.07	<0.1	<10	<10	-
Nickel	µg/L	5	8	7.17	11.8	8.41	9	8	8
Lead	µg/L	<2	<2	<0.02	0.175	<0.1	<1	<1	<5
Antimony	µg/L	<2	<2	1.89	<0.16	<0.16	<1	<1	-
Selenium	µg/L	<2	<2	0.397	<0.39	<0.81	<1	<1	-
Silver	µg/L	<2	<2	<1.5	<1.5	<1	<2	<2	-
Aluminium	µg/L	<2	<2	<2.9	<2.9	<2	<10	<10	-
Tin	µg/L	<2	<1	0.417	0.37	0.903	<1	<1	-
Zinc	µg/L	<2	11	20.5	7.87	2.25	5	2	7

Note: [1]calculated by laboratory from total ammonia results

Ammonium, orthophosphate, arsenic, barium and manganese have exceeded their relevant screening values, noting that:

- Arsenic exceeded the EQS of 7.5 µg/L and drinking water standard of 10 µg/L in one sample, in August 2016.
- Barium exceeded the IGV of 100 µg/L in all samples, but not the drinking water standard of 500 µg/L.

The construction details of the well are not known. Based on common well drilling practice in Ireland, it is anticipated that the well extends into bedrock with a steel casing set loosely through glacial till, and likely without the use of cement grout as a sealing material in the annular space outside the casing. In such a scenario, the well and the groundwater pumped is vulnerable to ingress of surface runoff along the annular space of the borehole outside the casing, which may also draw in water from shallower units (e.g. peat). The dwelling in question is also a farm.

Based on the information presented in Section 7.4.13, groundwater flow in the western part of TSB is towards Cushaling River. Because TSB extends west to the north of the farm, the well is downgradient of TSB, and not downgradient of the WMF. For this reason, the water quality documented in Table 7-17 is likely influenced by TSB, and the elevated detections are likely naturally occurring as described in preceding sections.

7.4.24 Groundwater Quality – Summary and Interpretation

Groundwater quality in TSB, including the WMF and planned landfill expansion areas, is characterised by:

- Consistently elevated concentrations of ammonia, above groundwater screening values.
- Generally low concentrations of other leachate indicators, including chloride, which are below groundwater screening values and within normal ranges.
- Periodically elevated concentrations of certain metals (notably As, Ba, Fe, Mn, Ni), above groundwater screening values.
- Absence (non-detects) of organic compounds, which are below respective LODs.

There are no clear spatial patterns in the available data that document impact by leachates on groundwater quality, noting that:

- Elevated concentrations of ammonia and certain metals also occur in wells that are located side gradient of, and distant from, the WMF.
- Elevated concentrations of ammonia and certain metals were also recorded in wells that were sampled at the WMF location but before the WMF was constructed and became operational.

However, greater variability and ranges of detections and concentrations, e.g., of chloride, are recorded in wells nearest the WMF. A gradual reduction of pH is also recorded in wells nearest the WMF.

Based on these key observations, it is considered that:

- The consistently elevated ammonia in groundwater is linked to leaching of ammonia from the extensively drained bog. Total ammonia concentrations are elevated across TSB, including remote areas of the bog (see also Chapter 8).
- The recorded metals are naturally occurring in the Quaternary sediments and bedrock, and are leaching as a function of the prevailing geochemical conditions in both.

If either of these were linked to leachates escaping the WMF, then the concentrations of other indicator parameters like chloride would be expected to be considerable higher and organic contaminants would be expected to be detected with greater frequency.

The observations made from the data can be explained by several processes:

- Stormwater influence on (shallow) wells near the WMF, via infiltration of stormwater in the WMF which drains to the perimeter swale around the WMF.
- Surface water influence on shallow (peat/Quaternary) wells that are downgradient of the discharge from the existing ICW.
- Decreasing pH of groundwater beneath and near the WMF.
- Temporal and spatial changes in oxidation-reducing conditions in the groundwater environment. Reducing conditions can explain the metals data (see Section 7.4.23.1) and low concentrations of nitrate and sulphate.

7.4.24.1 Influence of WMF on Groundwater Quality

The existing WMF influenced groundwater quality locally in two principal ways:

- The under-cell drainage system lowers groundwater levels beneath actively filled waste cells. This induces groundwater flow towards the WMF and draws in lower pH groundwater from the surrounding peat towards the WMF.

- Stormwater from the WMF is collected in a perimeter swale. This water is led to the existing attenuation ponds south of the WMF, which also receives the groundwater captured by the under-cell drainage system. As a result of discharges from the attenuation lagoons, groundwater-surface water interaction along the main channel south of the WMF causes temporal variability in groundwater quality south of the WMF, and may influence the hydrochemistry recorded in wells such as GW9. The stormwater influence is addressed further in Chapter 8.

The effects of the WMF, as described above, are exemplified in Figure 7-34 which shows pH, chloride and total ammonia in well GW9 south of the attenuation lagoons. The data show a gradual decrease in pH between 2008 and 2020, which is likely associated with the under-cell drainage system drawing in lower-pH water from the surrounding bog. The variability in chloride is likely caused by the stormwater contribution from the WMF which influences samples in and south of the attenuation lagoons. The ammonia concentrations have remained relatively stable although concentration ranges are slightly wider in 2021-2022.

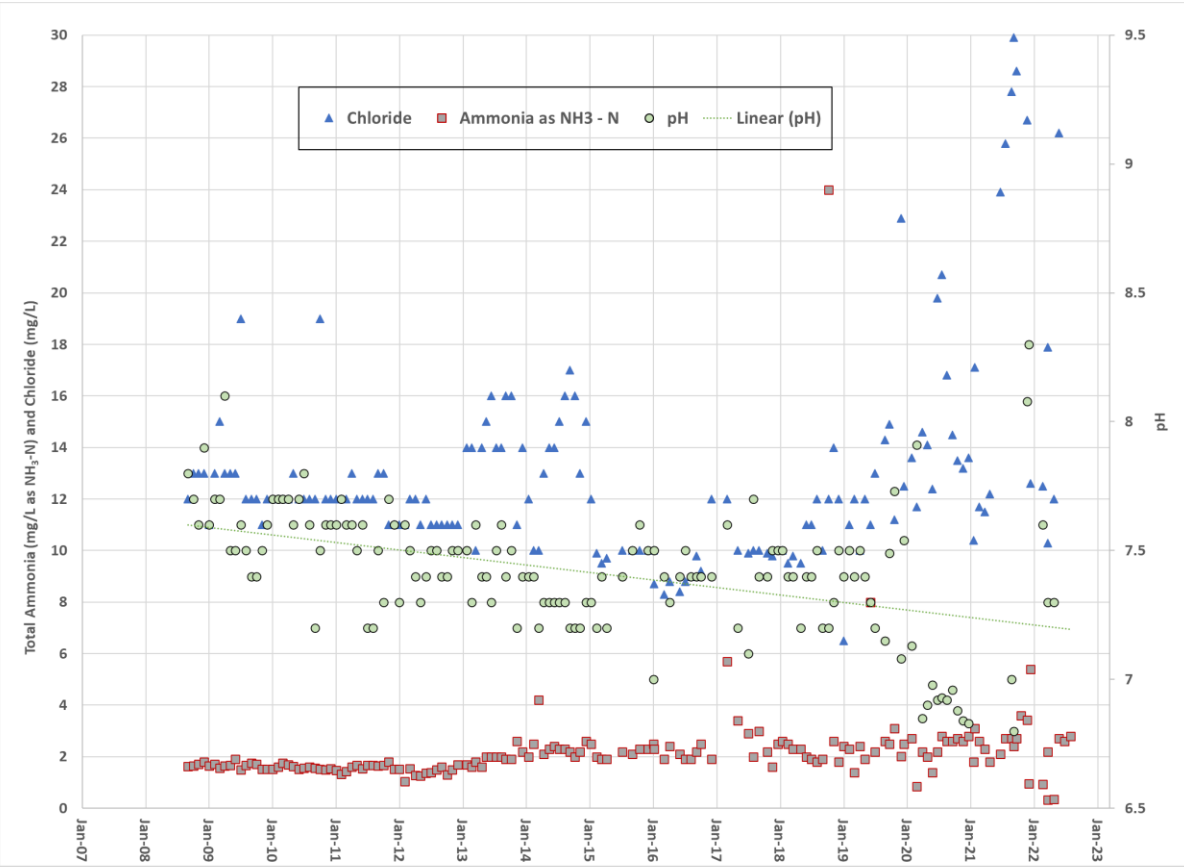


Figure 7-34 Total Ammonia, Chloride, and pH in GW-9, 2008-2022

7.4.24.2 Influence of Reducing Conditions on Groundwater Quality

In addition to pH, the oxidation-reduction ('redox') state of water exerts an important control on hydrochemistry, influencing the preservation (or degradation) of ammonia, mobilization or sequestration of naturally occurring metals, and the generation of by-products such as dissolved iron. This is significant because naturally occurring metals can leach under certain conditions, including pH and 'redox' conditions (e.g., McLean and Bledsoe, 1992).

The oxidation-reduction potential (ORP) of groundwater was measured in the field during the groundwater sampling campaign between September 2021 and May 2022. Although not conclusive by itself, higher (and positive) ORP values tend to indicate oxidising conditions whereas lower (and negative) ORP values tend to indicate reducing conditions (Horne and Goldman, 1976). Groundwater with lower ORP values tends to be less oxygenated and more reduced.

As presented in Figure 7-35, the majority of field measured ORP (in milli-Volts, mV) range from +50 mV (weakly positive values) to -200 mV (strongly negative values), the blue horizontal line marking the change from positive to negative ORP values.

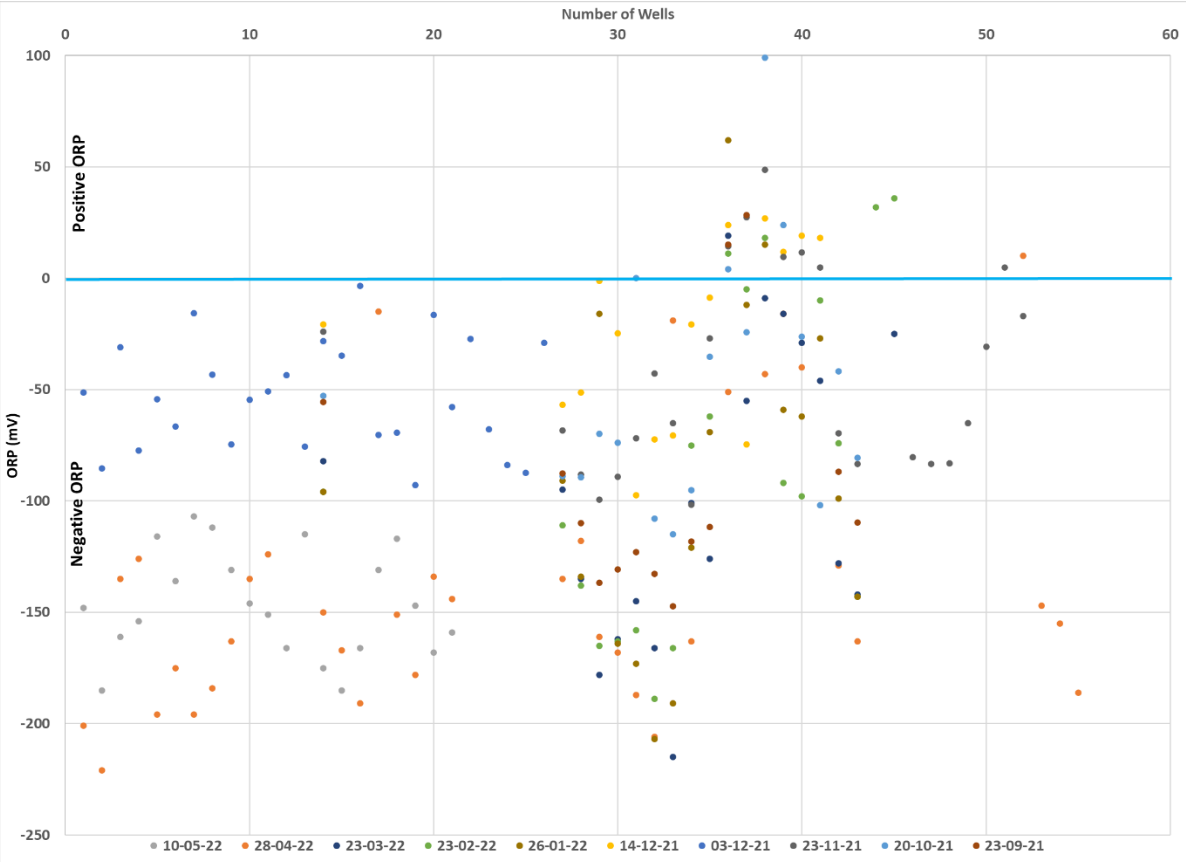


Figure 7-35 Oxidation-Reduction Potential Field Measurements, September 2021-May 2022

Further, as indicated by the plot of pH against ORP in Figure 7-36 for representative peat wells (MW3P, MW4P, RW10P), Quaternary wells (RW9A, GW3aS, GW-6), and bedrock wells (GW-3D, GW-4D, GW-5D), the highest negative ORP values occur in Quaternary and bedrock wells, although there is overlap with peat wells, attesting to reducing conditions also in the drained peat.

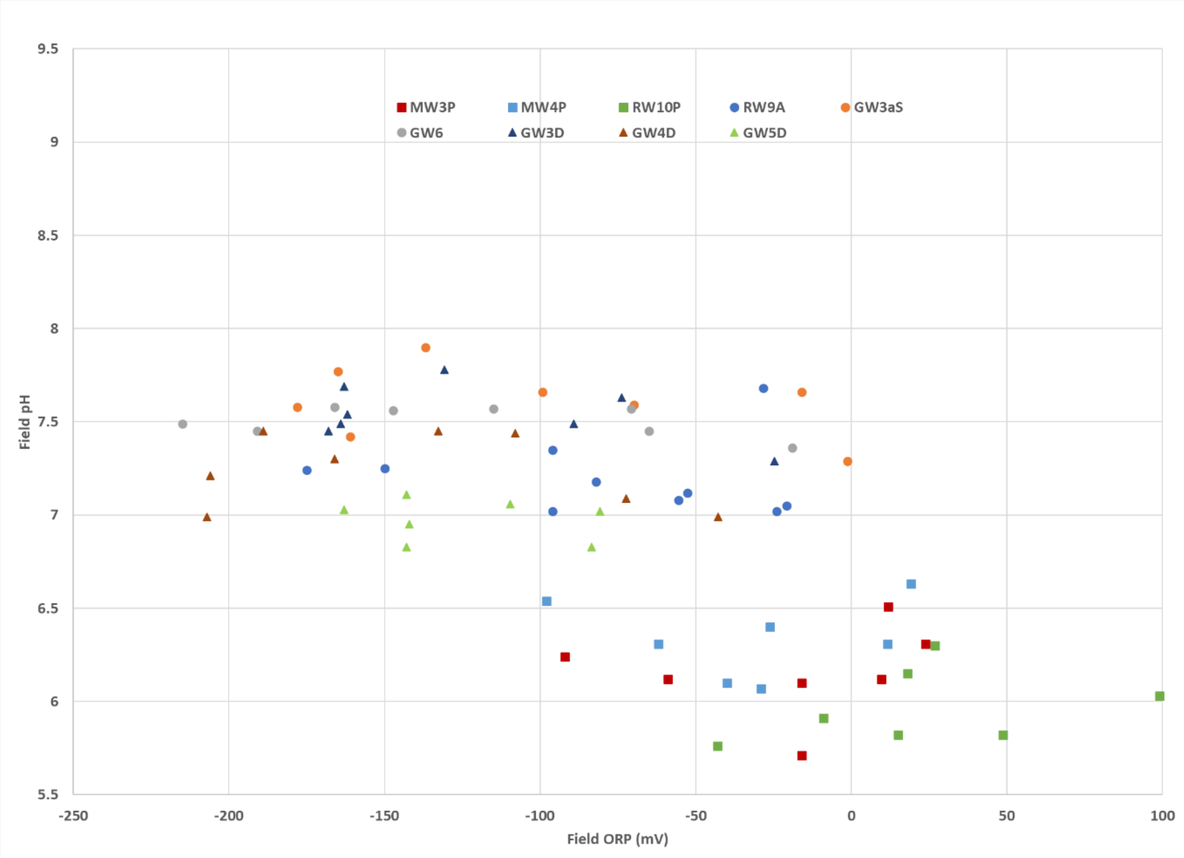


Figure 7-36 Field pH vs Field ORP in Nine Wells, September 2021-May 2022

Accordingly, natural geological and hydrogeological conditions across TSB (described in Sections 7.4.2 through 7.4.16) can account for the variability that is observed in the trace metals data. Arsenic is naturally occurring in iron oxide/minerals (ferric oxyhydroxides) and is highly adsorbed to iron minerals by a process referred to as co-precipitation (Stollenwerk and Colman, 2003). Arsenic can be mobilized and exists in different forms under a large range of environmental conditions which include the geochemical composition of subsoils and bedrock, and the pH and redox (oxidation-reduction) state of groundwater. Under iron-reducing conditions, the mobilization of naturally occurring arsenic is enhanced by a process of reductive dissolution, wherein iron oxide dissolves and arsenic (with iron and manganese) is released from the subsoil matrix to groundwater (Kent and Fox, 2004). Ravenscroft *et al.* (2009) highlighted that reductive dissolution of iron oxyhydroxides, influenced by a strong redox driver, such as organic matter in peat, can release arsenic upon reduction of the ferrous state. When or where reducing conditions dissipate, the related metals co-precipitate and adsorb onto sediments. Arsenic, iron and manganese behave similarly in groundwater (Stollenwerk and Colman, 2003).

Like arsenic, the concentrations of other metals like barium and manganese were also elevated in wells that were sampled in 2003 and 2006, *i.e.,* prior to WMF operations, including well GW-2S which is 1.5 km distant and side gradient from the WMF. As such, the recorded metals detections are considered naturally occurring.

7.4.25 Groundwater Compliance Monitoring

In 2015, the Drehid Waste Management Facility submitted a Technical Assessment Report (OCM, 2015) to EPA in relation to EPA's document entitled "*Guidance on the Authorisation of Discharges to Groundwater*" (EPA, 2011). In the technical assessment report, four monitoring wells were proposed as compliance wells for compliance monitoring purposes: GW-9, GW-10 and GW-3S and GW-3D. Compliance parameters, compliance limits and frequency of sampling are shown in Table 7-18.

Table 7-18 Groundwater Compliance Details

Parameter	Compliance Value	Frequency of Sampling
Total Ammonia (as NH_3-N)	10 mg/L	Annually
Chloride	50 mg/L	Annually
Specific Electrical Conductivity	1,000 µS/cm	Annually
pH	6.5-9.5	Annually
EPH (C_8-C_{35})	10 µg/L	Annually

Monthly groundwater data for 2021 in the four compliance wells GW-3S, GW-3D, GW-9 and GW-10 are presented in Table 7-19 with respect to their compliance parameters. All groundwater concentrations, both as ranges and annual means, meet the compliance values.

Table 7-19 Groundwater Compliance Data, 2021

Parameter	Compliance Value	GW-3S	GW-3D	GW-9	GW-10
Total Ammonia	10 mg/L (as NH_3-N)	Range: 0.39-0.51 Mean: 0.42 (n=14)	Range: 0.6-0.8 Mean: 0.65 (n=13)	Range: 0.96-5.4 Mean: 2.68 (n=14)	Range: 3.0-4.8 Mean: 3.57 (n=13)
Chloride	50 mg/L	Range: 11.6-13.6 Mean: 13.0 (n=13)	Range: 11.8-13.5 Mean: 13.0 (n=13)	Range: 10.4-31.1 Mean: 20.7 (n=13)	Range: 8.9-11.8 Mean: 10.7 (n=13)
SEC	1,000 µS/cm	Range: 287-326 Mean: 295 (n=14)	Range: 285-328 Mean: 296 (n=13)	Range: 434-636 Mean: 553 (n=15)	Range: 503-643 Mean: 588 (n=14)
pH	6.5-9.5	Range: 7.29-8.26 Mean: 7.83 (n=5)	Range: 7.5-8.24 Mean: 7.78 (n=3)	Range: 6.8-8.3 Mean: 7.50 (n=4)	Range: 6.9-8.3 Mean: 7.57 (n=4)
EPH (C_8-C_{35})	10 µg/L	Not detected	Not detected	Not detected	Not detected

Monthly compliance samples from the same wells in the fourth quarter of 2022 as reported by Marrion (2023) are presented in Table 7-20.

Table 7-20 Groundwater Compliance Data, 2022

Parameter	Compliance Value	GW-3S	GW-3D	GW-9	GW-10
Total Ammonia	10 mg/L (as NH_3-N)	0.41-0.50 (n=8)	0.58-0.80 (n=8)	1.2-2.8 (n=8)	1.9-7.9 (n=8)
Chloride	50 mg/L	10.3-13.1 (n=8)	10.7-13.2 (n=8)	17.4-33.4 (n=8)	8.5-14.5 (n=8)
SEC	1,000 µS/cm	286-309 (n=8)	284-314 (n=8)	403-648 (n=8)	524-748 (n=8)
pH	6.5-9.5	7.27-8.01 (n=3)	7.31-8.01 (n=3)	6.79-7.5 (n=3)	6.8-7.5 (n=3)
EPH (C_8-C_{35})	10 µg/L	Not detected	Not detected	Not detected	Not detected

None of the available results exceeded compliance values. It is noted that total ammonia concentrations are highest in well GW-10, which is located hydraulically upgradient of the Borrow Pit and is influenced by drained bog in the upgradient direction.

7.4.26 Conceptual Site Model

This section describes the conceptual site model (CSM) based on the description of the baseline environment. The CSM summarises source-pathway-receptor (SPR) linkages and flags the risk factors associated with the Proposed Development on peat, geology, and the groundwater environment. The summary serves as a segway to the surface water environment which is described in Chapter 8. The landfill expansion is an addition to the existing WMF. Hence, the WMF is a key ingredient of the CSM.

The CSM is presented in a cross-sectional view in Figure 7-37. The cross-section runs NE to SW across the landfill expansion area, incorporating the new, planned N-S drain, the expanded landfill with its under-cell drainage system, the new ICW and the existing main channel into which discharges from the new ICW will be directed.

In the CSM, the engineered leachate collection system will capture leachate in lined and contained waste cells. The collected leachate is transported offsite for treatment and disposal.

Runoff from the expanded landfill will be captured in a perimeter swale from where it is directed to new attenuation lagoons and an ICW system west of the expanded landfill. The discharge from the ICW is directed to the existing main channel which leads the water to Cushaling River via the old settlement ponds.

An under-cell drainage system will operate across waste cells that are actively being filled for the entire operational period of expanded landfill (Section 7.5). This system will capture shallow groundwater which is led to the same attenuation lagoon and ICW system referred to above and then onwards to the Cushaling River, also via the old settlement ponds.

A modified drainage network in TSB will continue to direct greenfield runoff from the bog to the Cushaling River and will also direct some runoff to the Mulgeeth Stream.

The groundwater flow system immediately beneath the landfill expansion area is defined by Quaternary sediments. This is primarily a low-permeability environment, but higher permeability lenses and likely sand/gravel channels are also present. These will serve to transmit groundwater preferentially towards the main channel and Cushaling River. Documented groundwater flow across the WMF and landfill expansion area in both the Quaternary unit and underlying bedrock is towards the main channel and Cushaling River, with lateral flow gradients ranging from 0.001 to 0.005. Groundwater flow directions in the northern part of the landfill expansion area are presently influenced by the under-cell drainage system beneath the WMF. Shallow groundwater flow is also influenced locally by the drainage network in the bog, which is conceptually well understood, whereby relative water levels in groundwater and the drains interact hydraulically at a local level.

The bedrock beneath the landfill expansion area is naturally protected by clays with vertical permeability values on the order of 10^{-10} m/s. The bedrock is also at depths of more than 10 m (range 14.75-21.80 m), attesting to a Low groundwater vulnerability setting across the expansion area. Bedrock is weathered and fractured, and fractures tending to be infilled with sediments, including clay. Overall, the bedrock displays low-permeability characteristics.

Nevertheless, shallow groundwater provides environmental supporting conditions for the bog and limited baseflow to the Cushaling River. The baseflow component is <20% of the mean estimated flow in the river (which is approximately 0.03 m^3/s).

A downward hydraulic gradient from the Quaternary unit to bedrock is documented across TSB except in locations near the WMF, where the under-cell drainage system lowers shallow groundwater levels locally, and in wells near the Cushaling River.

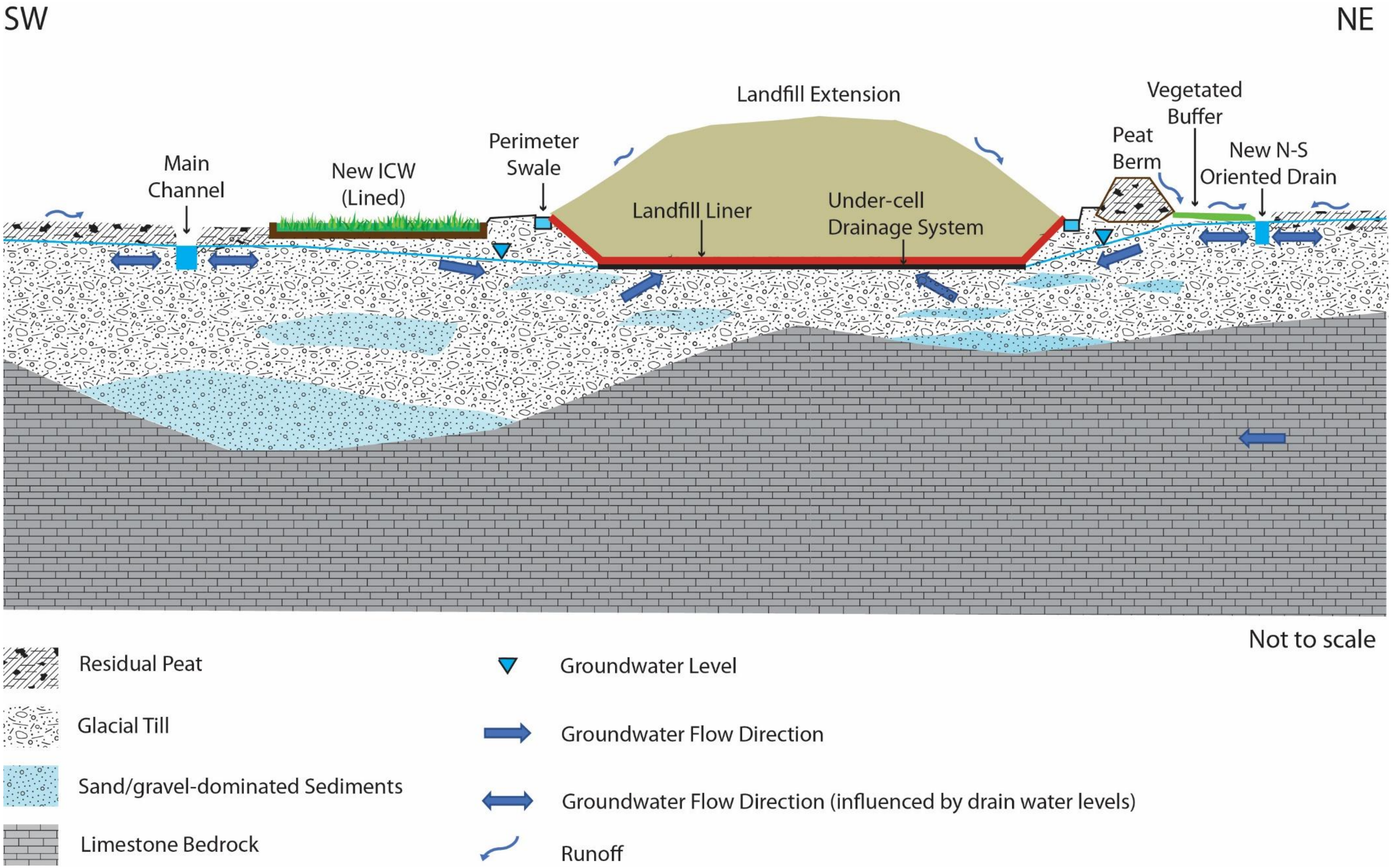


Figure 7-37 Conceptual Site Model, Cross-Section NE-SW

Groundwater and surface water are hydraulically interconnected and water levels respond similarly to changing climatic conditions.

Based on the CSM, a summary of potential sources of contamination associated with the WMF and Proposed Development are presented in Table 7-21. Potential receptors are presented in Table 7-22. Potential pathways connecting sources and receptors are presented in Table 7-23.

Table 7-21 Conceptual Model – Potential Sources

Potential Source	Pollutant Types
Existing WMF	
Landfill leachate	As described in Section 7.4.18 based on typical leachate constituents (EPA, 2003)
Drained peat/cutaway bog	Ammonia and other nutrient constituents, suspended solids/turbidity, organic matter, dissolved organic carbon, colour
Stormwater	Suspended solids/turbidity, salts
Composting facility	Ammonia and other nutrient constituents, BOD/COD
Fuel/chemical storage	Fuel, chemicals
Ancillary structures-offices, weigh bridge	Fuel, heating oil, hydraulic fluids
Vehicles and machines	Fuel, lubricating oil, hydraulic fluid
Historical spills	Fuel, lubricating oil, or hydraulic fluid
Landfill Expansion	
Landfill leachate	Leachate constituents (EPA, 2003)
Drained peat/cutaway bog	Ammonia and other nutrient constituents, suspended solids/turbidity, organic matter, dissolved organic carbon, colour
Stormwater	Suspended solids/turbidity, salts
Fuel/chemical storage	Fuel. Chemicals
Vehicles and machines	Fuel, lubricating oil, hydraulic fluids
Offsite Areas	
Agriculture	Nutrients, pathogens, pesticides and sediments
Wastewater discharges, including septic tanks	Nutrients and pathogens
Peaty soils drained for farming	Ammonia and other nutrient constituents, organic matter, sediments
Forestry along eastern boundary	Nutrients, pesticides and sediments
Former quarries west of western boundary, adjacent to Cushaling	General waste, including chemicals
Cutaway peat (downgradient and sidegradient of TSB)	Ammonia and other nutrient constituents, suspended solids/turbidity, organic matter, dissolved organic carbon, colour

Table 7-22 Conceptual Model – Potential Receptors

Potential Receptors	Name/Type
Subcatchment of WMF and Planned Expansion Area Within TSB	
Peat	TSB
Surface water	Drains, River Cushaling; Borrow Pit Lake
Shallow groundwater	Quaternary hydrogeological unit
Deeper groundwater	Bedrock aquifer (Kildare Groundwater Body)
Offsite Areas	
Surface water	Cushaling River (becoming Figile River downstream of Ticknevin)

Groundwater abstractions	Private wells around TSB
Surface water abstractions	River intake on River Barrow near Athy (Srowland water treatment plant)
Designated sites	River Barrow-River Nore SAC; River Boyne SAC (see Section 7.5. and 7.6)
Protected areas	'Barrow 130' Drinking Water Protected Area (near Athy); Trim Drinking Water protect Area (see Section 7.5 and 7.6)

Table 7-23 Conceptual Model – Potential Pathways

Pathways	
Surface runoff	From existing WMF and expanded landfill, and within TSB
Artificial drains	Drainage channels in TSB, Under-cell drainage systems, main channel from existing ICW to Cushaling (via old settlement ponds), and stormwater collector system along perimeter of the WMF and expanded landfill.
Groundwater flow	Peat, Quaternary, bedrock hydrogeological units
Cushaling/Figile Rivers	Connecting to River Barrow
Mulgeeth Stream	Connecting to River Boyne (see Section 7.5 and 7.6)

The potential interactions between the different features referenced above are summarised in Table 7-24. Surface water features are presented in detail in Chapter 8.

Table 7-24 Potential Interactions Between Site Features

Features	Potential Interaction
Leachate	• Groundwater collected in under-cell drain system (in a theoretical scenario where leachates escape the fully contained leachate collection systems)
Stormwater (rainfall-runoff)	• Drainage from landfill caps which is collected and led to attenuation ponds and ICWs • Stormwater collection system around landfill perimeters and along haul roads/ hard standing areas, roofs
Bog drainage network	• Groundwater in peat and Quaternary unit • Main channel south of WMF and Cushaling River • New south-to-north drain and Mulgeeth Stream (see Chapter 8)
Attenuation ponds (lined)	• ICWs into which the attenuation ponds discharge
ICWs	• Main channel south of WMF (into which the ICW outfall discharges)
Borrow Pit lake	• Bog drainage network • Groundwater in Quaternary unit
River Cushaling	• Bog drainage network • Main channel and settlement ponds south of WMF • Groundwater in Quaternary unit (possibly also bedrock)
Other streams/rivers leaving TSB	• Bog drainage network • Groundwater

7.4.27 Proposed Groundwater Monitoring

During all phases of works, groundwater quality monitoring will continue within TSB, according to BnM's existing monitoring regime and routines, including the compliance wells referred to in Section 7.4.25. It is proposed to add the following wells to compliance reporting, notably:

- The MW-02 well cluster, which is hydraulically downgradient of the landfill expansion and new ICW (see Figure 7-2).
- The MW-07 well cluster, which is hydraulically upgradient of the landfill expansion (see Figure 7-2).

It is proposed that monitoring be conducted according to Schedule C, Section C.3 (Ambient Monitoring) of existing IE discharge licence W0201-03, which covers the parameters listed in Table 7-25.

Table 7-25 Proposed Groundwater Monitoring Regime

All Construction Phases	Compliance and New Proposed Wells	
	Monthly	Annually
Visual inspection/odour	x	
Groundwater levels (wells)	x	
Specific Electrical Conductivity	x	
Ammoniacal Nitrogen	x	
Chloride	x	
Sulphate (as SO_4)		x
Metals/non-metals		x
List I/II Organic Substances		x
Mercury		x
Nitrate as N		x
Orthophosphate as P		x
Total Phosphorus as P		x
Faecal Coliforms		x
Total Coliforms		x

During each sampling event, field parameters will be measured in each well, as follows: groundwater temperature, pH, SEC, DO, and oxidation-reduction potential.

The Proposed Development offers an opportunity to review and update groundwater monitoring within TSB generally, especially since some of the existing monitoring wells were replaced during the most recent SI (see Section 7.3.4).

7.5 LIKELY SIGNIFICANT EFFECTS OF THE PROPOSED DEVELOPMENT

7.5.1 Do Nothing Scenario

In the Do Nothing scenario, the Proposed Development does not occur. However, implementation of the Timahoe Bog Decommissioning and Rehabilitation Plan proceeds as planned (see Chapter 8 of the EIAR and Appendix 8-4).

As described in Chapter 2 of the EIAR, the waste management activities at the WMF are authorised until 2028. In the post-closure phase of the WMF, leachate management and environmental monitoring continues under existing IE discharge license conditions.

With regard to soils, geology and hydrogeology, the baseline conditions that were documented in preceding sections will evolve as follows:

- The under-cell drainage system becomes inactive, which will result in a rebound of groundwater levels locally.
- The rebound of water levels will contribute to the re-wetting of TSB around the WMF. This will extend into the Proposed Development area, thereby contributing to the overall goals of the Timahoe Bog Decommissioning and Rehabilitation Plan.

In the Do Nothing Scenario, the hydrological and hydrogeological conditions of TSB around the WMF will not revert to pre-WMF conditions, because:

- Modifications to the bog drainage network are planned to the north and east of the WMF to accommodate other project initiatives, which is described further in Section 7.6.
- The WMF will remain an engineered, capped facility, and stormwater runoff collected in the WMF perimeter swale will continue to discharge to the existing attenuation lagoon and ICW system to the south of the WMF.

During post-closure of the WMF, environmental monitoring will continue under existing license conditions. The exiting groundwater monitoring well network across TSB is well suited to track shifts or the evolution of baseline conditions with regard to the peat and groundwater environments. The groundwater monitoring will supplement surface water monitoring, which is described in Chapter 8.

The Do Nothing scenario will not have any likely effects on the geological environment. It is expected, however, to have net positive effects on the hydrology of TSB and the hydrogeological functioning of groundwater in restoring the environmental supporting conditions for peat. As the peat becomes re-wetted, leaching (e.g. of ammonia) is reduced and co-benefits are improved habitat conditions in the bog.

7.5.2 Construction Phase

As described in Chapter 2 of the EIAR, the expanded landfill will be constructed in a staged manner over a total period of approximately 25 years. When completed, the expanded landfill will consist of 12 no. additional waste cells or 'phases' which are numbered from 16 through 27. The sequential numbering begins at 16, since Phase 15 is the last phase constructed and operated at the existing WMF.

The first stage of construction (Stage 1) is the most comprehensive in terms of scope, comprising:

- MSW Processing and Composting Building.
- Maintenance Building.
- Soil, Stones and C&D Rubble Processing Building.
- Contractor's yard.
- Surface water management infrastructure, including perimeter swales, berms and embankments, and the new attenuation lagoons and ICW system.
- Phase 16 of the expanded landfill
- Under-cell drainage system beneath Phase 16.

An overview of the sequence of activities related to Stage 1 construction, upon commencement of works, was provided in Chapter 2 of this EIAR.

The duration of Stage 1 construction is approximately 18 months. Subsequent stages involve the sequential development of phases along with expanded stormwater and underdrain management. The development of subsequent phases is planned such that a new phase is constructed to be ready at least six months prior to the previous phase reaching its void space capacity.

The construction of additional phases, starting with Phase 17, will require approximately 1.5 years each, and will be undertaken sequentially every 2 to 2.5 years. As such, construction of a new phase will commence c. 2 years after the previous phase. As defined in Chapter 2, the last phase (Phase 27) will be capped by 2050.

The construction period for each phase allows for pre-construction surveys, vegetation clearance, peat stripping and placement, subsoil excavation and placement, and construction of the engineered liner along with drainage management (e.g. the under-cell drainage system).

Likely significant effects of the Proposed Development on the soil, geological and hydrogeological environments, and proposed mitigation measures, during the construction phase are described below. Likely significant effects on surface water receptors, and proposed mitigation measures, are addressed in Chapter 8.

7.5.2.1 Clear-Brushing, Peat Stripping, and Earthworks

A total area of approximately 63.5 hectares (ha) will undergo vegetation removal and clear-brushing in order to accommodate the expanded landfill construction. The activity will occur in stages as the landfill phasing is progressed.

Removal of vegetation/brush is carried out in advance of peat stripping and subsoil excavation. The activity in each phase will last for less than two months.

The uprooting of vegetation/brush will disturb residual peat and subsoils. The disturbance results from vehicle tracking, skidding, and vegetation/brush extraction.

Earthworks involve stripping, excavation, movement, and staging of both peat and/or subsoil materials. The estimated total areas and volumes involved are (from Chapter 2 of the EIAR):

	Area (ha)	Volume (m^3)
Peat:	49.4	506,058
Subsoils:	35.75	747,855

The loss of peat area by the Proposed Development represents 3% of the total area of TSB (1,707 ha; BnM, 2022).

The peat in the Proposed Development area is already partially disturbed. Peat stripping and excavations will commence in the south-western corner of the Proposed Development area to allow for construction of the new attenuation lagoons and ICW system. Peat stripping and excavation will also commence in the footprint of Phase 16 so that the related infrastructure (e.g., liners, under-cell drainage system) can be completed.

Both stripped/excavated peat and subsoil will be reused to support environmental screening berms and landscaping. Subsoils may also be used for capping purposes, pending testing for suitability. No peat will be removed off-site. All stripped peat will be utilised within the Proposed Development area. A Peat and Spoil Management Plan has been prepared and is included in Appendix 2-5.

Earthwork activity will take place during the entire 24-year construction period. The scope of work is considerably greater during Stage 1 construction since this involves a much larger footprint of activity, approximately 22% of the total footprint of activity.

Earthworks will be required for each of the Stage 1 construction components itemised previously, which is additional to the construction of:

- Perimeter swales, berms and embankments around the expanded landfill footprint.
- A modified bog drainage network within the Proposed Development area.
- Subsequent landfills cells (beyond Phase 16).

Clear-brushing, peat stripping and earthworks involves physical disturbance, transport and emplacement of vegetation, peat and subsoils. The disturbance results mainly from vehicle tracking, skidding, and forward extraction and piling/stacking methods. Both the peat and subsoils excavated will be utilised within the Proposed Development area to support berms and embankments, and potentially also capping (pending testing for suitability).

The depth of excavation will be to a maximum level of 78.2 mOD on top of which the engineered landfill liner will be built.

The subsoils that will be permanently removed are not economically important, and there are no geological or geomorphological features of importance or significance that will be affected (Section 7.4.6). Excavations will not reach or expose the underlying bedrock aquifer, which is more than 10 mbgl (Section 7.4.4).

The excavation of peat and subsoils below the groundwater table will interrupt the hydrogeological conditions in the affected area. During construction, this involves changes to runoff and groundwater recharge, as well as groundwater lowering from seepage into open excavations. These are addressed in Sections 7.5.2.3 and 7.5.2.4.

Pre-Mitigation Potential Effects – Soils: Peat stripping will result in the permanent loss of residual peat, amounting to 49.4 ha by area. This is an inevitable effect of constructing the Proposed Development. The likely effects are considered moderate, permanent and irreversible. Based on Table 7-3, the magnitude of effect is considered major negative because the loss is permanent.

Pre-Mitigation Potential Effects – Geology: Earthworks will result in the removal of subsoil material, amounting to approximately 35.75 ha by area. This is an inevitable effect of constructing the Proposed Development. The subsoils that will be removed are not economically or otherwise important/sensitive, hence, potential effects are not significant. The loss of subsoil within the landfill footprint is permanent and irreversible. Because the subsoils are not important/significant, the magnitude of effect is neutral.

Pre-Mitigation Potential Effects – Hydrogeology: Clear-brushing, peat stripping and earthworks do not materially affect hydrogeological processes or the hydrogeology of either the Proposed Development area or TSB generally. The construction of infrastructure and changes in land cover does modify water balance elements locally, which is described in Sections 7.5.2.3 and 7.5.2.4 below.

Mitigation Measures by Avoidance: To reduce the further loss of residual peat, the landfill footprint and defined works areas have been minimized in the design to the extent possible.

Mitigation Measures by Design: The excavated peat (up to 3.5 m thick based on Section 7.4.2) and underlying sediments will be reused within the Proposed Development area (see Chapter 2). A Peat and Spoil Management Plan is included with Appendix 2-5.

Post-Mitigation Residual Effects - Soils: The loss of residual peat is permanent. The peat in question is already extensively drained, having partially lost its form and structure. Because the stripped peat will be reused in berms and landscaping, post-mitigation residual effects are considered slight negative.

Post-Mitigation Residual Effects – Geology: Because the subsoils that will be removed are not economically or otherwise important/sensitive, residual effects will not be significant. Post-mitigation, the effect is considered neutral.

Post-Mitigation Residual Effects – Hydrogeology: Post-mitigation residual effects on the hydrogeological environment are linked to groundwater lowering, which is a hydraulic effect addressed in Sections 7.5.2.3 and 7.2.5.4. There are otherwise no residual effects on the hydrogeological baseline conditions arising from clear brushing, peat stripping and earthworks. Hence, the effect is considered neutral.

7.5.2.2 Modification to Drainage Network in TSB

The existing drainage network in TSB will be modified to accommodate the Proposed Development. Existing drain segments that presently cross the landfill expansion area will be blocked to a) prevent draining of water into active works areas and b) divert drainage water in the construction footprint away and towards new bog drains which will be established as part of the TSB Decommissioning and Rehabilitation Plan (BnM, 2022), as presented further in Chapter 8.

The position of drain blocks are marked by locations where existing drains intersect the designed perimeter swale around the expanded landfill footprint. The existing drains which cross the expanded landfill footprint will be sequentially blocked off according to the sequencing of construction of landfill phases 16 through 27.

The modified drainage network includes a new south to north oriented drain to the east of the expanded landfill footprint (Figure 7-38) The modified drainage network will affect the current baseline drainage pattern in this part of TSB, which is addressed in Chapter 8.

With regard to soils and geology, the modification to the drainage network involves peat stripping and earthworks along new drain alignments, which was covered in Section 7.5.2.1.

With regard to hydrogeology, changes to drainage through peat and subsoils will result in changes to groundwater levels and flow in the Quaternary unit, as follows:

- In segments of blocked drains outside the landfill expansion footprint, water levels in drains and adjacent peat and groundwater will rise.
- Where new drains are opened, shallow groundwater levels along and between drains will respond to prevailing water levels in the drains (Figure 7-39).

In particular, the new south-north drain east of the expanded landfill footprint will intercept shallow groundwater that would otherwise flow westward across the landfill expansion area. The scale of this groundwater flux can be calculated from Darcy's Law (Section 7.4.15), where:

- $K = 1.47 \times 10^{-5}$ m/s, conservatively as a geometric mean for the more permeable fractions of the Quaternary unit (Section 7.4.14).
- $i = 0.005$, as a flow gradient for the Quaternary unit (Section 7.4.12.1).
- $A = 5{,}000\ m^2$, based on groundwater flow across a 10 m section of the Quaternary unit, over a 500 m long distance of new drain (based on Figure 7-38).

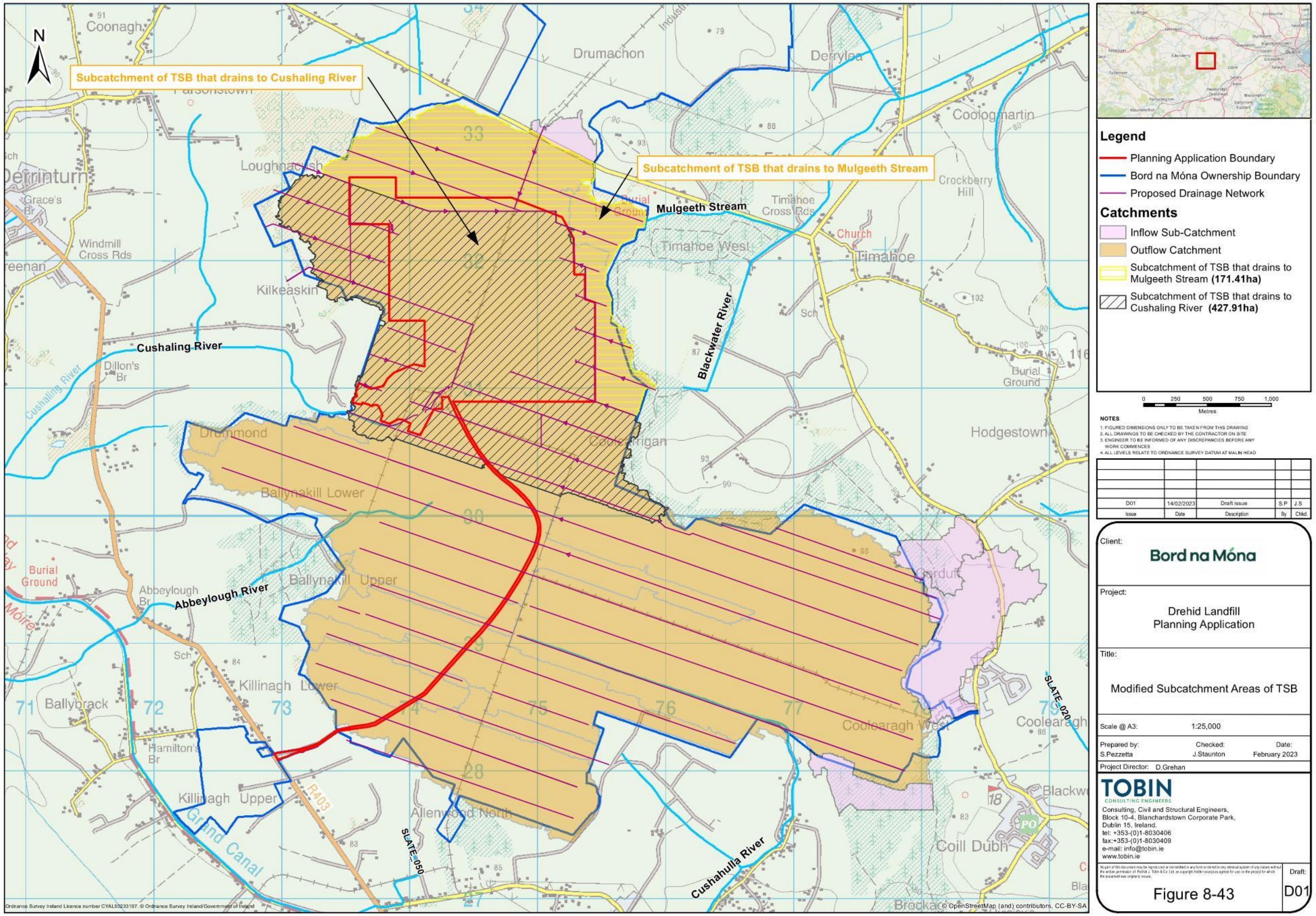


Figure 7-38 Modified Drainage Network and Relevant Subcatchment Areas in TSB

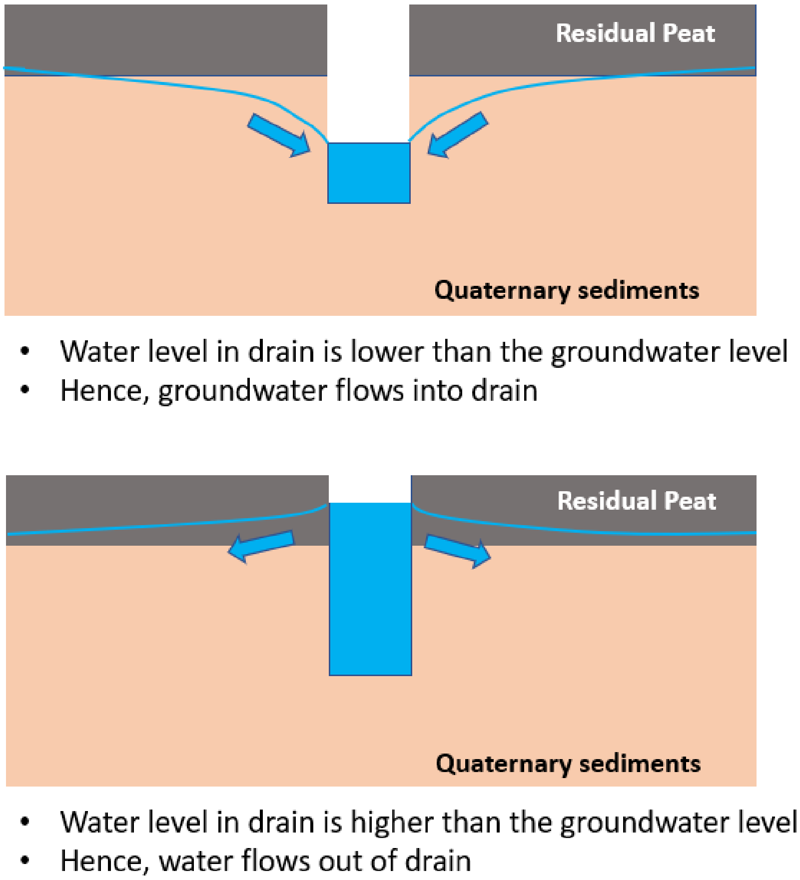


Figure 7-39 Interaction Between Drain and Groundwater Levels

Based on these inputs, Q is 3.68×10^{-4} m^3/s, or 0.37 l/s, which is roughly 2% of the estimated average groundwater baseflow from the Quaternary unit to the Cushaling River (Section 7.4.15). This water, which would flow to Cushaling River under current conditions, will in the future drain north to Mulgeeth Stream. It is a minor flux, and as described in Section 7.4.16, any reduced groundwater flux to Cushaling River will be compensated by:

- The added contribution of stormwater from the expanded landfill to the river.
- Groundwater flux which will be induced from the bedrock aquifer by the lowering of groundwater levels in the Quaternary unit. Groundwater in the Quaternary and bedrock aquifer unit are hydrogeologically connected (Sections 7.4.13 and 7.4.14) and changes in shallow groundwater levels will influence vertical flow gradients between the two units.

Pre-Mitigation Potential Effects - Soils: Pre-mitigation potential effects on soils relate to earthworks (Section 7.5.2.1) and localised drainage and re-wetting of peat, which is addressed in Chapter 8.

Pre-Mitigation Potential Effects – Geology: Pre-mitigation potential effects on geology relate to earthworks, which were described in Section 7.5.2.1.

Pre-Mitigation Potential Effects – Hydrogeology: Pre-mitigation potential effects related to hydrogeology are localised changes to the interaction between groundwater and drain levels, and the reduced flux towards the Cushaling River. The likely effects are permanent since the modified drainage network is part of the TSB Decommissioning and Rehabilitation Plan (Section 7.6). However, the likely effects are not significant since the reduced flux is on the order of 1% of baseflow to the river and the character and importance/sensitivity of the hydrogeological environment in the Proposed Development area will not change. As such, the magnitude of effect is considered imperceptible, i.e. capable of measurement but without significant consequences.

Mitigation Measures by Avoidance: The effects are inevitable, as the modifications to the drainage work are necessary to be able to construct the expanded landfill.

Mitigation Measures by Design: Modifications to the drainage network were minimised during drainage design by BnM's engineering team, and bog drains will be kept as shallow as practicable to reduce the interception potential of shallow groundwater. The trajectories and depths of individual drains also consider practicalities and costs of construction.

Post-Mitigation Residual Effects – Soils: Post-mitigation potential effects on soils relate to earthworks (Section 7.5.2.1) and localised drainage and re-wetting of peat, which is addressed in Chapter 8.

Post-Mitigation Residual Effects – Geology: Post-mitigation residual effects relate to earthworks, which were described in Section 7.5.2.1.

Post-Mitigation Residual Effects – Hydrogeology: Post-mitigation residual effects are the same as those described as pre-mitigation potential effects. Hence, the magnitude of effect is imperceptible.

7.5.2.3 Stormwater Runoff and Groundwater Recharge

The construction of the Proposed Development will influence existing runoff and groundwater recharge patterns locally across and around the expanded landfill footprint, including hardstanding areas.

As new landfill phases are being constructed, stormwater is intercepted and directed to the perimeter swale around the landfill expansion footprint, from where it is led to the new attenuation lagoon and ICW system. From here, the water is discharged to the Cushaling River via the main channel and old settlement ponds. Hence, stormwater continues to contribute to river flow (as it does now from the WMF).

The quantity of stormwater grows over the 24-year construction duration as phases are added and a greater proportion of the total landfill area is capped. As described in Appendix 2-3, the stormwater collection system is designed to manage total flows of 0.114 m^3/s for a 1-day duration, 1 in 100 year storm event (and accounting for climate change effects).

The construction of the landfill will reduce groundwater recharge within the landfill footprint and associated hardstanding areas. However, the rainwater is captured by the stormwater system. Hence, there is no net loss of water that discharges to the Cushaling River.

Pre-Mitigation Potential Effects - Soils: Pre-mitigation potential effects on peat are associated with the loss of peat (addressed in Section 7.5.2.1) and potential drainage of peat outside the landfill footprint, which is addressed in Section 7.5.2.4 below.

Pre-Mitigation Potential Effects – Geology: Geology and geological resources are not affected by stormwater runoff and groundwater recharge, hence pre-mitigation potential effects on geology are not applicable.

Pre-Mitigation Potential Effects – Hydrogeology: Reduced recharge across the landfill expansion area is a likely hydrogeological effect. Recharge in a peat environment is naturally low, on the order of <5% of effective rainfall (Hunter Williams et al, 2013). Based on the national groundwater recharge map produced by GSI, the estimated annual average recharge across TSB is 16 mm/yr, or 4.3×10^{-5} m/d, which is calculated from a recharge coefficient of 4%. The area of the landfill footprint is 593 m × 583 m, or 345,719 m^2 (from Chapter 2). Hence the volume of recharge 'lost' across the landfill footprint is 15 m^3/d, which is negligible in the context of the scale of TSB and the underlying groundwater body (as a resource).

The recharge component that is 'lost' would otherwise become part of the shallow groundwater flow system towards the Cushaling River. Part of this water would likely discharge to nearby drains as shallow groundwater interacts hydraulically with the open drains. As such, the water ends up in Cushaling River via modified pathways, but there is no net loss of water draining to the river.

Conceptually, the reduced recharge across the footprint area means that groundwater levels will be lowered locally, which also means that groundwater flow patterns will be affected locally. However, any such effect will be masked and made imperceptible by the broader changes to the drainage network in TSB, as described in Section 7.5.2.2, as well as the lowering of groundwater levels that will occur as a result of the new under-cell drainage system, as described in Section 7.5.2.4.

Mitigation Measures by Design: Stormwater management for the Proposed Development as a whole is described in Chapter 2 of this EIAR and Appendix 2-3. This includes measures that are based on principles of sustainable urban drainage systems (SUDS), which aim to reduce the quantities of stormwater generated by developments in order to maintain natural processes, including recharge, to the extent possible.

Post-Mitigation Residual Effects Soils: Residual effects on peat are associated with loss of peat (addressed in Section 7.5.2.1) and potential drainage of peat outside the landfill footprint, which is addressed in Section 7.5.2.4 below.

Post-Mitigation Residual Effects – Geology: Geology and geological resources are not affected by stormwater runoff and groundwater recharge, hence there will be no likely significant effects on geology.

Post-Mitigation Residual Effects – Hydrogeology: Reduced recharge across the landfill footprint area is a likely, permanent, and irreversible effect. It is, however, not a significant effect, given the small quantities involved. Hence, the effect is considered neutral and the magnitude of effects is imperceptible.

7.5.2.4 Seepage and Pumping of Water From Open Excavations/Pits

During sequential excavation of landfill phases, water will enter by direct rainfall and via groundwater seepage once the groundwater table is reached/intercepted.

Before excavation of landfill cells commences, a perimeter swale will be established around the expanded landfill footprint. This swale will control water levels outside the footprint and thus influence lateral seepage through sidewalls of excavations. However, seepage will also occur through excavation floors when the excavations are below the groundwater level.

Inside the excavated cells, a perimeter drain is also dug around the excavation floor (Photo 10). This will serve to drain water that will otherwise collect on the excavation floor. The water is directed via gravity to a sump (Photo 11) from where it is pumped out using standard sump pumps to the perimeter swale. The sump has an area of approximately 7.0m x 3.5m (and depth of 1m).

Photo 10 Perimeter Drain Inside Excavation at Existing WMF, June 2022

Photo 11 Sump Inside Excavation at Existing WMF, June 2022

Based on practical experiences from the construction of the existing WMF, the quantities of water that will need to be managed (*i.e.,* pumped) are expected to be generally less than 5 m^3/h (0.0013 m^3/s, or 1.3 l/s), although shorter term pumping can be higher, especially after significant rainfall events.

During Stage 1 construction, which includes landfill Phase 16, the water is pumped out to the existing perimeter swale around the WMF, from where the water is led to the existing attenuation lagoons and ICW system (south of the WMF). The use of this perimeter swale will continue until the new attenuation lagoons and ICW system for the expanded landfill is established (Chapter 2), after which the pumped water will be directed to this system. In all cases, the pumped water ultimately flows to the Cushaling River, which is addressed in Chapter 8.

The water will be pumped out periodically, on as-needed basis. It is not a continuous process, and quantities pumped will vary depending on the prevailing climatic (rainfall) conditions and the geology that is intersected. As documented in Section 7.4.5, sand and gravel lenses were encountered during drilling within the landfill footprint at levels that are shallower than the base level of excavations of 78.2 mOD (Chapter 2). The geology is relevant because sand and gravel lenses which may be part of smaller channel systems will release more water, faster, into pits. This is consistent with verbal accounts of construction at the existing WMF, where "springs" are occasionally reported as being intercepted during the excavation process. In the hydrogeological context of the site, such "springs" reflect water released from more permeable sediments. Sump pumping can be flexibly adapted (expanded) to accommodate higher pumping needs.

Both the existing and new ICWs can accommodate flows up to 0.187m^3/s, or 673 m^3/hr, which means flow capacity will not be an issue.

Sump pumping needs are repeated as landfill phases are sequentially added over the 24-year construction period. As construction advances from one phase to the next, construction-related pumping in one phase will overlap in time with the dewatering during operations of other phases (see Section 7.5.3.4). Once an under-cell drainage system in an operational cells is activated, the groundwater levels inside new phases being constructed will be influenced (lowered) by that system. This will reduce seepage into the phases being excavated or constructed.

Pre-Mitigation Potential Effects - Soils: Pre-mitigation potential effects involves seepage and resulting groundwater lowering around the perimeter of excavations. In theory, this could influence water levels in peat outside the footprint of a phase being constructed. However, a perimeter swale around the entire landfill has already been established which will control water levels around the landfill footprint and thus influence seepage into the open excavations. This is an operational matter and is addressed in Section 7.5.3.4.

Pre-Mitigation Potential Effects – Geology: Pre-mitigation potential effects from periodic pumping on geology during construction are not applicable. Pumping is a hydraulic effect and does not affect geology or geological resources.

Pre-Mitigation Potential Effects – Hydrogeology: Pre-mitigation potential effects during construction are linked to lowering of groundwater levels as a result of seepage into the open excavations. Given the low pumping rates involved (as guided by WMF experiences), this is a localised effect immediately around the perimeter of the landfill footprint. For this reason, there are no likely significant effects on hydrogeology. The effect is considered neutral and the magnitude of effect will be imperceptible.

Mitigation Measures by Design: Individual waste cells will be 268 m long and 97 m wide. During construction, sections of cells are opened sequentially with installations progressing across the cell in a sequenced manner. This process simplifies construction and water management. Based on procedures that are followed at the existing WMF, a shallow drain is dug around the area inside a cell that is under construction (Photo 10). This is a temporary measure to accommodate the installation of infrastructure (under-cell drainage system, sumps, liner) and facilitate the periodic pumping from open excavations.

Existing drains that presently cross the landfill footprint will be blocked off as a first step. While this will cause a rise in groundwater levels in subsoils and peat along drain trajectories outside the landfill footprint, this will also prevent ingress of water directly from the drains into the excavations. This is a permanent measure, which is integrated with the TSB Decommissioning and Rehabilitation Plan (Section 7.6).

Post-Mitigation Residual Effects – Soils: : The risk of draining peat beyond the perimeter of excavations (from seepage) are reduced by the blocking of drains outside the landfill expansion footprint. There are no likely significant effects on peat from seepage and pumping during the construction period, and the magnitude of effects is imperceptible.

Post-Mitigation Residual Effects – Geology: Pumping is a hydraulic effect and does not affect geology or geological resources. Rather, geology influences the magnitude of hydraulic effects and water management, as described below.

Post-Mitigation Residual Effects – Hydrogeology: Post-mitigation residual effects are linked to the lowering of groundwater levels as a result of seepage of groundwater into the open excavations. Given the small volumes and pumping rates that are expected based on WMF experiences to date, and the mitigation measure to block drains (which raises water levels outside the excavations), the anticipated effects of groundwater lowering during construction are brief and localised. Likely effects are expected to be imperceptible in consideration of the groundwater lowering that will result from operations of under-cell drainage systems in adjacent cells, which is addressed in Section 7.5.3.4.

The groundwater that seeps into excavations and is pumped to perimeter swales is water that would otherwise discharge naturally to Cushaling River. As described previously, there will be no net loss of flow contribution to the Cushaling River during construction.

For these reasons, the effects related to hydrogeology are neutral and imperceptible.

Monitoring: Groundwater monitoring will be undertaken as proposed in Section 7.4.27 and as practiced by BnM, during the entire construction and operational period, using existing monitoring wells. Groundwater levels will be measured manually on a monthly basis in all existing wells. Ten no. wells around the landfill expansion area will also be equipped with pressure transducers to record water levels automatically and continuously.

All monitoring is undertaken to check that the Proposed Development "*in practice conforms to predictions made in the current Chapter and to identify and record if any unforeseen effects occur, in order to undertake appropriate remedial action*" (EPA, 2022).

The detailed water level monitoring will begin six months prior to construction, and will continue through the post-closure period. Details of surface water monitoring are provided in Chapter 8 of this EIAR.

7.5.2.5 Accidental Spills and Leaks

In context of this Chapter 7, accidental spillage of fuels or chemicals represent a pollution risk to peat and groundwater in the Quaternary unit. Groundwater also represents a pathway to the Cushaling River as a surface water receptor, which is addressed in Chapter 8 of this EIAR.

Any chemical spills and leaks to peat and groundwater will be attenuated in the subsurface environment by mixing/dilution and bio-geochemical processes such as chemical sorption/desorption and degradation. Depending on locations and volumes or rates of spills and leaks, chemicals will flow according to prevailing, localised flow gradients towards drains, where the chemicals will be further attenuated by dilution and mixing in the drains, but will also migrate faster to the river.

Pre-Mitigation Potential Effects – Soils: Pre-mitigation potential effects on soils are related to the contamination of peat. Depending on the location, scale and nature of spill or leaks, effects can be negative to neutral, imperceptible to profound, and brief to long-term, and reversible to irreversible. In the worst case, spills or leaks can damage areas of peat permanently.

The same applies to the groundwater environment. The Quaternary unit is not a drinking water resource but provides supporting conditions for the bog and limited baseflow to the Cushaling River (Section 7.4.16). The density of drains in TSB means that groundwater pathways to drains are short (tens to hundreds of metres).

The bedrock aquifer unit is naturally protected by the thick subsoils (>10 m) in a Low groundwater vulnerability setting (Section 7.4.11). Hence, the risks of effects to the bedrock aquifer is also low. In Low groundwater vulnerability settings, the risk is transferred to the surface water environment (Chapter 8).

Mitigation Measures by Design: The prevention of, and response to, accidental spills and leaks of fuel and other chemicals during construction are covered by the Construction and Environmental Monitoring Plan (Appendix 2-5). The following mitigation measures will be implemented:

- Onsite refuelling will be carried out at dedicated locations by trained personnel only.
- Onsite refuelling of machinery will be done by mobile double-skinned fuel bowsers.
- Drip trays and fuel absorbent mats will be available and used during all refuelling operations
- A permit for the fuel system will be put in place.
- Fuel storage tanks will be bunded, self-contained and double-walled, conforming with EPA bunding specifications.
- The fuel-filling area will be fitted with a storm drainage system and an appropriate oil interceptor.
- The plant used during construction will be regularly inspected for leaks and fitness for purpose.
- Spill kits will be available to deal with and accidental spillages in and outside the re-fuelling area.

Post-Mitigation Residual Effects: Proven, routine, and effective measures to mitigate the risk of releases of fuels and chemicals are proposed which will break the link between potential sources (spills and leaks) and receptors (peat and the shallow groundwater environment). For this reason, post-mitigation residual effects are not considered likely or significant. Within the 24-year construction period, risk and unlikely residual effects are both long-term, and reversible (can be undone through remediation).

For the reasons outlined above, likely significant effects on soils, geology or hydrogeology will not occur.

7.5.2.6 Releases of Cement-Based Products

Releases of cement-based products could affect pH-sensitive peat by the accidental introduction of higher pH (alkaline) waters. Concrete and other cement-based products are alkaline and can be corrosive.

The main associated pathways are runoff and drains. The receptor is peat.

Pre-Mitigation Potential Effects: Pre-mitigation potential effects relate to physical damage to peat and associated habitat/biota. The effect is likely, long-term (or even permanent) and will change the character of the peat environment, even if locally. Based on Table 7-3, the magnitude of effect is considered moderate negative.

Mitigation Measures by Avoidance: Concrete will be delivered where it is needed in sealed concrete delivery trucks. Ready-mixed supply of wet concrete products such as pre-cast elements for culverts will be installed. Concrete trucks will be directed back to their batching locations for washout.

Mitigation Measures by Design: Batching of cement will be carried out at dedicated, existing locations within the WMF. Chute cleaning water will be undertaken at lined cement washout ponds, using the smallest volume of water practicable. Containment will be facilitated with straw bales. Ponds will be lined with an impermeable membrane. Ponds will also be covered when not in use to prevent rainwater collecting. Pour sites of cement will be kept free of standing water, and plastic covers will be ready in case of sudden rainfall events.

Risks of pollution will be further reduced as follows:

- Concrete will not be transported around the site in open trailers or dumpers so as to avoid spillage while in transport.
- All concrete used in the construction will be pumped directly into the shuttered formwork from the delivery truck. If this is not practical, the concrete will be pumped from the delivery truck into a hydraulic concrete pump or into the bucket of an excavator, which will transfer the concrete locally to the location where it is needed.
- Arrangements for concrete deliveries will be discussed with operators before work starts, confirming routes, prohibiting onsite washout and discussing emergency procedures.
- Clearly visible signage will be placed in prominent locations close to concrete pour areas specifically stating washout of concrete lorries is not permitted on the site.
- Using weather forecasting to assist in planning large concrete pours and avoiding large pours where prolonged periods of heavy rain is forecast.
- Restricting concrete pumps and machine buckets from slewing over watercourses while placing concrete.
- Ensuring that covers are available for freshly placed concrete to avoid the surface washing away in heavy rain.
- Disposing of any potential, small surplus of concrete after completion of a pour in suitable locations away from any watercourse or sensitive habitats.

The duration of the applicability of mitigation measures covers the entire construction period (24 years).

Post-Mitigation Residual Effects: Proven, routine, and effective measures to mitigate the risk of releases of cement-based products are in place which will break the link between potential sources and receptors. Based on Tables 8.1 and 8.3, post-mitigation residual effects are considered to be unlikely and neutral. The magnitude of effect is considered to be imperceptible.

7.5.2.7 Wastewater Management

As described in Chapter 2 of the EIAR, the Proposed Development includes a dedicated contractor's compound where welfare facilities for staff in the form of portacabins will be established for the duration of construction works and removed by the Contractor at the end of each construction contract.

Separate welfare facilities are already in place for operational staff in the existing WMF administration building and additional welfare facilities are being constructed for operational staff in the new MSW Processing and Composting Facility as well as in the new Maintenance Building.

As such, wastewater will not be treated or disposed of within the Proposed Development areas. Associated wastewater will be collected regularly and brought offsite in fully enclosed tanks for disposal by authorised means (permitted wastewater collector) to a wastewater treatment plant.

The use of sealed storage tanks and offsite disposal breaks the link between the source and receptor. Hence, likely significant residual effects on peat and groundwater from the Proposed Development will not occur.

7.5.2.8 WFD Status of Kildare and Trim Groundwater Bodies

As presented in Section 7.4.17 and in Appendix 8-5 of Chapter 8 of this EIAR, both the Kildare and Trim GWBs are classified to be at "Good" qualitative (chemical) and "Good" quantitative status, thus also "Good" status overall, for the latest available WFD status classification covering the period 2016-2021.

There are no groundwater abstractions planned with the Proposed Development, hence there will be no likely significant effects on the WFD quantitative status classification of either GWB.

There are also no activities planned with the Proposed Development that will influence the groundwater quality in the bedrock aquifer. Hence, there are also no likely significant effects on the WFD qualitative status classification.

7.5.2.9 Groundwater-Sourced Public and Private Water Supplies

As presented in Section 7.4.10, the nearest groundwater-sourced public water supplies are the Johnstown and Robertstown PWS to the north and south of TSB, respectively. These are not considered to be at risk from the Proposed Development, for the following reasons:

- The supplies are located in separate groundwater catchments from the landfill expansion area.
- The supplies and their source protection zones are far removed from TSB, by several kilometres.
- TSB is underlain by glacial till in a Low groundwater vulnerability setting.

The nearest private wells in a downgradient direction are west of TSB along the Cushaling River subcatchment, outside the BnM landholding. The private well described in Section 7.4.10 is not downgradient of the Proposed Development and, therefore, outside the zone of influence of the Proposed Development.

For this reason, there are no likely significant effects on public or private groundwater-based water supplies associated with the Proposed Development.

7.5.3 Operational Phase

Likely significant effects of the Proposed Development on soils, geology and hydrogeology, and proposed mitigation measures, during the operational period are described below.

Based on Chapter 2, waste filling and capping will evolve in 12 phases over a 25 year period, in series, in the same manner that the existing WMF has evolved. The associated risks of effects during operations are similar in nature and scope in each phase and hence also across the entire operational period (to year 2050).

7.5.3.1 Maintenance Works

The type of maintenance works that can affect soils, geology and hydrogeology are accidental spills and leaks of fuel and chemicals associated with fuel storage, machinery/plant, and transfer/transport of leachate from the collection tanks into contained trucks for offsite disposal.

Spills and leaks can affect the character/integrity of peat and can cause contamination of groundwater quality (directly) and surface water (indirectly, via groundwater).

Pre-Mitigation Potential Effects: Without mitigation measures, there are no controls or routines in place to manage risks of accidental spills and leaks. As with the construction period (Section 7.5.2.5), the significance and magnitude of potential pre-mitigation effects will depend on the locations, scales and nature of spills and leaks.

Mitigation Measures by Design: Maintenance works will be subject to routines and procedures which are based on BnM's extensive operational experience (under licence) at the existing WMF. Operational procedures for handling and management of leachate, fuels and chemicals are in place, as described in Chapter 2 of this EIAR.

Because operational maintenance activity is conducted in parallel with construction activity (in adjacent phases), and risks are of a similar nature, the key measures that apply for maintenance works are covered by those outlined in Section 7.5.2.

In the unlikely event that pollutants escape the lined waste cells during operations, the pollutants will attenuate in the subsurface (groundwater) environment and be captured by the under-cell drainage system which acts as a second protection barrier (additional to the liner and leachate collection system). This is a highly unlikely event, because a) the landfill expansion is planned and designed to prevent this from occurring, and b) this is not occurring at the existing WMF.

Post-Mitigation Residual Effects: Based on **Tables 7-1** and **7-3**, the likely post-mitigation residual effects are not significant. Mitigation measures are managed and maintained across the operational period.

For the reasons outlined above, likely significant residual effects on peat, geology or hydrogeology will not occur.

7.5.3.2 Modification to Drainage Network in TSB

The effects described in Section 7.5.2.2 for the construction period also apply to the operational period since the modified drainage network is established before construction commences. The modifications mainly affect surface water hydrology, which is described in Chapter 8. Small areas of peat along drains will be drained and re-wetted, depending on the changes made (Section 7.5.2.2), and the modifications will result in localised changes to groundwater-drain interactions. Existing drains that presently traverse the landfill footprint will be blocked (Section 7.5.2.2) which will serve to raise groundwater levels along these drains outside the landfill footprint.

The likely effects are permanent since the modified drainage network will be maintained throughout the operational period and are accommodated by the TSB Decommissioning and Rehabilitation Plan (Section 7.6). As described in Section 7.5.2.2, the expected effects on groundwater flux across the landfill expansion area and baseflow to the Cushaling River are negligible.

For the reasons outlined above, no significant effects on peat, geology or hydrogeology from the modified drainage system will occur during operations.

7.5.3.3 Stormwater Runoff and Groundwater Recharge

During operations, waste cells will be capped when capacities are reached. All runoff from the expanded landfill will be captured by the perimeter swale and led to the new attenuation lagoon and ICW system. Hence, the small proportion of rainwater that would otherwise recharge groundwater will be re-directed to the Cushaling River via the attenuation lagoon and ICW system. On the scale of the Kildare GWB, or even TSB, this quantity (see Section 7.5.2.3) is negligible.

As such, the hydrogeological change that will result is imperceptible. Moreover, the fraction of rainwater that would recharge the shallow groundwater system will still end up in Cushaling River via slightly different pathways involving the perimeter swale and attenuation lagoon and ICW system. Hence, there is no net loss of water and the discharge to the river is maintained.

As described in Chapter 2, the runoff from internal roads and hardstanding areas during operations will be collected centrally and diverted through a sediment grit trap and three-chamber oil interceptor to the attenuation lagoon and ICW system, which then discharges to the river.

For the reasons outlined above, no likely significant effects on soils, geology and hydrogeology will occur from localised changes to runoff and recharge. Residual effects are neutral, imperceptible, and permanent.

7.5.3.4 Groundwater Lowering by the Under-cell Drainage System

During operations, the under-cell drainage system constructed beneath each phase/cell will be actively draining shallow groundwater to prevent potential hydraulic 'heave' of the liner system. The under-cell drainage network consists of shallow trenches in a herringbone formation (Figure 7-40), with 150 mm diameter slotted pipes (Photo 12) that feed into larger collector 355 mm diameter collector pipes.

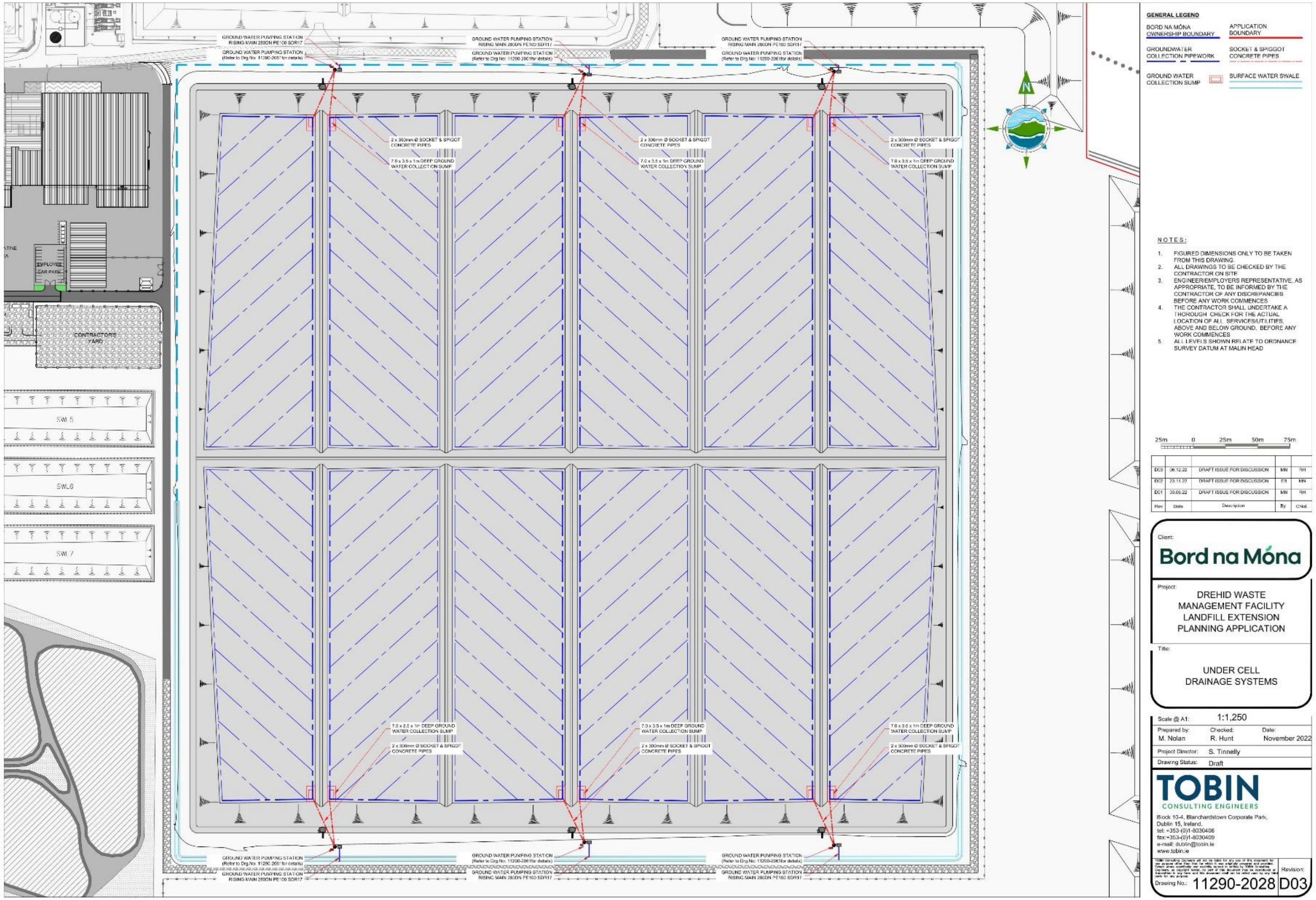


Figure 7-40 Layout of Under-cell Drainage System Beneath New Waste Cells

Photo 12 Under-cell Drainage Pipework at Existing WMF, June 2022

The collector pipes then transmit the captured groundwater to a pump station located outside the landfill footprint. From the pump station, the water is transferred to the new attenuation lagoon and ICW system associated with the expanded landfill.

The under-cell drainage system functions as a groundwater lowering system when it is operational. The system will operate sequentially across phases as waste cells are being filled. The invert of the system is designed at an elevation 77.745 mOD, which becomes the deepest dewatering level during operations.

The hydraulic effect of groundwater lowering will translate away from the waste cells. The lowering will likely contribute to draining of peat within the resulting zone of hydraulic influence. This can result in further loss of peat, but only as long as the drainage system is operational (c. 2.5 years for each phase).

The hydraulic effect dissipates with distance. The distance to 'zero drawdown' (*i.e.,* no hydraulic effect) was explored using commonly applied analytical solutions for dewatering operations. The analytical solutions, which are devised for calculating radial drawdown around dewatering (pumping) wells, were adapted to account for rectangular excavations by factoring in the "effective radius" of excavations.

As presented in Appendix 7-5, and using site-specific information, the estimated radius of hydraulic influence (from the centre of a cell) is approximately 132 m, extending approximately 40 m beyond the edge of a cell. The corresponding estimated dewatering rate for a 268 m × 97 m cell is approximately 0.04 m^3/s. This value lies within the historically recorded monthly discharge rates from the under-cell drainage system at the WMF, which ranges from zero to 0.085 m^3/s (Chapter 8), for an average monthly rate of 0.019 m^3/s between 2015 and 2022.

Some variability in discharge rates will occur between phases because the subsoils in the Proposed Development area (Section 7.4.3) and associated hydraulic properties (Section 7.4.15) are heterogeneous, *i.e.,* vary in three dimensions. The calculations in Appendix 7-5 are based on averages and assume steady state flow conditions as simplifying conditions in the analytical methods. Actual hydraulic influence will vary spatially and temporally according to prevailing, location-specific conditions. Nevertheless, the calculations in Appendix 7-5 serve as a useful indicator which is guided by site-specific data.

Pre-Mitigation Potential Effects - Soils: Pre-mitigation potential effects of the dewatering is draining of shallow groundwater and peat within an estimated 50 m of the perimeter boundaries of landfill phases. The under-cell drainage system is only active beneath waste cells that are being filled and each phase will be filled within a 2.5 year period. Hence, the dewatering effect moves from one phase to another. While the effect is short-term for individual cells, the effect applies for the entire operational period of the expanded landfill.

The actual effect that will occur is uncertain due to the heterogeneous nature of the materials being dewatered and the hydraulic interaction that will result from the modified drainage network. As described in Section 7.5.2.2, some drains will be blocked outside the expanded landfill footprint. This will cause shallow groundwater levels to rise and thus counteract any groundwater lowering beneath actively filled cells.

For this reason, the pre-mitigation potential effect of the under-cell drainage system will likely not be significant.

Pre-Mitigation Potential Effects - Geology: Dewatering effects do not influence geology or geological resources. Hence, the assessment of effects is not applicable.

Pre-Mitigation Potential Effects - Hydrogeology: The pre-mitigation potential effect is groundwater lowering in the Quaternary unit. The groundwater flow field will be influenced in the same manner that is experienced currently at the WMF (Section 7.4.13), whereby flow gradients are induced inward from surrounding areas towards the active under-cell drainage system. The groundwater that is captured will directed to the attenuation lagoon and ICW system, hence there is no effect on the discharge rates to Cushaling River.

The likely effect of lowering groundwater levels in the vicinity of the cells is short-term for individual cells and long-term over the period of landfill operations (the effect shifting with phases).

Mitigation Measures by Design: The under-cell drainage system is necessary as a control measure to prevent damage to the landfill liner during waste deposition. Dewatering effects will be countered near the landfill footprint by maintaining water levels in the drainage network as high as possible and as close to the landfill expansion as possible, by the blocking of drains (Section 7.5.2.2). The aim is to maintain water levels high in the peat outside the landfill expansion footprint.

Post-Mitigation Residual Effects - Soils: Groundwater lowering will occur as a result of under-cell drainage. However, drain blocking will help to maintain water levels high outside the landfill expansion footprint, and water levels will rebound after the under-cell drainage system becomes inactive. For this reason, likely significant effects on peat outside the landfill expansion footprint during operations will not occur.

Post-Mitigation Residual Effects - Geology: Dewatering effects do not influence geology or geological resources. Hence, the assessment of effects is not applicable.

Post-Mitigation Residual Effects – Hydrogeology: Groundwater lowering will occur as a result of the under-cell drainage system. This will be a localised effect in the vicinity of the phase/cell being filled, similar to what is experienced currently in the eastern portion of the existing WMF (Section 7.4.13). The lowering is a localised effect which will not affect the wider hydrogeological regime of the Proposed Development area. Moreover, groundwater levels will rebound after the under-cell drainage system becomes inactive.

For these reasons, likely significant effects on the hydrogeological conditions of the Proposed Development area will not occur.

7.5.3.5 WFD Status of Kildare and Trim Groundwater Bodies

For the same reasons described in Section 7.5.2.8, there will be no likely significant effects on the WFD status of the Kildare and Trim GWBs during the operational period.

7.5.3.6 Groundwater-Sourced Public and Private Water Supplies

For the same reasons described in Section 7.5.2.9, there will be no likely significant effects on groundwater-sourced water supplies from the Proposed Development.

7.5.4 Post-Closure

As described in Chapter 2, a Closure, Restoration and Aftercare Management Plan (CRAMP) will be required, to be approved by EPA. The anticipated landfill closure tasks and programmes were presented in Appendix 2-11.

Potential effects during the post-closure period are associated with decommissioning of infrastructure and plant, which involves risks from accidental spills and leaks, although risks are reduced as the scale of works is smaller.

Mitigation measures to avoid and reduce risk of contamination by accidental soil and leaks will be implemented as per the CEMP and CRAMP.

Environmental monitoring will continue under license to be able to track the rebound of groundwater levels and monitor for potential trends in groundwater quality. The latter is particularly relevant in context of the TSB Decommissioning and Rehabilitation Plan, which is described in Section 7.6.

7.6 CUMULATIVE EFFECTS

The Proposed Development will interact with two other planned projects within the boundaries of TSB:

- Firstly, the traversing of the planned Shannon Pipeline[8] across the northwestern 'corner' of TSB, i.e., to the northwest of the existing WMF. Agreement is in place between Uisce Éireann and BnM, pending decisions about the Uisce Éireann going ahead with the project in the future.

[8] https://www.water.ie/projects/national-projects/water-supply-project-east-1/

- The TSB Decommissioning and Rehabilitation Plan (Appendix 8-4). As described in Section 7.5.1, the plan will serve to raise water levels and re-wet parts of TSB, including parts immediately outside the landfill expansion area.

7.6.1 Shannon Pipeline

The Shannon Pipeline is a large diameter water supply pipeline which will bring treated drinking water from the Shannon River to new storage reservoirs near Dublin. Construction (installation) will involve vegetation stripping, clear-brushing, and earthworks. Details are not yet published but risks, potential effects, and mitigation measures that will be undertaken to address risks are likely to be the same as those described in Section 7.5.2.1 and 7.5.2.2. The construction will result in the permanent loss of peat along a pipeline corridor which will traverse TSB to the northwest of the existing WMF. The pipeline will also traverse TSB below ground. Pipeline excavations is expected to be backfilled with native peat and subsoil materials. As such, the pipeline construction and operations, in combination with the Proposed Development, is not expected to have any likely significant cumulative effects on the geology or hydrogeological environment of the Proposed Development.

7.6.2 TSB Decommissioning and Rehabilitation Plan

As presented in Chapter 8, the Proposed Development will interact hydrologically with the TSB Decommissioning and Rehabilitation Plan, with an anticipated net positive effect on water quality in Cushaling River, particularly with regard to ammonia. This effect arises because sections of TSB outside the Proposed Development area will be re-wetted and hydrologically stabilised. The re-wetting of peat reduces the leaching potential of ammonia (and certain metals), which means the chemical loading of Cushaling River from the bog is also reduced.

This same effect will translate to the groundwater environment. It is expected to lower the concentrations of ammonia and metals like arsenic, iron and manganese in groundwater. Current baseline conditions do not pose any threats, but reduced concentrations in groundwater will contribute to reducing chemicals loads overall to the river, albeit at levels that may not be measurable, given the very small groundwater baseflow component of the river (Section 7.4.16).

The TSB Decommissioning and Rehabilitation Plan also involves permanent modifications to the drainage network within TSB (Section 7.5.2.2) which will accommodate both the Proposed Development and the Shannon Pipeline project.

The modified drainage means that groundwater flow is affected locally, although the concepts of groundwater-drainage interactions are maintained and the overall water balance towards the Cushaling River is not affected. The necessary modifications to the drainage network do not significantly affect groundwater fluxes or baseflow contributions to Cushaling River.

For these reasons, there are no likely significant cumulative effects on the groundwater environment which support TSB and the groundwater flow contribution to Cushaling River.

7.6.3 Other Developments Outside TSB

BnM is planning to develop the Ballydermot Wind Farm[9] in areas to the west/southwest of TSB. The wind farm development is situated within the subcatchment of the Cushaling/Figile Rivers

[9] https://www.ballydermotwindfarm.ie/the-project/project-overview/

and the Abbeylough River. However, the development is more than 5 km downstream of the Proposed Development.[10] For this reason, the wind farm development will not interact with or influence the soils, geological or hydrogeological environments of the Proposed Development area. Accordingly, there will be no likely significant, related cumulative effects arising from either project.

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[10] https://www.ballydermotwindfarm.ie/wp-content/uploads/sites/17/2022/08/Ballydermot-Wind-Farm-Infrastructure-Map.pdf

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