2020 Annual Performance Report

Aberthaw Quarry Ash Disposal Site

Permit Number: BP3339BH

March 2021

RWE

The energy to lead

Summary

This document gives details on the performance of Aberthaw Quarry Ash Disposal Site over 2020, as required by condition 4.2.1 of the site's Environmental Permit (EP), BP3339BH.

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1. Operational Update

Aberthaw Quarry Ash Disposal Site was designed to be constructed and filled with Pulverised Fuel Ash (PFA) in four distinct phases (see Appendix A).

- Phase 1 was constructed in 2008, filled between Quarter 4 2008 to Quarter 4 2010 and then capped and hydroseeded in Spring 2011.
- Phase 2 was constructed in 2009/10 with filling commencing from Quarter 4 2010. Phase 2 East was filled until Quarter 3 2013 before being capped and hydroseeded whilst Phase 2 West was filled until Quarter 4 2014 before being capped and hydroseeded.
- Phase 3A (east) was constructed in 2012/13 with filling commencing in Quarter 3 2013 and remained the working phase throughout 2014 to 2015. The construction of Phase 3B (west) was completed in 2014 with filling commencing in Quarter 2 2015. These phases continued to be worked until the formal closure of Aberthaw Power Station.

The last time Aberthaw Quarry received PFA was during 2019. Aberthaw Power Station formally closed in March 2020. The main coal-fired generating units ceased generation in December 2019 with only the gas turbines remaining available for Quarter 1 of 2020.

2. Review of Results for Emission Monitoring

Monitoring has continued where possible during 2020, however the site has had to manage sampling visits within the evolving Coronavirus Pandemic restrictions. The first country wide lockdown resulted in the complete suspension of all site works by our appointed external contractor and difficulties accessing external laboratories for accredited analysis. This resulted in the Quarter 2 sampling round being missed and only three sets of 2020 monitoring results being available for the site. The scheduling of external contractor monitoring visits is currently still a concern due to the evolving early 2021 lockdown situation.

2.1. Hydrogeological Risk Assessment HRA Review

In accordance with the BP3339BH Permit requirement a 6-yearly review of the HRA was carried out during late 2017 and into 2018. The purpose of the review was to determine whether there had been any significant change in conditions at the site and whether the site remained in compliance with the Environmental Permitting Regulations. The review was carried out by an external specialist consultant Caulmert Ltd. The review process included an initial meeting between the consultant and RWE staff followed by a detailed review by the consultant of monitoring data gathered since the previous review.

The main conclusion from the review was that there is a discernible presence of PFA identifier species e.g. Molybdenum, Boron, Ammonia in both surface and groundwater but that the higher concentration in the surface water suggests the source of contamination is mainly driven by surface water run off which then effects the groundwater in some, but not all, boreholes. Work has historically been completed at the Quarry site to try to mitigate this effect by constructing new drainage ditches and channels. It was also recognised in the review that the final restoration plan should ensure all surfaces would be capped and seeded to consolidate the PFA and ensure any run off would be free of contamination.

Due to the closure of Aberthaw Power Station, the restoration plans are currently under review by RWE.

2.2. Groundwater Quality Review

Monitoring Objective
To carry out routine monitoring of groundwater to monitor the performance of the ash disposal site by measurement of absolute levels and concentrations and trends relative to relevant criteria including background levels and concentrations, control levels and compliance limits.

Number and Location of Monitoring Points
A summary of the monitoring boreholes is provided in Table 1 below and the locations are shown in Appendix A. Historically in January 2015, borehole improvement works were completed to improve water sampling. E05-03 and E06-01 were re-drilled and the top hat cover was replaced on E06-05. In addition, a new borehole was installed above Phase 3B, E15/1 to improve the understanding of groundwater quality potentially flowing into the site from the south-east. In total, there are 12 boreholes in natural ground, all completed in the Porthkerry Member limestone.

Groundwater flow beneath the ash disposal site is directed towards the cement work lagoons and the River Thaw to the west. Hence, monitoring boreholes, E09-01A, E09-01B, E09-02A and E09-02B on the north-eastern site boundary (approximately 200m apart) are upgradient. Borehole E15/1 on the south site boundary is also upgradient.

Monitoring boreholes along the western site boundary (E05-03, E05-04 and E06-01) with an average spacing of 100m are downgradient of the Pulverised Fuel Ash (PFA) disposal area (Phase 1 and 2). Along the south-western site boundary, two of the monitoring boreholes with an average spacing of 100m (E06-02 and E06-03) are downgradient of the last active PFA disposal area (Phase 3A & 3B) and the non-utilised area (Phase 4). Whilst the two remaining boreholes (E06-04 and E06-05) with an average spacing of 100m are located downgradient of the unworked Phase 4.

Table 1: Summary of Monitoring Boreholes

Monitoring Borehole	Formation Sampled	Lithology Type – Natural (N)	Response Zone Depth (m b GL)	Designation
E09-01A	Limestone	N	18-24	Upgradient
E09-01B	Limestone	N	24-30	Upgradient
E09-02A	Limestone	N	21-27	Upgradient
E09-02B	Limestone	N	27-33	Upgradient
E15-1	Limestone	N	17-29	Upgradient
E05-03	Limestone	N	3 - 15	Downgradient Phase 1&2 Active Area
E05-04	Limestone	N	2.5 - 20	Downgradient Phase 1&2 Active Area
E06-01	Limestone	N	3 - 15	Downgradient Phase 1&2 Active Area
E06-02	Limestone	N	2 - 10	Downgradient Phase 3A & 3B Active Area
E06-03	Limestone	N	2 - 10	Downgradient Phase 3A & 3B Active Area
E06-04	Limestone	N	2 - 10	Downgradient Potential Phase 4
E06-05	Limestone	N	2 – 8	Downgradient Potential Phase 4

m b GL – metres below ground level

Monitoring Measurements

The groundwater monitoring analytical suite contains a range of parameters which are monitored on a quarterly basis along with the groundwater level and standard field measurements in accordance with the Environmental Permit. An independent external contractor is responsible for the sampling of the groundwater boreholes and an independent external accredited laboratory is responsible for the analysis of the samples. Please note, that because of restrictions experienced due to the Coronavirus Pandemic the external accredited laboratory was changed from NLS to ALS from June 2020.

Figure 1 shows the recorded groundwater elevations for the previous 14 years which vary between +17 (E05-03) to +35m OD (E09-02B). Upgradient groundwater elevations are characterised by larger amplitude seasonal water level fluctuations with annual winter influxes of rainfall recharge. Downgradient groundwater elevations fluctuate only slightly due to the effect of dewatering from the Quarry which maintains groundwater at near-constant elevations.

Figure 1: Groundwater Hydrograph

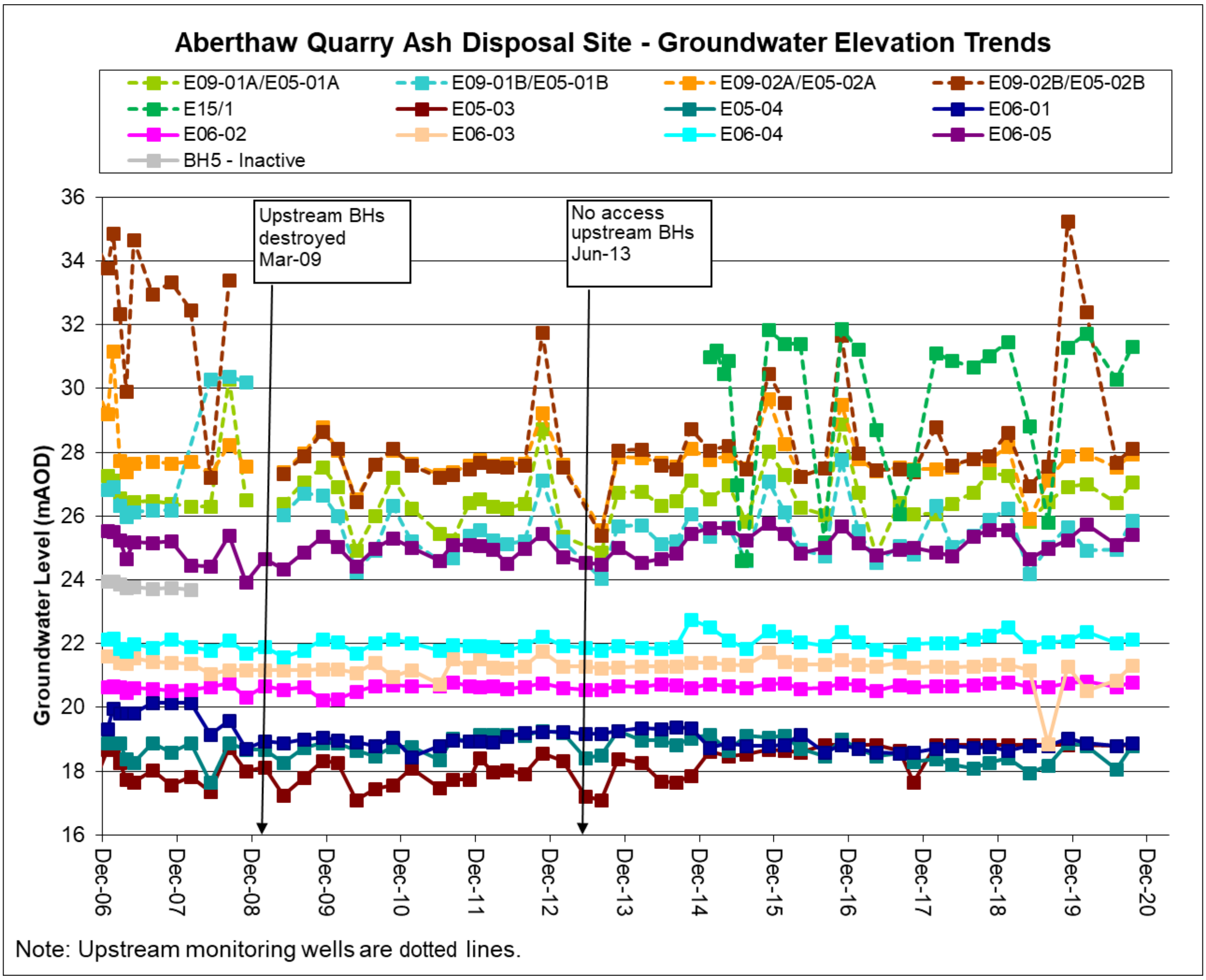


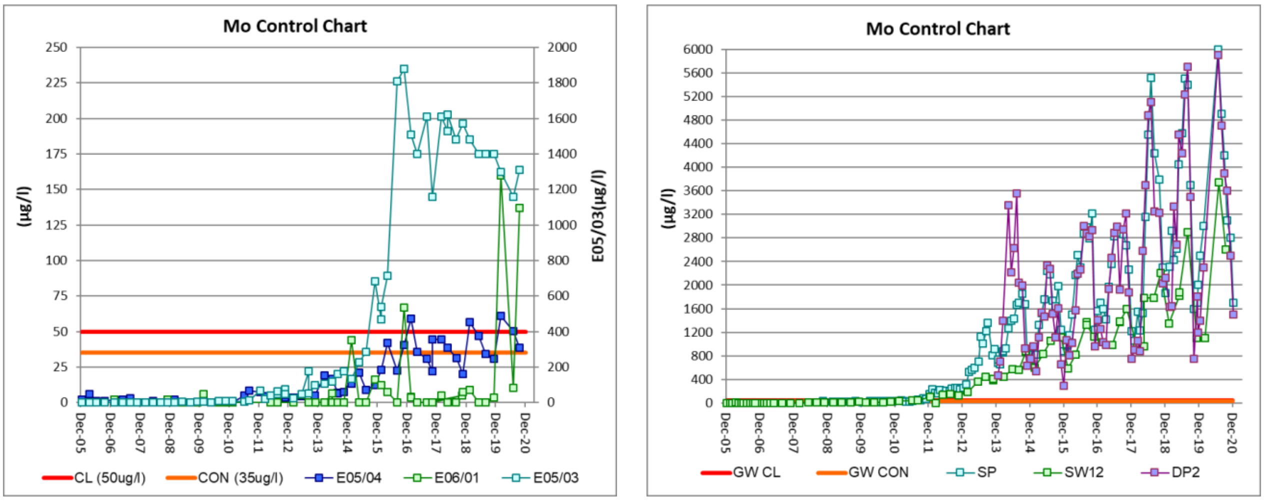
Figure 2 shows the general groundwater quality for the major ions in each of the site's boreholes. Natural groundwater quality varies between upgradient and downgradient locations. Calcium is depleted in downgradient boreholes, E05-03, E05-04, E06-01 and E06-02 and correlated with elevated sodium, suggesting ion exchange reactions are occurring along the groundwater flow path. Whilst in downgradient boreholes, E06-03, E06-04 and E06-05, major ion chemistry is distinctly different with elevation of calcium, magnesium and sulphate, suggesting a natural geological or quarry-related source in or upgradient of this area.

Figure 3 shows the groundwater control charts with concentrations of all downgradient boreholes plotted as well as the average upgradient concentration (representing concentrations in boreholes E09-01A, E09-01B, E09-02A, E09-02B and E15/1, i.e. background groundwater quality). It should be noted that the compliance limits apply to boreholes E05-03, E05-04 and E06-01 whilst the control levels (where defined) apply to all downgradient boreholes. An exceedance is defined as a result above the compliance limit or control level for 3 consecutive sampling events.

In 2020 there was a continued exceedance of the compliance limit and control level for Molybdenum at borehole E05-03, however the upward trend initially observed from 2012 peaked at 1880 ug/l in November 2016 and, although still high, has been on a general downwards trend since then. There were also elevated Molybdenum levels in boreholes E05/04, E06/01 & E06/02 during 2020.

Figure 4 shows the control chart for molybdenum for E05-03 and the two other boreholes closest to it, E05-04 and E06-01 as well as the surface water monitoring points (note there are no surface water compliance limits or control levels for molybdenum). The boreholes are located to the west of and adjacent to Phase 1 and are downgradient of the PFA fill. Natural background concentrations of molybdenum in the Porthkerry Formation are <3µg/l and the average pre-filling concentration for the cement works lagoon (SW12) is around 4µg/l.

Figure 4: Molybdenum concentrations



Molybdenum concentrations in E05-03 initially increased from January 2012, around a year after Phase 1 was completed, which suggested the source was unlikely to be from the deposited PFA. After reviewing the 2016 data it appeared there was a co-association of increasing concentrations in other indicative PFA leachate parameters; boron, sulphate and ammoniacal-nitrogen, suggesting PFA was the source of contamination. During site investigations in 2014, three possible sources were identified; discharges from the wheel wash pipe into an unlined ditch close to the borehole; surface water discharges of eroded PFA areas around the wheel wash pipe into the unlined ditch; and/or; leakage from adjacent cement works lagoon. In 2015, the wheel wash discharge pipe was re-routed into Settlement Pond 1, the unlined ditch cleaned out and the eroded areas smoothed. Since the improvements, molybdenum concentrations continued to increase until Q1 2017 when the results started to decrease. Boron, Ammoniacal Nitrogen and Sulphate have remained relatively consistent across the boreholes and stable within borehole E05-03, although boron has seen a slight uplift towards the end of the year.

In borehole E05-04, molybdenum concentrations were approximately double the natural background concentrations until March 2014. Since then concentrations have slowly increased up to 61µg/l in Mar 2020. The trend appears seasonal with higher results in the winter months. Prior to 2015, the molybdenum concentrations in E06-01 consistently reflected the natural background concentrations, since February 2015, results have been sporadically above the natural background concentrations. During 2020 two very elevated concentrations were recorded in Q1 (160µg/l) and Q4 (137µg/l) during 2020. E06-02 has come down since its Mo peak of 340µg/l in 2019, but the three results recorded in 202 were all still elevated above the control limit.

As in E05-03, molybdenum concentrations in the settlement ponds (SP) have been increasing since January 2012, however, since 2013, concentrations are characterised by large amplitude seasonal fluctuations, with the highest concentrations in the summer and the lowest in the winter. This seasonal fluctuation is reflected in DP2 which collects surface water and groundwater from the site, suggesting the source of contamination is intermittent. The water from the settlement ponds is discharged periodically into the cement works lagoon (SW12) and molybdenum concentrations have been rising steadily since January 2012.

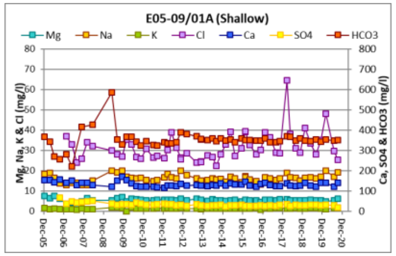
Figure 2: General Groundwater Quality Charts

Upgradient Boreholes

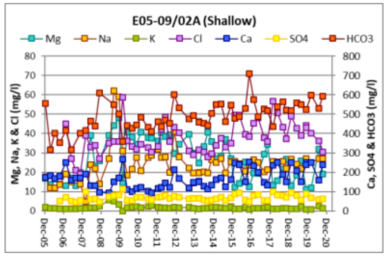
Downgradient Boreholes Phase 1/2

Downgradient Boreholes Phase 3/4

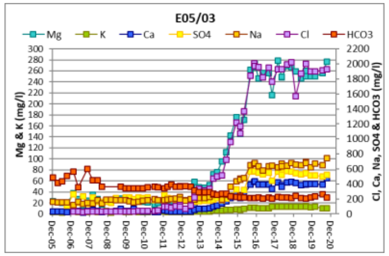
Downgradient Boreholes Future Phase



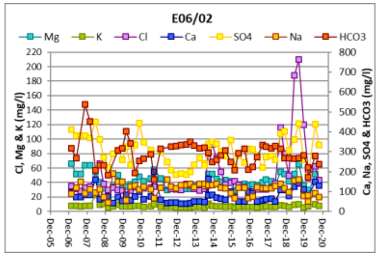
All analytes low and concentrations steady



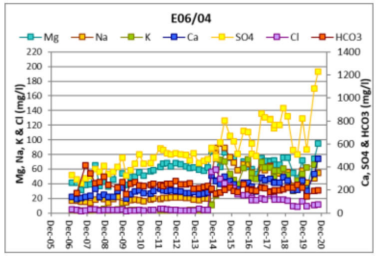
All analytes low but fluctuating.



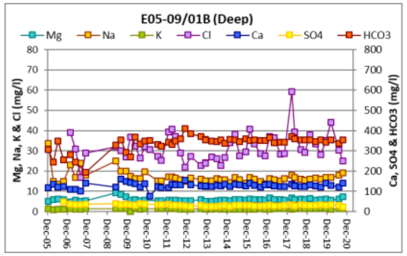
All analytes relatively steady since mid-2015



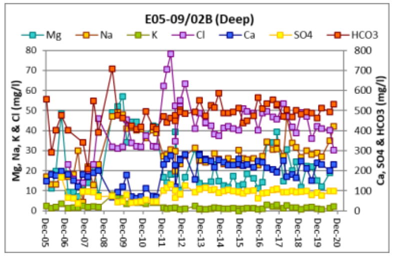
All analytes generally low but fluctuating.



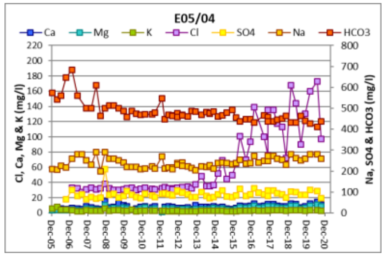
All analytes low except SO4 increasing.



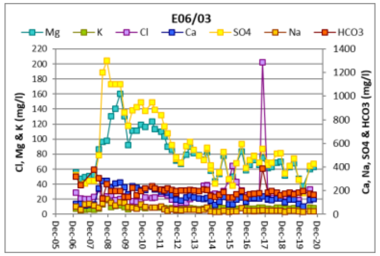
All analytes low and concentrations steady



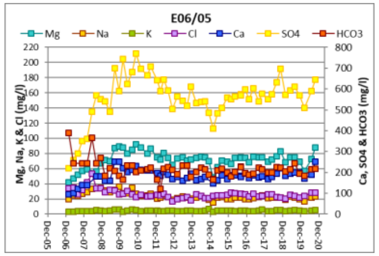
All analytes relatively low but fluctuating.



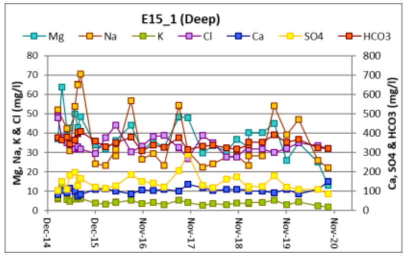
All analytes relatively steady, although chloride is gradually increasing



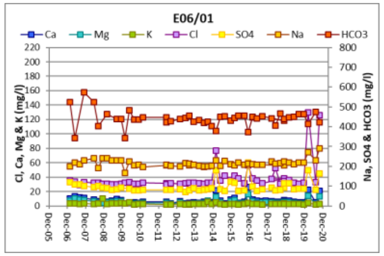
All analytes generally low , Mg & SO_4 gradually decreasing.



All analytes generally low and steady, although SO_4 is elevated.



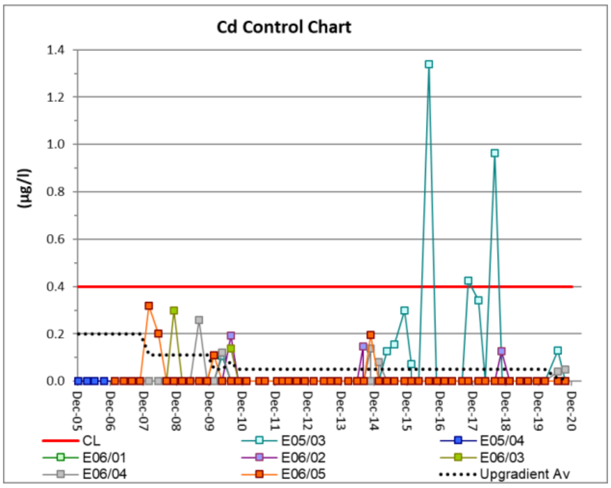
All analytes low and concentrations steady



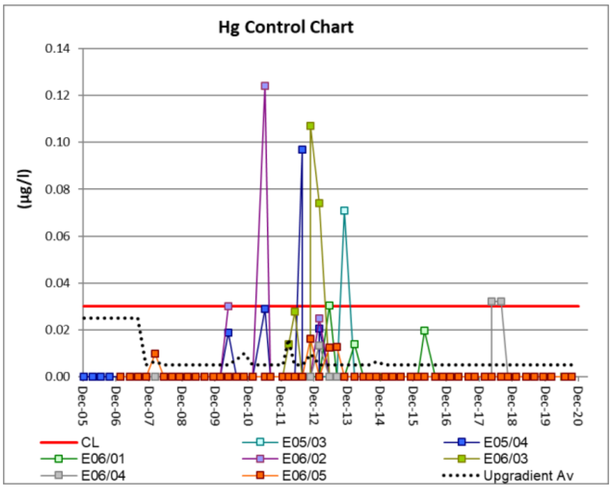
All analytes realtively steady, although a couple of spikes have been recorded in 2020.

Figure 3: Control charts for Down-gradient Groundwater boreholes

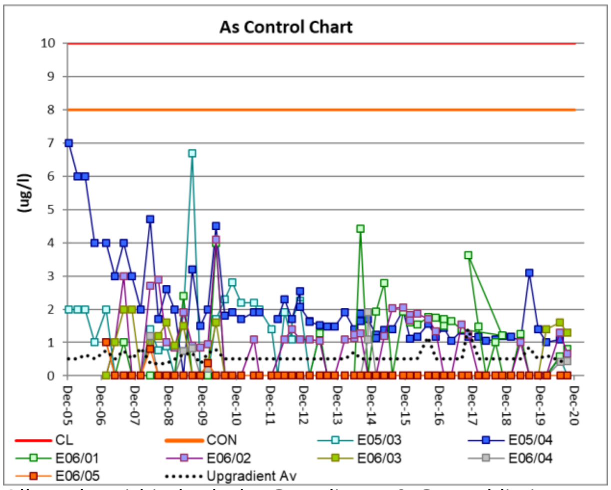
(CL – Compliance Limit, CON – Control Level, 0 – result at Method Detection Limit, Duplicate results also plotted)



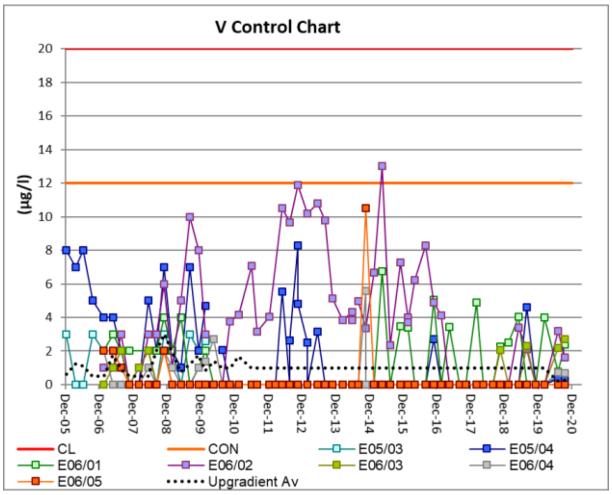
All results within Control Limit over the last year.



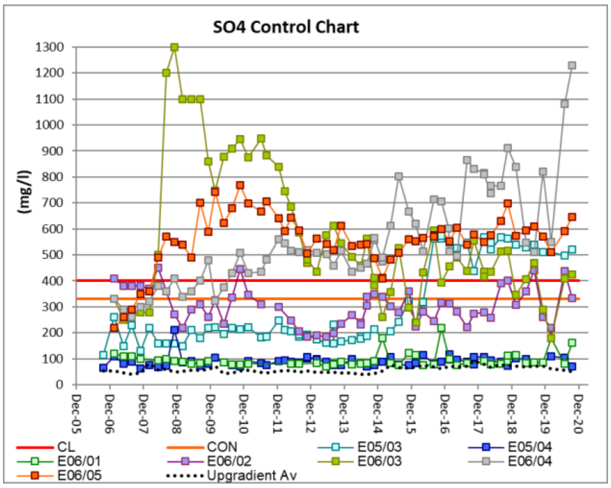
All results within Control Limit over the last year.



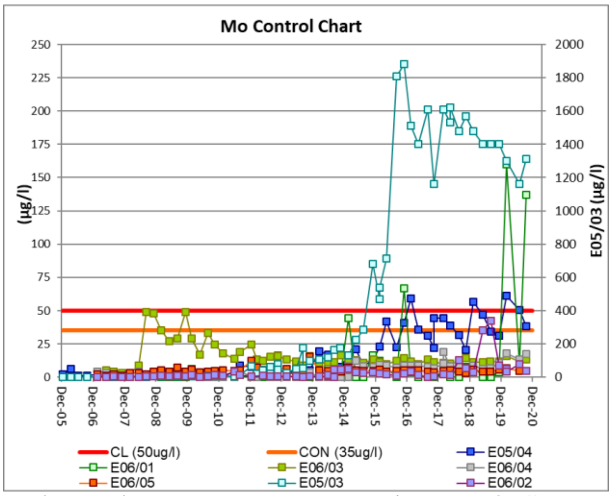
All results within both the Compliance & Control limits over the last year.



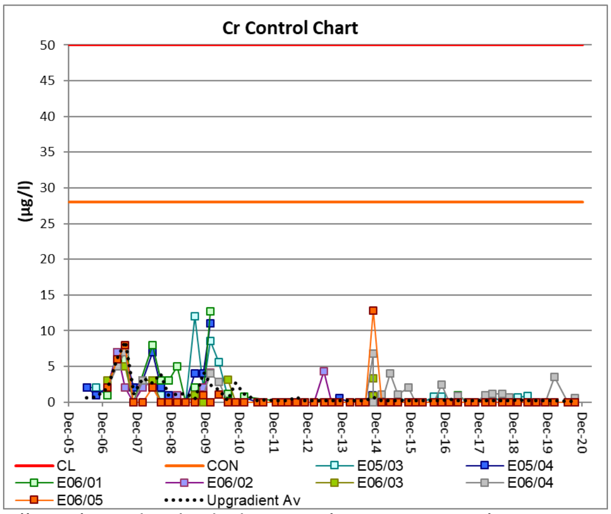
All results within both the Compliance & Control limits over the last year.



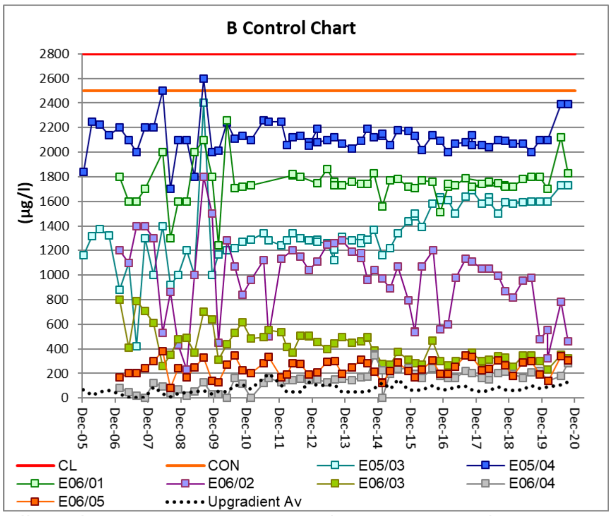
All results generally steady, although E06/04 has shown a significant increase.



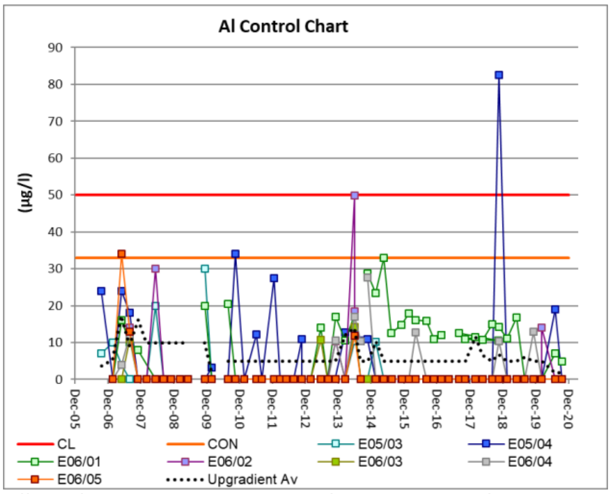
As discussed in Section 2.2 above, E05/03 is gradually decreasing, whilstE05/04 and E06/01 have results above the Control & Compliance limits. Other locations remain consistently low.



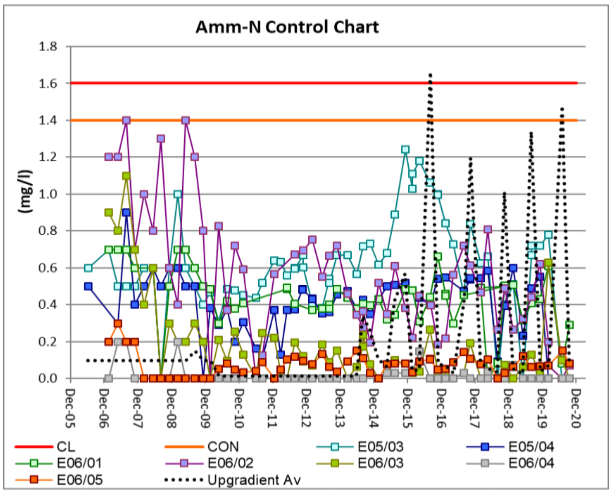
All results within both the Compliance & Control Limits over the last year.



All results within both the Compliance & Control Limits over the last year. Some uplift within E05/04.



All results within both the Compliance & Control Limits over the last year.



All results within both the Compliance & Control Limits over the last year. Upgradient locations have shown fluctuating background concentrations.

A summary of the average groundwater quality for all monitoring parameters between 2006 and 2020 is provided in Appendix B with a comparison of pre- and post-fill concentrations. The key trends in the data have been discussed above, however, it can be summarised that there may be some low-level contamination from fugitive emissions of PFA, which is considered to have not significantly impacted the groundwater receptors.

The difference in pH between field and laboratory measurements during 2020 was not as consistent as during the previous year with some sampling rounds showing differences of around 1 pH unit for some locations. The laboratory results are consistent with historical trends, so it is suspected that the issue originates from the manual readings taken upon the site by the sampling contractor. This will continue to be reviewed during 2021.

In terms of Electrical Conductivity for all sampling rounds, and sample locations, the field measurements were consistently above the laboratory measurements. A change greater than +10% may indicate a change in sample conditions and therefore for some samples precipitation of solids between sampling and analysis may be occurring. This is also confirmed by the major ionic balances which were wider than last year. Most downgradient samples were within +/-5%, except for E06/04 which was around 7% for Q4. All the upgradient locations were much more variable, especially during Q4 which ranged from 9-14%.

The external contractor reported that the duplicate samples collected during 2020 showed good repeatability and were within the expected laboratory error levels.

2.3. Surface Water Quality Review

Monitoring Objective

To carry out routine monitoring of surface water to;

- monitor the performance of the ash disposal site by measurement of absolute levels and concentrations and trends relative to relevant criteria including background concentrations and control levels; and;
- identify and quantify effects on surface water receptors.

Number and Location of Monitoring Points

A summary of the surface water monitoring points is provided in Table 3 below and the locations are shown in Appendix A. As detailed in a letter to NRW dated 13th June 2014 a new surface water monitoring point, DP2, was added to monitor the composition of water from the under-drainage. Routine monitoring of DP2 began in May 2014.

Table 3: Summary of Surface water monitoring points

Monitoring Point	Description	Direction from site	Designation
SW12	East shore of cement works lagoon in NW area	West	Surface water Receptor
Settlement Ponds (SP)	Two concrete ponds collecting groundwater and surface water	South-west	
DP2	Surface water and groundwater drainage channel at base of Phase 1 and 2	West within site	

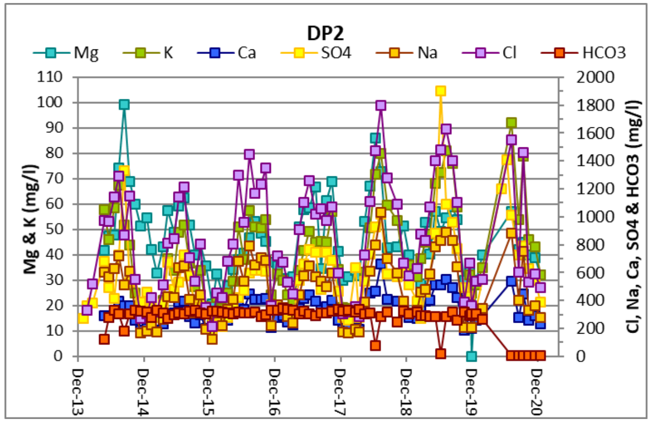
A proportion of the upstream and underlying groundwater will be collected in the groundwater drainage layer and directed towards the two settlement ponds along with any water that has infiltrated through the PFA and the barrier/attenuation layer. Surface water from runoff is also directed into the two settlement ponds via a series of perimeter ditches and toe drains. The settlement ponds are constructed on the quarry floor, contained by concrete and butyl lined 3m high bunds, and are designed to allow suspended solids to settle out before the water is discharged through penstocks into the nearby cement works lagoon (SW12).

Monitoring Measurements

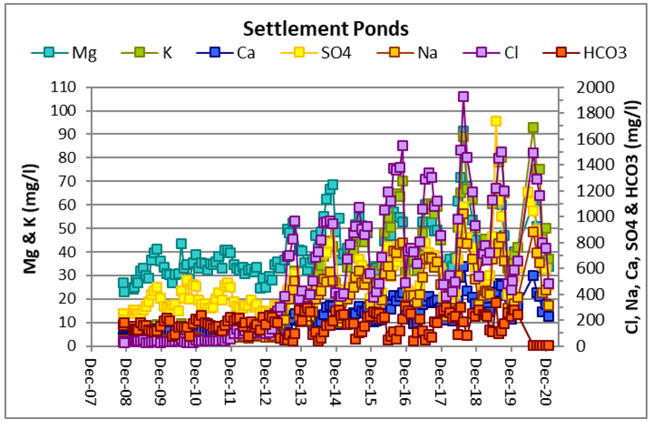
The surface water monitoring analytical suite contains a range of parameters which are monitored in accordance with the Environmental Permit on a quarterly basis for SW12 and a monthly basis for the SP and DP2. Trained in-house operatives are responsible for the sampling of the SP and DP2 and an independent external contractor is responsible for the sampling of SW12 (undertaken during the wider groundwater monitoring rounds). An independent external accredited laboratory is responsible for the analysis of the samples. Due to the Covid-19 pandemic there was a change to the analytical laboratory from June 2020 for all the surface water samples.

Figure 5 shows the general surface water quality for the major ions. Calcium, magnesium and sulphate concentrations appear naturally elevated in the cement works lagoon and the settlement ponds (i.e. prior to any PFA deposition), and are at similar concentrations to those in the downgradient boreholes, E06-03, E06-04 and E06-05, suggesting a natural geological or quarry-related source upgradient of this area. Concentrations appear to be seasonably variable in the settlement ponds and the cement works lagoon with highs in July to December and lows in February to June except for HCO_3 with lows in July to December and highs in February to June. When routine monitoring began in DP2 in May 2014 this seasonal pattern in concentrations was also evident. The seasonal pattern is much more marked in 2013-2020 with much higher chloride concentrations than seen previously, which could be related to the historic use of sea water for ash conditioning during the drier months of quarry operation.

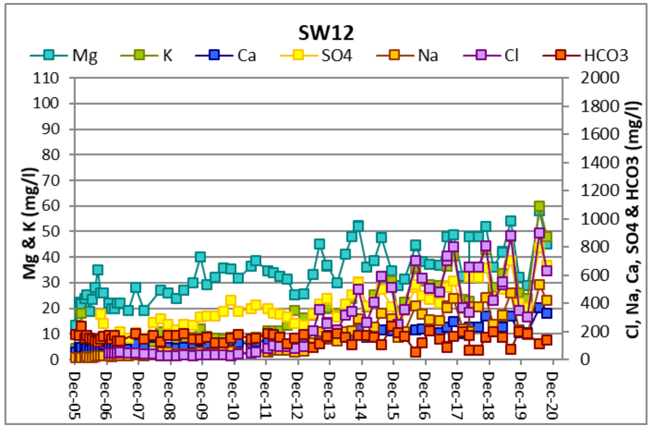
Figure 5: General Surface Water Quality Charts



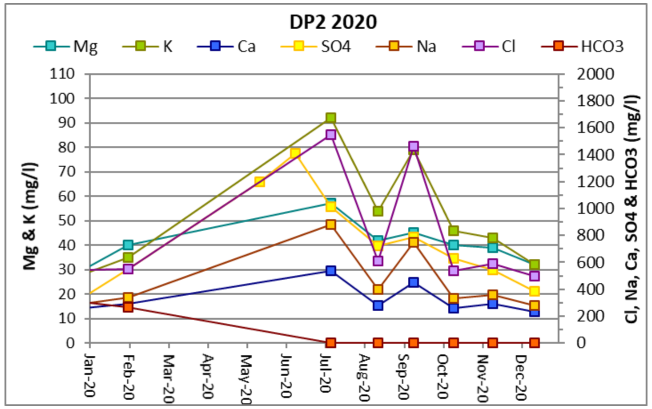
Fluctuations in SO4, Na & Cl with high concentrations in summer and low concentrations in winter.

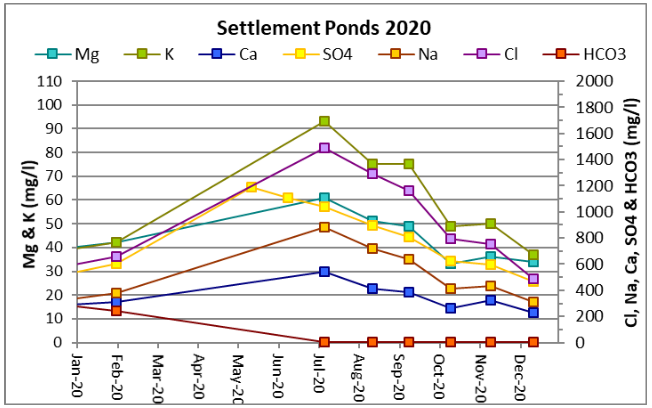


From 2013 fluctuations in Mg, K, Ca, SO4, Na & Cl with high concentrations in summer and low concentrations in winter and HCO3 with low concentrations in summer and high concentrations in winter.



From 2013 fluctuations in Mg, K, SO4, Na & Cl with high concentrations in summer and low concentrations in winter.





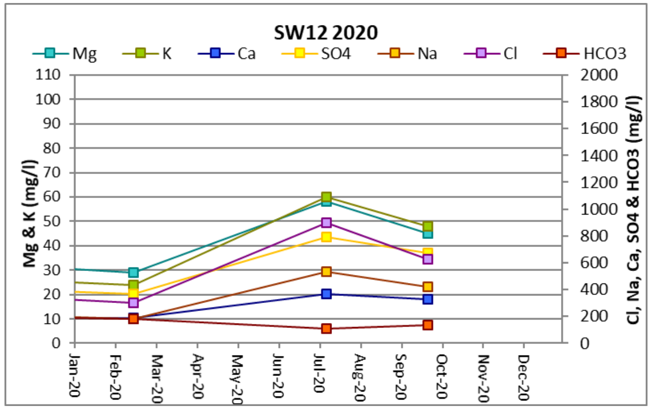


Figure 6 shows the surface water control charts. It should be noted that the compliance limits apply to the discharge from the settlement ponds whilst the control levels (where defined) apply to both the discharge from the settlement ponds and SW12. An exceedance is defined as a result above the compliance limit or control level for 3 consecutive sampling events.

In 2020, there were no exceedances of the compliance limit or control level for any critical parameter, except for:

- Boron – results have been recorded above the Control Level for all three locations during 2020, and overall there appears to be an upwards trend across all three locations. The Nov-2020 results for DP2 & the Settlement Ponds (13,000µg/l and 10,000µg/l respectively) are considered spurious as they are a factor of ten larger than anything recorded historically across the site. The last results recorded for the 2020 period (in early Jan 2021) have both DP2 and the Settlement Ponds back below the Control Level (at 600µg/l and 7300µg/l respectively).
- Chromium – briefly spiked above the Control Level in June for both DP2 & the Settlement Ponds (34µg/l and 38µg/l respectively). DP2 also exceeded the Compliance Level for one round in late June (at 64µg/l). All other results were well within the Control Level.
- Sulphate – all Settlement Pond Samples returned results above the Compliance Limit of 400mg/l. Both DP2 and SW_12 are also returning consistently elevated results. A temporary approval of the elevated discharge is in place with NRW on the basis of no environmental impact and the understanding that the elevated concentrations are being caused by drainage into the site from the south-east. This has also been suggested by the HRA conducted in 2018.
- Ammonia – is also consistently above the Compliance Level for both the Settlement Ponds and DP2, although sufficient oxidation or stripping appears to take place by the time the discharge passes to the cement works lagoon as concentrations are low and not increasing. Ammonia was injected into the Power Station flue gas stream to increase the efficiency of the Electrostatic Precipitators, this will have resulted in the deposited Ash being slightly Ammoniated. This is likely to be the source of the elevated Ammonia levels observed at DP2.

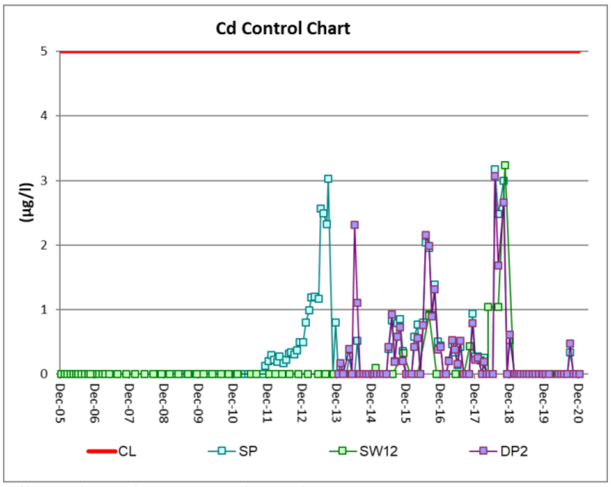
In general, Figure 6 shows that there are no increasing trends in critical parameter concentrations except for sulphate, boron and ammoniated nitrogen, as discussed above. Although concentrations of critical parameters have been variable over time there appears to be no impact on the water quality within the cement works lagoon, SW12 into which the settlement ponds discharge. The only exception may be in the case of boron, which has seen its highest level recorded within SW12 (1790µg/l) during October 2020.

A summary of the average surface water quality between 2006 and 2020 is provided in Appendix B with a comparison of pre- and post-fill concentrations. The key trends in the data have been discussed above, however, it can be summarised that there may be some low-level contamination from fugitive emissions of PFA, which is considered to have not significantly impacted the surface water receptors.

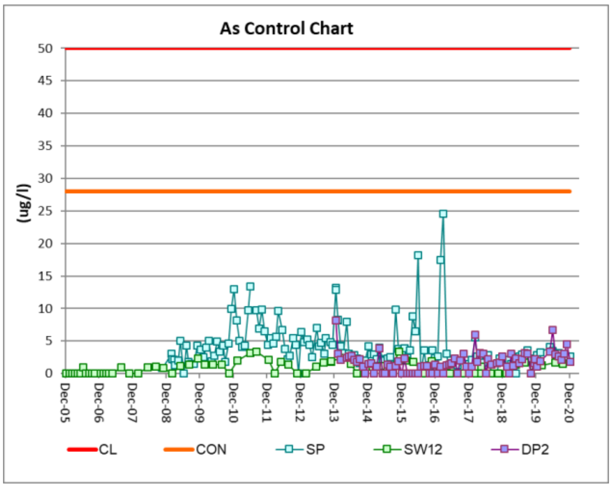
During 2021 it is expected that the restoration plans for the site will be fully reviewed in line with the closure of Aberthaw Power Station, taking account of the fact that no more PFA will be deposited at the quarry site. This review includes the potential reprofiling of sections of the site to improve the surface water management.

Figure 6: Surface Water Control Charts

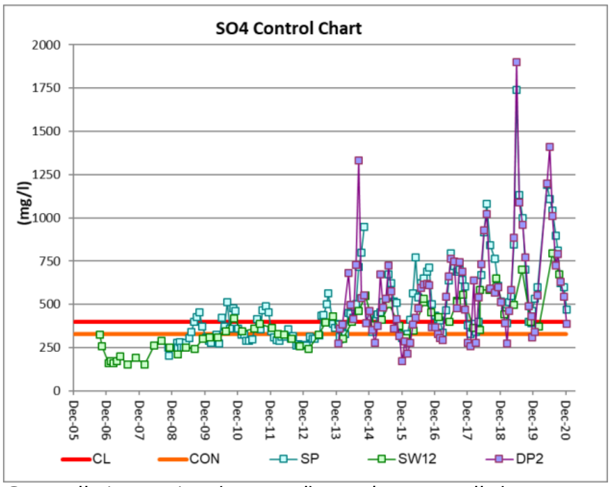
(CL – Compliance Limit, CON – Control Level, 0 – result at Method Detection Limit, Duplicate results also plotted)



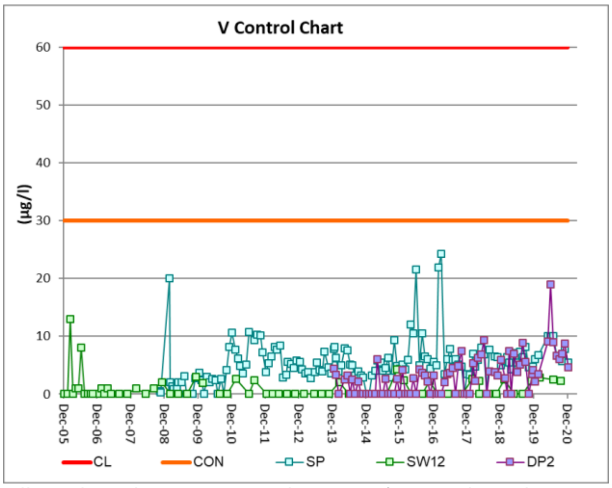
All results below Control Level.



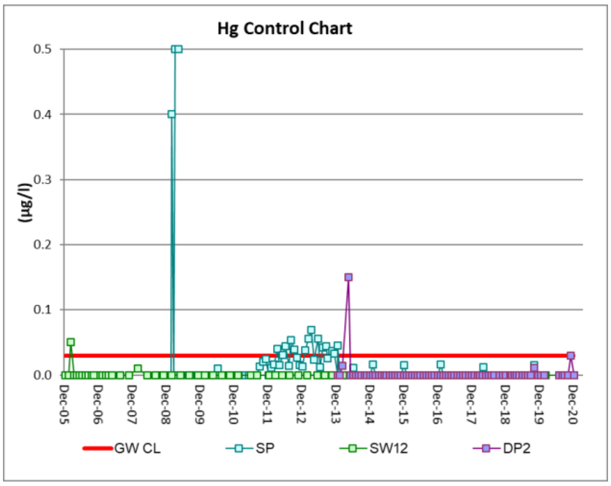
All results below Control Level.



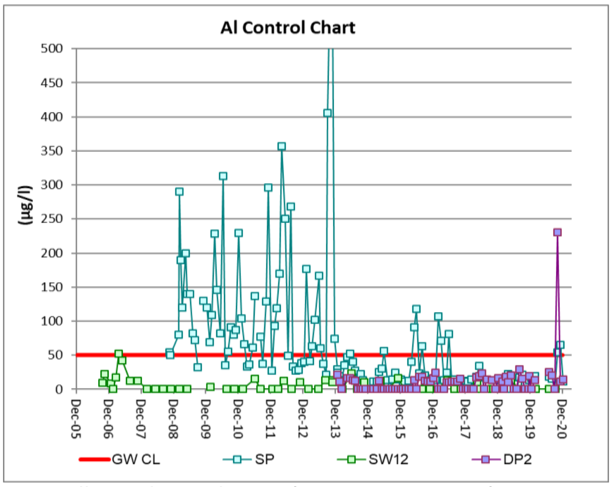
Generally increasing (seasonal) trends across all three locations.



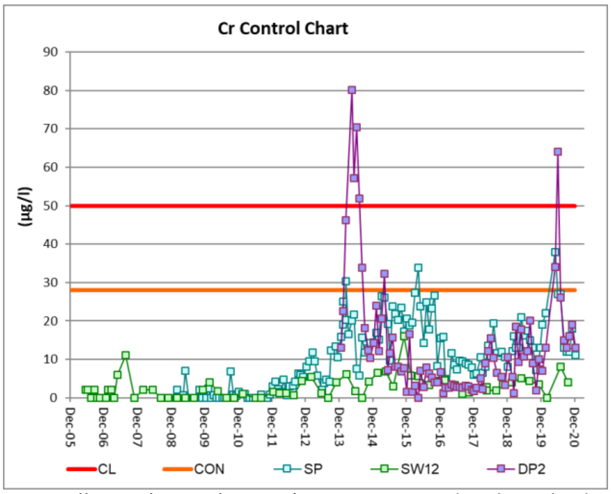
All results below both Compliance and Control Levels.



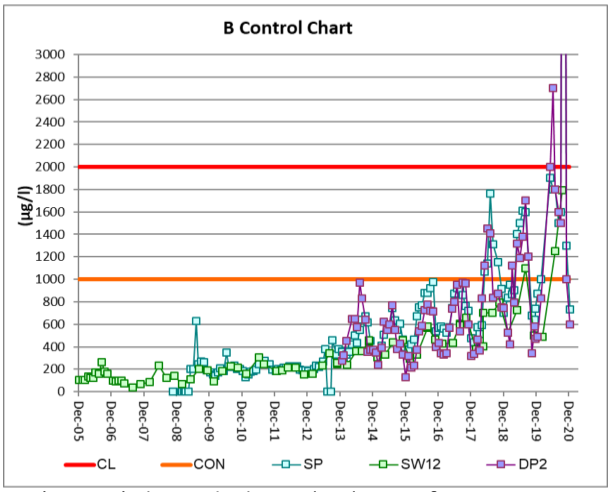
Generally results are low and consistent (Groundwater Control level applied for comparison).



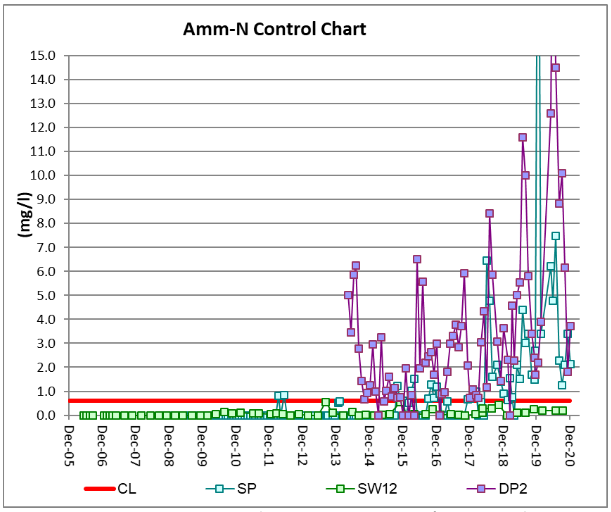
Generally results are low and consistent (Groundwater Control level applied for comparison). Spike in Nov-2020 for DP2 (230µg/l) is considered spurious.



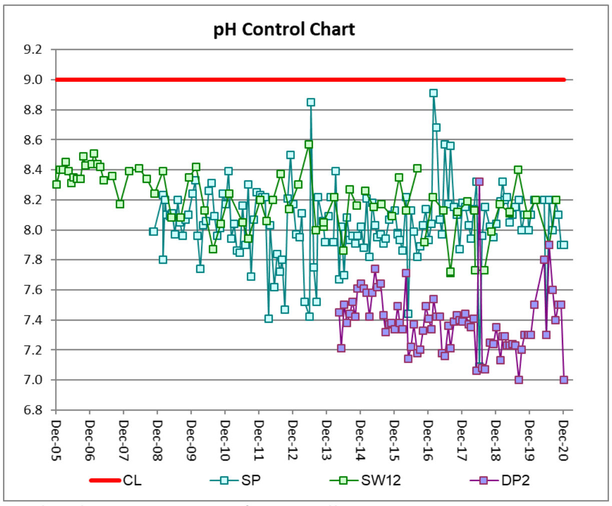
Generally results are low and consistent. Spike above both Compliance and Control Levels recorded in June.



As discussed above, the boron levels in surface water appear to be exhibiting an upwards trend.



Ammonia remains variable within DP2 and the Settlement Ponds.



pH levels have remained generally consistent across the three surface water locations.

3. Annual Production/Treatment Data

Table 5: Annual Production/Treatment Data(Table S5.2 EP)

Parameter	Value	Unit
Surface water disposed off site	0	m^3/yr
Groundwater disposed off site	0	m^3/yr

4. Contamination/Decontamination of Site

There have been no incidents or emissions which may have caused any site contamination during 2020, and, therefore, no requirement to decontaminate the site during 2020.

5. Topographical Survey

The last topographical survey to ordnance datum was carried out in July 2018 which is shown in Appendix C. It is expected that further topographical surveys of the site will take place to support any revised restoration plan agreed in the future.

6. Landfill Capacity

Table 6 below details the amount of PFA deposited at Aberthaw Quarry Ash Disposal Site during 2020 as reported to Natural Resources Wales via the Waste Return Form. It is estimated that around 2,478,843m^3 of void capacity remains (across Phases 1–4) although with the closure of Aberthaw Power Station this capacity will no longer be utilised for the disposal of PFA.

Table 6: PFA Deposited

Reporting Period	**PFA Deposited (tonnes)**
1st January – 31st December 2020	Nil

7. Waste Acceptance Compliance Testing

Aberthaw Quarry Ash Disposal Site is a mono-landfill site which is under the direct operational control of Aberthaw Power Station. All the ash was transported directly from the Power Station to the Quarry using lorries.

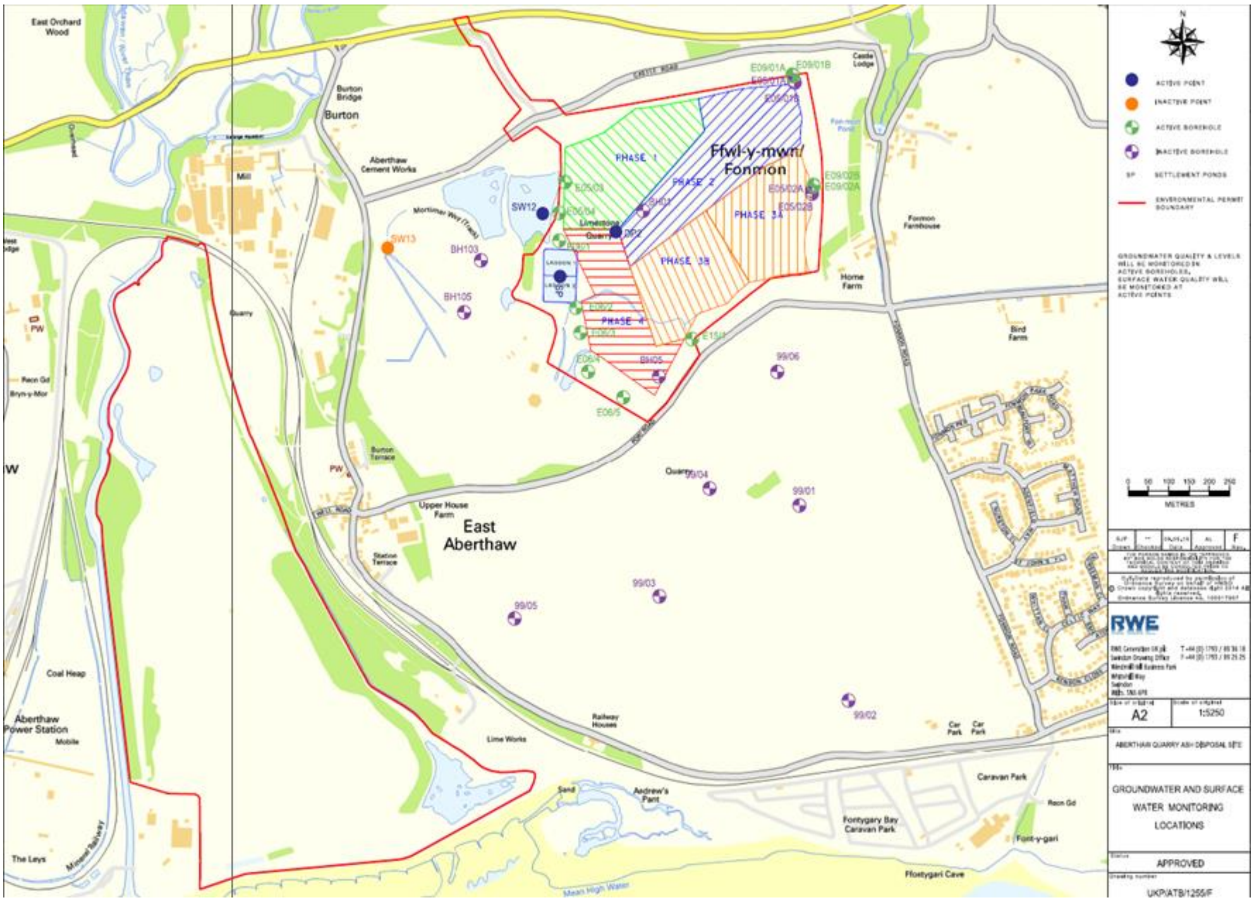
The exact composition of PFA was dependent upon the composition of the fuel utilised by Aberthaw Power Station. RWE has well established procedures which control the quality of fuel supplied to its stations.

Table 7 summarises the analytical data obtained for historic leachate tests performed on composite samples of conditioned PFA from Aberthaw Power Station between 2012 and 2017. The CEN two-stage method for leachate analysis was used (BS EN 12457-3:2002 Characterisation of waste – Leaching – Compliance test for leaching of granular waste materials and sludges of which Part 3).

Table 7: Summary of 10:1 Leachate Calculated Results (mg/kg)

Period	Jan-17	Apr-12 to Jan-17			
Analyte:	Latest Result	Minimum	Mean	Maximum	Number of results
Aluminium as Al (Dissolved)	8.1	2.4	21.9	75.4	15
Ammoniacal Nitrogen as N	156.6	4.2	83.5	158.1	15
Antimony as Sb (Dissolved)	0.192	0.020	0.163	0.256	15
Arsenic as As (Dissolved)	2.449	0.077	1.907	3.313	15
Barium as Ba (Dissolved)	1.4	0.1	2.5	5.9	15
Boron as B (Dissolved)	12.1	0.7	12.8	17.7	15
Bromide as Br	36.3	0.6	71.5	293.5	15
Cadmium as Cd (Dissolved)	0.0010	0.0004	0.002	0.0056	15
Chromium as Cr (Dissolved)	0.19	0.01	0.3	1.03	15
Copper as Cu (Dissolved)	0.010	0.004	0.015	0.028	15
Cyanide (Total) as CN	0.5	0.2	0.3	0.5	15
Dissolved Organic Carbon	25.5	2.2	22.6	43.3	15
Fluoride as F	21.7	2.3	23.5	45.1	15
Iron as Fe (Dissolved)	1.16	0.52	1.03	1.52	15
Lead as Pb (Dissolved)	0.043	0.013	0.034	0.083	15
Manganese as Mn (Dissolved)	0.025	0.006	0.066	0.174	15
Mercury as Hg (Dissolved)	0.0019	0.0004	0.0057	0.0132	15
Molybdenum as Mo (Dissolved)	8.1	0.7	9.4	17.8	15
Nickel as Ni (Dissolved)	0.040	0.003	0.028	0.062	15
Nitrate as N	4.6	2.3	3.1	4.6	15
Selenium as Se (Dissolved)	2.8	0.2	2.1	3.5	15
Sodium as Na (Dissolved)	327	9	821	2696	15
Total Dissolved Solids	6787	350	8888	21800	15
Total Nitrogen as N	162.7	5.0	92.1	166.0	15
Total Sulphur as SO4 (Dissolved)	3745	170	3422	4271	15
Vanadium as V (Dissolved)	3.59	0.40	2.39	3.59	15
Zinc as Zn (Dissolved)	0.17	0.01	0.14	0.57	15

Appendix A. Groundwater and Surface Water Monitoring Locations



Appendix B. Groundwater and Surface Water Quality

(Dark orange exceeds compliance limits, light orange exceeds EQS/DWS, blue exceeds background >25%)

	Aquifer	Response Zone Interval[1]	Al		Sb		As		B		Cd		Ca		Cr		Cu		Fe	
		m b GL	µg/l		µg/l		µg/l		µg/l		µg/l		mg/l		µg/l		µg/l		µg/l	
Background - Limestone			6.5		1.0		0.6		72		0.08		150		1.0		2.8		46	
Background - Seawater			256		<10		2		4166		0.07				1		12		<100	
GW EQS/DWL			200		5		10		2000		5.0		250		50		2000		200	
GW MRV							1				1.0									
GW CL			**50**				**10**		**2800**		**0.4**				**50**					
SW CL							**50**		**2000**		**5.0**				**50**					
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	6.2		0.9		0.5		47		0.08		133		1.0		1.5		24	
E05-09_01B		24-30	7.2		0.8		0.5		45		0.07		128		0.8		1.2		28	
E05-09_02A		21-27	6.1		1.1		0.6		80		0.08		167		1.0		4.4		97	
E05-09_02B		27-33	6.1		1.0		0.6		80		0.08		192		1.0		5.3		55	
E15_1		17-29	5.8		0.5		0.5		184		0.05		106		0.2		1.5		17	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	8.0	5.9	2.1	0.7	1.2	1.0	1109	1405	0.18	0.19	37	194	2.8	0.9	6.5	1.2	38	23
E05_04		2.5-20	15.3	9.3	3.9	1.1	4.1	1.6	2123	2122	0.18	0.05	6	9	3.7	0.7	4.5	0.9	42	18
E06_01		3-15	9.3	12.2	2.9	0.9	0.6	1.1	1667	1763	0.17	0.06	10	8	4.3	0.8	0.8	0.8	53	16
E06_02		2-10	11.2	6.4	4.1	0.7	1.6	1.0	1113	954	0.16	0.06	89	75	2.4	0.5	4.8	1.1	89	16
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	6.5	5.5	2.0	1.2	1.2	0.6	561	400	0.16	0.06	131	153	2.9	0.4	1.8	1.5	77	16
E06_04		2-10	7.0	6.7	1.8	0.7	0.7	0.5	57	159	0.16	0.06	147	225	2.9	0.7	5.1	2.8	59	22
E06_05		2-8	11.4	5.4	3.1	0.6	0.6	0.5	224	244	0.20	0.06	129	190	2.8	0.6	1.5	1.8	41	16
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				14.3		0.6		1.8		877		0.70		325		13.7		3.0		14
Settlement Ponds				62.5		0.8		4.2		651		0.59		230		11.1		2.7		37
SW12 Lafarge Lagoon			15.7	7.6	2.1	0.5	0.7	1.3	124	430	0.18	0.23	86	180	1.8	3.3	1.4	1.5	33	16

1 Response zone interval for latest well where time series data are compiled from the original and replacement monitor well

2 Background - Limestone is mean of upstream boreholes (E05-09/1A,E05-09/1B, E05-09/2A, E05-09/2B)

3 Background - Seawater is mean of CW Inlet data collected 2011-12

	Aquifer	Response Zone Interval[1]	Mg		Mn		Hg		Mo		Ni		K		Se		Na		V	
		m b GL	mg/l		µg/l		µg/l		µg/l		µg/l		mg/l		µg/l		mg/l		µg/l	
Background - Limestone			17.5		21.3		0.01		1.7		2.9		1.8		0.8		23		1.0	
Background - Seawater					<20		0.02		<30		9		380		<1				<20	
GW EQS/DWL			50		50		1.00		70		20		12		10		200		60	
GW MRV							0.10													
GW CL							**0.03**		**50**										**20**	
SW CL																			**60**	
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	5.5		5.8		0.01		1.3		1.6		1.3		0.6		16		1.0	
E05-09_01B	Limestone	24-30	5.9		5.2		0.01		1.5		1.2		1.3		0.7		17		0.9	
E05-09_02A	Limestone	21-27	26.7		44.2		0.01		1.6		3.9		1.7		0.9		24		1.0	
E05-09_02B	Limestone	27-33	22.6		25.5		0.01		1.6		4.8		2.1		0.9		29		1.0	
E15/1	Limestone	17-29	35.5		36.0		0.01		3.7		1.4		4.0		0.6		35		0.9	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	24.2	125.0	10.5	37.2	0.018	0.006	1.1	600.5	2.2	1.3	3.5	7.4	0.9	0.5	149	379	1.5	1.1
E05_04	Limestone	2.5-20	4.0	6.2	5.9	4.7	0.018	0.008	1.8	18.8	2.3	0.7	3.7	2.9	1.3	0.8	241	241	4.2	1.8
E06_01	Limestone	3-15	7.4	5.3	0.5	9.0	0.015	0.006	0.8	12.9	0.8	0.8	3.2	3.0	1.0	0.6	215	216	2.2	1.9
E06_02	Limestone	2-10	56.1	40.3	18.0	6.7	0.014	0.009	2.9	33.7	4.3	1.6	9.9	7.0	1.6	0.7	109	115	1.7	4.7
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	62.4	81.8	10.1	8.6	0.014	0.007	10.9	16.7	4.9	2.7	7.3	8.3	4.9	1.4	70	42	1.1	1.1
E06_04	Limestone	2-10	41.9	62.6	4.7	14.2	0.014	0.006	2.5	5.8	4.2	3.5	3.7	29.0	2.3	0.6	17	40	0.8	1.0
E06_05	Limestone	2-8	52.2	74.4	6.2	8.1	0.014	0.006	2.0	5.3	3.8	2.1	4.0	4.6	1.4	0.5	27	23	1.0	1.1
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				46.0		31.8		0.007		2215		15.2		41.2		14.8		465		3.6
Settlement Ponds				42.2		8.2		0.011		1516		9.6		31.3		8.5		331		5.9
SW12 Lafarge Lagoon			23.7	38.2	1.7	9.9	0.020	0.005	4	854	2.2	4.3	6.1	23.8	1.5	1.7	26	206	1.4	1.5

	Aquifer	Response Zone Interval[1]	pH		EC		Bicarbonate		Sulphate		Ammoniacal Nitrogen as N		Total Oxidised Nitrogen as N		Nitrate		Chloride		Fluoride		Total Organic Carbon	
		m b GL			µS/cm		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l	
Background - Limestone			7.4		825		408		59		0.21		10.4		11.5		35		0.2		4.4	
Background - Seawater			7.9				97		2396								16300		1.3			
GW EQS/DWL			8.5		2500		250		400		0.3				50		250		1.5			
GW MRV																						
GW CL									**400**		**1.6**											
SW CL			**9.00**						**400**		**0.6**											
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	7.4		675		350		33		0.04		5.6		10.1		31		0.1		3.7	
E05-09_01B	Limestone	24-30	7.4		665		337		32		0.04		5.2		6.3		31		0.1		3.1	
E05-09_02A	Limestone	21-27	7.3		925		489		68		0.42		11.0		11.9		37		0.2		4.4	
E05-09_02B	Limestone	27-33	7.3		1056		476		68		0.42		24.3		22.4		41		0.2		6.1	
E15/1	Limestone	17-29	7.5		805		346		145		0.17		2.7		2.4		34		0.2		1.7	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	8.5	7.7	977	3290	462	280	178	323	0.51	0.62	0.2	0.8	0.3	1.0	33	863	1.4	1.4	15.9	2.9
E05_04	Limestone	2.5-20	8.8	8.4	1010	1000	564	466	79	91	0.53	0.38	0.3	0.2	0.8	0.1	31	66	6.4	5.4	18.6	3.4
E06_01	Limestone	3-15	8.7	8.6	923	895	473	437	106	96	0.57	0.42	0.5	0.4	0.2	0.4	33	40	2.1	2.9	19.2	2.4
E06_02	Limestone	2-10	8.4	7.8	1214	1044	336	284	390	292	1.09	0.49	0.8	0.7	0.6	0.6	38	50	0.6	0.5	4.3	3.7
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	8.2	7.7	1224	1249	276	190	443	594	0.66	0.12	2.3	0.8	1.6	0.1	23	30	0.4	0.4	3.8	4.8
E06_04	Limestone	2-10	8.0	7.6	930	1463	290	223	320	588	0.13	0.04	0.2	1.0	0.5	0.6	26	92	0.3	0.4	11.3	3.2
E06_05	Limestone	2-8	8.1	7.6	1063	1248	289	206	363	586	0.17	0.08	0.4	0.2	3.3	0.1	37	25	0.3	0.4	8.3	1.3
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				7.4		3739		274		570		3.54		25.2		20.6		832		0.2		1.3
Settlement Ponds				8.0		2700		167		503		1.07		14.4		11.5		588		0.2		5.1
SW12 Lafarge Lagoon			8.4	8.1	710	1957	161	149	214	419	0.10	0.11	1.2	5.0	5.0	1.6	40	349	0.3	0.3	8.4	3.5

Please note, that for many of the parameters, a significant proportion of the results have been reported/recorded as being below the limit of detection (LOD). To prevent skewing of the data within the above assessment (e.g. as Excel views these as zeros/text cells), and in line with available guidance[1], the "<LOD" values have been replaced with half the reported LOD value (at the time of analysis). This has been applied on an individual result basis to take account of the <LOD values varying over time (predominantly due to the improvement of methods and laboratory standards since sampling commenced).

[1] E.g. UK Technical Advisory Group on the Water Framework Directive Groundwater Trend Assessment, Section 4.2, UKTAG, 2012.

Appendix C. Topographical Survey