MORFA NON-HAZARDOUS LANDFILL
PORT TALBOT

ENVIRONMENTAL PERMIT BV7311IE

Review of Hydrogeological Risk Assessment

Report Number 2238r1v1d0622

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1 INTRODUCTION

Tata Steel (UK) Limited (Tata Steel) operates the Morfa Non-Hazardous Landfill (MNHL) in accordance with Environmental Permit No. BV7311Ie dated 17 December 2004 (the Permit). Since this time the Permit has undergone several Variations. The latest Variation Notice number is EPR/BV7311IE/V007 issued 7 October 2021.

The Permit applies to only part of the original Morfa Landfill waste management site, with approximately 40% being closed upon the commencement of MNHL and Morfa Hazardous Landfill (MHL). The closed part of the site is referred to as Morfa Closed Landfill (MCL). The location of MNHL and its position relative to key site features including MNHL and MCL is shown on Figures 1, 2 and 3.

Figure 1 Site Location Plan

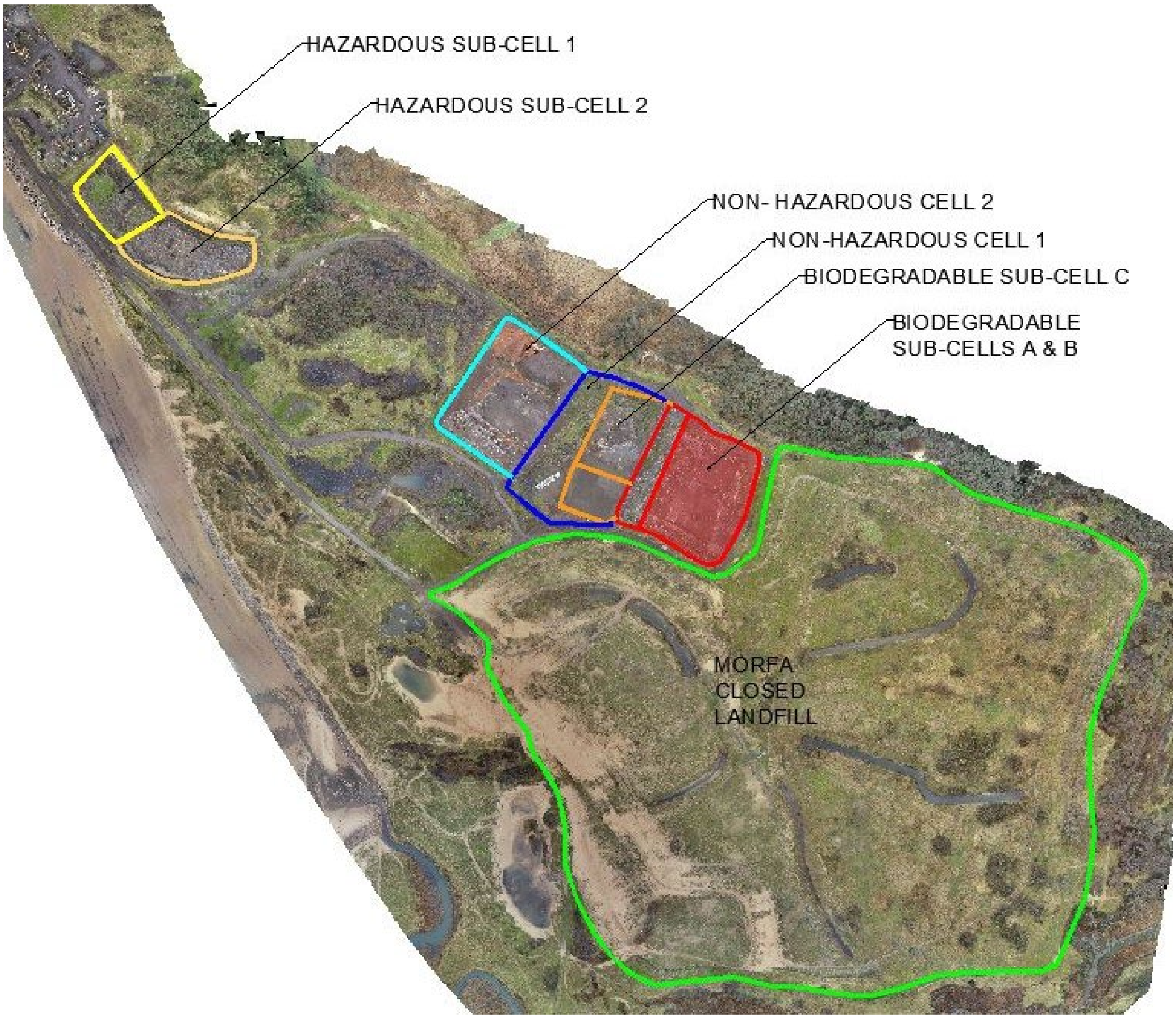


Figure 2 Aerial Image of Morfa Landfills

The Permit requires Tata Steel to submit a series of separate reports to Natural Resources Wales (NRW) regarding the environmental performance of each landfill. These reports include three monthly summaries of the monitoring results for landfill gas, leachate, surface and groundwater against the relevant control levels, emission limits and compliance levels. Additionally, a summary review of all monitoring data is required on an annual basis within three months of the end of each year.

In addition to these reports Permit Condition 3.1.7 states:

The operator shall submit to Natural Resources Wales a review of the Hydrogeological Risk Assessment:
(a) between nine and six months prior to the sixth anniversary of the granting of the permit, and
(b) between nine and six months prior to every subsequent six years after the sixth anniversary of the granting of the permit.

The Review of the Hydrogeological Risk Assessment is defined in the Permit as *a written review of the hydrogeological risk assessment included in the Application, together with any other parts of the Application that addressed the requirements of the EP Regulations. The* *review shall assess whether the activities of disposal or tipping for the purpose of disposal of waste authorised by the permit continue to meet the requirements of the EP Regulations.*

This report is the fourth review of the HRA as the Permit is 18 years old at the end of 2022. The previous reviews were also prepared by Geotechnology (see Geotechnology reports 711r1v1d0908, 1177r1v1d0712 and 1739r1v1d1217).

1.1 Review Objectives

In accordance with the Environmental Permitting Regulations, the specific objectives of the review are to:

- assess whether the level of risk to groundwater meets the terms of the Regulations

This review, therefore, includes an assessment of the conceptual hydrogeological model for MNHL in light of any new observations and monitoring data and the current quantitative HRA and a review of associated risk-management provisions and technical precautions.

1.2 Regulatory Context

The objective of this report is to prepare a HRA review for the site, in line with current Environment Agency (the Agency) guidance, to determine whether the site remains in compliance with the requirements of the Groundwater Directive (80/68/EEC), which is transposed into law in the United Kingdom by the Environmental Permitting (England and Wales) Regulations 2016 (EPR, 2016).

2 SITE LOCATION

Tata Steel operates the Morfa Landfills which are situated at the southern end of the Port Talbot steel plant (see Figure 1). One of the landfills accepts hazardous wastes and another accepts non-hazardous wastes. Both facilities are subject to requirements of an Environmental Permit issued by NRW. The landfills both operate in a cellular manner with the site footprint being progressively covered with discrete landfill cells. This systematic method of working minimises leachate generation and environmental impact and offers the opportunity of progressive site restoration. A large part of the Morfa site is also an historic unlined landfill which has now been capped.

2.1 Location

The centre of the site is located at National Grid Reference SS781 838. The site currently comprises a mixture of casually over-tipped land, landfills constructed in accordance with the current Landfill Directive since 2004 (MNHL and MHL), the unlined MCL, partially excavated sand dunes and pristine dune fields. Key features and boundaries are indicated on Figures 2 and 3.

The site was granted planning consent for sand extraction and waste disposal in 1973 and has been used in part for these purposes since. The planning boundary covers a large area (as shown on Figure 3), though restrictions within the conditions required a stand-off to be observed between the landfill site and the River Kenfig to the south and Margam Sands to the west. Tata Steel also adopted a voluntary stand-off between the development of MNHL and MHL and the Margam Moors, which was designated a SSSI in 1984, 11 years after planning consent for the landfill had been granted.

The site occupies a coastal location, adjacent to the dune system behind Margam Sands. The ground is generally flat with only 2 metres of relief between 6m and 8m AOD, though the western edge of the development encroaches into the dune system, where elevation rises to 14m AOD. The western edge of the site is the coastal dune field over its entire length and is roughly parallel to the beach which lies 75 metres further to the west. The southern edge of the site is occupied by MCL with the eastern edge following the fence line at the western edge of Margam Moors. The central part of the site is occupied by the current MNHL while the northwestern corner is occupied by MHL. The northern edge of the site is defined by a disused access track crossing from the coast road to the edge of the moors.

The site is remote and located at the southern end of the Port Talbot steel plant. It is surrounded by land entirely owned by the company. The adjacent Margam Moors as far as the railway line to the east is owned by Tata Steel as is the site as far south as the River Kenfig. KNNR is located to the south of the River Kenfig and is bound by the southern bank of the River Kenfig.

There are no inhabited buildings within 1.9km and the nearest industrial buildings are close to 1km from the site. There are no public roads within 1km of the site and the adjacent beach is also under the private ownership of Tata Steel. There are no services crossing the site. One public footpath crosses the moors close to the site.

2.2 Geology

Much of the site is underlain by an irregular sheet of wind-blown sand which extends from the ground surface down to an organic/alluvial clay layer. The sand deposit is typically several metres thick, though this locally increases due to sand dune topography. Being wind-blown, the dune sand is poorly graded, with a very uniform grain size throughout. The sand has blown inland from Margam Beach which lies to the west. Locally, the wind-blown sand is overlain by made ground comprising steel making wastes. The small woodland patches along the base of the northeastern flank of the site appear to be dune migration barriers and mark the extent of the blown sand.

Underlying the wind-blown sand is an organic and alluvial clay layer of up to 2.8m thickness. The alluvial clay layer is continuous with the clays found at the surface on the adjacent Margam Moors and therefore this layer represents the moorland surface prior to the deposition of the wind-blown sands. This clay layer is absent in the south, possibly being washed away by the meandering River Kenfig.

Where present, the clay layer overlies an estuarine alluvium sequence, comprising principally dirty sands with shell fragments. Locally, finer lenses are seen and on occasions the upper surface of the estuarine fines layer supports a thin organic layer. In the extreme north of the site, the estuarine fines dominate the sequence, with the upper 10m of the stratum comprising sandy silt and clays. Locally, within the estuarine deposits, gravels and even cobbles are noted occurring in bands, with one of these traceable between Boreholes 14 and 15.

The estuarine sands overlie glacial gravels at depth, which have been encountered in nearby deep boreholes. None of the investigation boreholes drilled at the site have continued sufficiently deep to intersect these strata. The glacial gravels, which also crop out beneath the seaward edge of the coastal barrier dunes, extend inland for some distance. Coal Measures Bedrock underlies the glacial gravels at a depth of approximately 26m at the nearby Newlands Colliery.

2.3 Hydrogeology

2.3.1 Shallow Aquifer

The shallow aquifer is the wind-blown sand deposit with vertical downward percolation eliminated or restricted by the presence of the underlying clay. Permeability tests have been undertaken (rising head tests), and these reveal a variation in permeability ranging from 2 x $10^{-3}ms^{-1}$ to 5 x $10^{-5}ms^{-1}$, with an average permeability of 2.3 x $10^{-4}ms^{-1}$. Due to the sand deposits limited thickness, the aquifer is thin, with perched water depths typically around 2 to 3 metres, extending from close to ground surface down to the underlying clay layer.

2.3.2 Deep Aquifer

Beneath the alluvial clay layer, the estuarine sands are saturated and piezometric levels are higher than the base of the clay. The water in the lower aquifer is therefore confined by the clay layer, where present. Rising head permeability tests have been undertaken in many of the boreholes, and these reveal that the lower aquifer is of lower permeability than the upper aquifer, with permeabilities ranging from 5.2 x $10^{-4}ms^{-1}$ to 1.5 x $10^{-7}ms^{-1}$. This is consistent with descriptions of the lower aquifer stratum as being silty sand.

Locally, thicker deposits of estuarine fines are found inter-bedded with the sands, with one principal fines stratum shown on the geological sections. At the northern edge of MHL, Boreholes 26 and 27 intersected a sequence dominated by silts and clays, with sand occurring as a minor constituent. Permeabilities here are expected to be accordingly smaller.

2.4 Hydrology

The site is surrounded by a sand dune field and there are no surface water courses within the site, or at its immediate perimeter. Surface water features in the vicinity of the site comprise the River Kenfig to the south, the Margam Moors ditch system to the north and the Bristol Channel to the west. A small number of isolated ponds are found on the low lying area to the north of MCL in an area that will be developed as part of MNHL. These are indicated on Figure 4.

Margam moors is a flat, poorly drained moorland which has been artificially managed over many centuries with a ditch or reen system. Precipitation is slow to run-off and the poor vegetation cover supports a small livestock rearing effort. The moors are characterised by the deep man-made reed filled ditches which allow the moors to drain water northwards where it is collected and pumped into the steel plant to be used as process water.

The flat lying moors have been managed for centuries and their configuration has been developed to address local ground conditions. The ditches are at their densest along the southern and western edge of the moors where there is a need to drain surface water originating from a pronounced springline. This springline is thought to be the result of the upper clay surface directing shallow groundwater in the upper aquifer to this area. All the ditches feed into the Mother Ditch which flows northward to a single gauged collection point. From here the entire flow of water is abstracted into the works for use as process water. The pumping is carried out after the water discharges over a weir, and therefore pumping cannot affect water levels in the ditches.

The River Kenfig drains a small catchment to the east of the site to the sea at Margam Beach. This is the principal watercourse in the area and separates the site from Kenfig National Nature Reserve which is bound by the southern bank of the Kenfig. The river has a 95 percentile low flow of 950 litres/sec.

2.5 Ecological Setting

The site lies in an area of great ecological interest. Some 40m to the south of MCL, on the opposite side of the River Kenfig is the Kenfig National Nature Reserve, a SAC. The site shares a common boundary to the east with the Margam Moors which has also been granted statutory protection by its SSSI designation. There are also significant ecological features on site, some of which are a direct consequence of the restoration activities undertaken by Tata Steel to date, particularly on the restored surface of MCL.

2.5.1 Kenfig National Nature Reserve

The northern boundary of Kenfig National Nature Reserve (KNNR) follows the southern bank of Kenfig River which flows to within 40m of the southern edge of MCL, as shown on Figure 3. KNNR is a Special Area of Conservation (SAC), designated because of:

1. Fixed dunes with herbaceous vegetation (grey dunes).
2. Dunes with *Salix repens* subsp. *argentea* (*Salicion arenarae*).
3. Humid dune slacks.
4. Atlantic salt meadows (*Glauco-puccinellietalia maritimae*).
5. Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.

Animal and plant species of community interest whose conservation requires the designation of Special Areas of Conservation; these are included on Annex II of the European Communities Council Directive on the Conservation of Natural Habitats and Wild Fauna and Flora:

1. Fen orchid Liparis loeselii
2. Petalwort Petalophyllum ralfsii

KNNR is also included under the following United Kingdom designations:

- Sites of Special Scientific Interest (United Kingdom)
- National Nature Reserves (United Kingdom).

2.5.2 Margam Moors SSSI

The western part of Margam Moors lies within 40m of the active MNHL and is shown on Figure 3. Margam Moors is a Site of Special Scientific Interest (SSSI) designated because of the mosaic of drainage ditches. In a Welsh context, only the extensive Wentlooge Levels support a similar assemblage of habitats and species.

2.5.3 On-site Ecological Features

Surveys of the ecological features on site have recently been undertaken as part of the review of mineral planning. Several significant ecological habitats were identified on site:

- Wet Woodland
- Reedbeds
- Ponds
- Coastal sand dunes
- Coastal vegetated shingle

Seven Nationally Scarce (BSBI Red List) and three Regionally Scarce plant species have also been recorded with the landfill site application boundary. A total of 35 Priority and Contributory sand dune specialists have been recorded to date with a further 37 species not confined to sand dunes but considered to be of local importance, as they are either important components of other valuable habitats, support scarce invertebrates or are locally scarce.

Plans showing the location of these features are set out in the Ecological Monitoring Plan.

3 OVERVIEW OF LANDFILL ACTIVITY

3.1 Construction of MNHL

Since issue of the Permit, four cells have been constructed; two biodegradable cells used for the deposition of wastes with a gassing potential and two cells for the deposition of non-hazardous waste without a significant gassing potential. A current topographic plan of the cells, as required by the Permit, is provided in Figure 5. This is based on a topographic survey completed on 14 January 2022. Table 3-1 provides a summary of the cells constructed to date.

Table 3-1 Landfill Cell Details

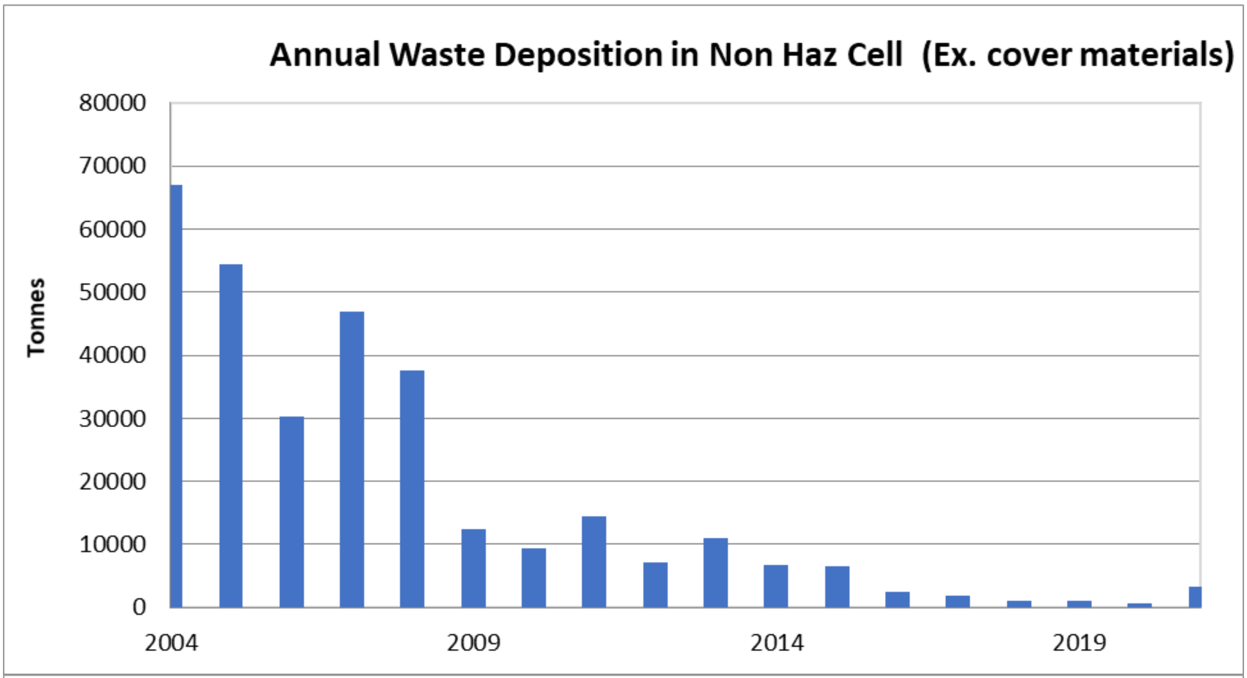
Cell Name	Leachate Sump	Waste Types
Cell 1	L7	Non-hazardous non-biodegradable
Cell 2	L8	
Biocell A	L1	Non-hazardous biodegradable
Biocell B	L6	

Each cell of MNHL is designed upon the containment principle. Pollutants are kept within the wastes by surrounding the wastes with barriers that are virtually impermeable to water, liquids and gases. The landfill is currently being constructed as a series of cells, each measuring some 200m x 115m. The Engineered Barrier System (EBS) of each cell comprises Bentonite Enhanced Sand (BES) overlain by a High-Density Polyethylene (HDPE) liner. Above the EBS is a leachate collection system. A cross-section of the key landfill engineering systems is provided in Figure 6.

3.1.1 Biocell Extension and Capping

Despite diminishing waste inputs (as shown in Chart 3-1), the existing biodegradable waste cells is now close to capacity, though there is large remaining industrial waste capacity in Non-Hazardous Cell 2. To address the shortage of biodegradable waste capacity, NRW recently approved the extension of Biocell capacity by recovering waste from Cell 1.

Up until 2021, and at the time of the previous HRA review, the existing Biocell was separated from non-hazardous Cell 1 by a deep narrow valley where the opposing south flank of Cell 1 met the north flank of the Biocells, as shown in Plate 3-1. The approved restoration contours for the landfill require that this valley is infilled to produce a single elevated landform. To secure additional biodegradable void space, NRW approved a cut into the upper part of the southern flank of Cell 1 (to enable waste recovery) and extension of the biodegradable waste cell lining system over the remaining Cell 1 waste to provide sufficient biodegradable waste capacity to 2028. The scheme is shown schematically in Figure 7 and Plate 3-3 shows construction progress as of June 2022. At the same time as the bio-cell extension, Tata Steel also capped Biocells A and B. This work was also largely complete at the end of May 2022, as shown in Plate 3-3.



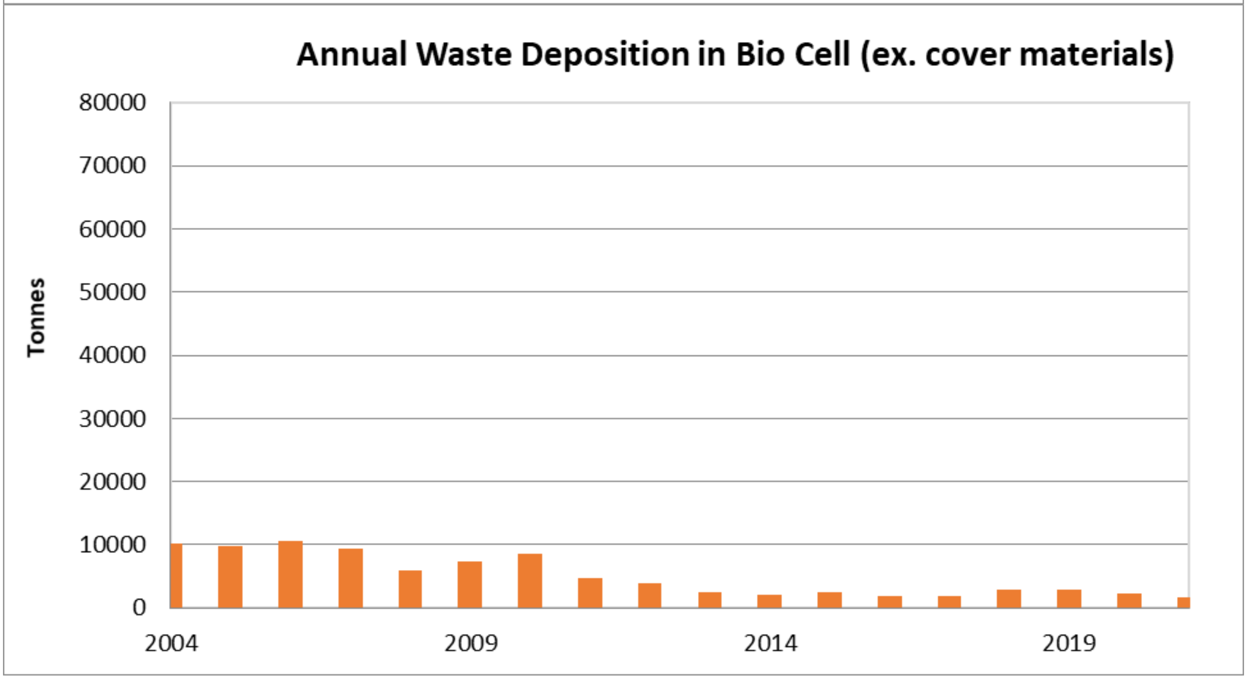


Chart 3-1 Tonnes of waste deposited each month at MNHL

Plate 3-1 View north towards Non-Hazardous Cell 1 prior to re-profiling, valley feature and uncapped Biocell

Plate 3-2 View north over new Biocell extension geomembrane lining

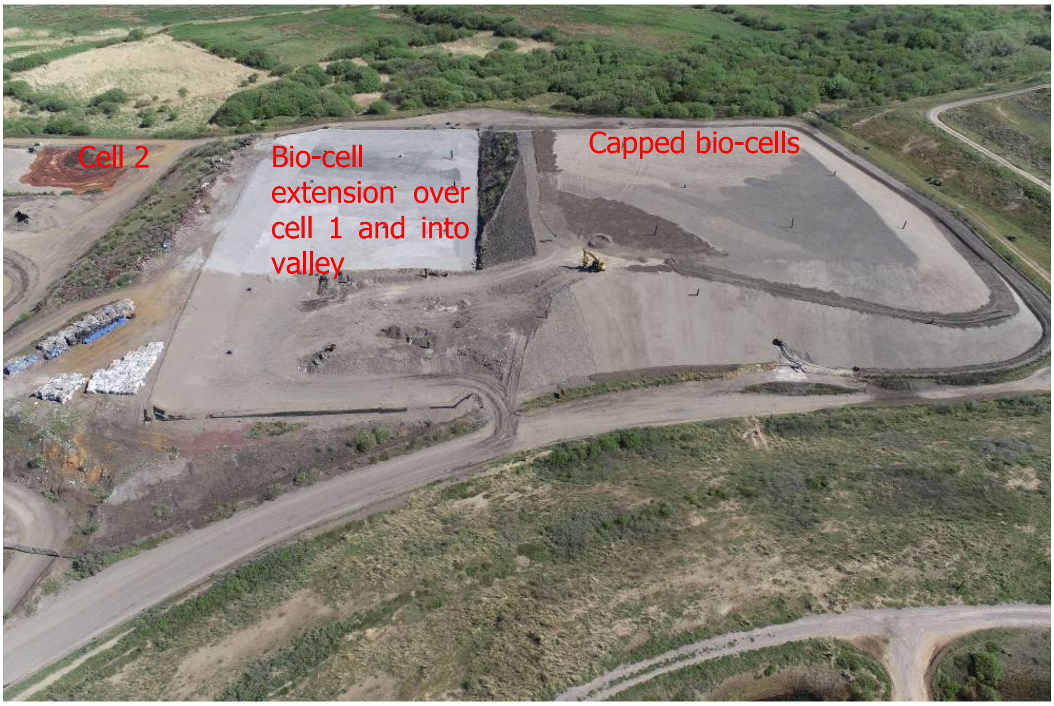


Plate 3-3 View north over biocell extension over valley feature and capped biocells

The lining system used in the construction of the biocell extension has involved the placement of the sequence of materials shown in Figure 7. The placement of such materials means that part of Cell 1 has now been effectively permanently capped. The extent of the extension is indicated on Figure 8.

3.1.2 Progressive Restoration

Progressive restoration of each cell should occur once it has been filled. This will limit leachate generation and enable better environmental control. At the time of the previous HRA, none of the cells at either MNHL had been capped.

During early 2022, Biocells A and B were capped and restored with much of the work complete by the end of May 2022, as shown by the landform in Plate 3-3. The capping system and landform was constructed in the same way as that used to cap MCL and the design is shown in Plate 3-4. The works involved the placement of a regulating layer; a protection/gas drainage geo-composite, a 1mm HDPE geomembrane comprising both smooth and double rough sided (DRS) types (for plateau and slope areas); placement of a geo-composite surface water collection layer and finally the restoration soils comprising site won sand. The construction of the recharge trench to accept run-off from the newly capped areas is currently ongoing in accordance with the approved designs.

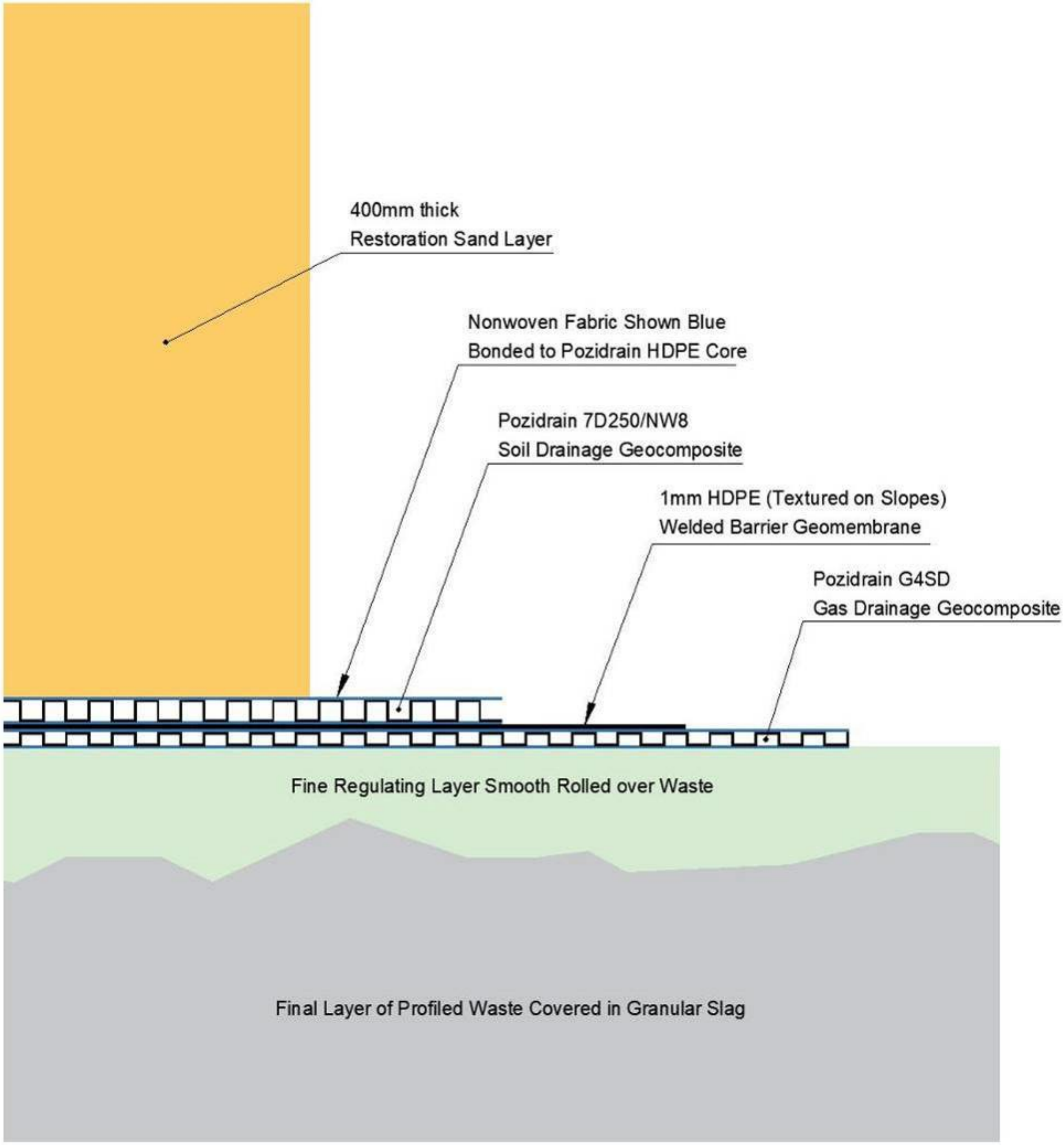


Plate 3-4 Capping System Layers

3.2 Landfilling at MNHL

3.2.1 Waste from Steelworks

A summary of the waste types and tonnages deposited at the landfill as recorded by the landfill operator is regularly submitted to NRW in accordance with the Permit requirements. A full graphical record of waste deposition is presented in Appendix 1 and a summary in Chart 3-1. This shows the data records up to the end of 2021. It is evident that the mass of waste being landfilled is declining significantly. Some of the waste being landfilled is shown in Plates 3-5 and 3-6.

Plate 3-5 Filtercake deposition adjacent to sump L8

Plate 3-6 Typical waste placed in bio-cell beneath daily cover

During 2006, part of the filter cake from the unlined Storage Bays located on MCL started to be deposited within Cell 1 of MNHL. Any leachate contained within or produced by this material would report to landfill sump L7. Leachate from similar material that has been historically landfilled in the upgradient unlined MCL is already influencing groundwater upgradient and down gradient of MNHL.

Since October 2008, hot mill sludge (HMS) filter cake generated by the steelworks has been landfilled in Biocell B. This process has subsequently continued at a rate of approximately 500-700 tonnes/month. In accordance with Improvement Condition 1 of the Variation Notice this prompted the monthly monitoring of Benzo(a)pyrene (BaP) on samples collected from sump L6. In September 2010, this data was reviewed to establish whether BaP control levels were required (see Geotechnology report 993r1v1d0910). As the data showed that BaP was not detected in the leachate, control levels were not considered to provide additional environmental protection. Since this time, Benzo(a)pyrene has not been detected in leachate.

3.3 Construction of Morfa Hazardous Landfill

Two cells have been constructed at MHL which is north of MNHL. Cell 2 was completed in August 2012. The rate of landfilling at the hazardous landfill has also reduced in recent years but as the current cell is reaching capacity, plans are being made for an extension.

3.4 Leachate Management

Leachate levels are regularly monitored in the sumps with the data summarised as a series of time series graphs in Appendix 2.

Until 2019, leachate was collected from the sump by vacuum pumps and tankered away from the landfill using $10m^3$ or $15m^3$ road-going tankers. These tankers took the leachate to the Tata Steel wastewater treatment facility at the steel works. This system has now been replaced by a fixed pumped system, discharging directly into the works via a holding/ balancing tank facility. A plan of the as-built system is reproduced in Figure 9.

The new system involves pumping leachate from all cells at MNHL and MHL (currently five cells). There are currently three individual leachate pipe runs, one for the two MNHL Biocell sumps, one for the two non-hazardous cell sumps and one for the MHL cell sump. Pumping at each cell is float controlled to ensure that leachate heads are within permitted trigger and maximum limits.

The three individual pipe runs discharge initially into a holding/balancing tank located at the permitted Waste Transfer Station area near to the DLS offices. The balance tank is also float controlled and combines all leachates for further pumping into the end discharge sump within the main works, located at Morfa Coke Ovens, Gas Holder Deep Sump. Flowmeters are located at each sump location and at the balance tank, to record individual and cumulative leachate outflows. The use of flowmeters will provide a check on the potential for leakage from any of the three pipes entering the balance tank.

Since the new system has become fully operational in early 2020, leachate levels have been reduced as the quantity of leachate removed from each cell has increased. This data is summarised in Appendix 2 and shows that leachate levels have been compliant with the Permit requirement of <1m depth at the leachate sump in recent months, since the system became fully functional and controlled. Controlling leachate levels in this way reduces the risk to the environment as it reduces the hydraulic pressure gradients within each cell. During 2021, 90,196 m^3 of leachate was removed from the non-hazardous cells.

3.5 Restoration of Morfa Closed Landfill (MCL)

Phased restoration of unlined MCL was undertaken between 2004 and 2013. The restoration involved the placement of site won dune sand over the plateau and parts of the re-profiled slopes. Below the sand, the restoration scheme involved placement of geomembranes shown in Plate 3-4 which, in combination, provide gas and surface water management as well as providing barriers to precipitation ingress and gas egress. The sympathetic restoration also involved the placement of sand on top of the geomembranes, creating dune morphology like the surrounding land. The restoration landscape, managed in accordance with an Ecological Management Plan, is shown in Plate 3-7.

Plate 3-7 Typical restoration profile on surface of MCL

During 2012 and 2013, restoration included the short-term recovery of materials to be used in the steel making process as the topography was re-profiled. During this phase, waste which had remained undisturbed for several decades was exposed. Such wastes will therefore have been temporarily susceptible to weathering and leaching prior to being re-profiled and capped. Seepage infiltrating to groundwater in these areas would be expected to pass beneath and around MNHL as MCL is hydraulically upgradient of MNHL.

3.6 Mitigation of Rainfall Shadow

The conceptual hydrogeological model of the Morfa landfills indicates that if recharge to groundwater becomes depleted due to capping and lining of waste management facilities, groundwater flow rate and groundwater elevation along the Moors would be expected to fall. In response, The Countryside Council for Wales (now NRW) indicated at the time of Permit issue, that as the groundwater-fed springlines along the edge of Margam Moors are afforded statutory protection as a SSSI any depletion in groundwater flows was considered likely to lead to a derogation of the wet alkaline patches which support this vegetation. Consequently, the concept of a recharge scheme was agreed that was aimed at restoring any shortfall in groundwater flow that might result from landfill capping and landfill lining.

The concept of the recharge trench, as part of the site wide restoration scheme, is relatively simple and outlined in Figure 10. Rainwater falling on the restored areas would be diverted to a series of storage ponds by gravity. The water from the ponds would then be fed by pipework down to the trenches running alongside the toe of MCL and MNHL. This would divert water from the ponds to the trenches, whilst ensuring that the ponds are not allowed to fully drain.

Restoration and capping of MCL and the development of cells at MNHL has resulted in direct rainwater infiltration being prevented in the areas identified on Figure 11. The current recharge shadow shown on Figure 11 has developed over a decade in line with the progressive development of MNHL and capping of MCL, as summarised in Table 3-2.

Table 3-2 Summary of site activity to date

Activity	Start	Finish
Construction of MNHL Cell 1	1 June 2004	19 October 2004
Construction of MHL Cell 1	1 June 2004	19 October 2004
Restoration of MCL	September 2004	8 June 2013
Construction of MNHL Biocell A	14 June 2004	8 September 2004
Construction and operation of waste treatment centre	5 December 2006	Ongoing
Construction of MNHL Biocell B	August 2007	13 October 2007
Construction of MNHL Cell 2	6 May 2008	31 July 2009
Landfilling of HMS filter cake in MNHL Biocell 2	28 October 2008	Ongoing
Construction of MHL Cell 2	October 2011	Ongoing
Temporary storage of fire waste	25 June 2011	14 March 2014
Construction of recharge trench pipeline sections A & B	30 Aug 2012	12 Oct 2012
Connection of recharge trenches to ponds and commissioning of system	Ongoing	(Partly completed during 2016 but damaged due to vandalism)
Installation and operation of new leachate pumping system	2018	October 2019
Construction of Biocell Extension	April 2020	May 2022 (work largely complete but not yet approved)
Capping of Biocells	December 2021	May 2022 (work largely complete but not yet approved)

Since the issue of the Permit and capping of MCL, two sections of the recharge trench at the toe of MCL have been constructed and further trenches are currently being installed along the toe of MNHL. The infrastructure at MCL includes the supply ponds on the surface of the capped landfill and associated pipework, subterranean pipelines, control chambers, wind turbines, electrical power and batteries. Much of this infrastructure is still in place but has unfortunately suffered from vandalism and theft. This has resulted in parts of the system becoming inoperable and others working under gravity and passive means. This has led to an amended approach to the operation of the system being recently agreed with NRW, as detailed in Geotechnology report 2132r1v2d0422. These works are currently being constructed.

3.7 Sand Extraction

Restoration of MCL was completed in 2013. Following completion, there was no immediate demand for sand. However, since this time parts of the restored cap of MCL have been subject to wind erosion as the self-seeding vegetation is yet to take hold. Therefore, approximately 5000 tonnes has been excavated from Borrow Pit 1, as part of aftercare maintenance. Further extraction is envisaged as set out in the ROMP phasing plans (see Geotechnology report 1914r1v1d0819).

Tata Steel has also been trialling new techniques for reducing wind-blow with the ecologist who prepared the Ecological Monitoring Plan.

3.8 Remaining Void Space

A topographic survey of the operational landfill cells was carried out on 8 January 2021 and a repeat survey on 14 January 2022. Following data acquisition, the digital data was imported into a digital terrain model for each of the cells to calculate the available void space.

Since 2013 the surveys have been completed using an unmanned aerial vehicle (UAV) with survey control established using dGPS land-based Hiper-SR survey equipment. The UAV data is then used together with ground control points to create a digital terrain model. This method of surveying collects data points at significantly closer intervals than methods previously used and is therefore able to create a more detailed topographic model, as shown in Figure 5.

Based on a comparison of the topographic levels observed at the start of 2022 with those previously measured in 2021, an updated assessment of void space available in each active cell has been made. This is summarized in Table 3-3.

Due to the construction of the new Biocell extension, the total volume of Non-Haz Cell 1 has decreased compared to the total previously provided and this cell is now considered full.

Table 3-3 Assessment of Remaining Landfill Capacity

Volumes (m^3)	Biodegradable Cell A	Biodegradable Cell B	Biodegradable Cell C	Non-Hazardous Cell 1	Non-Hazardous Cell 2
Total	78833.52	93067.88	70115.00	172006.25	208340.25
Used 2021	Full	Full	5813.00	164841.08	84132.78
Available 2022	Full	Full	64302.00	7165.17	124207.47
% Available Space	Full	Full	91.71	Full	59.62

4 MONITORING

To demonstrate that the site is functioning as designed, a rigorous monitoring programme is in place in accordance with the requirements of the Permit. The programme is managed by Tata Steel. The Plan covers ground and surface water monitoring, dust and noise emission, landfill gas production and stability. Control levels have been previously identified at which the landfill would be considered to be behaving differently from expected. If these control levels were to be breached, investigation and remediation will be actioned. If compliance limits are exceeded, the site is outside the scope of the Permit and the operators must take whatever action is necessary to keep the site within the terms of the Permit.

Continued environmental protection and the re-evaluation of the original HRA are intimately linked to the high quality monitoring programme. The detail of the routine monitoring has been reported elsewhere as part of the annual Permit reporting requirements.

4.1 Monitoring Network

Routine hydrogeological monitoring at MNHL has occurred since 2004. During this time the monitoring network has expanded and changed. The currently available monitoring network is shown in Figure 12. The monitoring network and the equipment used to take on-site measurements are routinely checked and calibrated where necessary. One of the key improvements to the monitoring network is the installation of dedicated inertial or submersible pumps at each position for the collection of samples. These enable samples to be collected more efficiently and avoid the potential for cross contamination between sample points. Unfortunately, the locked borehole headworks are sometimes vandalised, particularly in the remote parts of the site, and the equipment stolen.

In February 2022, replacement boreholes were installed at BH17 due to a blockage within the original well preventing routine sample collection.

4.2 Laboratory Analysis

Severn Trent Laboratories (STL) was the laboratory used at the start of the monitoring programme in February 2005. In July 2006, STL was replaced by Testing Solutions for all water analysis by Tata Steel. Testing Solutions is based at the Engineering Centre for Manufacturing and Materials (ECM) in Margam, adjacent to the steelworks. Testing Solutions, (now known as TDC) has been responsible for all water and leachate analysis since July 2006. All aspects of the analytical programme are directly managed by the Tata Steel Environment Department.

5 OVERVIEW OF LEACHATE

5.1 Leachate Levels

Based on the monitoring results provided by the landfill operator, the variation of leachate levels above the base of the sump is fully illustrated in Appendix 2 and summarised in Chart 5-1.

The monitoring reveals that leachate levels exceeded 0.75m above the concrete slab in the winter periods of 2013, 2014 and 2015. Between 2016 and winter 2019, the leachate levels regularly breached the compliance 1.0m level which means that this aspect was not in accordance with the Permit requirements.

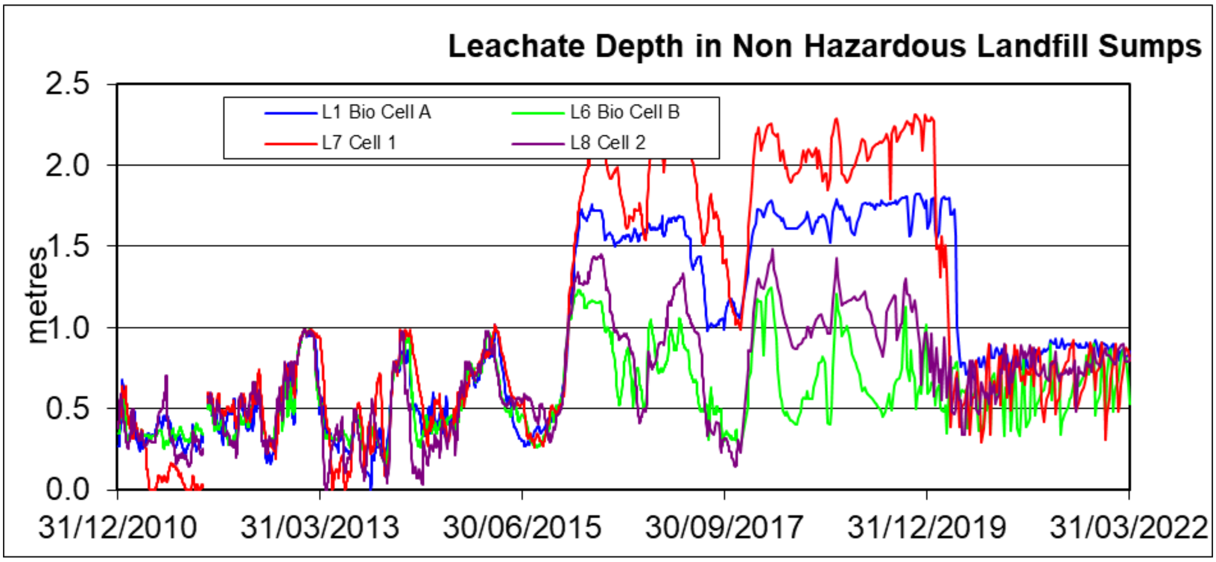


Chart 5-1 Leachate levels

Since 2019, the new leachate management system has had a dramatic influence on leachate levels with significant leachate level reductions in all cells. This step change is a direct consequence of the new system enabling the volume of leachate extracted to be significantly increased. This has enabled the landfill to be compliant with the 1.0m leachate level compliance limit set in the Permit.

Each landfill cell is monitored at a separate landfill sump. Leachate samples L1 and L6 are located in the sumps in Bio Cell A and B and L7 and L8 in Cell 1 and Cell 2 respectively. Samples are collected using dedicated pumping equipment.

5.2 Leachate Chemistry

At the time of the original HRA, there was a relatively small amount of leachate chemistry data available and the system was dynamic as it was only a few years old. Since this time, a significant dataset has been developed and the leachate quality has, in the most part, stabilised. During this time the range of wastes has remained relatively consistent but the quantities of waste landfilled has fallen. As the waste landfilled at MNHL is not largely biodegradable the evolution of the leachate is not following the typical trajectory often seen in municipal solid waste landfills. Rather, the leachate chemistry is being controlled by mostly inorganic processes i.e. the waste fractions (including the biodegradable waste) contains little reactive carbon to sustain significant biodegradation.

5.2.1 Non-Volatile Species

Analysis of the leachate samples to date has revealed that it is typically dominated by a highly characteristic signature comprising elevated pH, calcium and alkalinity and low sulphate. This signature is strongest in the leachate in Cells 1 and 2 (sumps L7 and L8). The hydrochemistry of the leachate is illustrated in the graphs included in Appendix 3.

In recent years, the leachate has become more dilute with the electrical conductivity declining, most likely because of dilution due to high rainfall and previously persistent high leachate levels. The lower mineralisation is characterised by lower levels of ammonia, calcium, alkalinity and most notably chloride.

Against this declining trend, the short-term spike in Electrical Conductivity observed in several leachate sumps in September 2021 is unusual. As the electrical conductivity was also found to be uncharacteristically elevated in a wide number of samples at the same time in September, including the rainwater fed ponds on MCL and groundwater upgradient of MNHL, it would appear that this particular data should be viewed with caution.

Filter cake (EWC code 11 01 10) has been placed into Cells 1 and 2 (with leachate draining to sumps L7 and L8) at a rate of up to 500 - 800t/month since the start of monitoring. Produced by the lime neutralisation of acidic ferrous chloride and pickling solutions at the cold mill effluent treatment plant, the waste principally comprises iron oxyhydroxide chloride phases, calcium chloride, iron chloride and mixed oxides. Within the landfill, the soluble components of the waste are leached by infiltration. This process is suspected to be the main source of the elevated levels of chloride and calcium. As the waste becomes buried and less oxygenated, the oxyhydroxide iron phases may also start to undergo changes. Some may start to age and crystallise, forming more stable iron oxide phases and some may undergo reductive dissolution in anaerobic conditions that may be present in parts of the landfill. This latter process could potentially release iron into the leachate along with other trace metals adsorbed to the iron precipitates.

This latter process was previously considered to be occurring within Cell 2 at L8, as iron significantly increased in concentration from <1mg/l to over 1000 mg/l during the latter part of 2012 and was elevated on several occasions during 2013. At the same time, the leachate sampled at sump L8 was found to be green in colour and the laboratory measured pH variable over a relatively brief time i.e. dropping from over pH 11 to pH 4 and then returning to pH 11 within 12 weeks (see chart below). Similar patterns were observed during 2014, 2015 and 2016. Since 2019, these variations have been less pronounced.

Nitrogen and phosphorous species are not typically persistently detected within the leachate.

Since the previous HRA, the UKTAG published a technical report on Hazardous substances groundwater hazardous substances. This revised the list of substances previously assessed to be hazardous. Of particularly relevance here is the re-classification of cadmium and naphthalene to non-hazardous pollutants. As noted in the previous HRA review and the subsequent annual reports, hazardous substances are rarely found at elevated concentrations in the leachate. Many non-hazardous pollutants are also either not detected above the analytical detection levels or present at very low levels, some of which are comparable to or below current Environmental Quality Standards (EQS). It is likely that the mobility of most of these substances is being limited by the elevated pH although substances capable of forming oxyanions, such as vanadium, are more frequently detected.

5.2.2 Volatile Species

Due to the nature of the waste streams very low levels of hydrocarbons, volatile organic compounds (VOCs) and semi VOCs have been detected to date. No substances have been detected in the recent years.

5.3 Contingency Actions Taken

Tata Steel and the landfill operator have pro-actively engaged with NRW regarding the plans to reduce the elevated leachate levels. This included the implementation of increased pumping in the short-term and construction of a dedicated leachate pumping system that became operational October 2019. This has had a step-change positive impact on leachate levels and directly reduced risk to the controlled water environment. Progressive restoration is also ongoing. NRW is also notified of breeches of Permit levels.

6 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual hydrogeological model for the landfill site developed as part of the original Permit Application was based on the ground investigations related to the installation of the extensive monitoring network. Since this time, the monitoring network has changed very little. As the conceptual site model underpins the landfill design and assessment of risk each aspect is discussed here. There have been no significant changes to the hydrogeological aspects of the model since the previous HRA review.

6.1 Strata Geometry

Several phases of site investigation and groundwater monitoring well installation have occurred as follows:

- April 1995 – Installation of boreholes with piezometers by Posford Duvivier. Piezometers targeted the shallow and deep aquifer. The positions installed were BH1, 2, 3, 4, 5, 6
- April and May 2000 - Excavation of 14 trial pits using a backhoe excavator and six boreholes using cable tool drilling. 19mm steel piezometers were installed in two trial pits and are referred to as TPG and TPV. Each of the boreholes were fitted with piezometers targeting the shallow and deep aquifer. The boreholes installed were BH11, 12, 13, 14, 15 and 16
- January/February 2005 – ground water/gas wells installed using cable tool drilling. At monitoring locations BH 15, 16, 17, 18, 19, 20, 25, 26 and 27, piezometers were installed in the upper and lower aquifers for groundwater monitoring purposes. At BH7 and GWT2a, piezometers were only installed in the upper aquifer for groundwater monitoring purposes. Boreholes GA7, 8, 9, 10, 11, 12, 15 and 16 were drilled for the installation of landfill gas monitoring wells and only partly penetrated the upper aquifer
- April 2005 - twenty four 19mm steel piezometers were manually driven into the shallow aquifer at depths of up to 3m below ground level. These piezometers are referred to as P1 – P24
- July 2007 - Cable tool drilling BH28 and BH29 which were instrumented with 50mm ID wells sampling the shallow and deep aquifer
- December 2008 – Cable tool drilling BH30 and GWT3a which were instrumented with 50mm ID wells sampling the shallow aquifer

All monitoring positions have been topographically surveyed to Ordnance datum using a differential GPS. The groundwater monitoring network has not changed since the previous HRA and no new waste cells have been constructed.

Relative to the data at the time of the Permit Application, the supplementary boreholes installed in 2005 confirmed the known sequence of strata beneath the site. Those that pierced the clay aquitard between the two aquifers demonstrated that the clay thickness shows little variation across the site and does not appear to be subject to localised variability. An interesting refinement to the conceptual understanding of the clay aquitard was noted following the investigations completed in 2005. Previously it was thought that the upper surface of the clay aquitard was planar and dipping gently to the north but these investigations revealed that whilst it does gently dip to the north, it is in fact slightly undulating. The principal feature of importance was the discovery of a broad shallow valley or trough running centrally through the site from south to north. Sufficient density of ground investigation data allowed this feature to be identified and it explained a phenomenon noted for some time but never adequately understood.

Contaminated groundwater emanating from MCL passes beneath the MNHL site in response to the shallow hydraulic gradient in the shallow aquifer. The water flows northwards until it reaches the edge of the wind-blown sand where it issues as a series of springs or wet patches. The original conceptual model, if correct, should have seen a uniform distribution of springs or issues along the edge of the sand sheet where it meets the clay. However, this was not the case as surface flows are typically concentrated in the vicinity of BH3 and BH4. This area can now be seen to be the down-gradient edge of the shallow trough present in the upper surface of the clay aquitard and thus a perfectly understandable location for a concentration of discharge from the shallow aquifer.

6.2 Groundwater Flow

Tata Steel monitors groundwater and surface water levels around the site at a series of shallow piezometers, groundwater wells and surface water gauging posts, as indicated on Figure 12.

6.2.1 Shallow Aquifer

The shallow aquifer is the wind-blown sand deposit with vertical downward percolation eliminated or restricted by the presence of the underlying clay. Permeability tests have been undertaken (rising head tests), and these reveal a variation in permeability ranging from 2 x $10^{-3}ms^{-1}$ to 5 x $10^{-5}ms^{-1}$, with an average permeability of 2.3 x $10^{-4}ms^{-1}$. Due to the sand deposits limited thickness the aquifer is thin, with perched water depths typically around 2 to 3 metres, extending from close to ground surface down to the underlying clay layer.

Examination of the shallow groundwater surface shown in contour plans included in Appendix 4 shows that it is domed and has been largely stable for the past decade, with a concentric series of groundwater elevation contours centred on the highest elevation, close to the centre of the site (typically around BH19).

The dune sand has been found to have limited extent, petering out along the site's boundary with Margam Moors. The moorland, which lies directly on the clay layer, is continuous with the clay underlying the windblown dune sand and therefore the presence of a spring-line where the groundwater surface meets the edge of the sand deposit is not unexpected. A significant spring-line along the northeast edge of the boundary along Margam Moors can be seen on the ground and this strip of wet ground supports a fen habitat which has been protected by SSSI status.

To the west of the site, the shallow aquifer discharges into Margam Beach in the inter-tidal zone. It is difficult to see the spring-line under conditions other than dry periods with spring tides but a linear seepage line at an elevation of 2.5m AOD is present.

The shallow aquifer may or may not have localised areas where it is in continuity with the underlying deep aquifer. At every point where an investigation borehole has been drilled sufficiently deep, the presence of the underlying clay layer has been confirmed. It is likely therefore that the clay aquitard is either complete or near complete.

Ground investigation data has revealed that the ground alongside the Kenfig and along the southern part of the existing site comprises wind-blown sand directly over estuarine sands. The clay layer, characteristic of a large part of the site and the entire MNHL Permit boundary, is absent. Geotechnology considers that this absence is most likely due to river erosion. There is, however, a permeability contrast between the wind-blown sand aquifer and the underlying estuarine sands and this causes stratification within the groundwater. Greater heads in the shallow groundwater indicates that recharge from the shallow aquifer is active, explaining the difference in chemistry between shallow and deep groundwater along this edge.

Despite the full extent of the current recharge shadow being in place since 2013, and having started in 2004, groundwater flow patterns are largely unchanged. This is clearly highlighted in the contour plots selected for illustration in Plate 6-1. Further plots are provided in Appendix 4.

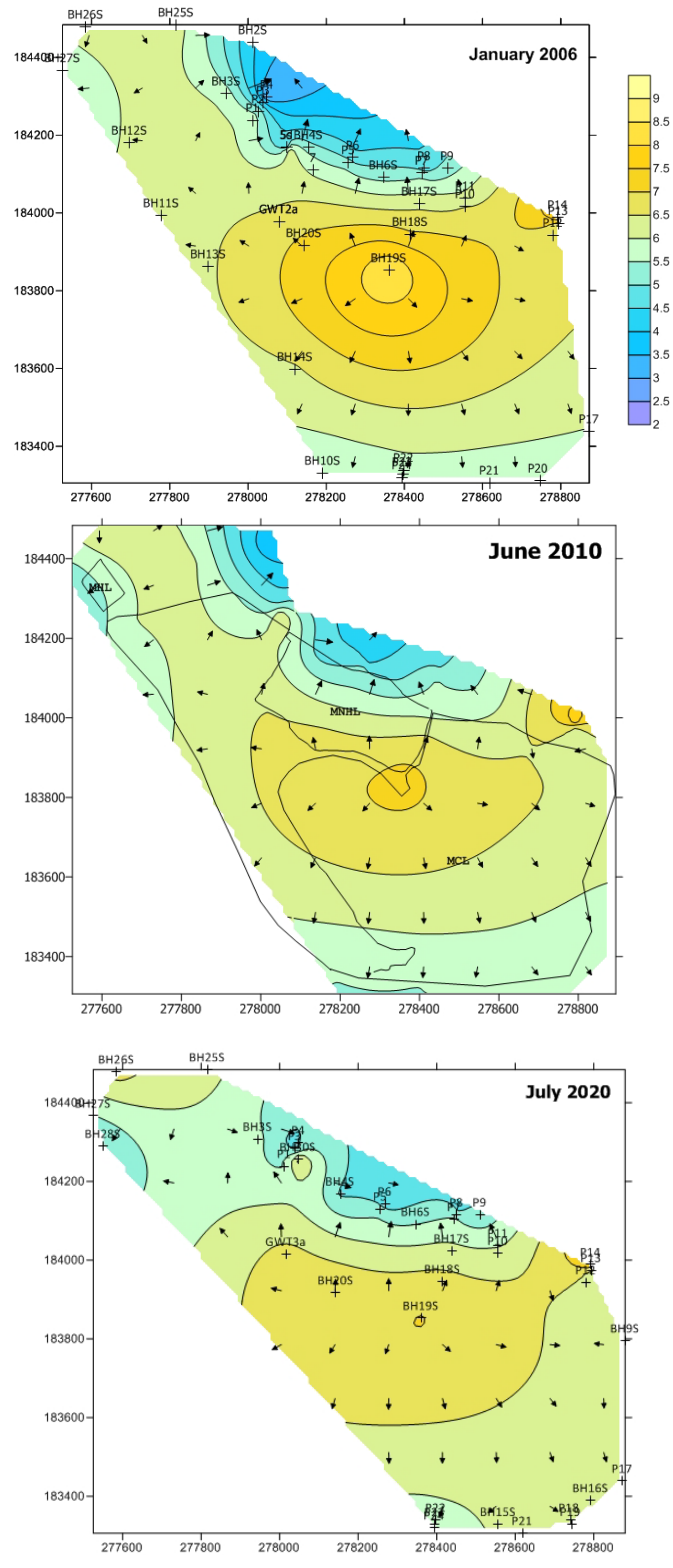


Plate 6-1 Groundwater contours

The reason that groundwater flow patterns have not altered significantly is that groundwater levels and surface water levels measured in the monitoring network have largely remained unchanged throughout the monitoring period that extends from 2005 to the current time. This is revealed by the temporal plots in Appendix 4, with key plots reproduced in Charts 6-1 to 6-3.

The selected plots show the waterlevels at the following key locations:

- Chart 6-1 - Mother Ditch in Margam Moors SSSI (Gauges 1 and 2)
- Chart 6-2 - River Kenfig (Gauges 6 and 7)
- Chart 6-3 - Groundwater levels in and close to Margam Moors SSSI (BH1, BH3 and BH17)

Each of these locations are shown on Figure 12.

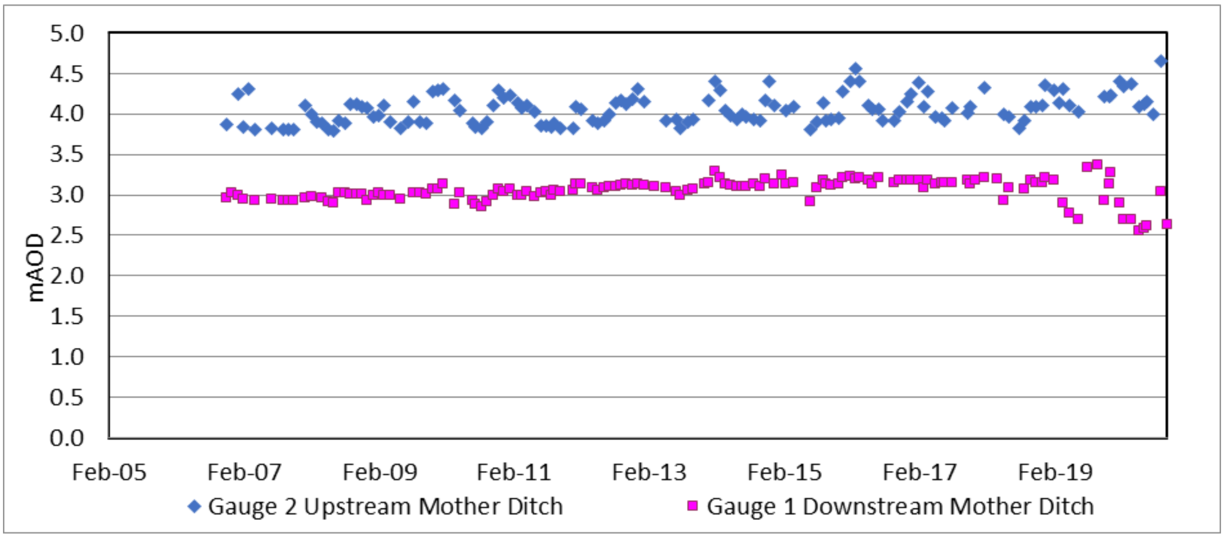


Chart 6-1 Water levels in Margam Moors SSSI Mother Ditch

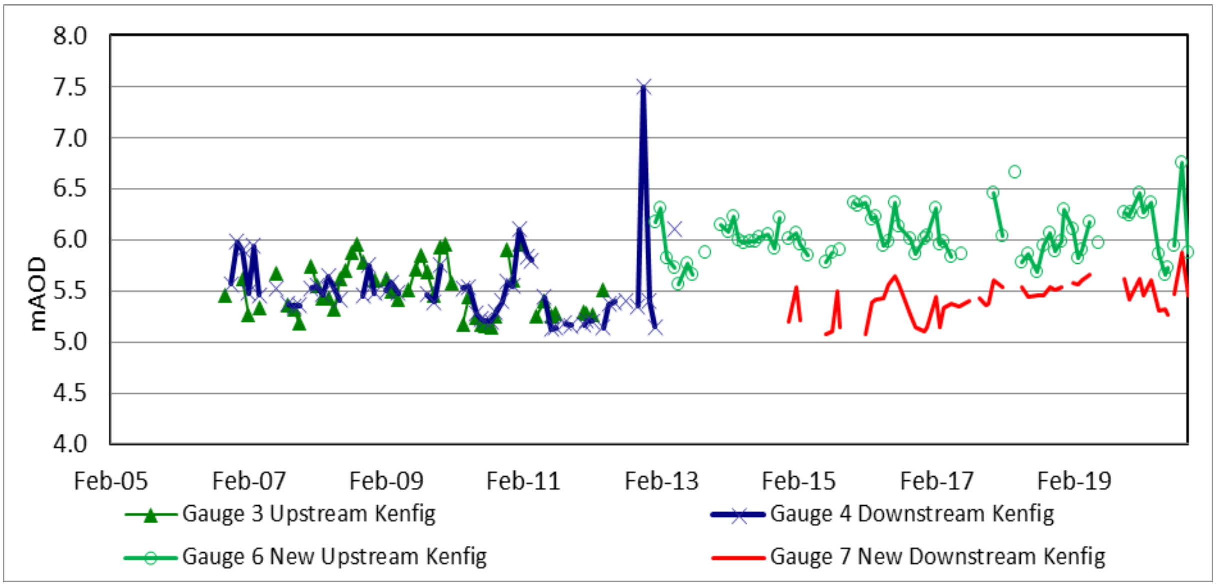
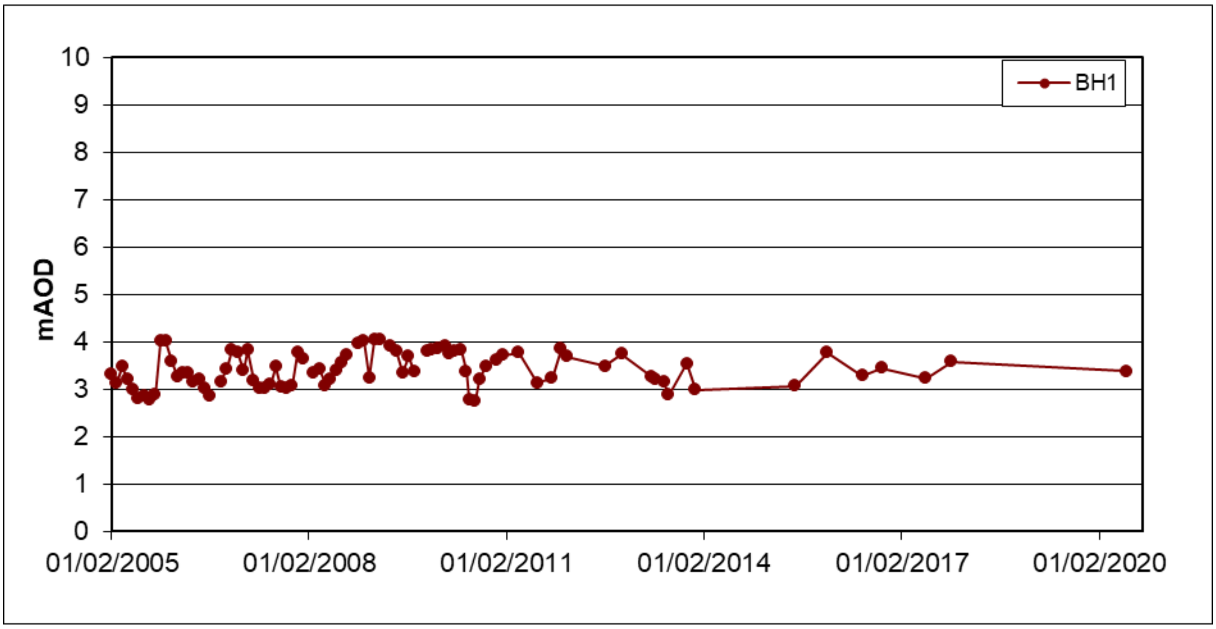
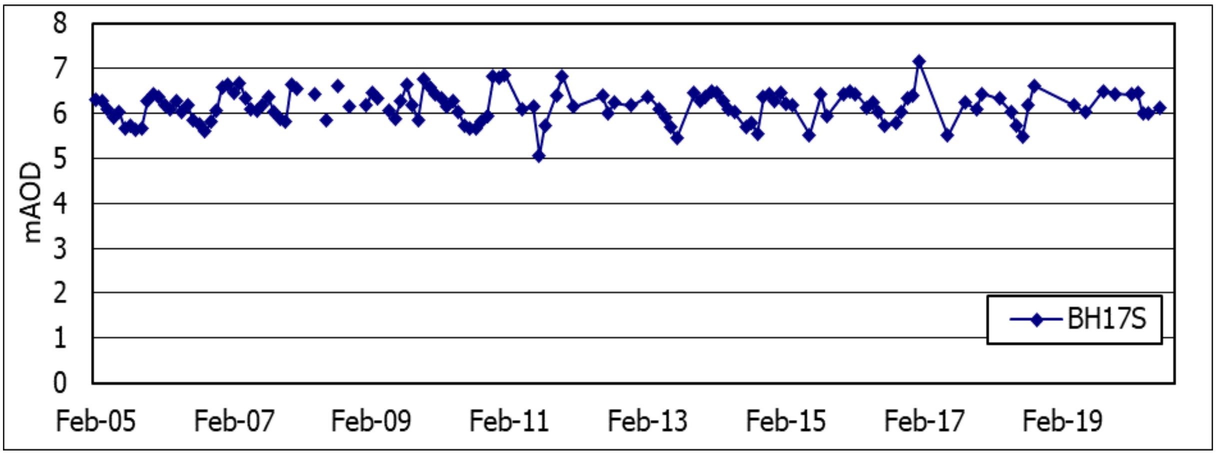


Chart 6-2 Water levels in River Kenfig





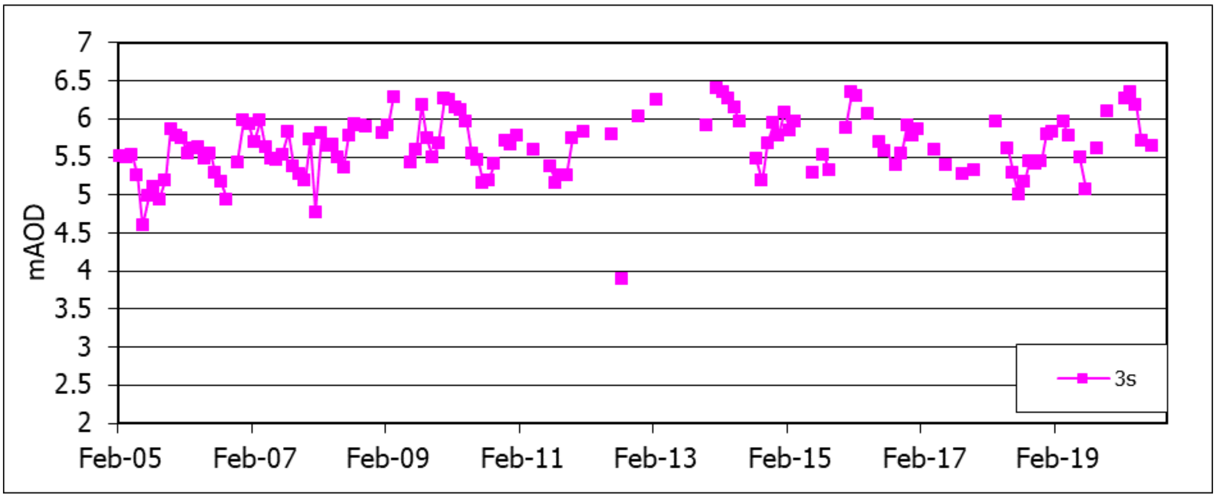


Chart 6-3 Selected groundwater in and along edge of Margam Moors SSSI

These time series charts illustrate that short-term seasonal variations in groundwater levels are evident but that there are no significant long-term trends in water levels. Critically, summer waterlevels have not declined. This is important and means that radial groundwater flow to the sensitive surrounding ecological features is still occurring and that groundwater and surface water levels in and around these sensitive receptors has been sustained throughout the capping and lining works to date.

Interestingly, the impact of ditch clearance in early 2019 on surface water levels in the Mother Ditch appears to be clearly evident in the monitoring data (see Chart 6-2). This highlights the importance, and influence, of SSSI maintenance.

6.2.2 Deep Aquifer

Beneath the alluvial clay layer the estuarine sands are saturated and piezometric levels are higher than the base of the clay. The water in the lower aquifer is therefore confined by the clay layer. Using data from the monitoring boreholes it has been possible to produce a map of the piezometric surface in the area surrounding the site. The typical piezometric surface plan of the deep aquifer is shown in Chart 6-4.

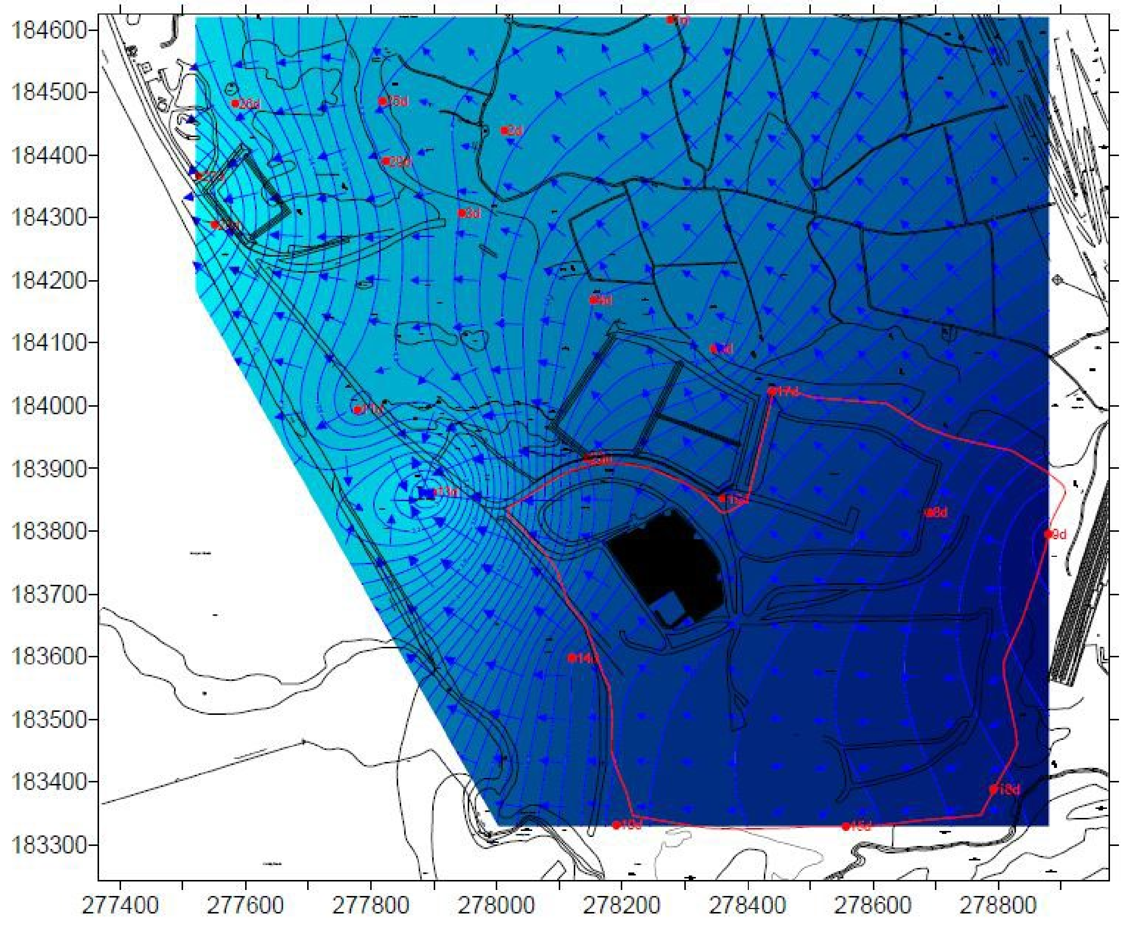


Chart 6-4 Typical contours observed in deep aquifer

Rising head permeability tests have been undertaken in many of the boreholes and these reveal that the lower aquifer is of lower permeability than the upper aquifer, with permeabilities ranging from 5.2 x $10^{-4}ms^{-1}$ to 1.5 x $10^{-7}ms^{-1}$. This is consistent with descriptions of the lower aquifer stratum as being silty sand.

Locally, thicker deposits of estuarine fines are found interbedded with the sands, with one principal fines stratum as shown on the geological sections. At the northern edge of MHL, Boreholes 26 and 27 intersected a sequence dominated by silts and clays, with sand occurring as a minor constituent. Permeabilities here are expected to be accordingly smaller.

The deep groundwater piezometric levels show a pattern of decreasing head toward the north and west. There is no element of a radial pattern to the contours as seen in the overlying shallow groundwater, but rather a uniform loss of head from the east toward the west. Based on the available information, recharge to the deep aquifer is taking place at some distance to the east of the site, where the sand and gravel deposits form undulating farmland in the Cornelly/Pyle/Margam district. Groundwater migrating seaward from this higher ground passes beneath the industrial areas (where it has been utilised for water resources), beneath the railway and then beneath the site.

Close examination of the deep groundwater surface shows that it is at the same level as the River Kenfig at the southern boundary of the site. This suggests that there is significant interaction with the surface water. In this area drilling has also revealed that the clay aquitard is absent, with the wind-blown sand aquifer directly overlying the estuarine sequence.

6.3 Groundwater Chemistry

6.3.1 Shallow Aquifer

The latest monitoring results are very similar to those observed previously with temporal variations illustrated in Appendix 5.

Upgradient of Landfill

The monitoring programme continues to confirm the continued but diminishing impact of leachate from the adjacent unlined but capped MCL on groundwater directly upgradient of MNHL.

Over the past few years, upgradient groundwater along the northern boundary of MCL has shown a sustained decrease in mineralisation, suggesting an overall change and improvement in water quality, most likely due to capping. This is most obvious at monitoring positions BH17S-BH20S which are directly upgradient of MNHL and downgradient of MCL. More recently, similar changes have also started to be observed to the south of MCL.

There have been sustained decreases in the concentration of several parameters including pH Electrical Conductivity, ammonia, chloride, calcium, alkalinity and Chemical Oxygen Demand (COD) in the shallow aquifer as shown by the time series charts in Appendix 5 and charts below. As the water quality changes, trace metals may potentially become slightly more mobile and this may explain some of the impersistent variations in trace metal concentrations. With time, the water quality is likely to become less alkaline as less slag-based waste is exposed.

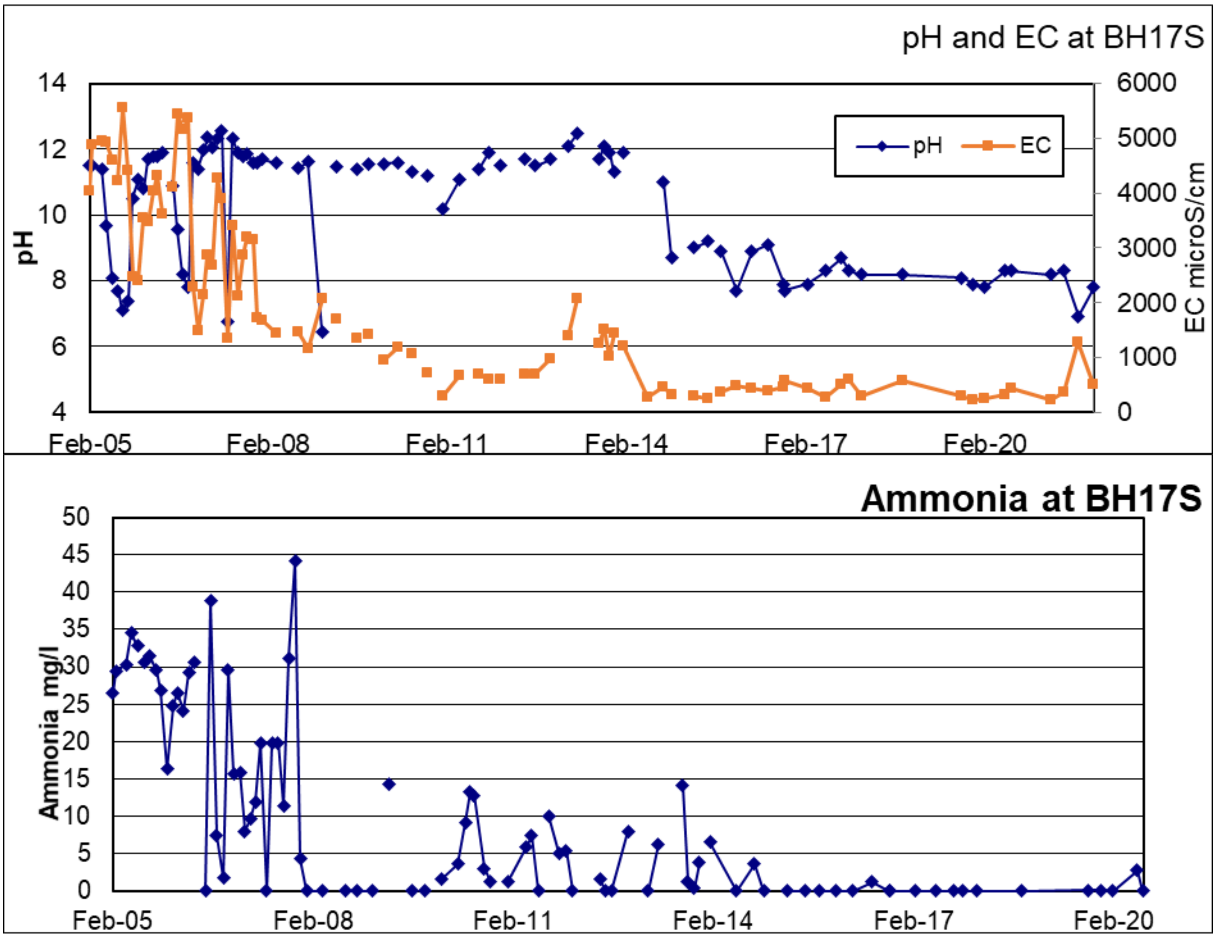
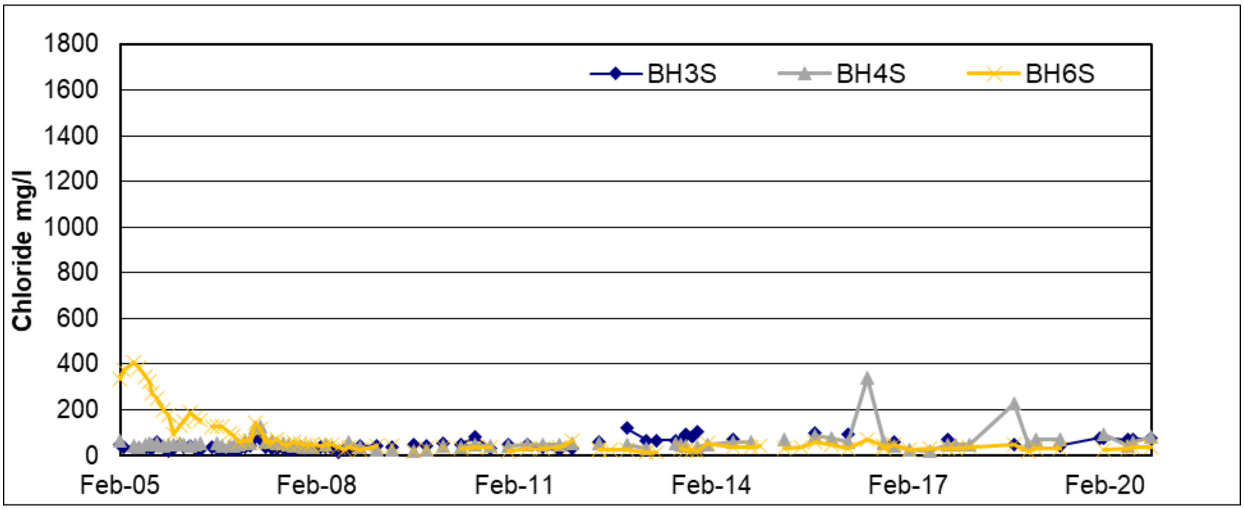


Chart 6-5 Temporal variation of water chemistry at BH17S

Downgradient of Landfill

In the shallow aquifer downgradient of the active cells, samples of groundwater have for some time revealed relatively short-term increases in alkalinity. These are considered to be related to the leaching of alkaline components from MCL, other areas of unlined waste and variations in shallow groundwater levels. Short–term variations (spikes) in the concentration of ammonia, calcium and several trace metals may also be due to the same processes and such occurrences are not currently persistent. There is currently no evidence to suggest seepage from MNHL is the cause of these variations as chloride, a key indicator of MNHL leachate, is not sustainably increased, as shown below.



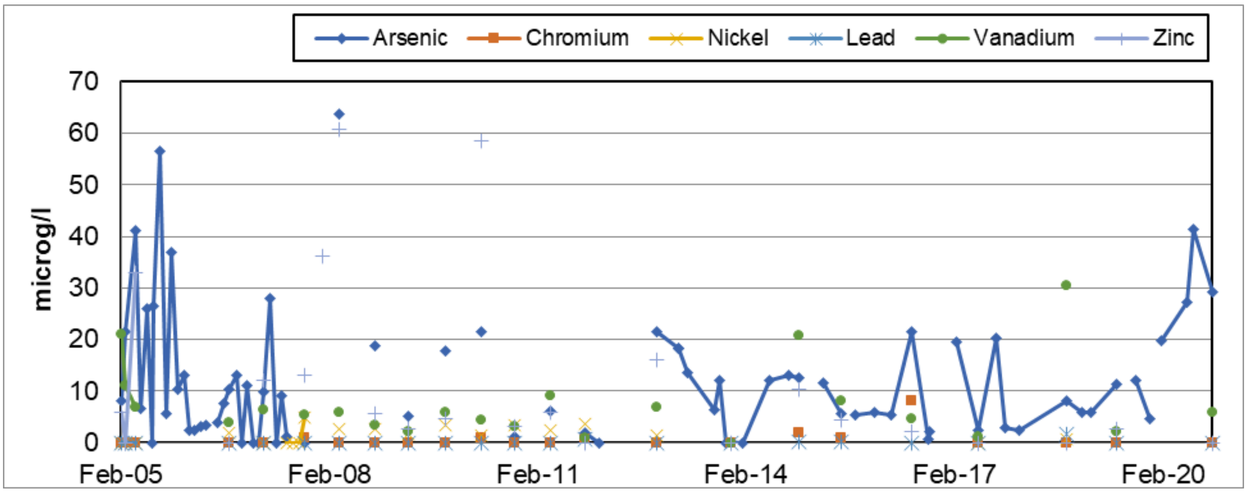


Chart 6-6 Temporal variation of water chemistry around edge of site

Groundwater quality downgradient of MNHL, along the boundary with Margam Moors SSSI (BH3, BH30, BH4 and BH6) is similar to the upgradient chemistry observed at GWT3A and BH17S – BH20S. At BH30 and BH4, the groundwater is less mineralised than groundwater to the west at BH3 and to the east at BH6. This may be indicative of variations in shallow groundwater quality caused by the occurrence of the springline to the west and historical seepage from MCL to the east.

At BH3S and BH4S, arsenic has recently increased to concentrations not seen for many years. The levels are low, impersistent and below EQS and trigger levels but the precise cause is unclear at this stage.

6.3.2 Deep Aquifer

Samples from the deep aquifer are now only collected annually. The data gathered to date suggests that there has been minor change in deep groundwater chemistry and that the reduced monitoring programme is not hampering understanding of the site conditions.

Interestingly, some of the deep groundwater wells around the toe of MCL and upgradient of MNHL have shown improvements in groundwater quality since the on-set of MCL capping. Others, such as BH19D and BH20D have sometimes revealed slightly different trends with increased concentration of sodium, arsenic and ammonia. These contrasting variations may be indicative of different drainage patters below and around MCL and the expected short-term influence from the exposure of wastes during capping.

6.4 Receptors

Controlled water receptor identification in the vicinity of the site is relatively straightforward. The groundwater beneath the site flows in a shallow sand aquifer toward Margam Moors and Margam Sands. There are no private or public abstractions of groundwater between the landfill and the receptors, so the spring line on the moor and the beach represents the closest receptor where groundwater meets the biosphere. All of the land between the development and the receptors is under the control of the applicant and therefore future abstraction consents from the shallow aquifer are unlikely to be sought.

The receptor for hazardous substances is the groundwater directly beneath the site. As this cannot be monitored directly, the compliance point for the groundwater receptor will be a down-gradient monitoring borehole located adjacent to the site.

The compliance point for non-hazardous pollutants is the spring line on the Moors, where groundwater breaks through to surface. Within the LandSim model this is referred to as the off-site compliance point with contaminant concentrations at this point reported as groundwater concentrations.

6.5 Model Update

A pictorial presentation of the current conceptual hydrogeological model is provided in Figure 13 and is based on the conceptual model previously presented. Following the past six years of monitoring, subtle improvements in understanding of the hydrogeological system within which MNHL sits are summarised below, alongside improvements in the understanding of leachate chemistry.

- Water levels in the River Kenfig remain higher than those in the Mother Ditch
- Water levels found in the shallow aquifer along the northern boundary of the shallow aquifer are comparable to the levels found in the River Kenfig. This suggests that the natural hydraulic gradient between the Kenfig and the spring line feeding the Moors is shallow, as previously noted
- Groundwater contours in the shallow aquifer at the edge of the Margam Moors are steeper than groundwater elsewhere, as this is where the shallow aquifer discharges to the environment
- Shallow groundwater directly upgradient of MNHL is impacted by seepage from unlined MCL. Restoration of MCL is resulting in improvements to the water quality upgradient of MNHL
- Deep groundwater up gradient of MNHL could be receiving contributions from the area of rail sidings to the east of MCL. Such contributions are not likely to be of good quality given the historical land use in this area. Therefore, groundwater up gradient of MNHL may be impacted by seepage from MCL and other off-site sources
- Leachate chemistry is characterised by elevated pH, alkalinity, calcium and chloride with concentrations of hazardous substances and non-hazardous pollutants low but variable

7 REVIEW OF NUMERICAL ASSESSMENT

In this section the existing quantitative model used to evaluate the risks to the water environment is evaluated within the context of the data gathered since it was last reviewed and updated in 2017. The aim of the model review is to ensure that the HRA is not divorced from the reality of the landfill facility. This link is made explicit by the reliance of the original Permit HRA on the essential and technical precautions at the landfill.

7.1 Approach to Numerical Modelling

Many iterative changes to the HRA model were made during the design process to determine the optimum landfill design to ensure environmental protection. LandSim 2 was the quantitative computer software chosen to simulate the performance of MNHL at the time, as the model was developed to meet the EA's need for a consistent approach to modelling the groundwater emissions from landfill sites.

Groundwater conditions beneath the site were represented in the LandSim 2 model by specifying the upper aquifer as the receiving aquifer. Leakage from the upper aquifer to lower aquifer was not modelled, as it was considered likely that with the depression of the piezometric surface in the upper aquifer, caused by loss of infiltration recharge, would result in groundwater levels being close to equilibrium. Therefore, the upper aquifer was considered to be hydraulically confined and the escape of pollutants into the lower aquifer was considered inconsequential.

Following issue of the Permit, the next time that the original HRA LandSim model was updated was during 2005 in response to Permit Improvement Conditions (IC) 3, 4 and 5 (see Geotechnology report 403.2/0/1205). The ICs required the establishment of groundwater trigger levels for all groundwater monitoring boreholes, which necessitated a review of the conceptual model and quantitative simulations. Following refinement of the conceptual hydrogeological model, LandSim 2.5 was used to simulate the performance of the landfill as this was the model available at the time. The model produced at this time was titled:

- mnhlcell1Dec2005.sim

As LandSim 2.5 still remains NRWs preferred model for the evaluation of landfills and because the updated model was agreed by NRW through discharge of ICs 3, 4 and 5, the above model is referred to as the 'base' model. Since this model superseded that derived using LandSim developed during the Permit Application, the previous HRAs completed in 2008 and 2012 provided an update to this base model rather than the LandSim 2 PPC Application model.

Although LandSim 2.5 was used as the updated computer model to evaluate landfill performance in 2008 and 2012, the overall philosophy remained the same as that adopted in the original model. As the actual groundwater flowpath diagonally crosses more than one cell, so the emissions predicted by LandSim under-report the concentrations likely at the springline adjacent to Margam Moors. This shortcoming of LandSim was previously conservatively dealt with by factoring the predicted emissions from one cell directly upward by 2.25 to account for this phenomenon. The factor of 2.25 was conservatively derived based on the maximum length of the flowpath between each cell and the receptor, as summarised in Table 7-1.

Table 7-1 Data used to calculate flowpath factor for MNHL

Receptor Location	Upgradient Cells	Number of Cells	Length of Flowpath	Proportional increase in concentration
B10 Cell	B10	1	200	1
Cell 1	1, B20	2	200	1
Cell 2	2, 1	2	250	1.25
Cell 3	3,2	2	300	1.5
Cell 4	4,8,9	3	550	**2.25**
Cell 5	5,4,8,9	4	500	2
Cell 6	6,7,8,9	4	500	2
Cell 7	7,8,9	3	500	2
Cell 8	8,9	2	300	1.5
Cell 9	9,10	2	300	1.5
Cell 10	10	1	150	0.75
Cell 11	11	1	150	0.75
Cell 12	12	1	220	1.1

In 2006, Tata Steel sought to expand the list of non-hazardous waste types that could be accepted at MNHL to include Hot Mill Sludge (HMS). This material is effluent sludge from water treatment on site that Tata Steel intended to dispose within the biodegradable cell. As part of the technical supporting information accompanying the Permit Variation application, LandSim 2.5 was used to assess the impact of the new waste stream on the environmental performance of the landfill. Based on an evaluation of the leaching properties of HMS, the model update assessed the influence of potentially higher concentrations of zinc (up to 12 mg/l) in the landfill leachate than originally predicted and also the presence of Benzo(a)Pyrene (see Geotechnology report 451.1/1/0606). The model predictions were considered to indicate that the water quality at the edge of the Margam Moors was not likely to be affected by the presence of increased zinc or the presence of BaP within the waste.

As LandSim 2.5 is still the validated model for assessing the long-term risks to groundwater from landfills, this HRA review has continued to use this model for all numerical modelling.

Appendix 6 presents a review of the parameters included within the LandSim 2.5 model. Some of the key parameters are reviewed further in following sections.

7.2 Cell Geometry

There has been no change to cell geometry footprint since the previous HRA review as no further cells have been constructed. However, the extension of Biodegradable Waste Cell 1 has meant that:

- waste has been recovered from Cell 1 – this means that there is less waste present at the site
- the remaining waste below the bio-cell extension is now effectively capped by the lining system placed for the biocell extension
- Bio-cells A and B have now been permanently capped but the leachate sumps will continue to receive leachate from the bio-cell extension (Sub-cell C)

This configuration is conceptually illustrated in Figure 7.

As each of the leachate sumps will continue to receive leachate the Landsim model has not been reconfigured at this stage - the bio-cell extension will drain to sumps L1 and L6, Cell 1 is only partly capped and will continue to drain to sump L7 and Cell 2 is still operational and drains to sump L8.

7.3 Leachate Inventory

In the original HRA that used LandSim 2, the leachate source term was based on data from the neighbouring MCL. This was because this landfill was considered to provide a good proxy for the proposed landfill, as the landfill had accepted very similar waste types. Following construction of MNHL and adjacent MHL, each time the LandSim 2.5 model was updated, the leachate source term was conservatively developed by adopting the worst case groundwater/leachate concentrations detected.

With the benefit of more leachate monitoring data, the 2012 HRA adopted a different approach to deriving the leachate inventory. Rather than considering worst case groundwater chemistry alongside leachate chemistry, Geotechnology used the leachate chemistry obtained by the analysis of leachate collected from sumps L1, L6, L7 and L8. This approach builds a significant degree of conservatism into the modelling as it does not take into account the differences in leachate concentration between the bio-cells and other cells i.e. the leachate in sumps L7 and L8 are more mineralised than the leachate in sump L1. In this review the same approach has been adopted.

Table 7-2 provides a comparison of recent leachate chemistry with the leachate inventory used in the most recent HRA review. This demonstrates that, in the most part, recent leachate chemistry is comparable to the lower end of the Probability Density Functions (PDFs) used to describe the leachate inventory in the previous HRA review. The only exception is the concentration of arsenic detected in Biocell sumps L1 and L6 in June 2021. Although the levels observed were close to the upper end of the PDF, they were not persistent, as summarised in Table 7-3 and shown on time series charts in Appendix 3.

Table 7-2 Evaluation of Leachate Chemistry

	Ammonia	**Arsenic**	**Chloride**
	mg/l	**mg/l**	**mg/l**
LandSim PDF*	Triangular (0.05, 10, 50)	Triangular (0.005, 0.3, 3)	Log Triangular (1000, 10000, 61000)
Leachate chemistry 2018			
Maximum 2018 Leachate chemistry (L1, L6, L7, L8)	2.15	0.004	2160
Leachate chemistry 2019			
Maximum 2019 Leachate chemistry (L1, L6, L7, L8)	1.19	1.09	3010
Leachate chemistry 2020			
Maximum 2020 Leachate chemistry (L1, L6, L7, L8)	6.08	0.005	14690
Leachate chemistry 2021			
Maximum 2021 Leachate chemistry (L1, L6, L7, L8)	5.53	3.04	15970
Leachate chemistry 2022 (data available up to April 2022)			
Maximum 2022 Leachate chemistry (L1, L6, L7, L8)	4.7	0.0034	9470

*PDF – Probability Density Function used to describe statistical distribution of parameter. Triangular and Log Triangular are the PDFs used in most recent HRA. Values in parenthesis are minimum, most likely and maximum values used in LandSim model

Table 7-3 Arsenic in Biocells

Leachate sump	Date	Arsenic (microg/l)
L1	23/03/2021	1.6
L6	23/03/2021	0.8
L1	10/06/2021	2450
L6	10/06/2021	3040
L1	07/09/2021	2.06
L6	06/09/2021	1.99
L1	06/12/2021	<0.75
L6	06/12/2021	0.9
L1	09/02/2022	<0.75
L6	09/02/2022	0.9
L1	09/02/2022	<0.75
L6	09/02/2022	2.3

In addition to evaluating whether the current PDFs are still conservative, a HRA review also provides opportunity for ensuring that the leachate inventory is still representative of current leachate chemistry. This analysis is summarised in Table 7-4 where the currently observed leachate chemistry is compared to Environmental Assessment Levels (EALs). As a minimum, if a parameter is to pose a risk to the water environment it needs to be present at levels that exceed the EALs. Table 7-4 presents an update to this assessment that includes the data gathered since 2017. The analysis indicates that the average leachate chemistry observed since the previous HRA review in 2017 poses no greater risk to the controlled water environment as the dilution factors (calculated as average chemistry/EAL) for the 2017-2022 dataset are comparable to or lower than those observed previously.

The only possible exception is non-hazardous substance Cadmium, where the dilution factor is 6. However, review of the raw data reveals that of the 50 measurements of cadmium in leachate in all sumps between 2017 and 2022, there were only 9 occasions where the laboratory reported a detectable concentration. The highest concentration recorded was 10 microg/l. On all other occasions the concentration was below the laboratory detection limit. As the Landsim model already considers a non-hazardous substance (arsenic) the inventory has not been modified as the inventory still provide a means of assessing the different types of parameters present in the leachate.

Table 7-4 Evaluation of leachate chemistry

	Units	Assessment Level (AL)	Leachate data in 2012 HRA		MNHL leachate up to Q2 2017		MNHL leachate from Q2 2017 – Q2 2022		2012 Dilution Factor	2017 Dilution Factor	2022 Dilution Factor
			Max	Average	Max	Average	Max	Average	(Av. Conc /AL)	(Av. Conc /AL)	(Av. Conc /AL)
Lab pH	pH units	6 - 9	13.2	11.5	13.2	10.44	12.06	10.057407			
Lab Conductivity	microS/cm		108800	15490.3	108800	16756	39700	6884.0383			
Lab Alkalinity	mg/l $CaCO^{3}$		1965	803.3	7105.25	601.52	1100	253.97078			
Calcium	mg/l		34700	5035.9	37585	4891.35	15260	1237.9968			
Sodium	mg/l	200	531	194.5	531	190	722	133.59388	1	1	1
Potassium	mg/l		757	160.3	757	117	154.4	53.518939			
Magnesium	mg/l		12.9	4	296.71	17.9	30.59	8.6833636			
Sulphate	mg/l	400	265	109.8	426	114	362.8	125.12529	0	0	0
Fluoride	mg/l	1 (AA)/3 (MAC)	16.9	7	16.88	2.34	2.34	0.8068947	6		1
Chloride	mg/l	250	60808	9287.2	91200	8830	15970	1913.5553	37	35	8
Chemical Oxygen Demand	mg/l	30	10080	879.9	10080	900	6045	724.23214	29	30	24
Biochemical Oxygen Demand	mg/l	4 - 9	110	20.1	110	10			5		
Total Organic Carbon	mg/l		54	18.7	561	20					
Ammoniacal Nitrogen as N	mg/l	0.3 - 2.5	36.8	10.9	54.3	4.6	6.08	1.7309653	36	15	6
Total Oxidised Nitrogen	mg/l		168.51	30.7	168.51	21.87					
Nitrate	mg/l	25 (AA)/50 (MAC)	197	35.9	197	15	70.2	15.00318	1	1	1
Nitrite	mg/l	0.01	93.61	10.3	93.6	3.2	42.01	1.6822346	1025	320	168
Phosphorous	mg/l	0.05 reactive phosphorous	327.1	68.6	327.1	62.4			1372	1248	
Phosphate	mg/l		11.2	3.7	142.6	1.8	28.337	12.263364			
Arsenic	ug/l	50	2007	277.9	2	0.0999	3040	96.560082	4	2	2
Aluminium	ug/l	200	3637.79	429.8	3637.7	276.4	1910	354.87413	2	1	2
Antimony	ug/l	5	4.4	3.1	4.4	0.5	13.7	4.178	1	0	1
Boron	ug/l	1000	3348.6	700	3348.6	527	2940	832.51538	1	1	1
Chromium (total)	ug/l	4.7 AA/32 (MAC)	32.1	8.4	50.1	7.5	38	9.3014286	2	2	2
Chromium (VI)	ug/l	3.4	2.3	1.9	2.3	0.1			1	0	
Cobalt	ug/l	3 (AA)/100(MAC)	11.9	8	187.7	12.3	2.03	0.4684444	3	4	0
Copper	ug/l	10	297.55	23.2	297.5	14.1	44.6	9.362641	2	1	1
Iron	ug/l	300	2334	319.5	1121710	29201	44.2	23.08	1	97	0
Lead	ug/l	20	38	10.2	38	3.6	40.5	5.7229412	1	0	0
Manganese	ug/l	30 (AA)/300(MAC)	161	35.8	54201	2276	5492	342.81533	1	76	11
Molybdenum	ug/l	70	22.9	22.9	11.8	0.7	62.2	22.504545	0	0	0
Nickel	ug/l	150	75.7	12.4	75.7	9.1	165	11.724706	0	0	0
Selenium	ug/l	10	22.6	12	22.6	0.8	180	11.87	1	0	1
Silica	ug/l		44.1	6.3	44.1	5.6	7.19	3.5738889			
Tin	ug/l	25	97.5	28.5	97.5	5.5	0	#DIV/0!	1	0	
Titanium	ug/l		18118.85	5280.1	18118.8	792.5	0	#DIV/0!			
Vanadium	ug/l	20	313.3	86.5	819	76	329.32	35.628571	4	4	2
Zinc	ug/l	75	687	55.8	687	31.8	382	44.728261	1	0	1
Cadmium	ug/l	0.15	0.1	0.1	9.85	0.34	10	0.92	1	2	6
Mercury	ug/l	0.05	0.2	0.1	0.77	0.15	0.77	0.14	3	3	3
VOC/SVOC and total hydrocarbons	ug/l	Various	Not specified in this table but typically all <1 microg/l								

7.4 Landfill Drainage System

There has been no change to the landfill drainage system within each cell since the previous HRA.

7.5 Engineered Barrier and Waste

Since the previous HRA review there has not been a need to construct any new cells. On this basis, the data included in the previous model has been retained.

7.6 Leachate Elevation

At the time of the previous HRA review, leachate levels were elevated above the Permit limit of 1.0m. In response a sensitivity analysis was undertaken to evaluate the potential influence such levels could make on pollution potential.

Since this time, leachate levels have fallen drastically and are now closely controlled by the new leachate extraction system. As a consequence, this aspect of the model has not been altered and a fixed head of 1m is conservatively assumed.

7.7 Geological Units and Aquifer Properties

There is no new evidence available to suggest that the properties given to the geological units below the landfill within the LandSim 2.5 base model require modification. Therefore, no changes have been made in this review.

7.8 Predicted Emissions to Groundwater

7.8.1 Hazardous Substances

Hazardous substances have been screened out of the assessment as they are currently either undetectable or present at such low concentrations that they do not pose a risk to the environment. This means that the landfill should continue to meet one of the requirements of the Regulations, provided the landfill continues to be designed and operated in accordance with the current practices.

The occurrence of hazardous substances is dictated by the properties of the waste streams. If these change the leachate chemistry should be scrutinised. Consideration should also be given to screening the leachate for emerging contaminants as the evidence base surrounding such parameters is increasing and receiving increased regulatory scrutiny.

7.8.2 Non-Hazardous Pollutants

The model has not changed since previous HRA review. The full model results are provided in electronic format in Appendix 7. A summary of the maximum predicted concentrations at the 95th percentile confidence limit are summarised in Table 7-5.

Table 7-5 Maximum Concentration Predicted at Compliance Point

Emissions to Groundwater at Compliance Point					
	Predicted LandSim Emissions (2012 HRA)	**Emissions factored upwards by 2.25 (2012 HRA)**	**Predicted LandSim Emissions (2017 HRA)**	**Emissions factored upwards by 2.25 (2017 HRA)**	**EQS**
	mg/l	**mg/l**			**mg/l**
Ammonia	0.08	0.2	0.09	0.2	0.3/0.6
Arsenic	0.005	0.01	0.006	0.01	0.05
Chloride	48	108	48	108	250

As all models are simplified representations of reality, the results should be viewed as aids to the decision-making process. Decisions as to whether the site complies with the Regulations must combine professional judgement, the model results and an understanding of the assumptions within each model.

Despite including several conservative assumptions, the factored model results clearly demonstrate that the predicted emissions at the Margam Moors spring line are imperceptible for all but the most mobile species. In understanding the predicted emission limits, it is useful to consider the assumptions built into the modelling.

Two of the most important assumptions are:

- assuming that the worst case leachate chemistry is present at all landfill cells. This has been shown not to be the case
- ignoring all retardation processes within the EBS and underlying geology

When taking these factors into consideration, it is evident that the landfill is not predicted to leach non-hazardous substances that could cause pollution provided the waste properties remain similar to those observed and the landfill continues to be operated in accordance with the design requirements.

7.9 Emissions to Surface Water

Provided the landfill is constructed and operated in accordance with the design, the landfill is not predicted to directly impact surface water at any stage. This is because each cell incorporates free board above leachate levels.

8 IMPLICATIONS OF UPDATED LANDFILL PERFORMANCE

8.1 Environmental Protection

The LandSim model continues to provide a line of evidence that MNHL will continue to meet the requirements of the Groundwater Regulations.

8.2 Review of Technical Precautions

Risks to controlled water at MNHL are being controlled and monitored through careful waste management and prudent landfill operation and monitoring. Key to the continued success of minimising and controlling the risks to the environment is the continued construction of cells under CQA supervision, active leachate extraction and implementation of an effective monitoring programme. As cells become no longer operational, progressive restoration should be taking place as this limits the amount of leachate requiring management and reduces the potential flux of contaminants.

8.3 Operational Management

Construction Quality Assurance (CQA) information gathered to date has enabled the LandSim 2.5 model to take account of as built engineering properties. The thickness of the BES and its hydraulic conductivity have at least matched the design requirements and in the majority of cases, significantly exceeded the requirements. As a consequence, the risks posed to the environment are reduced. Further, monitoring of the landfill operation has indicated that management controls are robust and highly effective.

The leachate level has in a number of sumps previously exceeded the permitted control and compliance levels. This issue is not being controlled by a new automated pumping system. It is important that leachate levels are controlled in order to prevent undesirable consequences such as:

- over spilling
- increasing the driving head for leakage
- reducing leaching and flushing of the waste mass during the landfill management phase

8.4 Requisite Surveillance

8.4.1 Leachate

Leachate chemistry is now well documented and largely well understood. The leachate is dominated by a small number of parameters that pose a risk to the environment and which require routine monitoring. The review suggests that no major change in chemistry has been observed. The review indicates that whilst some of the determinants show impersistent increased levels the leachate chemistry is largely consistent and currently poses no greater risk to the environment than was evident at the previous HRA.

8.4.2 Continued Monitoring Programme

Based on the findings of the HRA there is no reason to alter the monitoring programme detailed in the Permit.

8.4.3 Review of Control and Compliance Levels

Compliance and control levels are set and agreed with NRW for leachate, groundwater and surface water. The findings of the HRA suggest that the current leachate control levels are set at levels protective of the environment.

9 LANDFILL CLOSURE AND COMPLETION CRITERIA

9.1 Landfill Closure and Surrender

Landfill closure is an on-going process between the time when the site is 'closed' and ceases accepting waste for disposal and 'definitive closure' when the EA agrees that the site may enter the aftercare phase.

Definitive closure of the landfill will be granted by NRW following review of the reports requested in the Closure Notice and a final on-site inspection. Following definitive closure, the Aftercare Monitoring period will last until the authorisation is successfully surrendered. During this period, the agreed Aftercare Monitoring Plan will be followed and the operator shall continue monitoring and maintaining the landfill for as long as NRW consider the landfill poses a hazard to the environment. The landfill can only be surrendered when NRW accepts that the landfill does not pose a hazard to the environment. The aftercare period will likely last for many years.

The ultimate surrender application will need to contain a site report describing the condition of the site relative to the condition of the site as described in the original site application. The application will also need to contain a description of any steps that have been taken to avoid any pollution risk on the site resulting from the operation of the installation, or to return the site to a satisfactory state.

9.2 Completion Criteria

Completion of the landfill is defined as the point at which the landfill has stabilised physically, chemically and biologically to such a degree that the undisturbed contents of the site are unlikely to cause pollution of the environment or harm to human health. At completion, post monitoring procedures are no longer required and the licensing permit can be surrendered. Completion can only occur if certain criteria are met during the post closure monitoring.

For MNHL, the completion criteria will need to take consideration of the groundwater impacts caused by unlined MCL and the antecedent groundwater quality and receptor water quality at the time of closure. The current conservative predictions suggest that MNHL will not discharge detectable levels of Hazardous substances to groundwater and that the emission of non-hazardous pollutants will not cause pollution.

10 SUMMARY

As MNHL is constructed, a high quality CQA programme and environmental monitoring programme is being implemented. As a consequence, this enables the potential risks identified in the original HRA, to be continually updated based on as-built design details and monitoring data.

The potential risk posed to groundwater by the landfill is being controlled by the leaching properties of the waste. In previous years, leachate levels rose to levels not permitted, but this position is now under control.

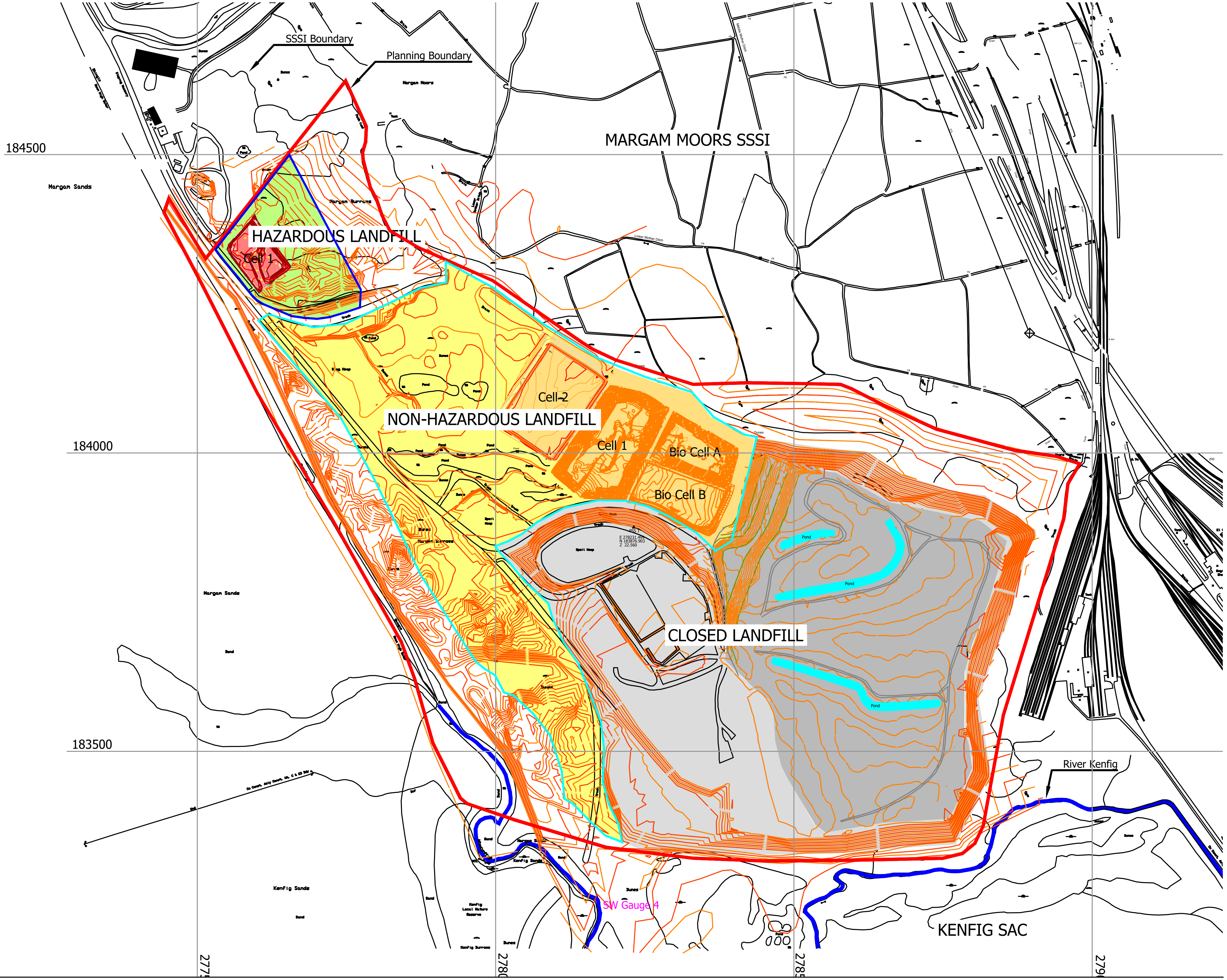
The assessment of the risks using LandSim and judgement of the predicted emissions indicates that the requirements of the Regulations continue to be satisfied. Based on the monitoring data collected to date, there is no evidence to suggest that the landfill is not behaving as initially predicted and the identified receptors remain protected from impacts related to MNHL. At MNHL there will always be significant difficulty in determining influences on groundwater as both the shallow and deep aquifers have been impacted by seepage from upgradient MCL and potentially other off-site sources.

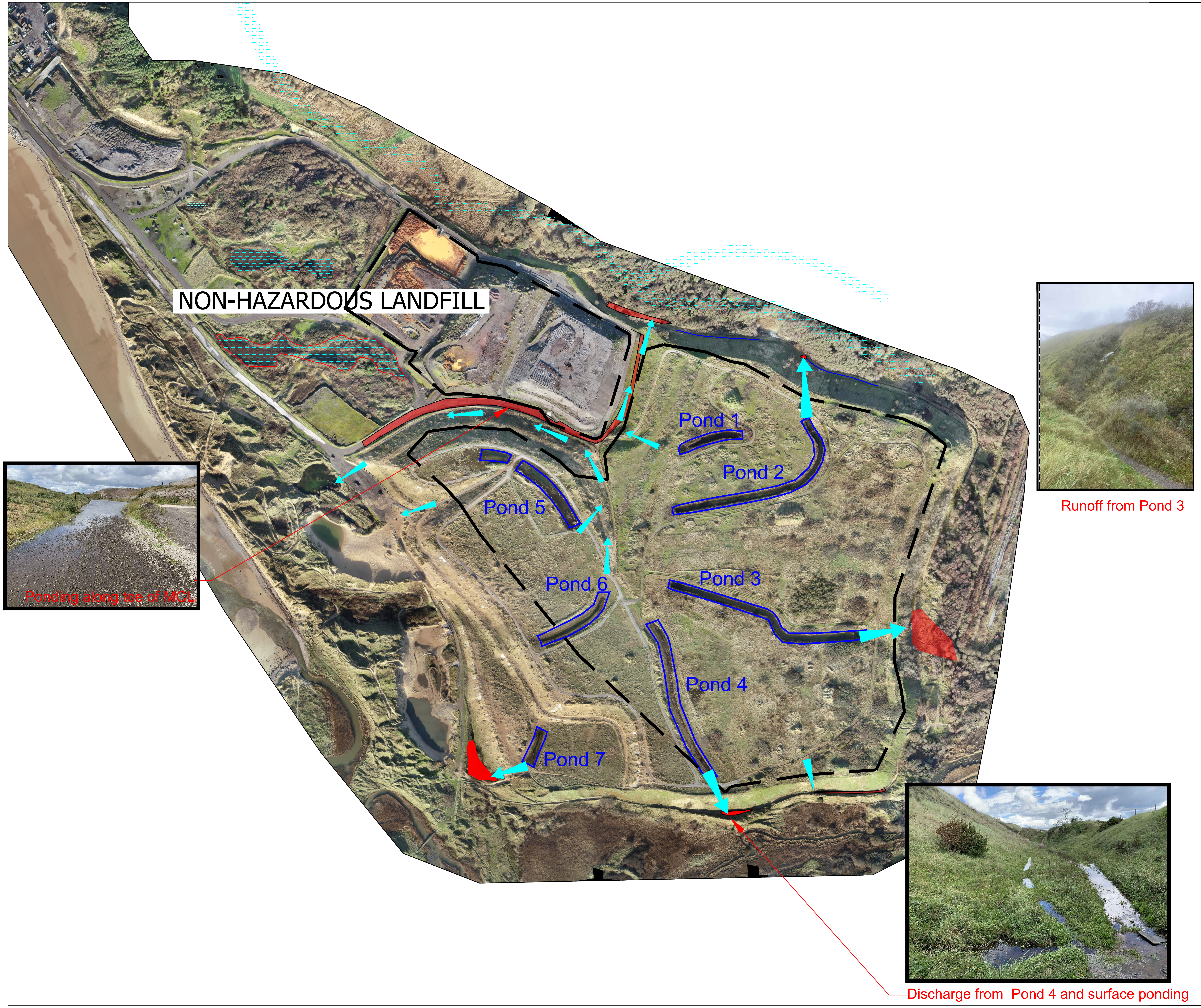
As cells cease to operate, progressive restoration should be taking place as this limits the amount of leachate requiring management, potentially reduces the mineralised content requiring treatment and reduces the potential flux of contaminants.

Figure 3 Envirnomental Permit Boundaries

LEGEND:

- Undeveloped Part of MHL
- Developed Part of MHL
- Developed Part of MNHL
- Undeveloped Part of MNHL
- Restored Part of MCL
- Unrestored Part of MCL
- 1973 Planning Permission Boundary





Drawing Number 2238/4

Legend

- Recharge zone
- Extent of lost recharge to Margam Moors
- Point Source Surface Runoff
- Springline in Moors
- Ponds in undeveloped areas of MNHL

Notes

Rev	Date	Status/Ammendments

CLIENT

Darlow Lloyd & Sons

PROJECT

Morfa Non-Hazardous Landfill
Review of Hydrogeological
Risk Assessment

TITLE

Aerial Image of Key Features

DRAWING NUMBER			REVISION
2238/4			0
DATE	DRAWN	CHECKED	SCALE AT A3
06.22	BR		1:500

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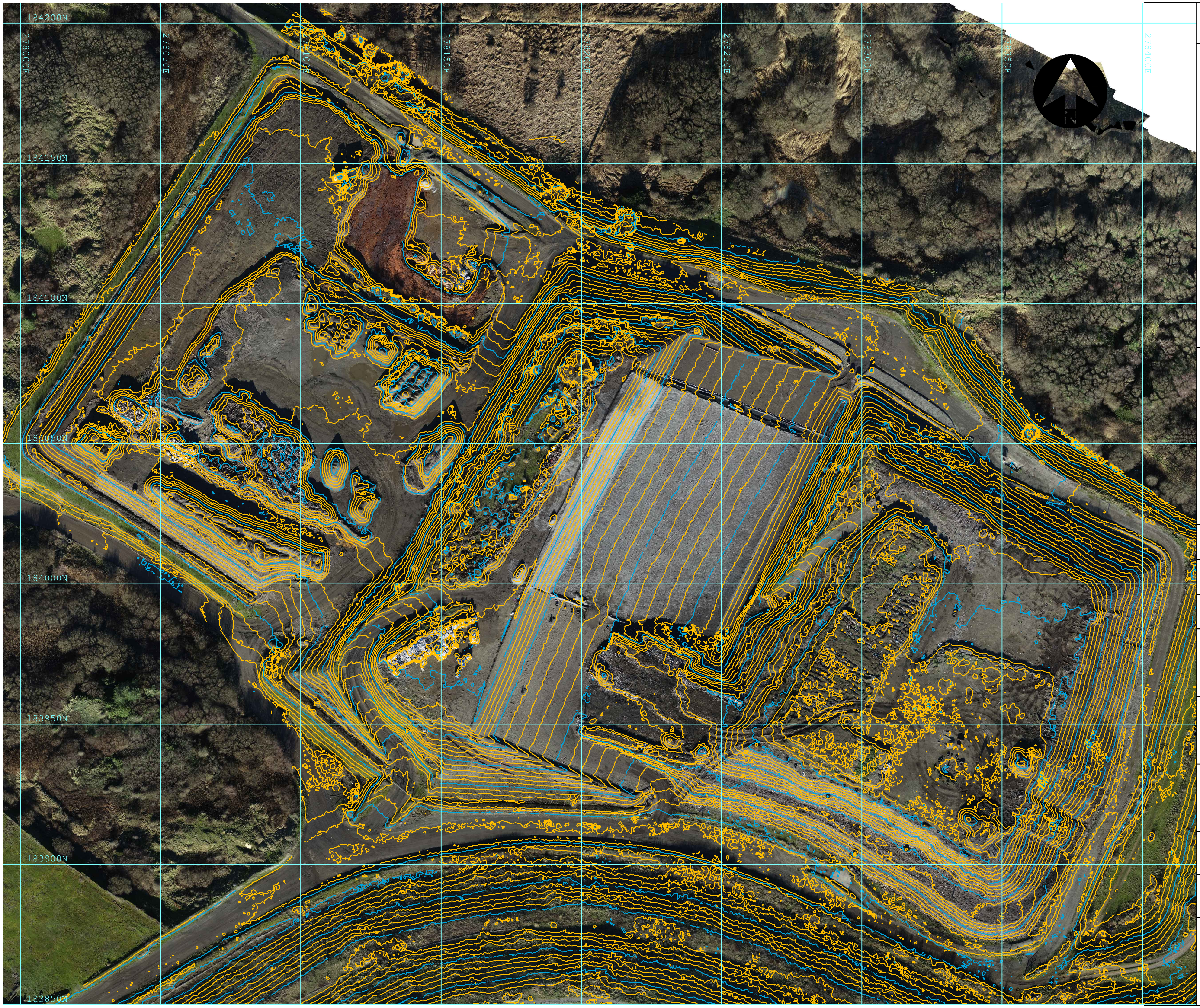

Drawing Number 2238/5

Legend

- Prominent Contour (2.5m)
- Normal Contour (0.5m)

Notes

Digital survey model generated using Pix4D image processing software.

Imagery acquired by DJI Phantom 4 pro RTK photogrammetry survey on 14 January 2022.

Survey control installed using Topcon Hiper SR dGPS Network Rover.

Rev	Date	Status/Ammendments

CLIENT

Darlow Lloyd & Sons

PROJECT

Morfa Non-Hazardous Landfill
Review of Hydrogeological
Risk Assessment

TITLE

Topographic Contours

DRAWING NUMBER	REVISION
2238/5	0

DATE	DRAWN	CHECKED	SCALE AT A3
06.22	KJT		1:1250

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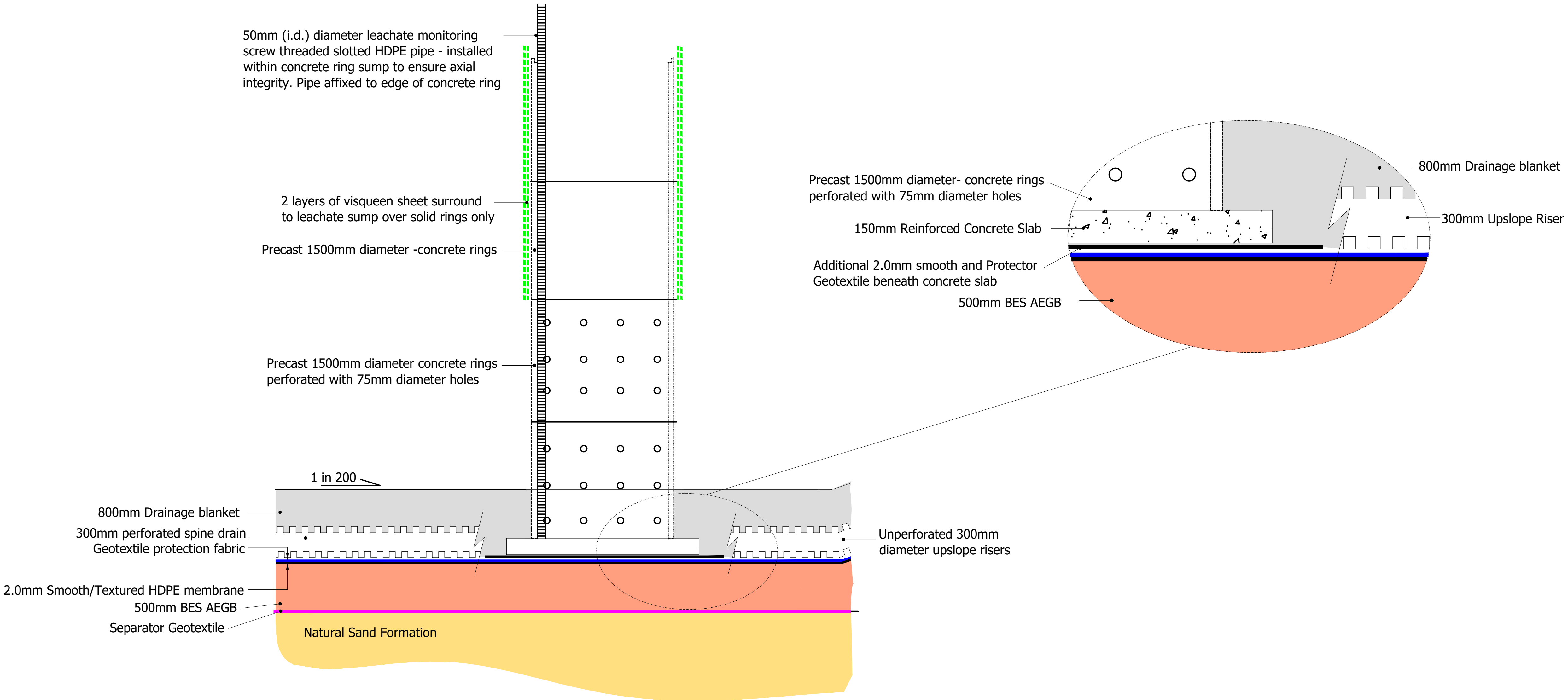
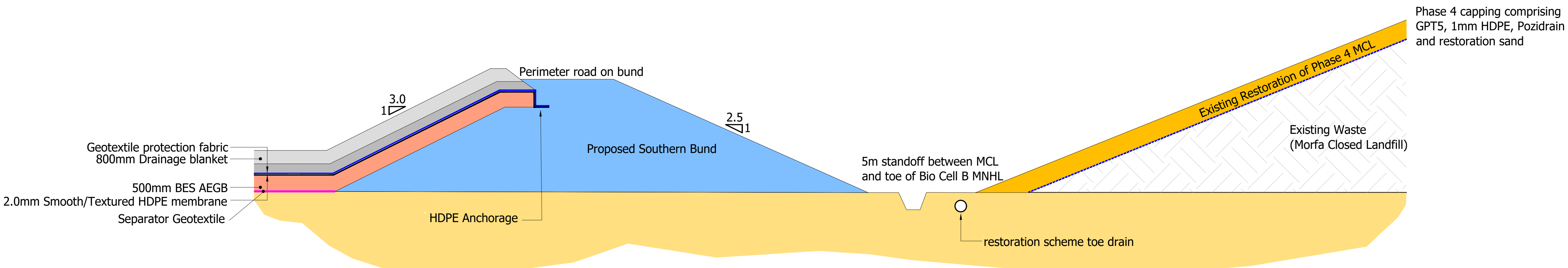
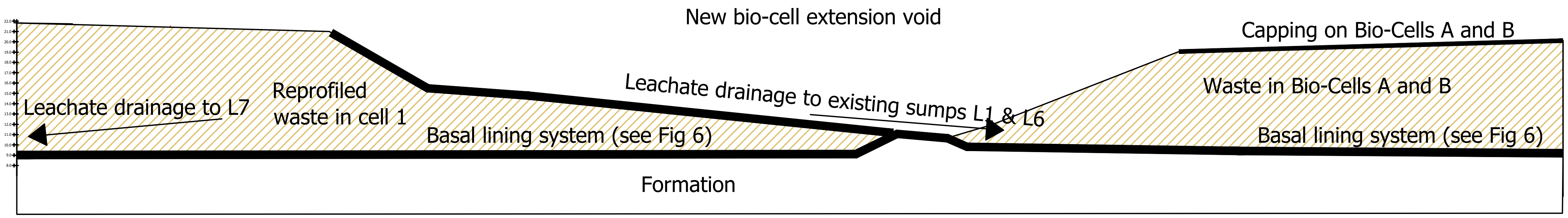
Figure 6 Cross Sections of Key Landfill Engineering Systems





Drawing Number 2238/7



Legend

Notes

Rev	Date	Status/Ammendments

CLIENT
Tata Steel Ltd

PROJECT
Morfa Non-Hazardous Landfill
Review of Hydrogeological
Risk Assessment

TITLE
Conceptual Section of Bio-cell
Extension

DRAWING NUMBER	REVISION
2238/7	0

DATE	DRAWN	CHECKED	SCALE AT A3
06.22	KJT		NTS

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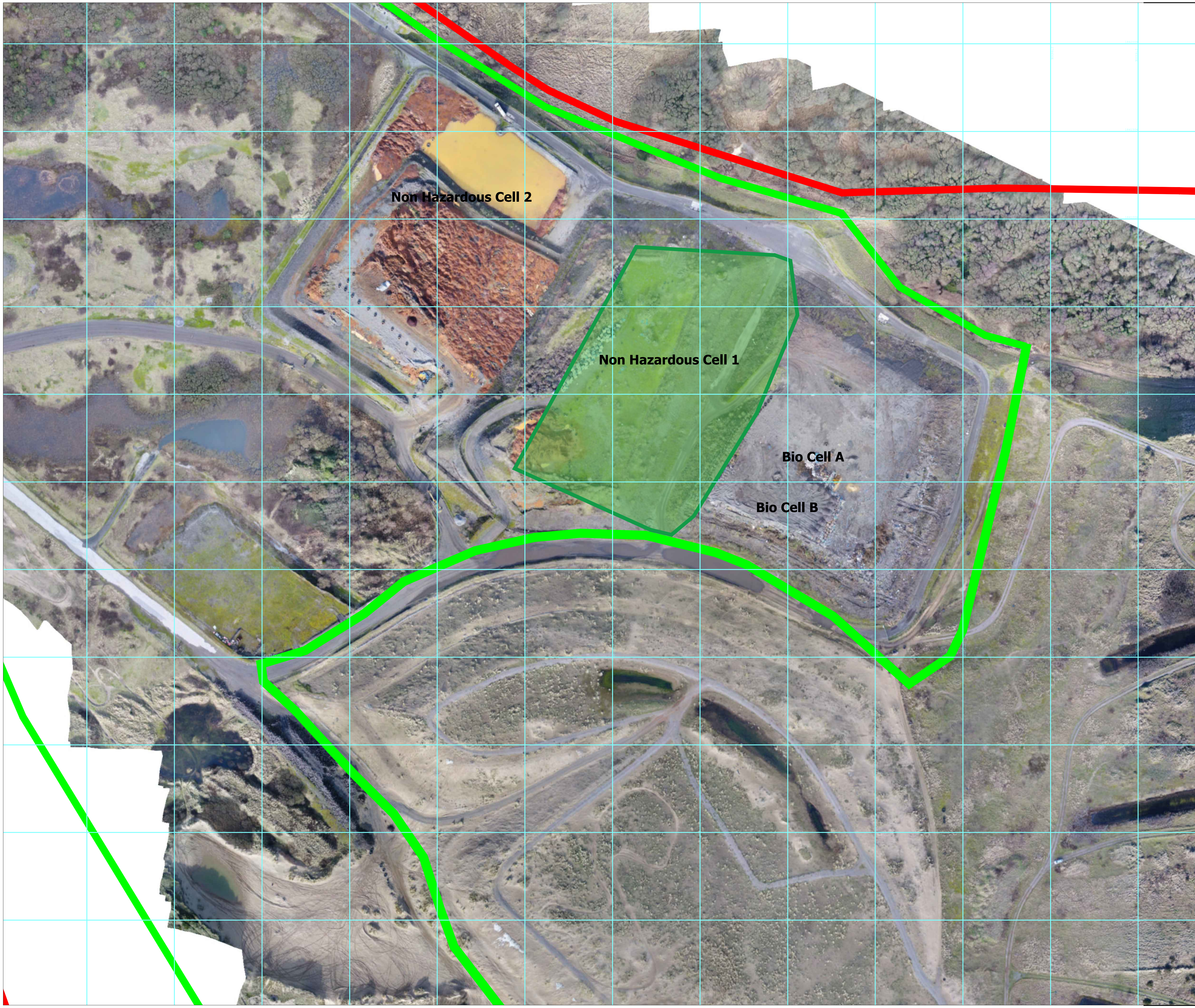

Drawing Number 2238/8

Legend

- Planning Boundary
- Non-Hazardous Landfill Permit Boundary
- Biocell Extension Area

Notes

Rev	Date	Status/Ammendments

CLIENT
Tata Steel Ltd

TATA

PROJECT
Morfa Non-Hazardous Landfill
Review of Hydrogeological
Risk Assessment

TITLE
Extent of Biocell Extension

DRAWING NUMBER			REVISION
2238/8			0
DATE	DRAWN	CHECKED	SCALE AT A3
06.22	KJT		1:2000

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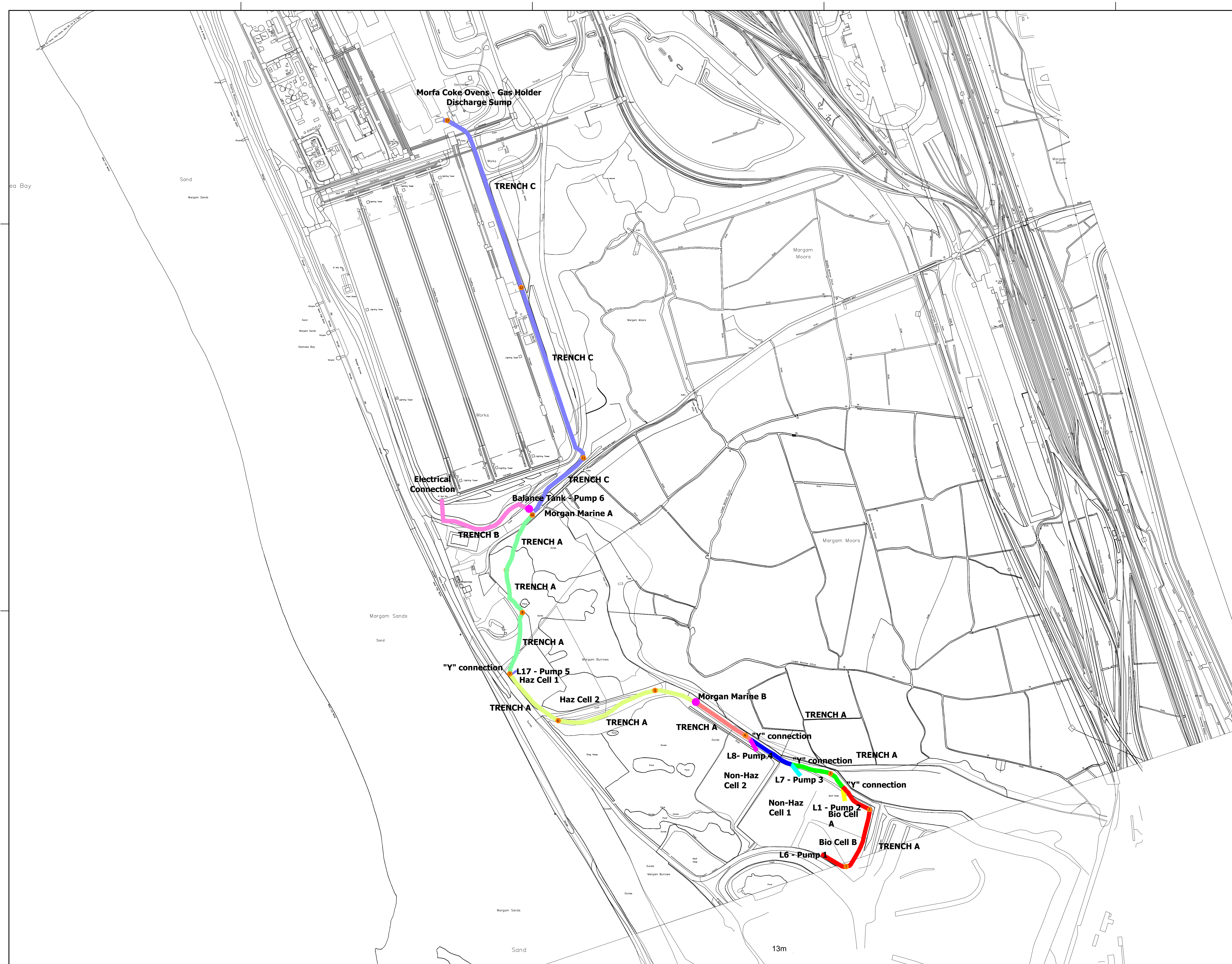

Drawing Number 2238/9

Legend

- L6 Sump Number
- Survey Check Point (see Table 7-1)
- Location of Electrical Control Panel - Morgan Marine A or B
- Chainage A
- Chainage B
- Chainage C
- Chainage D
- Chainage E
- Chainage F
- Chainage G
- Chainage H
- Chainage I
- Chainage J
- Chainage K
- Chainage L

NOTE

Rev	Date	Status/Ammendments

CLIENT: TATA STEEL (UK) LIMITED

PROJECT: MORFA NON-HAZARDOUS LANDFILL REVIEW OF HYDROGEOLOGICAL RISK ASSESSMENT

TITLE: LEACHATE PIPE ROUTE

DRAWING NUMBER	REVISION
2238/9	0

SCALE AT A1	DATE	DRAWN	CHECKED
1:4000	06.22	AJ/KT	

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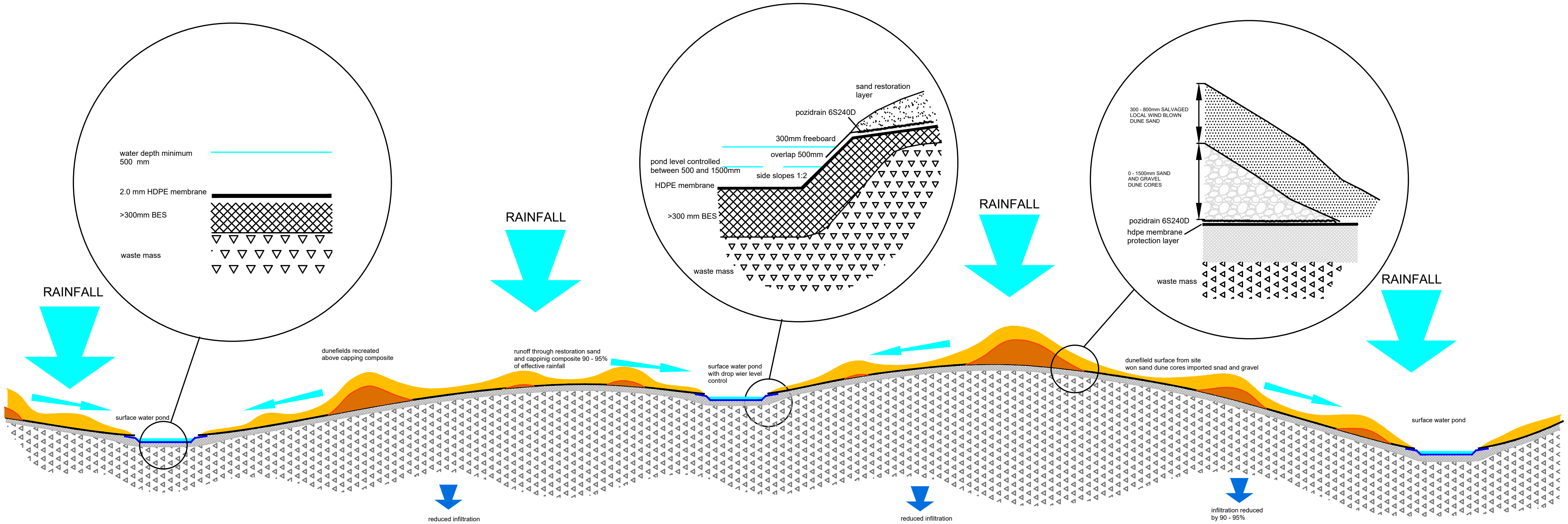

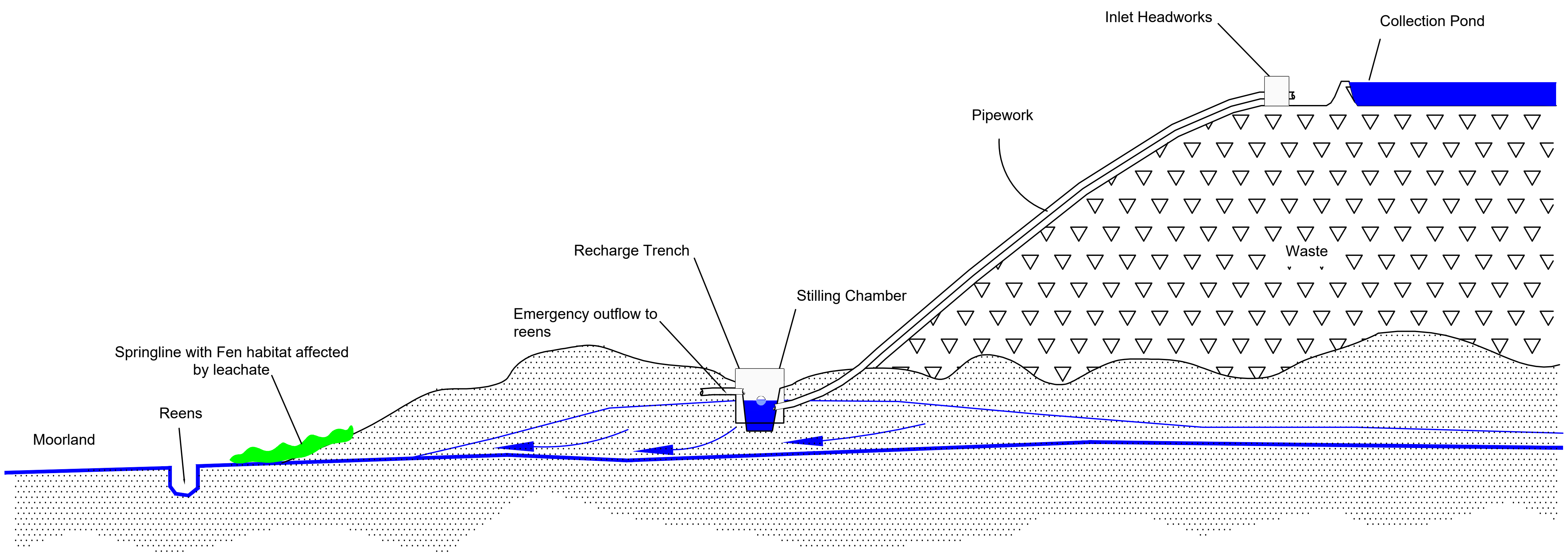

Drawing Number 2238/10

Legend

Notes

Rev	Date	Status/Ammendments

CLIENT

Tata Steel Ltd

PROJECT

MORFA NON-HAZARDOUS LANDFILL
REVIEW OF HYDROGEOLOGICAL
RISK ASSESSMENT

TITLE

Capping System Cross Sections

DRAWING NUMBER	REVISION
2238/10	0

DATE	DRAWN	CHECKED	SCALE AT A3
06.22	KJT		NTS

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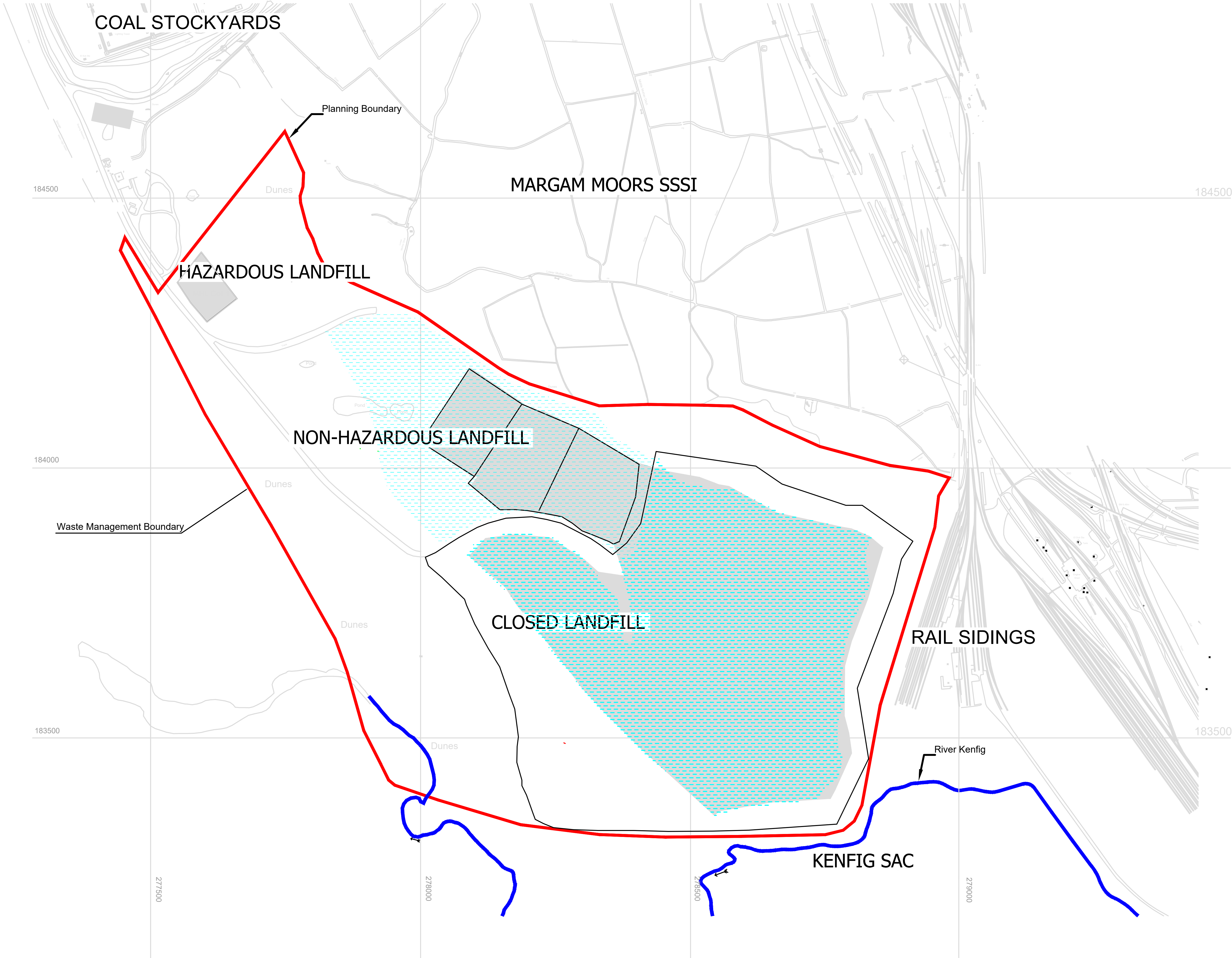

Drawing Number 2238/11

Legend

- Predicted full extent of rainfall shadow
- Current extent of rainfall shadow

Notes

Rev	Date	Status/Ammendments

CLIENT: Tata Steel Ltd

PROJECT: MORFA NON-HAZARDOUS LANDFILL REVIEW OF HYDROGEOLOGICAL RISK ASSESSMENT

TITLE: Recharge Shadow Development

DRAWING NUMBER	REVISION
2238/11	0

DATE	DRAWN	CHECKED	SCALE AT A3
06.22	BR		NTS

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Figure 12 Available Monitoring Network

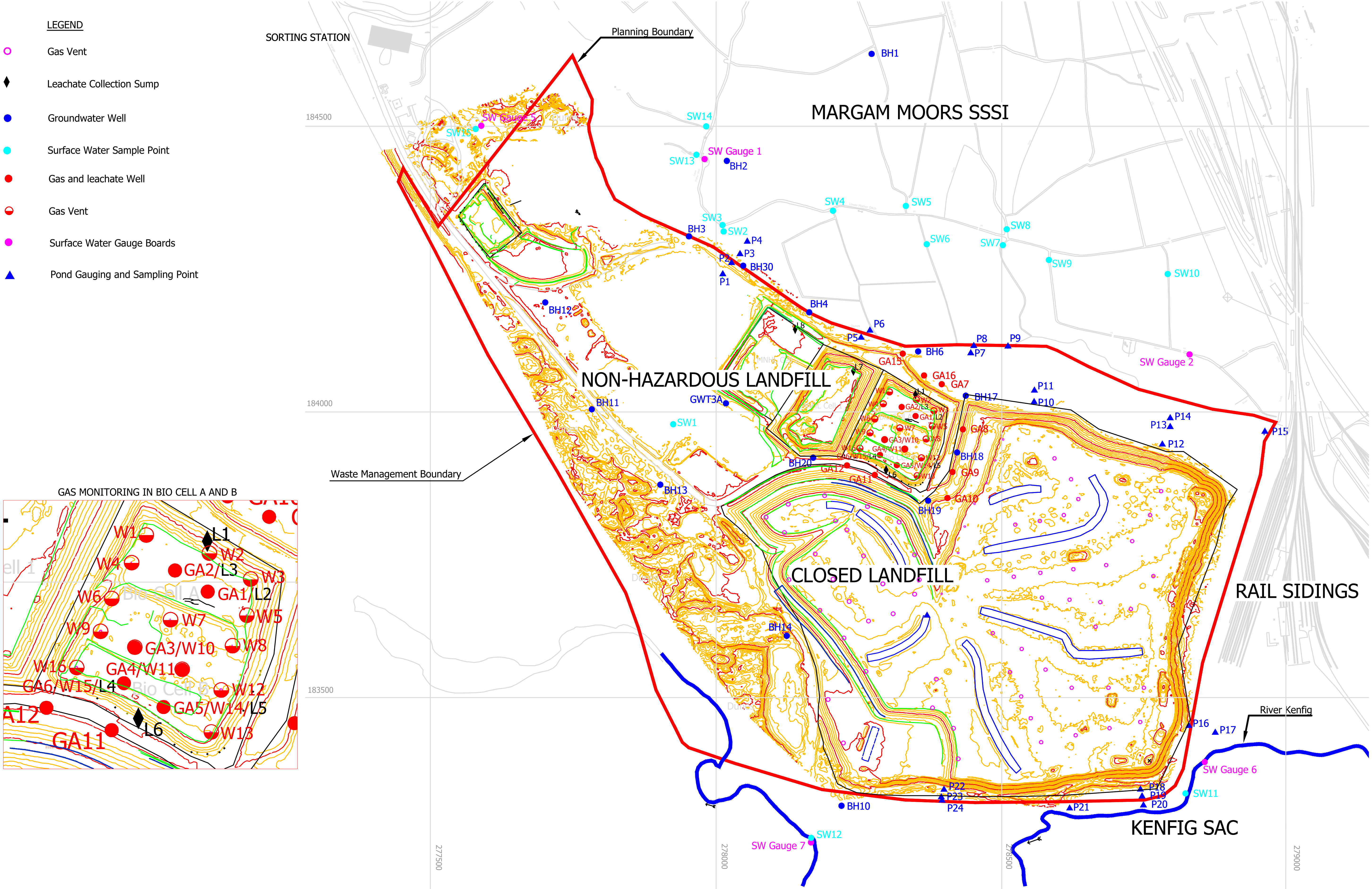
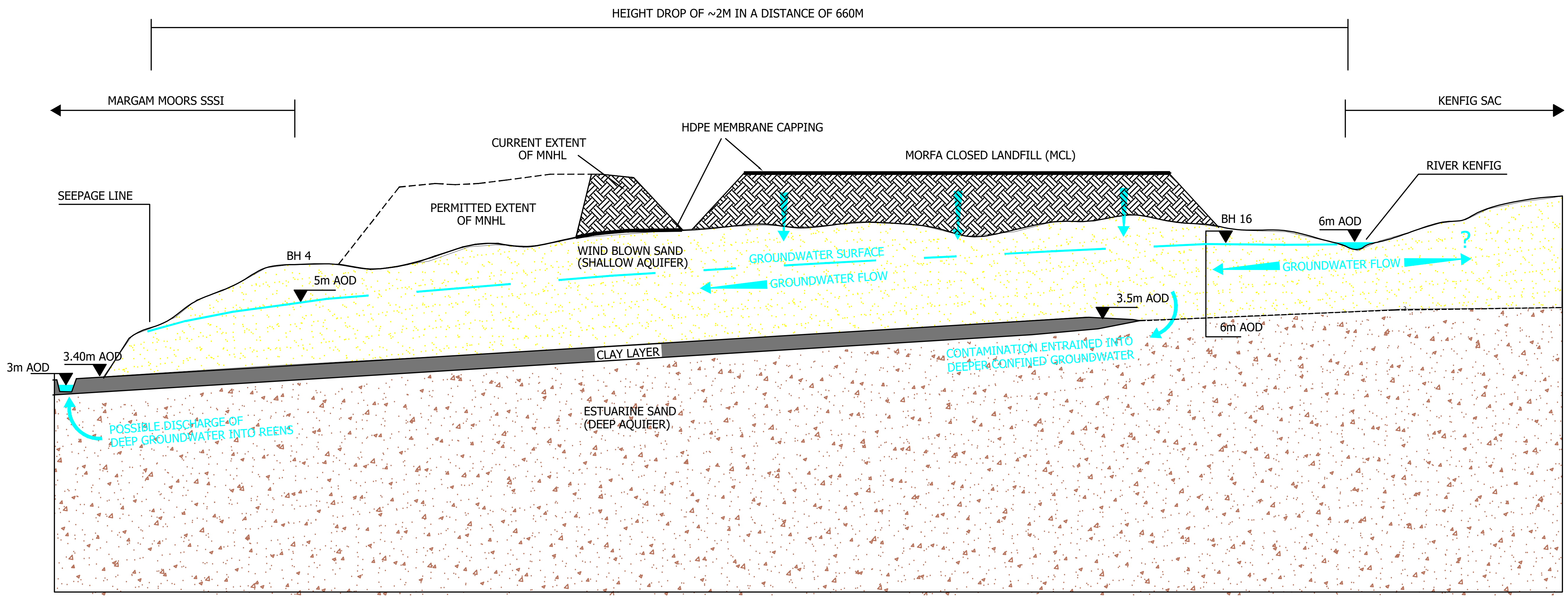


Figure 13 Current Conceptual Hydrogeological Model

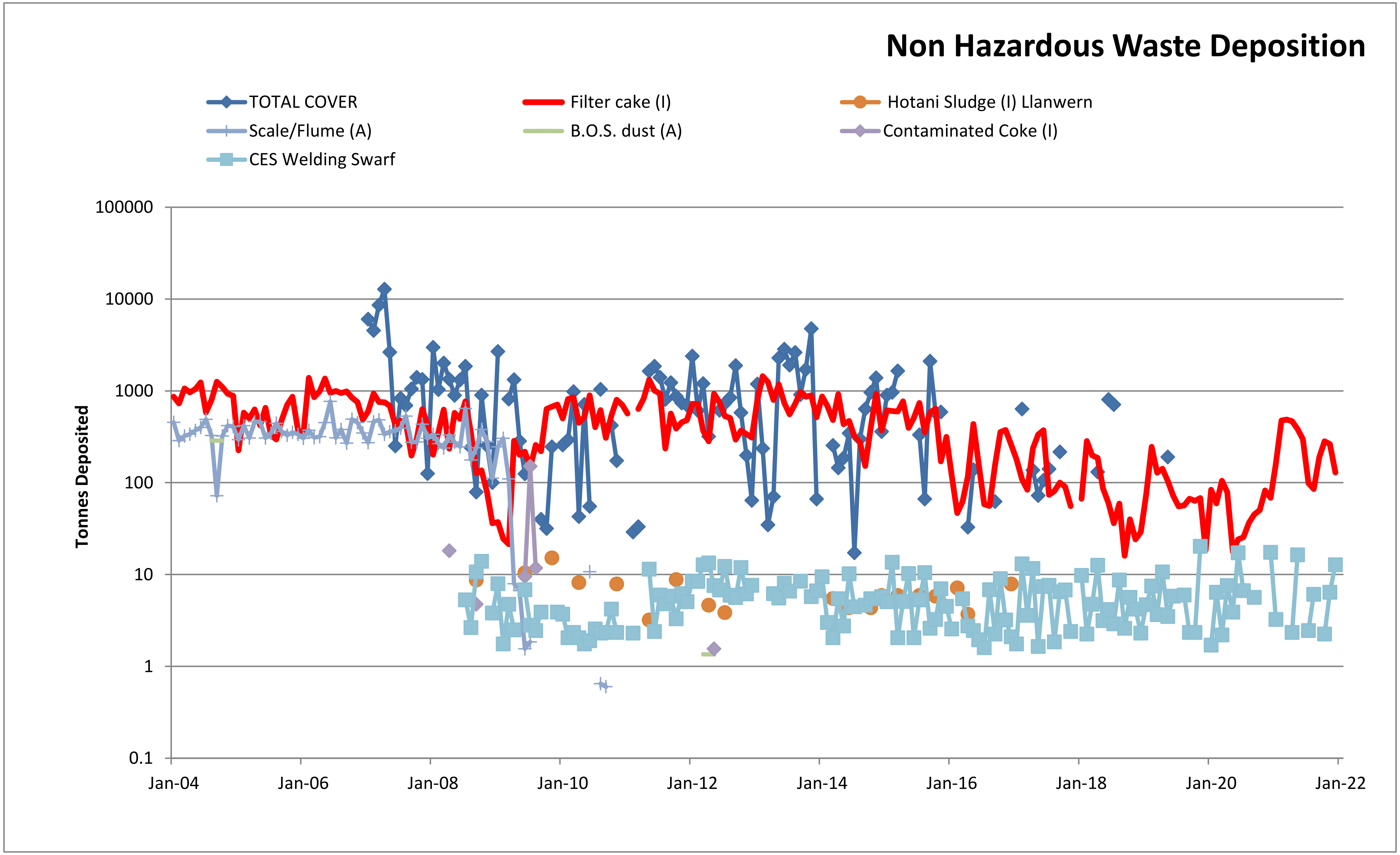


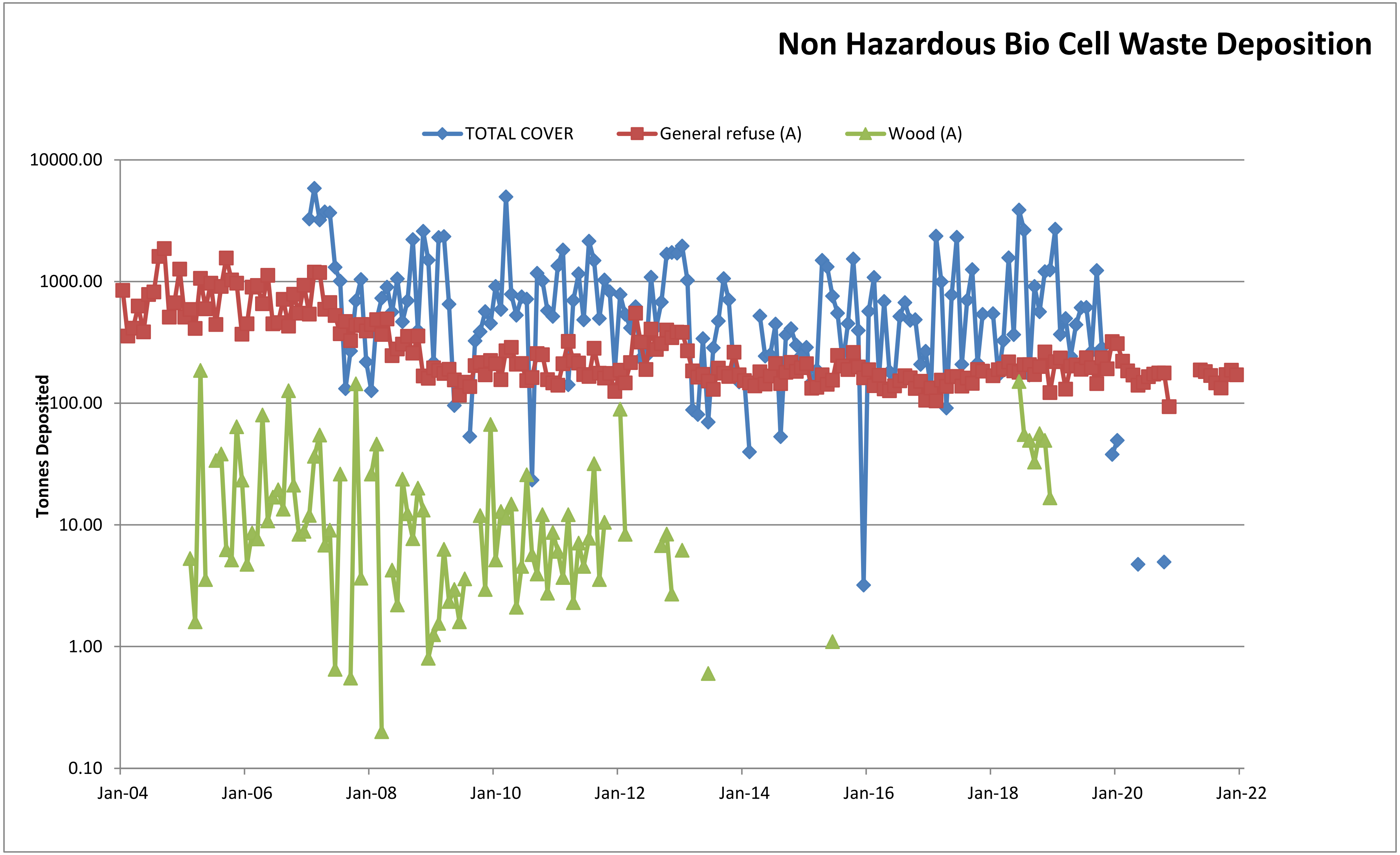
MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

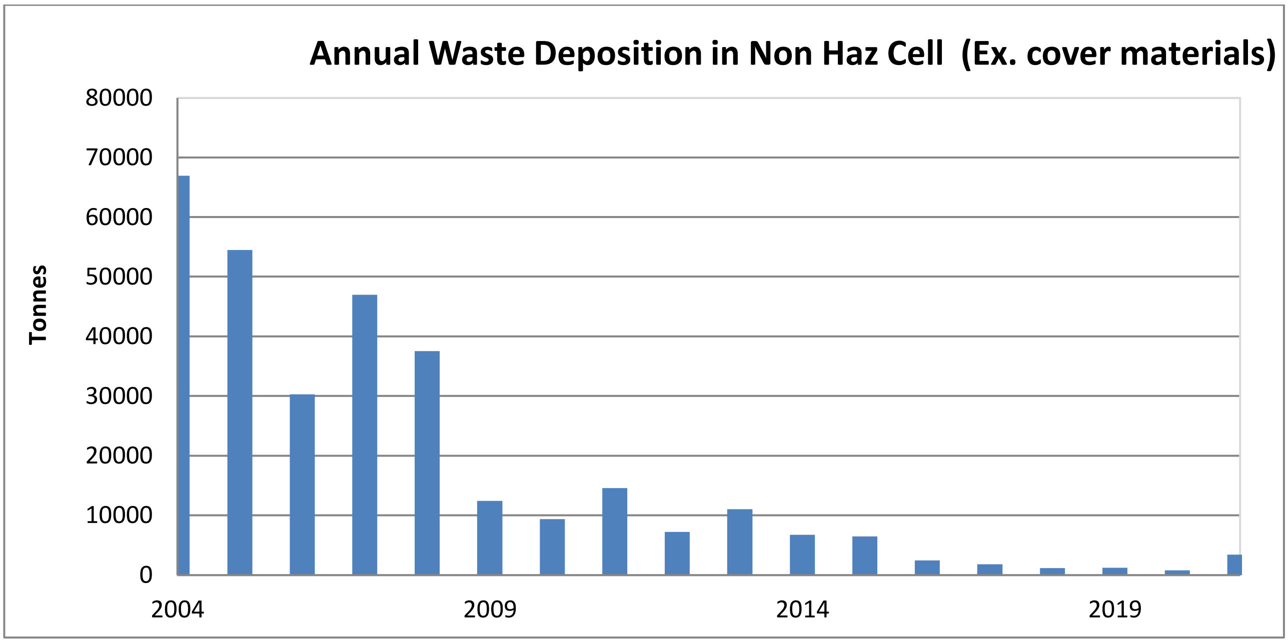
ENVIRONMENTAL PERMIT BV7311IE

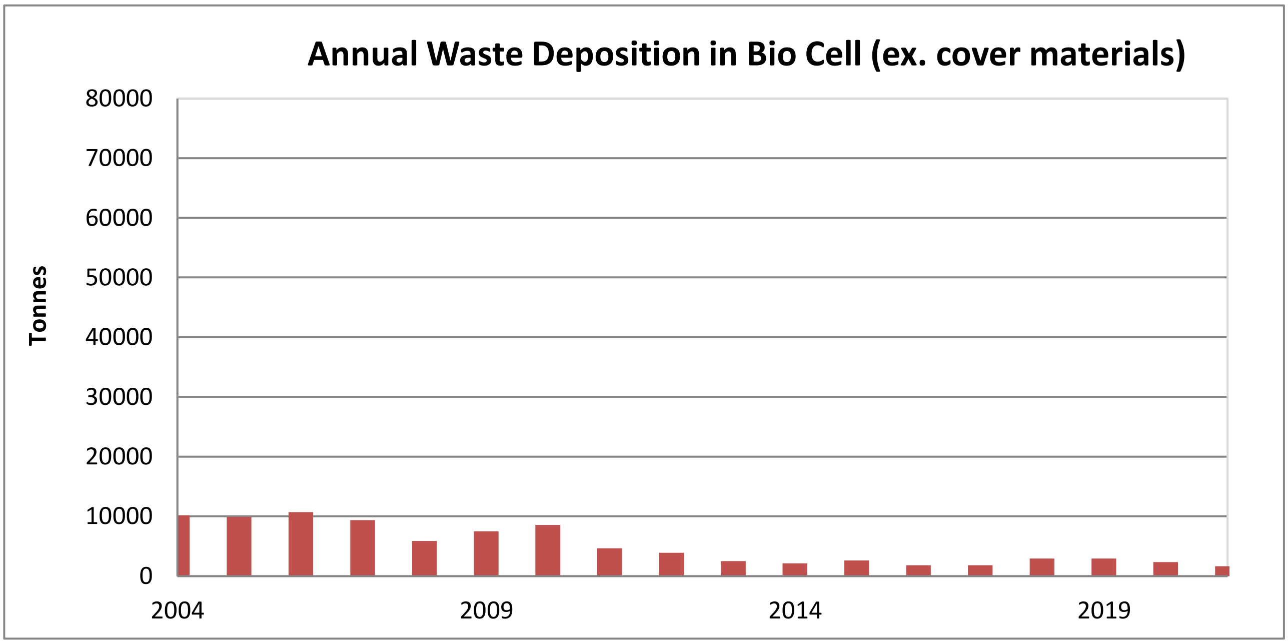
Review of Hydrogeological Risk Assessment

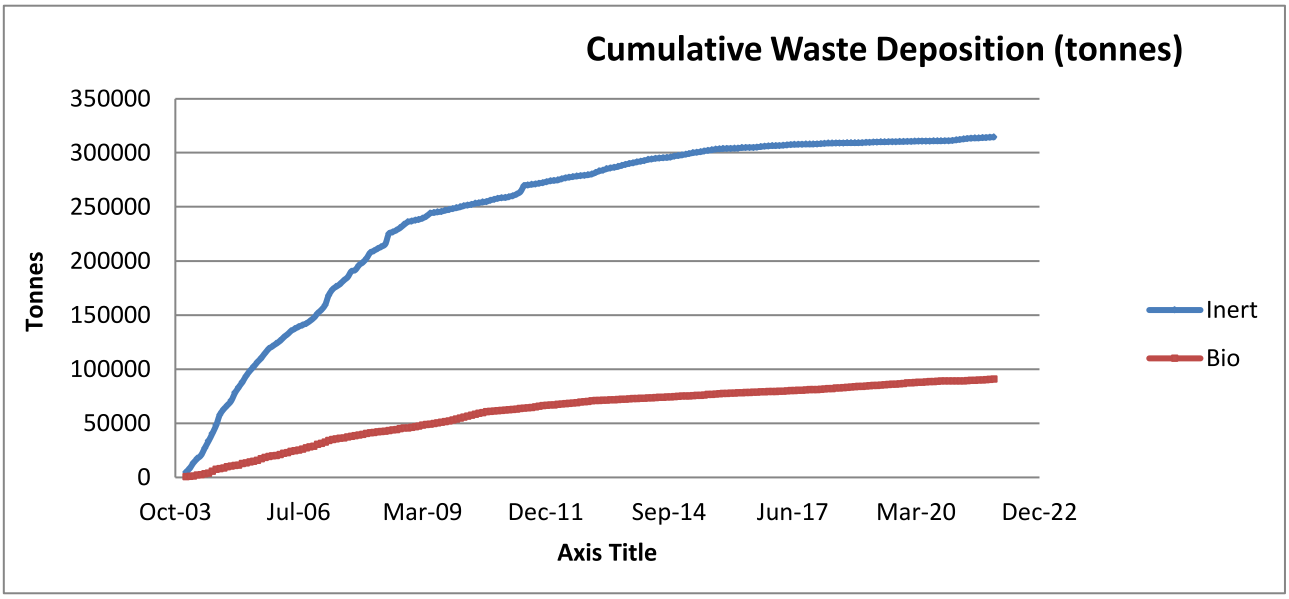
Appendix 1
Graphical Record of Waste Types Landfilled
Report Number 2238r1v1d0622


Non Hazardous Waste Deposition
TOTAL COVER
Filter cake (I)
Hotani Sludge (I) Llanwern
Scale/Flume (A)
B.O.S. dust (A)
Contaminated Coke (I)
CES Welding Swarf
Tonnes Deposited
100000
10000
1000
100
10
1
0.1
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22


Non Hazardous Bio Cell Waste Deposition
TOTAL COVER
General refuse (A)
Wood (A)
Tonnes Deposited
10000.00
1000.00
100.00
10.00
1.00
0.10
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22


Annual Waste Deposition in Non Haz Cell (Ex. cover materials)
Tonnes
80000
70000
60000
50000
40000
30000
20000
10000
0
2004
2009
2014
2019


Annual Waste Deposition in Bio Cell (ex. cover materials)
Tonnes
80000
70000
60000
50000
40000
30000
20000
10000
0
2004
2009
2014
2019


Cumulative Waste Deposition (tonnes)
Tonnes
350000
300000
250000
200000
150000
100000
50000
0
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Jun-17
Mar-20
Dec-22
Axis Title
Inert
Bio

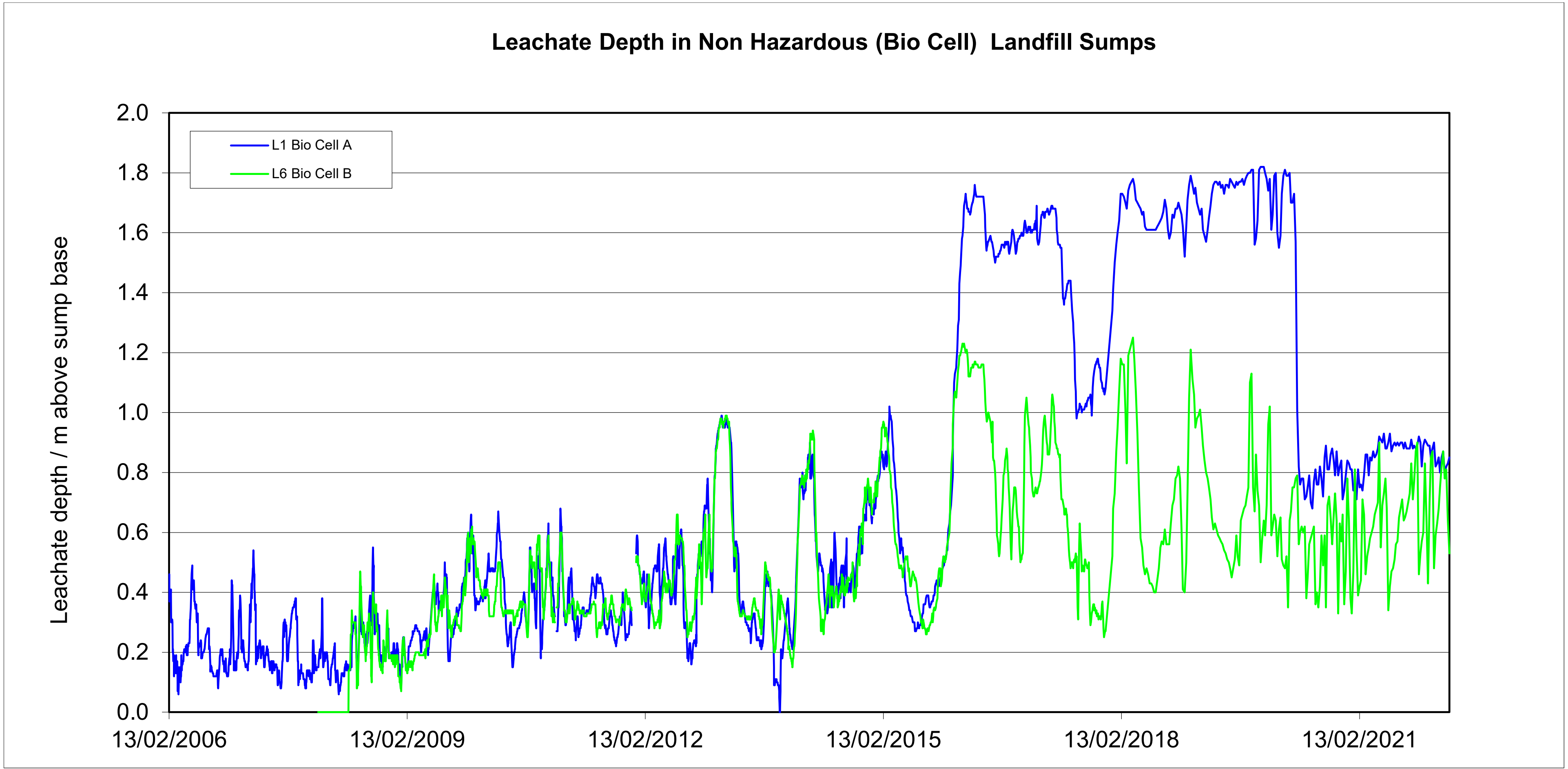
MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

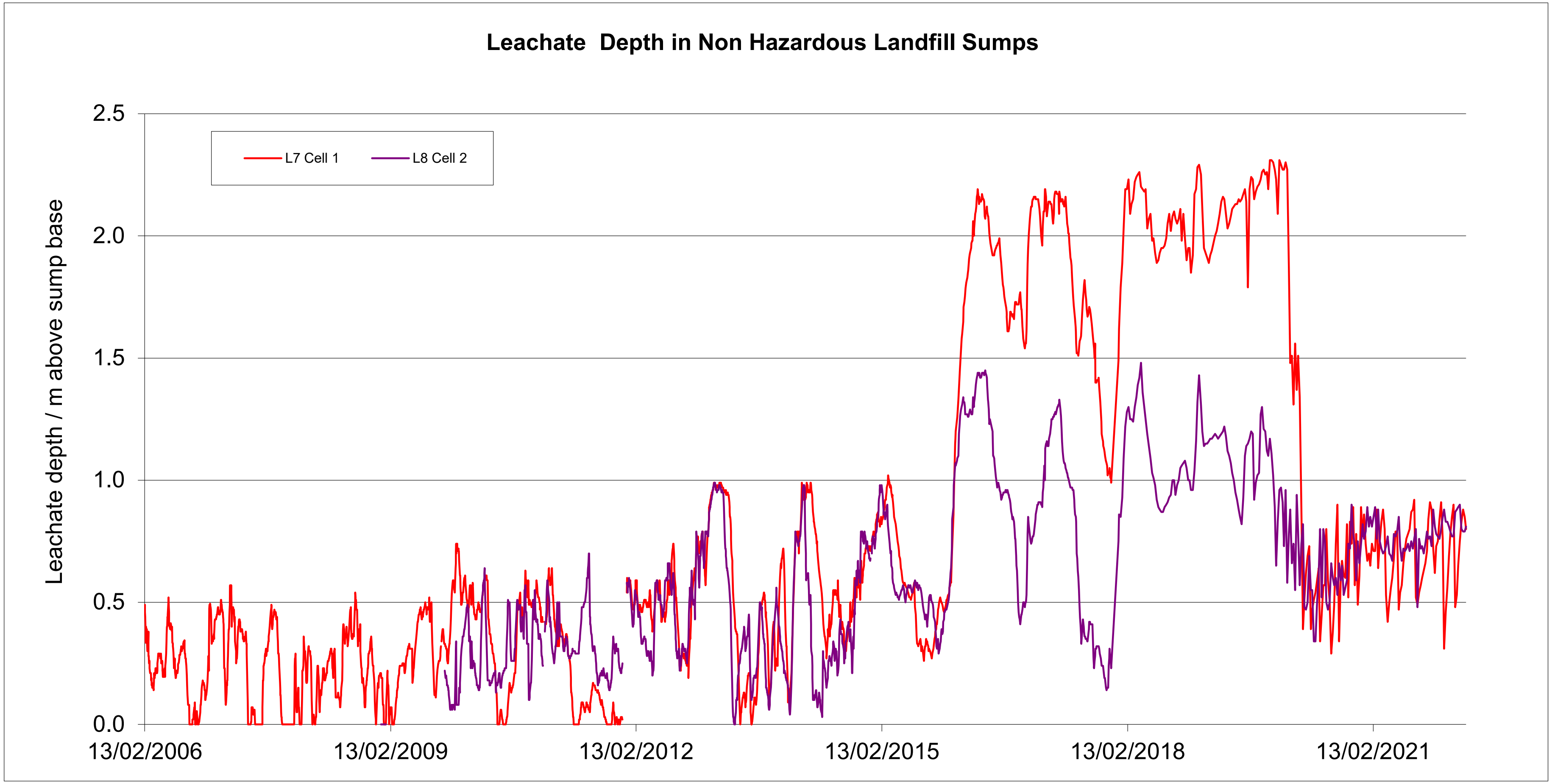
ENVIRONMENTAL PERMIT BV7311IE

Review of Hydrogeological Risk Assessment

Appendix 2 Leachate Depth in Sump

Report Number 2238r1v1d0622


Leachate Depth in Non Hazardous (Bio Cell) Landfill Sumps
L1 Bio Cell A
L6 Bio Cell B
Leachate depth / m above sump base
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
13/02/2006
13/02/2009
13/02/2012
13/02/2015
13/02/2018
13/02/2021


Leachate Depth in Non Hazardous Landfill Sumps
L7 Cell 1
L8 Cell 2
Leachate depth / m above sump base
2.5
2.0
1.5
1.0
0.5
0.0
13/02/2006
13/02/2009
13/02/2012
13/02/2015
13/02/2018
13/02/2021

MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

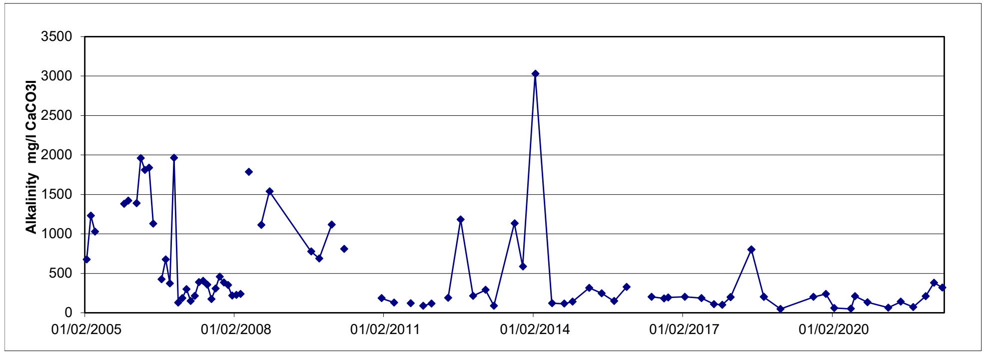
ENVIRONMENTAL PERMIT BV7311IE

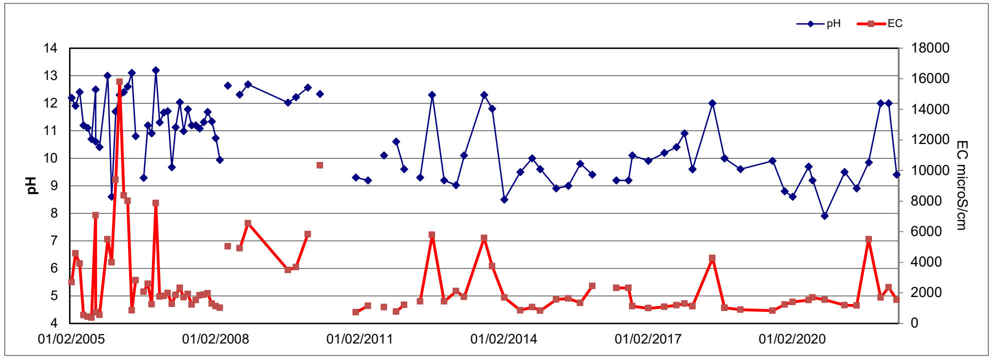
Review of Hydrogeological Risk Assessment

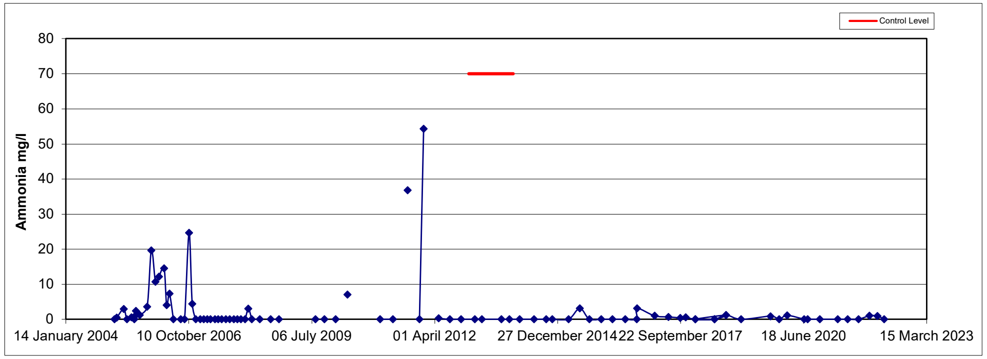
Appendix 3 Leachate Chemistry

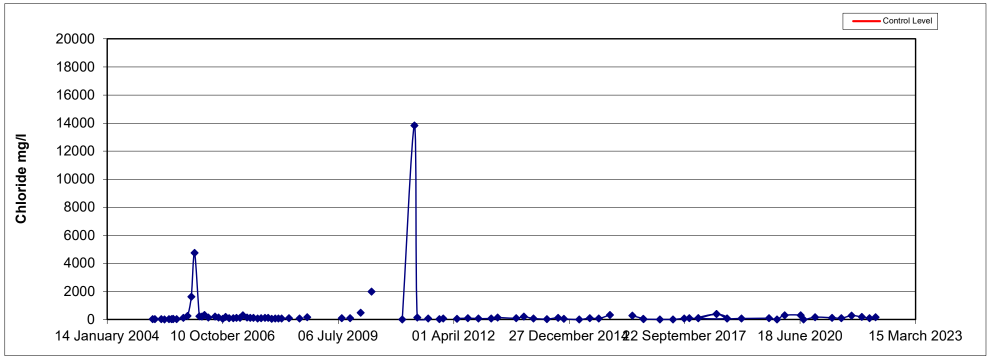
Report Number 2238r1v1d0622

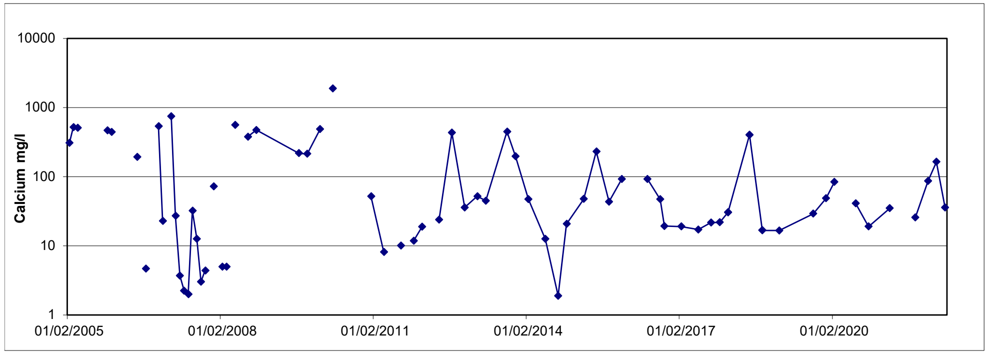
Monitoring Data for L1

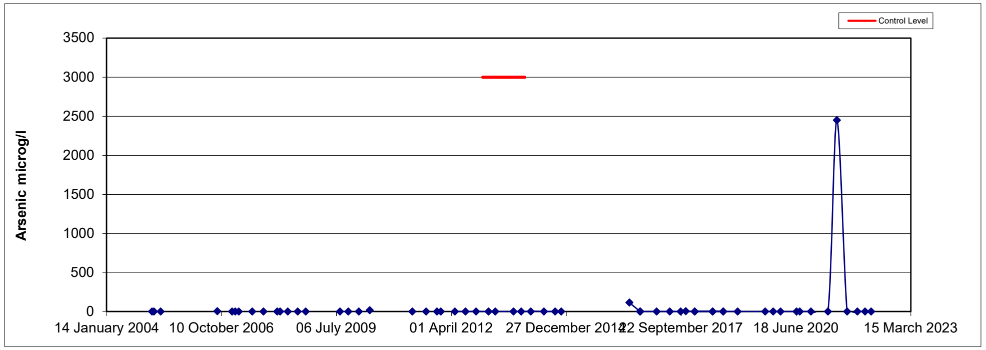


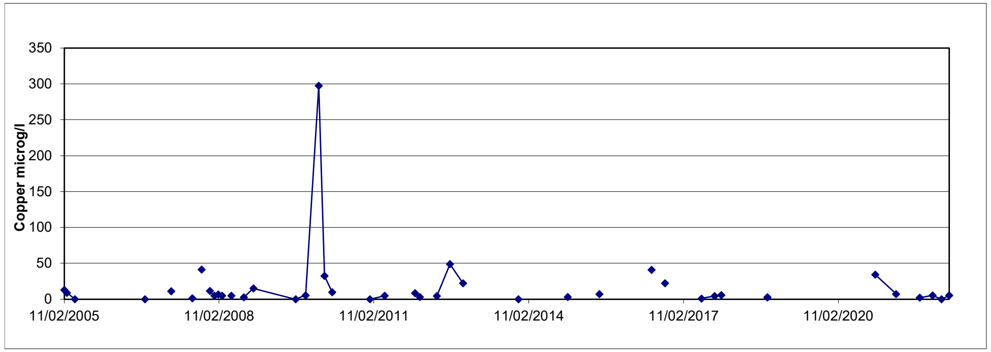


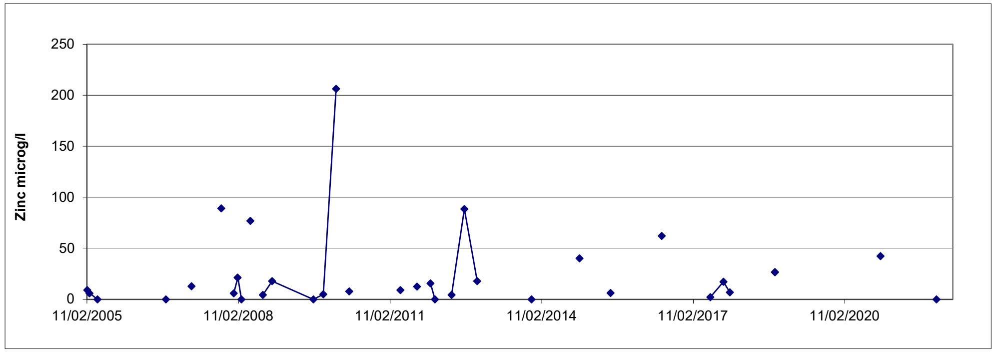


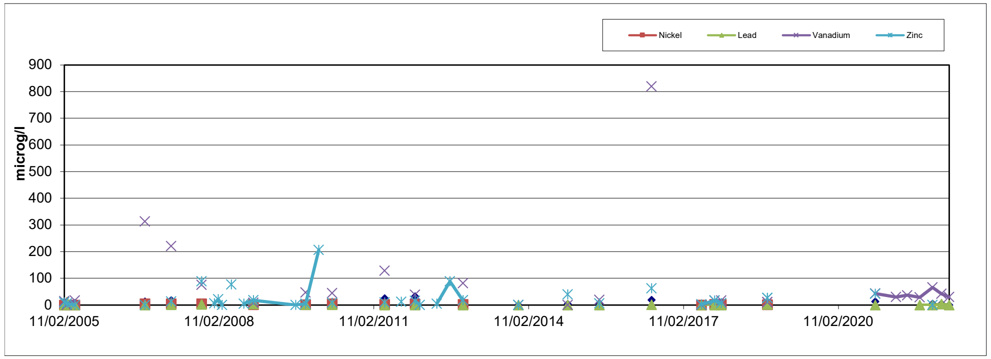


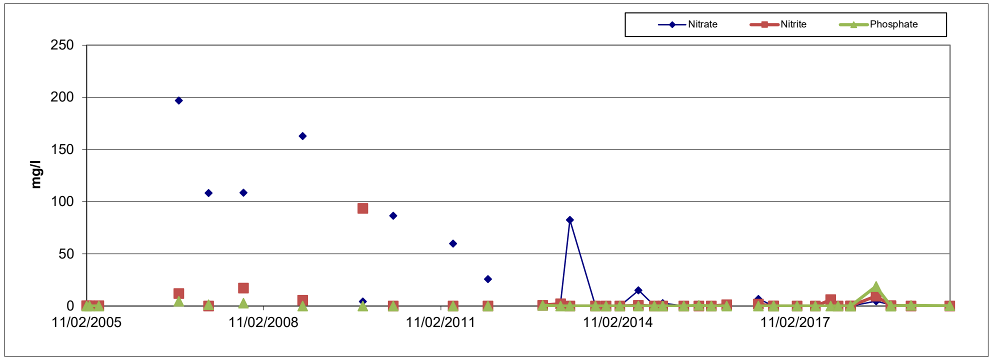


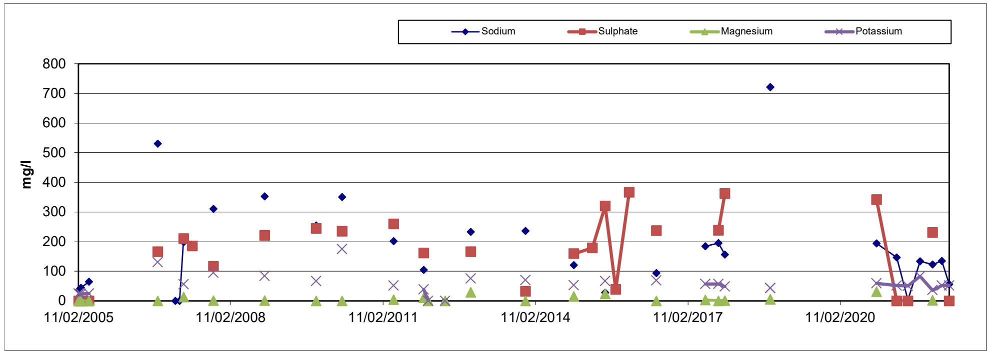


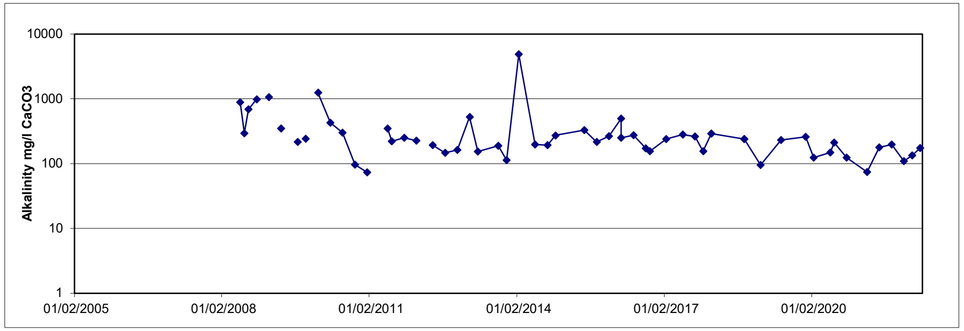

Copper microg/l
350
300
250
200
150
100
50
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

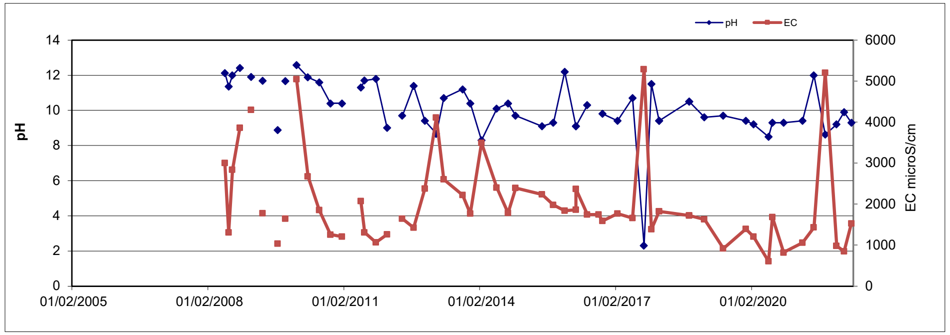

Zinc microg/l
250
200
150
100
50
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

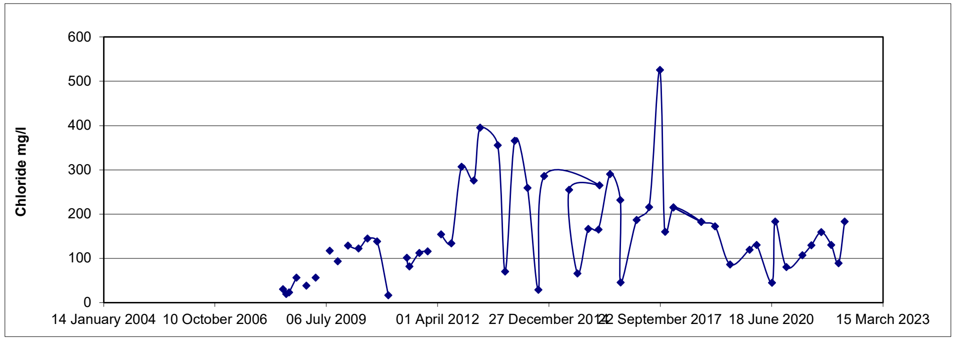

Nickel
Lead
Vanadium
Zinc
microg/l
900
800
700
600
500
400
300
200
100
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

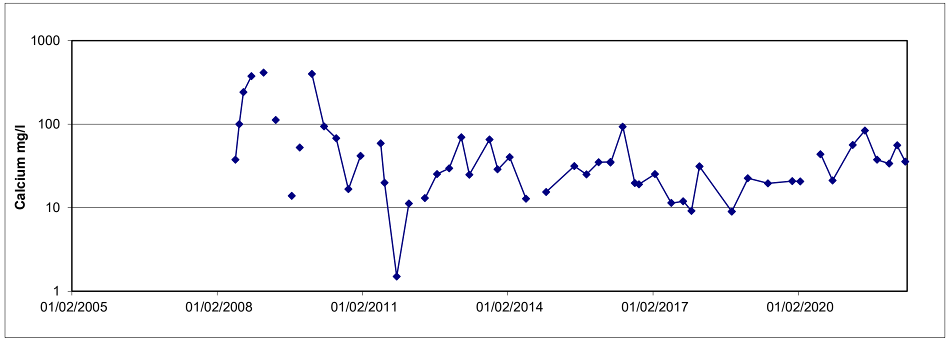

Nitrate
Nitrite
Phosphate
mg/l
250
200
150
100
50
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017

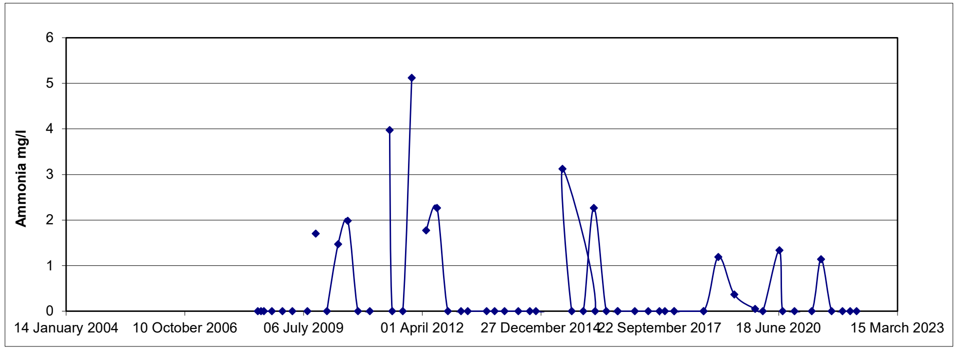

Sodium
Sulphate
Magnesium
Potassium
mg/l
800
700
600
500
400
300
200
100
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

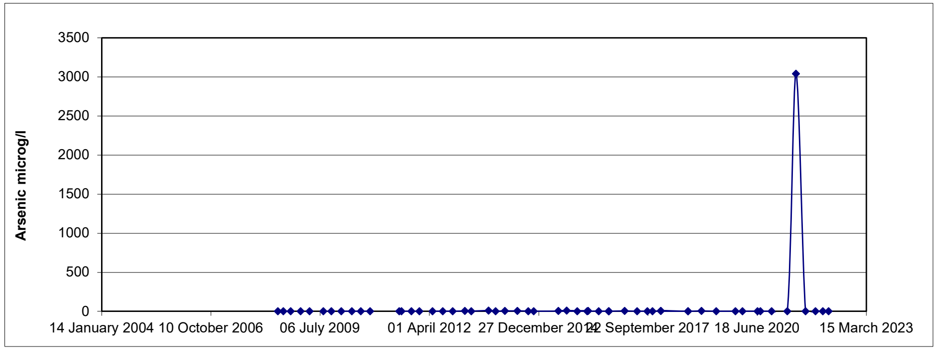

10000
1000
100
10
1
Alkalinity mg/l CaCO3
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

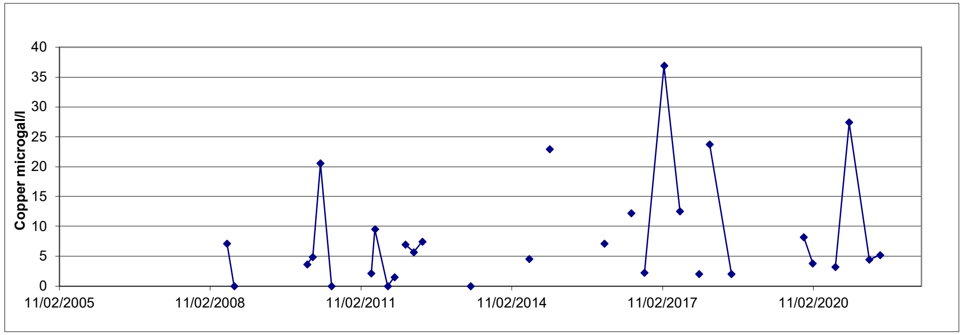

pH
EC
14
12
10
8
6
4
2
0
pH
6000
5000
4000
3000
2000
1000
0
EC microS/cm
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

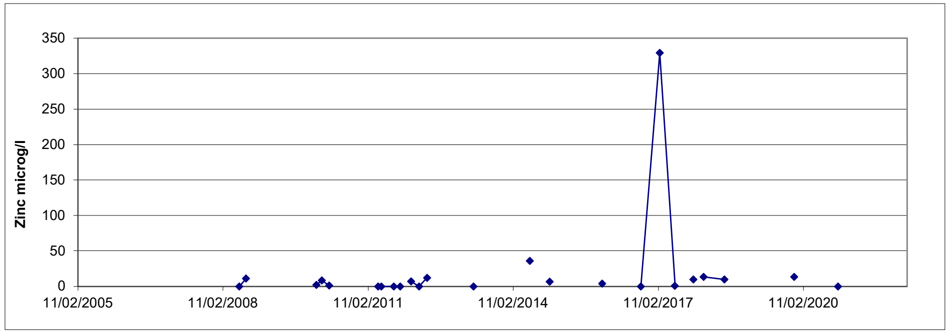

600
500
400
300
200
100
0
Chloride mg/l
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

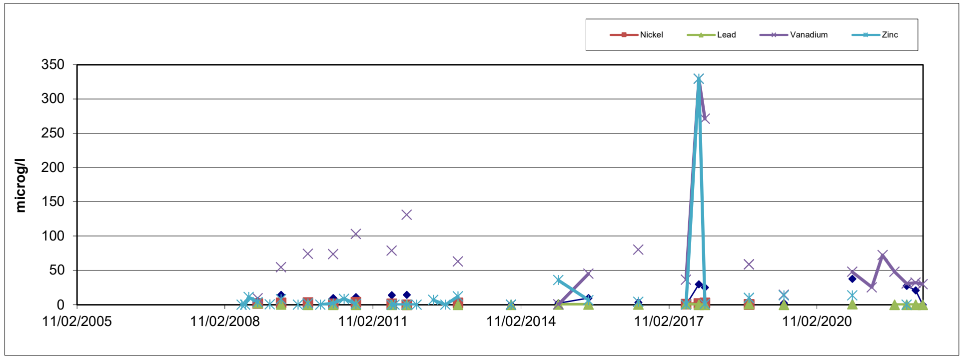

1000
100
10
1
Calcium mg/l
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

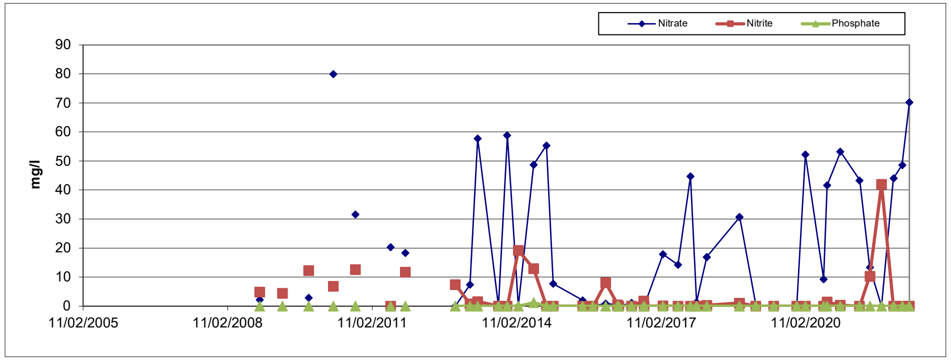

6
5
4
3
2
1
0
Ammonia mg/l
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

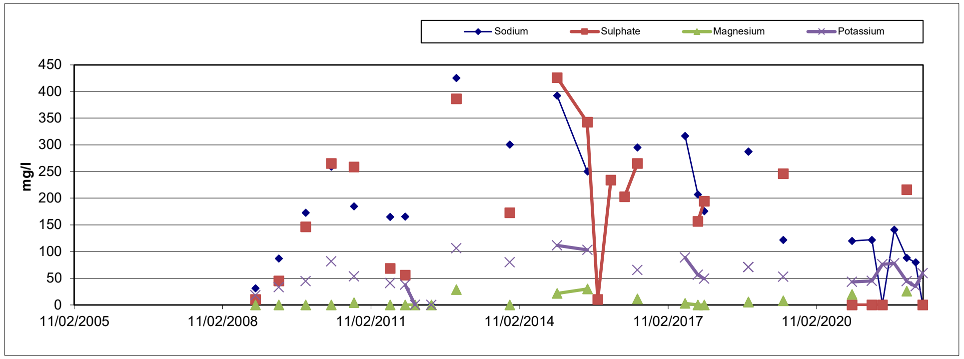

3500
3000
2500
2000
1500
1000
500
0
Arsenic microg/l
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

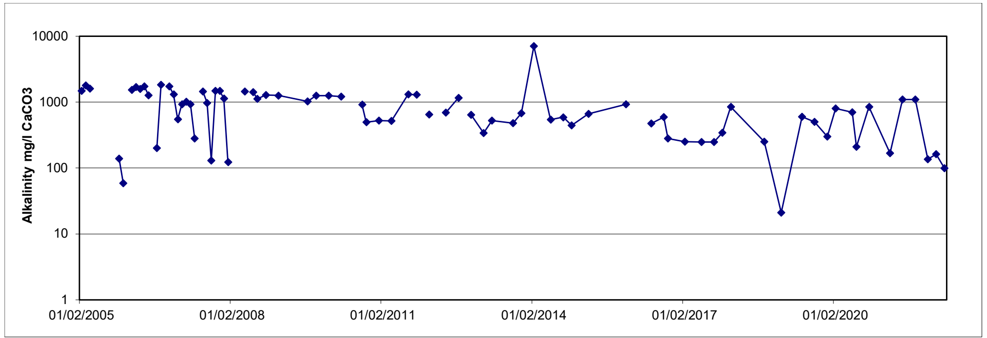

Copper microgal/l
0
5
10
15
20
25
30
35
40
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

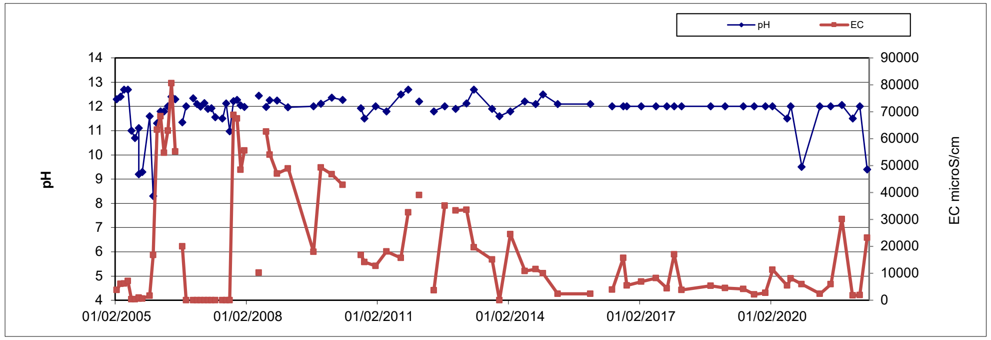

Zinc microg/l
0
50
100
150
200
250
300
350
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

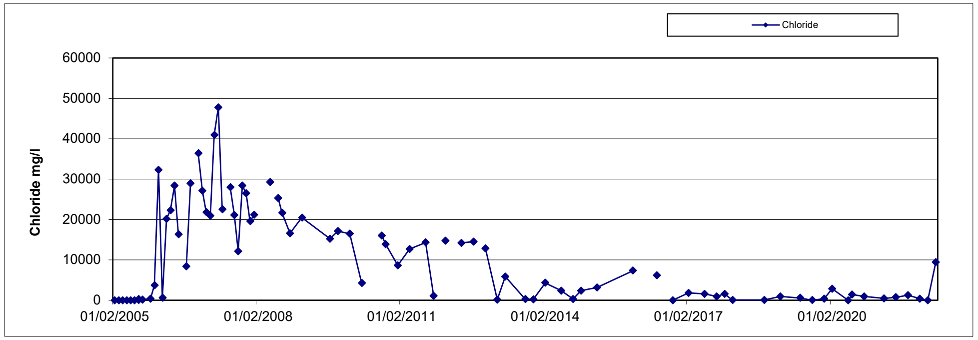

Nickel
Lead
Vanadium
Zinc
microg/l
0
50
100
150
200
250
300
350
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

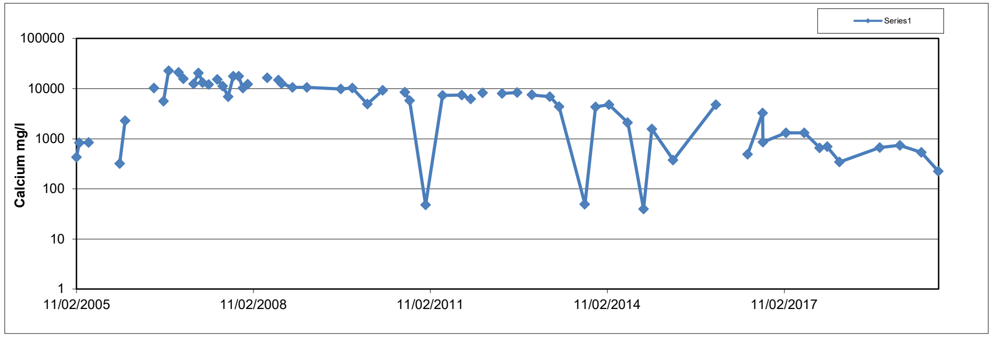

Nitrate
Nitrite
Phosphate
mg/l
0
10
20
30
40
50
60
70
80
90
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

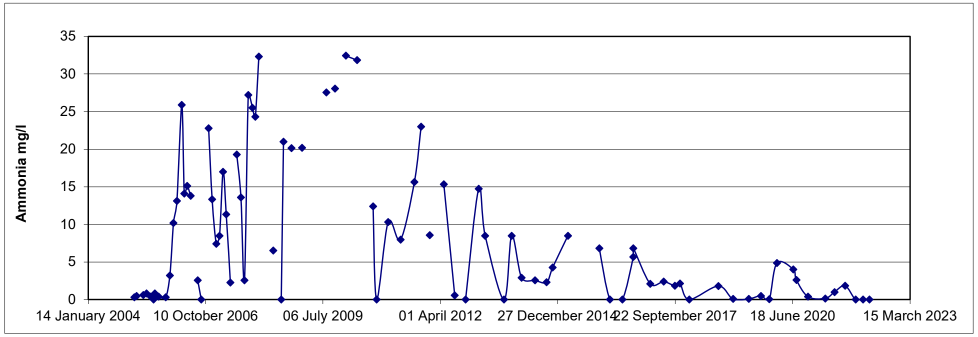

Sodium
Sulphate
Magnesium
Potassium
mg/l
0
50
100
150
200
250
300
350
400
450
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

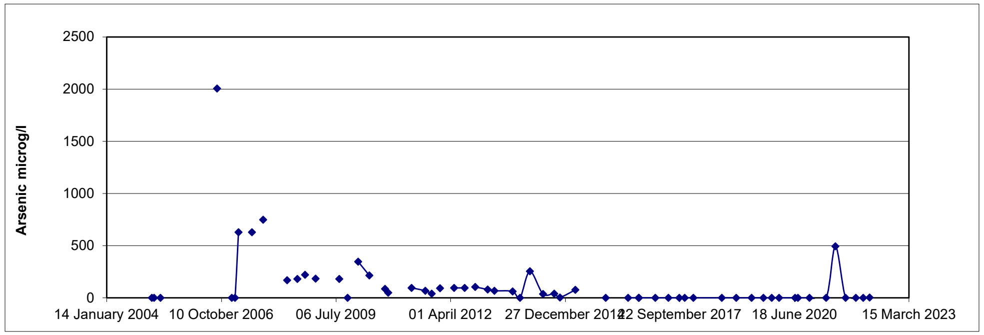

Alkalinity mg/l CaCO3
10000
1000
100
10
1
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

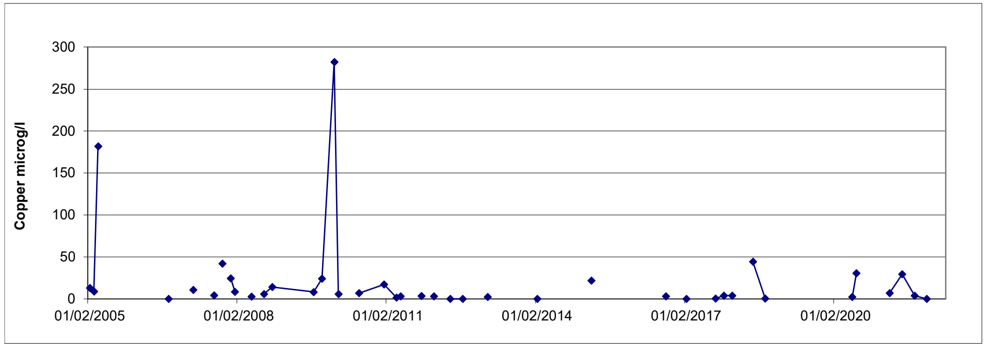

pH
EC
pH
EC microS/cm
14
13
12
11
10
9
8
7
6
5
4
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

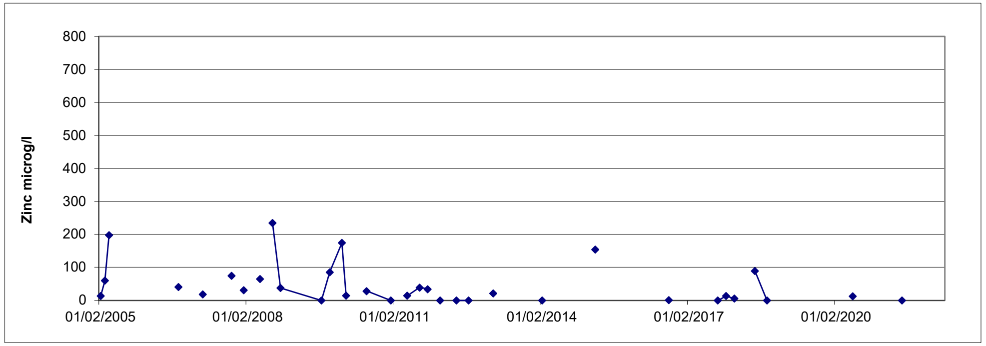

Chloride
Chloride mg/l
60000
50000
40000
30000
20000
10000
0
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

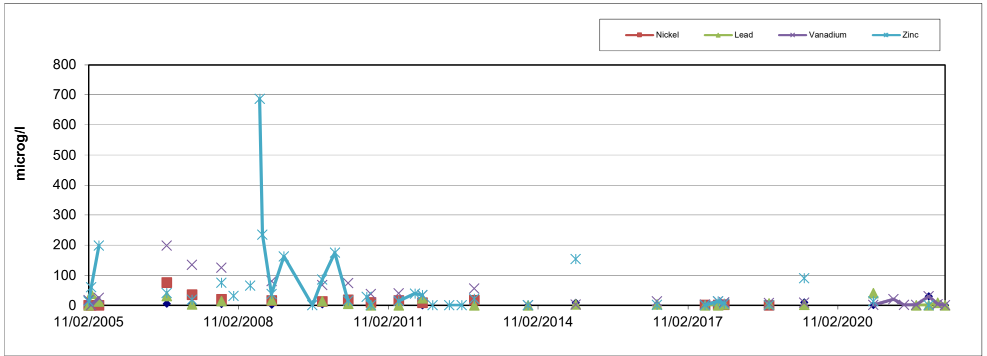

Series1
Calcium mg/l
100000
10000
1000
100
10
1
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017

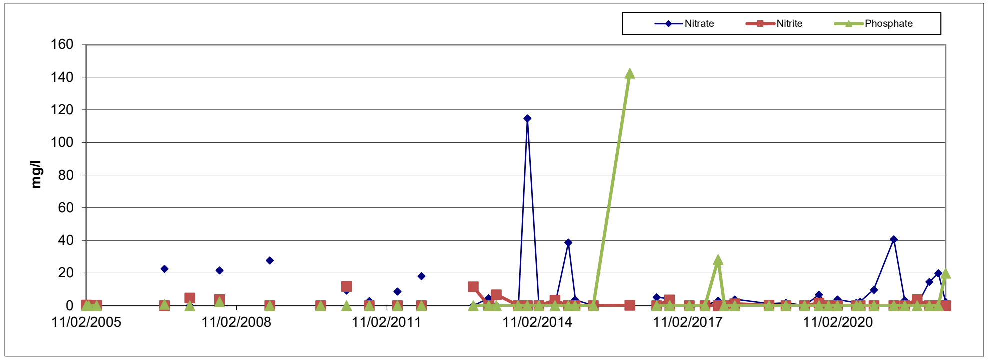

Ammonia mg/l
35
30
25
20
15
10
5
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

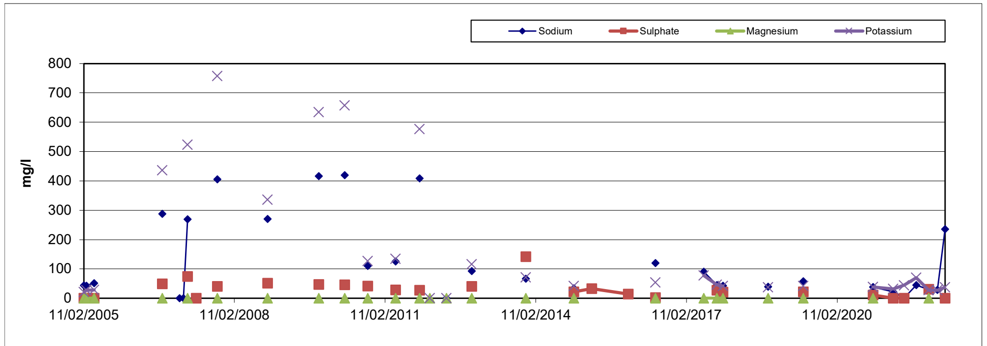

Arsenic microg/l
2500
2000
1500
1000
500
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

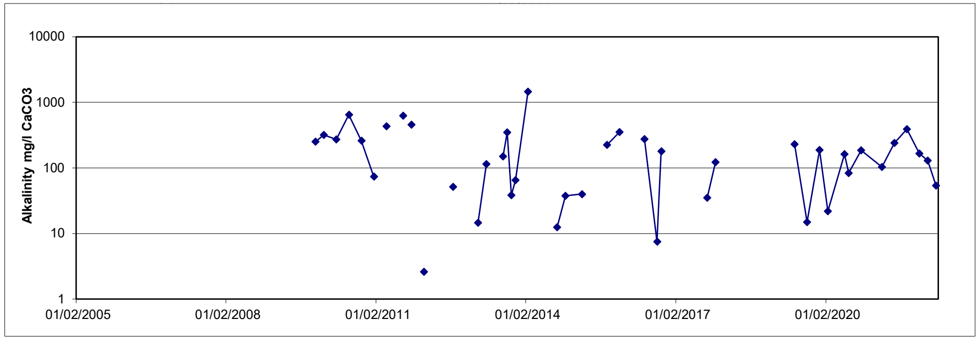

Copper microg/l
300
250
200
150
100
50
0
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

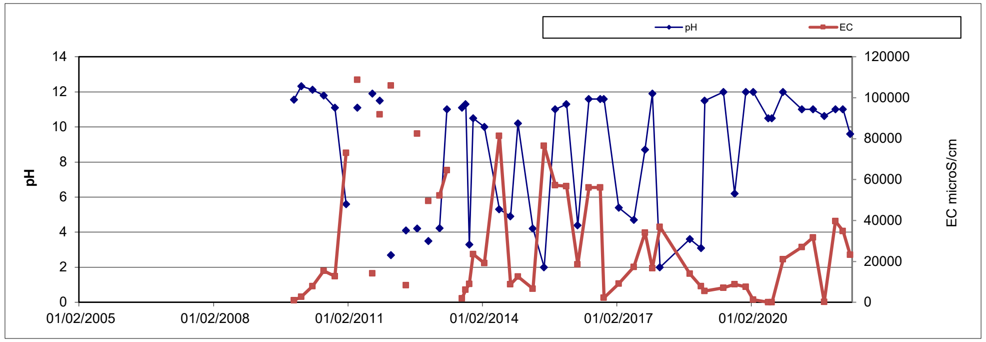

Zinc microg/l
800
700
600
500
400
300
200
100
0
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

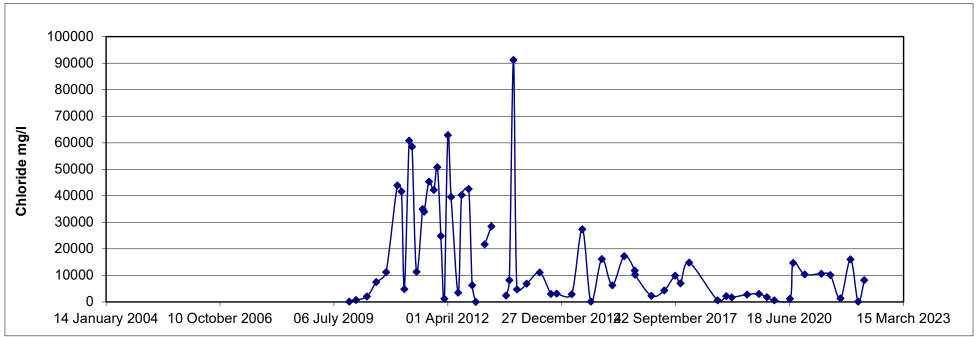

Nickel
Lead
Vanadium
Zinc
microg/l
800
700
600
500
400
300
200
100
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

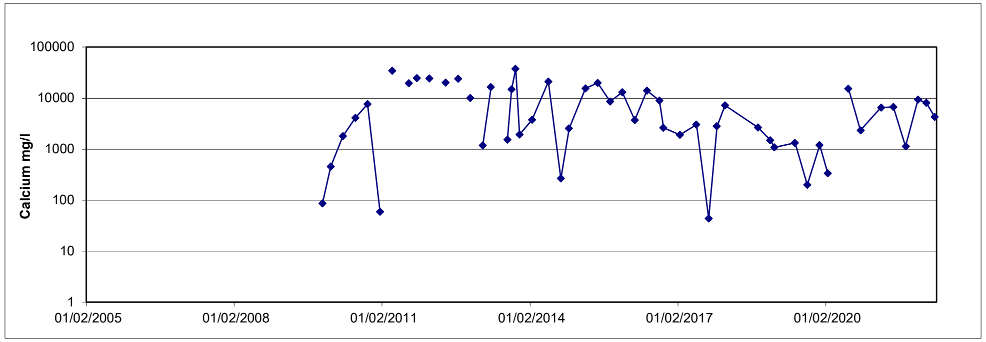

Nitrate
Nitrite
Phosphate
mg/l
160
140
120
100
80
60
40
20
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

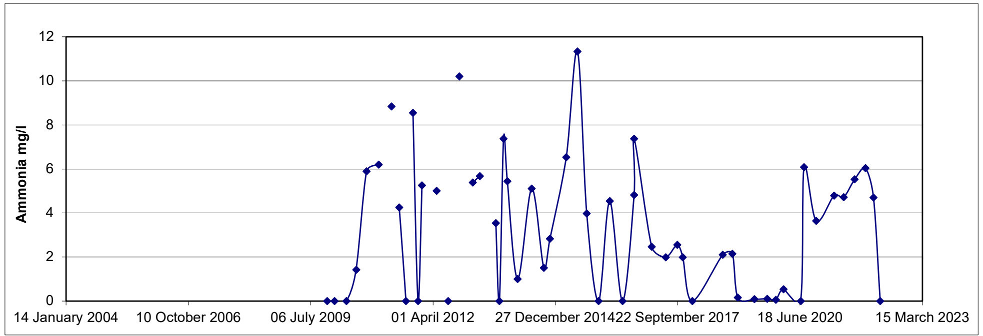

Sodium
Sulphate
Magnesium
Potassium
mg/l
800
700
600
500
400
300
200
100
0
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

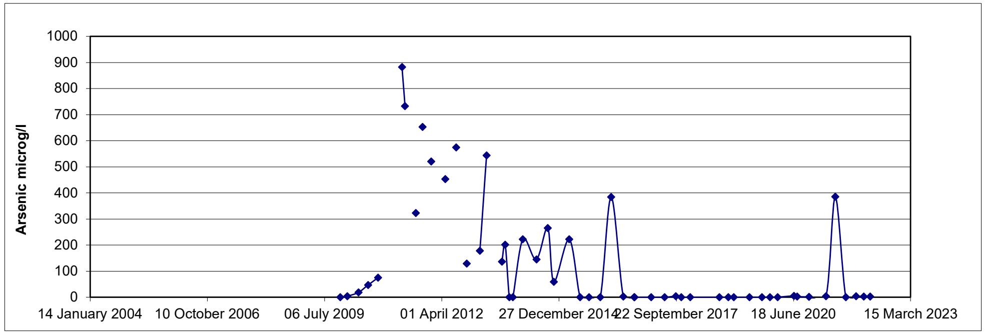

Alkalinity mg/l CaCO3
10000
1000
100
10
1
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

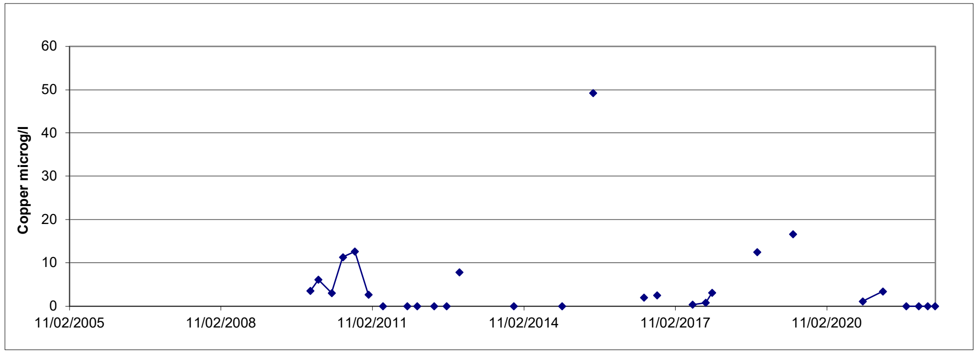

pH
EC
pH
EC microS/cm
14
12
10
8
6
4
2
0
120000
100000
80000
60000
40000
20000
0
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

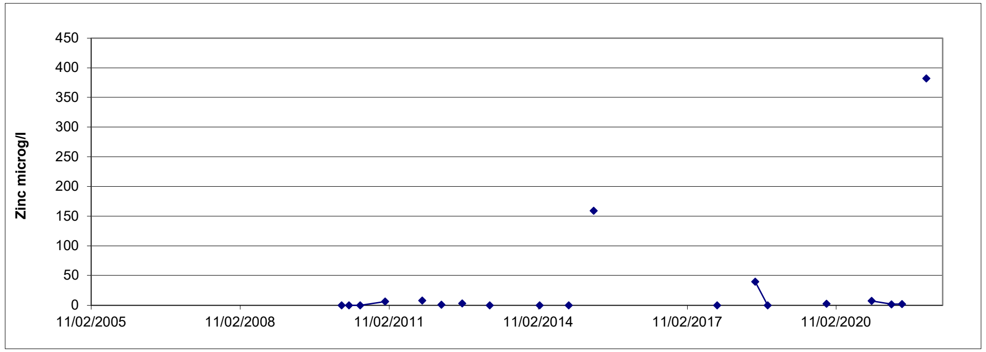

Chloride mg/l
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

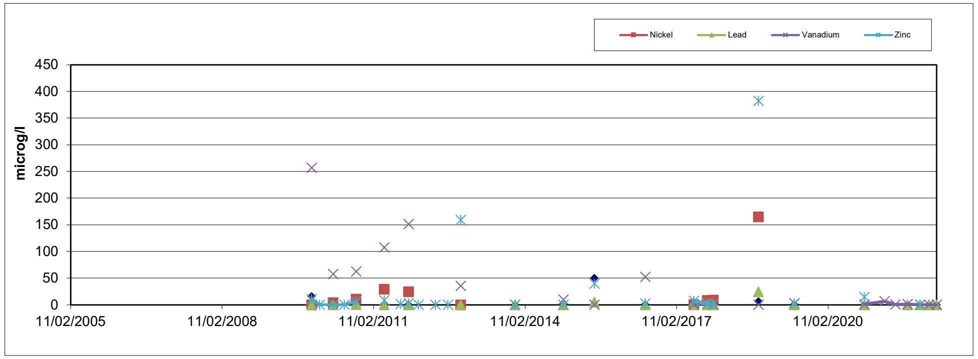

Calcium mg/l
100000
10000
1000
100
10
1
01/02/2005
01/02/2008
01/02/2011
01/02/2014
01/02/2017
01/02/2020

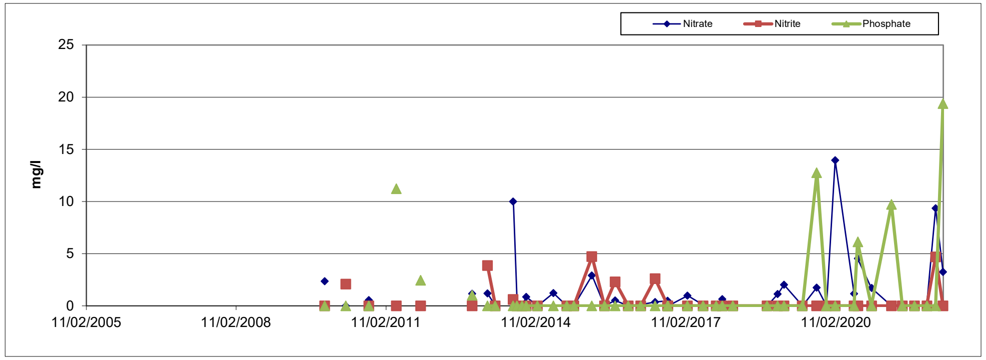

Ammonia mg/l
12
10
8
6
4
2
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

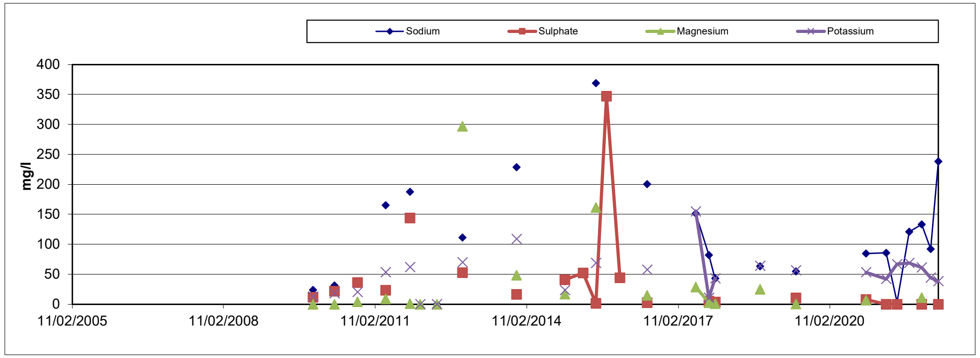

Arsenic microg/l
1000
900
800
700
600
500
400
300
200
100
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023


Copper microg/l
0
10
20
30
40
50
60
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Zinc microg/l
0
50
100
150
200
250
300
350
400
450
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Nickel
Lead
Vanadium
Zinc
microg/l
0
50
100
150
200
250
300
350
400
450
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Nitrate
Nitrite
Phosphate
mg/l
0
5
10
15
20
25
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020


Sodium
Sulphate
Magnesium
Potassium
mg/l
0
50
100
150
200
250
300
350
400
11/02/2005
11/02/2008
11/02/2011
11/02/2014
11/02/2017
11/02/2020

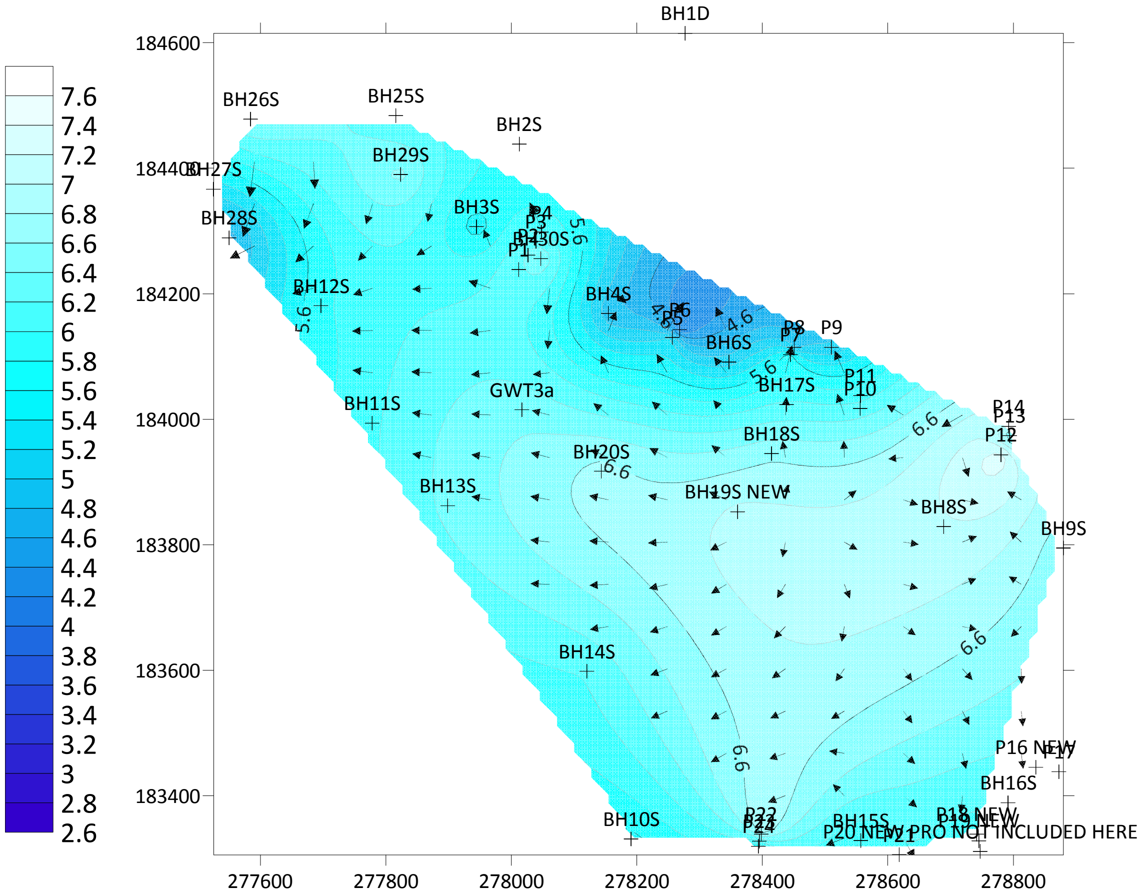
MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

ENVIRONMENTAL PERMIT BV7311IE

Review of Hydrogeological Risk Assessment

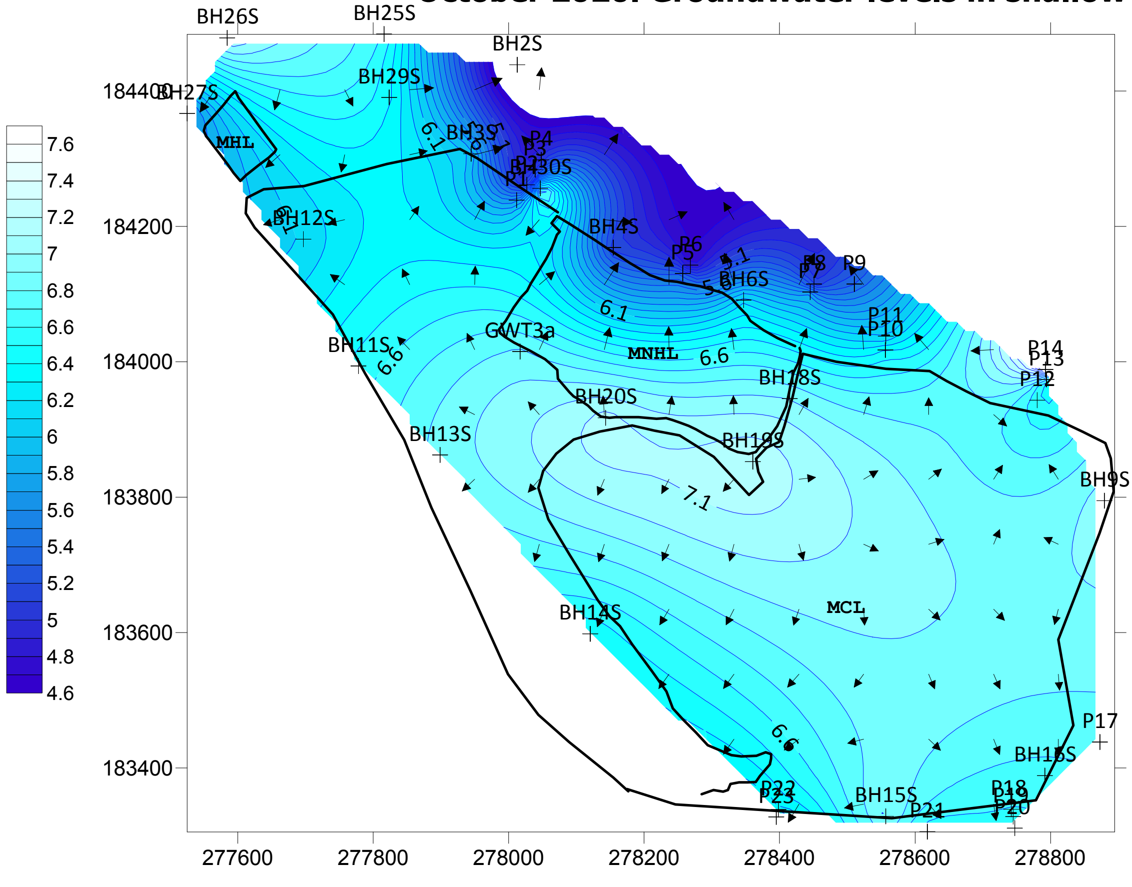
Appendix 4 Groundwater Levels

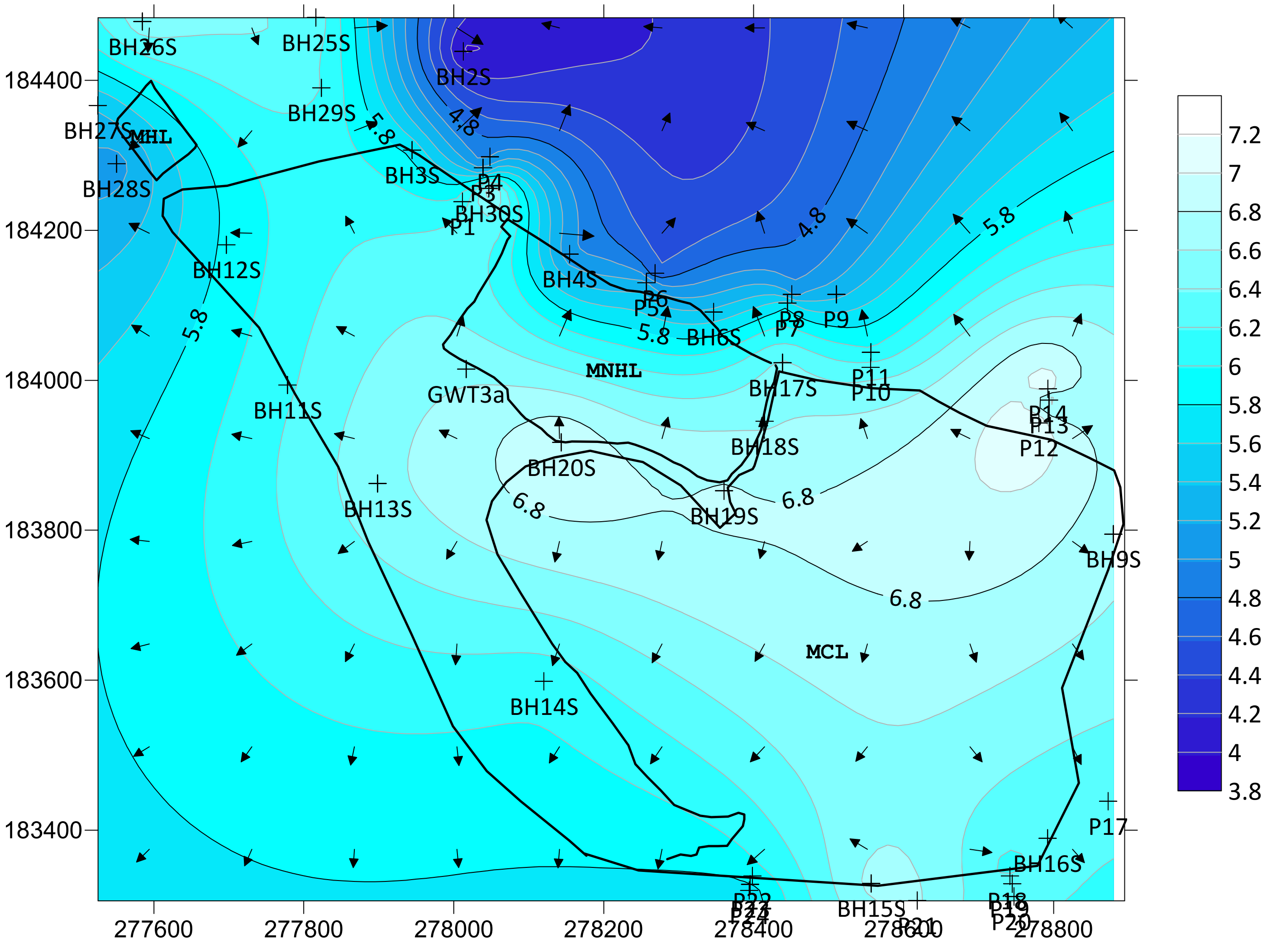
Report Number 2238r1v1d0622



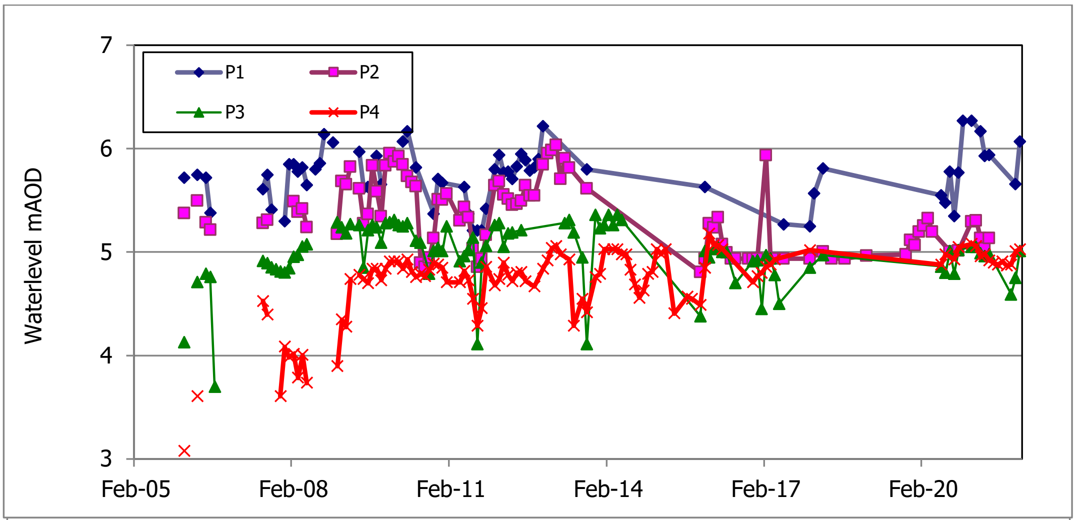
Shallow Groundwater Contours, June 2019

October 2020. Groundwater levels in shallow aquifer

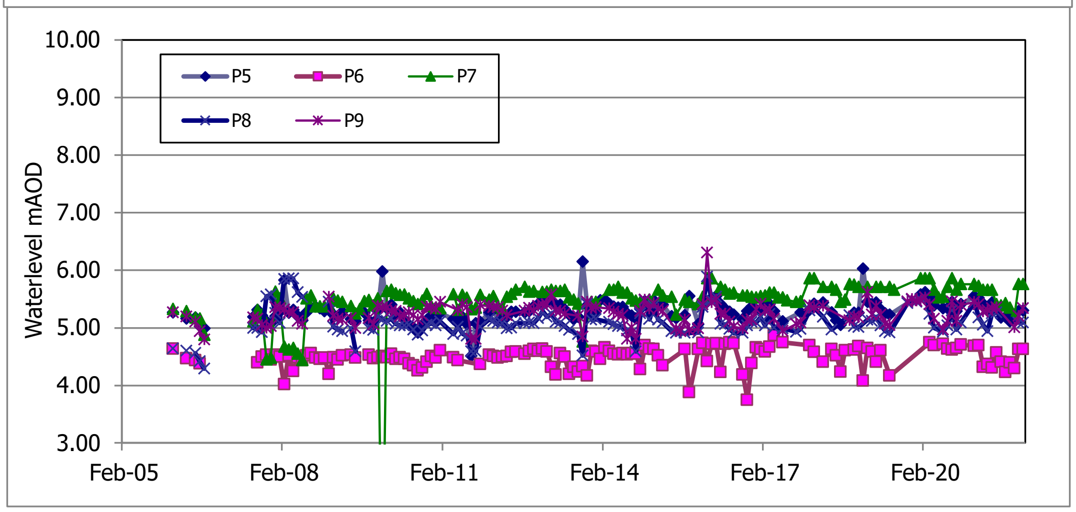




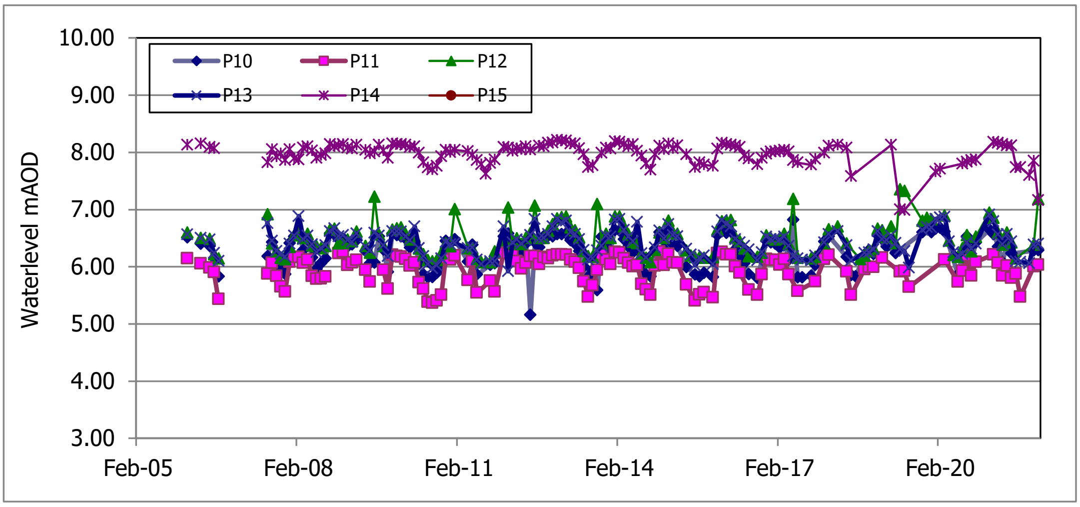
December 2021. Groundwater levels in shallow aquifer



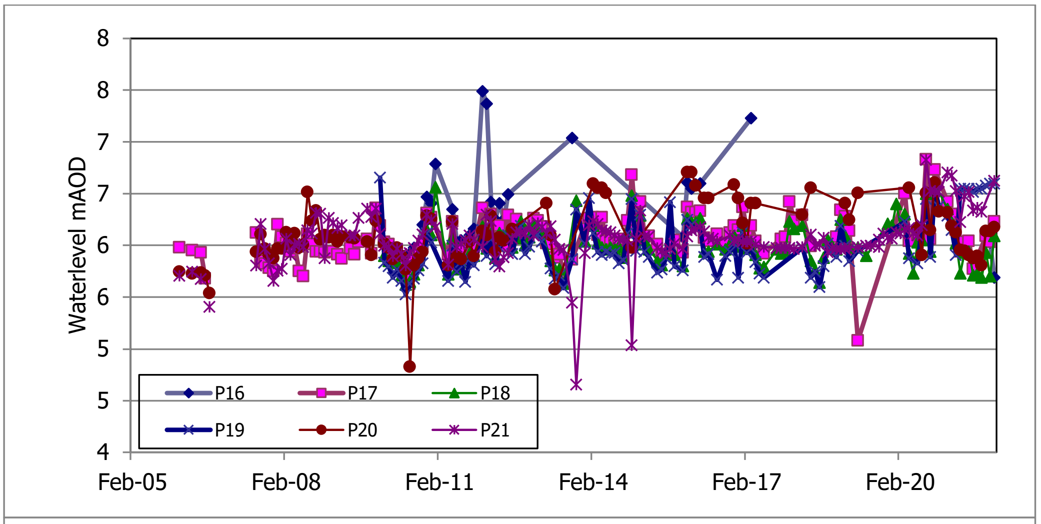
Waterlevel mAOD
7
6
5
4
3
P1
P2
P3
P4
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

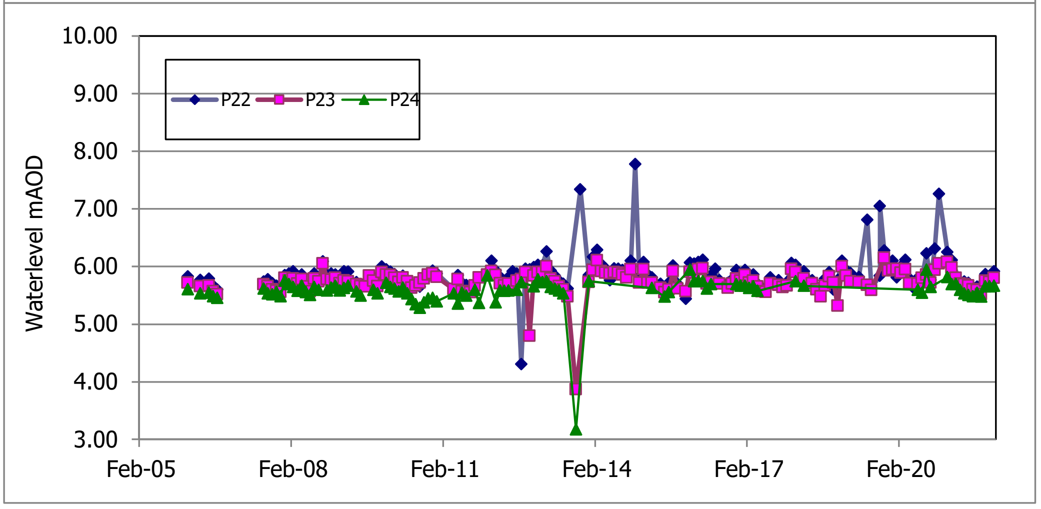


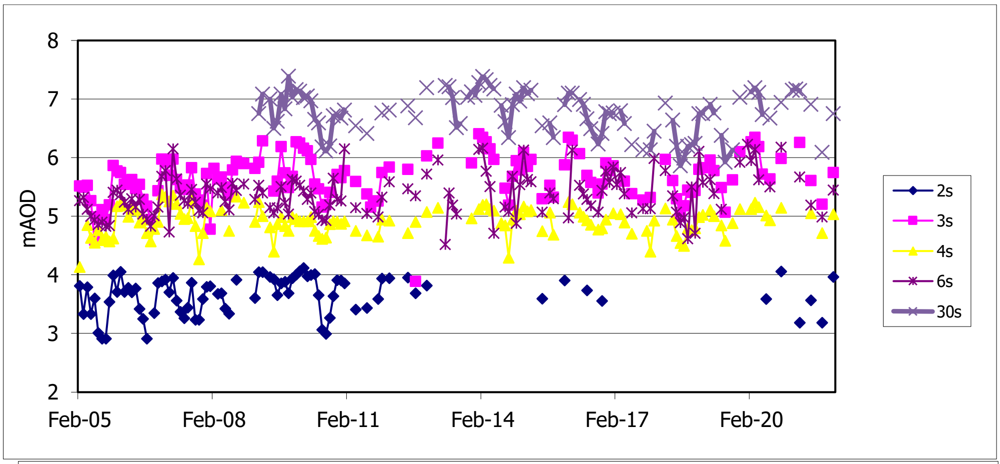
Waterlevel mAOD
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
P5
P6
P7
P8
P9
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

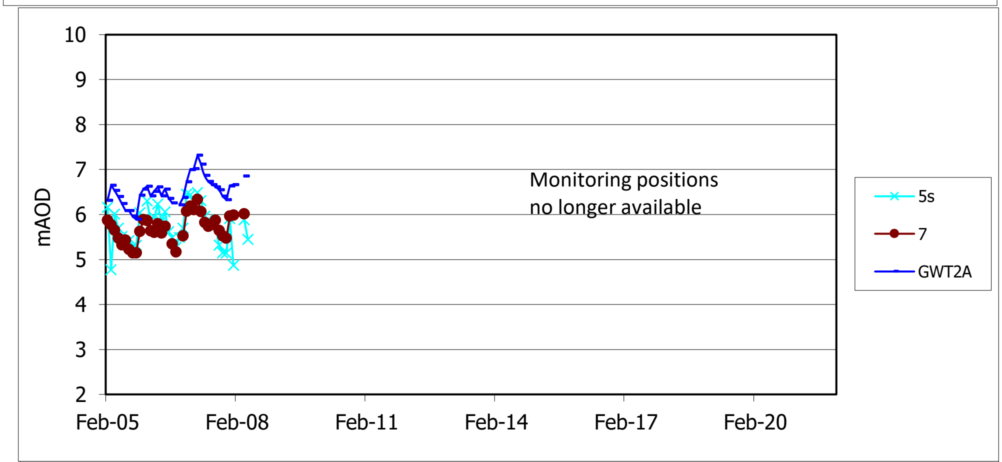


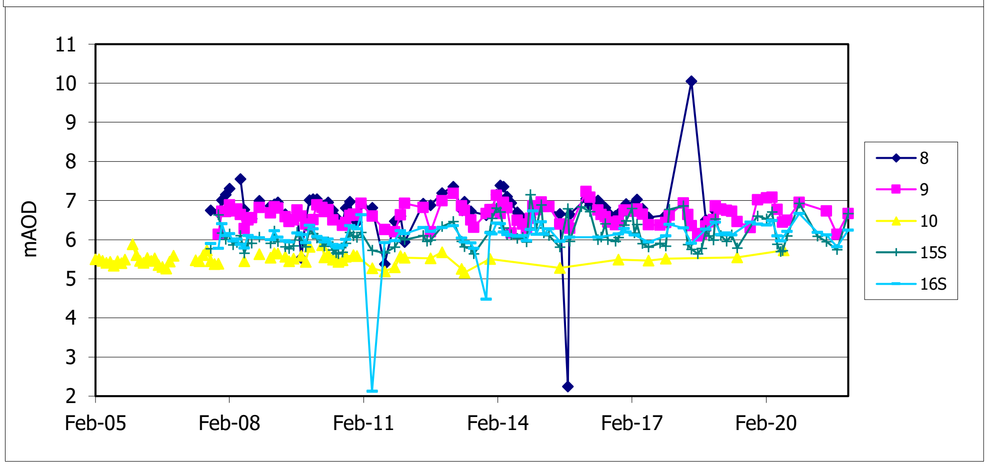
Waterlevel mAOD
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
P10
P11
P12
P13
P14
P15
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

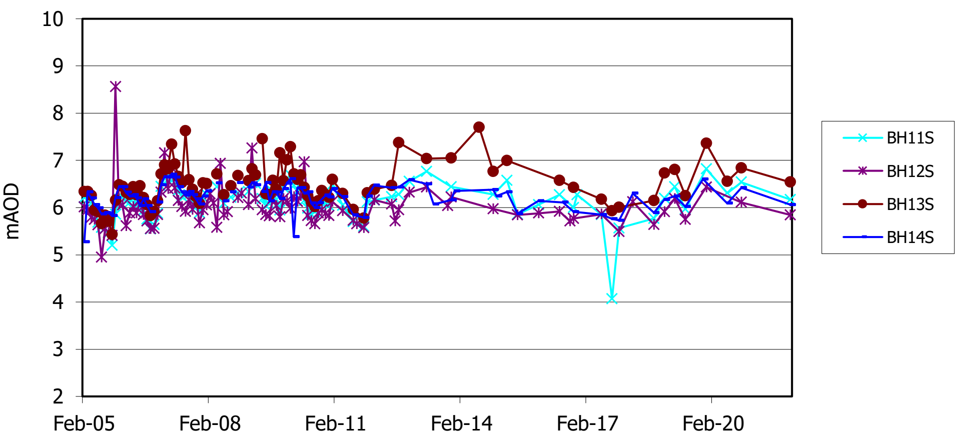

8
8
7
7
6
6
5
5
4
Waterlevel mAOD
P16
P17
P18
P19
P20
P21
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

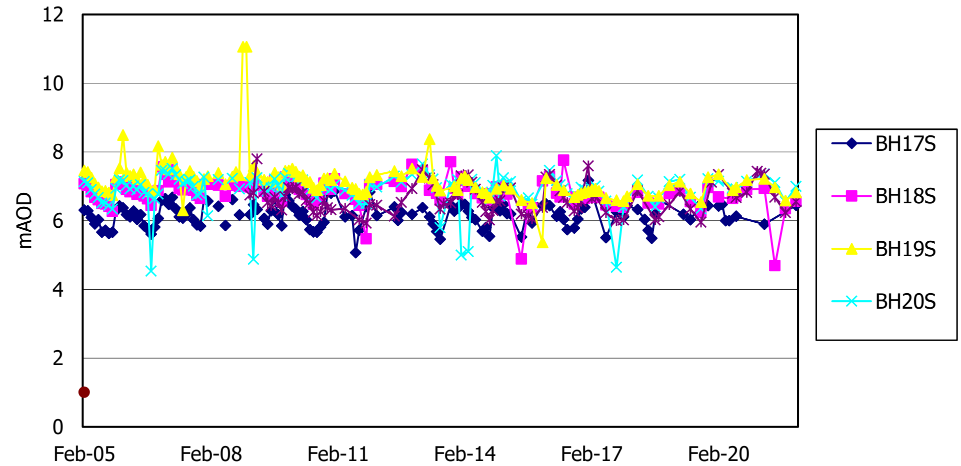

10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
Waterlevel mAOD
P22
P23
P24
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

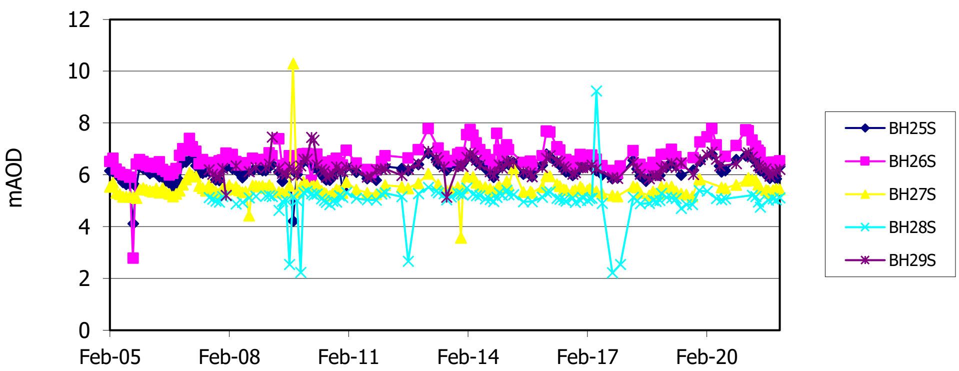

8
7
6
5
4
3
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
2s
3s
4s
6s
30s

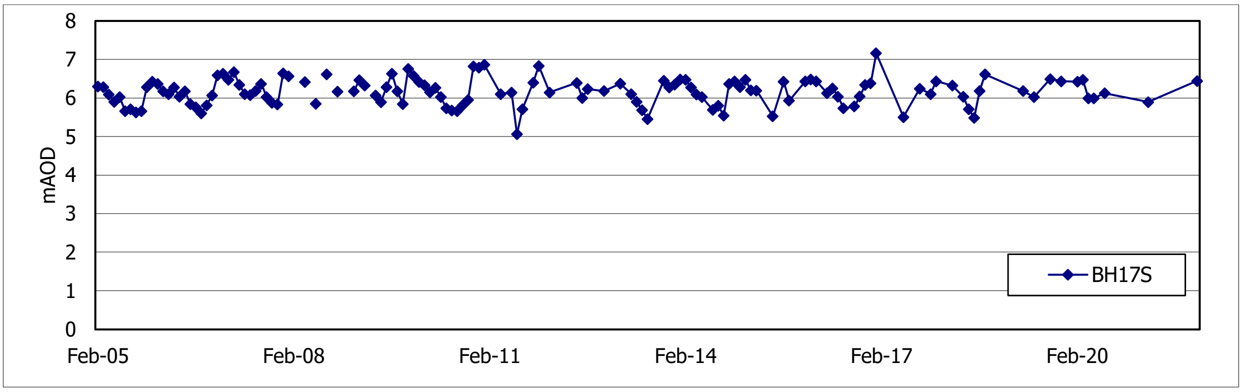

10
9
8
7
6
5
4
3
2
mAOD
Monitoring positions
no longer available
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
5s
7
GWT2A

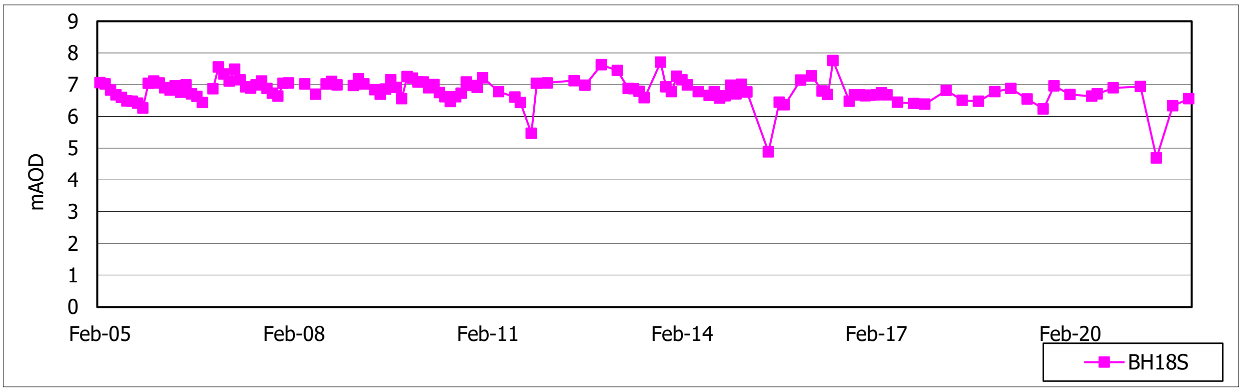

11
10
9
8
7
6
5
4
3
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
8
9
10
15S
16S

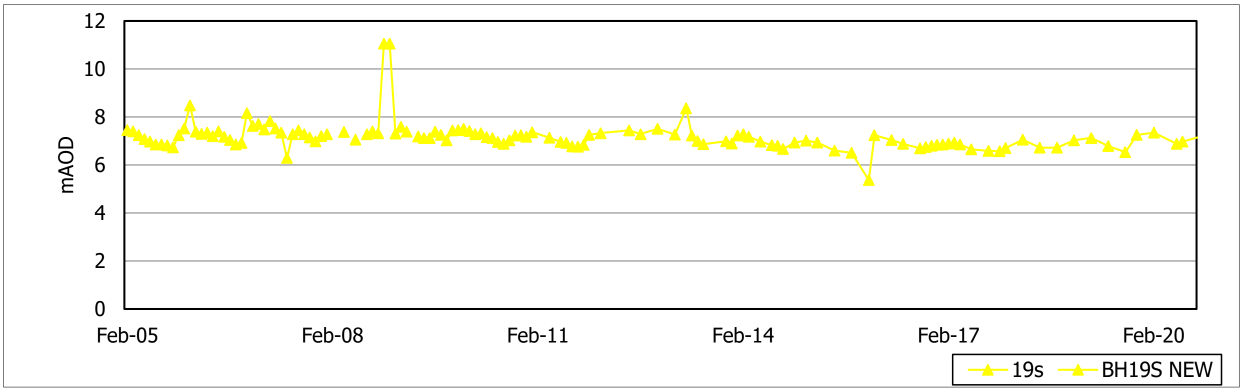

10
9
8
7
6
5
4
3
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH11S
BH12S
BH13S
BH14S

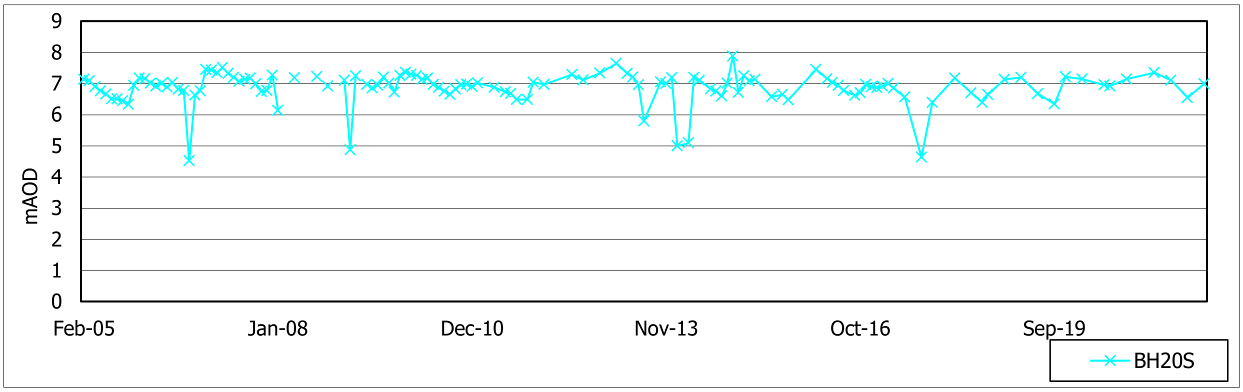

12
10
8
6
4
2
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH17S
BH18S
BH19S
BH20S

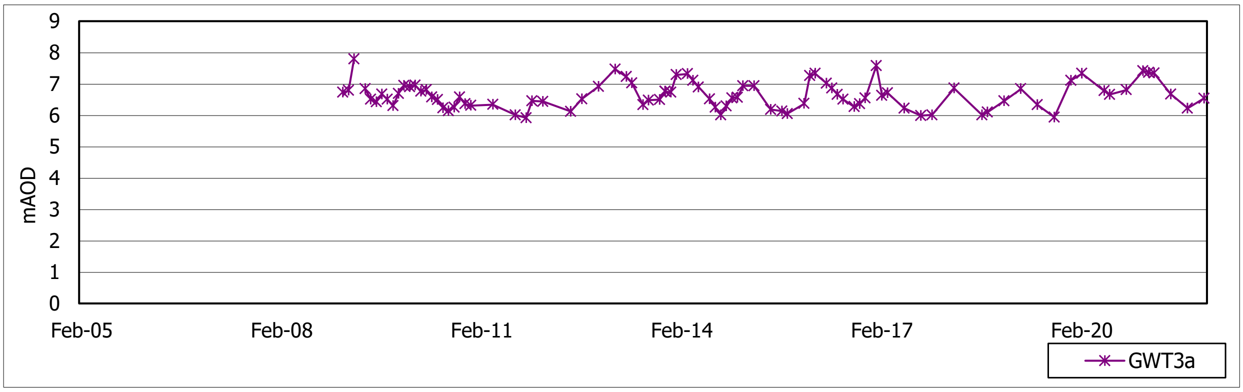

12
10
8
6
4
2
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH25S
BH26S
BH27S
BH28S
BH29S

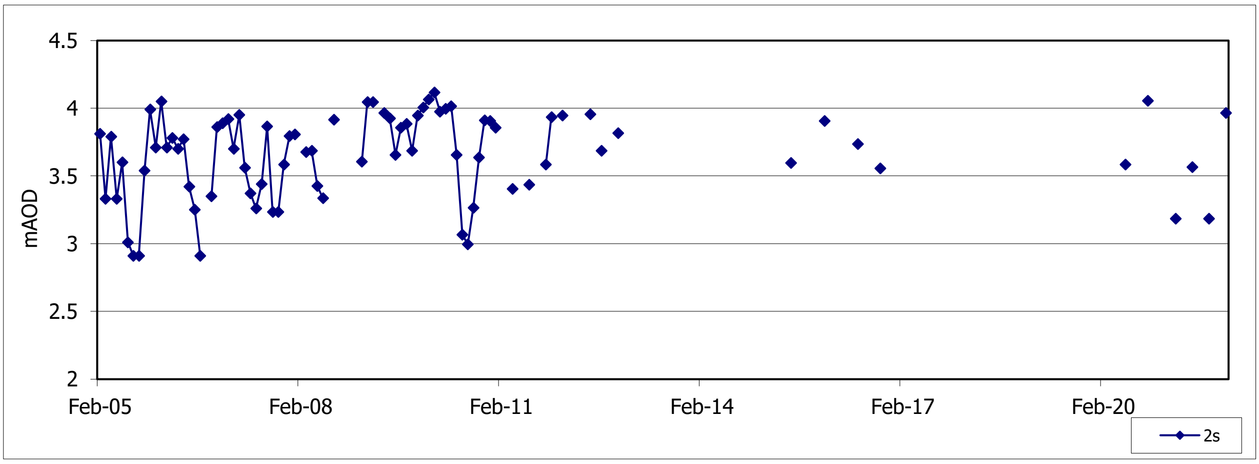

8
7
6
5
4
3
2
1
0
mAOD
BH17S
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20

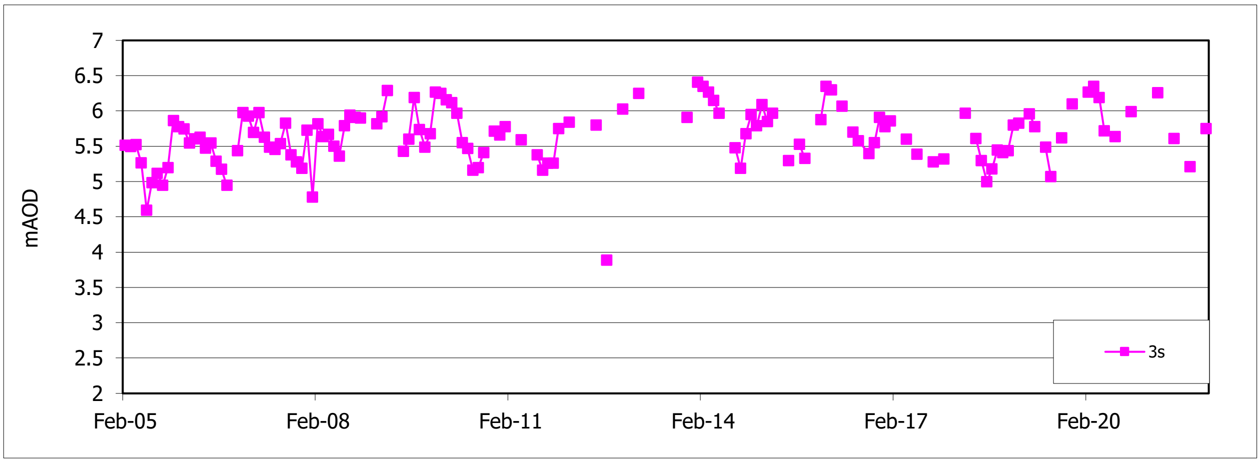

9
8
7
6
5
4
3
2
1
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
BH18S

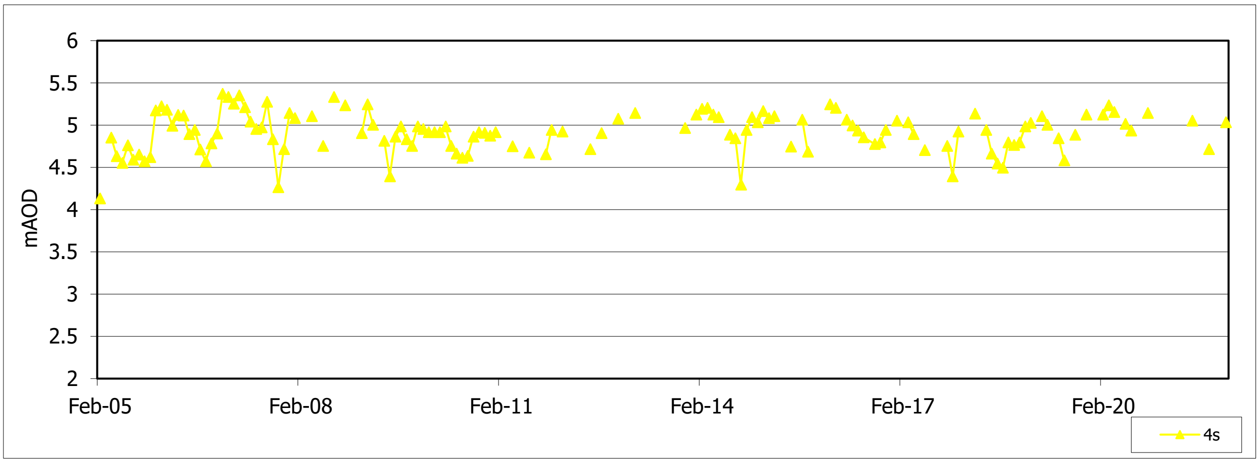

12
10
8
6
4
2
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
19s
BH19S NEW

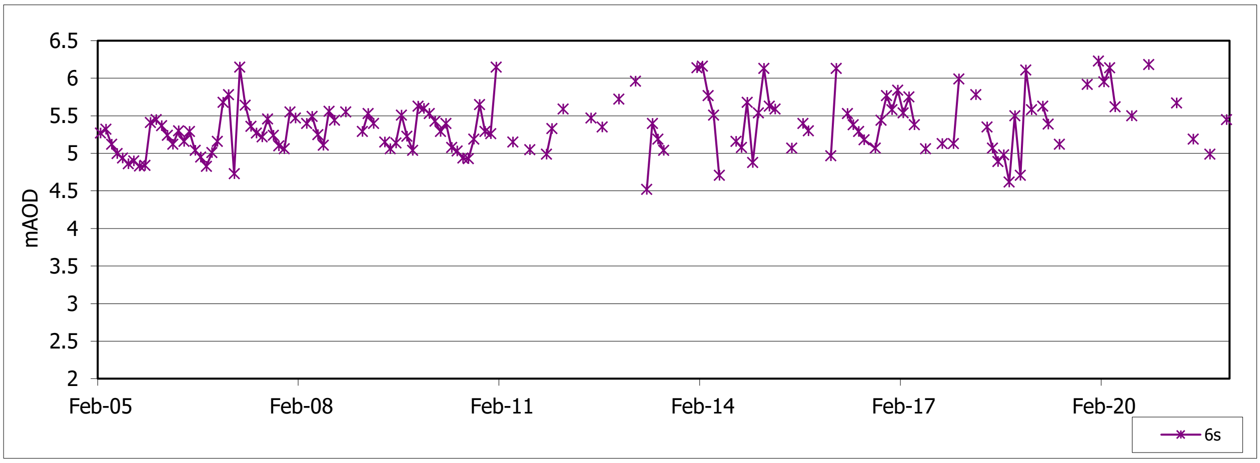

9
8
7
6
5
4
3
2
1
0
mAOD
Feb-05
Jan-08
Dec-10
Nov-13
Oct-16
Sep-19
BH20S

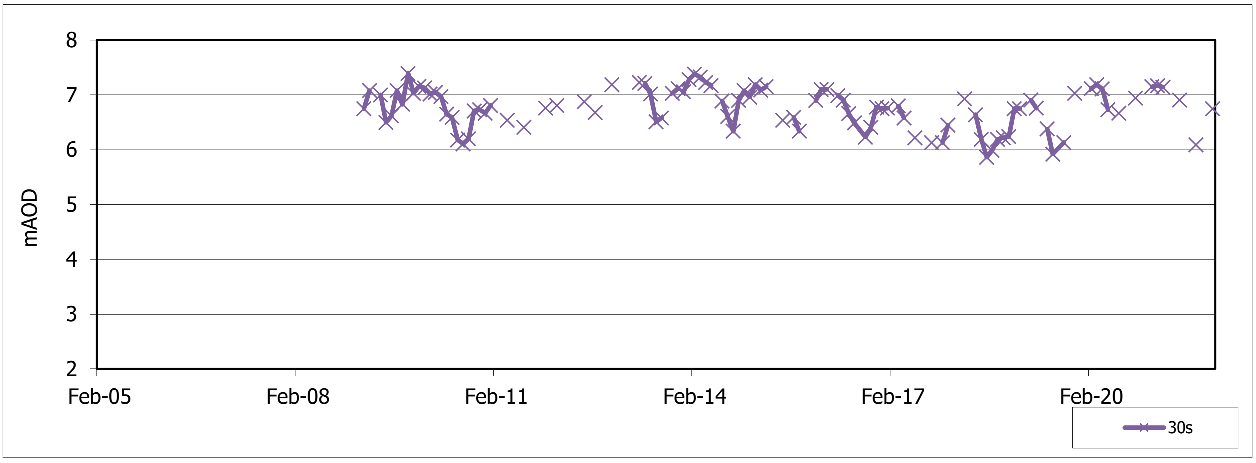

9
8
7
6
5
4
3
2
1
0
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
GWT3a

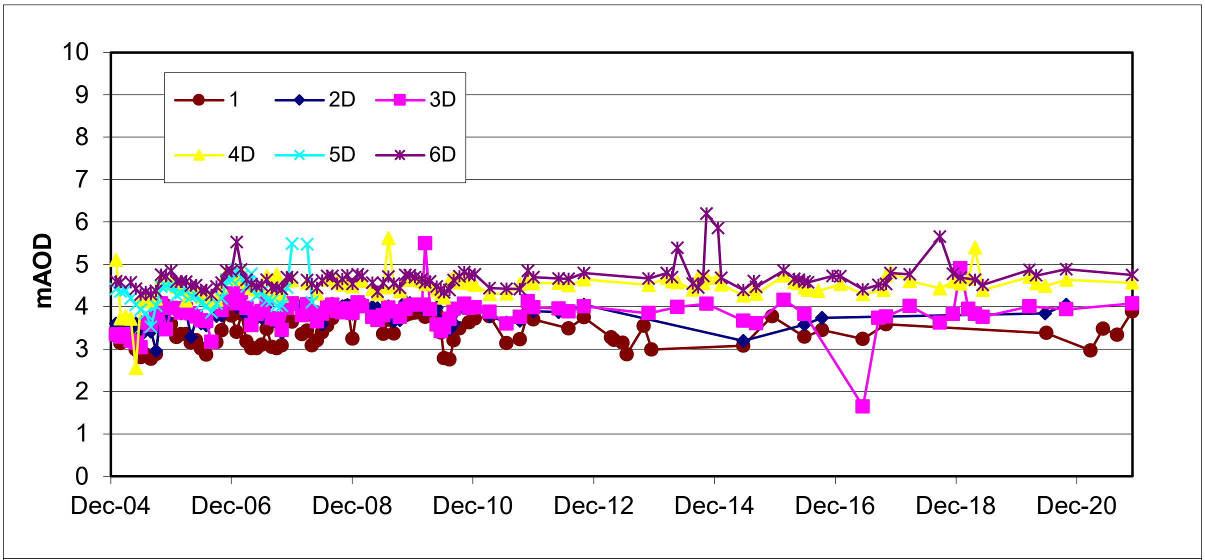

4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
2s

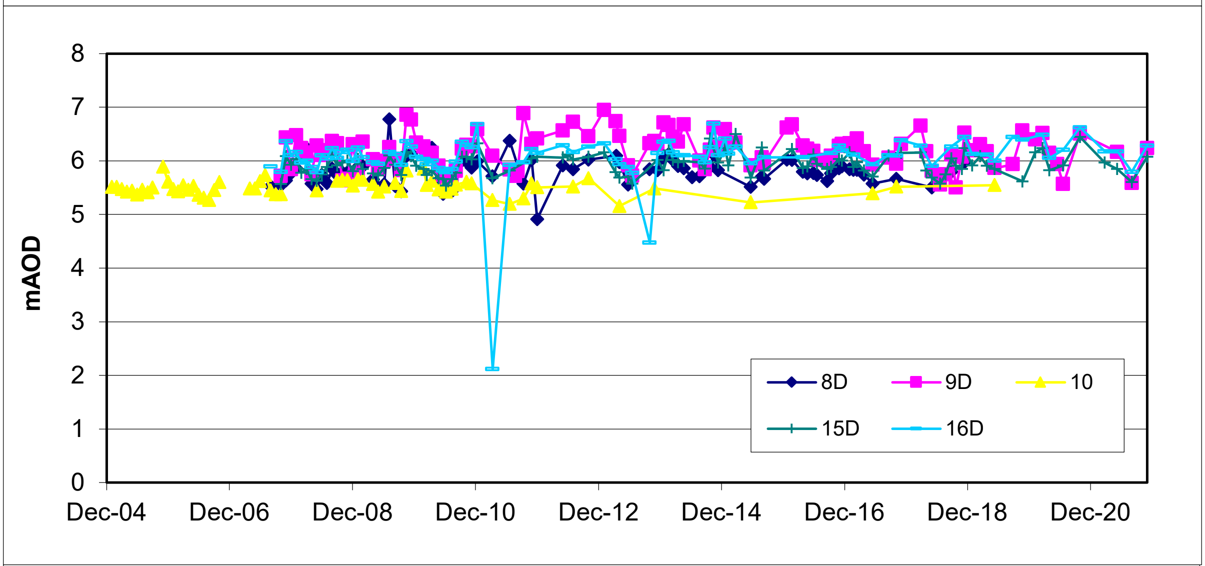

7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
3s

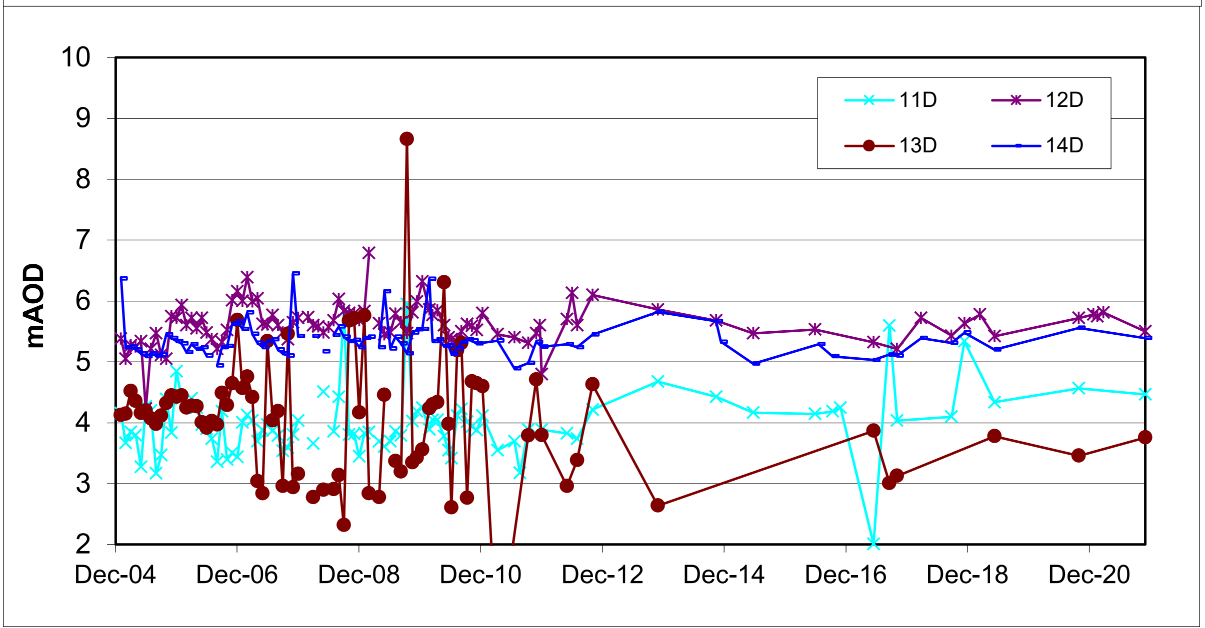

6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
4s

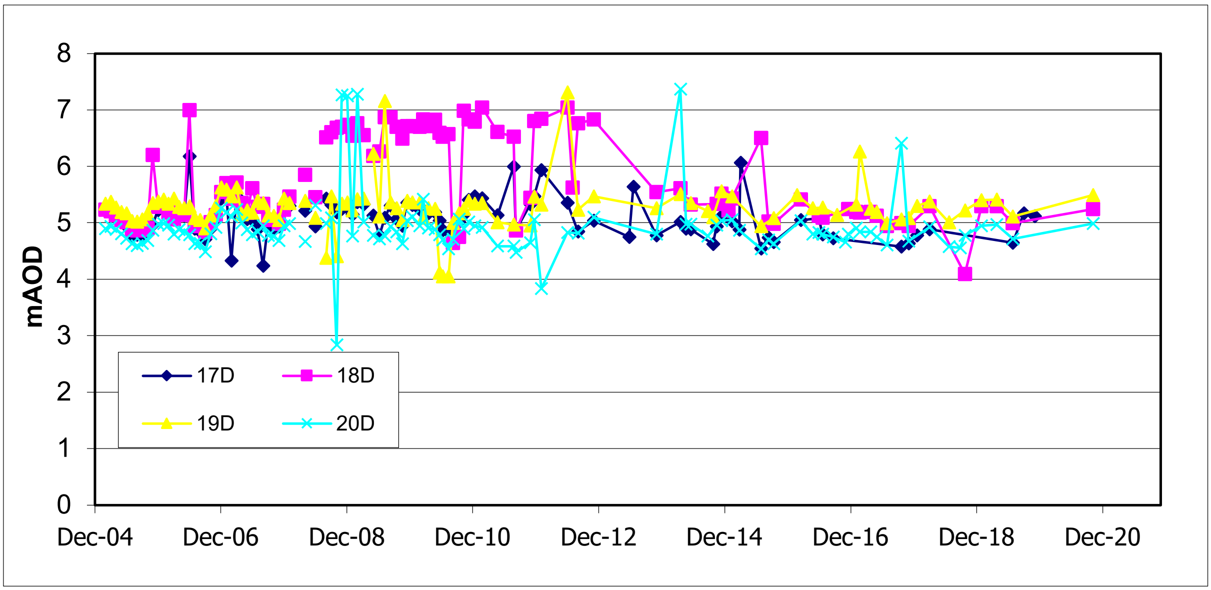

6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
6s

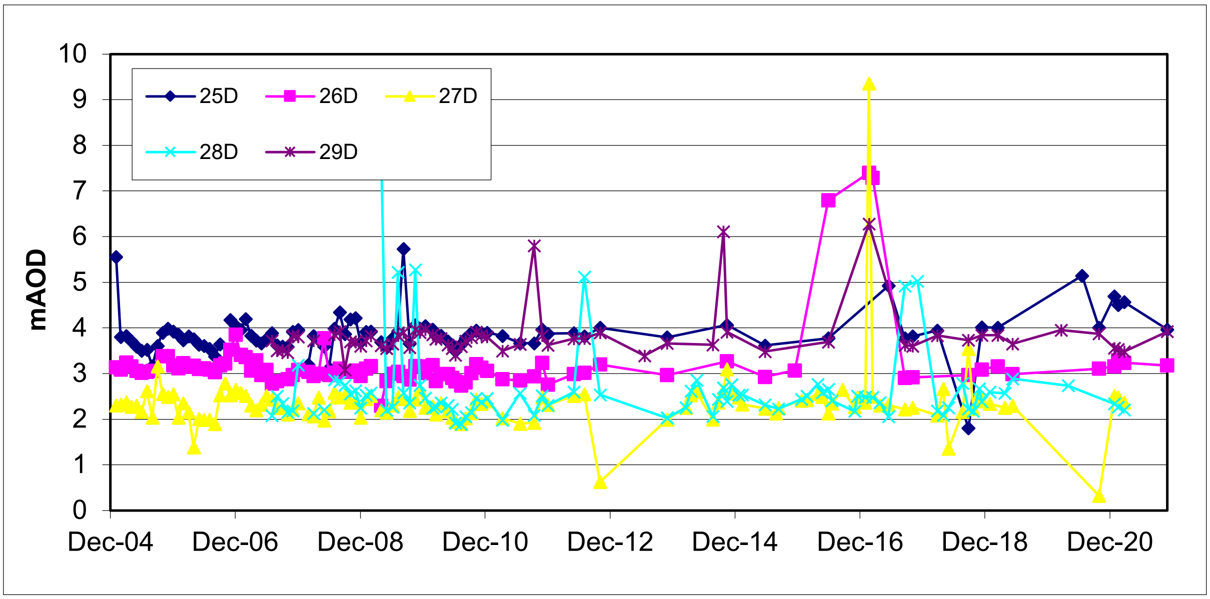

8
7
6
5
4
3
2
mAOD
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20
30s


mAOD
1
2D
3D
4D
5D
6D
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Dec-16
Dec-18
Dec-20


mAOD
8D
9D
10
15D
16D
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Dec-16
Dec-18
Dec-20


mAOD
11D
12D
13D
14D
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Dec-16
Dec-18
Dec-20


mAOD
0
1
2
3
4
5
6
7
8
17D
18D
19D
20D
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Dec-16
Dec-18
Dec-20


mAOD
0
1
2
3
4
5
6
7
8
9
10
25D
26D
27D
28D
29D
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Dec-16
Dec-18
Dec-20

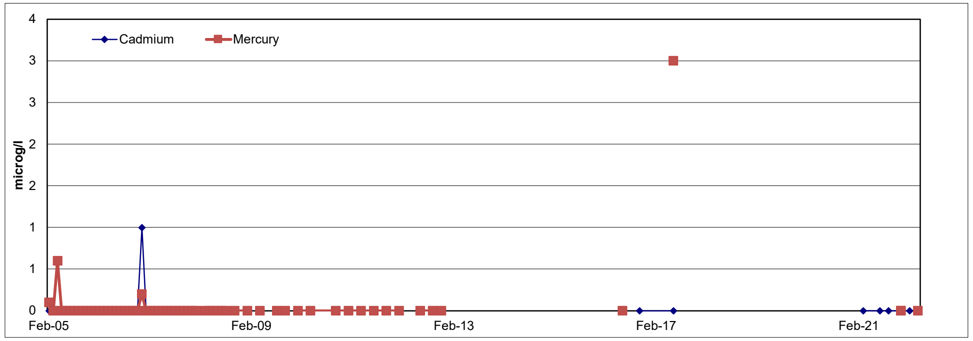
MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

ENVIRONMENTAL PERMIT BV7311IE

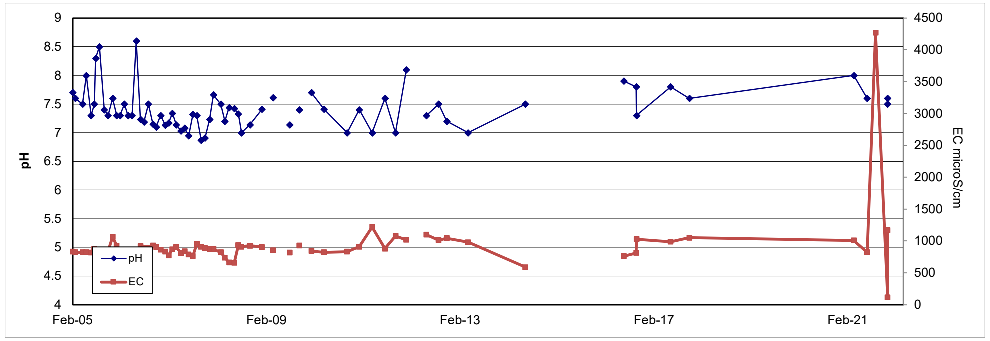
Review of Hydrogeological Risk Assessment

Appendix 5 Groundwater Chemistry

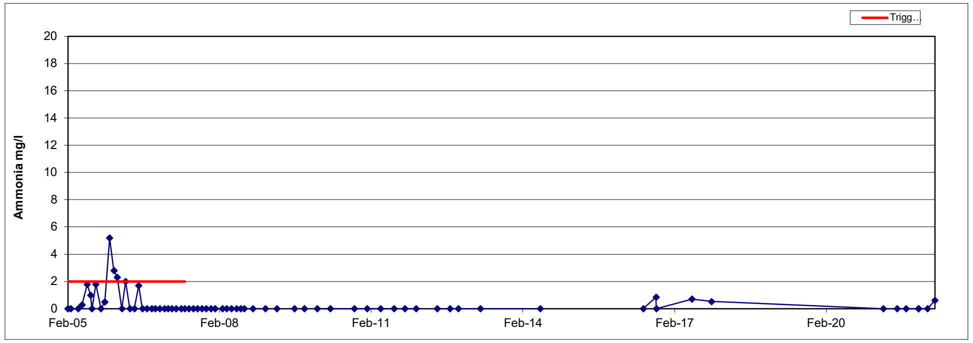
Report Number 2238r1v1d0622



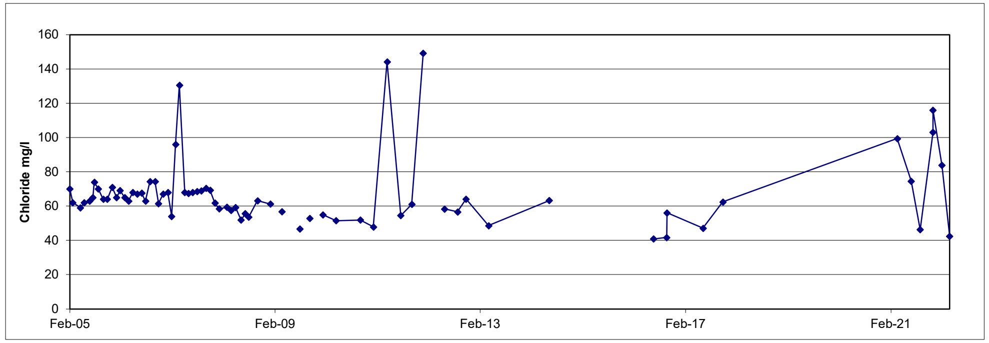
Cadmium
Mercury
microg/l
4
3
3
2
2
1
1
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



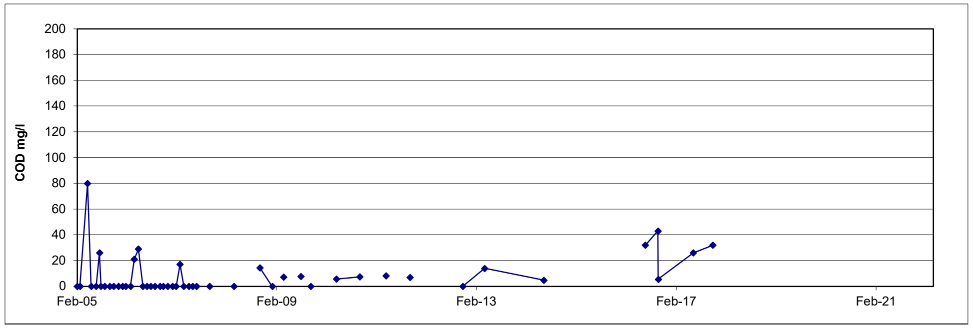
pH
EC microS/cm
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
4500
4000
3500
3000
2500
2000
1500
1000
500
0
pH
EC
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



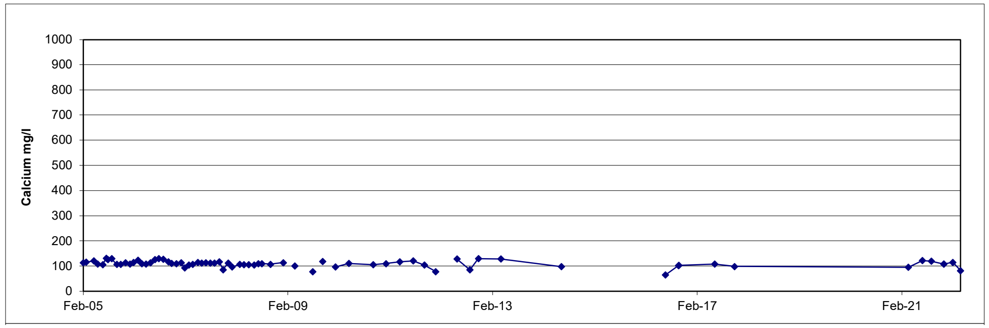
Trigg...
Ammonia mg/l
20
18
16
14
12
10
8
6
4
2
0
Feb-05
Feb-08
Feb-11
Feb-14
Feb-17
Feb-20



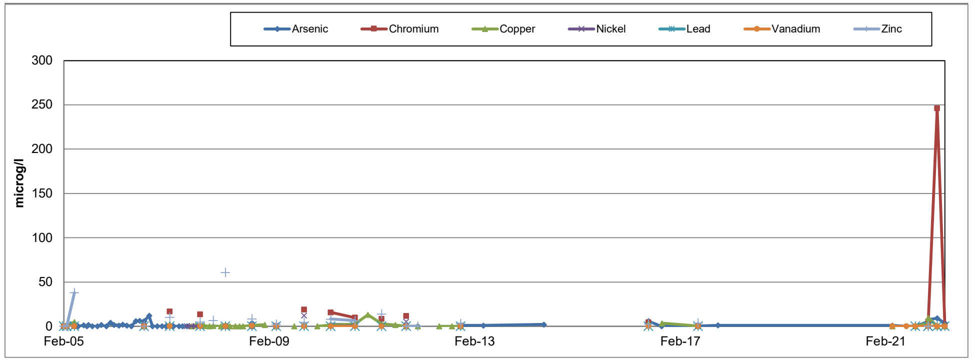
Chloride mg/l
160
140
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

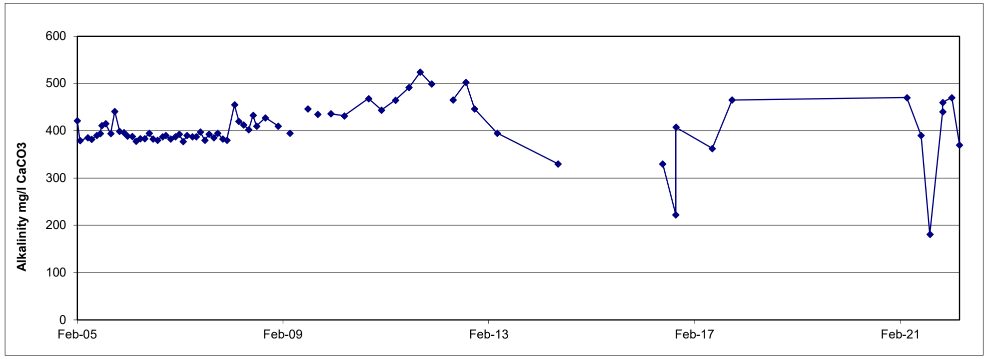


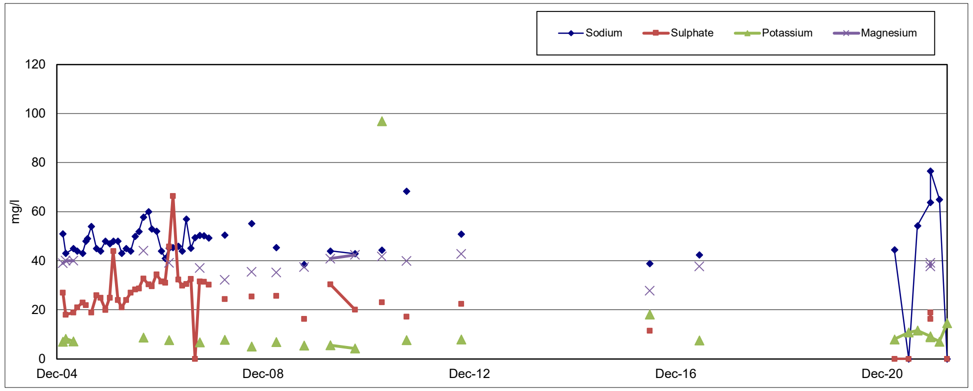
COD mg/l
200
180
160
140
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

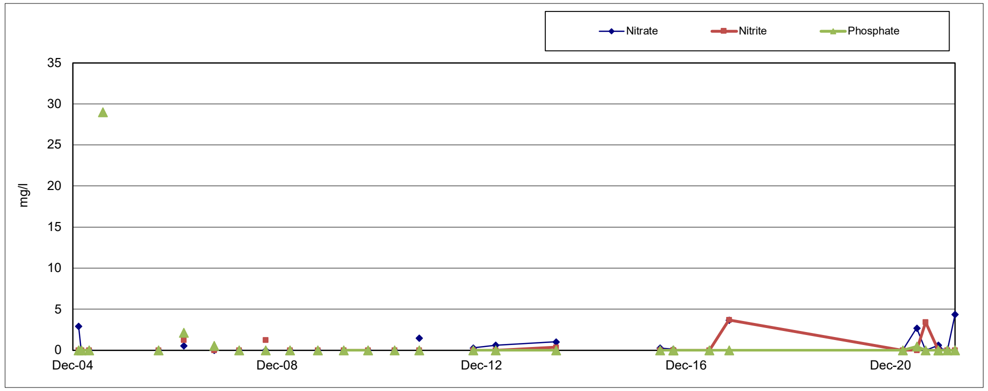


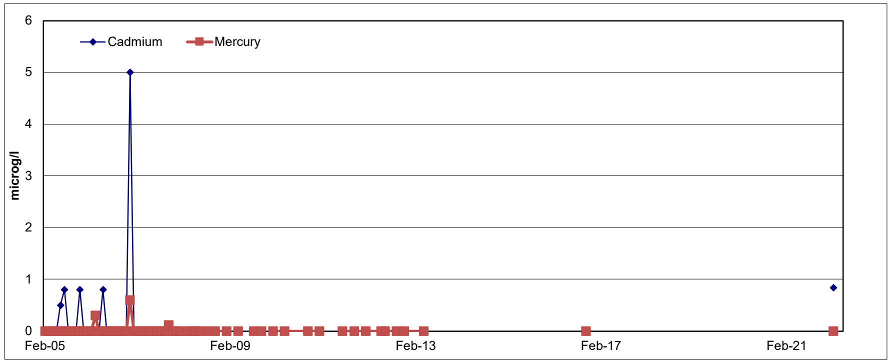
Calcium mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

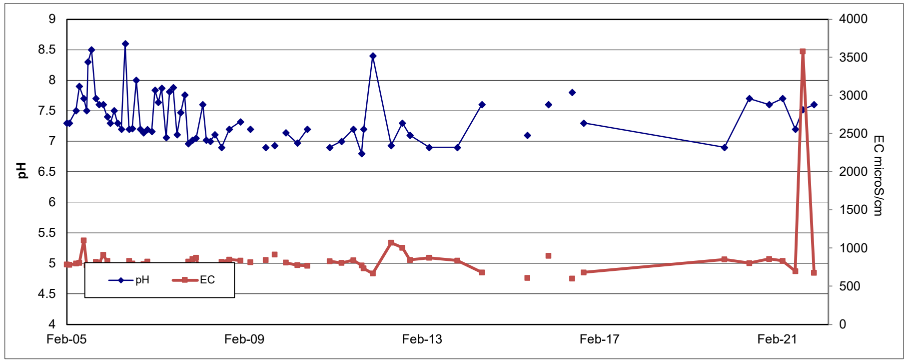

Arsenic
Chromium
Copper
Nickel
Lead
Vanadium
Zinc
microg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

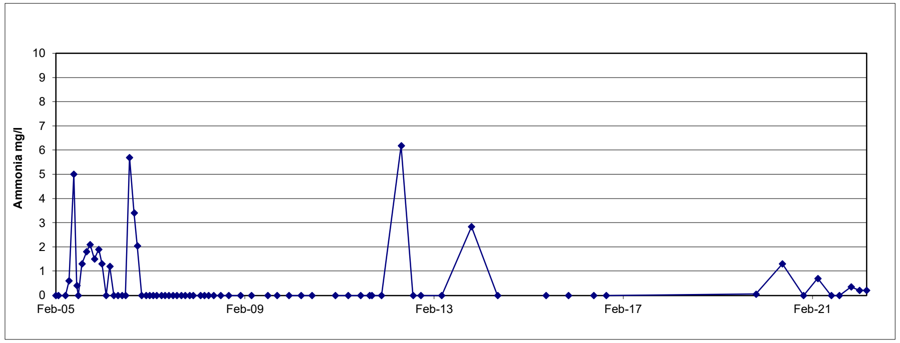

Alkalinity mg/l CaCO3
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

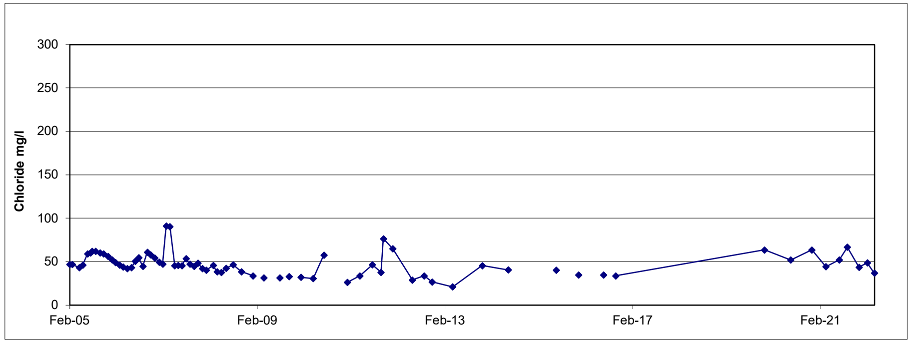

Sodium
Sulphate
Potassium
Magnesium
mg/l
120
100
80
60
40
20
0
Dec-04
Dec-08
Dec-12
Dec-16
Dec-20

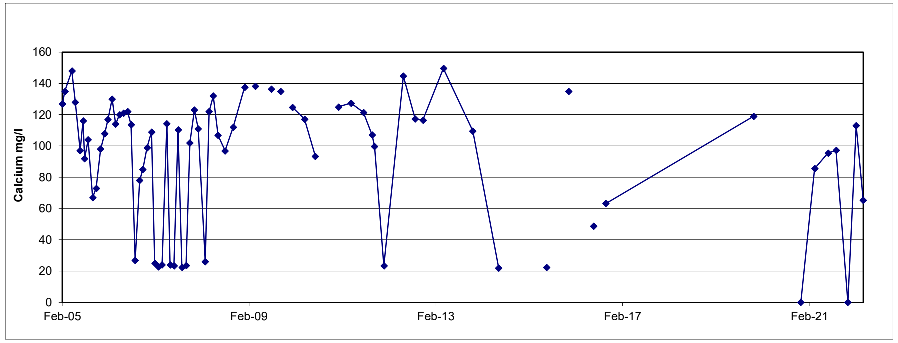

Nitrate
Nitrite
Phosphate
mg/l
35
30
25
20
15
10
5
0
Dec-04
Dec-08
Dec-12
Dec-16
Dec-20

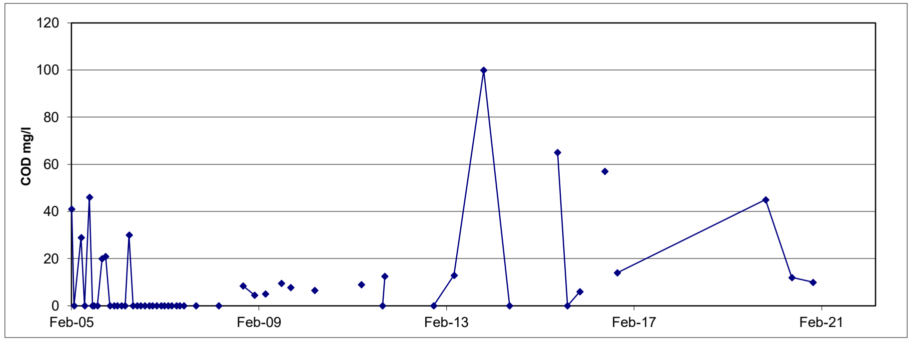

Cadmium
Mercury
microg/l
6
5
4
3
2
1
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

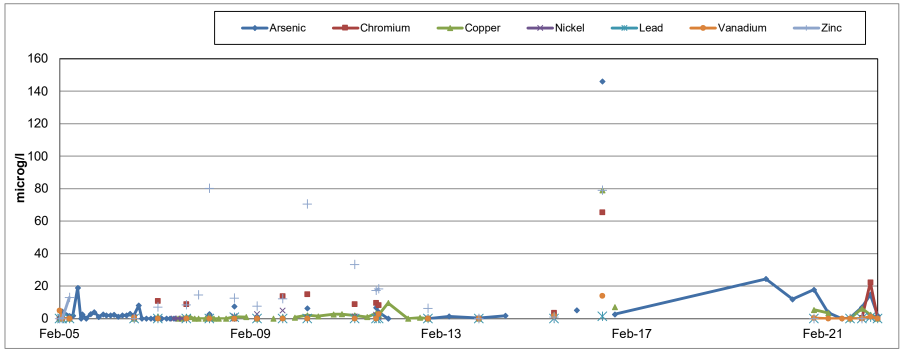

pH
EC
EC microS/cm
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
4000
3500
3000
2500
2000
1500
1000
500
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

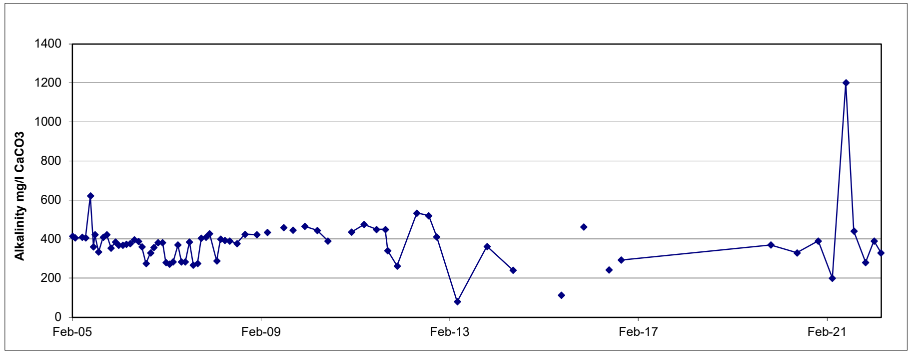

Ammonia mg/l
10
9
8
7
6
5
4
3
2
1
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

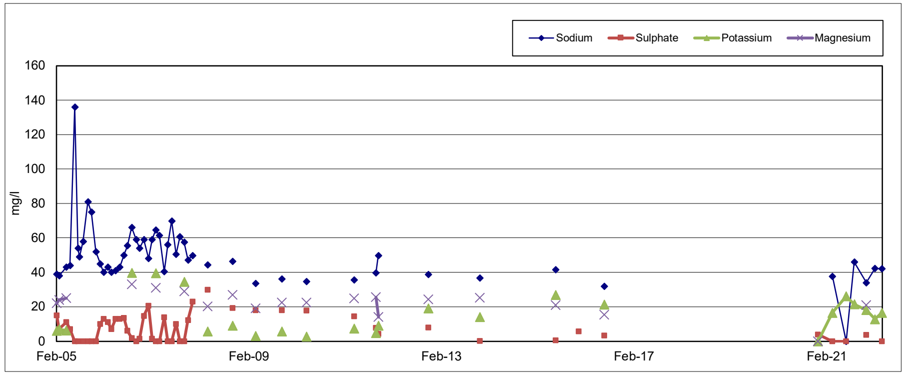

Chloride mg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

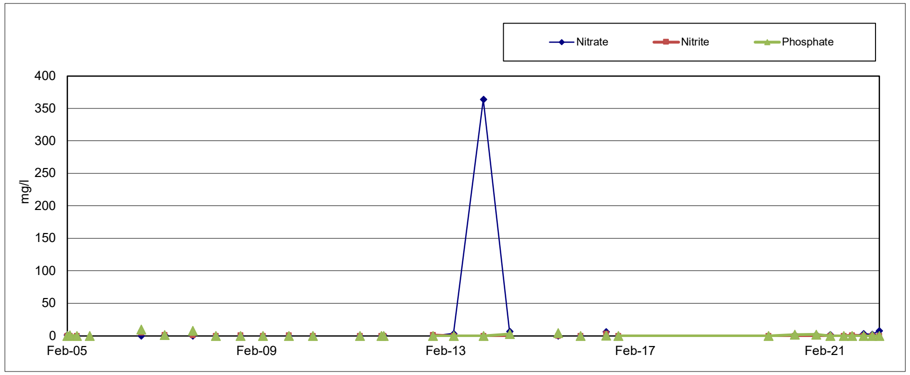

Calcium mg/l
160
140
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

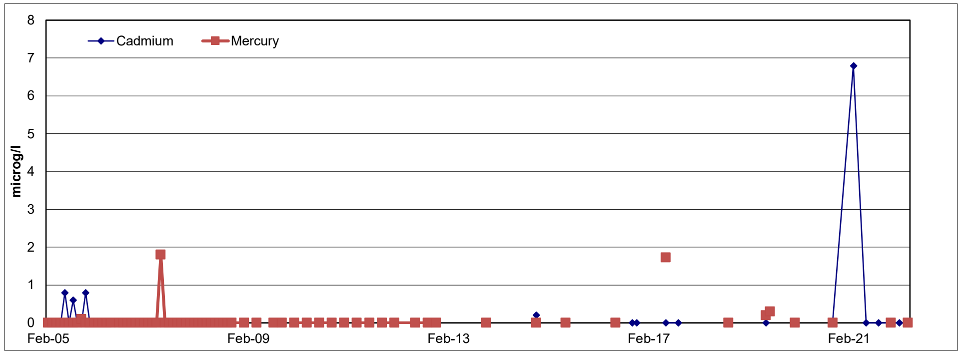

COD mg/l
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

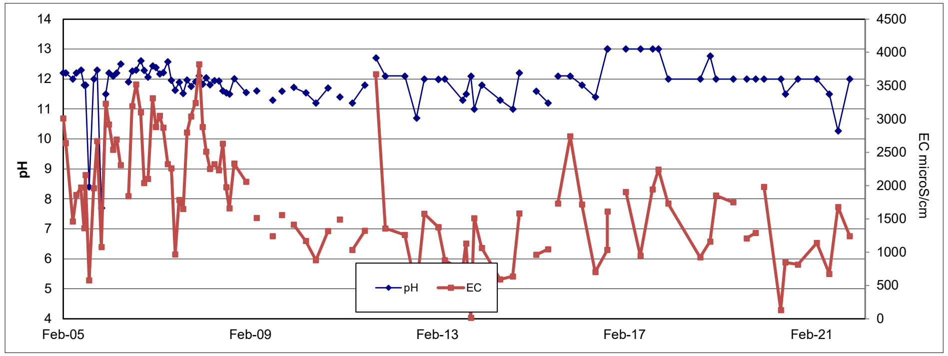

Arsenic
Chromium
Copper
Nickel
Lead
Vanadium
Zinc
microg/l
0
20
40
60
80
100
120
140
160
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

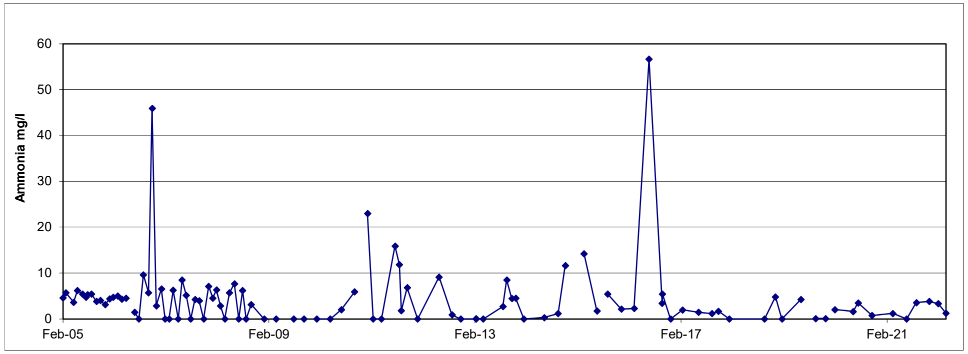

Alkalinity mg/l CaCO3
0
200
400
600
800
1000
1200
1400
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

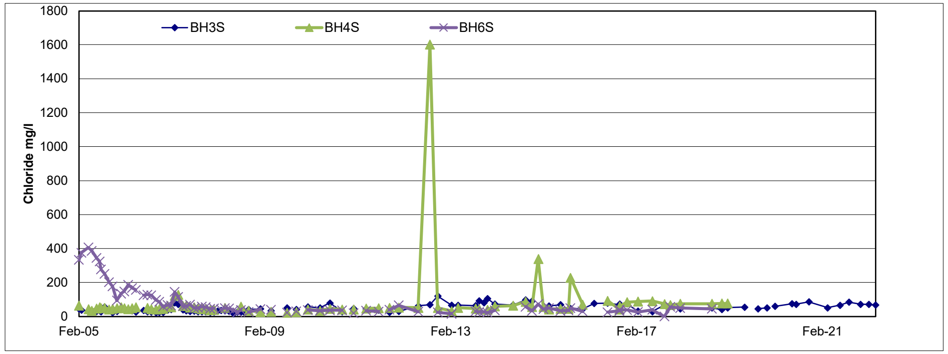

Sodium
Sulphate
Potassium
Magnesium
mg/l
0
20
40
60
80
100
120
140
160
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

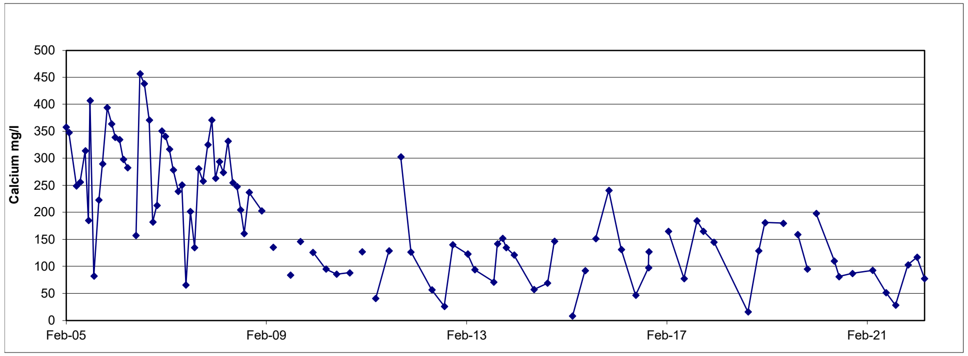

Nitrate
Nitrite
Phosphate
mg/l
0
50
100
150
200
250
300
350
400
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

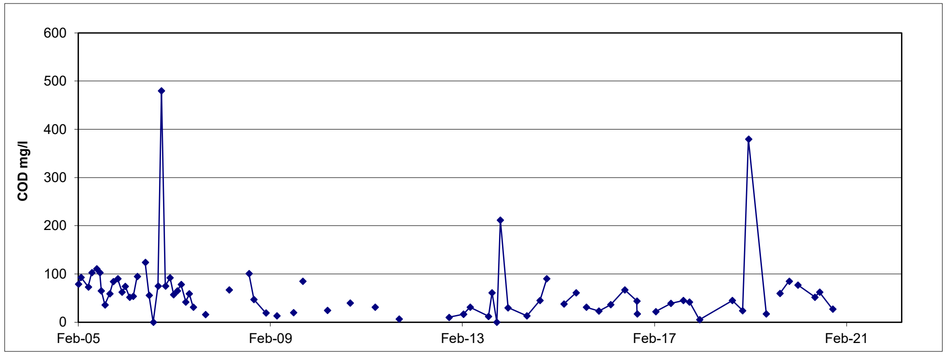

Cadmium
Mercury
microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

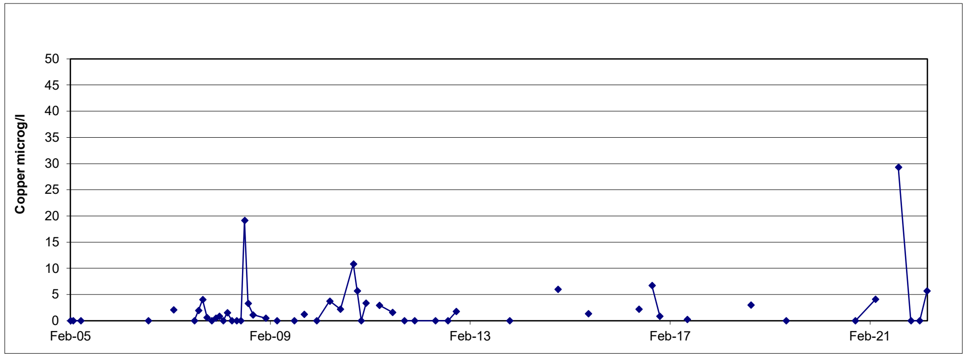

pH
EC
EC microS/cm
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

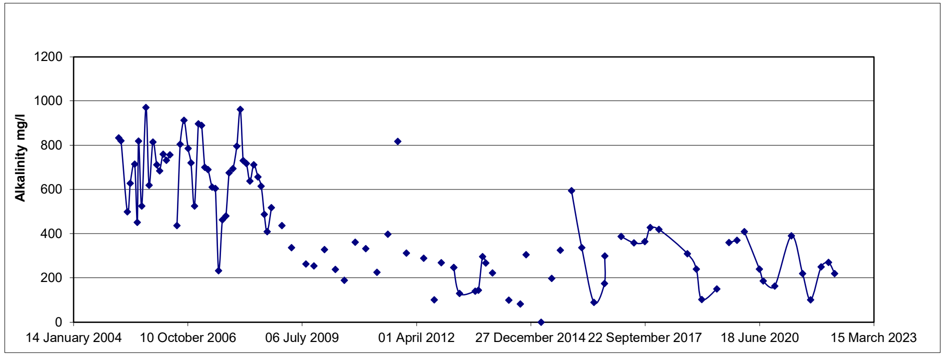

Ammonia mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

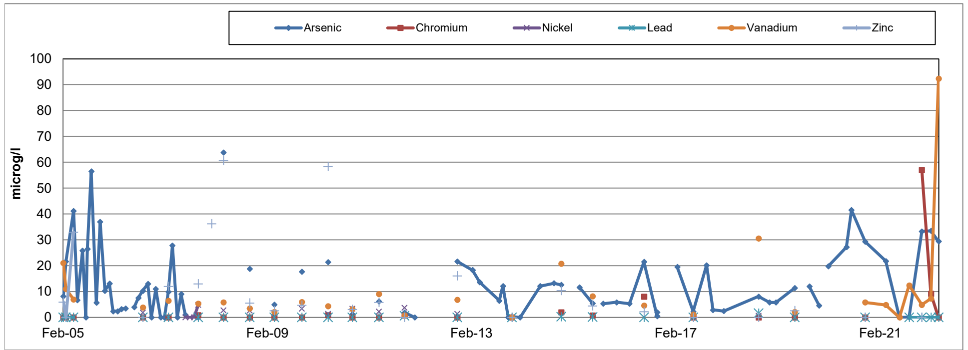

BH3S
BH4S
BH6S
Chloride mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

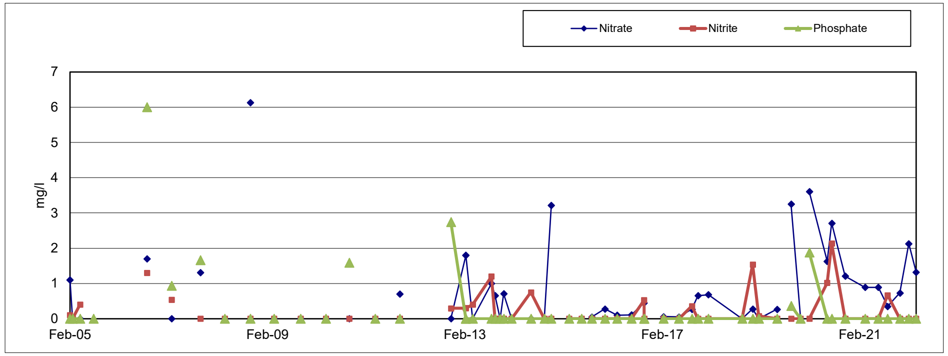

Calcium mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

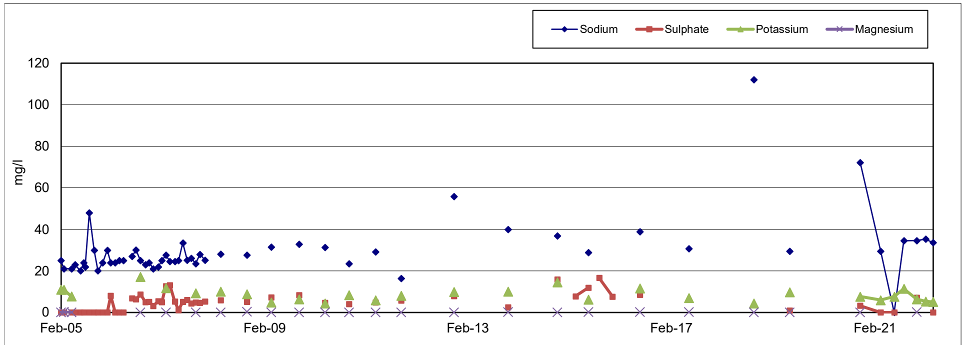

COD mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

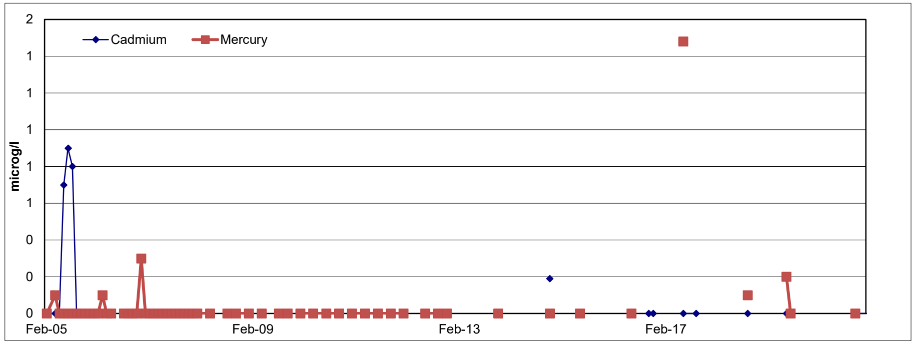

Copper microg/l
50
45
40
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

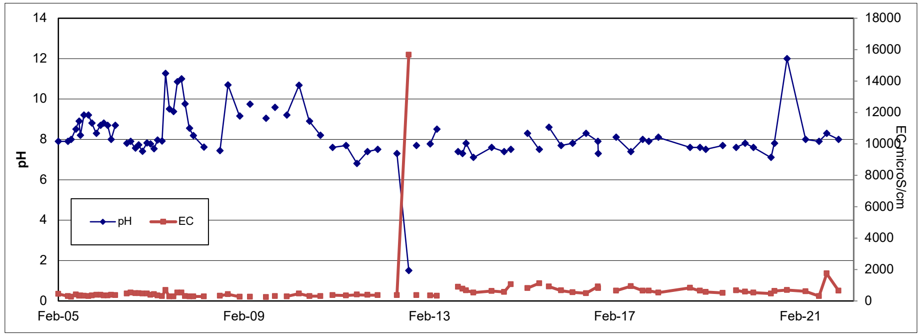

Alkalinity mg/l
1200
1000
800
600
400
200
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

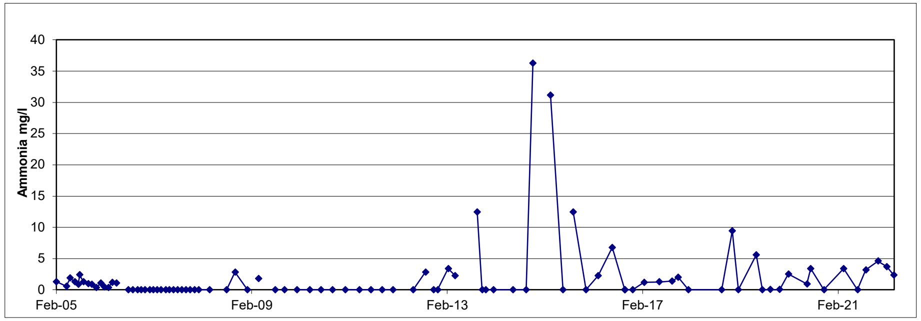

Arsenic
Chromium
Nickel
Lead
Vanadium
Zinc
microg/l
100
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

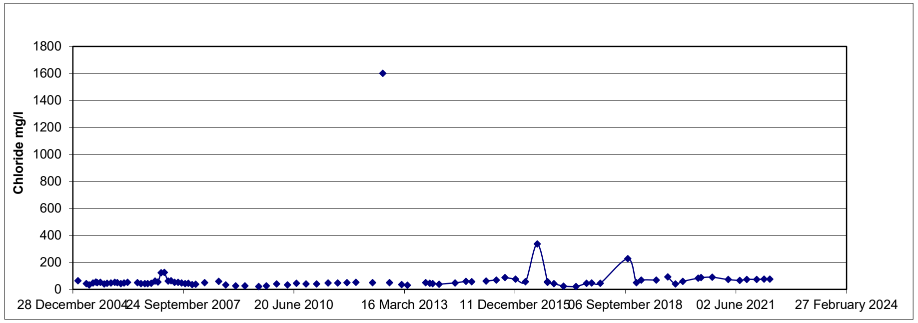

Nitrate
Nitrite
Phosphate
mg/l
7
6
5
4
3
2
1
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

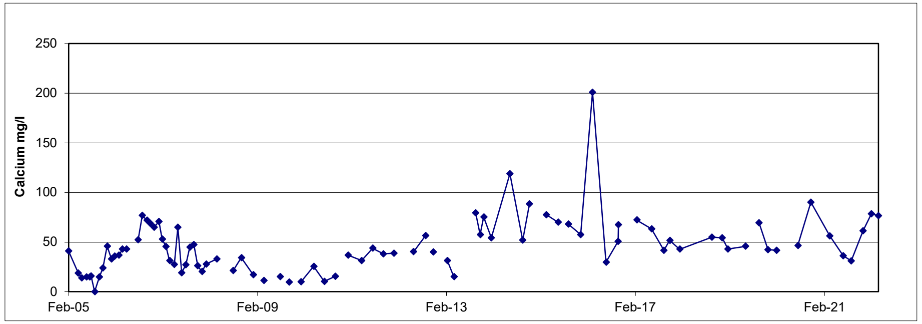

Sodium
Sulphate
Potassium
Magnesium
mg/l
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

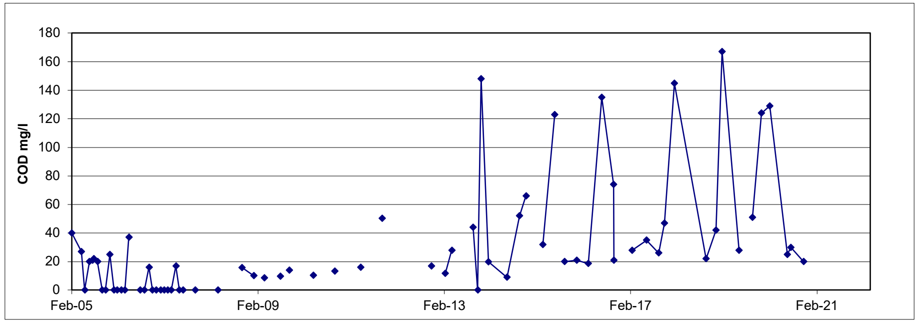

Cadmium
Mercury
microg/l
2
1
1
1
1
1
0
0
0
Feb-05
Feb-09
Feb-13
Feb-17

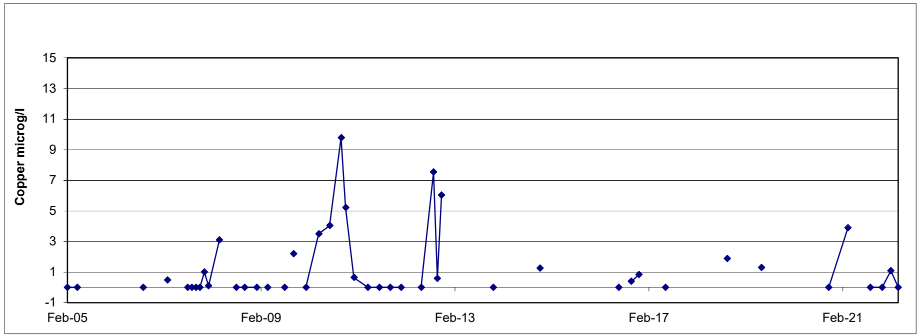

pH
EC
pH
EC microS/cm
14
12
10
8
6
4
2
0
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

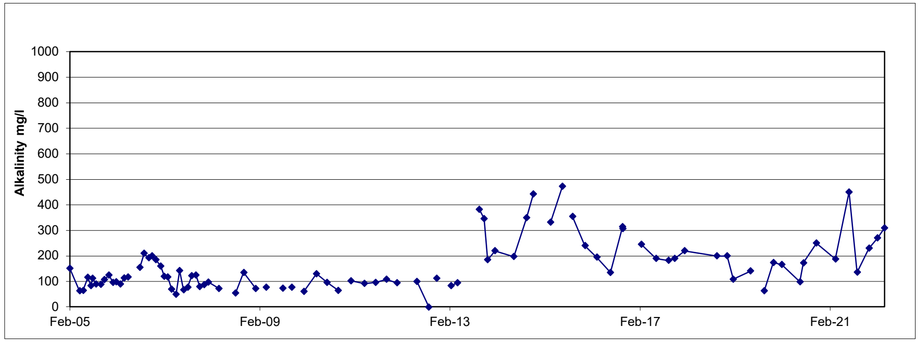

Ammonia mg/l
40
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

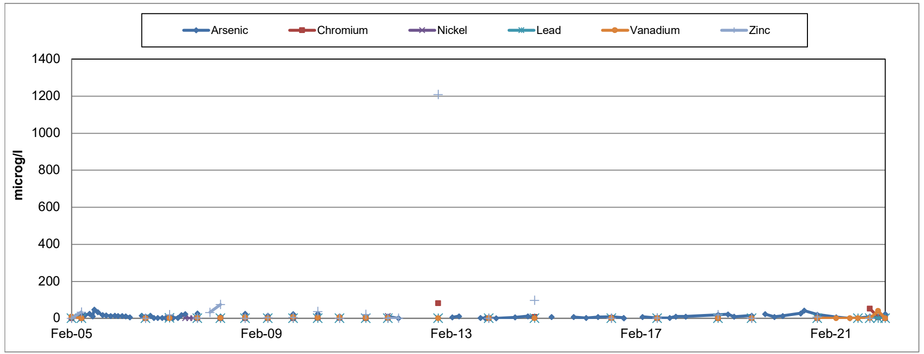

Chloride mg/l
1800
1600
1400
1200
1000
800
600
400
200
0
28 December 2004
24 September 2007
20 June 2010
16 March 2013
11 December 2015
06 September 2018
02 June 2021
27 February 2024

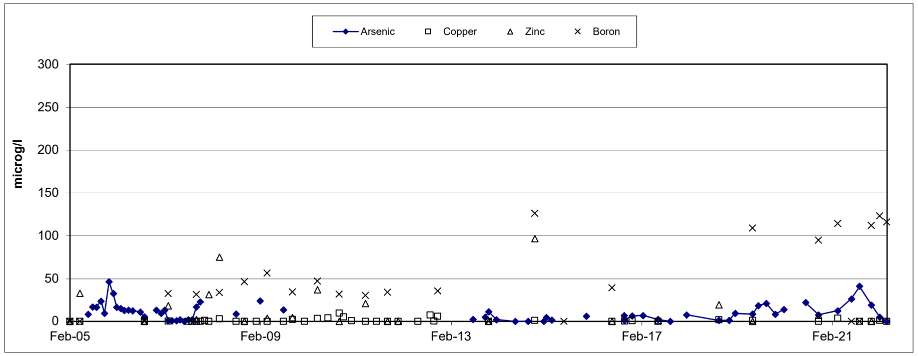

Calcium mg/l
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

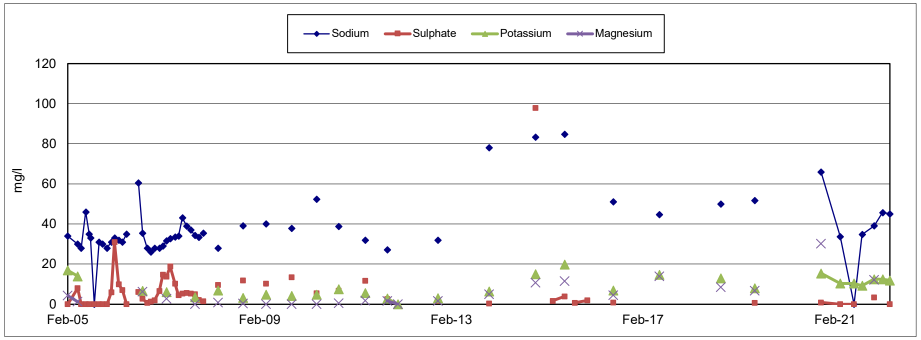

COD mg/l
180
160
140
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

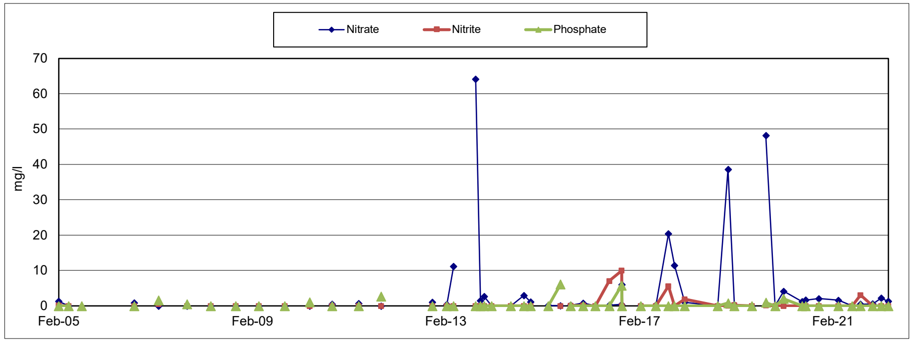

Copper microg/l
15
13
11
9
7
5
3
1
-1
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

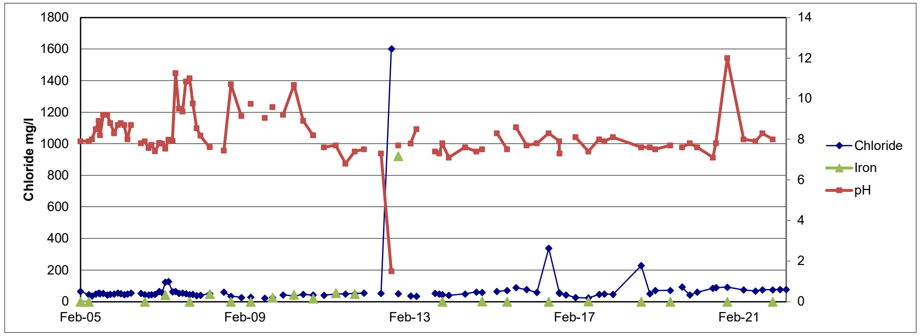

Alkalinity mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

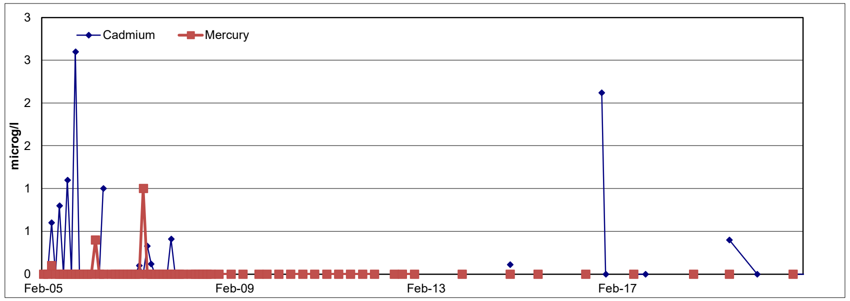

Arsenic
Chromium
Nickel
Lead
Vanadium
Zinc
microg/l
1400
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

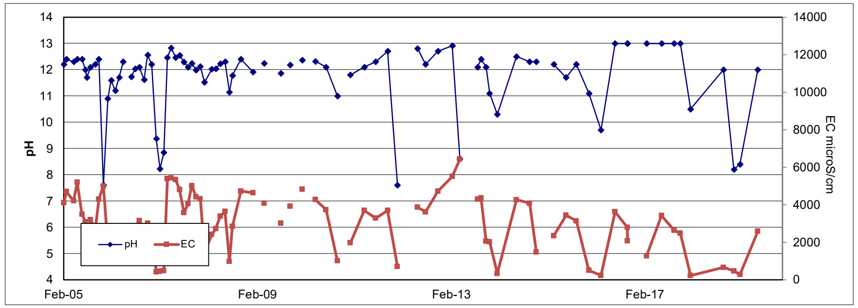

Arsenic
Copper
Zinc
Boron
microg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

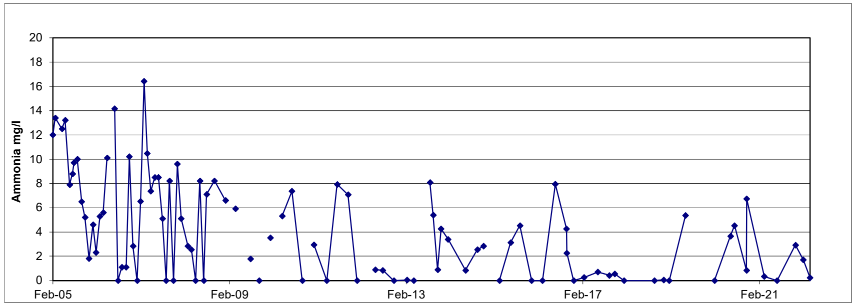

Sodium
Sulphate
Potassium
Magnesium
mg/l
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

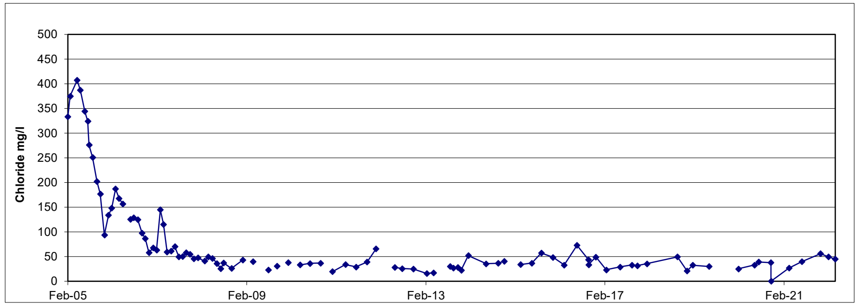

Nitrate
Nitrite
Phosphate
mg/l
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

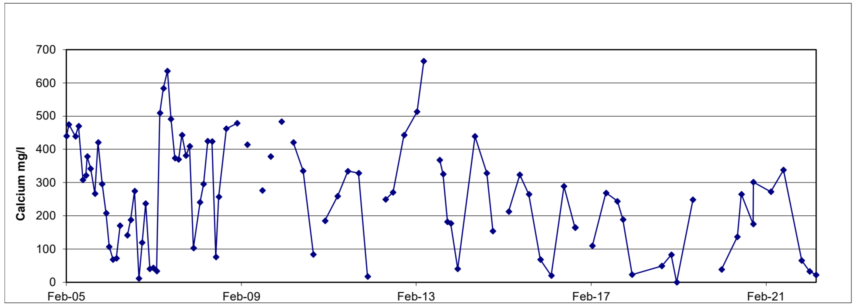

Chloride mg/l
1800
1600
1400
1200
1000
800
600
400
200
0
14
12
10
8
6
4
2
0
Chloride
Iron
pH
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

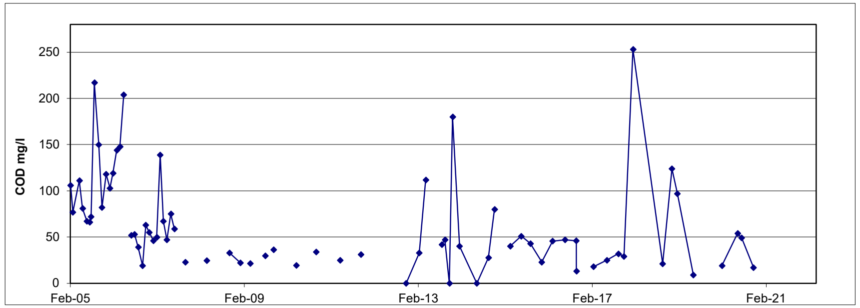

Cadmium
Mercury
microg/l
Feb-05
Feb-09
Feb-13
Feb-17

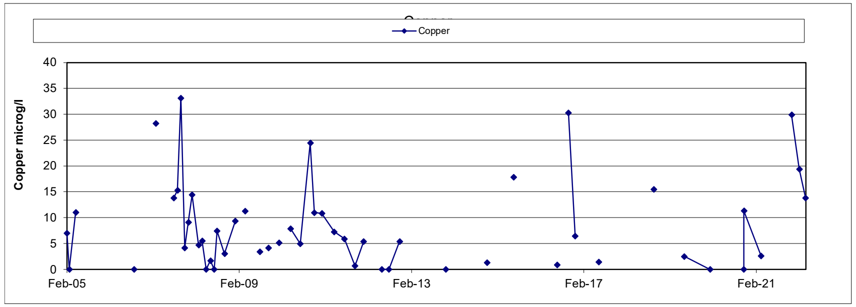

pH
EC
EC microS/cm
Feb-05
Feb-09
Feb-13
Feb-17


Ammonia mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

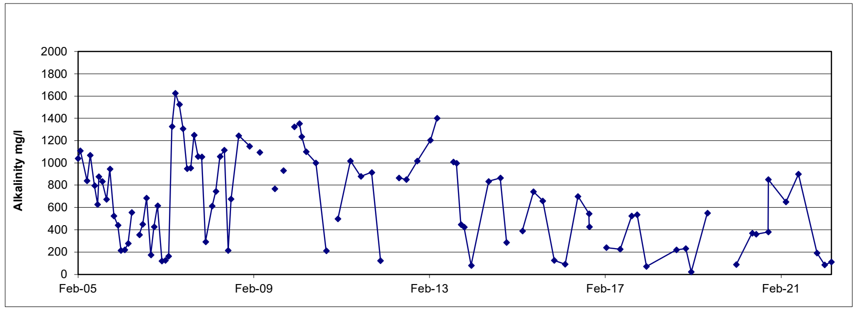

Chloride mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Calcium mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

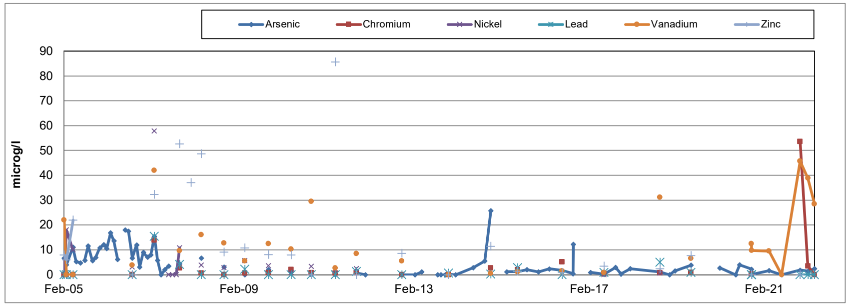

COD mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



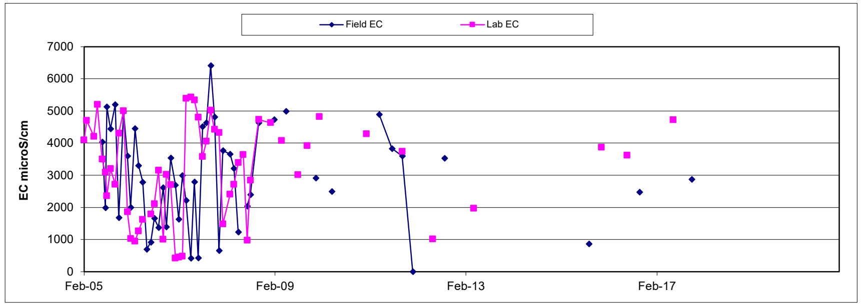
Copper
Copper microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



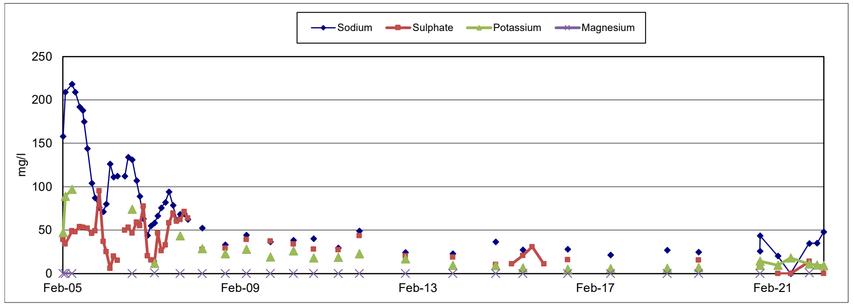
Alkalinity mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

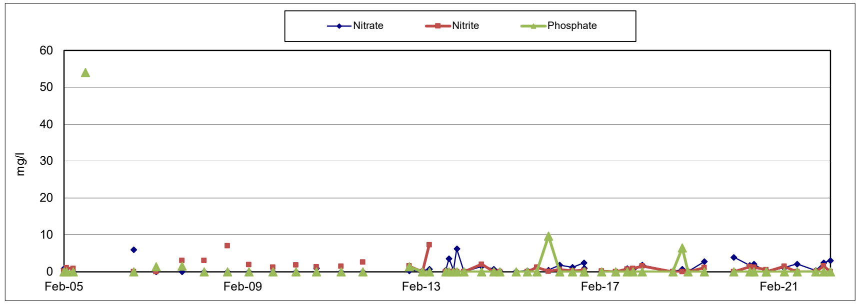


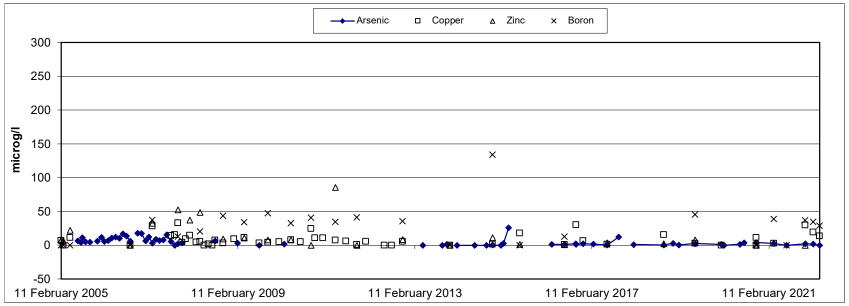
Arsenic
Chromium
Nickel
Lead
Vanadium
Zinc
microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

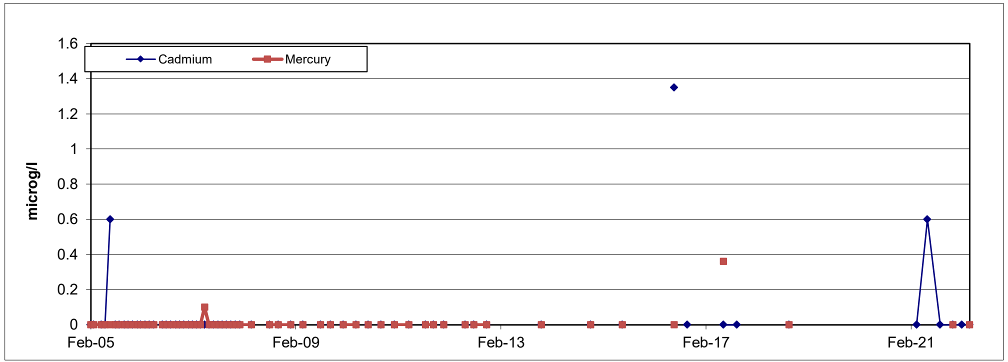


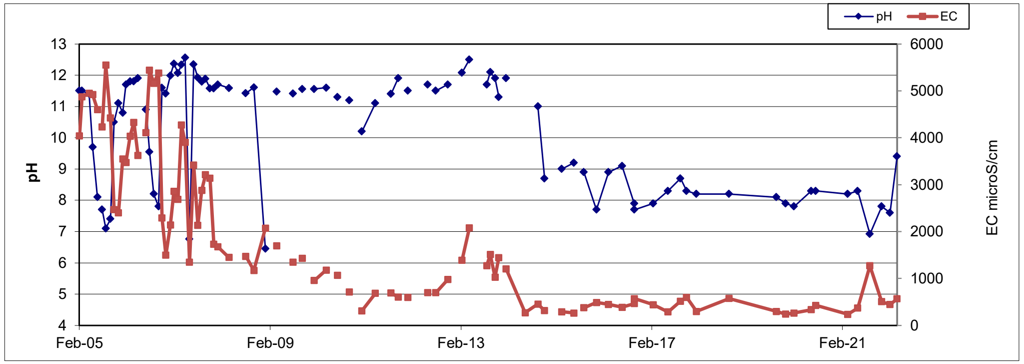
Field EC
Lab EC
EC microS/cm
Feb-05
Feb-09
Feb-13
Feb-17

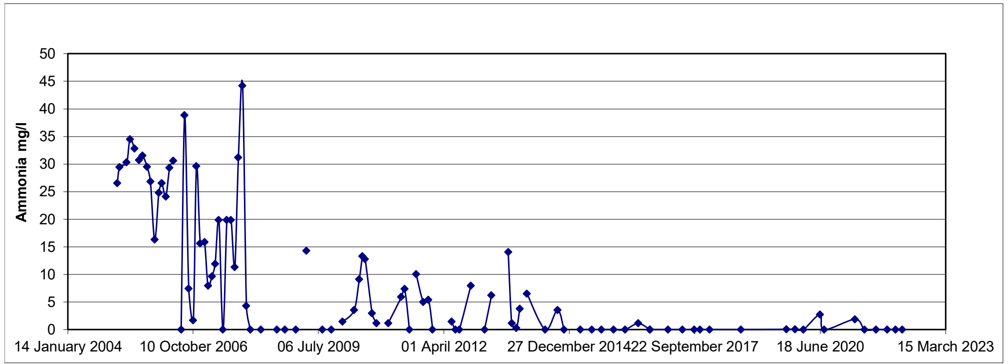

Sodium
Sulphate
Potassium
Magnesium
mg/l
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

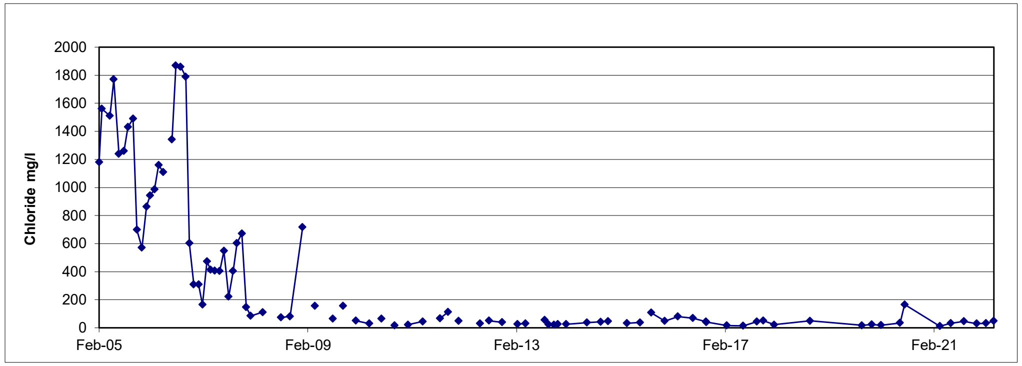

Nitrate
Nitrite
Phosphate
mg/l
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

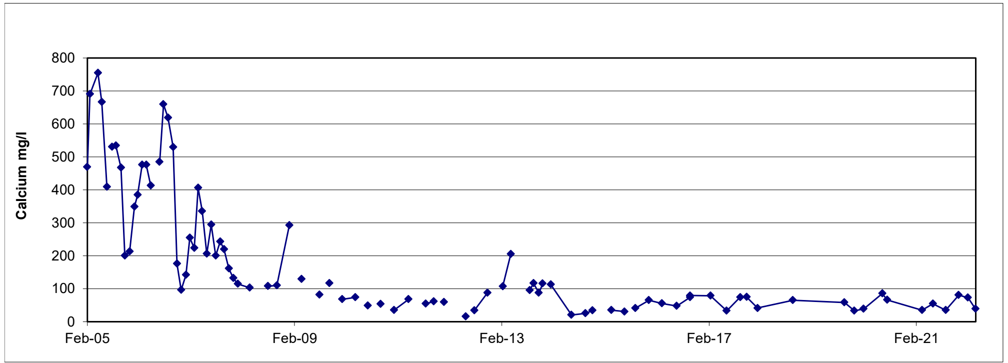

Arsenic
Copper
Zinc
Boron
microg/l
300
250
200
150
100
50
0
-50
11 February 2005
11 February 2009
11 February 2013
11 February 2017
11 February 2021

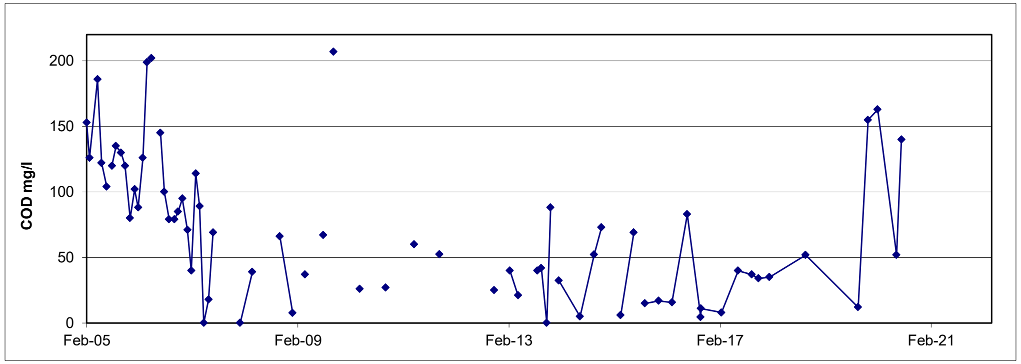

Cadmium
Mercury
microg/l
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

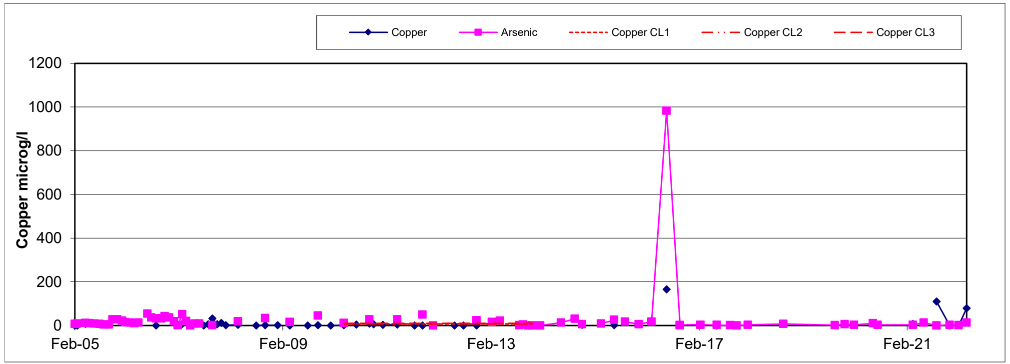

pH
EC
pH
EC microS/cm
13
12
11
10
9
8
7
6
5
4
6000
5000
4000
3000
2000
1000
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

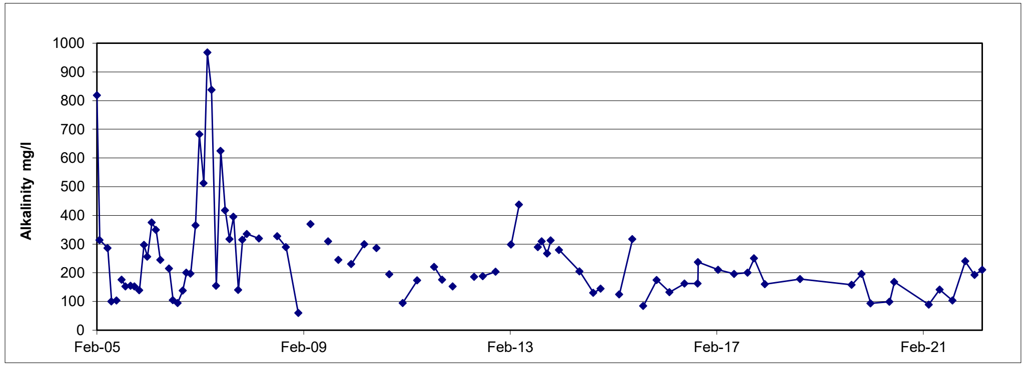

Ammonia mg/l
50
45
40
35
30
25
20
15
10
5
0
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

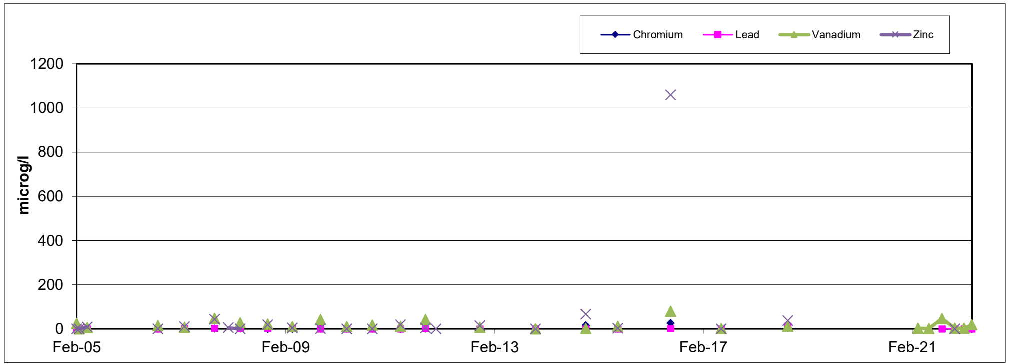

Chloride mg/l
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

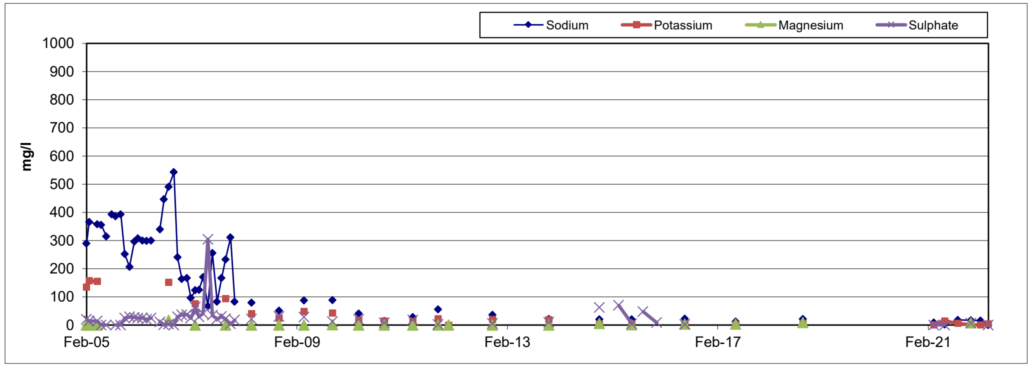

Calcium mg/l
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

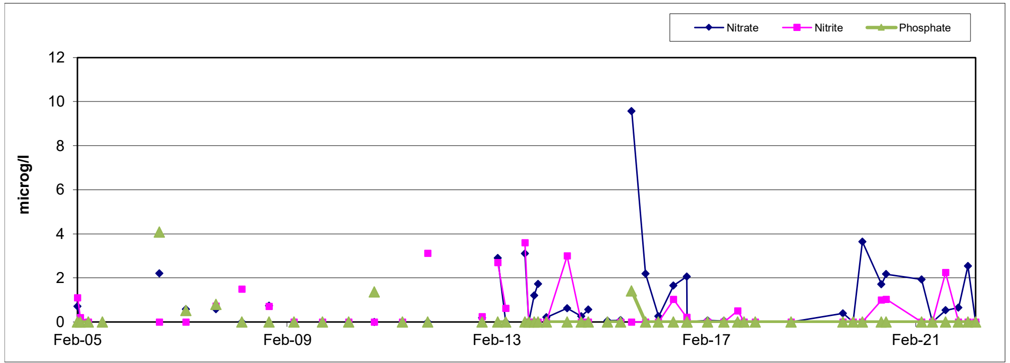

COD mg/l
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

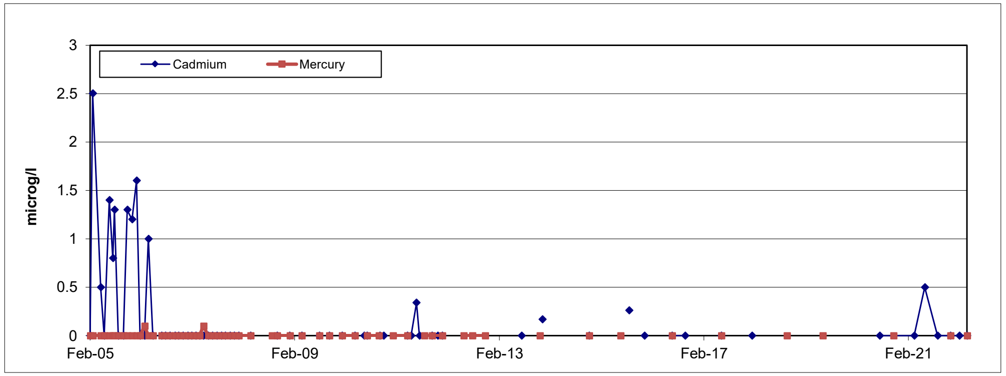

Copper
Arsenic
Copper CL1
Copper CL2
Copper CL3
Copper microg/l
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

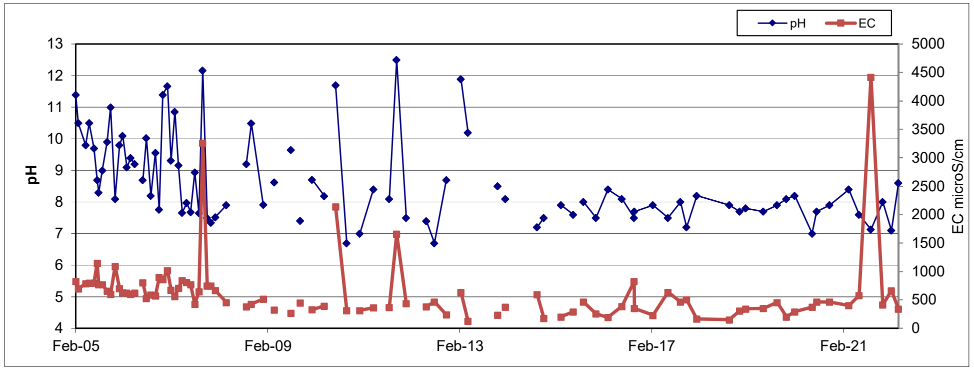

Alkalinity mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

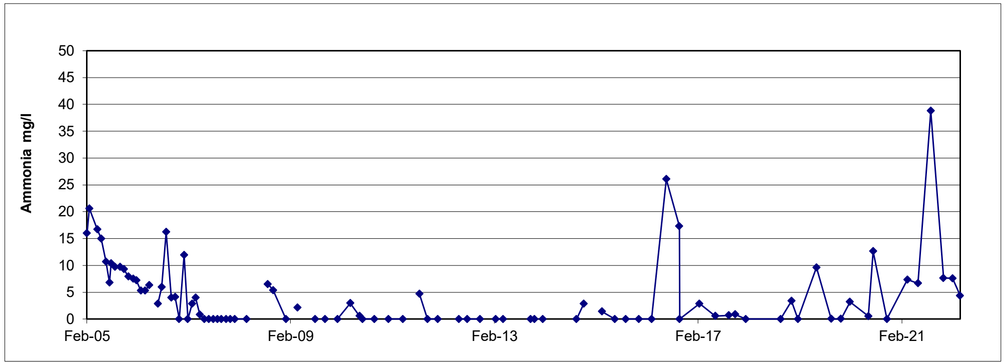

Chromium
Lead
Vanadium
Zinc
microg/l
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

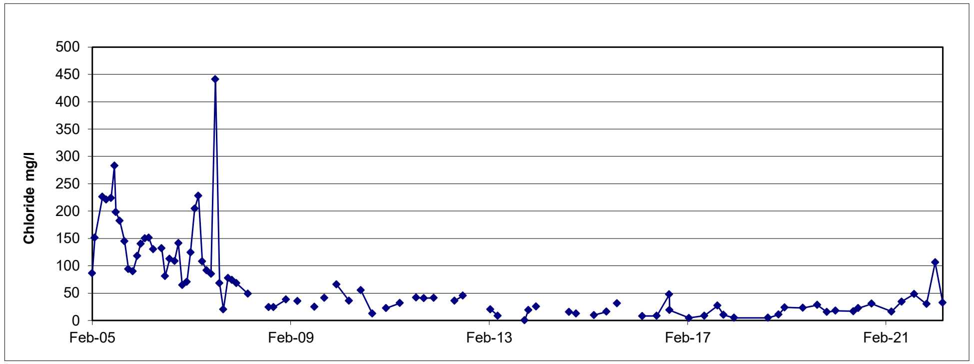

Sodium
Potassium
Magnesium
Sulphate
mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

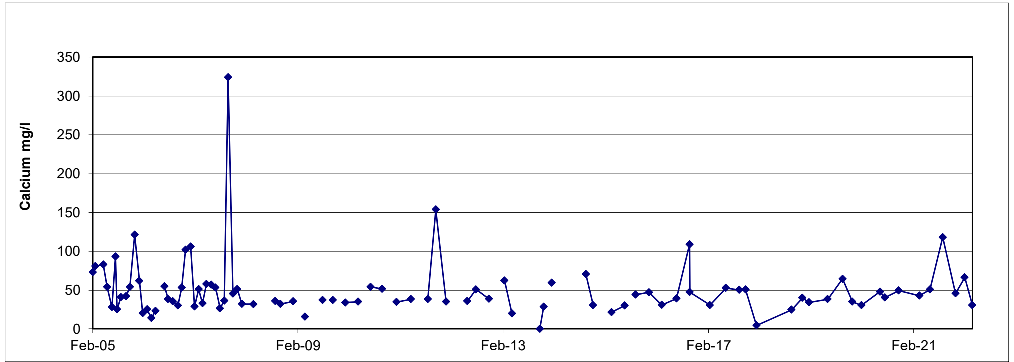

Nitrate
Nitrite
Phosphate
microg/l
12
10
8
6
4
2
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

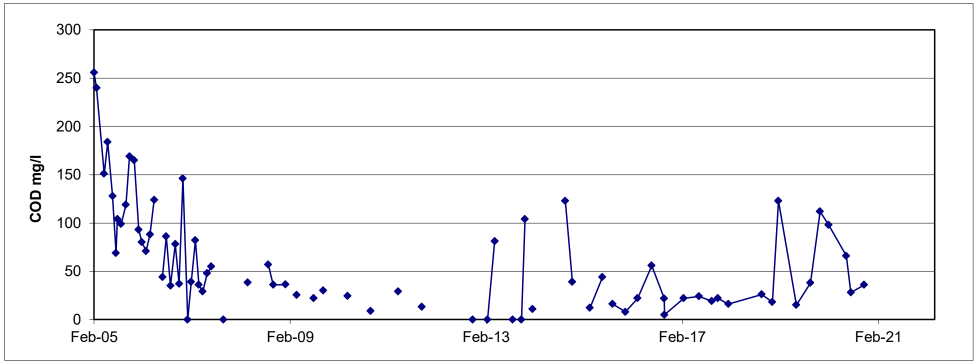

Cadmium
Mercury
microg/l
0
0.5
1
1.5
2
2.5
3
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

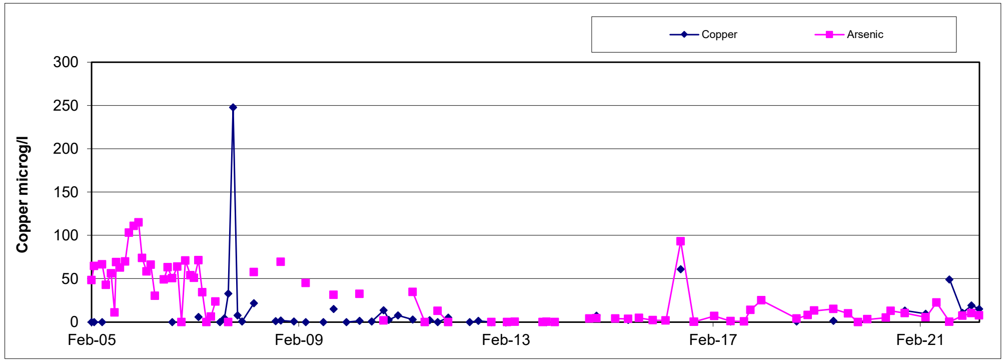

pH
EC
pH
EC microS/cm
4
5
6
7
8
9
10
11
12
13
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

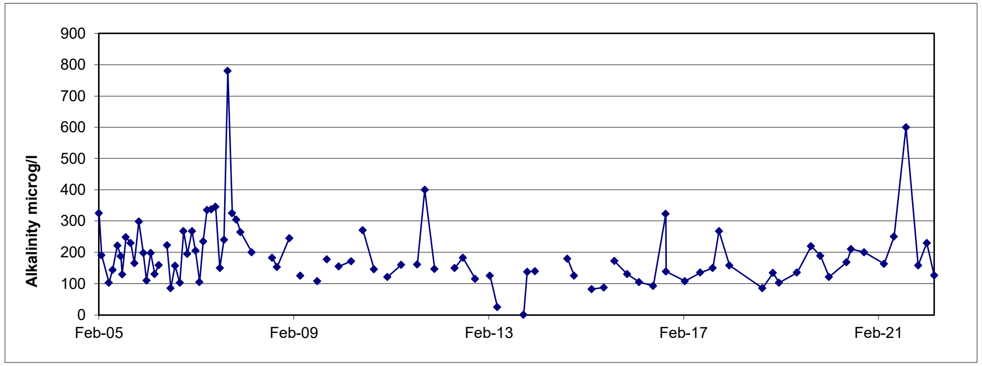

Ammonia mg/l
0
5
10
15
20
25
30
35
40
45
50
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

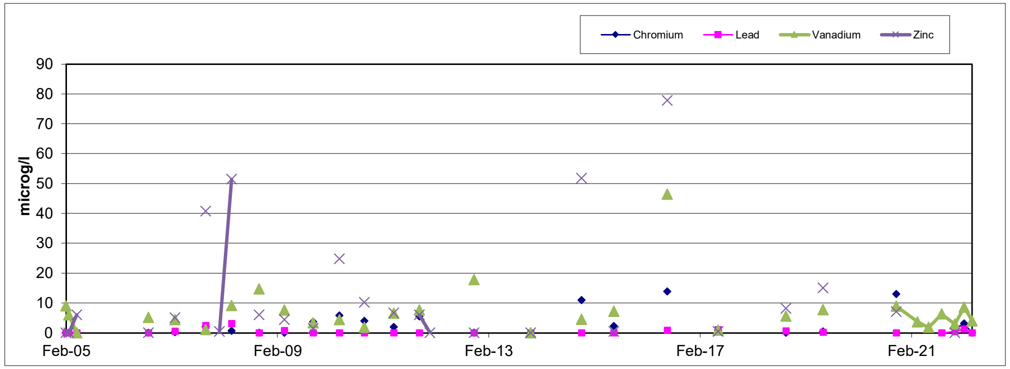

Chloride mg/l
0
50
100
150
200
250
300
350
400
450
500
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

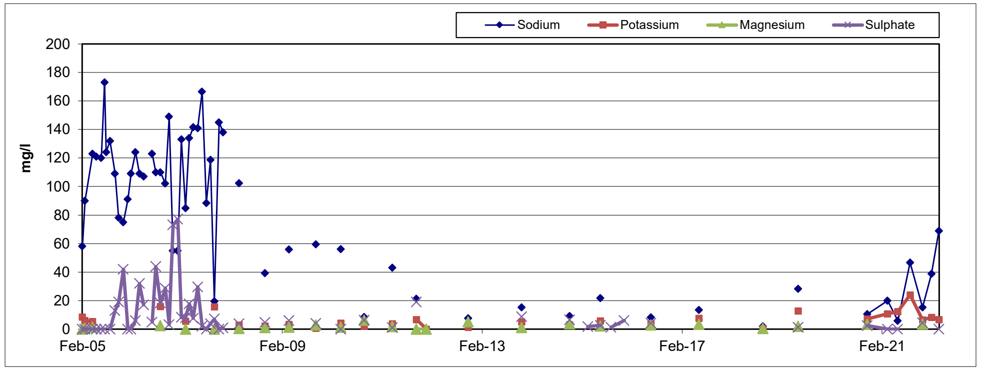

Calcium mg/l
0
50
100
150
200
250
300
350
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

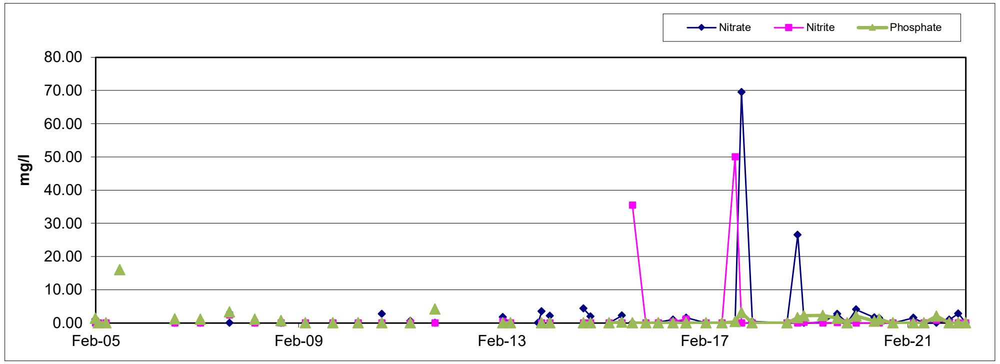

COD mg/l
0
50
100
150
200
250
300
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

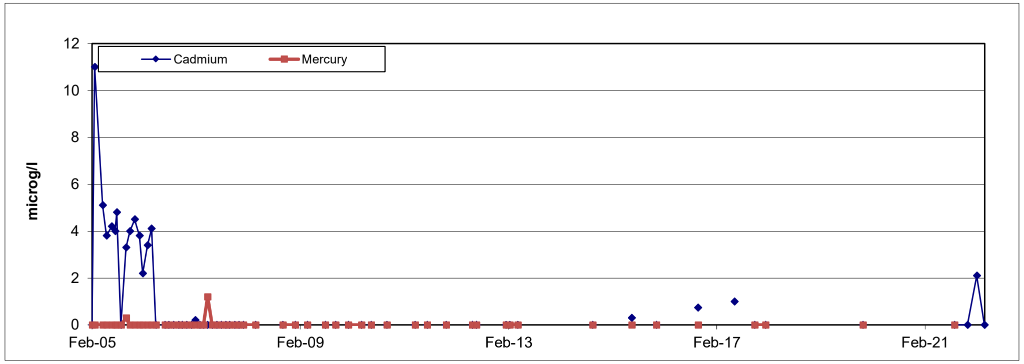

Copper
Arsenic
Copper microg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Alkalinity microg/l
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

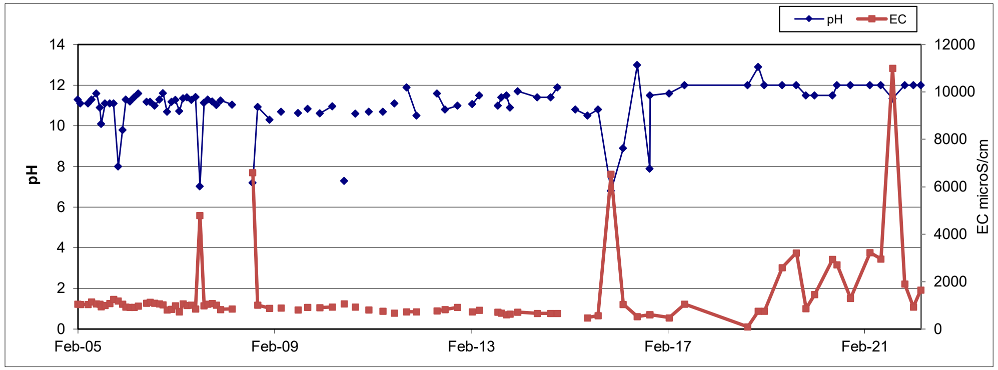

Chromium
Lead
Vanadium
Zinc
microg/l
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Sodium
Potassium
Magnesium
Sulphate
mg/l
200
180
160
140
120
100
80
60
40
20
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

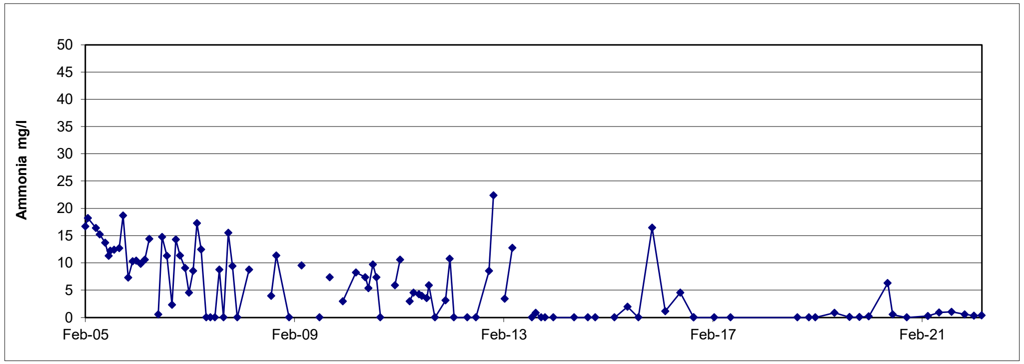

Nitrate
Nitrite
Phosphate
mg/l
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



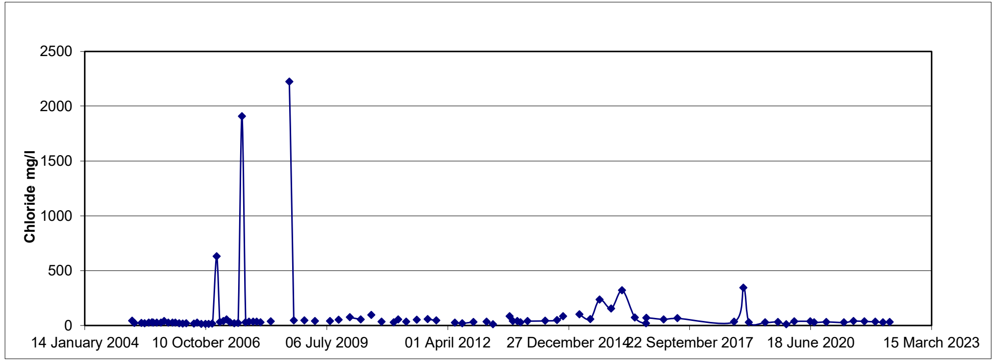
Cadmium
Mercury
microg/l
0
2
4
6
8
10
12
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



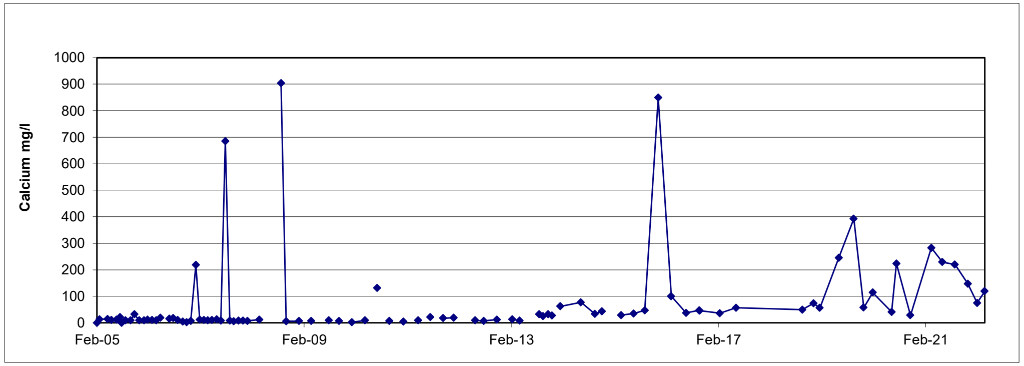
pH
EC
pH
EC microS/cm
0
2
4
6
8
10
12
14
0
2000
4000
6000
8000
10000
12000
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



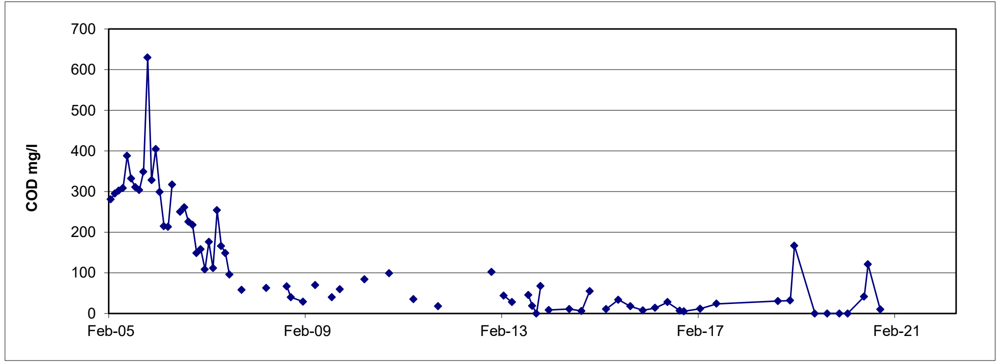
Ammonia mg/l
0
5
10
15
20
25
30
35
40
45
50
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



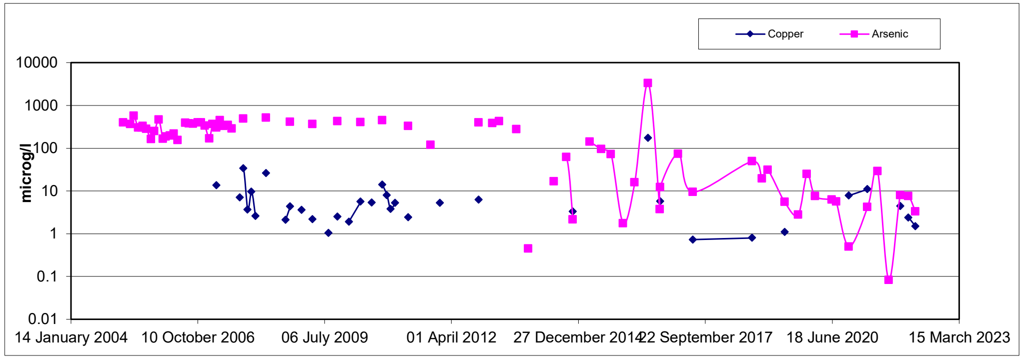
Chloride mg/l
0
500
1000
1500
2000
2500
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023

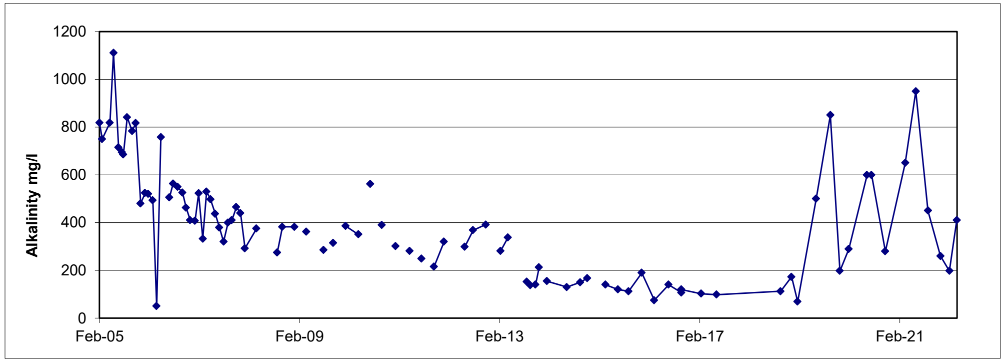


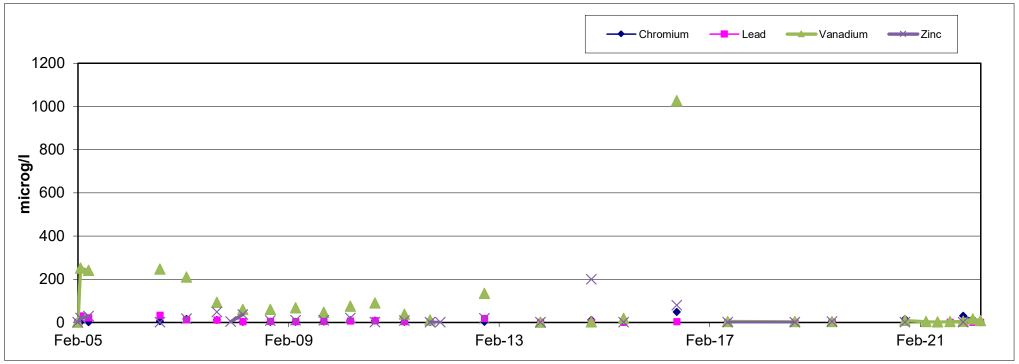
Calcium mg/l
0
100
200
300
400
500
600
700
800
900
1000
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

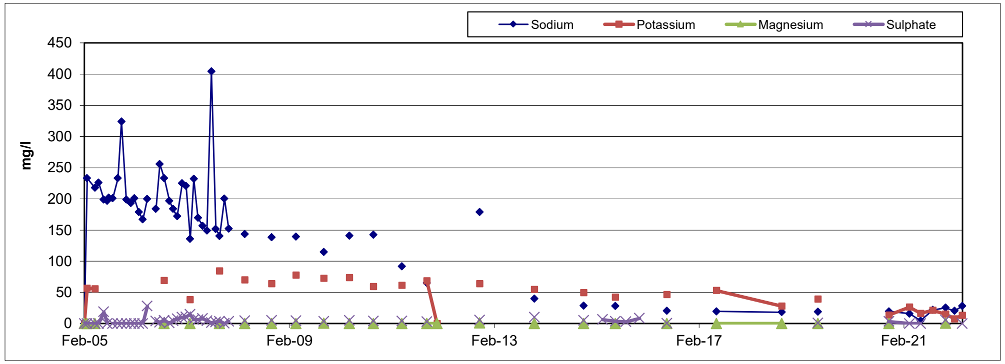


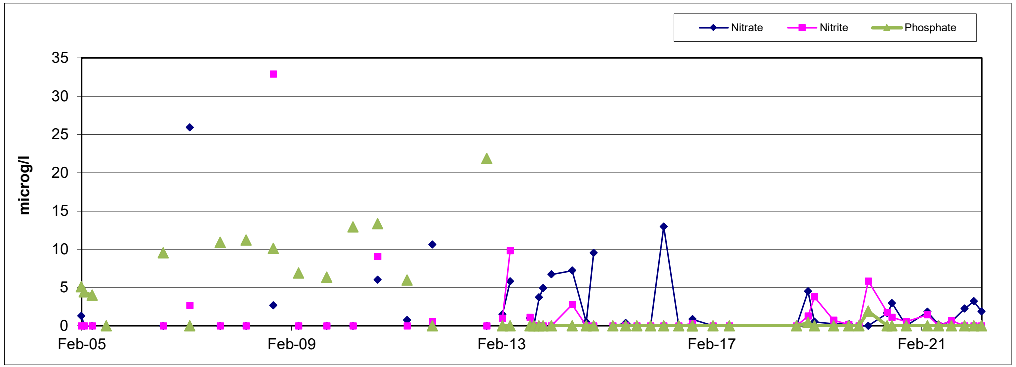
COD mg/l
0
100
200
300
400
500
600
700
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

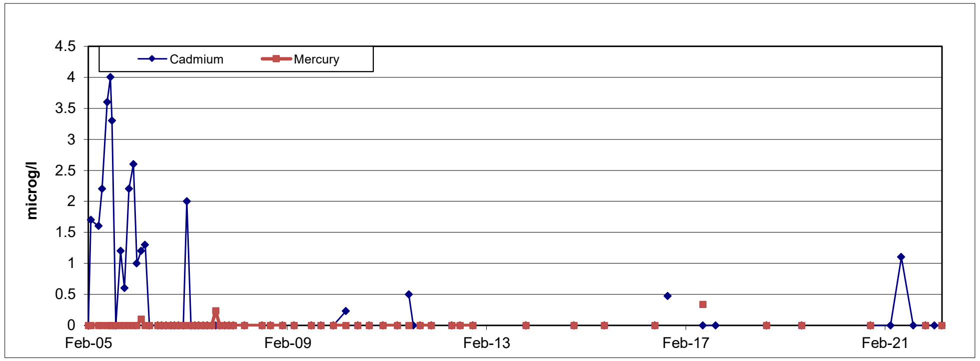

Copper
Arsenic
microg/l
10000
1000
100
10
1
0.1
0.01
14 January 2004
10 October 2006
06 July 2009
01 April 2012
27 December 2014
22 September 2017
18 June 2020
15 March 2023


Alkalinity mg/l
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

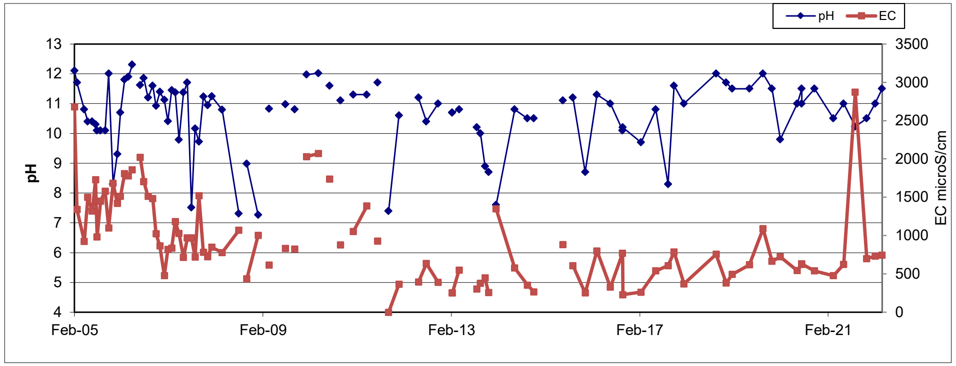

Chromium
Lead
Vanadium
Zinc
microg/l
1200
1000
800
600
400
200
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Sodium
Potassium
Magnesium
Sulphate
mg/l
450
400
350
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

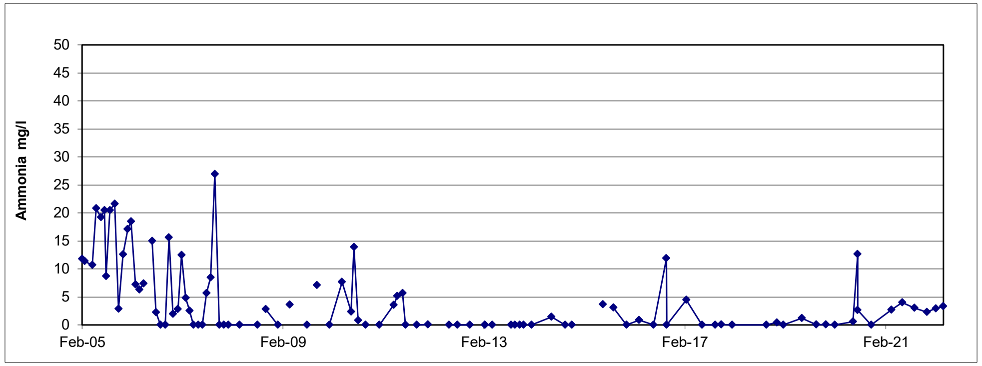

Nitrate
Nitrite
Phosphate
microg/l
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



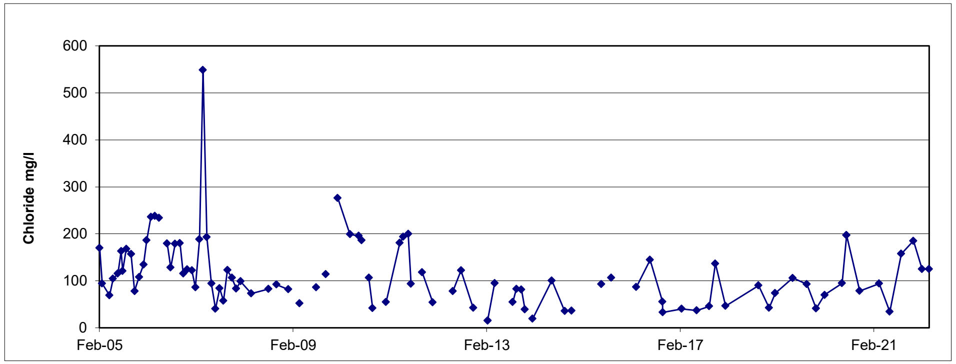
Cadmium
Mercury
microg/l
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



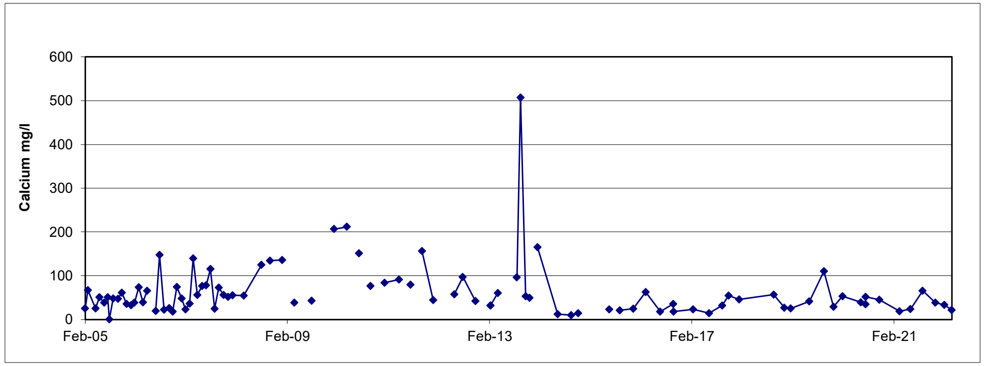
pH
EC
pH
EC microS/cm
13
12
11
10
9
8
7
6
5
4
3500
3000
2500
2000
1500
1000
500
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



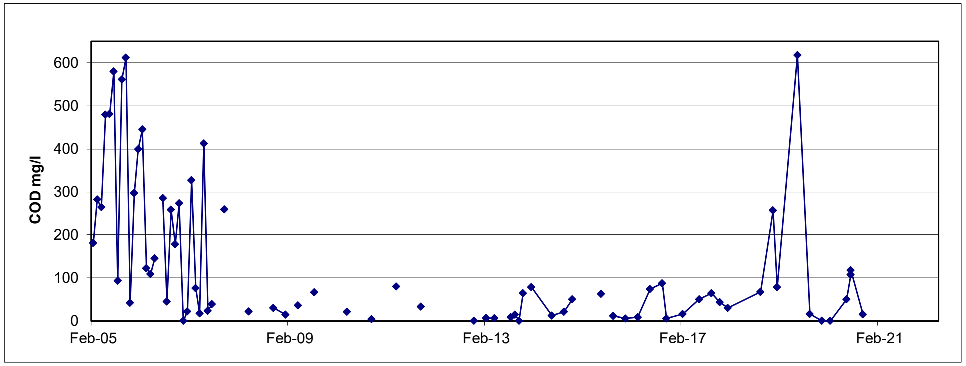
Ammonia mg/l
50
45
40
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21



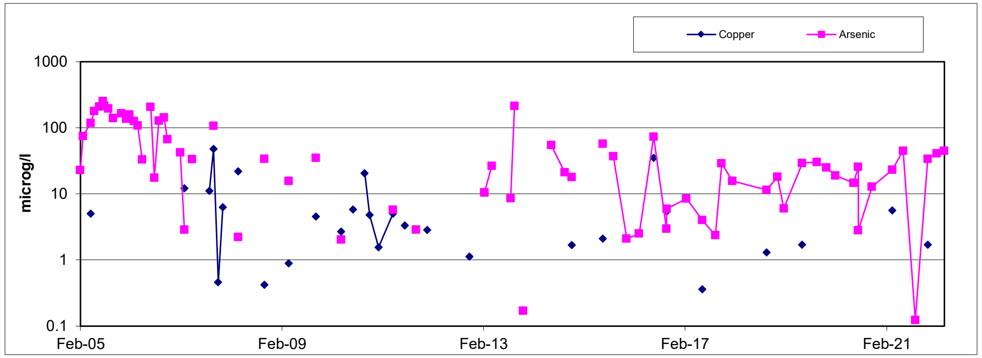
Chloride mg/l
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

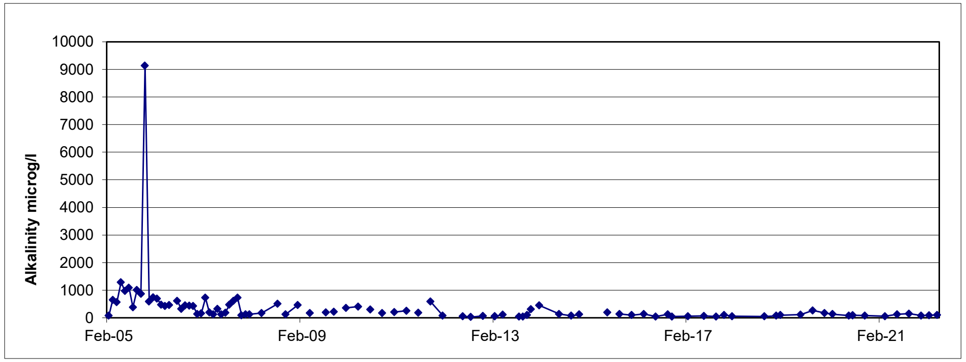


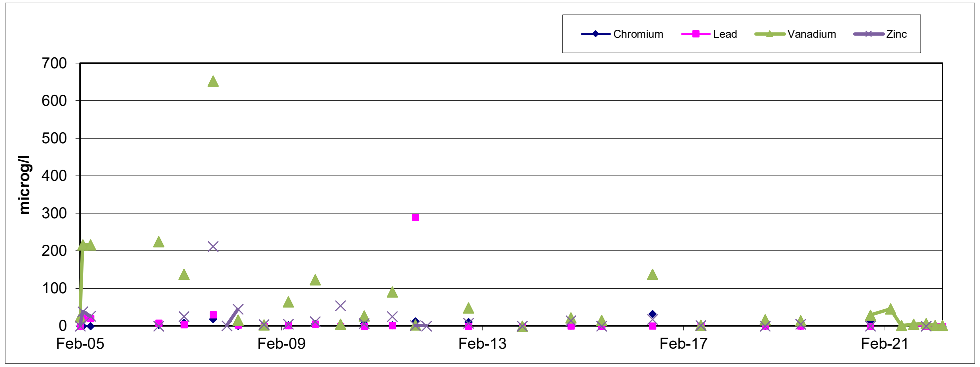
Calcium mg/l
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

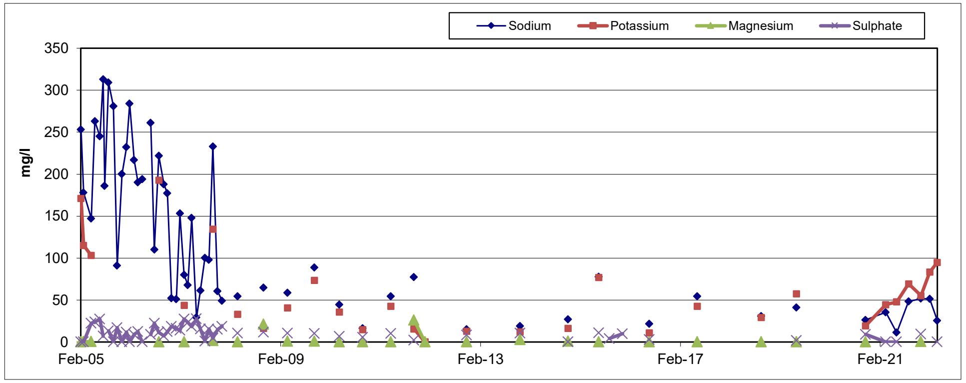


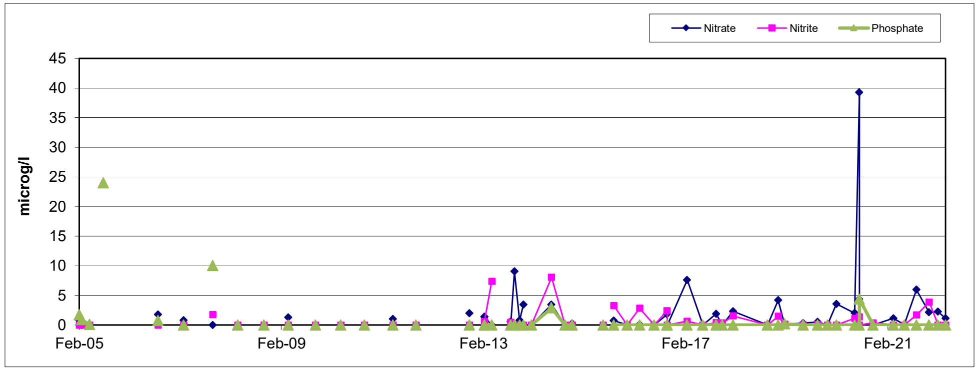
COD mg/l
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

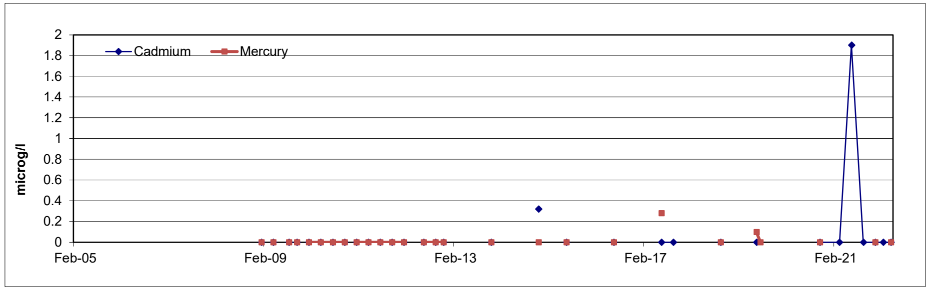

Copper
Arsenic
1000
100
10
1
0.1
microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

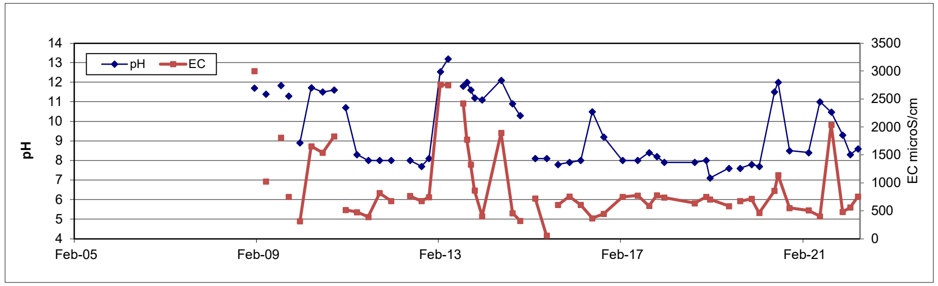

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Alkalinity microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

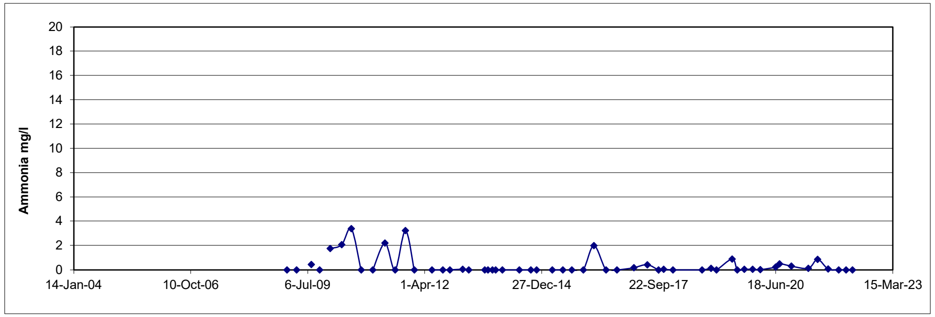

Chromium
Lead
Vanadium
Zinc
700
600
500
400
300
200
100
0
microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

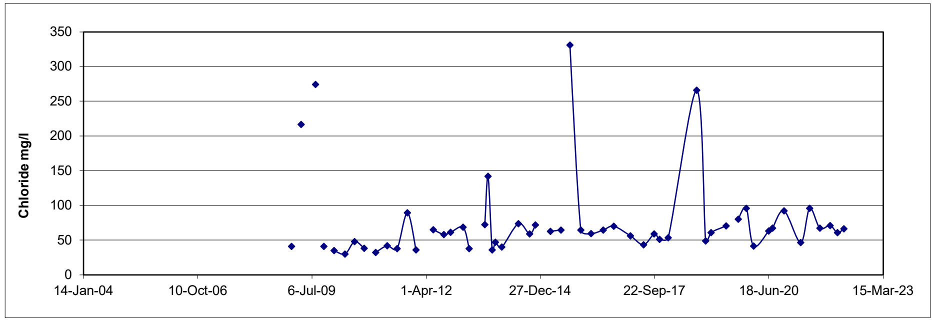

Sodium
Potassium
Magnesium
Sulphate
350
300
250
200
150
100
50
0
mg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

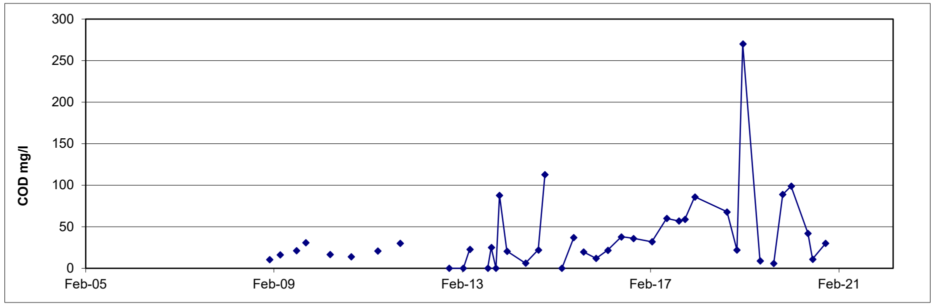

Nitrate
Nitrite
Phosphate
45
40
35
30
25
20
15
10
5
0
microg/l
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

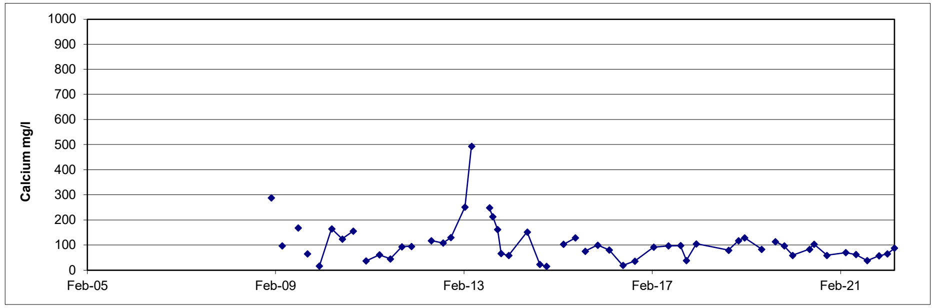

microg/l
Cadmium
Mercury
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

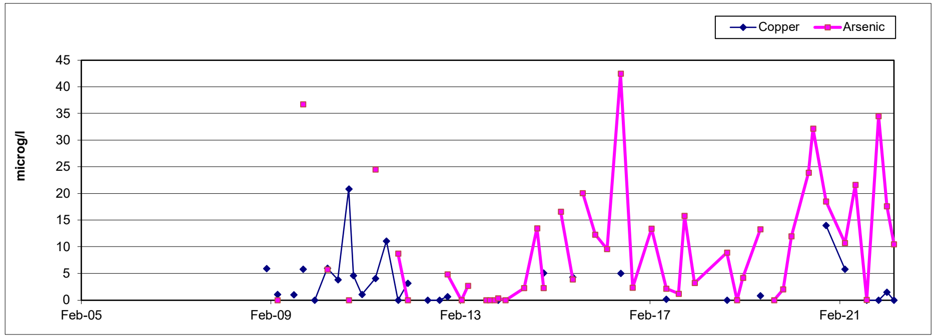

pH
EC
EC microS/cm
14
13
12
11
10
9
8
7
6
5
4
3500
3000
2500
2000
1500
1000
500
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

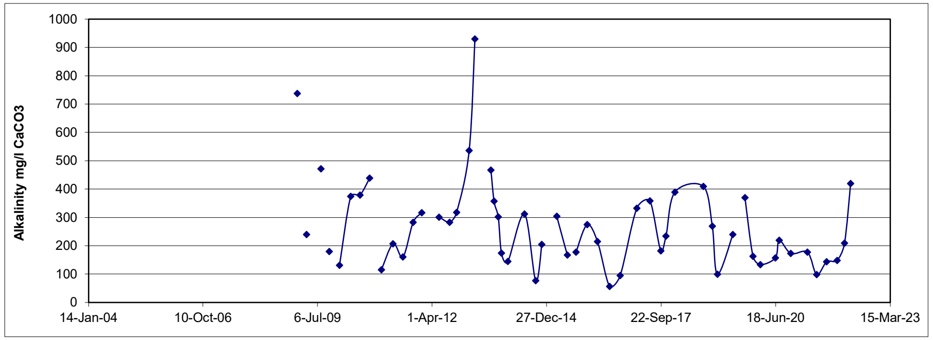

Ammonia mg/l
20
18
16
14
12
10
8
6
4
2
0
14-Jan-04
10-Oct-06
6-Jul-09
1-Apr-12
27-Dec-14
22-Sep-17
18-Jun-20
15-Mar-23

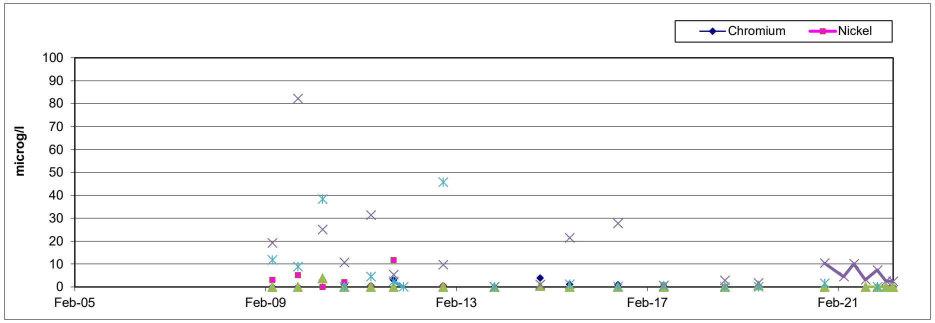

Chloride mg/l
350
300
250
200
150
100
50
0
14-Jan-04
10-Oct-06
6-Jul-09
1-Apr-12
27-Dec-14
22-Sep-17
18-Jun-20
15-Mar-23

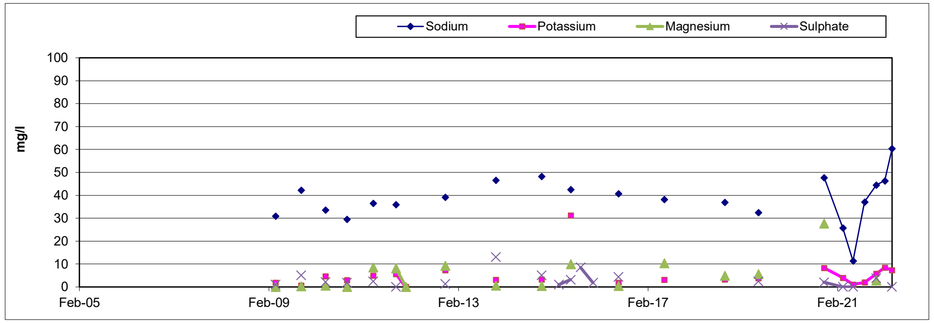

COD mg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

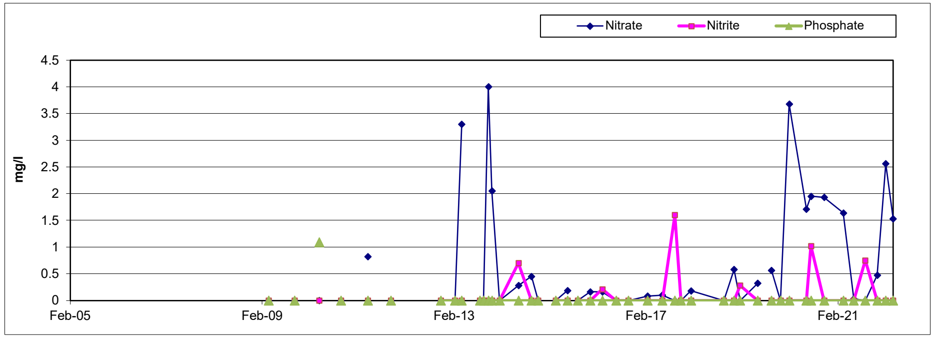

Calcium mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

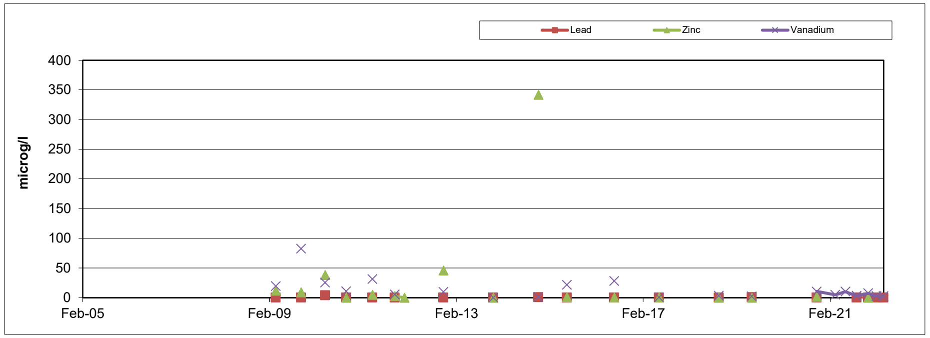

Copper
Arsenic
microg/l
45
40
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

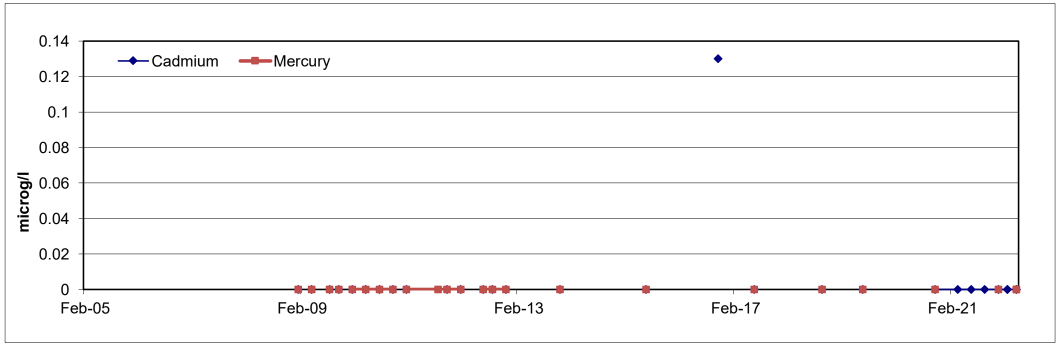

Alkalinity mg/l CaCO3
1000
900
800
700
600
500
400
300
200
100
0
14-Jan-04
10-Oct-06
6-Jul-09
1-Apr-12
27-Dec-14
22-Sep-17
18-Jun-20
15-Mar-23

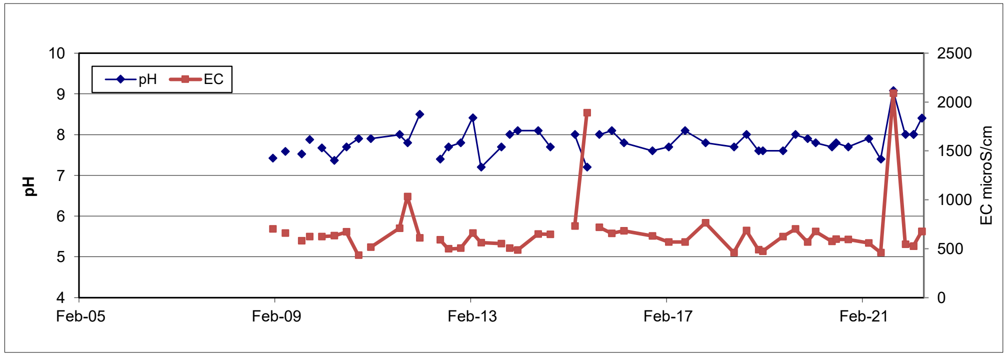

Chromium
Nickel
microg/l
100
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

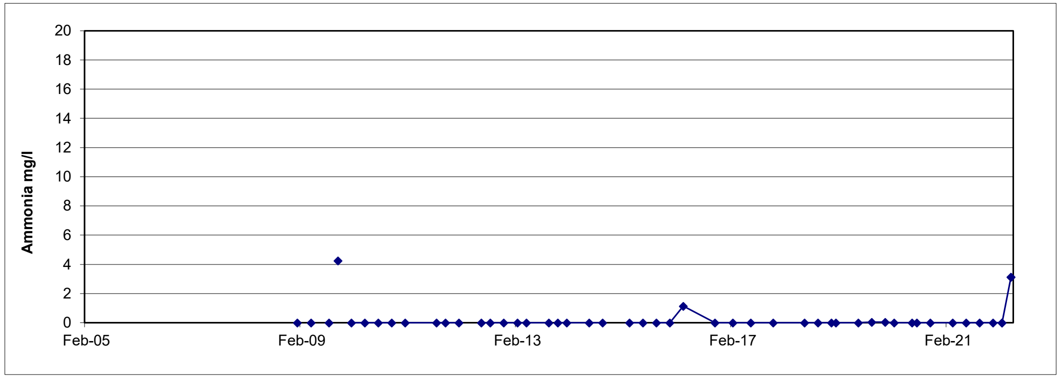

Sodium
Potassium
Magnesium
Sulphate
mg/l
100
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

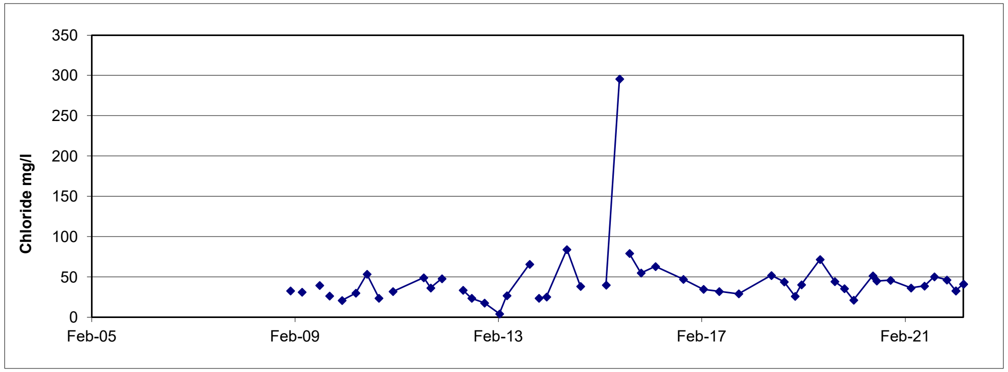

Nitrate
Nitrite
Phosphate
mg/l
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

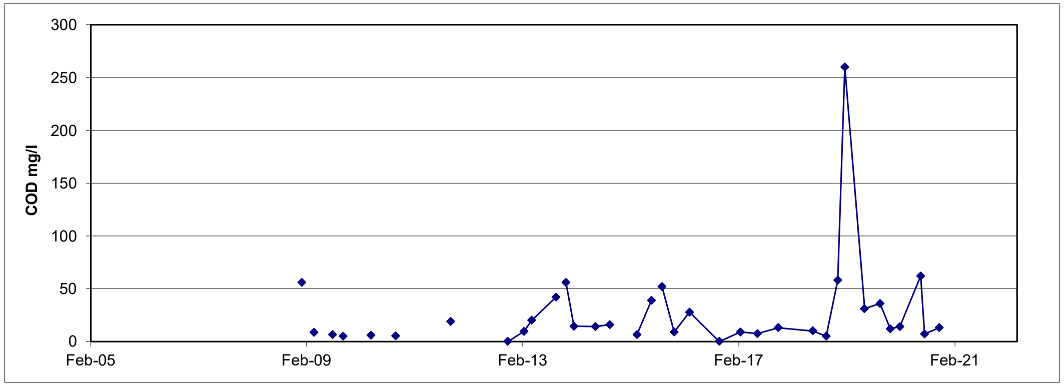

Lead
Zinc
Vanadium
microg/l
400
350
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

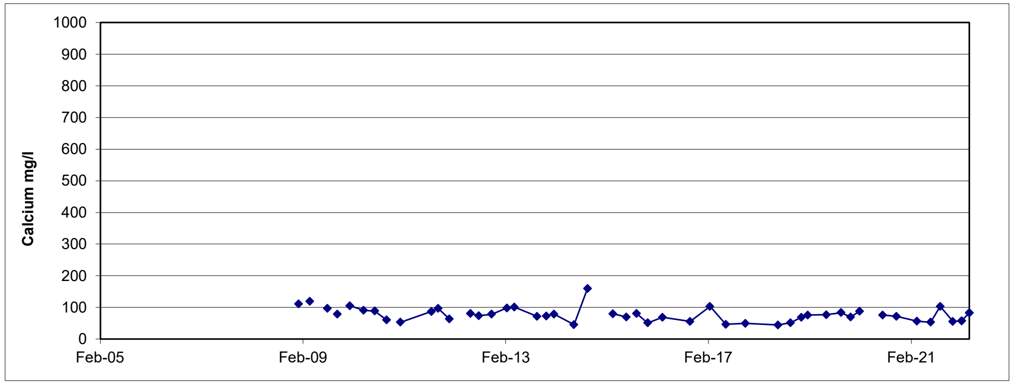

Cadmium
Mercury
microg/l
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

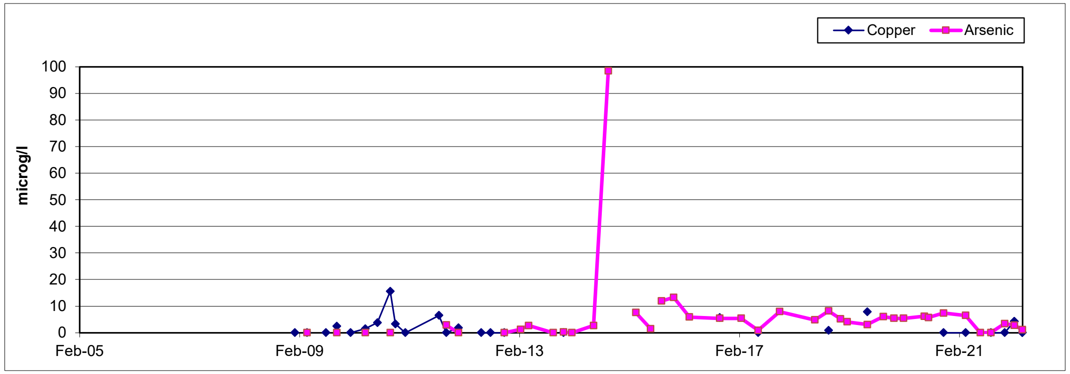

pH
EC
pH
EC microS/cm
10
9
8
7
6
5
4
2500
2000
1500
1000
500
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

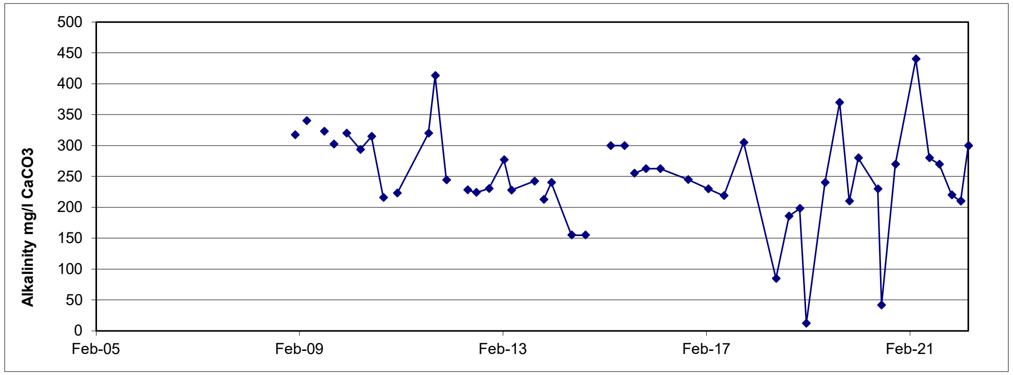

Ammonia mg/l
20
18
16
14
12
10
8
6
4
2
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

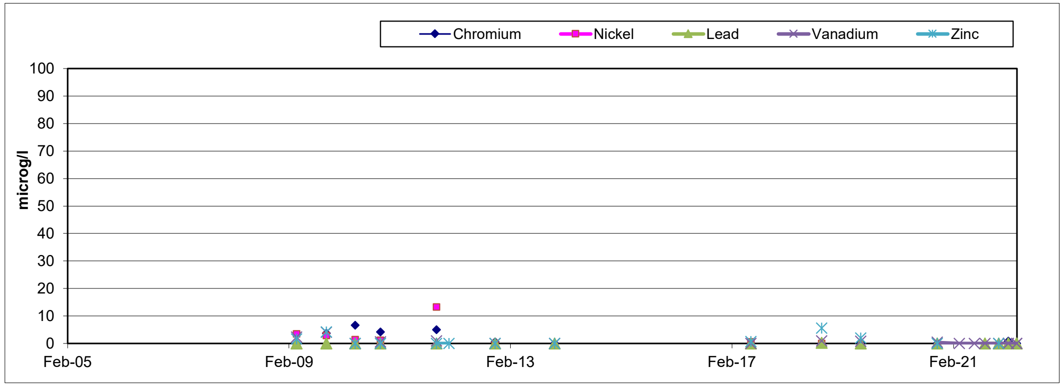

Chloride mg/l
350
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

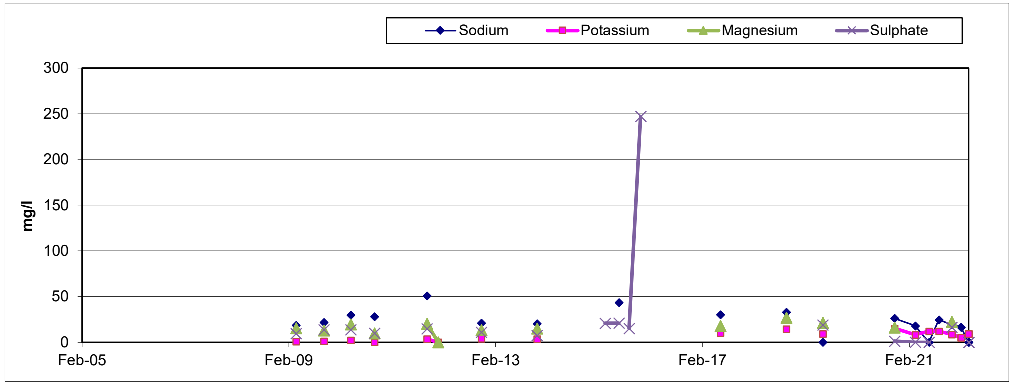

COD mg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

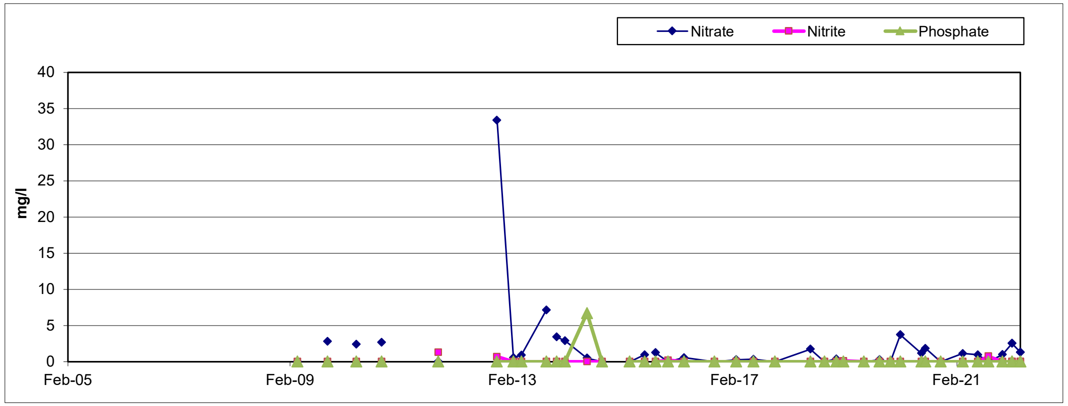

Calcium mg/l
1000
900
800
700
600
500
400
300
200
100
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Copper
Arsenic
microg/l
100
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Alkalinity mg/l CaCO3
500
450
400
350
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Chromium
Nickel
Lead
Vanadium
Zinc
microg/l
100
90
80
70
60
50
40
30
20
10
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Sodium
Potassium
Magnesium
Sulphate
mg/l
300
250
200
150
100
50
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21


Nitrate
Nitrite
Phosphate
mg/l
40
35
30
25
20
15
10
5
0
Feb-05
Feb-09
Feb-13
Feb-17
Feb-21

MORFA NON-HAZARDOUS LANDFILL PORT TALBOT

ENVIRONMENTAL PERMIT BV7311IE

Review of Hydrogeological Risk Assessment

Appendix 6
Review of LandSim Input Parameters
Report Number 2238r1v1d0622

LandSim Information

Project Information		Base Model Information			Modification to Base Model (HRA Review 2 2012)	Justification	Modification to Base Model (HRA Review 3 2017)	Justification	2022 HRA Review	Justification
Customer		Corus UK Ltd			Tata Steel UK Ltd		No change		No change	
Project		Morfa Non-Hazardous Landfill			No change		No change		No change	
Number		403			1177		1739		2238	
	Notes	Full simulation including declining source term with retardation. Simulation carried out to evaluate emission of pollutants using LandSim 2.5 in the recommended way. The original HRA simulations included several runs of LandSim 2 in order to determine emission time history. Management control is taken conservatively as 60yrs post-closure, representing the financial provision made available. This simulation is carried out after construction of the first Cells with the benefit of a 12 month monitoring period for gw and leachate. The construction records have allowed the design to be quantified accurately and the monitoring data has allowed a better understanding of leachate chemistry. This simulation takes a conservative approach in order to specify the source term, with 1.5 times the max recorded concentrations as a max and the recorded max as a most likely. The loss of management control is specified conservatively as 60yrs post closure (63 yrs after closure) as this represents the available Financial Provision.			Full simulation including declining source term without retardation. Simulation carried out to evaluate emission of pollutants using LandSim 2.5 in the recommended way as part of four year HRA Review. This simulation is carried out after construction of Bio Cell A and B and Non Hazardous Cell 1. The construction records have allowed the design to be quantified accurately and the monitoring data has allowed a better understanding of leachate chemistry. This simulation uses actual leachate chemistry. The loss of management control is specified conservatively as 60yrs post closure (63 yrs after closure) as this represents the available Financial Provision.		No change		No change	
Timescale	30/100/300/1000				No change		No change		No change	
Phase										
	Name	Morfa Non-Hazardous Landfill			No change		No change		No change	
	Project No.	403			1177		1739		No change	
			y							
	Location	900	1000		No change		No change		No change	
	Length	200	113		No change		No change		No change	
	Time Offset	0			No change		No change		No change	
	Duration of Management Control	63			No change		No change		No change	
Receptor										
	Name	spring								
		x	y							
	Location	1040	1000		No change		No change		No change	
Preferences									No change	
Use Expected Values Only	No				No change		No change		No change	
	Mineral Liner	Unsaturated Pathway	Vertical Pathway	Aquifer Pathway					No change	
Unretarded Contaminant Transport	No	No	No	No	Unretarded		No change		No change	
Biodegradation	No	No	No	No	No change		No change		No change	
Maximum number of trials	1001				No change		No change			

LandSim Information	Base Model Information		Modification to Base Model (HRA Review 2 2012)	Justification	Modification to Base Model (HRA Review 3 2017)	Justification	2022 HRA Review	Justification
Infiltration	Infiltration Open to Waste (mm/yr)	Triangular (744, 981, 1218)	No change		Triangular PDF (1000, 1200, 1600)	Based on rainfall records	No change	
	Cap Design Infiltration (mm/yr)	Triangular (15, 20, 25)	No change		Triangular (20, 24, 32)	Based on 0.02 of infiltration	No change	
	End of Filling (years from start of waste disposal)	P	No change		No change		No change	
	PE Cap	Yes	No change		No change		No change	
	Infiltration to Grassland (mm/yr)	Single (200)	No change		No change		No change	
	Start of cap degradation (years from end of waste disposal)	250	No change		No change		No change	
	End of cap degradation (years from end of waste disposal)	1000	No change		No change		No change	

Retardation properties used throughout model

All species unretarded in all parts of model						

LandSim Information	Base Model Information			Modification to Base Model (HRA Review 2 2012)	Justification	Modification to Base Model (HRA Review 3 2017)	Justification	2022 HRA Review	Justification
Cell Geometry	Cell Width at Base(m)	113		No change		No change		No change	
	Cell Length at base (m)	200		No change		No change		No change	
	Number of cells all the same	1		No change		No change		No change	
	Each cell (Ha)	Base Area 2.26	Top area 2.36	No change		No change		No change	
	Landfill area (Ha)	Base Area 2.26	Top Area 2.36	No change		No change		No change	
	Final Waste Thickness (m)	Single (8)		No change		No change		No change	
	Waste Porosity (Fraction)	Single (0.35)		No change		No change		No change	
	Waste density (kg/l)	Single (1.8)		No change		No change		No change	
	Waste Field Capacity (fraction)	Single (0.1)		No change		No change		No change	
	Head of leachate when surface water breakout occurs (m)	Single (4)		No change		No change		No change	

All modifications to the leachate inventory are discussed within Section 8 of Geotechnology report 1177r1v1d0712

Model: mnhlcell1Dec2005.sim

	Use Declining Source Term	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Species	Ammoniacal_N	Arsenic	Cadmium	Chloride	Copper	Zinc	Alkalinity
	Species concentration in leachate (mg/l)	Triangular (27.1, 44.7, 67)	Triangular (0.337, 0.576, 0.864)	Triangular (0.0016, 0.0053, 0.008)	Triangular (1180, 1770, 2655)	Triangular (0.016, 0.054, 0.081)	Triangular (0.054, 0.128, 0.192)	Triangular (1590, 2260, 2835)
	Kappa value constant m (mg/l)	0	0.0415	0.0823	0.0298	0.0664	0.0403	0
	Kappa value constant c (mg/l)	0.59	-0.086	0.1589	0.2919	-0.048	0.0561	0.04
	Data are spot measurements of leachate quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Substance to be treated as list 1	No	No	Yes	No	No	No	No

Model: mnhlSept2009.sim

	Use Declining Source Term	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Species	Ammoniacal Nitrogen as N	Arsenic in filtrate as As	Cadmium in filtrate as Cd	Chloride as Cl	Cu	Zn	Lab Alkalinity as CaCO3	BaP	Titanium
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Species concentration in leachate (mg/l)									
	Minimum	7.93	0.63	1.7E-03	10344.68	0.01	0.02	341.67	2.E-06	6.34
	Maximum	202.50	3.01	0.04	260239.50	0.37	0.32	13695.00	0.0000038	27.18
	Most Likely	135.00	2.01	0.03	173493.00	0.25	0.21	9130.00	-	18.12
	Kappa value constant m (mg/l)	0	0.0415	0.0823	0.0298	0.0664	0.0403	0	0	0.0298
	Kappa value constant c (mg/l)	0.59	-0.086	0.1589	0.2919	-0.048	0.0561	0.04	-0.1	0.2919
	Data are spot measurements of leachate quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Substance to be treated as list 1	No	No	Yes	No	No	No	No	Yes	No
	PDF	Triangular	Triangular	Triangular	Log Triangular	Triangular	Triangular	Log Triangular	Uniform	Triangular
	DATA SOURCE	BH15L	L7	BH3D	L7	BH18S	BH20s	BH20s	THEORETICAL SOLUBILITY	L7

Model: mnhlmay2012_HRA_REVIEW2

	Ammonia	Arsenic	Chloride
	mg/l	mg/l	mg/l
Minimum Value	0.05	0.005	1000
Most Likely Value	10	0.3	10000
Maximum Value	50	3	61000
PDF Used	Triangular	Triangular	Log Triangular

HRA Review 2017
No change to leachate inventory

HRA Review 2022
No change to leachate inventory

LandSim Information	**Base Model Information**			
Drainage System	Specified Head	Yes		
	Head on EBS (m)	Single (1.0)		
Engineered Barrier	Composite EBS	Yes		
	Properties			
	Construction includes a CQA system	Yes		
	Defects/hectare as waste is placed (triangular distribution)	Min	Most likely	Max
	Pinholes (0.1-5mm2)	0		25
	Holes (5-100mm2)	0		5
	Tears (100-10,000mm2)	0	0.1	2
	Onset of FML degradation (years since filling commenced)	150		
	Time for area of defects to double (years)	100		
	Clay or BES Substrate			
	Design thickness of mineral liner (m)	Single (0.5)		
	Moisture content (fraction)	Uniform (0.06, 0.1)		
	Hydraulic Conductivity (m/s)	Normal (7.76E-11, 1.7E-11)		
	Longitudinal Dispersivity (m)	Single (0.1)		

Modification to Base Model (HRA Review 2 2012)	**Justification**	**Modification to Base Model (HRA Review 3 2017)**	**Justification**	**2022 HRA Review**	**Justification**
TRIANGULAR(0.1,0.3,0.75)	Leachate monitoring results adopted	No change	Elevated leachate levels evaluated as part of sensitivity analysis	No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	
No change		No change		No change	

LandSim Information	Base Model Information		Modification to Base Model (HRA Review 2 2012)	Justification	Modification to Base Model (HRA Review 3 2017)	Justification	2022 HRA Review	Justification
Unsaturated Pathway	Geological unit	Wind Blown Sand	No change		No change		No change	
	Flow model	Porous medium	No change		No change		No change	
	Pathway length (m)	Triangular (2.6, 3.41, 4.1)	No change		No change		No change	
	Moisture Content (fraction)	Uniform (0.1, 0.12)	No change		No change		No change	
	Conductivity (m/s)	Uniform (2.4E-5, 0.0017)	No change		No change		No change	
Vertical Flow								
	Included in simulation	No	No change		No change		No change	
Aquifer Flow	Geological Unit	Wind Blown Sand	No change		No change		No change	
	Pathway width (m)	Single (223)	No change		No change		No change	
	Mixing zone thickness(m)	Single (2.5)	No change		No change		No change	
	Conductivity (m/s)	Uniform (2.4E-5, 0.0017)	No change		No change		No change	
	Regional Gradient (-)	Single (0.01)	No change		No change		No change	
	Pathway porosity (fraction)	Single (0.3)	No change		No change		No change	
	Dispersion							
	Longitudinal dispersivity (m)	Uniform (4, 15.3)	No change		No change		No change	
	Transverse dispersivity (m)	Uniform (0.4, 1.53)	No change		No change		No change	

MORFA NON-HAZARDOUS LANDFILL
PORT TALBOT

ENVIRONMENTAL PERMIT BV7311IE

Review of Hydrogeological Risk Assessment

Appendix 7
Digital Copy of LandSim Model and Results
Report Number 2238r1v1d0622