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MEECE 1 LANDFILL SITE
SWYNNERTON, STONE, STAFFORDSHIRE

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

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APPENDICES

DRAWINGS

1.0 INTRODUCTION

1.1 Project Introduction and Aims

Swan Environmental Services Ltd, on behalf of Biffa Waste Services Ltd (Biffa), has commissioned NSugg Ltd to undertake a Hydrogeological Risk Assessment Review (HRA Review) for Meece 1 Landfill, located near Swynnerton, Cold Meece, Stone, Staffordshire.

Meece 1 Landfill is managed in accordance with Environmental Permit EPR/BV4967IW, held by Biffa.

The site's most recent Hydrogeological Risk Assessment (HRA) Review was completed in May 2017[1] (hereafter referred to as the 2017 HRA Review). The 2017 HRA Review was developed over a number of years, in consultation with the Environment Agency, but provides a full review and update of the site's 2008 HRA Review[2]. The 2008 HRA Review in turn reviewed the site's original 2003 HRA[3] submitted in support of the site's Pollution Prevention and Control (PPC) permit application.

This document represents the six-year review of the 2017 HRA Review, as required by Condition 3.1.4 of the site's permit:

The operator shall submit to the Environment Agency a review of the Hydrogeological Risk Assessment:

- *(a) Between nine and six months prior to the fourth anniversary of the granting of the permit, and*
- *(b) Between nine and six months prior to every subsequent six years after the fourth anniversary of the granting of the permit.*

This report presents an update and review of the conceptual site model presented in the 2017 HRA Review through a comprehensive review of the site's long-term monitoring data record and site operations. The assumptions and parameterisation of the 2017 HRA Review risk assessment model are then reviewed.

This HRA Review has been prepared in accordance with current Environment Agency guidance[4],[5] and aims to determine the site's compliance with the relevant requirements of the Environmental Permitting (EP) Regulations 2016 and to review the long-term management and monitoring requirements for the site.

This report has the following structure:

- Section 2 presents an update and review of the hydrogeological conceptual site model;
- Section 3 presents the hydrogeological risk assessment;

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[1] Golder Associates, May 2017, Meece 1 Landfill: Hydrogeological Risk Assessment Review, Report number: 1666316.501/A.0.

[2] Golder Associates, October 2008, Meece 1 Landfill Site, Hydrogeological Risk Assessment Four Yearly Review.

[3] Golder Associates, September 2003, Meece 1 Landfill Site, Hydrogeological Risk Assessment.

[4] Environment Agency, February 2016 (last updated: October 2020), Landfill Developments: Groundwater Risk Assessment for Leachate.

[5] Environment Agency, January 2020 (last updated: February 2022), Landfill Operators: Environmental Permits, Review your Hydrogeological Risk Assessment.

- Section 4 reviews the site monitoring schedules and compliance limits and
- Section 5 includes a summary and report conclusions.

1.2 Sources of Information

The following primary sources of information have been reviewed and consulted during the preparation of this HRA Review:

- The 2003 HRA, 2008 HRA Review and 2017 HRA Review for the site, as referenced above.
- Site environmental monitoring data for leachate, groundwater and surface water provided by Biffa, together with supporting monitoring plans, site development information, as-built survey details and the latest site topographic survey.
- Published environmental mapping including British Geological Survey maps, Ordnance Survey mapping and Natural England’s MAGIC geographic information mapping.
- The Environment Agency was consulted to obtain up-to-date information regarding local public water supply abstractions.
- Stafford Borough Council was consulted to obtain up-to-date information regarding local private water supply abstractions.

2.0 HYDROGEOLOGICAL CONCEPTUAL SITE MODEL REVIEW

2.1 Introduction

This section of the report reviews the hydrogeological conceptual site model presented within the 2017 HRA Review. The sources, pathways and receptors have been reviewed and updated with reference to site monitoring data, information on site operations and site management and updated third party information (private and licensed water abstractions).

A comprehensive review of the conceptual site model has been undertaken, following review of all available site monitoring data.

2.2 Sources

It is appropriate to review the following elements of the source term as part of the HRA Review:

- Site development and operation;
- Leachate levels; and
- Leachate quality.

2.2.1 Site Development and Operation

Meece 1 Landfill has been developed on the site of the former Swynnerton Royal Ordnance Filling Factory (ROF Swynnerton). ROF Swynnerton was operational from 1940 until 1958 and was primarily used during WWII to fill shells and other armaments but included a burning ground where life-expired or substandard explosives were destroyed[6]. The site subsequently became part of the Ministry of Defence (MOD) training ground which extends to the south.

Landfilling at Meece 1 Landfill commenced in 1986 under the management of Staffordshire County Council (SCC). Landfilling of Phase 0 (also known as SCC/A – SCC/E) and Phase 1 (also known as SCC/F – SCC/G) was undertaken by SCC and it is understood that wastes within these early phases comprised municipal waste and incinerator ash.

Historically the landfill operated as a hazardous co-disposal landfill but has been operated as a non-hazardous landfill since July 2004, accepting primarily municipal waste.

Meece 1 Landfill comprises 12 landfilled phases, as detailed below in Table 1 and on Drawing 1. Historic phases 0, 1, 2, 3 and 13a were developed on the principle of natural or engineered containment with an unsaturated pathway present and are predominantly land-raise with minimal excavation prior to landfilling. Phases 4A, 4B, 4BB, 5A, 5B, 6 and 7 were developed on the principal of hydraulic containment, with the base of each phase excavated beneath local groundwater levels.

Waste acceptance for disposal ceased at Meece 1 Landfill in January 2012, with final capping completed in 2015, therefore no landfilling has been undertaken since the 2017 HRA Review, with the site remaining mothballed. However, placement of restoration material onto capped cells continues to be undertaken, as permitted.

Phases 8, 11, 12, 13B and 14 of Meece 1 Landfill, as indicated on Drawing 1, have not been developed to date.

[6] Subterranea Britannica (www.subbrit.org.uk)

The areas known as Phases 9 and 10 of Meece Landfill are outside of the Meece 1 permit boundary area; these phases represent the adjacent hazardous waste landfill site Meece 2 and are regulated by a separate hazardous landfill environmental permit. Therefore Phases 9 and 10 are not subject to this HRA Review although their proximity to Meece 1 Landfill must be taken into consideration. Meece 2 Landfill has not commenced development.

Table 1 presents a summary of the site development, after the 2017 HRA Review.

Table 1: Meece 1 Landfill – Site Development

Landfill Phase	Status	Lining System	Basal Elevation (top of liner)	Capping Specification
0	Filled by Staffordshire County Council pre-1996. Restored	Natural clay base	116.34 – 120.04	Clay
1		Local clay, HDPE & geotextile protective layer	118.49 – 121.14	300mm Mercia Mudstone, Bentomat GCL, 850mm Mercia Mudstone
2	Filled by 1996. Restored	0.5m clay, HDPE	118.30 – 120.12	
3	Filled by 1997. Restored	1.0m clay	120.00 – 121.03	Clay
4A	Filling began 1998. Closed	0.5m clay, GCL	115.07	Clay
4B	Filling began 2000. Closed		113.40	
4BB	Filling began 2001. Closed		111.97	
5A	Filling began 2003. Closed	0.5m clay, GCL	115.77	Bentomat GCL
5B			110.75	
6	Filling began 2008. Closed	1.0m reworked mudstone, HDPE	110.75 – 113.17	Bentofix NSP 4300 GCL
7	Filling began 2008. Closed	1.0m reworked mudstone, HDPE	111.09 – 113.03	Bentofix NSP 4300 GCL
13A	Landfilled. Closed	1.0m clay	121.00	Clay Cap and Flanks capped in 2015 with GCL

Table Notes: 1. Basal elevation assumed to be concurrent with base of leachate wells

The site is predominantly surrounded by agricultural land, with the MOD training area located immediately south of the site.

Review of the Environment Agency's online historic landfill mapping indicates the presence of historic landfills immediately west of the site, approximately 400m south-east of the site and approximately 1km south of the site, as indicated on Figure 1 below. The following site details are provided via the Environment Agency's historic landfill database:

- Highlows Farm: Site reference: W32, 4/D/91/0352, 9999/9791. Waste input: 1991-1993 (inert and industrial waste).
- Meece Refuse Tip: Site reference: Stafford Borough 18, 9999/9168. First waste input: 1970 (household waste).
- New Birch House: Site reference: 4/F/77/0050, Z03, 9999/9779. First Waste input: 1977 (industrial, commercial and household waste). Licence surrendered: 1986.
- Royal Ordnance Factory: Site reference: Stafford Borough 17, 9999/9169. Waste input: 1963-1971 (industrial, commercial and household waste).

The potential implications of these historic landfills on local groundwater and surface water quality are discussed within the relevant sections.

Figure 1. Historic Landfill Sites in the Vicinity of Meece 1 Landfill (extract from Environment Agency mapping)

The site remains mothballed, in accordance with the assumptions of the 2017 HRA Review and has relevant monitoring and management measures as required by the site permit. The permit (BV4967IW) for Meece 1 Landfill was issued in April 2005 and subsequently varied in June 2012 for the addition of a soil treatment facility. The current permit (EPR/BV4967IW/V012) was determined in April 2017 to vary and consolidate the permit for the addition of waste codes for the soil treatment plant and for site restoration. The site also has an Aggregate Treatment and Recycling Facility which is operated under a separate Environmental Permit (reference EPR/EB3603FM). This facility recovers usable aggregate from street sweepings and other similar waste streams.

2.2.2 Leachate Levels and Management

Section 3 of the 2003 ESID[7] report, prepared to support the original permit application, includes site development details and indicates the following leachate management measures:

- Phases 0 and 1: limited engineering details available; no leachate drainage system assumed.
- Phase 2: base of each cell falls at 1:100 to a central sump, 300mm gravel leachate drainage layer.

[7] Golder Associates, September 2003, Section A: Environmental Setting and Installation Design, Meece 1 Landfill Site.

- Phase 3: rubber tyre leachate drainage layer.
- Phase 4A and 4B: herringbone pattern of leachate collection pipes within a gravel blanket draining towards a central sump.
- Phase 5B and 13A: leachate collection pipes draining towards a central sump with 200mm gravel drainage surrounding the pipes.
- Future phases (i.e. Phases 6 and 7): proposed leachate drainage system comprising slotted HDPE drainage pipes laid in a herringbone pattern within a 300mm thick gravel drainage blanket and discharging to a central sump.

Table S3.1 of the site permit requires quarterly leachate level monitoring at Meece 1 Landfill and specifies the following leachate level permit compliance limits:

Table 2: Current Leachate Level Compliance Limits (after Table S3.1 of the site permit)

Monitoring Location	Compliance Limit
All leachate extraction and monitoring points in unlined phases 0, 1, 2, 3 and 13.	1m above base of cell
All leachate extraction and monitoring points in hydraulically contained phases 4BB, 6(2), 7(2), 8, 11 and 12(1)	113.5mAOD
leachate extraction and monitoring points in 4B	114.4mAOD

Table Notes:
1. Compliance limits and assessment levels have not been set for cells 4A, 5A and 5B as they are cells with only internal boundaries which are not subject to hydraulic containment.
2. The compliance limit does not apply to monitoring points 3214 (Phase 6, Monitoring Well 2) and 3216 (Phase 7, Monitoring Well 2).

The current leachate monitoring points are indicated on the Site Monitoring Plan, included as Appendix A. Tables 3 and 4 present leachate level monitoring data for September 2022 and October 2022 as depth of leachate above base of well and leachate elevation (mAOD) respectively. There is an assumption throughout that the base of the leachate monitoring well is equivalent to base of the cell and this is a worse-case assumption with regards leachate heads. It is understood that monitoring wells LW20, LW21 and Phase 6 MW2 (refer to Table 3 below) were re-drilled in October 2013 although the standoff from the base of the landfill is not known.

Leachate level data prior to September 2022 are not reliable because headworks (datum points) have been periodically raised but not surveyed; therefore, only data collected since the latest site survey are reliable and appropriate for use within the HRA Review.

Review of Drawing ESID7A of the 2003 ESID Report indicates that all current leachate monitoring points represent leachate extraction sumps, with the exception of the following wells within Phases 6 and 7: Phase 6,MW1, Phase 6,MW2, Phase 7,MW1 and Phase 7,MW2. Leachate levels at the extraction sumps will be influenced by leachate extraction and levels may be higher elsewhere within the landfill.

Biffa has confirmed that leachate is extracted via air and electrically powered pump systems installed within the extraction/monitoring wells, with approximately 250m^3 of leachate tankered off-site weekly (Monday to Friday) with leachate predominantly discharged to a third-party facility. Recently leachate extraction has increased to 450-500m^3 per week, when tankers are available, to ascertain the impact of increased leachate extraction on heads at the site.

Leachate interception drains have been installed retrospectively along the southern boundary of the landfill and around Phases 13A and 3 in the north, to intercept and manage surface leachate seepages. The leachate drains have been installed progressively under CQA during landfill capping, with the works undertaken in 2010 and 2013.

Biffa has also recently installed a leachate extraction system from 10 wells within the historic Phases 0 and 1, to discharge leachate via a holding and sampling tank to mains sewer. Consent has been obtained from Severn Trent for the discharge of up to 100m^3 per day of leachate to sewer and this system will commence operation subject to appropriate leachate quality analysis and following permit variation approval for the emission point (permit variation application submitted December 2022).

The 2017 HRA Review states that Phases 0, 1, 2, 3 and 13A were developed under the principle of natural or engineered containment, with the base of the landfill cells constructed above local groundwater levels. However, Phases 4A, 4B, 4BB, 5A, 5B, 6 and 7 were developed under the principle of hydraulic containment, with the base of the landfill cells constructed below local groundwater levels.

Recent leachate level data are reviewed below and the potential loss of hydraulic containment, due to elevated leachate levels, is considered in Section 2.3.3, where leachate levels are compared against local groundwater level data.

Table 3: 2022 Leachate Level Monitoring Data (depth above base of well)

Landfill Phase	Monitoring Point (historic reference)	Leachate Head (m above base of well)			Permit Limit (m above base of well)
		29th Sept 2022	11th Oct 2022	Average	
0	LW1 (3101)	5.65	3.22	4.44	1.0
	LW2 (3102)	6.58	7.29	6.94	
	LW3 (3103)	10.98	5.19	8.09	
	LW4 (3104)	8.21	6.48	7.35	
	LW7 (3107)	2.79	0.42	1.61	
1	LW5 (3105)	7.19	2.47	4.83	1.0
	LW6 (3106)	10.57	6.39	8.48	
2	LW8 (3108)	9.98	6.40	8.19	1.0
	LW9 (3109)	7.67	3.12	5.40	
	LW10 (3110)	6.99	4.98	5.99	
	LW11 (3111)	7.76	4.76	6.26	
3	LW12 (3112)	13.48	11.01	12.25	1.0
	LW13 (3113)	4.01	10.30	7.16	
	LW14 (3114)	8.79	11.22	10.01	
	LW15 (3115)	1.74	2.09	1.92	
13A	LW16 (3116)	4.95	4.21	4.58	1.0
4A	LW17 (3117)	11.84	6.43	9.14	N/A
4B	LW18 (3118)	7.93	5.00	6.47	1.0
4BB	LW20 (3120)	9.71	6.10	7.91	0.38
5A	LW21 (3121)	9.69	5.44	7.57	N/A
5B	LW19 (3119)	12.55	8.20	10.38	N/A
6	LW22 (3122)	9.79	5.63	7.71	2.75
	Phase 6, MW1 (3213)	9.86	7.98	8.92	1.48
	Phase 6, MW2 (3214)	10.72	5.31	8.02	N/A
7	LW23 (3123)	8.57	3.01	5.79	2.41
	Phase 7, MW1 (3215)	8.60	4.92	6.76	1.47
	Phase 7, MW2 (3216)	7.29	4.63	5.96	N/A

Table Notes: Monitoring point locations are derived from 2017 HRA Review and site plans. Permit compliance limits for Phases 4B, 4BB, 6 and 7 are reported as mAOD and have been converted to an equivalent leachate head (m above base of well), using base of well datum elevations.

Table 4: 2022 Leachate Level Monitoring Data (mAOD)

Landfill Phase	Monitoring Point (historic reference)	Leachate Level (mAOD)			Permit Limit (mAOD)
		Sept 2022	Oct 2022	Average	
0	LW1 (3101)	123.71	121.28	122.50	119.06
	LW2 (3102)	122.92	123.63	123.28	117.34
	LW3 (3103)	130.29	124.50	127.40	120.31
	LW4 (3104)	128.25	126.52	127.39	121.04
	LW7 (3107)	121.79	119.42	120.61	120.00
1	LW5 (3105)	128.33	123.61	125.97	122.14
	LW6 (3106)	129.06	124.88	126.97	119.49
2	LW8 (3108)	130.10	126.52	128.31	121.12
	LW9 (3109)	127.51	122.96	125.24	120.84
	LW10 (3110)	126.69	124.68	125.69	120.70
	LW11 (3111)	126.06	123.06	124.56	119.30
3	LW12 (3112)	133.48	131.01	132.25	121.00
	LW13 (3113)	124.91	131.20	128.06	121.90
	LW14 (3114)	128.86	131.29	130.08	121.07
	LW15 (3115)	122.77	123.12	122.95	122.03
13A	LW16 (3116)	125.95	125.21	125.58	122.00
4A	LW17 (3117)	126.91	121.50	124.21	N/A
4B	LW18 (3118)	121.33	118.40	119.87	114.40
4BB	LW20 (3120)	122.83	119.22	121.03	113.50
5A	LW21 (3121)	127.47	123.22	125.35	N/A
5B	LW19 (3119)	123.30	118.95	121.13	N/A
6	LW22 (3122)	120.54	116.38	118.46	113.50
	Phase 6, MW1 (3213)	121.88	120.00	120.94	113.50
	Phase 6, MW2 (3214)	125.02	119.61	122.32	N/A
7	LW23 (3123)	119.66	114.10	116.88	113.50
	Phase 7, MW1 (3215)	120.63	116.95	118.79	113.50
	Phase 7, MW2 (3216)	120.32	117.66	118.99	N/A

Table Notes: Monitoring point locations are derived from 2017 HRA Review and site plans. Permit compliance limits for Phases 0, 1, 2, 3 and 13A are reported as m above base of cell and have been converted to an equivalent leachate level (mAOD) using base of well datum elevations.

The average leachate level recorded in each landfill phase in September/October 2022 is presented in Table 5 and compared against the permit compliance limits, to provide an overview of the site's recent performance.

Table 5: 2022 Leachate Level Monitoring Data (depth above base of well)

Landfill Phase	Monitoring Point	Sept-Oct 2022 Average Leachate Head (m above base of well)	Permit Compliance Limit (m above base of well)	Difference Between 2022 Average Leachate Head & Permit Limit
0	LW1, LW2, LW3, LW4, LW7	5.68	1.0	4.68
1	LW5, LW6	6.66	1.0	5.66
2	LW8, LW9, LW10, LW11	6.46	1.0	5.46
3	LW12, LW13, LW14, LW15	7.83	1.0	6.83
13A	LW16	4.58	1.0	3.58
4A	LW17	9.14	N/A	N/A
4B	LW18	6.47	1.0	5.47
4BB	LW20	7.91	0.38	7.53
5A	LW21	7.57	N/A	N/A
5B	LW19	10.38	N/A	N/A
6	LW22	7.71	2.75	4.96
	Phase 6, MW1	8.92	1.48	7.44
	Phase 6, MW2	8.02	N/A	N/A
7	LW23	5.79	2.41	3.38
	Phase 7, MW1	6.76	1.47	5.29
	Phase 7, MW2	5.96	N/A	N/A

Table Notes: Monitoring point locations are derived from 2017 HRA Review and site plans. Permit compliance limits for Phases 4B, 4BB, 6 and 7 are reported as mAOD and have been converted to an equivalent leachate head (m above base of well), using base of well datum elevations.

Review of the available leachate level monitoring data indicates the following:

- Following a resurvey of the top heights of all leachate wells in Summer 2022 it was identified that there were discrepancies with some datum elevations within the database. Although leachate levels have been recorded throughout the period the most recent top datums recorded should be those used going forward as changes to wells have largely ceased following the placement of material. As such data from September 2022 is the most accurate representation of current and future top datums. Table 5 confirms average leachate heads of between 4.58m above base of well (Phase 13A) and 10.38m above base of well (Phase 5B). Where permit compliance limits exist, the average (2022) leachate levels exceeded the relevant permit compliance limit by between 3.38m and 7.53m.

- Meece 1 Landfill site is developed with a domed restoration profile with the top of the landfill elevated up to approximately 20m above perimeter ground levels. The available 2022 leachate level ranges are included on the hydrogeological cross-sections presented as Drawing 2. These confirm that recent leachate levels have exceeded perimeter bund heights, notably on the topographically lower, southern site boundary, indicating the potential for leachate outbreaks to surface. As previously noted, these boundaries benefit from a leachate interception system that limits leachate breakouts on these flanks.

- Drawing 2 also confirms that recent leachate levels exceed internal bund heights, where known, thus allowing internal leachate movement between landfill phases.

- The 2017 HRA Review proposed revised leachate level compliance limits, based on updated risk assessment modelling; however, these have not been incorporated within the site permit, which would require a formal permit variation. The risks posed by elevated leachate levels to local receptors are discussed in Section 2.3.3 and proposed revised leachate level compliance limits are presented in Sections 2.3.2 and 4.1 respectively.

The hydrogeological cross-section presented on Drawing 2 confirms that the elevated leachate levels (2022 data) introduce an outward hydraulic gradient between all phases of the landfill and the underlying aquifer; this is reviewed in further detail in Section 2.3.3.

2.2.3 Leachate Quality

Leachate at Meece 1 Landfill is routinely sampled and analysed for a range of determinands. Leachate quality monitoring was generally undertaken quarterly or six-monthly until 2015 when the frequency reduced to annually, in accordance with the site permit requirements for non-operational phases.

The 2017 HRA Review considered the following priority contaminants within the site leachate: chloride, ammoniacal-nitrogen, nickel, cadmium, o-xylene and 2,4-dimethylphenol. These priority contaminants remain largely unchanged from the 2003 HRA and 2008 HRA Review, with nickel added for the 2017 HRA Review.

It is considered appropriate to fully review the leachate source term and priority contaminants for the site based on all available leachate quality data.

Leachate risk factors are calculated by dividing the maximum concentration of a substance in the site leachate (removing any outliers from the dataset) by the relevant water quality standard. Updated leachate risk factors, based on all available leachate quality data, are presented within Appendix B. Risk factors have been calculated for all parameters recorded in the site leachate at a concentration of over 10μg/l, the Environment Agency's general lower reporting limit for substances in leachate. Water quality standards are set at the relevant freshwater Environmental Quality Standards (EQS) for non-hazardous pollutants and at the minimum reporting value (MRV) in groundwater for hazardous substances.

The priority contaminants included within the 2017 HRA Review are highlighted within Appendix B and the risk factors for chloride, ammoniacal-nitrogen, 2,4-dimethylphenol, nickel and cadmium remain moderate or high. The leachate risk factor for o-xylene is relatively low and therefore o-xylene is no longer considered a priority contaminant for the site.

Cadmium was reclassified in 2017 by the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) from a hazardous substance to a non-hazardous pollutant which will be reflected within this HRA Review.

Due to the reclassification of cadmium as a non-hazardous pollutant and the removal of o-xylene as a priority contaminant for the site, no hazardous substances are included within the list of priority contaminants. Therefore, it is considered appropriate to add arsenic as a priority contaminant, due to its elevated risk factor and persistence in the sub-surface environment.

Therefore, the following updated list of priority contaminants are considered appropriate for Meece 1 Landfill site:

- Ammoniacal-nitrogen - a non-hazardous pollutant commonly associated with landfill leachate and with a high risk factor. An inorganic cation, included within the 2017 HRA Review.
- Chloride – a non-hazardous pollutant commonly associated with landfill leachate and with a moderate risk factor. A conservative inorganic anion, included within the 2017 HRA Review.
- Nickel – a non-hazardous pollutant and a mobile metallic ion. Nickel has a moderate risk factor and was included within the 2017 HRA Review.
- 2,4-dimethylphenol – a non-hazardous pollutant with a high risk factor. A hydrophilic organic chemical, included within the 2017 HRA Review.
- Cadmium – a non-hazardous pollutant and a less mobile metallic ion. Cadmium has a moderate risk factor and was included within the 2017 HRA Review.
- Arsenic – a hazardous substance with a moderate risk factor and relatively high persistence in the sub-surface.

Table 6 presents a summary of all leachate quality data for the revised priority contaminants (excluding outliers), with summary statistics presented for the full data record and for recent (2015-2022) data. Appendix B includes long-term graphs of chloride and ammoniacal-nitrogen concentrations in leachate for each landfill phase.

Table 6: Leachate Quality Data Review

Substance	Concentrations in Site Leachate (1996 – 2022)			Concentrations Based on Recent Site Monitoring Data[1]			Maximum Concentration in 2017 HRAR[2]
	Min	Average	Max	Min	Average	Max	
Ammoniacal-N (mg/l)	0.19	1069	9310	0.19	870	6740	9310
Chloride (mg/l)	7.6	7147	54600	8.6	5971	44200	50200
Nickel (total) (mg/l)	0.0009	0.090	0.904	0.003	0.096	0.904	0.64
2,4-dimethylphenol (µg/l)	0.1	7.3	79.4	0.1	9.7	79.4	100
Cadmium (mg/l)	0.0003	0.0018	0.043	0.0006	0.0008	0.0138	0.018
Arsenic (mg/l)	0.0005	0.027	0.484	0.0005	0.034	0.484	N/A

Notes: 1. Recent site monitoring data are for the period January 2015 to June 2022. Values less than lower reporting limit (LRL) assumed to equal LRL for arsenic, cadmium and nickel. LRLs are variable and often elevated for 2,4-dimethylphenol, therefore values <1 assumed to equal 0.1, values between <10 and <1 assumed to equal 1 and values where the LRL is greater than 10 are assumed to equal 10.
2. The maximum concentration assumed in the 2017 HRA Review across all landfill phases.
3. Outliers have been removed from the dataset.

Review of the available leachate quality monitoring data indicates the following:

- Leachate quality at Meece 1 landfill is indicative of a mixed waste landfill site, with elevated concentrations of ammoniacal-nitrogen, chloride, metals and other indicator parameters. Recent (2015-2022) concentrations for the entire landfill remain elevated, indicating a relatively strong leachate. The average chloride (5971mg/l) and ammoniacal-nitrogen (870mg/l) concentrations remain elevated above typical average domestic waste leachate concentrations of 2270mg/l and 723mg/l[8] respectively.

- The chloride and ammoniacal-nitrogen graphs included within Appendix B confirm significant variation in leachate strength between landfill phases, with the historic Phases 0 and 1 reporting declining concentrations in recent years. The average chloride concentrations recorded in Phase 0 and Phase 1 in 2021 were 916mg/l and 208mg/l respectively, compared to a 2021 site-wide average chloride concentration of 4664mg/l. The average ammoniacal-nitrogen concentrations recorded in Phase 0 and Phase 1 in 2021 were 152mg/l and 11.5mg/l respectively, compared to a 2021 site-wide average ammoniacal-nitrogen concentration of 1318mg/l.

- The leachate strength is also starting to decline within the remaining landfill phases, as evidenced by a general fall in chloride concentrations in recent years, although ammoniacal-nitrogen concentrations remain elevated indicative of methanogenic conditions.

- Where priority contaminants were included in the 2017 HRA Review, the data review confirms that the maximum recorded concentrations within the site leachate remain comparable to the maximum values assumed in the 2017 risk assessment.

[8] After 'most likely' default leachate concentrations from LandSim 2.5 (Environment Agency R&D Publication 120.

This source term review confirms that Meece 1 Landfill continues to represent a potential source of hazardous substances and non-hazardous pollutants. The following substances are considered appropriate priority contaminants for the site based on the 2017 HRA Review and updated leachate quality data review: ammoniacal-nitrogen, chloride, nickel, 2,4-dimethylphenol, cadmium and arsenic.

2.3 Pathways

It is appropriate to review the following elements of the hydrogeological pathways as part of the HRA Review:

- Geology and aquifer characteristics;
- Groundwater levels and flow;
- Groundwater quality; and
- Surface water quality

2.3.1 Geology and Aquifer Characteristics

Meece 1 Landfill is developed on a former WWII Munitions factory and later a Ministry of Defence (MOD) training ground and the local ground conditions are confirmed in the 2003 HRA as follows:

- The site is developed within the Triassic Mercia Mudstone Group, a red marl with thin sandstones, rock salt and gypsum.
- Regional geological mapping indicates that the Swynnerton Fault cuts through the north-western corner of the site, bringing the underlying Sherwood Sandstone pebble beds to surface, although this has not been verified within the footprint of the site.
- Site-specific borehole logs confirm the presence of made ground in the majority of boreholes, with the greatest thickness (5m) on the southern edge of Phase 0.
- The underlying Mercia Mudstone is generally described within the site boreholes logs as a hard, red-brown, thinly laminated, silty or sandy clay with occasional fragments of gravel and sandstone. Regular siltstone bands are recorded and described as very weak red brown fine sandy siltstone.
- It is noted that ground levels step down into the site along the northern boundary by up to approximately 1m to 2m, as evidenced on cross-section B-B’ of Drawing 2.

The thickness of the Mercia Mudstone is unknown at the site; the 2003 ESID report notes a thickness of approximately 130m locally, based on published cross-sections, but acknowledges that the Swynnerton Fault may affect the dip and thickness of the Mercia Mudstone beneath Meece 1 Landfill.

The Mercia Mudstone Group contains evaporite minerals, mainly halite (sodium chloride) and gypsum (hydrous calcium sulphate). However, halite is very soluble in water and is never encountered at the natural ground surface, having been removed by groundwater to some depth (typically 40m to 60m below ground level). Similarly, gypsum, though less soluble, is frequently absent in the near surface zone[9].

Regionally, the Mercia Mudstone confines groundwater in the underlying Sherwood Sandstone aquifer. Groundwater within the Mercia Mudstone is generally associated with the

[9] British Geological Survey 2002, Engineering Geology of British Rocks and Soils, Mudstones of the Mercia Mudstone Group.

more permeable sandstone horizons[10]. Despite being generally thin (often less than 1 m thick) and very well cemented, the sandstone and siltstone horizons may contain and transmit limited quantities of groundwater through fractures. However, these more permeable horizons are often limited in lateral extent.

The CQA report for the installation of boreholes on the southern site boundary records that boreholes BH2, BH19, BH20, BH21 and BH26 had dry mudstone returns but had standing water after 10 minutes[11]. This suggests groundwater is present within discrete horizons, with groundwater within these boreholes sourced from a confined layer or from the overlying superficial deposits. The CQA report notes that BH3 had an artesian flow after drilling, confirming that this borehole had intercepted a confined groundwater horizon. All boreholes (except BH4) were drilled to a depth of 12m below ground level along the southern boundary where the ground level is relatively consistent, with a screened response zone within the basal 10m. BH4 which is located at a higher elevation was drilled through made-ground to a depth of 14m and has a screened response zone within the basal 3m only.

The 2003 HRA includes the results of rising and falling head permeability tests undertaken within the Mercia Mudstone at the site. The slug tests were undertaken in August 2003 within perimeter groundwater monitoring boreholes BH6, BH9 and BH16 (refer to the Site Monitoring Plan in Appendix A for locations) and yielded results of between 3.3 x 10^{-7}m/s and 3.6 x 10^{-6}m/s. However, water balance calculations included within the 2003 HRA back-calculate the Mercia Mudstone permeability as between 1.1 x 10^{-6}m/s and 3.4 x 10^{-5}m/s. These data suggest that the slug testing underestimates the bulk permeability of the Mercia Mudstone at the site, with groundwater flow likely to be dominated by fracture flow.

Table 7 presents a summary of the aquifer characteristics of the Mercia Mudstone beneath the site.

Table 7: Mercia Mudstone Aquifer Characteristics

Geological Description	Aquifer Designation	Groundwater Vulnerability	Groundwater Flow Characteristics
Hard, red-brown, thinly laminated, silty or sandy clay with occasional fragments of gravel and sandstone. Regular bands of very weak fine sandy siltstone are present.	Secondary B Aquifer - Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.	High	Groundwater flow dominated by fracture flow and predominantly within the more permeable siltstone/sandstone horizons. Isolated groundwater systems appear to exist within these horizons and may be confined by the overlying less permeable mudstone.

Table notes: Aquifer designation and groundwater vulnerability confirmed from Natural England's MAGIC online mapping.

No further site investigations, testing or other geological studies have been undertaken at the site since the 2017 HRA Review. Therefore, the assumptions of the 2017 HRA Review, with regards the local geology beneath the site, are considered to remain valid.

[10] British Geological Survey 2000, The Physical Properties of Minor Aquifers in England and Wales.

[11] Enviroarm Limited, 2004. Construction Quality Assurance Report for the Groundwater Monitoring Borehole Installation around Meece 1 and Meece 2 (Section 1.5).

2.3.2 Groundwater Levels and Flow

Groundwater levels at Meece 1 Landfill are monitored on a quarterly basis within a network of perimeter monitoring boreholes, as required by the site permit. Table 8 presents a review of recent groundwater level data (2015-2022), with long-term groundwater hydrographs (2000-2022) included in Appendix D.

Table 8: Groundwater Level Monitoring Data (2015-2022)

Monitoring Borehole (historic and permit reference)	Groundwater Level (mAOD) Data (Jan 2015 – Dec 2022)			
	Count	Min	Average	Max
BH2 (1002)	43	111.46	114.30	114.62
BH3 (1003)	43	115.51	116.18	116.62
BH4 (1004)	43	115.38	116.37	117.15
BH5 (1005)	43	113.73	115.49	116.86
BH6 (1006)	32	116.15	117.85	118.96
BH7 (1007)	*28*	*101.97*	*103.93*	*108.55*
BH8 (1008)	*27*	*116.14*	*119.25*	*120.97*
BH9 (1009)	28	120.62	121.26	121.69
BH10 (1010)	27	121.06	121.58	121.92
BH12 (1012)	31	118.82	120.53	121.68
BH13 (1013)	31	120.22	121.04	121.72
BH15 (1015)	31	120.26	120.53	120.86
BH19 (1019)	43	111.32	112.71	114.45
BH20 (1020)	43	114.36	115.00	115.36
BH21 (1021)	43	114.66	115.29	115.89
BH22 (1022)	43	115.28	115.81	116.12
BH23 (1023)	43	115.54	115.91	116.05
BH24 (1024)	43	115.14	116.01	116.58
BH25 (1025)	43	115.64	116.25	116.84
BH26 (1026)	43	115.85	116.67	117.75
BH27 (1027)	43	114.08	114.67	115.64

Recent groundwater level data, from September 2022, and inferred groundwater contours for the Mercia Mudstone Formation are presented on Drawing 1.

Review of the available groundwater level data indicates the following:

- The groundwater hydrographs confirm that groundwater levels typically display an annual seasonal fluctuation of 1.0m to 2.0m. A number of the boreholes, up-gradient and down-gradient of the site, record a gradual, long-term rising trend over the monitoring record (2000 to 2022) of up to 1.0m.

- Recent (2021-2022) groundwater level data are generally more consistent, with less seasonal fluctuation than previously observed and variable groundwater level responses between adjacent boreholes. This is particularly evident at BH2, where 2021/22 groundwater levels are consistent or declining and at BH26 where groundwater levels follow a rising trend during 2021/22. This may be indicative of localised surface ingress / seepages. It is also noted that the site's surface water management system was improved during this period, with ponding of surface water significantly reduced through pumping to the dedicated on-site attenuation lagoon and remediation of the drainage system. Meece Landfill has been developed with an historic shallow perimeter surface water drainage system discharging to the MOD drains to the south of the site. Whilst these outfalls have been sealed and grouted, the potential for shallow groundwater to discharge via this drainage system may exist if the seals are bypassed or have failed. CCTV surveys of the drainage system are currently being undertaken to provide better understanding of any potential connectivity.

- It is reported that BH26 frequently experienced flooding due to the borehole casing being at ground level; the casing was raised in May 2021 to minimise the risk of surface flooding. The area around boreholes BH8, BH9 and BH10 has also experienced surface water ponding, with the borehole casings raised in 2022 to reduce the risk of surface water inundation. Localised flooding of the boreholes is likely to have influenced groundwater levels in these areas.

- The lowest average groundwater levels (<115mAOD) are recorded in boreholes BH2, BH19 and BH27 located along the southern site boundary, with the highest average groundwater levels (>121mAOD) recorded in boreholes BH9, BH10 and BH13 located along the northern site boundary. The inferred groundwater flow direction in the Mercia Mudstone Formation therefore remains towards the south-west, as indicated on Drawing 1.

- Boreholes BH7 and BH8 located on the north-west site corner record significantly lower groundwater levels than adjacent boreholes. The 2017 HRA Review concludes that these boreholes are influenced by the Swynnerton Fault, and/or Sherwood Sandstone aquifer and are not therefore representative of the Mercia Mudstone beneath the site. Therefore, data from boreholes BH7 and BH8 are presented in *italics* in Table 8 and have been ignored within this risk assessment.

- Drawing 1 indicates that groundwater levels at BH5, BH2 and BH19 are lower than observed at the remaining boreholes on the southern (down-gradient) site boundary. These boreholes coincide with outfalls from the site's perimeter drainage system into the MOD drainage system, as indicated on Drawing 1. Whilst these outfalls were grouted up in 2010 and 2012, a residual pathway for shallow groundwater flow may still exist. In addition, the site's perimeter drains which discharged to the MOD drainage system, may remain in place; this is being investigated via CCTV surveying. It is also acknowledged that the landfill development is likely to locally influence groundwater flow pathways and levels, where the base of the landfill is below the local groundwater level.

- Drawing 2 presents hydrogeological cross-sections through Meece 1 landfill and confirms recent inferred groundwater levels relative to the landfill construction and recent (2022) leachate level ranges. The cross-sections confirm that the unsaturated zone thickness beneath the historic phases of the site is limited; this has been reduced over the monitoring record due to a gradual rise in groundwater levels. The cross-sections confirm that Phase 7, developed as a hydraulic containment phase, displays outward hydraulic gradients as a result of the elevated leachate levels.

- Therefore, all phases of the landfill are considered to have outward hydraulic gradients from leachate to groundwater in the underlying Mercia Mudstone; this was assumed within 2017 HRA Review and risk assessment modelling.

- Phases of the site constructed below the water-table have the potential to act as a barrier to groundwater flow. However, the 2003 ESID report states that a groundwater management system comprising stone filled geotextile wrapped drains is installed in the formation to control groundwater inflows during liner construction and it is assumed that these drains would provide long-term connectivity for groundwater flow around and beneath these phases of the site.

- In summary, groundwater levels, the inferred groundwater flow direction and hydraulic gradient in the Mercia Mudstone, remain comparable to those assumed in the 2017 HRA Review. There has been a slight overall rise in peak groundwater levels, with associated reduction in unsaturated pathway beneath the site (where present).

Table 9 represents an updated version of Table 4 of the 2017 HRA Review and presents an interpretation of the hydrogeological conceptual site model, in terms of leachate and groundwater levels, to derive appropriate leachate level compliance limits. The base of the leachate level monitoring well is assumed to represent the base of the waste / top of the engineered liner (where present).

A leachate level compliance limit is set for each perimeter monitoring well to ensure that leachate levels are maintained a minimum of 1.0m below the closest perimeter bund height (this is not feasible for monitoring well LW2, where a 1.0m leachate head is equivalent to 0.66m below the perimeter bund height). For internal leachate monitoring wells, a maximum leachate head of 2.0m above base of the site, or 2.0m above local groundwater levels has been assumed, as in the 2017 HRA Review.

Review of Table 9 confirms that the proposed leachate level compliance limits are significantly lower than recently recorded leachate levels. The implications on site performance and the requirement for enhanced leachate level management are discussed elsewhere within this report.

Table 9: Derivation of Leachate Level Compliance Limits

Phase	Leachate Well	Well Base	Sept-Oct 2022 Average Leachate Elevation	Top of nearest perimeter bund	Depth of average leachate level below nearest perimeter bund	Current leachate compliance limit	2022 Groundwater Elevation	Liner Thickness	Unsaturated Zone Thickness (beneath liner)	Proposed leachate compliance limit	Justification for proposed leachate compliance limit	Approx depth below nearest perimeter bund	Outward leachate head (for LandSim)	Comparison of 2022 average leachate level to proposed compliance limit
		mAOD	mAOD	mAOD	m	mAOD	mAOD	m	m	mAOD		m	m	m
Phase 0	LW1	118.06	122.50	N/A	N/A	119.06	117.50	In-situ clay	0.56	120.06	2m head	N/A	2.0	-2.44
	LW2	116.34	123.28	118.00	-5.28	117.34	116.50	In-situ clay	-0.16	117.34	1m head	0.66	1.0	-5.94
	LW3	119.31	127.40	122.00	-5.4	120.31	120.40	In-situ clay	-1.09	121.00	1m below bund height	1.00	0.6	-6.4
	LW4	120.04	127.39	N/A	N/A	121.04	119.60	In-situ clay	0.44	122.04	2m head	N/A	2.0	-5.35
	LW7	119.00	120.61	124.00	3.39	120.00	117.50	In-situ clay	1.50	121.00	2m head	3.00	2.0	0.39
Phase 1	LW5	121.14	125.97	128.00	2.03	122.14	120.70	In-situ clay	0.44	123.14	2m head	4.86	2.0	-2.83
	LW6	118.49	126.97	N/A	N/A	119.49	119.00	In-situ clay	-0.51	121.00	2m above GW	N/A	2.0	-5.97
Phase 2	LW8	120.12	128.31	N/A	N/A	121.12	119.20	0.5	0.42	122.12	2m head	N/A	2.0	-6.19
	LW9	119.84	125.24	128.00	2.76	120.84	120.00	0.5	-0.66	122.00	2m above GW	6.00	2.0	-3.24
	LW10	119.70	125.69	N/A	N/A	120.70	119.00	0.5	0.20	121.70	2m head	N/A	2.0	-3.99
	LW11	118.30	124.56	128.00	3.44	119.30	120.20	0.5	-2.40	122.20	2m above GW	5.80	2.0	-2.36
Phase3	LW12	120.00	132.25	N/A	N/A	121.00	119.20	1.0	-0.20	122.00	2m head	N/A	2.0	-10.25
	LW13	120.90	128.06	128.00	-0.06	121.90	120.20	1.0	-0.30	122.90		5.10	2.0	-5.16
	LW14	120.07	130.08	N/A	N/A	121.07	119.40	1.0	-0.33	122.07		N/A	2.0	-8.01
	LW15	121.03	122.95	128.00	5.05	122.03	120.50	1.0	-0.47	123.03		4.97	2.0	0.08
Phase 4A	LW17	115.07	124.21	118.00	-6.21	N/A	117.50	0.5	-2.93	N/A	N/A	N/A	N/A	N/A
Phase 4B	LW18	113.40	119.87	118.00	-1.87	114.40	116.00	0.5	-3.10	117.00	1m below bund height	1.0	1.0	-2.87
Phase 4BB	LW20	113.12	121.03	118.00	-3.03	113.50	116.40	0.5	-3.78	117.00		1.0	0.6	-4.03
Phase 5A	LW21	117.78	125.35	118.00	-7.35	N/A	118.20	0.5	-0.92	N/A	N/A	N/A	N/A	N/A
Phase 5B	LW19	110.75	121.13	118.00	-3.13	N/A	117.50	0.5	-7.25	N/A	N/A	N/A	N/A	N/A
Phase 6	LW22	110.75	118.46	118.00	-0.46	113.50	117.20	1.0	-7.45	117.00	1m below bund height	1.0	-0.2	-1.46
	Ph6, 1	112.02	120.94	118.00	-2.94	113.50	117.40	1.0	-6.38	117.00		1.0	-0.4	-3.94
	Ph 6, 2	114.30	122.32	118.00	-4.32	N/A	118.00	1.0	-4.70	N/A	N/A	N/A	N/A	N/A
Phase 7	LW23	111.09	116.88	118.00	1.12	113.50	117.00	1.0	-6.91	117.00	1m below bund height	1.0	0.0	0.12
	Ph7, 1	112.03	118.79	118.00	-0.79	113.50	117.50	1.0	-6.47	117.00		1.0	-0.5	-1.79
	Ph7, 2	113.03	118.99	118.00	-0.99	N/A	118.00	1.0	-5.97	N/A	N/A	N/A	N/A	N/A
Phase 13A	LW16	121.00	125.58	123.00	-2.58	122.00	119.20	1.0	0.80	122.00	1m head	1.0	1.0	-3.58

Notes: Top of perimeter bund generally assumed as 118mAOD for southern cells after ‘as built’ drawing for Phases 4-6 and 128mAOD for northern cells after site topography and 2017 HRAR. Cell 13A perimeter bund height confirmed as 123mAOD from CQA report. Phase 0 perimeter bund height after 2017 HRAR and site topography. N/A for internal monitoring wells. Groundwater elevation based on September 2022 contours (Drawing 1).

2.3.3 Groundwater Quality

Groundwater quality is monitored on a monthly basis within the down-gradient compliance boreholes for a limited range of parameters (i.e. the priority contaminants), in accordance with the site permit. Monitoring of the background, up-gradient groundwater quality ceased in 2010, but recommenced in November 2015, generally on a quarterly basis.

Limited, annual groundwater monitoring is undertaken for other parameters, as required by the site permit.

The current permit compliance limits for groundwater quality are presented in Table 10.

Table 10: Current Groundwater Quality Permit Compliance Limits

Compliance Borehole	Ammoniacal Nitrogen	Chloride	Cadmium	2,4-dimethylphenol	O-xylene
BH2	3mg/l	1000mg/l	0.001mg/l	0.002mg/l	0.003mg/l
BH3		2000mg/l			
BH4		1500mg/l			
BH5		250mg/l			
BH19					
BH20					
BH21					
BH22					
BH23					
BH24					
BH25					
BH26					
BH27					

Whilst Golders has no record of the derivation of the current groundwater quality compliance limits, they appear to be based on background groundwater concentrations and the site design for the majority of phases to be hydraulically contained[12]. The 2017 HRA Review includes revised proposed compliance limits, based on the updated risk assessment, but these have not been incorporated into the site permit, which would require a formal permit variation application.

Table 11 presents groundwater quality statistics for the revised priority contaminants for the period January 2015 to December 2022. Data are summarised in Table 11a for up-gradient boreholes located along the northern site boundary (BH9, BH10. BH12, BH13 and BH15) and in Table 11b for down-gradient groundwater quality, as monitored in boreholes on the southern site boundary (compliance boreholes BH2 – BH5 and BH19 – BH27).

[12] Golder Associates, 1 February 2018, Technical Memorandum, Meece Landfill Site: Background to Derivation of Compliance Limits.

Appendix D includes groundwater chemographs for priority contaminants chloride and ammoniacal-nitrogen within boreholes on the northern (up-gradient) and southern (down-gradient) site boundaries. Permit compliance limits are included where relevant and values <LRL have been assumed to equal the LRL for the purposes of the graphs.

Table 11a: Up-Gradient Groundwater Quality Monitoring Data (2015-2022)

Parameter	Concentration in Groundwater (2015-2022)			Concentration in Groundwater (2015-2022)		
	Min	**Average**	**Max**	**Min**	**Average**	**Max**
	BH9: Up-gradient			**BH10: Up-gradient**		
Ammoniacal-N (mg/l)	<0.06	-	149	<0.06	-	0.21
Chloride (mg/l)	7.1	95.5	921	4.6	10.3	16
Nickel (total) (mg/l)	<0.003	-	0.09	<0.003	-	0.003
2,4-dimethylphenol (µg/l)	<0.1	-	<1.0	<0.1	-	<1.0
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.0013	0.0021	0.0026	0.0014	0.0025	0.0039
	BH12: Up-gradient			**BH13: Up-gradient**		
Ammoniacal-N (mg/l)	<0.06	-	0.25	<0.06	-	0.23
Chloride (mg/l)	14.2	20.6	32.5	383	1028	1610
Nickel (total) (mg/l)	<0.003	-	0.005	<0.003	-	0.01
2,4-dimethylphenol (µg/l)	<0.1	-	<1.0	<0.1	-	<1.0
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.0034	0.0044	0.0056	<0.001	-	0.00044
	BH15: Up-gradient					
Ammoniacal-N (mg/l)	<0.06	-	0.1			
Chloride (mg/l)	18.3	61.5	394			
Nickel (total) (mg/l)	<0.003	-	0.003			
2,4-dimethylphenol (µg/l)	<0.1	-	<1.0			
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006			
Arsenic (total) (mg/l)	0.0047	0.0053	0.0056			

Notes: 1. Data are for the period January 2015 – December 2022. Average concentrations have not been calculated where values <LRL are present. Outliers have not been identified.

Table 11b: Down-Gradient Groundwater Quality Monitoring Data (2015-2022)

Parameter	Concentration in Groundwater (2015-2022)			Concentration in Groundwater (2015-2022)		
	Min	Average	Max	Min	Average	Max
	BH2: Down-gradient			BH3: Down-gradient		
Ammoniacal-N (mg/l)	0.15	5.7	14.9	0.17	5.2	61.1
Chloride (mg/l)	763	1594	2300	81.2	689	1180
Nickel (total) (mg/l)	<0.003	-	0.012	0.005	0.027	0.047
2,4-dimethylphenol (µg/l)	<0.10	-	0.14	<0.10	-	0.19
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.004	0.008	0.014	0.001	0.003	0.0072
	BH4: Down-gradient			BH5: Down-gradient		
Ammoniacal-N (mg/l)	<0.06	-	9.17	<0.06	-	25.1
Chloride (mg/l)	244	2266	2830	22.5	184	2240
Nickel (total) (mg/l)	<0.003	-	0.071	<0.003	-	0.032
2,4-dimethylphenol (µg/l)	<0.10	-	0.43	<0.10	-	<2.0
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.0056	0.011	0.024	<0.0010	-	0.0012
	BH19: Down-gradient of undeveloped phases			BH20: Down-gradient of undeveloped phases		
Ammoniacal-N (mg/l)	<0.06	-	0.44	<0.06	-	1.06
Chloride (mg/l)	34.9	129	285	132	217	376
Nickel (total) (mg/l)	<0.003	-	0.005	<0.003	-	0.004
2,4-dimethylphenol (µg/l)	<0.10	-	<5.0	<0.10	-	<2.0
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.00084	0.0013	0.0018	0.0031	0.0033	0.0036
	BH21: Down-gradient of undeveloped phases			BH22: Down-gradient of undeveloped phases		
Ammoniacal-N (mg/l)	<0.06	-	0.42	<0.06	-	8.96
Chloride (mg/l)	120	252	351	25	111	311
Nickel (total) (mg/l)	<0.003	-	0.005	<0.003	-	0.004
2,4-dimethylphenol (µg/l)	<0.10	-	<2.0	<0.10	-	<2.0
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.0034	0.0036	0.0038	0.0037	0.0041	0.0045
	BH23: Down-gradient			BH24: Down-gradient		
Ammoniacal-N (mg/l)	<0.06	-	0.66	<0.06	-	0.15
Chloride (mg/l)	9.68	27.5	90	6.8	29.9	318
Nickel (total) (mg/l)	<0.003	<0.003	<0.003	<0.003	-	0.003
2,4-dimethylphenol (µg/l)	<0.10	-	<1.0	<0.10	-	<10
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006	<0.0006	-	0.0006
Arsenic (total) (mg/l)	0.0091	0.0096	0.01	0.011	0.011	0.012

Parameter	Concentration in Groundwater (2015-2022)			Concentration in Groundwater (2015-2022)		
	Min	Average	Max	Min	Average	Max
	BH25: Down-gradient			BH26: Down-gradient		
Ammoniacal-N (mg/l)	<0.06	-	66.1	<0.06	-	402
Chloride (mg/l)	207	338	747	104	1285	6760
Nickel (total) (mg/l)	<0.003	-	0.003	0.003	0.0095	0.031
2,4-dimethylphenol (µg/l)	<0.10	-	<5.0	<0.10	-	<2.0
Cadmium (total) (mg/l)	<0.0006	-	0.003	<0.0006	<0.0006	<0.0006
Arsenic (total) (mg/l)	0.0052	0.0058	0.0064	<0.001	-	0.0043
	BH27: Down-gradient					
Ammoniacal-N (mg/l)	0.11	0.94	16.5			
Chloride (mg/l)	73.4	1501	2530			
Nickel (total) (mg/l)	<0.003	-	0.013			
2,4-dimethylphenol (µg/l)	<0.10	-	<10			
Cadmium (total) (mg/l)	<0.0006	<0.0006	<0.0006			
Arsenic (total) (mg/l)	0.0022	0.0047	0.014			

Notes: 1. Data are for the period January 2015 – December 2022. Average concentrations have not been calculated where values <LRL are present. Outliers have not been identified.

Review of the groundwater quality monitoring data indicates the following:

- Background, up-gradient groundwater quality, as monitored at boreholes BH10 and BH12 is very good, with maximum recorded concentrations of chloride and ammoniacal-nitrogen of 32.5mg/l and 0.25mg/l respectively, significantly below relevant water quality standards.

- Groundwater quality at up-gradient borehole BH9 has historically been very good and comparable to that observed at BH10 and BH12. However, recent (2021 and 2022) data for BH9 show apparent impact from Meece 1 Landfill, with elevated chloride (maximum: 921mg/l) and ammoniacal-nitrogen (maximum: 149mg/l). These sudden elevated concentrations of both chloride and ammoniacal-nitrogen are indicative of a rapid pathway to the borehole. It is noted that groundwater levels in BH9 during 2021/22 were very shallow, at less than 0.7m below the borehole casing, making groundwater vulnerable to any surface contamination sources. Boreholes BH8, BH9 and BH10 have a history of surface water flooding and were raised in March/April 2022 to minimise the future risk of surface water ingress. However, it is understood that the recent elevated concentrations of leachate indicator parameters in groundwater at BH9 are likely to be associated with surface water ingress from restoration material. The area around the borehole has been reshaped to prevent runoff directly reaching the borehole and attempts are planned to purge and rehabilitate the borehole.

- Groundwater within up-gradient borehole BH15 is generally good, with occasional, historic elevated chloride concentrations. Chloride concentrations at BH15 have remained below the freshwater EQS of 250mg/l since 2016, with an average 2022 concentration of 19.8mg/l.

- Groundwater within up-gradient borehole BH13 has recorded long-term chloride impact with an average concentration (2015 to 2022) of 1028mg/l. However, ammoniacal-nitrogen is not elevated within groundwater at BH13, with a maximum recent (2015 to 2022) concentration of just 0.2mg/l. The chloride concentrations at BH13 are seasonally variable but follow a long-term declining trend. The lack of ammoniacal-nitrogen within groundwater at BH13 indicates a non-landfill source of chloride or potential oxidation of ammoniacal-nitrogen to nitrates. Review of the groundwater quality data set confirms nitrate concentrations of <0.7mg/l from 2016 to 2020 annual monitoring events, with no data post-2020. Therefore, a non-landfill source of chloride contamination within groundwater at BH13 is likely and may be attributed to the site's historic land use prior to landfilling and/or an up-gradient source. It is noted that a highways depot is located immediately up-gradient of BH13 and has an environmental permit (reference: EPR/RP3835RD) for the temporary storage of hazardous waste.

- Groundwater quality within the down-gradient boreholes, located along the southern site boundary, is very variable, with average chloride concentrations (2015 to 2022) ranging from 27.5mg/l at BH23 to 2266mg/l at BH4.

- The spatial variability in groundwater quality is likely to reflect the aquifer characteristics, with groundwater flow predominantly via discrete fractures or more permeable water-bearing horizons, which may be laterally discontinuous. One borehole may intercept a key groundwater flow path, which is not encountered within an adjacent borehole. Boreholes displaying gradual, long-term trends in groundwater quality are likely to be influenced by slower, regional groundwater flow patterns; those displaying rapid fluctuations in water quality are likely to intercept higher permeability flow paths, or may be influenced by surface seepages.

- In addition, the potential influence of the historic surface water drainage network on shallow groundwater flow and quality is uncertain, with drainage surveys currently being undertaken. However, there is potential connectivity of shallow groundwater around the site perimeter via the historic drains, with associated implications for groundwater quality trends.

- Boreholes BH19 to BH22 are down-gradient of Meece 2 hazardous landfill (Phases 9 and 10) and other undeveloped phases of Meece 1 landfill; Drawing 1 confirms these boreholes are not hydraulically down-gradient of any landfilled phases of Meece 1 landfill. Groundwater quality at BH19 to BH22 is moderate, with average chloride concentrations ranging from 111mg/l to 252mg/l, comparable to or below the freshwater EQS of 250mg/l. BH20 to BH22, located down-gradient of Meece 2 landfill (undeveloped), record a gradual long-term rising trend in chloride concentrations.

- BH19, located on the south-east corner of the site, down-gradient of undeveloped phases of Meece 1 landfill reports a gradual long-term rising trend in chloride concentrations over recent years, with a spike in levels to >400mg/l between mid-2013 and late 2014. BH19 is adjacent to a perimeter surface water drainage outfall to the MOD drainage system and groundwater quality may be influenced by this artificial pathway, with the outfall blocked in approximately 2012. It is reiterated that BH19 to BH22 are not considered relevant compliance boreholes for Meece 1 landfill.

- Boreholes BH23 and BH24 on the southern site boundary are down-gradient of Meece 2 and the as yet undeveloped Phase 8 of Meece 1 and generally record good groundwater quality, with average chloride concentrations of 27.5mg/l and 29.9mg/l respectively. Chloride concentrations at BH23 remained consistently low (generally <20mg/l) until 2019 when levels rose slightly to approximately 50mg/l; chloride concentrations at BH23 have remained at approximately 50mg/l during 2021 and 2022. Chloride concentrations at BH24 are more variable, generally remaining low (<20mg/l), but occasionally exceeding the freshwater EQS of 250mg/l. Since 2015, elevated chloride concentrations (>100mg/l) have only been observed at BH24 in the periods July to October 2020, October 2021 to January 2022 and November 2022, with concentrations peaking rapidly, possibly in response to surface ingress.

- Boreholes BH2 to BH5 and BH25 to BH27 are down-gradient of completed phases of Meece 1 landfill and are considered appropriate groundwater compliance boreholes for the site. These boreholes record average (2015 to 2022) chloride concentrations ranging from 184mg/l (BH5) to 2266mg/l (BH4). Boreholes BH2, BH4, BH26 and BH27 record average chloride concentrations of >1000mg/l. However, ammoniacal-nitrogen concentrations in groundwater at these boreholes remain relatively low (compared to leachate quality data) and remain <20mg/l with the exception of BH26. BH26 has recorded elevated ammoniacal-nitrogen concentrations in recent years only, which appears to correlate with a period of surface seepage. The relatively low ammoniacal-nitrogen concentrations in groundwater at these boreholes, relative to chloride, may reflect the attenuation properties of the local geology.

- Chloride concentrations in groundwater at BH2, BH4 and BH27 follow a gradual long-term rising trend. In contrast, chloride concentrations at BH3, located between BH2 and BH4, follow a long-term declining trend, as observed for the site leachate. These trends will be influenced by the complex natural and artificial groundwater flow pathways and dilution factors and confirm the spatial variability along the down-gradient boundary.

- It is acknowledged that groundwater down-gradient of the site may also be impacted by the isolated, elevated up-gradient chloride concentrations. The highest up-gradient chloride levels are recorded at BH13 (average: 1028mg/l), which is located potentially up-gradient of boreholes BH24, BH25 and BH26 on the southern site boundary. The monitoring record for BH13 is incomplete, with no data available from April 2010 to November 2015, therefore it is difficult to review against down-gradient datasets. However, BH24, located down-gradient of undeveloped Phase 8, displays isolated peaks in chloride levels at significantly lower concentrations to those observed up-gradient at BH13, and may therefore reflect pulses of poor background groundwater quality.

- The graphs included within Appendix D confirm that recent (2020-2022) chloride concentrations have exceeded the relevant permit compliance limit at virtually all down-gradient compliance boreholes. The current permit compliance limit for ammoniacal-nitrogen has been exceeded in 2020-2022 at BH25 to BH27 and BH2 to BH6. BH6 is a mid-gradient borehole, adjacent to the area of historic landfilling (refer to Figure 1) and is not therefore considered an appropriate compliance borehole for the site.

- Cadmium has remained below the LRL of 0.0006mg/l in groundwater at all boreholes, with the exception of a single detection at the LRL in BH24 and a single isolated result of 0.003mg/l in BH25 in April 2019. Therefore, with the exception of the single outlier at BH25, all results remained below the current permit compliance limit for of 0.001mg/l.

- 2,4-dimethylphenol has not been detected in groundwater up-gradient of the site (all results <0.001mg/l); it has been detected at very low concentrations in down-gradient groundwater, with all results remaining below 0.001mg/l and therefore below the permit compliance limit of 0.002mg/l. It is noted however, that the LRL occasionally exceeds the permit compliance limit.

- Drawing 3 presents a summary of recent chloride impact on perimeter groundwater quality at Meece 1 landfill, with average 2022 chloride concentrations displayed. This snapshot summary confirms the variability of groundwater quality around the site, due to the complex interactions of leachate seepages, the discrete flow pathways within the Mercia Mudstone aquifer and the potential influence of shallow surface water drains. Ignoring the impact of recent surface seepages at BH26, the most significant groundwater quality impact is observed down-gradient of the historic, unlined phases of the site, as anticipated and previously reported. However, the declining leachate strength of these phases should lead to gradual improvements in groundwater quality.

- In summary, the elevated leachate levels, including isolated surface seepages, appear to have resulted in groundwater quality impacts in boreholes up-gradient and down-gradient of the site. However, this is not the only potential source, a highways depot also represents a potential off-site source of up-gradient groundwater quality impact in the vicinity of BH13. Down-gradient groundwater quality also appears to be locally influenced by preferential flow pathways, with relatively good (and improving) quality at BH3 located between relatively poor (and declining) quality groundwater at BH2 and BH4. The groundwater flow pathways are likely to be both natural and artificial via the site's historic drainage systems.

2.3.4 Surface Water Quality

Table S3.2 of the site permit includes monitoring schedules and compliance limits for surface water at emission points 2100, 2101, 2102, 2103 and 2104, which are located along the southern site boundary, as indicated on the Site Monitoring Plan (Appendix A) and Drawing 1. These represent historic outfalls for surface water runoff from restored parts of the site, with the site runoff discharged to an unnamed tributary of Meece Brook via a drainage system through the MOD training area.

The 2017 HRA Review states that surface water quality was monitored at emission points 2101, 2102 and 2103 between January 2008 and July 2013 but due to exceedances of permit emission limits, these outfalls were sealed in July 2013, when discharge to surface water and associated monitoring ceased.

Surface water monitoring at emission point 2100 ceased in 2007 as this location represents the discharge point for water accumulating during the preparation of new landfill phases and has not been used since this date.

The 2017 HRA Review also states that surface water monitoring has never been undertaken at compliance point 2104, as this location was not included in the original site licence and is thought to have originated from the old Swynnerton Army Camp drainage plans. The outfalls were sealed (grouted) prior to 2014, although the effectiveness of the seals is not currently known. The present-day groundwater contours (Drawing 1) indicate potential connectivity of shallow groundwater to the drainage systems; this is being investigated through appropriate drainage surveys.

Therefore, the surface water emission points included within the site permit are no longer operational, with no recent (post-2017 HRA Review) surface water monitoring data available for review.

Surface water runoff from the landfill is currently pumped to an on-site attenuation/settlement lagoon prior for testing and where necessary discharge to sewer.

The 2017 HRA Review recommended that surface water monitoring commence at the down-gradient receptor, Meece Brook, at a location upstream of the landfill (bridge at Meadow Lane) and a location downstream of the site (bridge at Swynnerton Road). These surface water monitoring locations are indicated on Figure 2.

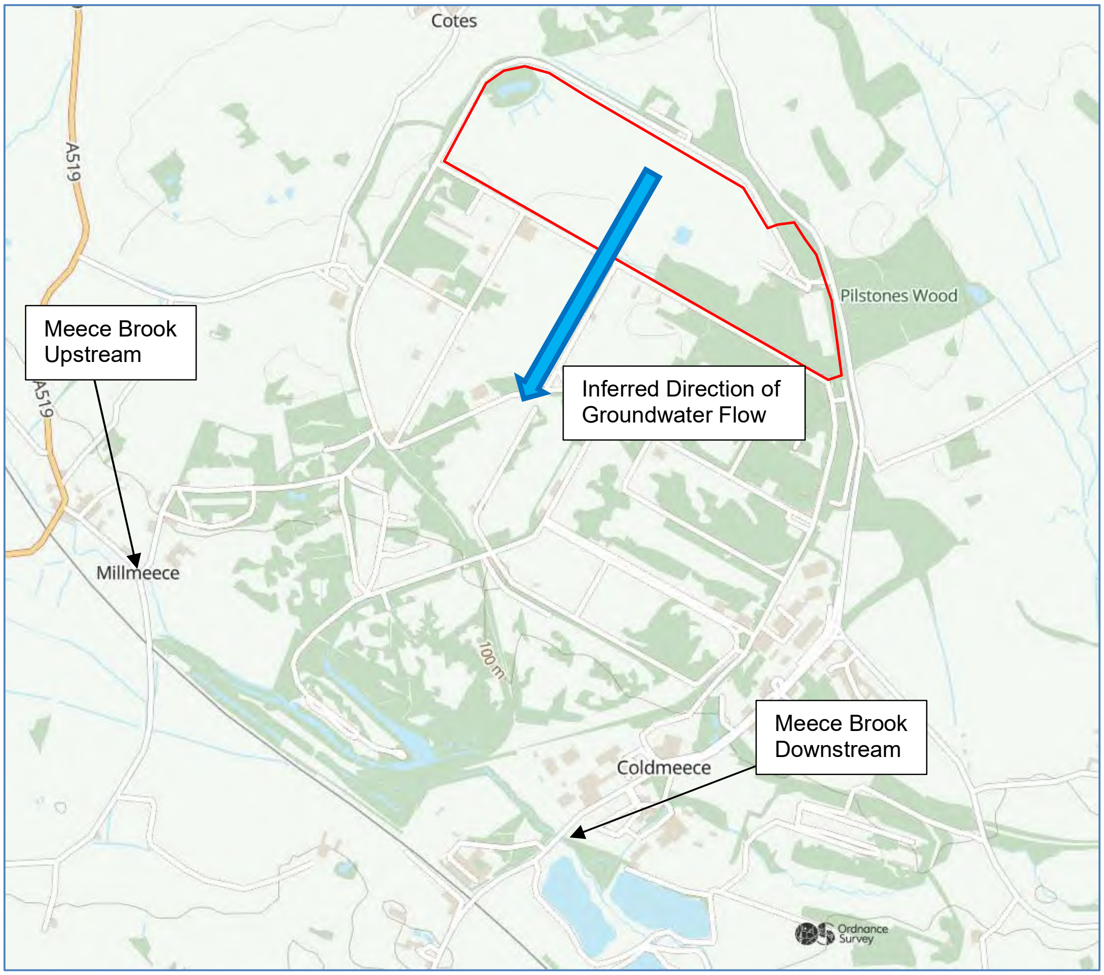


Figure 2. Meece Brook Monitoring Points

Surface water quality has been monitored on a monthly basis at these locations since October 2017, with data for the existing priority contaminants summarised in Table 12. No monitoring data are available for nickel or for the proposed priority contaminant arsenic. Appendix F includes graphs for chloride and ammoniacal-nitrogen concentrations in Meece Brook upstream and downstream of the site. Concentrations <LRL are assumed to equal the LRL for the purposes of the graphs.

Table 12: Surface Water Quality Monitoring Data – Meece Brook

Parameter	Water Quality Standard	Meece Brook Upstream			Meece Brook Downstream		
		Min	Average	Max	Min	Average	Max
pH (units)	<pH6; >pH9	7.6	8.0	8.4	7.6	8.0	8.4
Chloride (mg/l)	250	17.1	29.8	57.1	17.5	33.5	48.5
Ammoniacal-N (mg/l)	0.39	<0.06	-	1.56	<0.06	-	1.92
Cadmium (total) (mg/l)	0.00045	<0.0006	-	0.0022	<0.0006	<0.0006	<0.0006
O-xylene (µg/l)	0.03	<0.10	<0.10	<0.10	<0.10	-	0.38
2,4-dimethylphenol (µg/l)	0.10	<0.10	-	<0.30	<0.10	-	0.10

Notes: 1. Data are presented for the entire monitoring record (October 2017 to June 2022), with outliers removed. Average concentrations have not been calculated where values <LRL are present. Water quality standard set at freshwater EQS, where available. Water quality standard for ammoniacal-nitrogen set as UK Drinking Water Standard (DWS); standard for 2,4-dimethylphenol set at assumed UK DWS and standard for o-xylene set at MRV in groundwater.

Meece Brook is located approximately 1.5km down-stream (south-west) of Meece 1 Landfill and water quality within the brook will be influenced by other local land uses including the MOD training area. The available surface water quality data indicates the following:

- Table 12 confirms that the water quality within Meece Brook down-gradient of the landfill is generally good, with concentration ranges comparable upstream and downstream of the site.

- The graphs included in Appendix F indicate that chloride concentrations are marginally higher in Meece Brook downstream of the landfill (average: 33.5mg/l), compared to upstream concentrations (average: 29.8mg/l), but all concentrations remain significantly below the freshwater EQS limit of 250mg/l.

- Ammoniacal-nitrogen concentrations in Meece Brook are generally low and less than the UK DWS of 0.39mg/l. However, seasonal increases in ammoniacal-nitrogen are observed, upstream and downstream of the site, during late autumn to spring (maximum: 1.92mg/l, January 2021). This trend potentially relates to increased rainfall runoff inputs from the surrounding agricultural land.

- With regards to the remaining priority contaminants, 2,4-dimethylphenol has not been detected in Meece Brook. Cadmium has been detected on two occasions upstream of the site but has remained below the LRL at the downstream monitoring point. O-xylene has remained below the LRL at both monitoring points, with the exception of a single, low-level detection downstream of the site. O-xylene is no longer considered a priority contaminant for Meece 1 landfill.

The available data indicate a generally good water quality within Meece Brook, with some limited water quality impacts, upstream and downstream of the site, from local land uses. It is not possible to distinguish impacts from Meece 1 landfill from other potentially contaminative land uses, including agricultural runoff and drainage from the MOD training area.

2.4 Receptors

2.4.1 Licensed and Private Abstractions

Updated information on private water supplies and licensed water abstractions has been requested from Stafford Borough Council and the Environment Agency respectively.

Stafford Borough Council has confirmed[13] the presence of three private water supplies within a 3km radius of Meece 1 Landfill. The Council response includes grid reference locations of each private water supply, as detailed below in Table 13, but no further details due to GDPR restrictions.

Table 13: Private Water Supplies within 3km of Meece 1 Landfill

Address (inferred from Grid Reference)	Grid Reference	Distance and Direction from site
Darlaston Wood Farm	387700, 335100	2.6km ENE
Slindon House	382500, 332800	2.6km WSW
White House Farm	387100, 331200	3km SE

Review of the local private water supplies confirms that they are all located either up-gradient of Meece 1 landfill, or beyond Meece Brook, the receptor considered within the risk assessment. Abstractions located beyond Meece Brook are likely to be hydraulically isolated from groundwater beneath the landfill site, which is assumed to discharge as baseflow to the brook. However, if this risk assessment demonstrates compliance for groundwater at Meece Brook, it can be inferred that compliance will also be achieved for groundwater at a greater distance from the site.

The Environment Agency has confirmed[14] that there are no licensed water abstractions, from groundwater or surface water, within a 2km radius of Meece 1 Landfill.

However, Natural England's MAGIC website (accessed 21st September 2022) indicates that the north-western corner of the site is located within a Groundwater Source Protection Zone III (Total Catchment) associated with local public water supply abstraction. Review of the Groundwater Source Protection Zone (SPZ) extents, indicate they it is associated with an abstraction at Mill Meece Pumping Station, approximately 1.6km WSW of Meece 1 Landfill site. However, the SPZ is constrained by the local bedrock geology and is limited to the Sherwood Sandstone aquifer, the extent of which is faulted against the Mercia Mudstone in the vicinity of the site; therefore, the groundwater abstraction is not considered a potential receptor to Meece 1 Landfill.

2.4.2 Receptors and Compliance Points for Hazardous Substances and Non-hazardous Pollutants

The 2017 HRA Review assumed the following compliance points:

[13] Email dated 10th August 2022, from Shaun Baker, Environmental Protection Team Leader, Stafford Borough Council.

[14] Email dated 26th August 2022, from Matthew Weston, Customer & Engagement Officer, Environment Agency, West Midlands Area.

- For hazardous substances, the compliance point was groundwater within the Mercia Mudstone at the down-gradient site boundary; and

- For non-hazardous pollutants, the compliance point was groundwater within the Mercia Mudstone immediately prior to discharge to Meece Brook, located 1.5km down-gradient of the site. Appropriate compliance limits for groundwater within the down-gradient site monitoring boreholes were subsequently back-calculated.

It is considered that the above receptors and compliance points for both hazardous substances and non-hazardous pollutants are still applicable for the site.

2.4.3 Environmental Assessment Levels (EALs)

An Environmental Assessment Level (EAL) is a value set at the compliance point and is the maximum concentration allowable at that point in order to protect the receptors. EALs are based on water quality standards with due consideration of baseline groundwater quality.

The EALs determined in the 2017 HRA Review are presented in Table 14 below. Data from boreholes BH9, BH10 and BH12 were used to represent up-gradient groundwater quality within the Mercia Mudstone.

Table 14: 2017 HRA Review Environmental Assessment Levels

Substance	EAL for groundwater prior to entry at Meece Brook (non-hazardous)	EAL for groundwater at down-gradient site boundary (hazardous)	Justification for EAL
Chloride (mg/l)	250	n/a	EQS
Ammoniacal-N (mg/l)	3.1	n/a	Maximum background concentration
Cadmium (mg/l)	n/a	0.0011	Maximum background concentration
Nickel (mg/l)	0.034	n/a	EQS
2,4-dimethylphenol (µg/l)	7.7	n/a	In absence of EQS, Good standard as stated in WFD, 2010
O-xylene (µg/l)	n/a	3	MRV

Boreholes BH9, BH10 and BH12 are still considered representative of the true up-gradient, background groundwater quality based on inferred groundwater contours (Drawing 1) and water quality data. However, historic data (pre-2000) appears unreliable or has elevated LRLs and has therefore been ignored. In addition, recent (2021 and 2022) data for BH9 have been impacted by surface water inundation and have also been ignored.

The proposed EALs for the site derived using the latest background groundwater quality dataset and consideration of the revised priority contaminants for the site, are presented in Table 15.

Table 15: Proposed Environmental Assessment Levels

Substance	Maximum Concentration in Background Groundwater	Freshwater EQS	EAL	Derivation
Ammoniacal-N (mg/l)	3.1	0.39	3.1	Background Groundwater
Chloride (mg/l)	43.2	250	250	EQS
Nickel (mg/l)	0.05	0.034	0.05	Background Groundwater
2,4-dimethylphenol (mg/l)	Not detected	0.0077	0.0077	As 2017 HRA Review
Cadmium (mg/l)	0.006	0.00045	0.006	Background Groundwater
Hazardous Substance	**Maximum Concentration in Background Groundwater**	**MRV in Groundwater**	**EAL**	**Derivation**
Arsenic (mg/l)	0.0056	0.005	0.0056	Background Groundwater

Notes: 1. Background groundwater quality is based on up-gradient boreholes BH9, BH10 and BH12 (Jan 2000-Dec 2022, ignoring 2021 and 2022 data for BH9 due to apparent water quality impacts)
2. The MRV for arsenic is based on the limit of quantification for arsenic, after Table 1, UK Technical Advisory Group on the Water Framework Directive, September 2016, Technical Report on Hazardous Substances.
3. Freshwater Environmental Quality Standard (EQS) values are taken from Environment Agency tables. In the absence of an EQS value for ammoniacal-nitrogen, the UK Drinking Water Standard has been applied. No EQS is available for 2,4-dimethylphenol, the water quality standard is based on the 2017 HRAR ('good' standard as stated in WFD, 2010). The EQS for nickel is an annual average limit for dissolved nickel.

The proposed revisions to the EALs used in the 2017 HRAR are limited to cadmium and nickel, due to a slight increase in the concentrations recorded in background groundwater. An appropriate EAL has been derived for arsenic.

2.5 Summary of the Hydrogeological Conceptual Site Model

The review of the potential sources, pathways and receptors for Meece 1 Landfill, presented above, has confirmed that the general, overall hydrogeological conceptual site model presented in the 2017 HRA Review remains valid. The conceptual site model as developed in the 2017 HRA Review, and reviewed above, can be summarised as follows:

Source: Meece 1 Landfill is an historic landfill site that received waste between the late 1980s and January 2012. Final capping was completed in 2015 with the site currently mothballed and in the process of being restored. Phases 0, 1, 2, 3 and 13a were developed under the principal of natural or engineered containment in line with best practice at the time of their construction, with the base of each phase constructed above local groundwater levels. Phases 4 to 7 were engineered to Landfill Directive standards with Construction Quality Assurance (CQA) techniques and developed under the principal of hydraulic containment, with the management of leachate levels below external groundwater levels. Whilst leachate quality data confirm that the leachate strength is declining, especially for the oldest phases of the site, the leachate continues to represent a potential source of hazardous substances and non-hazardous pollutants. Leachate levels have remained elevated, with all phases of the landfill displaying outward hydraulic gradients.

Pathway: Vertical flow through the engineered lining system (where present) and unsaturated Mercia Mudstone (where present). Groundwater flow within the Mercia Mudstone is towards the south-west. These pathways offer the potential for retardation and degradation of hazardous substances and non-hazardous pollutants.

Receptors: Hazardous substances: Groundwater within the Mercia Mudstone at the down-gradient (south-western) site boundary.

Non-hazardous pollutants: Surface water within Meece Brook, approximately 1.5km down-gradient of the site.

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Numerical Modelling

3.1.1 Modelling Approach and Software

The 2017 HRA Review presented a complex hydrogeological risk assessment and included detailed quantitative risk assessment modelling undertaken stochastically using LandSim v2.5. The risk assessment model allows consideration of the entire lifecycle of the landfill, including the operational, post closure and long-term post closure scenarios. Review of the updated conceptual site model and the risks posed by the site indicate that the 2017 HRA Review risk assessment methodology and scenarios remain applicable. LandSim v2.5 remains the Environment Agency's recommended software for quantitative hydrogeological risk assessments for landfills.

3.1.2 Model Parameterisation

Appendix G presents the parameterisation of the LandSim model included in the 2017 HRA Review. The applicability of each model parameter value (or range of values) has been considered, based upon the updated conceptual site model and recent site monitoring data.

Review of Appendix G confirms that the majority of the model parameter values in the 2017 HRA Review are considered to remain applicable (or worse case) based on the updated conceptual site model. No additional phases of the landfill have been developed since the 2017 risk assessment.

The LandSim model considers the entire lifecycle of the landfill (operational, post closure and long-term post closure) and therefore consideration of the full monitoring dataset is required. The following model parameters have been identified as requiring an update or review, based on the latest conceptual site model:

- Priority contaminants: removal of o-xylene and the addition of arsenic as a priority contaminant; re-classification of cadmium from a hazardous substance to a non-hazardous pollutant.
- Leachate quality data: source term concentrations have been updated following a comprehensive review of all available site monitoring data.
- Leachate head: revised leachate level compliance limits have been derived in Table 9 above; the LandSim model assumes these maximum leachate levels. It is acknowledged that the proposed compliance limits are significantly lower than current leachate levels within the site and the requirement for enhanced leachate level management is discussed in Section 3.3.
- Unsaturated pathway thickness: the thickness of the unsaturated Mercia Mudstone pathway has been updated after Table 9 (above), based on recent groundwater level monitoring data.
- Background groundwater quality: the true background groundwater quality has been updated within the model, based on updated datasets for up-gradient boreholes BH9, BH10 and BH12, ignoring historic (pre-2000 data) and recent (2021/22) data for BH9 which is locally impacted.

Based on the above review of the 2017 risk assessment model parameterisation, it is considered necessary to remodel the site to reflect the updated conceptual site model. Only those parameters that require updating in response to changes in the conceptual site model have been revised within the LandSim model; all other parameters from the 2017 risk assessment model remain unchanged. Appendix G presents the updated model parameterisation, and a copy of the model is included as Appendix H.

The LandSim model (2022HRAR_Meece1MeeceBrook) represents all phases of the site and is based on the 2017 HRA Review risk assessment, with model parameters updated as indicated in Appendix G. The model includes a down-gradient compliance point located 1.5km down-gradient of the site, to represent Meece Brook.

3.2 Emissions to Groundwater

The predicted discharge from the site has been assessed against the EALs presented in Table 15 in order to determine whether the site complies with the requirements of the EP Regulations 2016. The results of the updated LandSim model are presented below.

3.2.1 Hazardous Substances

The HRA Review must demonstrate that the technical precautions at the landfill site would prevent Hazardous Substances from being discernible in groundwater. The predicted concentrations of hazardous substances in groundwater down-gradient of each landfill phase, and at the down-gradient site boundary, are presented in Table 16. The reported results are the predicted peak 95%ile worse-case concentrations.

Table 16: Hazardous Substances: Maximum Resultant Concentration in Groundwater at the Down-Gradient Phase Boundary

Substance	Landfill Phase	Maximum Leachate Source Term Concentration (mg/l)	Peak 95%ile Resultant Concentration at Down-Gradient Phase Boundary (mg/l)	EAL (mg/l)
Arsenic	0	0.075	0.0054	0.0056
	1	0.135	0.0050	
	2	0.215	0.0048	
	3	0.149	0.0051	
	13a	0.484	0.0048	
	4 & 5	0.360	0.011	
	6 & 7	0.303	0.0049	
	Down-gradient Site Boundary	0.484	0.0053	

Notes: 1. The 95%ile resultant concentrations presented are the highest resultant simulated concentrations for the whole landfill lifecycle.

Review of Table 16 indicates that the worse-case 95%ile resultant concentration of arsenic in groundwater at the down-gradient phase boundary, is less than the EAL for all areas of the site except Phases 4&5.

However, the concentration reported at the individual phase boundaries only relates to discharges from that phase. The resultant concentration in groundwater down-gradient of the entire site remains below the EAL, therefore the modelling demonstrates that there would be no discernible discharge of hazardous substances to groundwater over the entire lifecycle of the site.

3.2.2 Non-hazardous Pollutants

Meece Brook represents the receptor for non-hazardous pollutants, as detailed within the 2017 HRA Review; this remains applicable. The predicted concentrations of non-hazardous pollutants in groundwater at the point of discharge to Meece Brook, are presented in Table 17. The reported results are the predicted peak 95%ile worse-case concentrations for the entire lifecycle of the site. The EALs presented in Table 17 have been updated where appropriate to reflect the revised EALs derived in Table 15.

Table 17: Non-hazardous Pollutants: Maximum Resultant Concentration in Groundwater at the Point of Discharge to Meece Brook

Substance	Maximum Leachate Source Term Concentration	Maximum Concentration in Background Groundwater	Peak 95%ile Resultant Concentration in Groundwater at Meece Brook	EAL
Ammoniacal-N (mg/l)	9310	3.1	1.52	3.1
Chloride (mg/l)	54600	43.2	237	250
Nickel (mg/l)	0.904	0.05	0.026	0.05
2,4-dimethylphenol (mg/l)	0.0794	n/a	$3.5x10^{-5}$	0.046
Cadmium (mg/l)	0.043	0.006	0.0045	0.006

Notes: 1. The 95%ile resultant concentrations presented are the highest resultant simulated concentrations for the whole landfill lifecycle.

Review of Table 17 indicates that the worse-case 95%ile resultant concentrations of the non-hazardous pollutants in groundwater at the point of discharge to Meece Brook are below the relevant EAL.

Therefore, the modelling has demonstrated that the discharge of non-hazardous pollutants would be limited so as not to cause pollution at the receptor (Meece Brook) if the site is managed in accordance with the model assumptions.

As for the 2017 HRA Review, the Meece Brook LandSim model has been used to back-calculate groundwater compliance limits at each down-gradient site monitoring borehole. The compliance point within the model was relocated to represent each groundwater compliance borehole and the model re-run to assess the resultant groundwater concentrations at the compliance borehole. The results from each model are included in Table 18 and compared against recent groundwater quality data.

Table 18: Non-hazardous Pollutants: Resultant Concentration in Groundwater at the Down-Gradient Site Boundary

Substance	Average Recorded Concentration in Groundwater (2015-2022)	Predicted Peak 50%ile Resultant Concentration in Groundwater	Predicted Peak 95%ile Resultant Concentration in Groundwater
Compliance Borehole BH5			
Ammoniacal-N (mg/l)	2.33	0.37	1.59
Chloride (mg/l)	185	23.2	49.4
Nickel (mg/l)	0.0062	0.0055	0.026
2,4-dimethylphenol (mg/l)	<0.001	5.06×10^{-7}	1.13×10^{-5}
Cadmium (mg/l)	<0.0006	0.0022	0.0045
Compliance Borehole BH4			
Ammoniacal-N (mg/l)	0.70	0.93	3.26
Chloride (mg/l)	2259	51.5	150
Nickel (mg/l)	0.017	0.0055	0.026
2,4-dimethylphenol (mg/l)	<0.001	7.3×10^{-6}	8.4×10^{-5}
Cadmium (mg/l)	<0.0006	0.0022	0.0045
Compliance Borehole BH3			
Ammoniacal-N (mg/l)	5.4	0.93	3.33
Chloride (mg/l)	692	52.2	153
Nickel (mg/l)	0.027	0.0055	0.026
2,4-dimethylphenol (mg/l)	<0.001	7.6×10^{-6}	8.4×10^{-5}
Cadmium (mg/l)	<0.0006	0.0022	0.0045
Compliance Borehole BH2			
Ammoniacal-N (mg/l)	5.4	1.29	5.56
Chloride (mg/l)	1566	129	438
Nickel (mg/l)	0.0085	0.0059	0.026
2,4-dimethylphenol (mg/l)	<0.001	2.5×10^{-5}	3.4×10^{-4}
Cadmium (mg/l)	<0.0006	0.0021	0.0045
Compliance Borehole BH27			
Ammoniacal-N (mg/l)	0.96	1.28	4.59
Chloride (mg/l)	1462	118	493
Nickel (mg/l)	0.0073	0.0067	0.026
2,4-dimethylphenol (mg/l)	<0.001	2.15×10^{-5}	2.83×10^{-4}
Cadmium (mg/l)	<0.0006	0.0020	0.0046
Compliance Borehole BH26			
Ammoniacal-N (mg/l)	29.2	0.41	1.63
Chloride (mg/l)	1123	32.1	87.0
Nickel (mg/l)	0.0095	0.0053	0.028

2,4-dimethylphenol (mg/l)	<0.001	7.1x10^{-7}	8.8x10^{-6}
Cadmium (mg/l)	<0.0006	0.0023	0.047
Compliance Borehole BH25			
Ammoniacal-N (mg/l)	1.79	0.39	1.59
Chloride (mg/l)	332	40.4	134
Nickel (mg/l)	0.003	0.0055	0.023
2,4-dimethylphenol (mg/l)	<0.001	9.2x10^{-7}	1.0x10^{-5}
Cadmium (mg/l)	0.00069	0.0020	0.0047

Notes: 1. The resultant concentrations presented are the highest resultant simulated concentrations for the whole landfill lifecycle. Values of cadmium, nickel and ammoniacal-nitrogen <LRL assumed to equal LRL.

The peak 50%ile predicted resultant concentrations in groundwater are generally below the actual average concentrations recorded at the compliance boreholes. It is acknowledged that the leachate levels assumed within the model are lower than observed on site and a number of perimeter groundwater monitoring boreholes have also been impacted by surface water ingress.

The above groundwater monitoring boreholes are located along the southern, down-gradient boundary and are down-gradient of completed phases of Meece 1 landfill; therefore, these boreholes are considered the relevant groundwater compliance points for the site.

3.3 Review of Technical Precautions

This section of the report reviews the site's existing technical precautions and any improvements necessary to ensure the site's compliance with the relevant requirements of the EP Regulations 2016.

3.3.1 Capping

The 2017 HRA Review assumed an average infiltration rate through the landfill cap of 50mm/year, typically representative of engineered capping systems. The integrity of the landfill cap should be reviewed through visual inspection at least annually.

3.3.2 Lining Design

No new landfill phases have been developed at Meece 1 landfill since 2008 and no further development is proposed; waste ceased being accepted in 2012 with all areas of the site capped by 2015 and the site remains mothballed. Historic phases of the site were developed under the principal of natural containment; recent phases benefit from the presence of a low permeability engineered lining system. The HRA model results confirm that the natural and engineered lining systems sufficiently control the leakage of leachate from the landfill site if operating as designed and with appropriate leachate level management.

3.3.3 Leachate Control

As discussed above, it is essential that leachate levels across the site are managed through effective leachate abstraction. The risk assessment model assumes leachate levels are controlled to the proposed compliance limits, which are lower than existing leachate levels. Elevated leachate levels increase the hydraulic head for outward migration of leachate from the site and increase the potential for lateral leachate seepages.

Biffa has prepared a Leachate Action Plan for Meece Landfill which details proposed actions to reduce leachate generation, increase leachate extraction and disposal capacity and to ensure appropriate review and maintenance.

3.3.4 Monitoring Infrastructure

It is critical that a reliable, robust leachate and groundwater monitoring infrastructure are maintained at the site, in accordance with the site permit. The integrity of all groundwater monitoring points should be reviewed, to minimise the risk of localised surface water ponding and/or surface ingress. Any future alterations to monitoring point datum elevations should be promptly surveyed, with monitoring databases updated accordingly.

4.0 REVIEW OF SITE MONITORING SCHEDULES AND COMPLIANCE LIMITS

The site's permit includes routine monitoring schedules for leachate, groundwater and surface water at Meece 1 Landfill. The permit also includes compliance limits for leachate level within the landfill, surface water quality at site emission points and groundwater quality at down-gradient compliance boreholes.

This section of the report presents a review of the current site monitoring schedules and compliance limits based on the findings of the HRA Review. The proposed revisions to monitoring schedules and compliance limits would need to be incorporated into a subsequent permit variation application.

4.1 Leachate Monitoring Schedules & Compliance Limits

The current leachate monitoring requirements at Meece 1 landfill are specified in Tables S3.1 and S3.9 of the site permit.

The current leachate quality monitoring schedules remain appropriate for the site, although 2,4-dimethylphenol (a priority contaminant for the site) should be added to the routine annual schedule. A full hazardous substances analysis should be undertaken, in accordance with the permit, to inform the subsequent groundwater and surface water quality monitoring schedules. Concentrations of metals should be analysed for total content.

This HRA Review has introduced revised leachate level compliance limits, via a similar approach to that adopted in the 2017 HRA Review, and the updated risk assessment model assumes that leachate levels are managed to these revised limits. The proposed leachate level compliance limits are derived in Table 9 above and are presented below in Table 19 for clarity.

Table 19: Proposed Leachate Level Compliance Limits

Phase	Leachate Level Monitoring Point	Proposed Compliance Limit (mAOD)
Phase 0	LW1	120.06
	LW2	117.34
	LW3	121.00
	LW4	122.04
	LW7	121.00
Phase 1	LW5	123.14
	LW6	121.00
Phase 2	LW8	122.12
	LW9	122.00
	LW10	121.70
	LW11	122.20
Phase 3	LW12	122.00
	LW13	122.90
	LW14	122.07
	LW15	123.03
Phase 4A	LW17	N/A
Phase 4B	LW18	117.00
Phase 4BB	LW20	117.00
Phase 5A	LW21	N/A
Phase 5B	LW19	N/A
Phase 6	LW22	117.00
	Phase 6, MW1	117.00
	Phase 6, MW2	N/A
Phase 7	LW23	117.00
	Phase 7, MW1	117.00
	Phase 7, MW2	N/A
Phase 13a	LW16	122.00

Notes: The leachate level compliance limits are derived in Table 9.

4.2 Groundwater Monitoring Schedules & Compliance Limits

The current groundwater monitoring schedules and compliance limits are specified in Tables S3.3 and S3.7 of the site permit. Following review of the site monitoring data and the risks posed by the site, it is recommended that the groundwater monitoring schedule be updated, as outlined in Table 20. Metals (including arsenic) should be analysed for dissolved content.

Table 20: Proposed Groundwater Monitoring Schedule

Monitoring Borehole	Parameter	Frequency
Up-gradient: BH8, BH9, BH10, BH12, BH13, BH15, BH18 Mid-gradient: BH6 Down-gradient: BH2, BH3, BH4, BH5, BH19, BH20, BH21, BH22, BH23, BH24, BH25, BH26, BH27	Ammoniacal-nitrogen, Chloride, Nickel, 2,4-dimethylphenol, Cadmium, Arsenic, Nitrate, Electrical Conductivity Groundwater Level (mAOD)	Quarterly
	pH, Alkalinity, Magnesium, Potassium, Sulphate, Calcium, Sodium, Chromium, Copper, Iron, Lead, Zinc, Manganese, Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Total Oxidised Nitrogen (TON) Monitoring Point Base (mAOD)	Annually
	Hazardous substances detected in the site leachate	Every two years

Groundwater compliance limits should be set at monitoring boreholes located down-gradient of completed phases of Meece 1 landfill only (BH2 to BH5 and BH25 to BH27).

For hazardous substances (arsenic), the compliance point is groundwater at the down-gradient site boundary and compliance limits should be set at the relevant EAL. For non-hazardous pollutants, the compliance point is groundwater at the point of discharge to Meece Brook and the compliance limits have been back-calculated to the site boundary. The compliance limits for non-hazardous pollutants are set at the predicted (back-calculated) 95%ile concentration in groundwater at the compliance borehole, or at the relevant EAL, whichever is the higher.

Limited arsenic groundwater quality data are available for the site. Available data for the down-gradient compliance boreholes frequently exceed the EAL including BH23 and 24 which generally show good groundwater quality. In addition, chloride concentrations in down-gradient groundwater frequently exceed the EAL. Therefore, it is not considered appropriate to set compliance limits for chloride or arsenic at this time, and it is recommended that interim assessment levels be set at the compliance boreholes, to be reviewed annually within the monitoring review as enhanced leachate management measures are introduced. Similarly, ammoniacal-nitrogen concentrations at compliance boreholes BH2 and BH26 are locally elevated and would benefit from interim assessment levels. The aim would be to revise the interim assessment levels downwards annually over a number of years, within the site's Annual Monitoring Review, towards the final groundwater compliance limits. Reduced leachate leakage, due to enhanced leachate level management, would result in groundwater quality impacts beneath the landfill, which would subsequently be observed within the down-gradient monitoring boreholes. The potential groundwater travel time beneath Meece 1 landfill is significant, with an average groundwater velocity of 7.8m/year calculated from the LandSim model input parameters (based on an average hydraulic conductivity of 4.14×10^{-5}m/s and average hydraulic gradient of 0.012). Therefore, it is proposed that the site performance and groundwater quality trends be reviewed annually.

For the remaining non-hazardous pollutants, the compliance point is groundwater at the point of discharge to Meece Brook and the compliance limits have been back-calculated to the site boundary. The compliance limits for these non-hazardous pollutants are set at the predicted (back-calculated) 95%ile concentration in groundwater at the compliance borehole, or at the relevant EAL, whichever is the higher. The proposed groundwater compliance limits are presented in Table 21.

Table 21: Proposed Groundwater Compliance Limits

Determinand	Borehole	Compliance Limit
Ammoniacal-Nitrogen (mg/l)	BH2*	5.56*
	BH3	3.33
	BH4	3.26
	BH5	3.1
	BH25	3.1
	BH26*	3.1*
	BH27	4.59
Chloride* (mg/l)	BH2	438*
	BH3	250*
	BH4	250*
	BH5	250*
	BH25	250*
	BH26	250*
	BH27	493*
Arsenic* (dissolved) (mg/l)	BH2, BH3, BH4, BH5, BH25, BH26, BH27	0.0056*
Nickel (dissolved) (mg/l)		0.05
2,4-dimethylphenol (mg/l)		0.0077
Cadmium (dissolved) (mg/l)		0.006

Notes: * Interim assessment levels for ammoniacal-nitrogen at BH2 and BH26 and for arsenic and chloride to be determined annually and revised downwards towards the final compliance limits, in response to site management measures. The compliance limit for arsenic is interim only due to limited available data for dissolved arsenic; the final compliance limit shall be determined when sufficient data are available for review from up-gradient and down-gradient boreholes.

4.3 Surface Water Monitoring Schedules & Compliance Limits

The current surface water monitoring schedules and compliance limits are specified in Tables S3.2 and S3.10 of the site permit. These relate to emission points for site drainage that are blocked and no longer used and do not represent the down-gradient surface water receptor, Meece Brook.

Surface water monitoring of Meece Brook commenced in 2017; the proposed monitoring schedules and action levels are included as Tables 22 and 23. Action levels are set at the relevant EAL or maximum upstream concentration, whichever is higher. Metals (including arsenic) should be analysed for dissolved content.

Table 22: Proposed Surface Water Monitoring Schedule

Monitoring Location	Parameter	Frequency
Meece Brook Upstream Meece Brook Downstream	Ammoniacal-nitrogen, Chloride, Nickel, 2,4-dimethylphenol, Cadmium, Arsenic pH, Electrical Conductivity,	Monthly
	Dissolved Organic Carbon (DOC), Total Oxidised Nitrogen (TON), Calcium, Potassium	Quarterly

Table 23: Proposed Surface Water Action Levels

Compliance Point	Determinand	Action Level
Meece Brook Downstream	Ammoniacal-Nitrogen (mg/l)	3.1
	Chloride (mg/l)	250

Due to the potential for third party impacts on water quality in Meece Brook, including runoff from the surrounding agricultural land, drainage from the MOD training area and the area of historic landfilling, any action level exceedance should be reviewed against the upstream water quality data and site-specific groundwater quality data to assess the probable source(s) of contamination.

5.0 SUMMARY AND CONCLUSIONS

This report presents a review of the 2017 HRA Review for Meece 1 Landfill and has been informed through a review of all available site monitoring data, information on site operations and site management and updated third party information.

Meece 1 landfill is a site that was operational for a prolonged period and has been managed to the standards that were accepted at the time. This means that the early phases of landfill were either not engineered (dilute and disperse) or the containment engineering was not completed to a modern standard. Later Phases of the landfill benefit from fully containment engineering that was completed with construction quality assurance techniques. The influence of these early phases of landfill on the groundwater has been discussed in previous HRA, including that which accompanied the original PPC Permit application in 2003. The site is currently managed in accordance with the 2017 permit variation, which includes site monitoring schedules and compliance limits.

The review of the sources, pathways and receptors confirms that the overall conceptual site model presented in the 2017 HRA Review remains valid. However, the priority contaminants within the site leachate require updating and several model parameter ranges assumed within the 2017 HRA Review are no longer valid; therefore, the risk assessment modelling has been updated accordingly.

The risk assessment model assumes that leachate levels are managed in accordance with the proposed revised compliance limits. The actual leachate levels are higher than the limits proposed in the previous HRA review and are a potential contributor to the groundwater quality changes both upgradient and down gradient. Other possibly third-party and historic influences have also been discussed. The complex interaction of leachate seepages (both long-term advective migration and potential discrete seepages via weaknesses in the engineered containment system and surface outbreaks) and discrete groundwater flow pathways via fractures and dissolution features has resulted in highly variable groundwater quality around the perimeter of the site. In addition, potential artificial groundwater flow pathways exist via the site's historic shallow drainage system and wider MOD drainage network. However, improvements to the management of leachate levels across the site should improve the overall performance of the site and a leachate action plan has been implemented with short, medium and long term strategies. The site should be regularly assessed for leachate and groundwater performance within the required annual monitoring review.

The receptors to leachate migration presented in the 2017 HRA Review remain valid; these are groundwater prior to entry to Meece Brook for non-hazardous pollutants and groundwater at the down-gradient site boundary for hazardous substances.

The updated risk assessment model demonstrates that the technical precautions at the site are sufficient to prevent the discernible discharge of hazardous substances to groundwater at the down-gradient site boundary and to limit the discharge of non-hazardous pollutants to groundwater so as to avoid pollution to Meece Brook. Whilst this is not validated by site-specific groundwater monitoring data, the water quality at the down-gradient receptor, Meece Brook, remains good, with downstream water quality below relevant EALs.

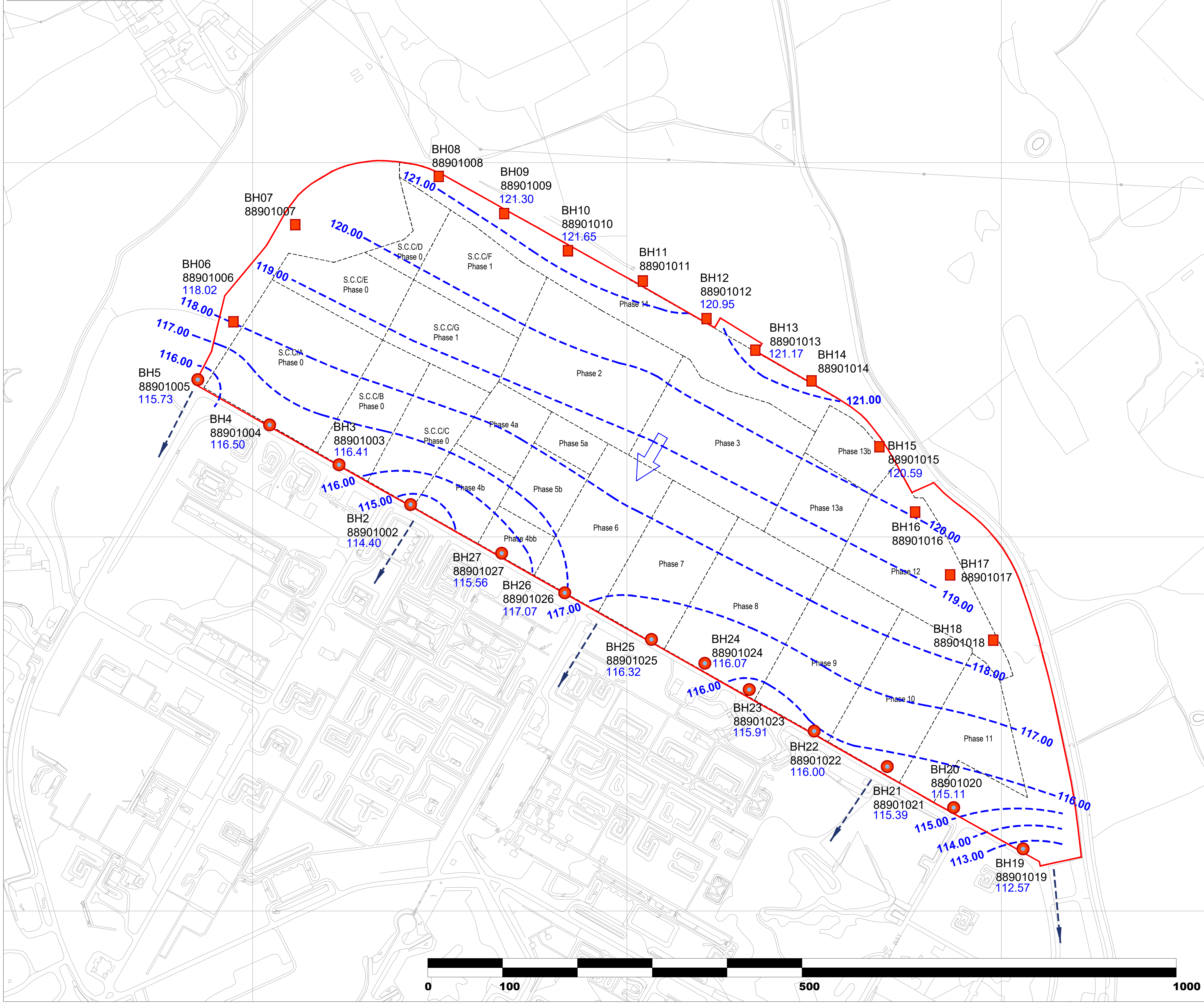
Revised monitoring schedules and compliance limits for leachate, groundwater and surface water are proposed, and would need to be incorporated into a future permit variation application.

6.0 CLOSURE

This report has been prepared by Nicola Sugg (trading style of NSugg Limited) with all reasonable skill and care, and in accordance with the services agreed with Swan Environmental Ltd. Relevant information provided by Swan Environmental Ltd. and Biffa has been accepted in good faith as being accurate and valid. This report is based on the relevant guidance and legislation in force at the date of the report and should be reviewed if such guidance and legislation are amended or superseded.

This report is for the exclusive use of Swan Environmental Ltd. and Biffa; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from Nicola Sugg.

DRAWINGS



NOTES

1. Monitoring plan provided by Biffa, Drawing No. M4180107 Dated 01.02.05

2. Revision 1 updated to reflect revised borehole datum elevations

3. September 2022 data for BH9 and BH10 are unreliable, therefore data are presented from 14th June 2022 and 10th March 2022 respectively

LEGEND

- Installation Boundary
- Gas Monitoring Wells
- Gas and Groundwater Monitoring Wells
- 114.40 — Groundwater Levels (mAOD) 21/09/2022
- Inferred Groundwater Contours (mAOD), Mercia Mudstone 21/09/2022
- Inferred Direction of Groundwater Flow
- Approximate location of outfall from perimeter site drainage to MOD drainage system

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SITE	
Meece 1 Landfill	
PROJECT	
2022 HRA Review (Ref: NS_0115_10)	
DRAWING TITLE	
Groundwater Levels & Inferred Groundwater Contours	
DRAWING NUMBER	REVISION
1	1
SCALE	DATE
1:5000 @ A3	31.05.2023

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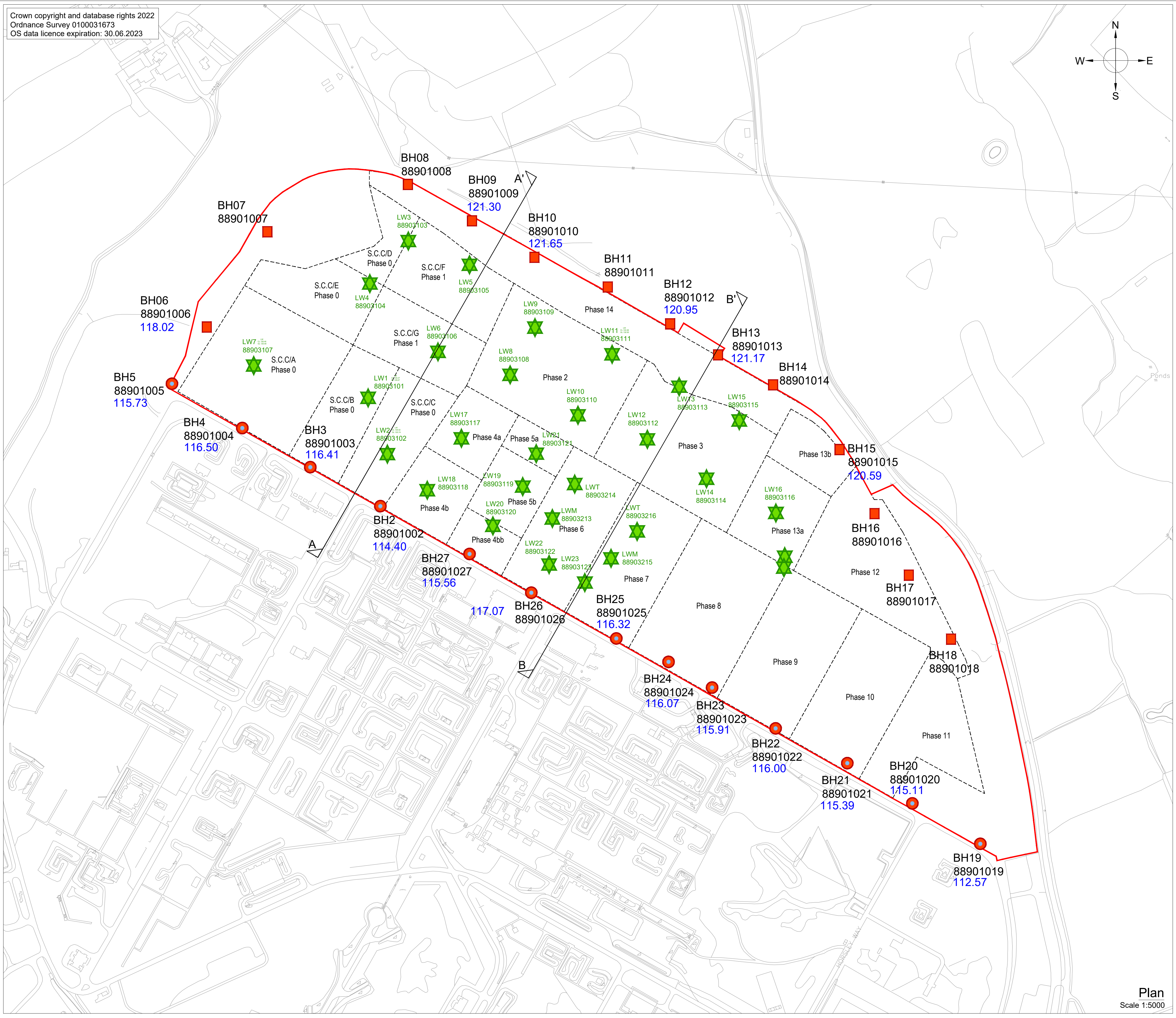
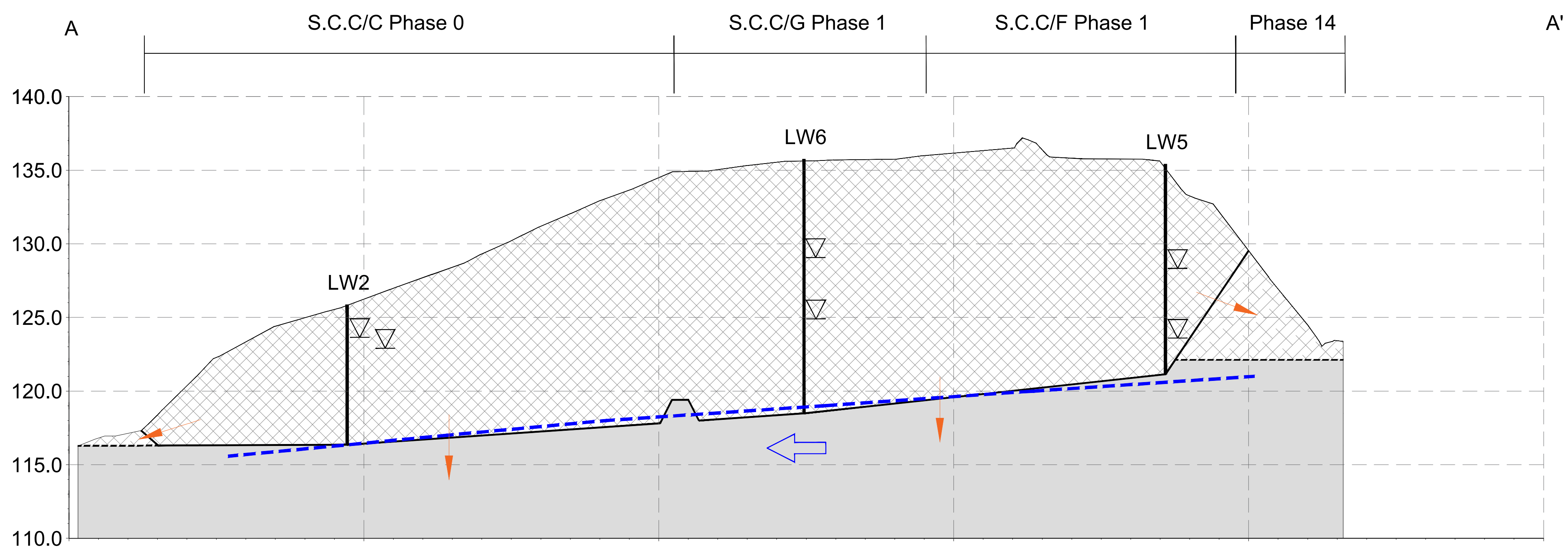


NOTES

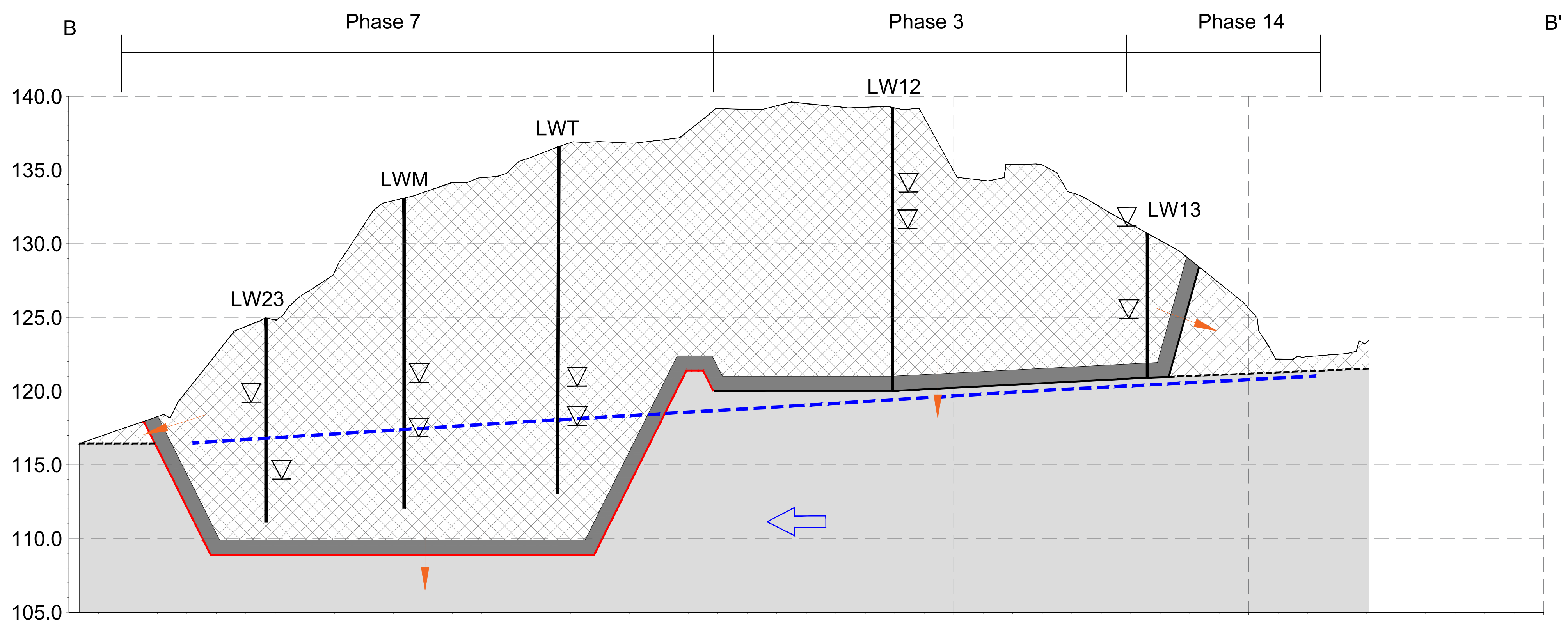
1. As-built and Closed Site surveys supplied by client

LEGEND

- Installation Boundary
- Gas Monitoring Wells
- Gas and Groundwater Monitoring Wells
- Leachate Monitoring Point
- 114.40 Groundwater Levels (mAOD) 21/09/2022



Section A - A
Scale H 1:2000
V x5



Section B - B
Scale H 1:2000
V x5

CROSS SECTION LEGEND

- Topographic Survey Profile (09/08/2022)
- As Built Profile (dwg supplied by client)
- Approximate Engineered Profile, Inferred From Base of Leachate Wells
- 1m Clay Liner
- Landfill Waste
- Made Ground/Fill
- Mercia Mudstone
- Inferred Mercia Mudstone Potentiometric Surface, March 2022
- Inferred Direction of Groundwater Flow
- Sept-Oct 2022 Leachate Level Ranges
- Potential Advective Flux of Landfill Leachate (Outward Hydraulic Gradient)

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SITE Meece 1 Landfill	
PROJECT 2022 HRA Review (Ref: NS_0115_10)	
DRAWING TITLE Hydrogeological Cross-Sections	
DRAWING NUMBER 2	REVISION 1
SCALE As Shown @ A2	DATE 01.06.2023

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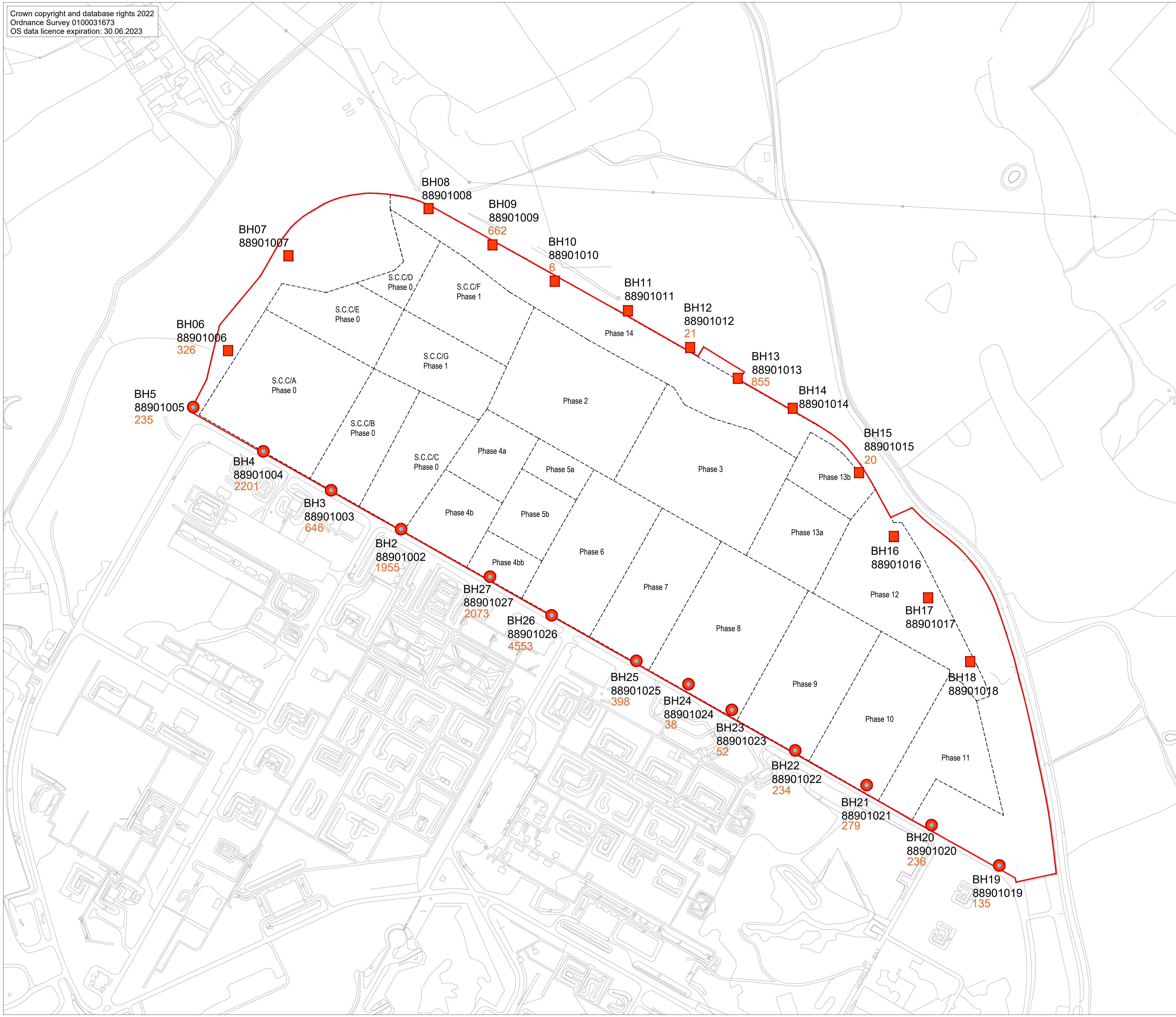

NOTES

1. Monitoring plan provided by Biffa, Drawing No. M4180107 Dated 01.02.05

LEGEND

- Installation Boundary
- Waste Boundary
- Gas Monitoring Wells
- Gas and Groundwater Monitoring Wells
- 1955 Average 2022 Chloride Concentration in Groundwater (mg/l)

SITE
Meece 1 Landfill

PROJECT
2022 HRA Review (Ref: NS_0115_10)

DRAWING TITLE
Average 2022 Groundwater Chloride Concentrations

DRAWING NUMBER	REVISION
3	1
SCALE	**DATE**
1:5000 @ A3	31.05.2022

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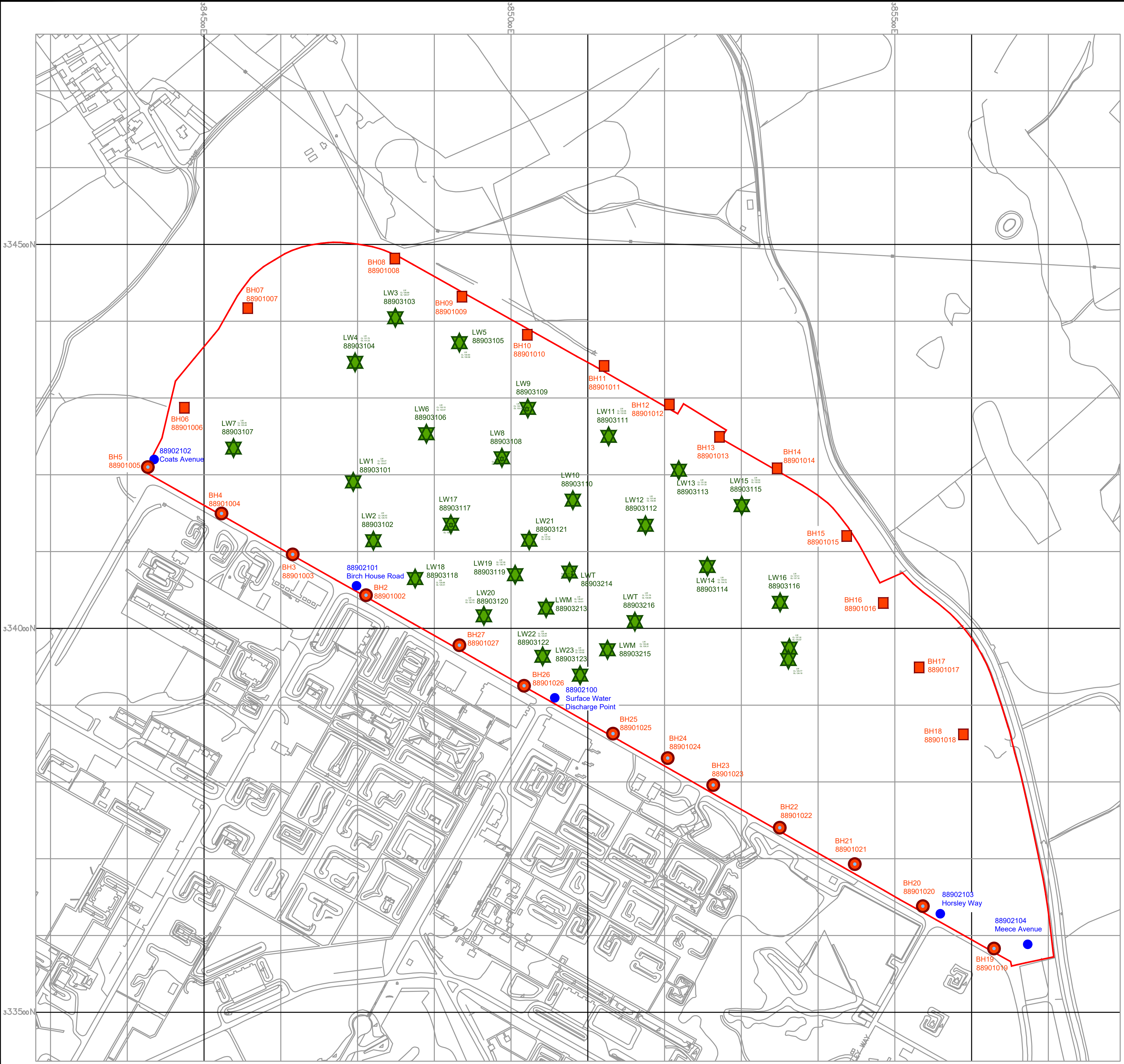
APPENDIX A



- Installation Boundary
- Gas Monitoring Borehole
- Groundwater Monitoring Borehole
- Gas and Groundwater Monitoring Borehole
- Leachate Monitoring Point
- Surface water Monitoring Point
- Noise Monitoring Point
- Dust Monitoring Point
- Asbestos Monitoring Point
- Asbestos Monitoring Point (Mobile)

Notes:

1. All BEDS references should have prefix "8890****".

2. Reproduced from Superplan Data ® (scale-free) by permission of Ordnance Survey ® on behalf of The Controller of Her Majesty's Stationery Office. © Crown copyright 2005 all rights reserved. Licence number 100036438.

3. Do not scale from this drawing.

REV.	DATE	DRAWN	DESCRIPTION
7	02/02/22	MLS	updated monitoring
6	08/03/21	MLS	updated monitoring
5	13/11/20	MLS	updated monitoring

Biffa Waste Services Ltd
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Staffordshire
WS11 8NQ
Tel: 01543 577890
Mob: 07834092155
e-mail michelle.saunders@biffa.co.uk

PROJECT	Monitoring
LOCATION	Meece Landfill Plan
DRAWING TITLE	Monitoring
DRAWING No.	COMPUTER REF. M4180107
DRAWN MLS	DATE 01/02/05
SCALE(S)	1:5000

APPENDIX B

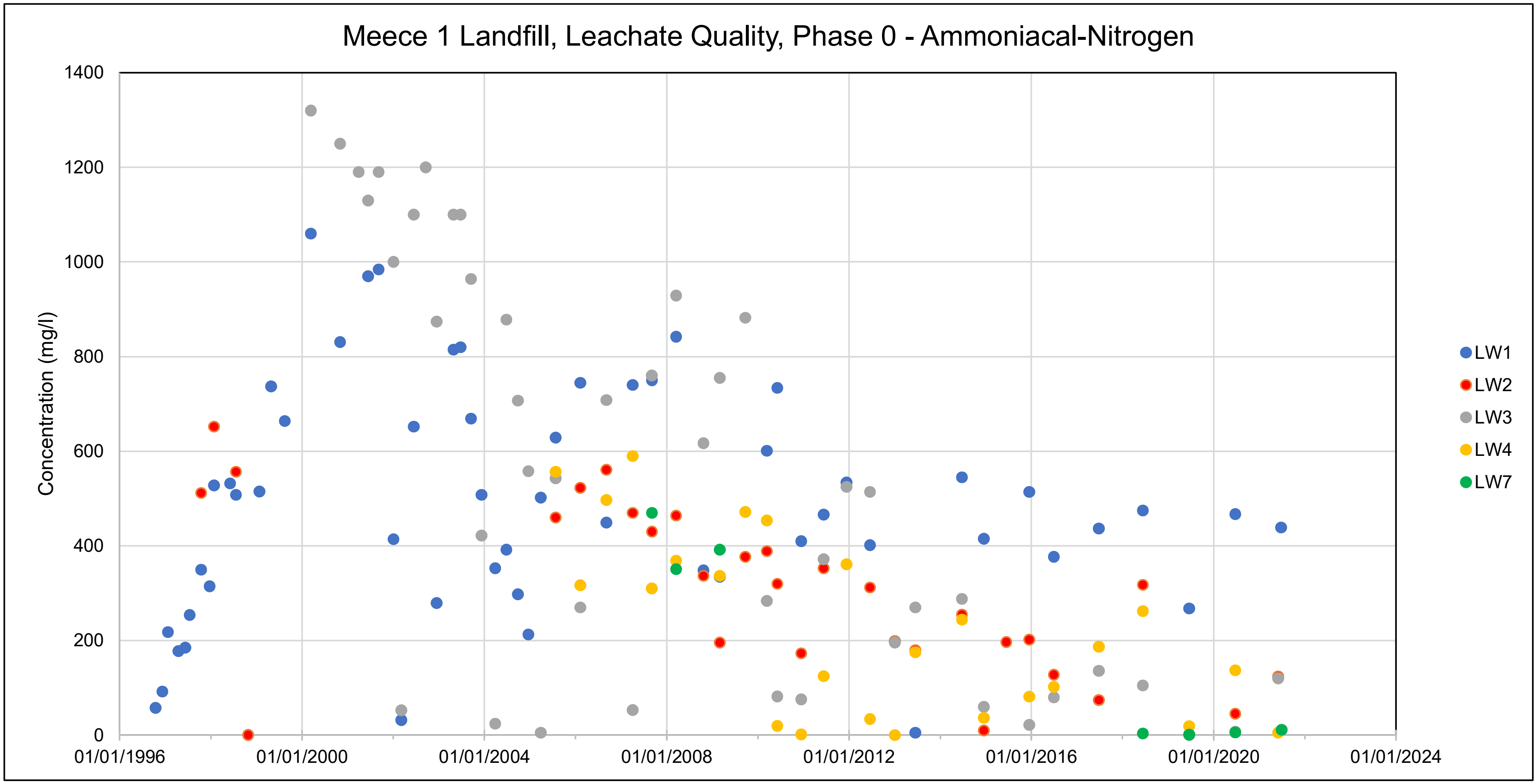
MEECE 1 LANDFILL - LEACHATE RISK FACTORS, BASED ON ALL AVAILABLE LEACHATE QUALITY DATA

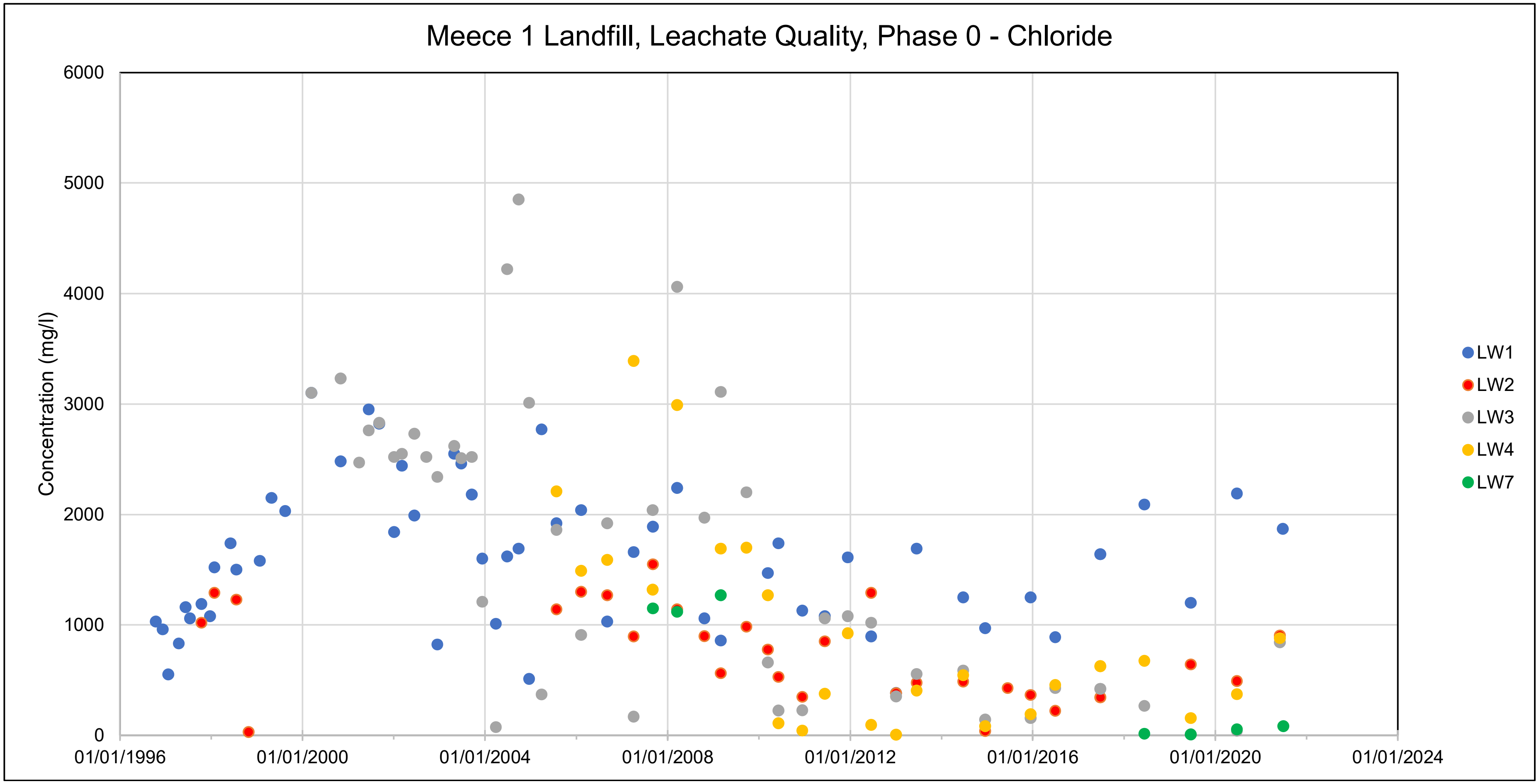
Maximum concentrations for all parameters detected >10ug/l (clear outliers removed)

priority contaminant in 2017 HRAR

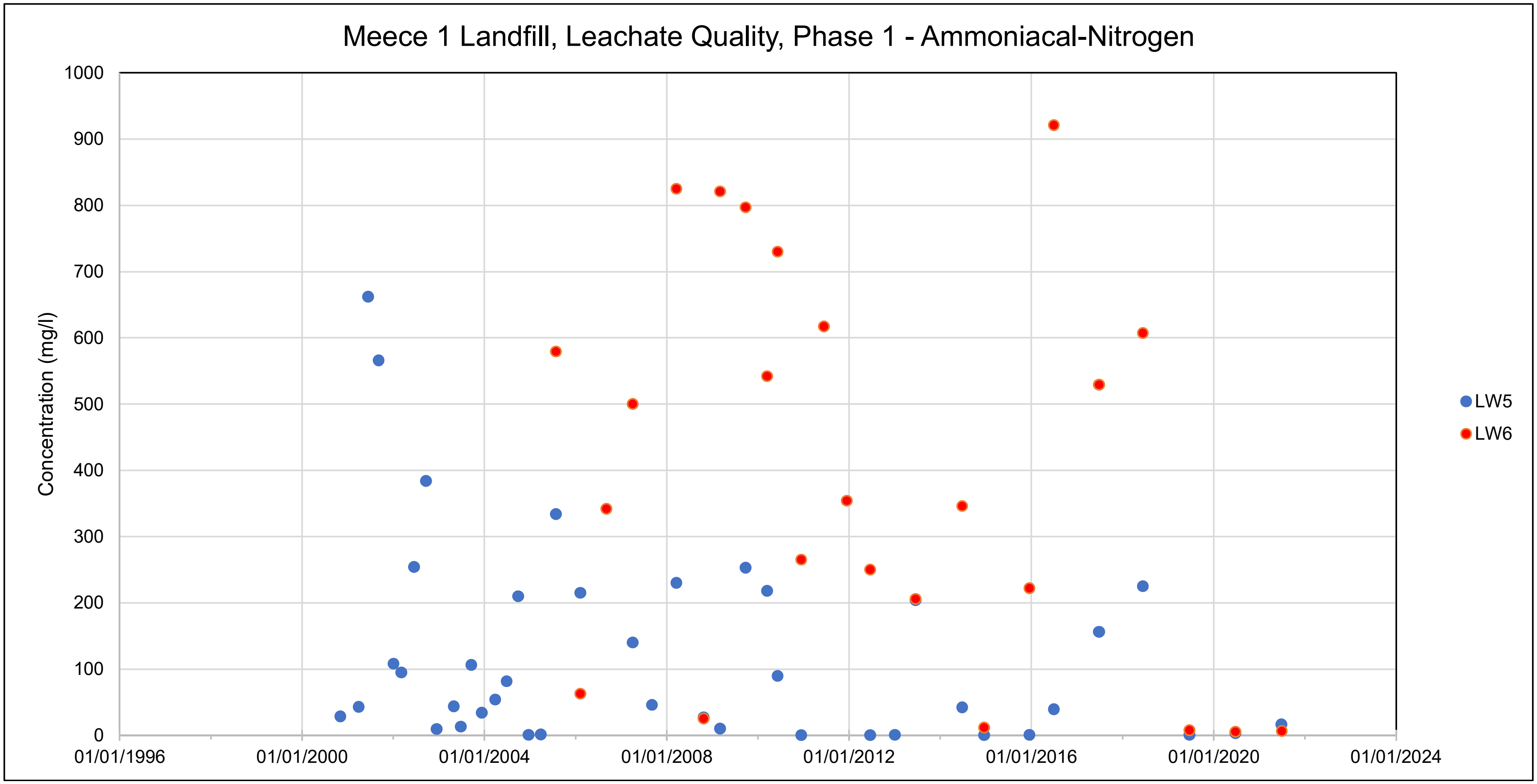
	Maximum concentration in site leachate		Water Quality Standard	Risk Factor	Source of Water Quality Standard
1,2,4-TRIMETHYLBENZENE	50.7	ug/l	1	51	After MRV for benzene
1,3,5-TRIMETHYLBENZENE	22	ug/l	1	22	After MRV for benzene
1,4-DICHLOROBENZENE	16.1	ug/l	1	16.1	After MRV for benzene
2,4,6-TRICHLOROPHENOL	51.6	ug/l	0.1	516	After MRV for 2,4-Dichlorophenol
2,4-DICHLOROPHENOL	19.3	ug/l	0.1	193	MRV (hazardous substance)
2,4-DIMETHYLPHENOL	79.4	ug/l	0.1	794	assumed, worse case DWS
2-METHYLPHENOL	105	ug/l	0.1	1050	assumed, worse case DWS (after PAHs and pesticides)
3 & 4-METHYLPHENOL	11000	ug/l	0.1	110000	assumed, worse case DWS (after PAHs and pesticides)
ALKALINITY AS CaCO3	22700	mg/l	n/a	n/a	
AMMONIACAL NITROGEN	9310	mg/l	0.39	23872	No EQS, set at UK Drinking Water Standard (DWS)
ANTIMONY	0.31	mg/l	0.005	62	No EQS, set at UK DWS
ARSENIC	0.484	mg/l	0.005	97	UK TAG on the WFD - limit of quantification (hazardous substance)
BARIUM, TOTAL AS BA	34.4	mg/l	n/a	n/a	
BENZENE	35	ug/l	1	35	MRV (hazardous substance)
BIS(2-CHLOROETHOXY)METHANE	44.4	ug/l	0.1	444	assumed, worse case DWS (after PAHs and pesticides)
BIS(2-ETHYLHEXYL)PHTHALATE	249	ug/l	1000	0.2	after MAC EQS for diethylphthalate
BOD + ATU (5 DAY)	45600	mg/l	n/a	n/a	
BORON	37.1	mg/l	2	19	AA EQS (no MAC EQS)
BROMOMETHANE	10.3	ug/l	0.1	103	assumed, worse case DWS (after PAHs and pesticides)
CADMIUM, TOTAL AS CD	0.043	mg/l	0.00045	95.6	minimum MAC EQS (non-hazardous pollutant)
CALCIUM TOTAL AS CA	18800	mg/l	n/a	n/a	
CHEMICAL OXYGEN DEMAND	72700	mg/l	n/a	n/a	
CHLORIDE AS CL	54600	mg/l	250	218	AA EQS (no MAC EQS)
CHLOROMETHANE	14.6	ug/l	0.1	146	assumed, worse case DWS (after PAHs and pesticides)
CHROMIUM, TOTAL AS CR	1.84	mg/l	0.032	58	MAC EQS
COBALT TOTAL AS CO	0.11	mg/l	0.1	1	MAC EQS
COPPER TOTAL AS CU	*15*	mg/l	0.001	*15000*	AA EQS (no MAC EQS) **unreliable - incorrect units in dataset?**
Cyanide, total as CN	0.51	mg/l	0.005	102	MAC EQS
DICHLOBENIL	10400	ng/l	100	104	DWS for individual pesticides/insecticides/herbicide
DICHLOROMETHANE	77.1	ug/l	20	4	AA EQS (no MAC EQS)
DICHLORPROP	32.2	ug/l	0.1	322	DWS for individual pesticides/insecticides/herbicide
DIETHYL PHTHALATE	54.3	ug/l	1.3	42	AA EQS (no MAC EQS)
EH C10-C16	2380	ug/l	n/a	n/a	
EH C16-C24	4470	ug/l	n/a	n/a	
EH C24-C40	9120	ug/l	n/a	n/a	
EH C6-C40	15600	ug/l	n/a	n/a	
EH C6-C8	237	ug/l	n/a	n/a	
EH C8-C10	496	ug/l	n/a	n/a	
ELECTRICAL CONDUCTIVITY	130000	uS/cm	2500	52	No EQS, set at UK DWS
ETHYL BENZENE	46.5	ug/l	1	47	After MRV for benzene
FLUORIDE	20.9	mg/l	n/a	n/a	
FREE CYANIDE	0.143	mg/l	0.005	28.6	MAC EQS
IRON, TOTAL AS FE	374	mg/l	1	374	AA EQS (no MAC EQS)
LEAD TOTAL AS PB	1.44	mg/l	0.014	103	MAC EQS
M,P-XYLENE	71.9	ug/l	3	24	MRV (hazardous substance)
MAGNESIUM AS MG	722	mg/l	n/a	n/a	
MANGANESE AS MN	22.6	mg/l	0.123	184	AA EQS (no MAC EQS)
MECOPROP	189	ug/l	187	1.01	MAC EQS
MERCURY TOTAL AS HG	0.002	mg/l	0.00002	100	UK TAG on the WFD - limit of quantification (hazardous substance)
MOLYBDENUM	0.255	mg/l	n/a	n/a	
NAPHTHALENE	354	ug/l	130	2.72	MAC EQS
NICKEL TOTAL AS NI	0.904	mg/l	0.034	27	MAC EQS (dissolved nickel)
NITRATE AS N	186	mg/l	50	3.7	
NITRITE AS N	9.4	mg/l	0.5	19	
NITROGEN TOTAL OXIDISED AS N	197	mg/l	n/a	n/a	
N-PROPYLBENZENE	13.5	ug/l	0.1	135	assumed, worse case DWS (after PAHs and pesticides)
O-XYLENE	39.6	ug/l	3	13.2	MRV (hazardous substance)
pH	9.4	units	6.5-9.5	-	
PHENOL	28800	ug/l	46	626	MAC EQS
PHENOLS, MONOHYDRIC	14	mg/l	0.046	304	MAC EQS for phenol
PHOSPHORUS, TOTAL INORGANIC	17100	mg/l	n/a	n/a	
P-ISOPROPYLTOLUENE	59.2	ug/l	4	14.8	After MRV for toluene
POTASSIUM AS K	20000	mg/l	n/a	n/a	
SELENIUM	0.637	mg/l	0.01	63.7	No EQS, set at UK DWS
SILVER	0.063	mg/l	0.0001	630	MAC EQS for dissolved silver
SODIUM AS NA	26300	mg/l	200	132	No EQS, set at UK DWS
SULPHATE AS SO4	1730	mg/l	400	4.3	AA EQS (no MAC EQS)
SUSPENDED SOLIDS	118000	mg/l	n/a	n/a	
TELLURIUM	20.5	ug/l	n/a	n/a	
THALLIUM	0.2	mg/l	n/a	n/a	
TIN	0.216	mg/l	0.025	8.6	AA EQS (no MAC EQS)

TITANIUM	1	mg/l	n/a	n/a	
TOLUENE	190	ug/l	4	48	MRV (hazardous substance)
TOTAL ORGANIC CARBON	19360	mg/l	n/a	n/a	
URANIUM	15.4	ug/l	30	0.5	US EPA DWS (no EQS or UK DWS)
VANADIUM	0.31	mg/l	0.02	15.5	AA EQS (no MAC EQS)
VINYL CHLORIDE	6.85	ug/l	0.5	13.7	No EQS, set at UK DWS
Xylene (o+p+m)	51.6	ug/l	3	17.2	MRV (hazardous substance)
ZINC	6.43	mg/l	0.0109	590	AA EQS for dissolved, bioavailable Zn (no MAC EQS)

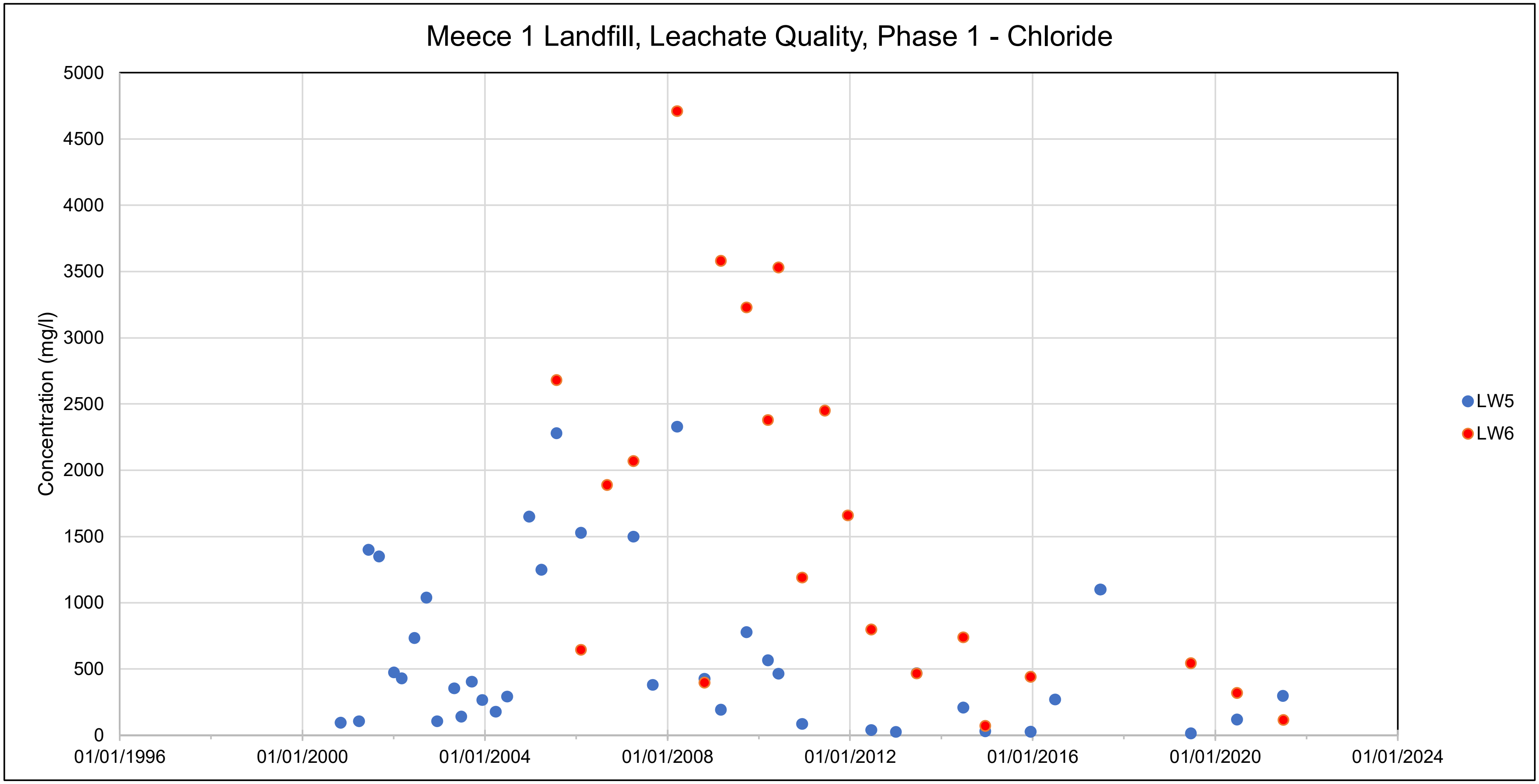

Meece 1 Landfill, Leachate Quality, Phase 0 - Ammoniacal-Nitrogen
Concentration (mg/l)
1400
1200
1000
800
600
400
200
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW1
LW2
LW3
LW4
LW7



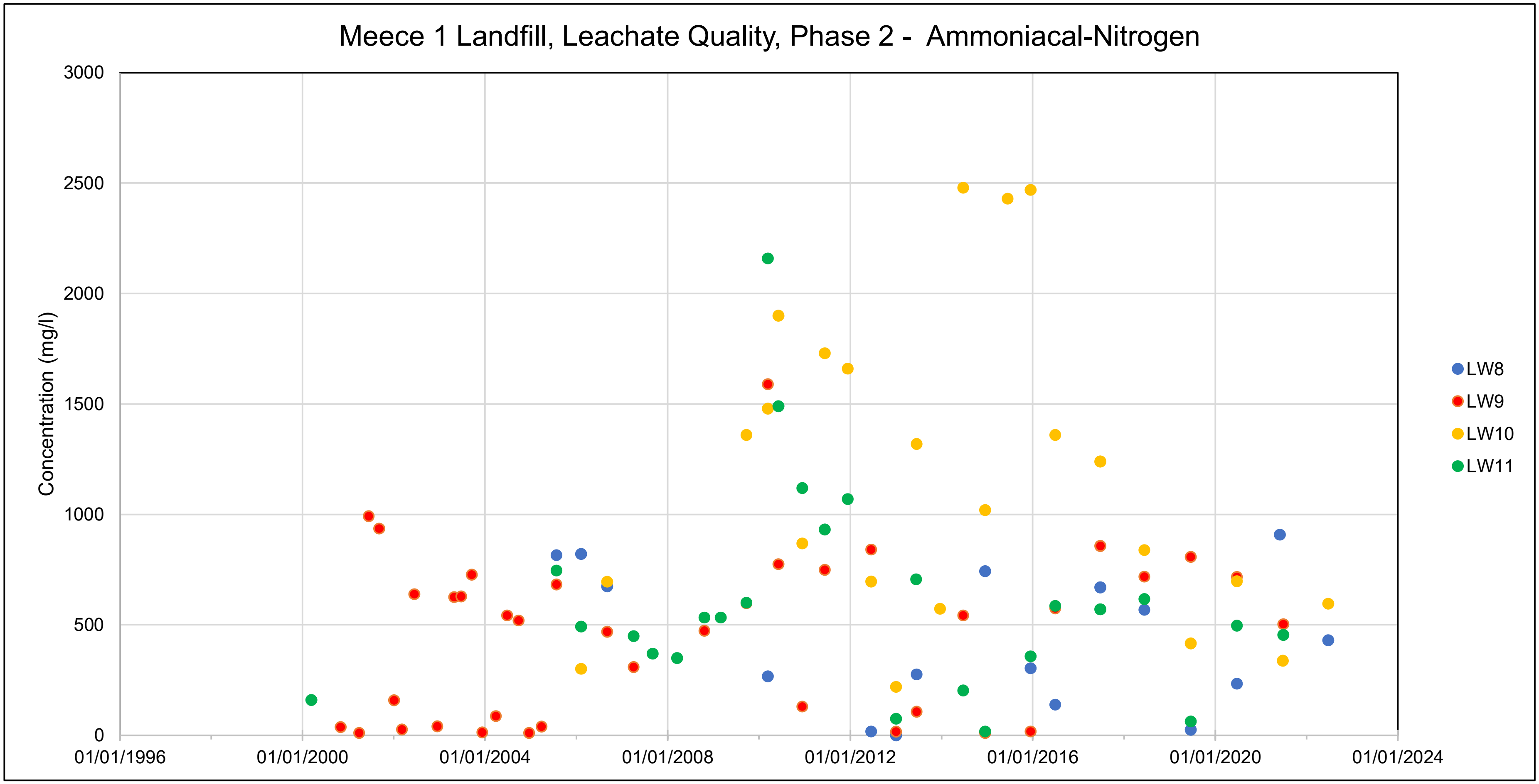
Meece 1 Landfill, Leachate Quality, Phase 0 - Chloride
Concentration (mg/l)
6000
5000
4000
3000
2000
1000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW1
LW2
LW3
LW4
LW7

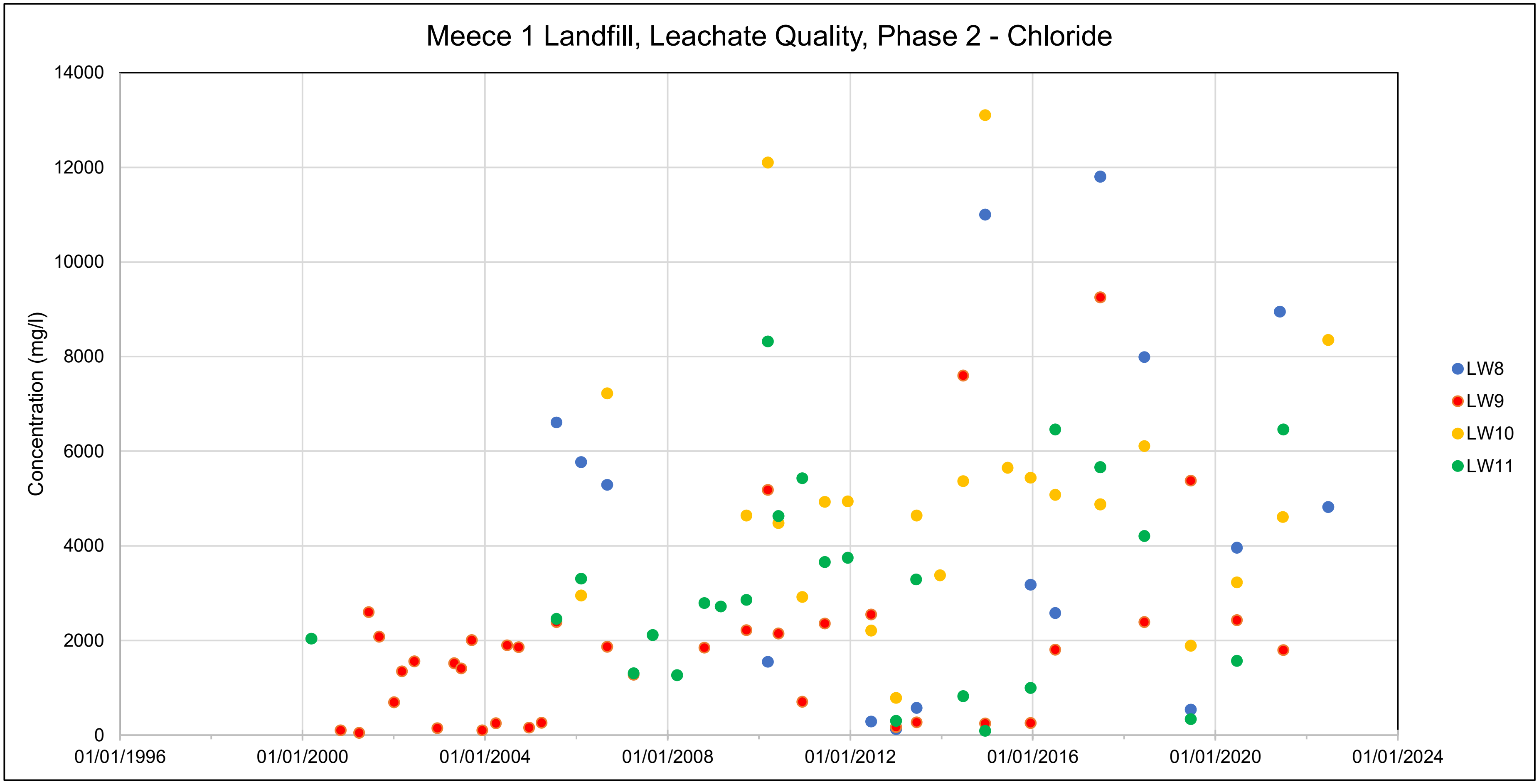


Meece 1 Landfill, Leachate Quality, Phase 1 - Ammoniacal-Nitrogen
Concentration (mg/l)
1000
900
800
700
600
500
400
300
200
100
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW5
LW6

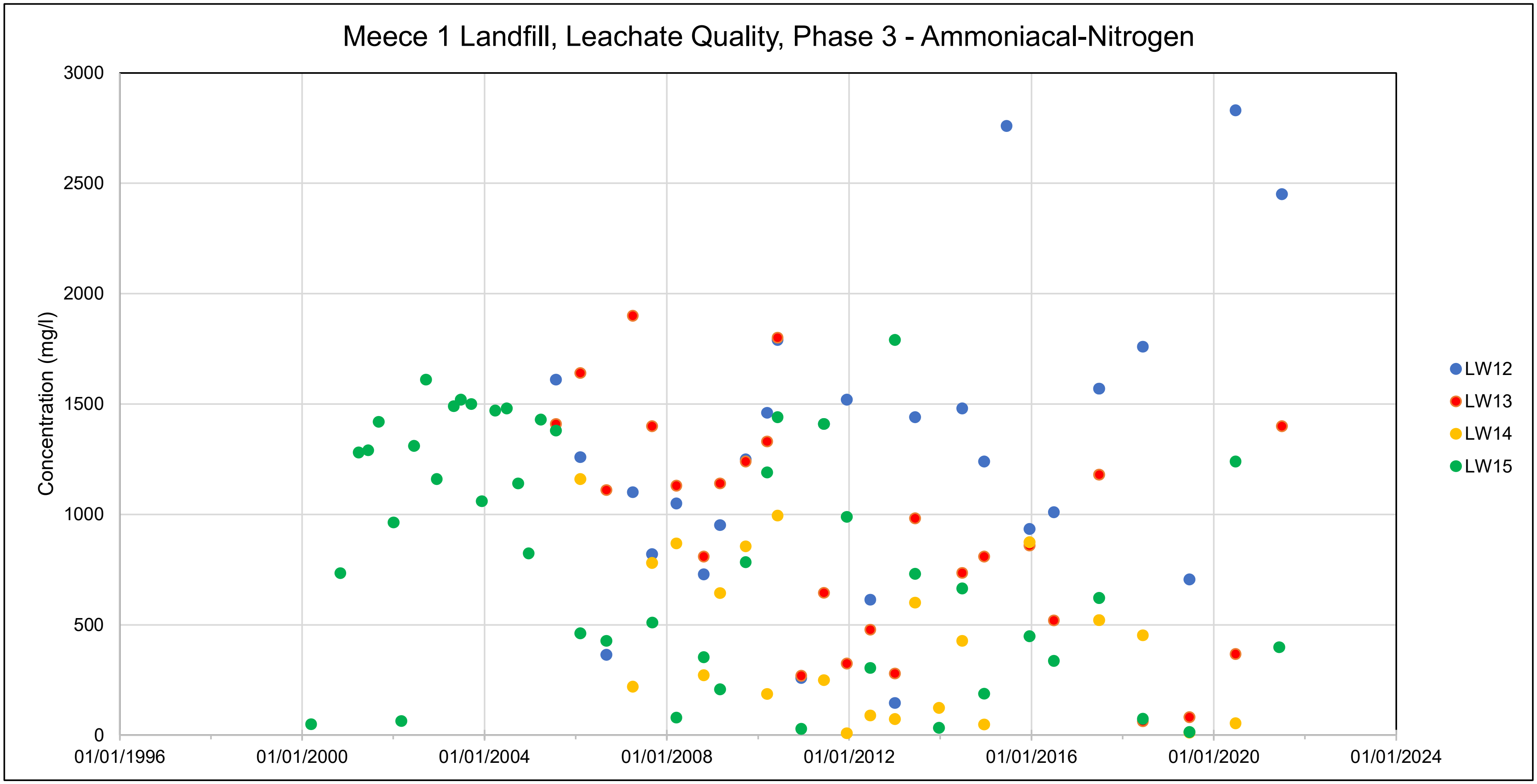


Meece 1 Landfill, Leachate Quality, Phase 1 - Chloride
Concentration (mg/l)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW5
LW6

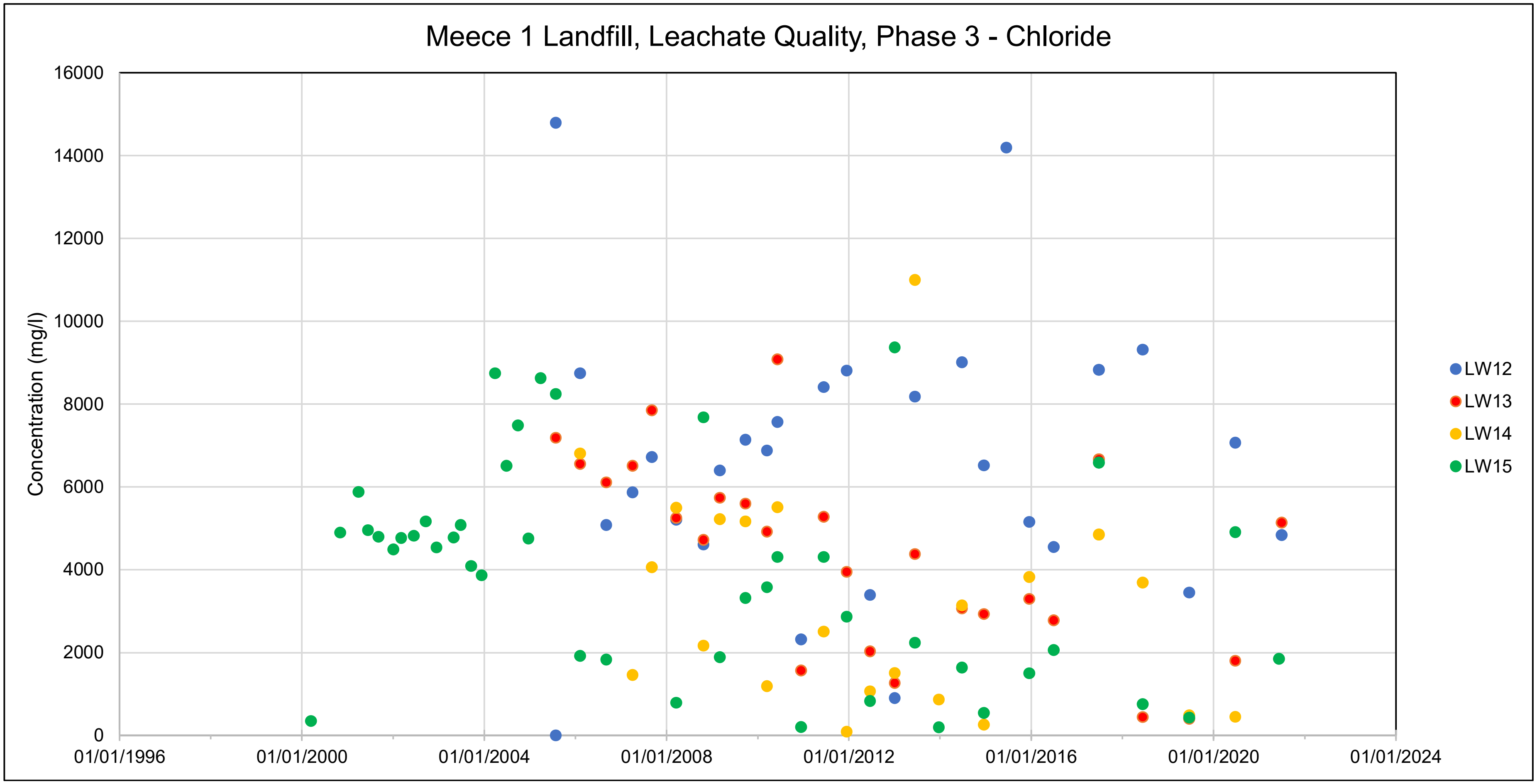

Meece 1 Landfill, Leachate Quality, Phase 2 - Ammoniacal-Nitrogen
Concentration (mg/l)
3000
2500
2000
1500
1000
500
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW8
LW9
LW10
LW11

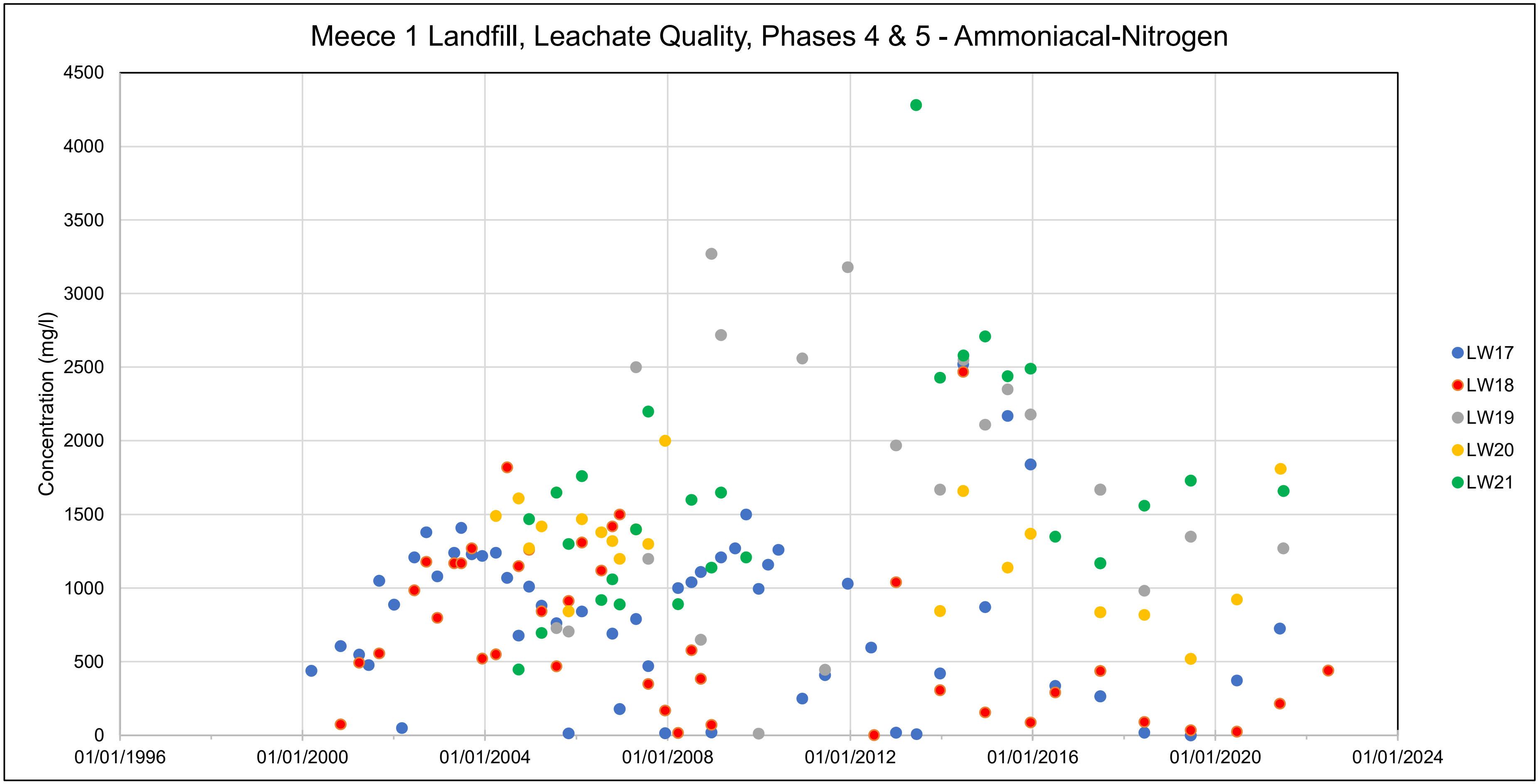


Meece 1 Landfill, Leachate Quality, Phase 2 - Chloride
Concentration (mg/l)
14000
12000
10000
8000
6000
4000
2000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW8
LW9
LW10
LW11

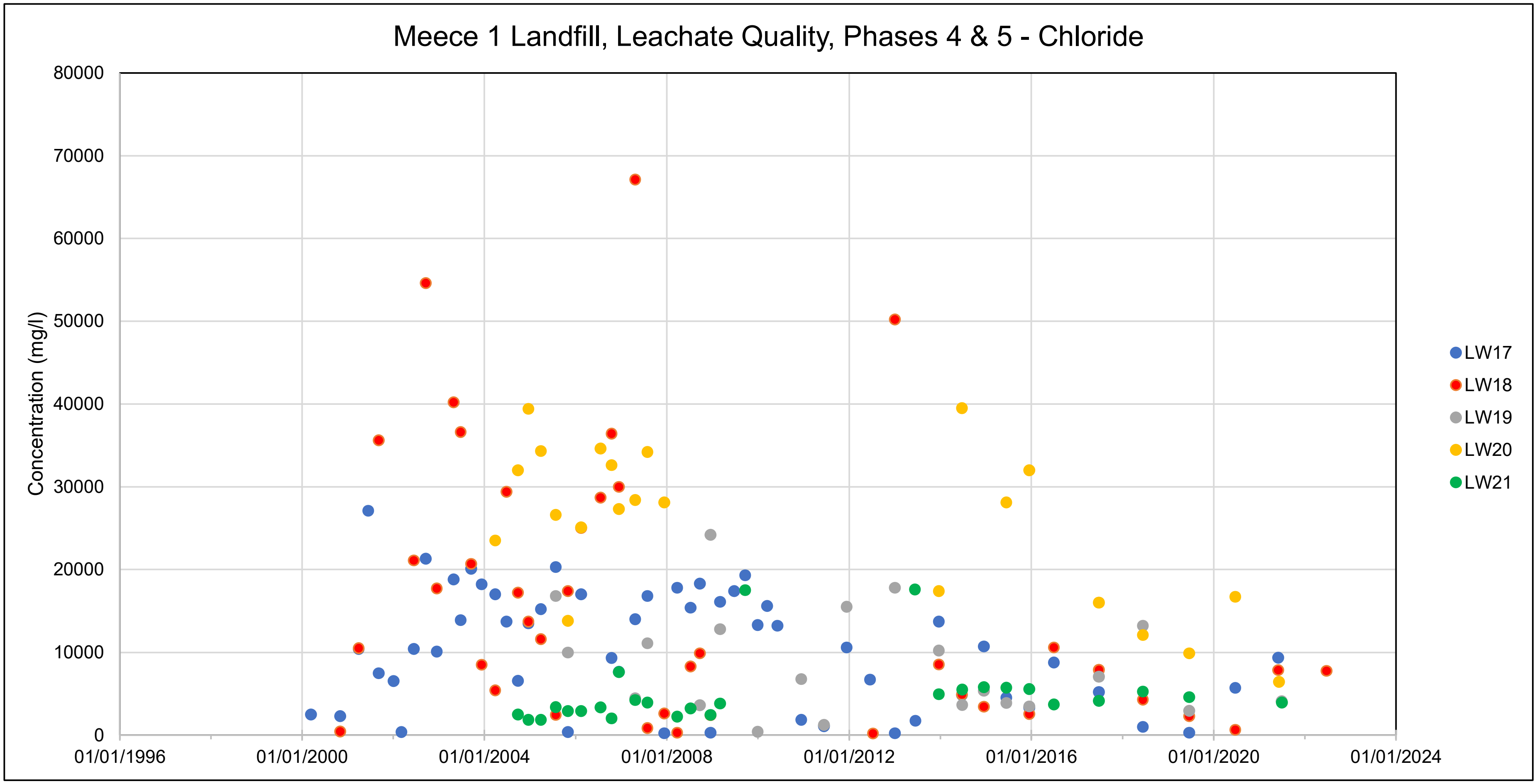


Meece 1 Landfill, Leachate Quality, Phase 3 - Ammoniacal-Nitrogen
Concentration (mg/l)
3000
2500
2000
1500
1000
500
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW12
LW13
LW14
LW15

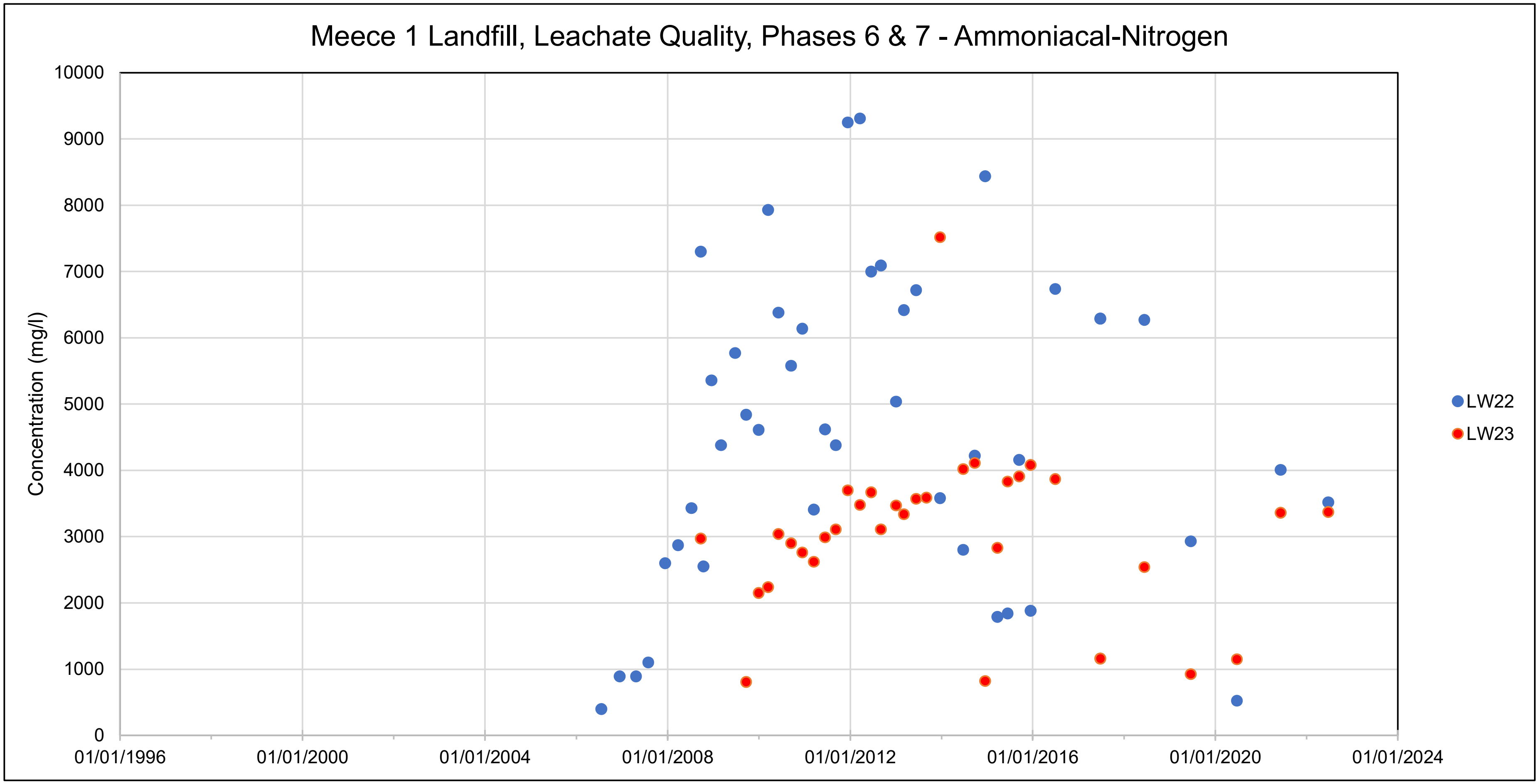

Meece 1 Landfill, Leachate Quality, Phase 3 - Chloride
Concentration (mg/l)
16000
14000
12000
10000
8000
6000
4000
2000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW12
LW13
LW14
LW15

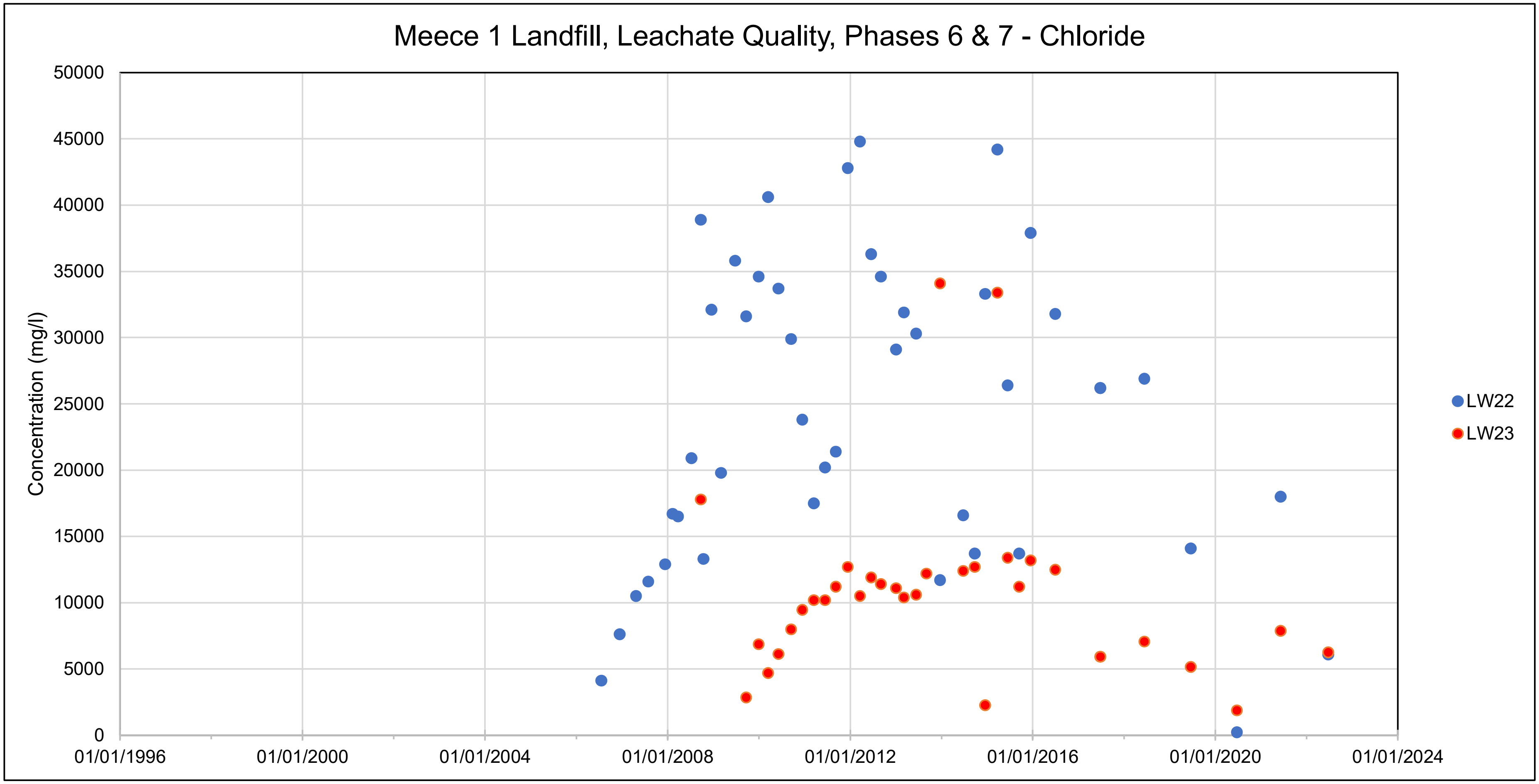


Meece 1 Landfill, Leachate Quality, Phases 4 & 5 - Ammoniacal-Nitrogen
Concentration (mg/l)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW17
LW18
LW19
LW20
LW21

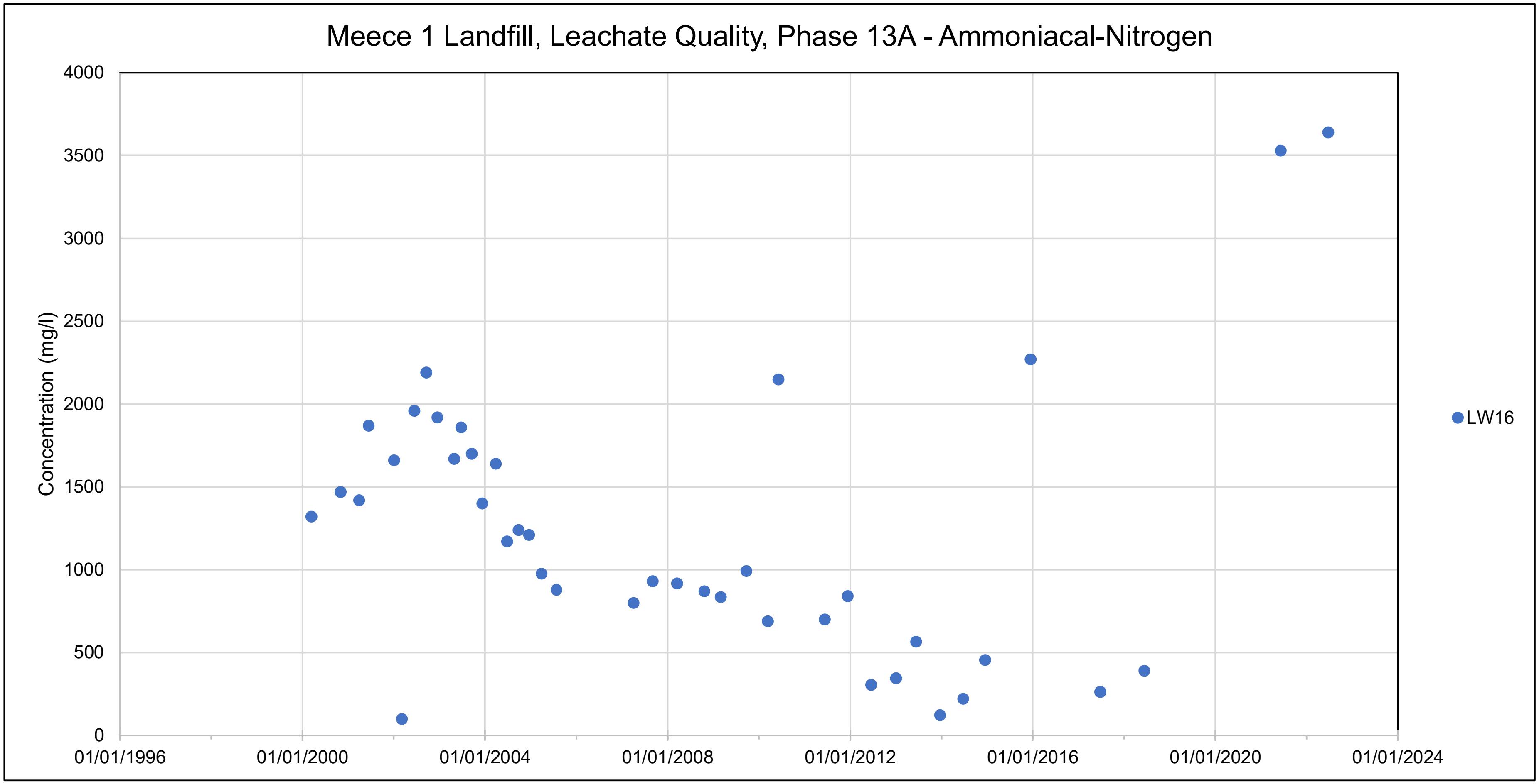


Meece 1 Landfill, Leachate Quality, Phases 4 & 5 - Chloride
Concentration (mg/l)
80000
70000
60000
50000
40000
30000
20000
10000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW17
LW18
LW19
LW20
LW21

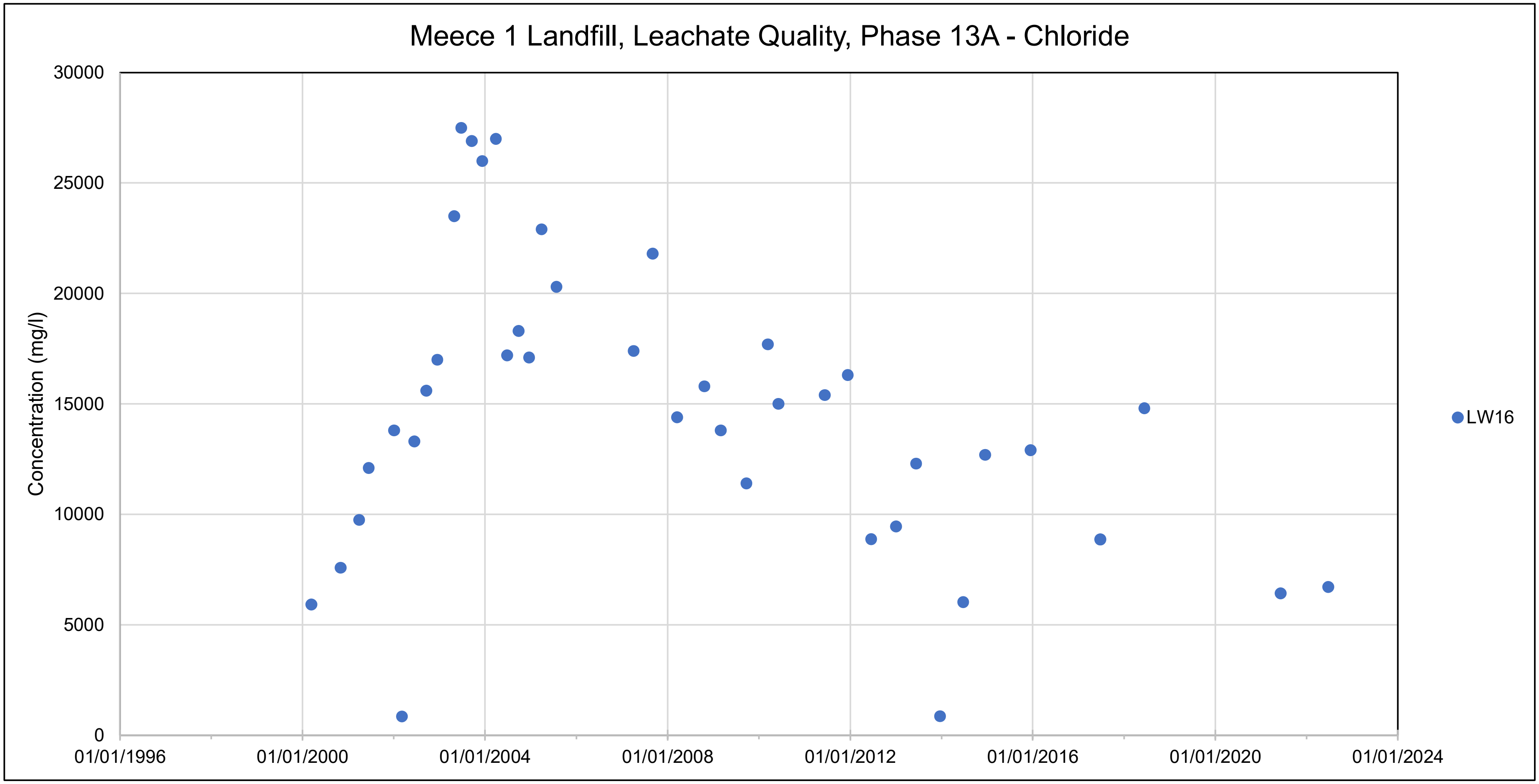

Meece 1 Landfill, Leachate Quality, Phases 6 & 7 - Ammoniacal-Nitrogen
Concentration (mg/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW22
LW23



Meece 1 Landfill, Leachate Quality, Phases 6 & 7 - Chloride
Concentration (mg/l)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW22
LW23

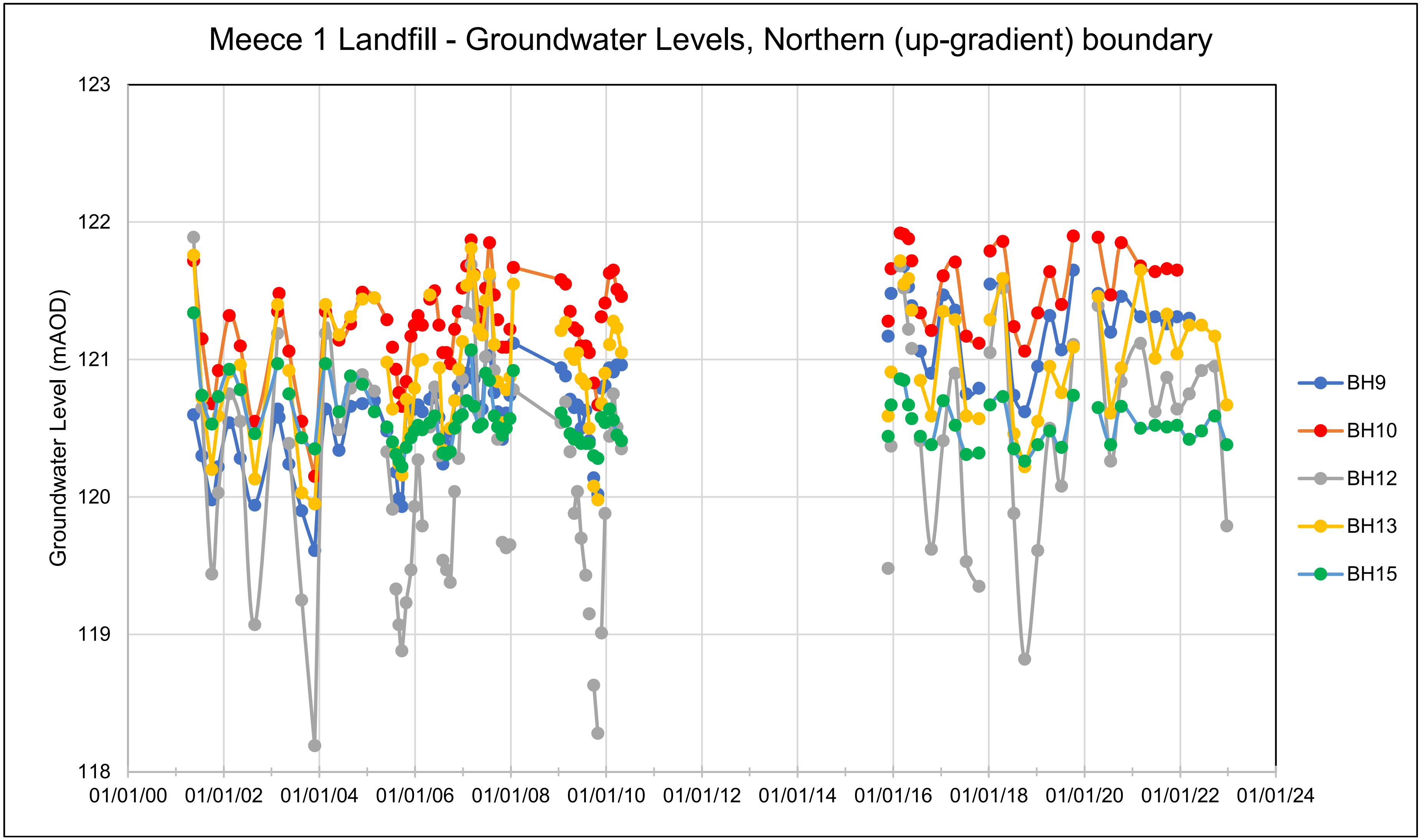


Meece 1 Landfill, Leachate Quality, Phase 13A - Ammoniacal-Nitrogen
Concentration (mg/l)
0
500
1000
1500
2000
2500
3000
3500
4000
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW16

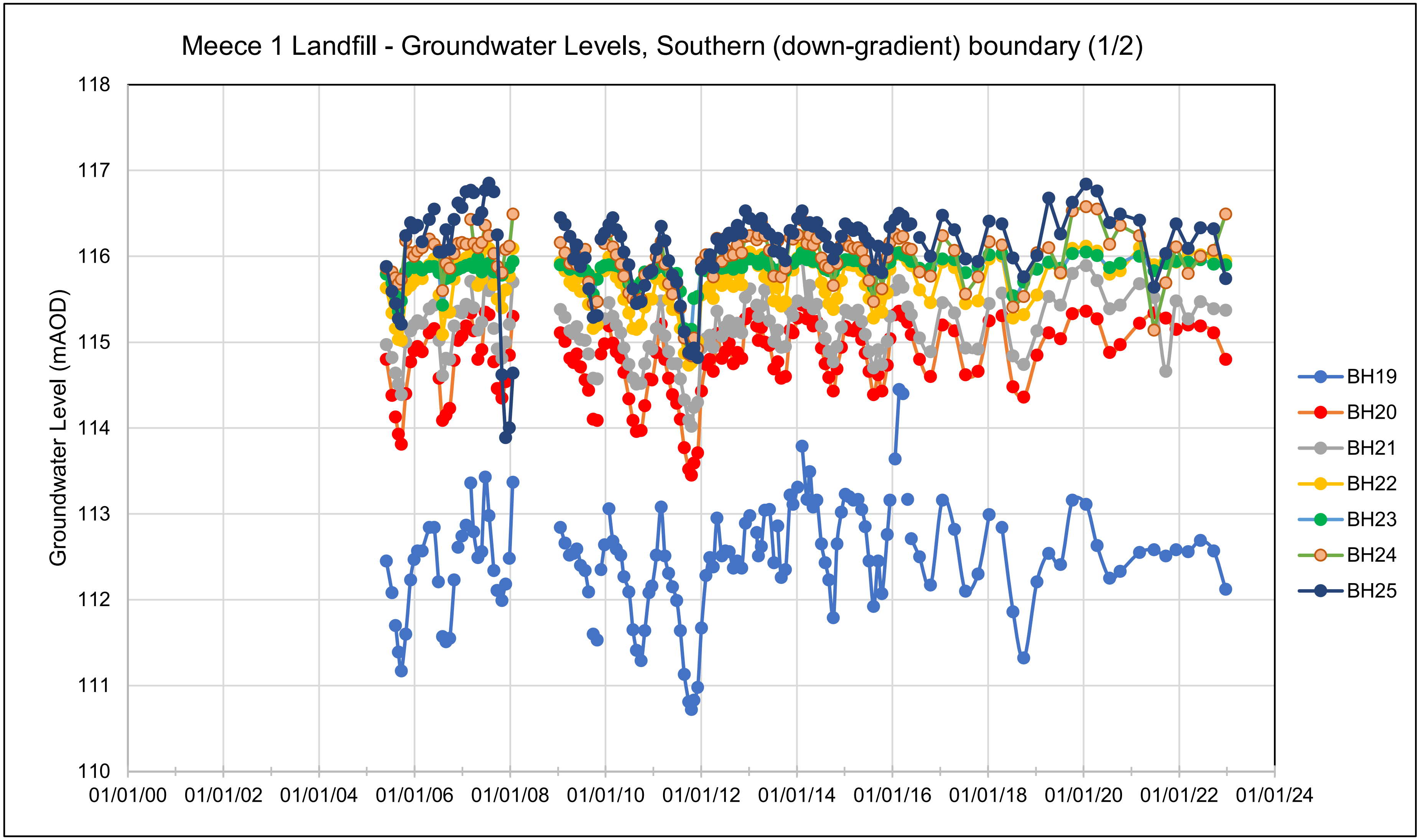


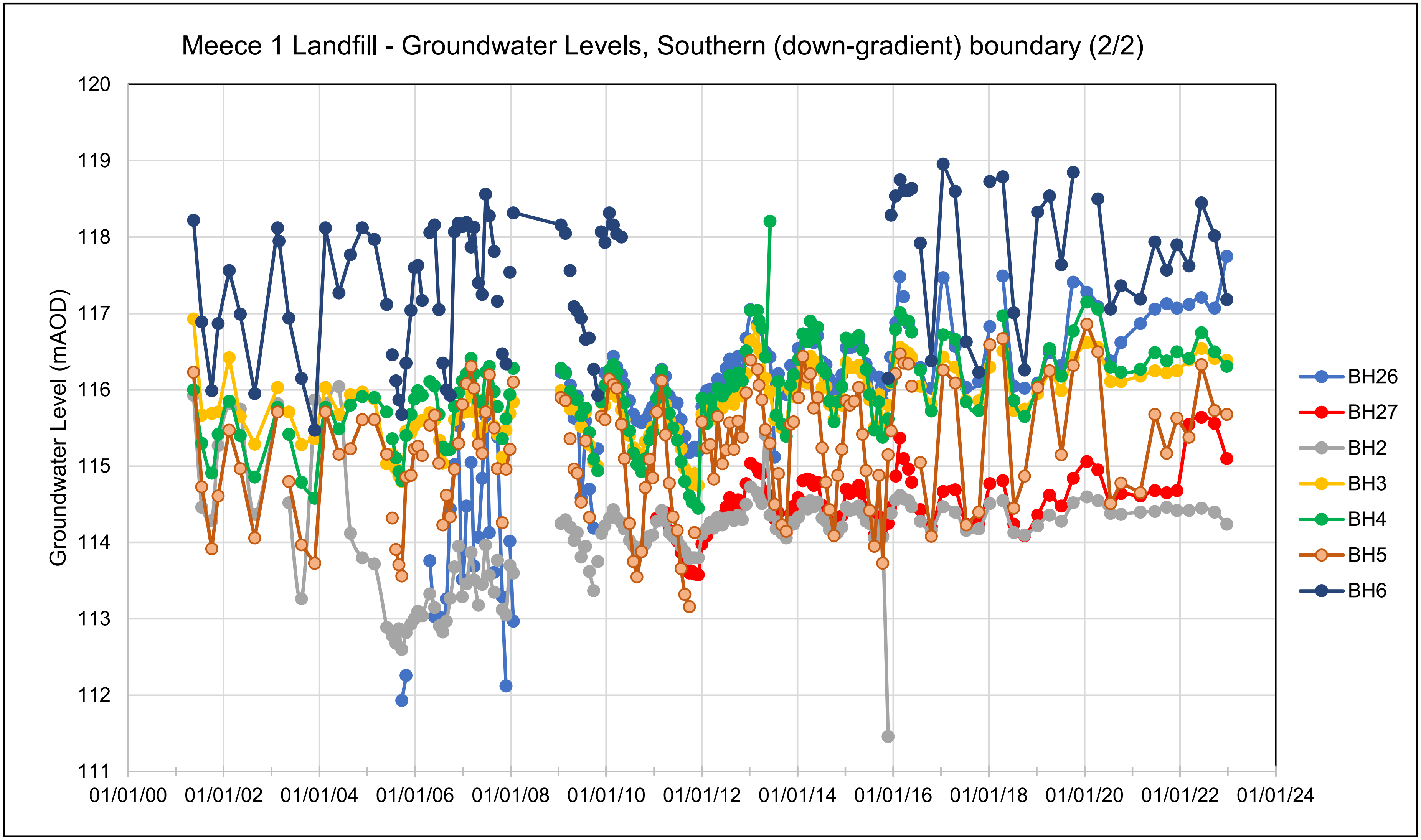
Meece 1 Landfill, Leachate Quality, Phase 13A - Chloride
Concentration (mg/l)
30000
25000
20000
15000
10000
5000
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
LW16

APPENDIX C

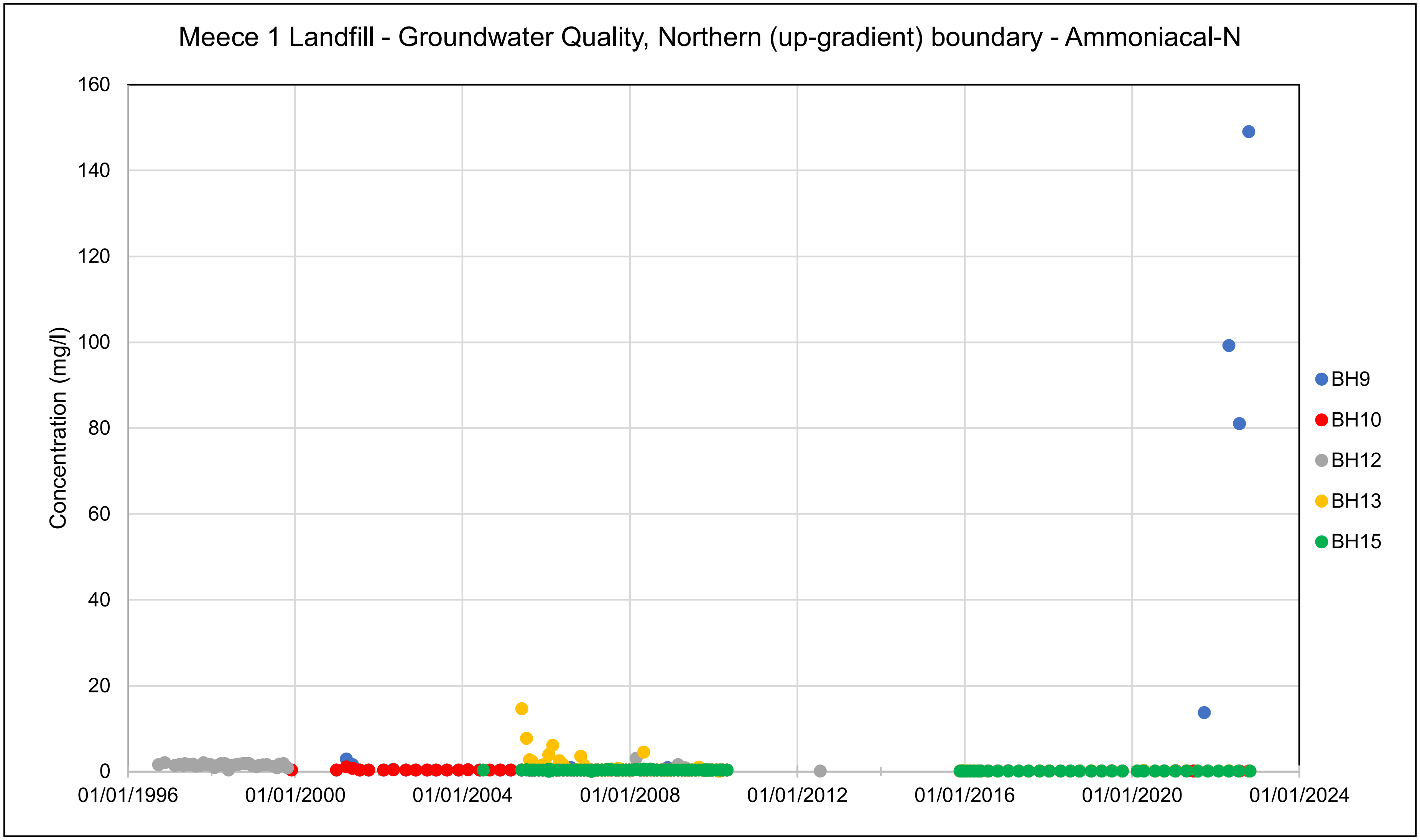


Meece 1 Landfill - Groundwater Levels, Northern (up-gradient) boundary
Groundwater Level (mAOD)
123
122
121
120
119
118
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH9
BH10
BH12
BH13
BH15

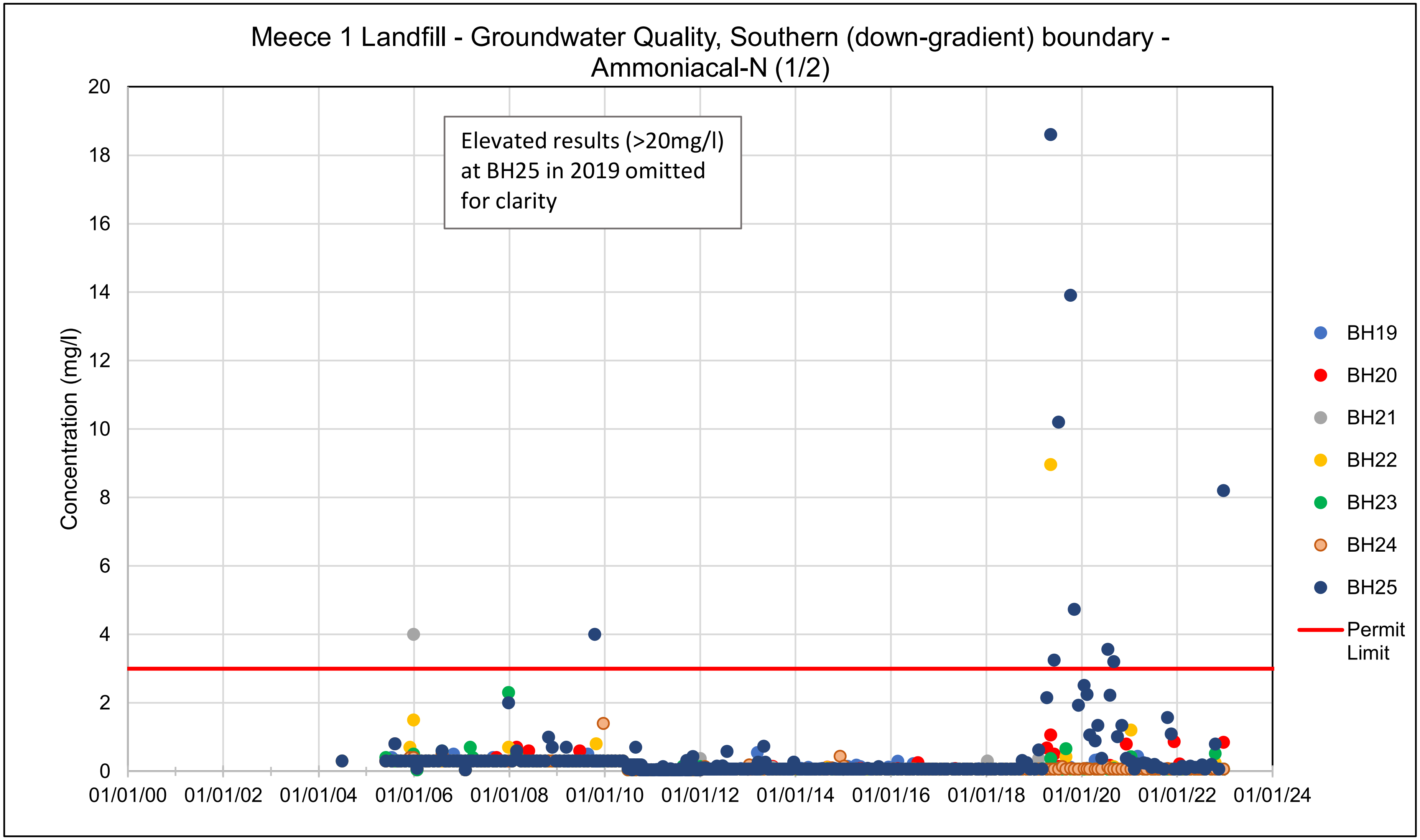

Meece 1 Landfill - Groundwater Levels, Southern (down-gradient) boundary (1/2)
Groundwater Level (mAOD)
118
117
116
115
114
113
112
111
110
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH19
BH20
BH21
BH22
BH23
BH24
BH25


Meece 1 Landfill - Groundwater Levels, Southern (down-gradient) boundary (2/2)
Groundwater Level (mAOD)
120
119
118
117
116
115
114
113
112
111
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH26
BH27
BH2
BH3
BH4
BH5
BH6

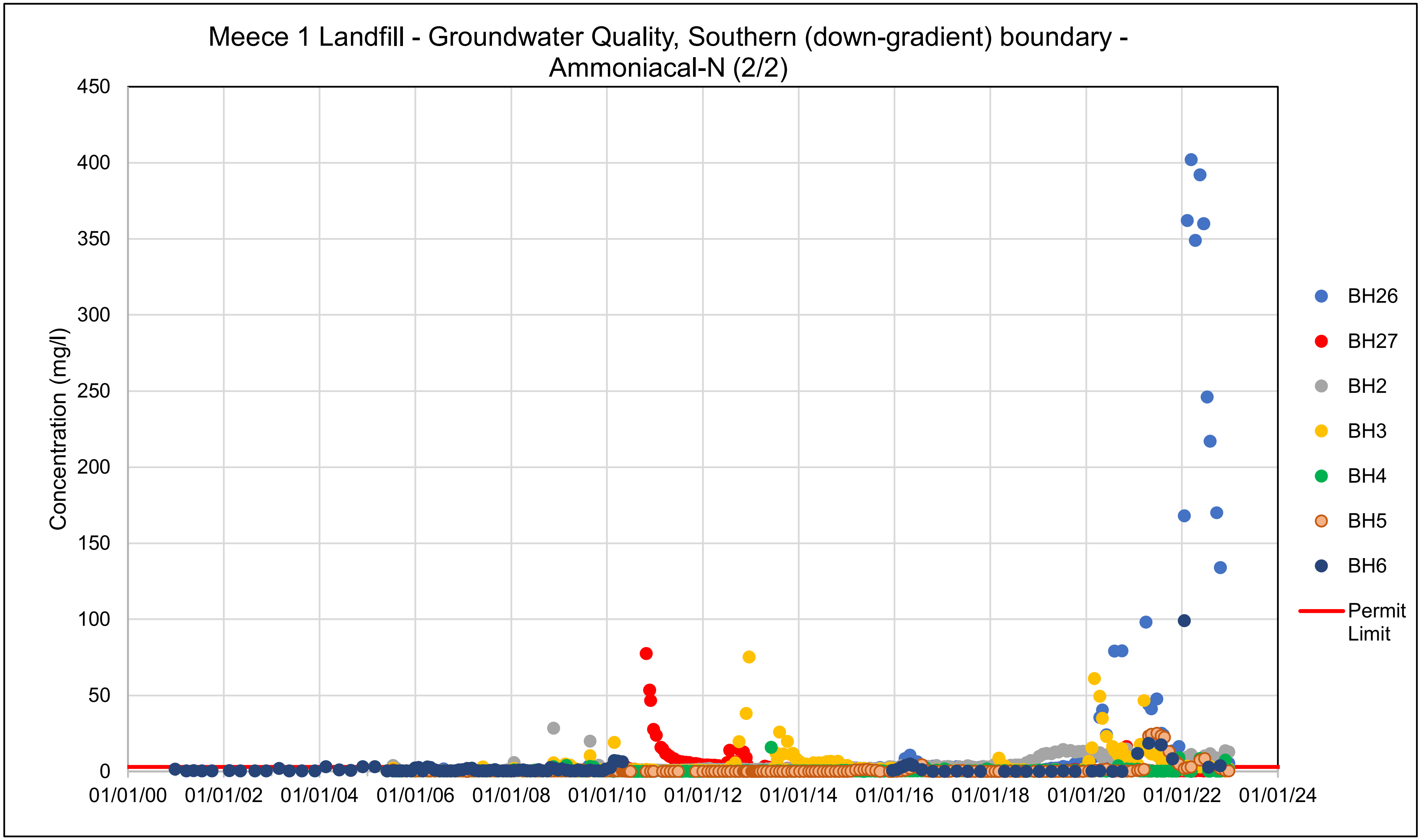
APPENDIX D

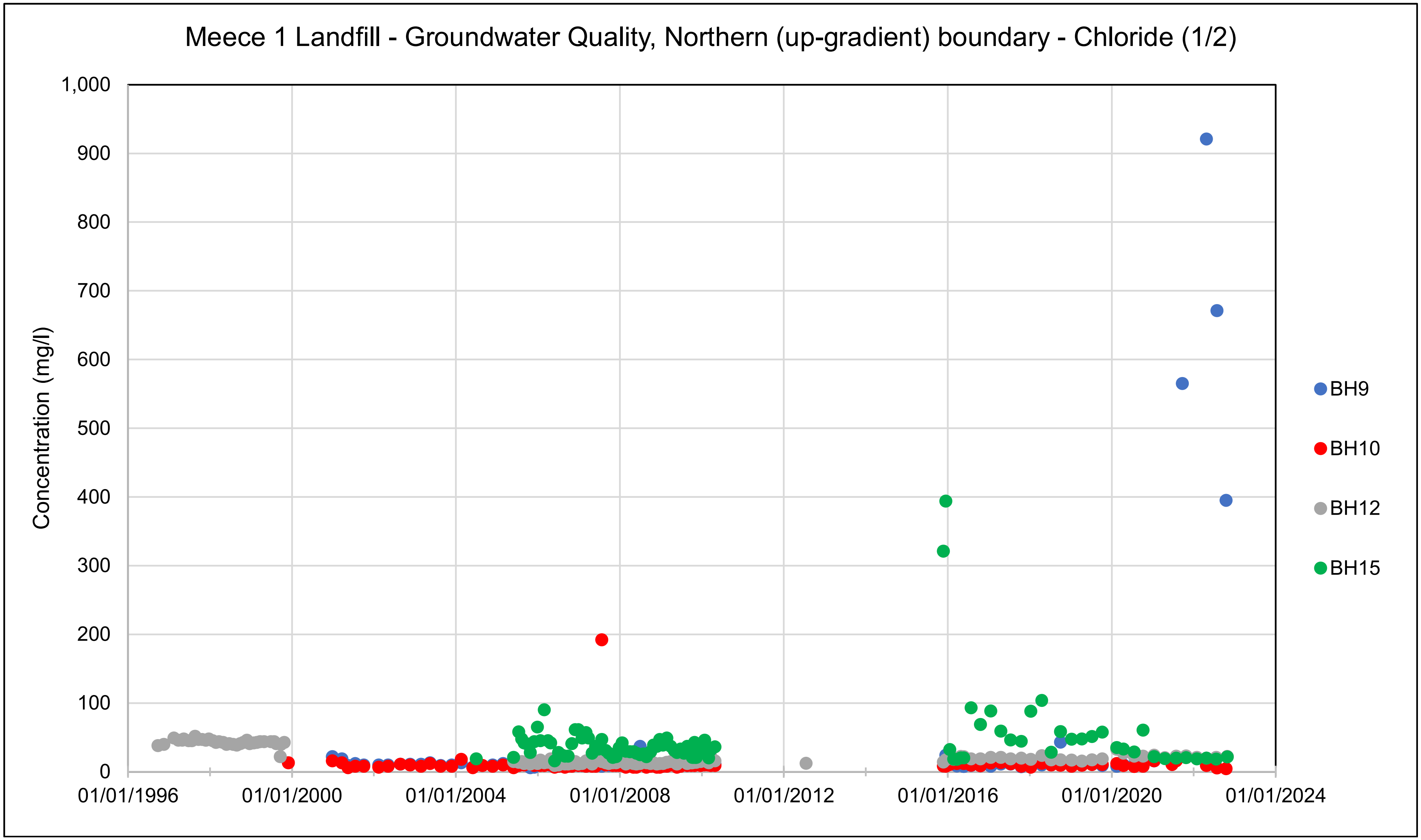


Meece 1 Landfill - Groundwater Quality, Northern (up-gradient) boundary - Ammoniacal-N
Concentration (mg/l)
160
140
120
100
80
60
40
20
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
BH9
BH10
BH12
BH13
BH15

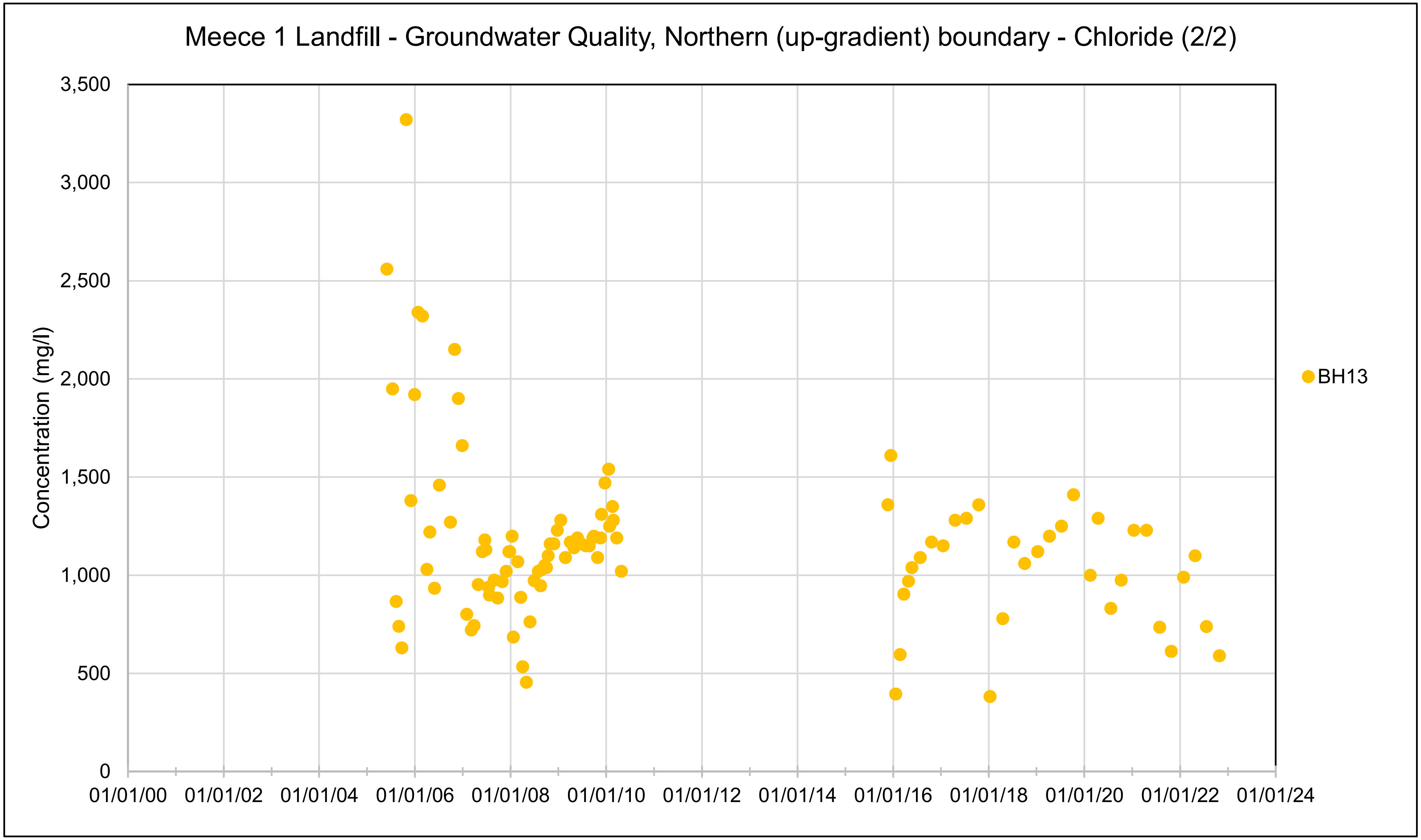


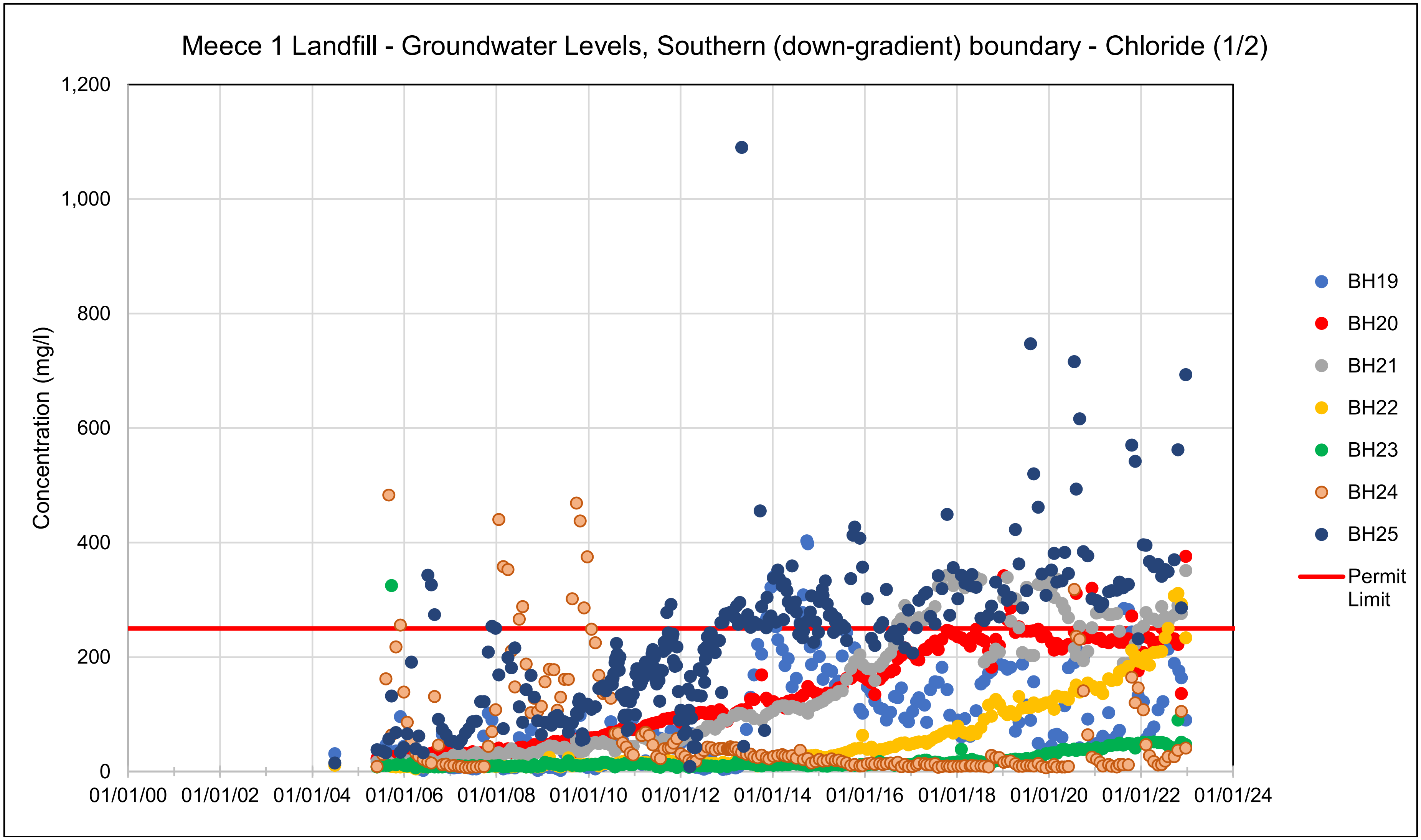
Meece 1 Landfill - Groundwater Quality, Southern (down-gradient) boundary - Ammoniacal-N (1/2)
Elevated results (>20mg/l) at BH25 in 2019 omitted for clarity
Concentration (mg/l)
0
2
4
6
8
10
12
14
16
18
20
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH19
BH20
BH21
BH22
BH23
BH24
BH25
Permit Limit

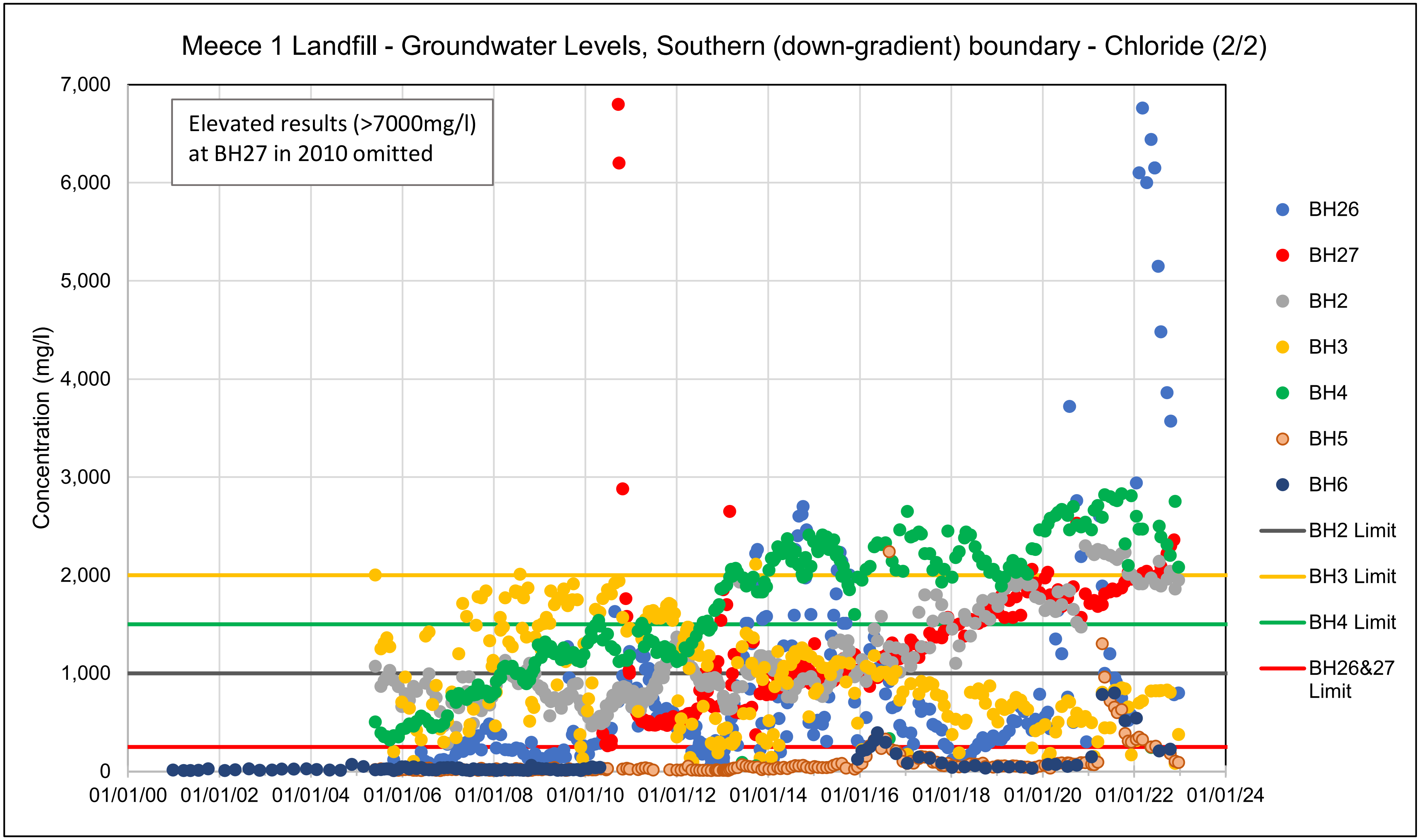

Meece 1 Landfill - Groundwater Quality, Southern (down-gradient) boundary - Ammoniacal-N (2/2)
Concentration (mg/l)
450
400
350
300
250
200
150
100
50
0
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH26
BH27
BH2
BH3
BH4
BH5
BH6
Permit Limit



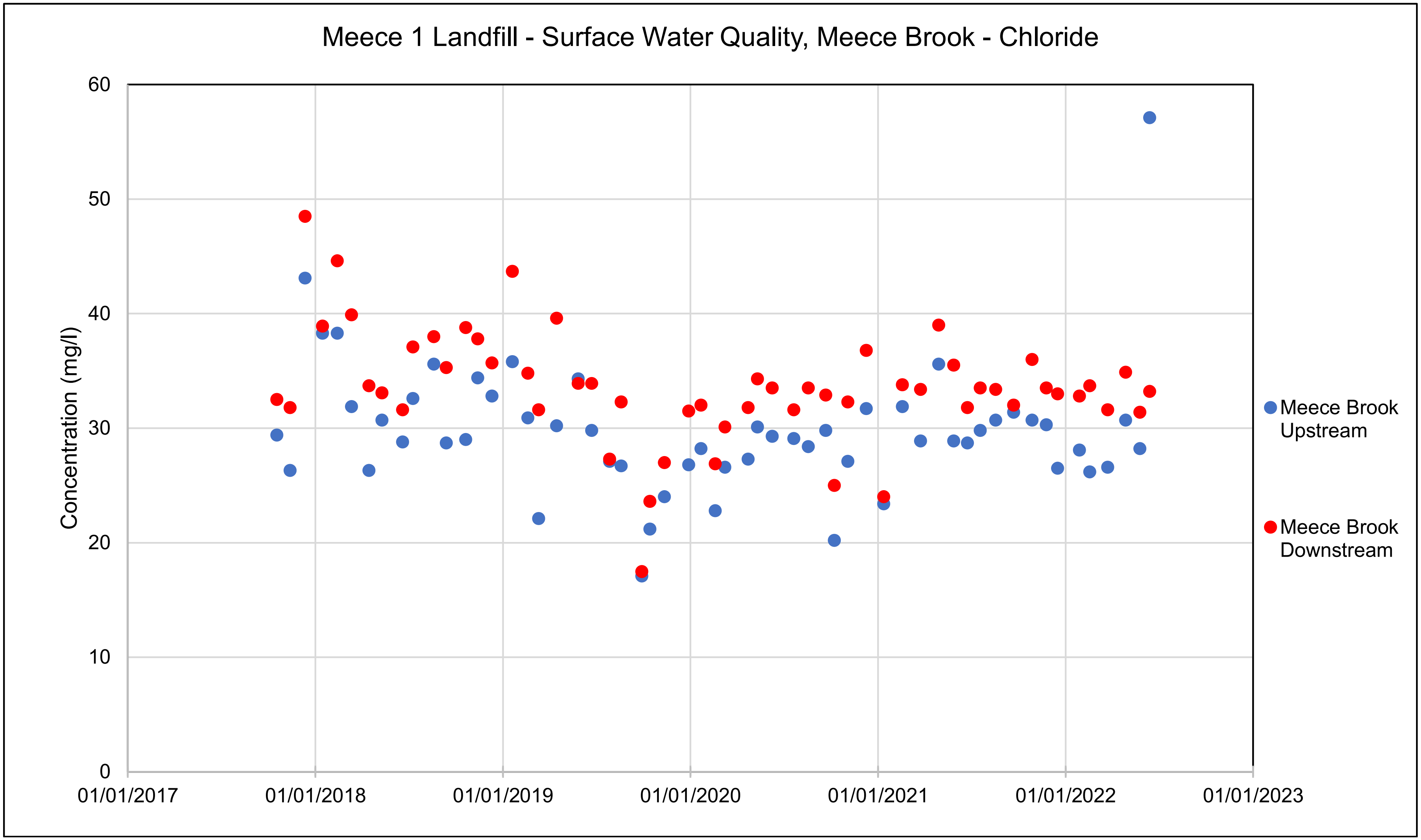
Meece 1 Landfill - Groundwater Quality, Northern (up-gradient) boundary - Chloride (1/2)
Concentration (mg/l)
1,000
900
800
700
600
500
400
300
200
100
0
01/01/1996
01/01/2000
01/01/2004
01/01/2008
01/01/2012
01/01/2016
01/01/2020
01/01/2024
BH9
BH10
BH12
BH15


Meece 1 Landfill - Groundwater Quality, Northern (up-gradient) boundary - Chloride (2/2)
Concentration (mg/l)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH13

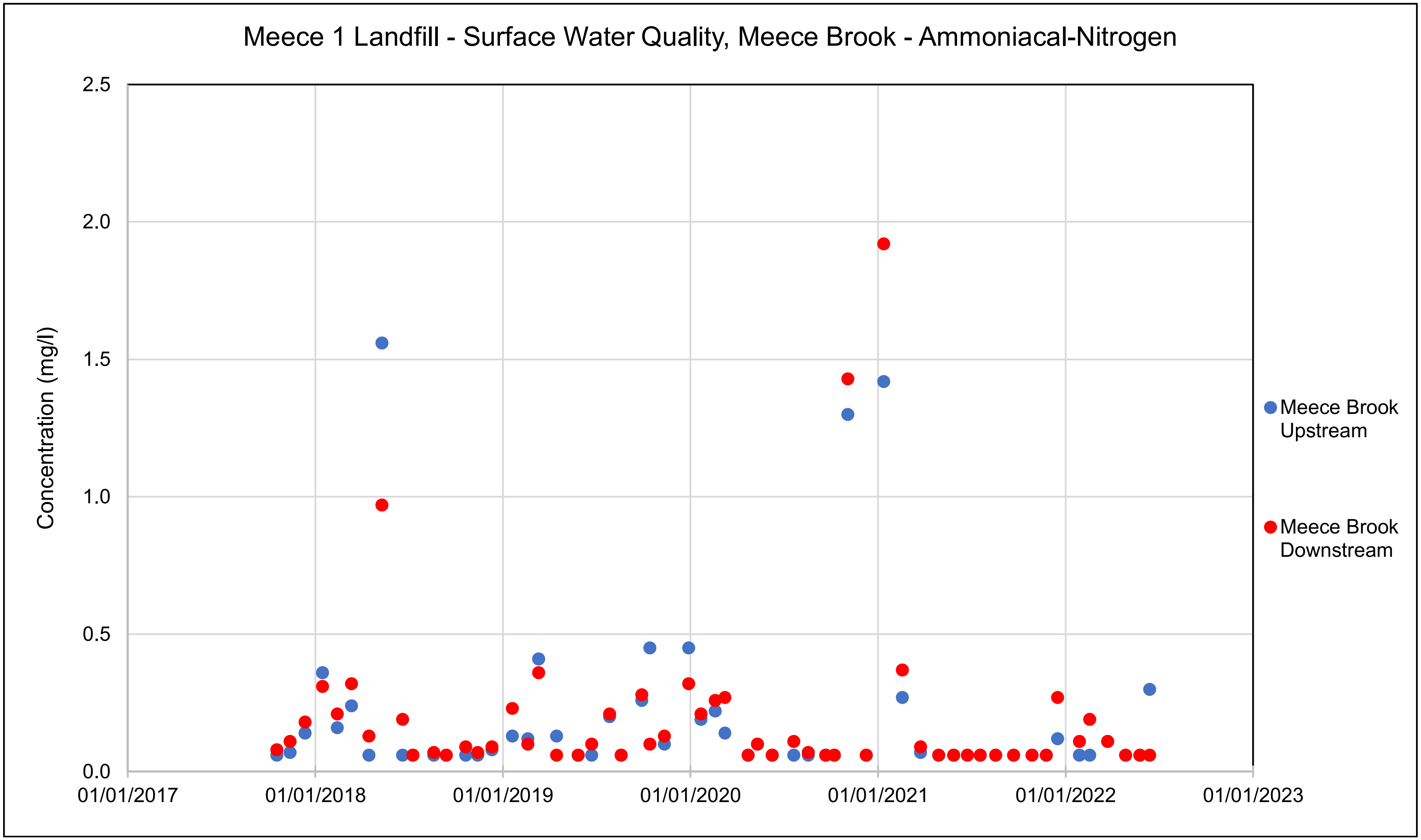

Meece 1 Landfill - Groundwater Levels, Southern (down-gradient) boundary - Chloride (1/2)
Concentration (mg/l)
1,200
1,000
800
600
400
200
0
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH19
BH20
BH21
BH22
BH23
BH24
BH25
Permit Limit


Meece 1 Landfill - Groundwater Levels, Southern (down-gradient) boundary - Chloride (2/2)
Elevated results (>7000mg/l) at BH27 in 2010 omitted
Concentration (mg/l)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12
01/01/14
01/01/16
01/01/18
01/01/20
01/01/22
01/01/24
BH26
BH27
BH2
BH3
BH4
BH5
BH6
BH2 Limit
BH3 Limit
BH4 Limit
BH26&27 Limit

APPENDIX E



Meece 1 Landfill - Surface Water Quality, Meece Brook - Chloride
Concentration (mg/l)
60
50
40
30
20
10
0
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
01/01/2022
01/01/2023
Meece Brook Upstream
Meece Brook Downstream



Meece 1 Landfill - Surface Water Quality, Meece Brook - Ammoniacal-Nitrogen
Concentration (mg/l)
2.5
2.0
1.5
1.0
0.5
0.0
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
01/01/2022
01/01/2023
Meece Brook Upstream
Meece Brook Downstream

APPENDIX F

APPENDIX F – REVIEW OF THE 2017 HRA REVIEW LANDSIM MODEL PARAMETERISATION

SITE GEOMETRY AND CHARACTERISTICS				
Parameter	**2017 HRA Review Value**	**Derivation (2017 HRA Review)**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Parameters common to all landfill phases:				
Infiltration to open waste (mm/year)	230 ± 23 Normal Distribution	After Entec 1997 Groundwater Risk Assessment	Remains applicable	As 2017 HRAR
Cap Infiltration rate following site restoration (mm/year)	50 ± 5 Normal Distribution	After Entec 1997 Groundwater Risk Assessment	Remains applicable	As 2017 HRAR
Waste Field Capacity (fraction)	Min: 0.15 Mode: 0.20 Max: 0.25 Triangular Distribution	After Entec 1997 Groundwater Risk Assessment (assumed)	Remains applicable	As 2017 HRAR
Waste Porosity (fraction)	Min: 0.25 Mode: 0.30 Max: 0.40 Triangular Distribution	After Entec 1997 Groundwater Risk Assessment (assumed)	Remains applicable	As 2017 HRAR
Waste Density (kg/l)	Min: 0.6 Max: 1.0 Uniform Distribution	After Entec 1997 Groundwater Risk Assessment (assumed)	Remains applicable	As 2017 HRAR
Total Cap Area (hectares)	Phase 0: 7.20002 Phase 1: 2.7378 Phase 2: 2.924 Phase 3: 2.856 Phase 13a: 1.2544 Phase 4 & 5: 2.5001 Phase 6 & 7: 4.00023 Single Values	After site plans.	Remains applicable	As 2017 HRAR
Total Base Area (hectares)	Phase 0: 7.2 Phase 1: 2.7378 Phase 2: 2.924 Phase 3: 2.856 Phase 13a: 1.2544 Phase 4 & 5: 2.5 Phase 6 & 7: 4.0 Single Values	After site plans.	Remains applicable	As 2017 HRAR

Final Waste Thickness (m)	Phase Min Max 0 1 11.44 1 1 14.01 2 1 13.2 3 1 13.5 13a 1 12.5 4 & 5 1 15 6 & 7 1 20 Uniform Distribution	After site plans	Remains applicable	As 2017 HRAR
Leachate Head During Period of Management Control (m above liner)	Phase Min Max 0 1 2 4 & 5 0.01 0.8 6 & 7 0.01 1.0 Uniform Distribution Phase Value 1 2.0 2 2.0 3 2.0 13a 2.0 Single Values	Maximum based on proposed leachate head compliance limits	Phase Min Max 0 0.6 2 4 & 5 0.01 1.5 6 & 7 0.01 1.0 Uniform Distribution Phase Value 1 2.0 2 2.0 3 2.0 13a 1.0 Single Values	After updated conceptual site model (Table 9 of HRA Review, (maximum for Phases 4&5 and 6&7 increased to allow for natural groundwater level variation). Maximum based on proposed compliance limits (as head on base of site or head above local groundwater level)
Head of Leachate when Surface Water Breakout Occurs (m)	Phase Value 0 1.66 1 9.51 2 9.7 3 8.0 13a 9.0 4&5 6.03 6&7 6.91 Single Values	After site plans	Remains applicable	As 2017 HRAR
End of Landfilling (years from start of waste disposal)	Phase Value 0 1.0 1 1.0 2 2.0 3 1.0 13a 2.0 4&5 2.0 6&7 2.0 Single Values	After Entec 1997 Groundwater Risk Assessment (assumed)	Assumed to remain applicable	As 2017 HRAR
Duration of Management Control (years from start of waste disposal)	All phases: 20,000 Single Value	After Entec 1997 Groundwater Risk Assessment (assumed).	Remains applicable	As 2017 HRAR

LEACHATE SOURCE TERM				
Parameter	**2017 HRA Review Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Leachate Source Term Concentrations				
Ammoniacal-N (mg/l)	Phase min mode max 0 0.32 240.74 1110 1 0.095 9.36 921 2 0.39 1454.6 2480 3 9.25 948.18 2760 13a 122 1375.4 2270 4 & 5 2.41 2093.1 4280 6 & 7 807 3843.8 9310 Log Triangular Distribution	Revised source term derived in 2017 HRA Review, based on updated site monitoring data	Phase min mode max 0 0.32 407 1320 1 0.19 227 921 2 0.39 657 2480 3 9.25 885 2830 13a 99.3 1213 3640 4 & 5 0.5 1097 4280 6 & 7 400 3894 9310 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed)
Chloride (mg/l)	Phase min mode max 0 7.6 1103.2 10600 1 25 1991.3 13000 2 92 4527 13100 3 92 5520 14200 13a 866 16318 17700 4 & 5 209 15509 50200 6 & 7 2260 27651 46800 Log Triangular Distribution	Revised source term derived in 2017 HRA Review, based on updated site monitoring data	Phase min mode max 0 7.6 1303 4850 1 15.2 958 4710 2 53 3534 13100 3 92 4625 14800 13a 854 14400 27500 4 & 5 209 11994 54600 6 & 7 214 18408 44800 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed)
Nickel (mg/l)	Phase min mode max 0 0.0045 0.039 0.21 1 0.004 0.012 0.15 2 0.0015 0.11 0.36 3 0.001 0.069 0.28 13a 0.004 0.05 0.64 4 & 5 0.0025 0.031 0.374 6 & 7 0.045 0.25 0.63 Log Triangular Distribution	Revised source term derived in 2017 HRA Review, based on updated site monitoring data	Phase min mode max 0 0.0009 0.035 0.32 1 0.004 0.026 0.15 2 0.003 0.082 0.37 3 0.002 0.131 0.36 13a 0.004 0.071 0.641 4 & 5 0.0049 0.082 0.904 6 & 7 0.007 0.225 0.633 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed)
2,4 Dimethylphenol (mg/l)	Phase min mode max 0 5.0E-05 9.8E-04 0.01 1 5.0E-05 5.5E-04 0.02 2 5.0E-05 0.00695 0.05 3 5.0E-06 0.01369 0.05 13a 3.0E-04 0.00878 0.02 4 & 5 5.0E-05 0.01962 0.1 6 & 7 0.001 0.03728 0.1 Log Triangular Distribution	Revised source term derived in 2017 HRA Review, based on updated site monitoring data	Phase min mode max 0 1.0E-04 0.0012 0.01 1 1.0E-04 0.0026 0.01 2 1.0E-04 0.0065 0.034 3 1.0E-04 0.0053 0.0112 13a 3.0E-04 0.0086 0.0207 4 & 5 1.0E-04 0.0128 0.0783 6 & 7 1.0E-04 0.0161 0.0794 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed). Values <LRL assumed to equal LRL.

Cadmium (mg/l)	Phase min mode max 0 0.00015 0.000381 0.018 1 0.00015 0.00027 0.003 2 0.00015 0.00024 0.0039 3 0.00015 0.00022 0.0029 13a 0.00015 0.00095 0.0022 4 & 5 0.00015 0.0006 0.0038 6 & 7 0.00015 0.000754 0.0138 Log Triangular Distribution	Revised source term derived in 2017 HRA Review, based on updated site monitoring data	Phase min mode max 0 3.0E-04 0.0026 0.041 1 3.0E-04 0.0011 0.01 2 3.0E-04 0.0012 0.01 3 3.0E-04 0.00097 0.01 13a 3.0E-04 0.00429 0.041 4 & 5 3.0E-04 0.00238 0.043 6 & 7 3.0E-04 0.00116 0.0138 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed). Values <LRL assumed to equal LRL.
Arsenic (mg/l)	Not included in 2017 HRA Review		Phase min mode max 0 0.001 0.0065 0.075 1 0.001 0.0094 0.135 2 0.001 0.0191 0.215 3 0.001 0.0123 0.149 13a 0.0023 0.0695 0.484 4 & 5 0.001 0.0388 0.36 6 & 7 0.013 0.115 0.303 Log Triangular Distribution	After review of all site monitoring data, up to June 2021, for individual phases (outliers removed). Values <LRL assumed to equal LRL.

Parameter	**2017 HRA Review Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Values of m and c used to calculate the kappa value				
Ammoniacal-N (kg/l)	m = 0 c = 0.59	After LandSim 2.5 default values.	Remains applicable	As 2017 HRAR
Chloride (kg/l)	m = 0.0298 c = 0.2919			
Nickel (kg/l)	m = 0.0987 c = -0.1479			
Cadmium (kg/l)	m = 0.0823 c = 0.1589			
Arsenic (kg/l)	Not included in 2017 HRA Review		m = 0.0415 c = -0.0862	After LandSim 2.5 default values.
Half-life (years) (decline in contaminant concentration in leachate)				
2,4 Dimethylphenol (kg/l)	10 Single Value	After LandSim 2.5 default value for VOCs	Remains applicable	As 2017 HRAR

ENGINEERED LINING SYSTEM				
Parameter	**2017 HRA Review Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Type of Engineered Lining System	Phase 0: No engineered barrier Phases 1, 2, 6&7: Clay & HDPE Phases 3, 13a: Clay barrier Phases 4&5: Clay & GCL barrier	After site development information	Remains applicable	As 2017 HRAR
Thickness of Clay Liner (m)	Phase Min Max 1 0.5 1.0 Uniform Distribution Phase Value 2 0.5 3 1.0 13a 1.0 4 & 5 0.5 6 & 7 1.0 Single Value	After 2008 HRAR and CQA data	Remains applicable	As 2017 HRAR
Moisture Content (fraction)	Min: 0.203 Max: 0.421 Uniform Distribution	After 2008 HRAR and CQA data	Remains applicable	As 2017 HRAR
Density (kg/l)	Min: 1.61 Max: 2.07 Uniform Distribution	After 2008 HRAR and CQA data	Remains applicable	As 2017 HRAR

Hydraulic Conductivity (m/s)	Phases 1, 2 & 3: Min: 1.52E-11 Max: 5.9E-10 Log Uniform Distribution Phase 13a: Min: 1.52E-11 Max: 2.22E-10 Log Uniform Distribution Phase 4 & 5: 8.69E-10 (single value) Phase 6 & 7: Min: 4.3E-11 Most likely: 1.23E-10 Max: 8.7E-10 Log Triangular Distribution	Phase 1: after CQA reports from later phases. Phase 2, 3 & 13a: after CQA reports Phase 4&5: calculated from known hydraulic conductivity of the GCL and clay Phase 6&7: from CQA report	Remains applicable	As 2017 HRAR
Longitudinal Dispersivity (m)	Phase Min Max 1 0.05 0.1 Uniform Distribution Phase Value 2 0.05 3 0.1 13a 0.1 4 & 5 0.05 6 & 7 0.1 Single Value	After LandSim approach (10% of pathway length)	Remains applicable	As 2017 HRAR
HDPE Defects (per Ha) Pinholes: Holes: Tears: Pinholes: Holes: Tears:	Phase 1: Min Most Likely Max 0 750 0 150 0 0.5 10 Triangular Distribution Phases 2, 6&7: Min Most Likely Max 0 25 0 5 0 0.1 2 Triangular Distribution	Based on LandSim default values assuming no CQA for Phase 1 and CQA for Phases 2, 6&7.	Remains applicable	As 2017 HRAR

BIODEGRADATION AND RETARDATION PARAMATERS ASSUMED WITHIN THE ENGINEERED CLAY LINER				
Parameter	**2017 HRAR Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Retardation Parameters				
Fraction of Organic Carbon	Min: 0.0001 Average: 0.0006 Max: 0.009 Triangular Distribution	After site specific data for the Mercia Mudstone	Remains applicable	As 2017 HRAR
Ammoniacal-N Kd (l/kg)	Min: 0.5 Max: 5.0 Uniform Distribution	After NGWCLC report, 2003 (*Review of ammonium attenuation in soil and groundwater)*	Remains applicable	As 2017 HRAR
Chloride Kd (l/kg)	0 Single Value	No retardation assumed	Remains applicable	As 2017 HRAR
Nickel Kd (l/kg)	Min: 20 Max: 800 Uniform Distribution	LandSim defaults for sand and loam soils	Remains applicable and worse case	As 2017 HRAR
Cadmium Kd (l/lg)	Min: 281 Average: 1052 Max: 2337 Triangular Distribution	After US EPA	Remains applicable	As 2017 HRAR
2,4 Dimethylphenol Koc (l/kg)	430 Single Value	Value from TOXNET	Remains applicable	As 2017 HRAR
Arsenic Kd (l/kg)	Not included in 2017 HRA Review		Min: 25 Max: 250 Uniform Distribution	LandSim defaults for sand and loam soils
Degradation Half Lives				
Ammoniacal-N, Chloride, Nickel, Cadmium 2,4 Dimethylphenol half-life (years)	$1x10^9$ Single Value	No degradation assumed	Remains applicable (and worse case for 2,4 Dimethylphenol)	As 2017 HRAR
Arsenic half-life (years)	Not included in 2017 HRA Review		$1x10^9$ Single Value	No degradation assumed

UNSATURATED PATHWAY – MERCIA MUDSTONE				
Parameter	**2017 HRA Review Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Unsaturated Pathway Thickness (m)	Phase Min Max 0 1E-10 2.4 1 1E-10 0.94 2 1E-10 1.02 3 1E-10 0.2 Uniform Distribution Phase 13a: 1.2 Phase 4&5: 1E-10 Phase 6&7: 1E-10 Single Values	Based on updated conceptual site model	Phase Min Max 0 1E-10 2.0 1 1E-10 0.8 2 1E-10 0.5 3 1E-10 0.5 Uniform Distribution Phase 13a: 1.0 Phase 4&5: 1E-10 Phase 6&7: 1E-10 Single Values	After updated conceptual site model (Table 9 of HRA Review, allowing for natural groundwater level variation) and hydrogeological cross-sections (Drawing 2 of HRA Review)
Density (kg/l)	Min: 1.61 Max: 2.07 Uniform Distribution	After ConSim default values	Remains applicable	As 2017 HRAR
Hydraulic Conductivity (m/s)	Phase 0: Min: 1.4E-07 Max: 5.0E-07 Phases 1,2,3,13a,4&5,6&7: Min: 1.4E-07 Max: 3.6E-06 Log Uniform Distribution	Phase 0: after natural range reported for Mercia Mudstone with upper end of range limited to reflect reworking of the clay. Remaining phases: after site-specific hydraulic conductivity values.	Remains applicable	As 2017 HRAR
Moisture Content (fraction)	Min: 0.203 Max: 0.421 Uniform Distribution	After 2008 HRAR and CQA data	Remains applicable	As 2017 HRAR
Longitudinal Dispersion	Phase Min Max 0 1E-11 0.19 1 1E-11 0.094 2 1E-11 0.072 3 1E-11 0.02 13a 0.03 0.06 4&5 1E-11 0.072 6&7 1E-11 0.02 Uniform Distribution	LandSim approach (10% of pathway length) (It is noted that the input values do not all correspond to 10% of pathway length)	Phase Min Max 0 1E-11 0.2 1 1E-11 0.08 2 1E-11 0.05 3 1E-11 0.05 Uniform Distribution Phase 13a: 0.1 Phase 4&5: 1E-11 Phase 6&7: 1E-11 Single Values	LandSim approach (10% of pathway length)

BIODEGRADATION AND RETARDATION PARAMATERS ASSUMED WITHIN THE UNSATURATED PATHWAY				
Parameter	**2017 HRAR Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Retardation Parameters				
Fraction of Organic Carbon	Min: 0.0001 Most Likely: 0.0006 Max: 0.009 Log Triangular Distribution	Based on site specific data	Remains applicable	As 2017 HRAR
Ammoniacal-N Kd (l/kg)	Min: 0.5 Max: 5.0 Uniform Distribution	After NGWCLC report, 2003 (*Review of ammonium attenuation in soil and groundwater)*	Remains applicable	As 2017 HRAR
Chloride Kd (l/kg)	0 Single Value	No retardation assumed	Remains applicable	As 2017 HRAR
Nickel Kd (l/kg)	Min: 20 Max: 800 Uniform Distribution	LandSim defaults for sand and loam soils	Remains applicable	As 2017 HRAR
Cadmium Kd (l/kg)	Min: 281 Average: 1052 Max: 2337 Triangular Distribution	After US EPA	Remains applicable	As 2017 HRAR
Arsenic Kd (l/kg)	Not included in 2017 HRA Review		Min: 25 Max: 250 Uniform Distribution	LandSim defaults for sand and loam soils
2,4 Dimethylphenol Koc (l/kg)	430 Single Value	Value from TOXNET	Remains applicable	As 2017 HRAR
Degradation Half Lives				
Ammoniacal-N, Chloride, Nickel, Cadmium, 2,4 Dimethylphenol half-life (years)	$1x10^9$ Single Value	No degradation assumed	Remains applicable	As 2017 HRAR
Arsenic half-life (years)	Not included in 2017 HRA Review		$1x10^9$ Single Value	No degradation assumed

AQUIFER PATHWAY (MERCIA MUDSTONE)				
Parameter	**2017 HRAR Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Mixing Zone Thickness (m)	Min: 5 Max: 20 Uniform Distribution	After previous HRAs for the site (assumed)	Remains applicable	As 2017 HRAR
Pathway Width (m)	Phase Value 0 360 1 160 2 210 3 210 13a 105 4&5 125 6&7 200 Single Values	Width of pathway perpendicular to groundwater flow.	Remains applicable	As 2017 HRAR
Pathway Length (m)	Phases 0, 4&5, 6&7: Min: 1500 Max: 1700 Phases 1, 2, 3, 13a: Min: 1700 Max: 1870 Uniform Distribution	After site geometry, assuming compliance point is Meece Brook	Remains applicable	As 2017 HRAR
Hydraulic Conductivity (m/s)	Min: 1.97×10^{-6} Max: 3.94×10^{-5} Uniform Distribution	After slug tests undertaken within site boreholes and water balance calculations.	Remains applicable	As 2017 HRAR
Hydraulic Gradient	Min: 0.011 Max: 0.013 Uniform Distribution	Based on site monitoring data and inferred groundwater contours for July 2001 and February 2002.	Remains applicable based on latest site monitoring data	As 2017 HRAR
Pathway Porosity (fraction)	Min: 0.15 Max: 0.421 Uniform Distribution	After previous HRAs for the site (assumed)	Remains applicable	As 2017 HRAR
Longitudinal Dispersion (m)	Min: 150 Max: 200 Uniform Distribution	LandSim approach (10% of pathway length). Pathway length based on distance to Meece Brook.	Remains applicable	As 2017 HRAR

Transverse Dispersion (m)	Min: 50 Max: 67 Uniform Distribution	LandSim approach (3% of pathway length). Pathway length based on distance to Meece Brook.	Remains applicable	As 2017 HRAR
BIODEGRADATION AND RETARDATION PARAMATERS ASSUMED WITHIN AQUIFER PATHWAY (MERCIA MUDSTONE)				
Parameter	**2017 HRAR Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Retardation Parameters				
Ammoniacal-N Kd (l/kg)	Min: 0.5 Max: 5.0 Uniform Distribution	After NGWCLC report, 2003 (*Review of ammonium attenuation in soil and groundwater)*	Remains applicable	As 2017 HRAR
Chloride Kd (l/kg)	0 Single Value	No retardation assumed	Remains applicable	As 2017 HRAR
Nickel Kd (l/kg)	Min: 20 Max: 800 Uniform Distribution	LandSim defaults for sand and loam soils.	Remains applicable	As 2017 HRAR
Cadmium Kd (l/kg)	Min: 281 Average: 1052 Max: 2337 Triangular Distribution	After US EPA	Remains applicable	As 2017 HRAR
Arsenic Kd (l/kg)	Not included in 2017 HRA Review		Min: 25 Max: 250 Uniform Distribution	LandSim defaults for sand and loam soils.
Fraction of Organic Carbon	Min: 0.0001 Most Likely: 0.0006 Max: 0.009 Triangular Distribution	After Sherwood et al, 1966 and site specific data	Remains applicable	As 2017 HRAR
Pathway density (kg/l)	Min: 1.61 Max: 2.07 Uniform Distribution	After ConSim default values	Remains applicable	As 2017 HRAR
Degradation Half Lives				
Ammoniacal-N half-life (years)	Min: 5 Max: 10 Uniform Distribution	After NGWCLC report, 2003 (*Review of ammonium attenuation in soil and groundwater)*	Remains applicable	As 2017 HRAR
Chloride, Nickel, Cadmium, 2,4 Dimethylphenol half-life (years)	$1x10^9$ Single Value	No degradation assumed	Remains applicable	As 2017 HRAR
Arsenic half-life (years)	Not included in 2017 HRA Review		$1x10^9$ Single Value	No degradation assumed

BACKGROUND GROUNDWATER QUALITY				
Parameter	**2017 HRA Review Value**	**Derivation**	**Review for 2022 HRAR**	**2022 HRAR Derivation**
Ammoniacal-N (mg/l)	Min: 0.15 Most Likely: 0.19 Max: 3.1 Log Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 and BH12	Min: 0.04 Most Likely: 0.28 Max: 3.1 Log Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 & BH12 with outliers removed. Data from pre-2000 ignored as appears unreliable. Recent (2021/22) data for BH9 also ignored as groundwater quality is locally impacted. Values <LRL assumed to equal LRL (applies to cadmium, nickel and ammoniacal-N only)
Chloride (mg/l)	Min: 7 Most Likely: 11.5 Max: 37 Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 and BH12	Min: 6 Most Likely: 12.2 Max: 43.2 Triangular Distribution	
Nickel (mg/l)	Min: 0.00015 Most Likely: 0.00031 Max: 0.0011 Log Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 and BH12	Min: 0.0009 Most Likely: 0.005 Max: 0.05 Log Triangular Distribution	
Cadmium (mg/l)	Min: 0.00015 Most Likely: 0.00031 Max: 0.0011 Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 and BH12	Min: 0.0003 Most Likely: 0.00064 Max: 0.006 Triangular Distribution	
2,4 Dimethylphenol (mg/l)	Not present in background groundwater	Not detected in up-gradient boreholes BH9, BH10 and BH12	Not present in background groundwater	After review of all site monitoring data. Not detected in up-gradient boreholes BH9, BH10 and BH12
Arsenic (mg/l)	Not included in 2017 HRA Review		Min: 0.001 Most Likely: 0.0029 Max: 0.0056 Triangular Distribution	Based on site specific data for up-gradient boreholes BH9, BH10 & BH12 with outliers removed. Data from pre-2000 ignored as appears unreliable. Recent (2021/22) data for BH9 also ignored as groundwater quality is locally impacted.

APPENDIX G

Calculation Settings

Number of iterations: 201

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Retarded values used for simulation

Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Ammoniacal_N
c (kg/l): 0.59
Non-Volatile
m (kg/l): 0

Arsenic
c (kg/l): -0.0862
Non-Volatile
m (kg/l): 0.0415

Cadmium
c (kg/l): 0.1589
Non-Volatile
m (kg/l): 0.0823

Chloride
c (kg/l): 0.2919
Non-Volatile
m (kg/l): 0.0298

Nickel
c (kg/l): -0.1479
Non-Volatile
m (kg/l): 0.0987

2,4 Dimethylphenol
Half life (years): 10
Volatile

Contaminant Half-lives (years)

Clay Liner:	
Ammoniacal_N	SINGLE(1e+009)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Nickel	SINGLE(1e+009)
2,4 Dimethylphenol	SINGLE(1e+009)
Unsaturated Pathway:	
Ammoniacal_N	SINGLE(1e+009)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Nickel	SINGLE(1e+009)
2,4 Dimethylphenol	SINGLE(1e+009)
Aquifer Pathway:	
Ammoniacal_N	UNIFORM(5,10)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Nickel	SINGLE(1e+009)
2,4 Dimethylphenol	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Refer to parameterisation table

All units in milligrams per litre

Ammoniacal_N	LOGTRIANGULAR(0.04,0.28,3.1)
Arsenic	TRIANGULAR(0.001,0.0029,0.0056)
Cadmium	TRIANGULAR(0.0003,0.00064,0.006)
Chloride	TRIANGULAR(6,12.2,43.2)
Nickel	LOGTRIANGULAR(0.0009,0.005,0.05)

Phase: Phase 0

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	1

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	120
Cell length (m):	120
Cell top area (ha):	1.44
Cell base area (ha):	1.44
Number of cells:	5
Total base area (ha):	7.2
Total top area (ha):	7.20002
Head of Leachate when surface water breakout occurs (m)	SINGLE(1.66)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,11.44)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(0.32,407,1320)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.001,0.0065,0.075)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0003,0.0026,0.041)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(7.6,1303,4850)
	Data are spot measurements of Leachate Quality
Nickel	LOGTRIANGULAR(0.0009,0.035,0.32)
	Data are spot measurements of Leachate Quality
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0012,0.01)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.6,2)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is no barrier

Justification for Engineered Barrier Type
Phase 0 is an unlined area of the site.

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(1e-010,2)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,5e-007)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	UNIFORM(1e-011,0.2)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species
Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1500,1700)
Pathway width (m):	SINGLE(360)

Phase: Phase 1

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	1

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	117
Cell length (m):	117
Cell top area (ha):	1.3689
Cell base area (ha):	1.3689
Number of cells:	2
Total base area (ha):	2.7378
Total top area (ha):	2.7378
Head of Leachate when surface water breakout occurs (m)	SINGLE(9.51)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,14.01)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(0.19,227,921) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.001,0.0094,0.135) *Data are spot measurements of Leachate Quality*
Cadmium	LOGTRIANGULAR(0.0003,0.0011,0.01) *Substance to be treated as List 1*
Chloride	LOGTRIANGULAR(15.2,958,4710) *Data are spot measurements of Leachate Quality*
Nickel	LOGTRIANGULAR(0.004,0.026,0.15) *Data are spot measurements of Leachate Quality*
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0026,0.01) *Substance to be treated as List 1*

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.

Head on EBS is given as (m):	SINGLE(2)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Liner NOT installed under CQA	
Design thickness of clay (m):	UNIFORM(0.5,1)
Density of clay (kg/l):	UNIFORM(1.61,2.07)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	UNIFORM(0.05,0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 750
Holes:	Minimum 0, Maximum 150
Tears:	Minimum 0, Most Likely 0.5, Maximum 10

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Refer to parameterisation table

Hydraulic conductivity of mineral lower liner (m/s):	LOGUNIFORM(1.52e-011,5.9e-010)

Justification for Composite: Clay or BES Substrate Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(1e-010,0.8)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	UNIFORM(1e-011,0.08)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway	
Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species
Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1700,1870)
Pathway width (m):	SINGLE(160)

Phase: Phase 2

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	85
Cell length (m):	86
Cell top area (ha):	0.731
Cell base area (ha):	0.731
Number of cells:	4
Total base area (ha):	2.924
Total top area (ha):	2.924
Head of Leachate when surface water breakout occurs (m)	SINGLE(9.7)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,13.2)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(0.39,657,2480) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.001,0.0191,0.215) *Data are spot measurements of Leachate Quality*
Cadmium	LOGTRIANGULAR(0.0003,0.0012,0.01) *Substance to be treated as List 1*
Chloride	LOGTRIANGULAR(53,3534,13100) *Data are spot measurements of Leachate Quality*
Nickel	LOGTRIANGULAR(0.003,0.082,0.37) *Data are spot measurements of Leachate Quality*
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0065,0.034) *Substance to be treated as List 1*

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(2)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	UNIFORM(1.61,2.07)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Refer to parameterisation table

Hydraulic conductivity of mineral lower liner (m/s): LOGUNIFORM(1.52e-011,5.9e-010)

Justification for Composite: Clay or BES Substrate Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(1e-010,0.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	UNIFORM(1e-011,0.05)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species

Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1725.5,1864.5)
Pathway width (m):	SINGLE(210)

Phase: Phase 3

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	1

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	119
Cell length (m):	120
Cell top area (ha):	1.428
Cell base area (ha):	1.428
Number of cells:	2
Total base area (ha):	2.856
Total top area (ha):	2.856
Head of Leachate when surface water breakout occurs (m)	SINGLE(8)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,13.5)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(9.25,885,2830)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.001,0.0123,0.149)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0003,0.00097,0.01)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(92,4625,14800)
	Data are spot measurements of Leachate Quality
Nickel	LOGTRIANGULAR(0.002,0.131,0.36)
	Data are spot measurements of Leachate Quality
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0053,0.0112)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(2)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	UNIFORM(1.61,2.07)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)

Justification for Clay: Liner Thickness
Refer to parameterisation table

Hydraulic conductivity of liner (m/s):	UNIFORM(1.52e-011,5.9e-010)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(1e-010,0.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	UNIFORM(1e-011,0.05)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species
Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1717,1853)
Pathway width (m):	SINGLE(210)

Phase: Phase 13a

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	112
Cell length (m):	112
Cell top area (ha):	1.2544
Cell base area (ha):	1.2544
Number of cells:	1
Total base area (ha):	1.2544
Total top area (ha):	1.2544
Head of Leachate when surface water breakout occurs (m)	SINGLE(9)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,12.5)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(99.3,1213,3640) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.0023,0.0695,0.484) *Data are spot measurements of Leachate Quality*
Cadmium	LOGTRIANGULAR(0.0003,0.00429,0.041) *Substance to be treated as List 1*
Chloride	LOGTRIANGULAR(854,14400,27500) *Data are spot measurements of Leachate Quality*
Nickel	LOGTRIANGULAR(0.004,0.071,0.641) *Data are spot measurements of Leachate Quality*
2,4 Dimethylphenol	LOGTRIANGULAR(0.0003,0.0086,0.0207) *Substance to be treated as List 1*

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	UNIFORM(1.61,2.01)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)

Justification for Clay: Liner Thickness
Refer to parameterisation table

Hydraulic conductivity of liner (m/s):	LOGUNIFORM(1.52e-011,2.22e-010)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species
Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1725.5,1844.5)
Pathway width (m):	SINGLE(105)

Phase: Phase 4 and 5

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration
Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	125
Cell length (m):	200
Cell top area (ha):	2.5001
Cell base area (ha):	2.5
Number of cells:	1
Total base area (ha):	2.5
Total top area (ha):	2.5001
Head of Leachate when surface water breakout occurs (m)	SINGLE(6.03)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,15)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry
Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(0.5,1097,4280)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.001,0.0388,0.36)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0003,0.00238,0.043)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(209,11994,54600)
	Data are spot measurements of Leachate Quality
Nickel	LOGTRIANGULAR(0.0049,0.082,0.904)
	Data are spot measurements of Leachate Quality
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0128,0.0783)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.

Head on EBS is given as (m): UNIFORM(0.01,1.5)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	UNIFORM(1.61,2.07)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)

Justification for Clay: Liner Thickness
Refer to parameterisation table

Hydraulic conductivity of liner (m/s):	SINGLE(8.69e-010)
Pathway longitudinal dispersivity (m):	SINGLE(0.05)

Justification for Clay: Hydraulics Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Mercia Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1e-010)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s):	LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m):	SINGLE(1e-011)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species
Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1500,1700)
Pathway width (m):	SINGLE(125)

Phase: Phase 6 and 7

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,5)
Infiltration to waste (mm/year):	NORMAL(230,23)
End of filling (years from start of waste deposit):	2

Justification for Specified Infiltration

Refer to parameterisation table

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	100
Cell length (m):	200
Cell top area (ha):	2.00011
Cell base area (ha):	2
Number of cells:	2
Total base area (ha):	4
Total top area (ha):	4.00023
Head of Leachate when surface water breakout occurs (m)	SINGLE(6.91)
Waste porosity (fraction)	TRIANGULAR(0.25,0.3,0.4)
Final waste thickness (m):	UNIFORM(1,20)
Field capacity (fraction):	TRIANGULAR(0.15,0.2,0.25)
Waste dry density (kg/l)	UNIFORM(0.6,1)

Justification for Landfill Geometry

Refer to parameterisation table

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	TRIANGULAR(400,3894,9310)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.013,0.115,0.303)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0003,0.00116,0.0138)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(214,18408,44800)
	Data are spot measurements of Leachate Quality
Nickel	LOGTRIANGULAR(0.007,0.225,0.633)
	Data are spot measurements of Leachate Quality
2,4 Dimethylphenol	LOGTRIANGULAR(0.0001,0.0161,0.0794)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Refer to parameterisation table

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.01,1)

Justification for Specified Head
Refer to parameterisation table

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Refer to parameterisation table

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	UNIFORM(1.61,2.07)
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s):	LOGTRIANGULAR(4.3e-011,1.23e-010,8.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Refer to parameterisation table

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Liner Kd Values by Species
Refer to parameterisation table

Merica Mudstone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1e-010)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.203,0.421)
Pathway Density (kg/l):	UNIFORM(1.61,2.07)

Justification for Unsat Zone Geometry
Refer to parameterisation table

Pathway hydraulic conductivity values (m/s): LOGUNIFORM(1.4e-007,3.6e-006)

Justification for Unsat Zone Hydraulics Properties
Refer to parameterisation table

Pathway longitudinal dispersivity (m): SINGLE(1e-011)

Justification for Unsat Zone Dispersion Properties
Refer to parameterisation table

Retardation parameters for Merica Mudstone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0006,0.009)

Justification for Kd Values by Species

Refer to parameterisation table

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(1500,1700)
Pathway width (m):	SINGLE(200)

pathway parameters

No Vertical Pathway

Mercia Mudstone pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(5,20)

Justification for Aquifer Geometry

Refer to parameterisation table

Pathway regional gradient (-):	UNIFORM(0.011,0.013)
Pathway hydraulic conductivity values (m/s):	UNIFORM(1.97e-006,3.94e-005)
Pathway porosity (fraction):	UNIFORM(0.15,0.421)

Justification for Aquifer Hydraulics Properties

Refer to parameterisation table

Pathway longitudinal dispersivity (m):	UNIFORM(150,200)
Pathway transverse dispersivity (m):	UNIFORM(50,67)

Justification for Aquifer Dispersion Details

Refer to parameterisation table

Retardation parameters for Mercia Mudstone pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,5)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(281,1052,2337)
Chloride	SINGLE(0)
Nickel	UNIFORM(20,800)
2,4 Dimethylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(430)

Fraction of Organic Carbon (fraction)	TRIANGULAR(0.0001,0.0006,0.009)

Justification for Aquifer Kd Values by Species

Refer to parameterisation table

Pathway Density (kg/l):	UNIFORM(1.61,2.07)

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