Caulmert Limited

Engineering, Environmental & Planning
Consultancy Services

Aberthaw Ash Disposal Site

RWE Generation Aberthaw

Hydrogeological Risk Assessment Review 2018

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DISCLAIMER

ABERTHAW ASH DISPOSAL SITE – HYDROGEOLOGICAL RISK ASSESSMENT REVIEW 2017
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1 INTRODUCTION

1.1 Background

1.1.1 Caulmert Limited has been commissioned by RWE Generation plc (the operator) to undertake a review of the existing hydrogeological risk assessment for the Ash Mound, Aberthaw in accordance with the Permit DP3432SW.

1.1.2 The original HRA was produced in May 2005 in support of the application for a Permit under the Pollution Prevention and Control Regulations 2000 (PPC). The application was submitted in May 2005. A Schedule 4 Notice was issued in May 2006 with a response by RWE in June 2006. The PPC Permit was issued by the Environment Agency in March 2007.

1.1.3 MMI Engineering Ltd, a subsidiary of Geosyntec Consultants Inc produced the most recent HRA Review in July 2012. Therefore, the objective of this review is to assess whether there has been any significant change in conditions at the site and whether the site remains in compliance with the Groundwater Daughter Directive (2006) as implemented into UK Law via the Environmental Permitting Regulation (2010). The review will also reflect recent changes in the regulatory environment.

1.1.4 An initial meeting was between NRW, RWE and Caulmert prior to the commencement of the project. The scope of the HRA review was discuss and specific items relating to change in legislation were raised by NRW.

1.1.5 In lieu of specific NRW guidance, this report utilises the Environment Agency's template for Hydrogeological Risk Assessment Reviews (2009) and adopts the terminology within the Groundwater Daughter Directive and Environmental Permitting Regulations 2014.

1.1.6 The following reports have been used for reference purposes:

- NRW, 21/06/2013, EPR Compliance Assessment Report, RDR/120713/DP3432SW
- NRW, 27/08/2015, EPR Compliance Assessment Report, DP3432SW/0247452
- RWE Generation, March 2017, 2016 EP Annual Performance Report;
- RWE Generation, March 2016, 2015 EP Annual Performance Report;
- RWE Generation, March 2015, 2014 EP Annual Performance Report;
- RWE Generation, March 2014, 2013 EP Annual Performance Report;
- MMI, 2012, Aberthaw Ash Disposal Site, Four Yearly Review of Hydrogeological Risk Assessment (HRA), MMUK11-143
- MMI, July 2013, Aberthaw Ash Disposal Site, Four Yearly Review of Hydrogeological Risk Assessment (HRA),Response to Comments from Natural Resources Wales

- Groundwater and surface water monitoring data 2012-2017;
- Public domain data sources including:
    - Geological and hydrogeological maps
    - Historic maps online viewing
    - Historic borehole records
    - Aerial imagery online.

2 REVIEW OF THE CONCEPTUAL HYDROGEOLOGICAL MODEL

2.1 Introduction

2.1.1 The conceptual site model (CSM) has been developed and updated during the development history of the site. The most recent hydrogeological risk assessment review undertaken by MMI in 2012.

2.1.2 Summary of the 2012 hydrogeological risk assessment review:

- The review contained a detailed assessment of the quality of the source term and compared and contrasted the different test methods and a revised source term was proposed
- The results of the leach tests were compared and contrasted to the concentrations observed in boreholes screened within the PFA fill.

2.1.3 In agreement with the guidance only changes and a summary of the conceptual model are presented in the section below.

2.2 Site setting and development

2.2.1 Aberthaw Ash Disposal Site is located directly east of Aberthaw Power Station, Aberthaw, Barry. The Ash Disposal site is operated by RWE generation (UK) plc under the Environmental Permit no. DP3432SW (the Permit).

2.2.2 The Ash disposal site comprises the initial location for the disposal of ash following the construction of the power station. The ash was brought from the site via a conveyer and deposited on the tidal mudflats of the River Thaw. Prior to this time the area of the ash disposal comprised a series of leys with drainage channels and the as indicated the tidal mudflats. These are described on historic maps as 'saltings'. This indicates that the influence of the tide historically extended beyond the norther boundary of the disposal area.

2.2.3 The natural channel of the River Thaw is shown as a very sinuous meandering channel across the flood plan and it is likely that the channel had migrated across this tidal flood plain and consequently channelised deposits are likely to be present beneath the ash mound.

2.2.4 Prior to 1964, the River Thaw was canalised directly from the north of the site along the western boundary of the disposal area with a lined channel out to the Bristol Chanel. A remnant of the old course of the River appears to form the brackish lagoon in the south eastern boundary of the site.

2.2.5 In addition, the historic OS maps for the area (viewed online) indicate that there was a sewage treatment works with settlement beds located in close proximity to BH6. An extract from the 1964 OS map is presented below.

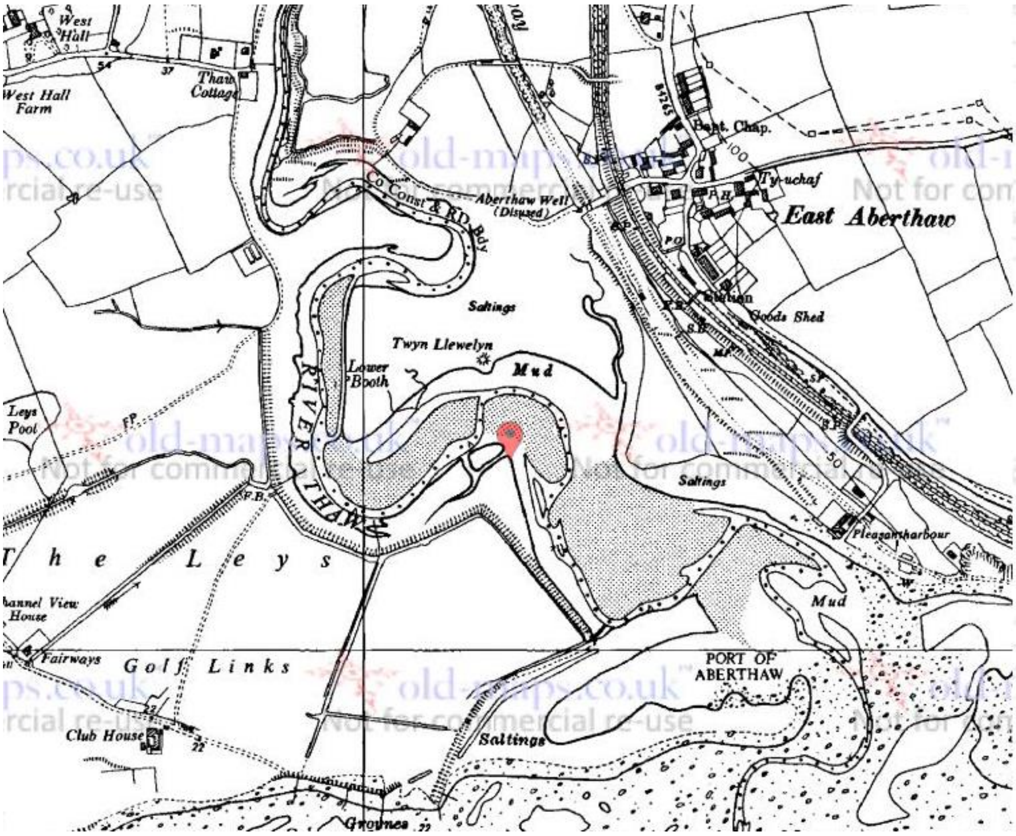


Figure 1- Extract from historic OS map showing former course of River Thaw.

2.2.6 The total area of the ash disposal area is estimated to be 54.5 ha and has a central spine ridge which effective sheds water to both the east and west of the centre. The catchment with flow entering the River Thaw is estimated to be 31ha based on the current aerial photographs for the area.

Figure 2: Site layout and surface water divide.

2.2.7 It is understood that the temporary ash storage area located along the southern section of the western boundary remans active and in addition an ash conditioning plnat is located in the far south western corner of the site.

2.3 Source

2.3.1 A detailed assessment of the leachate source term was undertaken by MMI in 2012. This suggested that some of the leach tests historically undertaken may have underestimated the source term and a review of results from column tests was undertaken.

2.3.2 The HRA review was consistent with regards to indicator species associated with PFA namely molybdenum and boron.

2.3.3 Subsequent review by NRW suggested that the boreholes installed within the PFA should be viewed as monitoring leachate. The majority of these boreholes ceased to be monitored in 2015.

2.3.4 The concentrations in the PFA boreholes are summarised below:

Table 1: Summary of leachate from boreholes screened in PFA

		BH9A (18/11/2014 & 18/5/2015)			BH10A (18/3/2014-18/5/2015)			BH11A (17/1/2012-07/11/2017)		
	Units	Mean	Max	No.	Mean	Max	No.	Mean	Max	No.
Alkalinity to pH 4.5 as CaCO3	mg/l	251.50	274	2	446.00	658	6	434.39	580	30
Ammoniacal Nitrogen as N	mg/l	0.03	0.03	2	0.11	0.216	6	1.34	30	30
Chloride	mg/l	18.50	23.1	2	136.75	219	6	272.51	787	30
Nitrogen : Total Oxidised as N	mg/l	0.34	0.42	2	0.26	0.31	6	0.89	2.35	30
Phosphate : Total as P	mg/l		0	2		0	6	5.71	14.3	30
Fluoride	mg/l	0.23	0.273	2	0.30	0.534	6	0.11	0.413	30
Carbon, Organic : Total as C :- {TOC}	mg/l	3.00	3	2	121.86	495	6	65.23	594	30
Conductivity at 20C	µS/cm	481.50	528	2	1521.83	2820	6	2786.43	4860	30
pH	pH units	7.51	7.55	2	7.51	7.67	6	7.46	7.68	30
Arsenic Dissolved	µg/l		0	2	71.32	81.7	6	18.73	49.3	30
Selenium Dissolved	µg/l		0	2	2.12	3.7	6	7.12	22.1	30
Antimony, Dissolved	µg/l		0	2	12.13	18.9	6	8.62	12.7	30
Molybdenum, Dissolved	µg/l	5.02	5.66	2	653.17	1990	6	1375.43	2790	30
Vanadium, Dissolved	µg/l		0	2	70.33	97.6	6	8.88	47.1	30
Aluminium, Dissolved	µg/l	12.30	12.3	2	17.68	21.3	6	16.35	24.5	30
Cadmium, Dissolved	µg/l		0	2	0.26	0.26	6	0.34	0.831	30
Chromium, Dissolved	µg/l		0	2		0	6	1.21	1.43	30
Copper, Dissolved	µg/l	2.12	2.12	2	1.90	2.98	6	1.96	4.53	30
Nickel, Dissolved	µg/l	1.12	1.12	2	2.17	4.32	6	1.54	2.23	30
Zinc, Dissolved	µg/l		0	2		0	6	0.43	0.43	30
Boron, Dissolved	µg/l	101.00	101	2	7330.00	18700	6	12270.67	19700	30
Calcium, Dissolved	mg/l	77.15	83.3	2	165.83	328	6	348.17	502	30
Iron, Dissolved	µg/l		0	2		0	6		0	30
Magnesium, Dissolved	mg/l	8.29	9.91	2	85.83	238	6	99.88	131	30
Manganese, Dissolved	µg/l		0	2	155.00	155	6	510.15	1670	30
Potassium, Dissolved	mg/l	6.95	7.56	2	29.12	45	6	52.99	86.1	30
Sodium, Dissolved	mg/l	24.20	27.6	2	88.28	176	6	206.08	544	30
Sulphate, Dissolved as SO4	mg/l	14.30	16.7	2	312.12	1050	6	893.40	1630	30
Mercury, Dissolved	µg/l		0	2		0	6	1.90	5.66	30
Bicarbonate as HCO3	mg/l	306.83	334.28	2	544.12	802.76	6	502.69	707.6	30
Ionic Balance	%	-0.94	-0.76	2	0.77	4.17	6	1.61	21.6	30

Shading is only to distinguish between dataset – it carries no significance.

The above data indicates that the water quality in BH9A was representative of a very weak leachate with contaminant concentrations consistently at low levels representative of uncontaminated water. Insufficient water was available to sample and this well ceased to be monitored. The concentrations in BH10A are similar to those in BH11A with high molybdenum and boron concentration. Although there is some variation in the average concentrations the maximum concentrations are consistent. These results are consistent with the reported findings in 2012.

2.4 Pathway

2.4.1 The geology and hydrogeology of the area have been established throughout the development of the site. It is acknowledged that the groundwater flow within the area is complicated by the canalisation of the Afon Thaw and natural heterogeneity of channel deposits within an estuarine environment. In summary the geological succession around the perimeter of the ash disposal site can be summarised as:

Table 2: Summary of lithology

Lithology	Description
Made Ground	Ash – variable thickness. A number of boreholes are screened through this layer
Estuarine Deposits	brown silty to sandy, locally shelly clays, organic clays and beds of peat, interbedded with sands and gravels, and beds of cobble gravel. Boreholes have proved up to 17 m of these deposits in the central part of the power station site, thinning to between 5 m and 8 m in the northern and western parts of the power station site and feathering to the extremities of their outcrop.[1]
Lower Lias Limestone	thinly interbedded limestones and calcareous mudstones of Jurassic age, colloquially known as the 'Blue Lias'. The proportion of limestone to mudstone varies throughout the sequence, but limestone is generally more than 50% in that part of the succession (the Porthkerry Member) that immediately underlies the power station and ash disposal sites.

2.4.2 Therefore, in order to interpret the hydrogeological data, it is essential to consider the units that the boreholes are screened within (PFA/Limestone/Clay) and how this relates to the established pathways at the site. A summary of the boreholes is presented below.

Table 3: Summary of borehole infrastructure

	Easting	Northing	Top of Standpipe Level	Ground Level	unit	response zone (m bgl)	top response zone mAOD	Base response zone mAOD
BH03A	302951.29	166204.56	9.76	9.52	PFA	2 - 6m	7.52	3.52
BH03B	302952.37	166204.45	10.09	9.75	Limestone	13.5 - 23m	-3.7531	-13.25
BH05	303276.39	166721.16	12.10	11.74	Limestone	2.5 - 11.5m	9.2354	0.24
BH06	303091.35	167101.80	20.54	20.25	Limestone	13 - 20.5m	7.248	-0.25
BH07A	303624.16	165926.62	9.38	9.00	Gravelly CLAY	2 - 9.5m	6.9982	-0.50
BH7B	303622.86	165931.06	9.46	9.02	Limestone	18 - 26m	-8.98	-16.98
BH08A	302945.48	166868.20	11.91	11.53	Silty Sand	5.3 - 7m	6.226	4.53
BH08B	302944.49	166870.00	11.82	11.49	Limestone	30 - 38m	-18.5111	-26.51
BH09A	303670.27	166192.43	6.48	6.25	Fill	2.2 - 6m	4.052	0.25
BH09B	303671.15	166191.94	6.61	6.31	Limestone	6 - 13m	0.308	-6.69
BH10A	303148.12	165840.60	10.64	10.20	Fill	1 - 3m	9.1983	7.20
BH10B	303150.90	165840.54	10.65	10.19	Clay	23 - 30m	-12.8096	-19.81
BH11A	303375.15	165888.00	13.35	12.93	Fill - ash and clay	1.5 - 5m	11.4318	7.93
BH11B	303377.68	165888.31	13.44	13.07	Clay	9.5 - 19m	3.57	-5.93
BH12FC	302048.79	166379.05	7.99					
BH13FC	302048.32	166435.60	7.91					

Sand silts and clays have been interpreted as Alluvium

[1] MMI 2012, Hydrogeological Risk Assessment Review.

Aquifer Characteristics

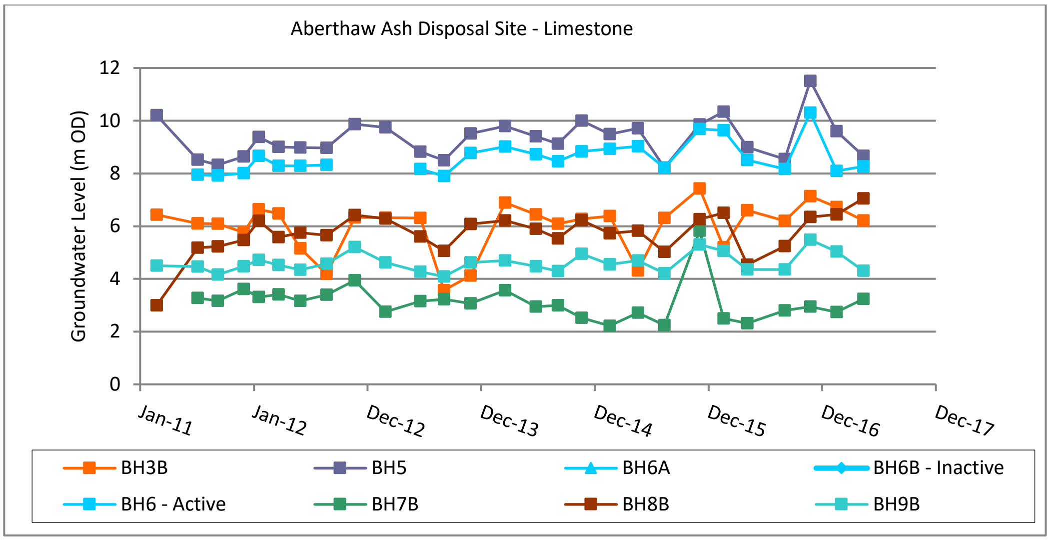
2.4.3 The aquifer comprises Lower Lias Porthkerry Formation limestones and mudstones. The Porthkerry Formation is a Secondary Aquifer of local importance. Groundwater flow is likely to be predominantly through fractures in the limestone and mudstones. Entec 2005 reported on-site measurements of hydraulic conductivity of the Porthkerry Formation in the range 2 x 10-8 to 7 x 10-6 m/s, with a logarithmic mean of 1.5 x 10-7 m/s. Therefore the Porthkerry Formation has relatively low hydraulic conductivity.

2.5 Groundwater Levels and Flow Direction-Limestone

2.5.1 The groundwater levels in the boreholes screened in the limestone display relatively consistent patterns within the groundwater. Boreholes 5 and 6 consistently display the highest groundwater levels and typically seasonal variation appears to be around 2m however the winter high in November 2011 is higher than previously recorded in both boreholes.

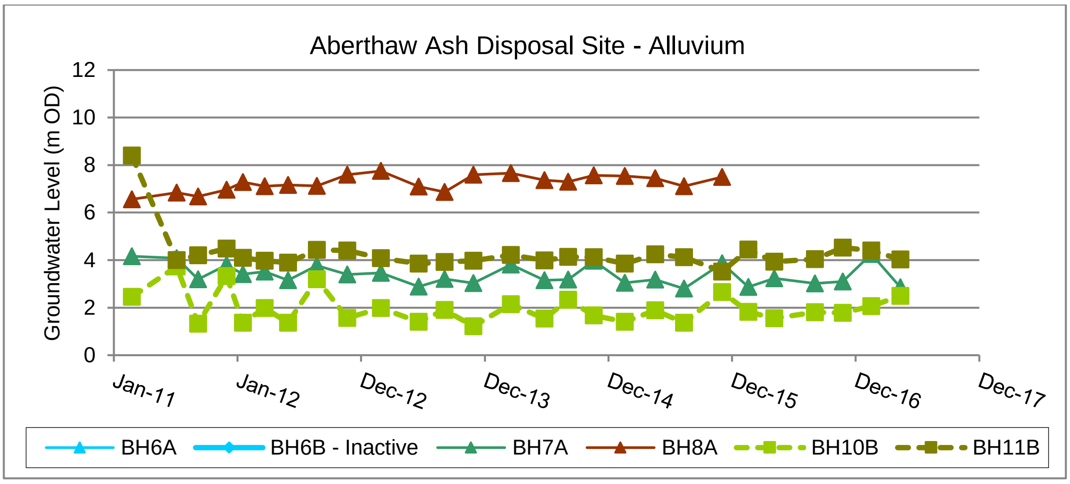
2.5.2 The groundwater contours for February 2016, representing a high groundwater period is presented below. This indicates that the groundwater head gradient within the underlying limestone is predominantly southerly and towards the Bristol Channel. This is consistent with the previous review and implies that there has been no discernible change in groundwater flow within the Limestone.

Figure 3: Groundwater contours

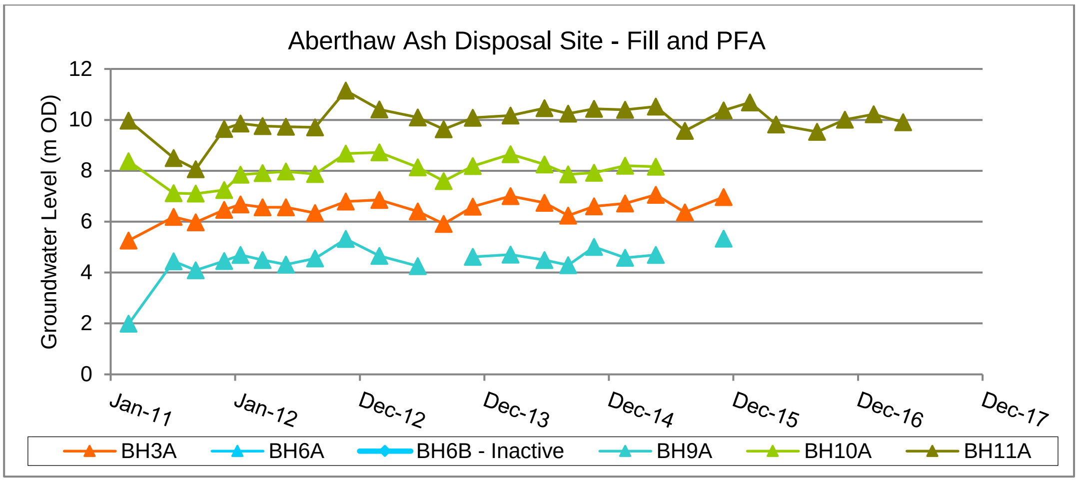


2.5.3 Borehole BH3B appears to be more variable with a total range over the period of just under 4m. This borehole is closer to the Severn estuary and may be influenced by the tide. Borehole BH7B appears to have a slight overall decrease in levels through the review period where as BH8B has a slight overall increase. BH9B remains relatively steady.

2.5.4 There are insufficient boreholes remaining within the alluvium to be able to generate a groundwater contour plot with sufficient degree of confidence. Due to the heterogeneous nature of these deposits and the historic tidal flat area, it is considered most likely that the overall flow direction is also to the south rather than the canalised Afon Thaw. This is supported by relatively higher groundwater elevations in BH8 within the alluvium compared to the three installations along the southern boundary as indicated in the time series data below. The hydrograph also indicates that there is some degree of variability within the dataset with groundwater levels changing by over 1m on consecutive monitoring occasions. This may be due to natural fluctuations in groundwater in response to rainfall events however it may also be due to tidal influences on groundwater levels.

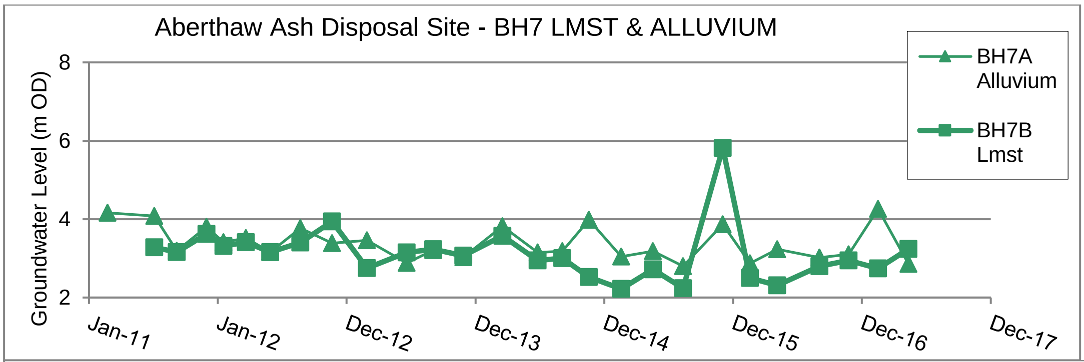


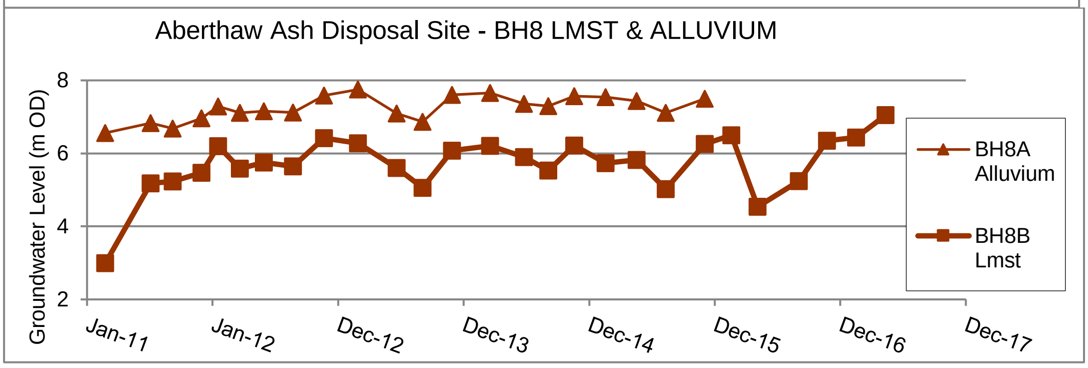
2.5.5 The remaining boreholes are screened either within or across the PFA fill. All boreholes appear to have relatively stable groundwater levels and relative similar patterns with respect to groundwater fluctuations.



Vertical Groundwater Heads

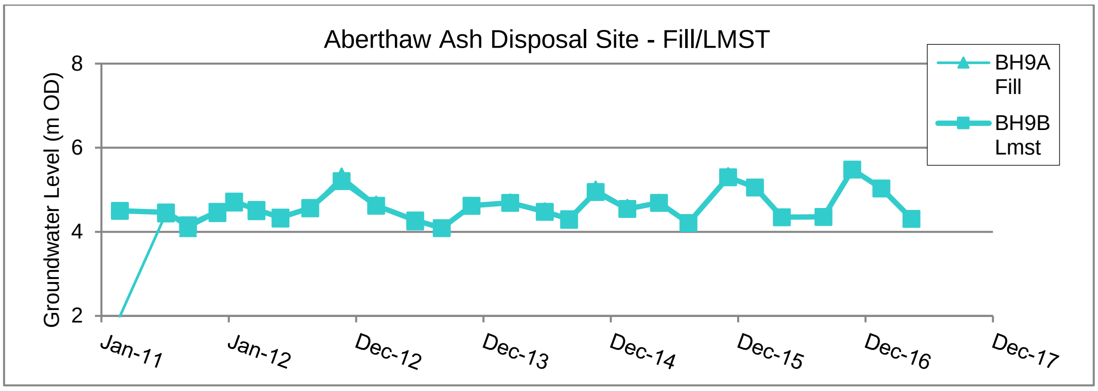
2.5.6 In order to understand further the interactions of the various groundwater bodies present around the site, the borehole have been plotted in their respective pairs



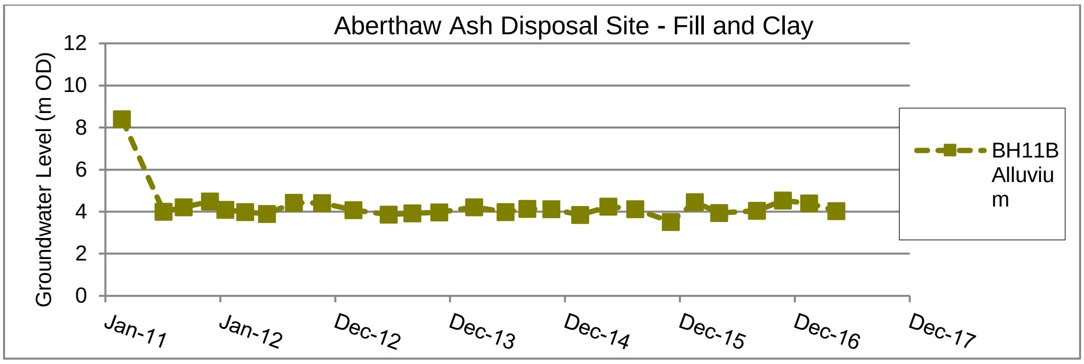


2.5.7 The above charts indicate that there is a minor head difference between the alluvium and the underlying limestone. As expected this head gradient is greatest in the more up gradient location compared to the down gradient locations. This indicates that the permeability contrast is sufficient to enable the development of a driving head across this boundary. In contrast the recorded piezometric pressures between the fill and limestone monitored by BH9A and BH9B respectively are identical. This implies that:

a) The two installations have become linked
b) The two units are hydraulically connected.
c) Levels are controlled by mean high water springs (MHWS)



2.5.8 In contrast there is a significant difference (circa 6m) in piezometric pressures between the boreholes installed within the fill material and the underlying alluvium (specifically described as clay).



2.5.9 The above assessment of the long term groundwater levels at the site demonstrates that there are complex interactions between the various units present at the site and that this should be taken into account during the assessment of the groundwater and surface water quality at the site. Notwithstanding the above, due consideration should be given to the interface between saline and fresh water groundwater at the coastal boundary with particular regard to the depth of installation of the active screened section.

2.5.10 In addition, the tidal range at the site is large with a maximum range of 12.37m[2]. The potential for tidal /cyclic groundwater within the boreholes in close proximity to channels within the alluvium, the Bristol channel (southern boundary) and within the boreholes adjacent to Afon Thaw, is considered to be high and therefore a proportion of the inherent variability in the groundwater level may be attributed to tidal effects. Only monitoring at

[2] Information for Barry docks taken from https://www.tidetimes.org.uk/barry-tide-times, accessed 6/5/2018

set intervals throughout the duration of the tidal cycle would be able to demonstrate the extent of any tidal groundwater.

2.6 Groundwater Quality

2.6.1 During the review period, the legislation regarding the classification of hazardous substances in groundwater has changed. In January 2018 JAGDAG published a list of confirmed hazardous substances[3]. Within this list Cadmium is defined as non-hazardous, nickel (as Nickel 2) has been revised down from an interim hazardous substance and remains classified non-hazardous. Chromium VI, Arsenic, lead and mercury are all defined as hazardous substances.

2.6.2 It is noted that lead is not required to be monitored at the site and that chromium is monitored as total dissolved Cr which prevents its direct comparison against the relevant screening criteria. It is recommended that chromium is monitored as Cr (III) and Cr(VI) within future monitoring rounds.

Selection of assessment criteria

2.6.3 The 2012 hydrogeological review assessed the monitoring results against the UK Drinking water standards. Within the CAR report RDR/120713/DP3432SW, NRW have suggested that it would be more appropriate to assess the groundwater data against the EQS for transitional and coastal waters and that this was addressed by MMI within their response documents to NRW. A summary of the existing compliance and control levels is presented in the table below together with the background water quality from the most up-gradient limestone borehole present on the site, BH5. It is noted that this borehole has chloride concentrations <150mg/l and is therefore representative of a freshwater chemistry whereas the site cross les across the interface between freshwater and saline conditions. It is noted that the control levels apply to all potentially down gradient boreholes however the compliance limits are only assigned to BH7B and BH3B.

Table 4: Environmental Acceptable Limits

Parameter	Units	Reference Values							Control Levels		Compliance Limits	
		EAL (transitional and Coastal)			LSB		Site Baseline					
							Lmst BH5					
		AA	MAC	Source	Value	Source	95%	MAX				
Hazardous Substances:									**10%**	**Applies to:**	**25%**	**Applies to:**
Mercury	µg/l	-	0.07	EQS	0.1	MRV	0.11	0.1	18	BH6	20	BH7B
Arsenic*	µg/l	25	-	EQS	1.3	LSB	1.5	1	275	BH7B BH8B BH9B BH10B BH11B	310	
Chromium (VI)	µg/l	0.6	32	EQS	0.36	total Cr	<0.5	2.24	135		N/A	N/A

[3] JAGDAG, January 2018, 2018 01 31 Confirmed hazardous substance list.pdf as published on https://www.wfduk.org/resources/groundwater-hazardous-substances-standards

Non-Hazardous Substances:										**25%**	**Applies to:**	**50%**	**Applies to:**
Aluminium	µg/l			DWS	23	BC		19	110	750	BH3B BH5	N/A	N/A
Ammoniacal-Nitrogen	mg/l	(unionised EQS 21 ug/l)				LSB		0.04	0.09	5.5	BH6 BH7B BH8B BH9B BH10B BH11B BH3B BH5	6.6	BH3B BH7B
Cadmium	µg/l	0.2		EQS	2.3	LSB		0.1	0.1	13		15	BH3B
Boron	mg/l	7		EQS	3.7	LSB		1068	1170	48		60	
Molybdenum	µg/l	*70*		WHO	<30	LSB		23	30	7700		9000	BH3B
Selenium	µg/l	10		DWS	1.7	LSB		1	1	290		350	BH7B
Sulphate	mg/l	-	-	DWS	2,345	LSB		547	576	2,660		N/A	N/A
Vanadium	µg/l	*100*		EQS	<10	LSB		2	20	180		N/A	N/A
Chloride								110	142	FRESH			

Assessment of Salinity

2.6.4 The salinity of the boreholes is important as it indicates whether the well has been affected by saline intrusion (a natural process at the coast) or whether the elevated concentrations are solely the result of PFA contamination. The ratio of chloride to fluoride ions has been used to assess the wells with respect to their salinity based on average concentrations of the current database (see Appendix 1). This table indicates that there is a wide range of groundwater conditions from saline to brackish to freshwater and that the saline water is not contained by one horizon/ unit but in present in PFA / Alluvium and Limestone. A number of parameters including boron are present in seawater and therefore due consideration of the salinity of the wells has been included in the follow discussion on groundwater quality

Table 5: Summary of salinity assessment data

	Location	Cl:F ratio	Comment	screen section (mAOD)		Lithology
				Top	Bottom	
Seawater	Literature	14615				
	Site Data	12036				
Leachate	2:1 leachate 2005[4]	15				
Groundwater	BH3A	9673	Brackish/Saline	7.52	3.52	PFA
	BH3B	13705	Saline	-3.7531	-13.25	LMST
	BH5B	593		9.2354	0.24	Alluvium
	BH6A	13178	Saline	7.248	-0.25	LMST
	BH6B	10307	Saline			LMST
	BH8A	880		6.226	4.53	Alluvium
	BH8B	13706	Saline	-18.5111	-26.51	LMST
	BH7A	6893	Brackish	6.9982	-0.50	Alluvium
	BH7B	6154	Brackish	-8.98	-16.98	LMST
	BH9A (FILL)	82		4.052	0.25	PFA
	BH9B	205		0.308	-6.69	LMST
	BH10A (FILL)	455		9.1983	7.20	PFA

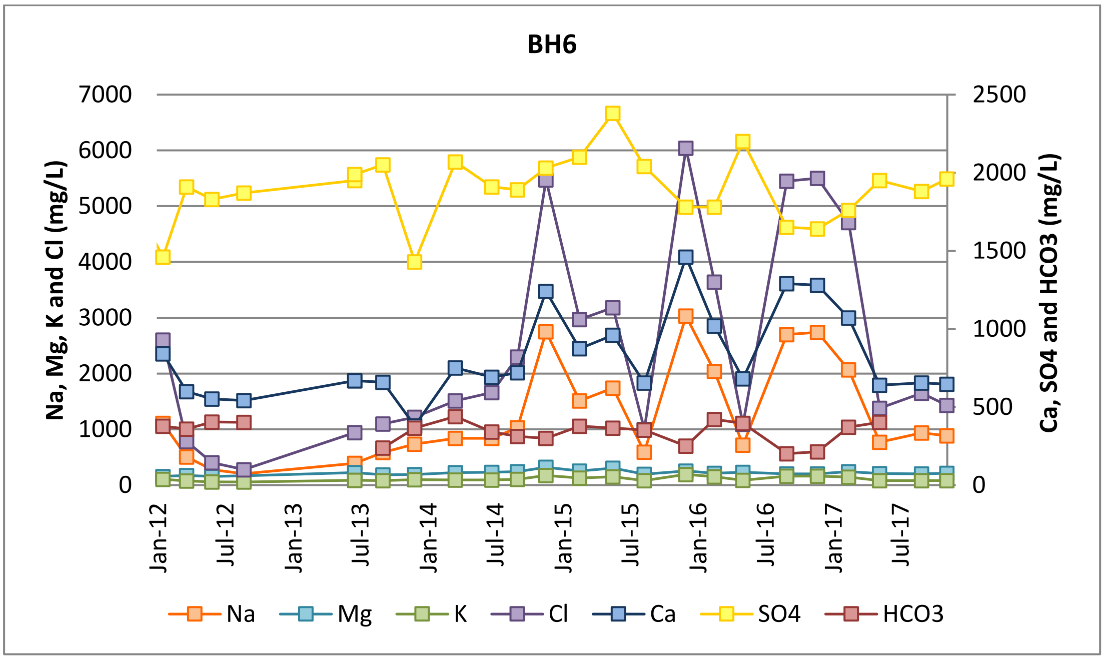
[4] Presented in RWE database

	Location	Cl:F ratio	Comment	screen section (mAOD)		Lithology
				Top	Bottom	
	BH10B	18267	Saline	-12.8096	-19.81	Alluvium
	BH11A (FILL)	2550	Brackish	11.4318	7.93	PFA
	BH11B	3587	Brackish	3.57	-5.93	Alluvium
Surface Water	Group 5 Spring	2367	Brackish			
	Saline Lagoon	3521	Brackish			
	EPD	415				

Groundwater Quality – Trends and Spatial Analysis

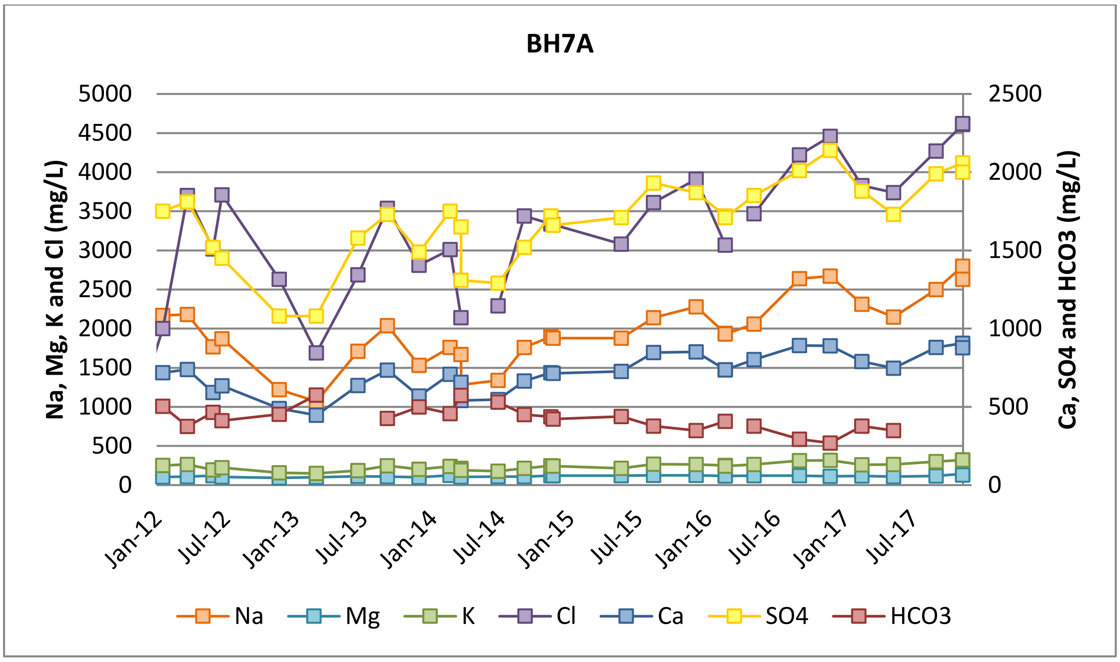
2.6.5 Groundwater quality has been monitored at the site for a significant amount of time. The ash mound has been restored and vegetation is established across the surface. Therefore the potential significant deviation from the current situation, is considered to be small.

2.6.6 The timeseries data presented in Appendix 1 indicates that whilst there is variability/uncertainty with the database the overall trend is generally of stable conditions. This is shown in BH6 below.



2.6.7 The peaks relate to the concentrations of sodium, chloride and calcium which may be related to the coincidence of the monitoring with or just following spring tides. This appears to correlate for 2016 and 2017 however it does not correlate for 2015. Alternatively, it may be related to storm events /surges resulting in increased salinity. The overriding trend, however, is that the concentrations return to similar levels suggesting overall stability in the groundwater major ion chemistry.

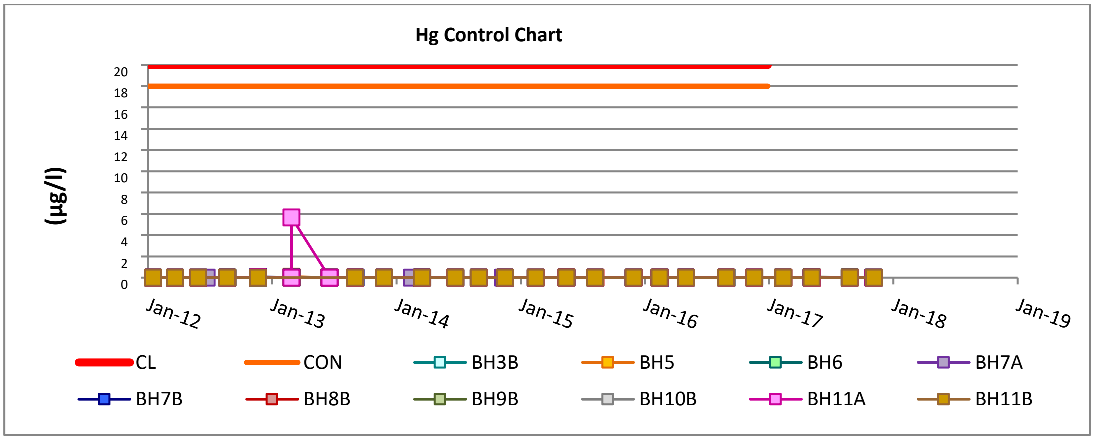
2.6.8 Conversely borehole BH7A appears to be the only borehole which has a rising trend within the major ion chemistry. The increase is observed in the chloride, sodium sulphate and tentatively calcium concentrations. The cause of the increase in concentration is unknown. No associated increases are observed within the control charts for leachate indicator species.



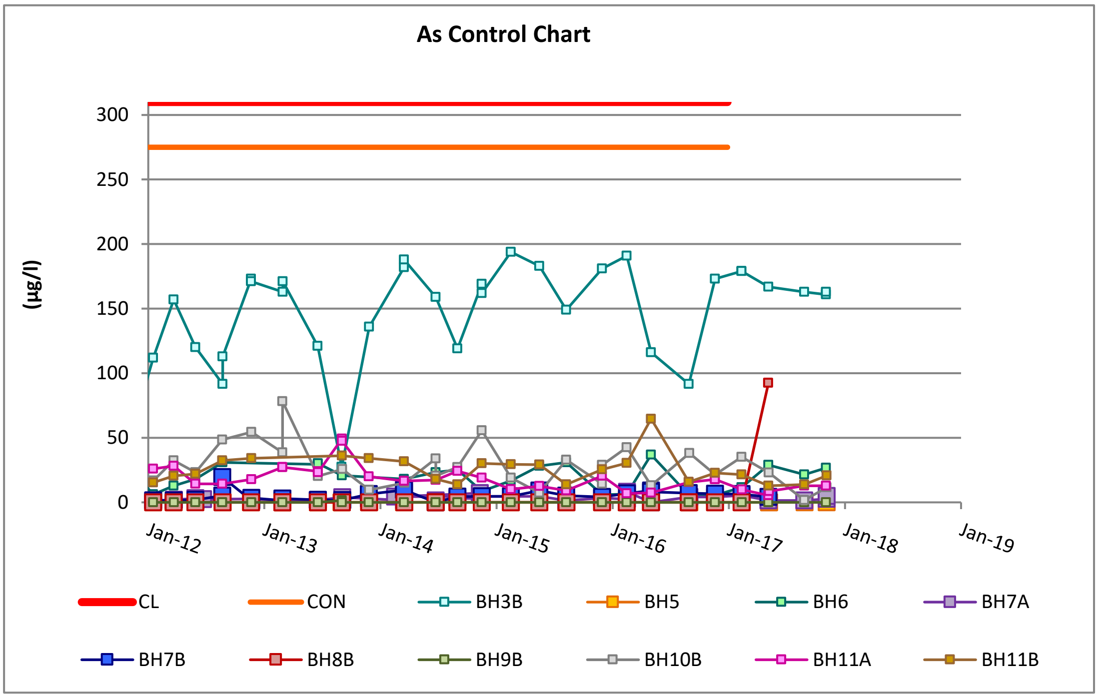
Review of Groundwater against RWE Control Levels

2.6.9 The timeseries graphs are presented in Appendix 1. An electronic copy of the database will be provided in the E copy of the report only. Control charts have been produced for all determinants with compliance limits. These are discussed in turn below:

2.6.10 **Mercury:** No exceedences were observed above the current compliance limit of 20 ug/l. It is noted that this is significantly above the Water Framework directive value for coastal and transitional waters at 0.07 ug/l (maximum admissible concentration). The majority of results are consistently below the detection limit with the exception of two isolated results for BH3B in March 2011 and one in BH11A in Feb2013. These are single values and are not associated with any trend. There are no associated peaks in other parameters which correlate in time. Therefore these two results are considered to be anomalous possible due to sediment within the sample as we note that these occurred prior to the improvements in monitoring techniques which occurred in 2013.



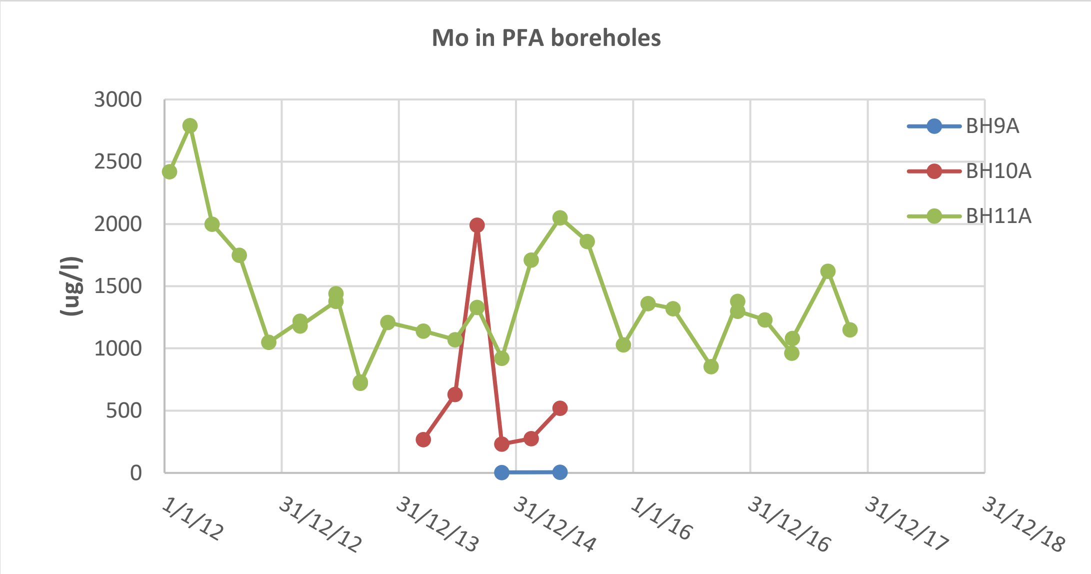
2.6.11 **Arsenic:** No exceedences occurred of the control or compliance limit for this parameter. The timeseries data presented below indicates that the water quality in BH3B contains between 2 and 3 times as much arsenic as the other locations. This is a stable trend taking into account the variability in the dataset. The current EQS for arsenic is 25 ug/l and if this was applied boreholes BH11B, BH10B and BH11A would all exceed this criteria. These boreholes are all located at the southern end of side in down gradient locations.

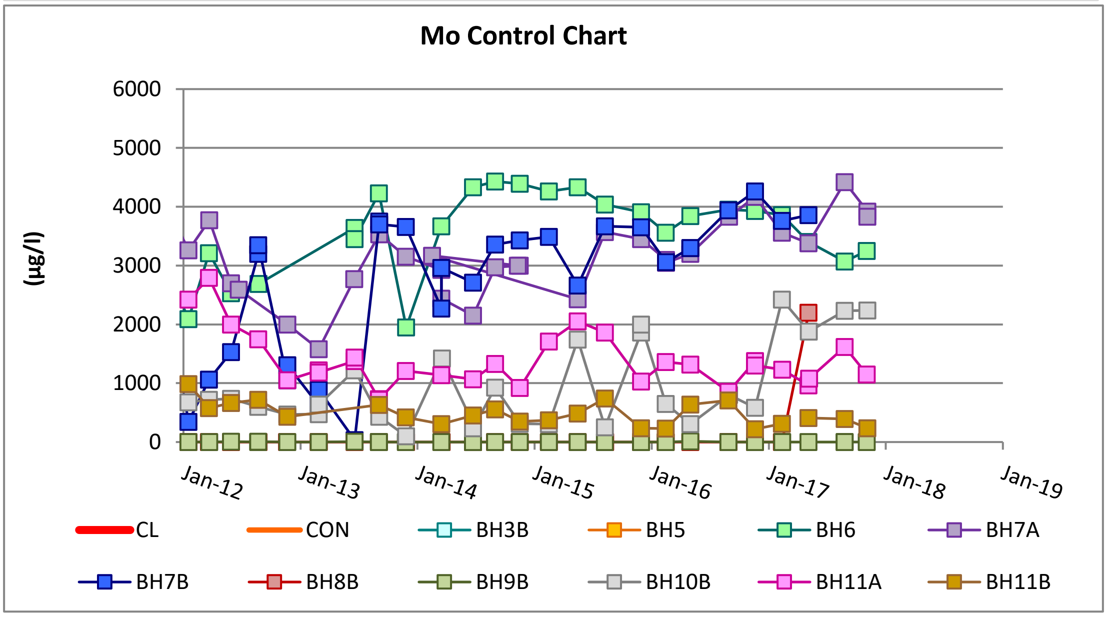


2.6.12 Chromium: Cr (VI) is defined as a hazardous substance however currently total chromium is currently monitored at the site therefore it is not possible to directly compare the concentrations on site with the EQS of 0.6 ug/l (Annual average for transitional waters). The current control levels (no compliance levels set) is 136ug/l. The peak concentration was observed in BH6 at 20ug/l. It is noted that this peak concentration is less than the maximum allowable concentrations (MAC) of 32ug/l.

Non hazardous substances

2.6.13 Molybdenum is widely regarded as the key indicator species for the leachate derived from PFA. There is no prescribed environmental water quality standard for transitional and coastal waters as documented under the surface water pollution risk assessment guidance. There are no specific UK quality standards for this parameter and only a World Health Organisation (2004) value is available. This suggests a water quality standard of 70 ug/l. Boreholes BH6 and BH7B have consistently higher concentrations than the other boreholes. These are located in the Limestone and alluvium respectively.





2.6.14 The two charts above indicate that BH6, BH7B and BH7A, exceed the concentrations of the ‘leachate source term’ as defined by boreholes installed in the PFA. It is also noted that since 2015 the Molybdenum concentrations in BH7A and BH7B are extremely similar which appears to confirm the earlier conclusion that these boreholes are hydraulically linked.

2.6.15 The distribution of average molybdenum concentrations (ug/l) is presented on the surfer plot below. This indicates that high concentrations are observed in all locations with the exception of the 2-3 wells which record 'Fresh water' type salinities. The image indicates that there is potentially an area of low concentrations across the centre of the site however it is consider highly unlikely that the low concentrations will extend beneath the ash.

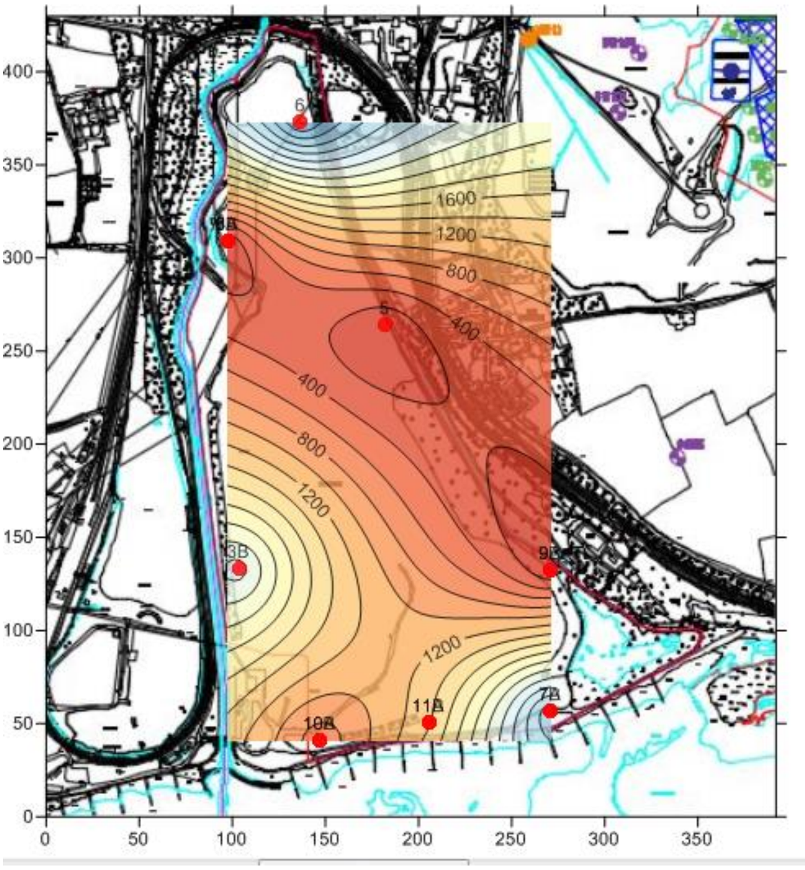
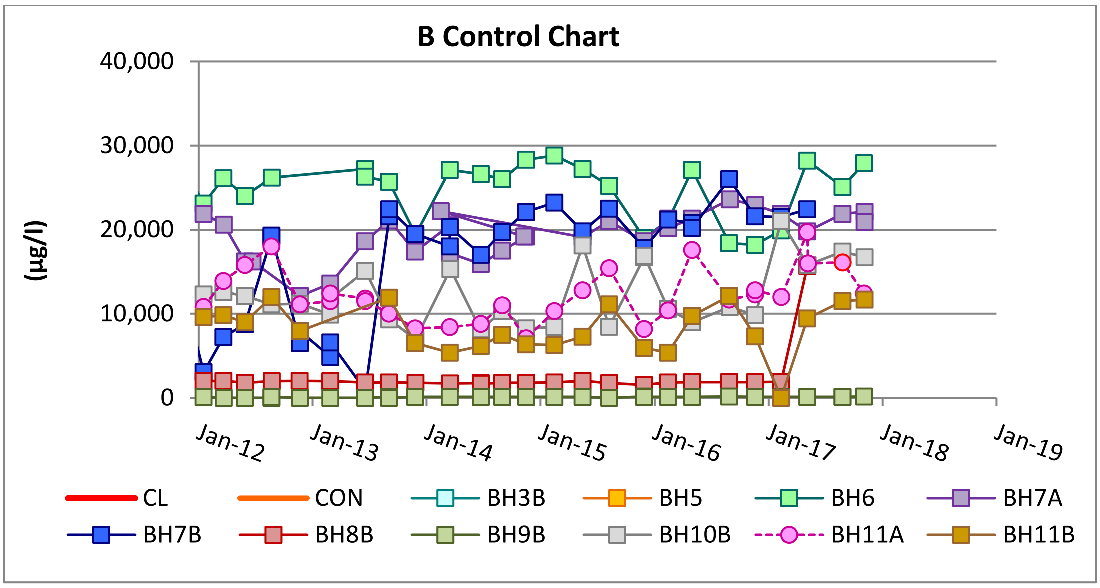


Figure 4: Distribution of Average Molybdenum (ug/l)

2.6.16 **Boron:** Boron is another indicator species for PFA however boron is also naturally occurring within sea water and consequently it is necessary to understand the saline intrusion to assist in the review. The chart below is similar in appearance to the molybdenum chart above with respect to the relative concentrations within the boreholes. Borehole BH6, BH3B, BH7B, BH11B, BH10B, BH7A are all above the EQS for transitional water at 7000 ug/l. Borehole BH11A indicates the concentration in the PFA leachate onsite.



2.6.17 The spatial distribution of the boron concentrations is also very similar to Molybdenum, with low concentrations observed in BH5 and BH9B. The main apparent difference is the steepness in the concentration gradient between boreholes with 'fresh water' and those experiencing saline/brackish water.

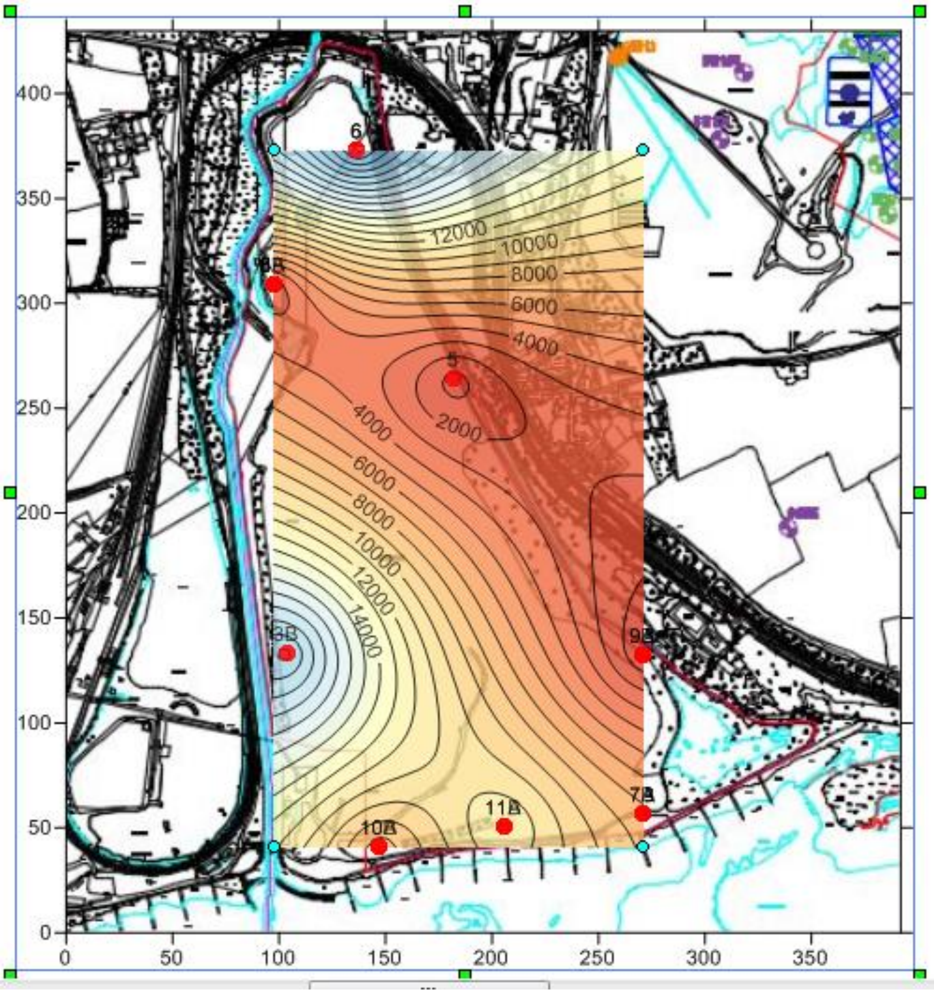
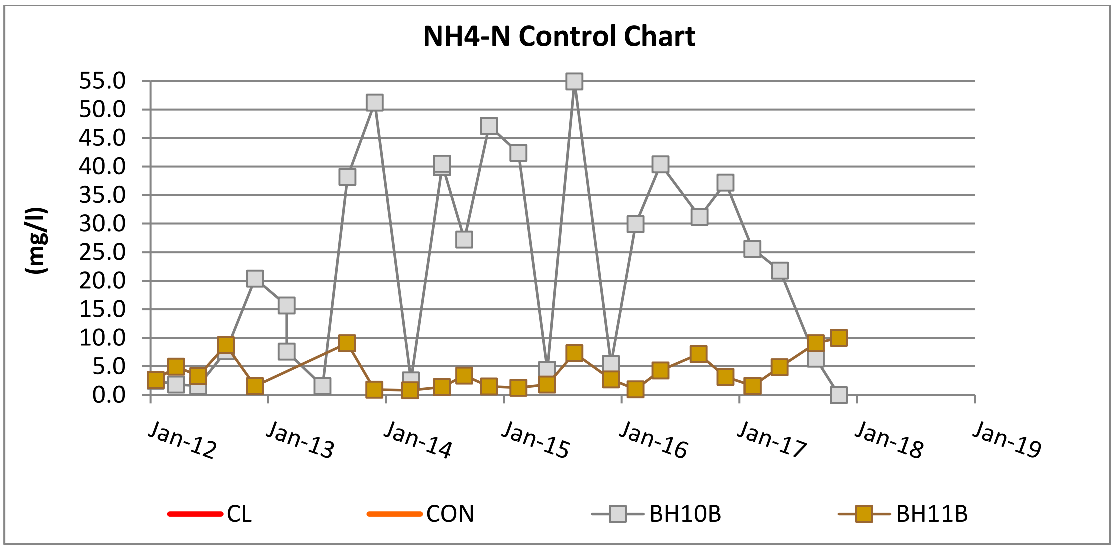
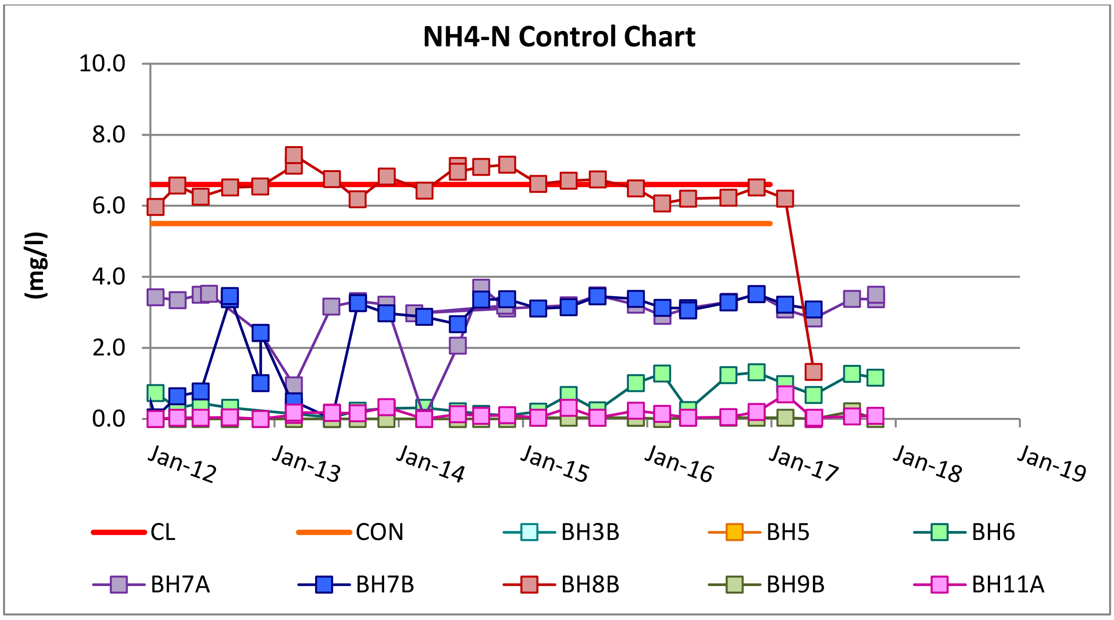


Figure 5: Spatial distribution of Boron concentrations (ug/l).

2.6.18 **Ammoniacal nitrogen** is elevated in BH10B and BH11B. Both these boreholes are located along the southern boundary of the site down gradient of the temporary storage area. Ammonia is used in the clean air technology at the power station and therefore the potential source may relate to the temporary storage area for PFA located up gradient of these boreholes, however based on location borehole BH3B would also be expected to have been affected. In addition the shallow borehole BH10A had ammoniacal nitrogen concentrations less than detection limits in 2015 which would suggest that this is not related to runoff from the temporary stock pile area as concentrations would be expected to be higher in the shallow boreholes.



2.6.19 The remaining boreholes are all less than the control levels with the exception BH8B. This borehole is next to a pond with sample point S1. S1 is known to contain elevated ammonia and it is potentially related to the concentrations of ammoniacal nitrogen within this borehole. It should also be noted that both BH8B and the pond with S1 are located in close proximity to the River Thaw and the former sewage settlement beds which may be complicating the groundwater chemistry in this area.



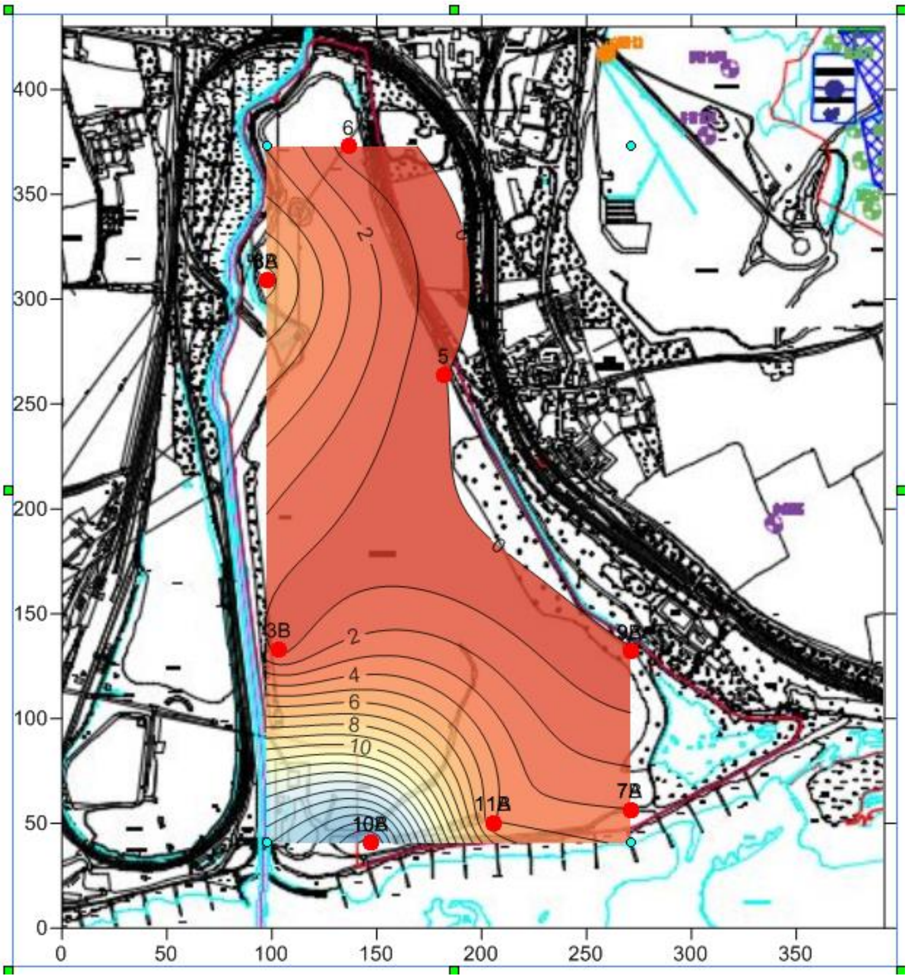
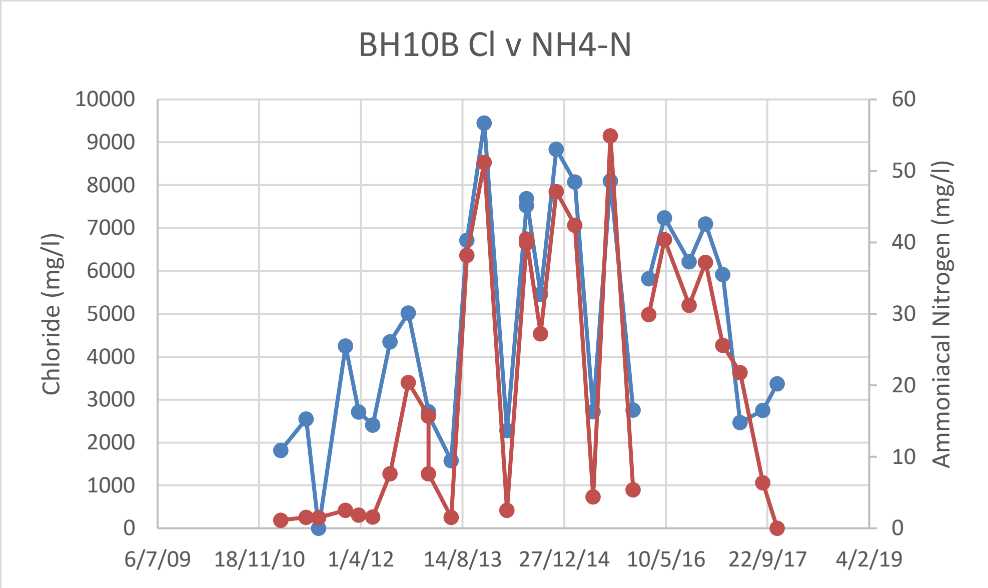
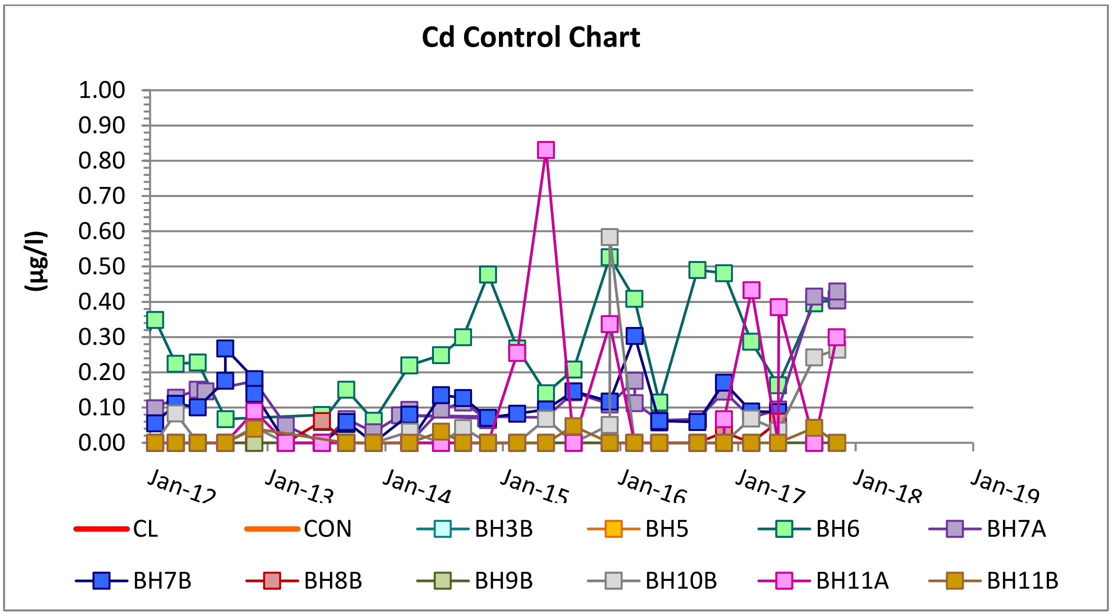


Figure 6: Spatial Distribution of Ammoniacal Nitrogen (mg/l)

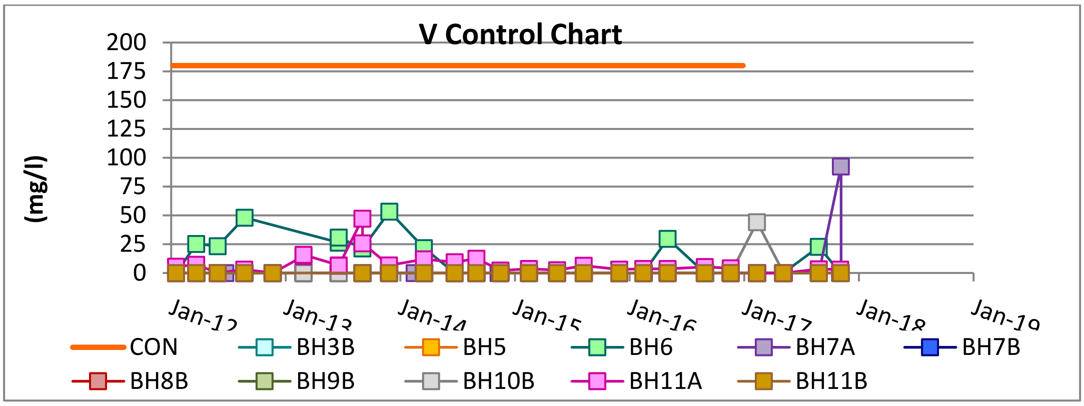
2.6.20 The peak ammoniacal nitrogen concentrations appear to occur at times when the chloride concentrations in these boreholes is greater than 2500 mg/l with the highest concentrations associated with the highest chloride. The elevated ammoniacal nitrogen concentrations are therefore potentially related to tidal (saline) influences on these wells or due to interference in analysis by the high salinity values.

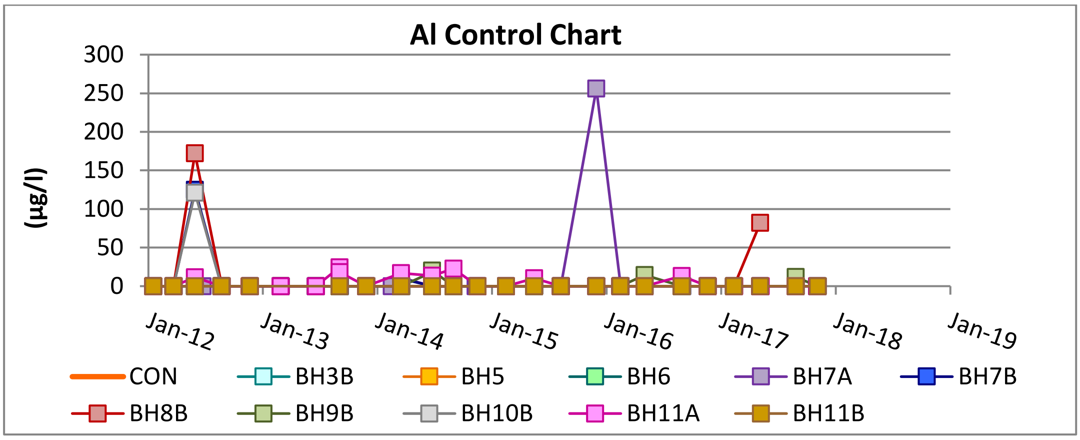


2.6.21 Cadmium is now defined as a non-hazardous substance and consequently discernible concentrations are permitted in groundwater provided that they do not constitute pollution. The EQS for transitional and coastal water is defined as an annual average value of 0.2 ug/l. All boreholes with the exception of BH6, BH10A(fill) and BH11A(fill) had mean concentrations less than this assessment criteria. Boreholes BH6 and BH10A both have mean concentrations of 0.26 ug/l whereas borehole BH11A had 0.34 ug/l.

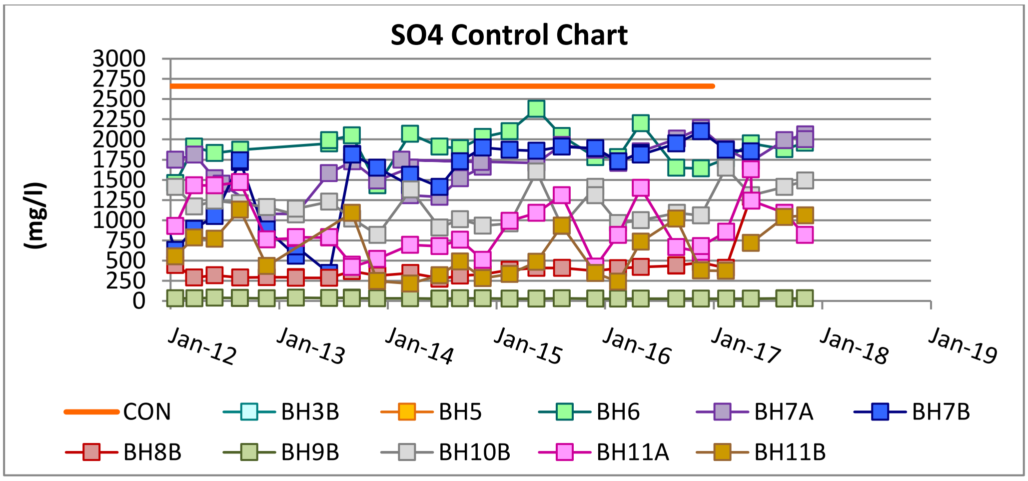


2.6.22 **Aluminium, and vanadium:** The concentrations of these determinands remain variable as identified in the 2012 review despite improvements in the sampling technique. The concentrations remain below the control level and are therefore not of concern. There are no patterns or correlations with regards to the spikes and therefore are not considered to be indicative of any event within the groundwater quality.



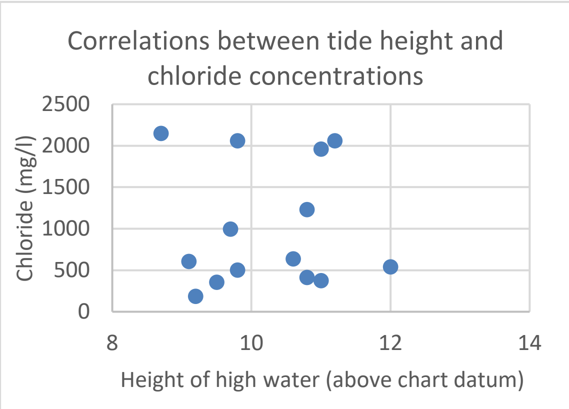


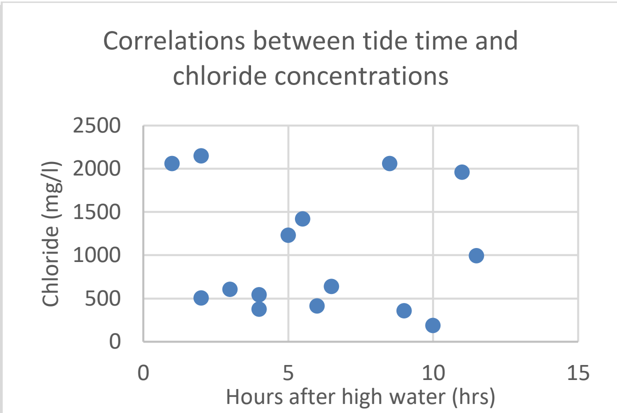
2.6.23 **Sulphate**: The sulphate concentrations mirror the pattern identified in the boron concentrations. The source of the sulphate may be related to the leachate generated from the PFA but also from saline groundwater conditions. Local seawater background concentrations are recorded as 2345 mg/l. Therefore the concentrations observed in the boreholes are not considered to be discernible from the saline groundwater.



2.7 Summary and Discussion

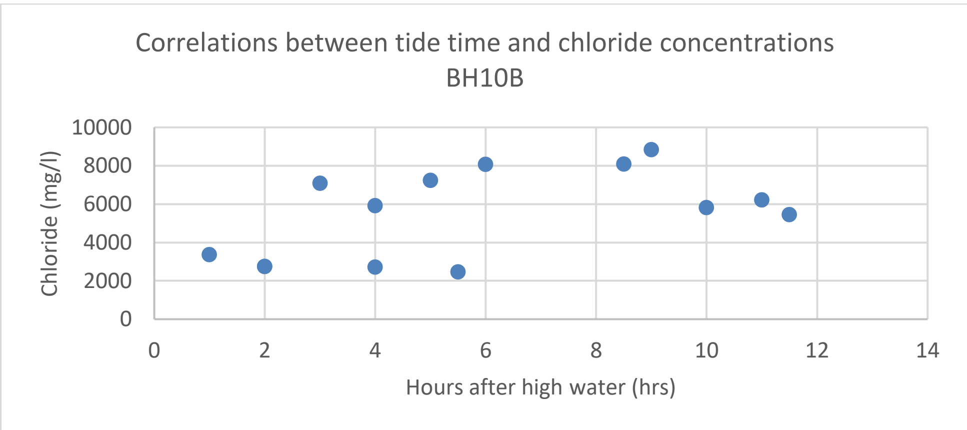
2.7.1 The above assessment indicates that the groundwater quality is consistent with previous HRA review in 2012. The concentrations have remained stable within the variability limits within each borehole, that is, there are peaks which suggest changing groundwater conditions however the concentrations return to consistent level (see BH06 above). Unsurprisingly these cycles appear to affect the parameters both characteristic of PFA and saline water, for example, chloride, sodium, and boron. As part of the review, the time and date of the sampling rounds were reviewed against records of high water spring tides. This review has focussed on boreholes along the southern boundary and utilised the tidal data from Barry Docks.



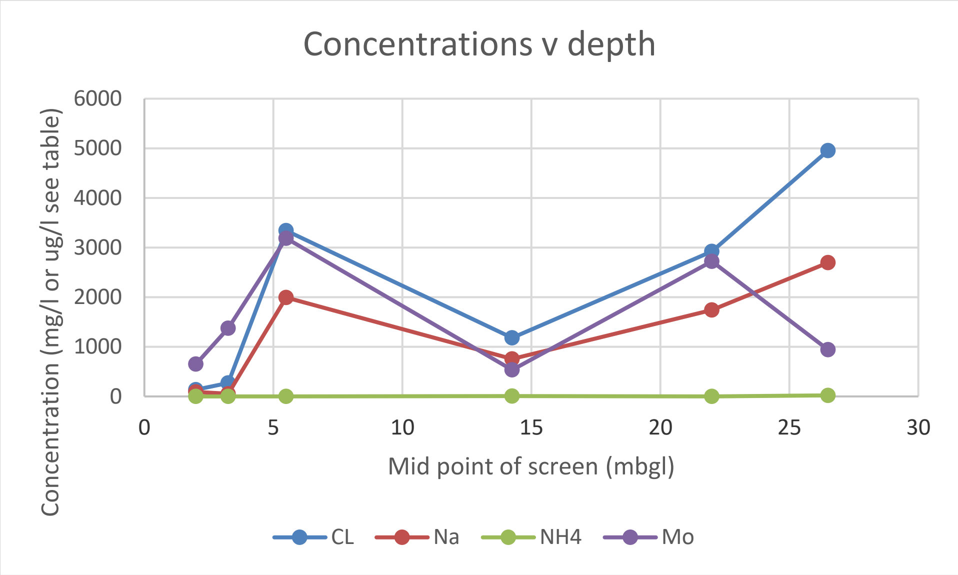


2.7.2 The two charts indicate that there is no correlation between tide heights or times on the chloride concentrations in BH11B(installed in alluvium).

2.7.3 The same exercise was undertaken for BH10B (installed at depth in the alluvium). These charts may tentatively suggest that there is a correlation with high chloride concentrations observed 6 hours after high water which would imply a lag time between the surface tide and groundwater. This implies that an aspect of the variability within the monitoring results is due to tidal influences on the groundwater quality within these boreholes.



2.7.4 During the course of this review the middle screen depths were plotted against the major ions concentrations for the boreholes along the southern boundary. There is a good correlation with increasing depth resulting in increasing salinity with the exception of the data at 5.5m which relates to BH7A. As discussed earlier, this borehole appears to be hydraulically linked to BH7B (midpoint screen 22m). This suggests that the natural freshwater /saline groundwater interface occurs close to this boundary.



BH ID	depth
10A	2
11A	3.25
7A	5.5
11B	14.25
7B	22
10B	26.5

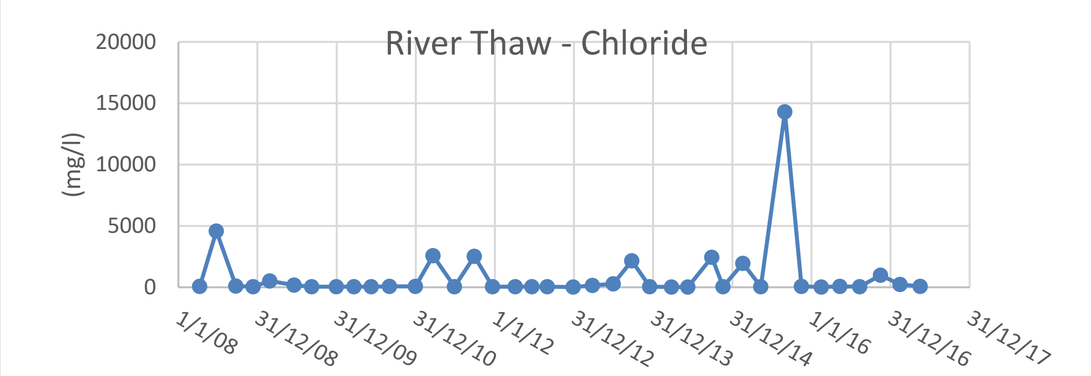
2.8 Surface water quality

2.8.1 The surface water quality is monitored at the following locations:

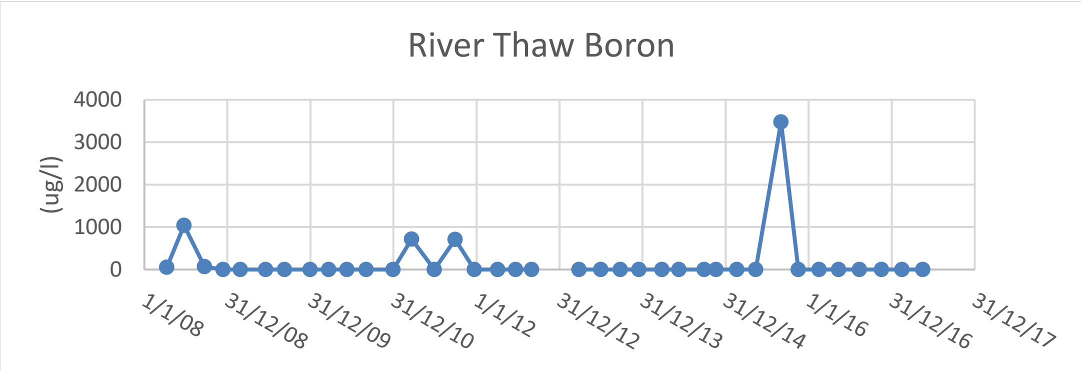
- S3 River Thaw – up gradient of the site
- S1 – surface water ponds near borehole BH8
- EPD (Eastern perimeter ditch). Midway between boreholes BH5 and BH9B
- BL brackish lagoon- catchment for runoff from south eastern area of the site

2.8.2 Surface water monitoring is undertaken on a quarterly basis for the full suite of parameters identified in the groundwater suite. The quality of the water is discussed separately below. The full database from 1/1/2008 has been used in this section to help identify long term trends in the water quality.

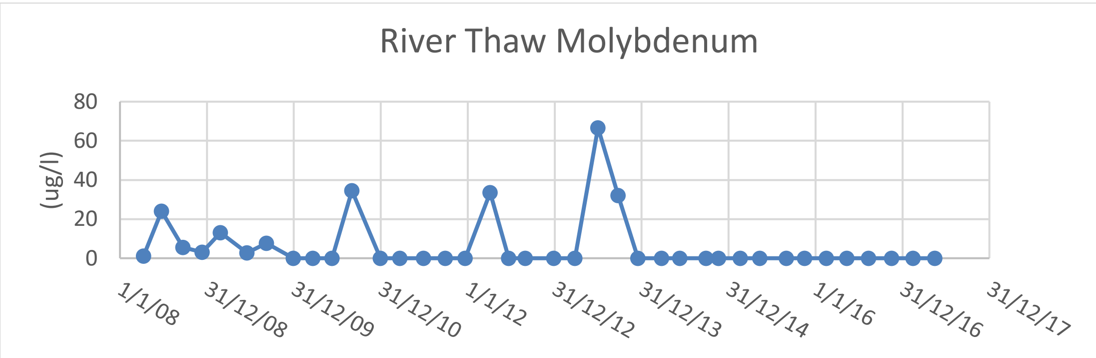
2.8.3 Upstream River Thaw. The surface water monitoring point is located upstream of the majority of the site and is tidal. This can be observed in the range of chloride concentrations monitored at this site.



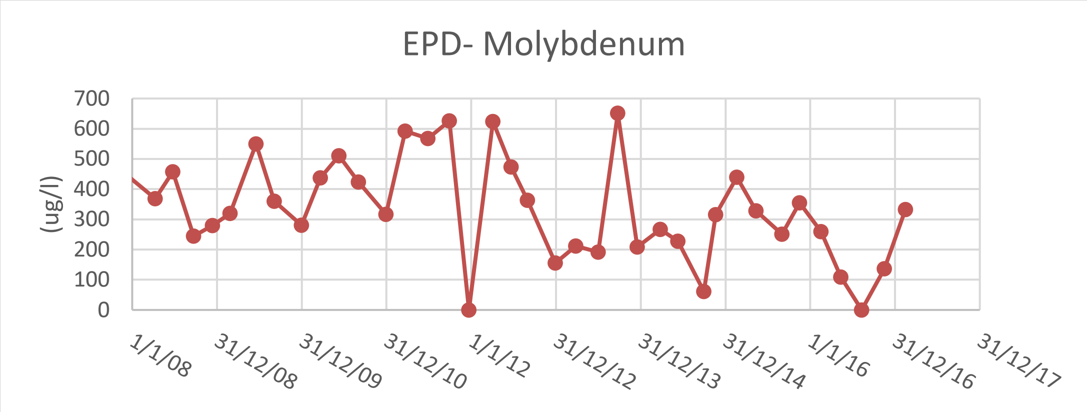
2.8.4 The ammoniacal nitrogen concentrations are low with occasions spike to 0.2 mg/l. The PFA indicator species are present in the water quality however at low concentrations. Two graphs for boron and molybdenum are presented below. It is noted that there is a correlation between the chloride and boron concentrations which is as expected due to boron also being found with sea water.



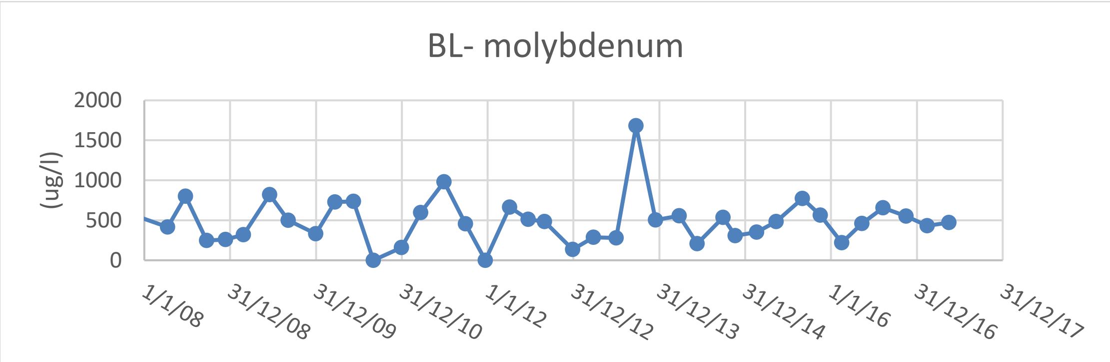
2.8.5 There is no correlation between the molybdenum concentrations, chloride or ammoniacal nitrogen. The molybdenum concentrations are generally low however there three isolated spikes between 2010 and 2014 with a maximum of 67ug/l, thereafter the concentrations are below detection limit.



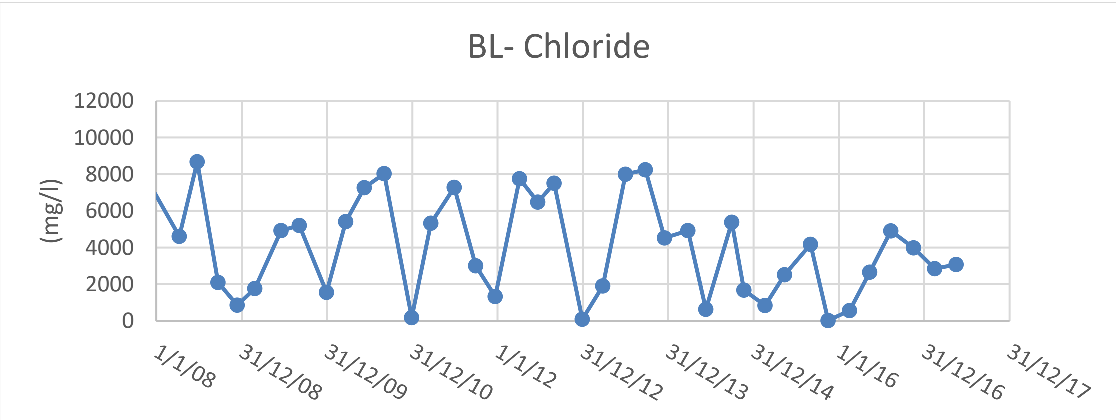
2.8.6 The concentrations in the Eastern Perimeter Ditch (EPD) are more indicative of the influence of the ash with ammoniacal nitrogen concentrations consistently below 0.06 mg/l and the chloride concentrations range from 22 mg/l to 586 mg/l. The range of chloride concentrations is considered to be influenced by rainfall events and the effect of dilution and /or flushing and migration of contaminants from the ash. Molybdenum and boron show a similar response over time. The maximum concentration of molybdenum is 651 ug/l. Overall, there are no increasing or decreasing trends suggestion conditions have stabilised.



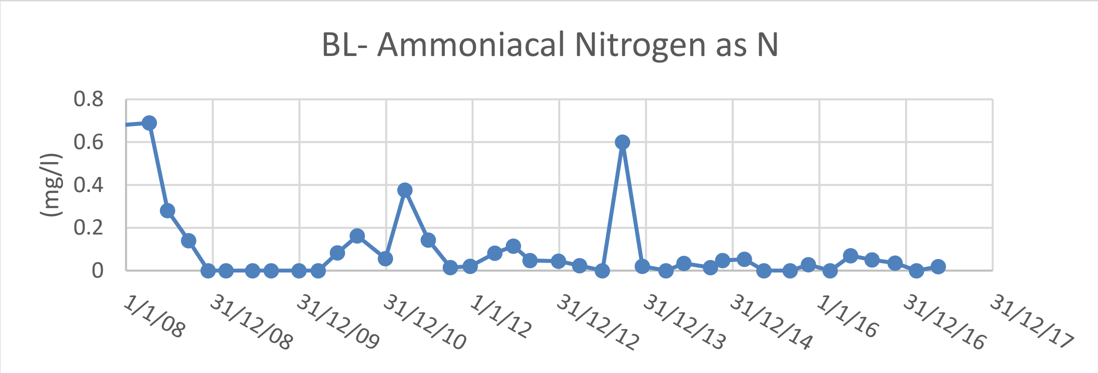
2.8.7 The Brackish lagoon (BL) is located downstream of the EPD monitoring point and the ash mound. The molybdenum concentrations have increased relative to the EPD location with average concentrations of 515 ug/l and peak concentrations of 1680ug/l confirming the effect of the ash on the surface water environment.



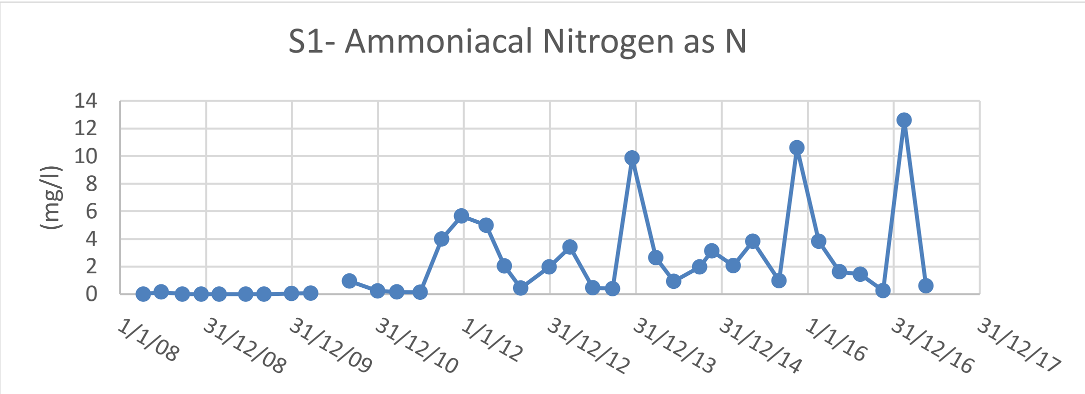
2.8.8 The chloride concentrations are very variable and indicative of the brackish water. It is reported that during storms, sea water can flood (via spray) this area so although we would expect an increase in chloride associated with the PFA this is masked by the natural salinity.



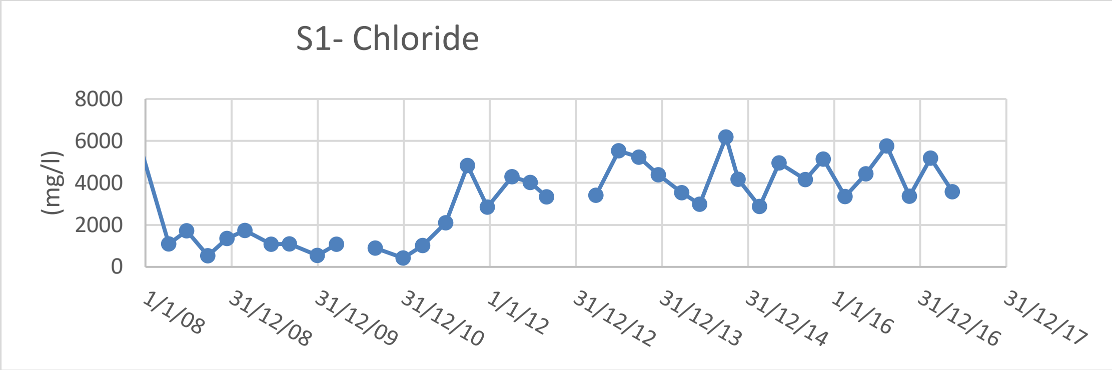
2.8.9 The ammoniacal nitrogen concentrations are also variable however they have been consistently below 0.1 mg/l since December 2013.



2.8.10 The monitoring location S1 has a significantly different quality compared to the above locations. The data indicates a change in the quality from 2010 onwards with increased concentrations of ammoniacal nitrogen. The peak concentrations appear to correlate to mid winter which may relate to the degradation of organic matter within this isolated pond Similarly ammoniacal nitrogen concentrations in BH8B have remained relatively stable ammoniacal nitrogen concentrations between 5.5mg/l and 7.4 mg/l which indicates that the seasonally elevated ammoniacal nitrogen concentrations are unlikely to be associated with the historic ash mound.



2.8.11 The chloride concentrations below also show an increase in levels in 2011 with the concentrations being variable but stable over this period. The seasonal peaks observed within the ammoniacal nitrogen concentrations are absent however any change in chloride concentrations associated with decay of organic matter would be masked by the brackish nature of this pond.



2.8.12 There is no apparent change in the molybdenum concentrations overtime as indicated in graph below. It is therefore considered that the increase in ammoniacal nitrogen concentrations is not related to the adjacent ash. The change in quality is observed in the chloride and ammonia concentrations which may suggest the degradation of organic matter and 2 out of the 3 peaks do correlation to winter monitoring (the 3rd being February), however the concentrations are significantly higher than preceding and following results which would indicate a rapid improvement in quality.

2.8.13 This location is midway along the western boundary of the ash mound and the tidal River Thaw. RWE have confirmed that there is no route for runoff from the temporary storage area to reach this pond and the age of the waste mass in this area would predate the use of ammonia (for CSR) at the power station.

2.8.14 The pond appears to have become brackish in 2011 with the increase in chloride from circa 500 mg/l to circa 3000mg/l.

2.8.15 Therefore there are multiple line of evidence that suggest that the ammoniacal nitrogen in S1 is not associated with the permitted activities.

2.8.16 High concentrations of ammoniacal nitrogen (50mg/l) are observed in BH10B which is also located along this western boundary of the site although at a significant distance. This borehole is also close to the boundary with the Severn Estuary. The chloride concentrations in this borehole vary between approximately 1500 mg/l and 10,000mg/l displaying a wide range of salinity most likely due to the influence of the Severn Estuary. This data does appear to show a correlation between the peak chloride concentrations and the ammoniacal nitrogen concentrations. There is no apparent source for the ammoniacal nitrogen results within this borehole and the adjacent shallow borehole BH10A did not record elevated ammoniacal nitrogen or chloride concentrations. It is therefore queried whether the ammoniacal nitrogen results in samples with high salinity are a true reflection of the water quality or whether there is the potential for interference/competition of ions during the analysis potentially resulting in false results.

3 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 The nature of the hydrogeological risk assessment

3.1.1 The above review of the environmental data is in agreement with the existing conceptual model for the site (2012 HRA review). The conceptual model remains complex with various water bearing units, potential for preferential flow paths with channels such that traditional numerical models would not aid the assessment of the risks presented by the site to the wider hydrogeological environment.

3.1.2 It was discussed and agreed with NRW at the pre-commencement meeting that numerical modelling of the site would not further the understanding and assessment of the risks at the site and that the risk assessment review should focus upon the direct evidence collected from the environmental monitoring and the validation of this data. In addition the assessment of the significance of the onsite monitoring data has been compared to the risks to the wider environment. This has been undertaken using a simplified approach using a water balance, surface water pollution risk assessment approach. The objective is to provide an indication of the most likely potential impact on the Afon Thaw at its discharge to the Bristol Channel and consequently the results are only intention to provide context to the potential risk the site poses to the wider environment.

3.2 Proposed assessment scenarios

3.2.1 The review of the most likely potential impact of the site on the River Thaw has been calculated using as water balance technique to generate the potential volume of leachate generated at the site which could potentially discharge into the River Thaw.

3.2.2 The volume of leachate generated is based on an assumed infiltration rate into the PFA. The average annual rainfall for the site is estimated to be 998mm/yr based on published rain data for St Athan weather station (1km north north west of the ash mound). This is based in data from 1981 to 2010.

Extract from www.metoffice.gov.uk/public/weather/climate/gcjs3tzpf#averages table.

Month	Max. temp (°C)	Min. temp (°C)	Days of air frost (days)	Sunshine (hours)	Rainfall (mm)	Days of rainfall >= 1 mm (days)	Monthly mean win speed at 10m (knot
Jan	7.9	2.8	6.7	55.5	91.9	14.0	11.0
Feb	7.9	2.4	7.3	79.4	71.8	10.9	10.4
Mar	10.0	4.0	2.7	119.9	68.2	13.1	10.2
Apr	12.4	5.4	1.3	178.9	61.5	11.0	9.3
May	15.6	8.4	0.0	221.7	64.2	10.1	9.1
Jun	18.3	11.2	0.0	217.0	60.9	9.5	8.3
Jul	20.1	13.3	0.0	223.9	76.4	10.4	8.5
Aug	19.9	13.3	0.0	192.0	83.5	11.3	8.2
Sep	17.9	11.5	0.0	161.1	82.1	11.0	8.4
Oct	14.3	8.7	0.3	105.2	122.4	14.7	9.5
Nov	10.9	5.6	2.3	67.6	100.7	15.1	9.8
Dec	8.3	3.1	6.3	50.7	115.4	14.0	10.5
Annual	13.7	7.5	27.0	1673.0	998.9	145.1	9.4

3.2.3 The annual average potential evapotranspiration is reported to be 510 mm/yr[5], resulting in an equivalent effective rainfall of 488 mm/yr. A proportion of this rainfall will infiltrate the ground as recharge (leachate generation) with the remaining proportion as runoff. Based on the steepness of the slopes and the natural low permeability of the PFA itself, the proportion of runoff is anticipated to be high, however a range of values has been assessed to review the sensitivity of this parameter.

Table 6: Summary of estimate of recharge

Percentage of effective rainfall as recharge	Justification
30%	The NCB reported infiltration rates of 50% through temporary cover systems. This site has established vegetation and therefore this is considered to be a service estimate
10%	Considered to be a more realistic assessment of recharge base on the slope angles and low permeability of the PFA

3.2.4 The total area of the site is approximately 54.5 Ha, however only a proportion of this area drains to the River Thaw, the remaining area drains to the Eastern Perimeter Ditch. The proportion draining to the River Thaw has been estimated from aerial photography and

[5] Ministry of agriculture fisheries and food, technical bulletin 35 The agricultural climate of England and Wales – Area 52.

equates of 311,700 m2. Assuming two different recharge rates, this generates leachate volumes of :

Table 7: Summary of leachate generation estimate

Percentage of effective rainfall as recharge	Leachate volume (m3/yr)	Leachate volume (m3/s)
30%	45633	0.0014
10%	15211	0.0005

Flow in the River Thaw

3.2.5 The River Thaw only has one gauging station located at Gigman Bridge. The average flow within the river at this point is $0.715m^3/s$[6], however the image below indicates that at this point the catchment less than 50%of the total catchment for the stretch which flows past the ash mound. Therefore the average flow past the ash mound is assumed to be $1.43m^3/s$. Further details on the hydrology are presented in Appendix 2.

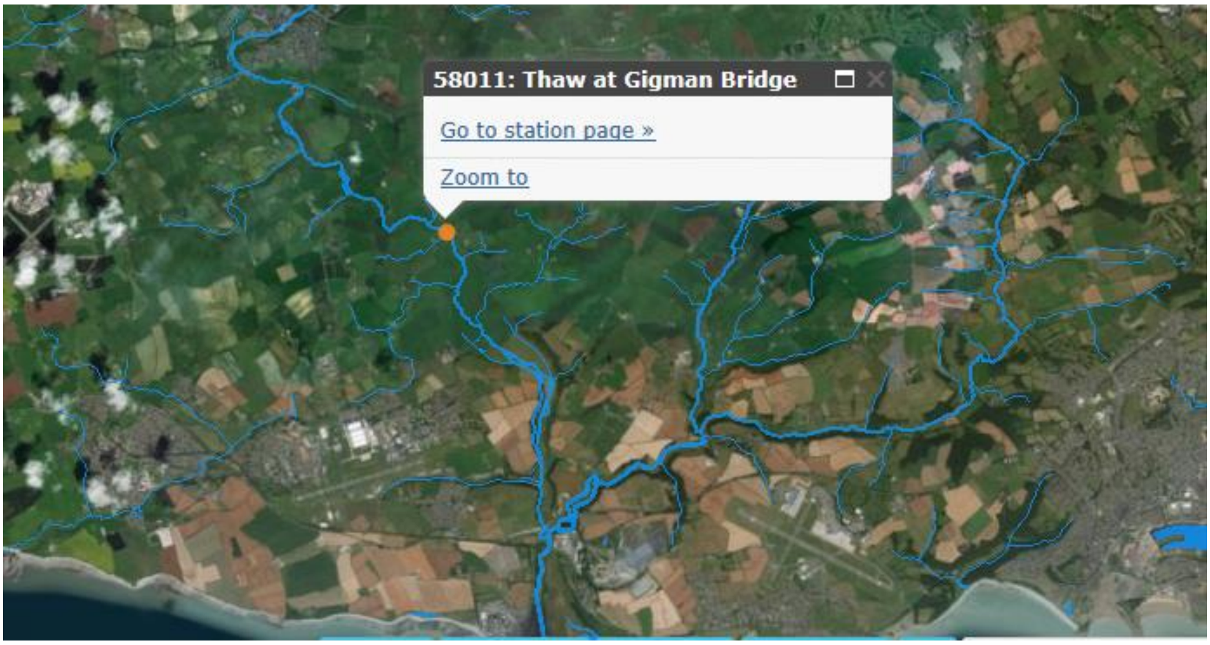


Figure 7: River Thaw Catchment

3.2.6 It is noted that this does not include any additional dilution offered by the flushing effect of the tide.

3.3 Priority contaminants to be modelled

3.3.1 Based on the assessment above the priority substances to be modelled are:

Table 8: Summary of priority substances

Parameter	Units	Concentration	Location	EQS Transitional water	Background Sea water
Molybdenum	μg/l	3607	BH06	70 (WHO)	<30
Boron	μg/l	25119	BH06	7000	3700

[6] National River archive

Parameter	Units	Concentration	Location	EQS Transitional water	Background Sea water
Ammoniacal Nitrogen	mg/l	21.01	BH10B	-	0.04
Cr (VI)	µg/l	4.47	BH06	0.6	0.36
Arsenic	µg/l	25.18	BH11B	25	1.3
Mercury	µg/l	1.9	BH11A	0.07	0.1

3.3.2 Based on mass balance calculations where the volume of leachate generated at the 'maximum' average concentrations is release to the River Thaw (assuming saline water quality) the predicted concentrations are as follows:

Table 9: Summary of predicted impacts on River Thaw

Parameter	Units	Concentration	10%	30%	Seawater Background	EQS Transitional water
Molybdenum	µg/l	3607	31.21	33.61	30	70 (WHO)
Boron	µg/l	25119	3707	3722	3700	7000
Ammoniacal Nitrogen	mg/l	21.01	0.05	0.06	0.04	-
Cr (VI)	µg/l	4.47	0.36	0.36	0.36	0.6
Arsenic	µg/l	25.18	1.3	1.3	1.3	25
Mercury	µg/l	1.9	0.10	0.10	0.1	0.07

3.3.3 Therefore the above table indicates that on an annual average basis the leachate generated though infiltration to the waste mass will not have a discernible effect on the tidal areas of the River Thaw.

3.4 Sensitivity analysis

3.4.1 A sensitivity analysis has been carried out with regards to the assumed infiltration coefficient with two values being considered. The results presented above indicate that the calculations are not overly sensitive to this value.

3.4.2 The assessment reviewed the potential impact on the River Thaw. It is assumed that the dilution within the Bristol Chanel even at the site boundary would negate any discernible effect on water quality. Therefore, due to the large tidal range and the small volume of discharge no assessment on the Bristol Channel is proposed.

3.5 Review of technical precautions

This section of the guidance is not applicable at the Ash disposal site as no infrastructure or engineered systems are in place.

4 REQUISITE SURVEILANCE

4.1 Leachate monitoring

4.1.1 There is no leachate infrastructure at the site. Groundwater has been identified within boreholes screened within the PFA deposits. Currently only BH11A remains actively monitored on a quarterly basis. This is considered to be a limited spatial extent, however the leachate from the waste has been characterised over 10 years and the concentrations have remained stable.

4.1.2 It is considered that there is little to be gained with respect to detailed knowledge of the source term by the construction of any new boreholes within the PFA and therefore no additional wells are recommended.

4.2 Groundwater monitoring

4.2.1 The groundwater quality is currently monitored on a quarterly basis for a range of PFA indicator species. The current database has demonstrated that the groundwater quality has stabilised and that change in concentrations are limited. Therefore it is considered that there is the potential to further reduce the monitoring to reflect the risks posed by the site to the environment.

4.2.2 It is recommended that the following amendments are made:

- Aluminium is removed from the monitoring schedule on the basis that since the improved monitoring techniques have been employed this parameter is below the laboratory detection limits on almost every occasion. This indicates that this is not a persistent/consistent PFA indicator species and that the continued requirement to monitoring this parameter does not further the understanding at the site.

- Selenium and Antimony are removed. Again, following improvements in the monitoring technique such that sediment is prevented to enter the sample, the concentrations of these parameters are predominantly below their respective laboratory detection limits. In addition, these parameters do not have defined transitional/coastal water EQS and are considered to be of limited benefit in the continued assessment of the site.

- Nickel is removed on the basis that it was retained as an interim hazardous substance. This has now been reclassified as non-hazardous. The potential impact from non-hazardous substances are presented by a number of substances including molybdenum which have a higher ratio in leachate to EQS (assessment) levels.

- Additional of Chromium (VI) to the monitoring suite. This has been defined as a hazardous substance with a very low transitional/saline EQS. The continued monitoring of total chromium does not enable the site to demonstrate compliance with the WFD.

Compliance levels

4.2.3 Following the improvement in the groundwater monitoring techniques, a number of the existing compliance levels are significantly higher than the current baseline groundwater quality. Historically these were derived to reflect the uncertainty within the database.

4.2.4 The object of compliance and control levels is to identify change in groundwater quality prior to pollution occurring. However, the environmental monitoring data has indicated that a number wells have been affected by the ash and therefore the objective of the control levels are to identify any change or further deterioration in the water quality. In light of the improved techniques and the more stringent environmental water quality standards imposed by the WFD, the control and compliance levels have been reviewed against the baseline conditions. New control levels have been proposed were applicable to be protective of the groundwater and surface water environments. These control and compliance level have been determined from the time series charts with due consideration of the EQS and background water quality. These are presented in Appendix 3 Compliance limits are only proposed for selected down gradient wells

Table 10: Proposed Compliance Limits

Parameter	Units	Reference Values				Control Levels			Compliance Limits		
		EAL (transitional and Coastal)			Local seawater			Location			Location
		AA	MAC	Source							
Hazardous Substances:											
Mercury (dissolved)	µg/l	-	0.07	EQS		N/A		N/A	*20*	0.1	BH7B BH3B
Arsenic	µg/l	25	-	EQS	1.3	N/A		N/A	*310* *310*	25 200	BH7B BH3B
Chromium (VI)	µg/l	0.6	32	EQS		N/A		N/A		32*	BH7B BH3B
Non-Hazardous Substances:											
Ammoniacal-Nitrogen as N	mg/l	(unionised EQS 21 ug/l)		EQS			5.5	BH7B BH3B	*6.6*	6.6	BH7B BH3B
Cadmium (dissolved)	µg/l	0.2		EQS	2.3	*13*	0.5	BH7B BH3B	*15*	2.3	BH7B BH3B
Boron	mg/l	7		EQS	3.7	*40*	40	BH7B BH3B	*60*	50	BH7B BH3B
Molybdenum	µg/l	*70*		WHO	<30		6000	BH7B BH3B	*9000*	7000	BH7B BH3B
Greyed Cells – Former compliance limits				Former compliance limits presented for comparative purposes							

N/A not applicable. Control levels are not applied to hazardous substance.
* No background quality data is available for Cr(VI), compliance level should be reviewed after 12 monitoring rounds. Currently set at MAC for Cr(VI)

It is not proposed to set ammoniacal nitrogen compliance limits of BH10B on the basis that the assessment criteria would not be protective of the groundwater or surface water given the existing concentrations recorded in the borehole. The brief review presented above indicates that there are no known sources of ammoniacal nitrogen in the area and therefore the cause of the elevated concentrations is unknown. RWE have confirmed that although ammonia is used in the Clean Air Technology at the site, there have been no changes to this process in the last 5 years. In addition since no new waste has been placed adjacent to this borehole it would not be expected to be associated with ash disposal. This is confirmed by the adjacent shallow borehole BH10A not recording elevated ammoniacal nitrogen concentrations. However there appears to be a correlation between high chloride (and sodium) concentrations and recorded ammoniacal nitrogen concentrations. It is recommended that the potential for saline water to result in interference during the analysis is discussed with the laboratory as there are a number of techniques accredited for the analysis of ammoniacal nitrogen which may be more applicable to saline waters if interference is a realistic issue.

4.3 Surface Water monitoring

4.3.1 The surface water monitoring is undertaken at 4 location around the ash disposal area which includes an upstream location on the River Thaw. It is recommended that an additional point downstream on the River Thaw is included to be able to assess any change in the water quality downstream of the site.

4.3.2 There are no surface water compliance limits defined for the site. The points down stream include the River Thaw and the Bristol Chanel. A new downstream monitoring point is proposed for the River Thaw. It is not proposed to monitor the Bristol Channel as no effect from the site would be identifiable due to the massive dilution factors.

4.3.3 The monitoring of the new downstream location should be undertaken in accordance with the current analytical regime. Due to the tidal nature of the River Thaw at this point, it would be advantageous to monitor this location at similar times to the up stream location and ideally during periods of low tide (least dilution).

5 CONCLUSIONS

5.1.1 This Hydrogeological Risk Assessment review has been undertaken in line with the guidance on Hydrogeological Risk Assessment reviews and has comprised a detailed review of the environmental monitoring data from 2012 to 2017.

5.1.2 The environmental monitoring data has demonstrated that there is a discernible effect from the ash on the groundwater and surface water environments however this effect has stabilised overtime and there is very little change in quality over this review period.

5.1.3 The exceptions to the above comprise the ammoniacal nitrogen concentrations in BH10B, and S1. The report indicates that there are no known sources of ammoniacal nitrogen primarily as there is no recent ash deposited in these areas. Further review of the data indicates that the very have concentrations appear to correlate to high salinity and therefore it is recommended that the potential for high salinity to interfere with the ammoniacal nitrogen analysis is investigated. In addition, RWE should investigate whether there are any other potential sources which may influence the water quality of the western boundary.

5.1.4 The absence of elevated ammoniacal nitrogen concentrations in the adjacent shallow boreholes screened within PFA would indicate that this is not the source and therefore the elevated concentrations are not associated with the permitted activity.

5.1.5 The report has updated the conceptual model with respect to legislation changes in parameters defined as hazardous substances.

5.1.6 The improvements in monitoring techniques proposed in the 2012 HRA have had a significant effect on reducing the variability and uncertainty within the environmental data to the point that the current compliance limits are significantly above the observed baseline water quality. Therefore, the permit compliance limits have been reviewed and lower levels proposed to be protective of groundwater and surface water environments.

5.1.7 The stabilisation of the effect of the ash on the groundwater quality has provided confidence in the selection of the priority substance to monitor and assess the site. This combined with the new monitoring techniques has resulted in a number of parameters no longer being of concern with recommendations to remove these parameters from the monitoring requirements.

5.1.8 An assessment of the potential impact of the site on the River Thaw at the point of discharge to the Bristol Chanel has been undertaken to provide confidence that although there is evidence of contamination from the ash, the potential impact on the wider environment remains within acceptable limits.

Recommendations:

5.1.9 The following recommendations have been made throughout the report:

- Amend monitoring regime to add Chromium (VI) and remove aluminium, selenium, nickel and antimony.
- Revise the compliance limits in accordance within Table 10 above.
- Add downstream monitoring point on River Thaw.
- Investigate the potential for ammonia to be present in current ash
- Investigate the potential for runoff from the temporary storage area to collect in pond S1

DRAWINGS

ENVIRONMENTAL PERMIT BOUNDARY

INACTIVE POINT

ACTIVE BOREHOLES

ACTIVE POINT

INACTIVE BOREHOLES

EPD - EASTERN PERIMETER DITCH
BL - BRACKISH LAGOON

GROUNDWATER QUALITY & LEVELS WILL BE MONITORED WITHIN ACTIVE BOREHOLES & SURFACE WATER QUALITY WILL BE MONITORED AT ACTIVE POINTS

REV	MODIFICATIONS	BY	RE	AP	DATE
P1	ISSUED FOR COMMENT	EJD	SV	SV	15.11.18

RWE GENERATION UK PLC

PROJECT:
CONCEPTUAL MODEL

TITLE:
HRA ASH DISPOSAL MOUND

DRAWN BY	DATE	
EJD	15.11.2018	
REVIEWED BY: SV	SCALE @ A3: NTS	JOB REF: 3220
AUTHORISED BY: SV	ISSUE: S1	REVISION: P1

DRAWING NUMBER
HRA 01 - ASH

Caulmert
engineering environmental planning

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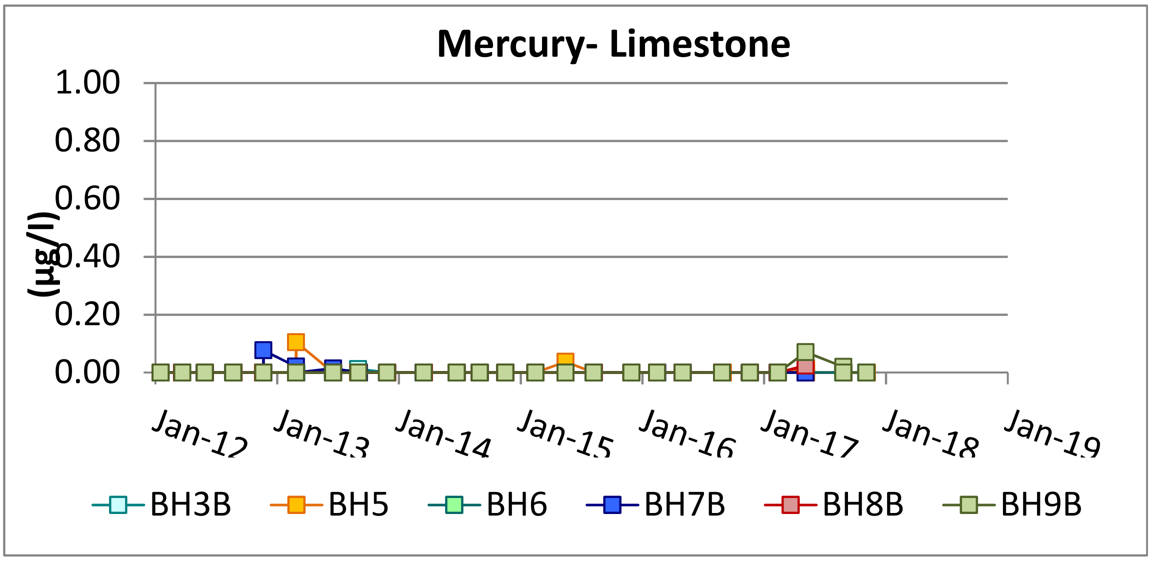
APPENDIX 1

Environmental Monitoring Data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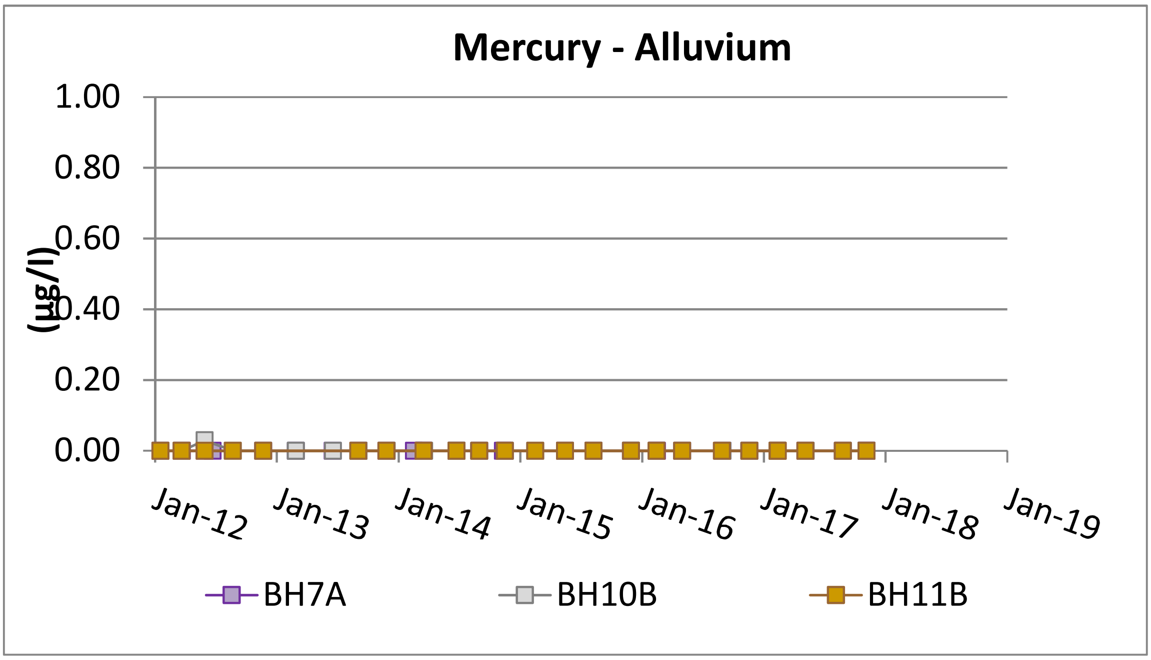
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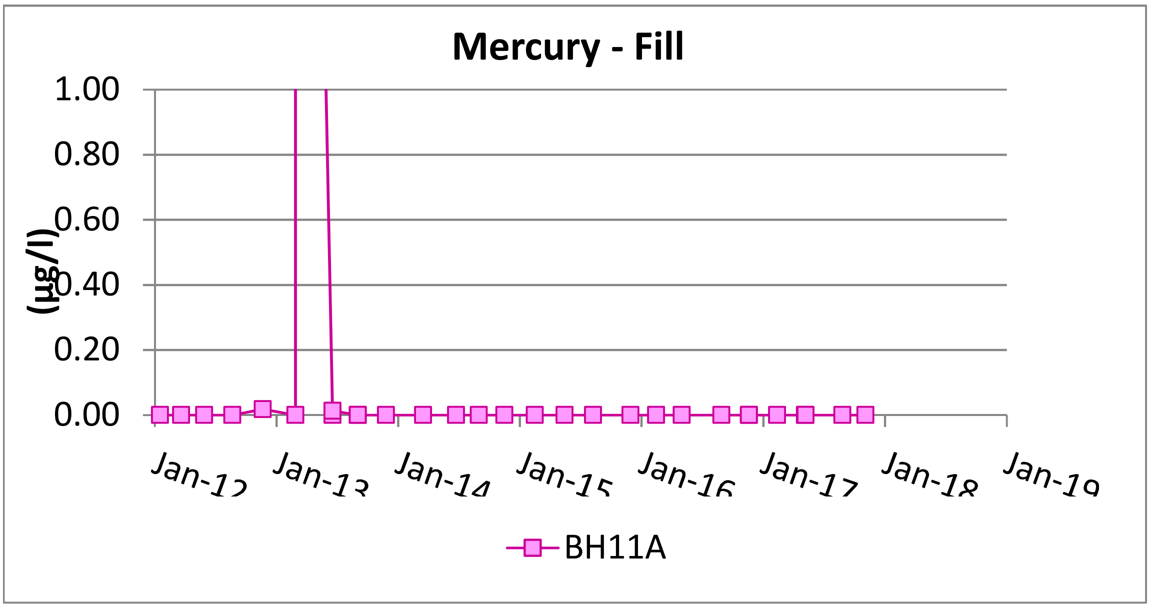
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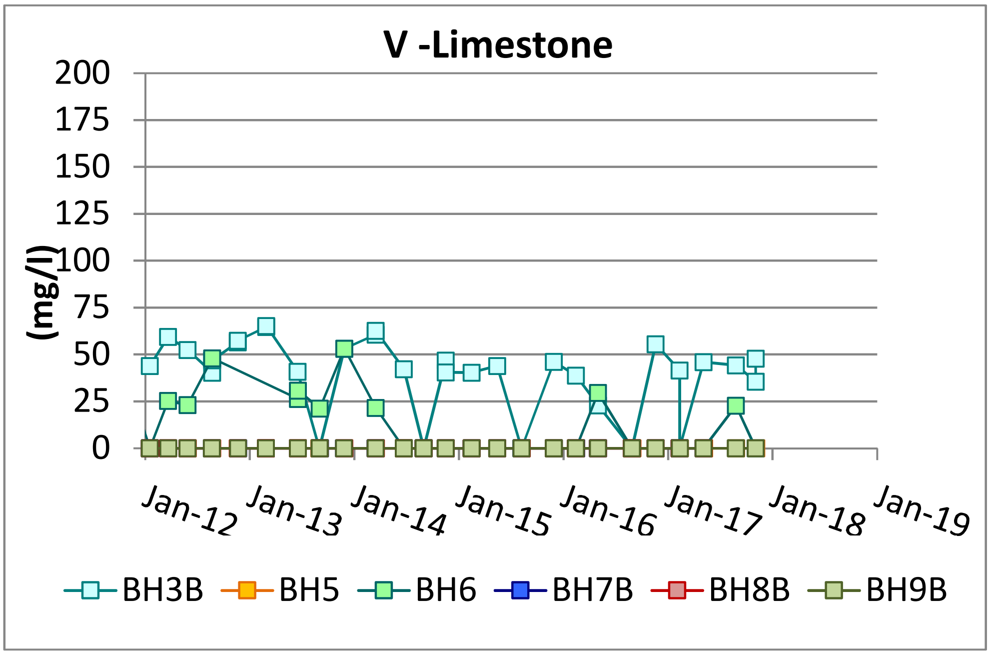
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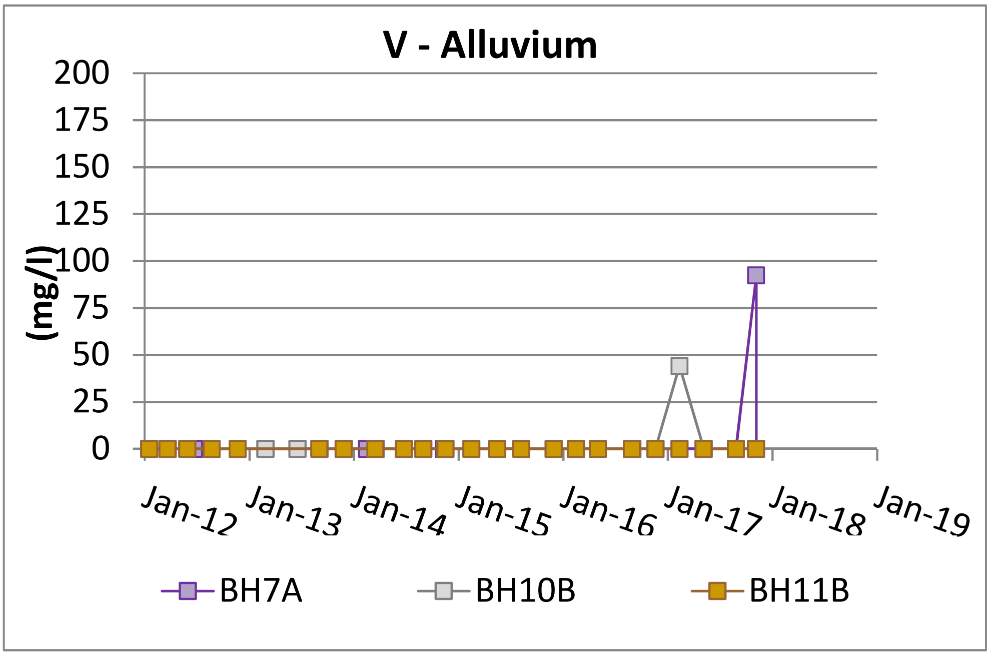
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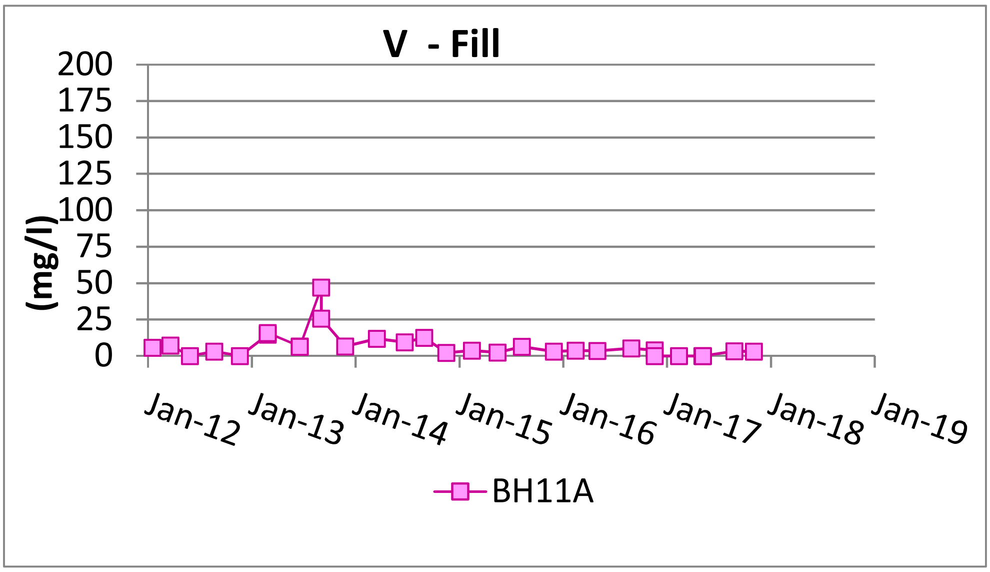
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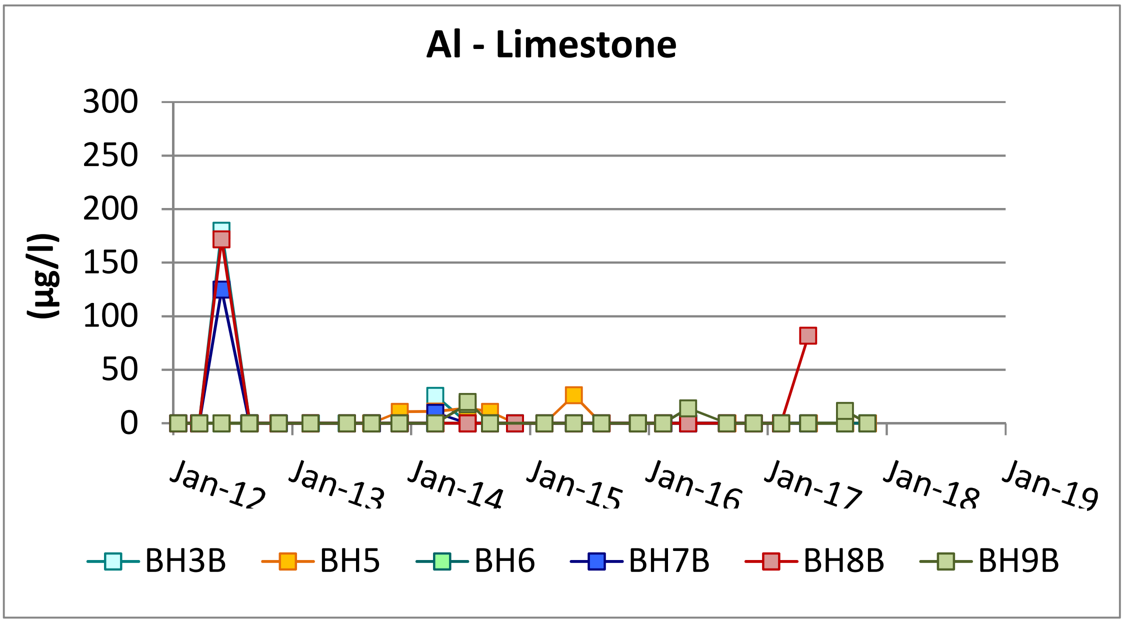
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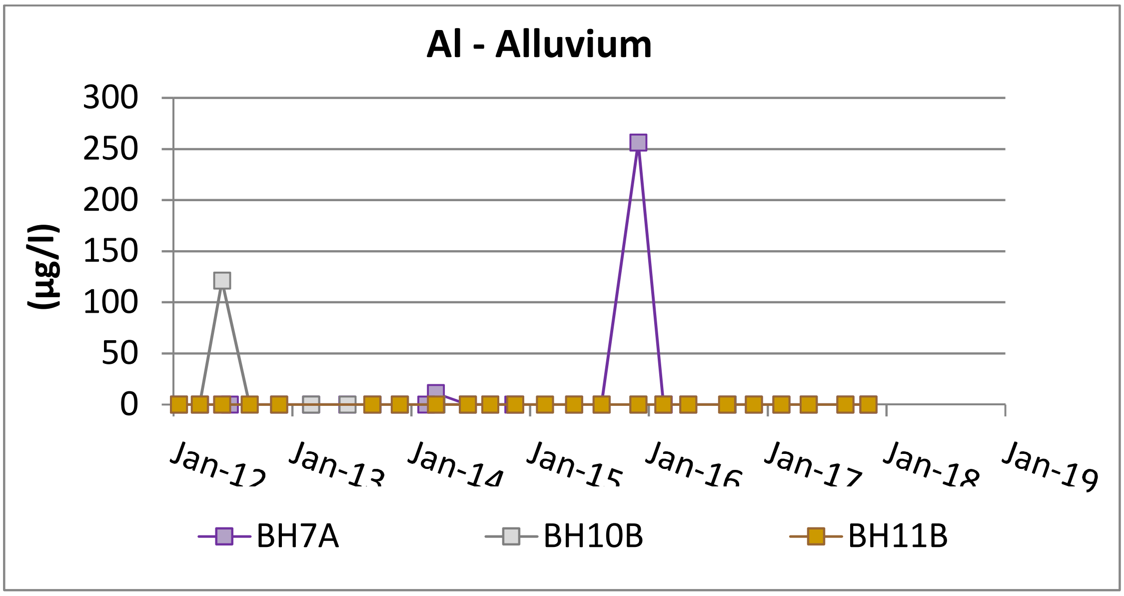
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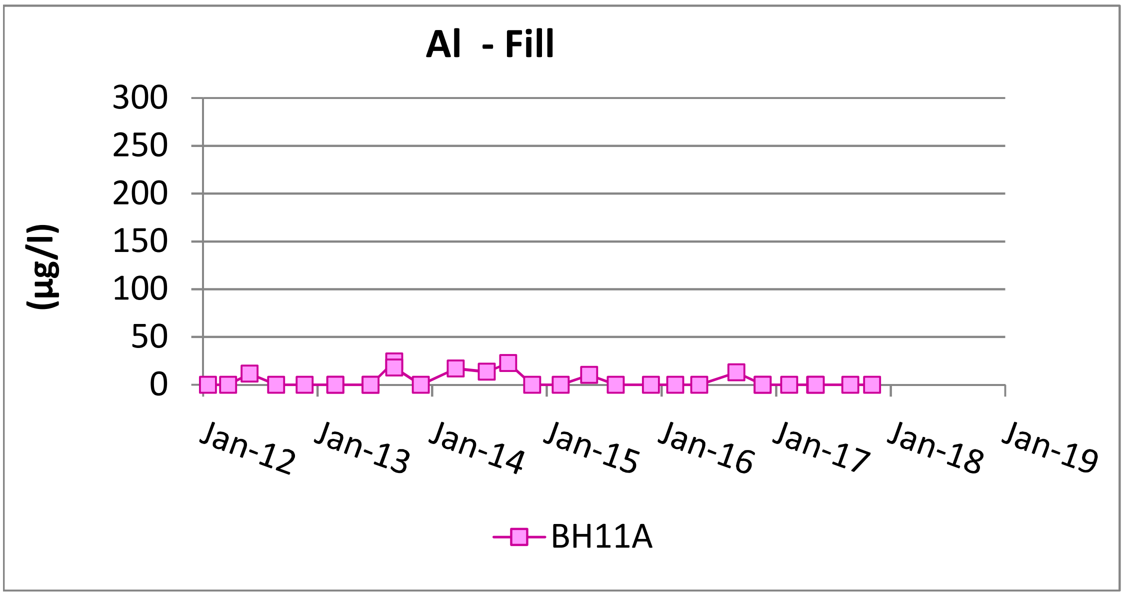
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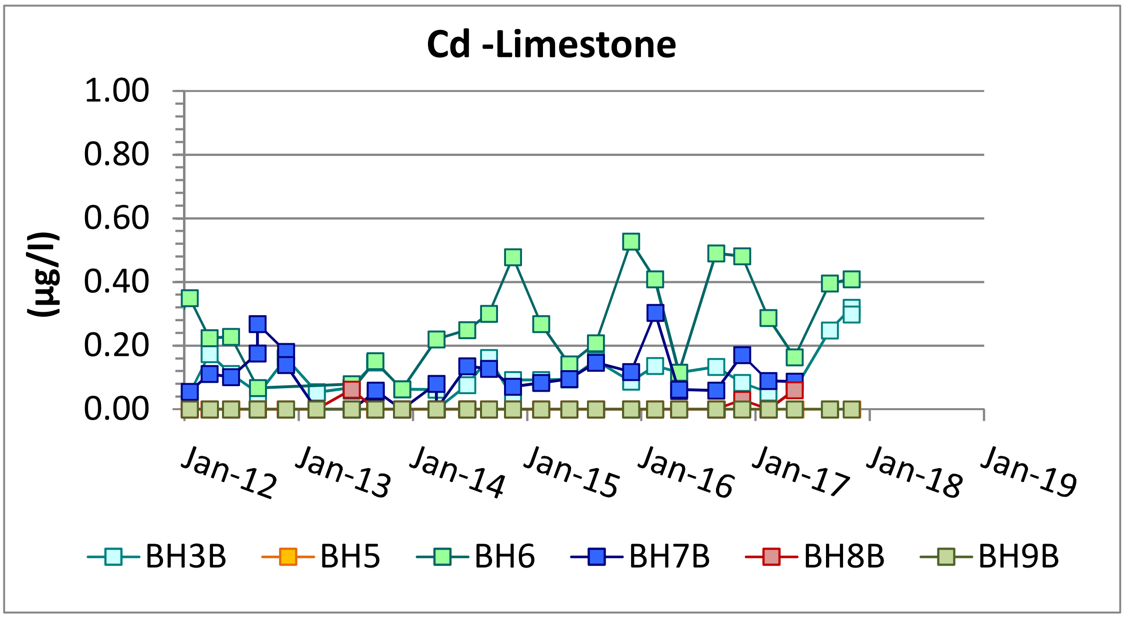

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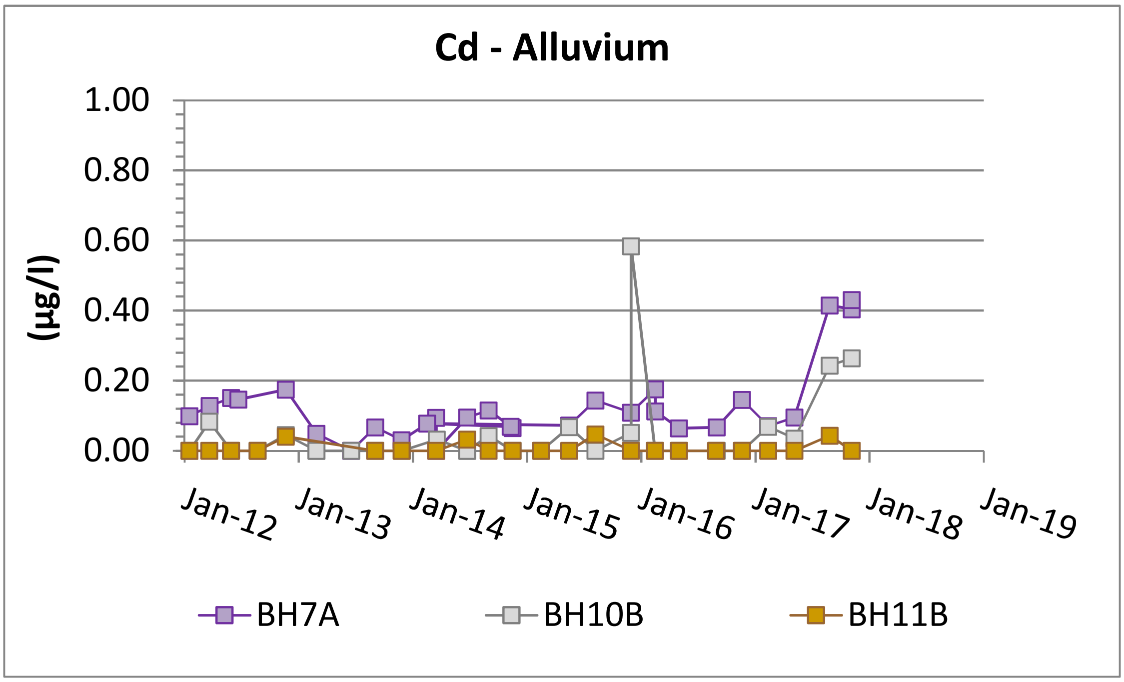

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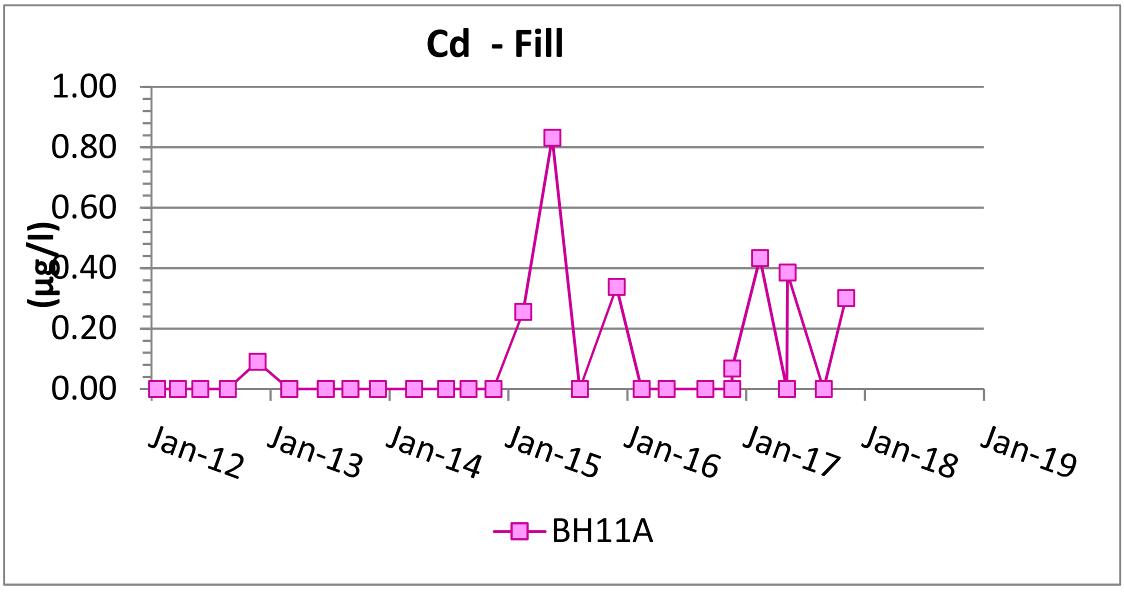

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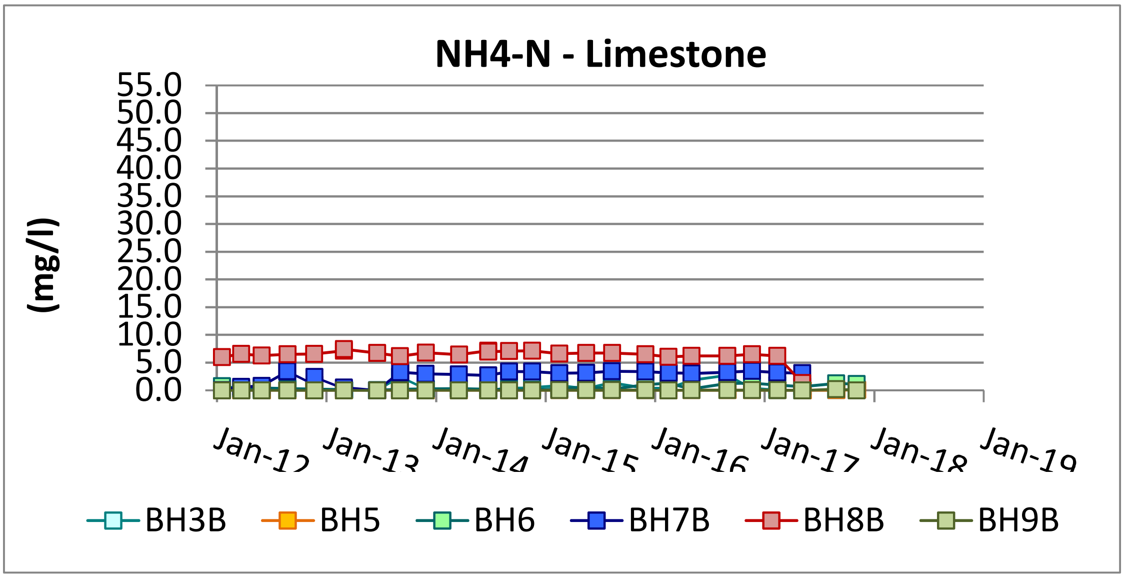
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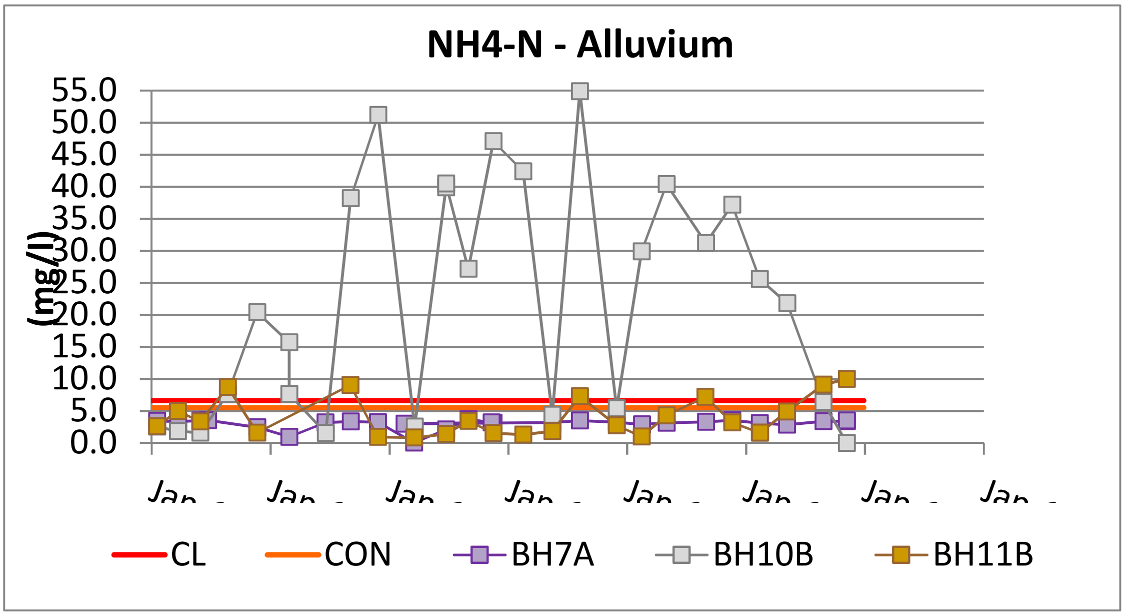
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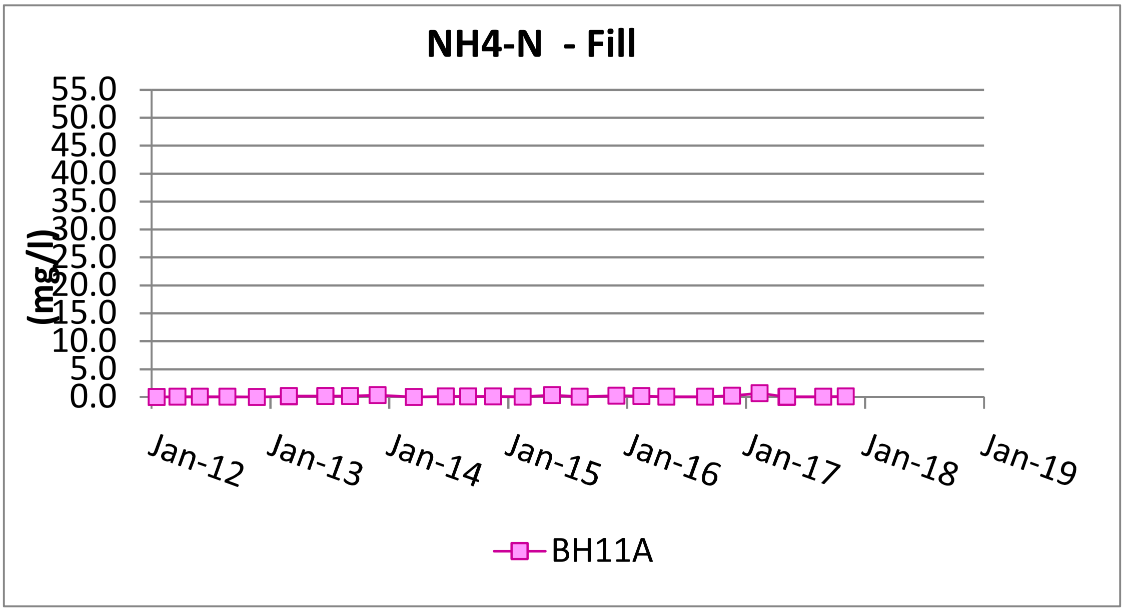
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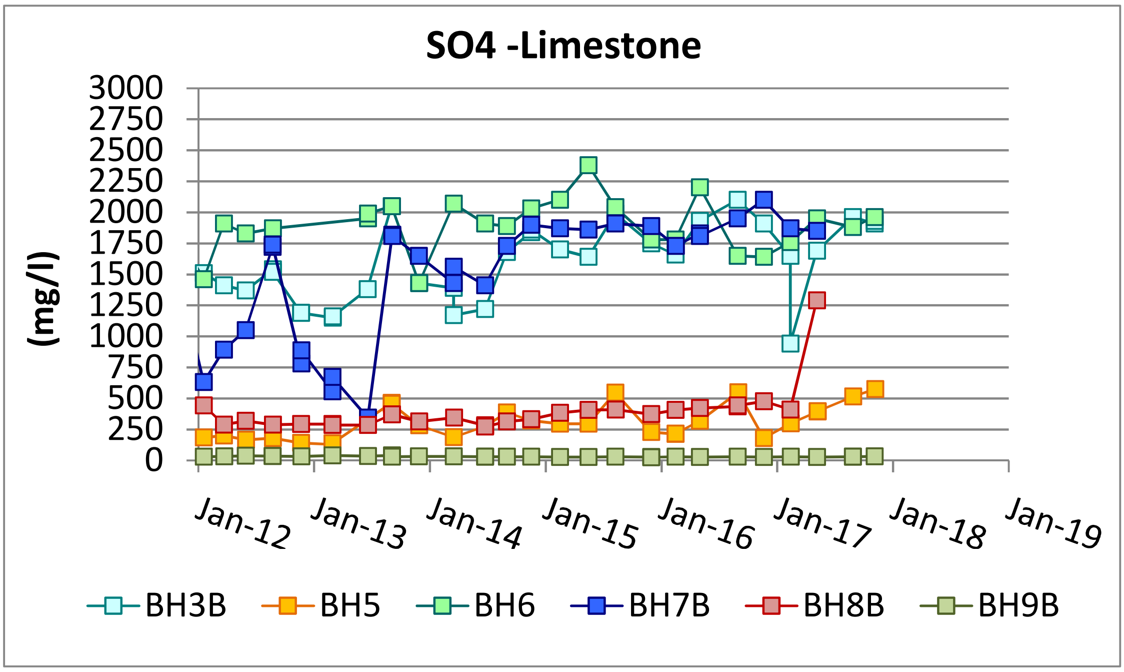
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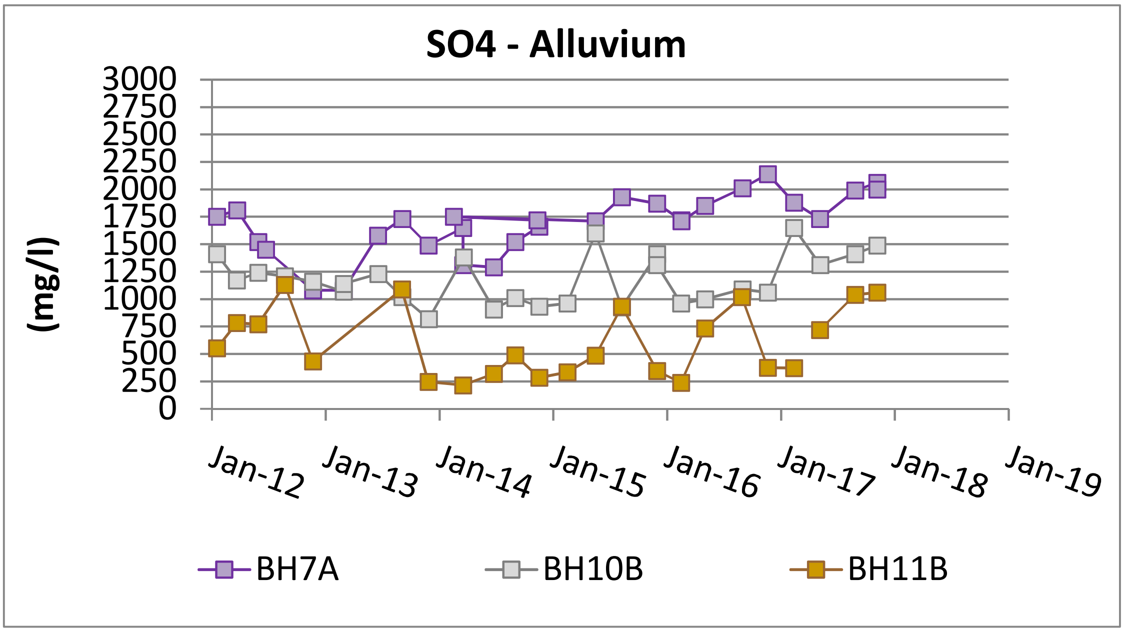
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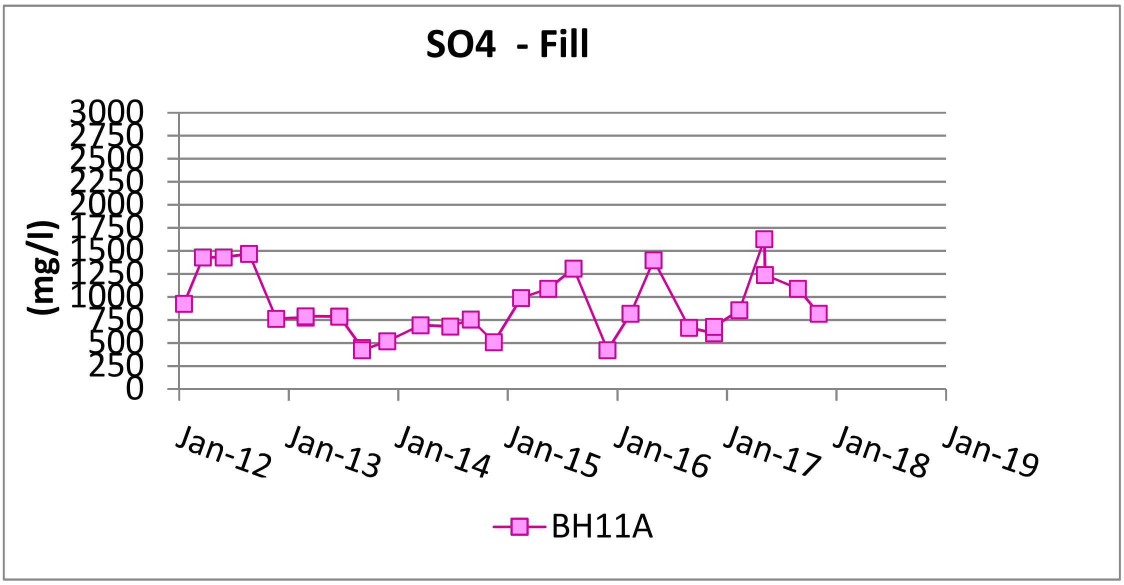
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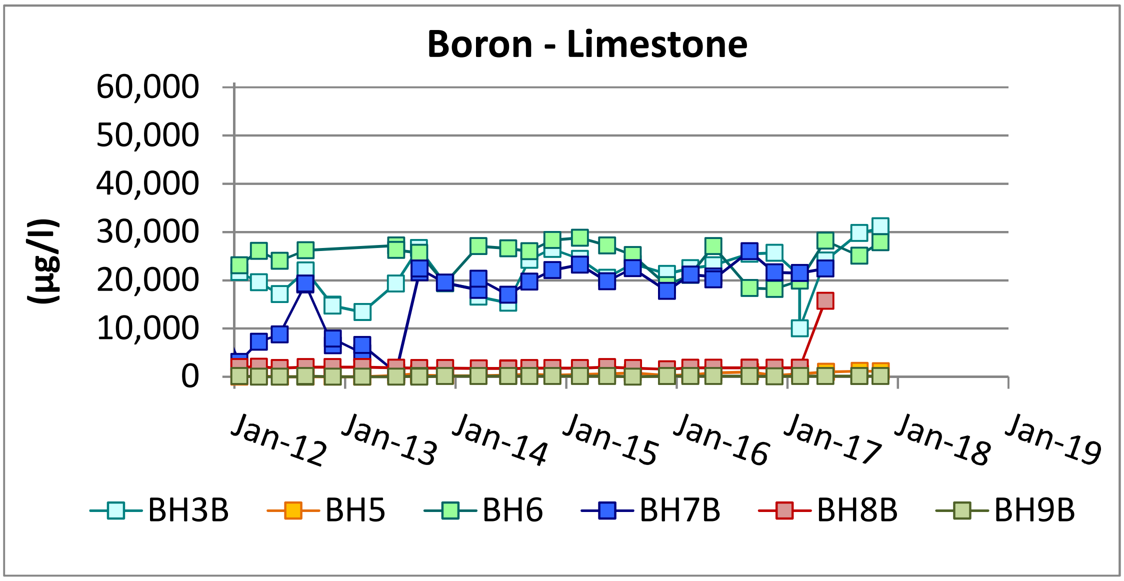
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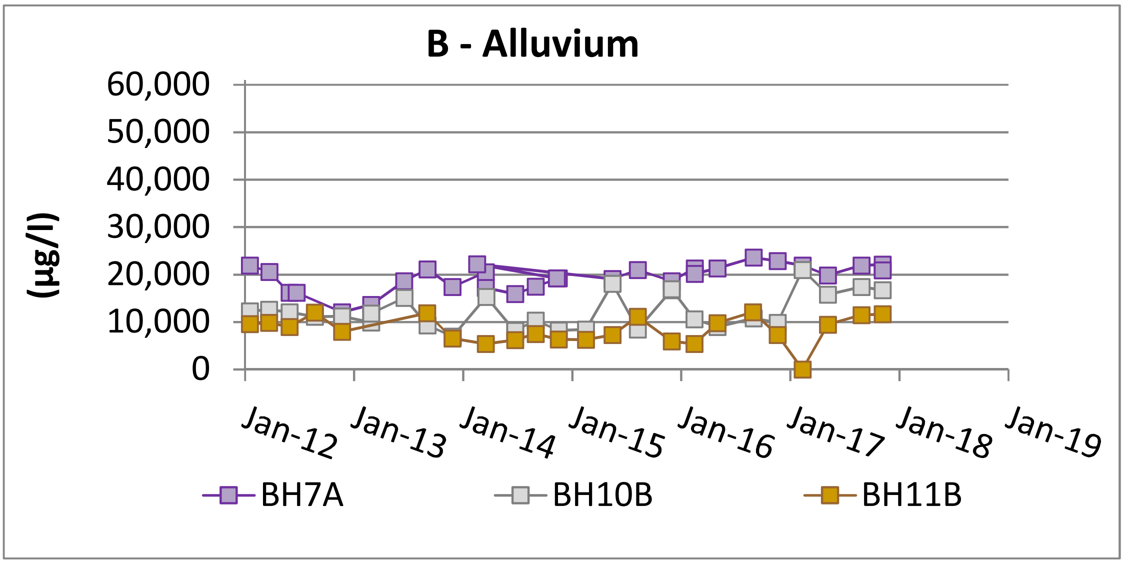
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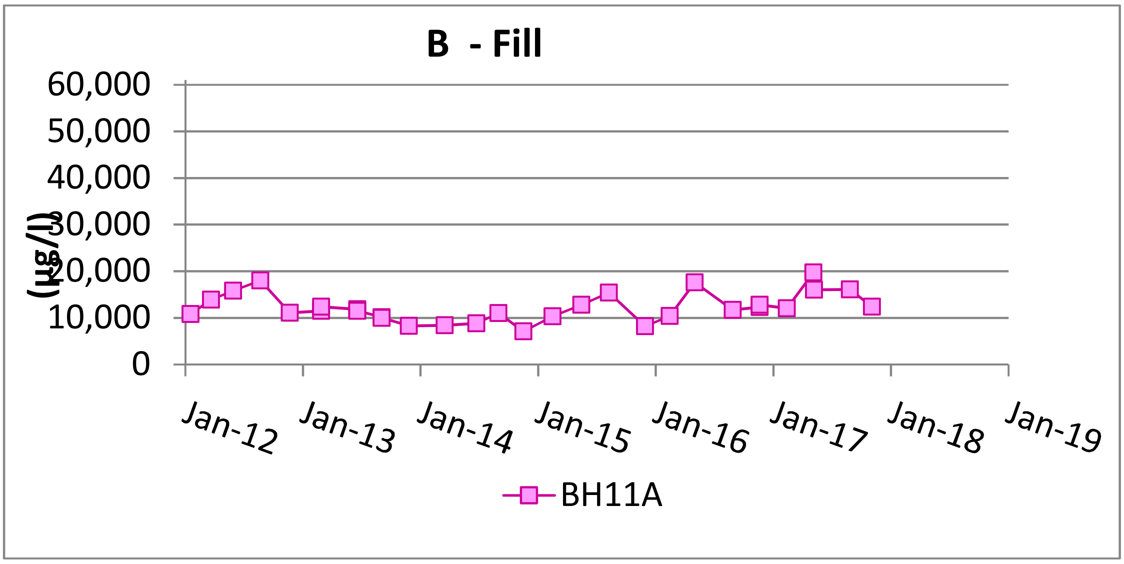
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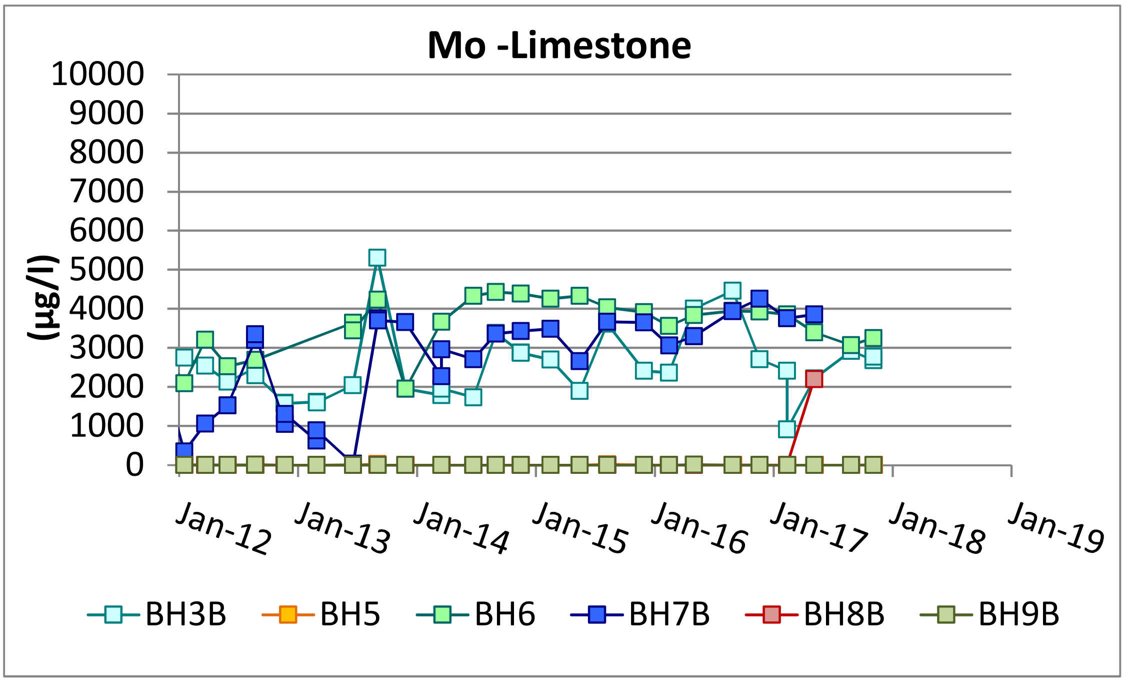
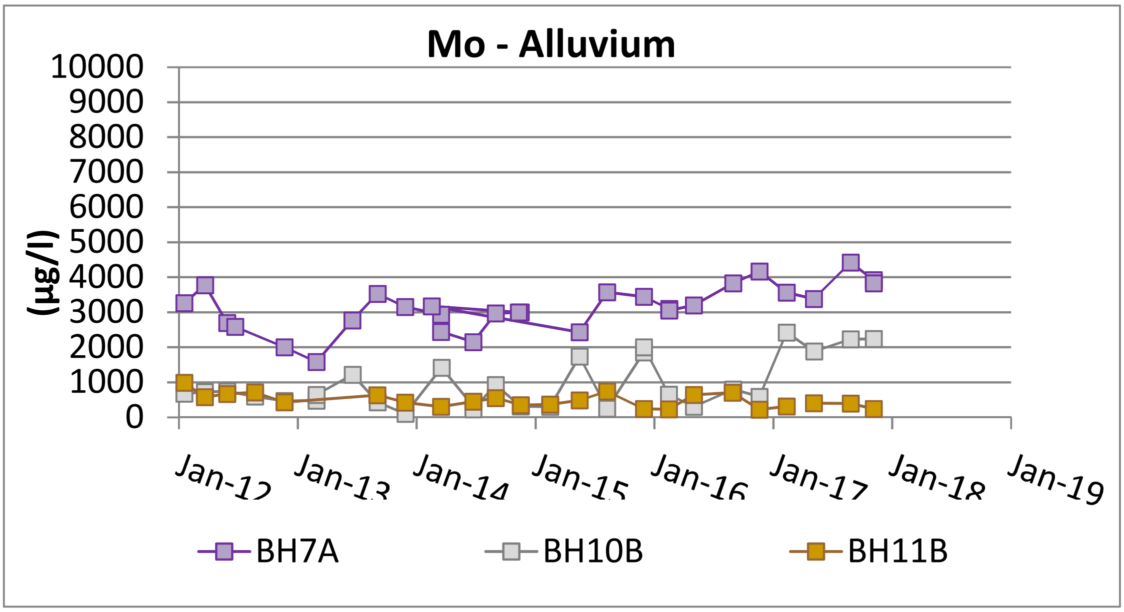
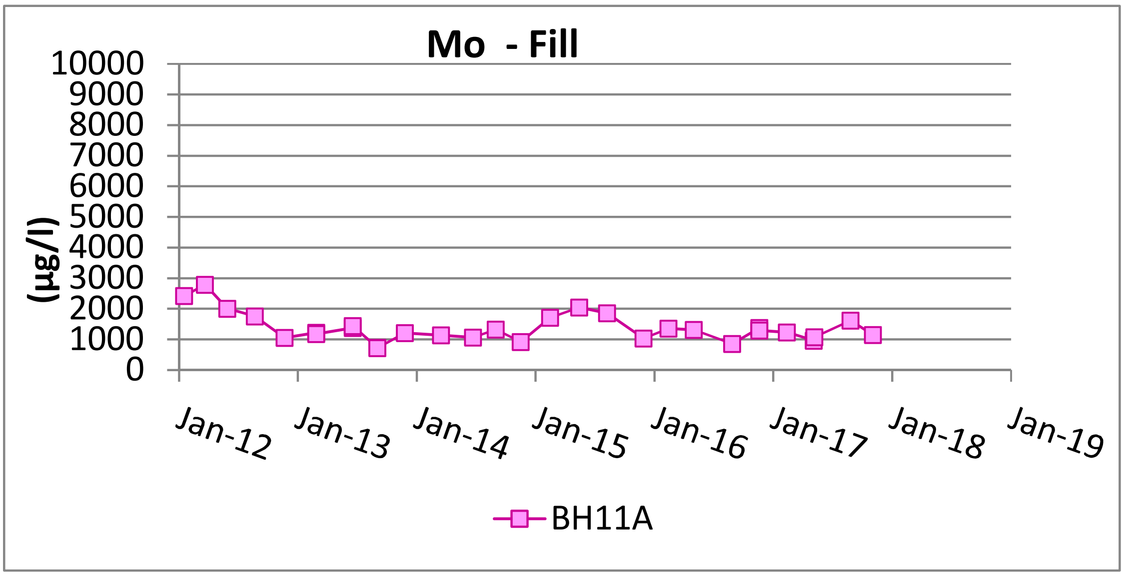
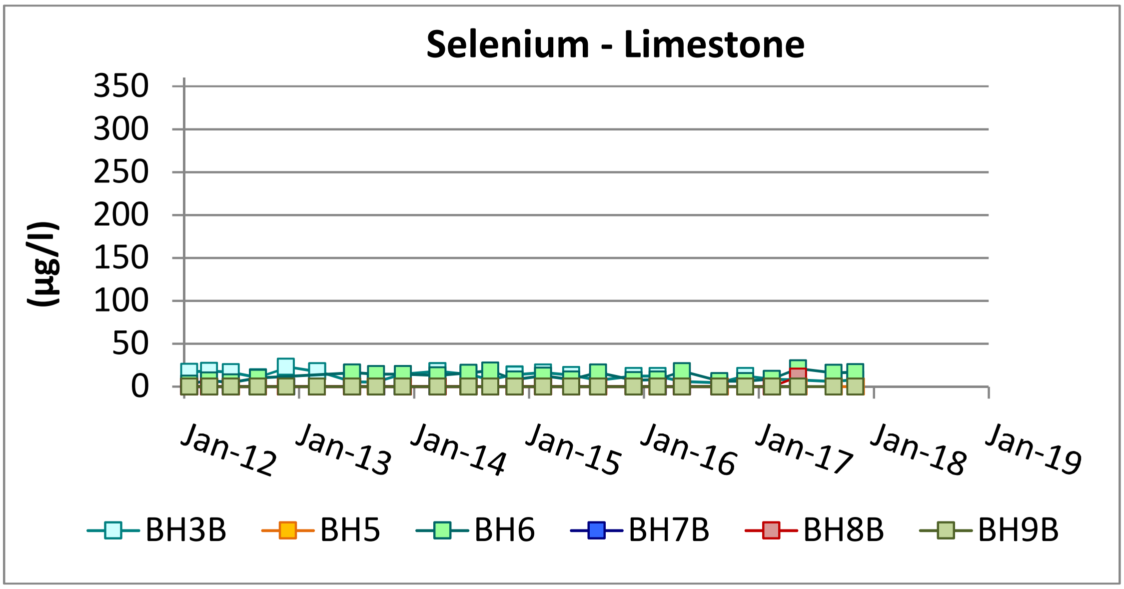
Jan-17
Jan-18
Jan-19
BH11A

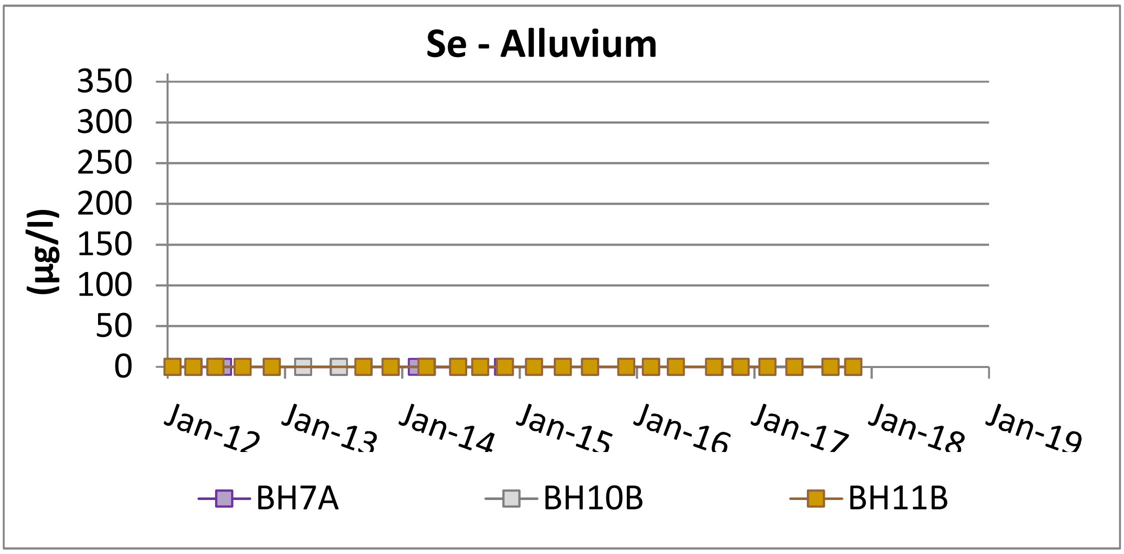

Mo -Limestone
(µg/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH3B
BH5
BH6
BH7B
BH8B
BH9B


Mo - Alluvium
(µg/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH7A
BH10B
BH11B

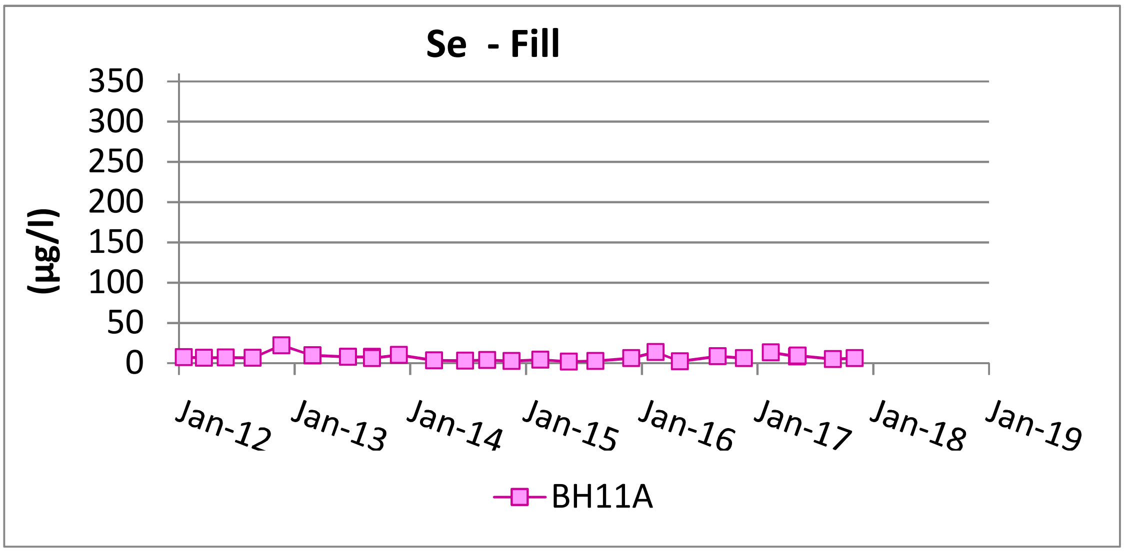

Mo - Fill
(µg/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH11A



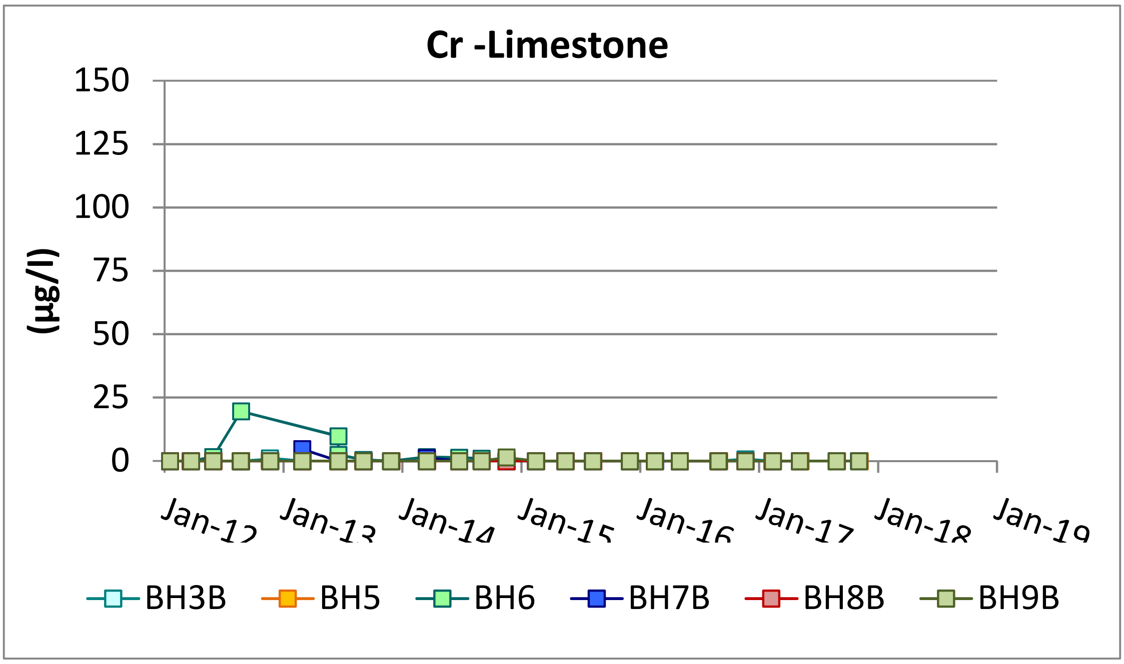
Selenium - Limestone
(µg/l)
350
300
250
200
150
100
50
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH3B
BH5
BH6
BH7B
BH8B
BH9B

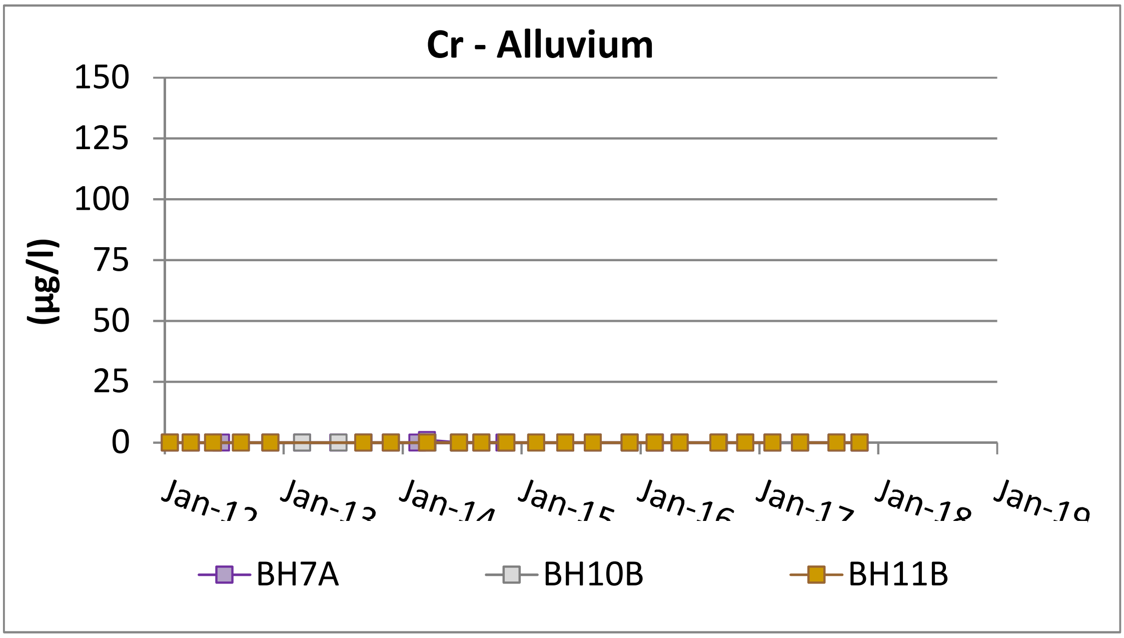


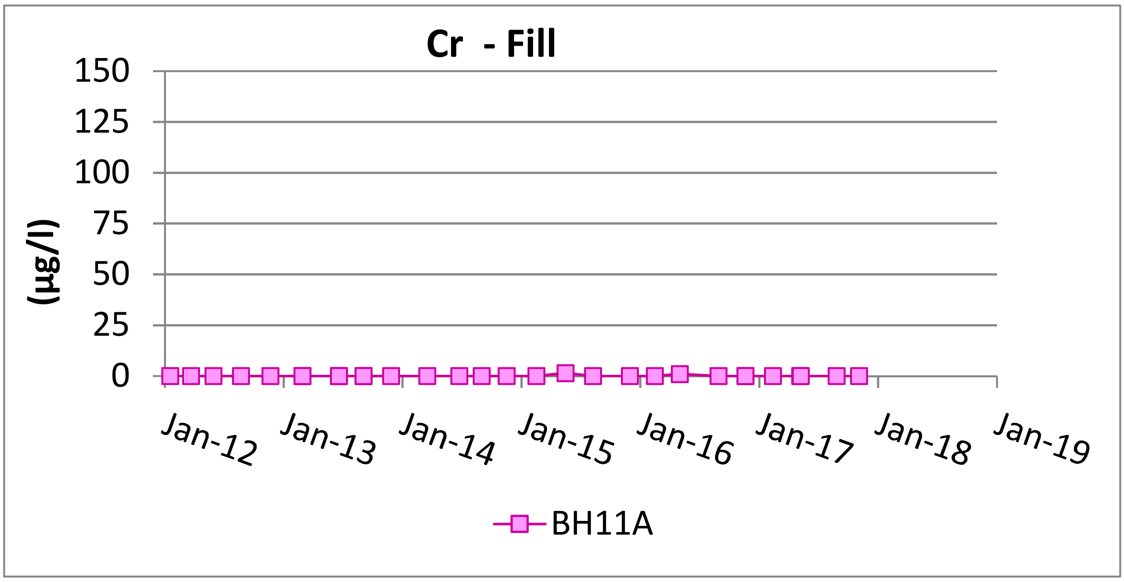
Se - Alluvium
(µg/l)
350
300
250
200
150
100
50
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH7A
BH10B
BH11B

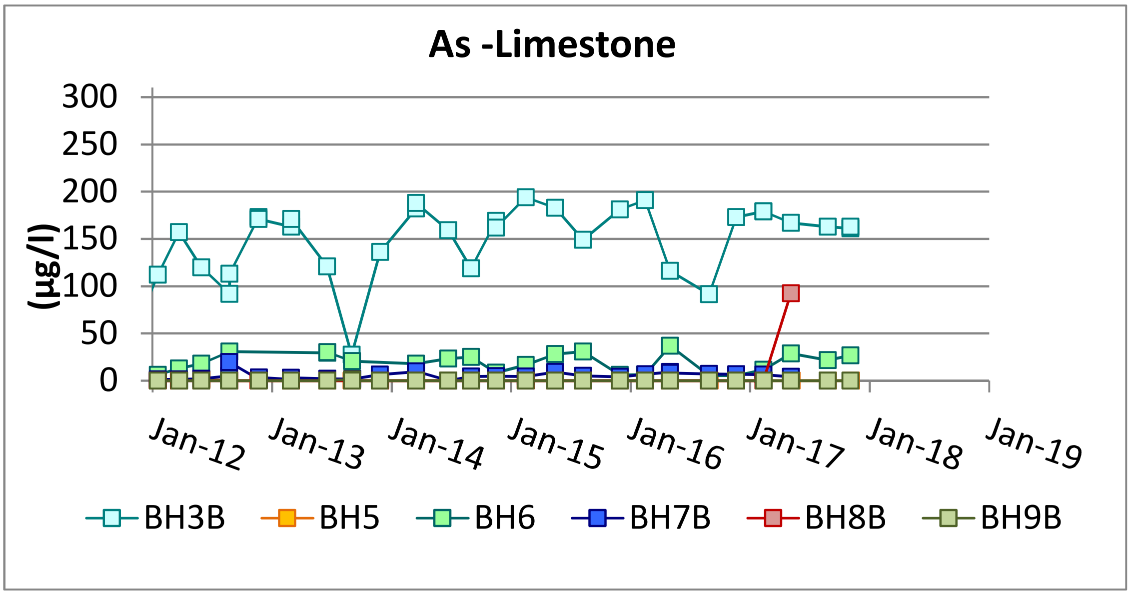


Se - Fill
(µg/l)
350
300
250
200
150
100
50
0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH11A

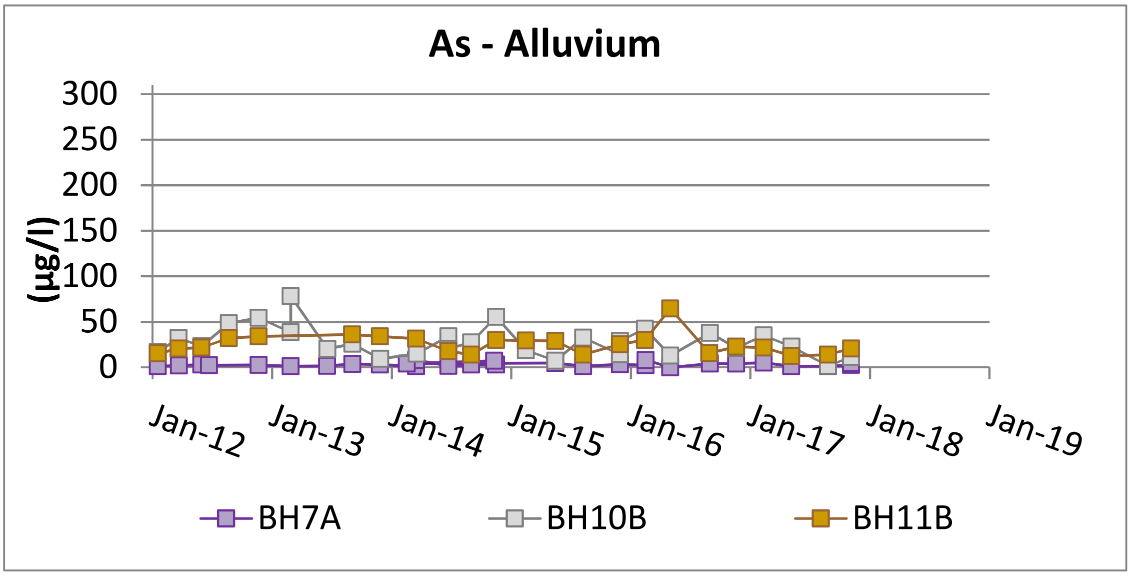

Cr -Limestone
150
125
100
75
50
25
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH3B
BH5
BH6
BH7B
BH8B
BH9B


Cr - Alluvium
150
125
100
75
50
25
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH7A
BH10B
BH11B

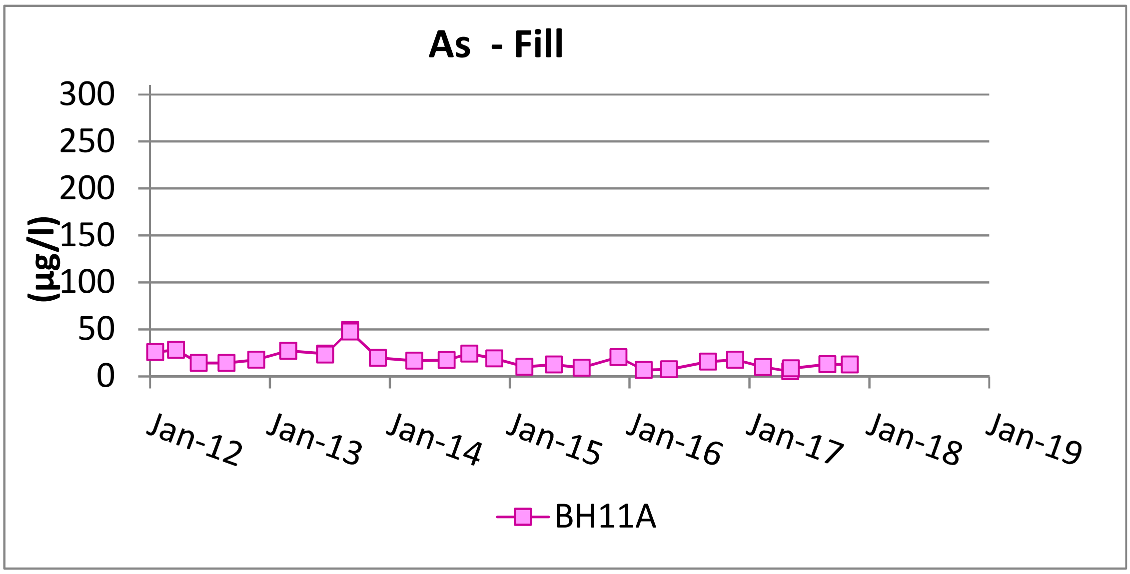

Cr - Fill
150
125
100
75
50
25
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH11A



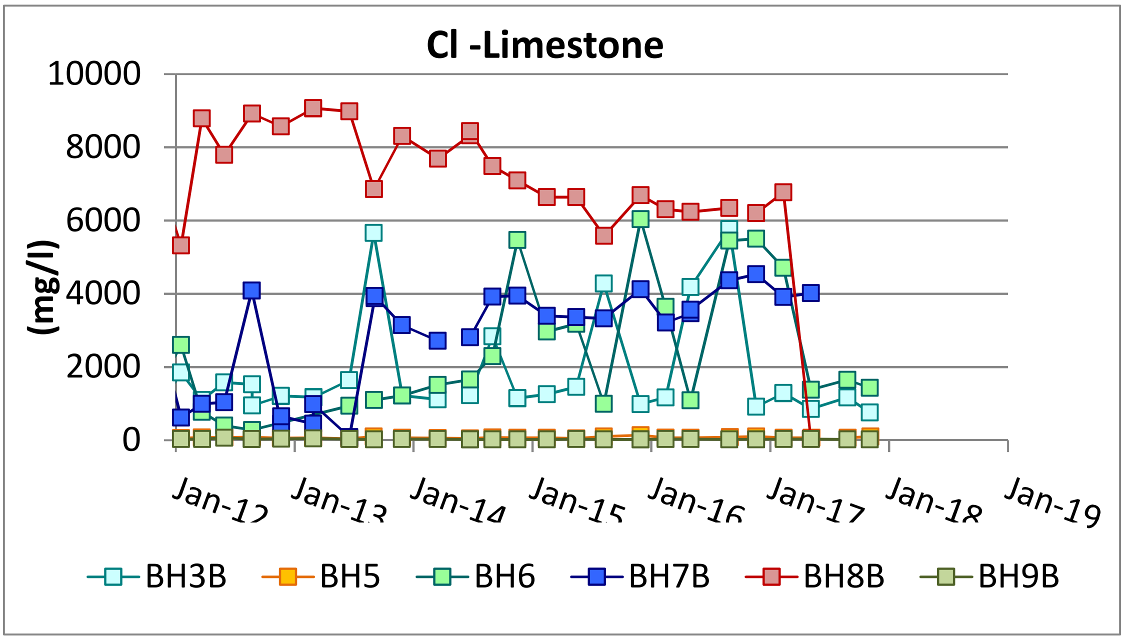
As -Limestone
300
250
200
150
100
50
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH3B
BH5
BH6
BH7B
BH8B
BH9B

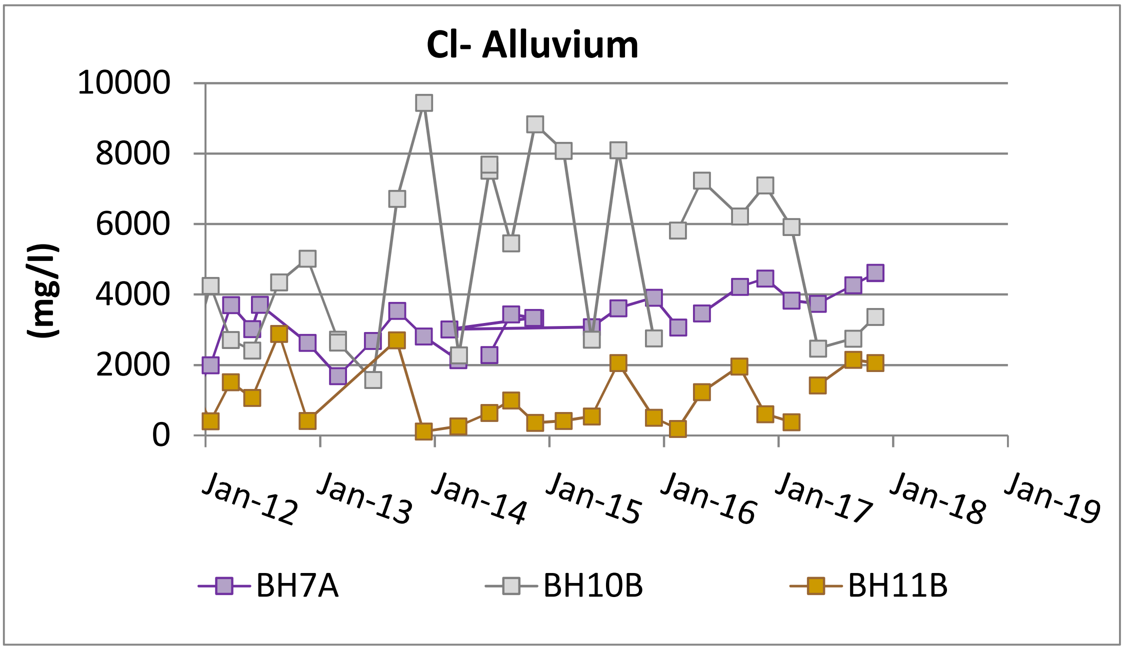


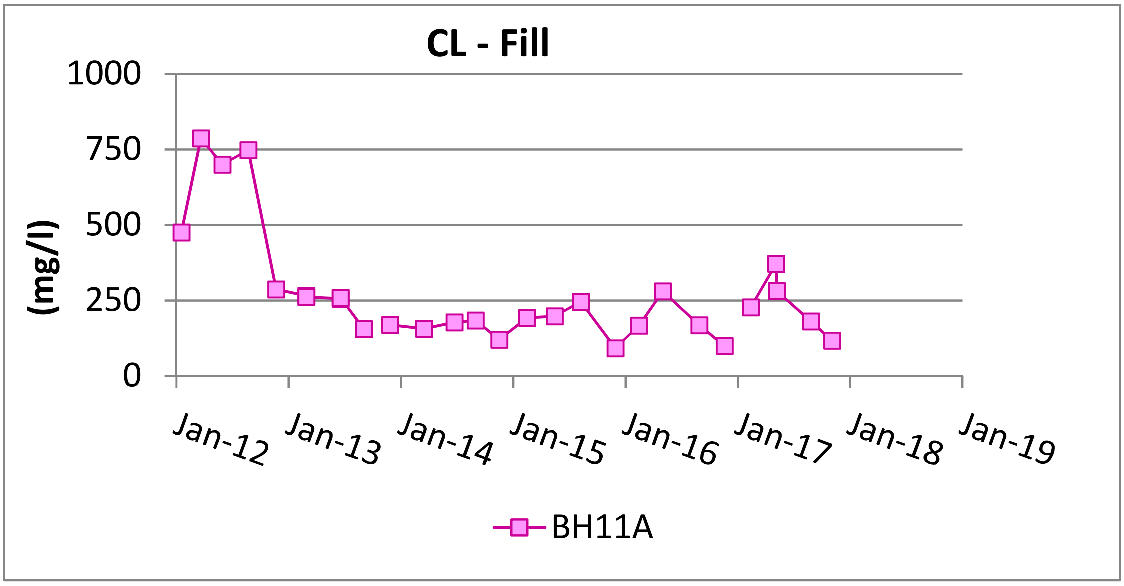
As - Alluvium
300
250
200
150
100
50
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH7A
BH10B
BH11B



As - Fill
300
250
200
150
100
50
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH11A

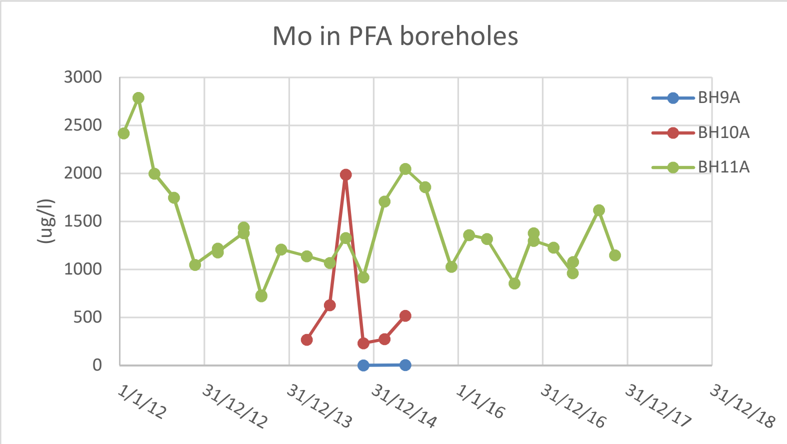

Cl -Limestone
10000
8000
6000
4000
2000
0
(mg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH3B
BH5
BH6
BH7B
BH8B
BH9B


Cl- Alluvium
10000
8000
6000
4000
2000
0
(mg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH7A
BH10B
BH11B

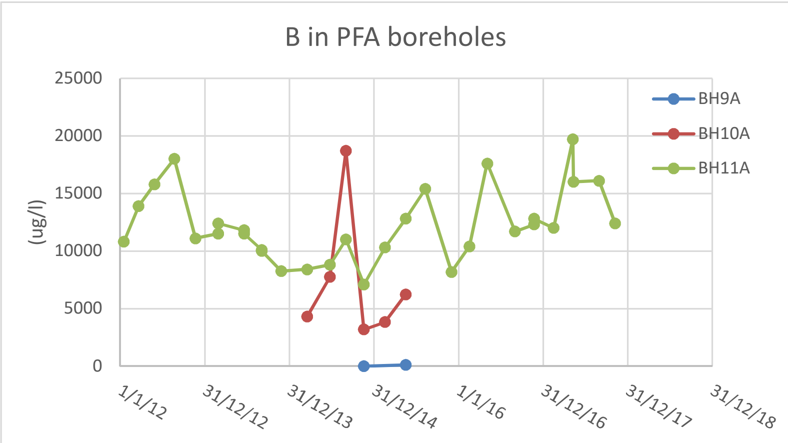

CL - Fill
1000
750
500
250
0
(mg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
BH11A

PFA BOREHOLE SUMMARY

		BH9A (18/11/2014 & 18/5/2015)			8/3/2014-18/5/2015)			BH11A (17/1/2012-07/11/2017)		
		Mean	Max	no. Samples	Mean	Max	no. Samples	Mean	Max	no. Samples
kalinity to pH 4.5 as CaC	mg/l	251.50	274	2	446.00	658	6	434.39	580	30
mmoniacal Nitrogen as	mg/l	0.03	0.03	2	0.11	0.216	6	1.34	30	30
Chloride	mg/l	18.50	23.1	2	136.75	219	6	272.51	787	30
rogen : Total Oxidised as	mg/l	0.34	0.42	2	0.26	0.31	6	0.89	2.35	30
Phosphate : Total as P	mg/l		0	2		0	6	5.71	14.3	30
Fluoride	mg/l	0.23	0.273	2	0.30	0.534	6	0.11	0.413	30
n, Organic : Total as C :-	mg/l	3.00	3	2	121.86	495	6	65.23	594	30
Conductivity at 20C	µS/cm	481.50	528	2	1521.83	2820	6	2786.43	4860	30
pH	pH units	7.51	7.55	2	7.51	7.67	6	7.46	7.68	30
Arsenic Dissolved	µg/l		0	2	71.32	81.7	6	18.73	49.3	30
Selenium Dissolved	µg/l		0	2	2.12	3.7	6	7.12	22.1	30
Antimony, Dissolved	µg/l		0	2	12.13	18.9	6	8.62	12.7	30
Molybdenum, Dissolved	µg/l	5.02	5.66	2	653.17	1990	6	1375.43	2790	30
Vanadium, Dissolved	µg/l		0	2	70.33	97.6	6	8.88	47.1	30
Aluminium, Dissolved	µg/l	12.30	12.3	2	17.68	21.3	6	16.35	24.5	30
Cadmium, Dissolved	µg/l		0	2	0.26	0.26	6	0.34	0.831	30
Chromium, Dissolved	µg/l		0	2		0	6	1.21	1.43	30
Copper, Dissolved	µg/l	2.12	2.12	2	1.90	2.98	6	1.96	4.53	30
Nickel, Dissolved	µg/l	1.12	1.12	2	2.17	4.32	6	1.54	2.23	30
Zinc, Dissolved	µg/l		0	2		0	6	0.43	0.43	30
Boron, Dissolved	µg/l	101.00	101	2	7330.00	18700	6	12270.67	19700	30
Calcium, Dissolved	mg/l	77.15	83.3	2	165.83	328	6	348.17	502	30
Iron, Dissolved	µg/l		0	2		0	6		0	30
Magnesium, Dissolved	mg/l	8.29	9.91	2	85.83	238	6	99.88	131	30
Manganese, Dissolved	µg/l		0	2	155.00	155	6	510.15	1670	30
Potassium, Dissolved	mg/l	6.95	7.56	2	29.12	45	6	52.99	86.1	30
Sodium, Dissolved	mg/l	24.20	27.6	2	88.28	176	6	206.08	544	30
ulphate, Dissolved as SC	mg/l	14.30	16.7	2	312.12	1050	6	893.40	1630	30
Mercury, Dissolved	µg/l		0	2		0	6	1.90	5.66	30
Bicarbonate as HCO3	mg/l	306.83	334.28	2	544.12	802.76	6	502.69	707.6	30
Ionic Balance	%	-0.94	-0.76	2	0.77	4.17	6	1.61	21.6	30



Mo in PFA boreholes
3000
2500
2000
1500
1000
500
0
(ug/l)
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17
31/12/18
BH9A
BH10A
BH11A



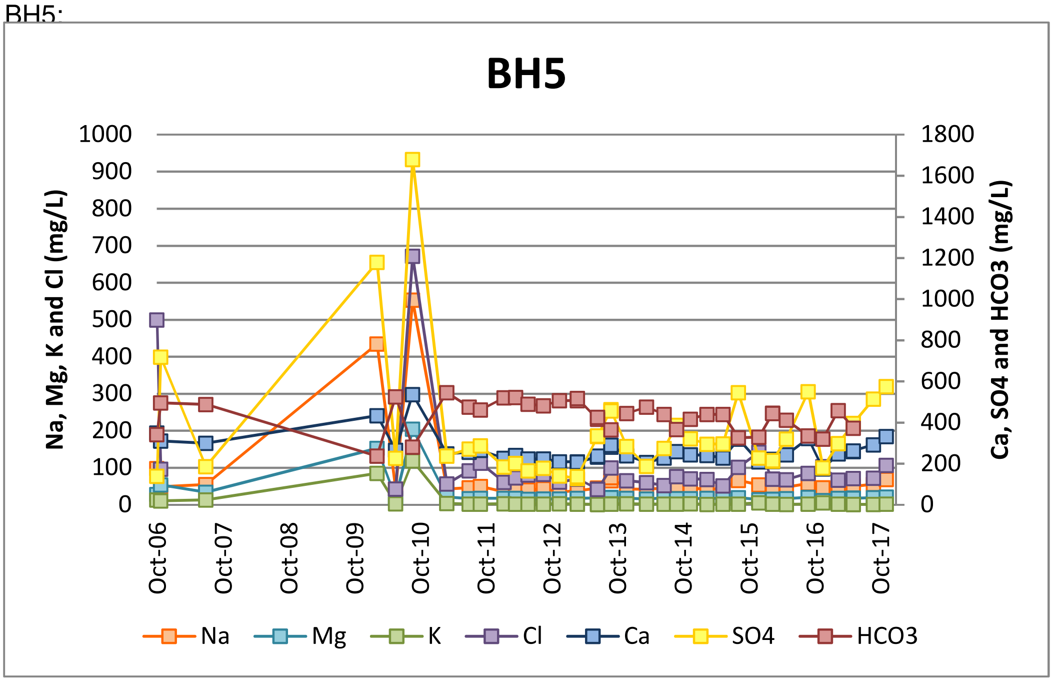
B in PFA boreholes
25000
20000
15000
10000
5000
0
(ug/l)
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17
31/12/18
BH9A
BH10A
BH11A

Quality Charts

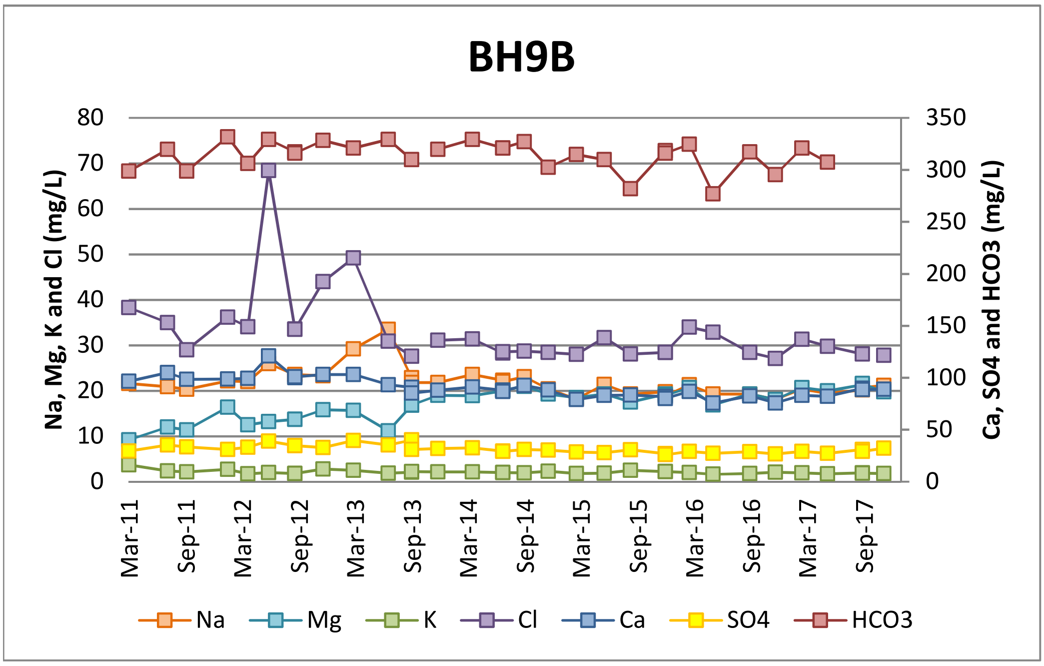
Boreholes

<u>Upstream</u>

BH5:

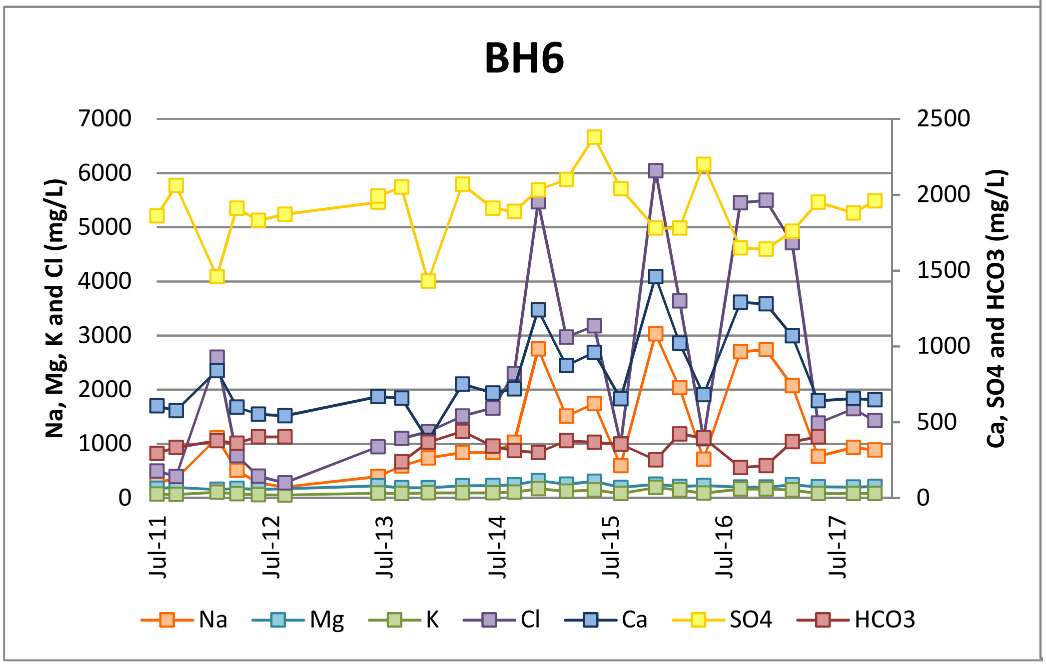


BH9B: East

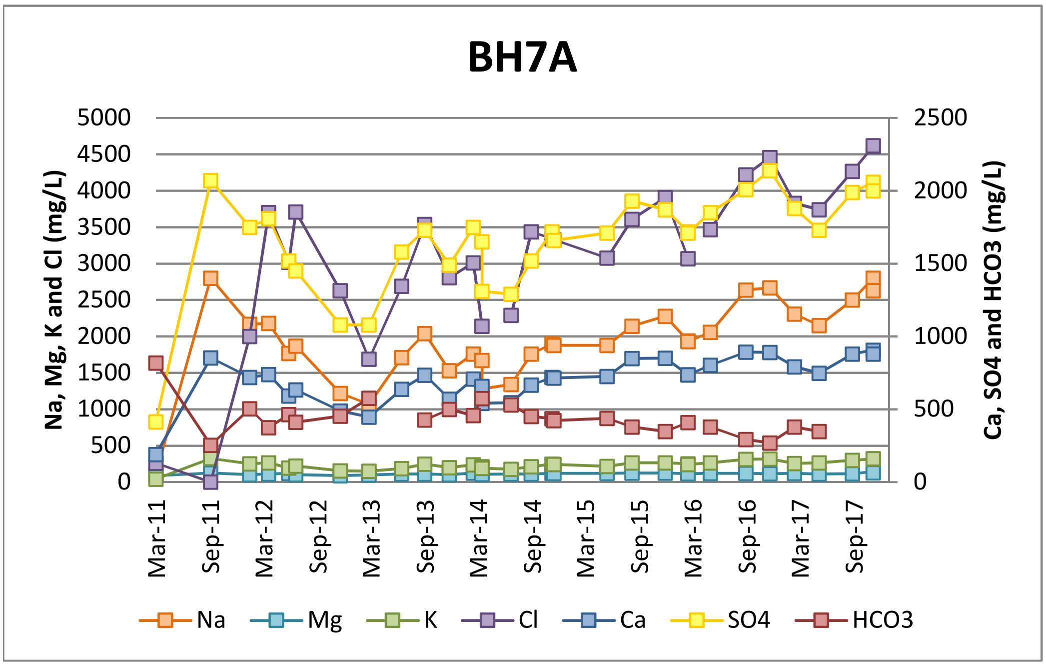


East

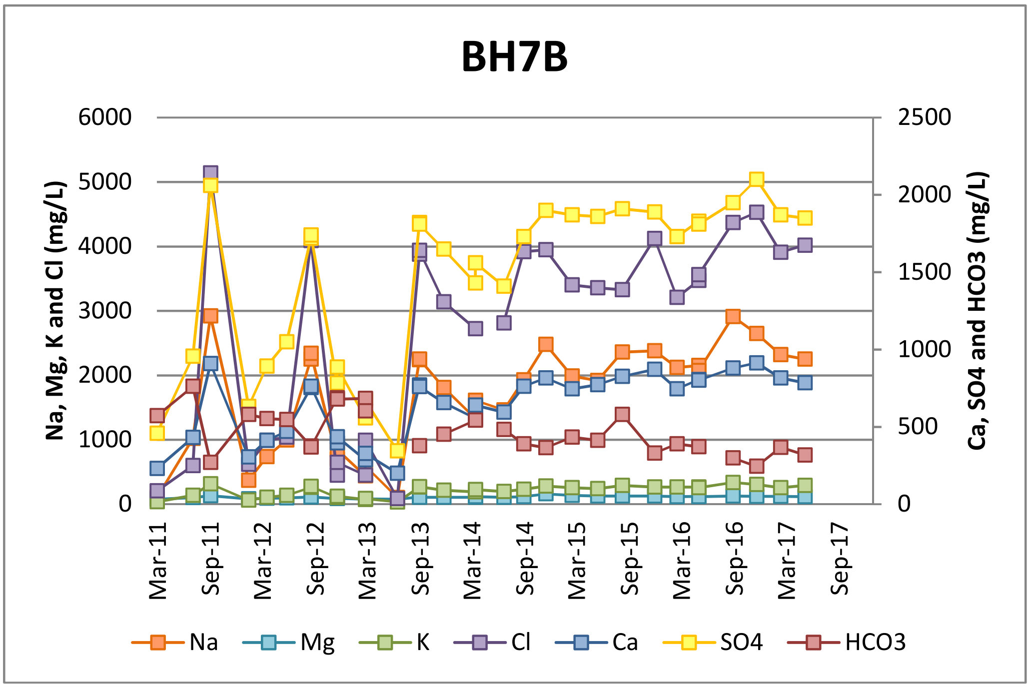
BH6:



BH7A:

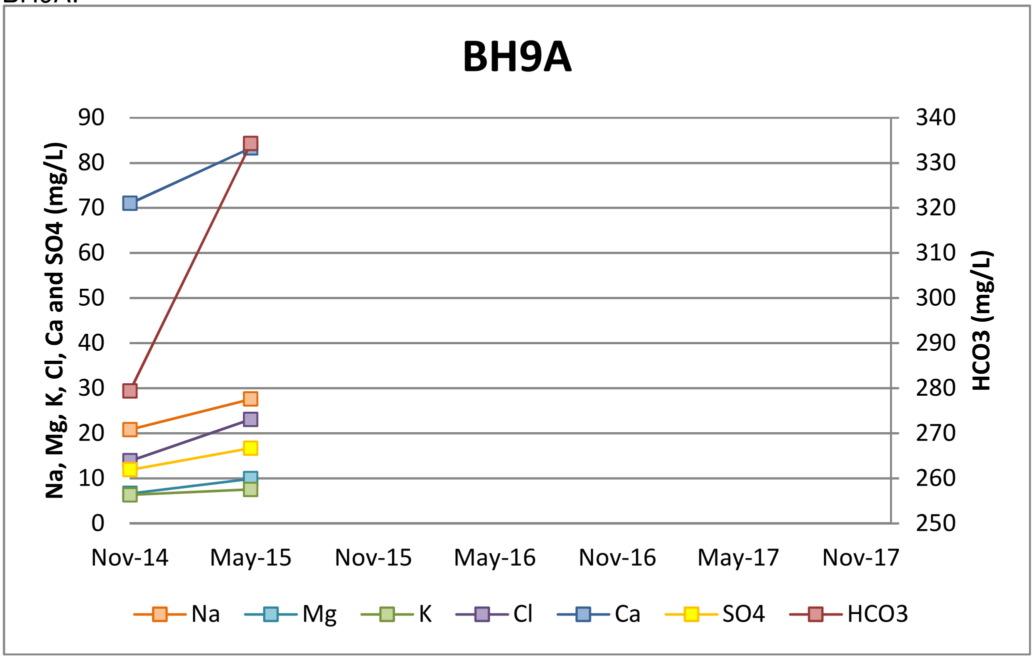


BH7B:



BH7B
6000
5000
4000
3000
2000
1000
0
Na, Mg, K and Cl (mg/L)
2500
2000
1500
1000
500
0
Ca, SO4 and HCO3 (mg/L)
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Na
Mg
K
Cl
Ca
SO4
HCO3

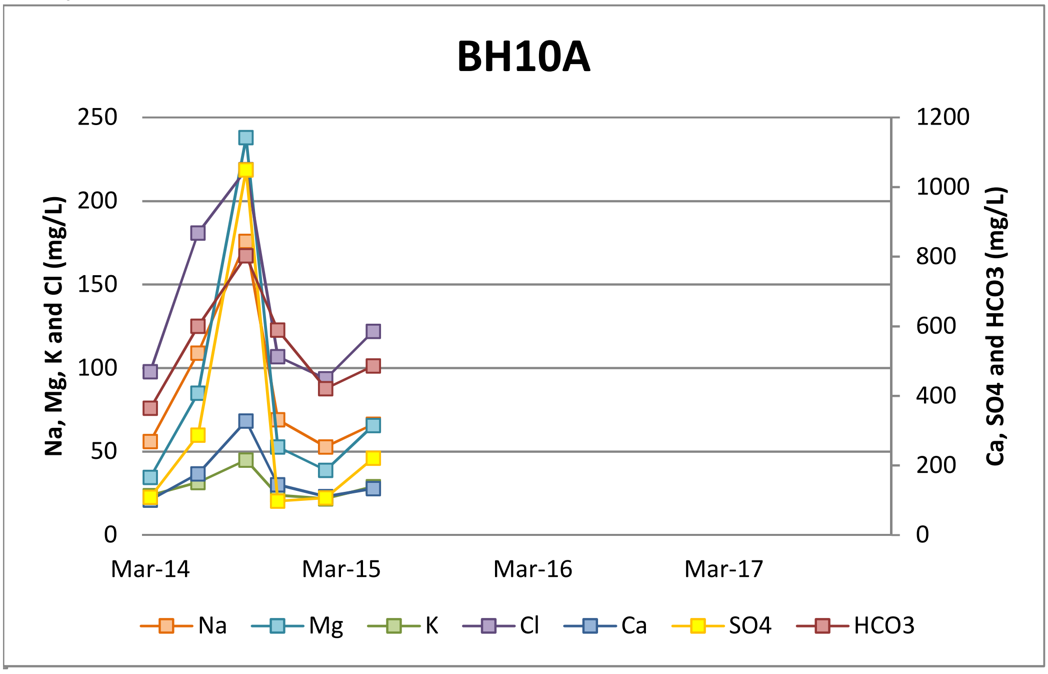
BH9A:



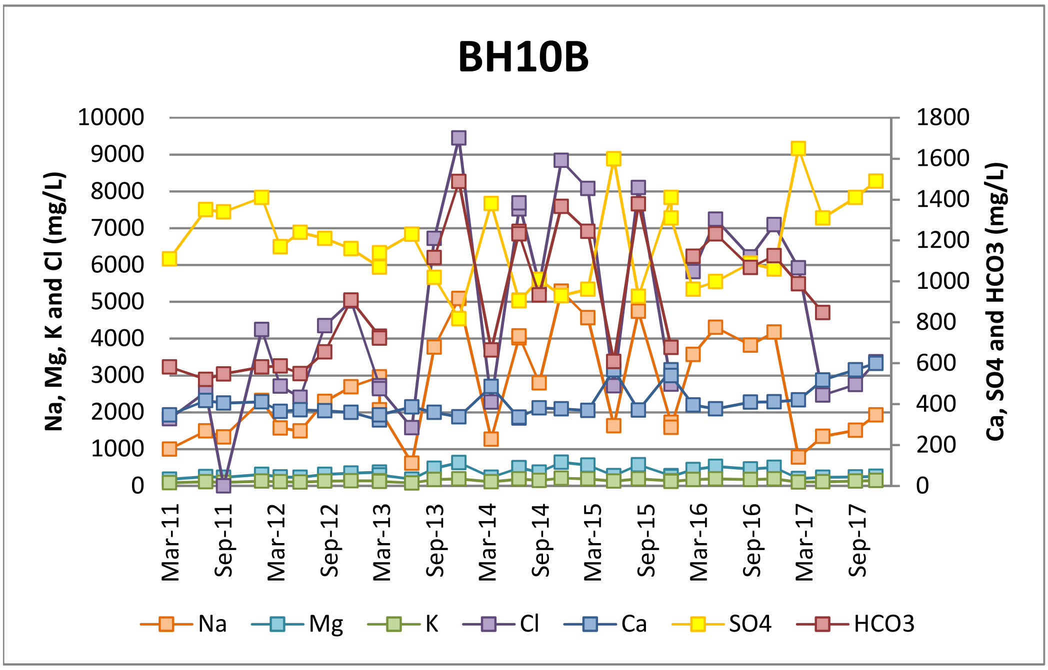
BH9A
90
80
70
60
50
40
30
20
10
0
Na, Mg, K, Cl, Ca and SO4 (mg/L)
340
330
320
310
300
290
280
270
260
250
HCO3 (mg/L)
Nov-14
May-15
Nov-15
May-16
Nov-16
May-17
Nov-17
Na
Mg
K
Cl
Ca
SO4
HCO3

South

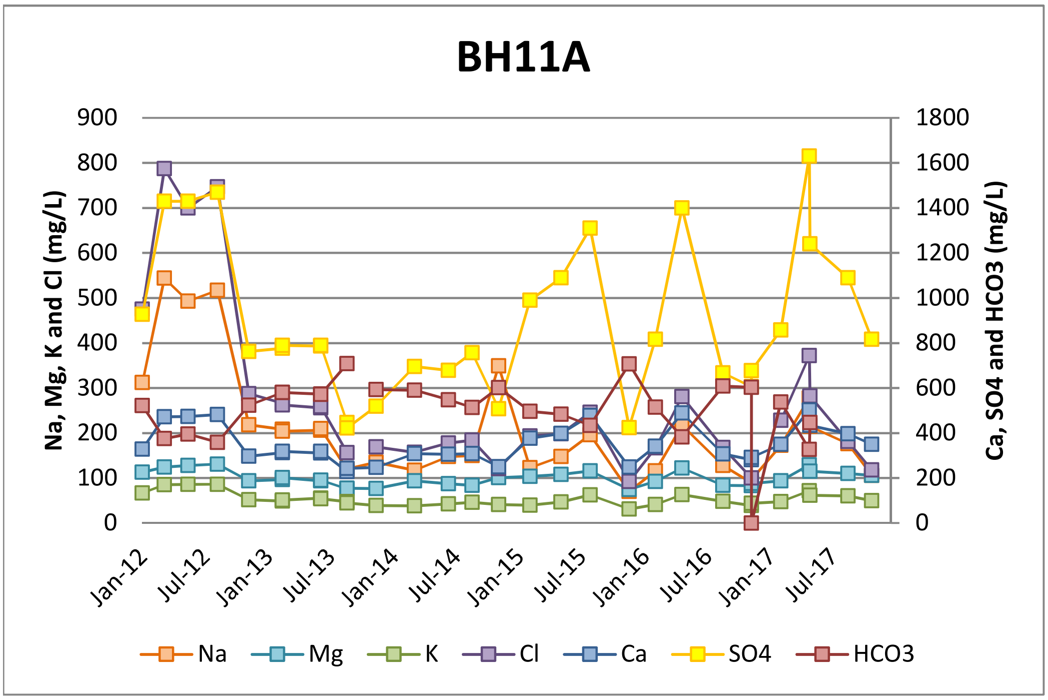
BH10A:



BH10B:

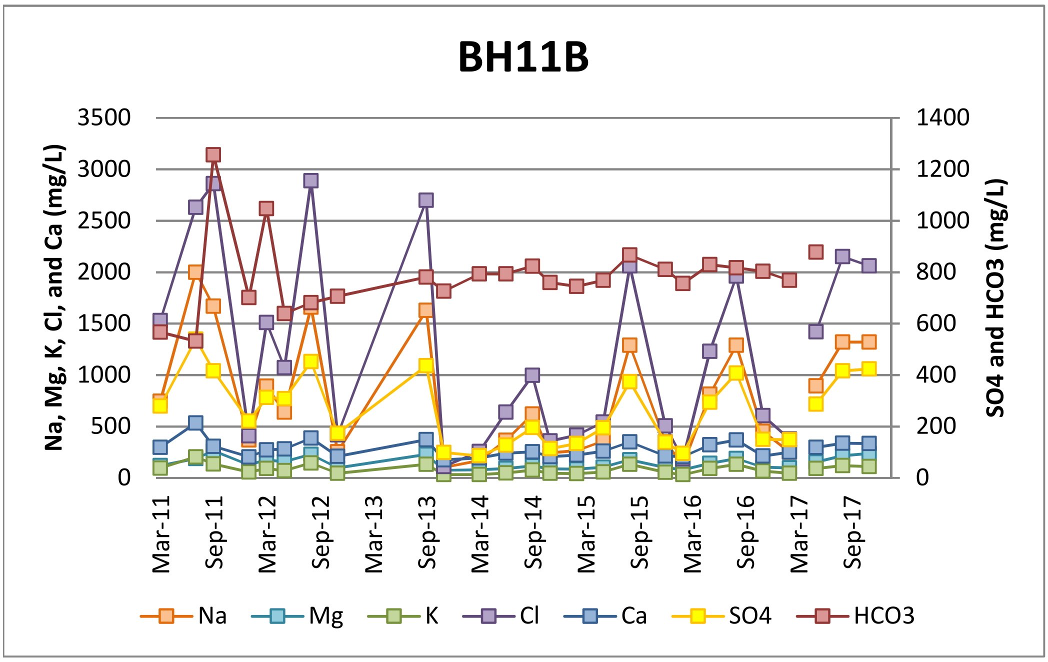


BH11A:



BH11A
Na, Mg, K and Cl (mg/L)
Ca, SO4 and HCO3 (mg/L)
900
800
700
600
500
400
300
200
100
0
1800
1600
1400
1200
1000
800
600
400
200
0
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Na
Mg
K
Cl
Ca
SO4
HCO3

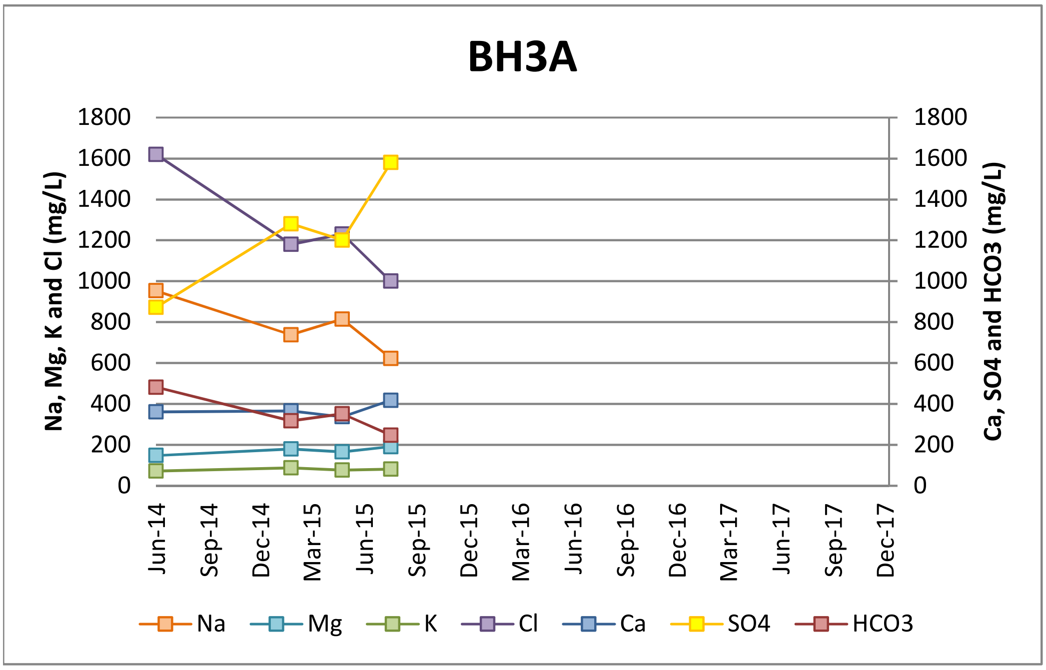
BH11B:



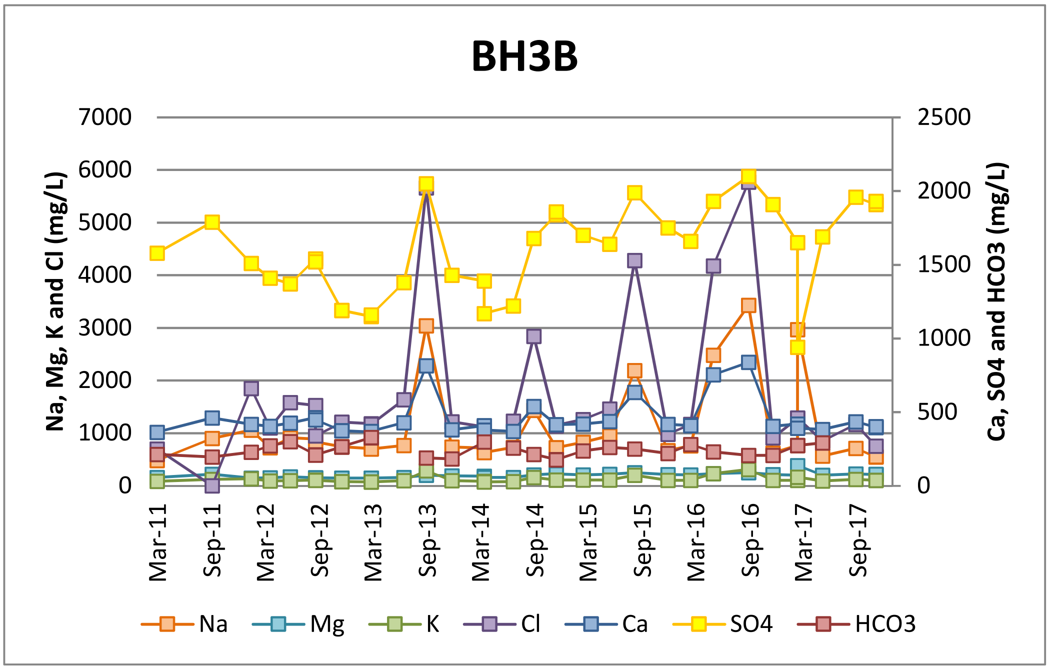
BH11B
Na, Mg, K, Cl, and Ca (mg/L)
SO4 and HCO3 (mg/L)
3500
3000
2500
2000
1500
1000
500
0
1400
1200
1000
800
600
400
200
0
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Na
Mg
K
Cl
Ca
SO4
HCO3

<u>West</u>

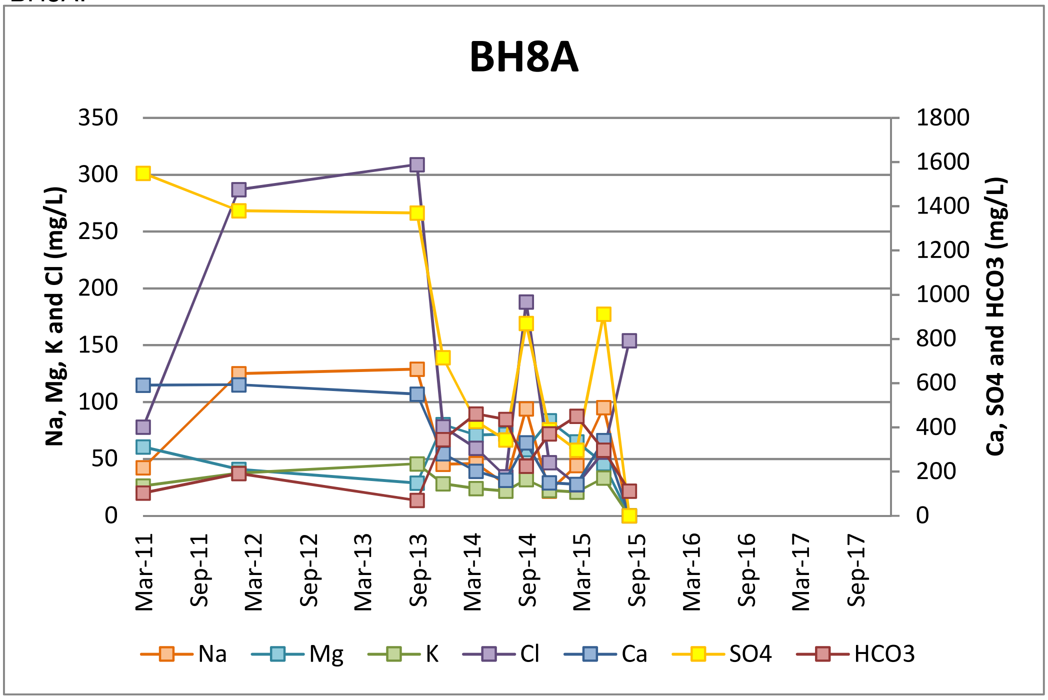
BH3A:



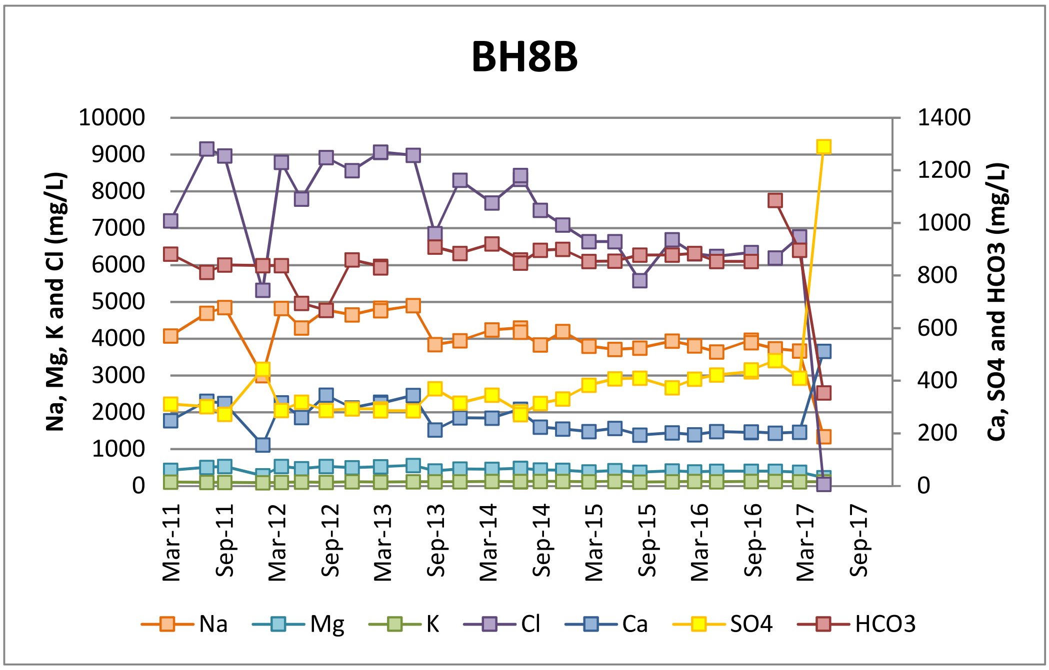
BH3B:



BH8A:


BH8A
Na, Mg, K and Cl (mg/L)
Ca, SO4 and HCO3 (mg/L)
350
300
250
200
150
100
50
0
1800
1600
1400
1200
1000
800
600
400
200
0
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Na
Mg
K
Cl
Ca
SO4
HCO3

BH8B:

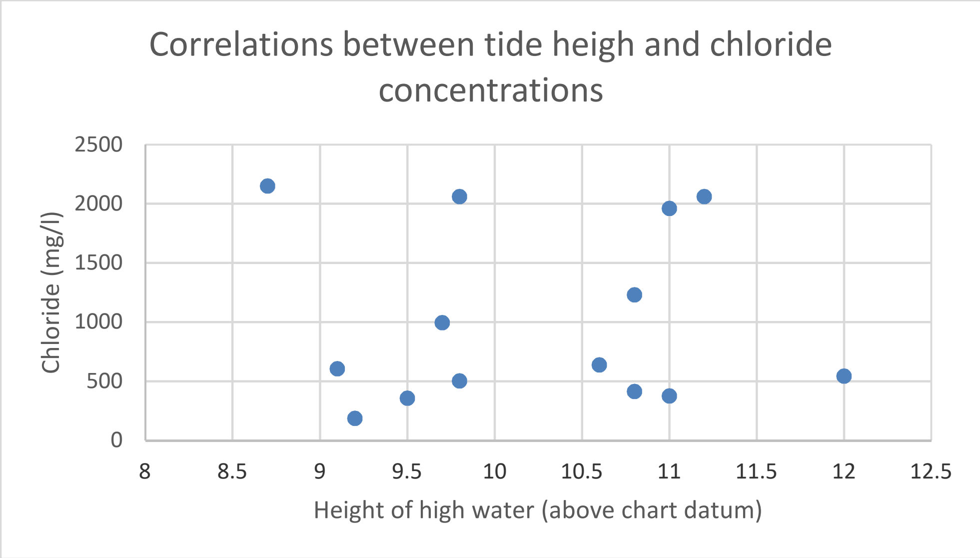

BH8B
Na, Mg, K and Cl (mg/L)
Ca, SO4 and HCO3 (mg/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1400
1200
1000
800
600
400
200
0
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
Sep-15
Mar-16
Sep-16
Mar-17
Sep-17
Na
Mg
K
Cl
Ca
SO4
HCO3

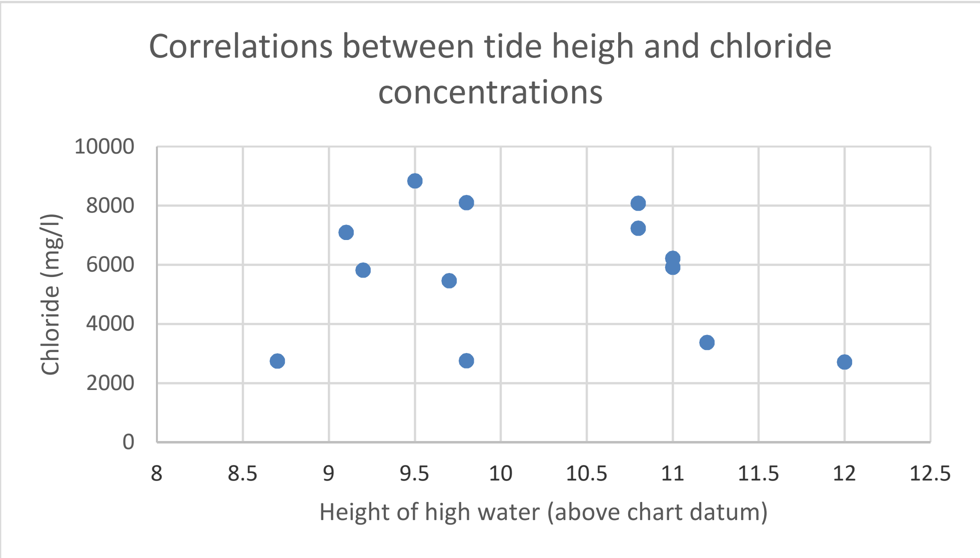
			BH3A				BH9A				BH10A				BH11A		
			PFA				PFA				PFA				PFA		
Screen depths			2 - 6m				2.2 - 6m				1 - 3m				1.5 - 5m		
		N MDL	Mean	95%ile	Max		Mean	95%ile	Max	No	Mean	95%ile	Max	No	Mean	95%ile	Max
Alkalinity to pH 4.5 as CaCO3	mg/l		286.75	379.10	395	4	251.50	271.75	274	2	446.00	616.50	658	6	434.39	578.65	580
Ammoniacal Nitrogen as N	mg/l	0.01	0.24	0.44	0.483	4	0.03	0.03	0.03	2	0.08	0.20	0.216	6	1.16	0.55	30
Chloride	mg/l	10	1257.50	1561.50	1620	4	18.50	22.64	23.1	2	136.75	209.50	219	6	272.51	730.55	787
Nitrogen : Total Oxidised as N	mg/l	0.2	0.49	0.86	0.93	4	0.34	0.41	0.42	2	0.22	0.29	0.31	6	0.89	2.03	2.35
Phosphate : Total as P	mg/l		#DIV/0!	#NUM!	0		#DIV/0!	#NUM!	0	0	#DIV/0!	#NUM!	0	0	5.71	13.14	14.3
Fluoride	mg/l	0.05	0.13	0.20	0.214	4	0.23	0.27	0.273	2	0.30	0.53	0.534	6	0.07	0.08	0.413
Carbon, Organic : Total as C :- {TOC}	mg/l	1	19.25	63.05	74	4	2.00	2.90	3	2	101.72	398.75	495	6	46.86	198.90	594
Conductivity at 20C	µS/cm	10	5692.50	6341.50	6490	4	481.50	523.35	528	2	1521.83	2550.00	2820	6	2786.43	4748.50	4860
pH	pH units	0.05	7.81	8.01	8.04	4	7.51	7.55	7.55	2	7.51	7.67	7.67	6	7.46	7.66	7.68
Arsenic Dissolved	µg/l	1	136.25	184.30	190	4	1.00	1.00	1	2	71.32	81.63	81.7	6	18.73	38.77	49.3
Selenium Dissolved	µg/l	1	18.14	26.91	27.7	4	1.00	1.00	1	2	1.56	3.12	3.7	6	7.12	13.34	22.1
Antimony, Dissolved	µg/l	10	57.70	72.61	73.3	4	1.00	1.00	1	2	12.13	17.53	18.9	6	8.67	12.11	12.7
Molybdenum, Dissolved	µg/l	30	1830.00	2603.00	2630	4	5.02	5.60	5.66	2	653.17	1650.25	1990	6	1375.43	2253.50	2790
Vanadium, Dissolved	µg/l	20	131.00	249.40	271	4	2.00	2.00	2	2	70.33	92.78	97.6	6	8.77	23.19	47.1
Aluminium, Dissolved	µg/l	40	60.25	123.30	138	4	11.15	12.19	12.3	2	16.40	21.00	21.3	6	13.69	33.03	40
Cadmium, Dissolved	µg/l	0.03	0.10	0.17	0.179	4	0.10	0.10	0.1	2	0.13	0.22	0.26	6	0.16	0.41	0.831
Chromium, Dissolved	µg/l	0.5	0.58	0.76	0.803	4	0.50	0.50	0.5	2	0.50	0.50	0.5	6	0.55	0.77	1.43
Copper, Dissolved	µg/l	0.2	0.62	1.60	1.84	4	2.12	2.12	2.12	2	1.45	2.63	2.98	6	1.86	3.71	4.53
Nickel, Dissolved	µg/l	0.3	1.67	2.76	2.98	4	1.06	1.11	1.12	2	1.78	3.76	4.32	6	1.18	2.10	2.23
Zinc, Dissolved	µg/l		#DIV/0!	#NUM!	0		#DIV/0!	#NUM!	0	0	#DIV/0!	#NUM!	0	0	4.35	5.00	5
Boron, Dissolved	µg/l	700	12537.50	19095.00	19500	4	100.50	100.95	101	2	7330.00	15960.00	18700	6	12270.67	17820.00	19700
Calcium, Dissolved	mg/l	10	370.50	410.20	418	4	77.15	82.69	83.3	2	165.83	290.00	328	6	348.17	485.85	502
Iron, Dissolved	µg/l		#DIV/0!	#NUM!	0		#DIV/0!	#NUM!	0	0	#DIV/0!	#NUM!	0	0	40.00	79.00	100
Magnesium, Dissolved	mg/l	3	171.25	189.35	191	4	8.29	9.75	9.91	2	85.83	199.78	238	6	99.88	128.55	131
Manganese, Dissolved	µg/l	20	641.00	1235.10	1350	4	10.00	10.00	10	2	34.17	118.75	155	6	360.10	1437.50	1670
Potassium, Dissolved	mg/l	1	79.48	86.80	87.7	4	6.95	7.50	7.56	2	29.12	41.63	45	6	52.99	85.68	86.1
Sodium, Dissolved	mg/l	20	782.25	932.30	953	4	24.20	27.26	27.6	2	88.28	159.25	176	6	206.08	506.20	544
Sulphate, Dissolved as SO4	mg/l	5	1233.25	1535.00	1580	4	14.30	16.46	16.7	2	312.12	859.50	1050	6	893.40	1452.00	1630
Mercury, Dissolved	µg/l	0.01	0.01	0.01	0.01	4	0.01	0.01	0.01	2	0.01	0.01	0.01	6	0.20	0.02	5.66
Bicarbonate as HCO3	mg/l		349.84	462.50	481.9	4	306.83	331.54	334.28	2	544.12	752.13	802.76	6	502.69	677.10	707.6
Ionic Balance	%		1.28	1.77	1.78	4	-0.94	-0.78	-0.762	2	0.77	3.54	4.17	6	1.59	2.91	21.6
Nitrate as N	mg/l			#NUM!	0			#NUM!	-1.11	0		#NUM!	-1	0		0.69	-2.59
Nitrite as N	mg/l			#NUM!				#NUM!		0		#NUM!		0		0.01	
Field Measurements										0				0			
EC	µS/cm		5162.50	5320.50	7090		676.50	751.65	760	2	1200.67	1541.00	1620	6	3263.71	6854.00	8030
Temp	deg C		11.33	11.92	12.3		11.50	11.68	11.7	2	12.62	13.70	13.9	6	13.61	17.10	19.1
DO	mg/l		2.61	4.28	4.38		6.55	7.50	7.61	2	4.95	6.85	7.13	6	4.87	8.68	8.68
pH	pH Units		7.91	7.91	8.09		7.22	7.33	7.34	2	7.67	7.92	7.97	6	7.45	7.68	7.73
Diff Field/Lab			Min		Max		Min		Max		Min		Max		Min		Max
EC	µS/cm		-0.09	0.29	0.3014862		-0.54	-0.14	-0.1159679	2	-0.23	0.81	0.89974293	6	-1.19	0.28	0.55718475
pH	pH Units		-0.03	0.25	0.26		-0.46	-0.14	-0.12	2	0.03	0.29	0.3	6	-0.26	0.18	0.28

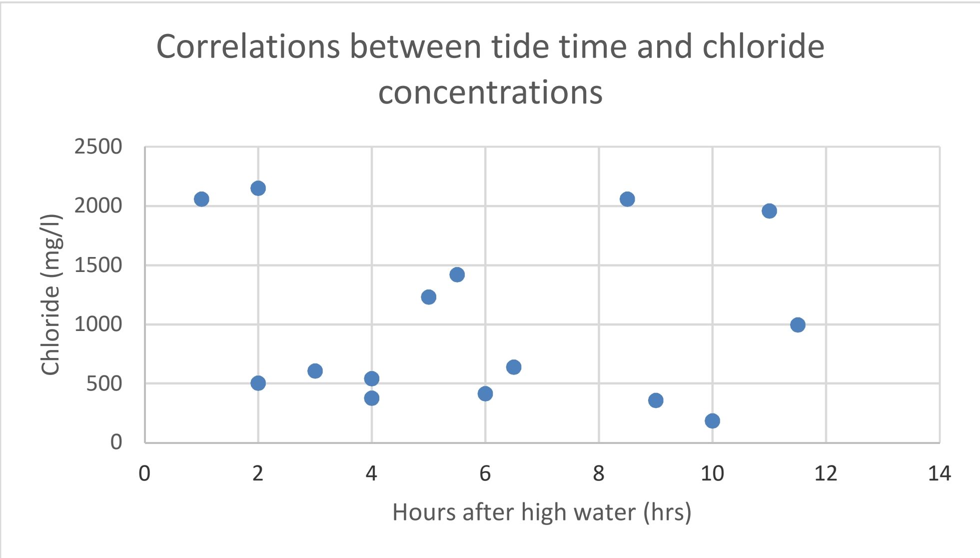
			BH3B				BH5			
			Limestone Down gradient				Cross gradient			
Screen depths			13.5 - 23m				2.5 - 11.5m			
		No	Mean	95%ile	Max	No.	Mean	0.95	Max	No
Alkalinity to pH 4.5 as CaCO3	mg/l	28	200.21	259.20	269		347.71	425.95	428	28
Ammoniacal Nitrogen as N	mg/l	29	0.46	2.16	2.74	30	0.03	0.04	0.095	28
Chloride	mg/l	28	1771.40	5039.00	5770	30	74.40	105.60	142	28
Nitrogen : Total Oxidised as N	mg/l	28	0.79	1.25	1.38	30	1.46	3.16	3.91	28
Phosphate : Total as P	mg/l	4	3.25	8.03	8.84	3	0.67	1.20	1.27	3
Fluoride	mg/l	27	0.10	0.27	0.348	30	0.10	0.17	0.535	28
Carbon, Organic : Total as C :- {TOC}	mg/l	28	3.88	5.93	70	30	10.47	30.34	94	28
Conductivity at 20C	µS/cm	28	7383.00	16225.00	18000	30	1246.07	1533.00	1620	28
pH	pH units	28	7.68	7.85	7.87	30	7.01	7.15	7.21	28
Arsenic Dissolved	µg/l	30	150.80	189.35	194	32	1.02	1.00	1.5	30
Selenium Dissolved	µg/l	29	12.54	19.85	23.2	31	1.00	1.00	1	29
Antimony, Dissolved	µg/l	30	13.19	15.65	16.7	32	1.00	1.00	1	30
Molybdenum, Dissolved	µg/l	30	2518.00	4207.00	5310	32	4.90	16.37	26.5	30
Vanadium, Dissolved	µg/l	30	43.65	63.65	65.2	32	2.00	2.00	2	30
Aluminium, Dissolved	µg/l	30	52.68	110.00	180	32	10.77	12.80	26.3	30
Cadmium, Dissolved	µg/l	30	0.11	0.27	0.319	32	0.10	0.10	0.1	30
Chromium, Dissolved	µg/l	30	0.54	0.76	1.06	32	0.50	0.50	0.5	30
Copper, Dissolved	µg/l	30	0.83	3.84	4.03	32	1.71	2.31	2.84	30
Nickel, Dissolved	µg/l	30	0.57	1.59	2.84	32	1.22	1.83	2.35	30
Zinc, Dissolved	µg/l	8	1.64	3.67	4.27	9	5.00	5.00	5	7
Boron, Dissolved	µg/l	30	21393.75	30205.00	31200	32	465.17	1086.00	1170	30
Calcium, Dissolved	mg/l	30	454.47	782.00	838	32	244.20	321.65	333	30
Iron, Dissolved	µg/l	7	93.00	100.00	100	10	30.00	30.00	30	7
Magnesium, Dissolved	mg/l	30	198.88	250.80	388	32	17.42	20.27	21.3	30
Manganese, Dissolved	µg/l	30	261.26	790.45	1070	32	13.28	35.23	50	30
Potassium, Dissolved	mg/l	30	123.68	259.65	312	32	2.22	4.35	5.55	30
Sodium, Dissolved	mg/l	30	1090.66	3001.50	3430	32	47.77	67.51	73.8	30
Sulphate, Dissolved as SO4	mg/l	30	1588.16	2017.00	2100	32	306.87	548.20	576	30
Mercury, Dissolved	µg/l	30	0.01	0.01	0.0117	32	0.01	0.03	0.105	30
Bicarbonate as HCO3	mg/l	27	245.85	318.91	328.18	27	431.69	520.03	522.16	26
Ionic Balance	%	28	3.27	7.09	50.6805224	29	0.65	2.26	3.14	28
Nitrate as N	mg/l	2	1.27	1.37	1.38	2		0.56	-1.07	2
Nitrite as N	mg/l	2	0.01	0.02	0.0166	2		0.00		2
Field Measurements		0						#NUM!		2
EC	µS/cm	17	8013.59	15423.00	17435	17	2256.12	4696.00	16360	17
Temp	deg C	17	12.28	13.20	13.2	18	12.06	14.52	16.6	17
DO	mg/l	17	2.07	5.04	5.84	16	3.38	5.13	5.14	16
pH	pH Units	17	7.59	7.99	8.36	18	6.99	7.22	7.28	17
Diff Field/Lab			Min		Max		Min		Max	
EC	µS/cm	16	-0.13	0.30	0.31069807	17	-1.66	0.12	0.16494845	17
pH	pH Units	16	-1.30	0.28	0.52	18	-0.30	0.12	0.15	17

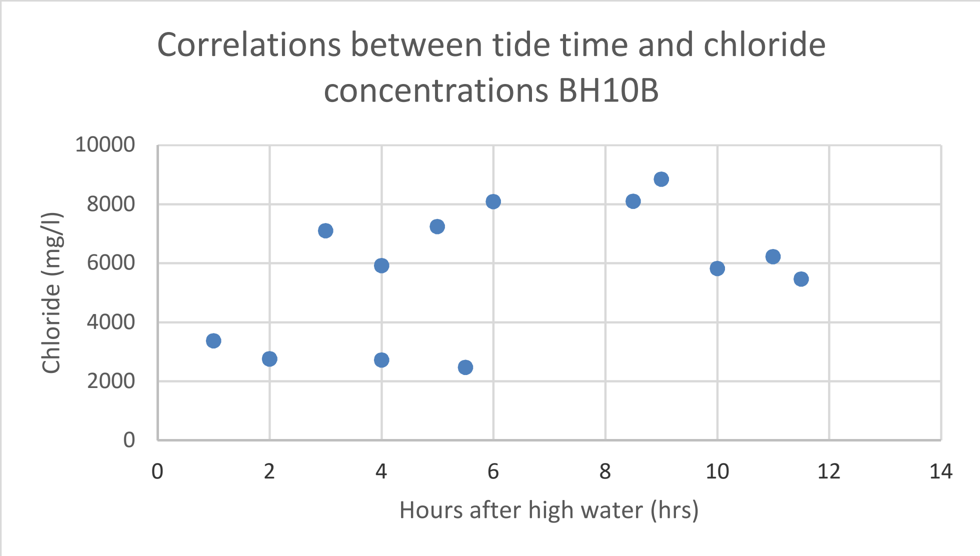
		BH6				BH7B				BH8B				BH9B			
		Limestone up gradient of part				Limestone Down gradient				Limestone Down gradient				Limestone Down gradient			
Screen depths		13 - 20.5m				18 - 26m				30 - 38m				6 - 13m			
		Mean	95%ile	Max	No	Mean	95%ile	Max	No	Mean	95%ile	Max	No	Mean	95%ile	Max	No
Alkalinity to pH 4.5 as CaCO3	mg/l	290.00	360.00	370	22	371.65	562.50	624	32	689.56	752.00	890	27	258.39	271.00	273.00	31
Ammoniacal Nitrogen as N	mg/l	0.58	1.28	1.31	23	2.48	3.48	3.91	34	6.40	7.15	7.43	28	0.03	0.03	0.21	31
Chloride	mg/l	2447.87	5497.00	6040	23	2835.76	4434.00	5140	34	7267.64	9066.50	9160	28	32.91	46.60	68.40	31
Nitrogen : Total Oxidised as N	mg/l	18.68	39.43	48.8	23	0.44	1.31	2.24	34	0.45	0.56	6.69	28	2.83	3.35	3.41	31
Phosphate : Total as P	mg/l	0.59	1.07	1.13	3	0.65	1.20	1.38	7	0.16	0.30	0.331	6	0.05	0.08	0.08	6
Fluoride	mg/l	0.18	0.38	0.586	23	0.46	0.53	0.561	34	0.55	0.66	0.973	28	0.16	0.21	0.22	31
Carbon, Organic : Total as C :- {TOC}	mg/l	12.69	59.50	77	23	8.06	43.24	95	34	22.88	153.29	200	28	10.71	62.50	170.00	31
Conductivity at 20C	µS/cm	9412.17	17340.00	18500	23	10229.39	14880.00	16300	34	20242.14	24100.00	24600	28	597.06	655.00	734.00	31
pH	pH units	7.42	7.64	7.96	23	7.22	7.39	7.4	34	7.15	7.33	8.02	28	7.47	7.55	7.59	31
Arsenic Dissolved	µg/l	19.46	30.90	36.9	23	4.66	9.56	19.5	35	4.15	1.00	92.4	29	1.01	1.00	1.46	33
Selenium Dissolved	µg/l	12.09	18.61	21.1	24	1.02	1.07	1.4	35	1.38	1.00	11.6	28	1.00	1.00	1.00	32
Antimony, Dissolved	µg/l	13.13	15.18	15.5	24	9.47	10.00	10	35	10.42	10.00	22.1	29	1.55	4.60	10.00	33
Molybdenum, Dissolved	µg/l	3583.75	4381.00	4430	24	2663.89	4110.50	4290	35	104.83	30.00	2200	29	5.94	25.26	30.00	33
Vanadium, Dissolved	µg/l	30.22	50.86	53.2	24	24.24	20.00	200	35	20.00	20.00	20	29	3.09	9.20	20.00	33
Aluminium, Dissolved	µg/l	#DIV/0!	#NUM!	0	24	53.09	110.00	125	35	57.10	110.00	172	29	14.82	29.06	110.00	32
Cadmium, Dissolved	µg/l	0.27	0.49	0.527	24	0.12	0.28	0.472	35	0.04	0.07	0.1	29	0.10	0.10	0.10	33
Chromium, Dissolved	µg/l	4.73	16.15	19.6	24	0.66	1.08	4.73	35	0.50	0.50	0.5	29	0.53	0.50	1.41	33
Copper, Dissolved	µg/l	4.60	19.54	42.1	24	1.89	5.10	25.6	35	1.19	2.00	21.4	29	1.02	1.41	1.72	33
Nickel, Dissolved	µg/l	5.62	9.19	9.46	24	1.05	3.19	5.01	35	0.53	1.38	2.19	29	0.98	1.14	1.19	33
Zinc, Dissolved	µg/l	36.26	81.86	92.1	4	8.83	22.73	23	14	10.26	25.64	36.8	10	4.41	5.00	5.00	11
Boron, Dissolved	µg/l	24670.83	28285.00	28800	24	16270.03	22875.00	26000	35	2342.07	2096.00	15700	29	149.24	370.00	700.00	33
Calcium, Dissolved	mg/l	814.21	1288.50	1460	24	643.74	889.80	914	35	259.86	345.60	512	29	90.69	103.80	121.00	33
Iron, Dissolved	µg/l	#DIV/0!	#NUM!	0	4	525.38	2408.00	5570	14	507.30	2329.35	3750	10	44.00	100.00	100.00	10
Magnesium, Dissolved	mg/l	217.54	299.35	320	24	114.64	145.35	261	35	439.97	534.80	561	29	17.24	21.12	21.60	33
Manganese, Dissolved	µg/l	1489.78	2558.00	3570	24	1144.74	1741.50	3960	35	112.87	125.40	922	29	10.72	16.28	20.00	33
Potassium, Dissolved	mg/l	109.08	170.80	193	24	208.47	306.85	337	35	113.65	125.20	129	29	2.13	2.74	3.71	33
Sodium, Dissolved	mg/l	1224.54	2748.50	3030	24	1709.59	2741.00	2920	35	4048.97	4842.00	4900	29	21.86	27.28	33.50	33
Sulphate, Dissolved as SO4	mg/l	1896.25	2185.00	2380	24	1476.47	2053.50	2100	35	381.83	463.80	1290	29	31.42	39.38	40.20	33
Mercury, Dissolved	µg/l	#DIV/0!	#NUM!	0	24	0.01	0.02	0.0768	35	0.01	0.02	0.034	29	0.01	0.01	0.07	33
Bicarbonate as HCO3	mg/l	344.65	421.82	439.2	20	465.60	686.80	761.28	29	841.26	917.44	1085.8	27	314.13	329.40	331.84	29
Ionic Balance	%	1.17	4.08	4.65	24	4.42	18.94	22.2	29	3.23	6.58	51.38	26	0.01	2.26	2.71	30
Nitrate as N	mg/l		11.30	-2.14	2		0.20	-1.94	2		#NUM!	-2.68	0		3.35	-3.52	2
Nitrite as N	mg/l		0.02		2		0.00		2		#NUM!		0		0.01		2
Field Measurements					2				2				0				0
EC	µS/cm	9011.06	17115.75	18153	16	11768.42	15831.00	16560	19	16042.73	21681.50	22363	16	700.59	916.40	1142.00	17
Temp	deg C	12.95	15.46	15.7	17	12.96	14.92	16	19	12.14	13.02	14.3	17	12.29	14.92	17.00	17
DO	mg/l	3.34	5.43	6.7	16	0.63	1.18	1.25	15	1.30	4.41	7.56	15	5.86	8.11	9.95	16
pH	pH Units	7.38	7.73	8.11	17	7.10	7.37	7.42	19	6.95	7.28	7.99	17	7.20	7.61	7.71	17
Diff Field/Lab		Min		Max		Min		Max		Min		Max		Min		Max	
EC	µS/cm	-0.94	1.73	1.72933207	16	-0.20	0.24	1.09201038	19	-0.47	0.43	0.57038755	11	-0.75	0.16	0.21	17
pH	pH Units	-0.46	0.20	0.37	17	-0.51	0.12	0.12	19	-0.56	0.01	0.01	17	-1.09	0.13	0.22	17

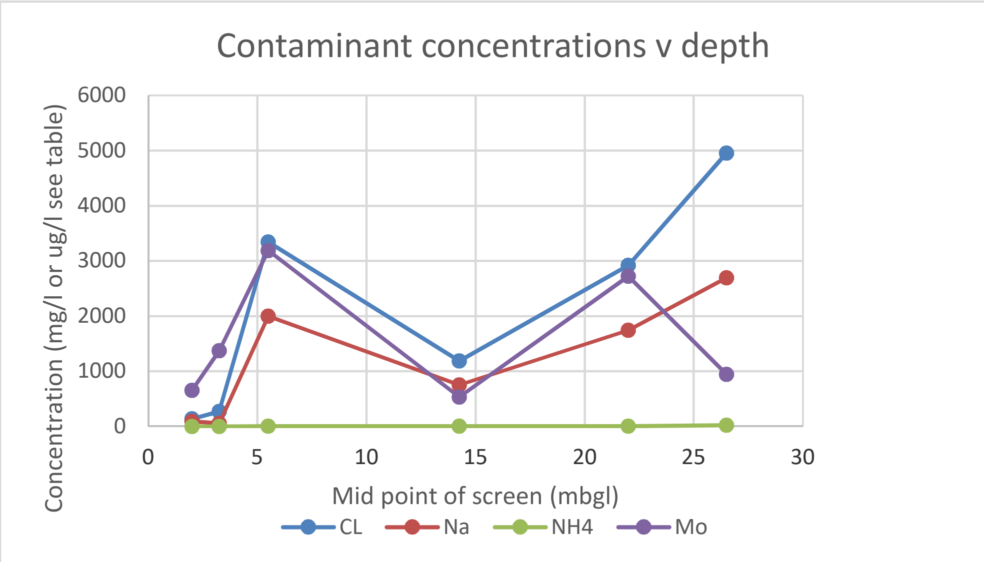
		BH7A				BH8A				BH10B				BH11B			
		Alluvium Down gradient				Alluvium Down gradient				Alluvium Down gradient				Alluvium Down gradient			
Screen depths		2 - 9.5m				5.3 - 7m				23 - 30m				9.5 - 19m			
		Mean	95%ile	Max	No	Mean	95%ile	Max	No	Mean	95%ile	Max	No	Mean	95%ile	Max	No
Alkalinity to pH 4.5 as CaCO3	mg/l	344.00	471.30	671	28	228.30	374.00	378	11	734.17	1126.00	1220	29	650.41	822.60	1030	27
Ammoniacal Nitrogen as N	mg/l	2.94	3.62	4.12	29	0.17	0.46	0.513	11	20.31	49.36	54.9	30	4.12	9.72	10.5	27
Chloride	mg/l	3231.79	4557.50	5266	29	119.89	298.00	309	11	4846.90	8544.00	9450	30	1226.35	2820.00	2890	26
Nitrogen : Total Oxidised as N	mg/l	0.43	1.84	2.48	29	0.52	1.55	2.25	10	0.33	0.91	2.83	30	0.42	0.20	6.23	27
Phosphate : Total as P	mg/l	4.37	7.63	18.2	5	112.40	168.74	175	2	1.14	1.72	1.82	6	2.18	3.22	3.29	6
Fluoride	mg/l	0.47	0.57	0.7	29	0.09	0.22	0.307	11	0.27	0.43	0.438	30	0.34	0.64	0.797	26
Carbon, Organic : Total as C :- {TOC}	mg/l	7.51	39.50	56	29	24.80	99.55	100	10	10.86	47.95	82	30	27.50	108.38	131	26
Conductivity at 20C	µS/cm	11580.00	15100.00	16200	29	1889.09	3120.00	3140	11	14989.67	24395.00	26700	30	5199.62	9810.00	9960	26
pH	pH units	7.23	7.33	7.44	29	8.31	8.77	8.98	11	7.42	7.56	7.63	30	7.40	7.58	7.62	26
Arsenic Dissolved	µg/l	3.16	7.55	559	31	94.19	134.00	142	11	29.27	66.95	90.5	31	25.18	38.53	64.7	26
Selenium Dissolved	µg/l	1.00	1.00	20	30	16.47	25.30	26.4	11	1.00	1.00	1	30	1.02	1.00	1.4	26
Antimony, Dissolved	µg/l	9.42	10.00	10	31	20.89	25.25	25.8	11	9.54	10.00	13.7	31	10.00	10.00	10	26
Molybdenum, Dissolved	µg/l	3086.90	4295.00	4740	31	2924.55	3245.00	3270	11	938.12	2235.00	2420	31	561.27	1042.00	2090	26
Vanadium, Dissolved	µg/l	32.79	146.25	200	31	137.64	170.00	176	11	19.62	20.00	44.2	31	20.00	20.00	20	26
Aluminium, Dissolved	µg/l	56.36	110.00	6450	31	207.05	554.00	726	11	48.74	110.00	121	31	55.00	110.00	110	26
Cadmium, Dissolved	µg/l	0.13	0.41	2	31	0.23	0.80	1.1	11	0.08	0.25	0.584	31	0.04	0.06	0.1	26
Chromium, Dissolved	µg/l	0.55	1.00	51.8	31	4.44	18.45	21.1	11	0.50	0.50	0.5	31	0.50	0.50	0.5	26
Copper, Dissolved	µg/l	2.81	4.29	64.7	31	1.26	1.95	2.01	10	0.56	1.73	4.64	31	0.63	1.32	9.58	26
Nickel, Dissolved	µg/l	0.42	0.88	4.34	31	1.03	1.51	2	11	0.72	1.26	6.98	31	1.04	3.75	4.99	26
Zinc, Dissolved	µg/l	2.47	5.70	5900	9	2.70	4.77	5	2	13.23	52.29	66.6	10	4.92	10.12	11.5	9
Boron, Dissolved	µg/l	18974.52	23050.00	23600	31	9110.91	13800.00	14400	11	12344.19	17750.00	21000	31	8921.92	12075.00	13900	26
Calcium, Dissolved	mg/l	704.71	891.50	907	31	303.91	592.00	593	11	413.55	568.00	599	31	280.38	383.00	532	26
Iron, Dissolved	µg/l	91.22	136.60	33400	9	65.00	96.50	100	2	869.00	4030.50	4170	10	532.50	2394.50	3630	8
Magnesium, Dissolved	mg/l	114.45	126.50	150	31	55.21	82.00	83.6	11	360.52	604.00	644	31	142.35	234.25	263	26
Manganese, Dissolved	µg/l	1351.19	1585.00	6900	31	11.91	17.85	20	11	720.92	1130.00	1200	31	820.08	1055.00	1430	26
Potassium, Dissolved	mg/l	237.55	320.00	325	31	26.55	41.60	45.8	11	144.52	193.50	211	31	83.49	140.75	204	26
Sodium, Dissolved	mg/l	1935.32	2735.00	2800	31	61.16	127.00	129	11	2640.26	4915.00	5290	31	772.50	1667.50	2000	26
Sulphate, Dissolved as SO4	mg/l	1660.45	2065.00	5553	31	751.27	1465.00	1550	11	1180.06	1545.00	1650	31	655.88	1120.00	1350	26
Mercury, Dissolved	µg/l	0.01	0.01	4	31	0.57	3.09	6.17	11	0.01	0.02	0.0295	31	0.02	0.01	0.369	27
Bicarbonate as HCO3	mg/l	435.64	575.35	818.62	25	278.53	456.28	461.16	11	915.72	1374.94	1488.4	27	785.43	1021.51	1256.6	24
Ionic Balance	%	3.71	14.83	59	27	-9.74	1.64	1.8	10	5.66	38.23	49.06	28	0.78	4.12	9.46	26
Nitrate as N	mg/l		0.18	-7.84	3		#NUM!	-100	0		2.70	-3.92	2		0.2	-4.68	2
Nitrite as N	mg/l		0.18		3		#NUM!		0		0.02		2		0.004		2
Field Measurements					3				0				0				2
EC	µS/cm	12477.13	18101.50	18940	16	2652.33	7224.00	10380	9	12628.67	20151.85	21413	19	5046	12716.25	22200	16
Temp	deg C	13.10	16.10	16.5	17	12.18	12.98	13.1	9	13.27	15.05	15.3	18	13.33125	15	19.2	16
DO	mg/l	3.35	4.83	4.96	17	4.03	6.49	7.55	9	0.72	2.32	2.69	15	0.90333333	3.053	3.2	15
pH	pH Units	7.10	7.42	7.45	17	8.47	9.16	9.21	9	7.27	7.75	8.13	18	7.29625	7.5575	7.73	16
Diff Field/Lab		Min		Max		Min		Max		Min		Max		Min		Max	
EC	µS/cm	-0.34	0.59	1.82099828	16	-1.08	0.19	0.3	9	-0.22	1.03	1.28872352	12	-0.79245283	0.397877706	1.09219858	16
pH	pH Units	-0.87	0.14	0.24	17	-1.07	0.77	0.85	9	-0.43	0.28	0.77	18	-0.43	0.1525	0.22	16

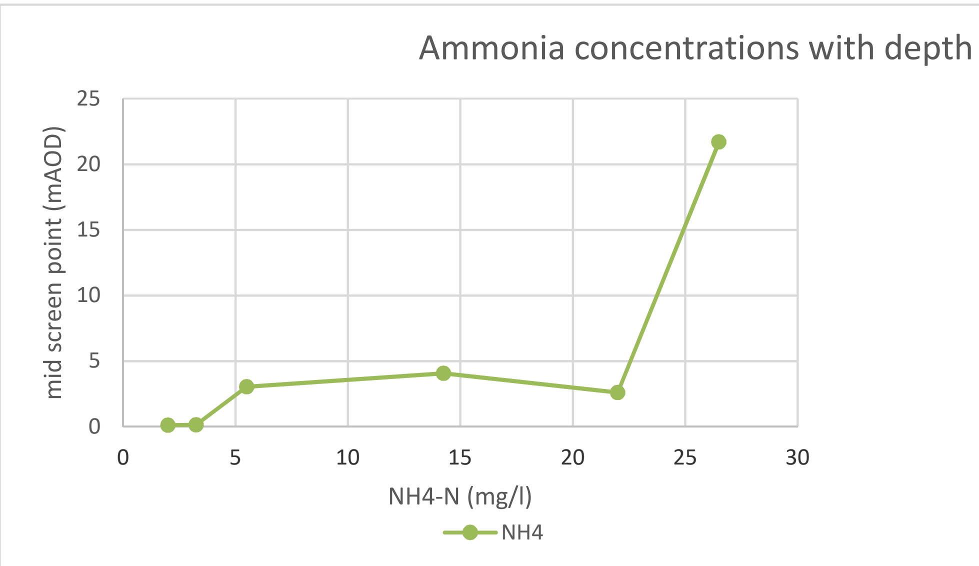

Correlations between tide heigh and chloride concentrations
Chloride (mg/l)
2500
2000
1500
1000
500
0
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
Height of high water (above chart datum)

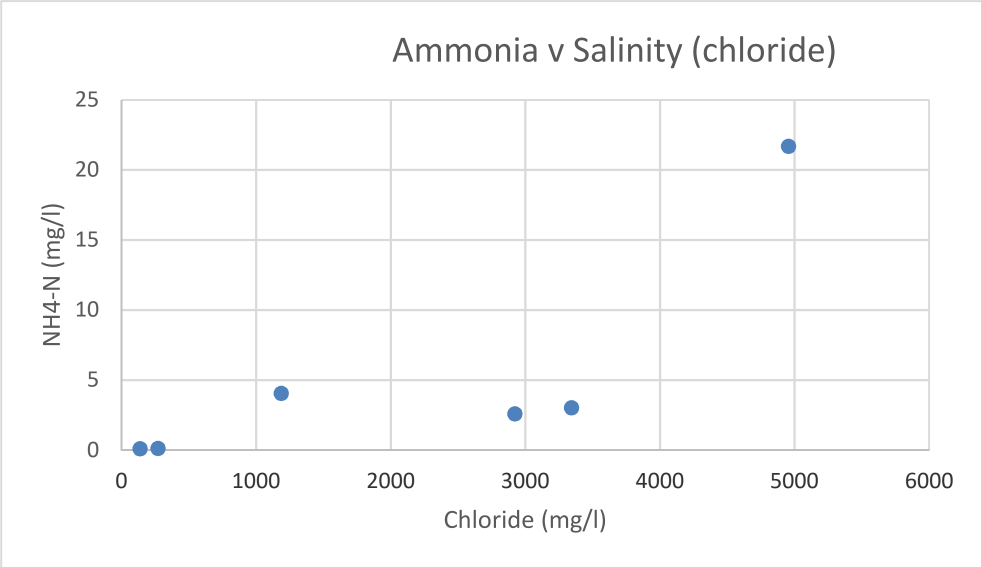

Correlations between tide heigh and chloride concentrations
Chloride (mg/l)
10000
8000
6000
4000
2000
0
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
Height of high water (above chart datum)

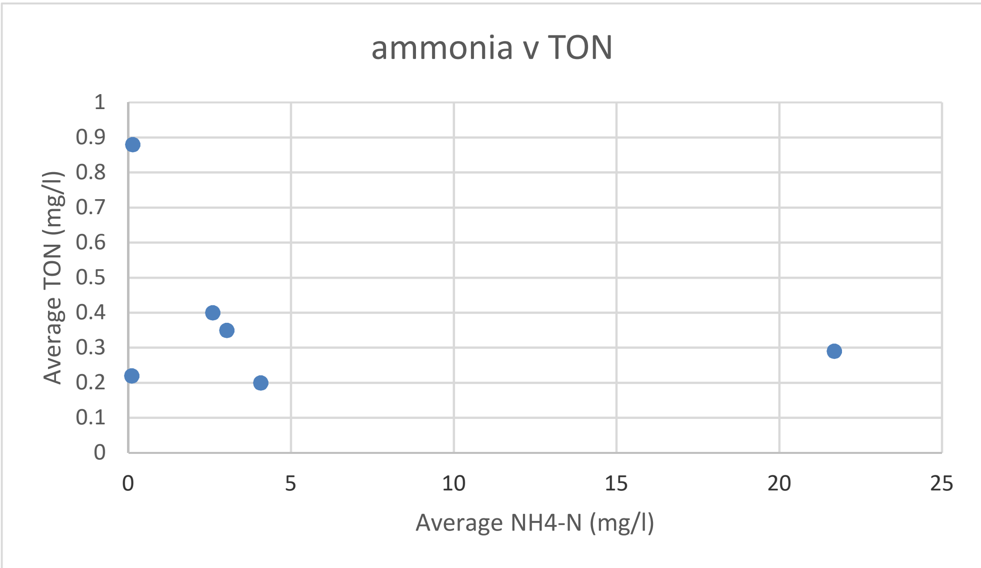

Correlations between tide time and chloride concentrations
Chloride (mg/l)
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
Hours after high water (hrs)


Correlations between tide time and chloride concentrations BH10B
Chloride (mg/l)
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
Hours after high water (hrs)


Contaminant concentrations v depth
Concentration (mg/l or ug/l see table)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
Mid point of screen (mbgl)
CL
Na
NH4
Mo


Ammonia concentrations with depth
mid screen point (mAOD)
25
20
15
10
5
0
0
5
10
15
20
25
30
NH4-N (mg/l)
NH4


Ammonia v Salinity (chloride)
NH4-N (mg/l)
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
Chloride (mg/l)


ammonia v TON
Average TON (mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
Average NH4-N (mg/l)

APPENDIX 2

Surface water pollution model Calculations

Calculation of Impact on R Thaw based on Mass balance

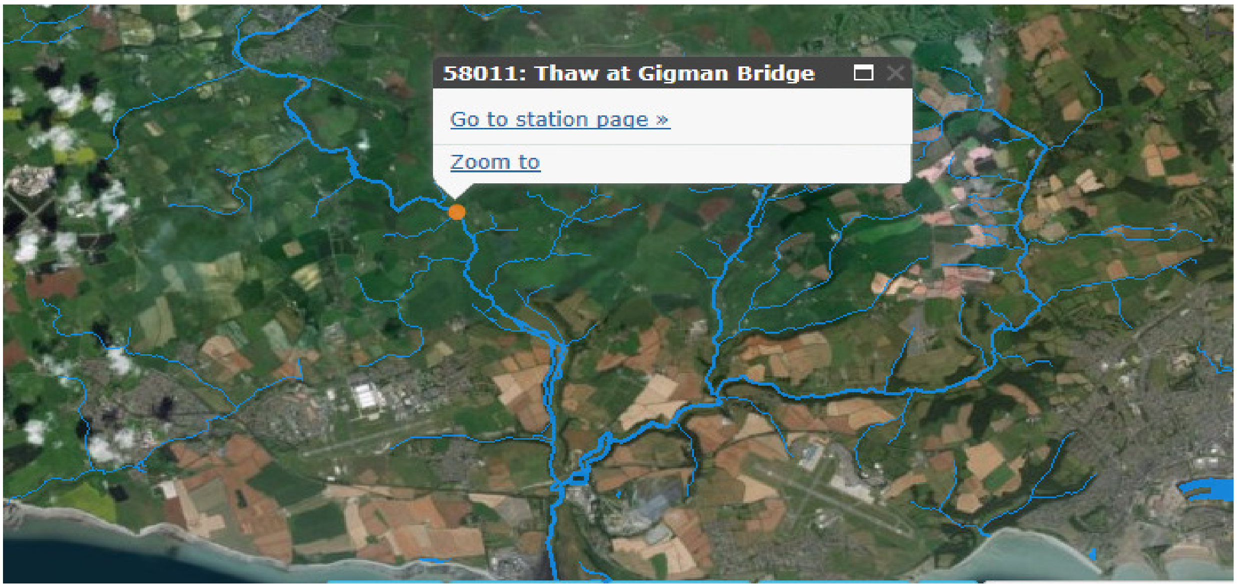
Step 1 - calculation of leachate generation

water shed area	311700	m2	See Figure 2
Total Rainfall	998		St Athan
Potential Evapotranspiration (ET	510	mm/yr	MAFF
Effective Rainfall	488	mm/yr	
Volume of water less ET	152109.6	m3/yr	
Infiltration factor	10%		Steep sided, low permeability material (PFA)
Leachate generation	15210.96	m3/yr	
	41.64534	m3/day	
	0.000482	m3/s	
Infiltration factor	30%		
	45632.88	m3/yr	
Leachate generation (Lg)	124.936	m3/day	
	0.001446	m3/s	

Calculation of Impact based on Average flow and Average concentrations
Information for R. Thaw obtained from National River archive

Q50	0.715	m3/s	
Catchment enlargement factor	2	-	Catchment of R Thaw has more than doubled at the stretch adjacent to site. See attached image
Q50 flow in River at site (Qr)	1.43	m3/s	

58011 - Thaw at Gigman Bridge



Period of Record:	1976 - 2016
Percent Complete:	98 %
Base Flow Index:	0.67
Mean Flow:	1.037 m^3/s
95% Exceedance (Q95):	0.171 m^3/s
70% Exceedance (Q70):	0.416 m^3/s
50% Exceedance (Q50):	0.715 m^3/s
10% Exceedance (Q10):	2.38 m^3/s

Predicted Impact
Calculation based on following equation
Conc = ((Lg*St)+(Qr*BQ))/(LG+Qr)

Parameter	Units	Source Term (St)	10%	30%	Bcakground Sea water (BQ)	EQS Transitional water
Molybdenum	µg/l	3607	31.21	33.61	30	70 (WHO)
Boron	µg/l	25119	3707	3722	3700	7000
Ammoniacal Nitrogen	mg/l	21.01	0.05	0.06	0.04	-
Cr (VI)	µg/l	4.47	0.36	0.36	0.36	0.6
Arsenic	µg/l	25.18	1.3	1.3	1.3	25
Mercury	µg/l	1.9	0.10	0.10	0.1	0.07

APPENDIX 3

Groundwater Compliance Limit Chart

Groundwater

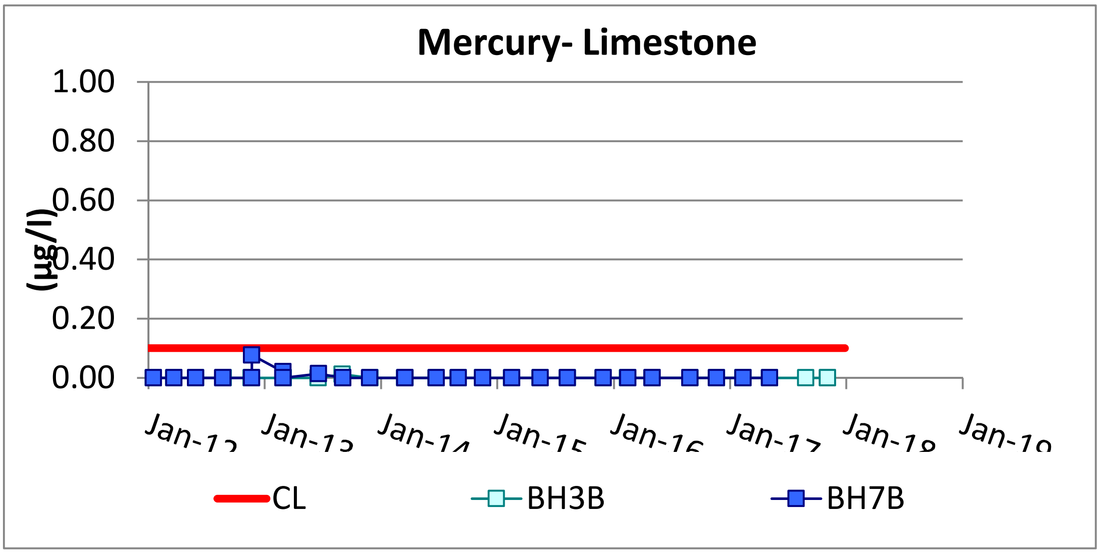
REVISED Compliance Limits			
		01/09/2006	01/01/2018
Conversion	1000		
Cadmium	µg/l	2.3	2.3
Mercury	µg/l	0.10	0.10
Arsenic	µg/l	310	310
Aluminium	µg/l	N/A	N/A
Ammoniacal-N (mg/l)	mg/l	6.6	6.6
Boron	µg/l	60000	60000
Chromium	µg/l	N/A	N/A
Molybdenum	µg/l	7000	7000
Selenium	µg/l	350	350
Sulphate	mg/l	N/A	N/A
Vanadium	µg/l	N/A	N/A

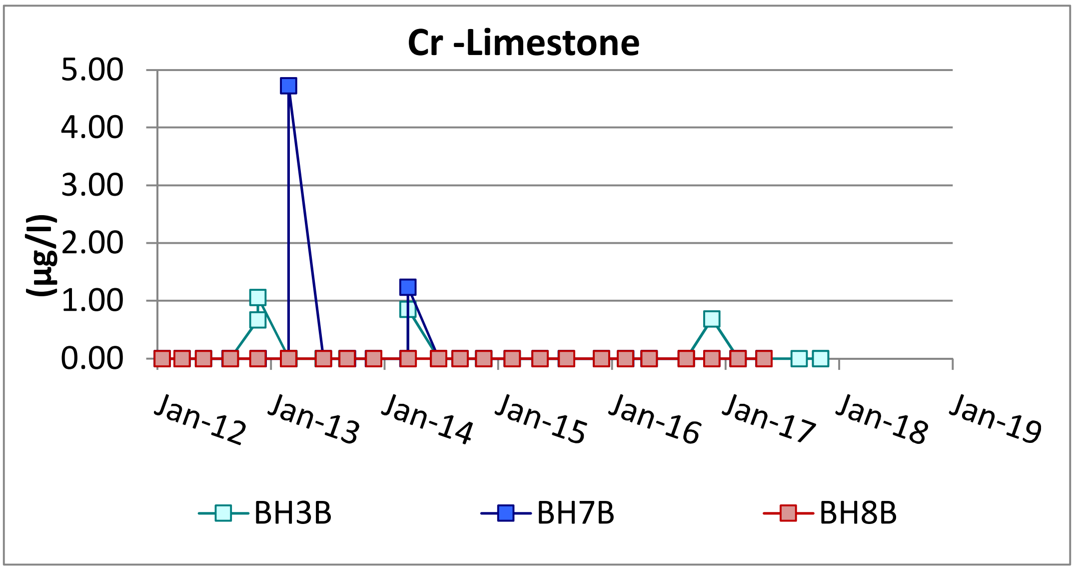
REVISED Control Levels			
		01/09/2006	01/01/2018
Conversion	1000		
Cadmium	µg/l	0.5	0.5
Mercury	µg/l	18.00	18.00
Arsenic	µg/l	275	275
Aluminium	µg/l	750	750
Ammoniacal-N (mg/l)	mg/l	5.5	5.5
Boron	µg/l	48000	48000
Chromium	µg/l	135	135
Molybdenum	µg/l	6000	6000
Selenium	µg/l	290	290
Sulphate	mg/l	2,660	2,660
Vanadium	µg/l	180	180

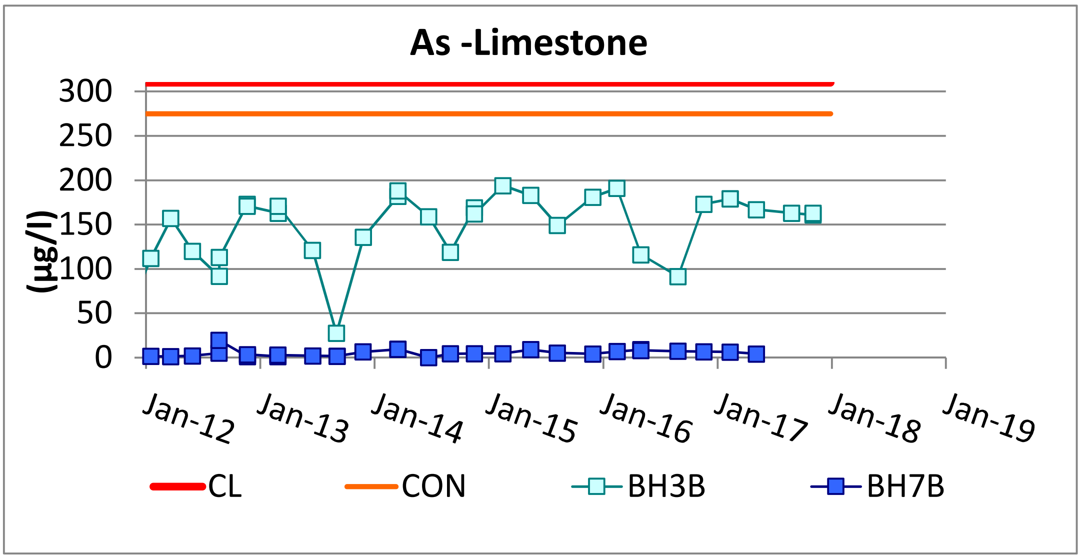
01/09/2006	38718	42005
01/01/2015	38961	41882
		2921
		365.125

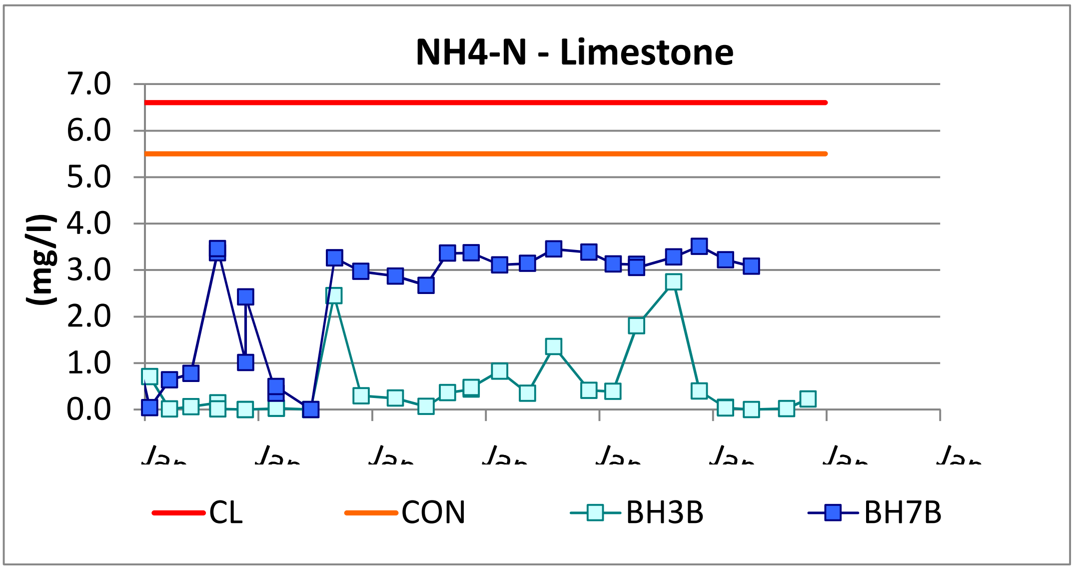
Surface Water

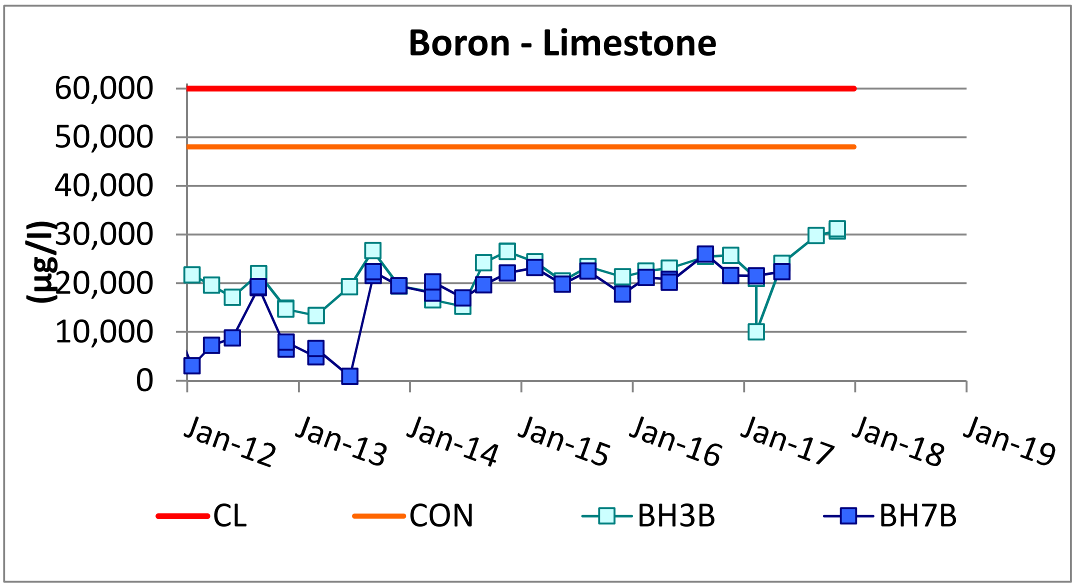
Groundwater

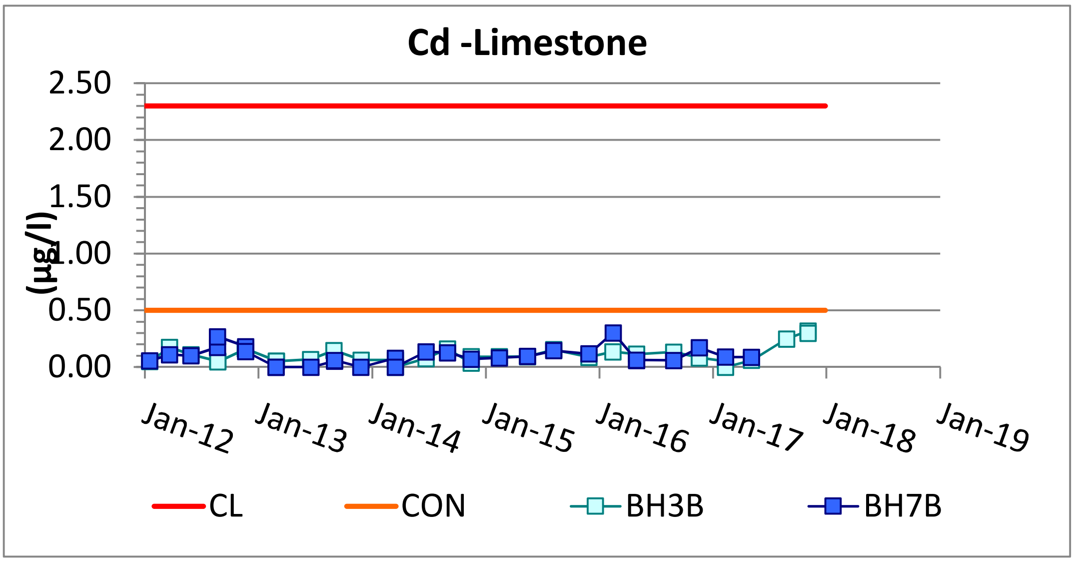


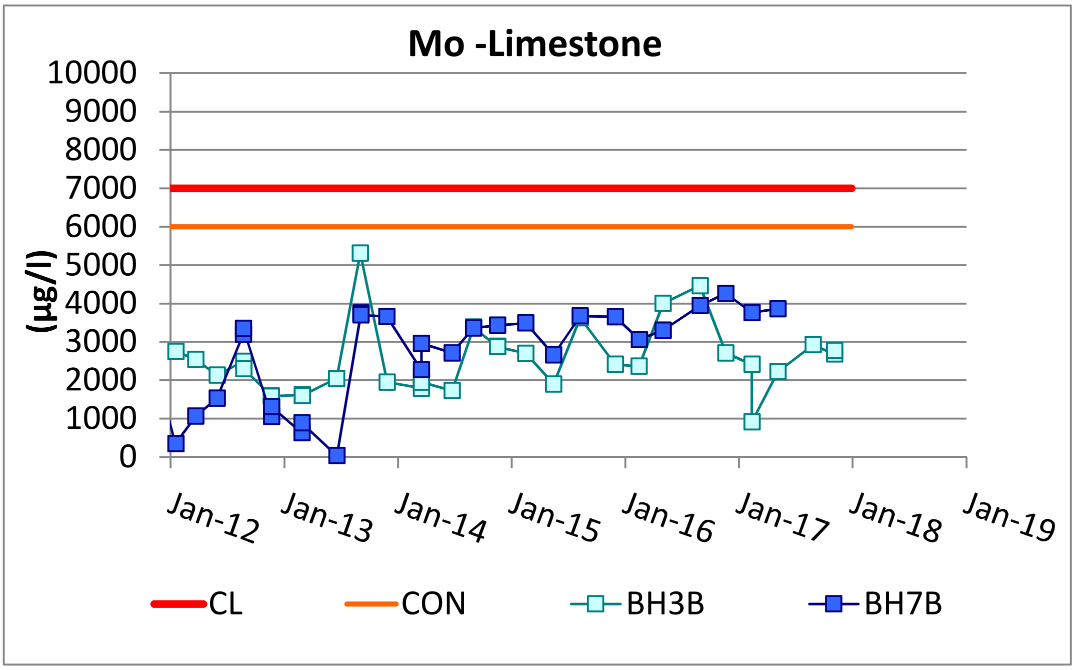


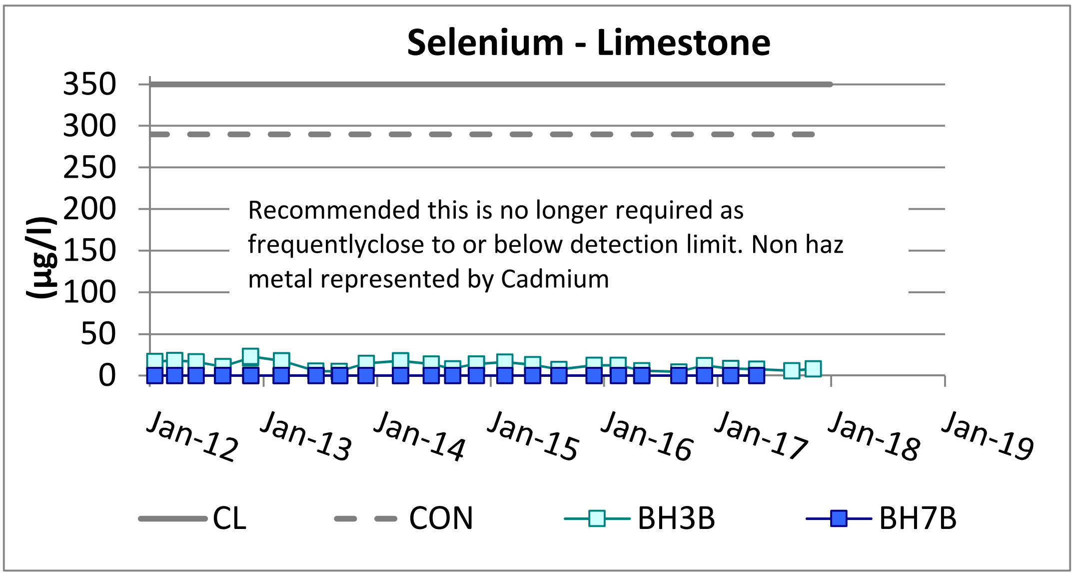



NH4-N - Limestone
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(mg/l)
CL
CON
BH3B
BH7B


Boron - Limestone
60,000
50,000
40,000
30,000
20,000
10,000
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
CL
CON
BH3B
BH7B

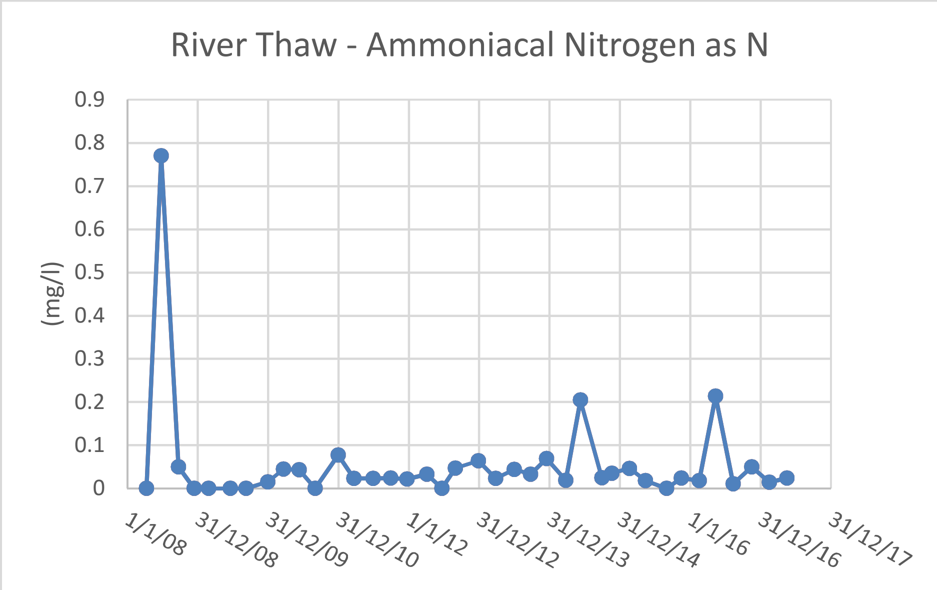

Cd -Limestone
2.50
2.00
1.50
1.00
0.50
0.00
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
CL
CON
BH3B
BH7B


Mo -Limestone
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
(µg/l)
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
CL
CON
BH3B
BH7B

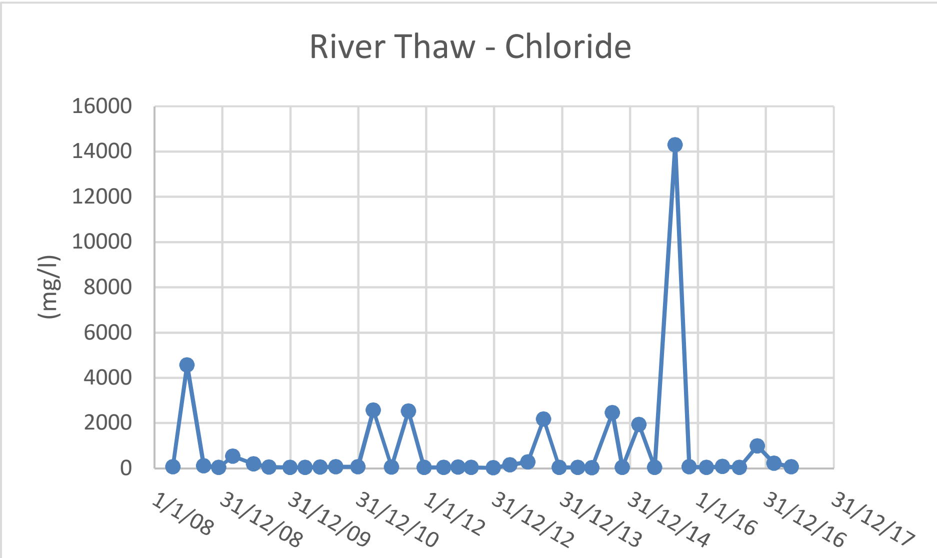

Selenium - Limestone
350
300
250
200
150
100
50
0
(µg/l)
Recommended this is no longer required as frequentlyclose to or below detection limit. Non haz metal represented by Cadmium
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
CL
CON
BH3B
BH7B

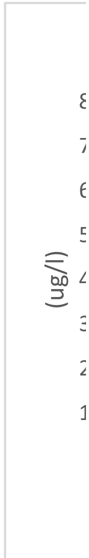
APPENDIX 4

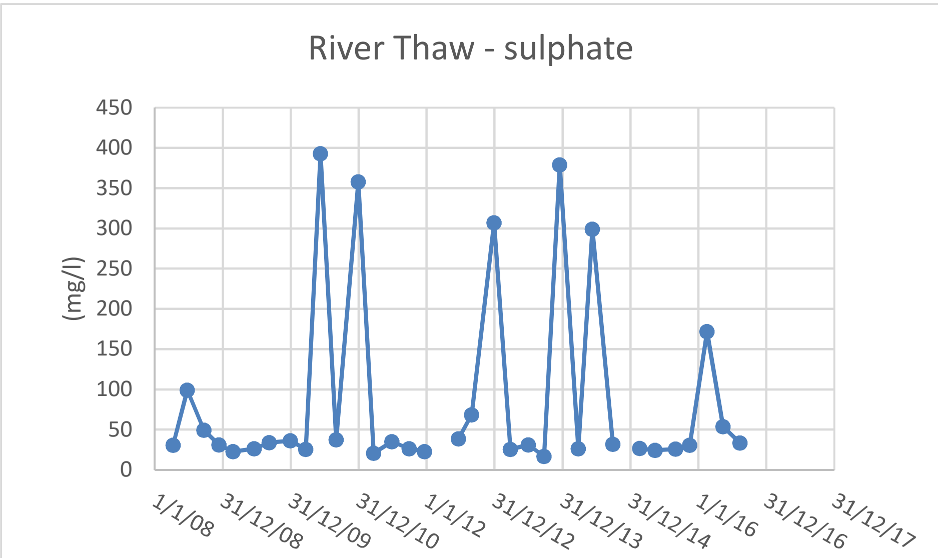
Surface water quality


River Thaw - Ammoniacal Nitrogen as N
(mg/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

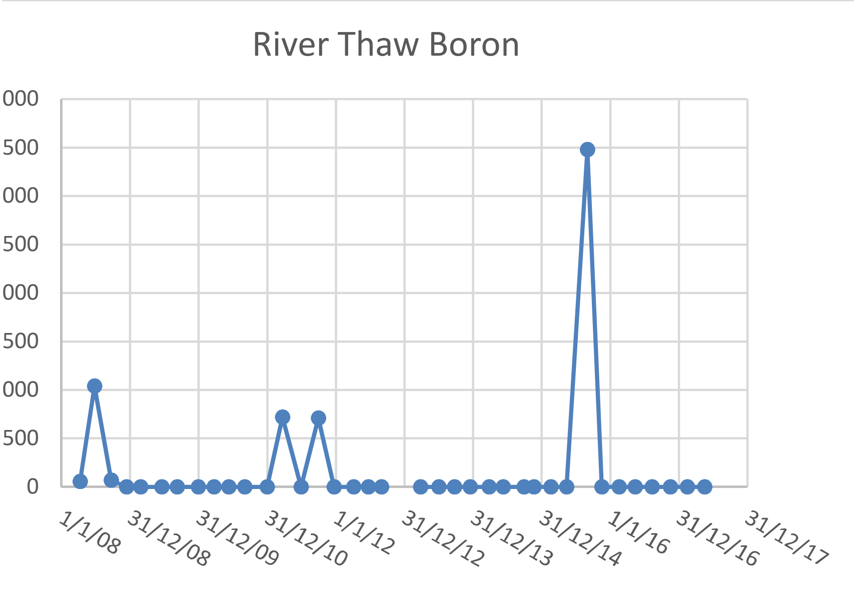

(ug/l)

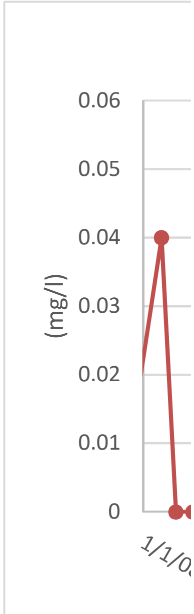

River Thaw - Chloride
(mg/l)
16000
14000
12000
10000
8000
6000
4000
2000
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

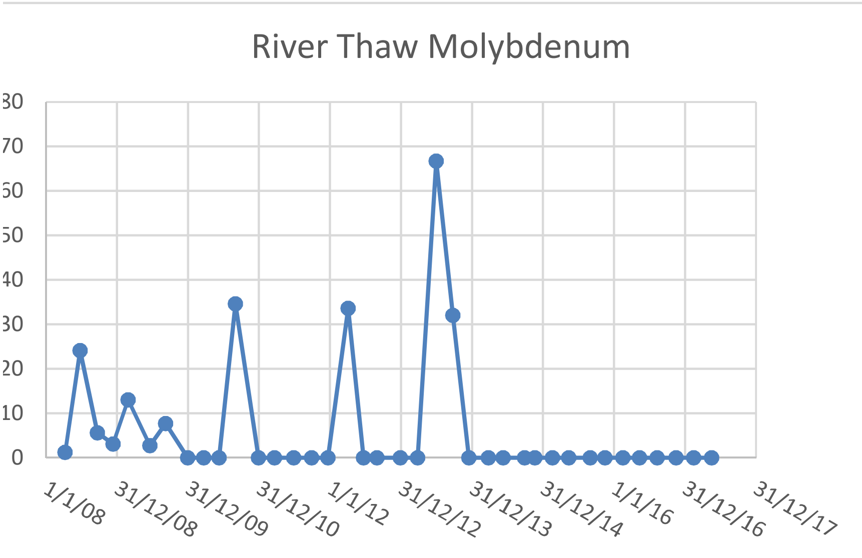

(ug/l)

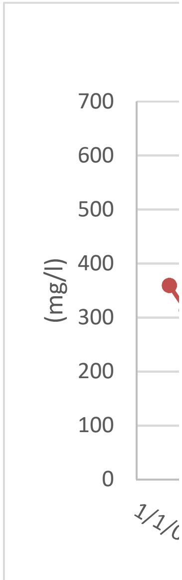

River Thaw - sulphate
(mg/l)
450
400
350
300
250
200
150
100
50
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

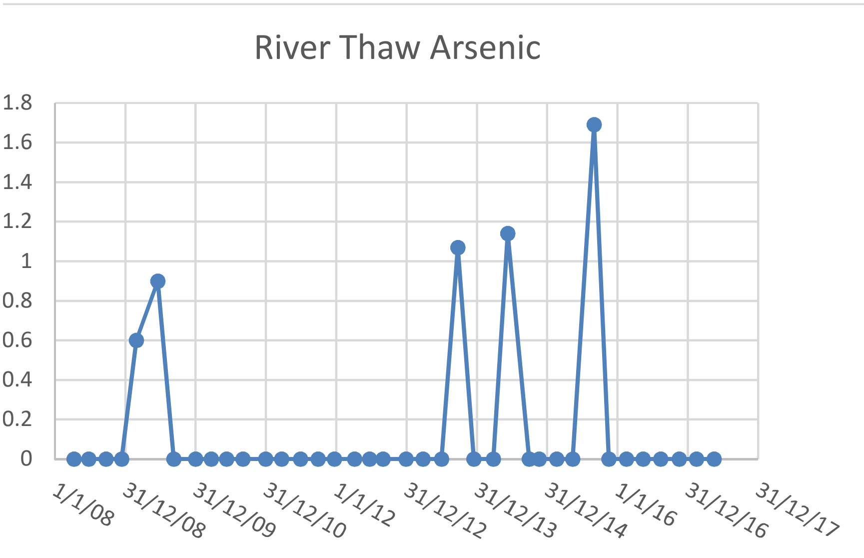

(ug/l)

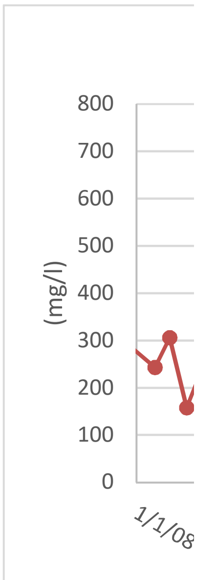

River Thaw Boron
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

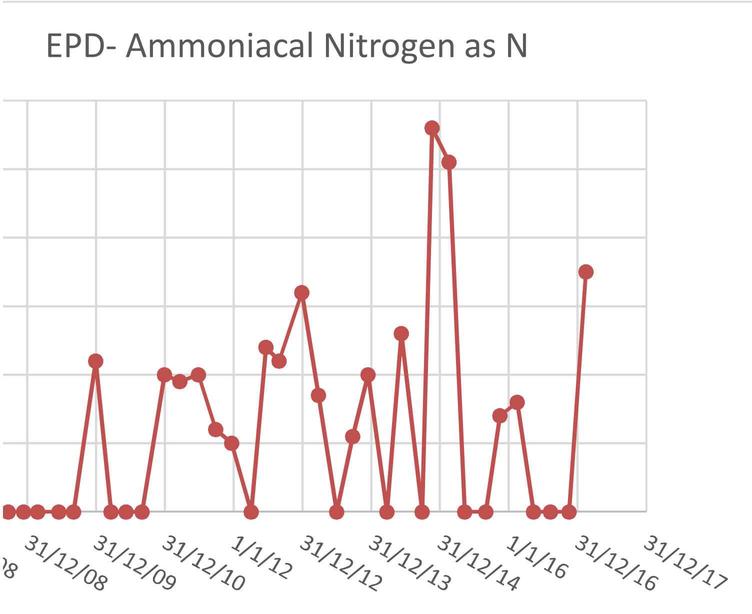

(mg/l)
0.06
0.05
0.04
0.03
0.02
0.01
0

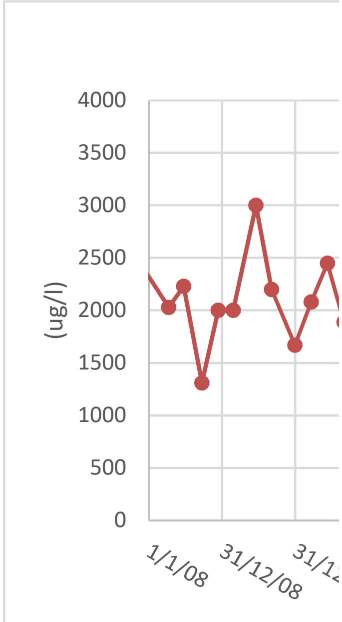

River Thaw Molybdenum
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

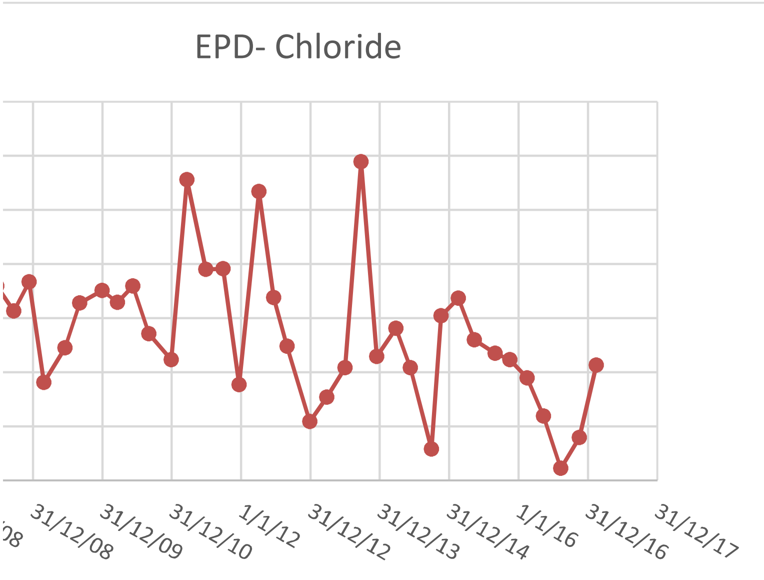

(mg/l)
700
600
500
400
300
200
100
0

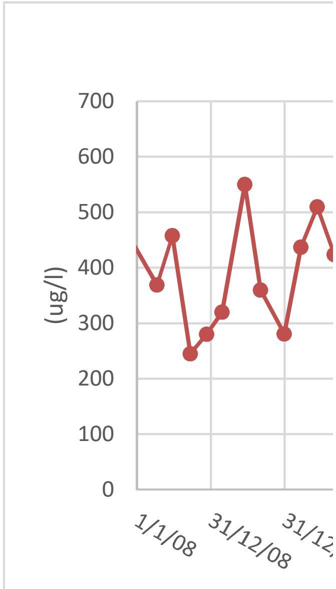

River Thaw Arsenic
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

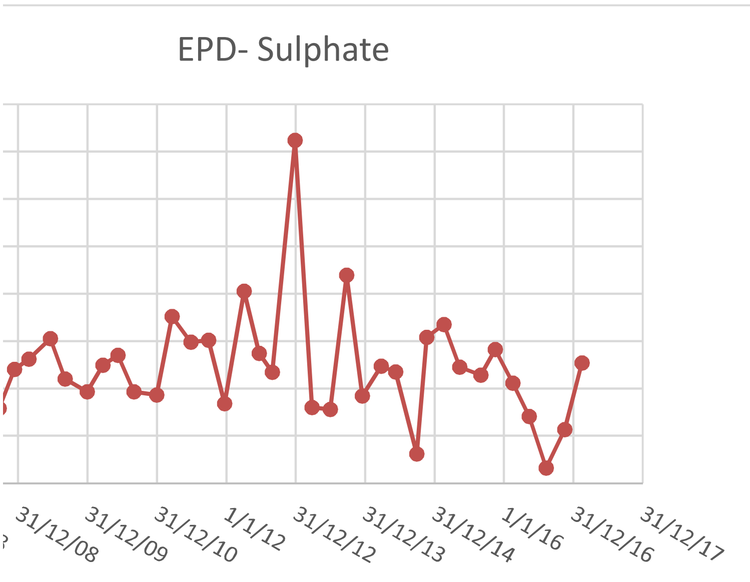

(mg/l)
800
700
600
500
400
300
200
100
0
1/1/08

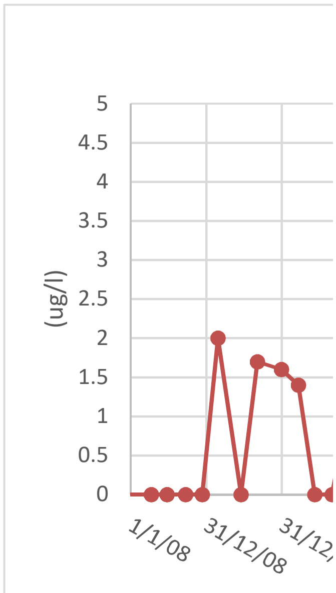

EPD- Ammoniacal Nitrogen as N
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

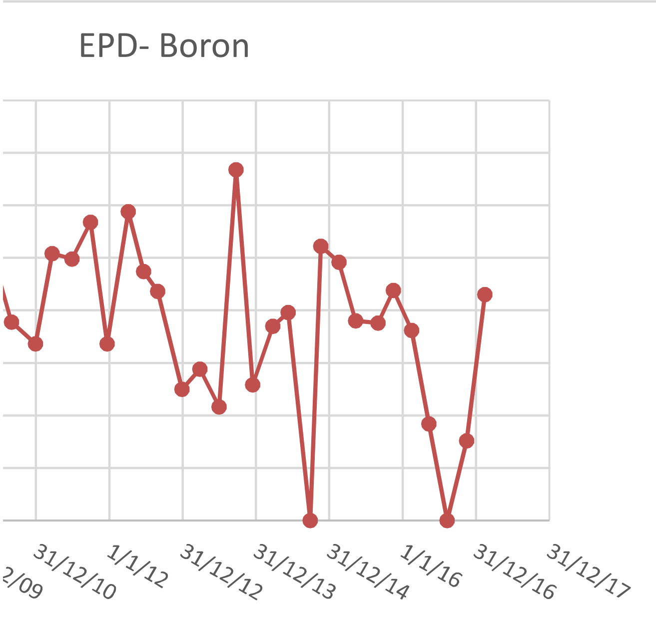

4000
3500
3000
2500
2000
1500
1000
500
0
(ug/l)
1/1/08
31/12/08

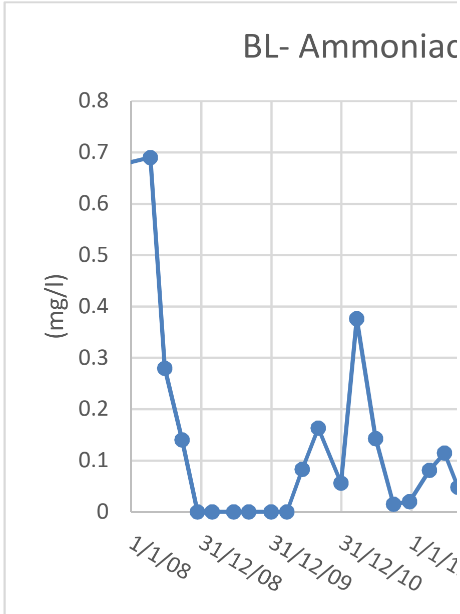

EPD- Chloride
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

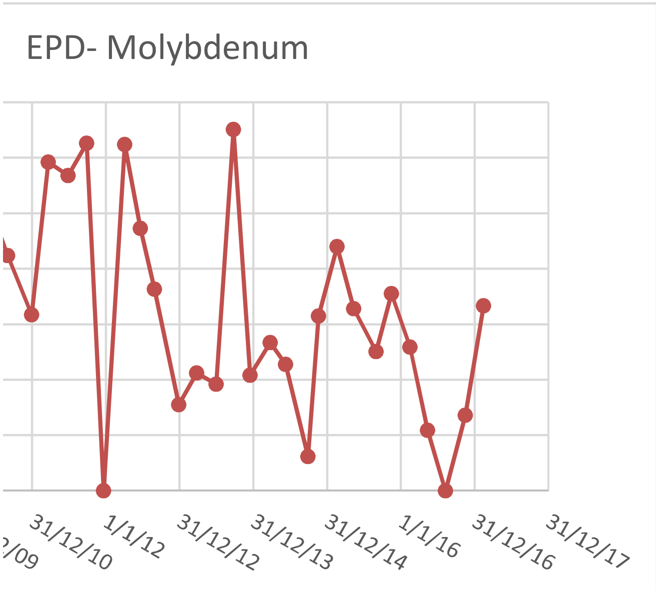

700
600
500
400
300
200
100
0
(ug/l)
1/1/08
31/12/08

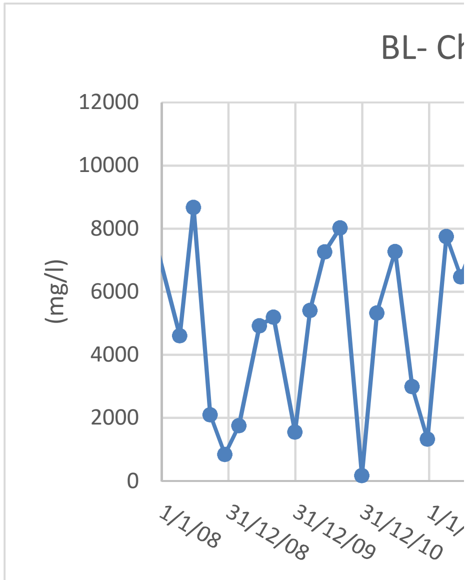

EPD- Sulphate
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

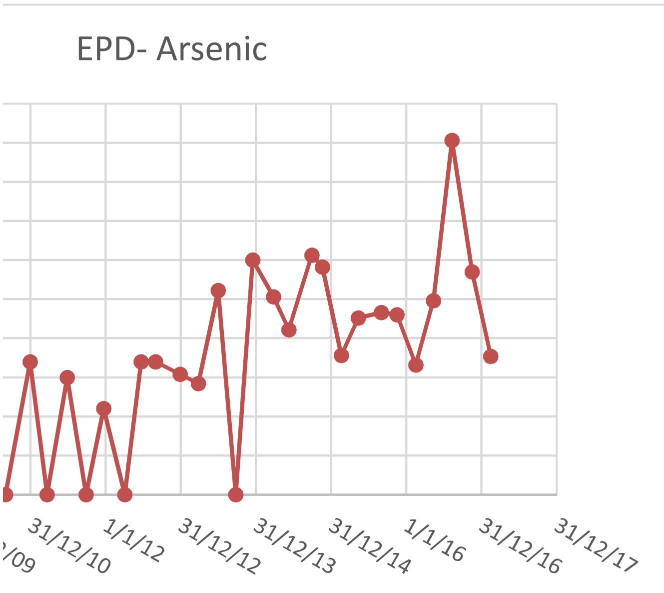

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
(ug/l)
1/1/08
31/12/08

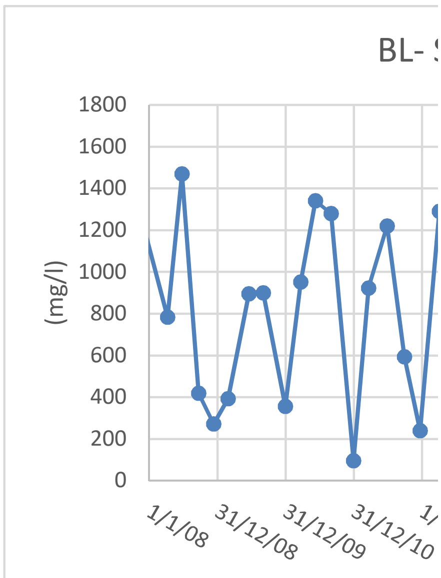

EPD- Boron
2/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

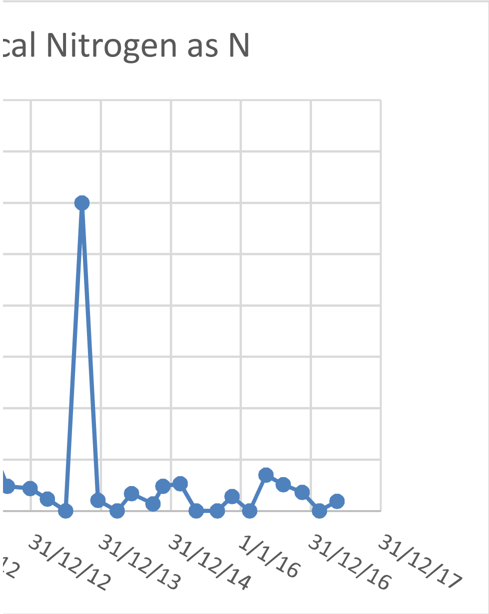

BL- Ammoniac
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
(mg/l)
1/1/08
31/12/08
31/12/09
31/12/10

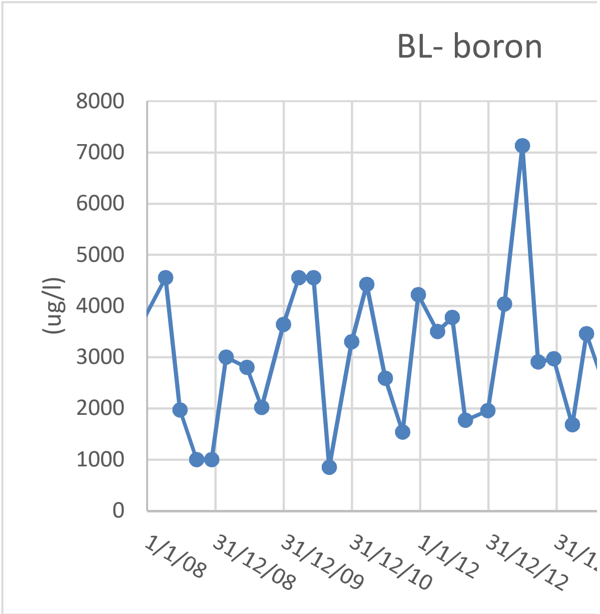

EPD- Molybdenum
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

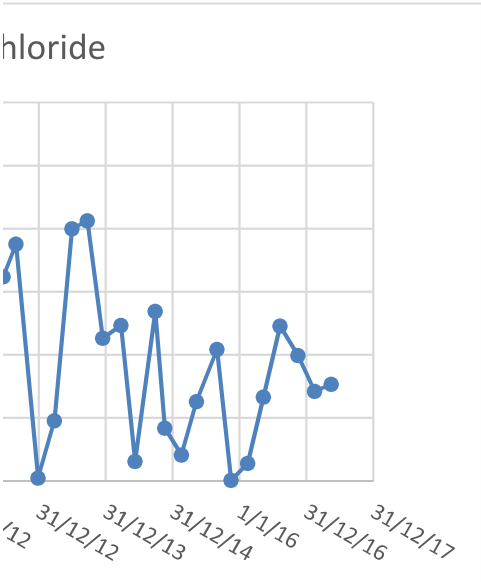

12000
10000
8000
6000
4000
2000
0
(mg/l)
1/1/08
31/12/08
31/12/09
31/12/10

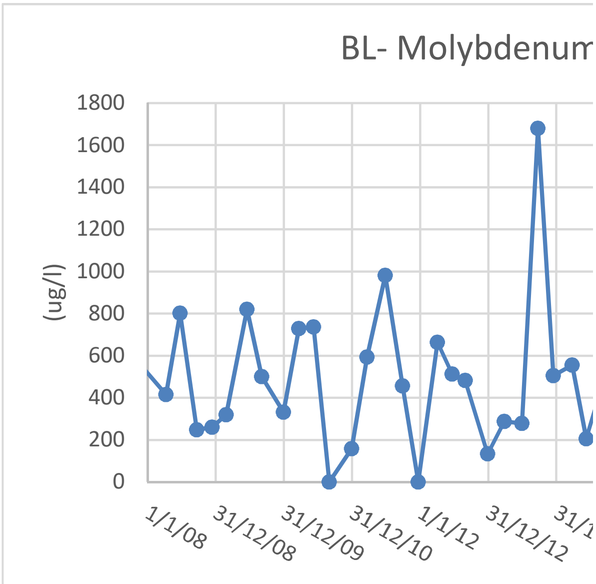

EPD- Arsenic
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

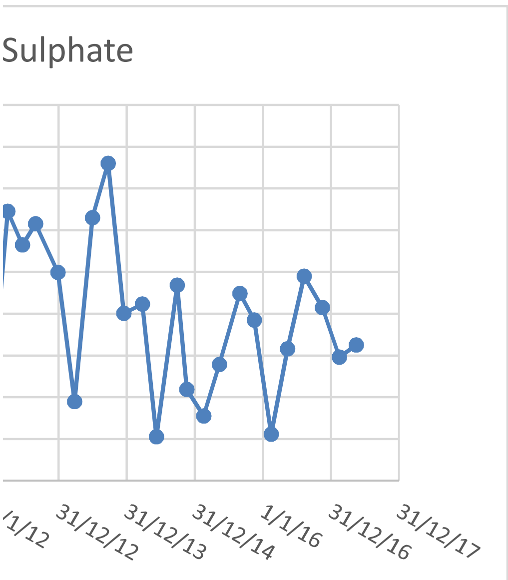

1800
1600
1400
1200
1000
800
600
400
200
0
(mg/l)
1/1/08
31/12/08
31/12/09
31/12/10

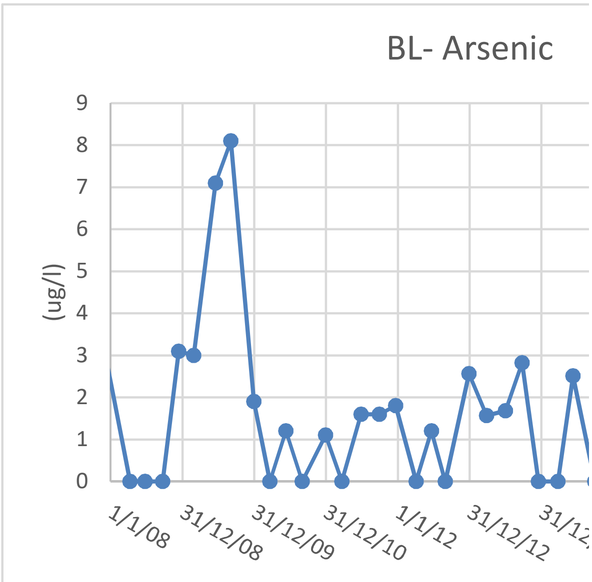

cal Nitrogen as N
/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

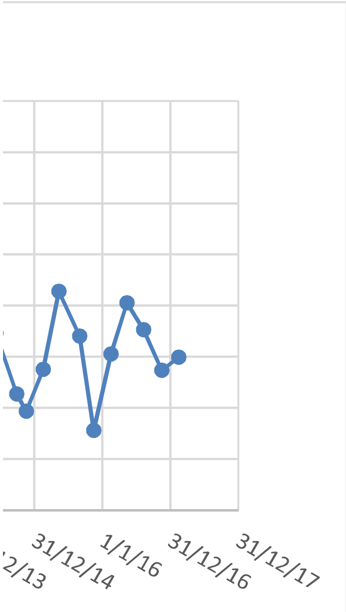

BL- boron
8000
7000
6000
5000
4000
3000
2000
1000
0
(ug/l)
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12

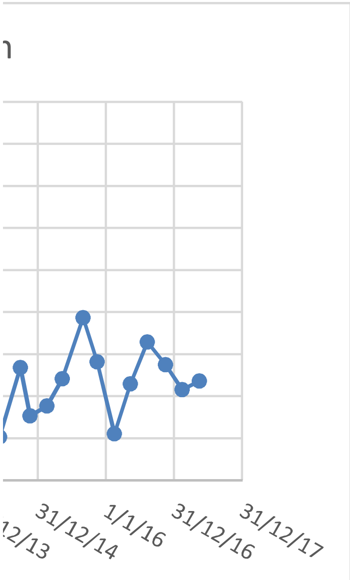

hloride
/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

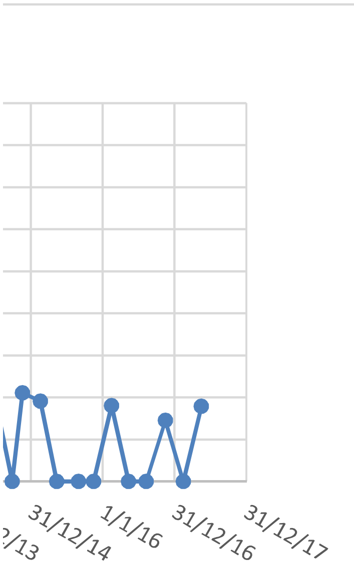

BL- Molybdenum
1800
1600
1400
1200
1000
800
600
400
200
0
(ug/l)
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12

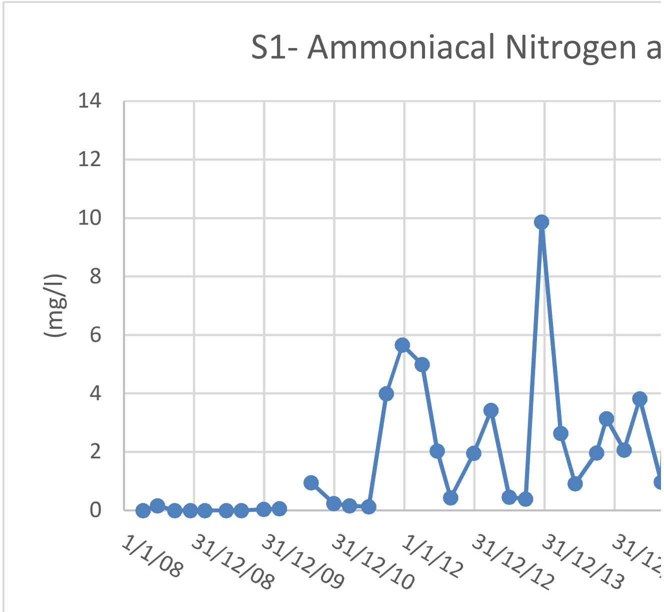

Sulphate
/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

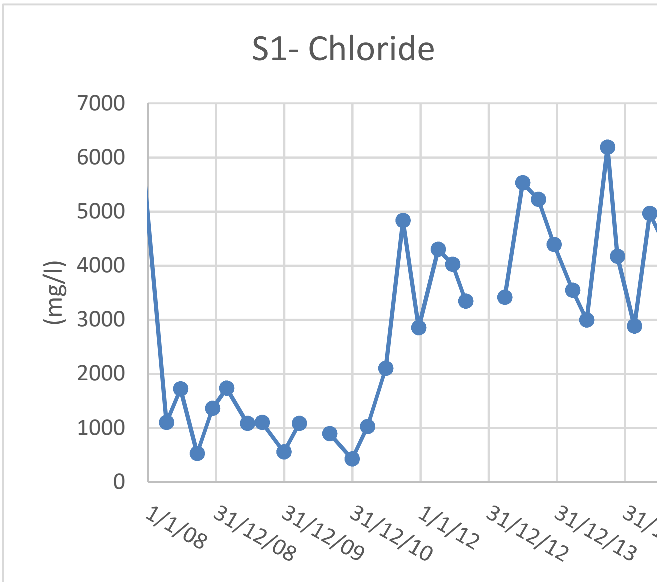

BL- Arsenic
9
8
7
6
5
4
3
2
1
0
(ug/l)
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12

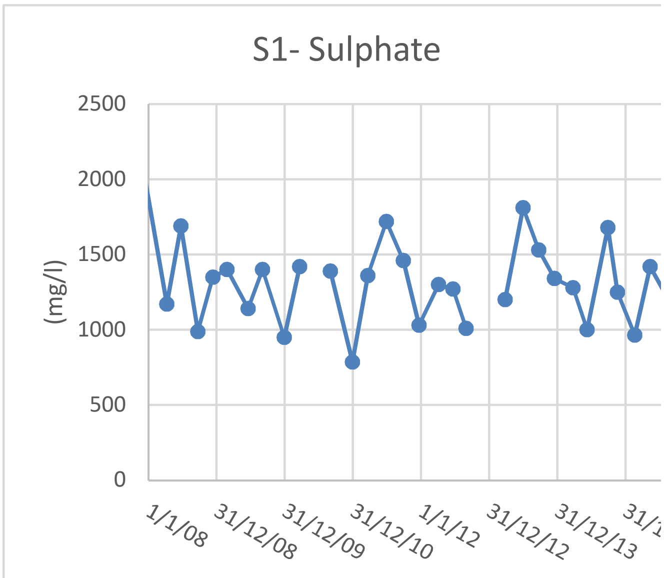

2/13
31/12/14
1/1/16
31/12/16
31/12/17

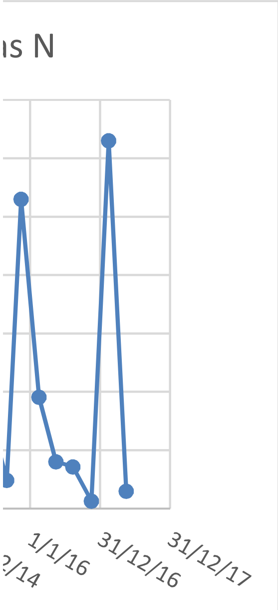

2/13
31/12/14
1/1/16
31/12/16
31/12/17

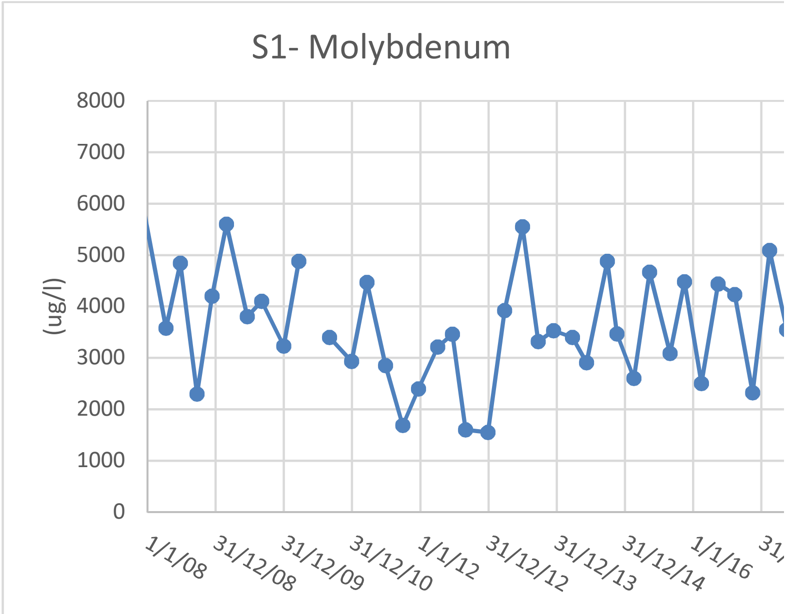

2/13
31/12/14
1/1/16
31/12/16
31/12/17

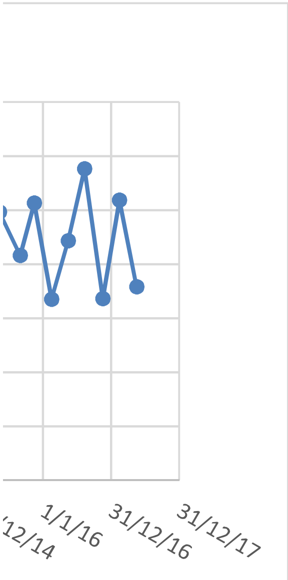

S1- Ammoniacal Nitrogen a
(mg/l)
14
12
10
8
6
4
2
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13

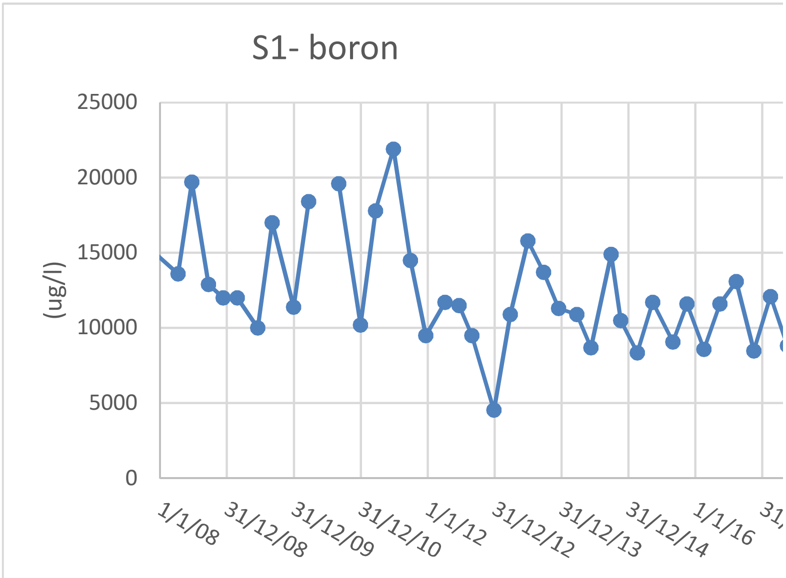

S1- Chloride
(mg/l)
7000
6000
5000
4000
3000
2000
1000
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13

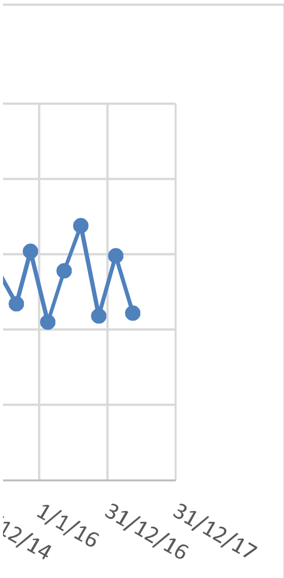

S1- Sulphate
(mg/l)
2500
2000
1500
1000
500
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13

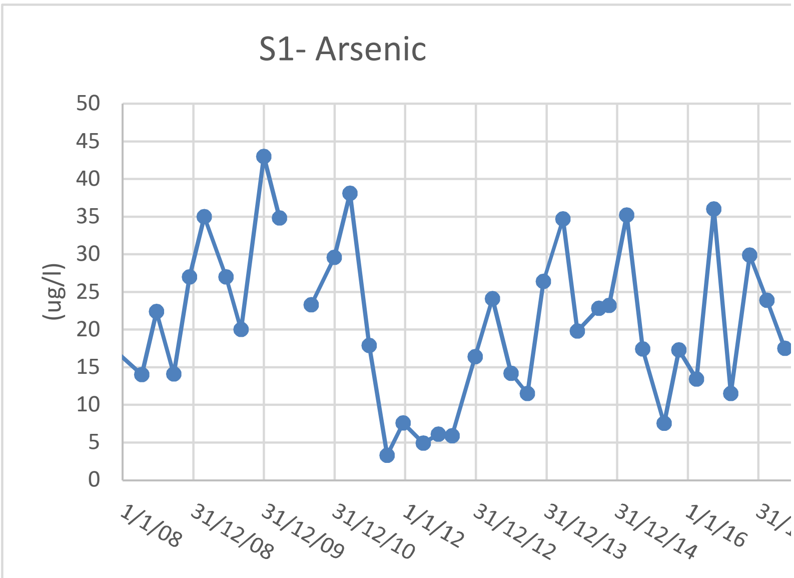

ıs N
2/14
1/1/16
31/12/16
31/12/17

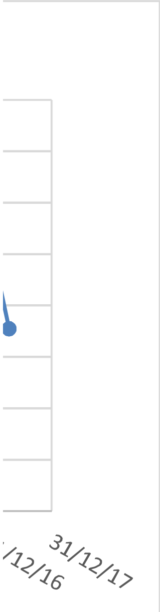

S1- Molybdenum
(ug/l)
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16

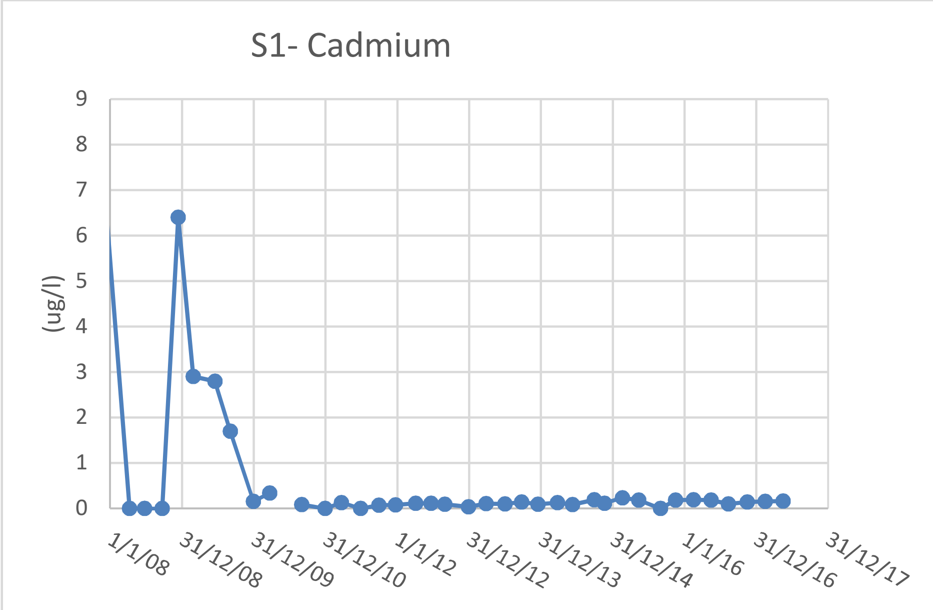

12/14
1/1/16
31/12/16
31/12/17

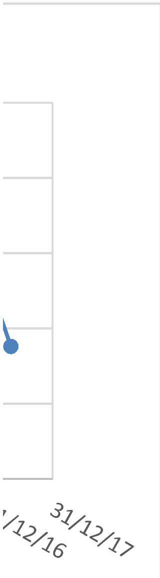

S1- boron
(ug/l)
25000
20000
15000
10000
5000
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16

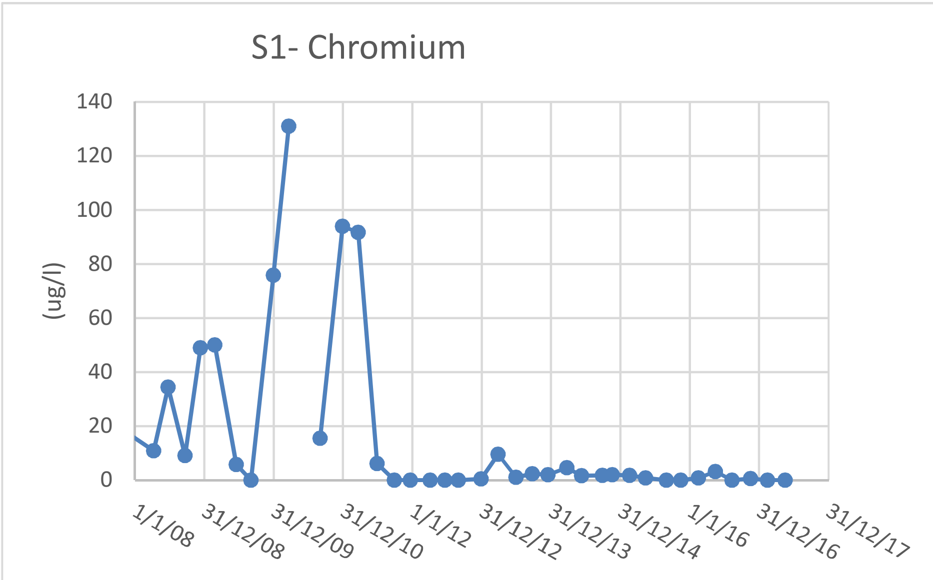

12/14
1/1/16
31/12/16
31/12/17


S1- Arsenic
(ug/l)
50
45
40
35
30
25
20
15
10
5
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16

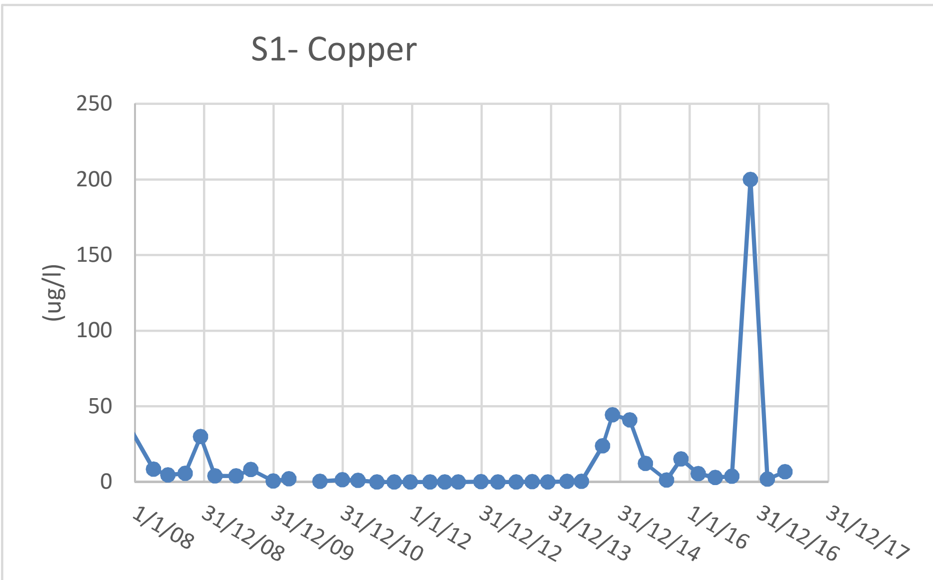

/12/16
31/12/17

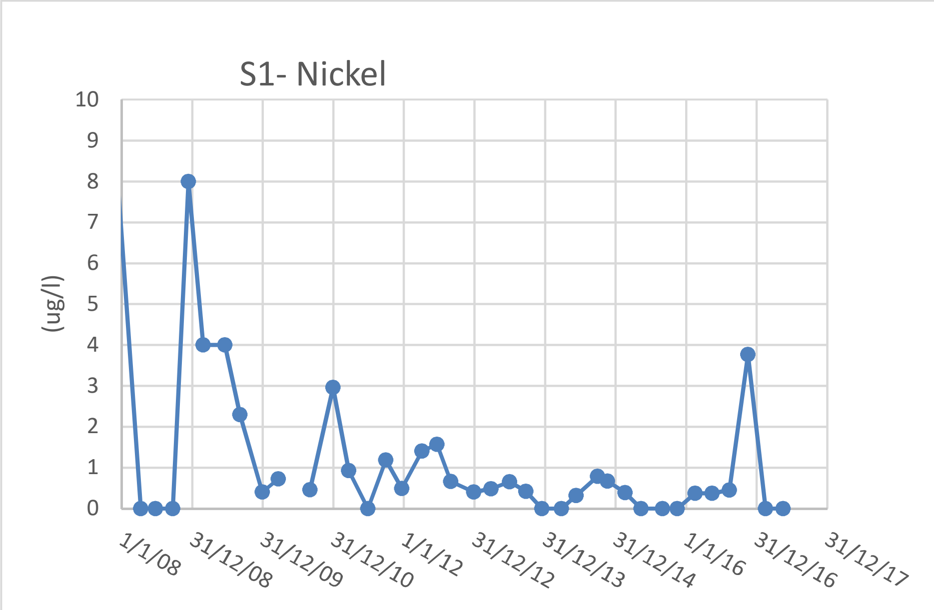

S1- Cadmium
(ug/l)
9
8
7
6
5
4
3
2
1
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

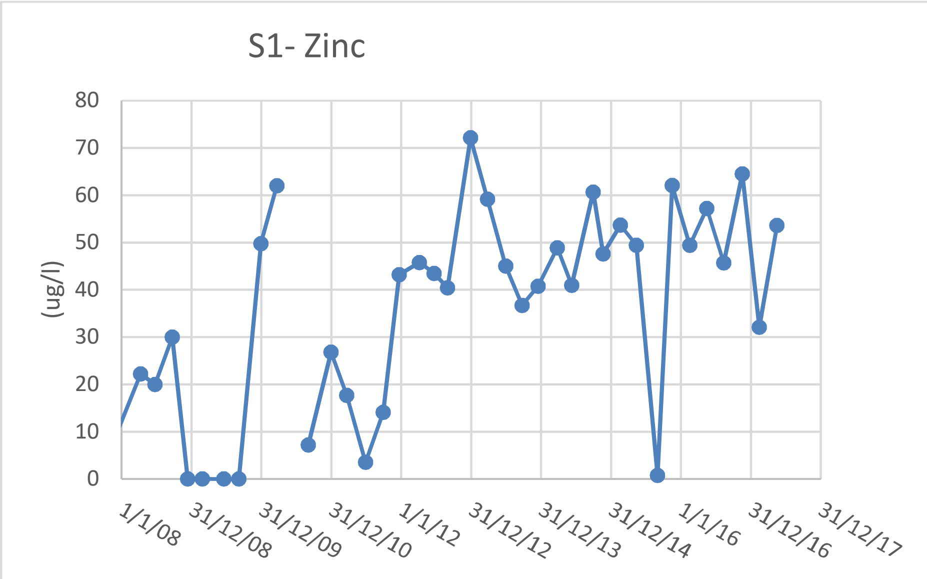

/12/16
31/12/17

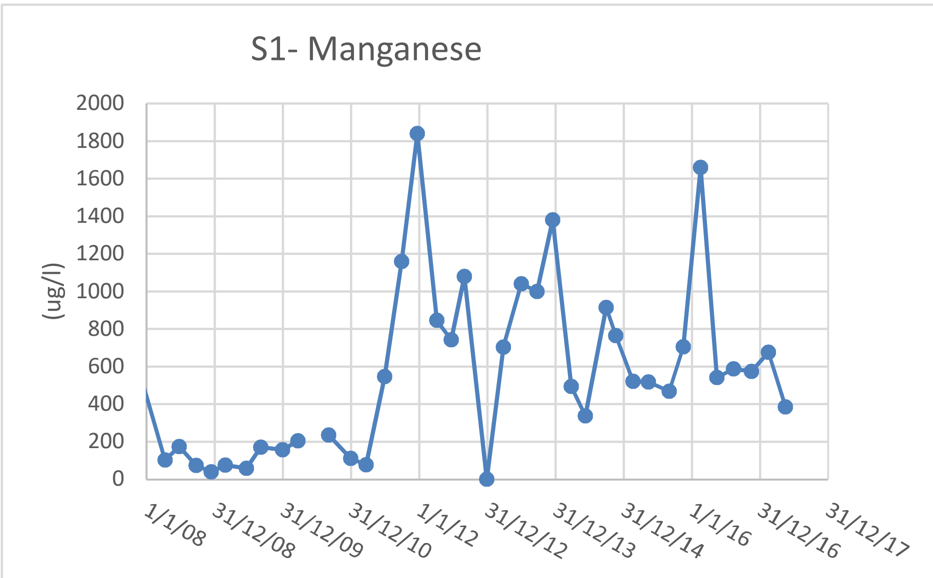

S1- Chromium
(ug/l)
140
120
100
80
60
40
20
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

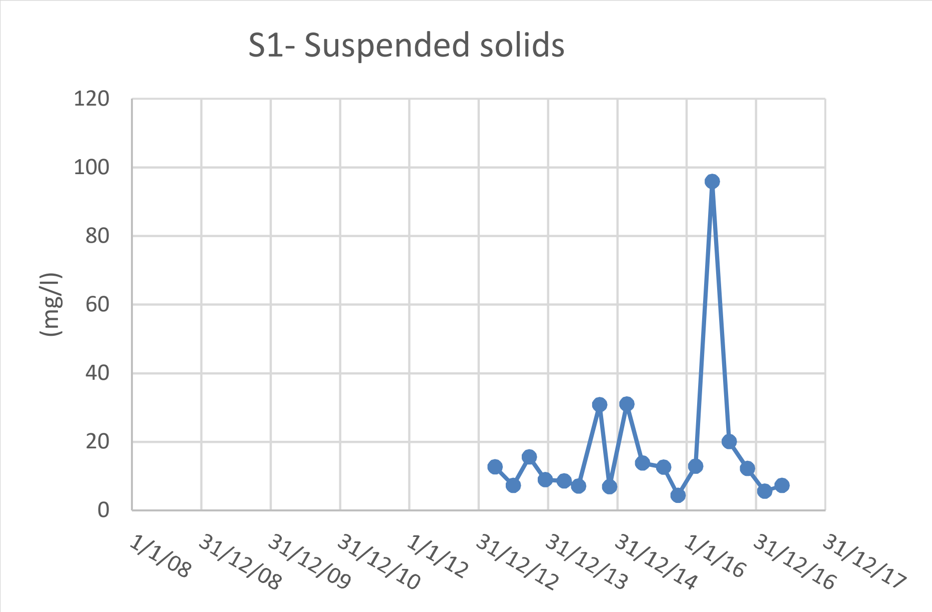

31/12/17

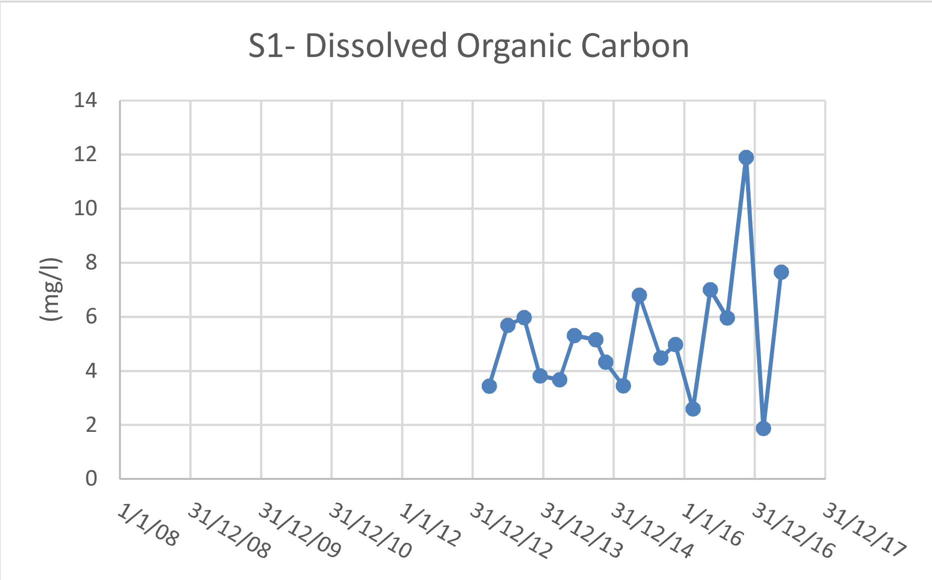

S1- Copper
(ug/l)
250
200
150
100
50
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

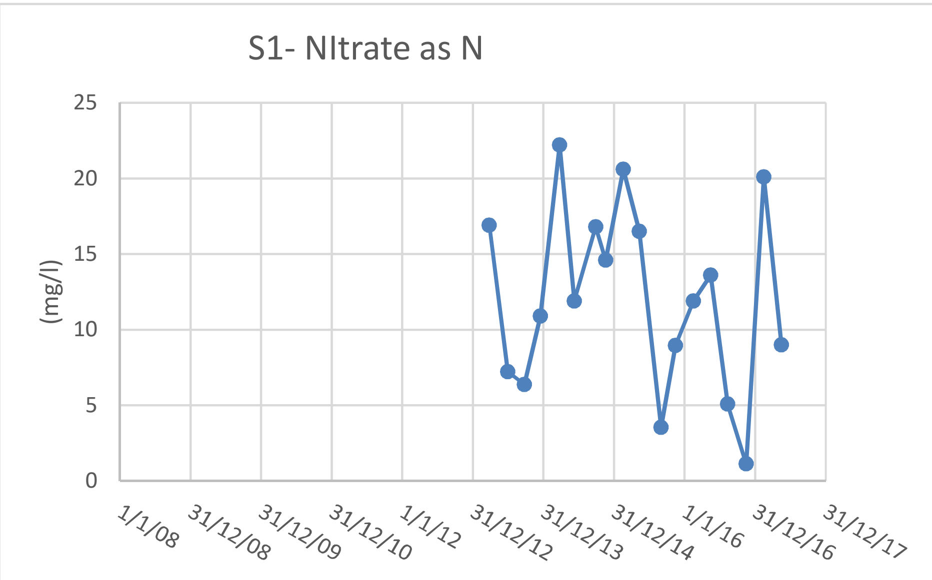

S1- Nickel
(ug/l)
10
9
8
7
6
5
4
3
2
1
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17


S1- Zinc
(ug/l)
80
70
60
50
40
30
20
10
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17


S1- Manganese
(ug/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17


S1- Suspended solids
(mg/l)
120
100
80
60
40
20
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17


S1- Dissolved Organic Carbon
(mg/l)
14
12
10
8
6
4
2
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17


S1- NItrate as N
(mg/l)
25
20
15
10
5
0
1/1/08
31/12/08
31/12/09
31/12/10
1/1/12
31/12/12
31/12/13
31/12/14
1/1/16
31/12/16
31/12/17

DATA from 1.1.2008 to 17.5.2017
values with '<' not included in stats

		G5 SPRING	G5 SPRING	EPD	EPD	3 RIVER THAV	3 RIVER THAV
		Mean	**Max**	**Mean**	**Max**	Mean	Max
Alkalinity to pH 4.5 as CaCC	mg/l	164	248	247	308	258	320
Ammoniacal Nitrogen as N	mg/l	2.22	12.60	0.04	0.20	0.09	0.77
Chloride	mg/l	3118	6190	268	589	583	4570
Nitrogen : Total Oxidised as	mg/l	8.94	23.10	2.50	3.63	3.69	4.93
Phosphate : Total as P	mg/l	0.28	5.00	4.92	129	255	5000
Fluoride	mg/l	1.17	13	0.73	11	0.98	10
Carbon, Organic : Total as C	mg/l	5.80	12.00	1.74	4.79	2.96	8.28
Conductivity at 20C	µS/cm	10258	19000	1569	2820	2181	12200
pH	pH units	7.33	7.88	8.02	8.20	8.03	8.30
Arsenic Dissolved	µg/l	21	43	1.83	4.53	1.07	1.80
Selenium Dissolved	µg/l	14	63	1.49	8.00	1.48	8
Antimony, Dissolved	µg/l	10	17	8.65	10.00	7.58	10
Molybdenum, Dissolved	µg/l	3569	5600	333	651	26	67
Vanadium, Dissolved	µg/l	51	188	18	20	17	30
Aluminium, Dissolved	µg/l	130	468	105	400	208	733
Cadmium, Dissolved	µg/l	0.51	6.40	0.07	0.50	0.10	0.40
Chromium, Dissolved	µg/l	17	131	0.70	6.00	0.99	6.00
Copper, Dissolved	µg/l	12	200	1.12	7.75	1.85	10
Nickel, Dissolved	µg/l	1.16	8.00	0.78	2.00	0.82	2.78
Zinc, Dissolved	µg/l	48	400	14	400	25	400
Boron, Dissolved	µg/l	12373	21900	1954	3340	603	1040
Calcium, Dissolved	mg/l	707	1200	177	289	119	174
Iron, Dissolved	µg/l	313	2690	113	357	278	1410
Magnesium, Dissolved	mg/l	66	123	18	26	48	268
Manganese, Dissolved	µg/l	567	1840	177	827	28.01	121
Potassium, Dissolved	mg/l	151	269	18.19	30.80	14.70	84.80
Sodium, Dissolved	mg/l	1718	3350	156	318	317	2170
Sulphate, Dissolved as SO4	mg/l	1300	1810	249	724	106	663
Mercury, Dissolved	µg/l	0.85	13	0.41	11	0.74	14.00
Bicarbonate as HCO3	mg/l	201	303	301	376	326	390
Ionic Balance	%					#DIV/0!	0.00
							0.00

Solids, suspended at 105C	mg/l	17	96	6.8	38	18	102
Hardness; Total as CaCO3	mg/l	2434	3400	508	827	747	5190
Nitrate as N	mg/l	12.08	22.20	2.72	3.63	3.36	4.02
Nitrite as N	mg/l	0.51	1.06	0.01	0.01	0.02	0.08
Carbon, Organic, Dissolved	mg/l	5.23	11.90	1.51	2.08	2.99	7.89
Salinity	ppt	0.00	0.00	#DIV/0!	0.00	#DIV/0!	0.00

V

N MDL		SALINE LAGO Mean	SALINE LAGOON Max
Alkalinity to pH 4.5 as CaCC	mg/l	171	270
Ammoniacal Nitrogen as N	mg/l	0.13	0.69
Chloride	mg/l	4023	8680
Nitrogen : Total Oxidised as	mg/l	1.09	3.47
Phosphate : Total as P	mg/l	0.32	7.00
Fluoride	mg/l	1.20	15.00
Carbon, Organic : Total as (	mg/l	3.91	14.60
Conductivity at 20C	µS/cm	11634.7	23400.0
pH	pH units	8.28	8.83
Arsenic Dissolved	µg/l	1.97	8.10
Selenium Dissolved	µg/l	3.53	47.00
Antimony, Dissolved	µg/l	7.94	10.00
Molybdenum, Dissolved	µg/l	483.5	1680.0
Vanadium, Dissolved	µg/l	18.29	61.00
Aluminium, Dissolved	µg/l	100.6	627.0
Cadmium, Dissolved	µg/l	0.11	0.54
Chromium, Dissolved	µg/l	1.01	10.00
Copper, Dissolved	µg/l	2.32	30.00
Nickel, Dissolved	µg/l	0.77	5.00
Zinc, Dissolved	µg/l	4.82	50.00
Boron, Dissolved	µg/l	2982.2	7130.0
Calcium, Dissolved	mg/l	227.4	433.0
Iron, Dissolved	µg/l	419.3	10000.0
Magnesium, Dissolved	mg/l	270.6	503.0
Manganese, Dissolved	µg/l	135.4	2000.0
Potassium, Dissolved	mg/l	112.8	233.0
Sodium, Dissolved	mg/l	2449.9	5180.0
Sulphate, Dissolved as SO4	mg/l	785.5	1520.0
Mercury, Dissolved	µg/l	0.30	2.00
Bicarbonate as HCO3	mg/l	215.8	329.4
Ionic Balance	%	#DIV/0!	0.00
	Min	#DIV/0!	0.00

Solids, suspended at 105C	mg/l	7.56	27.10
Hardness; Total as CaCO3	mg/l	1517.7	3050.0
Nitrate as N	mg/l	1.23	3.13
Nitrite as N	mg/l	0.01	0.03
Carbon, Organic, Dissolved	mg/l	2.91	5.61
Salinity	ppt	7.00	15.60

Registered Office: InTec, Parc Menai, Bangor, Gwynedd, LL57 4FG
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Fax: 01248 672601
Email: contact@caulmert.com
Web: www.caulmert.com