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Fletcher Bank Quarry Landfill Site

Hydrogeological Risk Assessment Review

Churchill Enviro Limited

Report No. K0047-ST-R003
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Contents

1 Introduction

1.1 Background

This document prepared by ByrneLooby Partners (UK) Ltd (BLP) provides a Hydrogeological Risk Assessment Review (HRAR) for Fletcher Bank Landfill ('the Site'). The permit holder is Churchill Enviro Limited. As part of the document preparation, the following reports and data sources have been consulted:

- TerraConsult 2011[1], Fletcher Bank East Landfill: Environmental Permit Application. FBP1-4 Environmental Setting and Installation Design (ESID). Ref. FBP1-4.
- TerraConsult 2011[2], Fletcher Bank East Landfill: Environmental Permit Application. FBP2-1 Hydrogeological Risk Assessment. Ref. FBP2-1.
- TerraConsult 2014[3], Hydrogeological Risk Assessment Review: Fletcher Bank Landfill Site. Ref. 1772/R/003/1.
- TerraConsult 2020[4], Phase 1 – Cell 1 Non-hazardous Construction Works. Validation Report. Fletcher Bank Landfill Site. Ref. 3125/R/006/2.
- Churchill Enviro Ltd Monitoring data & drawings.

1.2 Risk Assessment Objectives

This report has been prepared in response to the requirement of Environmental Permit (EPR/GP3733FE) condition 3.1.3(b) to undertake a Hydrogeological Risk Assessment Review (HRAR).

The reviews were originally required on a 4-yearly cycle through the life of the Permit; however, this frequency has subsequently been reduced to a 6-year cycle (EPR 2010)[5].

HRAR's are required to validate the assumptions used within the original risk assessment or previous reviews. HRAR's assess whether the waste disposal activities authorised by the permit continue to meet the requirements of The Environmental Permitting (England and Wales) Regulations 2016 (EPR), particularly compliance with Schedule 22 (Groundwater Activities). These Regulations require that Hazardous Substances are not discharged to groundwater, and that the discharge of Non-Hazardous Pollutants is limited *"so as to prevent pollution"*.

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[1] TerraConsult 2011, Fletcher Bank East Landfill: Environmental Permit Application. FBP1-4 Environmental Setting and Installation Design (ESID). Ref. FBP1-4.
[2] TerraConsult 2011, Fletcher Bank East Landfill: Environmental Permit Application. FBP2-1 Hydrogeological Risk Assessment. Ref. FBP2-1.
[3] TerraConsult 2014, Hydrogeological Risk Assessment Review: Fletcher Bank Landfill Site. Ref. 1772/R/003/1.
[4] TerraConsult 2020, Phase 1 – Cell 1 Non-hazardous Construction Works. Validation Report. Fletcher Bank Landfill Site. Ref. 3125/R/006/2.
[5] Revised conditions to reflect the terminology used by the Groundwater Directive and to require hydrogeological risk assessment reviews every 6years rather than every 4 years https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate

Where discrepancies or changes are observed (which may have an impact on pollution potential) then numerical re-modelling should be considered, following relevant guidance and appropriate modelling tools.

The Site is operated on the principle of “*Engineered Containment*”.

2 Site Location, History & Key Design Summary

2.1 Location

The Site is located within the wider Fletcher Bank Quarry complex (Figure 2.1), near Ramsbottom in the northwest of England. The Site occupies an area of approximately 15.5 ha at an elevation of between 180mOD to 230mOD. The complex is located approximately 8 km to the north of Bury and 13 km to the northwest of Rochdale. Outside the quarry area are agricultural fields, isolated farmhouses and interspersed dwellings that lie to the north, east and south of the site. Moorland dominates land to the east and pockets of woodland can be found to the south of the site. To the west of the quarry is the town of Ramsbottom and to the north is the village of Shuttleworth.

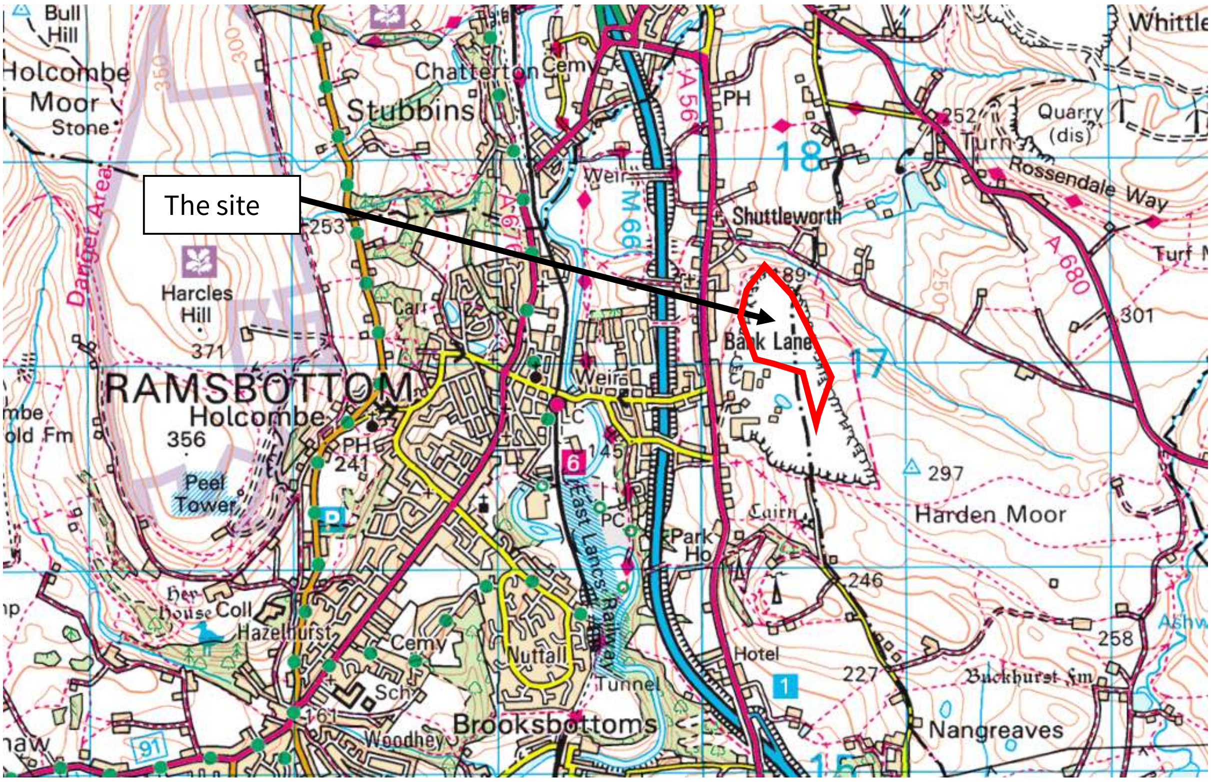


Figure 2.1 – Site Location

2.2 Site History

The Site was founded in the 1880’s and has been subject to sandstone and gritstone quarrying. The site was acquired by Marshalls Mono Ltd in 1969 when they purchased Richard Wild and

Company. The quarry also accommodates a substantial concrete products manufacturing plant operated by Marshalls. These works are located in the southwest of the site.

The Site is a substantial minerals extraction operation which is being progressively restored with a combination of minerals wastes and imported wastes under a separate restoration scheme. The Site is located in existing quarry void and is indicated by the green boundary on Drawing No. 1772/3/013 Rev D. The landfill forms a constituent part of the larger restoration scheme for the quarry.

A Pollution Prevention Control (PPC) Permit (DP3638ST) was issued to Marshalls in 2007 prior the transfer to Churchill Enviro Ltd in 2011. It is understood from correspondence from the Operator that waste deposit activities commenced at Fletcher Bank in December 2016 under Environmental Permit EPR/GP3733FE.

Churchill Enviro Limited operate Fletcher Bank Quarry Landfill Site (the Site) under Environmental Permit reference EPR/GP3733FE/V002. The Environmental Permit was varied and a consolidated permit issued in modern condition format in August 2020 by the Environment Agency.

Although the Site is classified as non-hazardous, the waste types listed effectively exclude the readily biodegradable wastes normally associated with non-hazardous landfill sites. The bulk of the materials to be deposited will be excavated soils which typically having been in the ground for many years and would not contain any significant residual quantities of readily biodegradable materials. The waste types accepted are predominantly inert in composition with a very low proportion of biodegradable material. The permitted waste types are listed in Table S2.1 of the Environmental Permit and includes concrete, bricks, tiles and ceramics, and soil and stones. The variation issued in 2020 now limits waste inputs at the site to inert waste only.

2.3 Site Engineering

The base of the landfill sits on historic quarry backfill and restoration material, deposited prior to the issue of the EPR permit to landfill in 2016. This backfill and restoration material was deposited for engineering structures, under a number of exemptions to the PPC permit and standard rules permits. The eastern side of the site is the location of the non-hazardous waste landfilling (drawing 1772/3/011), with the inert waste landfilling occupying the western side. It is understood that the site is split in to 3 phases, however the locations and lateral extents of these phases are unclear.

2.4 Engineering Properties

Full engineering details are contained within Section 2.3 of the 2014 HRAR, a summary is provided below for completeness.

For the area of the site with non-hazardous waste, an artificial sealing liner of minimum 500mm of engineered clay at a maximum permeability of $1x10^{-8}$ m/s is present on the base of the site. The

500mm engineered clay will extend along the sidewall lining system too, with stone draining installed where necessary to mitigate for any seepages in the sidewall spotted during construction. At long slopes greater than a gradient of 1 in 2, the liner will extend in lifts up the quarry walls in a ‘Christmas tree formation’ as the waste is placed in each cell.

For the area of inert waste, there is a minimum of 2m of material with a maximum permeability of 1×10^{-7} m/s, with no artificial sealing liner due to the inert nature of the waste. No drains are required within the area of inert waste deposits.

The conceptual layout of the completed site is shown on the cross-sectional drawings on drawing 1772/3/011.

3 Source Term

3.1 Leachate Levels

As there is no leachate monitoring infrastructure currently constructed onsite, there are no records for the leachate levels over the monitoring period.

For the purpose of modelling, the 2014 HRA Review used a fixed leachate head of 1m above base for both operational and post-closure phases of the LandSim modelling.

3.2 Leachate Chemistry

As with the leachate levels monitoring, there is no leachate quality data available for the reporting period.

The 2014 HRA Review derived a simulated leachate source term by running multiple outlier tests (statistical analysis) to the proposed waste acceptance criteria.

Table 1 – Simulated Leachate Source Term (mg/l)

Substance	Min	Most Likely	Max Recorded	Statistically Significant Max
NH4-N	0.01	0.58	16.9	8.05
Arsenic	0.0008	0.002	0.07	0.015
Cadmium	0.00005	0.000056	0.06	0.0004
Zinc	0.002	0.0071	1.59	0.044
Sulphate	29	N/A	1300	1300
Phenol	0.001	N/A	0.02	0.02

3.3 Source Term Summary

Due to there being no site specific leachate level or quality data, the values utilised for the modelling in the 2014 HRA Review are again the data only available for this HRA Review. The 2014 HRAR values are considered to be very conservative because the data was based on leachate samples from a non-hazardous landfill site. The Fletcher Bank Site however has a source term that represents both inert waste and non-hazardous waste and as such will generate a leachate with lower contaminant concentrations than non-hazardous waste alone.

4 Pathways

4.1 Geological Succession – Overview

The surrounding geological sequence comprises:
Superficial Strata:

1. Devensian Till – Boulder Clay – present off site in all directions

The underlying bedrock sequence comprises:
Bedrock Strata:

1. Helmshore Grit & Fletcher Bank Grit (Upper and Lower Leaf) – Part of the Marsden Formation - Sandstone. Sedimentary bedrock consisting of sandstones interbedded with siltstones and mudstones.
2. Main Kinderscout Grit - Part of the Hebden Formation – Sandstone. Sedimentary bedrock consisting of sandstones interbedded with siltstones and mudstones.

4.2 Superficial Geology

There are no superficial deposits present on the site itself, most probably due to their removal as part of the quarrying process, however there are superficial deposits present in the area around the site. The BGS website http://mapapps.bgs.ac.uk/geologyofbritain/home.html[6] and BGS map sheet 76 (Rochdale)[7] identify that the site is located within an area of Devensian Till. Alluvium is present in the valley 500m west of the site, associated with the River Irwell.

The Devensian Till is the BGS description for boulder clay, and is characterised by clay rich deposits, with subordinate sand and silt lenses with very limited spatial range. There are occasional cobbles and boulders within the clay matrix.

4.3 Bedrock Geology

The site sits on the Milstone Grit Group formations comprised of the Marsden Formation sandstones and the Hebden Formation (Figure 4.1). The Marsden Formation overlies the Hebden

[6] BGS, Geological Viewer Britain
[7] Geological Survey of England and Wales 1:50,000 geological map series, 76 Rochdale (Solid and Drift Edition) 2008

Formation sandstones (Figure 4.2). Both the Marsden Formation and the Hebden Formation are characterised by very coarse to fine grained sandstones, often interbedded with siltstones and mudstones, and occasionally some subordinate shales and coals. The Rossendale Formation sits geologically above the Marsden Formation, consisting of coarse sandstones, however it is not present at site.

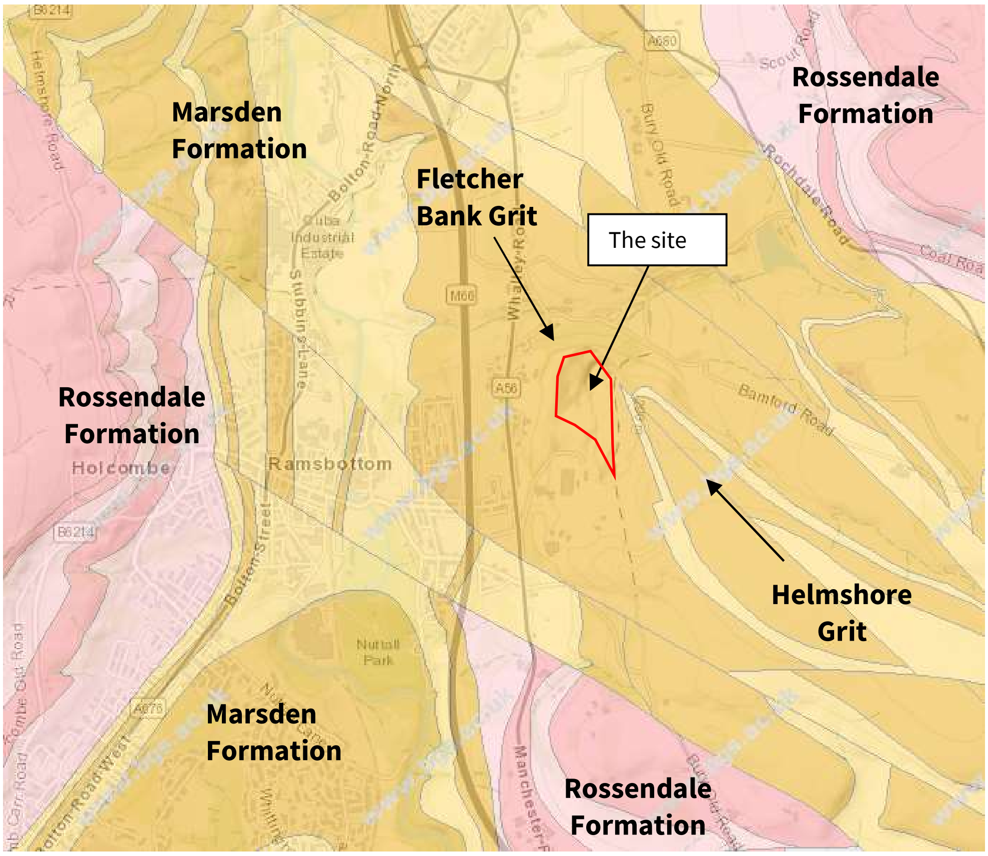


Figure 4.1 – Bedrock Geology

The 2014 HRA Review detailed the individual units within the bedrock beneath the site, isolating specific sandstone and mudstone/siltstone bands. At the site, the primary sandstone units intersected by the quarrying are the Helmshore Grit and the Fletcher Bank Grit beneath. There is approximately 3m of mudstone/siltstone between the base of the Helmshore Grit and the top of the Fletcher Bank Grit, as well as another 2m of siltstone within the Fletcher Bank Grit, separating it into an upper and lower Fletcher Bank Grit (called Upper Leaf and Lower Leaf respectively). Beneath the Fletcher Bank Grit is another mudstone/siltstone or unproven thickness.

The bedrock units are dipping 5 to 6 degrees to the north, and with the bedrock in the surrounding area heavily faulted, including a large fault onsite with a downthrow of 2.5m (2014 HRA Review).

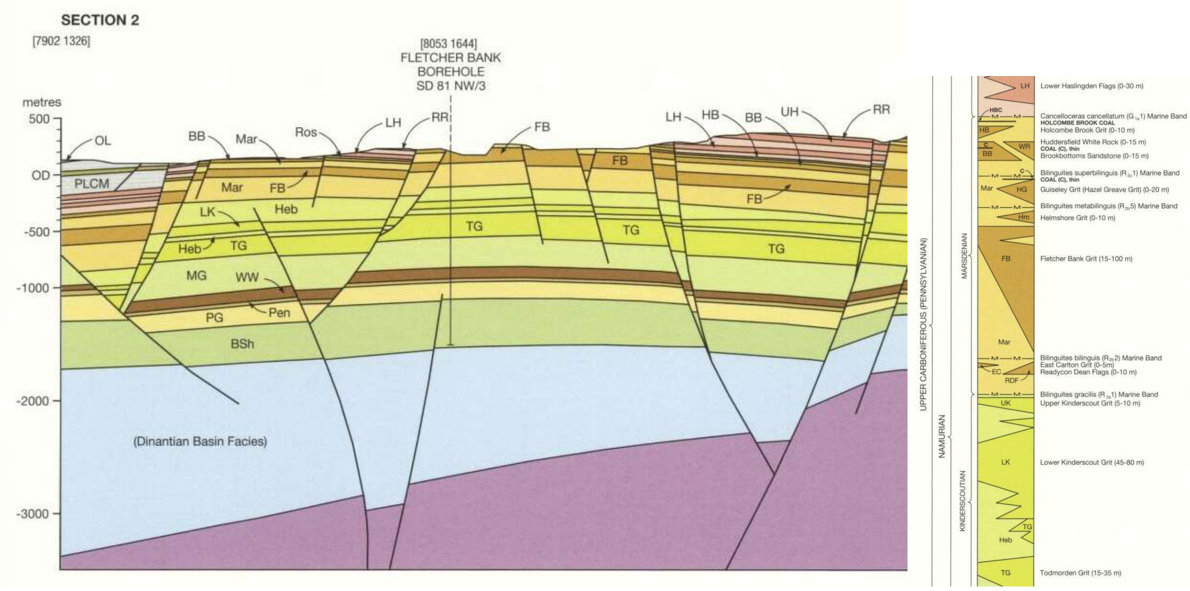


Figure 4.2 – Geological Cross-section (from BGS Bedrock Map Sheet 76)

4.4 Pathway Properties

The 2014 HRA Review assume an unsaturated zone hydraulic conductivity of $2.1x10^{-5}$ m/s based on a typical hydraulic conductivity for heterogenous coal measures (taken from Jones et al. 2008[8]). No new data is available to amend this assumption.

5 Receptors

5.1 Groundwater and Surface Water

The site is not located within a source protection zone, with the closest located over 9km to the North of the site. The Millstone Grit Group bedrock is designated as a Secondary A aquifer, along with the alluvium in the River Irwell valley to the west. A Secondary A aquifer comprises permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. The local Devensian Till deposits are designated as Secondary Undifferentiated Aquifers – these are not considered receptors.

The site is situated within the catchment of the River Irwell which is located approximately 800m to the west of the site. The site is situated on the watershed of two small brooks, Cross Bank Brook to the north and north-east of the site and Park Brook to the south. The watershed divide is formed by the topographical ridge of Harden Moor. Cross Bank brook (or Harden Brook) is located approximately 300m to the east of the site, flows in proximity to the northern boundary in a north-westerly direction prior to being culverted under the M66 and A56 and discharging to the River

[8] Jones et al. 2008, Discussion of "Transport of Ammonium in Aquifers: Retardation and Degradation" by A.D. Erskine. Submitted to Q.J.Eng Geol. and Hydrogeology.

Irwell. Park Brook is understood to be fed by springs located to the south of the site and will likely receive runoff from the southern boundary of the Fletcher Bank complex prior to discharging to the River Irwell in the west. The surface water features surrounding the site, primarily the streams, are considered to be in hydraulic continuity with the groundwater within the Millstone Grit Group, due to the steep topography and the assumption that groundwater flow follows the topography.

The Environment Agency have confirmed they have no records of any groundwater or surface water abstractions within 1km of the site.

The 2014 HRA Review identified 7 groundwater abstractions within 1km of the site, with all being north or northeast of the site. The closest are between 400m and 650m from the site. However, the presence of the Cross Bank Brook 100m to 150m north of the site is expected to present a barrier to any migration of contaminants passed this point, as the Brook is considered to be in hydraulic continuity with the groundwater due to the relative ordnance datums.

The 2016 HRA Review also identified a surface water abstraction on the Cross Bank Brook, for 34,096m^3 per annum, however it is considered that this is for the small reservoirs to the east of the site, and which are no longer present.

Enquiry with the Environment Agency in 2021 as to known groundwater and surface water abstractions within 1km of the site confirmed that the Environment Agency were not aware of any abstractions currently existing within 1km of the site.

5.2 Groundwater Levels and Hydraulic Direction

The groundwater is monitored in 6 perimeter boreholes, as shown on drawing 1772/3/013 (Environmental Monitoring Plan), which are all monitoring the groundwater within the Millstone Grit Group rocks.

The monitoring borehole utilised during the past 6 years reporting period are different to those used for the groundwater monitoring in the 2014 HRA Review. Although the boreholes are monitoring similar strata, their locations are different, therefore long-term patterns cannot be attributed on a borehole-to-borehole scale. However, the general groundwater level across site and the groundwater flow direction can be directly compared between the 2014 HRA Review and this HRA Review.

For the reporting period 2015 to 2021, the following groundwater monitoring boreholes were monitored; BH803, FB104R, SLR2, FBE11-01, FBE11-02 and FBE11-02A. The groundwater levels in the current dataset still indicate a groundwater flow direction towards the north/north-west, which is concurrent with that reported in the 2014 HRA, and it appears the groundwater flow follows the topography. The groundwater drops from approximately 195mAOD and 200mAOD in the south/southeast to between 160mAOD and 170m in the north/northwest.

The groundwater level monitoring data (Figure 5.1) indicates that, for all but one of the boreholes, there is little seasonal variation in groundwater level (between 2m and 3m for boreholes FB104R, FBE11-01, FBE11-02 and FBE11-02A, and 7m for borehole SLR2). This is similar to what is described in the 2014 HRA Review.

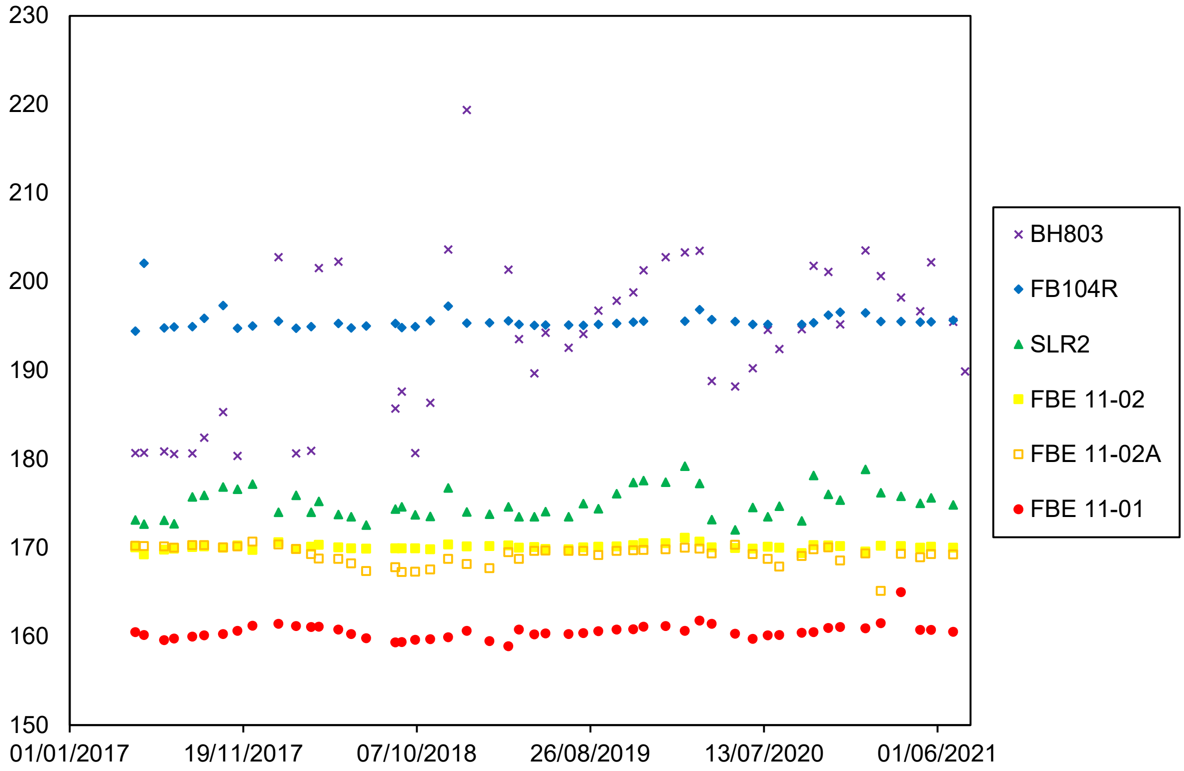


Figure 5.1 – Groundwater Levels Time Series (mAOD)

Borehole BH803 does not appear to follow the same pattern as the other boreholes, as it has large fluctuations over 20m. In addition, since mid-2018 the water level appears to undergo a cyclic gradual increase then dramatic drop in level. It is considered that this borehole is being impacted by dewatering operations for the active quarrying that has occurred to the east and southeast of the site.

Borehole BH803 is still considered to be useful for groundwater quality monitoring, as it is still located upgradient from the landfill, and as such can provide background quality data for comparison.

5.3 Groundwater Quality

Groundwater quality is monitored in the same 6 perimeter boreholes that the groundwater levels are monitored in. The groundwater is a calcium bicarbonate solution with secondary calcium sulphate, chloride and sodium chloride. Groundwater is monitored in accordance with Permit table S3.5 with water level, ammoniacal-N, chloride, electrical conductivity, and pH monitored on a quarterly basis and the remaining matrix ions and metals on an annual basis. Compliance limits are applied to boreholes FBE-11/01, FBE-11/02, FBE-11/02A and SLR2 for ammoniacal-N, chloride, cadmium and mercury (Permit table S3.2). Groundwater quality data from 2017 onwards has been made available for the purposes of this review, with no environmental monitoring data collected in 2015 or 2016.

The groundwater matrix chemistry, which includes the primary leachate indicators ammoniacal-N, chloride and potassium is summarised in Table 2.

Table 2 – Groundwater Matrix Ions Summary (2017 – 2021)

Borehole		EC	NH4-N	Ca	Mg	K	Na	Cl	SO4	Alk
		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Upgradient										
BH803	Max	950	0.5	47	10	41	100	160	253	420
	Avg	191	0.1	14	5	7	13	12	80	63
FB104R	Max	1,200	0.3	170	63	9	28	22	453	260
	Avg	952	0.1	132	44	6	20	14	376	189
Cross-gradient										
SLR2	Max	1,600*	0.6*	58	12	82	120*	200*	254	220*
	Avg	659*	0.1*	43	8	33	44*	57*	139	132*
Down-gradient										
FB11-02	Max	416	0.3	71	6	1	16	24	31	170
	Avg	320	0.1	53	5	1	9	12	22	126
FB11-02A	Max	531	0.5	85	9	2	20	61	27	210
	Avg	325	0.1	51	7	1	10	14	21	122
FB11-01	Max	550	0.3	65	19	2	26	20	129	130
	Avg	432	0.1	54	14	1	16	13	100	75

Note: Asterix indicates where outliers removed for statistical purposes (1,100mg/l Alk on 20/02/2019, 1,050mg/l Cl, 650mg/l Na and 3,700µS/cm EC on 16/02/2021 and 2.3mg/l NH4-N on 20/05/2021 – all in borehole SLR2). Green shaded cells highlight exceedances of Drinking Water Standards (DWS), Limits: EC (2500µS/cm); Chl (chloride) & SO4 (250mg/l); Na (200mg/l); NH4-N (0.39mg/l or 0.5mg/l DWS) – http://www.legislation.gov.uk/uksi/2016/614/pdfs/uksi_20160614_en.pdf page 38

Concentrations for ammoniacal-N and chloride within groundwater are stable and do not indicate any impact from the landfill (Figure 5.2 and Figure 5.3). The highest concentrations of ammoniacal-N, chloride and sodium are in upgradient borehole BH803 and cross-gradient borehole SLR2. Upgradient borehole FB104R has the highest concentrations of calcium and sulphate, with average sulphate concentration (376mg/l) above the EQS for sulphate (250mg/l). The source of the elevated sulphate has been interpreted in the 2008 Environmental Management and Monitoring Plan[9] to be from water percolating through the mudstone from a slurry lagoon upgradient of the borehole.

In the downgradient boreholes, concentrations of ammoniacal-N and chloride are typically below their respective DWS values throughout the reporting period, with the downgradient groundwater being of better quality than the upgradient groundwater. Average groundwater ammoniacal-N

[9] TerraConsult 2008, Fletcher Bank Landfill Site: Environmental Management and Monitoring Plan: Reference 1040-1

and chloride concentrations are typically at 0.1mg/l and 14mg/l respectively in the downgradient boreholes.

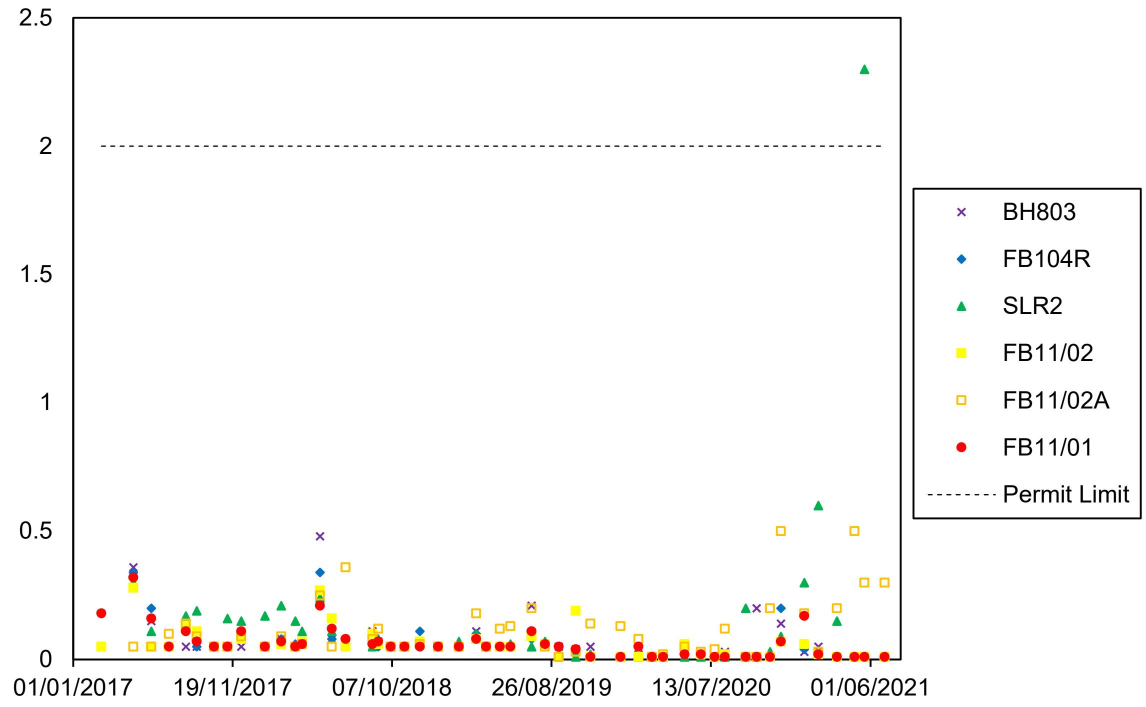


Figure 5.2 – Groundwater NH4-N (mg/l)

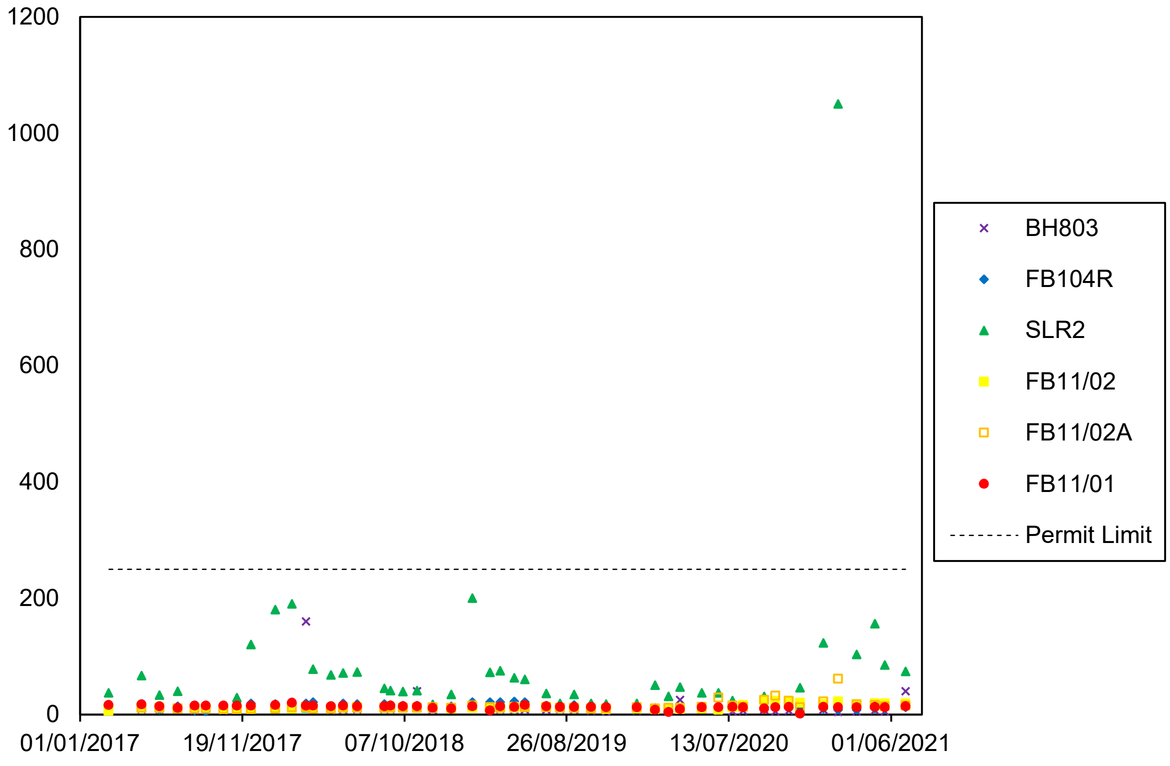


Figure 5.3 – Groundwater Chloride (mg/l)

Data reported for BH11-02A shows fluctuating concentrations of ammoniacal-nitrogen. Any increases in ammoniacal-nitrogen do not appear to coincide with chloride. SLR2 exhibited an increase in both ammoniacal-nitrogen and chloride concentrations in February 2021. The source of the elevated concentrations is not clear however the recent data indicates that concentrations have returned to within the normal range of data and the concentrations reported in February 2021 are considered as anomalous. Concentrations for ammoniacal-N and Chloride are typically stable for all boreholes, consistent with the 2014 HRA Review. Further time-series data is presented at Appendix B for the remaining compliance limited substances cadmium and mercury. As with ammoniacal-N and chloride, there are no adverse trends noted for cadmium, mercury or any other substance.

Groundwater Priority Metals

A summary of average concentrations of the priority metals is provided in Table 3 for the reporting period. The hazardous metals arsenic and mercury are not present in the groundwater down-gradient of the site, being below the limit of detection throughout the reporting period, and lead concentrations are below the limit of detection 83% of the time in borehole FB11-01, 92% of the time in FB11-02 and 100% of the time in FB11-02A.

Table 3 – Groundwater Metals Summary (2017 – 2021)

Borehole		As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Upgradient									
BH803	Max	<1	0.21	18.0	5.3	0.6	<0.05	12.0	41.0
	Avg	<1	0.06	2.3	1.3	0.2	<0.05	3.4	11.0
FB104R	Max	<1	0.06	<1	0.8	<0.3	<0.05	5.0	9.0
	Avg	<1	0.02	<1	0.5	<0.3	<0.05	2.2	4.1
Cross-gradient									
SLR2	Max	4.0	0.29	66.0	6.0	0.9	0.08	2.0	24.0
	Avg	1.0	0.10	17.1	3.5	0.5	0.02	0.7	6.8
Downgradient									
FB11-02	Max	<1	0.23	3.0	1.5	0.4	<0.05	4.0	63.0
	Avg	<1	0.03	0.6	0.6	<0.15	<0.05	0.7	7.2
FB11-02A	Max	<1	1.70	16.0	1.7	<0.3	<0.05	20.0	20.0
	Avg	<1	0.22	1.4	0.7	<0.3	<0.05	6.1	6.6
FB11-01	Max	<1	0.30	1.0	5.5	0.6	<0.05	5.0	21.0
	Avg	<1	0.06	<1	1.0	0.2	<0.05	1.3	6.7
DWS		10	5	50	2,000	10	1	20	5,000

All the metals are below their respective Drinking Water Standards (DWS) except for the maximum chromium in cross-gradient borehole SLR2. Chromium concentrations were 66µg/l and 41µg/l respectively in November and December 2017 in SLR2, however prior to and after these months the concentrations have been consistently below 20µg/l.

The most prevalent metal within the groundwater is zinc, with average concentrations between 4µg/l and 11µg/l and being above the limit of detection 86% of the time over the reporting period. Both the max and average concentrations are well below the DWS standard of 5,000µg/l, and the highest average concentration is in the upgradient borehole BH803.

Hazardous Organic Substances

A hazardous organics substances screen has been performed in 2019 and 2021 for the groundwater. The only substances detected were PAHs. In 2019, PAHs were detected in all 5 monitoring boreholes (BH803 was not monitored), with cross-gradient borehole SLR2 having the greatest concentrations (total PAH of 7.8µg/l). In 2021, PAHs were detected in SLR2 only. The concentration of total PAHs in 2021 for borehole SLR2 was 0.74µg/l, which is a ten-fold decrease from 2019.

Due to the difference in sampling frequency between the hazardous substances and the matrix ions, it is difficult to draw a relationship between the identification of the two data sets. However, the dates of the detection of PAHs do not appear to coincide with any increases in ammoniacal-N and chloride in SLR2 (Feb 2021)), indicating the source is not linked to waste in the site.

Due to the absence of any PAHs in the rest of the site's boreholes, and the dramatic decrease at SLR2, an assessment of PAH concentrations needs to conducted in the following years to determine whether the decreasing trend is ongoing, and whether PAHs are detected down gradient of SLR2 in the future.

it can be determined that whatever caused the PAH in the groundwater has since been removed, and that whatever the source was, it must have been upgradient of the site.

Table 4 – Groundwater Permit limit Comparison (2018 – 2021)

Borehole	Substance	Compliance limit (mg/l)	Exceedances 2018	Exceedances 2019	Exceedances 2020	Exceedances 2021
FB11-01	NH4-N	2	0	0	0	0
	Cl	250	0	0	0	0
	Cd	0.0001	0	0	0	0
	Hg	0.0001	0	0	0	0
FB11-02	NH4-N	2	0	0	0	0
	Cl	250	0	0	0	0
	Cd	0.0001	0	0	0	0
	Hg	0.0001	0	0	0	0
FB11-02A	NH4-N	2	0	0	0	0
	Cl	250	0	0	0	0
	Cd	0.0001	1	1	1	1

Borehole	Substance	Compliance limit (mg/l)	Exceedances 2018	Exceedances 2019	Exceedances 2020	Exceedances 2021
	Hg	0.0001	0	0	0	0
SLR2	NH4-N	2	0	0	0	1
	Cl	250	0	0	0	1
	Cd	0.0001	1	2	1	0
	Hg	0.0001	0	0	0	0

A comparison of Permit Limits (as detailed in Permit table S3.2) with the observed groundwater concentrations (Table 4) indicates there were only exceedances of the permit limits for cadmium between 2018 and 2021, namely in boreholes FB11-02A and SLR2. In addition, these exceedances are isolated one-off events (cadmium time series in Appendix B), rather than sustained breaches of the permit limit as would be expected if there were leachate in the groundwater.

The low stable concentrations of typical leachate indicators ammoniacal-N chloride and sulphate (especially in FB11-02A), coupled with the low concentrations of the priority metals indicates that leachate from the landfill is not impacting the groundwater at the site. In addition, there is no correlation between highest down-gradient cadmium concentrations (FB11-02A) and any trends within the chloride or sulphate concentrations (Figure 5.4). Therefore, the source of the cadmium within the groundwater down-gradient of the site is not considered to be from fugitive leachate from the landfill site.

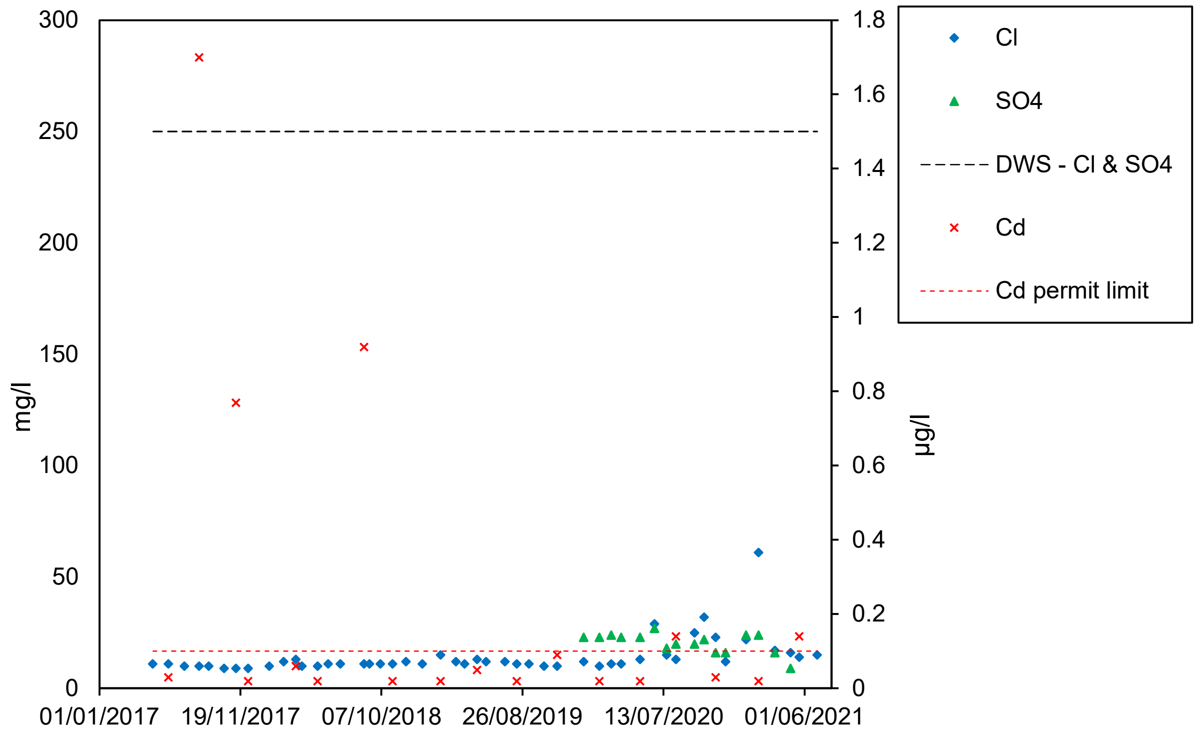


Figure 5.4 – Groundwater Chloride, Sulphate and Cadmium in FB11-02A

In addition to the source of the cadmium down-gradient of the site not being linked to leachate due to the lack of other leachate indicators within the groundwater, cadmium concentrations in the upgradient borehole BH803 are above the down-gradient compliance limit of 0.1µg/l on 5 occasions between 2018 and 2021, indicating cadmium is present upgradient of the landfill. Therefore, cadmium is not considered to be a suitable compliance limited substance to detect for failure of the engineered control system of the landfill site.

5.4 Surface Water Quality

Surface water monitoring is undertaken at 2 locations, SW1 and SW2, both of which are on the Cross Bank Brook. SW1 is considered the upstream monitoring point, located northeast of the site, and SW2 is considered the downstream monitoring point, located northwest of the site (drawing 1772/3/013).

All sampling is done as per Table S3.8 of the permit. The permit requires the monthly monitoring of surface water for ammoniacal-N, chloride, EC, pH and suspended solids.

Surface water monitoring (summarised in Table 5 and charts in Appendix B), indicates no discernible impact from the landfill, with average ammoniacal-N and chloride concentrations well below their respective environmental standards (0.39mg/l for ammoniacal-N and 250mg/l for chloride).

Table 5 – Surface Water Monitoring Summary (2017 – 2021)

Monitoring Point		NH4-N	Cl	EC	pH	Suspended Solids
SW1	Max	0.3	19	310	7.8	52
	Avg	0.1	9	141	7.3	16
SW2	Max	0.8	30	350	7.8	37
	Avg	0.1	15	214	7.3	14

Note: Outliers removed for NH4-N, Cl and EC (2.4mg/l, 360mg/l and 760µS/cm respectively) for SW1, and NH4-N and Cl (2.7mg/l and 660mg/l respectively) for SW2, all on 27/02/2017. Single outlier of 2,200mg/l suspended solids removed for SW1 on 26/03/2018.

5.5 Receptor Summary

There are effectively two receptors which could be affected by the Fletcher Bank landfill site, these have not changed since the previous HRAR, namely:

- Groundwater within the Millstone Grit Group
- Surface Water

The water quality data review within this document has not identified any deterioration in water quality at any of the monitored boreholes or surface water monitoring points that can be attributed to the operation of the landfill.

6 Conceptual Site Model

6.1 Source-Pathway-Receptor Framework

A simple conceptual model can be constructed for the site, based on the relationship

Source $\rightarrow$ Pathway $\rightarrow$ Receptor

Where the

- landfill is the source,
- the Pathway is the sidewall engineering and the geological pathway towards a water resource; and
- the receptor is an underlying or adjacent water resource.

The conceptual model is unchanged from previous understandings; based on an engineered clay liner of $1x10^{-8}$ m/s permeability in the non-hazardous area of the site and a compacted *in-situ* quarry backfill of $1x10^{-7}$ m/s permeability for the inert area of the site restricting vertical leachate migration through the base of the site. An unsaturated zone of 4m beneath the site to groundwater is also present, providing attenuation potential for the vertical migration of leachate through the base of the site. An engineered clay sidewall liner of $1x10^{-8}$ m/s permeability is also present to restrict horizontal leachate migration through the side of the site.

The leachate strategy for the site is based on the principle of the leachate quality being of sufficiently low strength due to the nature of the inert and non-hazardous waste, therefore not requiring any leachate management.

6.2 Requirement for Remodelling

Previous modelling in 2014 considered the following substances NH4-N, arsenic, cadmium, sulphate, zinc and Phenol.

As there is no leachate quality or leachate level data, the leachate source term is assumed to be within the previous HRA assumptions. However, in reality it is likely to have lower concentrations of all substances due to the presence of the inert fill within the site, when the concentrations modelled were just for the non-hazardous Waste Acceptance Criteria.

Groundwater and surface water monitoring indicates no impact on the surrounding environment from leachate from the landfill.

It is not proposed at this point (based on the above) to undertake additional modelling, however if future requirements dictated by changes to the conceptualisation are identified then future modelling may be required.

7 Risk Assessment

7.1 Justification for Modelling Approach and Software

The modelling performed in 2014 utilised LandSim (Version 2.5), as approved by the Environment Agency, due to the presence of an unsaturated zone beneath the site.

LandSim (Version 2.5) is a probabilistic model that allows the representation of uncertainty in key input parameters by the requirement for specification of input data ranges and distribution types. LandSim generates estimates of impacts at receptors based on statistical probability, i.e., it generates estimates of the likelihood and timing of impacts occurring at specified receptors downgradient of the landfill. In order to calculate a robust 95%ile value, the results are calculated over 999 model iterations and are presented indicating the likelihood of chemical breakthrough at a specified receptor or compliance point.

The LandSim model is designed and constructed to assess the performance and hence risk associated with discharged to groundwater over the full lifecycle of the landfill. The scenarios simulate the effects of the operational and post closure stages of the landfill incorporating capping.

The source term, as explained in Section 3, is derived from statistical analysis of the Waste Acceptance Criteria for the specific non-hazardous wastes that are permitted to be deposited under the permit, which are non-hazardous soils. The source term didn't use values for the inert waste. No degradation of the cap or lining system was required, as the landfill does not have a flexible membrane liner, and leachate levels are expected to be limited to infiltration and seepage rather than through any leachate level management.

Although LandSim is a probabilistic model, and therefore reduces the need for retrospective sensitivity analysis to clarify how specific parameters influence the overall results; a sensitivity analysis was conducted to determine the likely impact of rising groundwater levels upon a thinner unsaturated zone.

As the engineering and hydrogeological setting of the site has not changed, the modelling approach is still deemed appropriate should future modelling be required.

7.2 Previous Emissions to Groundwater

The 2014 modelling using LandSim provided simulated emissions of the hazardous substances cadmium and arsenic at concentrations below their respective minimum reporting values (MRVs) at the immediate downgradient boundary of the site. The model also simulated emissions of the non-hazardous substance ammoniacal-N, zinc, phenols and sulphate at either well below their respective EAL or not posing a risk of breaking through to the receptor.

8 Review of Technical Precautions

8.1 Engineering Measures

The landfill site was constructed based on engineered containment and comprises

- Engineered clay basal and sidewall liner
    - Engineered basal lining system, 0.5m Clay (non-hazardous waste area) at $1x10^{-8}$ m/s permeability. 2m historic quarry waste and imported soils (inert waste area) at $1x10^{-7}$ m/s permeability.
    - Engineered sidewall lining system, 0.5m Clay (non-hazardous waste area only) at $1x10^{-8}$ m/s permeability, in a 'Christmas-tree' design.
- Engineered groundwater seepage drains
    - Engineered 1x1m stone drains around the perimeter of the site to intercept groundwater seepages, covered with a geotextile to prevent ingress of fines.

The engineering precautions were designed to ensure that the requirements of the groundwater and landfill directives were met.

8.2 Active Management

The site is not currently capped; however no active management of leachate levels currently occurs due to the lack of leachate extraction infrastructure. Groundwater is passively managed via the use of gravel drains around the sidewalls of the landfill.

9 Requisite Surveillance

Surface water and groundwater monitoring is undertaken in accordance with the schedules contained within the site's Environmental Permit. Leachate requisite surveillance is outlined within the permit, and upon the construction of the leachate collection and monitoring infrastructure at the site leachate monitoring will be performed as per Table S3.1 and Table S3.7 of the permit.

Leachate

Table S3.1 of the permit states a leachate head limit of 5m above cell base for both operational and non-operational cells. Leachate quality is required to be monitored in accordance with Table S3.9 of the permit, which is summarised below in Table 6.

Table 6 – Leachate Quality Requisite Surveillance

Monitoring Point Reference	Parameter	Monitoring Frequency	Monitoring Standard
Operational Cells or Phases (Any cells or phase that does not have a final engineered cap in accordance with condition 2.6)			As specified in Environment Agency Guidance TGN02 'Monitoring of Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency.
MEPP	pH, EC, total alkalinity, ammoniacal-N, chloride, COD, BOD, cadmium, chromium, copper, lead, nickel, iron, arsenic, magnesium, potassium, total sulphates, calcium, sodium, zinc and manganese	Quarterly	
MEPP	Hazardous Substances	Annually	
MEPP	Depth to base (mAOD)	Annually	
Non-Operational Cells or Phases (Any cell or phase that has final engineered capping in accordance with condition 2.6)			
MEPP	pH, EC, total alkalinity, ammoniacal-N, chloride, COD, BOD, cadmium, chromium, copper, lead, nickel, iron, arsenic, magnesium, potassium, total sulphates, calcium, sodium, zinc and manganese	Annually	
MEPP	Hazardous Substances	Once every four years	
MEPP	Depth to base (mAOD)	Annually	

Groundwater

Groundwater monitoring is conducted in accordance with Table S3.5 of the permit and is summarised below in Table 7. Groundwater compliance limits are outlined in Table S3.2 of the permit. The revised Table S3.2 is summarised in Table 8 below.

Table 7 – Groundwater Requisite Surveillance

Monitoring Point	Parameter	Monitoring Frequency	Monitoring Standard
Up gradient MEPP (BH803 & FB104R)	Water level, EC, chloride, ammoniacal-N, pH	Quarterly	As specified in Environment Agency Guidance TGN02 'Monitoring of Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental
	Total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium,	Annually	

Monitoring Point	Parameter	Monitoring Frequency	Monitoring Standard
	copper, iron, lead, nickel, zinc, manganese		permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency.
	Hazardous substances	Annually for first six years of operation	
Down or cross gradient MEPP (SL2, FBE11-01, FBE11-02 & FBW11-02A)	Water level, EC, chloride, ammoniacal-N, pH	Quarterly	As specified in Environment Agency Guidance TGN02 'Monitoring of Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency. After the initial 6 year monitoring period for hazardous substances, if the results of quarterly or annual monitoring suggest an increase in contamination, the operator shall also undertake a full leachate hazardous substances screen.
	Total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel, zinc, manganese	Annually	
	Hazardous substances detected in leachate	Annually for first six years of operation then every two years	
MEPP (BH803, FB104R SL2, FBE11-01, FBE11-02 & FBW11-02A)	Base of monitoring point (mAOD)	Annually	

Table 8 – Groundwater Compliance Limits

Monitoring Point Reference	Parameter	Limit (including unit)	Monitoring Frequency	Monitoring Standard	Other Specifications
FBE-11/01, FBE-11/02, FBE-11/02A, SLR2	Ammoniacal-N	2 mg/l	Monthly	Spot sample	As specified in Environment Agency Guidance TGN02 'Monitoring of Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency.
	Chloride	250 mg/l	Monthly		
	Mercury	0.0001 mg/l	Quarterly		

Although changes to the compliance limits were proposed within the 2014 HRA review, they were not applied for. The inclusion of cadmium as a compliance limited substance is considered inappropriate for down-gradient groundwater monitoring. As the analysis of the groundwater data has shown there are concentrations of cadmium within the groundwater downgradient of the site that cannot be linked to fugitive leachate from the site, as there is no correlation with other typical leachate indicator species such as ammoniacal-nitrogen, chloride and sulphate. Therefore, there must be a source of cadmium within the groundwater that is not linked to the landfill thus making it an unsuitable substance to detect failure of the engineering control measures.

Surface Water

Surface water monitoring is conducted in accordance with Table S3.8 of the permit and is summarised below in Table 9.

Table 9 – Surface Water Requisite Surveillance

Monitoring Point Reference	Parameter	Monitoring Frequency	Monitoring Standard	Other Specifications
MEPP (SW1 & SW2)	Ammoniacal-N, chloride, suspended solids, visual oil and grease, pH and EC	Monthly	Spot sample	As specified in Environment Agency Guidance TGN02 'Monitoring of Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency.

10 Conclusions

The groundwater and surface water environmental monitoring conducted at the site between 2017 and 2021 indicates that there is no clear impact from the landfill site on the surrounding environment.

Modelling is not considered necessary for the following reasons: the environmental monitoring indicates that the site is not impacting the surrounding environment; and in the absence of source term data, the site is assumed to be operating within the assumptions of the previous HRA. The non-hazardous source term modelled previously for the site is incredibly conservative since the extant permit allows only for the use of inert fill.

The site operator is required to construct the necessary leachate monitoring infrastructure to assess leachate level compliance against the leachate level limits outlined in Table S3.1 of the permit. Additionally, the monitoring data obtained from the proposed leachate monitoring points will help inform the site conceptual model.

The Fletcher Bank landfill site is designed to be operated as an engineered containment landfill site. This HRAR has been undertaken for the site which demonstrates there are no changes to the CSM or current management practices.

The Landfill Regulations have been superseded by The Environmental Permitting (England and Wales) Regulations 2016. Both these regulations implement the same underlying Landfill Directive therefore the justifications for compliance remain the same for both sets of regulations.

The conclusions of this review are consistent with those from previous HRAR's, namely that:

- The development does not pose a hazard to groundwater and surface water quality, subject to the technical precautions identified with regards to passive controls (*i.e.* engineered containment) and operational leachate management is being implemented;

The site therefore complies with the necessary Environmental Permitting Regulations (Schedule 10, Landfill).

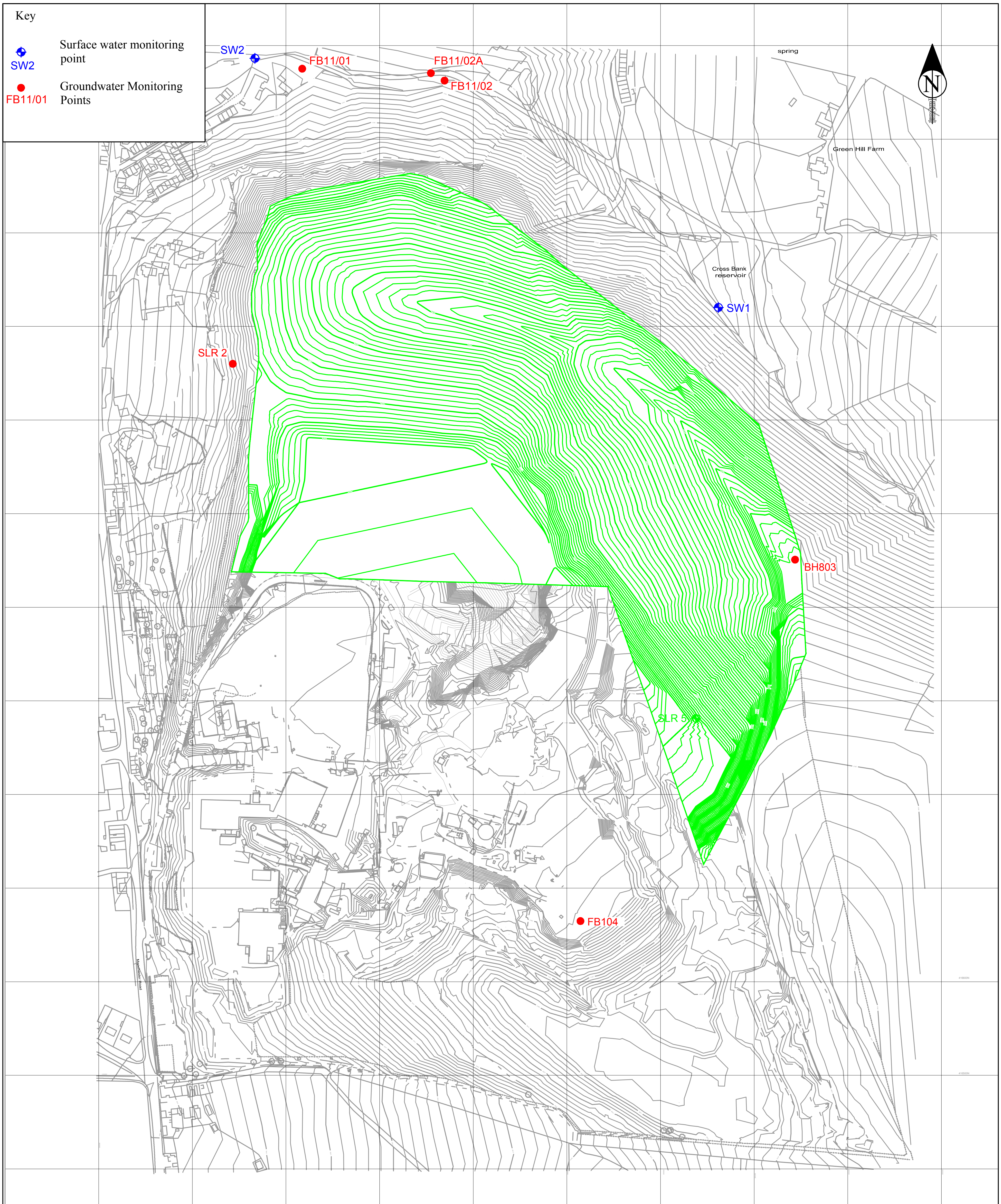
Analysis of the environmental monitoring indicates that there is not considered to be any impact from the landfill on the identified receptors, namely the groundwater in the underlying Millstone Grit Group, and the surface water around the perimeter of the site.

Appendix A – Drawings

Key

Surface water monitoring point — SW2

Groundwater Monitoring Points — FB11/01



TerraConsult

Bold Business Centre, Bold Lane, Sutton, St Helens WA9 4TX

Client

Churchill Enviro Ltd.

Site

Fletcher Bank Landfill Site

Title

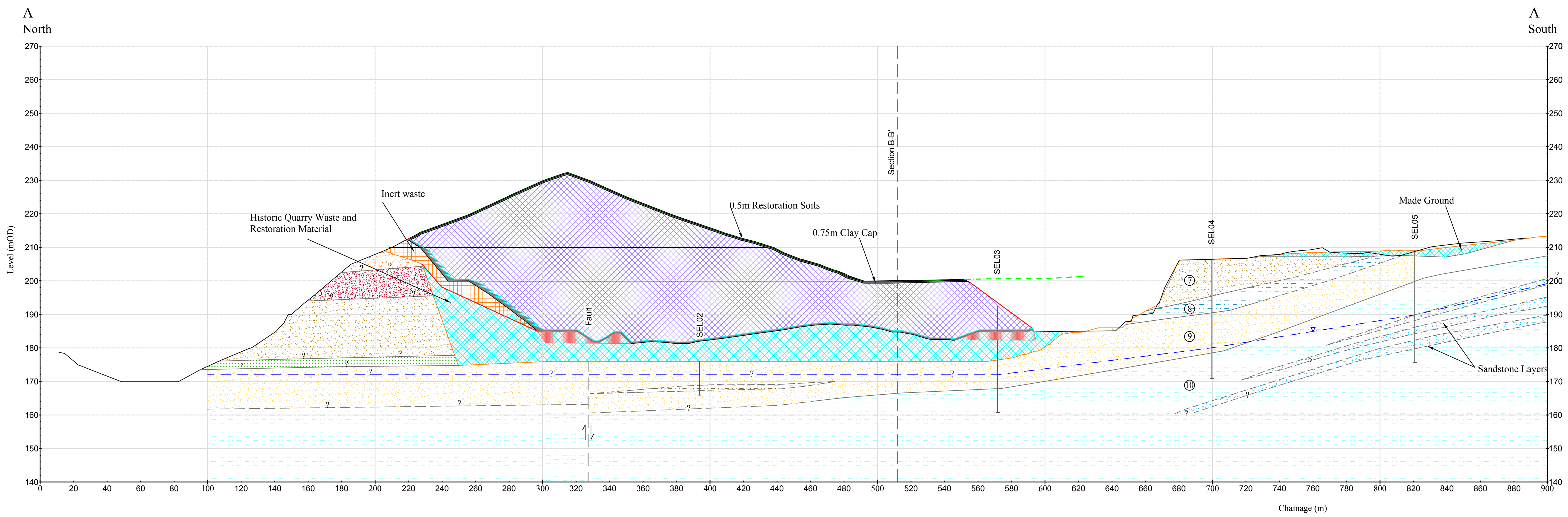
Environmental Monitoring Plan

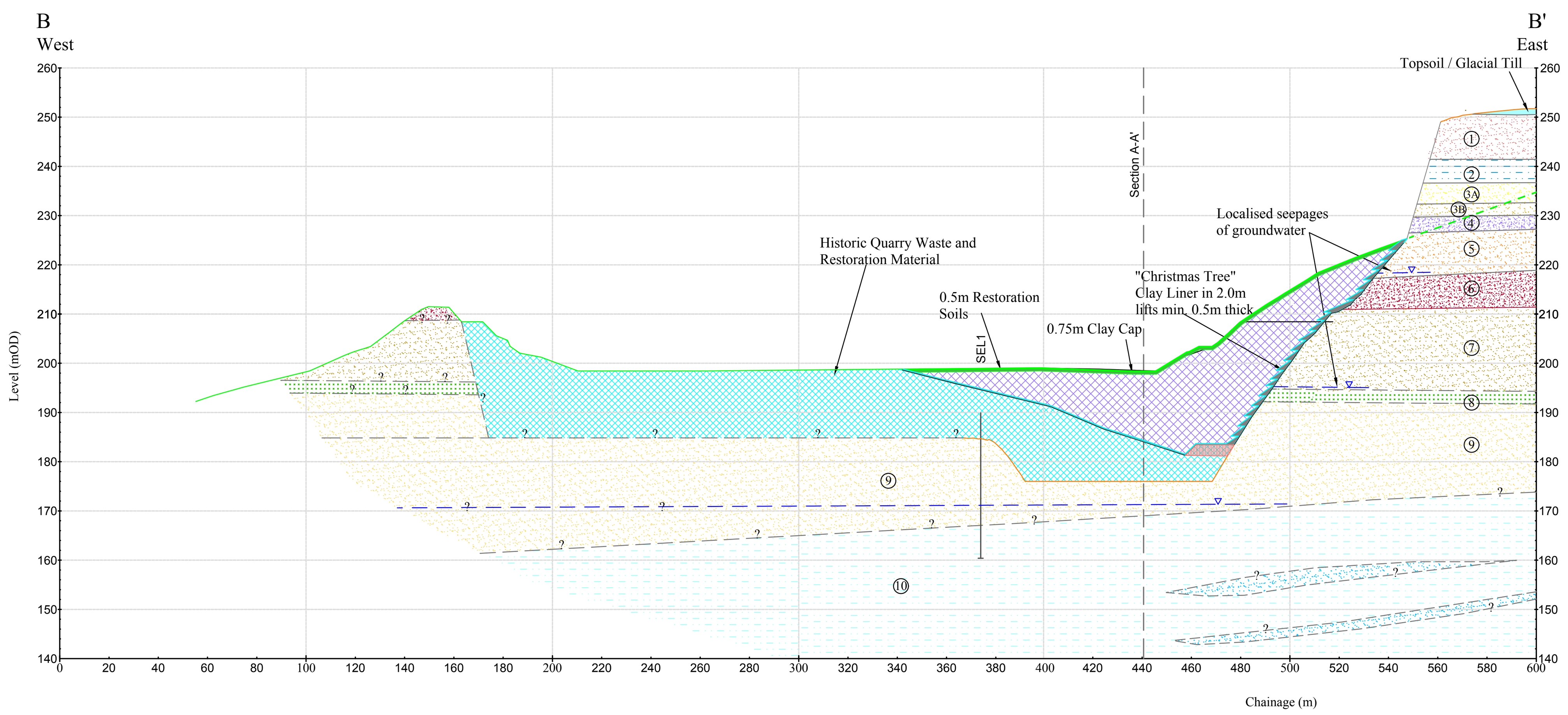
Scale	1:4,000	@ A3
Drawing No.	1772/3/013	

Rev	Date	Description
A	25/04/16	Added Leachate points
B	23/08/16	Added Eastern BH Mon location
C	24/08/16	Added Western BH Mon location
D	30/09/16	Groundwater Monitoring Points Added

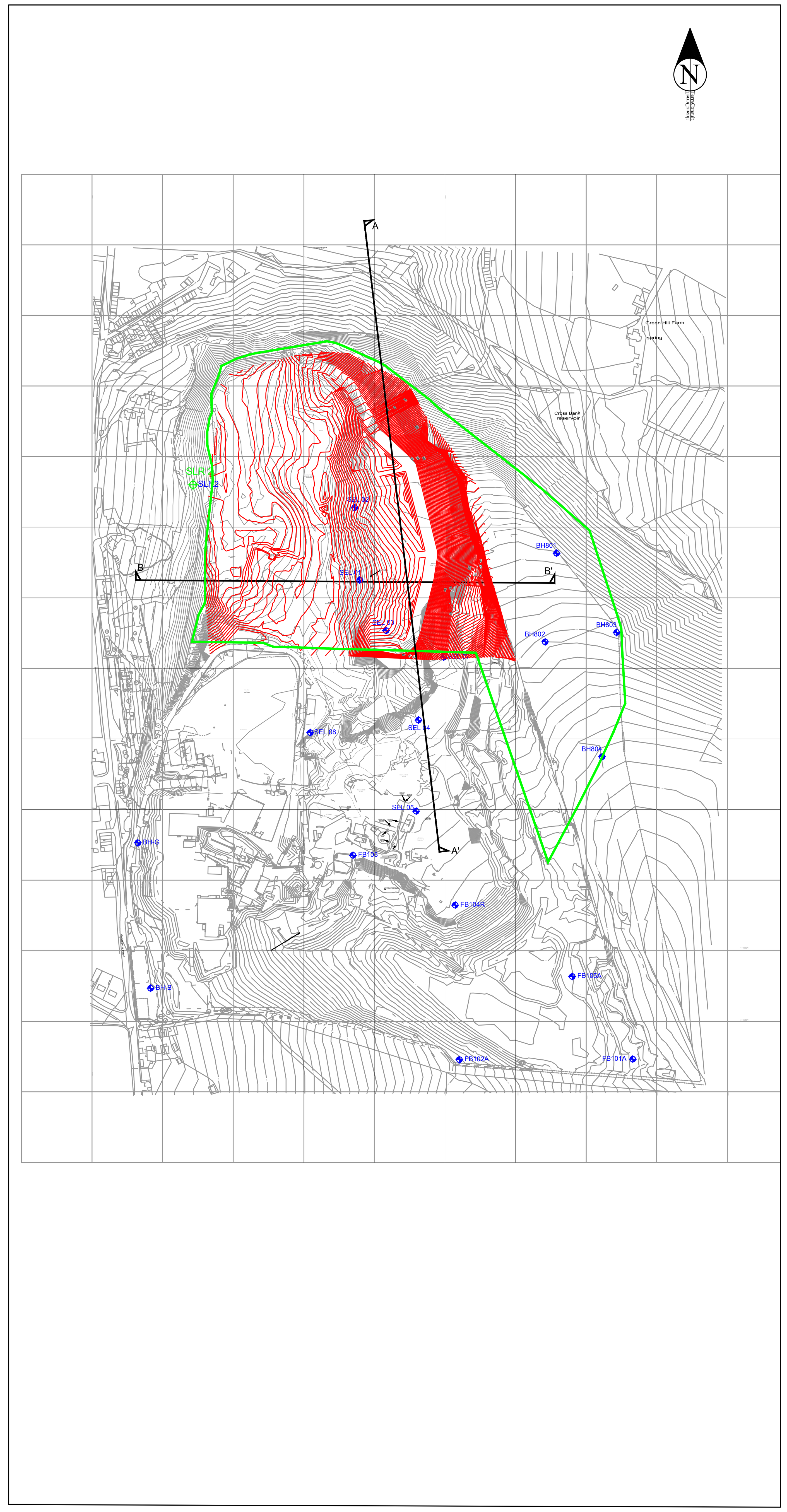
File 17723013envmonplan Rev D.dwg

Date	09/16	Engineer	RB
Drawn	PG	Checked	RB





Sections
Scale H=1:2,000
V=1:1,000



Plan
Scale: 1:5,000

Key

Plan

- Permit Application Boundary
- Formation Contours
- BH804 Exploratory Borehole

Sections

- August 2010 Topographic Survey Profile
- Formation Profile
- Approx. Top of Lining System Profile
- Approx. Top of Capping Profile
- Engineered Bunds / Formation Layer
- Engineered Clay Liner (0.5m) / Cap (0.75m)
- Restoration Soils (1.0m)
- EP Waste Deposits
- Historic Quarry Waste and Restoration Material
- Groundwater (highest recorded)
- 1 Medium to thick beds of light yellow brown SANDSTONE (weathered at top)
- 2 Dark grey (typically weathered red brown in places) fissile MUDSTONE
- 3A Thin to medium beds of orange brown SANDSTONE inter-bedded with thin beds and laminations of shale and siltstone
- 3B Medium to thick beds of yellow brown SANDSTONE
- 4 Laminated grey MUDSTONE, SILTSTONE and fine SANDSTONE inter-bedded with beds of sandstone. Base of unit marked by medium band of black coal underlain by greenish grey siltstone
- 5 Thick to very thick beds of light yellow brown medium to coarse SANDSTONE (HELMSHORE GRIT)
- 6 / 6A / 6B Dark grey MUDSTONE and SILTSTONE (unit 6A) over thin to medium beds of yellow brown SANDSTONE with occasional beds of dark grey siltstone / mudstone (unit 6B)
- 7 Thick to very thick beds of light brownish grey medium to coarse SANDSTONE (FLETCHER BANK GRIT UPPER LEAF)
- 8 Laminated grey SILTSTONE and fine SANDSTONE.
- 9 Brownish grey medium to coarse SANDSTONE (Fletcher Bank Grit Lower Leaf). In places interbedded with finer beds of mudstone and siltstone
- 10 Mudstone / Siltstone with minor bands of sandstone.

Notes

Colours included in generalised description are based on that observed in fresh exposure of rock.

Question marks denote a high level of uncertainty.

Analysis of boreholes SEL09, SEL03, SLR4 and 5 and BEL5 indicates that strata dip in a northerly direction at between 5-6 degrees. Becoming shallower in places.

TerraConsult

Bold Business Centre, Bold Lane, Sutton, St Helens WA9 4TX

Client
Churchill Enviro Ltd.

Site
Fletcher Bank Quarry Landfill

Title
Hydrogeological Cross Sections

Scale	As Shown	@ A1
Drawing No.	1772/3/011	
Rev	Date	Description
File	17723011hydrogeoxsections.dwg	
Date 08/14	Engineer PR	
Drawn PT	Checked RB	

BYRNELOOBY

Appendix B – Groundwater Quality

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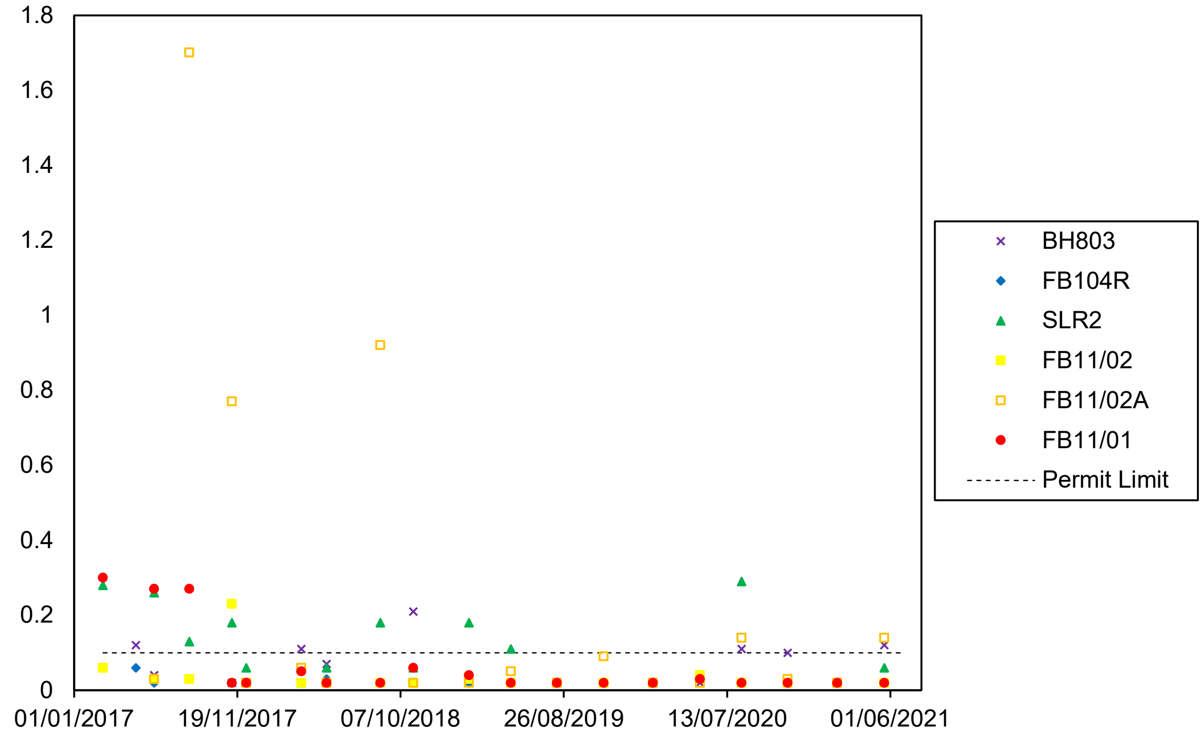
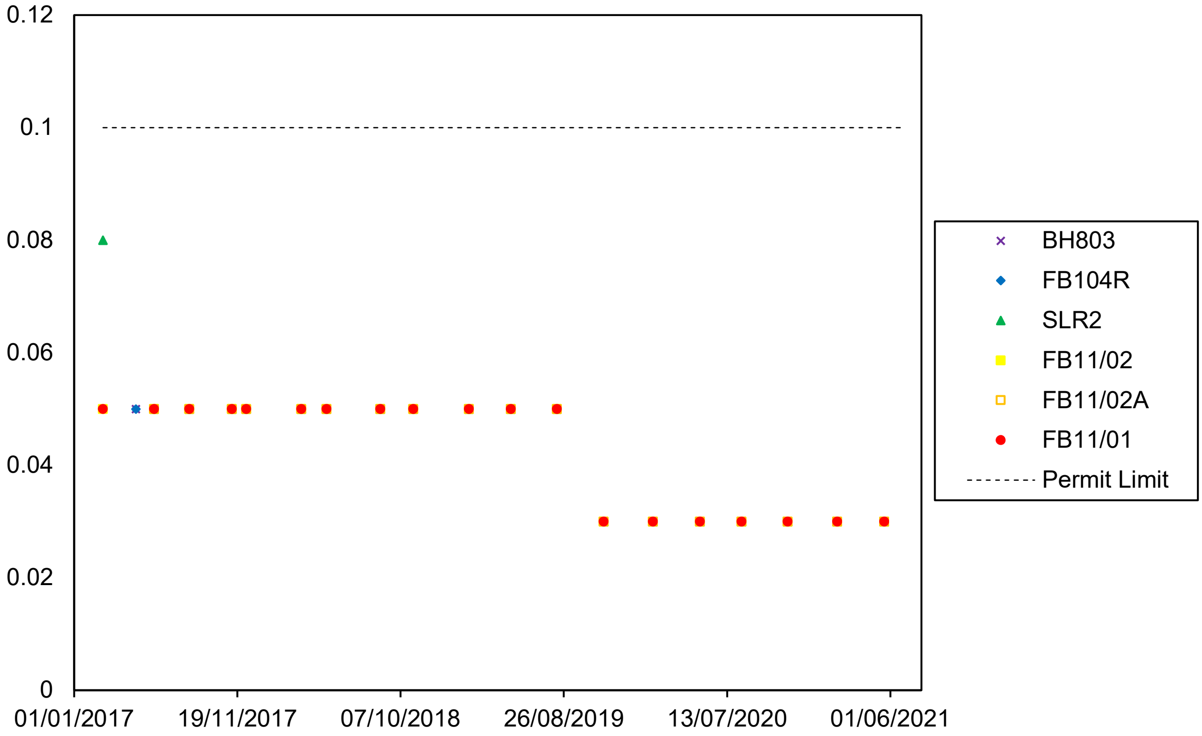
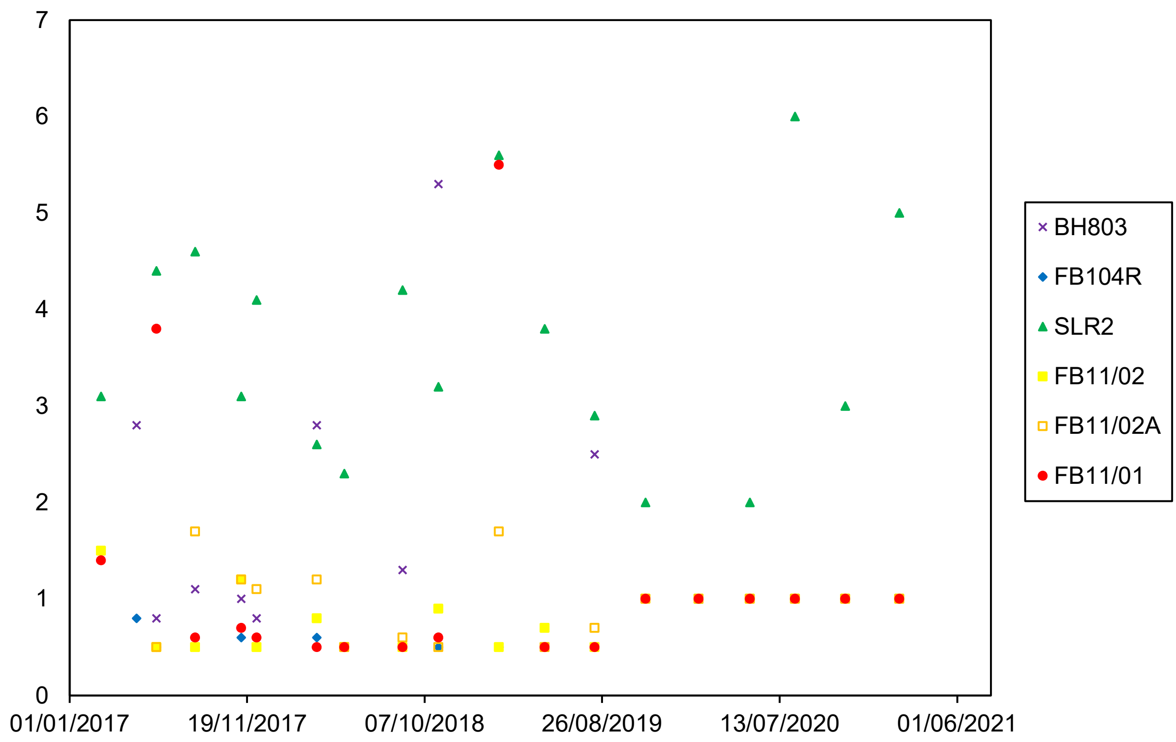
B1 – Groundwater Cadmium (µg/l)



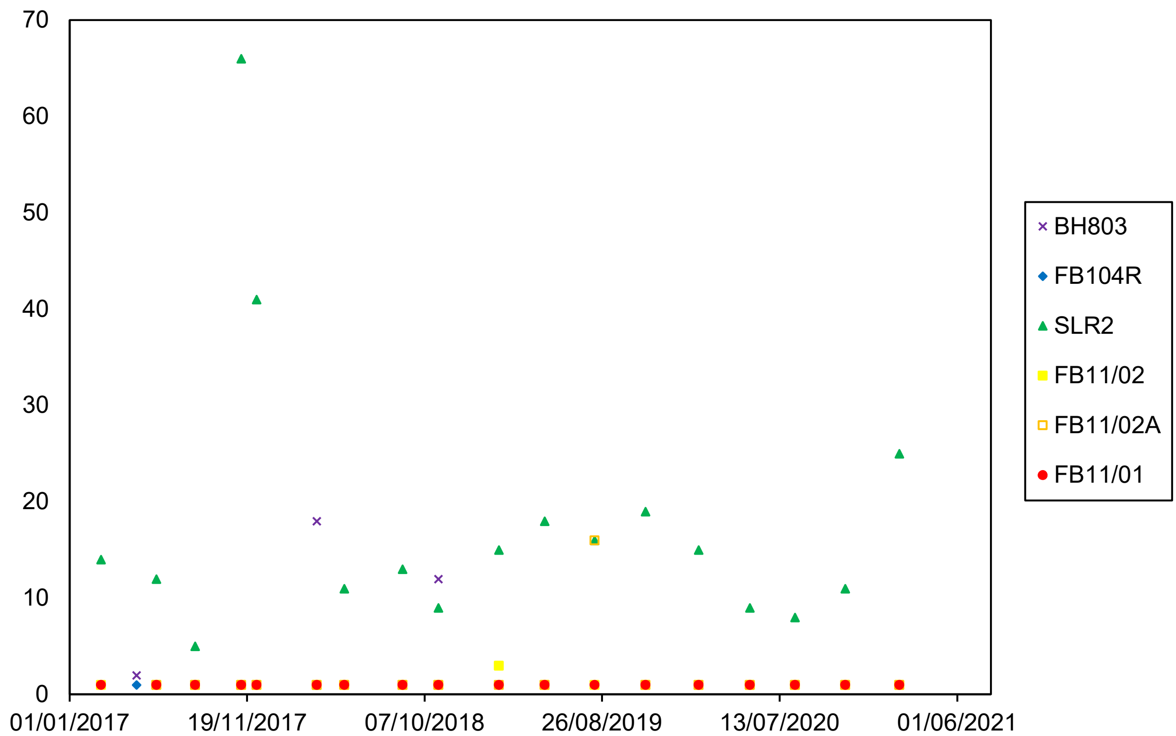
B2 – Groundwater Mercury (µg/l)



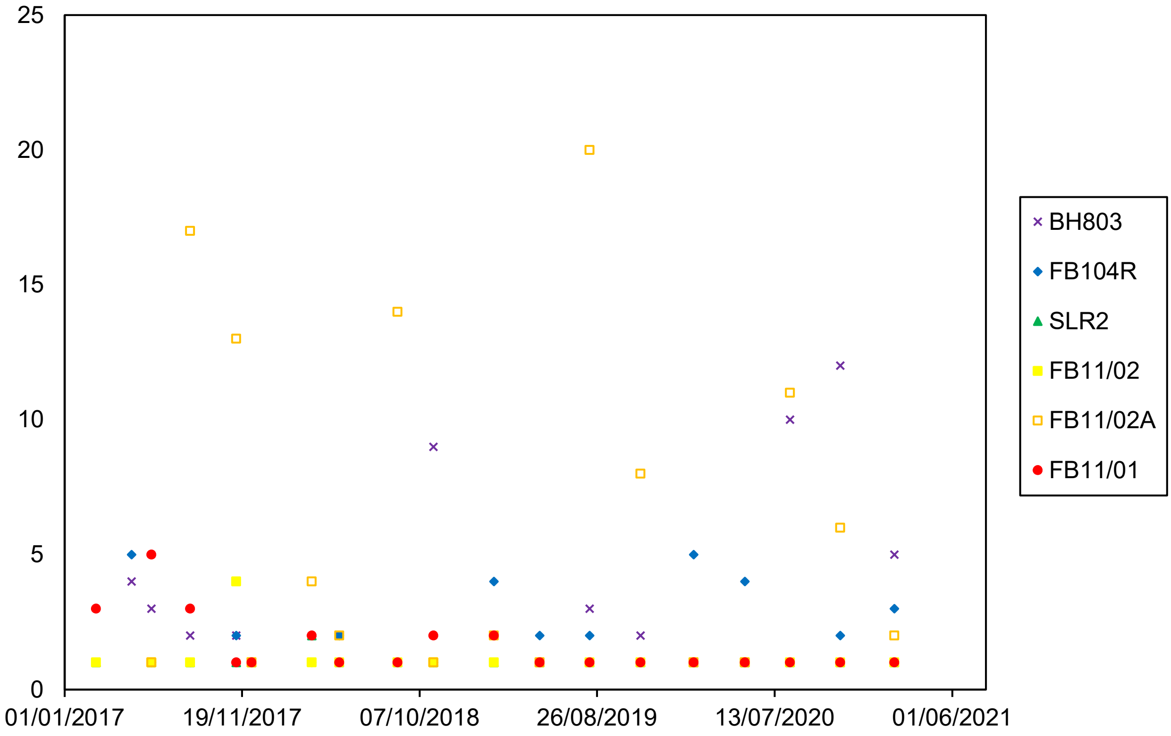
B3 – Groundwater Copper (µg/l)



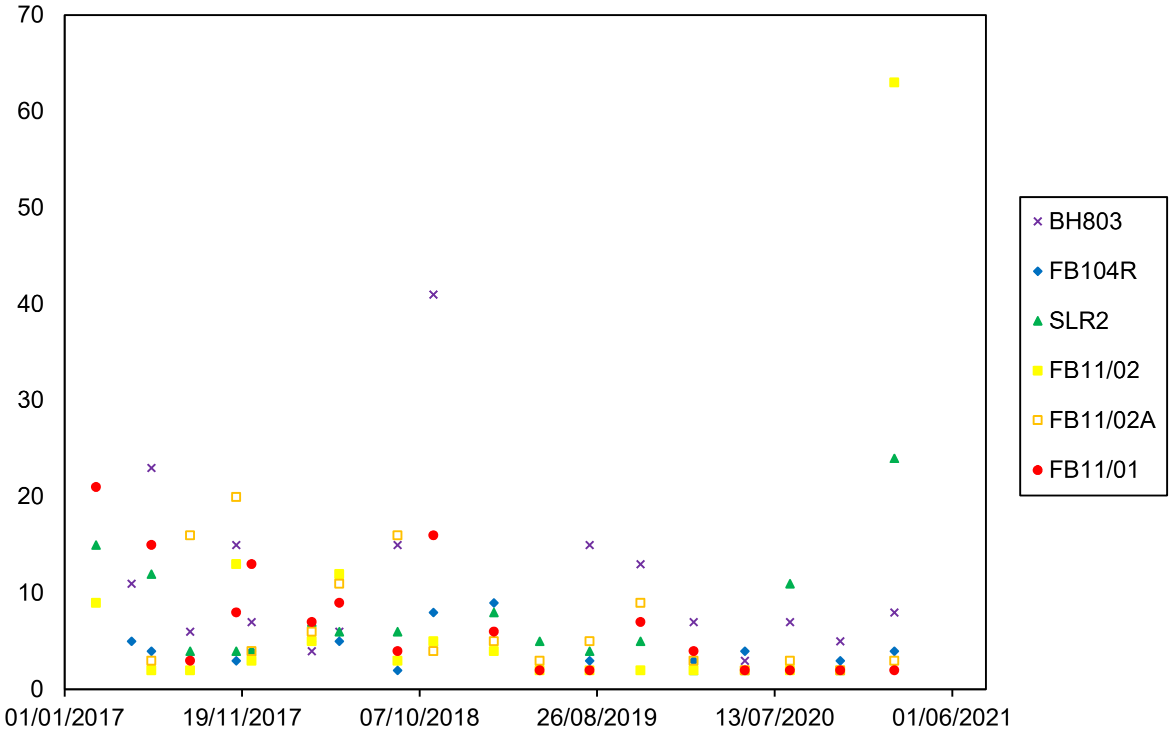
B4 – Groundwater Chromium (µg/l)



B5 – Groundwater Nickel (µg/l)



B6 – Groundwater Zinc (µg/l)



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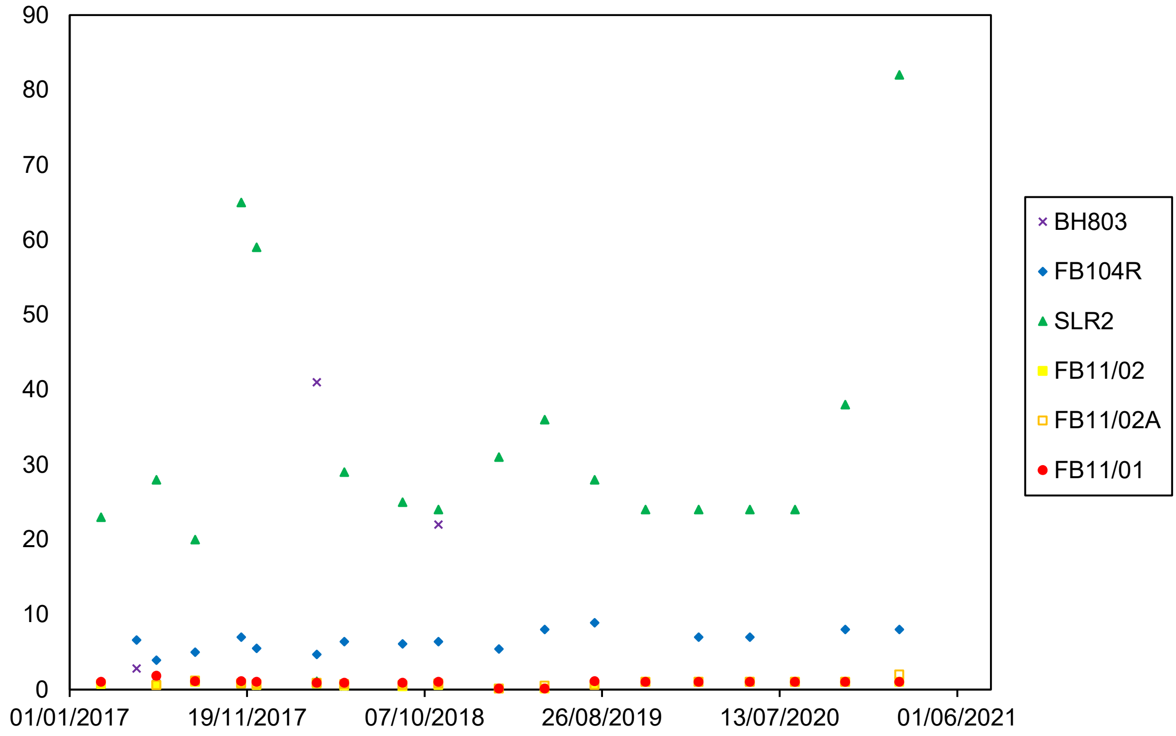
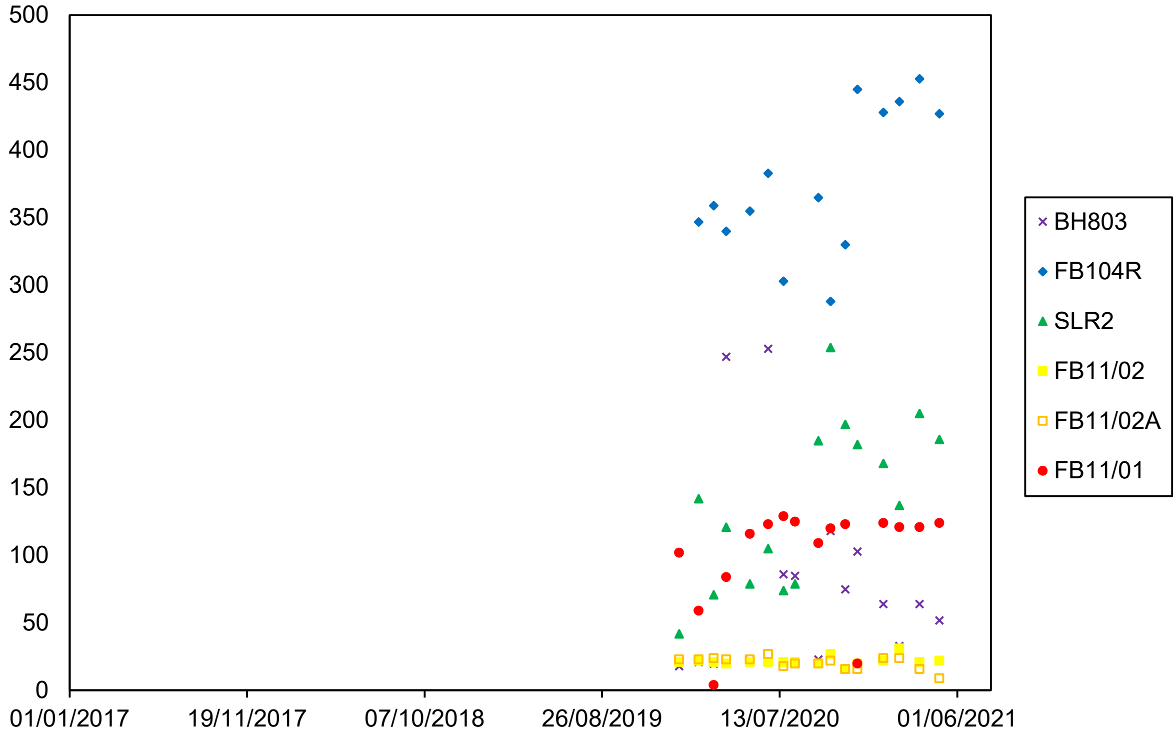
B7 – Groundwater Potassium (mg/l)



B8 - Groundwater Sulphate (mg/l)



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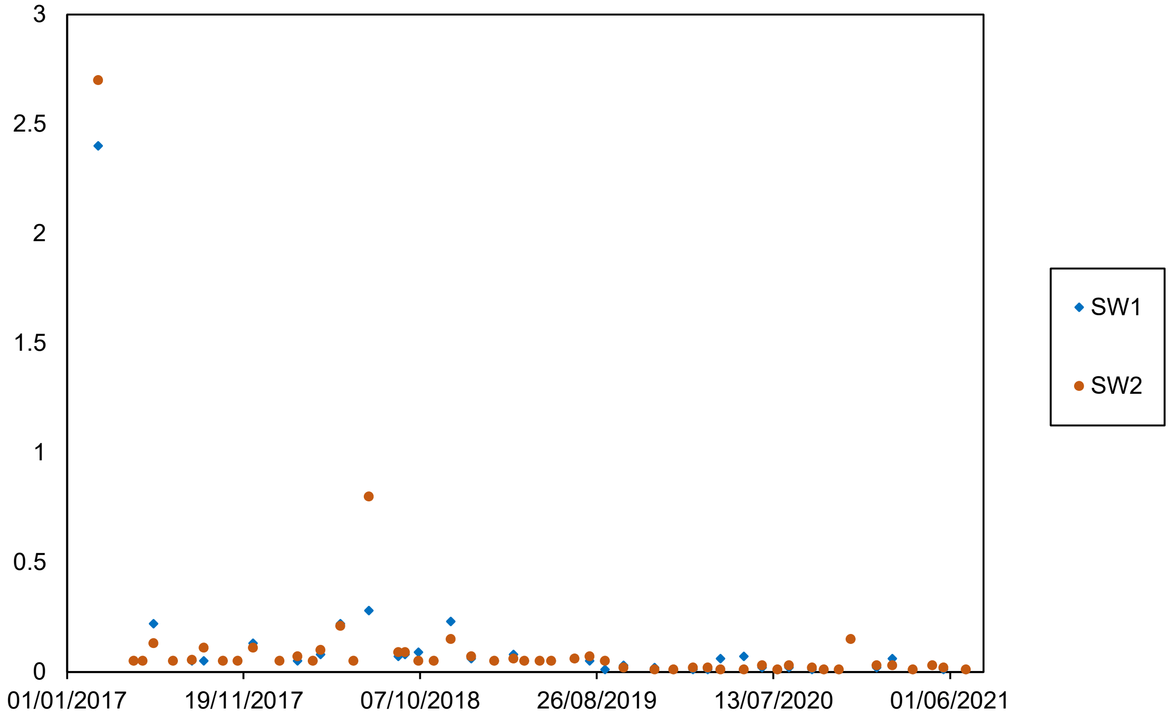
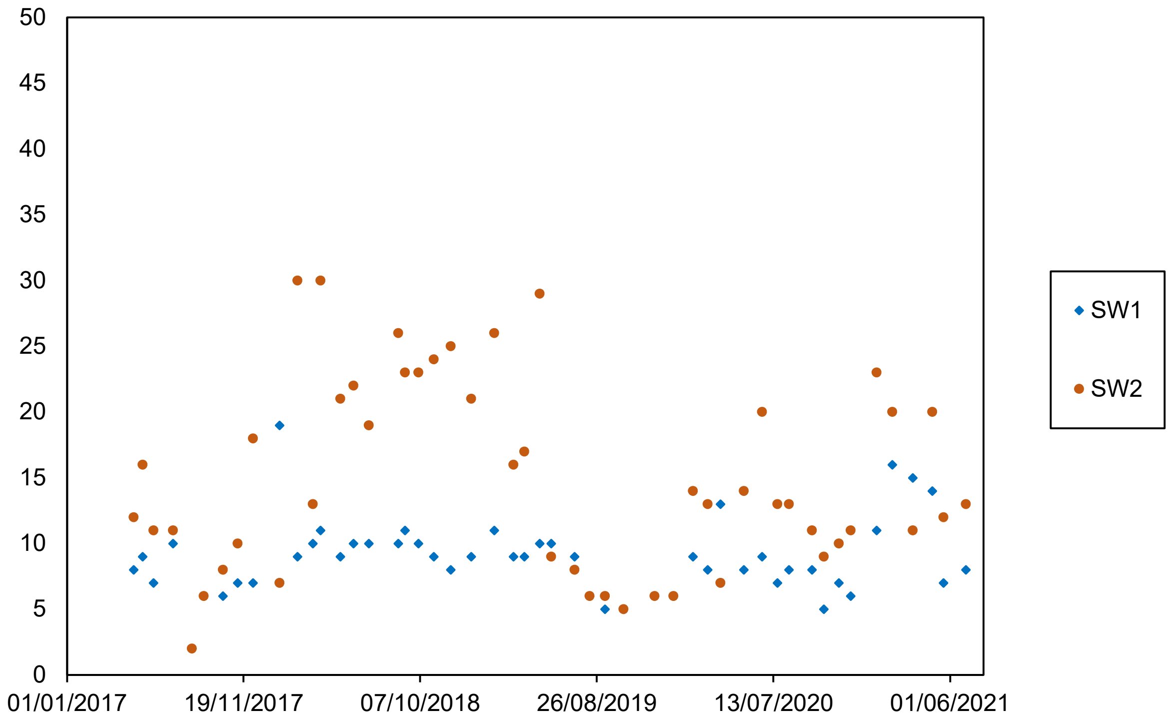
Appendix C – Surface Water Quality

C1 – Surface Water Ammoniacal Nitrogen (mg/l)

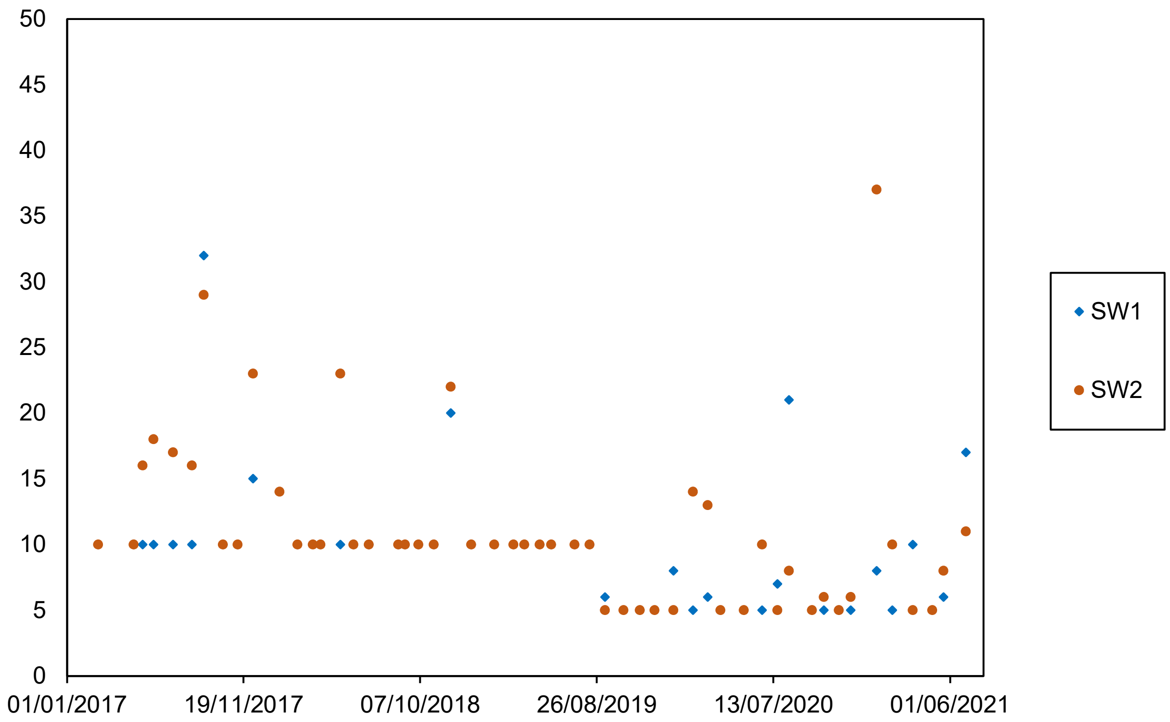


C2 – Surface Water Chloride (mg/l)



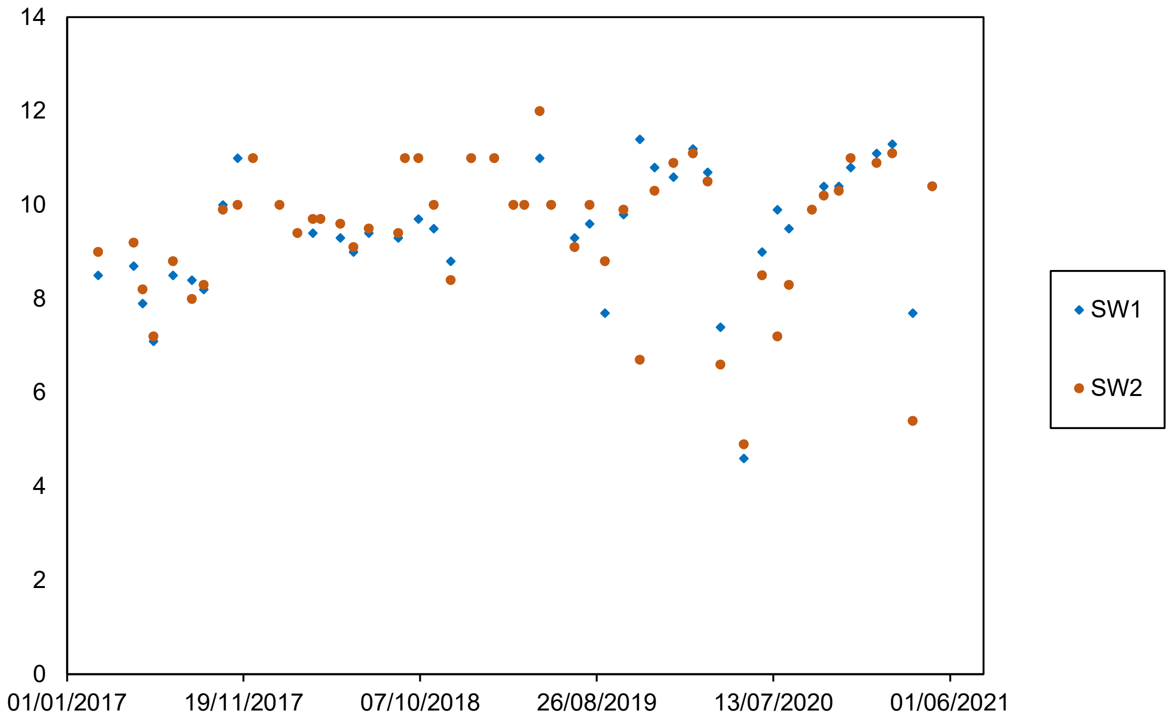
Note: Y-axis cropped to remove anomalous outliers of 360 mg/l in SW1 and 660 mg/l in SW2, both on 27/02/2017

C3 – Surface Water Suspended Solids (mg/l)

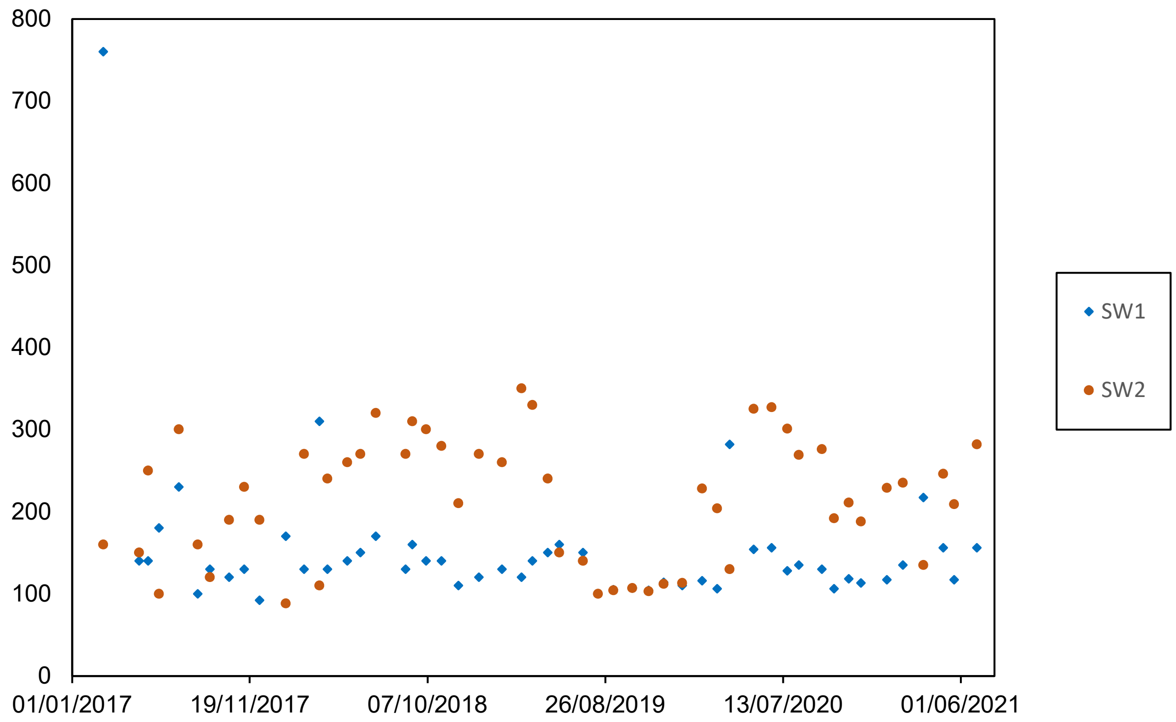


Note: y-axis cropped to remove anomalous outlier of 2,200 mg/l in SW1 on 26/03/2018

C4 – Surface Water Dissolved Oxygen (mg/l)



C5 – Surface Water Electrical Conductivity (µS/cm)



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