HYDROLOGICAL/HYDROGEOLOGICAL RISK ASSESSMENT

Aberthaw Quarry, East Aberthaw, Rhoose, Barry CF62 3ZR

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1 INTRODUCTION

1.1 Background

1.1.1 RPS Consulting Services Limited (RPS) has been commissioned to undertake an updated hydrogeological risk assessment review and controlled waters monitoring strategy at the Aberthaw Quarry site in East Aberthaw, Barry, CF62 3ZR.

1.1.2 The scope of works has been prepared in accordance with a request from RWE for a hydrogeological and hydrological risk assessment review to evaluate the landfill impact on local controlled waters and assess the changes based on a final restoration scheme. The aim and objective of the review and assessment is to provide robust support for an appropriate aftercare-controlled waters monitoring strategy. The controlled water data collected during the permit aftercare period will be used to support any potential future application to Natural Resources Wales (NRW) for the surrender of Environmental Permit Reference BP3339BH.

1.1.3 The Environmental Permit relates to the disposal of Pulverised Fuel Ash (PFA) from the RWE Aberthaw coal fired Power Station into limestone quarry excavated for cement manufacture. The permit was issued on the 4th of May 2007 to accept a single source of waste, this being PFA, designated as a non-hazardous waste. The quarry covers an area of c. 27 hectares and with waste reaching a maximum filled depth of c. 24 m. The quarry landfill is located northeast of the old Aberthaw power station, which formally closed in March 2020 and the quarry last received PFA during 2019.

1.1.4 From the information currently available, it is noted that the quarry was engineered to meet the requirements of the Landfill Directive. This included a 750 mm low permeability lining/attenuation layer on the base of the quarry. A 500 mm thick drainage layer was installed below the liner/attenuation layer and separated by a geotextile. This basal groundwater drainage layer is connected to a 300 mm drainage layer on the batters of the quarry to facilitate the discharge of collected groundwater into a permitted surface water drain installed along the southwestern boundary of the site prior to the waters being discharged into settlement ponds. The fall of the base of the quarry was designed to direct any infiltrated water to a central spine and discharge to the surface water drain along the southwestern boundary.

1.1.5 The pozzolanic nature of PFA limits the potential for leachate generation at the site and therefore there was no regulatory requirement for any leachate management and or control system.

1.1.6 Monitoring at the site has recorded a degree of local impact on sampled controlled waters from the PFA infill operation as indicated in the RWE 2020 Annual Performance Report (RWE, 2020). The principal pathway of this suggested to be surface runoff from uncapped areas of landfill with some fugitive emissions of PFA dust into the surface water drains along the boundary of the site.

1.1.7 It is noted that RWE are currently reviewing the final restoration plan to ensure that all surfaces are appropriately capped and seeded to consolidate the PFA and ensure that run off is free from PFA contamination and the current pathway is broken.

1.2 Scope of Works

1.2.1 The objective of the works is the collection and collation of appropriate controlled water information with respect to concentrations of concern pertaining to PFA used to infill the quarry void, within the terms the Environmental Permit BP3339BH. It is noted that a surface water and groundwater monitoring programme has been implemented across the site in line with the site permit and monitoring reports have been issued to NRW.

1.2.2 RPS propose to review available site information to appraise the evidence of potential impact to the local environment during its operational phase. RPS will also review the proposed restoration scheme for the site, part of the mitigation measures, to reduce infiltration and encourage clean runoff into the adjoining surface water features.

1.2.3 RPS note that due to the site being filled to a lesser extent than originally proposed, as a direct consequence of RWE Power Station closing early than scheduled (2024), a detailed quantification of available restoration material and proposed restoration profiles has been undertaken. A revised restoration scheme is now being considered for the site. The restoration profile that requires consideration in terms of its viability in providing a stable and effective cap that minimises infiltration into the PFA mass balanced with controlled runoff of clean water is based on the following geometry:

1. A 450 mm soil layer, comprising 250 mm topsoil overlying c100 mm sub soil and c100 mm soil forming material. The soil forming material will be generated on site by the processing and screening of quarry backfill to a grain size < 60 mm.
2. A 150 mm drainage layer, generated on site by the processing and screening of quarry backfill to a grain size between 125 mm -60 mm.
3. A 700 mm capping layer of very low permeability compacted PFA below restoration soils and drainage layer.

1.2.4 The above replicates that approved in the planning permission in terms of 600 mm restoration soils /drainage layer and a 700 mm low permeability cap above the PFA mass. The design of the restoration scheme is to capture percolating water after a rainfall event and covey the water into the surface water drainage system and therefore minimise any potential of infiltration into or erosion of the landfill mass.

1.2.5 The hydrological assessment of the above restoration scheme will consider the revised landform, topographical gradient, and proposed surface water drainage network.

1.2.6 To deliver an appropriate assessment of the theoretical risk to the local water environment from this permitted landfill facility the following works shall be undertaken in this report:

- Review of the most recent Hydrogeological Risk Assessment (HRA) report undertaken by Caulmert Ltd (Caulmert, 2018) to check any issues with potential compliance.
- Review of the 2020 Annual Performance report together with more recent data (2020 to 2022) with regard to water quality during infilling and post coal power generation in December 2020.
- Review of conceptual geological / hydrogeological / hydrological model for the site based on the 2020 Annual Performance Report and 2018 Caulmert report. Due to the proposal for 'JFR2775 PFA Quarry Landfill Hydrogeological / Hydrological Risk Evaluation' being submitted in December 2021, the 2021 and 2022 Annual Performance Reports have subsequently been submitted to NRW under permit DP3339BH;
- Collation and interpretation of detailed time-series groundwater quality dataset for all relevant boreholes in the general environs of the quarry and the water quality dataset for surface drainage system and surface waters;
- Collation and review of any available leachate data for PFA from the site;
- Acquisition of relevant information and data where appropriate including surface water body and groundwater body information, climatic data (rainfall), general catchment, trigger level exceedances, pollution incidents;
- Review site-specific groundwater level data;
- Review of the proposed restoration design for the site and evaluate any potential impact on 2018 HRA findings with regards sources, pathways, and receptors;

- Assess the potential for land slip based on saturation of modified 'drainage layer'; (*Reference 230524_R_JFR2782_GJ_Stability_Risk_Assessment_Report_V01 R01.docx*
- Review alternative drainage strategies to promote cap flow conveyance; *(Reference AAC5891 Surface water Drainage design and attenuation scheme)*
- Design a controlled water monitoring strategy as part of the aftercare process when the landfill is in closure phase. The aim of the monitoring would be to demonstrate that the revised restoration works (mitigation measures) are effective in reducing the impact on the local environment;
- Evaluation of the appropriateness of the emission limits specified in the Environmental Permit (Table S4.1 & S4.2). This will be based on review of available baseline data, the 2018 HRA submitted to the NRW and regulatory guidance on water quality standards.

1.2.7 The results shall be incorporated into a hydrogeological /hydrological risk assessment and controlled waters monitoring strategy report.

2 SITE SETTING

2.1 General Description

2.1.1 Aberthaw Quarry Ash Disposal Site (AQAD) is located to located to the east of the former Aberthaw Power Station and to the west of the village of Rhoose, approximately 8 km to the west of Barry, South Wales. The Site is located within the eastern area of the quarry and can be located by national coordinates 304469, 167295 and is accessed from the north via a metal gate off Castle Road.

2.1.2 It is the site of a former limestone quarry of which has been infilled by PFA from the Aberthaw Power Station from 2008 to 2019. The site is operated under permit EPR/BP3339BH.

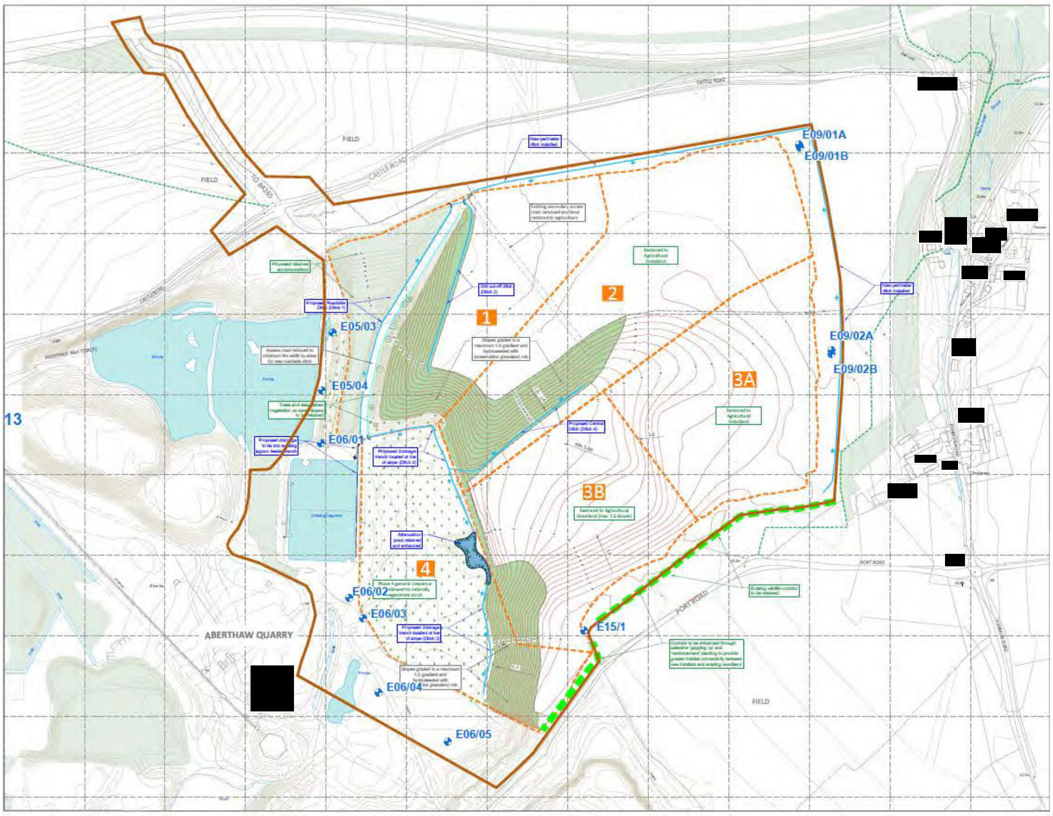
- The PFA has been deposited over five main phases. Phase 1 was filled between 2008 and 2010 and then capped and hydroseeded in Spring 2011. Phases 2A and 2B (Phase 2) was filled between 2010 and 2014 then capped and hydroseeded in 2013/2014. Infilling of Phase 3A commenced in 2013 and remained the working phase for the deposit of PFA. Infilling of 3B commenced in 2015. These phases continued to be worked until the formal closure of Aberthaw Power Station.

2.1.3 The last time Aberthaw Quarry received PFA was during 2019. Aberthaw Power Station formally closed in March 2020. Phases 3A &3B are currently uncapped.

2.1.4 Phase 4 has not received any PFA as the Aberthaw power station ceased operating earlier than its original projected closure date of 2024.

2.1.5 The Site is irregular in shape and is bounded to the north, east and west by agricultural land and to the west by the remaining areas of Aberthaw Quarry. A site location plan is presented in Figure 1 indicating the Environmental Permit (EP) boundary under consideration.

Figure 1. Site Location Plan



2.1.6 The topography indicates relatively high ground elevations of c. 40 to 46 mAOD to the southeast and east boundaries of the landfill site, with ground elevations of c.36 to 40 mAOD near the north western entrance to the site. The ground generally reduces in elevation from east to west, with elevations of c. 20 to 26 mAOD near the settlement pond and cement works lagoon near the western boundary of the site.

2.2 Environmental Setting

2.2.1 Aberthaw quarry is located in the Tawe to Cadoxton Water Framework Directive (WFD) management operational catchment, and within the WFD river catchment of the Kenson River (conference with Waycock to conference with Thaw) of which is located 517 m to the northwest. This is an area of 6.4 km^2 with the Kenson River located in the northern region of this area. It has been indicated the overall status of the catchment is classified as poor, with the chemical status classified as good (based on 2016 assessment).

2.2.2 It is understood that the Kenson River flows from the northeast to the southwest where it joins the River Thaw (Afon Ddawan) to the northwest of the catchment, which flows towards the Bristol Channel.

2.2.3 The WFD groundwater body at the site is the Thaw and Cadoxton (ref. GB41002G201400) which has an overall rating and chemical rating of good (based on 2017 assessment).

2.2.4 As is detailed in Section 2.1.2 the site is an area of landfilling operated by RWE. There is also a landfill that is indicated as closed of which is located at 196 m to the southwest of the site and was operated by Blue Circle Industries Limited. The waste input at the Blue Circle landfill facility was industrial waste. Two further historical landfills are indicated to be present further to the southwest and west by the same operator.

2.2.5 It is evident that there are two surface water features near the western boundary of the site, these being the silt settlement ponds (SP) within the EP boundary, and the lagoon for the Aberthaw Tarmac Plant to the west of the EP boundary.

2.2.6 The site is indicated to be at negligible risk of groundwater flooding. The majority of the site is not considered to be at risk from flooding however there are some areas in the west of the site (near the lagoons) that are considered to be at risk from 1 in 30-year period (depth between 0.3 m and 1 m) with others between this period and the 1 in 1000 year period.

2.3 Pollution Incidents

2.3.1 A Groundsure report of the site (ref. GS-9351278) indicates two pollution incidents on site, one in 2013 and 2015, however these were associated with fugitive dust and nuisance noise pollution respectively. The land and air impact was indicated to be of no impact, with the impact to water being not applicable.

2.3.2 There are three records of pollution incidents within 500 m of the site, with the closest being located at 121 m west, all occurring in 2016 and with no records of impact to water.

2.3.3 There are no records of discharges of substances identified on List I or List II of the European Directive E 2006/11/EC and regulated under the Environmental Damage (Prevention and Remediation) Regulations 2015.

2.4 Abstractions and Source Protection Zones

2.4.1 There are no recorded surface water abstractions identified at the site, with the nearest active abstraction being located at 645 m to the west of the site and associated with LaFarge Tarmac and Cement and Lime Limited (cement works) under licence ref. 21/58/21/0004. This is associated with evaporative cooling and transfer between sources. The direct source of the abstraction is the River Kenson.

2.4.2 There are no records of a potable abstraction within 2 km of the site, and no source protection zones within 500 m of the site.

2.4.3 There are no licensed discharges to controlled waters on site. The nearest off-site record as is indicated in the Groundsure report is located 374 m to the east of the site, of which is sewage discharge via a soakaway at Rock House (revoked in 2018).

2.5 Surface Water and Borehole Monitoring Locations

2.5.1 The surface water and borehole locations that have been part of the routine monitoring programme are presented in Figure 2. Please note groundwater flow has been indicated to be towards the River Thaw located to the west of the site.

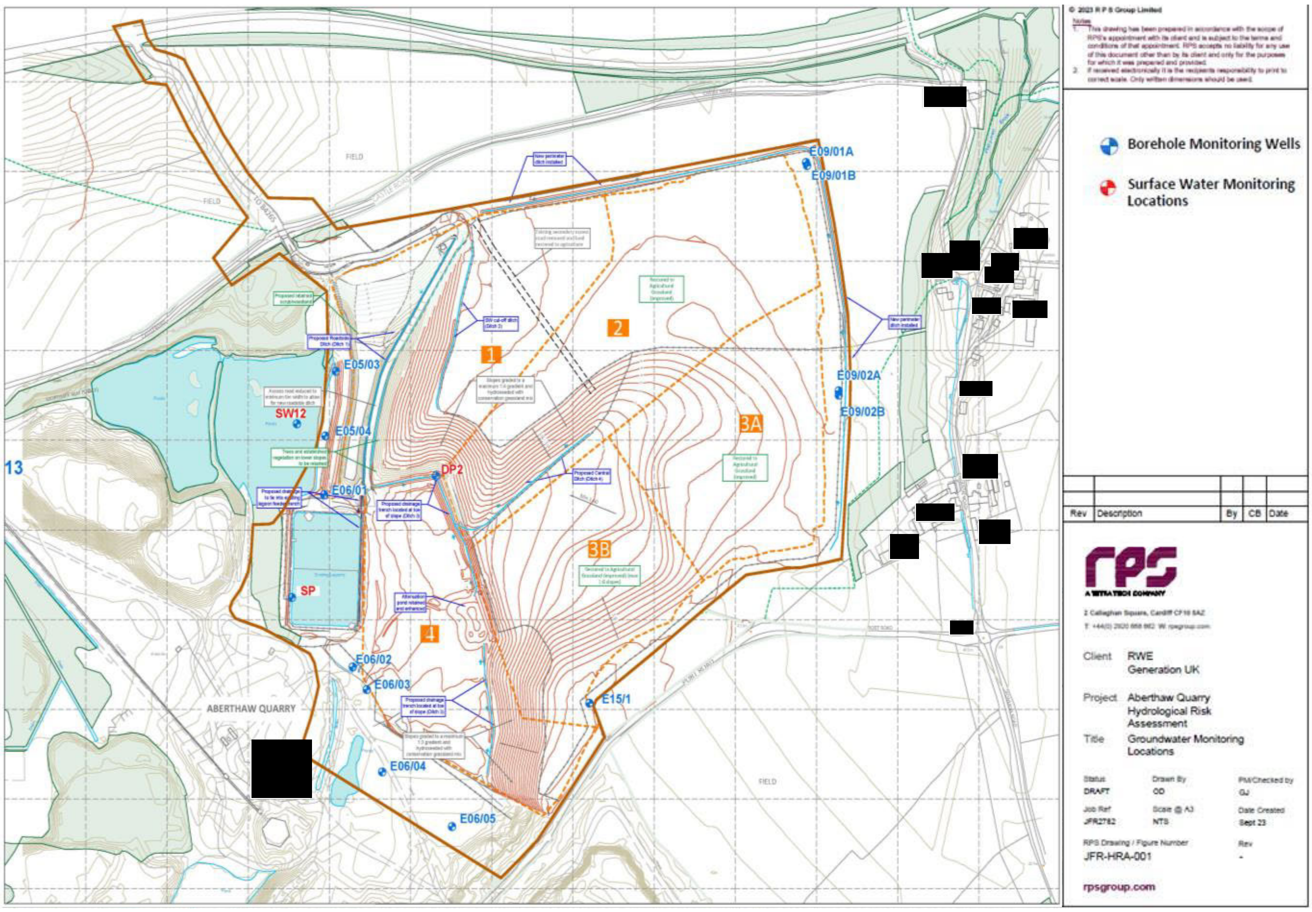
2.5.2 Monitoring boreholes E09-01A, E09-01B, E09-02A and E09-02B are located on the north-eastern site boundary with a spacing of approximately 200 m from one another from north to south. Borehole E15/1 is located on the southern boundary of the site. All of the above boreholes are also considered to be up gradient with respect to groundwater flow. It is considered that concentrations in these boreholes represent background quality prior to the migration of groundwater to the west and across the site.

2.5.3 Monitoring boreholes E05-03, E05-04 and E06-01 are located along the western boundary with an average spacing of 100 m. These are considered to be down gradient with respect to groundwater flow. These are located down gradient of Phases 1 and 2 of the PFA disposal site, with boreholes E06-02 and E06-03 located down-gradient of the most recent PFA disposal area, these being Phases 3A and 3B, and Phase 4 (not used). Boreholes E06-04 and E06-05) are located down gradient of the Phase 4 area.

2.5.4 The surface water monitoring points DP2 (discharge point 2), SP (hard engineered silt settlement ponds) and SW12 (cement works lagoon) are also shown in Figure 2.

Note Surface water monitoring point SW13 to the west of the Aberthaw Quarry has not been included in the monitoring as this was removed in 2013 following agreement with NRW (please see section 3.1.36).

Figure 2. Surface Water and Borehole Monitoring Locations



3 REVIEW OF REPORTS

3.1.1 A number of previous reports that have been undertaken with regard to the hydrological and hydrogeological regime at the site are summarised in this section.

Arup. April 2006. Hydrogeological Risk Assessment. Aberthaw PFA Disposal Facility

3.1.2 The hydrogeological risk assessment was required as part of the IPPC permit application for the site. This was undertaken in accordance with Environment Agency TGN01 and TGN02 guidance. It was undertaken prior to the proposed placement and compaction of PFA at the site.

3.1.3 Numerical modelling using LandSim was undertaken. With regard to leachate collection this was not considered necessary as no unacceptable discharge to groundwater over the lifecycle of landfill site was identified.

3.1.4 The report recommended that no leachate drainage layer or artificial sealing liner is proposed. An artificial geological barrier was proposed in addition to a geosynthetic clay liner in place of a mineral layer.

3.1.5 The proposed disposal of PFA was considered to fall under the scope of the Groundwater Regulations. Leachate testing results suggested that cadmium was the only discernible List I substance to potentially pose an issue with groundwater however the numerical modelling suggested that the artificial geological barrier is posed to provide an effective barrier. With regard to List II substances, the only contaminant of concern identified from the numerical modelling was aluminium however this was considered to be limited by the artificial barrier layer and therefore was not considered to pose a potential risk to groundwater.

3.1.6 The requirement for four systems, these being groundwater drainage, the liner, the cap and surface water control are essential.

RWE Npower plc, Aberthaw Quarry Ash Disposal Site, Permit Ref. BP3339BH: Hydrogeological Risk Assessment Review, 2013

3.1.7 The above review included an improvement plan for the monitoring programme and details the derived compliance limits and control levels for potential contaminants of concern in groundwater and surface water.

3.1.8 The assessment test indicated was for exceedances of control level and compliance limits for three consecutive sampling events. Design and implementation of corrective actions were recommended following informing the Environment Agency and if the risk were deemed to be unacceptable.

3.1.9 Derivation of the limits and levels detailed in this report is discussed in Section 8.

3.1.10 Section 8 also details the removal of surface water monitoring point SW13 of which monitored a drainage channel present near the entrance to LaFarge's quarry to the west of the Aberthaw Quarry site. This channel does not collect surface water from the ash disposal site so recommendation for removal from the permit was indicated. It is understood from RWE that SW13 was removed from the monitoring programme following agreement with the NRW Site Inspector via a Compliance Assessment Report (CAR).

EPR Compliance Assessment Report (CAR), Barrier evaluation, CQA plan, HRA review, monitoring audit, Report ID: BP3339BH/0193845 26/11/2013

3.1.11 A review of the above 2013 HRA review was undertaken in this CAR.

3.1.12 One of the key points was a request for '*RWE npower to provide reports on field and laboratory filtering and monitoring comparison*.' This was addressed in the 2013 Annual Performance Report for the site which indicated that the field filtered, and laboratory filtered samples results were generally comparable. However, to provide representative samples and improve sample quality a change to the sampling protocol to a low flow sampling method was undertaken in 2013.

3.1.13 The proposed compliance limits detailed in the 2013 HRA review (RWE, 2013) were accepted by NRW with a review of the data proposed approximately 2 years after following further data acquisition and a review of a UK and Ireland project addressed environmental quality standards for hazardous substances. The removal of zinc from monitoring suite was also subject to review.

3.1.14 Another key point raised was 'RWE npower to review and if appropriate incorporate under-drainage outflow sampling into the landfill monitoring programme'. This is discussed in the Npower letter report (June 2014) discussed below for which including the recommendation for monitoring of drainage point DP2 in the monitoring programme to address the point above.

RWE npower plc, Aberthaw Quarry Ash Disposal Site, Permit Ref. BP3339BH: Response to CARs BP3339BH/0194816 & BP3339BH/0193845, June 2014

3.1.15 To address the rising trends in some of the trace element concentrations including cadmium, chromium and molybdenum in the settlement ponds, additional discharge points had been included in the monitoring programme, of which included discharge point DP2 of which is the drain that collects the under-drainage from Phase 2 West. It was recommended that monitoring at this location was continued to monitor under-drainage water quality on site and to satisfy the CAR (November 2013).

Caulmert Limited. November 2018. Hydrogeological Risk Assessment Review 2018. Aberthaw Quarry

3.1.16 This HRA review was comprised a review of the 2012 to 2017 results. The review suggested that the ash at the site is impacting the groundwater and surface water quality. Concentrations of PFA markers (including beryllium) were recorded to be higher in surface water than groundwater in down hydraulic gradient borehole locations.

3.1.17 The report provided alternative compliance limits for some of the chemical contaminants in water based on the findings.

3.1.18 It was indicated that the LandSim model that has previously been used to model the migration of chemical contaminants by Arup in 2006 from the site to groundwater and off-site surface water receptors is not considered appropriate due to the contaminant migration appearing to be dominated by a surface water migration mechanism.

3.1.19 It was recommended in this report that chromium VI was included in the monitoring suite with removal of aluminium, selenium, nickel, and antimony. Other recommendations included investigation of the potential for ammonia to be present in ash and an ongoing review of the effectiveness of recent measures that have been put in place within the quarry.

RWE 2020. 2020 Annual Performance Report. Aberthaw Quarry Ash Disposal Site. Permit Number: BP3339BH. March 2021.

3.1.20 The performance of the Aberthaw Quarry Ash Disposal Site in 2020 in accordance with its permit was detailed in the above report. The contaminant concentrations were assessed up until the end of 2020.

3.1.21 Routine monitoring of down and up hydraulic groundwater monitoring boreholes at the landfill site has been undertaken at quarterly intervals.

3.1.22 The main conclusion from the review was that there is a discernible presence of PFA identifier species, these being Molybdenum, Boron, Ammonia in both surface and groundwater. The suggested source of groundwater contamination was indicated to be surface water based on the presence of high concentrations of these species within surface water bodies.

3.1.23 It was indicated that new drainage ditches and channels have been constructed at the quarry over its operational period to mitigate the effect of this potential cause of contamination.

3.1.24 This report recommended that for the final restoration plan all surfaces are capped and seeded to ensure PFA consolidation in the landfill mass and a minimal impact from surface runoff.

3.1.25 The report details the borehole improvement works that were historically undertaken to improve the water quality sampling in the area. This included re-drilling of boreholes E05-03 and E06-01 and raised cover replacement for E06-05 in 2015.

3.1.26 The summary of the results indicated that natural groundwater quality varies between upgradient and downgradient locations.

3.1.27 The down gradient boreholes to the north (E05-03, E05-04, E06-01 and E06-02) consistently have elevated concentrations of sodium with lower concentrations of calcium. Up gradient boreholes to the south (E06-03, E06-04 and E06-05) indicate elevated concentrations of calcium, magnesium, and sulphate. The report suggests that those down-gradient boreholes further north may be subject to ion exchange reactions, with those further south being subject to impact from a natural or quarry related source up hydraulic gradient in that area.

3.1.28 The elevated concentrations of molybdenum were discussed with regard to borehole E05-03 and those boreholes to the west of the Phase 1 area down hydraulic gradient of the fill materials were still highly elevated.

3.1.29 It is understood that natural background molybdenum concentrations in the Porthkerry are less than 3 µg/l with the average pre-filling concentration for the cement works lagoon being 4 µg/l.

3.1.30 It has been indicated that the Phase 1 area was completed about a year prior to the increase in molybdenum concentrations indicated in E05-03 from January 2012. This suggested that the source was unlikely to be from these PFA materials. However, a review of the 2016 dataset indicated an increase in PFA indicator species (boron, sulphate, ammoniacal nitrogen) suggesting that PFA was the contaminant source.

3.1.31 Site investigations in 2014 indicated three potential contaminant sources:

- Discharge from wheel wash pipe into unlined ditch in close vicinity of the borehole;
- Potential erosion PFA materials around the wheel wash pipe into the above unlined ditch;
- Leakage from adjacent cement works lagoon.

3.1.32 Following this, the wheel wash discharge pipe was re-routed into Settlement Pond 1 in 2015. Improvement works of the unlined ditch comprised cleaning out and smoothing of the eroded areas. In terms of the impact in the quality of sampled waters from borehole E05-03, the molybdenum concentration increased until the start of 2017 before beginning to stabilise. Boron, ammoniacal nitrogen and sulphate were relatively stable following these improvement works at borehole E05-03 however they remain at elevated concentrations.

3.1.33 The report details the increase in concentrations of molybdenum between March 2014 and March 2020 to double that of background concentrations, with concentrations showing seasonal variations (higher in winter months). Occasional elevated concentrations of molybdenum were observed in borehole E06-01 post February 2015, including two results in 2020. The report indicated that molybdenum concentrations peaked in 2019 (340 µg/l) in this borehole but was still elevated in 2020 before reducing to concentrations below the trigger level from 2021 and onwards.

3.1.34 The report indicated that the molybdenum concentrations in the settlement pond (SP) have increased since 2012, with large seasonal fluctuations over more recent years (highest in summer months, lowest in winter months). Intermittent nature of groundwater and surface water contamination was suggested at the DP2 location.

3.1.35 Molybdenum concentrations were indicated to have increased consistently at the cement works lagoon monitoring location (SW12) since the start of 2012. It is understood that surface water is intermittently discharged into the cement works lagoon.

3.2 Summary of Findings

3.2.1 The findings of the previous reports indicate:

- The LandSim model cannot be used to produce a realistic hydrogeological assessment. The local bedrock is a formation of intercalated limestones and mudstones with groundwater movement predominantly through fractures.
- The presence of anomalous highly elevated PFA marker species in E5-03 and to a lesser degree in E05-04 cannot be represented in LandSim modelling;
- Improvement of drainage ditches and channels to limit any potential surface water ingress into groundwater does not appear to have improved the situation;
- The concentrations of these PFA marker species (in particular molybdenum) appear to be continuously elevated in borehole E05-03 and have not declined since the improvement works undertaken in 2014 (detailed in section 3.1.23);
- The re-drilling of borehole E05-03 in 2015 does not appear to have resulted in an improvement in water quality with respect to PFA species indicators.

3.2.2 Based on an evaluation of the previous reports, RPS has undertaken the following:

- A site walkover survey to be undertaken of the site to identify any potential contamination issues, particularly in the area of borehole E05-03;
- A further assessment of the time-series data for those determinands since 2020 to evaluate if there have been any more recent changes.
- A qualitative hydrological and hydrogeological assessment focussing on localised potential causes of contamination at key monitoring stations, and not the whole site in general.
- Recommendations for further ground investigation if required to provide site specific information to improve our understanding of the groundwater and surface water regime at the site.

3.2.3 This information will be used to produce an appropriate aftercare controlled waters monitoring strategy. This shall include newly proposed compliance limits if deemed appropriate based on the findings of the environmental monitoring of which will include the 2021 and 2022 datasets.

4 HYDROGEOLOGICAL SITE MODEL

4.1 Introduction

4.1.1 A conceptual site model (CSM) for this site is detailed in this section which consists of an appraisal of the *source-pathway-receptor* 'contaminant linkages' of which applies to the groundwater regime at the site. Based on the presence of the man-made drainage system underneath the landfill site, this includes a hydrological aspect as groundwater is captured in the surface water network.

4.1.2 This is described in the sections below.

4.2 Source

4.2.1 Aberthaw Quarry has be used solely for the disposal of pulverised fuel ash (PFA) from the Aberthaw B coal fired power station. The fill depth across the majority of the site is understood to be up to 24 metres.

4.2.2 PFA is a fine-grained material, and the particles are spherical in shape produced by the coal burning process. The particle size and shape means that compacted PFA will exhibit a low intrinsic permeability (hydraulic conductivity), typically less $1x10^{-8}$ m/s. The low hydraulic conductivity will result in low infiltration rates. Any significant flow through PFA is unlikely to occur as it is dependent on the permeability of the PFA and degree of saturation as well as the hydraulic gradient.

4.2.3 The 2018 HRA (Caulmert, 2018) has provided a summary of leachate compliance testing (BSEN 10:1) that has been undertaken from 2012 to 2017. The results suggest that based on the relative risk rating of the results calculated with respect to assessment screening criteria, the risk rating was highest (in order) for the following determinands:

- Ammoniacal Nitrogen, arsenic, selenium, molybdenum, and chromium.

4.2.4 The assessment screening criteria that were used are Environmental Quality Standards (EQS) or applicable standards where EQS are not available.

4.2.5 The environmental monitoring has indicated that molybdenum, chloride, and boron concentrations are those of which are significantly higher than background concentrations along the western boundary (borehole E05-03 area). This contradicts the results of the leachate testing to some extent where these concentrations are not significantly elevated (except chloride which was not included in the leachate testing).

4.2.6 Also, the concentrations of chloride affect the groundwater quality and it has been indicated by RWE that Power Station Cooling Water (sea water abstraction) has been used to condition ash in prolonged dry periods.

4.2.7 Leachate testing has been undertaken during a ground investigation in 2022 which indicates generally low leachability of molybdenum and chloride for samples of PFA in the landfill mass close to borehole E05-03 (concentrations of <0.002 mg/l and <1.2 mg/l respectively).

4.2.8 The PFA encountered appears be of a typical PFA composition. These materials have been used for a wide range of construction processes across the UK. The nature of the PFA with regard to retainment of trace elements and its low permeability once compacted suggest that the potential risk of leaching is likely to be restricted on site. Based on the typically pozzolanic nature of PFA which limits the potential for leachate generation at the site, there was no regulatory requirement for any leachate management and or control system.

4.2.9 Currently the PFA materials of which are deposited in the three of the four main phased areas only Phases 1 & 2 of these have been fully restored. The PFA deposited in Phase 1 and Phase 2 have been restored with 300 mm topsoil which overlies 150 mm subsoil followed by a 150 mm drainage layer. Underneath the drainage layer is 750 mm of compacted PFA. The overall drainage layer is 1.3 m thick and designed to transmit infiltrated water into a surface water drainage system, which will discharge via the existing silt settling ponds, located to the west of the site.

4.3 Pathway and Receptors

4.3.1 The bedrock underlying the site comprises the Lower Lias Limestone (Porthkerry Member), of which is indicated to comprise thinly interbedded limestones and calcareous mudstone (BGS) with limestone indicated to be comprise more than 50% of the composition beneath the power station and ash disposal sites (Caulmert, 2018).

4.3.2 The Porthkerry Member indicated to be classified as a Secondary A aquifer with high groundwater vulnerability and leaching potential.

4.3.3 Fracture flow has been identified as the predominant flow mechanism in this formation. Hydraulic conductivities in the Porthkerry Formation of between 2 x 10^{-8} m/s and 7 x 10^{-6} m/s have been identified on site by in situ testing (Entec, 2005) indicating a relatively low hydraulic conductivity.

4.3.4 Borehole installation details for those boreholes that are monitored in the area are presented in Table 4-1.

4.3.5 Groundwater elevations have indicated flow to be towards the west and northwest, i.e. towards the lagoons in the northwest of the site. This is based on groundwater monitoring from wells that are located up and down gradient of the landfill areas.

4.3.6 From the information currently available, it is understood that the quarry was engineered to meet the requirements of the Landfill Directive. This included a 750 mm low permeability lining attenuation layer at the base of the quarry. A 500 mm thick drainage layer was installed below the liner/attenuation layer and separated by a geotextile membrane.

4.3.7 It is noted that this basal groundwater drainage blanket layer is connected to a 300 mm drainage layer on the batters of the quarry to facilitate the discharge of collected groundwater into a permitted surface water drain installed along the southwestern boundary of the site prior to the waters being discharged into the settlement ponds. The fall of the base of the quarry was designed to direct any infiltrated water to a central spine and discharge to the surface water drain along the southwestern boundary.

4.3.8 The conceptual cross section which has been obtained from the Caulmert hydrogeological risk assessment (Caulmert, 2018) presented in Figure 3. Cross Section of Landfill Drainage with respect to Groundwater (Caulmert, 2018). Figure 3 indicates the flow up hydraulic gradient of the landfill site, if not already flowing beneath the landfill, is likely to migrate into the drainage blanket layer at the sides and base of the landfill and then flow beneath it.

4.3.9 It understood that unlined surface water drainage channels located throughout the site will collect shallow groundwater flow from within the drainage blanket layer and overland flow from across the surface of the landfill site. The restored surface of the landfill site is suggested to allow limited infiltration of rainfall into the landfill mass.

4.3.10 It is understood that the hydraulic conductivity of the Lower Lias Limestone is low with water being transmitted via fractures and fissures. This comprises low primary permeability and limited secondary permeability via the fractures and fissures. The drainage blanket layer will be a significant permeability contrast and therefore readily dewaters groundwater discharge under the landfill via the drainage blanket to the surface water ditch which connects to the silt settlement ponds. Effectively, the groundwater in the formation beneath the site is controlled and should not enter the landfill mass.

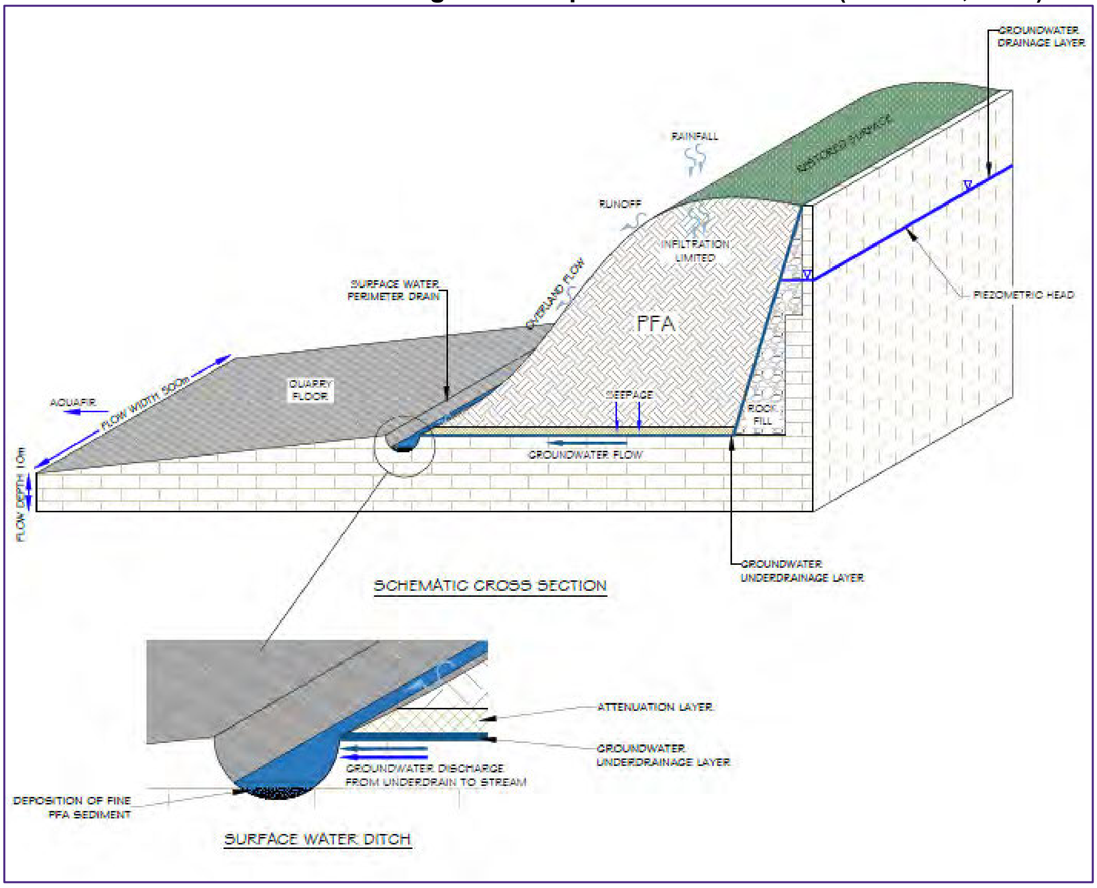
4.3.11 Contour plans for those monitored boreholes detailed in Table 4-1 are presented in Drawing JFR2782-HRA-01.

4.3.12 Shallow depths to groundwater have been identified on the western boundary. Based on the natural groundwater flow direction in the area (without involvement from the landfill site drainage system) it is considered likely that flow would continue to the west. However, based on its shallow depth, there is potential for groundwater to provide a small element of base flow to the surface water lagoons located on the western boundary. As discussed earlier in this section, with regard to the landfill site itself, infiltration, and percolation through the PFA is considered likely to be negligible. Any percolation that reaches the base of the landfill site, is likely to be collected by the drainage system and then drained to the silt settling ponds.

Table 4-1. Monitoring Borehole Installations

Borehole ID	Response Zone Depths (mbGL)	Drilled Base Depth (mbGL)	Groundwater level (26-Apr-2022) (mbGL / mAOD)	Screened Geology
E05-03	3 – 15	15	0.15 / **18.67**	Limestone and shale bands
E05-04	2.5 – 20	20	0.58 / **18.30**	Limestone and shale bands
E06-01	3 – 15	15	1.74 / **18.97**	Limestone and shale bands
E06-02	2 – 10	10	1.23 / **20.54**	Limestone and shale bands
E06-03	2 – 10	10	1.19 / **21.47**	Limestone and shale bands
E06-04	2 – 10	10	1.79 / **22.11**	Limestone and shale bands
E06-05	2 – 8	8	1.81 / **24.89**	Limestone and shale bands
E09-01A	18 – 24	25	18.79 / **25.97**	Limestone and shale bands
E09-01B	24 – 30	31	20.08 / **24.67**	Limestone
E09-02A	21 – 27	28	17.41 / **27.39**	Limestone and shale bands
E09-02B	27 – 33	34	15.73 / **29.08**	Limestone and shale bands
E15-1	17 – 29	30	17.29 / **30.13**	Limestone and shale bands
E15-2	1 – 7	7	No longer monitored	Made Ground

Figure 3. Cross Section of Landfill Drainage with respect to Groundwater (Caulmert, 2018)



(Caulmert, 2018)

4.3.13 It is understood that these drainage channels flow to the west with drainage channels focused in the southwest of the site. Discharge point 2 (DP2) located along these channels, which is one of the surface water monitoring locations, is fed by the landfill areas to the north and east. The surface water runs west above ground and through then underground pipework to be discharged into the settlement ponds (SP). The settlement ponds are constructed on the quarry base, with concrete and butyl lined 3 m high bunds.

4.3.14 PFA entrained in surface water runoff from unrestored areas of the site is allowed to settle out in the attenuation ponds. Ultimately, waters from the settlement ponds are discharged into the adjoining surface water lagoon through penstocks to the northwest, where sample SW12 is collected from the eastern shores. SP and DP2 samples have been collected monthly with SW12 sample being collected quarterly by an external contractor. The surface water monitoring points are presented in Figure 2.

4.4 Northeast of Lagoon Area (Borehole E05-03)

4.4.1 Groundwater monitoring undertaken has recorded relatively high concentrations of molybdenum, a PFA species indicator, and chloride have been identified in borehole E05-03.

4.4.2 As is detailed in Table 4-1, this borehole was drilled to 15 metres below ground level (mbGL), with a screened section between 3 mbGL and 15 mbGL. This monitoring well was installed in January 2015 to replace a previously groundwater monitoring borehole in this location. The water strike was indicated to 3.5 mbGL with the rest water level raising to ground level.

4.4.3 The molybdenum concentrations in this area appear to be associated with the surface water. Sampled waters from SP and DP2 exhibit higher concentrations than SW12 as is expected as the drainage channels have collected water which has been in contact with PFA surfaces from the unrestored areas of site.

4.4.4 SW12 is an open body of water with any waters from the settlement ponds draining into this feature. This body of water appears to collect drainage from other areas to the west of the site. The water in the lagoon appears to be at a similar elevation to ground level at E05-03 and this large open body of water is very close to the groundwater monitoring station. The anomalous water quality data recorded at E05-03 appears to be consequence of there being a significant degree of hydraulic connectivity between the lagoon and local shallow groundwater monitored at this location.

4.4.5 Time series concentration plots in Section 5.5 detail that borehole E05-03 and SW12 are exhibiting a close relationship with regard to molybdenum signatures and concentrations of the same order of magnitude. Sampled waters from E05-03 have, since 2016, recorded three orders magnitude concentration higher than the eluate analysis of leached PFA (c. 1,250 µg/l and c. 2 µg/l respectively).

4.4.6 The rapid increase in molybdenum concentrations between 2015 and the end of 2016 in borehole 05-03 following a more stable period of elevated concentration (2016 to 2022) appears likely to be related to the installation of the new borehole. It is probable that the replacement borehole installed in January 2015 is exhibiting a greater degree of hydraulic connectivity with the adjoining lagoon than the original installation.

4.4.7 By 2014, phases 1 and 2 were restored and infilling of Phase 3 A commencing in August 2013 followed by the commencement of infilling of Phase 3B in April 2015. Concentrations of molybdenum recorded increase in maximum molybdenum concentration in the sampled water from the silt settlement ponds (SP) from c. 1,850 µg/l (2012 to 2013) to c. 3250 µg/l (2015 to Q3 2018). Between 2018 and 2020 concentrations have fluctuated at a high level.

4.4.8 The current unrestored area and evidence of surface water rills and channels developed across Phase 3A and 3B is the likely mechanism for the elevated concentrations recorded at SP. Erosion of PFA surfaces by turbulent surface water flow over dry PFA during the summer months will result in the mobilisation of dissolved species into the surface water drainage system.

4.4.9 With respect to chloride, the difference in concentrations between borehole E05-03 and the surface water concentration at SW12 is more significant than molybdenum with much higher concentrations encountered in the borehole.

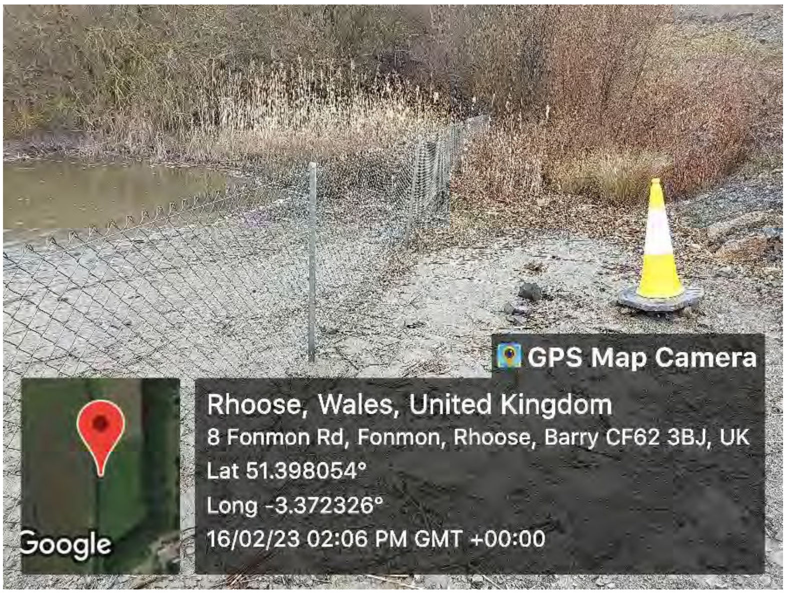
4.4.10 An overlay of the location of the borehole compared to the original cement works lagoon location is provided in Figure 5 below. The overlay indicates that the location of the borehole is very close the original lagoon location.

4.4.11 Concentrations of molybdenum recorded in sampled waters from E05-03 appear likely to be consequence of a preferential pathway, via fractures in the limestone, from the lagoon to the borehole.

Figure 4. Borehole E05-03 and Lagoon Location

In addition to the above contaminant pathway there is evidence of the area around borehole E05-03 being periodically flooded from the adjacent lagoon. Figure 6 show an area of flooding to the immediate west of borehole E05-03. Under such conditions it is considered that there is the potential of lagoon water to directly recharge waters in the borehole via any failures in the annular seal around the cased section of the installation.

Figure 5. Borehole E05-03 area of flooding from adjoining open body of water



5 CONTAMINATION ASSESSMENT

5.1 Introduction

5.1.1 To provide a more recent assessment of the water quality at the site, chemical analysis data provided from 2013 to the end of 2022 has been reviewed at the following locations:

- Down-gradient boreholes: E05-03, E05-04, E06-01, E06-02, E06-03, E06-04, E06-05;
- Up-gradient boreholes: E09-01A, E09-01B, E09-02A, E09-02B, E15-1;
- Surface water monitoring locations: SW12, SP (Settlement Ponds), DP2.

5.1.2 This provides an assessment of data over a 10 year period ("the monitoring period") based on the data provided by RWE.

5.1.3 In permit BP3339BH, the emission limits for the discharge point to the settlement ponds is detailed in Table S4.1 for point source emissions to water (for discharge point from settlement ponds) and in Table S4.2 for emissions into groundwater (boreholes E05-03 and E05-04). The requirements from this permit and summarised in the table below.

5.1.4 In accordance with the permit, an exceedance is defined as a result above the compliance limit (indicated to be emission limits for surface water as measured at monitoring point SP, and emission limits for groundwater as measured at monitoring points E05-03 & E05-04).

5.1.5 RWE have employed control levels, set at levels below the permit emission limits, as part of their proactive monitoring strategy for the site. Annual performance reports predicated on outputs from their monitoring strategy underpins the hydrological/hydrogeological conceptual model for the site.

5.1.6 For the purpose of the assessment in this section, only the compliance limits specified in the permit have been used for comparison.

5.1.7 Contours plots showing concentrations for a number of contaminants in groundwater in 2021 and 2022 are presented in Drawings JFR2782-HRA-02 to JFR2782-HRA-01.

Table 5-1. Summary of Emissions Limits (Trigger Levels) from Permit BP3339BH

	Parameter	Emission Limit	Unit	Monitoring Frequency
Discharge point from settlement ponds to surface water course	Total Ammonia as N	0.6	mg/l	Monthly
	Arsenic	50	µg/l	
	Boron	2	mg/l	
	Cadmium	5	µg/l	
	Chromium	50	µg/l	
	Sulphate	400	mg/l	
	Vanadium	60	µg/l	
	pH	<9	pH units	
E05/03; E05/04	Aluminium	50	µg/l	Quarterly
	Ammoniacal Nitrogen	1.6	mg/l	
	Arsenic	10	µg/l	
	Boron	2.8	mg/l	
	Cadmium	0.4	µg/l	
	Chromium	50	µg/l	
	Molybdenum	50	µg/l	
	Sulphate	400	mg/l	
	Vanadium	20	µg/l	

5.2 Groundwater Quality – Down Gradient Boreholes

5.2.1 Time-series graphs for concentrations of key contaminants in the down gradient boreholes have been plotted between February 2013 and the end of 2022. The graphs are presented in **Appendix A**. The results are summarised below for down-gradient boreholes.

Ammoniacal Nitrogen

5.2.2 There were no concentrations above the compliance limit of 1.6 mg/l in boreholes E05-03 and E05-04. The highest concentrations observed since 2013 were in borehole E05-03 where a concentration of 1.24 mg/l was encountered in December 2015. From 2020 onwards, the concentrations reached a maximum of 0.86 mg/l in September 2021 in this borehole.

5.2.3 In the boreholes without compliance limits, the concentrations did not exceed the E05-03/04 compliance limit except for at borehole E06-02 where an anomalous concentration of 2.81 mg/l was identified in October 2022 and was attributed to localised flooding around the borehole at the time of sampling. The ammoniacal nitrogen did not exceed 1 mg/l at this location during any other monitoring rounds over the monitoring period.

Aluminium

5.2.4 There were no concentrations above the compliance limit of 50 µg/l in boreholes E05-03 and only one concentration above this limit for borehole E05-04 (82.6 µg/l in November 2018).

5.2.5 The majority of concentrations were below 50 µg/l. The concentration at borehole E06-01 in September 2021 exceeded the E05-03/04 compliance limit on one occasion where a concentration of 580 µg/l was recorded but this was considered spurious as it falls well outside of the historical, and subsequent future, trend for this location.

Arsenic

5.2.6 There were no concentrations above the compliance limit of 10 µg/l in boreholes E05-03 and E05-04.

Boron

5.2.7 There were no concentrations encountered above the E05-03/04 compliance limit of 2,800 µg/l for any downgradient location.

5.2.8 The highest concentrations were observed in borehole E05-04 where from 2020, concentrations of between 1850 µg/l and 2460 µg/l (with an arithmetic mean of 2134.0 µg/l from September 2013 to end of 2022) were encountered. Concentrations were also relatively high in boreholes E05-03, E06-01 and E06-02 where concentrations were consistently above 1,000 mg/l. Moving south away from the settlement ponds and lagoons the concentrations are generally reduced.

Cadmium

5.2.9 There were no exceedances of the E05-03/04 compliance limit of 0.4 µg/l for cadmium since 2020, with the exception of exceedances in March 2020 and November 2022 for borehole E05-03 where the applied laboratory limit of detection (LOD) of 2 µg/l and 0.5 µg/l respectively were higher than the trigger level so it is unclear whether these were exceedances or not however it is considered unlikely based on the previous results.

5.2.10 Between September 2013 and 2020, there were a number of exceedances of the compliance limit, but all results were at or below 2 µg/l and again many were due to the application of an LDL greater than the compliance limit by the external accredited laboratory.

5.2.11 Generally, the concentrations of cadmium appear to be very low.

Chromium

5.2.12 The concentrations of chromium were generally very low, with no exceedances above the trigger level of 50 µg/l during the entire historical monitoring period for boreholes E05-03 and E05-04.

5.2.13 In the boreholes without compliance limits, there were also no exceedances of the compliance limit.

5.2.14 The inclusion of hexavalent chromium in the monitoring suite began in 2019. It was only occasionally identified above LOD, with a maximum concentration of 3.8 µg/l observed in E06-04 in March 2020 which was considered spurious at the time.

5.2.15 Molybdenum

5.2.16 The concentrations of molybdenum have shown continuous exceedances above a trigger level of 50 µg/l for borehole E05-03 between the September 2013 and November 2022 monitoring period. The exceedances for this borehole are discussed further in Section 5.5.

5.2.17 With regard to the boreholes without compliance limits, exceedances of this concentration have been encountered on three occasions during the monitoring period for borehole E06-01 (maximum of 160 µg/l in March 2020) and on six occasions for borehole E06-02 (maximum of 340 µg/l in August 2019).

Sulphate

5.2.18 Concentrations of sulphate were frequently encountered above the E05-03/04 compliance limit of 400 mg/l in borehole E05-03 (13 no. exceedances from 2020 onwards reaching 808 mg/l in October 2022).

5.2.19 In boreholes without trigger levels, there were frequent exceedances of this concentration in borehole E06-05 (10 no. exceedances from 2020 onwards reaching 646 mg/l in October 2020), E06-04 (10 no. exceedances from 2020 onwards reaching 1,230 mg/l in October 2020), and E06-03 (6 no. exceedances from 2020 onwards reaching 487 mg/l in October 2022). Two occasional marginal exceedances were also encountered from 2020 onwards for borehole E06-02.

5.2.20 Elevated concentrations of sulphate have been observed in the majority of down-gradient boreholes. It is understood that sea water has historically been used for conditioning ash at the site.

Vanadium

5.2.21 There were no exceedances observed for vanadium above the trigger level of 20 µg/l during the monitoring period for boreholes E05-03 and E05-04.

5.2.22 For boreholes without trigger levels, there were also no exceedances of the trigger level. The maximum recorded result was 13 µg/l for E06/02 in May 2015.

Chloride

5.2.23 The concentrations of chloride have shown continuous exceedances above the EQS of 250 mg/l for borehole E05-03 between November 2013 and November 2022 monitoring period. The exceedances for this borehole are discussed further in Section 5.5.

5.2.24 For other boreholes no concentrations have been encountered above 250 mg/l from 2020 onwards with the exception of E05/04 which recorded a level of 258 mg/l in February 2022. It is noted that there is no trigger level for chloride specified in the permit.

5.2.25 Generally low concentrations of contaminants were encountered for a range of determinands including metals in the down gradient monitoring boreholes. Mercury concentrations were only occasionally encountered above LOD. It is understood that zinc has been removed from the monitoring suite for down hydraulic gradient borehole locations since 2013 based on generally low concentrations being encountered prior to this.

5.3 Groundwater Quality – Up Gradient Boreholes

5.3.1 Time-series graphs for concentrations of key contaminants in the up hydraulic gradient boreholes have been plotted between February 2013 and to the end of 2022. The graphs are presented in **Appendix A**. The results are summarised below for up-gradient boreholes. It should be noted that the trigger levels (compliance limits) specified in the permit are in place for boreholes E05-03 and E05-04. Assessment of the up hydraulic gradient boreholes allows an assessment of the nature and extent of any contamination entering the site, which may contribute towards any elevated concentrations of contaminants at the western boundary.

Ammoniacal Nitrogen

5.3.2 Ammoniacal nitrogen concentrations have remained below the trigger level of 1.6 mg/l for all boreholes except borehole E09-2A where 7 no. exceedances have been observed since 2013, with the most recent being 2.47 mg/l in October 2022.

Aluminium

5.3.3 Aluminium concentrations were generally very low with concentrations typically below LOD and only one exceedance above the trigger level of 50 µg/l in borehole E09-2B in March 2018 (450 µg/l) which was attributed to being due to an excursion from sampling practice.

Arsenic

5.3.4 Arsenic concentrations were very low, and not exceeding 4 µg/l over the monitoring period.

Boron

5.3.5 Boron concentrations were all significantly below the trigger level of 2.8 mg/l, with a maximum concentration of 0.917 mg/l observed in borehole E15-1 in September 2021.

Cadmium

5.3.6 Very low concentrations of cadmium were identified in these boreholes, not exceeding 0.2 µg/l.

Chromium

5.3.7 Very low chromium concentrations were observed over the monitoring period, not exceeding 5 µg/l in the boreholes. Hexavalent chromium concentrations were also very low, and only occasionally elevated above LOD.

5.3.8 Molybdenum

5.3.9 No exceedances above the trigger level of 50 µg/l were observed for molybdenum in the boreholes over the 2013 to 2022 monitoring period, with the exception of borehole E15-1 in September 2021 where a concentration of 112 mg/l was encountered. The next highest concentration from 2020 and onwards was 23 µg/l (E09-2B, April 2021). Otherwise concentrations are typically below 10 µg/l.

Sulphate

5.3.10 There were no exceedances of the trigger level of 400 mg/l at any of the borehole locations. The highest concentration was observed in borehole E15-1 (292 mg/l, November 2017).

Vanadium

5.3.11 Vanadium concentrations did not exceed the trigger level of 20 µg/l over the monitoring period, with the majority of concentrations below 2 µg/l.

Chloride

5.3.12 Concentrations in the up-gradient boreholes did not exceed 250 mg/l, and were generally below 50 mg/l.

5.3.13 Mercury concentrations were only occasionally encountered above a LOD of 0.01 µg/l.

5.4 Surface Water Quality

5.4.1 Time-series graphs for concentrations of key determinands have been plotted between January 2013 and the end of 2022 for the surface water monitoring locations (SW12, SP, DP2). The graphs are presented in **Appendix A**.

5.4.2 A comparison with the emission limits specified in the permit have been undertaken using the SP samples. Location SW12 is listed as an emission point in the permit. RWE has informed RPS that location DP2 was locally agreed with the site inspector to be added to the permit in 2014. Location SW12 (cement works lagoons) is the nearest sampling location off-site from the discharge point that is down gradient in the system. The results are summarised below for the surface water monitoring locations.

Ammoniacal Nitrogen

5.4.3 Concentrations of ammoniacal nitrogen were frequently elevated above the emission limit of 0.6 mg/l for location SP. At SP, from 2020 onwards, an anomalously high concentration of 28 mg/l was identified in January 2020 with concentrations not exceeding 7.5 mg/l in any other monitoring round.

5.4.4 The concentrations in DP2 showed a general increase with fluctuations (highest in summer months) from 2018 onwards and from 2020 onwards a maximum concentration of 23.3 mg/l was encountered (June 2020).

5.4.5 At location SW12, the concentrations were very low, and did not exceed 0.6 mg/l during the monitoring period.

Arsenic

5.4.6 Arsenic concentrations did not exceed the emission limit of 50 µg/l at any of the surface water locations over the monitoring period.

Boron

5.4.7 Three exceedances of the emission limit of 2,000 µg/l were observed in SP from 2020 and onwards, with the highest being 10,000 µg/l in November 2020. The other exceedances from 2020 onwards did not exceed 2,200 µg/l.

5.4.8 A highly elevated concentration of 13,000 µg/l was also observed at DP2 in November 2020, but has not been repeated since. Occasionally elevated concentrations were also observed at locations SP and DP2 but not exceeding 2,300 mg/l.

Cadmium

5.4.9 Cadmium concentrations were generally very low and did not exceed the emission limit of 5 µg/l. All concentrations have been below 0.5 µg/l from 2020 onwards.

Chromium

5.4.10 Over the monitoring period there were no exceedances above the emission limit of 50 µg/l for SP for chromium.

5.4.11 For DP2, there were 5 no. occasions where the concentration was above the discharge limit with a maximum concentration of 80.1 µg/l in May 2014. From 2020 onwards, there was one exceedance, this being 64 mg/l at DP2. Concentrations are generally low.

Sulphate

5.4.12 Sulphate concentrations were consistently elevated at SP with the majority of concentrations at concentrations above the emission limit of 400 mg/l including all results since January 2021 for all three surface water locations.

5.4.13 The results are also generally increasing and highly fluctuating with results from 2020 and onwards typically between 400 mg/l and 1200 mg/l for SP and DP2, and between 500 mg/l and 800 mg/l for SW12. The concentrations at the SP and DP2 locations tend to be at similar levels with the concentrations at SW12 being generally lower For example, in July 2022, sulphate concentrations were 1,190 mg/l (DP2), 1,160 mg/l (SP) and 856 mg/l (SW12).

Chloride

5.4.14 Chloride concentrations have shown a gradual increase at the surface water monitoring locations since the 2013 to 2022 monitoring period reaching 1,970 mg/l in the SP (August 2022) albeit with highly fluctuating concentrations (highest in summer months). Concentrations reduced to the end of year with a concentration of 658 mg/l at the SP in December 2022.

Molybdenum

5.4.15 Molybdenum concentrations have fluctuated but shown an increase over the monitoring period at reaching 6,100 µg/l at SP and 7,100 µg/l at DP2 in August 2022. A more gradual increase was observed at SW12 with lower concentrations, and a maximum concentration of 3,740 µg/l in July 2020. A graph of chloride and molybdenum concentrations at SP is shown in Figure 7.

Vanadium

5.4.16 Vanadium concentrations were all below the emission limit of 60 µg/l at surface water monitoring locations over the 2013 to 2022 monitoring period and were below 20 µg/l from 2020 onwards. The concentrations are generally low although have indicated a steady rise in concentration from 2.5 µg/l in February 2022 to 19 µg/l in August 2022 in DP2 prior to reducing to lower concentrations by the end of the year.

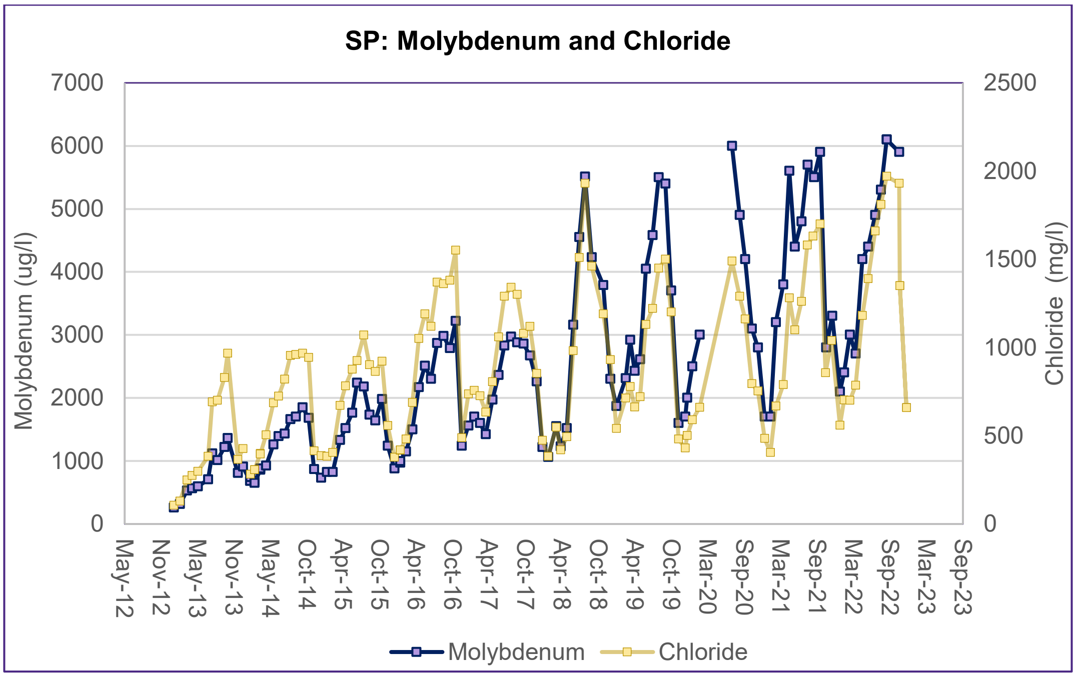
PH

5.4.17 No exceedances of the trigger level of 9 pH units have been indicated in the 2013 to 2022 monitoring period. The results have also not dropped below 7 pH units, with results typically between 7.5 and 8.5 pH units. Results are slightly lower for DP2 compared to the other two surface water locations.

Cyclical Trends

5.4.18 Time series data for surface waters indicates cyclical peaking and troughing of concentrations, with peaks occurring in July/August when dry weather is expected and there is less dilution of PFA species. During drier periods, PFA surfaces may also be prone to heightened runoff following intense summer rain fall events. This may lead to small and localised erosion features (rills) being developed in exposed PFA surfaces and the mobilisation of PFA species into the surface water drainage system.

Figure 6: Molybdenum & Chloride: SP



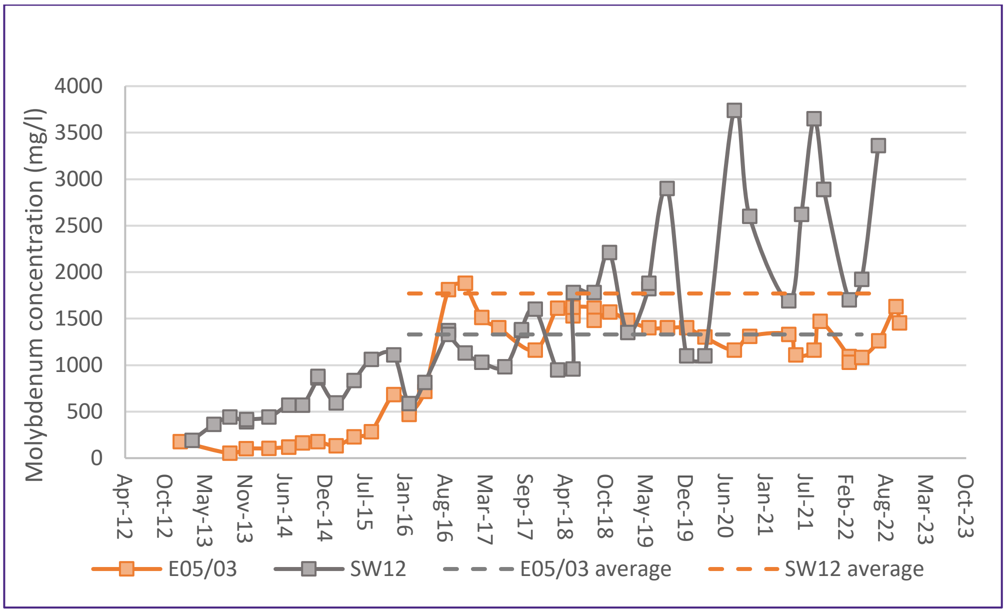
5.5 Borehole E05-03

5.5.1 An anomalous elevated nature of molybdenum and chloride concentrations has been identified in borehole E05-03 from 2015 to 2020 appears to have been maintained over the monitoring undertaken in 2021 and 2022, although the molybdenum concentrations have shown a slight reduction. Figures 8, 9 and 10 show these concentrations at borehole E505-03.

5.5.2 Concentrations of molybdenum at borehole E05-03 and surface water monitoring location SW12 from the routine monitoring between January 2013 and July 2022 have been presented in Figure 8.

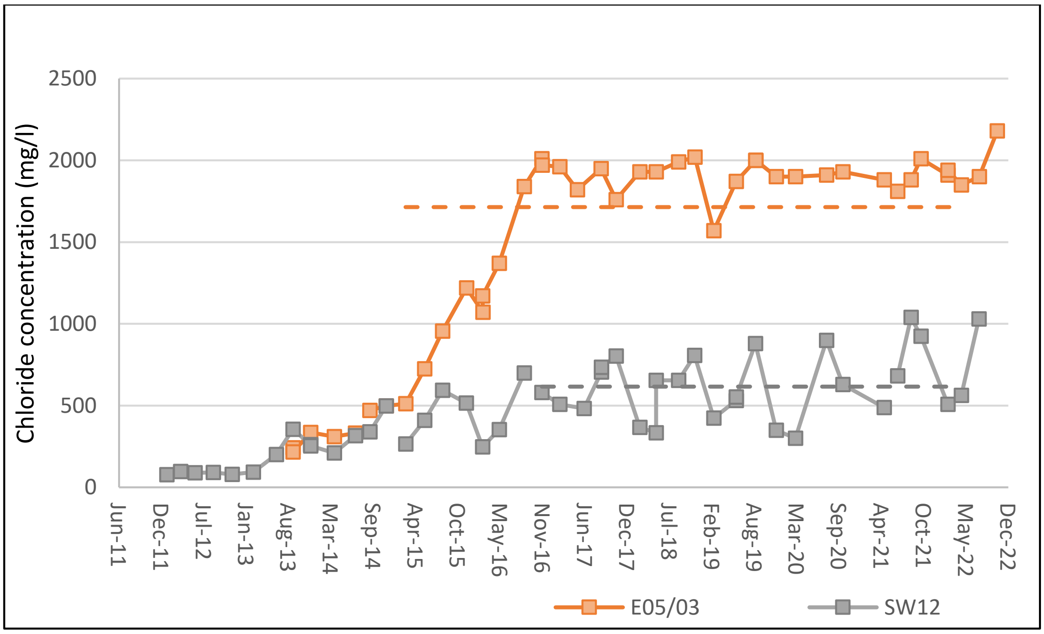
5.5.3 Molybdenum concentrations at borehole E05-03 have gradually increased from a maximum of 177 µg/l in 2013 to a peak of 1,880 µg/l in November 2016. The results then have shown a gradual reduction down to concentrations of 1,080 µg/l by April 2022 before increasing to 1,630 µg/l in October 2022. With regard to surface water location SW12, the results have appeared to be higher than those for E05-03, with concentrations ranging from 190 µg/l in February 2013 to a peak of 3,740 µg/l with significant fluctuations.

Figure 7. Molybdenum: Borehole E05-03 & SW12



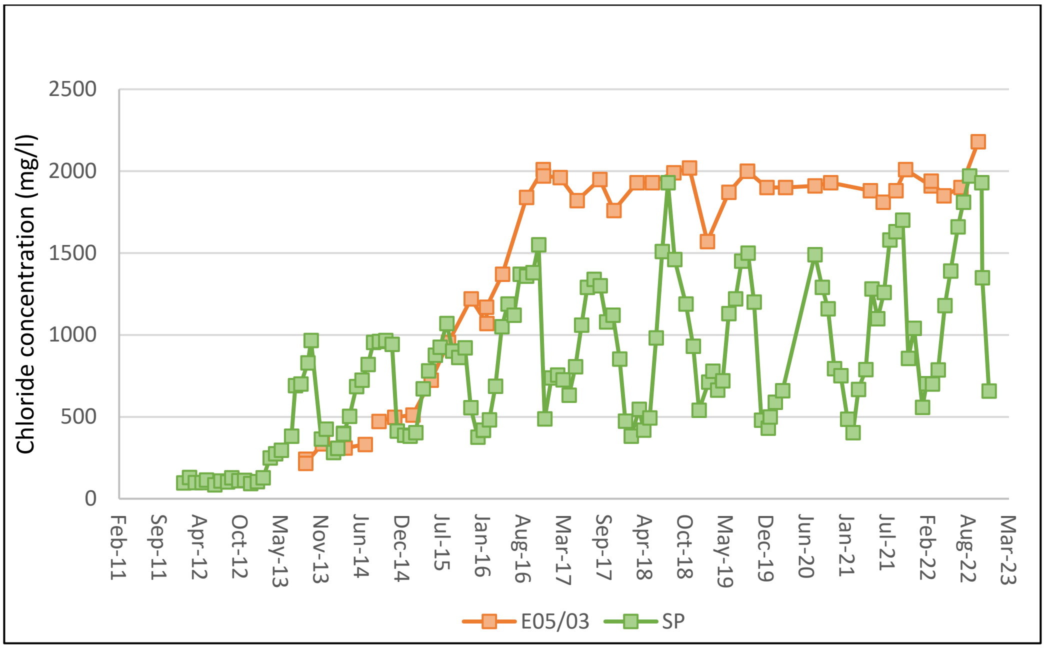
5.5.4 The higher concentration of molybdenum in the surface water monitoring location initially indicates that the lagoon is the principal source of the elevated concentrations identified in the monitoring point E05-03. A replacement borehole was installed at 05/03 in January 2015 and water quality date from this new borehole has recorded a steep increase in Molybdenum concentration from Q4 2015. This suggest there being a significant degree of hydraulic connectivity between the lagoon and local shallow groundwater monitored at this location.

Figure 8. Chloride: Borehole E05-03 & SW12



5.5.5 As is discussed in Section 5.5, the chloride concentrations are anomalous at borehole E05-03 with significantly higher concentrations than the neighbouring water feature at SW12. The concentrations at DP2 and SP had higher fluctuating concentrations than SW12, but the average concentrations were significantly lower than for borehole E05-03. The concentrations have remained relatively stable at a high level between 2020 and 2022 although have shown some increase between July and October 2022.

Figure 9. Chloride: Borehole E05-03 & SP



5.5.6 Boron was also indicated to be relatively elevated, particularly at boreholes E05-04, E06-01, E06-02 and E05-03 although concentrations did not exceed the E05-03/04 compliance limit. This is also the case for the surface water monitoring locations.

5.6 Summary of Results

5.6.1 The review of the environmental monitoring data from 2013 to 2022 (“the monitoring period”), has indicated elevated concentrations above compliance limits for the following determinands in surface water for surface water locations SP:

- Ammoniacal nitrogen;
- Sulphate (frequent exceedances);
- Boron.

5.6.2 Surface water monitoring location DP2, which does not have permitted emission limits, exhibits some exceedance slightly elevated concentrations ammoniacal nitrogen, boron, chromium, and sulphate.

5.6.3 Frequent high concentrations of chloride and molybdenum were encountered at all surface water monitoring locations.

5.6.4 Overall, elevated concentrations at SW12 (external lagoon that ultimately receives the SP discharge) were only observed for molybdenum, sulphate, and chloride,

5.6.5 The review of the environmental monitoring data from 2013 to 2022, has indicated elevated concentrations above emission limits for boreholes E05-03 and E05-04 for the following determinands in down hydraulic gradient boreholes:

- Molybdenum;
- Sulphate.

5.6.6 With regard to the other down gradient boreholes (further south for which compliance limits do not apply) it is evident that there have been occasional elevated concentrations of aluminium, arsenic, cadmium, molybdenum, and sulphate.

5.6.7 Highly elevated concentrations of molybdenum and chloride have been identified at borehole E05-03. Based on the findings, it is recommended that further investigation was recommended to assess the potential causes of the elevated concentrations. This is detailed in Section 6.

6 FURTHER ASSESSMENT OF BOREHOLE E05-03 AREA

6.1 Site Reconnaissance Survey

6.1.1 A site walkover survey was undertaken on 17th May 2022 by an RPS consultant to assess the site condition, with focus on the area to the northwest of the site, where elevated molybdenum and boron concentrations were identified.

6.1.2 Borehole location E05-03 is located in the north-eastern corner of the beach to the east of the cement works lagoon. At the time of the visit, it was evident that the water level was raised above ground level within its raised metal cover at approximately 0.25 m above ground level. It was also evident that the metal cover was in poor condition, being heavily rusted with no top. Rusted metal was evident in the water that was present above ground level.

6.1.3 Figure 9 presents the location of borehole E05-03 and its surroundings.

6.1.4 Borehole location E05-04 was located in the central area of the beach to the east of the cement works lagoon. This location also had a rest water level above ground level. The raised metal cover was also loose and was leaning against the internal pipework.

6.1.5 Although the water level in the lagoon appeared to be below the ground level of the borehole locations (estimate of approximately 0.5m to 1m) it appeared possible that following periods of heavy rainfall, the water level could rise above this ground level at these locations, indicating a potential pathway for contaminant migration into the groundwater.

6.1.6 To the immediate east of the lagoon there is a raised ridge of approximately 7 to 8 metres width. Between this ridge and the slopes of the Phase 1 landfill area to the east, this is the drainage ditch that drains to the south raised drainage channel.

6.1.7 It was understood from 2014 investigations of the site that potential causes of contamination of groundwater with PFA species indicators in the area of borehole E05-03 prior to re-drilling included wheel wash discharges (from the north of Phase 1 area) which was close to areas of exposed PFA which previously transported through an unlined ditch close to the borehole. Leakage from the adjacent cement works lagoon was also indicated to be a potential cause. The potential leakage from the wheel wash area was subsequently rerouted to what appears to be a drainage ditch along the road east of Phase 1 area to the settlement pond. Potential leakage from the cement works lagoon cannot be discounted based on its close proximity to the borehole. Presence of contamination from infilled ground associated with the lagoon in close proximity to the borehole could also be a cause of contamination.

6.2 Ground Investigation

6.2.1 Groundwater sampling for environmental permit compliance has indicated elevated concentrations of molybdenum and boron to be present at borehole E05/03 located at the western boundary of RWE's site permit boundary. A ground investigation undertaken between 31 October and 3 November 2022 was undertaken of which included geo-environmental sampling of soils to determine whether the contaminant concentrations identified could be attributed to shallow local soil sources, specifically:

- The berm material area adjacent to the borehole;
- Material on the 'beach' immediately adjacent to the borehole; and
- The PFA materials present immediately opposite the berm.

6.2.2 Borehole E05-03 is located along the western boundary of the RWE site permit boundary, to the east of what is described as the ‘beach’ which is a flat area of ground adjacent to a pond located to the west of the RWE site boundary. This area comprises of a berm which is a linear stockpile of material located adjacent to the ‘beach’, with a PFA stockpile located to the east of the berm. The portion of the PFA stockpile in this area is also generally linear in shape and sits at an elevation of 25.4 m and 25.8 m AOD.

6.2.3 The ground investigation works (RPS, January 2023) comprised:

- Two machine excavated trial pits into the berm adjacent to the borehole E05/03, one hand excavated trial pit into the adjacent PFA stockpile and one surface scrape from immediately adjacent to borehole E05/03 to assess any impact the material may have on the borehole;
- Collection of two groundwater samples from borehole E05/03. One pre and one post purging of the borehole, with an analytical suite including a range of metal and inorganics;
- Chemical laboratory testing of four soil samples collected from the area adjacent to borehole E05/03 for soil and soil leachability analysis for a range of inorganic parameters including metals, chloride, and other ions (two soil samples from the Berm, one sample from immediately adjacent to borehole E05/03 and one sample from the PFA stockpile deposited immediately adjacent to the Berm);
- Collection of two groundwater samples from borehole E05/03. One pre and one post purging of the borehole, with an analytical suite including a range of metal and inorganics. These results were used for the graphs in Section 5.2, using the highest concentrations encountered.

6.2.4 Trial Pits TP1 and TP2 were excavated into the berm to depths of 1.1 m and 1.0 m respectively. Material encountered at TP1 comprised of dark grey to black slightly clayey gravelly cobbles and small boulders of limestone with pockets of firm gravelly clay. At TP2 material comprised of dark grey to black silty cobbly very clayey gravel with occasional small boulders of limestone.

6.2.5 As the excavator was unable to gain access onto the PFA stockpile in Area D a hand excavated trial pit, TP3, was excavated instead. The encountered material comprised a stiff to very stiff black slightly sandy silt. This material was only confirmed to a maximum depth of 0.4 m as the excavation could not be advanced further due to hard ground.

6.2.6 To assess the potential impact materials adjacent to borehole E05/03 are having on the borehole, four soil samples were collected for soil and soil leachability analysis for a range of inorganic parameters including metals, chloride, and other ions (two soil samples from the Berm, one sample from the beach area and one sample from the PFA deposited immediately adjacent to the Berm).

6.2.7 Previous groundwater monitoring undertaken by Wood identified elevated molybdenum, boron and chloride concentrations at borehole E05-03. As part of these works it was proposed that groundwater samples were collected prior to, and after purging of the borehole. It should be noted that it was RPS intention to purge the borehole for between 2.5 and 3.0 hours, however, as explained in correspondence between RPS and RWE, this was not feasible, therefore a lower purge volume was achieved.

6.2.8 Two groundwater samples were collected from borehole E05/03, one prior to purging of the well (E05/03-1) and a second following the purge (E05/03-2).

6.2.9 Samples were then scheduled for analysis for a range of metals and inorganics, including molybdenum, boron, and chloride. The results indicated similar concentrations pre and post purging suggesting that the contamination is well established within the general environs of this monitoring station.

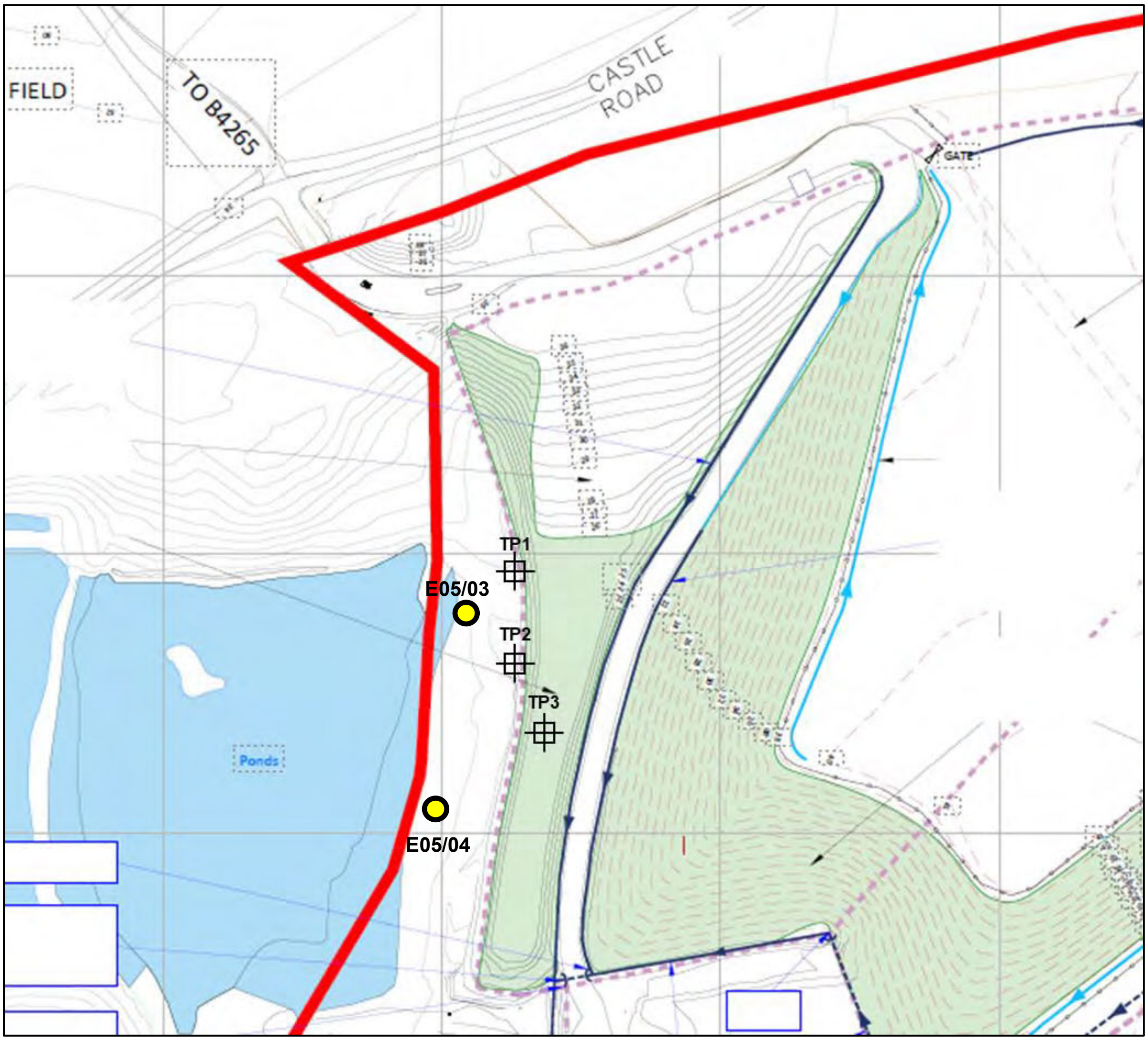
6.2.10 Soil sampling has been undertaken in the vicinity of the borehole to determine whether the elevated concentrations can be attributed to nearby soil sources.

6.2.11 4 no. soil samples were collected; 2 no. soil samples from the berm (TP1 and TP2), 1 no. immediately adjacent to the borehole (SS-1), and 1 no. from the PFA stockpile east of the berm (TP3), and tested for molybdenum, boron, and chloride content. The soil samples also underwent soil leachability analysis for molybdenum, boron and chloride, as well as a range of other inorganic parameters. The results of these chemical analyses are found in Appendix C.

6.2.12 The results do not indicate elevated molybdenum, chloride or boron concentrations in either the soil or soil leachability analysis. This suggests that the significantly elevated concentrations identified in groundwater at the nearby borehole are not attributed to the soil sources sampled during this investigation.

6.2.13 The laboratory analysis results are presented in Appendix C. Borehole logs from the ground investigation are presented in Appendix D.

Figure 10: Trial Pit Locations



7 HYDROLOGICAL/HYDROGEOLOGICAL RISK ASSESSMENT

7.1 Background

7.1.1 As discussed in earlier sections, the findings of the LandSim modelling undertaken previously at the site (Arup, 2006) are not considered relevant based on the findings of environmental monitoring which produce contradictory results, including high concentrations of PFA species indicators (including molybdenum, boron, and chloride).

7.1.2 This section provides a qualitative assessment of the potential risk posed from contaminants to controlled waters comprising the underlying limestone and nearby surface water receptors. This has been undertaken in the context of the restoration scheme.

7.2 Restoration and Drainage Scheme

7.2.1 Details for the proposed 2023 restoration and associated drainage scheme for the site are presented in Appendix B.

7.2.2 The key information from the plans for the now completed Phase 1 and 2 areas is summarised below:

- The restoration across these phases comprises of a 700 mm of compacted PFA fill overlain by 150 mm of drainage stone, 150 mm of subsoil and 300 mm of topsoil.
- Intermediate drainage ditches comprise the above thicknesses of drainage stone, subsoil and topsoil.
- Ditches around the quarry boundary include 300 mm of drainage stone overlain by a membrane and deep stone protection. The drainage layer has been installed along batters of the quarry to intercept any small makes of groundwater and pass the waters into the surface water drain installed along the southwestern boundary of the site prior to the waters being discharged into the settlement ponds.
- Road filter trenches with 450 mm and 250 mm diameter shall be utilised and will be filled with gravel around the pipe.

7.2.3 With regard to the Phase 3A and 3B areas, the restoration layer shall comprise the following:

- The 700 mm layer compacted PFA overlain by 150 mm of drainage layer which in turn is overlain by 450 mm soil layer.

7.2.4 It is understood that in the new design the majority of effective rainfall percolating into the restoration layer will flow principally horizontally when it hits the low permeability compacted PFA and will migrate via the sites drainage system into the large settlement ponds. It is understood that the drainage system has been designed to accommodate all of the effective rainfall that enters on site.

7.3 Current CSM

7.3.1 The current conceptual hydrological and hydrogeological model for the current restored areas, indicates that rainfall/precipitation is collected in the perimeter drains and is discharged into the existing lagoons through the settlement ponds.

7.3.2 For the proposed restoration scheme, the low intrinsic permeability of compacted PFA (700 mm thick in the restoration profile) and the falls across the site will limit the potential for any significant infiltration into the PFA waste mass.

7.3.3 Furthermore, analysis of the eluate from laboratory leaching PFA indicates that there will be minimal potential contaminant load even if infiltration through the restoration cap was to occur. Extensive time series groundwater monitoring around the site (with the exception of borehole E05-03) has not suggested any significant impact from PFA deposition. This is expected based on the CSM as there is no significant source term with regards to leach quality and/or volumes and no pathway to groundwater as waters under the landfill mass is collected in the surface water system and discharged via the existing lagoon.

Currently unrestored phases of the site and areas where surface water runoff is concentrated will have the potential to mobilise PFA species into the surface water drainage system. This is due to the fact that when areas of PFA are not capped and restored, then rainwater can disturb PFA surfaces. This is especially true when areas of PFA have inclined surfaces. Some small erosion features have been noted in area 3B and the controlled water monitoring has confirmed elevated metal concentrations in the surface water drainage system.

Monitoring has recorded elevated Molybdenum in boreholes E05/03 *(Figure 8)* and to a lesser extent E05/04 down groundwater hydraulic gradient of the site. The quality of sampled water in E05/03 exhibits a chemical signature similar to the sampled waters in the open surface water body to the West i.e. SW12. Due to the proximity of this to E05/03 it would appear that this monitoring station is being heavy impacted by the adjoining surface water body.

7.4 Potential Risk Rating

7.4.1 A qualitative assessment of risk has been provided in Table 7-1. This has been undertaken for the potential risks posed pre and post restoration from the PFA in the landfill site to the surface water discharge point (that ultimately discharges to cement works lagoon) and to underlying groundwater of the Lower Lias Limestone.

Table 7-1. Qualitative Risk Assessment

Contaminants of Concern	Exposure Pathway	Receptor	Qualitative Assessment of Risk	Justification
Prior to Restoration				
PFA Landfill site. PFA marker indicators e.g. molybdenum, sulphate, chloride, inorganics	Overland flow, shallow runoff and groundwater capture from drainage blanket layer.	Cement Works Lagoons (discharge release from silt settlement ponds)	Moderate	Unrestored areas and heightened runoff following intense summer rainfall events is a possible mechanism for PFA species recorded at monitoring point SP. Small erosion features can occur when the surface water flow is concentrated in certain areas, and the dry PFA may not be able to absorb the energy of the flow. (*See Para 5.4.18)*
	Leaching from landfill site into underlying groundwater	Groundwater (Lower Lias Limestone)	Low	Concentrations of molybdenum, sulphate and chloride have been highly elevated at borehole E05-03 but contaminant concentrations have been generally low at other down gradient borehole locations. The drainage blanket layer should collect majority of the underdrainage from the site for discharge via the surface water system. Low permeability PFA should minimise leaching of contaminants.

Contaminants of Concern	Exposure Pathway	Receptor	Qualitative Assessment of Risk	Justification
Post Restoration (based on Restoration Scheme for all Phases)				
PFA Landfill site. PFA marker indicators e.g. molybdenum, sulphate, chloride, inorganics	Overland flow, shallow runoff and groundwater capture from drainage blanket layer.	Cement Works Lagoons (Discharge release from silt settlement ponds)	Low	It is considered that the proposed restoration scheme across all phases will result in a significant reduction in potential mobilisation of PFA species into the surface water system.
	Leaching from landfill site into underlying groundwater	Groundwater (Lower Lias Limestone)	Low	The potential risk to groundwater should be further reduced with the restoration scheme in place. Full restoration of the site will further reduce the low infiltration capacity into the PFA waste mass.

7.4.2 As detailed above, based on the drainage design information, post installation of the restoration scheme, and the pozzolanic nature of PFA it is considered that the amount of leachate that will discharge into the underlying natural groundwater is considered to be very low.

7.4.3 The issue of borehole E05-03 has not been included in the risk assessment of which focuses on those potential risks posed from the landfill site, and not potential off-site sources (e.g. lagoon).

7.5 Potential for Leachate Generation within the Landfill Mass

7.5.1 PFA particles, particularly those below 50 μm, are spherical in shape means that it exhibits a very low intrinsic permeability/hydraulic conductivity, typically 10^{-7} to 10^{-8} m/s.

7.5.2 Permeability testing on disturbed PFA samples from Aberthaw record a range of 2.7 x10^{-7} to 4.3 x 10^{-10} m/s. The provision of a 700 mm compacted PFA layer in the restoration scheme will therefore afford a comparatively impermeable barrier to any vertical flow from rainfall infiltration into the soils and subsoil.

7.5.3 The restoration layer, including falls, is designed to encourage any infiltrated water from rainfall events to move laterally when it reaches the compacted PFA and discharge into the surface water drainage system around the site.

7.5.4 The drainage system designed for the restored landform (29 ha) has been designed on the bases of a 1:200 year plus 40% climate change rainfall event. The mean annual flood flow i.e. the quick flow element of the rainfall event, has been computed to be 0.235132 m3/sec on the restored area. The drainage system and associated settlement ponds has adequate capacity to manage such flood event. The runoff water i.e. the quick flow element of a rainfall event will be followed by a lower rate of flow via infiltration and percolation within the soil/subsoil layers. When the percolated waters reaches the drainage layer the water will run principally horizontally on top of the low permeability compacted PFA and mirror the topographical fall to discharge into the surface water drainage system . This slow movement of water after a rainfall event is interflow. Interflow is the lateral movement of water in the unsaturated zone, or vadose zone, which returns to the positive surface drainage. Post antecedent rainfall events a large volume of water will arrive in the settlement ponds after a relatively short period of time the majority of the infiltrated and percolated water will arrive via interflow sometime later. A portion of the infiltrated water will be available for evapotranspiration and crop uptake and only a very small amount of water has the potential to infiltrate into the 700 mm compacted PFA layer.

7.5.5 The low hydraulic conductivity of compacted PFA means that water infiltration occurs at a very low rate. It is unlikely that when compacted PFA is subjected to heavy rainfall event that it would become saturated below the top 100 mm. The flow rate through unsaturated PFA will depend on the permeability and the degree of saturation, as well as the hydraulic gradient, so any significant hydraulic flow through PFA is unlikely to occur.

7.5.6 To provide some quantum as to very conservative flow rate through the 700 mm compacted PFA layer Darcy's velocity (Darcy Flux) can be calculated based circa 0.100 m of water head in the drainage layer.

$v= K(\Delta h/L) = 1X10^{-9}$ m/s (0.100m/0.7m)=1.43×10^{-10} m^3 /s.

The theoretical potential flow through the compacted PFA can be determined (Q=vA).

Q= volume of flow in m/s

V= Darcy Flux (1.43×10^{-10} m^3 /s)

A = Area of the landfill (24.47 hectares)

Q= $1.79 \times 10^{-10} \times 244700= 3.5 \times 10^{-5}$ m3/sec= 0.0350 l/sec.

This solution assumes that a head of water will be maintained in the drainage layer on top of the compacted low permeability PFA layer. There is no drainage through the restoration layer into the surface water system. However, because of the permeability contrast between the PFA and the drainage layer together with the restoration gradients and the surface water drainage system as part of the restoration scheme, any head of water will decrease after an infiltration event. Furthermore, the solution assumes that the full thickness of the 700 mm compacted PFA is saturated to allow flow to take place into the PFA mass.

7.5.7 The extremely low infiltration potential through the low permeability compacted PFA will prevent leaching of soluble material from the landfill.

7.5.8 Eluate from a 2 -stage laboratory leachability test on PFA from the site recorded very low concentrations of soluble material.

7.5.9 Based on the foregoing, it is considered that there is no credible pathway for any discernible contaminant migration from the landfill mass to groundwater.

7.5.10 The quality of water recorded at E05/03 is a result of the borehole's proximity to the adjoining surface water lagoon. Time series data for E05/03 and SW12 demonstrates a very strong degree of hydraulic connectivity between the two monitoring points. E05/03 is not an appropriate groundwater monitoring location as it is effectively a proxy monitoring point for surface water.

8 MONITORING STRATEGY

8.1 Introduction

8.1.1 A controlled waters monitoring strategy is required as part of the aftercare process when the landfill site is in closure phase.

8.1.2 The aim of this monitoring would be to demonstrate that the restoration works (mitigation measures) are effective in reducing the impact on the local environment.

8.1.3 E05-03, a down hydraulic gradient borehole, exhibits anomalous quality when compared to other groundwater monitoring points. Elevated molybdenum and chloride at this monitoring point is attributed to the proximity of the adjoining surface water lagoon, which receives surface water from the site, via the silt settlement ponds.

8.1.4 The current compliance limits and control levels for surface water and down gradient boreholes are presented in Tables 8-1 and 8-2. The principles of how these limits were derived were detailed in a hydrogeological review of the Assessment Site undertaken in 2013 and detailed in the following report:

- RWE Npower plc, Aberthaw Quarry Ash Disposal Site, Permit Ref. BP3339BH: Hydrogeological Risk Assessment Review, Npower, for Natural Resources Wales (NRW), 24th July 2013.

8.1.5 These compliance limits and control levels for groundwater for some of the determinand were derived based on the following:

- Arsenic: Compliance limits for hazardous substances were set at DWS; due to low detection levels. Control levels appear to have been set at the background concentrations 2006 to 2011 plus 10%.
- Mercury: Compliance limits were based on upgradient background concentrations 2006 to 2011. Due to low detection levels, control levels were not set for hazardous substances.
- Cadmium: Compliance limits were based on upgradient background concentrations 2006 to 2011. Due to low detection levels, control levels were not set for hazardous substances.
- Non-Hazardous Substances: Compliance limits set at background concentrations reported in Arup HRA (2006), DWS and EQS. Control levels for these substances excluding ammonium and boron were set at background concentrations from Arup HRA (2006) plus one third of the difference between these concentrations and the Environmental Assessment Level. For ammonium and boron, control levels were set at 25% increase of background concentrations from Arup HRA (2006).

8.1.6 Exceedances were defined by concentrations that were above compliance limits and/or control levels on three consecutive occasions. The control levels apply to all down gradient boreholes whilst the compliance limits only applied to boreholes downgradient of the current filling operations.

8.1.7 The existing compliance limits and control levels have been assessed following a review of the water monitoring dataset provided in Section 5. For those determinands where consistently elevated concentrations have been identified and are likely to be related to the drainage from the landfill site prior to the proposed restoration works, it is considered that these are modified temporarily so that any further unacceptable trends (i.e. increases in concentrations) are identified rather than exceedances continuing to identify consistently elevated concentrations. It is considered that these should then be re-evaluated at approximately one year after the restoration scheme is completed with the temporary compliance limits and control levels revised to lower concentrations.

Table 8-1. Current Compliance Limits and Control Levels (Surface Water)

Permit Info.	Parameter	Emission Limit (Compliance Limit)	Unit	Monitoring Location(s)	Assessment Criteria (Control Level)	Monitoring Location(s)
Discharge point from settlement ponds to surface water course	Total Ammonia as N	0.6	mg/l	SP	-	SP, SW12
	Arsenic	50	µg/l	SP	28	SP, SW12
	Boron	2	mg/l	SP	1	SP, SW12
	Cadmium	5	µg/l	SP	-	SP, SW12
	Chromium	50	µg/l	SP	28	SP, SW12
	Sulphate	400	mg/l	SP	330	SP, SW12
	Vanadium	60	µg/l	SP	30	SP, SW12
	pH	<9	pH units	SP	-	SP, SW12

Table 8-2. Current Compliance Limits and Control Levels (Down Gradient Boreholes – E05-03, E05-04)

Permit Info.	Parameter	Trigger Level (Compliance Limit)	Unit	Assessment Criteria (Control Level)	Up-gradient Concentrations (2021-2022) [boreholes E09-1A/B, E09-2A/B, E15-1)
E05/03; E05/04	Aluminium	50	µg/l	33	<3.5 – 4.2
	Ammoniacal Nitrogen	1.6	mg/l	1.4	<0.06 – 6.01
	Arsenic	10	µg/l	8	<0.2 – 1.9
	Boron	2.8	mg/l	2.5	<56 – 917
	Cadmium	0.4	µg/l	-	<0.02 – 0.07
	Chromium	50	µg/l	28	<0.2
	Molybdenum	50	µg/l	35	<2.5 – 112
	Sulphate	400	mg/l	330	21.9 - 198
	Vanadium	20	µg/l	12	<0.15 – 1
	Mercury	0.03	µg/l	-	<0.01 – 0.04

8.2 Surface Water Limits

8.2.1 The discharge from the settlement ponds is measured at sample location SP which it is understood is the discharge weir on the discharge chamber / channel from the settlement ponds and not the ponds themselves. This provides the ‘Discharge point from settlement ponds to surface water course’ as is recognised by the permit.

8.2.2 The monitoring programme also includes sample location SW12, located within the cement works lagoon outside of the EP boundary, however it is considered that the SW12 sample may be subject to off-site dilution or contamination from external sources and may not be accurately representing the water quality at discharge off-site.

8.2.3 Monitoring at sample location DP2 should be continued to allow an assessment of the water quality of drained waters immediately from the ash storage areas, and the relationship with the waters discharged off-site.

8.2.4 With regard to arsenic, although very low concentrations have been encountered over the monitoring period, it is considered that the current limit of which is also the EQS is still most suitable. This is a PFA indicator species and a hazardous substance, so it is considered important to retain this as a compliance limit.

8.2.5 Total Ammonia as N uses the EQS for good quality rivers (type 3, 5 and 7). It is proposed that this is modified due to the frequent exceedances above this conservative compliance limit. It has been identified that locations SP and DP show seasonal fluctuations. Elevated concentrations of ammonia has also been directly attributed to less dilution and evaporation during the summer months. Please note that total nitrogen based analysis can also be impacted by seasonal algal blooms attributed to lower flow conditions. Location SW12 (cement works lagoon) shows very low concentrations compared to SP. The average (arithmetic mean) concentration of ammoniacal nitrogen recorded at SP from 2020 to 2022 is 4.54 mg/l. It is suggested that a higher compliance limit be considered using the EQS for poor quality rivers (type 3,5 and 7), this being 2.5 mg/l.

8.2.6 There have been no exceedances for chromium with respect to surface water monitoring locations SP and SW12 over the monitoring period. It is considered that the current conservative compliance limit and control levels be retained for this determinand. It is suggested that the EQS for fresh water (long term) of 3.4 µg/l is utilised as a compliance limit for chromium VI, which is defined as a hazardous substance. A Chromium VI control level has not been suggested due to limited data however this can be reviewed following the restoration works.

8.2.7 Even though there have been no exceedances It is considered that cadmium should retain its current control limit. As cadmium is a hazardous substance it should still continue to be monitored. The limits for vanadium and pH also seem reasonable with no exceedances identified over the 2013 to 2022 monitoring period.

8.2.8 Average (arithmetic mean) sulphate concentrations for monitoring from 2020 to the end of 2022 for SP and SW12 were 864 mg/l and 684 mg/l respectively indicating continuous breaches of the current compliance limit. Based on this it is considered that the compliance limit should be set as the recent average concentration of the sulphate at SP, this being 864 mg/l. This is based on the high sulphate discharge currently being drained from the site. The EQS of 400 mg/l has been used as a control level.

8.2.9 With regard to molybdenum, this remains highly elevated with average (arithmetic mean) concentrations from 2020 to July or August 2022 being 4165 µg/l (DP2), 4016 µg/l (SP) and 2527 µg/l (SW12) respectively. Based on the current concentrations, a compliance limit of 3884 µg/l is recommended (average concentration at SP) with a control limit being the average concentration at SW12 in the assessed dataset.

8.2.10 Boron, another PFA species indicator, has also shown elevated concentrations with average (arithmetic mean) concentrations from 2020 to the end of 2022 of 1922 µg/l (DP2), 1745 µg/l (SP) and 1190 µg/l (SW12) respectively. It is recommended that the compliance limit is retained with the previous control level removed (as there are frequent exceedances above 1000 µg/l). The arithmetic mean concentration for SP detailed above has been used as the control level.

8.2.11 Proposed compliance limits and control levels for surface water are provided in Table 8-2.

Table 8-2 Proposed Compliance Limits and Control Levels (Surface Water)

Parameter	Proposed Compliance Limit	Monitoring Location	Proposed Control Level	Monitoring Location
Total Ammonia as N	2.5 mg/l	SP	-	-
Arsenic	50 µg/l	SP	-	-
Boron	2 mg/l	SP	1.745 mg/l	SP

Cadmium	5 µg/l	SP	-	-
Chromium	50 µg/l	SP	28 µg/l	SP
Chromium VI	3.4 µg/l	SP	-	-
Sulphate	864 mg/l	SP	400 mg/l	SP
Molybdenum	4016 µg/l	SP	2527 µg/l	SP
Vanadium	60 µg/l	SP	30 µg/l	SP
pH	<9	SP	-	-

8.2.12 Sampling should continue to be collected at locations DP2 and SW12 to allow an assessment of the contaminant concentrations including PFA indicator species.

8.3 Down Gradient Borehole Limits

8.3.1 With regard to the down gradient boreholes, it is understood that the following trigger levels apply as detailed in Table 8-3. This comprises trigger levels (compliance limits) for boreholes É05-03 and E05-04. It is understood that the more recently drilled down gradient boreholes (E06-01, E06-02, E06-03, E06-04, E06-05) have also been included in the trigger level screening assessments undertaken for the site since 2013 for comparison purposes (including the 2020 Annual Performance Report (RWE, 2020).

8.3.2 It is recommended that the existing compliance limit be retained for arsenic of which the latter is 20% of the freshwater EQS (50 µg/l) and is also the DWS. This limit is conservative but have been able to identify occasional exceedances but results are largely below these values. The up-gradient borehole concentrations have also occasionally been elevated above LOD in recent years suggesting that any elevated arsenic concentrations identified in the down gradient boreholes are likely to be a result of the landfill site. Based on the very low concentrations observed in up gradient boreholes and the conservative compliance limit used, it is considered that the previous control limit (8 µg/l) can remain in place for arsenic. With regard to mercury, it is considered that the conservative compliance limit can be retained for which results have only occasionally been encountered above LOD during the recent monitoring period. It is proposed that the compliance limit for cadmium which has also shown very low concentrations is also retained.

8.3.3 Very low concentrations of vanadium and aluminium have typically been observed. It is proposed that the existing compliance limits are retained. With regard to control levels it is proposed that the arithmetic mean of the concentrations from up-gradient boreholes (E09-1A, E09-1B, E09-2A, E09-2B, E15-1) between 2020 and 2022 plus half of the difference between this concentration and the compliance limit should be utilised. This calculation assumes that concentrations below LOD are equal to the LOD.

8.3.4 With regard to chromium, the same proposed limits for surface water are proposed for the down gradient boreholes. This includes chromium VI, a hazardous substance, which is recommended for inclusion.

8.3.5 It is also proposed that the existing compliance limits and control limits for boron are retained. This is based on recent data has indicated concentrations below the compliance limit of 2.8 mg/l but occasionally exceeding the control level in borehole E05-04. These compliance limits and control levels should address any further unacceptable trends in boron concentrations.

8.3.6 With regard to molybdenum, the current compliance limit has shown some exceedances for boreholes E05-04, E06-01 and E06-02 for down gradient boreholes however all results exceeded for borehole E05-03. It is suggested that a separate trigger level is utilised for borehole E05-03 of which shows highly anomalous results. Our recommendation is to decommission and replace borehole E05-03 as is discussed further in Section 9. The average (arithmetic mean) concentration observed between 2020 and 2022 in this location is 1266 µg/l. Based on a general trend of reducing but fluctuating concentrations it is considered that this can be used as an indicator of increasing concentrations, and therefore can be used as a control level. The compliance limit has been set at 1600 µg/l, a concentration that was not exceeded between 2018 and July 2022 with the exception of a marginal exceedance in October 2022 (1630 µg/l) so any exceedances are considered to show an unacceptable trend in the data (significant increase in concentration). The November 2022 result was below the trigger level of 1600 µg/l.

8.3.7 With regard to the compliance limit for molybdenum for the proposed redrilled borehole (to replace E05-03) and E05-04 it is proposed that the arithmetic mean of the concentrations from up-gradient boreholes (E09-1A, E09-1B, E09-2A, E09-2B, E15-1) plus half of the difference between this concentration (4 µg/l to nearest one significant figure) and the compliance limit should be utilised. This calculation assumes that concentrations below LOD are equal to the LOD.

8.3.8 It is considered that the ammoniacal nitrogen compliance limit and control levels should be retained. The up-gradient concentrations are generally low (average of 0.39 mg/l from 2020 to 2022 results) and trigger levels that are already in place appear to be conservative.

8.3.9 It should be noted that sulphate concentrations are highest in boreholes to the south of the site which may be due to the nature of the limestone bedrock in these areas. In boreholes further north (E05-03, E05-04 and E06-01) there were only occasional concentration above 600 mg/l prior to July 2022 with many exceedances of 400 mg/l. It is recommended that 400 mg/l of which is also the EQS be used as the control level, with 600 mg/l (50% above the control level) used as the compliance limit for those boreholes in the north.

8.3.10 It is recommended that boreholes E05-03, E05-04 and E06-01 should be those with set compliance limits. Borehole E06-01 is recommended to be included as it is located adjacent to the immediate south of the Phase 1 area, and based on its location with respect to groundwater flow direction. It is considered that the boreholes that are located further to the south (E06-02 to E06-05) should not be included as there is potential for these boreholes to intercept groundwater that is located off-site based on the flow direction to the northwest and west. The boreholes E05-03, E05-04 and E06-01 appear most likely to intercept groundwater flow down hydraulic gradient of the PFA infill.

8.3.11 The proposed compliance limits and control levels for down gradient monitoring boreholes are provided in Table 8-4 below. It is proposed that for control levels, concentrations above this level for three consecutive monitoring periods is considered to be an exceedance for each determinand. For compliance limits, a single concentration above this limit for each determinand would be considered to be an exceedance.

Table 8-4 Proposed Compliance Limits and Control Levels (Down Gradient Boreholes)

Parameter	Proposed Compliance Limit	Location	Proposed Control Level	
Aluminium	50 µg/l	E05-03* E05-04 E06-01	27 µg/l	E05-03* E05-04 E06-01
Ammoniacal Nitrogen	1.6 mg/l		1.4 mg/l	
Arsenic	10 µg/l		8 µg/l	
Boron	2.8 mg/l		2.5 mg/l	
Cadmium	0.4 µg/l		-	
Chromium	50 µg/l		32 µg/l	
Chromium VI	3.4 µg/l		-	
Sulphate	600 mg/l		400 mg/l	
Vanadium	20 µg/l		12 µg/l	
Mercury	0.03 µg/l			
Molybdenum**	1600 µg/l	E05-03*	1266 µg/l	E05-03*
Molybdenum	50 µg/l	E05-04, redrilled borehole (to replace E05-03)	28 µg/l	E05-04, E06-01, redrilled borehole (to replace E05-03)

*It is recommended that E05-03 is replaced and the redrilled borehole to be used for future monitoring works.

**Temporary limit to be used until borehole is redrilled.

8.4 Monitoring Programme

Current Regime - Surface Water

8.4.1 The permit a requirement for monthly monitoring at the discharge point SP as specified in Table S4.1.

8.4.2 The current RWE programme of monitoring comprises:

- Settlement Ponds (SP) and Discharge Point 2 (DP2): Monthly.
- Cement Works Lagoon (SW12): Quarterly.

8.4.3 With regard to Table S4.3 of the permit, it is understood that due to access constraints and the non-representative nature of surface water at the location from the PFA deposit, location SW13 is no longer monitored as agreed with NRW.

8.4.4 Monitoring is undertaken for a range of determinands as detailed in Table S4.1 for SP. Emission limits are specified for the discharge from the settlement ponds to the adjoining surface water lagoon.

8.4.5 Monitoring is undertaken for a range of determinands as detailed in Table S4.3 for SW12. No quality limits are set for this monitoring point.

Current Regime – Groundwater

8.4.6 The permit indicates the requirement for quarterly monitoring of boreholes E05-03 and E05-04. Based on further down gradient boreholes being installed after the permit was issued, these were included in the monitoring regime.

Proposed Monitoring Regime – Groundwater and Surface Water

8.4.7 The proposed surface water monitoring programme is presented in Table 8-5. Please note that this details all the proposed monitoring determinands although there are no compliance limits or control levels for many of them.

8.4.8 The time series data has been assessed to determine the requirement for monitoring of a range of determinands on site. Antimony and selenium are proposed for removal from the monitoring suite based on typically very low concentrations (mainly below LOD) being encountered. These parameters do not have defined water EQS and are therefore not considered relevant as part of the monitoring on site.

8.4.9 It is proposed that the metal analysis continues to be dissolved analysis as has been the case over recent years at the site. This will prevent any suspended solids within boreholes providing inaccurate results.

Table 8-3. Proposed Monitoring Regime

<table>
<tr><th>Determinand</th><th>Location</th><th>Frequency</th><th></th><th>Location</th><th>Frequency</th></tr>
<tr><td>Aluminium</td><td rowspan="8">E05-03*
E05-04
E06-01
E06-02
E06-03
E06-04
E06-05
E09-01A
E09-01B
E09-01A
E09-01B
E15-01</td><td rowspan="8">Quarterly</td><td>Aluminium</td><td rowspan="8">SP2
SW12
DP2</td><td rowspan="8">Monthly</td></tr>
<tr><td>Ammoniacal Nitrogen / Total Ammonia as N</td><td>Ammoniacal Nitrogen / Total Ammonia as N</td></tr>
<tr><td>Arsenic</td><td>Arsenic</td></tr>
<tr><td>Boron</td><td>Boron</td></tr>
<tr><td>Calcium</td><td>Calcium</td></tr>
<tr><td>Cadmium</td><td>Cadmium</td></tr>
<tr><td>Chloride</td><td>Chloride</td></tr>
<tr><td>Chromium</td><td>Chromium</td></tr>
</table>

Determinand	Location	Frequency		Location	Frequency
Chromium VI			Chromium VI		
Copper			Copper		
Fluoride			Fluoride		
Iron			Iron		
Magnesium			Magnesium		
Manganese			Manganese		
Molybdenum			Molybdenum		
Mercury			Mercury		
Nickel			Nickel		
Phosphate			Phosphate		
Potassium			Potassium		
Sodium			Sodium		
Sulphate			Sulphate		
Vanadium			Vanadium		
Alkalinity			Alkalinity		
Electrical Conductivity			Electrical Conductivity		
Total Organic Carbon			Total Organic Carbon		
Total Organic Nitrogen			Total Organic Nitrogen		
pH Ionic balance %			pH		
Groundwater Level	E05-03* E05-04 E06-01 E06-02 E06-03 E06-04 E06-05 E09-01A E09-01B E09-02A E09-02B E15-01	Quarterly			

*It is proposed that E05-03 is decommissioned and a new borehole is drilled to monitor groundwater.

8.4.10 To support the hydrological/hydrogeological model for the site it is proposed that appropriate records of engineering works are undertaken during the restoration of Phases 3A & 3B. The installation of the restoration capping layers will progressively reduce the current surface area of PFA being exposed to rainfall events which is currently impacting the quality the surface water system as a consequence of turbulent runoff events.

8.4.11 The frequency of monitoring can be reviewed based upon the nature and degree of improvement in surface water quality during the aftercare period following the reprofiling of the site.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 A review of a previous hydrogeological risk assessment review and environmental performance report of the site, and an assessment of the time series data up to the end of 2022 has been undertaken to allow an up-to-date assessment of the potential risks posed by PFA to controlled waters receptors, including surface water and the underlying limestone aquifer.

9.1.2 The results indicate that elevated values have been identified down hydraulic gradient of the landfill site for a range of parameters including PFA marker species. These parameters are typically occasionally elevated which is not unexpected at locations in immediately proximity to the landfill site. However the exception is a borehole located to the immediate northeast of the cement works lagoon, borehole E05-03, which has shown anomalously high molybdenum and chloride concentrations in groundwater.

9.1.3 Surface water monitoring analysis data from the settlement ponds, discharge point on site and the cement works lagoon (where discharge from the site is ultimately released) has been reviewed and has indicated that elevated levels of some parameters, most notably molybdenum, sulphate and chloride. However the majority of monitored determinands have concentrations that are at acceptable levels.

9.1.4 The restoration scheme planned site will significantly improve the current quality of the surface water runoff from the site. The restoration layers will comprise of 700 mm low permeability compacted PFA l, overlain by a 300 mm drainage layer /subsoil layer, which in turn is overlain by a 300 mm topsoil. The restoration profile together with appropriate falls, not exceeding 1:4, will ensure that infiltrated rainfall will be transported via laminar flow to the surface drainage system.

9.1.5 A study of the time-series water quality data, current hydrogeological and hydrological conditions and a site walkover survey of the borehole E05-03 area, it is considered that the anomalous water quality recorded in this monitoring station is directly associated with the quality of water in the adjoining lagoon.

9.2 Recommendations

9.2.1 RPS has provided recommendations for updated programme based on a review of the time-series data up to to the end of 2022 and based on the site being in closure.

9.2.2 The anomalous nature of the results at borehole E05-03 suggests that a replacement monitoring borehole should be drilled to provide a more representative dataset of groundwater. It is recommended that borehole E05-03 is decommissioned and the replacement borehole is redrilled. This borehole is recommended for use in the permit. The location should be agreed with RWE following a site visit. It should be at sufficient distance from borehole E05-03 to ensure that it is not impacted in the same manner but should be in a location that represents the down hydraulic water quality in the western and north western area of the site. At this time, a location of about 10 m to 15 m to the south and southeast of the current borehole appears to be a potential option (subject to clearance of any obstructions).

9.2.3 It is proposed also that borehole E06-01 is included as an additional compliance location as this is considered likely to intersect groundwater flowing off site to the west.

9.2.4 In line with the current permit annual performance review requirement, the proposed compliance limits and control levels for surface water and groundwater should be re -evaluated approximately one year following the completion of the planned restoration works for the site.

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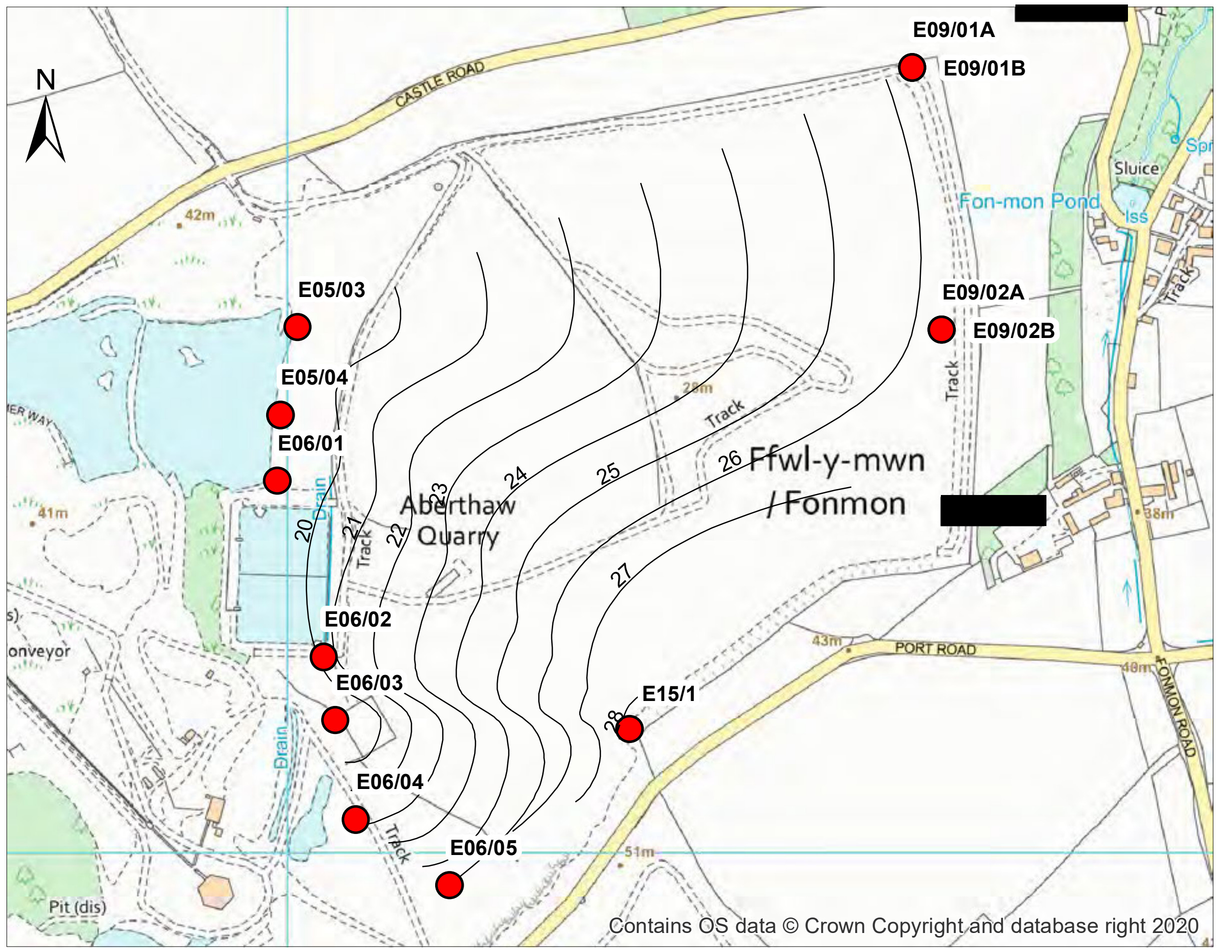
DRAWINGS

30th June 2021



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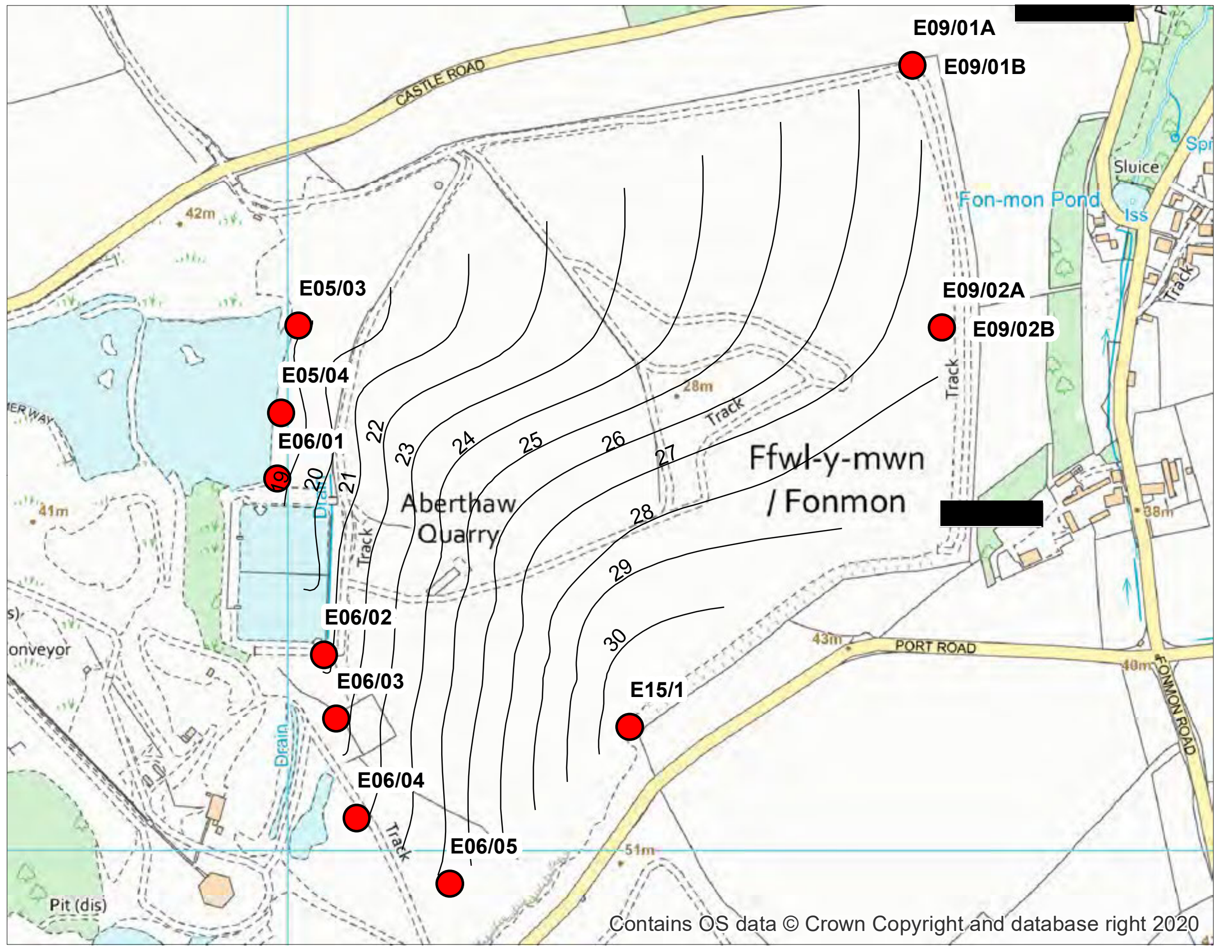

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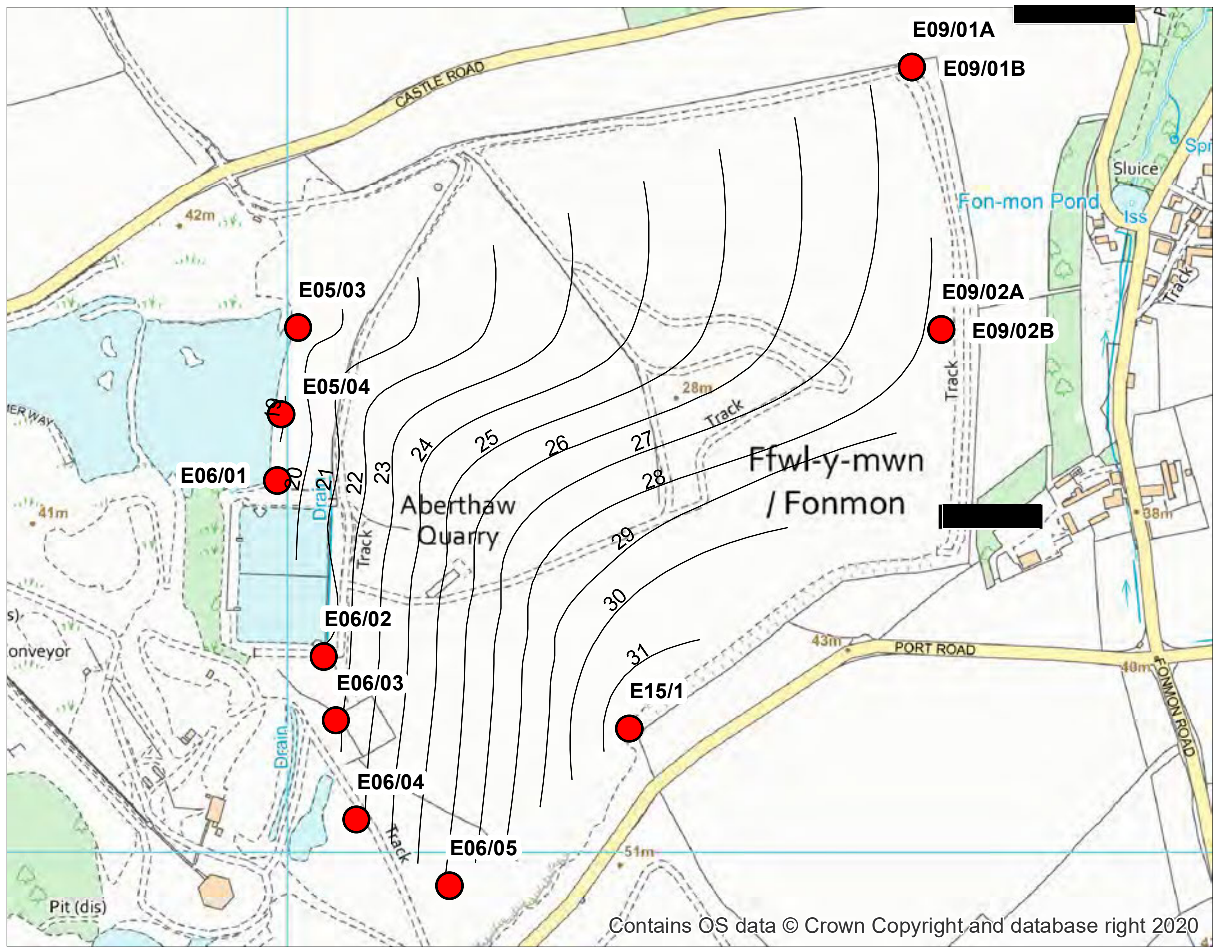

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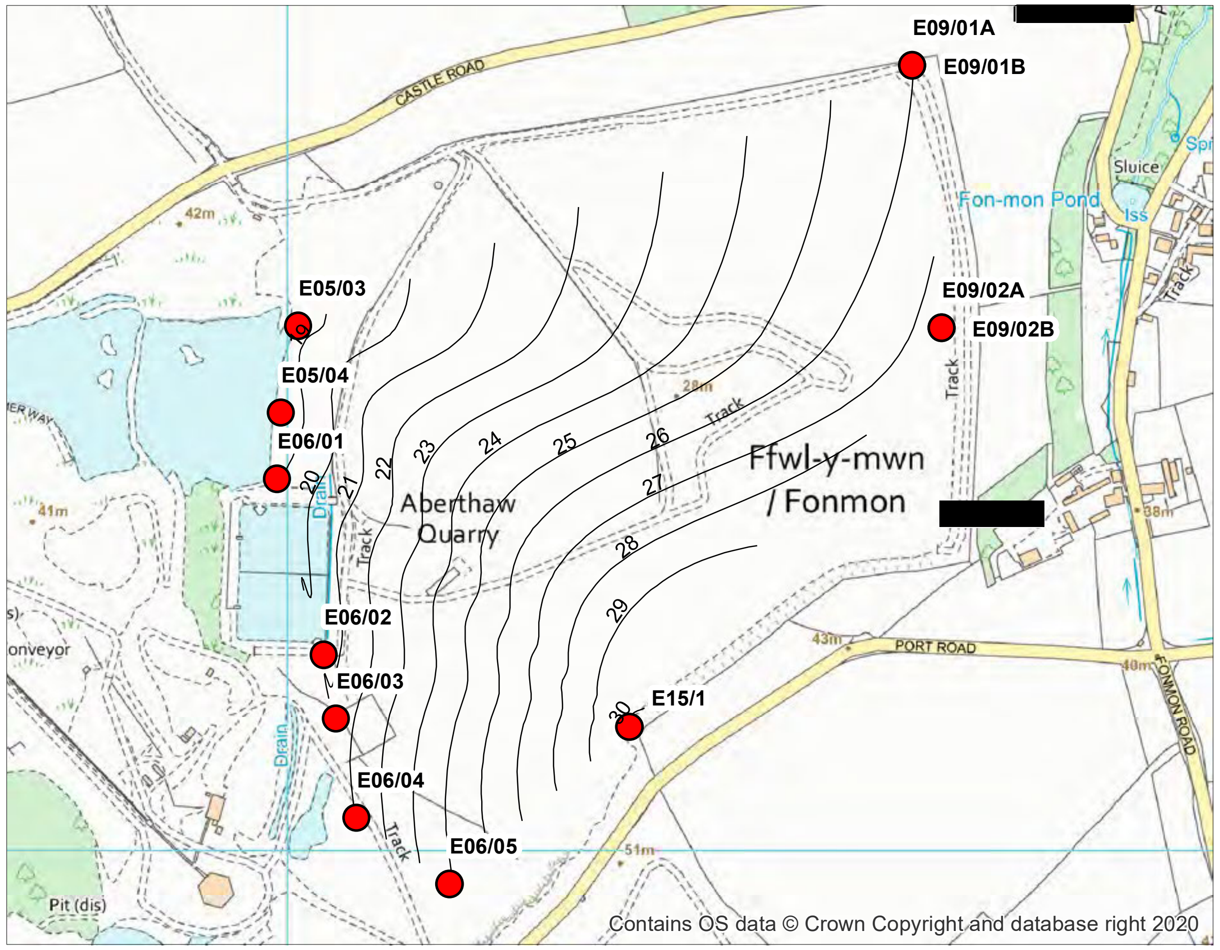

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Legend

- Borehole Location
- Groundwater Elevation Contour Plots (mAOD) - 2021 and 2022

Rev	Description	By	CB	Date

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Client -

Project Aberthaw Quarry

Title Groundwater Elevation Contour Plots - 2021 and 2022

Status	Drawn By	PM/Checked By
ISSUE	RD	AP
Project Number	**Scale @ A3**	**Date Created**
JFR2782	1:7,000	FEB 2023

Figure Number **HRA-01**

Rev **-**

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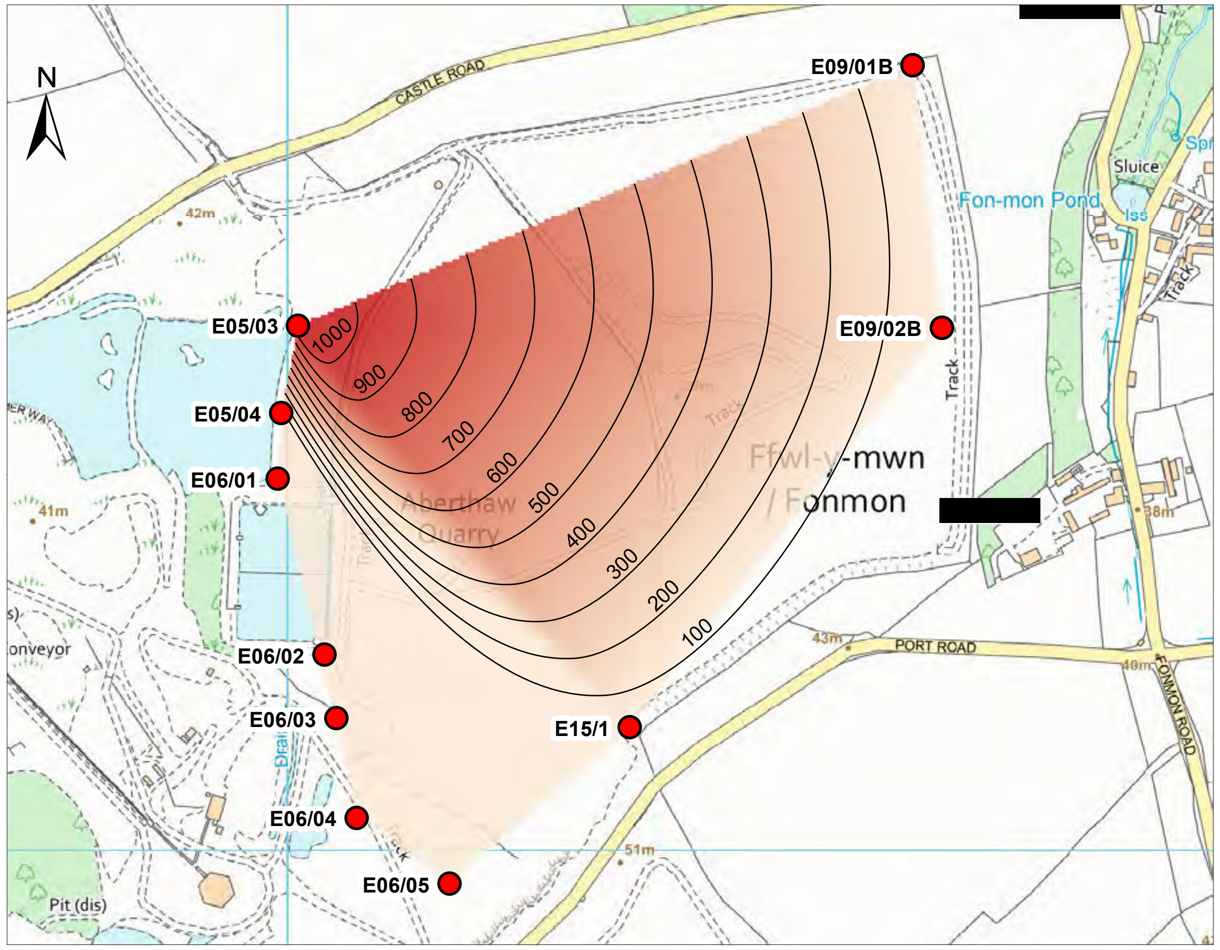

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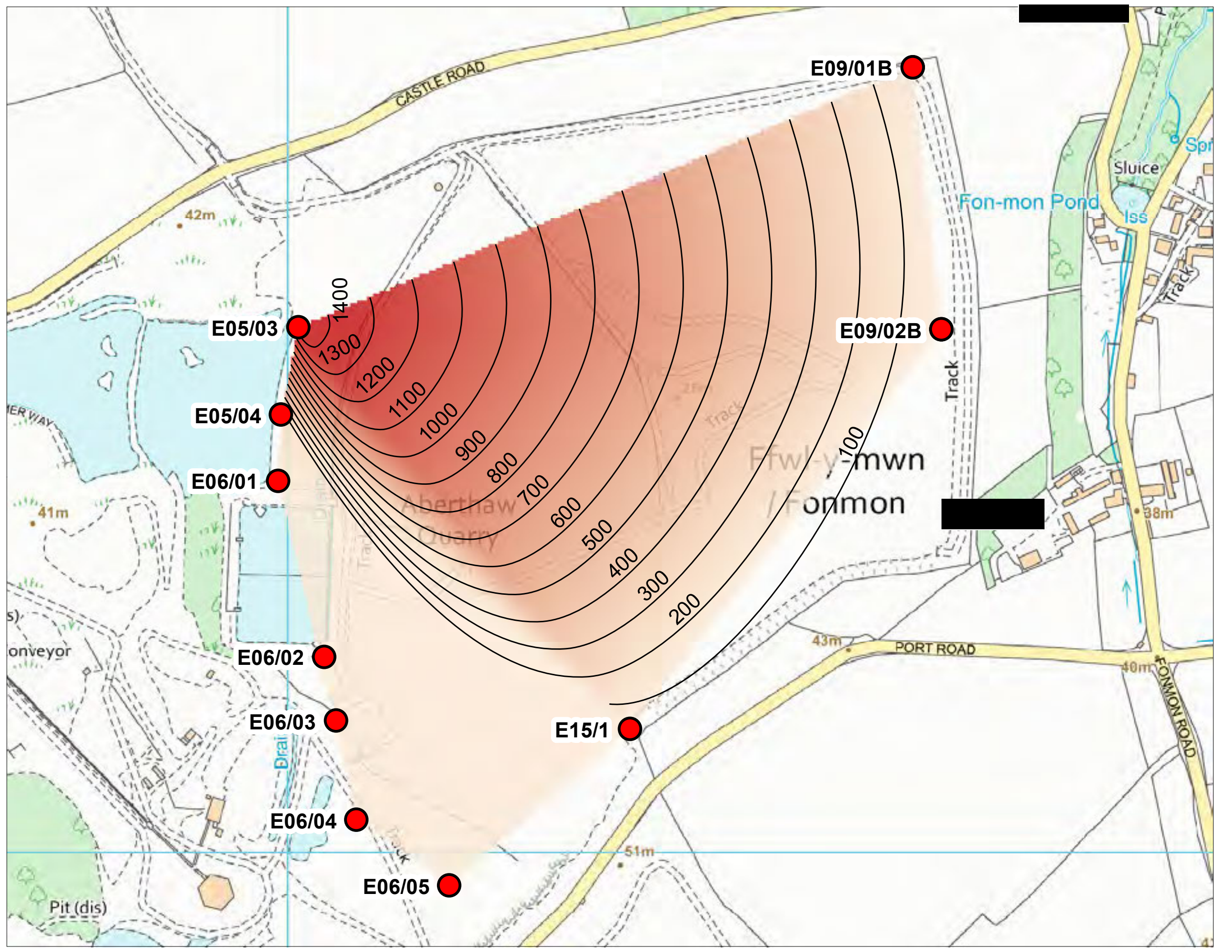

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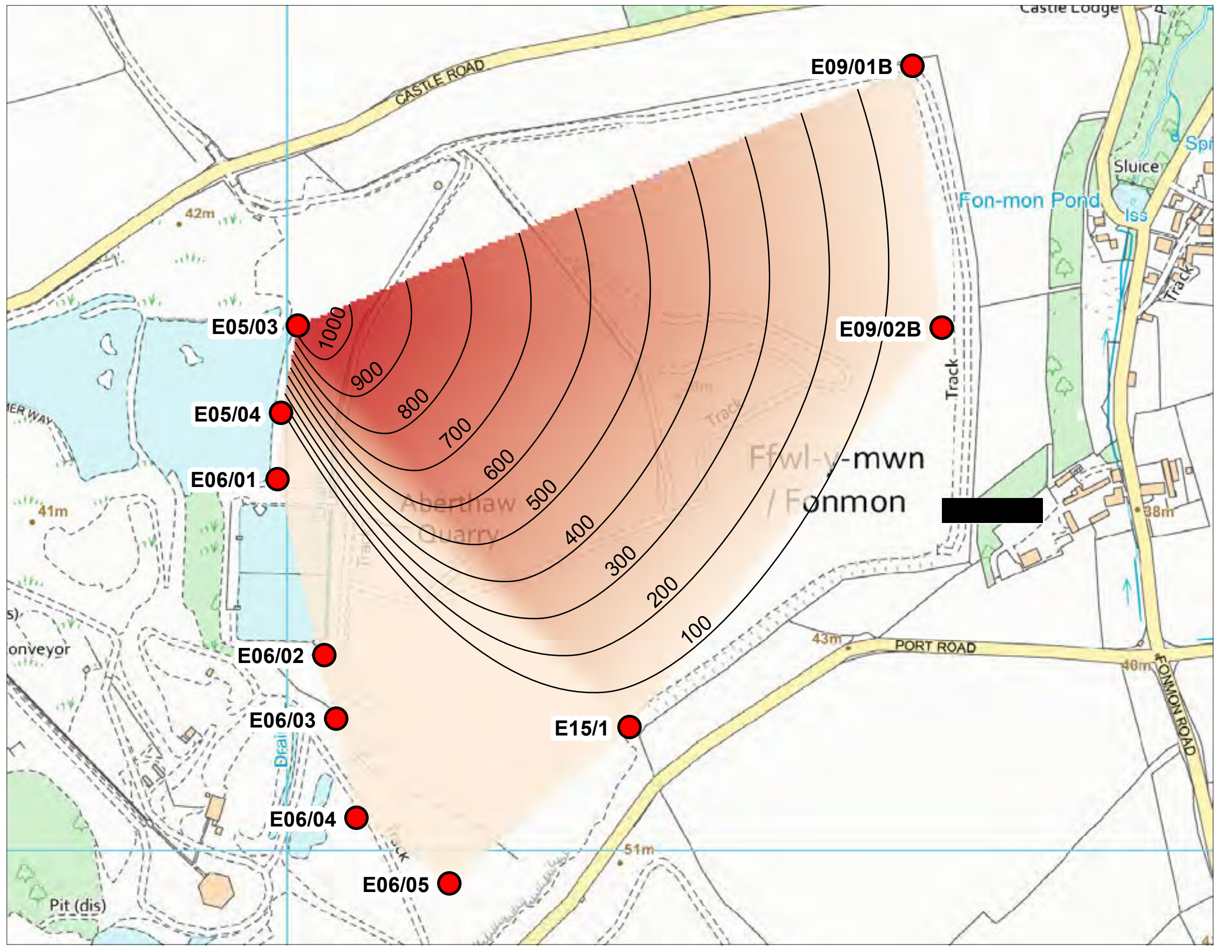

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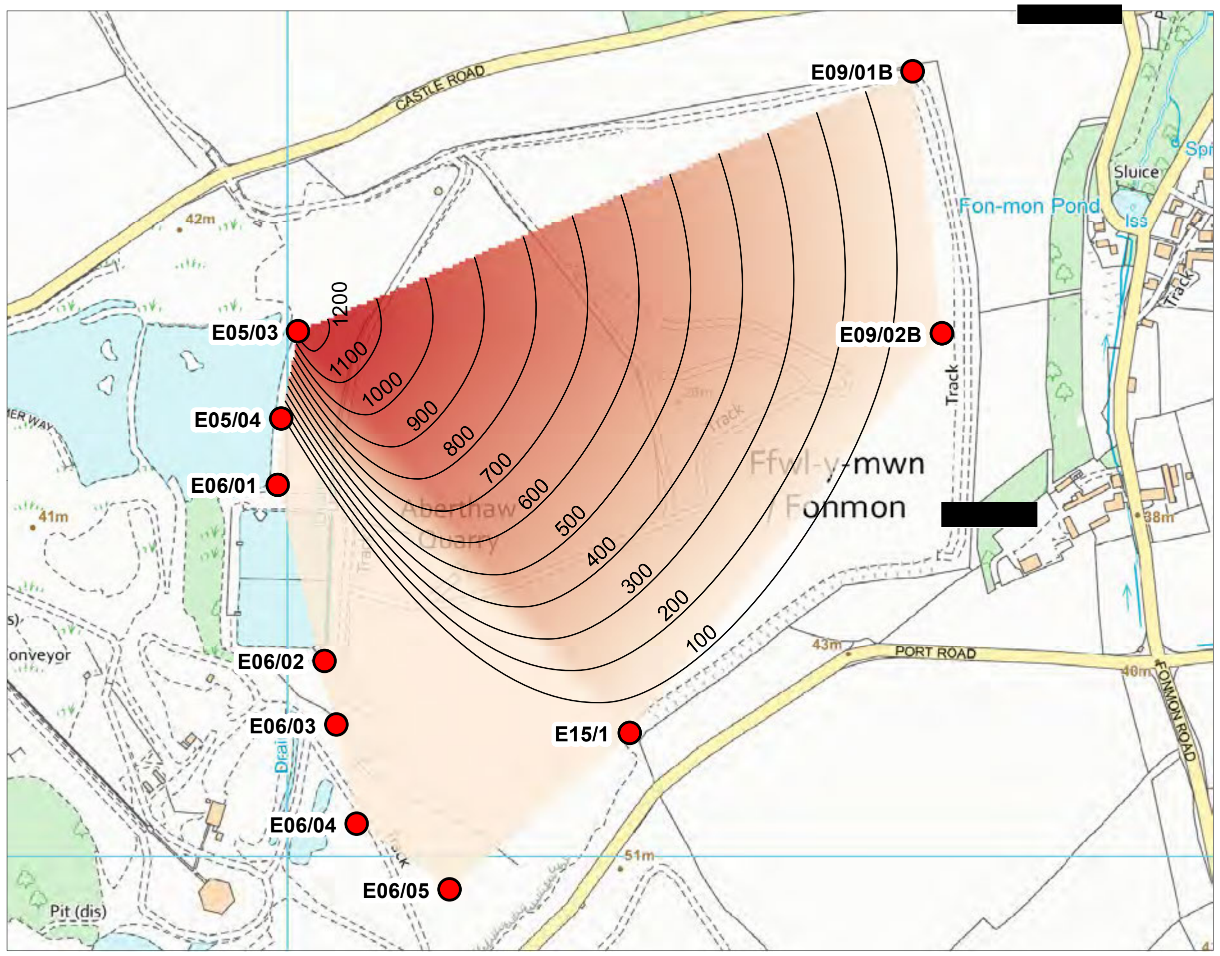

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Title Molybdenum Concentrations in Groundwater – 2021 and 2022

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Project Number	Scale @ A3	Date Created
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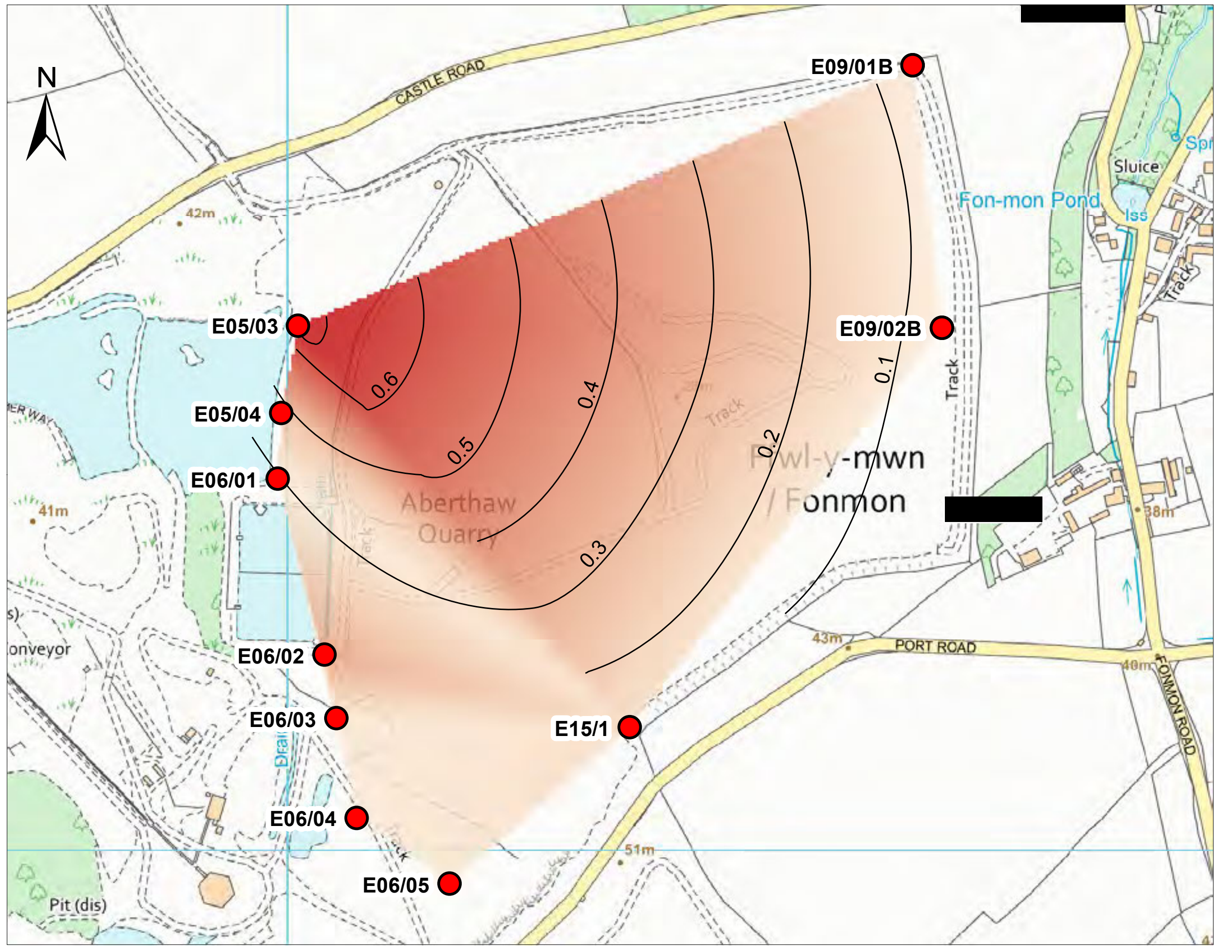

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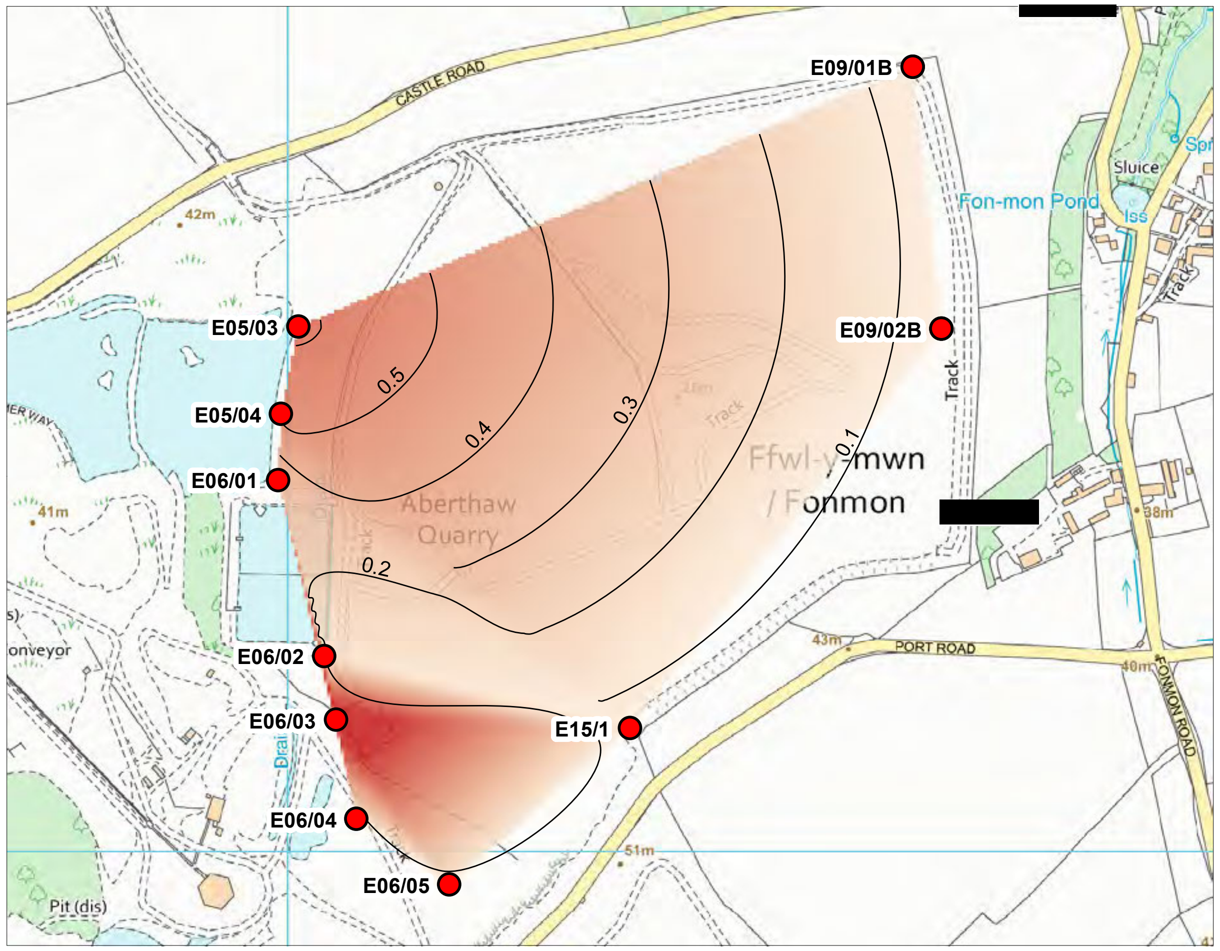

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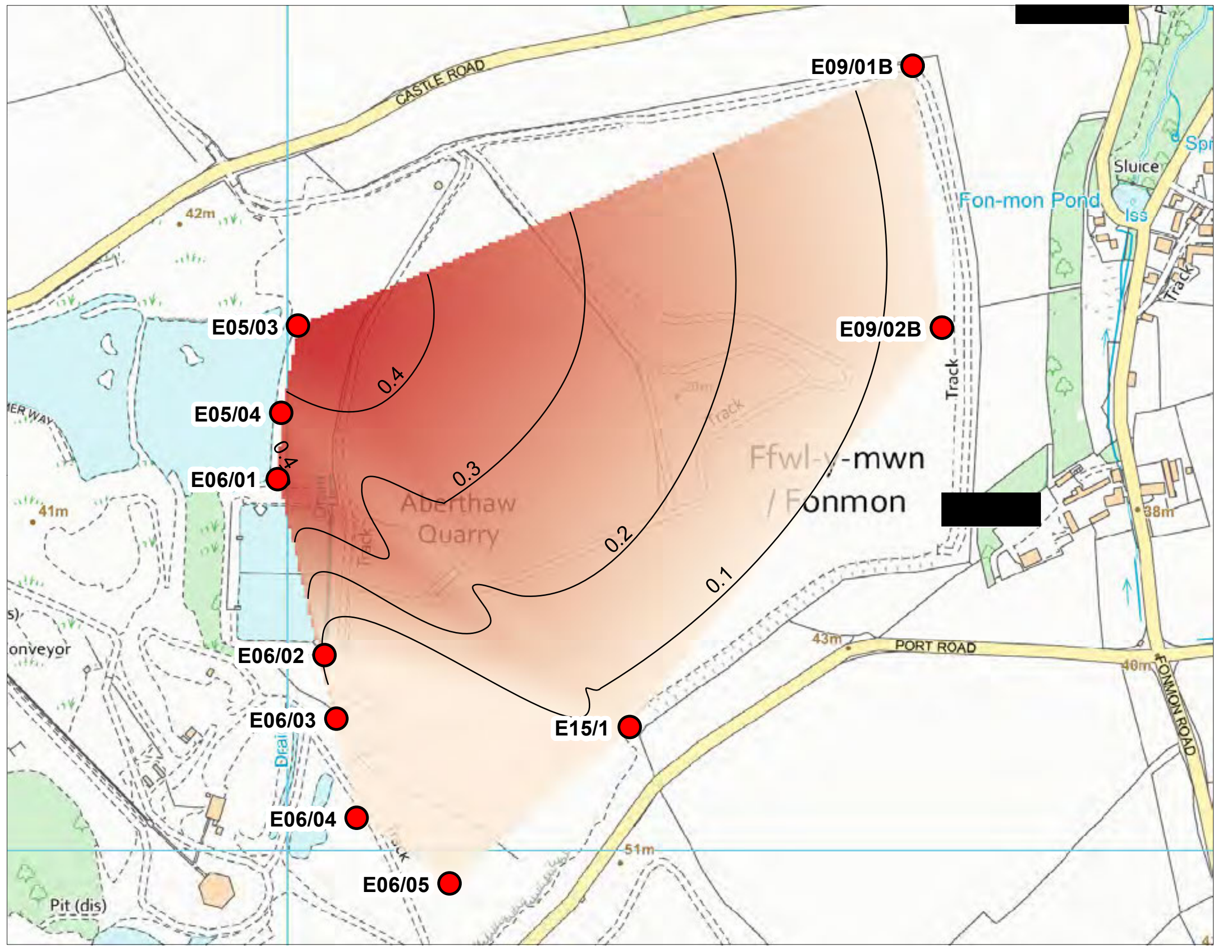

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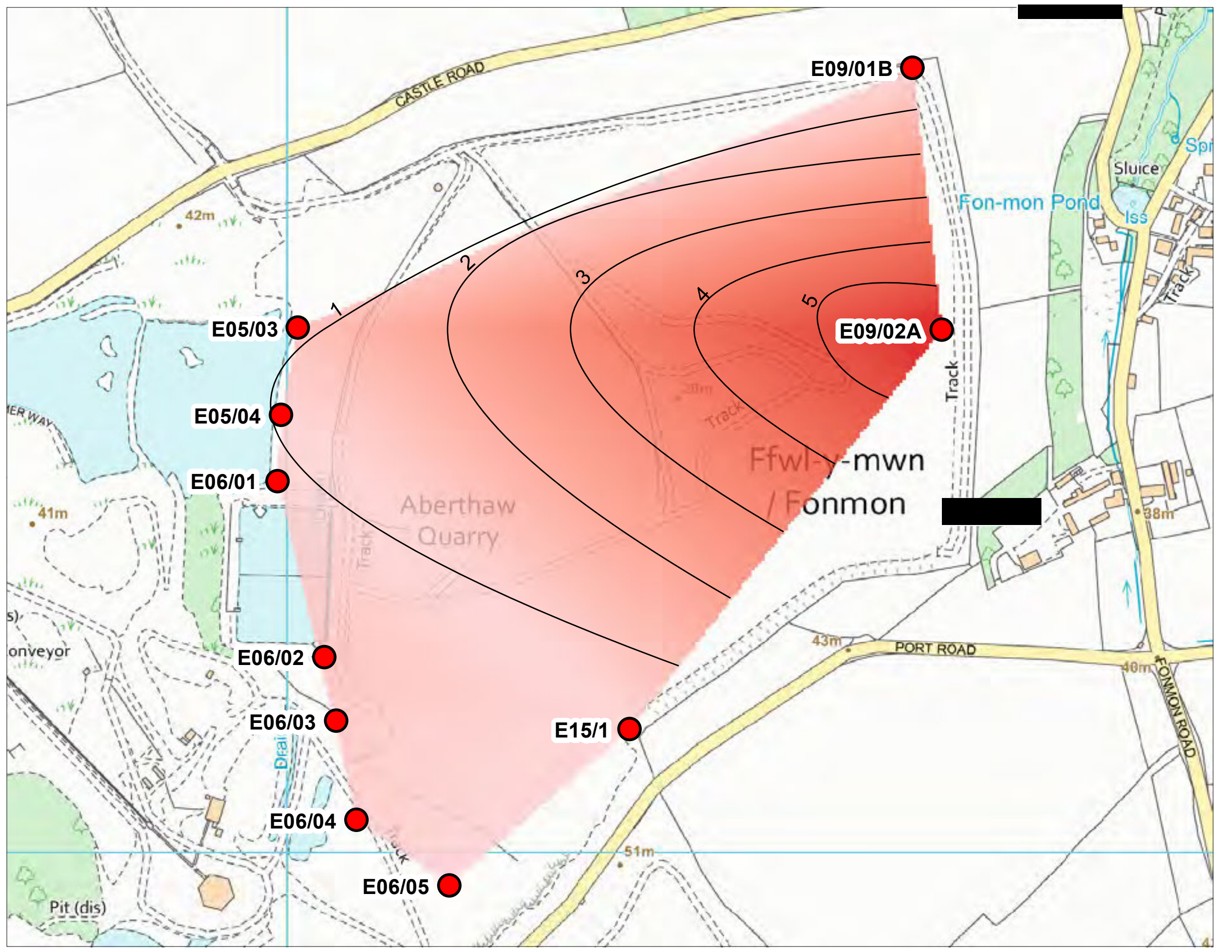

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Title Ammonical Nitrogen (mg/l) Concentrations in Groundwater – 2021 and 2022

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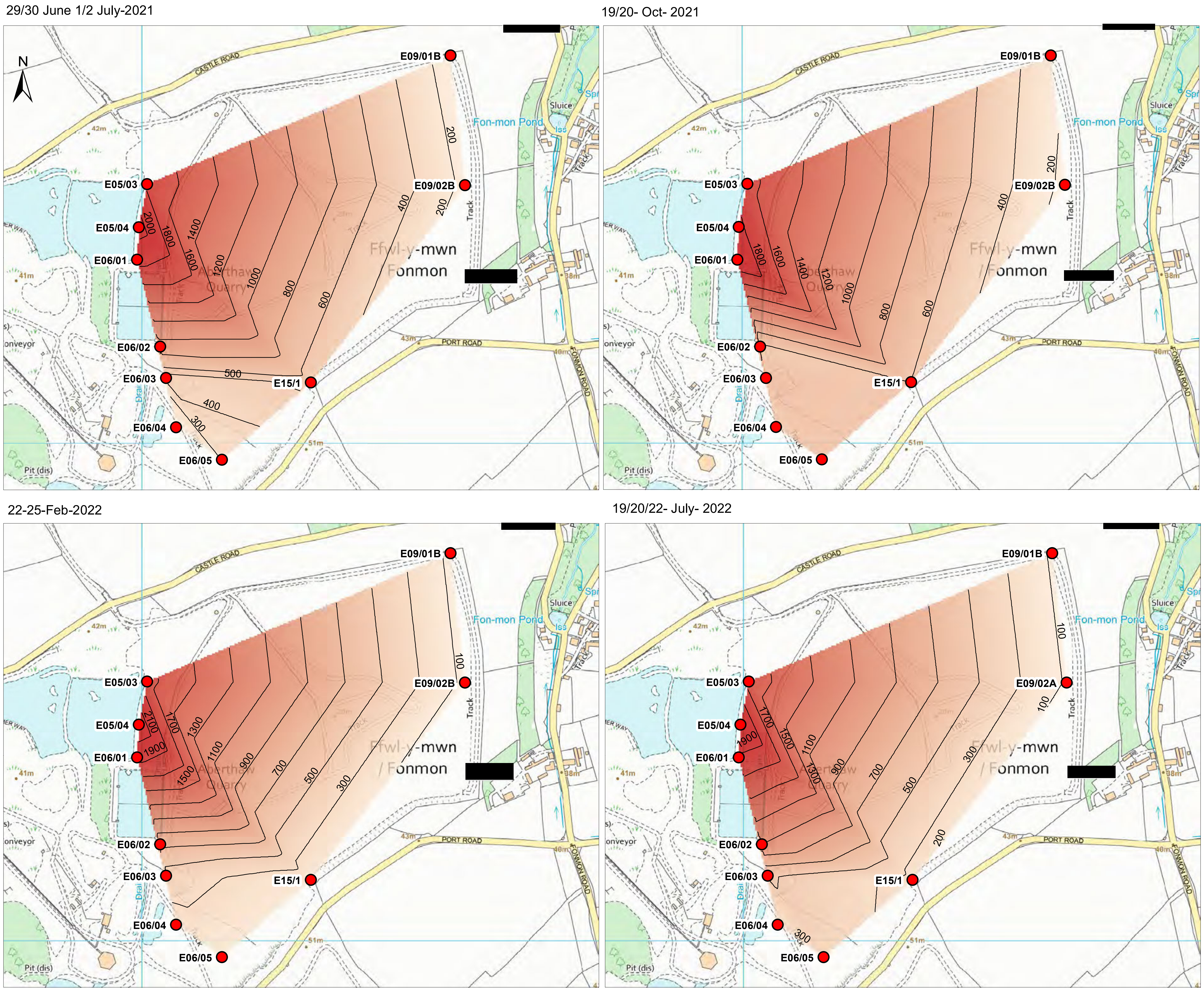

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Title Boron (mg/l) Concentrations in Groundwater – 2021 and 2022

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Figure Number: **JFR2782-HRA-04** Rev: **-**

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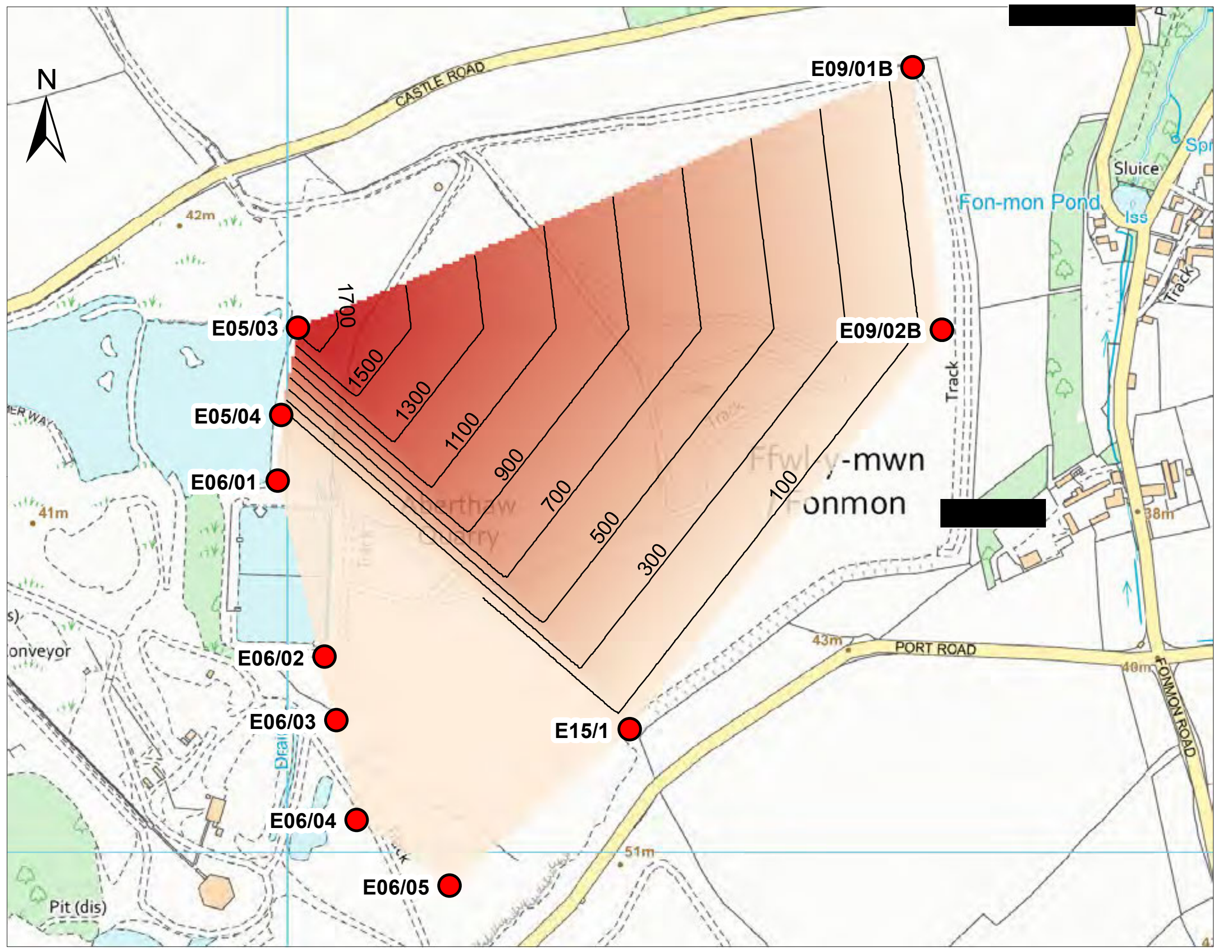

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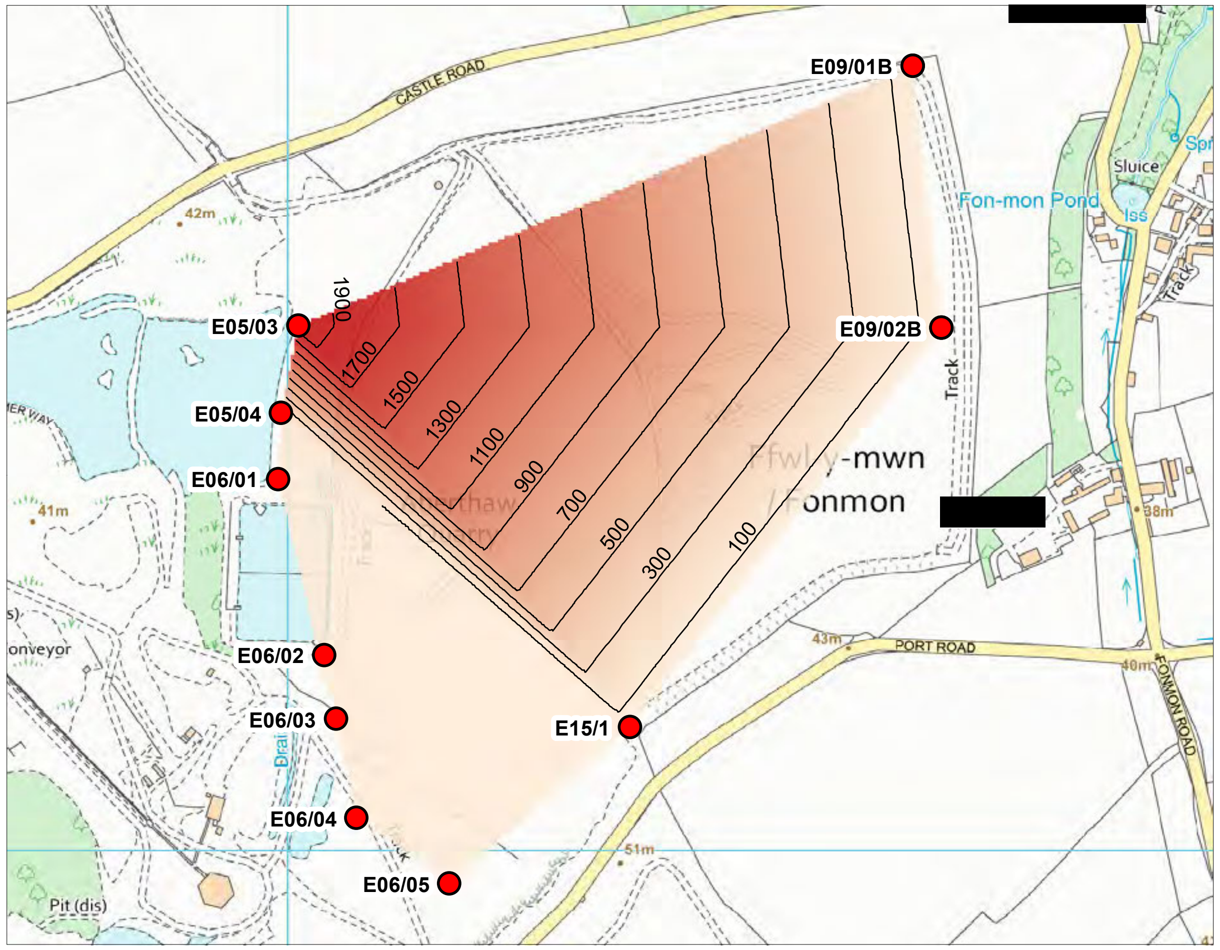

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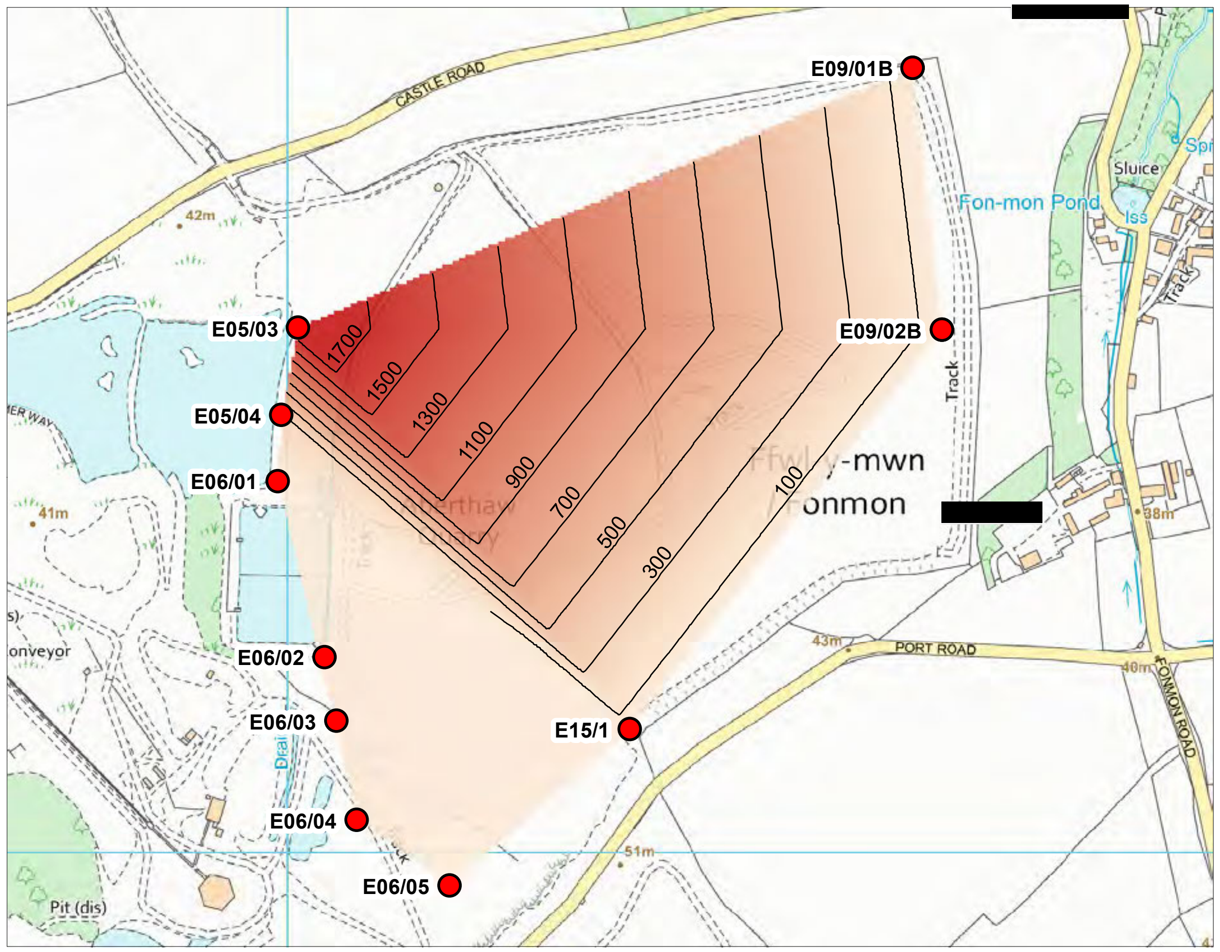

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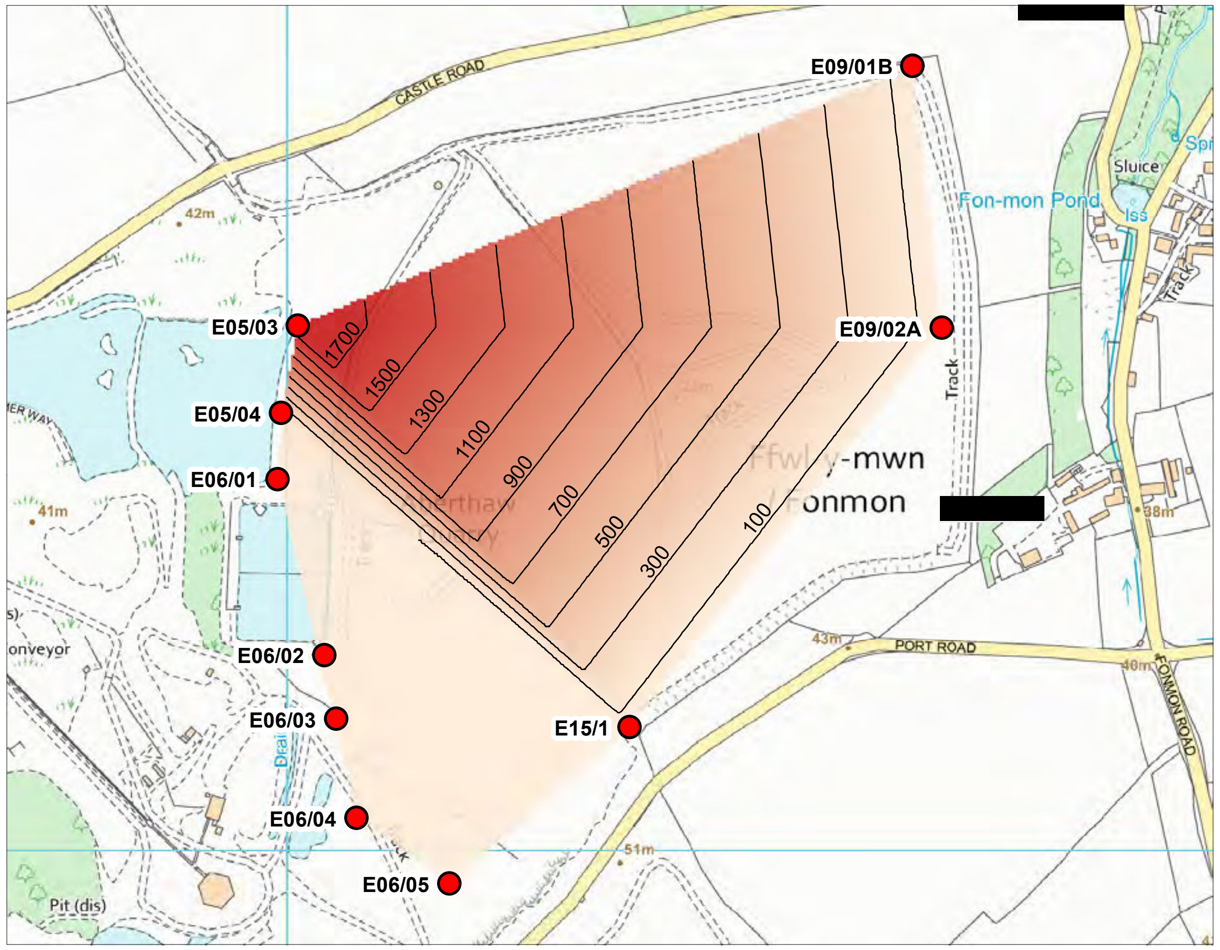

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Project Aberthaw Quarry

Title Chloride (mg/l) Concentrations in Groundwater – 2021 and 2022

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Figure Number: **JFR2782-HRA-05** Rev: **-**

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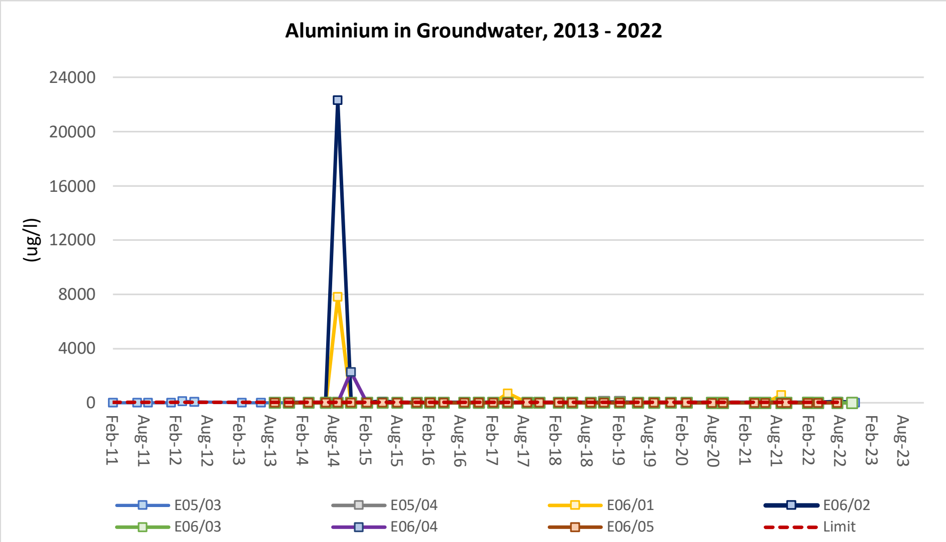
Appendix A
Time Series Graphs – Contaminant Concentrations



Aluminium in Groundwater, 2013 - 2022
(ug/l)
24000
20000
16000
12000
8000
4000
0
Feb-11
Aug-11
Feb-12
Aug-12
Feb-13
Aug-13
Feb-14
Aug-14
Feb-15
Aug-15
Feb-16
Aug-16
Feb-17
Aug-17
Feb-18
Aug-18
Feb-19
Aug-19
Feb-20
Aug-20
Feb-21
Aug-21
Feb-22
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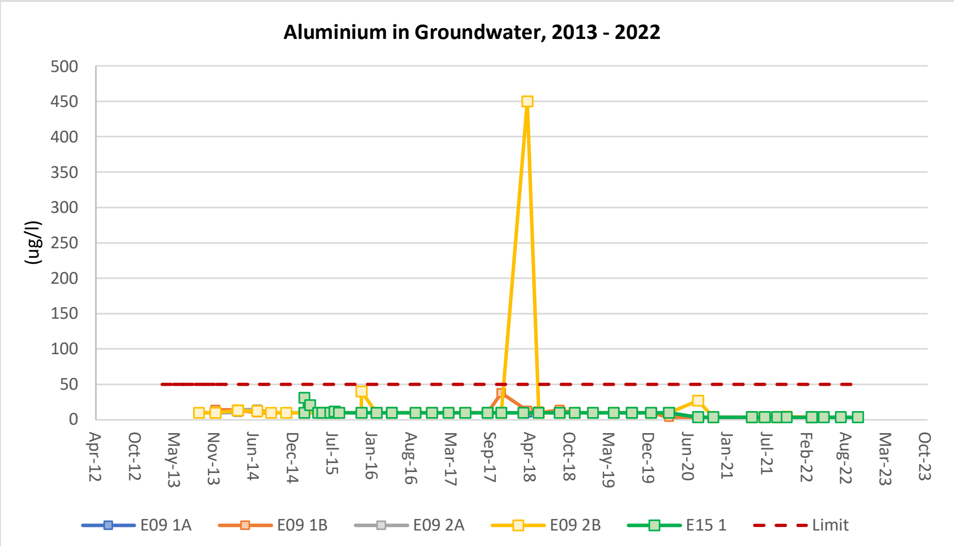
E06/04
E06/05
Limit



Aluminium in Groundwater, 2013 - 2022
(ug/l)
500
450
400
350
300
250
200
150
100
50
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
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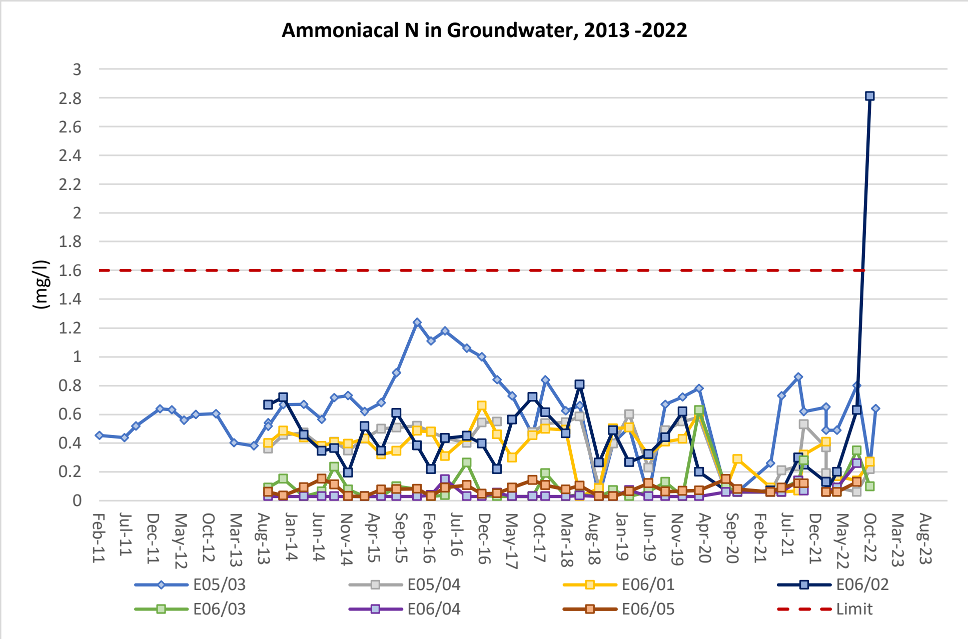
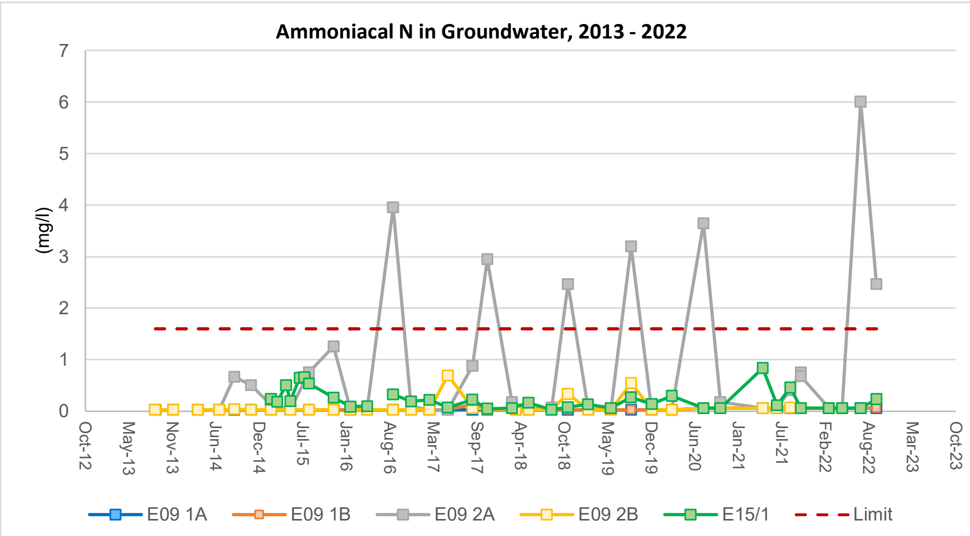
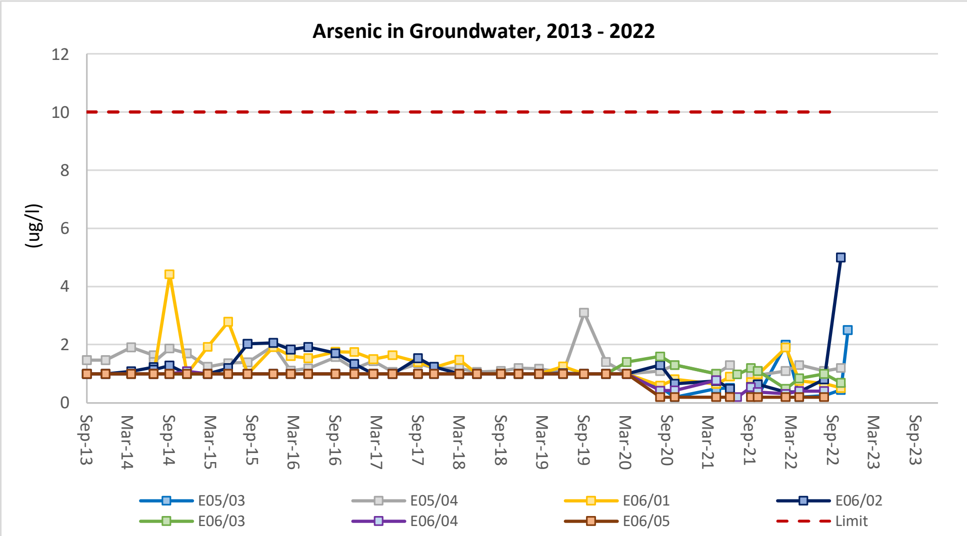
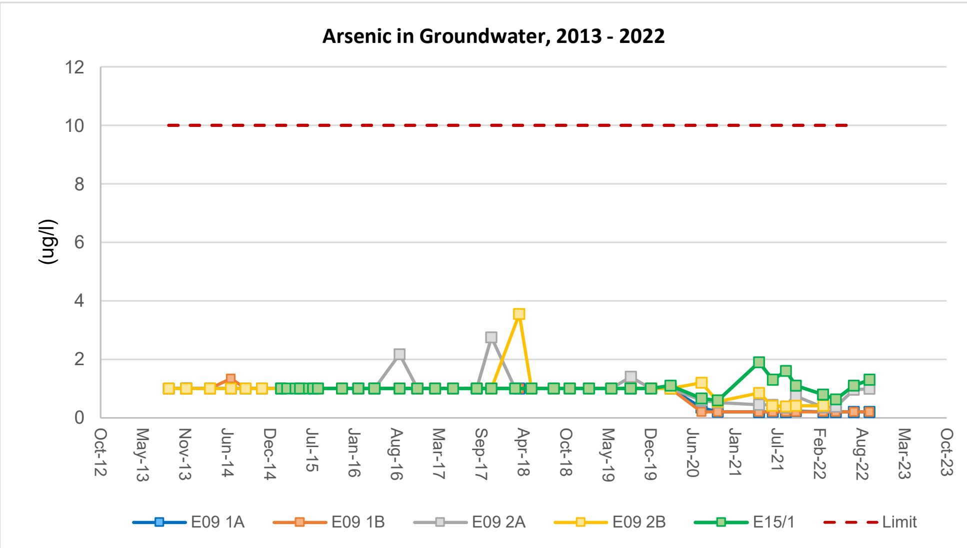
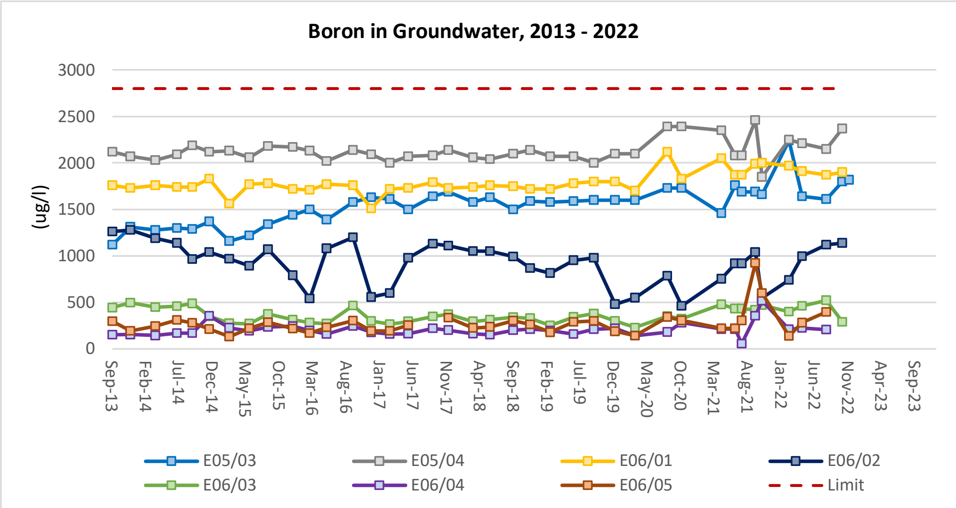
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15 1
Limit


Ammoniacal N in Groundwater, 2013 -2022
(mg/l)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Feb-11
Jul-11
Dec-11
May-12
Oct-12
Mar-13
Aug-13
Jan-14
Jun-14
Nov-14
Apr-15
Sep-15
Feb-16
Jul-16
Dec-16
May-17
Oct-17
Mar-18
Aug-18
Jan-19
Jun-19
Nov-19
Apr-20
Sep-20
Feb-21
Jul-21
Dec-21
May-22
Oct-22
Mar-23
Aug-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

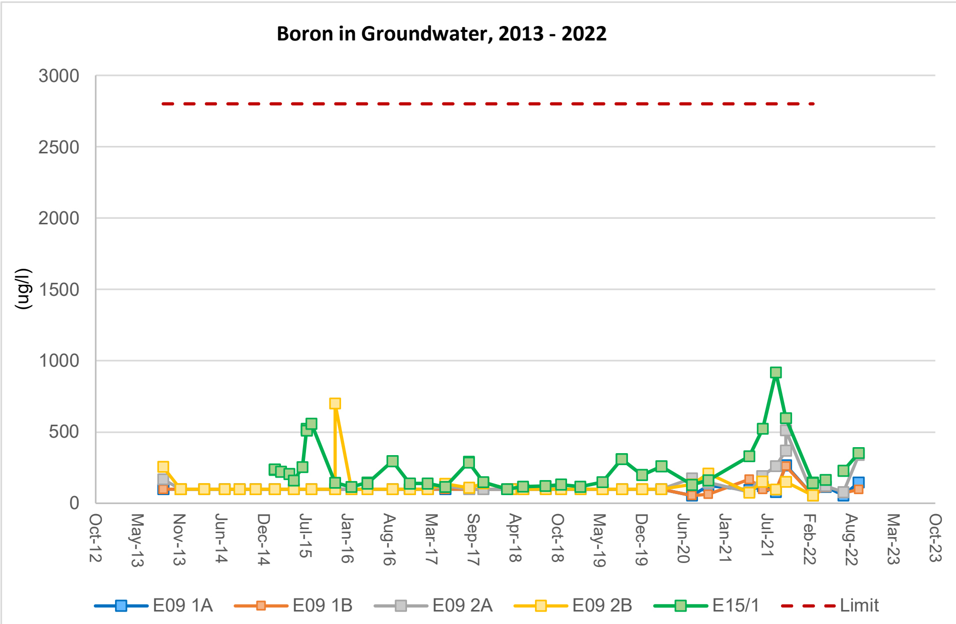

Ammoniacal N in Groundwater, 2013 - 2022
(mg/l)
7
6
5
4
3
2
1
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit


Arsenic in Groundwater, 2013 - 2022
12
10
8
6
4
2
0
(ug/l)
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Mar-18
Sep-18
Mar-19
Sep-19
Mar-20
Sep-20
Mar-21
Sep-21
Mar-22
Sep-22
Mar-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

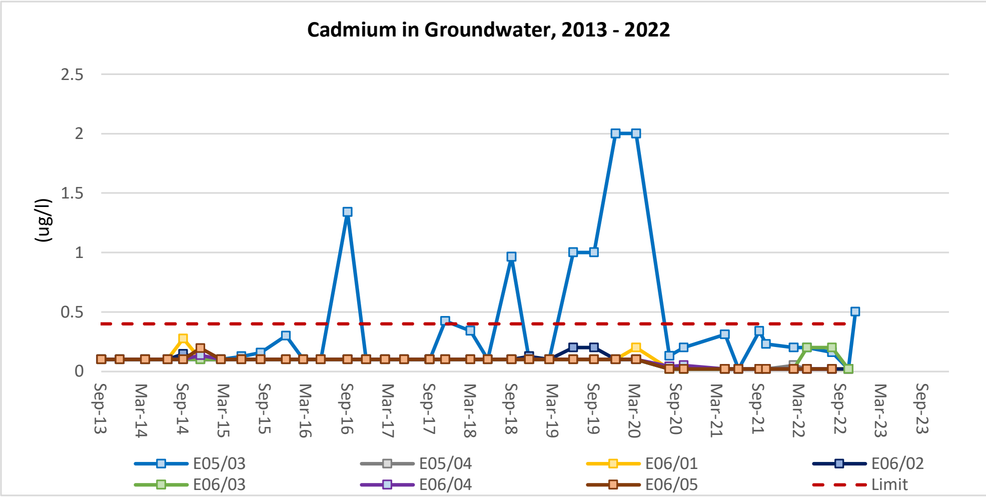

Arsenic in Groundwater, 2013 - 2022
12
10
8
6
4
2
0
(ug/l)
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit

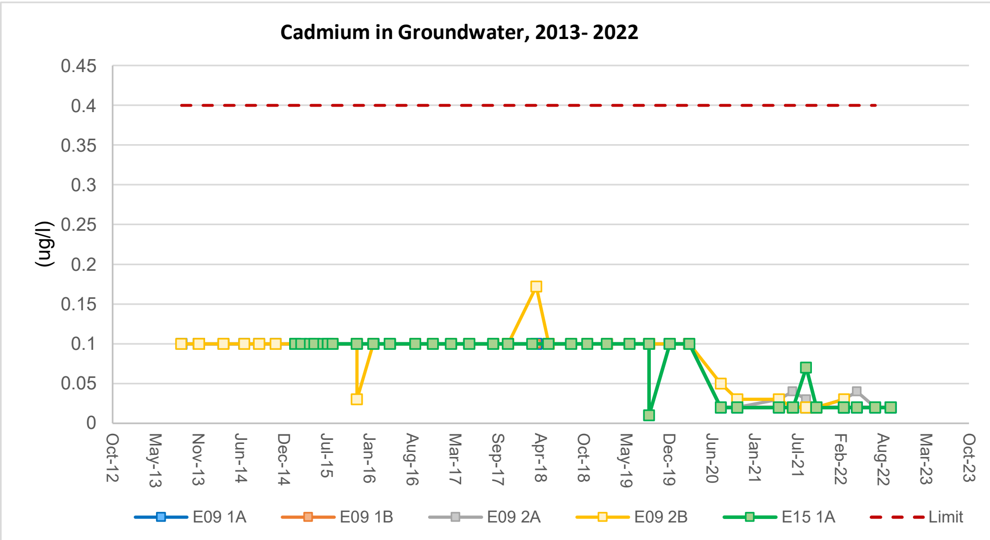


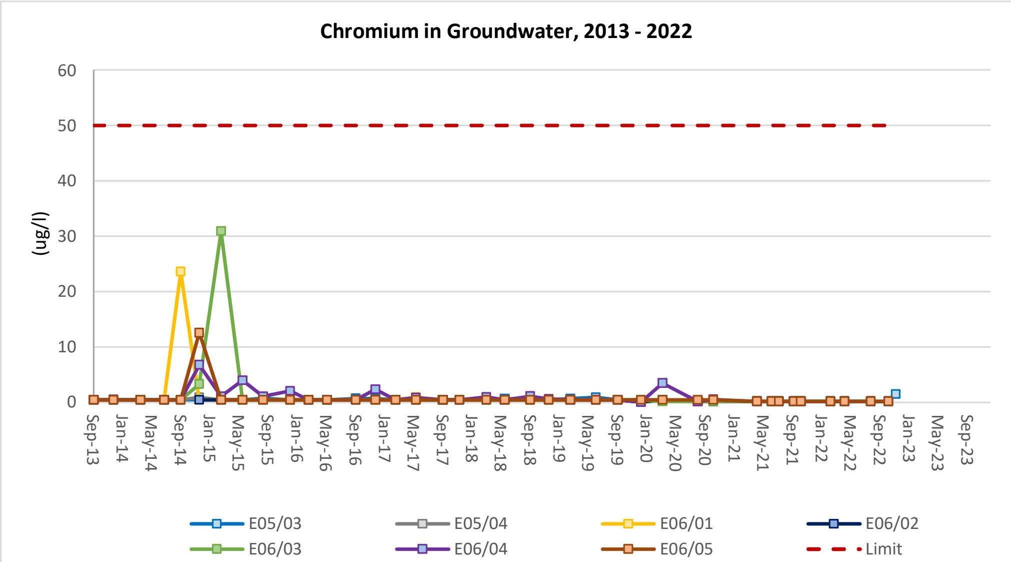
Boron in Groundwater, 2013 - 2022
(ug/l)
3000
2500
2000
1500
1000
500
0
Sep-13
Feb-14
Jul-14
Dec-14
May-15
Oct-15
Mar-16
Aug-16
Jan-17
Jun-17
Nov-17
Apr-18
Sep-18
Feb-19
Jul-19
Dec-19
May-20
Oct-20
Mar-21
Aug-21
Jan-22
Jun-22
Nov-22
Apr-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

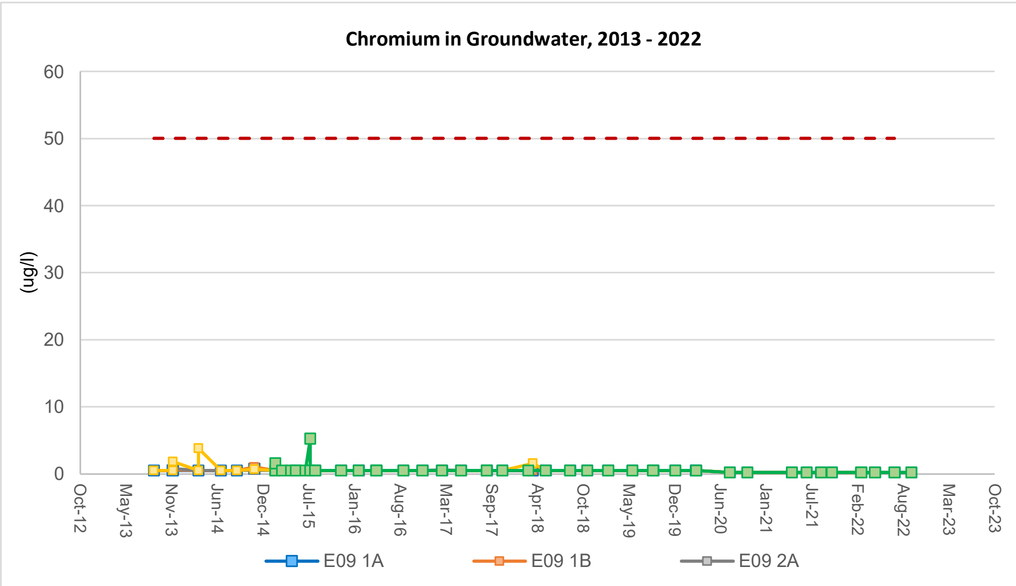


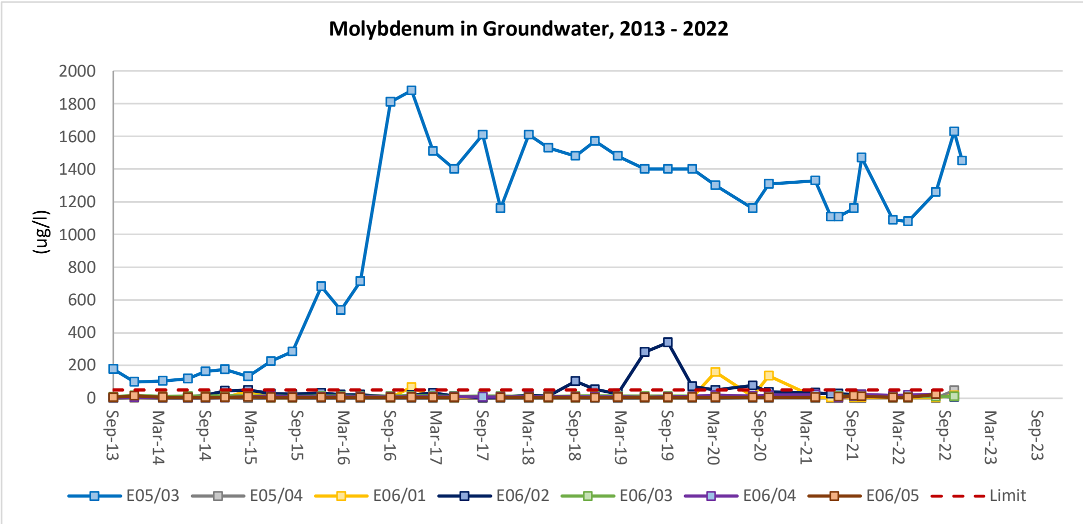
Boron in Groundwater, 2013 - 2022
(ug/l)
3000
2500
2000
1500
1000
500
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit

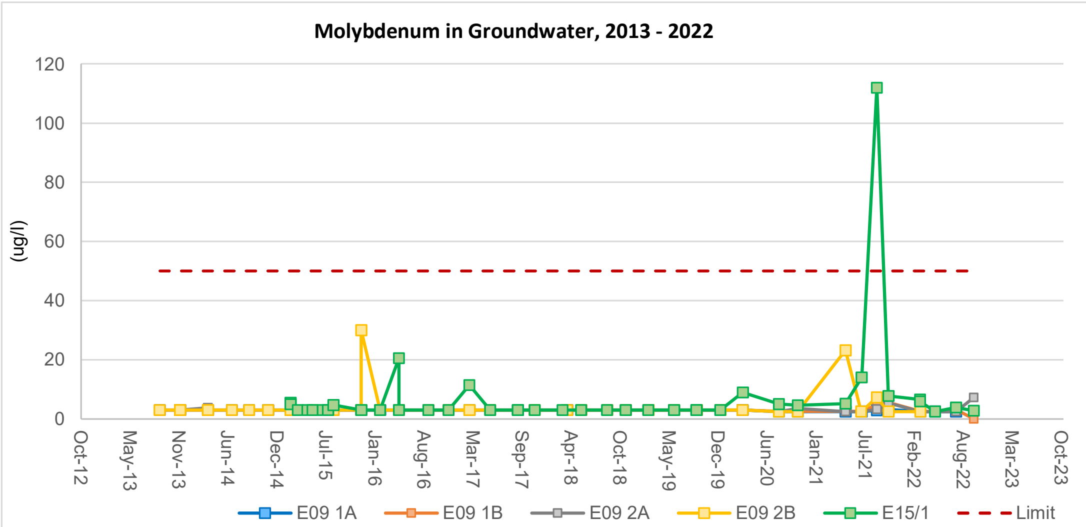

Cadmium in Groundwater, 2013 - 2022
(ug/l)
2.5
2
1.5
1
0.5
0
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Mar-18
Sep-18
Mar-19
Sep-19
Mar-20
Sep-20
Mar-21
Sep-21
Mar-22
Sep-22
Mar-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

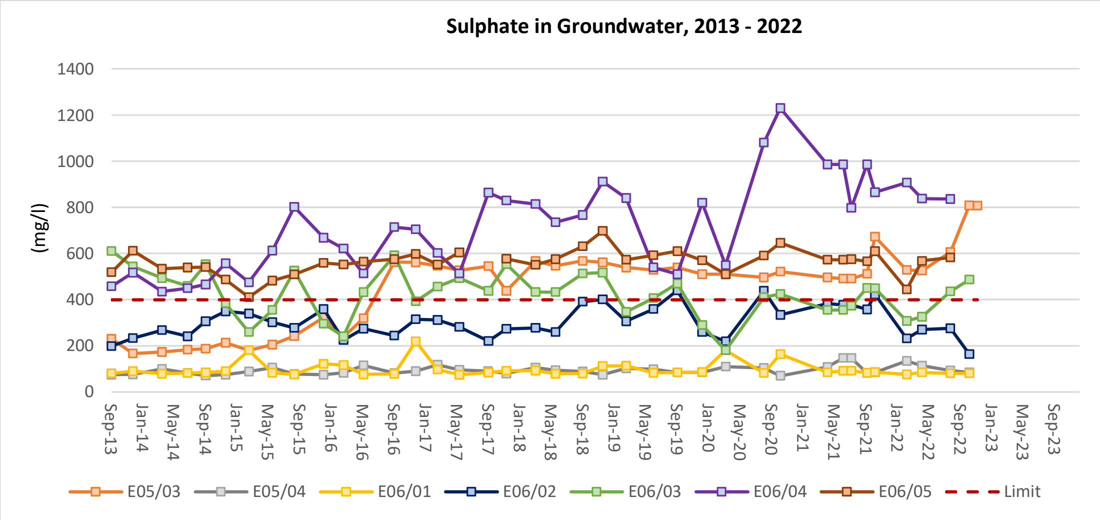

Cadmium in Groundwater, 2013- 2022
(ug/l)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15 1A
Limit

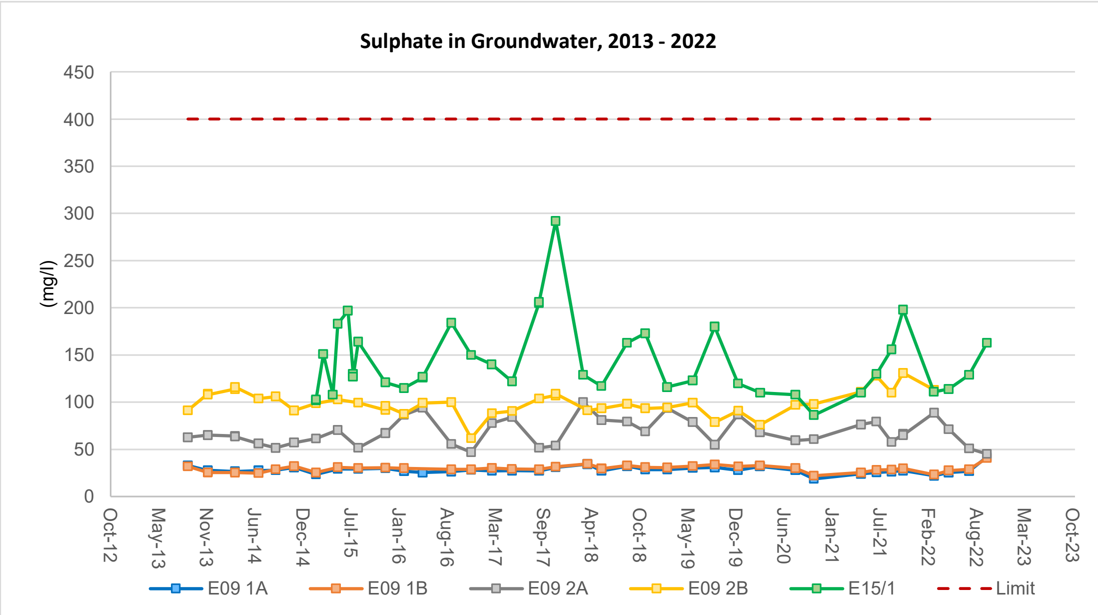

Chromium in Groundwater, 2013 - 2022
(ug/l)
60
50
40
30
20
10
0
Sep-13
Jan-14
May-14
Sep-14
Jan-15
May-15
Sep-15
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Sep-20
Jan-21
May-21
Sep-21
Jan-22
May-22
Sep-22
Jan-23
May-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

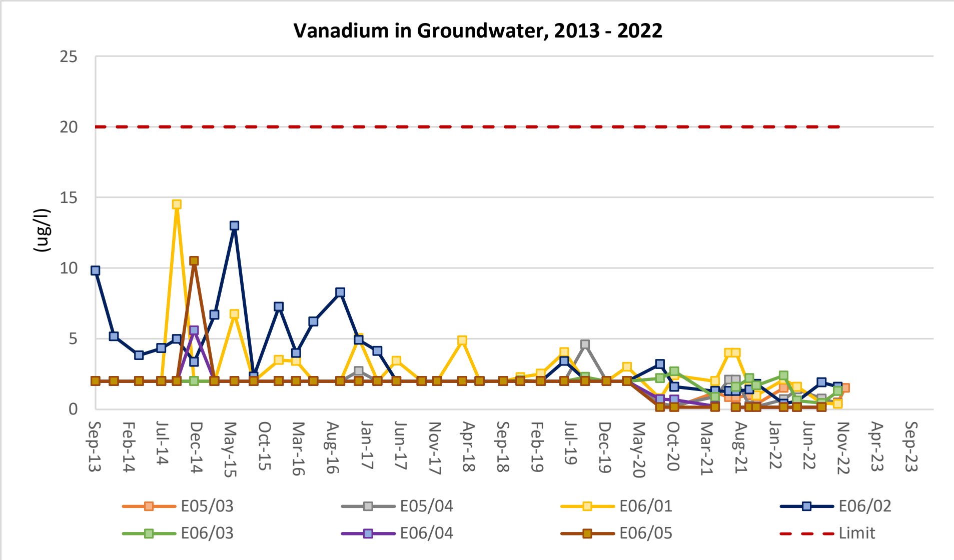

Chromium in Groundwater, 2013 - 2022
(ug/l)
60
50
40
30
20
10
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A

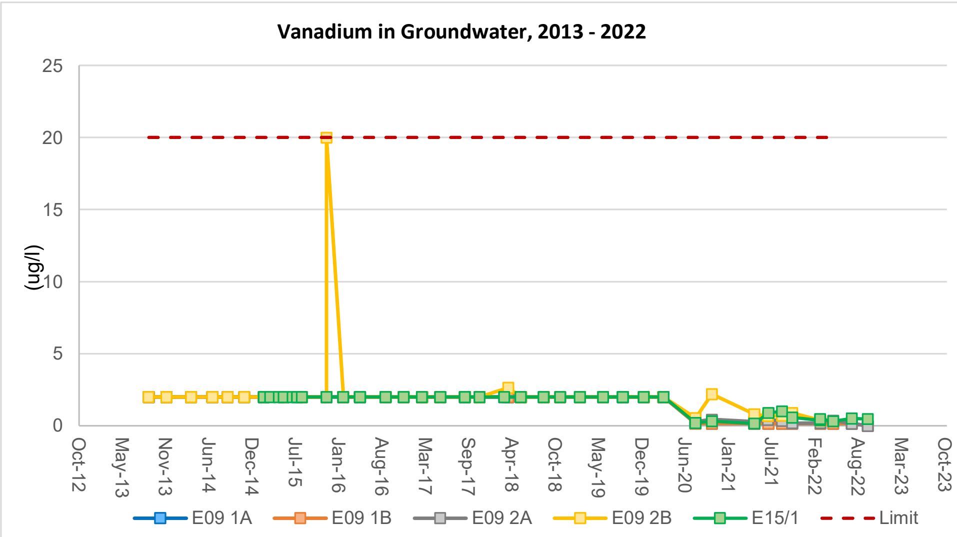

Molybdenum in Groundwater, 2013 - 2022
(ug/l)
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

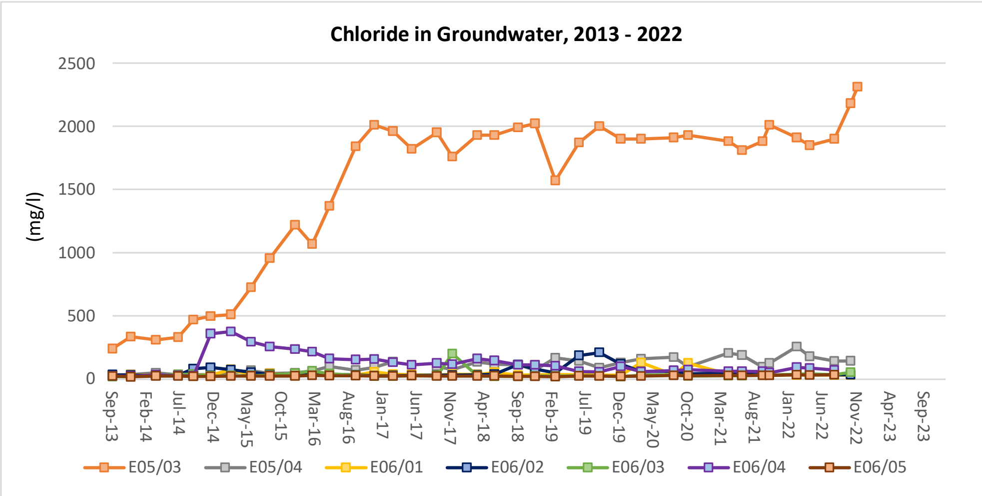

Molybdenum in Groundwater, 2013 - 2022
(ug/l)
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit

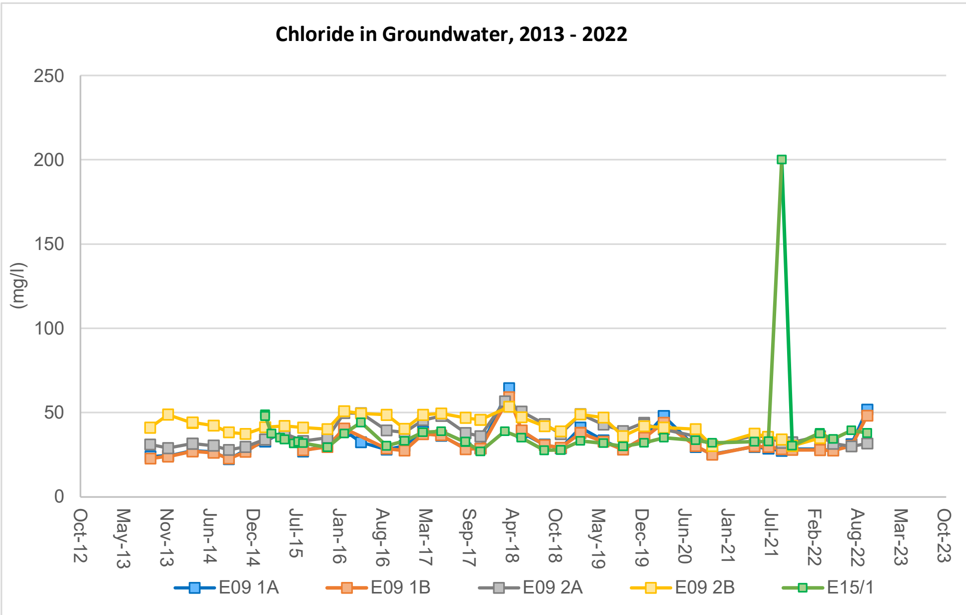

Sulphate in Groundwater, 2013 - 2022
(mg/l)
0
200
400
600
800
1000
1200
1400
Sep-13
Jan-14
May-14
Sep-14
Jan-15
May-15
Sep-15
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Sep-20
Jan-21
May-21
Sep-21
Jan-22
May-22
Sep-22
Jan-23
May-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

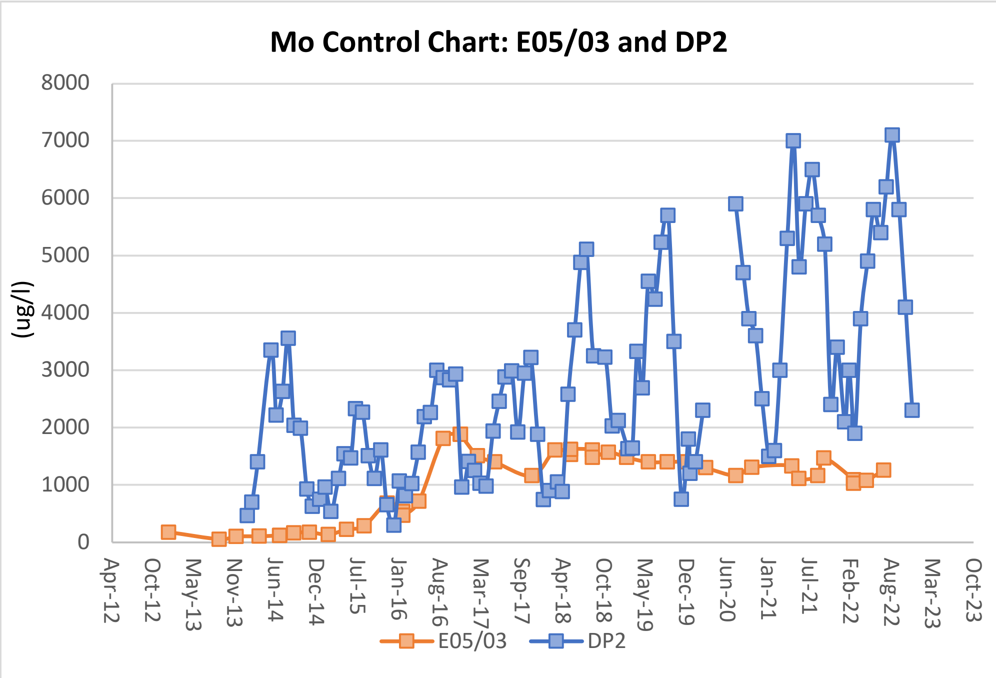

Sulphate in Groundwater, 2013 - 2022
(mg/l)
0
50
100
150
200
250
300
350
400
450
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit

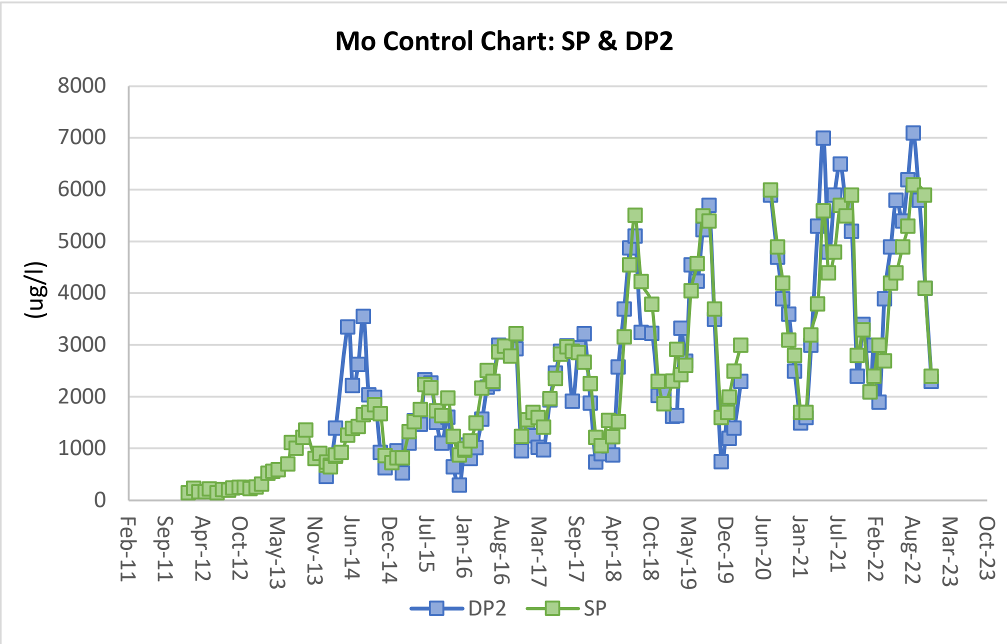

Vanadium in Groundwater, 2013 - 2022
25
20
15
10
5
0
(ug/l)
Sep-13
Feb-14
Jul-14
Dec-14
May-15
Oct-15
Mar-16
Aug-16
Jan-17
Jun-17
Nov-17
Apr-18
Sep-18
Feb-19
Jul-19
Dec-19
May-20
Oct-20
Mar-21
Aug-21
Jan-22
Jun-22
Nov-22
Apr-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05
Limit

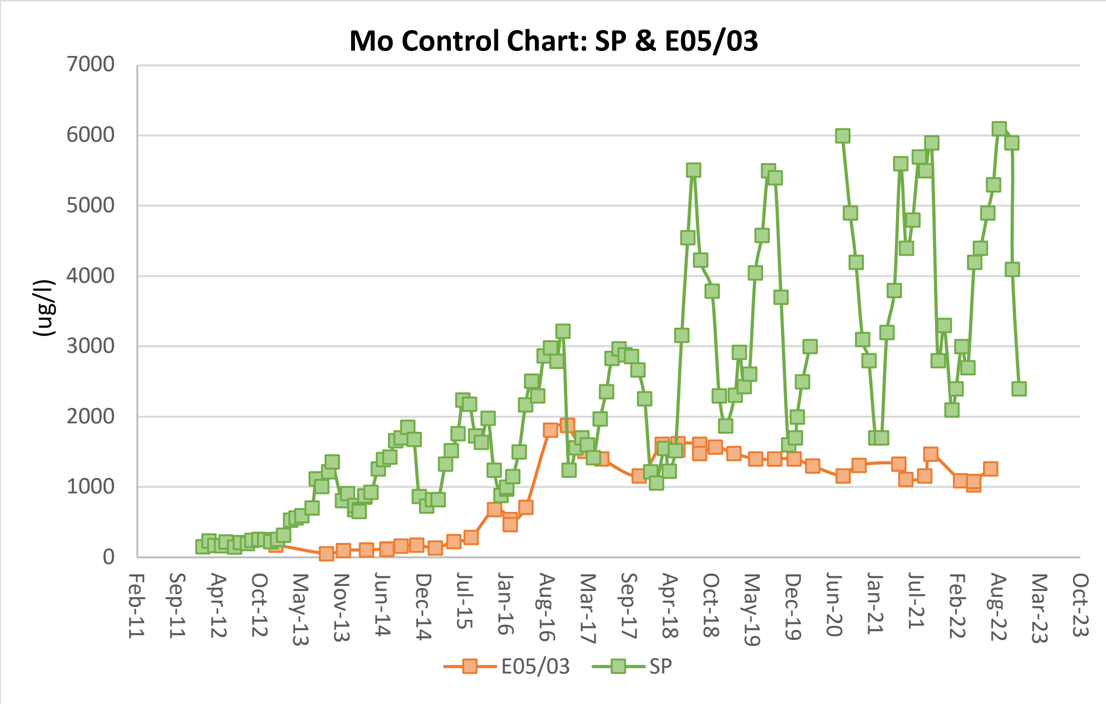

Vanadium in Groundwater, 2013 - 2022
25
20
15
10
5
0
(ug/l)
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1
Limit

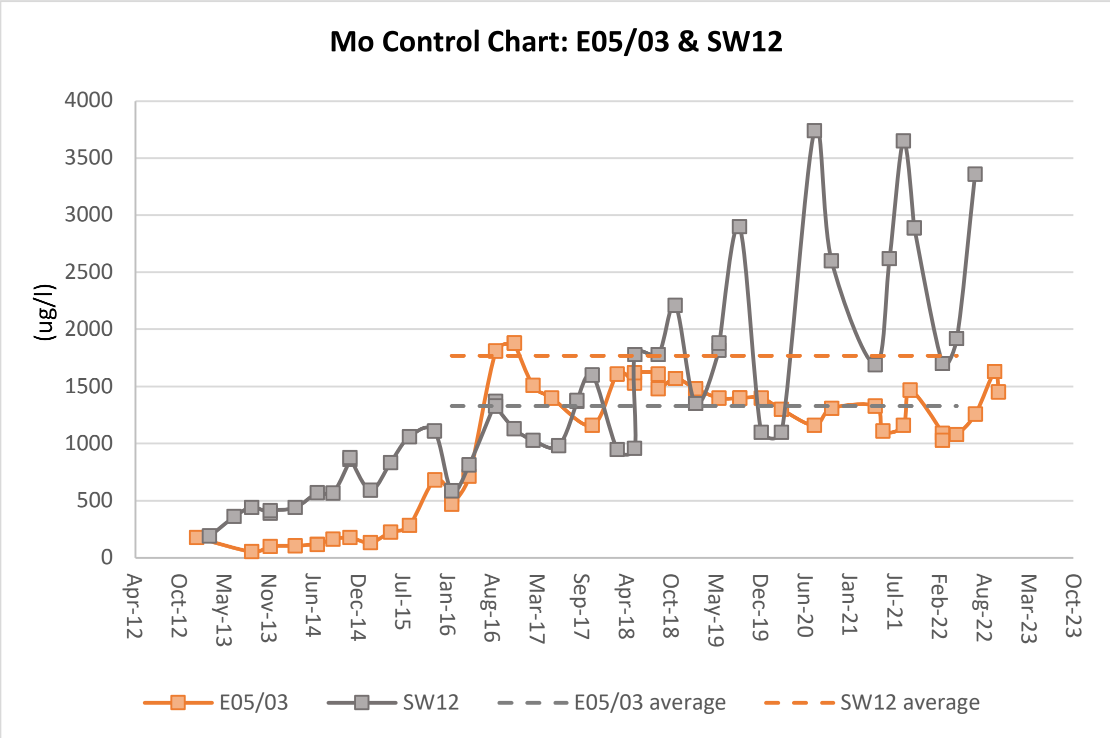

Chloride in Groundwater, 2013 - 2022
(mg/l)
2500
2000
1500
1000
500
0
Sep-13
Feb-14
Jul-14
Dec-14
May-15
Oct-15
Mar-16
Aug-16
Jan-17
Jun-17
Nov-17
Apr-18
Sep-18
Feb-19
Jul-19
Dec-19
May-20
Oct-20
Mar-21
Aug-21
Jan-22
Jun-22
Nov-22
Apr-23
Sep-23
E05/03
E05/04
E06/01
E06/02
E06/03
E06/04
E06/05

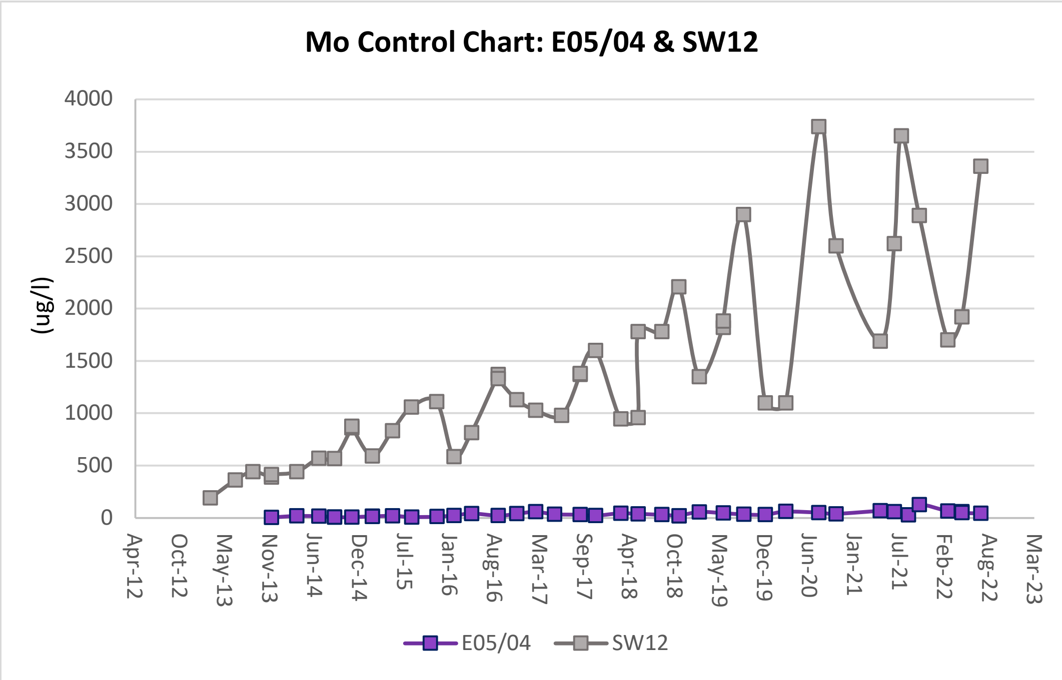

Chloride in Groundwater, 2013 - 2022
(mg/l)
250
200
150
100
50
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E09 1A
E09 1B
E09 2A
E09 2B
E15/1

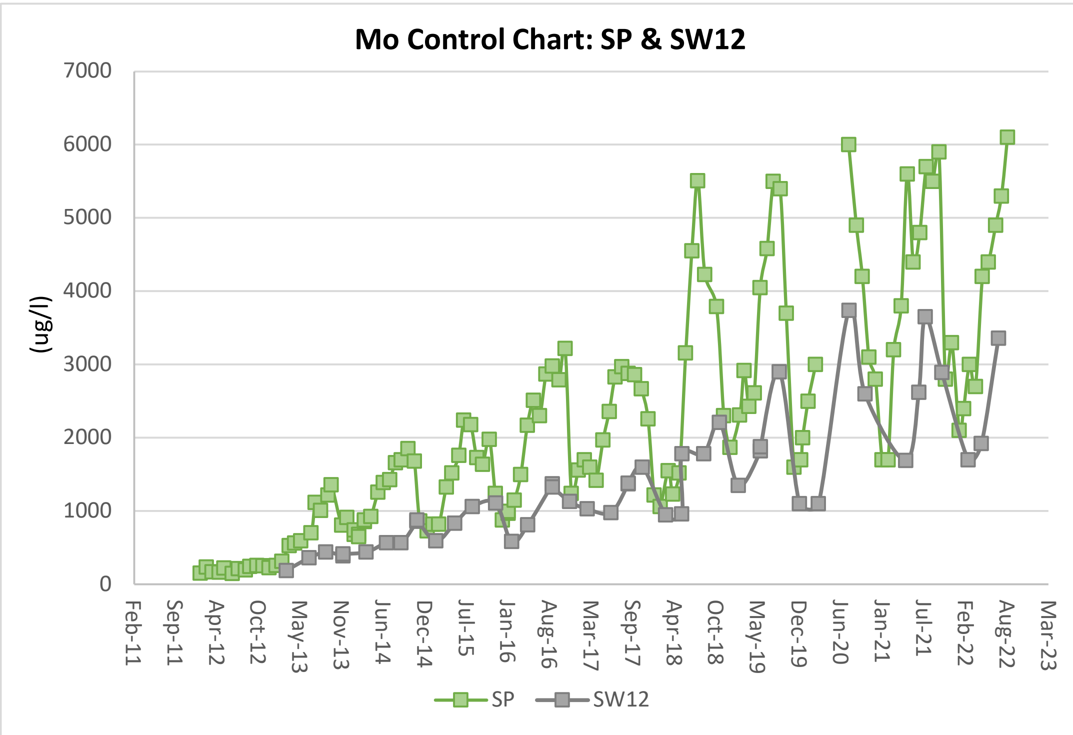

Mo Control Chart: E05/03 and DP2
(ug/l)
8000
7000
6000
5000
4000
3000
2000
1000
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E05/03
DP2

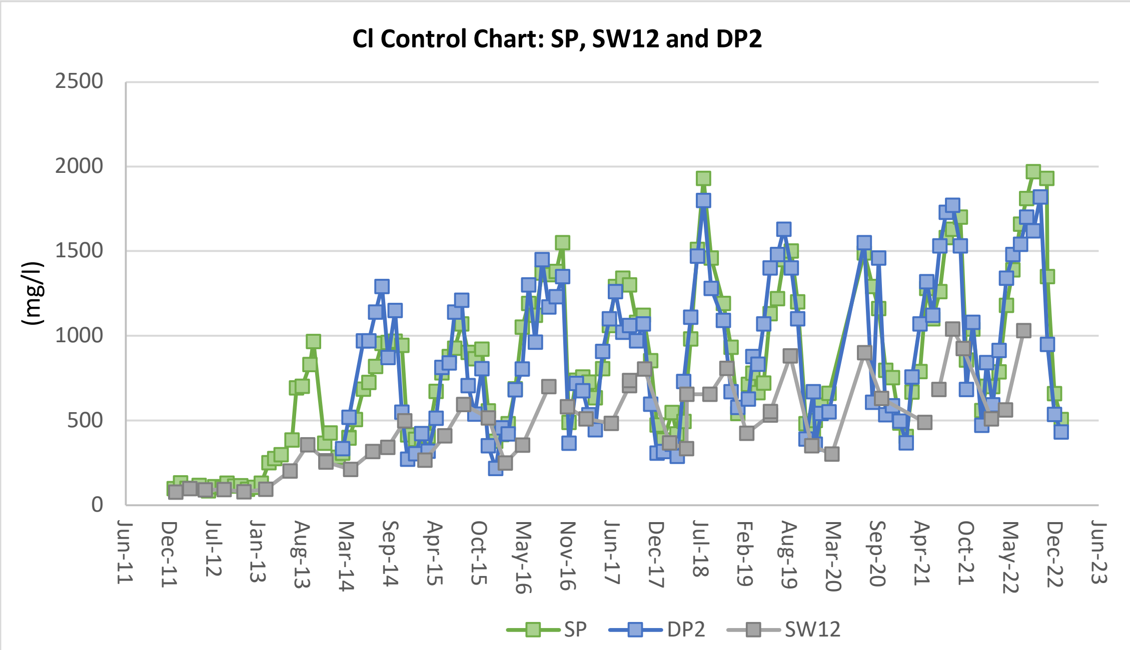

Mo Control Chart: SP & DP2
(ug/l)
8000
7000
6000
5000
4000
3000
2000
1000
0
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP

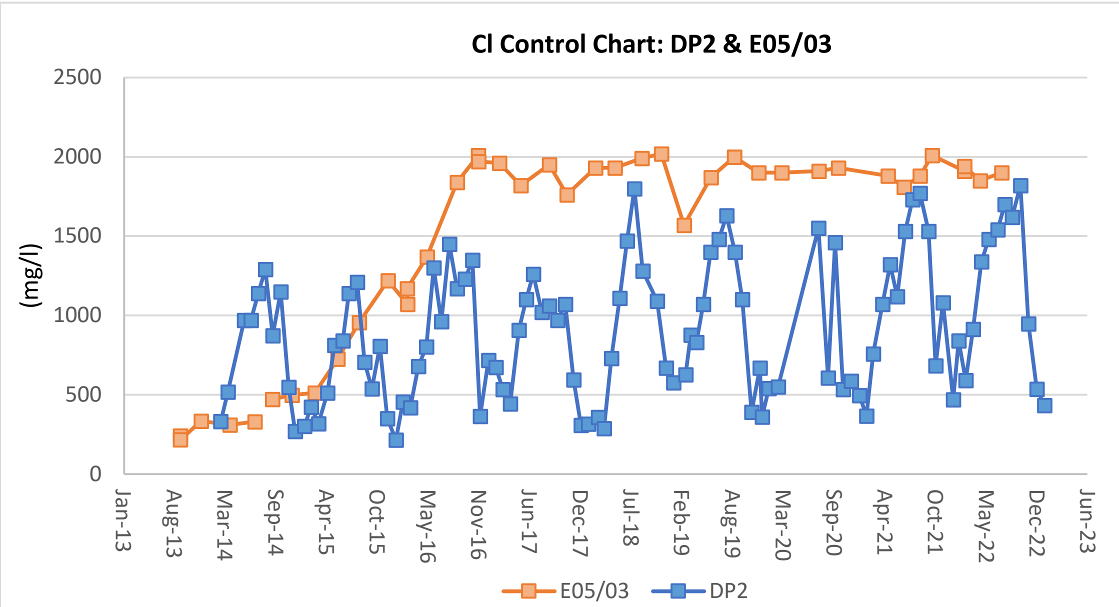

Mo Control Chart: SP & E05/03
(ug/l)
7000
6000
5000
4000
3000
2000
1000
0
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E05/03
SP

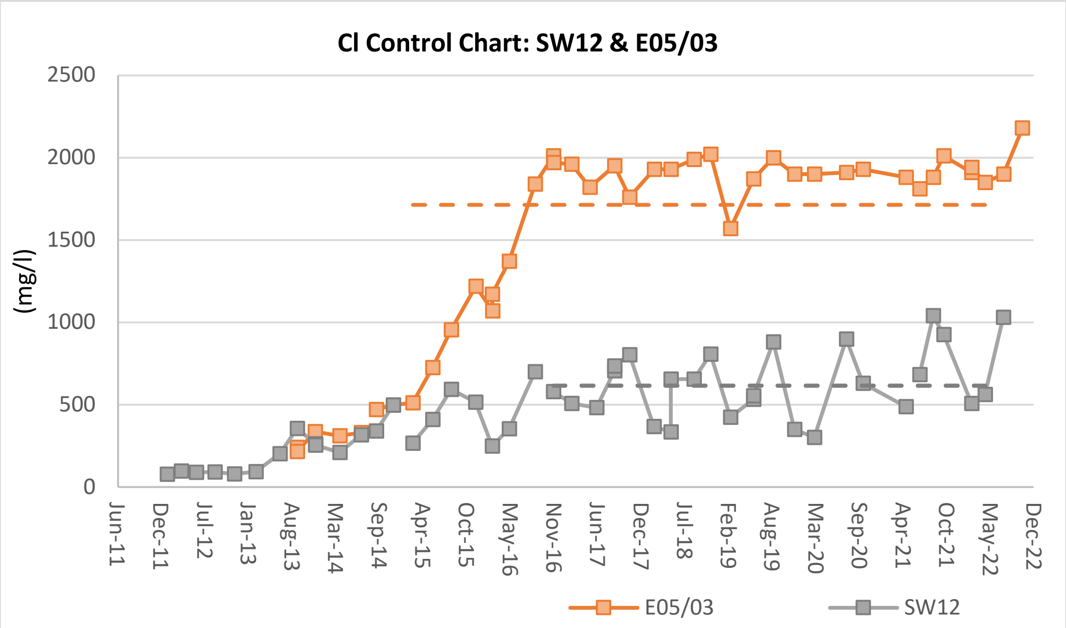

Mo Control Chart: E05/03 & SW12
(ug/l)
4000
3500
3000
2500
2000
1500
1000
500
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
E05/03
SW12
E05/03 average
SW12 average

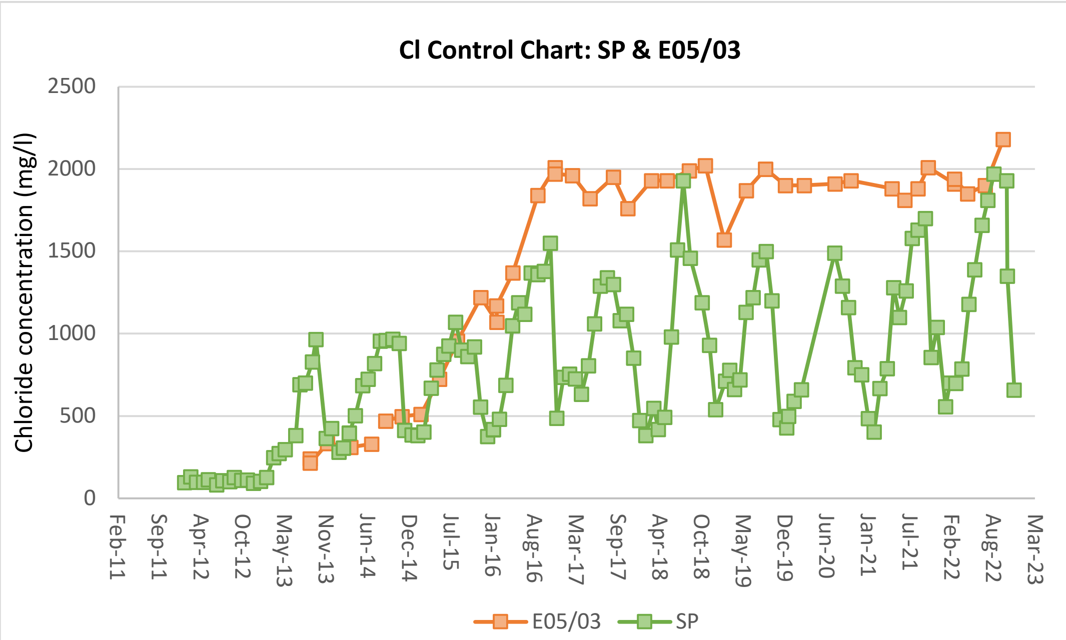

Mo Control Chart: E05/04 & SW12
(ug/l)
4000
3500
3000
2500
2000
1500
1000
500
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
E05/04
SW12

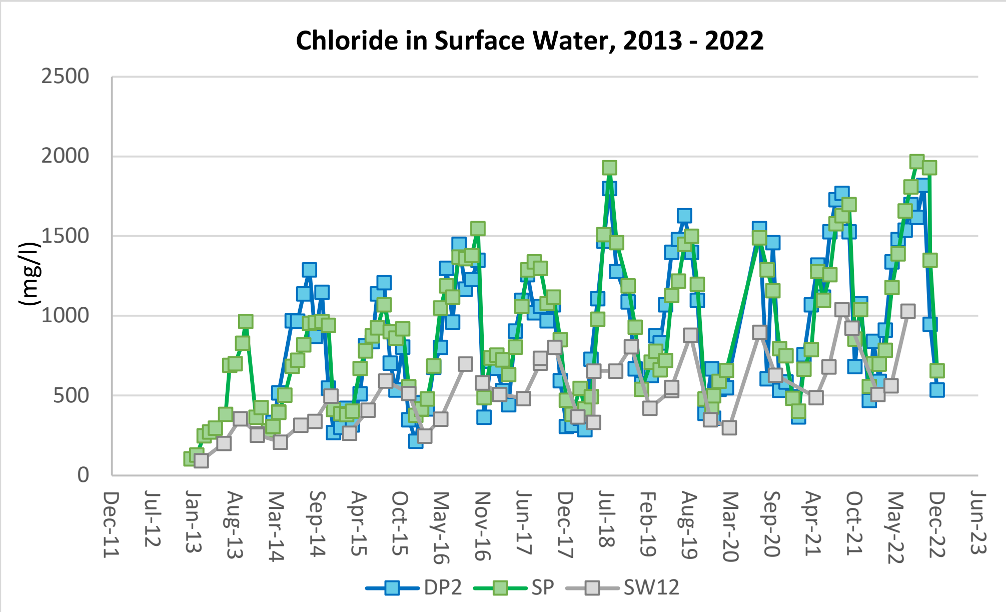

Mo Control Chart: SP & SW12
(ug/l)
7000
6000
5000
4000
3000
2000
1000
0
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
SP
SW12

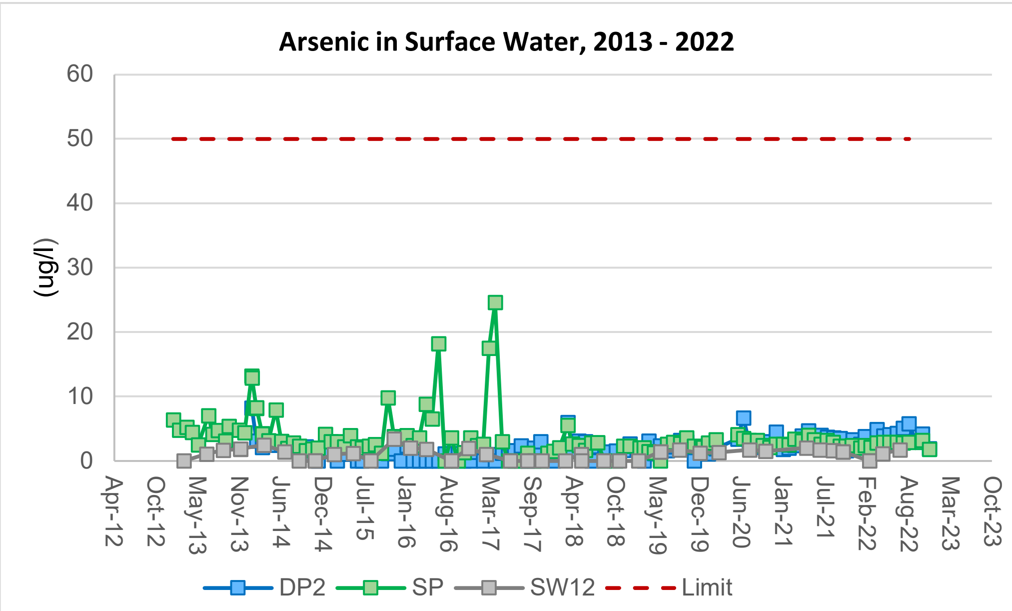

Cl Control Chart: SP, SW12 and DP2
2500
2000
1500
1000
500
0
(mg/l)
Jun-11
Dec-11
Jul-12
Jan-13
Aug-13
Mar-14
Sep-14
Apr-15
Oct-15
May-16
Nov-16
Jun-17
Dec-17
Jul-18
Feb-19
Aug-19
Mar-20
Sep-20
Apr-21
Oct-21
May-22
Dec-22
Jun-23
SP
DP2
SW12

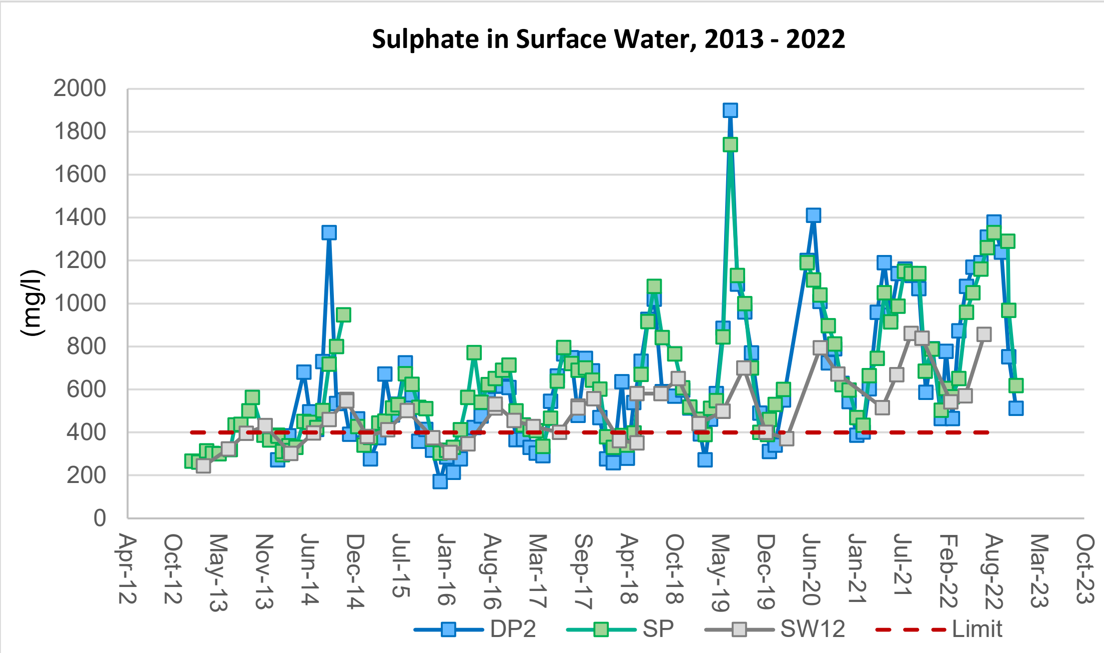

Cl Control Chart: DP2 & E05/03
2500
2000
1500
1000
500
0
(mg/l)
Jan-13
Aug-13
Mar-14
Sep-14
Apr-15
Oct-15
May-16
Nov-16
Jun-17
Dec-17
Jul-18
Feb-19
Aug-19
Mar-20
Sep-20
Apr-21
Oct-21
May-22
Dec-22
Jun-23
E05/03
DP2


Cl Control Chart: SW12 & E05/03
(mg/l)
2500
2000
1500
1000
500
0
Jun-11
Dec-11
Jul-12
Jan-13
Aug-13
Mar-14
Sep-14
Apr-15
Oct-15
May-16
Nov-16
Jun-17
Dec-17
Jul-18
Feb-19
Aug-19
Mar-20
Sep-20
Apr-21
Oct-21
May-22
Dec-22
E05/03
SW12

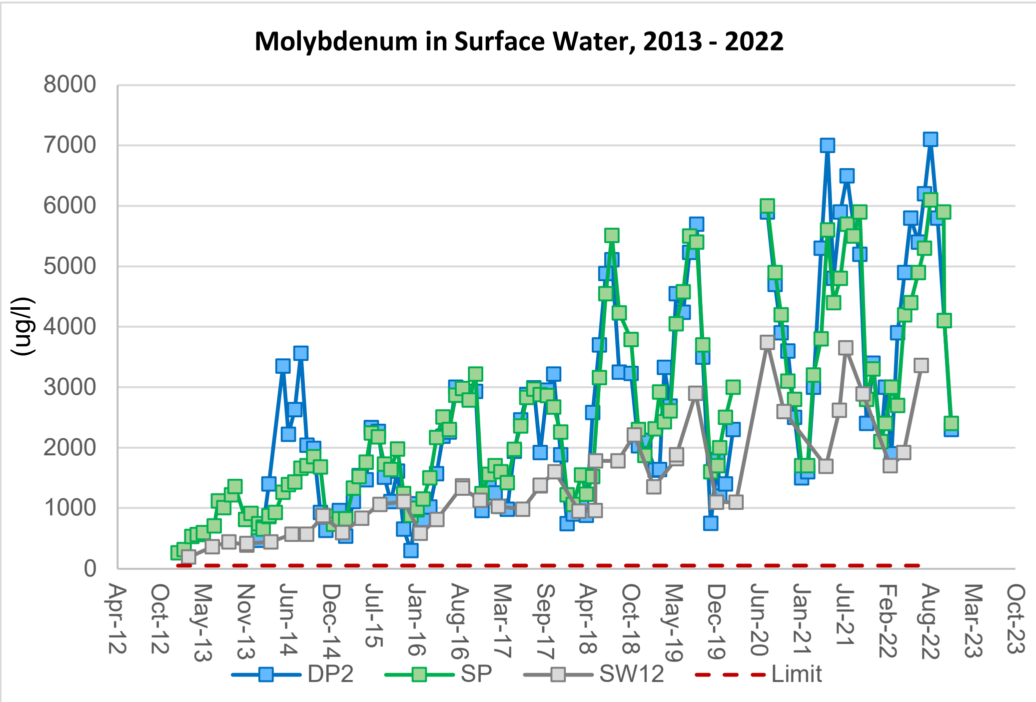

Cl Control Chart: SP & E05/03
Chloride concentration (mg/l)
2500
2000
1500
1000
500
0
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
E05/03
SP


Chloride in Surface Water, 2013 - 2022
(mg/l)
2500
2000
1500
1000
500
0
Dec-11
Jul-12
Jan-13
Aug-13
Mar-14
Sep-14
Apr-15
Oct-15
May-16
Nov-16
Jun-17
Dec-17
Jul-18
Feb-19
Aug-19
Mar-20
Sep-20
Apr-21
Oct-21
May-22
Dec-22
Jun-23
DP2
SP
SW12

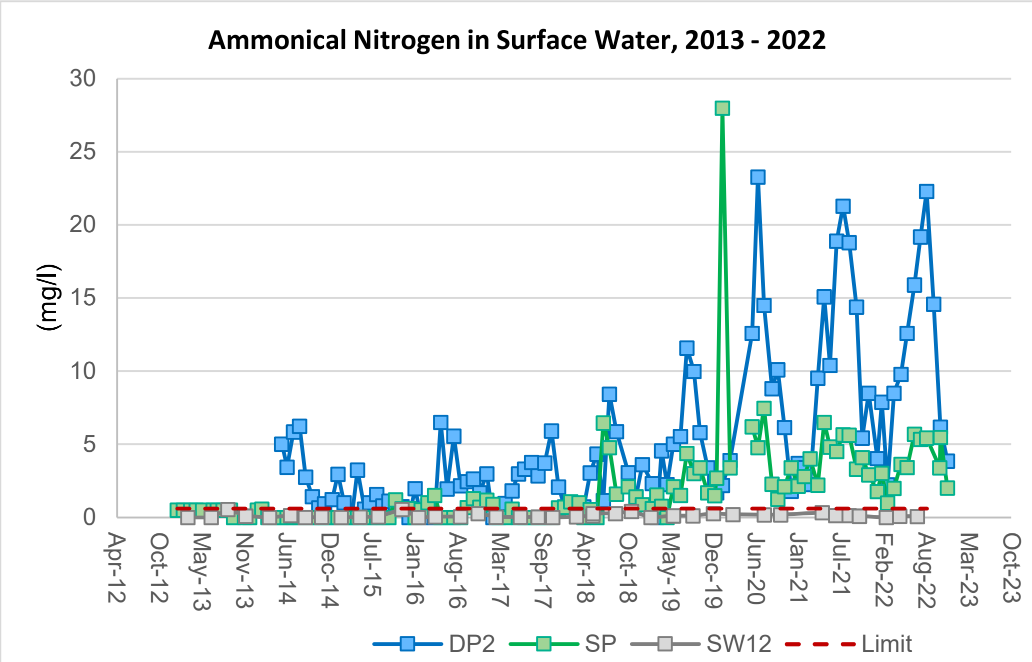

Arsenic in Surface Water, 2013 - 2022
(ug/l)
60
50
40
30
20
10
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit



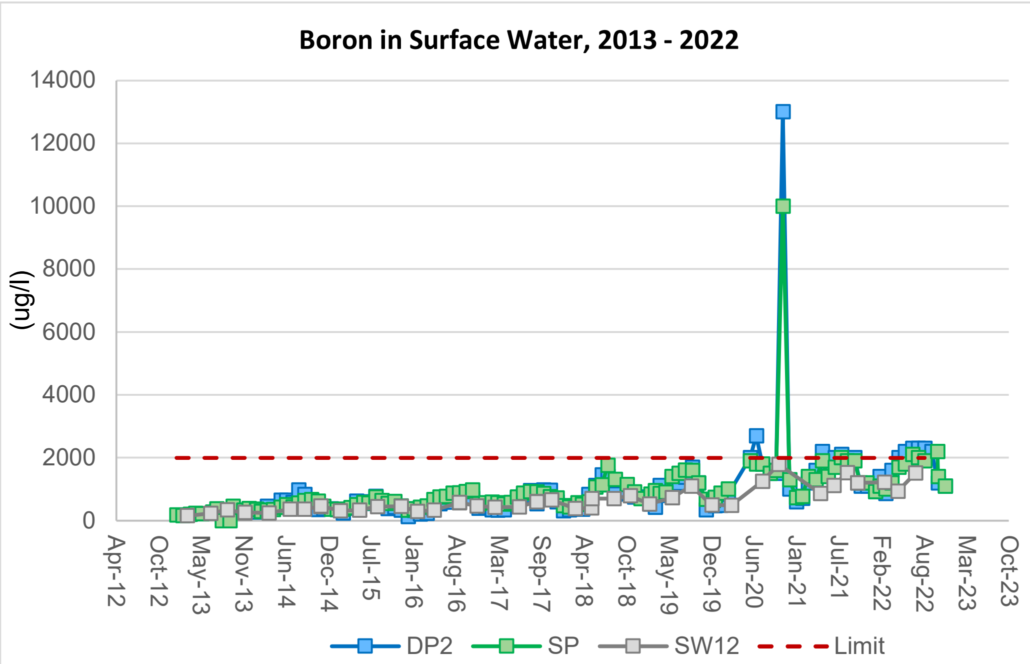
Sulphate in Surface Water, 2013 - 2022
(mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit



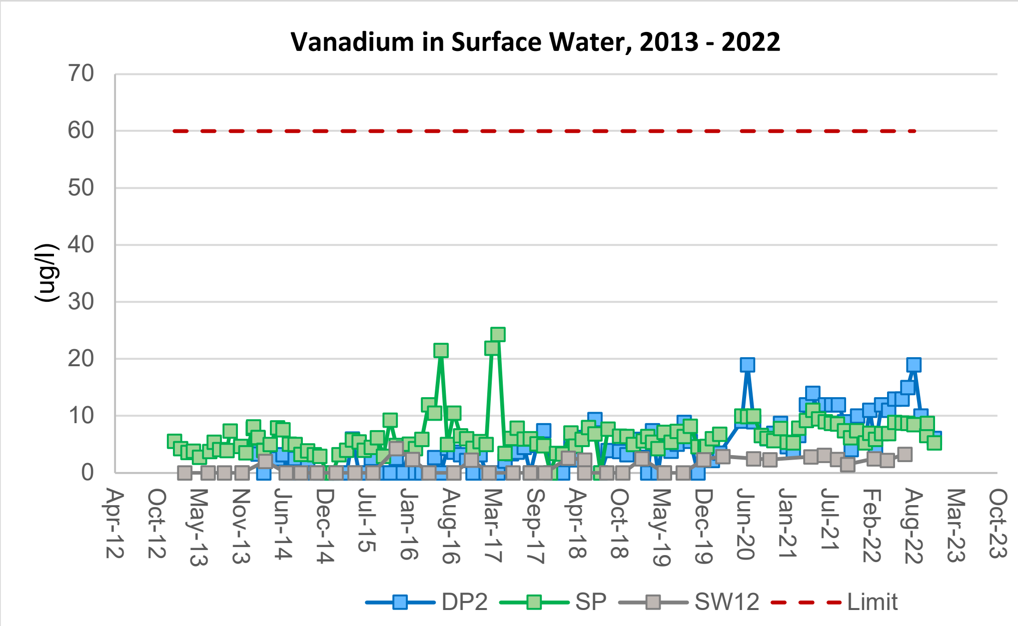
Molybdenum in Surface Water, 2013 - 2022
(ug/l)
8000
7000
6000
5000
4000
3000
2000
1000
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit

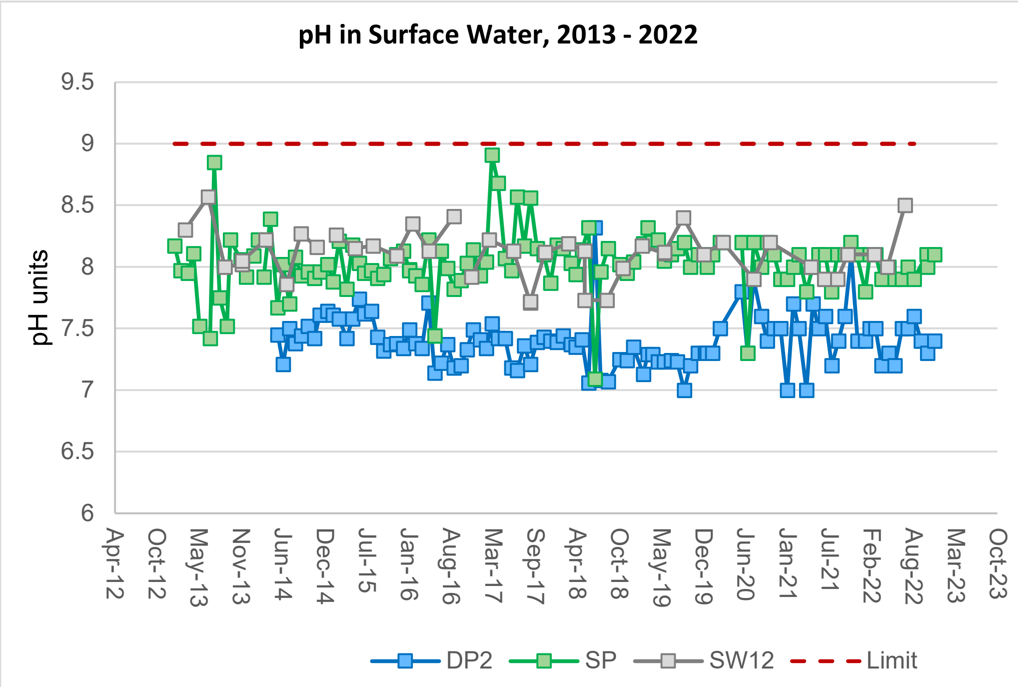


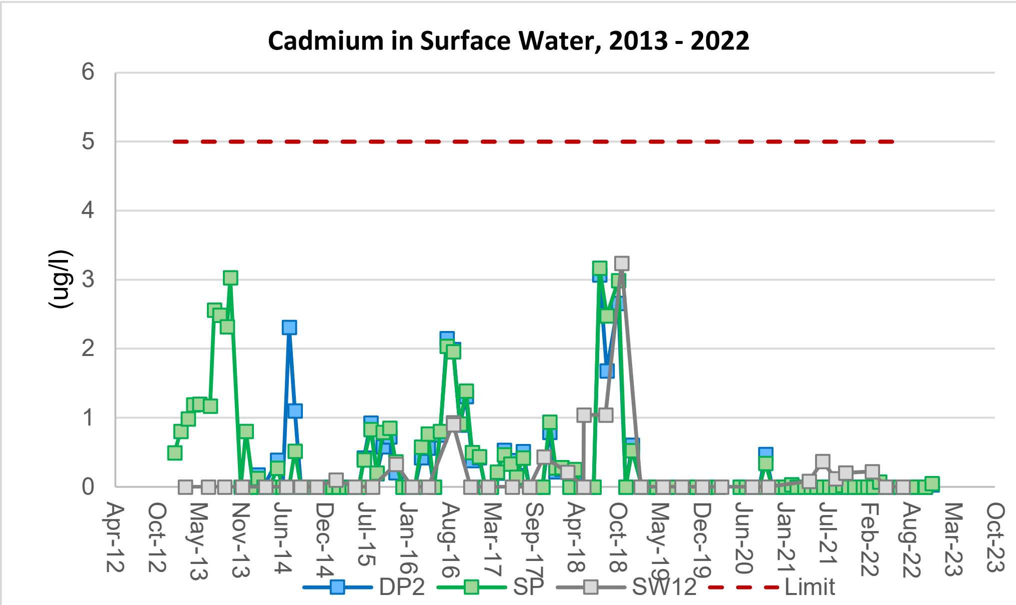
Ammonical Nitrogen in Surface Water, 2013 - 2022
30
25
20
15
10
5
0
(mg/l)
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit

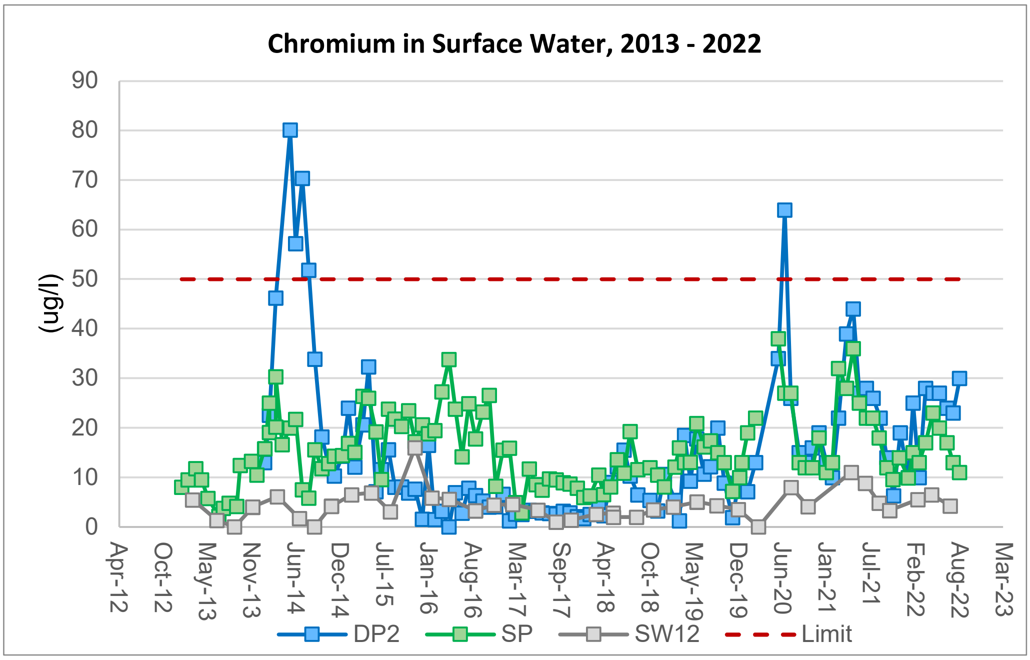


Boron in Surface Water, 2013 - 2022
14000
12000
10000
8000
6000
4000
2000
0
(ug/l)
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit


Vanadium in Surface Water, 2013 - 2022
(ug/l)
70
60
50
40
30
20
10
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit


pH in Surface Water, 2013 - 2022
pH units
9.5
9
8.5
8
7.5
7
6.5
6
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit


Cadmium in Surface Water, 2013 - 2022
(ug/l)
6
5
4
3
2
1
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
Oct-23
DP2
SP
SW12
Limit


Chromium in Surface Water, 2013 - 2022
(ug/l)
90
80
70
60
50
40
30
20
10
0
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Dec-19
Jun-20
Jan-21
Jul-21
Feb-22
Aug-22
Mar-23
DP2
SP
SW12
Limit