REPORT

Elsenham Landfill

Hydrogeological Risk Assessment Review

Submitted to:

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1.0 INTRODUCTION

1.1 Background

Golder Associates (UK) Ltd (Golder) have been appointed by Viridor Waste Management (Viridor) to prepare a Hydrogeological Risk Assessment (HRA) Review for Elsenham Landfill, hereby referred to as 'the Site'.

Elsenham Landfill is located to the east of Elsenham village, approximately 2 km north of Stanstead airport. The Site has accepted non-hazardous commercial and industrial waste since 2004. The Site is comprised of Phase 1, Phase 2, Phase 3, Phase 4A and Phase 4B. Phases 1, 2 and 4A accepted non-hazardous waste, Phase 4B partially accepted non-hazardous inactive waste and was subsequently restored with inert waste and Phase 3 is proposed to accept inert waste only.

The original HRA was carried out in October 2003 (Enviros Consulting Ltd, 2003) in support of the Pollution Prevention Control (PPC) Permit application, with the PPC permit issued in August 2004. A subsequent PPC application was submitted during 2005, which included an extension area, a revision to the restoration contours and a number of design and operational revisions. HRA reviews were undertaken in 2008 (SLR, 2008), 2012 (SLR, 2012) and 2013 (SLR, 2013).

This HRA review is based on monitoring, construction and Site investigation data available for the Site over the past six years (January 2014 to April 2020).

1.2 Objectives

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

This HRA review has been completed in-line with Agency guidance 'Landfill development: groundwater risk assessment for leachate' published in February 2016. The purpose of the guidance is to ensure that leachate from a landfill will not pose an unacceptable risk to groundwater at any stage of its lifecycle. This HRA review will assess the risk to groundwater and/or surface water posed by the landfill throughout the aftercare and management stage of the landfill operation.

The HRA review will also define specification design principles for Phase 3 for depth, basal engineering, sidewall engineering and capping and 4B for sidewall engineering and capping such that the accepted inert wastes may be managed appropriately.

1.3 Sources of Information

The information on which this HRA review is based has been obtained from the following sources:

- Permit Variations;
- HRA/HRARs;
- Cell Construction Specification; and
- Annual monitoring reports.

Leachate, groundwater and surface water monitoring data for the period January 2014 to April 2020 has also been provided by Viridor for use in this HRA review. Golder has not independently verified this data.

2.0 SITE DETAILS

2.1 Permit Details

Following the PPC Permit application in 2003, Permit EPR/MP3235KP was issued in August 2004. The current variation of the Permit is EPR/MP3435KP/V006 issued in March 2016. Since the submission of the 2013 HRAR the updates in Table 1 have been made to the Permit.

Table 1: Summary of Changes to the Permit since the last HRAR.

Description	Date	Comments
Variation determined EPR/MP3435KP/V004	29/05/13	Agency variation to implement the changes introduced by IED
Variation determined EPR/MP3435KP/V005	24/04/15	Varied permit issued. Annual waste input limit increased to 800,000 tonnes per year.
Environment Agency Landfill Sector Review 2015 Permit reviewed Variation determined EPR/MP3435KP/V006	22/03/16	Varied and consolidated permit issued

2.2 Geology

The British Geological Society (BGS) (BGS, 2020) 1:50,000 geological map depicts the bedrock geology at the Site to be the London Clay Formation (London Clay). The London Clay is underlain by the Thanet Formation and Lambeth Group (London Tertiaries).

The succession of superficial deposits at the Site is the Lowestoft Formation comprising Boulder Clay (Boulder Clay) overlying the Kesgrave Catchment Subgroup comprising sand and gravel (Kesgrave Sand and Gravels) which sits unconformably on the London Clay.

The Kesgrave Sand and Gravels has been removed prior to landfilling with the base of the landfill developed into the London Clay.

It has been accepted that beneath each existing landfill phase that a thickness of engineered and *insitu* London Clay of at least 10 m exists above the London Tertiaries. It is understood that the depth to the London Tertiaries and hence total thickness of the London Clay at the Site has been proven in a single borehole to a thickness of 10.5 m (SLR, 2005) whilst other investigations have identified thicker units of London Clay without proving the London Tertiaries.

The following information is available regarding the underlying geology at the Site:

- A site investigation undertaken in 1993 proved the London Clay to be at least 10 m thick;
- A site investigation undertaken in 2001 around the eastern perimeter of the installation boundary, proved the London Clay to a minimum thickness of 15 m to the north of the Site and 5 m to the south east of the installation boundary; and

- A Site investigation in January 2019 proved the London Clay to a minimum thickness of 6 m in the Phase 3 area. At this depth a mudstone was observed which caused refusal of the borehole, hence, the total thickness of the London Clay was not proven in this investigation.

2.3 Hydrogeology

The Kesgrave Sand and Gravels aquifer is classified by the Environment Agency as a Secondary A Aquifer.

The London Clay and Boulder Clay are classified as Unproductive Strata.

Groundwater flow within the Kesgrave Sand and Gravels is west, towards the Stansted Brook. Groundwater elevations contours for April 2020 are presented in Drawing 1. Groundwater flow is locally influenced by the effects of active on-site dewatering relating to Phase 4 and the presence of a passive groundwater drain surrounding Phases 1 to 3.

The average hydraulic gradient across the Site is estimated to be 0.003 in the north of the Site, and 0.02 in the south.

The groundwater vulnerability is designated as low across the majority of the Site, with the south east corner classified as medium-low (Defra, 2020).

A Zone III – Total Catchment Source Protection Zone (SPZ) crosses a proportion of the east of the Site (Defra, 2020). A Zone III area is defined by the Environment Agency as the total area needed to support the abstraction or discharge from the protected groundwater source. However, the defined area does not appear to intercept any part of the Site that has had or proposed to have landfilling activities.

As there is no site-specific data available for groundwater levels within the London Tertiaries, published data for Chalk groundwater elevation from the hydrogeological map provided by BGS have been used. It is noted that this data relates to the Chalk and not the London Tertiaries and that the data is over 40 years old, therefore should be used indicatively. Figure 1 is extracted from the regional hydrogeological map (BGS, 1981) from August/September 1976. During this period, groundwater levels within the Chalk in the area surrounding the Site are shown to be approximately 65 m AOD. The base of the London Tertiaries are reported by BGS (1984) to be in the order of approximately 75 m (BGS, 1984), indicating that based on these data there is the potential that the Chalk is unconfined with the London Tertiaries unsaturated above this.

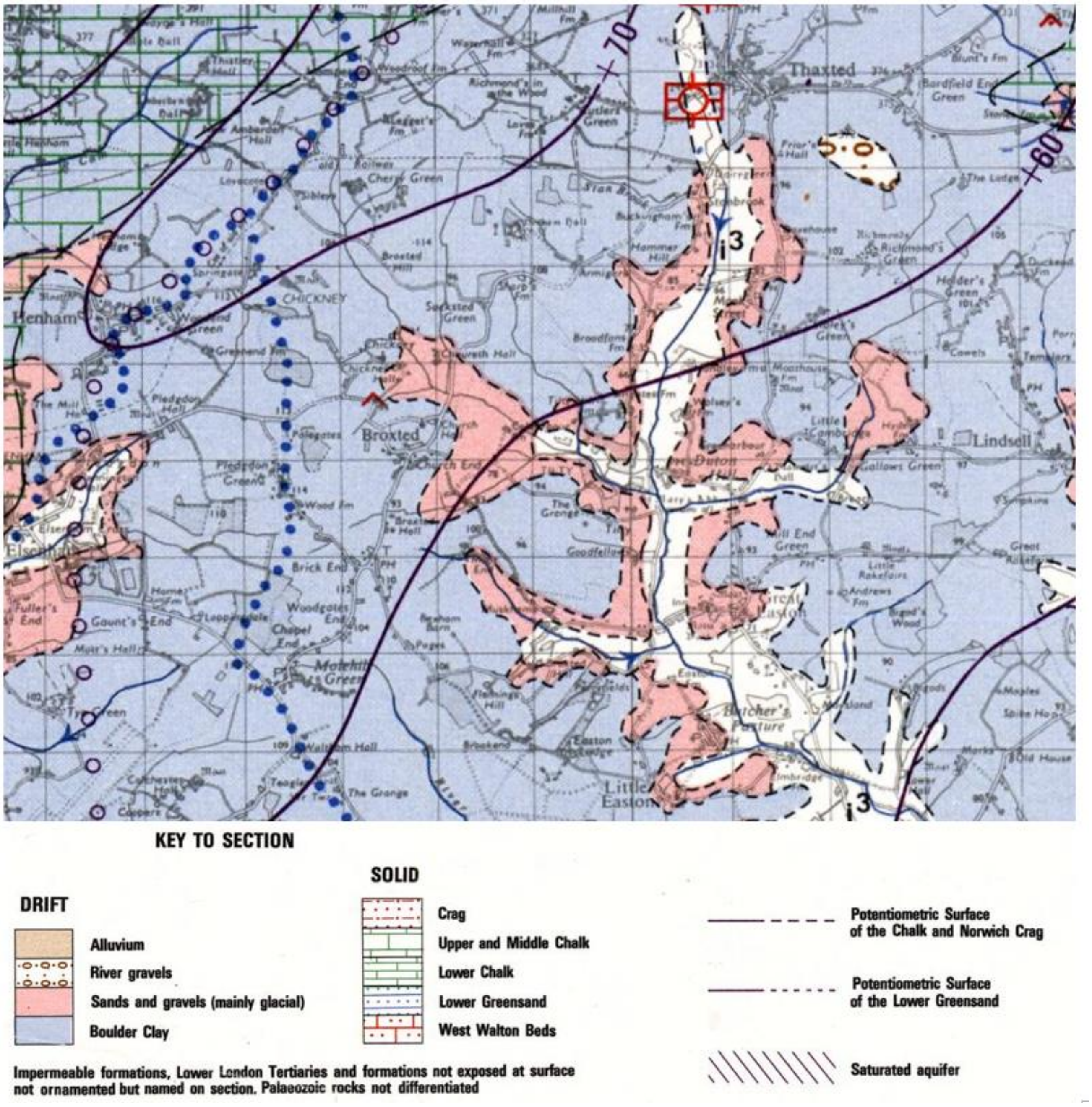

Figure 1: Hydrogeological Map of the Chalk

2.4 Hydrology

The Site is located within the Stanstead Brook catchment. Stanstead Brook is located approximately 80 m north west of the Site boundary, flowing towards the south west. Stanstead Brook joins the River Stort approximately 6 km downstream of the Site (SLR, 2005).

2.5 Basal and Sidewall Engineering

The Kesgrave Sand and Gravels have been removed prior to landfilling with the base of the void excavated into the underlying London Clay. The London Clay forms the basal geological barrier at the Site.

In Phases 1, 2 and 4A the artificial liner comprises 0.5 m of reworked London Clay overlain by 2 mm HDPE which extends 3 m up the side slope. No artificial liner is proposed for Phases 3 and 4B.

The side slope liner in Phase 1 comprises 15 to 23 m of engineered Boulder Clay and London Clay. Phase 2 and 4A, 3 to 11 m of engineered Boulder Clay and London Clay. Phase 4B has 2 m of engineered Boulder Clay.

2.5.1 Specification for Basal and Sidewall Engineering of Phase 3

Inert landfills must have a geological barrier to protect soil and groundwater. The geological barrier may be derived from *in situ* materials or artificially established.

A geological barrier must extend along the base and up the sides of the void.

Phase 3 will be developed in the void generated from the excavation of Boulder Clay, Kesgrave Sand and Gravels and London Clay, hence the geological barrier in the base and lower sidewalls of Phase 3 will comprise *in situ* London Clay. Where *in situ* geological barriers are relied on, they must be equivalent to 1 m thick with a hydraulic conductivity of less than or equal to $1x10^{-7}$ m/s. The hydraulic conductivity of the London Clay is much lower than $1x10^{-7}$ m/s, hence a minimum thickness over the base and lower sidewalls of 1 m would be adequate; it is noted that there is a greater thickness of London Clay present beneath the Site.

The total thickness of the London Clay has not been proven beneath Phase 3. In accordance with the requirements of an inert landfill, the void could be further deepened to 1 m above the proven depth of the base of the London Clay. If further deepening of the phase is required beyond that has been already characterised, this would need to be supported by further geological characterisation.

Further deepening of the void should also be accompanied by an investigation of piezometric pressure in the London Tertiaries accompanied by an assessment of the potential for basal heave.

For the upper sidewalls coincident with the Kesgrave Sand and Gravels, an artificially established geological sidewall barrier will be required. Artificially established geological barriers must be at least 500 mm thick and afford environmental protection equivalent to a layer 1 m thick with hydraulic conductivity of less than or equal to $1x10^{-7}$ m/s. If a thickness of less than 1 m is proposed this is required to be supported by a hydrogeological assessment.

It is proposed that active leachate management of Phase 3 and Phase 4B will not be necessary due to the composition of the inert leachate. The specification of the hydraulic conductivity of the upper sidewall will be defined such that infiltration through the restored surface of Phase 3 and Phase 4B does not accumulate leachate within the phase and cause an associated leachate breakout. This is because whilst the leachate from inert wastes is very weak, without natural attenuation in the subsurface the breakout of leachate to surface watercourses could contain unacceptable concentrations of non-hazardous pollutants. The risk assessment component of this report will define upper sidewall properties such that leachate management will not be required in Phase 3 and Phase 4B.

2.6 Cap Engineering

Phases 1, 2 and 4A are capped and restored with a 1 m clay liner.

Environment Agency (2020) states that an engineered cap is not required for landfills of inert waste as long as the water management at the site is planned. The previous HRA (SLR, 2013) predates the current guidance, and stated that to control leachate generation an engineered cap would be required.

It is proposed that Phase 3 will not be required to be capped. Furthermore, the assessment component of this report defines upper sidewall properties such that leachate management will not be required in Phase 3.

The inactive waste accepted in Phase 4B is also inert with respect to leachate and landfill gas generation, hence it is accepted that capping of Phase 4B will also not be required.

2.7 Leachate Management

Leachate monitoring points and sumps have been installed into all built phases.

Leachate levels are managed at the site using recirculation and off-site disposal via road tanker.

Both sumps and wells are used for compliance and monitoring purposes, as follows:

- Phase 1 (7 monitoring points / 4 sumps) with a Compliance Limit of 3 m above the base of the Cell;
- Phase 2 (7 monitoring points / 5 sumps) with a Compliance Limit of 3 m above the base of monitoring well; and
- Phase 4 (2 monitoring points / 2 sumps) with a Compliance Limit of 3 m above the base of monitoring well.

2.8 Groundwater Management

Groundwater levels and flow within the Kesgrave Sand and Gravels are locally controlled to facilitate site construction and tipping.

Phases 1, 2 and 3 benefit from the perimeter gravity drain, which discharges to the west of the Site at GWD1. Phase 4 was developed with a temporary, closed groundwater drainage system which was pumped to facilitate the engineering of this phase. Once waste levels in Phase 4 are at an appropriate level above the surrounding groundwater levels in the Kesgrave Sand and Gravels, pumping from the groundwater drain will cease.

2.9 Surface Water Management

Surface water is managed at the Site via surface water ditches around the Site perimeter. Surface water is then discharged from the Site to the Stansted Brook.

3.0 MONITORING DATA REVIEW

3.1 Leachate Levels

Leachate levels are monitored on a monthly and quarterly basis as required by the Permit. Leachate elevation graphs are presented in Appendix A. Summary statistics of leachate head for the period between February 2014 and January 2020 are presented in Table 2. The highest leachate elevations were generally observed in Phase 4, with lowest elevations typically observed in Phase 1.

Within Phase 1 leachate heads have remained below 3 m in all locations except ELSEL03, ELSEL07 and ELSEL08. Leachate heads at ELSEL03 and ESEL07 were observed to be subject to a rising trend prior to the exceedance of the Compliance Limit in May 2015 and September 2017, respectively. Following the exceedance of the Compliance Limit leachate heads were maintained at or below a head of 1 m. The exceedance of a Compliance Limit at ELSEL08 appears to be anomalous with all other results presenting a consistent leachate head below this. No sustained upwards trends in leachate head have been identified in Phase 1.

Within Phase 2 three generalised trends are identified in the leachate head timeseries graphs presented in Appendix A. Within ELSEL12, ELSEL13, ELSEL16, ELSEL19, ELSEL20, ELSEL21, ELSEL22 and ELSEL23 leachate levels were routinely higher than the Compliance Limit at the start of the review period and have been reduced to typically be below the Compliance Limit. Leachate heads observed at ELSEL14, ESEL17 and ELSEL18 have been typically maintained below the Compliance Limit over the review period with sporadic periods of exceedance. Without exception leachate heads at ELSEL15 have been maintained below the Compliance Limit, although a rising trend throughout the review period is observed.

Within Phase 4 leachate heads are required by the Permit to be managed in leachate wells ELSEL24, ELSEL25 and ELSEL26. All leachate levels are maintained below the Compliance Limit with no sustained upwards trend.

No Compliance Limit exists for ELSEL27 and future Phase 3 and Phase 4 monitoring points. In ELSEL27 a sustained upwards trend in leachate head exists between March 2016 and the end of the review period which reflects the recharge to this area and there being no requirement for leachate management.

Table 2: Leachate Head

Phase	Monitoring Point	Compliance Limit	Count	Min	Mean	Max
1	ELSEL01	3 m above cell base	82	0.98	1.39	1.83
	ELSEL02		69	0.45	1.45	1.69
	ELSEL03		70	0.65	1.25	**3.49**
	ELSEL04		71	0	1.17	1.31
	ELSEL05		71	1.48	1.93	2.33
	ELSEL06		70	0	1.77	2.20
	ELSEL07		61	0	1.45	**3.56**
	ELSEL08		70	1.54	2.11	**3.02**
	ELSEL09		71	0	1.78	2.32
	ELSEL10		69	1.46	2.33	2.98

Phase	Monitoring Point	Compliance Limit	Count	Min	Mean	Max
	ELSEL11		70	0.11	1.18	2.34
2	ELSEL12	3 m above base of monitoring well	73	0	1.56	**3.63**
	ELSEL13		75	0.80	2.63	**4.50**
	ELSEL14		75	1.14	2.21	**5.09**
	ELSEL15		71	1.46	2.08	2.43
	ELSEL16		70	0	2.09	**9.26**
	ELSEL17		53	0.73	1.86	**4.15**
	ELSEL18		62	1.18	2.10	**4.75**
	ELSEL19		67	0.62	**3.11**	**16.88**
	ELSEL20		68	0.69	2.71	**9.08**
	ELSEL21		72	0.81	**3.67**	**15.03**
	ELSEL22		59	0	0.79	**7.50**
	ELSEL23		63	0	2.38	**15.71**
4	ELSEL24	3 m above base of monitoring well	51	0	0.01	0.15
	ELSEL25		56	0	0.02	0.3
	ELSEL26		58	0	1.68	2.96
	ELSEL27	-	50	0.93	12.76	21.40

*Values in **bold** denote an exceedance of the associated compliance limit.*

A summary of the leachate elevation against groundwater elevation are shown in Table 3. A review of this data indicates that groundwater levels remain above corresponding leachate levels across the Site, except in ELSEL04 where minimum and mean levels are shown to be above those recorded in the closest groundwater monitoring well. The monitoring data confirms that an inward hydraulic gradient is dominant across the Site, with some outward gradients expected on a local basis where the groundwater management system, is lowering groundwater levels within the Kesgrave Sand and Gravels.

Table 3: Comparison of Groundwater and Leachate Elevations

Monitoring point	Groundwater Levels (m AOD)			Nearby Leachate Well	Leachate Elevation (m AOD)		
	Min	Mean	Max		Min	Mean	Max
ELSEBH02	89.94	90.91	91.59	ELSEL06	86.5	88.3	88.7
ELSEBH04	88.47	90.55	91.46	ELSEL07	86.3	87.8	89.9
ELSEBH06	89.52	90.29	91.35	ELSEL10	87.5	88.4	89.1
				ELSEL11	86.6	87.7	88.8
ELSEBH75	98.81	98.97	99.07	ELSEL17	86.5	87.7	89.9
ELSEBH78	86.11	87.68	88.35	ELSEL04	87.7	87.9	88.1
ELSEBH94	89.81	90.49	92.82	ELSEL01	87.8	88.2	88.6
ELSEBH95	90.36	90.90	91.47	ELSEL03	87.4	87.9	90.2

3.2 Leachate Quality

Leachate quality is monitored for a range of determinands on a quarterly, annual and four-yearly basis in accordance with the Permit. Summary statistics for the period between January 2014 and April 2020 are presented in Table 4. Time-series graphs of key leachate indicator species are presented in Appendix B.

Generally, leachate concentrations have remained stable over the review period. Several key trends were noted:

- Concentrations of ammoniacal nitrogen and chloride in Phase 4A showed to decrease over the review period;
- Concentrations of cadmium in Phase 4A increased over the review period; and
- Ammoniacal nitrogen concentrations present at low levels in Phase 4B show a slight increase since the start of the review period.

The following determinands were not detected above LOD during the review period:

- Cadmium in Phase 4B;
- Naphthalene in Phase 4A;
- Xylene in Phase 4B; and
- Fluoranthene in Phases 1 and 4A.

Table 4: Leachate Quality

Determinand	Phase	Count	Min	Mean	95th %ile	Max
Ammoniacal Nitrogen (mg/l)	1	35	0.7	243.61	465.9	506
	2	51	1.52	931.7	1565	1800
	4A	8	1.71	233.2	555.9	572
	4B	23	<0.27	3.08	5.97	7.13
Chloride (mg/l)	1	35	8.3	540.3	911.2	1080
	2	51	64.4	783	1195	1290
	4A	8	54.9	462	864.3	914
	4B	23	53	186.1	438.7	483
Sulphate (mg/l)	1	16	2.2	122.0	441.8	537
	2	30	2.2	136.9	393.5	1640
	4A	6	302	1017.3	1455	1470
	4B	16	939	1174.9	1337.5	1360
Nickel (µg/l)	1	35	12	71.8	255.2	346
	2	51	6.5	80.7	133.5	533
	4A	8	10	146.8	500.4	668
	4B	20	4.6	12.4	25.6	45
Lead (µg/l)	1	35	0.97	13.8	77.4	122
	2	51	<3	15.6	44	258
	4A	8	<6	70.5	324.2	472
	4B*	20	1	4.7	8.69	23
Arsenic (µg/l)	1	35	51	335.5	810	2640
	2	51	0.5	219.8	676	1760
	4A	8	7.2	43.5	81.8	94
	4B	20	1.7	17.3	34.3	116
Cadmium (µg/l)	1	35	<0.07	1.23	4.12	9.5
	2	51	0.3	0.816	2.9	6.9

Determinand	Phase	Count	Min	Mean	95th %ile	Max
	4A	8	<0.6	0.98	2.96	3.9
	4B	20	<0.6	<0.6	<0.6	<0.7
Mecoprop (µg/l)	1	20	0.15	12.8	36.3	40.1
	2	21	0.43	50.67	99.6	102
	4A	2	25.9	28	29.82	30.1
	4B	8	<0.04	0.54	1.17	1.44
Naphthalene (µg/l)	1	20	<0.04	1.35	7.39	7.89
	2	21	<0.04	7.05	13	19
	4A	2	<0.10	0.13	0.193	<0.4
	4B	8	<0.01	0.14	0.53	0.75
Toluene (µg/l)	1	20	0.26	6.81	20	20
	2	21	0.81	17.69	35.5	40
	4A	2	0.87	2.94	4.79	5
	4B	7	0.1	2.09	7.6	10
Xylene (µg/l)	1	12	<0.4	5.46	20	20
	2	13	1.68	22.65	54.94	70
	4A	2	1.18	3.09	4.81	5
	4B	5	<0.2	0.82	1.8	<4
Fluoranthene (µg/l)	1	20	<0.02	0.025	0.05	<0.1
	2	21	<0.04	0.393	1.35	1.88
	4A	2	<0.10	<0.10	<0.10	<0.10
	4B	8	<0.01	0.07	0.190	0.198
Phenol (µg/l)	1	13	<5	17.56	64.6	124
	2	13	<15	42.42	146.1	309
	4A	1	<15	<15	<15	<15
	4B	7	<5	3.61	6.45	6.55

For the purpose of statistical analysis values at LOD limit have bene put equal to half the detection limit value.
**Excluding outlier of <6000 25/07/2018*

In the previous HRA source terms for Phase 3 and Phase 4B were derived based on literature sources and the results of inert Waste Acceptance Criteria (WAC) testing at such sites. Phase 4B is now operational with leachate quality monitoring being undertaken in accordance with the Permit. Source term concentrations for Phase 4B have therefore been derived from leachate quality samples taken from monitoring borehole ELSEL27. As Phase 4B and Phase 3 will accept inert waste streams formal assessment of the impact from these areas is not required. The derived Source Term Concentrations are presented in Table 5.

In Phase 1 the following observations were made:

- Minimum concentrations of ammoniacal nitrogen, mecoprop, cadmium, toluene and lead increased;
- Most likely concentrations of xylene increased;
- Minimum and most likely concentrations of chloride increased; and
- Minimum, most likely and maximum concentrations of sulphate, nickel, arsenic and fluoranthene increased,

In Phase 2 the following observations were made:

- Minimum concentrations of chloride, cadmium, lead and xylene increased;
- Most likely concentrations of naphthalene increased;
- Minimum and most likely concentrations of ammoniacal nitrogen, mecoprop and toluene increased; and
- Minimum, most likely and maximum concentrations of sulphate, nickel, arsenic and fluoranthene increased.

In Phase 4A the following observations were made:

- Minimum concentrations of ammoniacal nitrogen, mecoprop, naphthalene, cadmium, toluene, lead, arsenic and xylene increased;
- Minimum and most likely concentrations of chloride increased; and
- Minimum, most likely and maximum concentrations of sulphate, nickel and fluoranthene increased.

In Phases 3 and 4B the following observations were made:

- Most likely and maximum concentrations of ammoniacal nitrogen and mecoprop increase, although remain at concentrations reflective of an inert landfill; and
- Minimum, most likely and maximum concentrations of chloride, naphthalene, sulphate, toluene, lead, arsenic, xylene and fluoranthene increased, although remain at concentrations reflective of an inert landfill.

Table 5: Comparison of Source Terms

Parameter (mg/l)		Phase 1		Phase 2		Phase 4A		Phase 4B	
		SLR(2013)	2014-20	SLR(2013)	2014-20	SLR(2013)	2014-20	SLR(2013)	2014-20
Ammoniacal Nitrogen	Min	0.01	**0.7**	0.01	**1.52**	0.01	**1.71**	0.135	0.135
	Most Likely	491	244.69	491	**1480**	683	544.6	0.16	**3.63**
	Max	3640	506	3640	1800	3640	572	0.504	**7.13**
Chloride	Min	5.08	**8.3**	5.08	**64.4**	5.08	**54.9**	0	**53**
	Most Likely	683	**1075**	683	589.7	683	**800**		**278**
	Max	7760	1080	7760	1290	7760	914		**483**
Mecoprop	Min	4×10^{-5}	**0.00015**	4×10^{-5}	**0.00043**	4×10^{-5}	**0.0259**	2×10^{-5}	2×10^{-5}
	Most Likely	0.0436	0.00992	0.0436	**0.09**	0.0436	-	3.6×10^{-5}	**0.001**
	Max	0.14	0.0401	0.14	0.102	0.14	0.0301	0.00023	**0.00144**
Naphthalene	Min	5×10^{-6}	2×10^{-6}	5×10^{-6}	2×10^{-5}	5×10^{-6}	**5×10^{-5}**	0	**5×10^{-6}**
	Most Likely	0.002	0.0004	0.002	**0.0122**	0.002	-		**6.14×10^{-5}**
	Max	0.042	0.0079	0.042	0.019	0.042	2×10^{-4}		**0.00075**
Cadmium	Min	2.5×10^{-6}	**3.5×10^{-5}**	2.5×10^{-6}	**0.0003**	2.5×10^{-6}	**0.0003**	0.0003	3.5×10^{-5}
	Most Likely	0.00252	0.00033	0.00252	0.0003	0.00252	0.0003	0.00034	0.0003
	Max	0.105	0.0095	0.105	0.0069	0.105	0.0039	0.00084	0.0003
Nickel	Min	0	**0.012**	0	**0.0065**	0	**0.01**	0.0063	0.0046
	Most Likely		**0.046**		**0.0806**		**0.0817**	0.02	0.014
	Max		**0.346**		**0.533**		**0.668**	0.074	0.045

Parameter (mg/l)		Phase 1		Phase 2		Phase 4A		Phase 4B	
		SLR(2013)	2014-20	SLR(2013)	2014-20	SLR(2013)	2014-20	SLR(2013)	2014-20
Toluene	Min	5×10^{-5}	**0.00026**	5×10^{-5}	**0.00082**	5×10^{-5}	**0.00087**		**0.0001**
	Most Likely	0.0104	0.0017	0.0104	**0.033**	0.0104	-	0	**0.001**
	Max	1.287	0.02	1.287	0.04	1.287	0.005		**0.01**
Lead	Min	5×10^{-7}	**0.00097**	5×10^{-7}	**0.0015**	5×10^{-7}	**0.003**		**0.001**
	Most Likely	0.0179	0.0067	0.0179	0.014	0.0179	0.00739	0	**0.0065**
	Max	1.02	0.122	1.02	0.258	1.02	0.472		**0.023**
Arsenic	Min	2.5×10^{-5}	**0.00051**	2.5×10^{-5}	**0.0005**	2.5×10^{-5}	**0.0072**	0.00057	**0.0017**
	Most Likely	0.134	**0.15**	0.134	**0.548**	0.134	0.0506	0.001	**0.014**
	Max	0.612	**2.64**	0.612	**1.76**	0.612	0.094	0.00372	**0.116**
Xylene	Min	0.00039	0.0002	0.0001	**0.0017**	0.00039	**0.00118**		**0.0001**
	Most Likely	0.0058	**0.012**	0.059	0.0245	0.0058	-	0	**0.0012**
	Max	0.208	0.02	0.208	0.07	0.208	0.005		**0.002**
Fluoranthene	Min		**1×10^{-5}**		**2×10^{-5}**				**5×10^{-6}**
	Most Likely	0	**2×10^{-5}**	0	**0.00014**	0	**5×10^{-5}**	0	**-**
	Max		**5×10^{-5}**		**0.0019**				**0.002**

Values in bold denote an increase in concentration.

3.2.1 Hazardous Substances

Hazardous substances (as defined by JAGDAG) (Joint Agencies Groundwater Directive Advisories Group, 2019) within the leachate at a concentration in excess of the minimum detection limit are presented in Table 6. Since the previous HRA review cadmium and naphthalene have been reclassified from a hazardous substance to a non-hazardous pollutant.

Table 6: Hazardous Substances detected during the Review Period.

Determinand (µg/l)	Detects / Number of Samples	Min	Mean	Max	LOD
2,4-Dichlorophenol	2 / 34	<1	2.39	<15	<1
Acenaphthene	45 / 51	<0.01	0.63	2.82	<0.01
Anthracene	12 / 51	<0.01	0.08	0.733	<0.01
Benzene	20 / 50	0.12	7.64	40	<1
Benzo(a)pyrene	3 / 51	<0.01	0.04	0.163	<0.01
Benzo(b)fluoranthene	3 / 51	<0.01	0.04	0.22	<0.02
Benzo(ghi)perylene	3 / 48	<0.01	0.104	0.181	<0.01
Chlorobenzene	2 / 33	<1	10.12	40	<1
Chromium	94 / 114	<0.51	86.07	391	<0.51
Dichlorprop	12 / 51	<0.05	3.16	17.4	<0.05
Ethylbenzene	16 / 50	<0.1	8.98	40	<0.1
Mercury	2 / 33	0.04	0.05	0.1	<0.1
TPH >C10-C16	1 / 1	28	28	28	<10
TPH >C16-C24	1 / 1	28	28	28	<10
TPH >C8-C40	31 / 34	<10	1270	7820	<10
Vinyl Chloride	1 / 33	<0.5	5.0	20	<0.5
Triclopyr	1 / 21	<0.05	0.95	10	<0.05

For the purpose of statistical analysis values at LOD limit have bene put equal to half the detection limit value. Where there is more than one LOD the smallest LOD has been reported.

3.3 Groundwater Level

The groundwater monitoring wells at Site are all screened within the Kesgrave Sand and Gravels with groundwater levels monitored on a quarterly basis in accordance with the Permit. Groundwater levels are locally controlled around the perimeter of the site by a groundwater drain.

A groundwater elevation hydrograph is presented in Appendix C. Summary statistics for groundwater elevations for the period between January 2014 and April 2020 are presented below in Table 7.

Groundwater levels were generally lowest in borehole ELSEBH92, located in the west of the Site. The lowest groundwater elevation reported for the review period was 86.11 m AOD in ELSEBH78. The highest groundwater levels were consistently observed in borehole ELSEBH75 located to the south east of the Site. The highest groundwater elevation recorded during the review period was 99.07 m AOD.

It is interpreted from the groundwater elevation hydrograph (Appendix C) that the Kesgrave Sand and Gravels demonstrates some seasonal variability in the order of 0.5 m to 1 m. Since 2016 groundwater levels in ELSEBH98 have decreased by approximately 1 m. In general, groundwater elevations have remained stable over the review period.

Table 7: Groundwater Levels (m AOD)

Monitoring Point	Count	Min	Mean	Max	Range (m)
ELSEBH02	25	89.94	90.91	91.59	1.65
ELSEBH04	25	88.47	90.55	91.46	2.99
ELSEBH06	25	89.52	90.29	91.35	1.83
ELSEBH75	27	98.81	98.97	99.07	0.26
ELSEBH78	25	86.11	87.68	88.35	2.24
ELSEBH90	26	88.07	88.51	89.24	1.17
ELSEBH91	27	87.96	88.52	89.23	1.27
ELSEBH92	25	87.09	87.30	87.52	0.43
ELSEBH93	25	88.84	89.28	89.90	1.06
ELSEBH94	25	89.81	90.49	92.82	3.01
ELSEBH95	22	90.36	90.90	91.47	1.11
ELSEBH97	25	89.33	90.14	90.84	1.51
ELSEBH98	26	88.21	89.29	90.07	1.86

3.4 Groundwater Quality

3.4.1 Background Groundwater Quality

A summary of the concentrations of key determinands recorded in the upgradient groundwater monitoring boreholes during the period January 2014 to February 2020 is presented in Table 8. Time-series graphs for background groundwater quality are presented in Appendix C.

Based on the groundwater elevation plots (Drawing 1) background groundwater quality within the Kesgrave Sand and Gravels is based on upgradient boreholes ELSEBH02, ELSEBH04 and ELSEBH06

Summary statistics for background groundwater quality are presented in Table 8.

Fluoranthene, mecoprop and naphthalene were not analysed for in the upgradient boreholes during the review period. Cadmium and toluene were not modelled in the previous HRAR, however concentrations above the LOD were present in the background groundwater during this review period. Lead and xylene were not detected above the LOD.

The time-series graphs (Appendix C) indicate that concentrations of sulphate have increased slightly since the start of the review period. Concentrations of other determinands have remained relatively stable.

Table 8: Combined Background groundwater quality

Determinand (mg/l)	Values used in previous HRAR			2014 – 2020			
	Min	Most Likely	Max	Count	Min	Mean	Max
Ammoniacal Nitrogen	0.01	0.166	2.07	82	**<0.06**	0.16	0.21
Chloride	2.2	34.6	161	86	**15.8**	**36.68**	91.3
Cadmium	-	-	-	51	**<2 x 10^{-5}**	**0.00029**	**0.0006**
Sulphate	12.6	46.8	129	23	**18.5**	33.2	70.2
Nickel	0.002	0.0021	0.0088	23	<0.001	**0.00182**	0.0037
Toluene	-	-	-	14	**<0.0001**	**0.00012**	**0.00049**
Lead	0.0002	0.00275	0.0133	51	nd	nd	nd
Xylene	-	-	-	14	nd	nd	nd
Phenol	-	-	-	na	na	na	na

For the purpose of statistical analysis values at LOD limit have bene put equal to half the detection limit value.
nd – not detected above LOD
na – Not analysed for during the review period
Values in bold denote an increase in concentration or where previously unreported.

3.4.2 Cross Gradient Groundwater Quality

Cross gradient groundwater quality is monitored on a quarterly and annual basis as required by the Permit.

3.4.3 Downgradient Groundwater Quality

The permit requires downgradient groundwater quality to be monitored at monitoring points ELSEBH95, ELSEBH97 and ELSEGWD1 (the groundwater drain system). These are situated to the west of the Site. Summary statistics for downgradient groundwater quality are presented in Table 9 and where applicable have been compared to the associated compliance limits.

Throughout the review period there were no exceedances of the compliance limits. The highest concentrations of determinands were generally observed in ELSEBH59.

Review of further downgradient groundwater quality points ELSEBH90, ELSEBH91, and ELSEBH98 confirm the conclusions presented in the previous HRAR (SLR, 2013) that elevated concentrations within these boreholes (particularly ammoniacal nitrogen and chloride) may be related to the historic uncontained landfill Areas, B, C and E which are located outside the installation boundary.

Table 9: Downgradient Groundwater Quality

Determinand	Monitoring Point	Compliance Limit	Count	Min	Mean	Max
Ammoniacal Nitrogen (mg/l)	ELSEBH95	2.7	27	<0.06	0.17	0.28
	ELSEBH97		30	<0.06	0.16	<0.41
	ELSEGWD1	3.8	30	<0.06	0.16	<0.41
Chloride (mg/l)	ELSEBH95	250	27	18.7	34.1	45.7
	ELSEBH97		30	21.5	28.3	35.4
	ELSEGWD1		30	27.9	34.0	38.5
Sulphate (mg/l)	ELSEBH95	-	7	51.8	79.4	97.5
	ELSEBH97		8	81.7	87.6	97.2
	ELSEGWD1		8	61.1	74.9	97.7
Nickel (µg/l)	ELSEBH95	-	8	1.1	2.1	3.8
	ELSEBH97		8	<1	2.5	5.3
	ELSEGWD1		8	<1	2.1	4.8

Determinand	Monitoring Point	Compliance Limit	Count	Min	Mean	Max
Lead (µg/l)	ELSEBH95	240	26	<0.3	2.89	<6
	ELSEBH97		28	<0.3	2.89	<6
	ELSEGWD1		28	<0.3	2.89	<6
Cadmium (µg/l)	ELSEBH95	8.4	24	<0.6	0.3	0.6
	ELSEBH97	1.6	27	<0.6	0.3	0.6
	ELSEGWD1	1.6	28	<0.6	<0.6	<0.6
Mecoprop (µg/l)	ELSEBH95	-	3	<0.04	<0.04	<0.04
	ELSEBH97		3	<0.04	<0.04	<0.04
	ELSEGWD1		3	<0.04	0.08	0.16
Naphthalene (µg/l)	ELSEBH95	-	3	<0.01	<0.01	<0.01
	ELSEBH97		3	<0.01	<0.01	<0.01
	ELSEGWD1		3	<0.01	<0.01	<0.01
Toluene (µg/l)	ELSEBH95	4	15	<0.10	0.18	0.72
	ELSEBH97		15	<0.1	0.15	<1
	ELSEGWD1		15	<0.1	0.14	<1
Xylene (µg/l)	ELSEBH95	3	12	<0.20	0.14	0.53
	ELSEBH97		12	<0.20	<0.20	<0.20

Determinand	Monitoring Point	Compliance Limit	Count	Min	Mean	Max
	ELSEGWD1		12	<0.20	<0.20	<0.20
Fluoranthene (µg/l)	ELSEBH95	-	3	0.234	0.509	0.859
	ELSEBH97		3	<0.01	<0.01	<0.01
	ELSEGWD1		3	<0.01	<0.01	<0.01
Phenol (µg/l)	ELSEBH95	-	3	<5	<5	<5
	ELSEBH97		3	<5	<5	<5
	ELSEGWD1		3	<5	<5	<5

For the purpose of statistical analysis values at LOD limit have been included at half the detection limit value.

3.5 Surface Water Quality

The Permit requires surface water quality to be monitored monthly at ELSECP937, the point at which surface water discharge from the Site is discharged to the Stanstead Brook along with monitoring points outlined in the MEPP.

Surface water discharge to the on-site pond is measured at ELSESWM13. Upstream surface water quality is measured at two locations along the Brook (ELSESWM01 and ELSESWM12) and downstream surface water quality at ELSESWM10. The monitoring network comprises of a further five upstream monitoring points along the Stanstead Brook.

Surface water quality for the period January 2014 to April 2020 is summarised in Table 10.

Table 10: Surface Water Quality

Determinand		ELSECP937	ELSESWM01	ELSESWM08	ELSESWM10	ELSESWM11	ELSESWM12	ELSESWM13	ELSESWM14	ELSESWM15
Ammoniacal Nitrogen (mg/l)	Count	95	83	31	92	12	47	18	9	50
	Min	<0.06	<0.06	<0.41	<0.06	<0.27	<0.06	<0.06	<0.06	<0.06
	Mean	0.39	0.19	103	1.24	0.74	4.44	0.12	0.20	0.27
	Max	3.09	1.06	143	89.6	3.00	44.7	<0.41	0.68	2.32
Chloride (mg/l)	Count	80	72	24	78	11	40	13	7	40
	Min	29.4	16.3	231	20.7	17.1	1.85	9.40	5.6	12.4
	Mean	4.7	45.6	446	55.4	34.5	43.2	17.8	9.4	28.1
	Max	70.5	81.2	549	1040	93.6	308	27.7	13.8	70.5
BOD (mg/l)	Count	77	28	23	30	7	18	9	3	17
	Min	<1	<1	4	<1	<1	<1	<1	<1	<1
	Mean	1.6	1.21	13.8	1.23	2.07	3.39	0.67	1	1.97
	Max	12	4	24	5	4	16	2	2	6
Total Iron (mg/l)	Count	78	28	23	30	7	18	9	3	17
	Min	<0.23	<0.23	2.71	<0.23	0.36	<0.23	<0.23	0.49	<0.23
	Mean	0.43	0.77	54.6	0.66	1.33	0.70	0.53	0.79	0.69
	Max	5.64	2.59	94.6	2.61	2.42	1.51	1.12	1.02	1.96
Suspended Solids (mg/l)	Count	77	71	24	77	11	40	13	7	40
	Min	1	2	40	2	14	3	2	12	2
	Mean	10.1	25.9	182	33.4	107.5	34.7	18.4	149	32.1

Determinand		ELSECP937	ELSESWM01	ELSESWM08	ELSESWM10	ELSESWM11	ELSESWM12	ELSESWM13	ELSESWM14	ELSESWM15
	Max	60	208	822	386	288	156	36	574	172
Conductivity (uS/cm)	Count	80	72	24	78	11	40	13	7	40
	Min	591	360	1920	446	376	124	462	502	438
	Mean	755	718	3450	770	513	529	609	713	724
	Max	1050	1050	4350	3650	839	1330	837	921	1450
pH	Count	80	72	24	78	11	40	13	7	40
	Min	7.3	7.5	6.9	7.6	7.6	7.1	8.1	7.3	7.4
	Mean	7.7	8.1	7.0	7.0	8.0	8.0	8.3	7.9	8.0
	Max	8.4	8.6	7.7	8.5	8.4	8.5	8.7	8.3	8.5

For the purpose of statistical analysis values at LOD limit have bene put equal to half the detection limit value.

4.0 CONCEPTUAL MODEL REVIEW

A cross section depicting the conceptual model for the Site is presented in Drawing 2.

The 2013 HRAR considered two assessment methodologies:

- An assessment of potential impacts if leachate levels are above above the adjacent groundwater levels creating outward hydraulic gradients (considering scenarios while dewatering is being undertaken and in the long-term). It is noted that the Site is now predominantly hydraulically contained with the exception of less than 50 m of the Phase 1 sidewall where periodically the groundwater level falls below the permitted leachate level. For conservatism this scenario has been considered in this HRA review although will be removed from subsequent assessments as the whole site continuously remains in hydraulic containment; and
- An assessment of the potential impacts if leachate levels remained below adjacent groundwater levels, with inward hydraulic gradient present, this assessment will be updated to reflect changes to the conceptual model. For conservatism the lowest clay hydraulic conductivity and highest concentrations have been incorporated to consider a worst case assessment.

4.1 Source

Following the review of the conceptual site model that was assumed for the last HRA review, it is considered that for the source:

- An organo-metallic substance has not been quantitively assessed previously. Although it is noted that due to the relative low mobility and low concentrations in the source, this had been previously screened out qualitatively. Given the requirement to re-assess the impact of other parameters, this will be included to validate the qualitative screening using source data from a similar site in the Viridor portfolio;
- Concentrations of several determinands in Phases 1, 2 and 4A have changed with a most likely or maximum leachate strength exceeding that previously modelled, including ammoniacal nitrogen and chloride;
- Leachate samples have been obtained from Phase 4B (from monitoring well ELSEL27) allowing for site specific Source Term Concentrations to be derived where the leachate composition had previously been assumed, whilst Phase 4B has accepted inert and non-hazardous inactive wastes only it has been retained in the assessment for consistency;
- Average leachate heads typically remained below the compliance limit; and
- Cadmium and naphthalene have been reclassified as non-hazardous substances.

Several types of substances considered in the previous HRA, as defined in LFTGN01 (Environment Agency, 2003), were over represented, whilst an organic hydrophilic substance under represented. For this HRA review a contaminant from each category has been selected for the source term. A summary of the changes is presented below:

- Arsenic and lead, both less mobile metals have been screened out of the assessment as cadmium, another less mobile metal, is present at higher concentrations compared to the quality standards;
- Sulphate has been screened out of the assessment as chloride, another inorganic anion is present at higher concentrations compared to the quality standards;

- Xylene, naphthalene and fluoranthene have been screened out of the assessment due to over representation of a hydrophobic organic substance. Toluene, another hydrophobic organic substance is present at higher concentrations compared to the quality standards and therefore has been chosen to be modelled; and
- Phenol has been included into this assessment to represent an organic hydrophilic substance.

4.2 Pathway

Since the previous HRA there has been no change to the conceptual understanding of the pathway.

4.3 Receptor

The receptor continues to be groundwater within the Kesgrave Sand and Gravels.

The Environment Agency and Local Authority have been contacted to identify the presence of off-site licensed and private abstractions of groundwater from this unit respectively. A response to this request to identify off site receptors has not been received, however the following on-site compliance points for assessment of the risk the Site poses to downgradient receptors have been selected which would be protective of off-site receptors.

4.3.1 Compliance Points

According to the Groundwater Directive, hazardous substances should be prevented from entering the groundwater. An input is considered to have been prevented if the substance concerned is not discernible in the groundwater above natural background concentrations or a relevant MRV after the immediate dilution as the leachate enters the groundwater. The receptor at risk from hazardous substances is commonly considered to be the groundwater adjacent to the Site (i.e. immediately downgradient of the waste mass). The discharge of non-hazardous pollutants should also be limited such as to prevent pollution.

Therefore, the compliance points for this assessment are as follows:

- For hazardous substances the receptor point will be the within the Kesgrave Sand and Gravels directly adjacent to each phase after the immediate dilution in groundwater; and
- For non-hazardous pollutants the receptor points will be groundwater within the Kesgrave Sand and Gravels at the downgradient Site boundary.

On this basis the groundwater monitoring boreholes ELSEBH95, ELSEBH97 and ELSEGWD1 adequately characterise the groundwater quality with regard to the defined compliance points.

4.3.2 Environmental Assessment Limits

The sensitivity of the receptors can be gauged by the specification of Environmental Assessment Limits (EALs). It is acknowledged that no discernible discharge of hazardous substances would be justifiable. Non-hazardous substance increases caused by the landfill operation should not increase background groundwater concentrations above the EALs.

A comparison between the previous EALs and background groundwater quality are presented in Table 11.

This table demonstrates that:

- The EAL's for ammoniacal nitrogen, chloride, mecoprop, cadmium, nickel and toluene remain appropriate; and
- The EAL for phenol reflects the FW EQS due to lack of background groundwater quality data for this determinand.

Table 11: Environmental Assessment Limit Review

Determinand (mg/l)	UK DWS (mg/l)	FW EQS (mg/l)	EA Minimum Reporting Values (mg/l)	2013 HRAR EAL	Maximum Background concentration (2014 – 2020)	Proposed EAL
Ammoniacal Nitrogen	0.39	0.247	-	2.07	0.21	2.07
Chloride	250	250	-	250	91.3	250
Mecoprop*	0.0001	0.018	-	0.0005	-	0.0005
Cadmium	0.005	8×10^{-5}	-	0.0016	0.0006	0.0016
Nickel	0.02	0.004	-	0.02	0.0037	0.02
Toluene	-	0.074	0.004	0.004	0.00049	0.004
Phenol*	-	0.0077	-	-	-	0.0077

Nd – not detected above LOD

** Not analysed for in background groundwater samples during the current review period*

5.0 HYDROGEOLOGICAL RISK ASSESSMENT

5.1 Collated Summary of Changes since previous HRAR

There have been changes in parameters that feed into the risk assessment since the last HRAR.

5.1.1 Source Term

Changes to the Source Term are detailed in Table 5. Source Term Concentrations for Phase 4B are to be updated with Site specific data. In Phases 1, 2 and 4A determinands where most likely and/or maximum concentrations have increased are also to be updated. Formal quantitative assessment for the inert waste in Phase 3 is not required, in accordance with Environment Agency (2020).

The following aspects of the parameterisation of the conceptual model have been revised from those detailed in the 2013 HRAR:

- Phase 4B: All probability density functions were derived based on literature sources and the results of inert Waste Acceptance Criteria (WAC) testing at such sites. Leachate samples have been obtained from Phase 4B (from monitoring well ELSEL27) allowing for site specific source term concentrations to be derived;
- Ammoniacal Nitrogen: In Phase 2 minimum and most likely concentrations have increased from 0.01 mg/l and 491 mg/l to 1.52 mg/l and 1480 mg/l. An updated probability density function based on the 2014 to 2020 monitoring data have been derived;
- Chloride: Minimum and most likely concentration in Phase 1 have increased from 5.08 mg/l and 683 mg/l to 8.3 mg/l and 1075 mg/l. Minimum and most likely concentrations also increased in Phase 4A from 5.08 mg/l and 683 mg/l to 54.9 mg/l and 800 mg/l. Updated probability density functions based on the 2014 to 2020 monitoring data have been derived;
- Mecoprop: Minimum and most likely concentrations in Phase 2 increased from 4×10^{-5} mg/l and 0.0436 mg/l to 0.00043 mg/l and 0.09 mg/l. An updated probability density function based on the 2014 to 2020 monitoring data have been derived;
- Phenol: The assessment conducted in the last HRA review omitted the assessment of an organic hydrophilic substance as required in LFTGN01 (Environment Agency, 2003). Phenol was selected as the source concentration was the highest in proportion to quality standards. Probability density functions based on the 2014 to 2020 monitoring data have been derived;
- Toluene: Minimum and most likely concentrations in Phase 2 increased from 5×10^{-5} mg/l and 0.0104 mg/l to 0.00082 mg/l and 0.033 mg/l. An updated probability density function based on the 2014 to 2020 monitoring data have been derived;
- Cadmium: Most likely and maximum concentration remained below those in the previous review. Therefore, there have been no updates to the probability density functions; and
- Nickel: Minimum, most likely and maximum concentrations in Phases 1, 2 and 4A have all increased. Probability density functions based on the 2014 to 2020 monitoring data have been derived.

5.1.2 Phase 3 Leachate Generation

Phase 3 will be developed as a purely inert phase. Current Environment Agency guidance (Environment Agency, 2020) states that inert landfills must have a geological barrier although an artificial sealing layer and engineered cap is not required as long as the water management at the site is planned.

Active leachate management of Phase 3 will not be necessary due to the composition of the leachate. The hydrogeological risk assessment presents calculations to support the specification of the hydraulic conductivity of the geological barrier comprising the upper sidewall. The assessment takes into consideration the infiltration rate to the phase without a cap and demonstrates that water will not be impounded in the phase to the point of surface breakout. This is because whilst the leachate from inert wastes is very weak, without natural attenuation in the subsurface, the breakout of leachate to surface watercourses could contain unacceptable concentrations of non-hazardous pollutants.

5.2 The Nature of the Hydrogeological Risk Assessment

Golder has adopted a complex risk assessment methodology to Elsenham. This approach recognises the leachate concentrations within the landfill and the aquifer status of the surrounding Kesgrave sands and gravels.

5.3 The Proposed Assessment Scenarios

Within this Hydrogeological Risk Assessment, we consider the various scenarios as outline below during landfill lifecycle.

5.3.1 Normal Operating Conditions - Leachate Elevation above Groundwater Elevation

The Normal Operating Conditions model during groundwater management considers leakage as a function of time. This is for the existing engineering of the Site. Leakage will be determined with respect to a head of leachate above the elevation of groundwater that allows for an outward hydraulic gradient through the sidewall.

5.3.2 Normal Operating Conditions – Hydraulic Containment

Post closure, groundwater management will cease, and the Site will be managed by hydraulic containment. This assessment considers the potential for diffusion through the sidewall liner into the sand and gravels aquifer.

5.3.3 Failure Scenario

To consider the risk from leachate breakout following the cessation of leachate management after the Site has been managed by hydraulic containment a failure scenario in LandSim 2.5 has been prepared that takes account of the landfill hydraulics and the time for leachate to break out at surface.

5.4 The Priority Contaminants to be Modelled

The source term for the Site has been defined based on the leachate quality monitoring data, as summarised in Section 3.2. Following the review of the leachate data quality from the period between January 2014 and April 2020, the choice of priority substances to represent the range of compounds observed in the Site and therefore modelled are:

- Ammoniacal Nitrogen, an inorganic cation;
- Chloride, an inorganic anion;
- Mecoprop, an acid herbicide;
- Phenol, a hydrophilic organic chemical;
- Toluene , a hazardous hydrophobic organic compound;
- Cadmium, a less mobile metal;
- Nickel, a highly mobile metal; and
- Tributyltin an organo-metallic substance.

5.5 Numerical Modelling

5.5.1 Justification for Modelling Approach and Software

5.5.1.1 Normal Operating Conditions – During Construction

During construction the sidewall groundwater drainage will be active. Once sufficient waste is present in the landfill, groundwater drainage will cease allowing groundwater levels to rebound such that the Site becomes hydraulically contained, the hydrogeological risk associated with this phase is considered in the 'Hydraulic Containment' scenario.

Given that during construction the Site is managed such that the elevation of leachate is above the water table, the probabilistic risk assessment package; LandSim 2.5 (using the Monte Carlo Method) developed by Golder for the Environment Agency is appropriate to be used in order to assess the concentration of substances from the source term in downgradient groundwater.

LandSim 2.5 assumes groundwater underflow beneath the landfill and leakage through the landfill base. In this case the model has been repurposed to consider leakage through the sidewall and dilution in groundwater flow around the landfill.

Exact values of input parameters are rarely known. However, in LandSim each parameter can be described by a range of possible/probable values incorporating the available information. During each simulation, the parameters are assigned a value from within the defined ranges. After, say, 500 iterations, a range of possible predicted leakage or outcome values are obtained, and it becomes possible to quantify the likelihood of a certain outcome.

This approach uses statistical distributions or probability density functions (PDFs) to characterise some of the input parameters. Each time a calculation is carried out, one value from the defined input distributions is chosen by the computer code and, for example, a concentration at the receptor is calculated. Each result is stored such that after repeating the same calculation many times, an output distribution for the concentration at the receptor is obtained. The distribution output is given in terms of percentiles (%iles). These percentiles specify the probability with which a certain value (e.g. leakage rate) will not be exceeded. For instance, if the 95%ile of a leakage rate distribution is given as 0.1 m^3/day, there is a 95% chance that the actual leakage rate will be below or equal to 0.1 m^3/day. It follows that there is also a 5% chance that the actual leakage rate will be greater than 0.1 m^3/day. The 50%ile output is viewed as the most likely result from the model. Golder considers that the 95%ile output is sufficient to represent the reasonable worst-case output for this HRA review update.

5.5.1.2 Normal Operating Conditions – Hydraulic Containment

Once sufficient waste is present in the landfill, groundwater drainage will cease allowing groundwater levels to rebound such that the Site becomes hydraulically contained. The elevation of groundwater will be above the elevation of leachate, this means that leakage by advection can no longer occur. In order to assess the degree of hydraulic containment at the Site and understand the likelihood and concentration of contaminants breaking through the sidewall engineering of the cells by diffusion, the previous HRAR was completed using the EA spreadsheet "Contaminant Fluxes from Hydraulic Containment Landfills" (EA, 2004). This deterministic spreadsheet package uses site-specific and literature source term and pathway values to calculate the likely contaminant outputs at the defined compliance points and at which point they break through. The model considers retardation within the clay constructed sidewall and dilution in the groundwater flow. For conservatism the lowest clay hydraulic conductivity and highest concentrations have been incorporated to consider a worst case assessment.

5.5.2 Model Parameterisation

Updated parameters are detailed in the following sections.

5.5.2.1 Source Term

The source term used is based on Site specific data from Phases 1, 2 4A and 4B. Where most likely or maximum concentrations have increased during the HRA review period, probability density functions were derived from data for the period between January 2014 and April 2020. Where concentrations remained below those of the previous source term, the previous source term probability density functions were used. All source terms have been updated for Phase 4B to reflect the availability of site-specific data.

Table 12 below specifies the range of concentrations applied within the LandSim Phases. Details of how the source term probability density functions were derived are provided in Appendix E.

Table 12: LandSim Source Term

Distribution	Contaminant	Minimum (mg/l)	Most Likely (mg/l)	Maximum (mg/l)	Justification
Phase 1					
LogTriangular	Ammoniacal Nitrogen	0.01	491	3640	Consistent with 2013 HRAR
LogTriangular	Chloride	8.3	1075	1080	Updated based on 2014 to 2020 monitoring data
LogTriangular	Mecoprop	4×10^{-5}	0.0436	0.14	Consistent with 2013 HRAR
LogTriangular	Phenol	0.0025	0.009	0.124	Derived based on 2014 to 2020 data
LogTriangular	Toluene	5×10^{-5}	0.0104	1.287	Consistent with 2013 HRAR
LogTriangular	Cadmium	2.5×10^{-6}	0.00252	0.105	Consistent with 2013 HRAR
LogTriangular	Nickel	0.012	0.046	0.346	Updated based on 2014 to 2020 monitoring data
Phase 2					
LogTriangular	Ammoniacal Nitrogen	1.52	1480	1800	Updated based on 2014 to 2020 monitoring data
LogTriangular	Chloride	5.08	683	7760	Consistent with 2013 HRAR
LogTriangular	Mecoprop	0.00043	0.09	0.102	Updated based on 2014 to 2020 monitoring data
LogTriangular	Phenol	0.0075	0.026	0.309	Derived based on 2014 to 2020 data

Distribution	Contaminant	Minimum (mg/l)	Most Likely (mg/l)	Maximum (mg/l)	Justification
LogTriangular	Toluene	0.00082	0.033	0.04	Updated based on 2014 to 2020 monitoring data
LogTriangular	Cadmium	2.5 x 10^{-6}	0.00252	0.105	Consistent with 2013 HRAR
LogTriangular	Nickel	0.0065	0.0806	0.533	Updated based on 2014 to 2020 monitoring data
Phase 4A					
LogTriangular	Ammoniacal Nitrogen	0.01	683	3640	Consistent with 2013 HRAR
Triangular	Chloride	54.9	800	914	Updated based on 2014 to 2020 monitoring data
LogTriangular	Mecoprop	4 x 10^{-5}	0.0436	0.14	Consistent with 2013 HRAR
Single	Phenol	0.0075			Derived based on 2014 to 2020 data
LogTriangular	Toluene	5 x 10^{-5}	0.0104	1.287	Consistent with 2013 HRAR
LogTriangular	Cadmium	2.5 x 10^{-6}	0.00252	0.105	Consistent with 2013 HRAR
LogTriangular	Nickel	0.01	0.0817	0.668	Updated based on 2014 to 2020 monitoring data
Phase 1, 2 & 4A					
LogTriangular	Tributyltin	1 x 10^{-5}	0.000137	0.00189	PDF for Broadpath, a similar portfolio site with similar waste inputs
Phase 4B					
Triangular	Ammoniacal Nitrogen	0.135	3.63	7.13	Derived based on 2014 to 2020 monitoring data
LogTriangular	Chloride	53	278	483	
LogTriangular	Mecoprop	2 x 10^{-5}	0.001	0.00144	

Distribution	Contaminant	Minimum (mg/l)	Most Likely (mg/l)	Maximum (mg/l)	Justification
Triangular	Phenol	0.0025	0.0025	0.00655	
LogTriangular	Toluene	0.0001	0.001	0.01	
Triangular	Cadmium	3.5×10^{-5}	3×10^{-4}	3×10^{-4}	
LogTriangular	Nickel	0.0046	0.014	0.045	

5.5.2.2 Retardation and Decay

For the substance included in the source term that were not included previously, partitioning coefficients are defined in Table 13.

Table 13: Retardation and Decay

Distribution	Contaminant	Min	Most Likely	Max	Justification
Koc (mg/l)					
Single	Phenol		27		ConSim Help files (Environment Agency, 1995)
Kd (l/kg)					
LogUniform	Tributyltin	12000	-	200000	ConSim Help Files (Environment Agency, 1995)

5.5.2.3 Leachate Head

The following leachate head has been incorporated into the assessment for the different model scenarios.

Table 14: Updated leachate Head

Scenario	Phase	Distribution	Value	
Normal operating conditions	All	Single	3	Assumed range with active leachate control. Based on current compliance limits.

5.5.2.4 Background Groundwater Quality

Table 15 outlines the substances included in the source term during the previous review that did not include background groundwater concentrations. These concentrations have been updated to reflect the 2014 to 2020 monitoring data.

Table 15: Background Groundwater Quality

Distribution	Contaminant	Min	Most Likely	Max	Justification
Triangular	Cadmium	1×10^{-5}	0.0003	0.0006	Updated based on 2014 to 2020 monitoring data
Triangular	Toluene	5×10^{-5}	5×10^{-5}	0.00049	

5.5.2.5 LandSim Model Simulation

For the duration of management control for leachate management in the normal operating conditions the model inputs have been updated to reflect a maximum control period of 20,000 years. For the duration of management control in the failure scenario the model inputs have been updated to reflect a management period of 60 years after the end of filling.

5.6 Emissions to Groundwater

5.6.1 Hazardous Substances

Hazardous substances have been assessed in groundwater immediately down gradient to each phase following dilution in the immediate groundwater flow. The resultant concentrations reflect the degree of attenuation each contaminant has undergone as it passes through the mineral liner and immediate dilution in groundwater. Reported concentrations do not include dispersion or attenuation in groundwater.

5.6.1.1 Normal Operating Conditions – During Construction

Under the normal operating conditions – during construction scenario, it is predicted that toluene and tributyltin will not breakthrough in the 20,000-year time period considered. Hence, the predicted concentration of all hazardous substances is below the defined EALs.

5.6.1.2 Normal Operating Conditions – Hydraulic Containment

Under the normal operating conditions – hydraulic containment scenario, it is predicted that toluene and tributyltin will not breakthrough in the 20,000-year time-period considered. Hence, the predicted concentration of all hazardous substances is below the defined EALs.

5.6.1.3 Sensitivity Analysis

Under the sensitivity analysis scenario of an increased leachate head to 4 m, it is predicted that toluene and tributyltin will not breakthrough in the 20,000-year time-period considered. Hence, the predicted concentration of all hazardous substances is below the defined EALs.

5.6.2 Non-Hazardous Substances

Non-hazardous substances have been assessed at the downgradient compliance point.

5.6.2.1 Normal Operating Conditions – During Construction

The concentration of non-hazardous pollutants are detailed below in Table 16 at the downgradient compliance point. Under this normal operating conditions scenario, the predicted concentration of all non-hazardous pollutants are below the defined EALs. It is also noted however that the Site is hydraulically contained before these results would be observed.

Table 16: Normal Operating Conditions - LandSim - Non-hazardous pollutants

	50% less than		95% less than	
	Time to peak impact (years)	Peak concentration (mg/l)	Time to peak impact (years)	Peak concentration (mg/l)
Ammoniacal* Nitrogen	1100	0.16	820	0.86
Chloride*	130	25.8	420	88.6
Mecoprop*	>20,000	1×10^{-12}	>20,000	$<1 \times 10^{-12}$
Phenol*	510	4.2×10^{-6}	520	5.5×10^{-5}
Cadmium*	>20,000	2.0×10^{-4}	>20,000	4.7×10^{-4}
Nickel*	>20,000	4.2×10^{-3}	>20,000	7.2×10^{-3}

**Includes observed background concentrations*

5.6.2.2 Normal Operating Conditions – Hydraulic Containment

Under the normal operating conditions – hydraulic containment scenario the concentration of non-hazardous pollutants are detailed below in Table 17 at the downgradient compliance point. Under this normal operating conditions, hydraulic containment scenario, the predicted concentration of all non-hazardous pollutants are below the defined EALs.

Table 17: Normal Operating Conditions – Hydraulic Containment - Non-hazardous pollutants

Substance	Peak concentration (mg/l)
Ammoniacal Nitrogen	0.16
Chloride	5.9
Mecoprop	1×10^{-12}
Phenol	1×10^{-12}
Cadmium	1×10^{-12}
Nickel	3.3×10^{-5}

5.6.2.3 Sensitivity Analysis

The operational sensitivity to varying leachate head during the construction phase has been considered in order to compare the sensitivity of this parameter to the outcome of the modelling.

The concentration of non-hazardous pollutants are detailed below in Table 18 at the downgradient compliance point. Under this sensitivity analysis scenario, the predicted concentration of all non-hazardous pollutants are below the defined EALs. It is also noted however that the Site is hydraulically contained before these results would be observed.

Table 18: Sensitivity Analysis - Non-hazardous pollutants

	50% less than		95% less than	
	Time to peak impact (years)	Peak concentration (mg/l)	Time to peak impact (years)	Peak concentration (mg/l)
Ammoniacal* Nitrogen	1020	0.17	460	0.87
Chloride*	230	25.8	420	88.6
Mecoprop*	>20,000	1×10^{-12}	>20,000	$<1 \times 10^{-12}$
Phenol*	470	4.8×10^{-6}	420	6.3×10^{-5}
Cadmium*	>20,000	2.0×10^{-4}	>20,000	4.7×10^{-4}
Nickel*	>20,000	4.2×10^{-3}	>20,000	7.2×10^{-3}

**Includes observed background concentrations*

5.6.3 Failure Scenario

The failure scenario considers the cessation of active leachate management after 60 years following a managed leachate head during hydraulic containment of 3 m. The results of the modelling indicate that leachate breakout following a 9 m to 12 m rise in leachate head is likely within 8 years.

At this time there may still be hazardous substances or non-hazardous pollutants present in the leachate in sufficient quantities that this volume of leachate breakout could cause a discernible impact on surface water or groundwater quality.

5.7 Review of Technical Precautions

5.7.1 Capping

Phases 1, 2 and 4A are capped and restored with a 1 m clay liner. The capping was agreed with the Environment Agency and complies with the requirements of the Landfill Directive.

Phase 3 will be developed as a purely inert phase. Current Environment Agency guidance (Environment Agency, 2020) states that an engineered cap is not required, as long as the water management at the site is planned.

The inert and inactive waste accepted in Phase 4B is also inert with respect to leachate and landfill gas generation, hence it is accepted that capping of Phase 4B will also not be required.

5.7.2 Leachate Management

Leachate is actively pumped from wells at the Site to control leachate levels to the leachate head Compliance Limits. The infrastructure in place has actively managed leachate head and hence is sufficient to control leachate at the Site.

The risk assessment has demonstrated that the existing lining design offers sufficient environmental protection for the permitted head levels. Hence the Site is compliant with the Groundwater Directive and Landfill Directive. Leachate control will continue and there will be ongoing monitoring of both leachate and groundwater to validate the model.

Active leachate management of Phase 3 will not be necessary due to the composition of the leachate.

5.7.3 Lining Design

In Phases 1, 2 and 4A the basal artificial liner comprises 0.5 m of reworked London Clay overlain by 2 mm HDPE which extends 3 m up the side slope. No artificial liner is proposed for Phases 3 and 4B.

The risk assessment scenarios demonstrate that the basal lining design and the sidewall design provides sufficient environmental protection for compliance with the Groundwater Directive and Landfill Directive.

Due to the inert status of the waste, capping and active leachate management of Phase 3 and 4B will not be necessary. However surface breakout of inert waste leachate to surface watercourses would not be acceptable, hence, an assessment of the specification of the upper sidewall of Phase 3 is required to ensure that excessive heads of leachate cannot collect at the site, this assessment also applies to Phase 4B due to the similarities in conceptual model.

Phase 3 has a restored area of 10.8 hectares. Annual effective rainfall is reportedly 150 mm per year (SLR, 2005). This means that a recharge volume of 16,200 m^3 per year would enter Phase 3.

Water collecting within Phase 3 will discharge along the external phase boundaries to the west and south. The length of external phase boundaries of Phase 3 is 700 m

For the purpose of this assessment it is assumed that the saturated thickness of the Kesgrave Sand and Gravels is 2 m and that the base of the Kesgrave Sand and Gravels is 10 m below ground level. The required hydraulic conductivity of a 1 m thick geological sidewall barrier is estimated based on equation 1:

$$\frac{Q}{i.a} = k$$

Where:

Q = Rate of leakage through geological barrier = recharge rate = 16,200 m^3 per year = 0.00051 m^3/s

i = average hydraulic gradient across sidewall geological barrier

a = area = 700 x Height of leachate above adjacent base of Kesgrave Sand and Gravels (m)

The required hydraulic conductivity for a range of heads of inert leachate are detailed in Table 12 below.

Table 19: Minimum Specification of Upper Sidewall Geological Barrier

Height of leachate above base of Kesgrave Sand and Gravels (m)	Height of leachate above adjacent groundwater (m)	Minimum k (m/s)
3	1	2.9×10^{-7}
4	2	1.2×10^{-7}
5	3	7.0×10^{-8}
6	4	4.6×10^{-8}
7	5	3.3×10^{-8}
8	6	2.4×10^{-8}
9	7	1.9×10^{-8}

Based on these calculations it is indicated that the hydraulic conductivity range for the upper sidewall geological barrier is required to be in the range from a minimum of 1.9×10^{-8} m/s to the allowable maximum of 1×10^{-7} m/s.

The hydraulic conductivity of unconsolidated sediments detailed by Fetter (1994) are reproduced in Table 20. Based on these properties the likely sediment types in the specified range for the upper sidewall geological barrier could comprise silt, sandy silts, clayey sands or till.

It is noted that the hydraulic conductivity properties of the London Clay are orders of magnitude lower than the defined range, hence the upper sidewall geological barrier would be required to be constructed from either selected inert material or the clayey sand component of on-site deposits of Boulder Clay. The properties of the geological barrier will be either characterised in advance from stockpiles of consistent material or by CQA validation after construction.

Table 20: Ranges of Hydraulic Conductivities for Unconsolidated Sediments (after Fetter, 1994)

Sediment	Minimum hydraulic conductivity (m/s)	Maximum hydraulic conductivity (m/s)
Clay	10^{-11}	10^{-8}
Silt, sandy silts, clayey sands, till	10^{-8}	10^{-6}
Silty sands, fine sands	10^{-7}	10^{-5}
Well sorted sands, glacial outwash	10^{-5}	10^{-3}
Well sorted gravel	10^{-4}	10^{-2}

5.7.4 Groundwater Management

Groundwater management during construction and tipping at the Site has been required, no long-term active groundwater management is required at the Site. Groundwater level monitoring will continue to confirm this conceptual understanding of the hydraulic setting of the Site.

6.0 REQUISITE SURVEILLANCE

The purpose of this section is to review the existing monitoring programme (including locations, monitoring frequency and compliance levels) and to present revisions where appropriate.

This proposed requisite surveillance programme has been developed with consideration to the following:

- Phases 1, 2 and 4A have been capped and restored, Phase 4B is operational;
- The primary receptor is the groundwater within the Kesgrave Sands Aquifer;
- There is no discernible discharge of hazardous substances to groundwater; and
- There is no pollution (compared to drinking water standards or upgradient groundwater quality) with respect to non-hazardous pollutants.

The requisite surveillance has been designed with respect to the Environment Agency Regulatory Position Statement (RPS) 156 (Environment Agency, 2013) which has subsequently been absorbed into the Environmental Permitting Regulations.

6.1 Leachate Monitoring

Leachate monitoring is essential to develop an understanding of the quality of leachate present at the Site and how it evolves with time. Leachate levels will be monitored regularly across the Site to ensure the Site remains in compliance with respect to the leachate levels.

6.1.1 Leachate Level Monitoring

Phases at the Site are either non-operational or inert. Hence it is recommended that monitoring is conducted on a quarterly basis and Table S3.1 in the Permit updated in accordance with Table 21.

Table 21: Update to Table S3.1 - Leachate Level limits and monitoring requirements

Monitoring Point	Limit	Frequency
Non Operational Cells or Phases *(Any cells or phases that have a final engineered cap agreed in accordance with the existing 'landfill engineering' condition)* ***and Inert Cells or Phases***		
Phase 1 ELSEL01, ELSEL02, ELSEL03, ELSEL04, ELSEL05, ELSEL06, ELSEL07, ELSEL08, ELSEL09, ELSEL10, ELSEL11	3 m above cell base	Quarterly
Phase 2 ELSEL12, ELSEL13, ELSEL14, ELSEL15, ELSEL16, ELSEL17, ELSEL18, ELSEL19, ELSEL20, ELSEL21, ELSEL22, ELSEL23	3 m above the base of any leachate monitoring point or extraction point	
Phase 4A ELSEL24, ELSEL25, ELSEL26	3 m above the base of any leachate monitoring point or extraction point	
ELSEL27 and all future Phase 3 and Phase 4 Monitoring Points	No Limit	

6.1.2 Leachate Quality Monitoring

Leachate quality should continue to be monitored in accordance with the regime presented in Table S3.9 in the Permit that is already aligned with the RPS.

6.2 Groundwater Monitoring

The objective of groundwater monitoring at the Site is to provide routine monitoring of groundwater levels in order to understand groundwater levels and flow directions, and to provide groundwater quality information from which to assess any potential impact from the Site. Groundwater monitoring is important to ensure the Site does not cause any degradation to down gradient groundwater, or to monitor if other natural or anthropological sources upgradient of the Site cause degradation to the groundwater entering the Site.

6.2.1 Groundwater Level Monitoring

It is recommended that groundwater level monitoring continues on a quarterly basis in line with the RPS (EA, 2013) as outlined in Table S3.7 of the Permit.

6.2.2 Groundwater Quality Monitoring

Compliance with regard to groundwater is addressed in Table S3.4 of the Permit. No changes to Table 3.4 are proposed as it is already aligned with the RPS. It is proposed to include mecoprop, naphthalene and cadmium into the annual groundwater screen in Table S3.7 of the Permit.

6.3 Surface Water Monitoring

Surface water quality should continue to be monitored in accordance with the regime presented in Tables S3.3 and S3.10 in the Permit that are already aligned with the RPS.

7.0 CONCLUSIONS

In accordance with the Groundwater Directive, hazardous substances should be prevented from forming a discernible discharge in groundwater immediately downgradient of each phase. Discharge of non-hazardous pollutants also needs to be limited so as to prevent pollution. Both hazardous substances and non-hazardous pollutants are present within the leachate produced at the Site and there is the potential for this leachate to migrate through the liner system and unsaturated zone to the surrounding water environment.

This risk assessment demonstrates that under the proposed operational leachate heads, no hazardous substances are predicted to be discernible in groundwater beneath the Site and non-hazardous pollutants will be less than the relevant quality standards in downgradient groundwater. Therefore, the Site is compliant with the Groundwater Directive.

Hydraulic containment and non-hydraulic containment scenarios have been considered for the Site, the outcome of these assessments are that if either approach was followed in the long term the predicted impact from the Site would be acceptable. The Site is currently mostly in hydraulic containment with only localised areas or short periods of time during the season when this is not the case, given that non-hydraulic containment and hydraulic containment scenarios are acceptable, if following full cessation of groundwater management full hydraulic containment is not achieved, the assessments demonstrate that this would still be acceptable in terms of hydrogeological risk.

The consideration of technical precautions is a requirement of the Groundwater Directive and has been completed for the Site. This review concluded that the Site remains in line with the Groundwater Directive for all items considered: capping, lining design, leachate drainage systems and head control, and groundwater management. Therefore, the Site is compliant with the Landfill Directive.

The provision of suitable requisite surveillance of groundwater is a requirement of the Groundwater Directive. The requisite surveillance for the Site has been reviewed and some changes are proposed to reflect the closed status of the Site and to include an additional substance in the groundwater screen.

This HRAR has considered the risk to the water environment from the Site and reviewed the technical precautions and requisite surveillance. Based on the findings of the report, the Site is considered to be compliant with the Groundwater Directive. It is recommended that the HRA continues to be reviewed at least every six years in order to monitor the performance of the Site and meet the legislative requirements.

8.0 REFERENCES

1) BGS, 1981. Hydrogeological Map of Southern East Anglia. http://www.largeimages.bgs.ac.uk/iip/hydromaps.html?id=southern-east-anglia.jp2

2) BGS, 1984. Hydrogeological Map of the area between Cambridge and Maidenhead. http://www.largeimages.bgs.ac.uk/iip/hydromaps.html?id=cambridge-maidenhead.jp2

3) British Geological Survey, 2020. GeoIndex Onshore, http://mapapps2.bgs.ac.uk/geoindex/home.html

4) Defra, 2020. MAGIC Online Database

5) Enviros Consulting Limited. 2003. PPC Application

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7) Environment Agency, 2013. Regulator Position Statement: Landfill monitoring and reporting standards. Reference RPS 156.

8) Fetter, C.W, 1994 Applied Hydrogeology, Third Edition

9) Joint Agencies Groundwater Directive Advisory Group, 2019. JAGDAG Confirmed Hazardous Substances, https://www.wfduk.org/sites/default/files/Confirmed_Haz-NonHaz_January2019.pdf

10) SLR, 2005. Elsenham Landfill: PPC Variation Application. Section A – Environmental Setting and Installation Design. SLR Ref: 4A-738-003/ESID. March 2005

11) SLR, 2013. Elsenham Landfill. Hydrogeological Risk Assessment Review and IC3. SLR Ref:402-00036-00645/HRA. December 2013.

12) The Environmental Permitting Regulations (England and Wales) (Amendment) 2018

Signature Page

Golder Associates (UK) Ltd

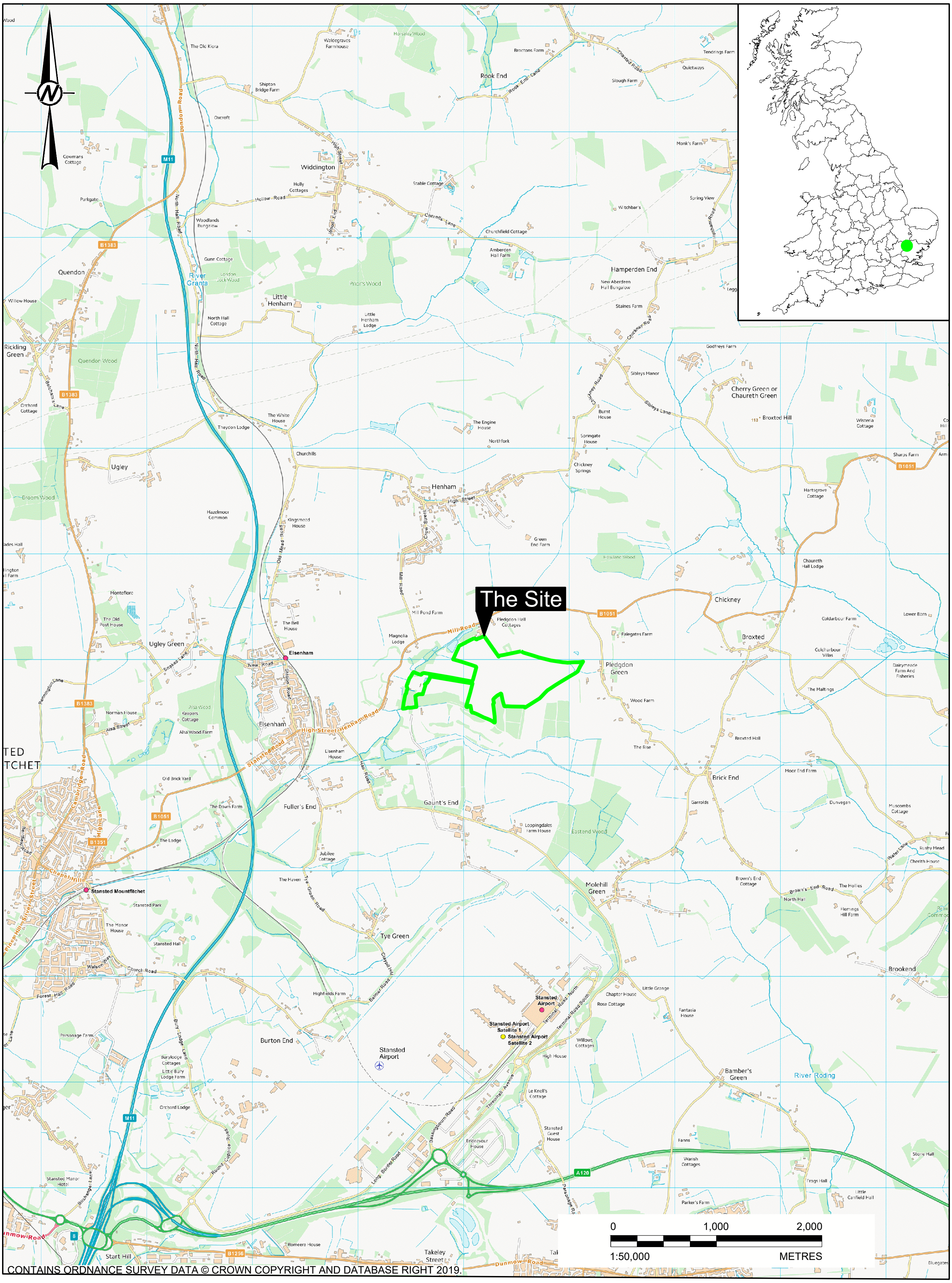
Laura Eckersley
Hydrogeologist

Richard Lansley
Senior Hydrogeologist

Date: 6 January 2021

LE/RJL/ab

Drawings



CLIENT
VIRIDOR WASTE MANAGEMENT LTD

PROJECT
ELSENHAM HRA REVIEW

CONSULTANT

GOLDER

YYYY-MM-DD	2020-09-17
DESIGNED	LE
PREPARED	ECS
REVIEWED	RL
APPROVED	RL

TITLE
SITE LOCATION PLAN

PROJECT NO.	CONTROL	REV.	DRAWING
19125348	1000-HR-0001	A	HRAR1

Last Edited By: lskinner Date: 2020-09-17 Time:3:28:59 PM | Printed By: lskinner Date: 2020-09-17 Time:3:46:20 PM | File Name: 19125348-1000-HR-0001.dwg
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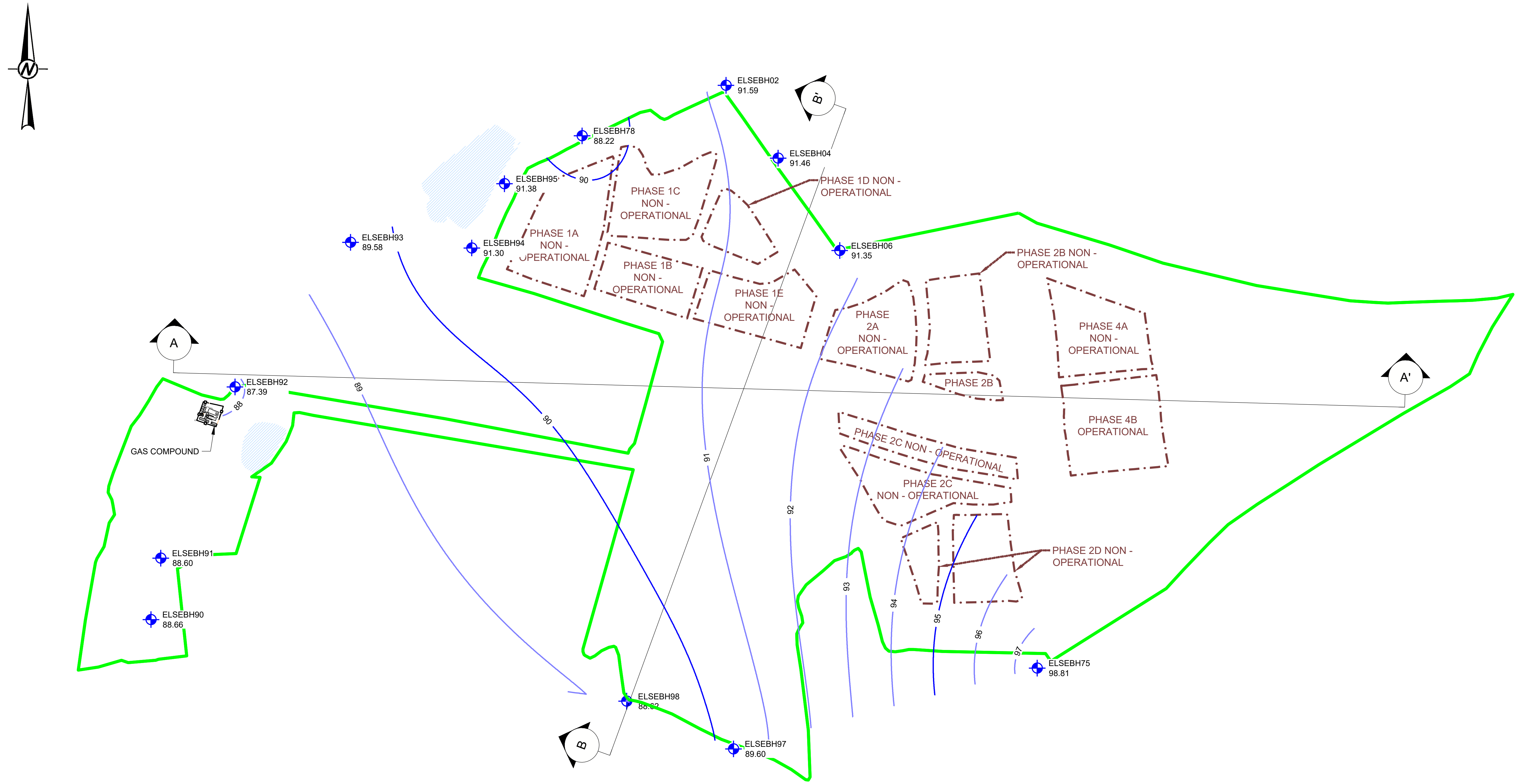


LEGEND

- ENVIRONMENTAL PERMIT BOUNDARY
- BOREHOLE LOCATIONS
- GROUNDWATER CONTOURS

REFERENCE(S)

BASE MAP TAKEN FROM CLIENT SUPPLIED DRAWING REF. EL3000-OCT'2016 REV B NB.

0 100 200
1:5,000 METRES

CLIENT
VIRIDOR WASTE MANAGEMENT LTD

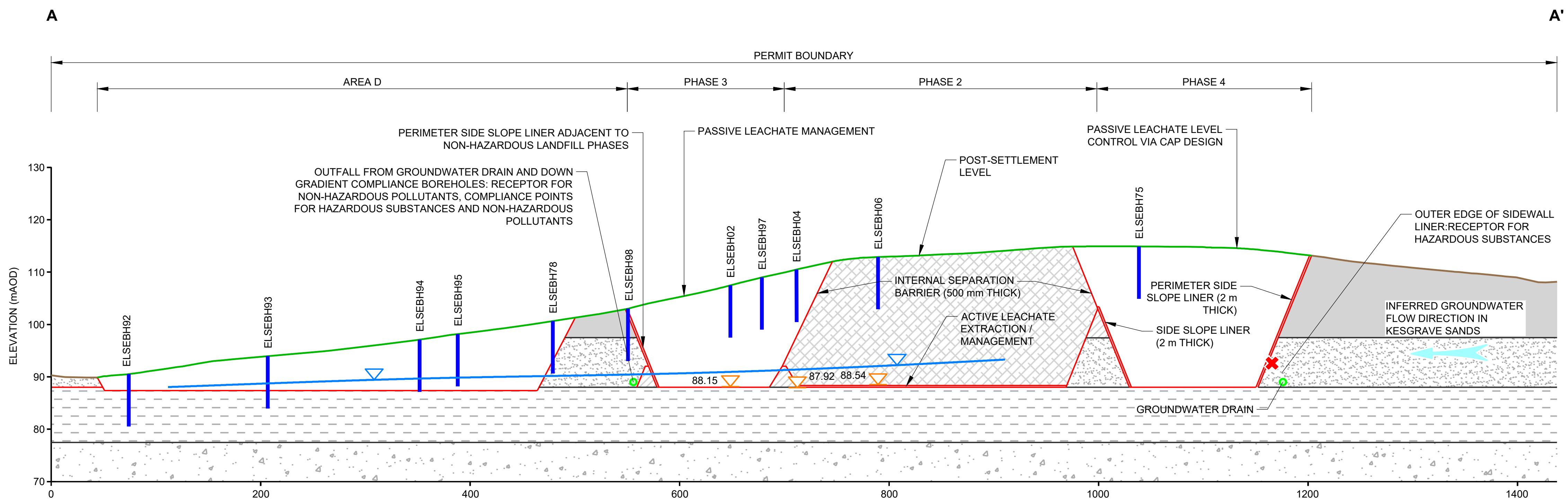
PROJECT
ELSENHAM HRA REVIEW

TITLE
GROUNDWATER ELEVATION CONTOURS

CONSULTANT
GOLDER

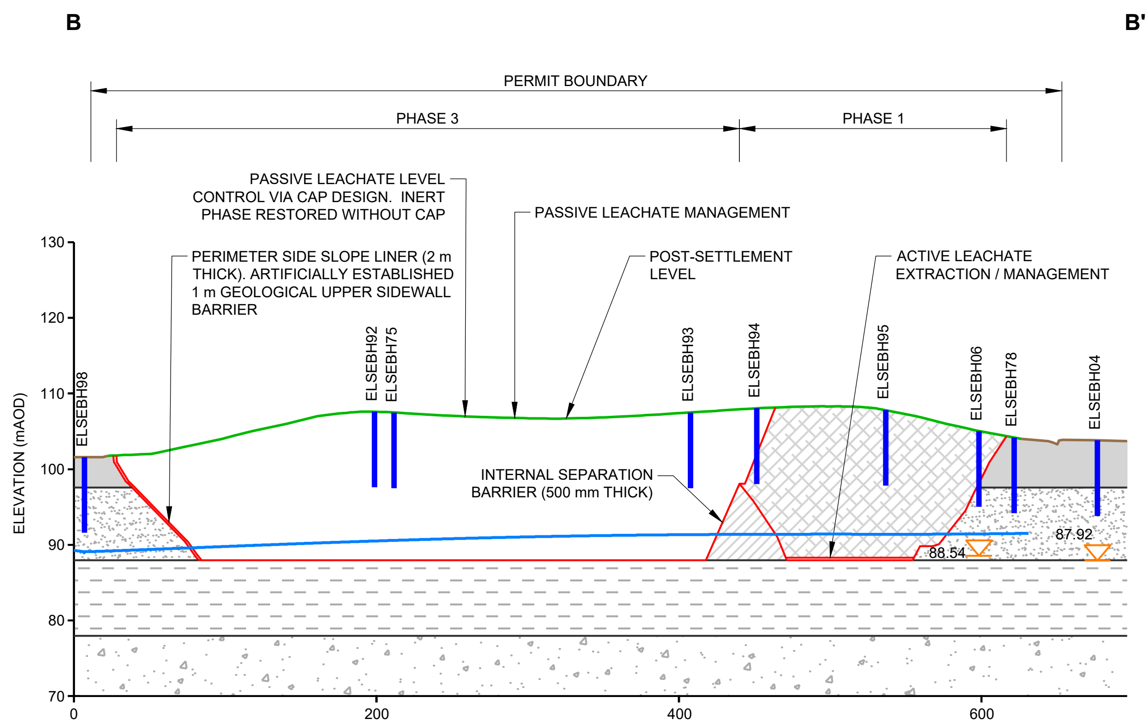
YYYY-MM-DD	2020-09-17
DESIGNED	LE
PREPARED	ECS
REVIEWED	RL
APPROVED	RL

PROJECT NO.	CONTROL	REV.	DRAWING
19125348	1000-HR-0002	A	HRAR2



SECTION A-A'

SCALE HORIZONTAL 1:5,000, VERTICAL 1:1,000



SECTION B-B'

SCALE HORIZONTAL 1:5,000, VERTICAL 1:1,000

LEGEND

- RESTORATION CONTOUR
- LEACHATE LEVELS
- GROUNDWATER LEVEL
- EXISTING WASTE DEPOSITS
- INSITU WASTE
- ENGINEERED CLAY
- CHALKY BOULDER CLAY
- KESGRAVE SANDS
- LONDON CLAY
- LOWER LONDON TERTIARIES

0 25 50
1:1,000 METRES

0 25 50
1:1,000 METRES

CLIENT
VIRIDOR WASTE MANAGEMENT LTD

PROJECT
ELSENHAM HRA REVIEW

TITLE
CONCEPTUAL MODEL

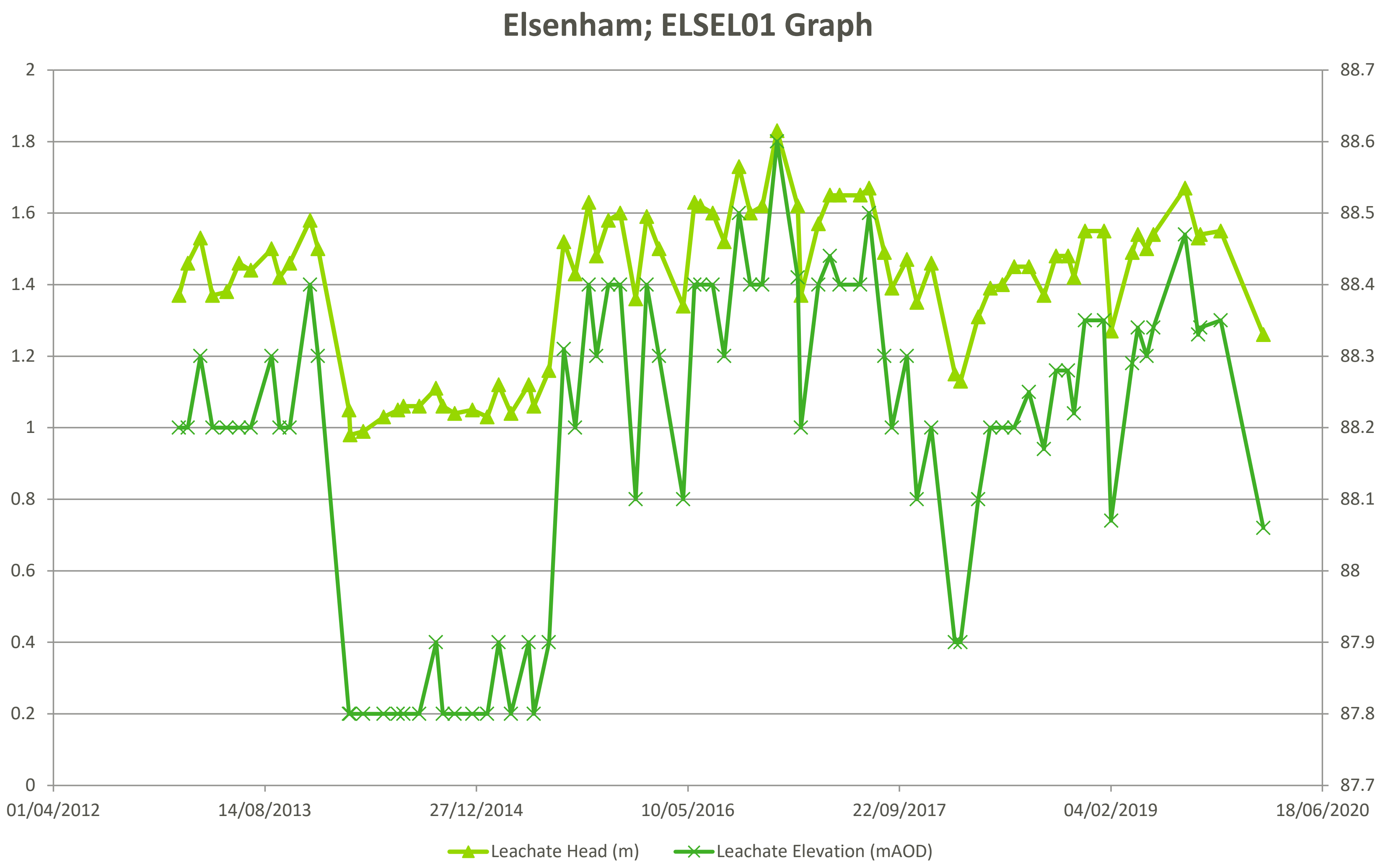
CONSULTANT
GOLDER

YYYY-MM-DD	2020-09-17
DESIGNED	LE
PREPARED	ECS
REVIEWED	RL
APPROVED	RL

PROJECT NO.	CONTROL	REV.	DRAWING
19125348	1000-HR-0003	A	HRAR3

APPENDIX A

Leachate Level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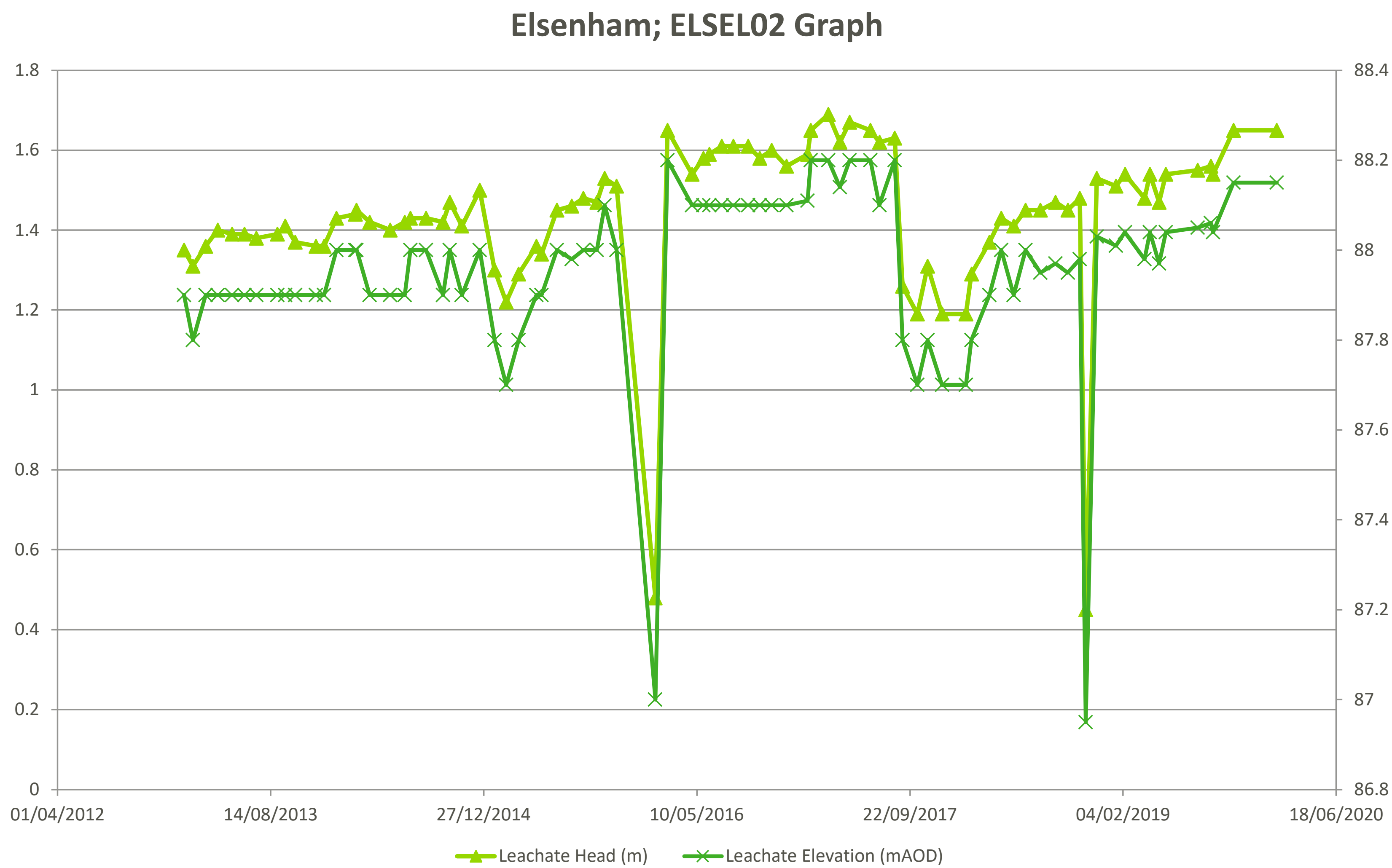
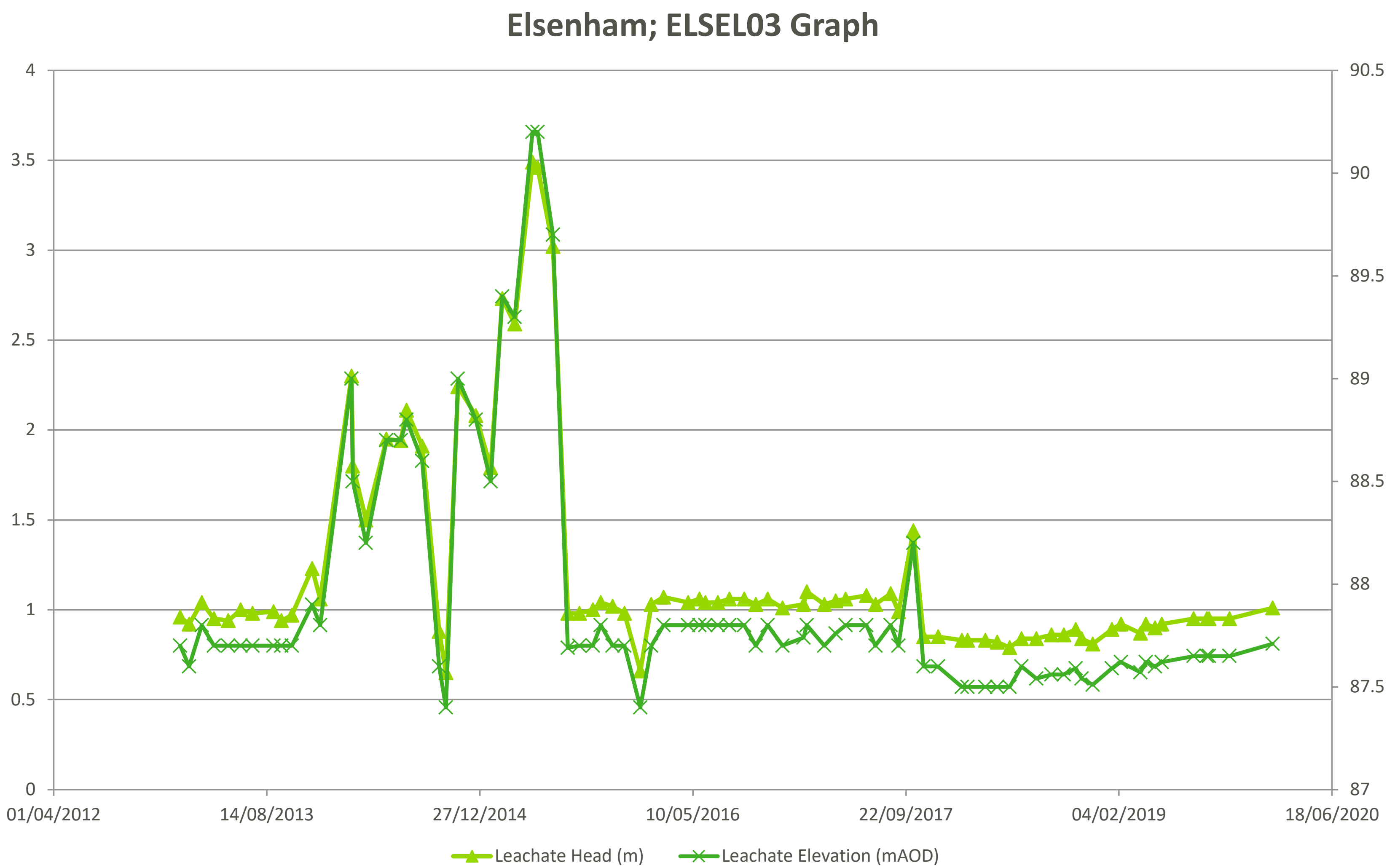
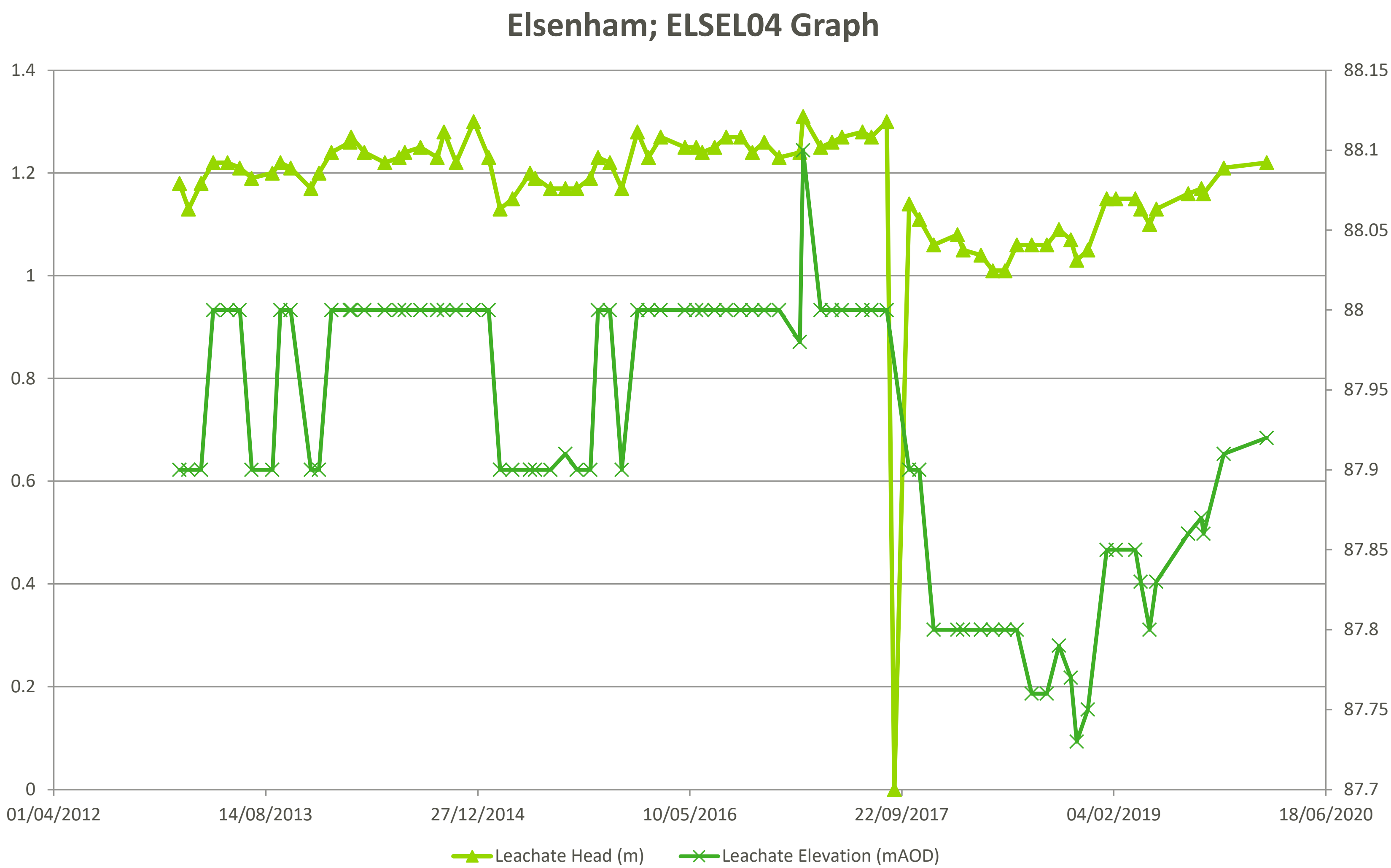
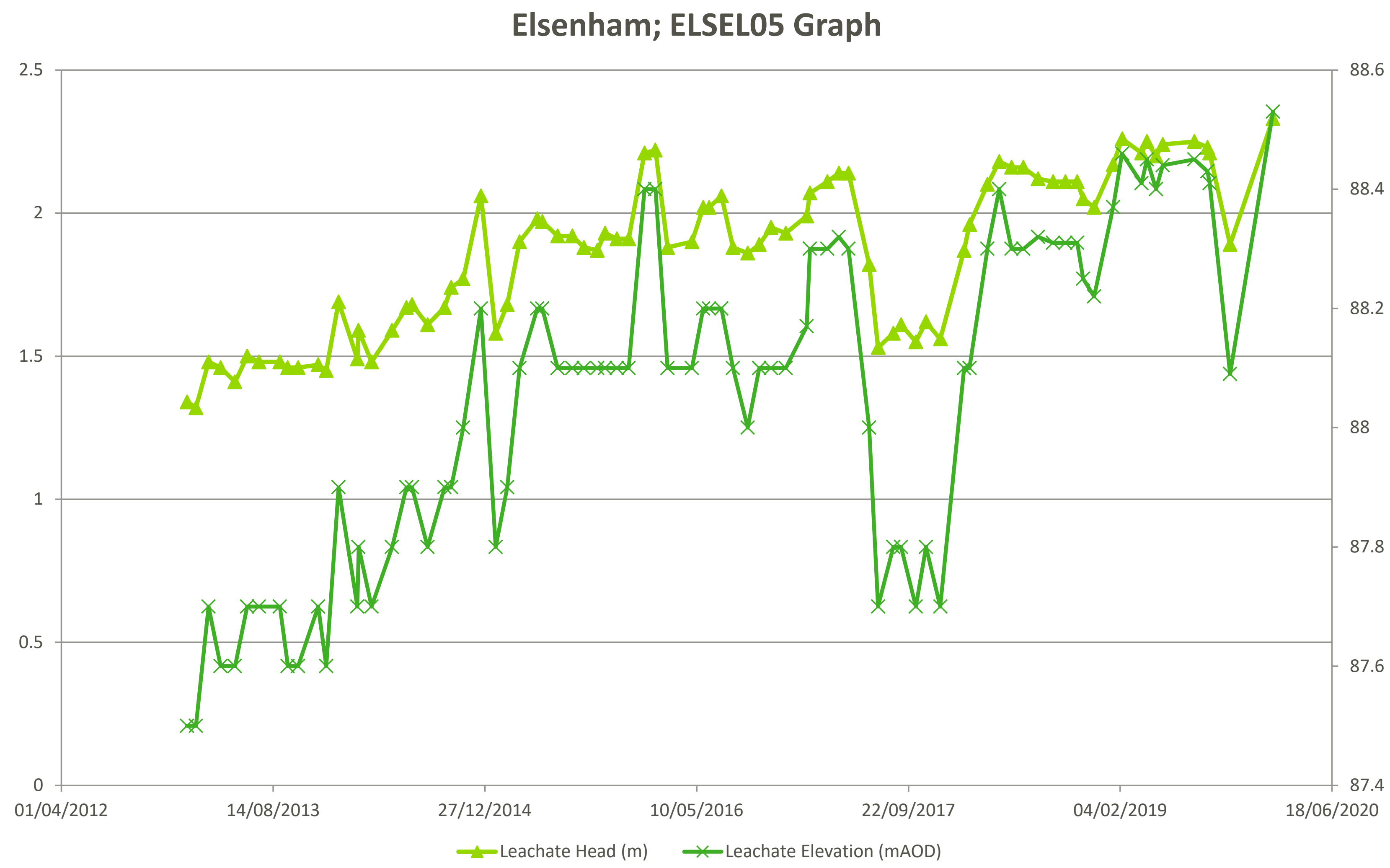
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
88.7
88.6
88.5
88.4
88.3
88.2
88.1
88
87.9
87.8
87.7
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL02 Graph
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
88.4
88.2
88
87.8
87.6
87.4
87.2
87
86.8
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

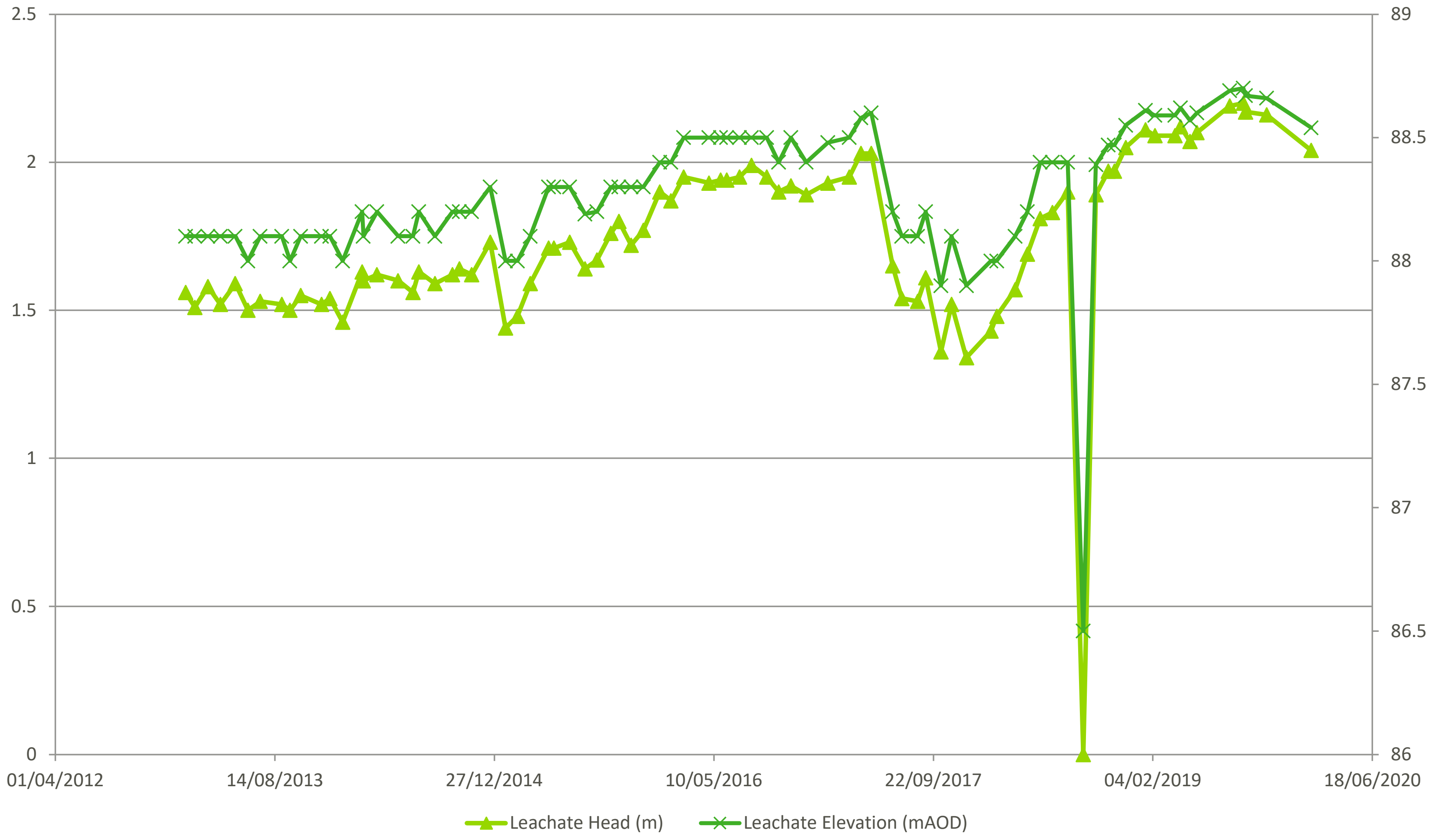

Elsenham; ELSEL03 Graph
4
3.5
3
2.5
2
1.5
1
0.5
0
90.5
90
89.5
89
88.5
88
87.5
87
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

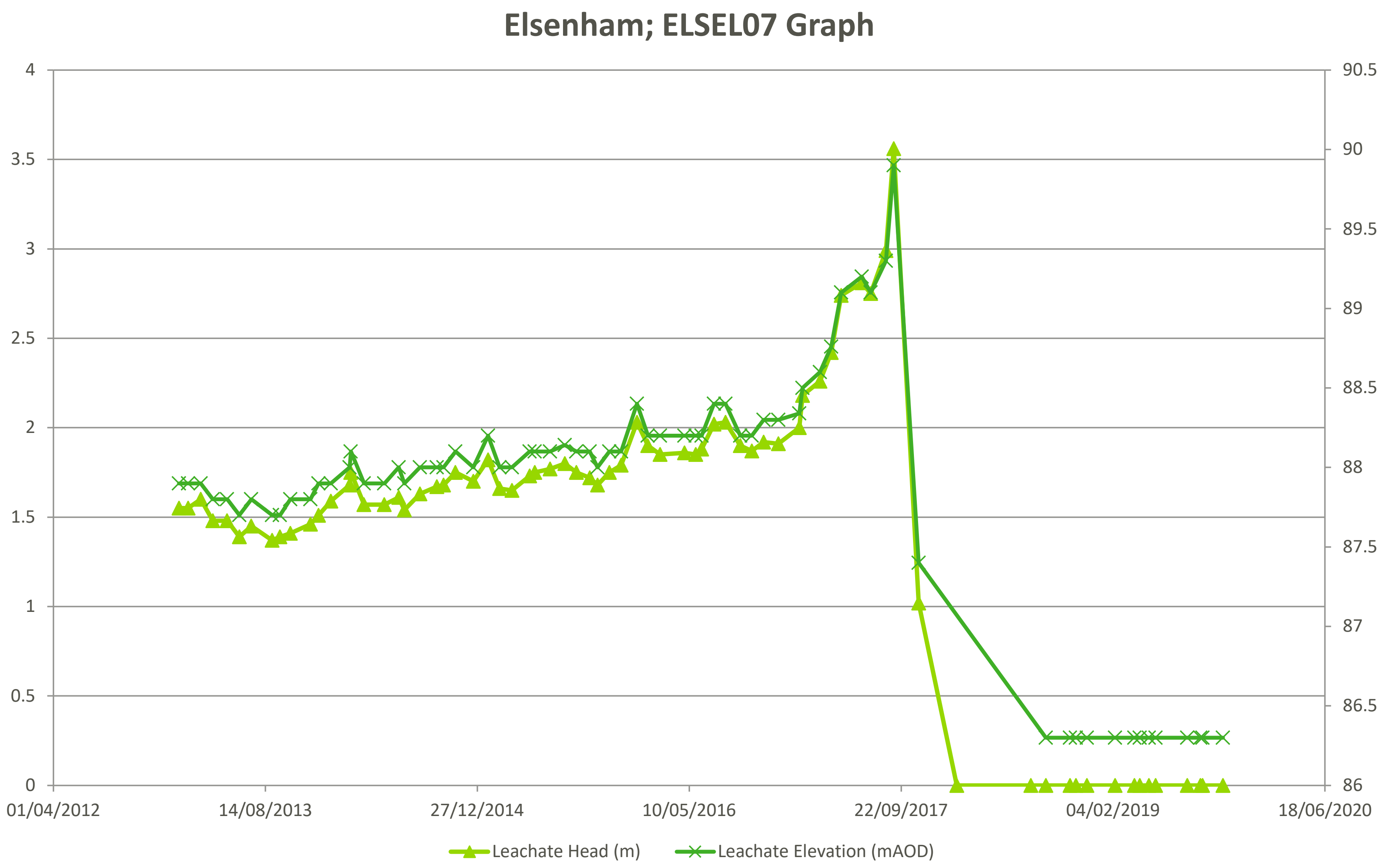
GOLDER


Elsenham; ELSEL04 Graph
1.4
1.2
1
0.8
0.6
0.4
0.2
0
88.15
88.1
88.05
88
87.95
87.9
87.85
87.8
87.75
87.7
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

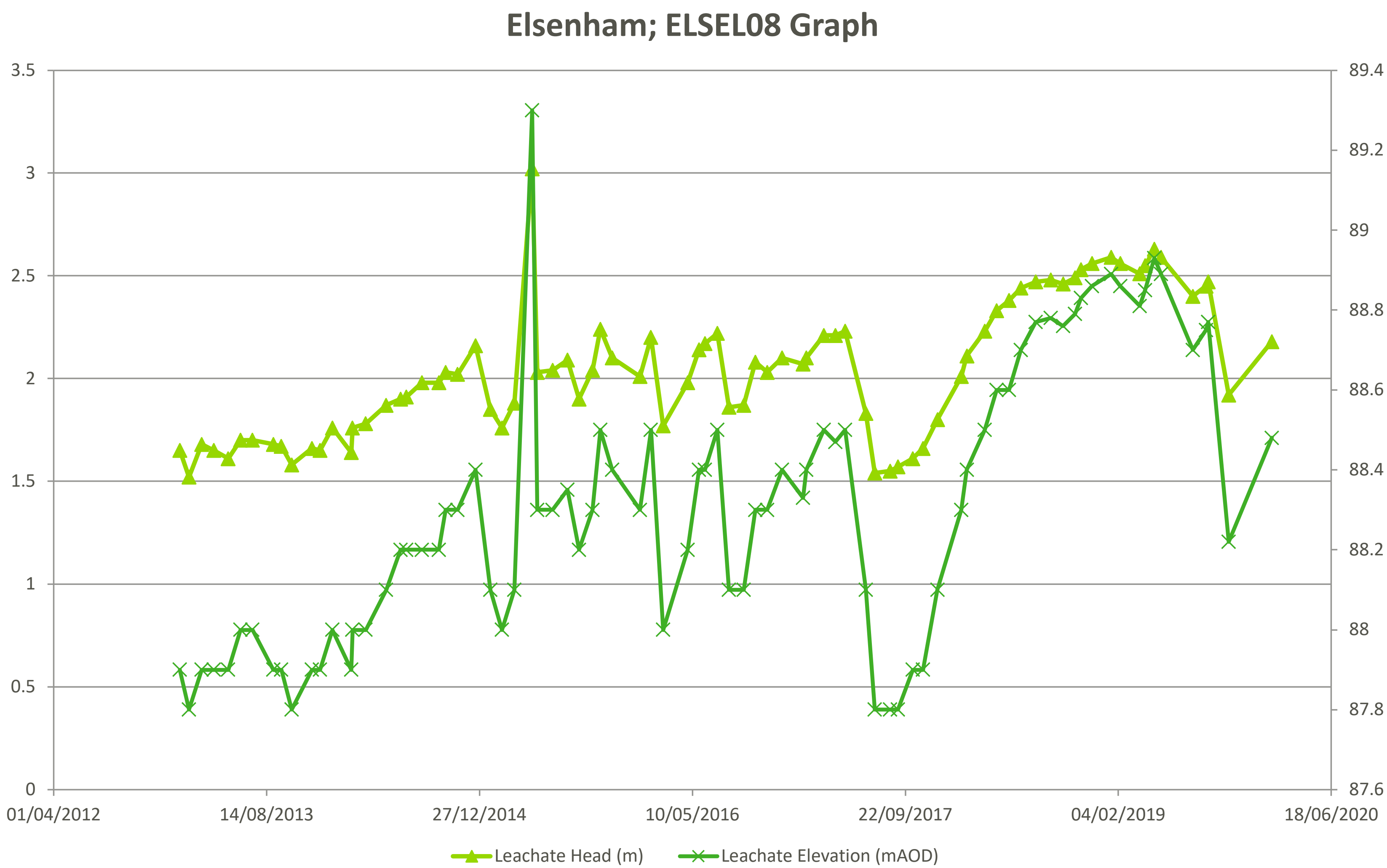

Elsenham; ELSEL05 Graph
2.5
2
1.5
1
0.5
0
88.6
88.4
88.2
88
87.8
87.6
87.4
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

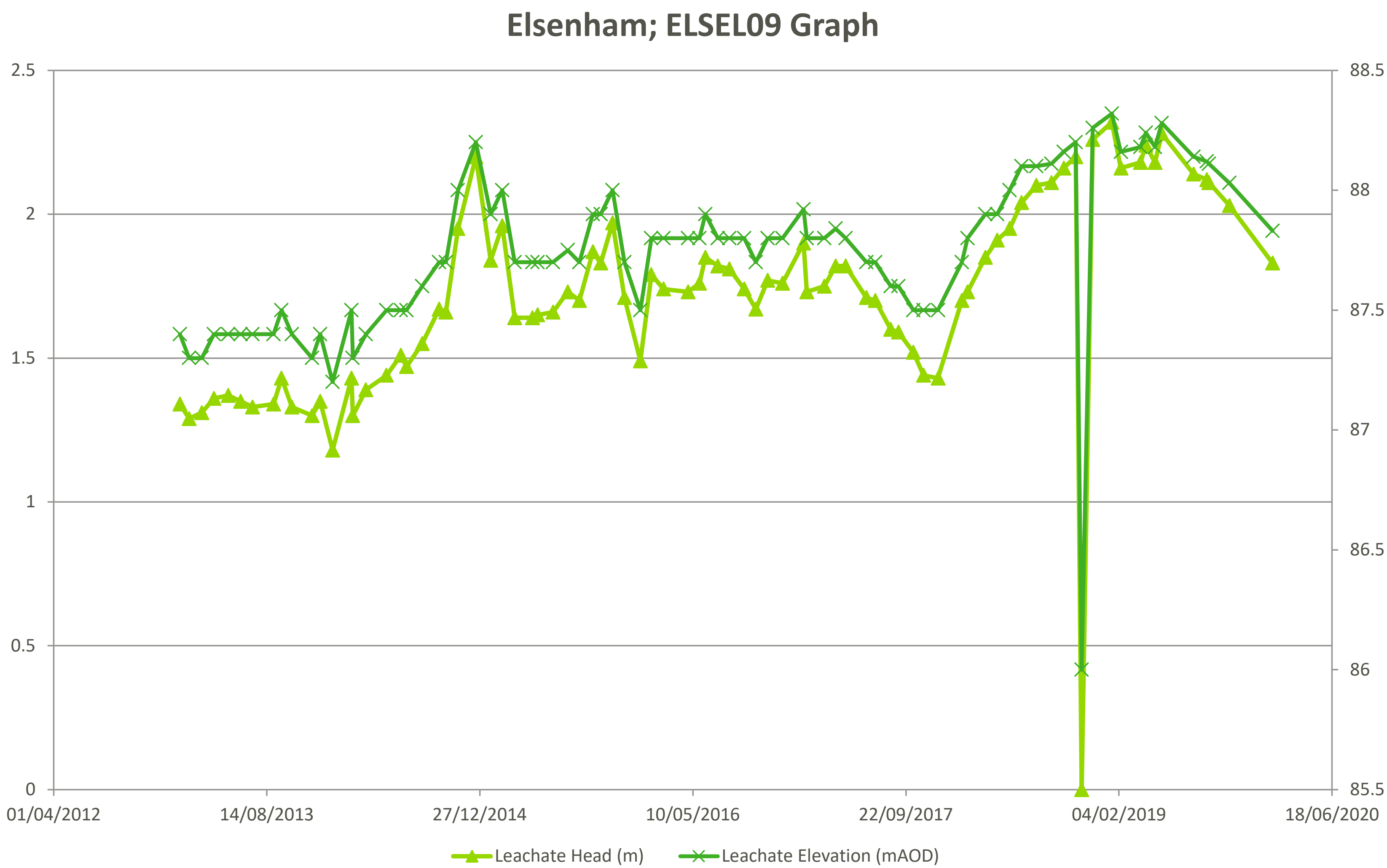
Elsenham; ELSEL06 Graph



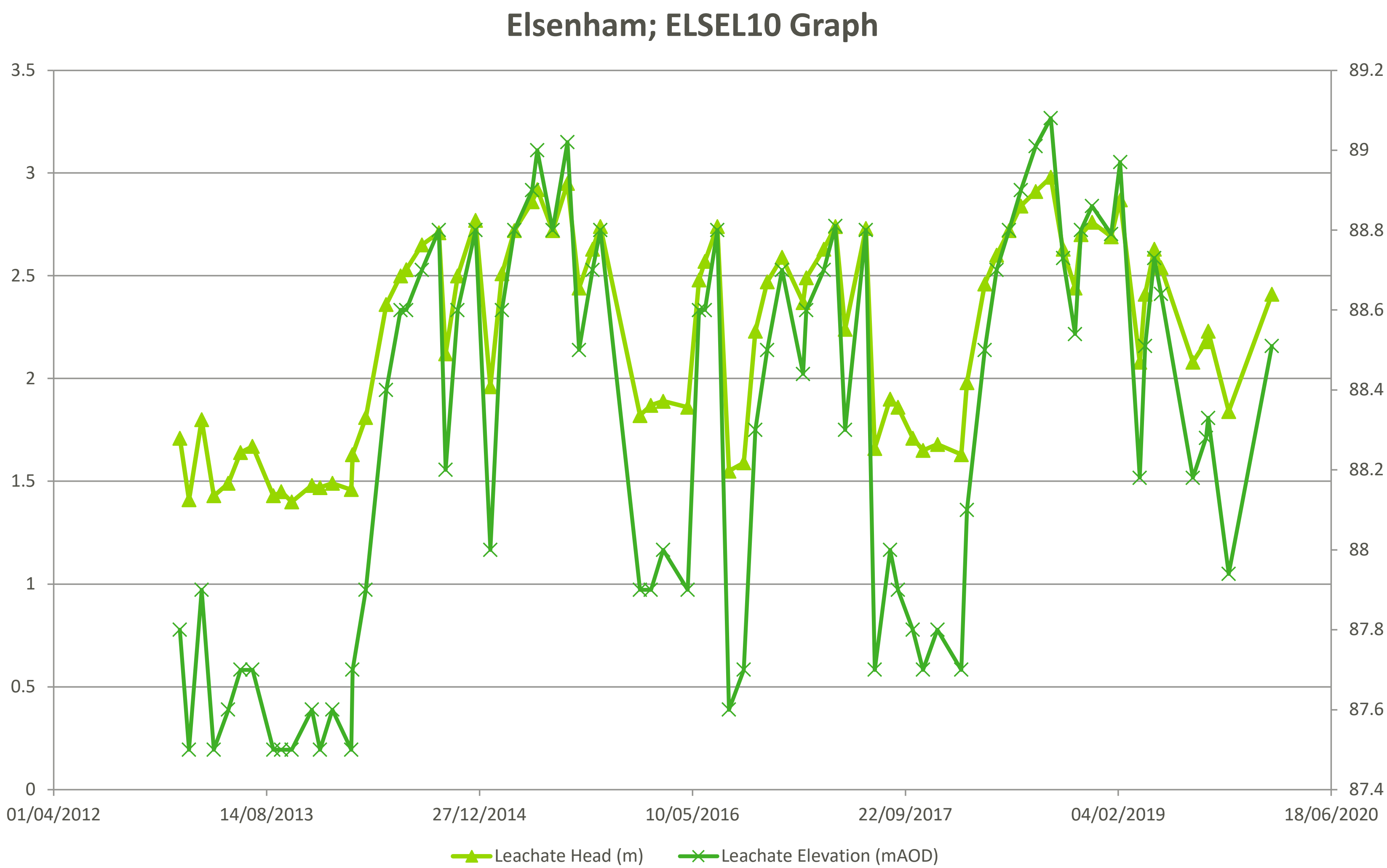

Elsenham; ELSEL07 Graph
4
3.5
3
2.5
2
1.5
1
0.5
0
90.5
90
89.5
89
88.5
88
87.5
87
86.5
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

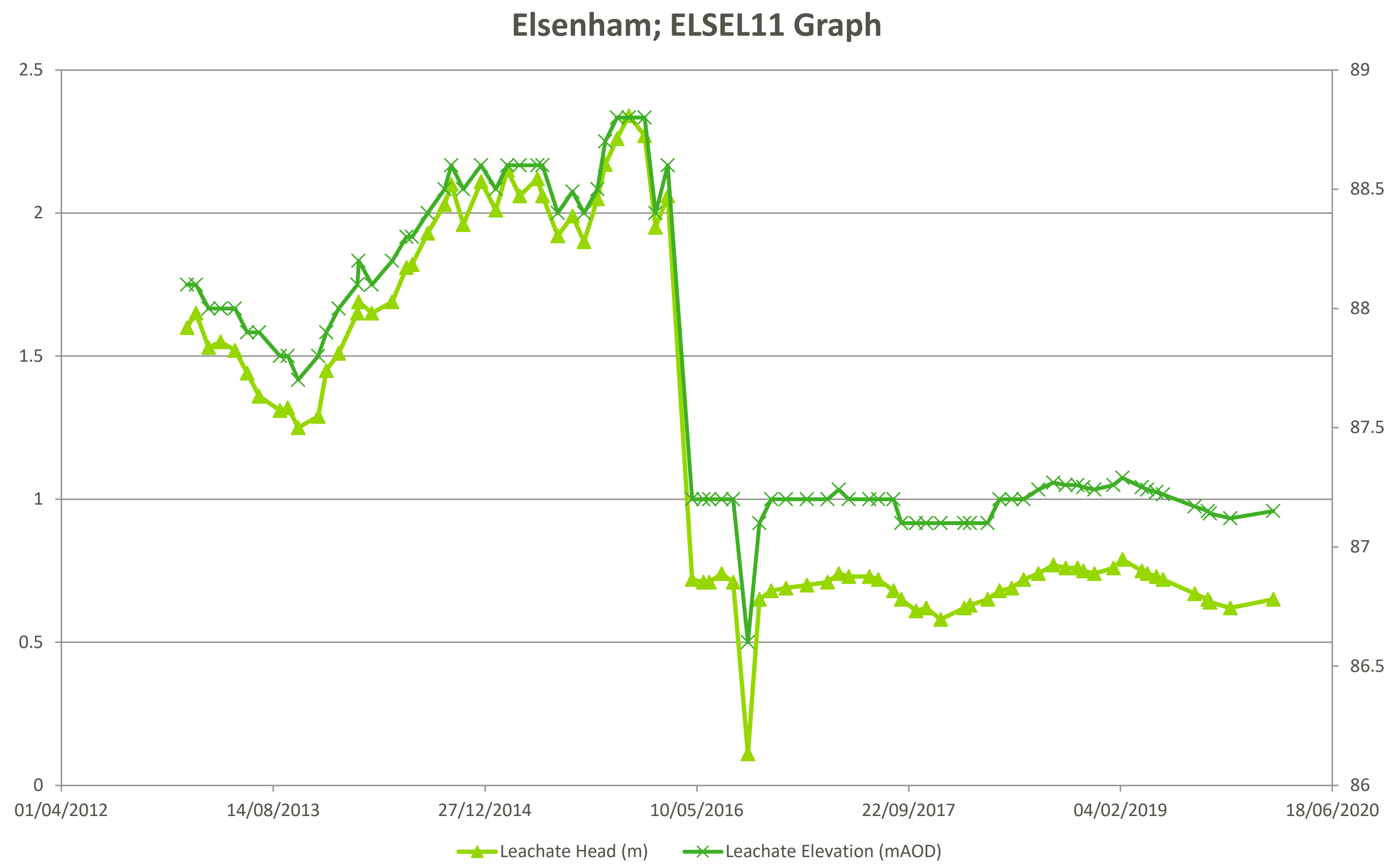
GOLDER


Elsenham; ELSEL08 Graph
3.5
3
2.5
2
1.5
1
0.5
0
89.4
89.2
89
88.8
88.6
88.4
88.2
88
87.8
87.6
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

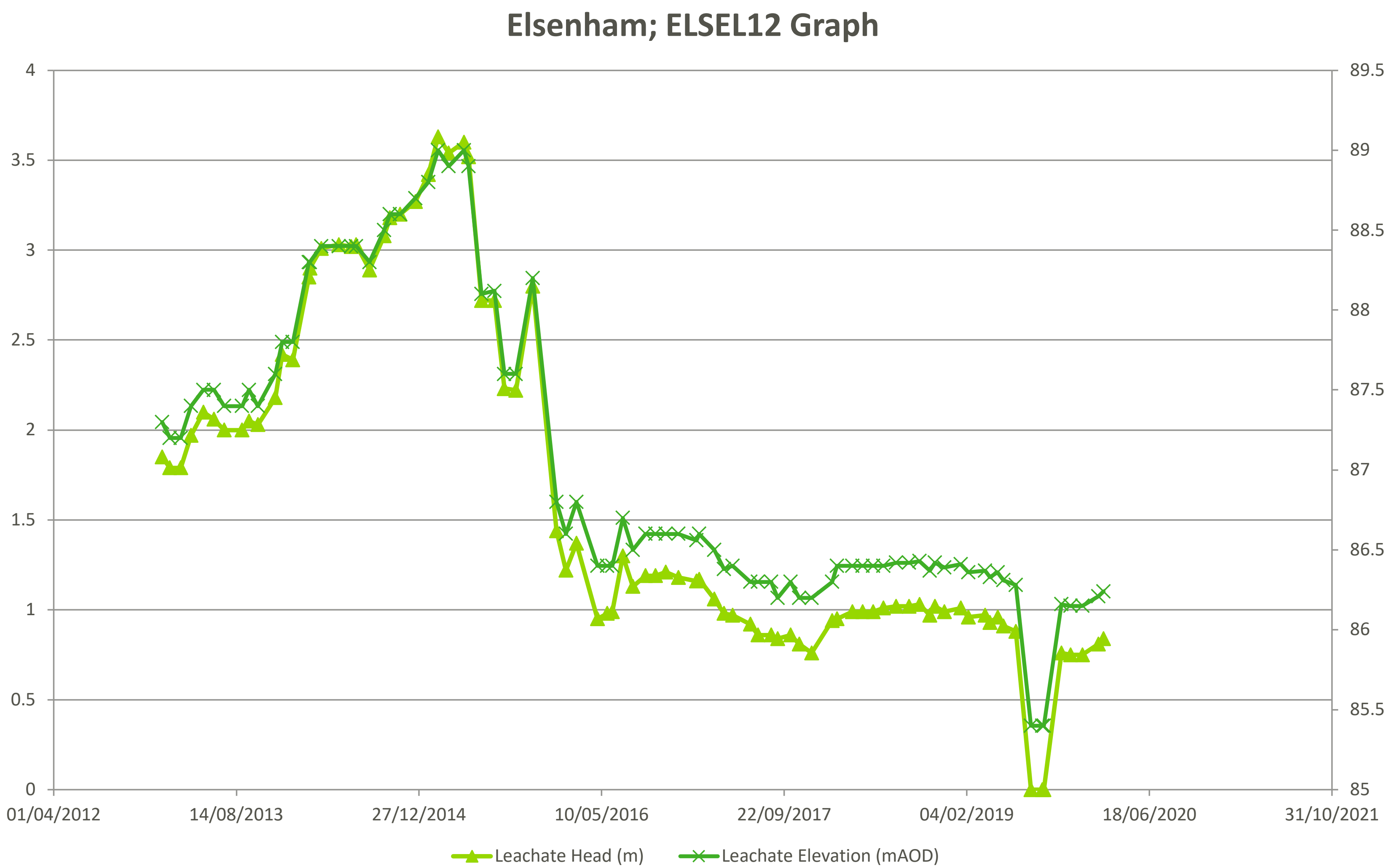

Elsenham; ELSEL09 Graph
2.5
2
1.5
1
0.5
0
88.5
88
87.5
87
86.5
86
85.5
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

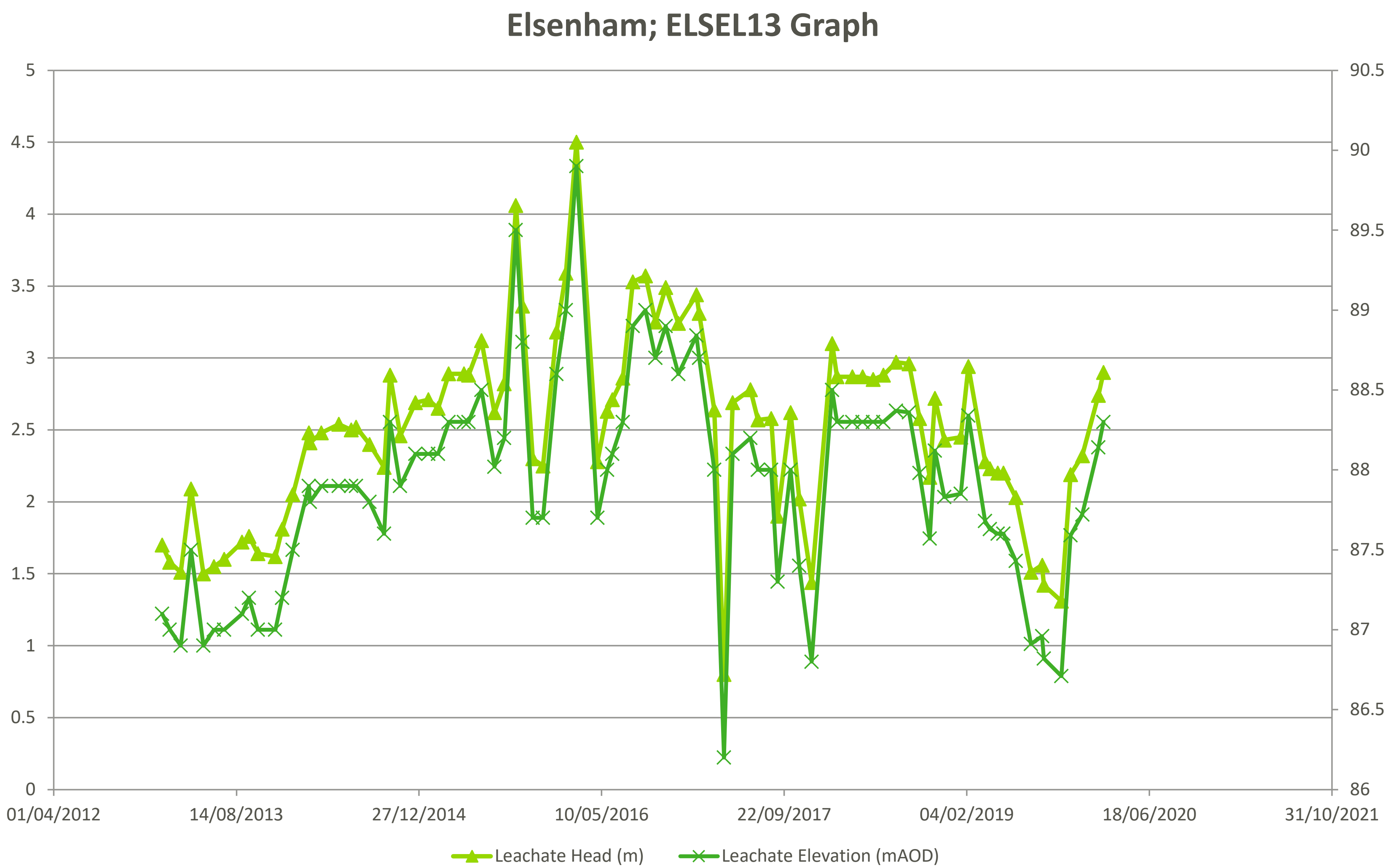
GOLDER

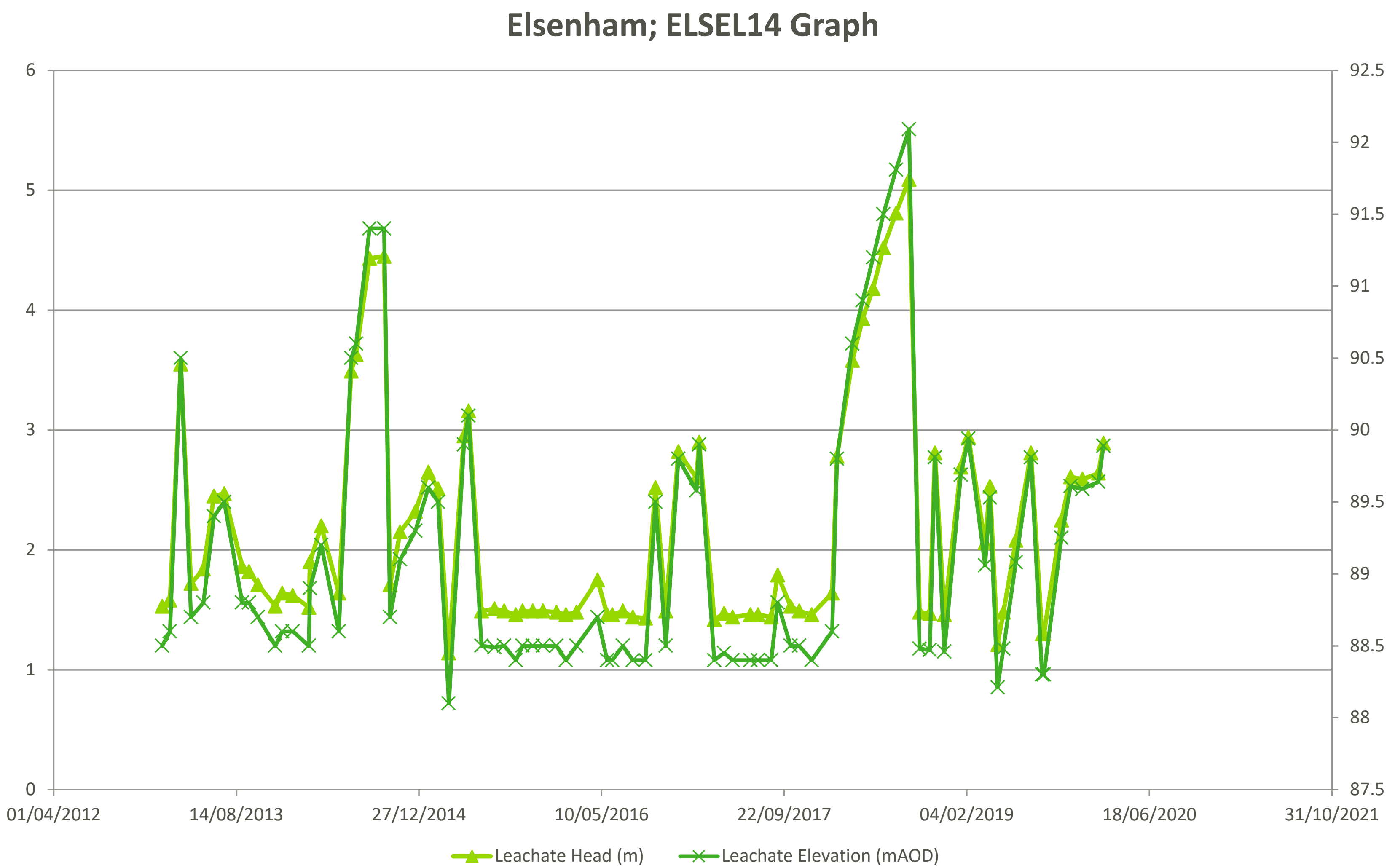

Elsenham; ELSEL10 Graph
3.5
3
2.5
2
1.5
1
0.5
0
89.2
89
88.8
88.6
88.4
88.2
88
87.8
87.6
87.4
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

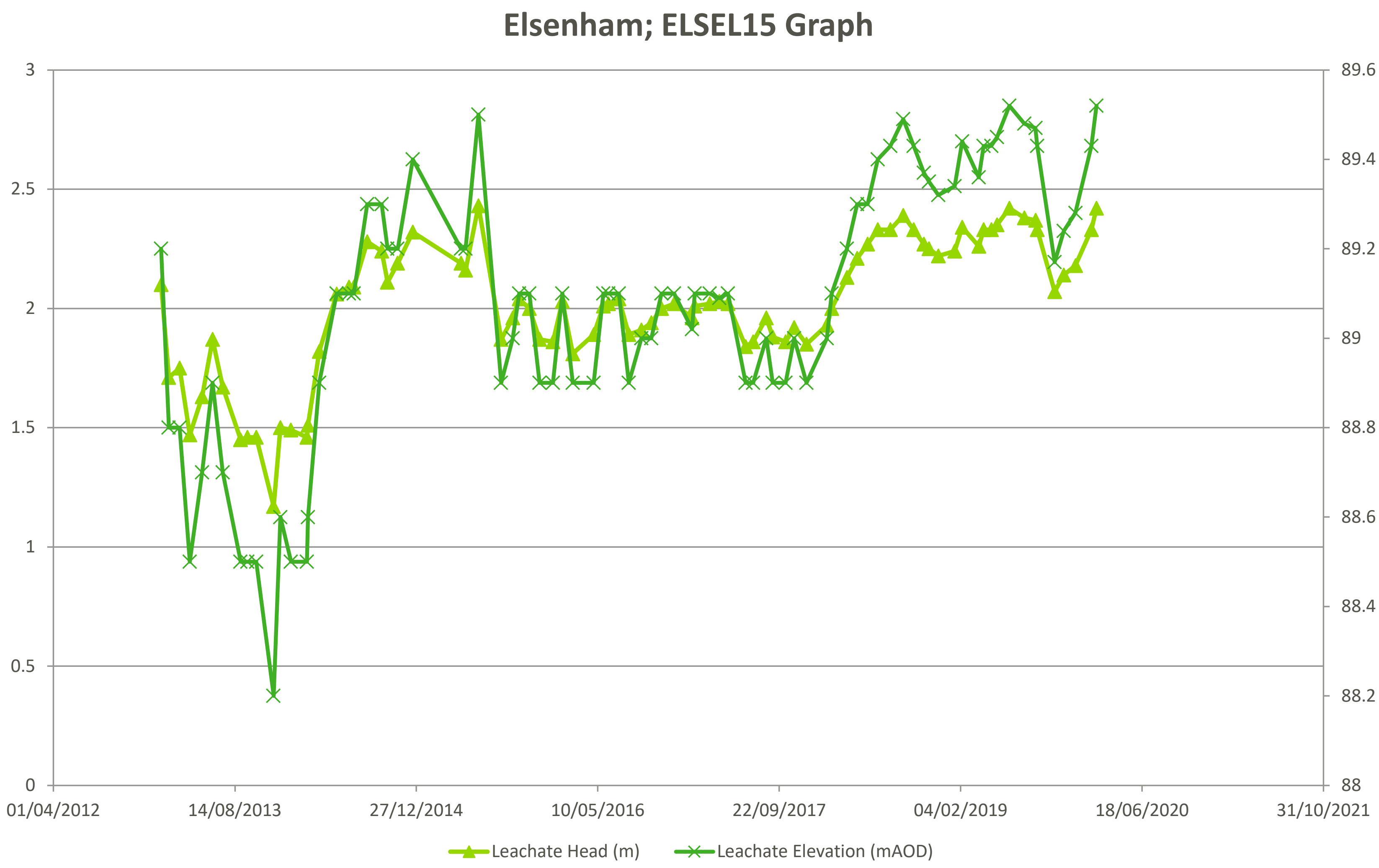

Elsenham; ELSEL11 Graph
2.5
2
1.5
1
0.5
0
89
88.5
88
87.5
87
86.5
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

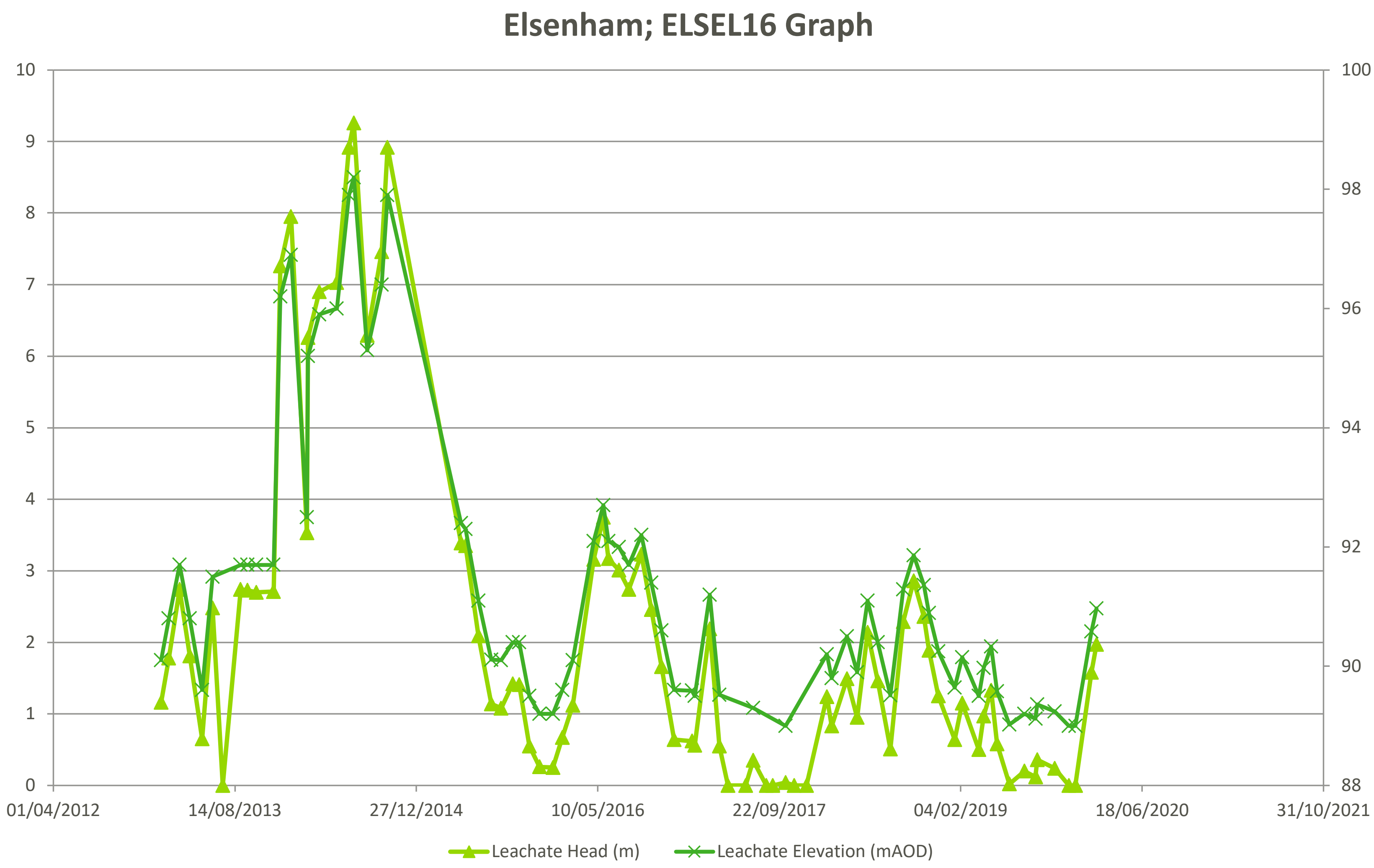
GOLDER


Elsenham; ELSEL12 Graph
4
3.5
3
2.5
2
1.5
1
0.5
0
89.5
89
88.5
88
87.5
87
86.5
86
85.5
85
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

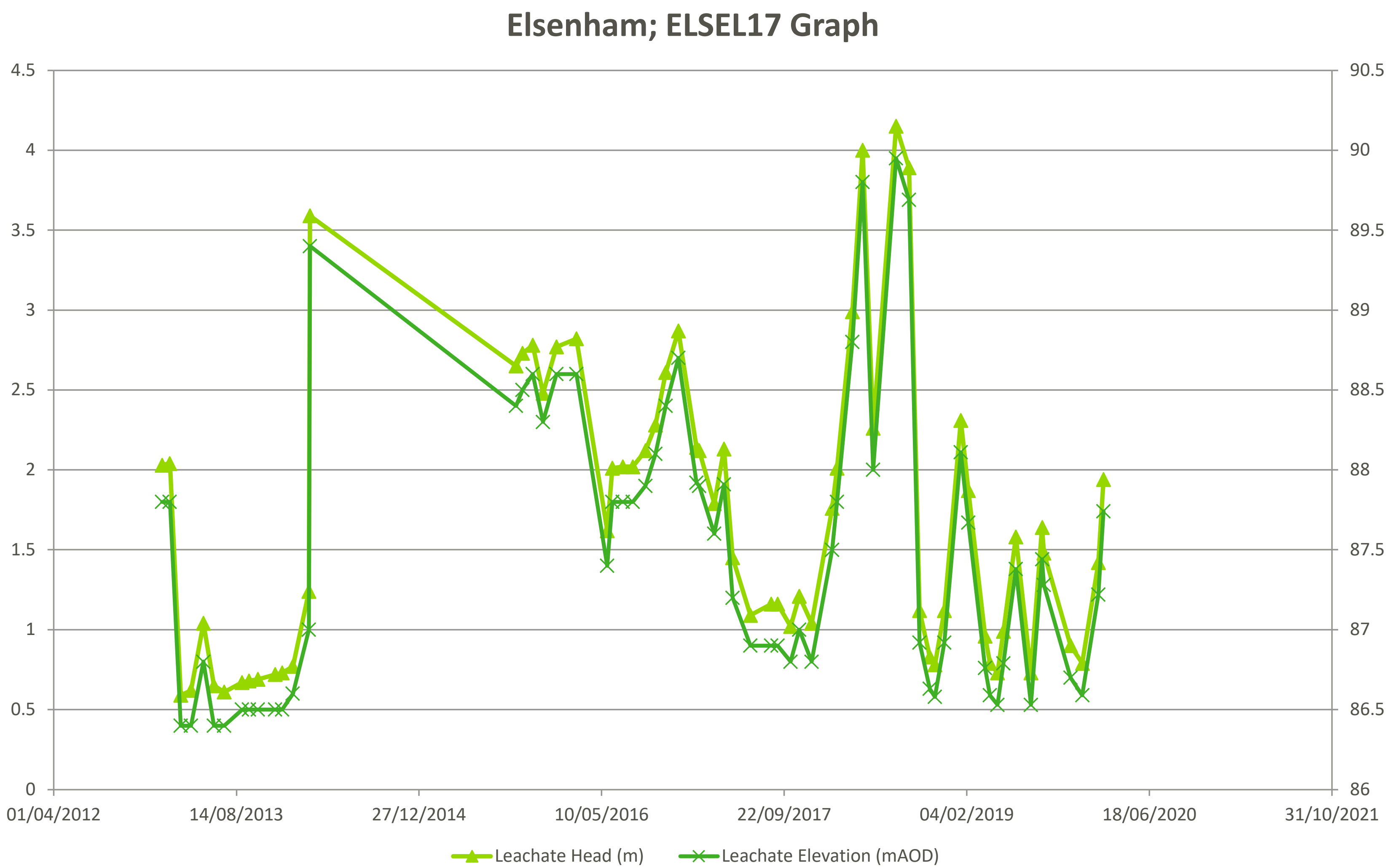

Elsenham; ELSEL13 Graph
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
90.5
90
89.5
89
88.5
88
87.5
87
86.5
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL14 Graph
6
5
4
3
2
1
0
92.5
92
91.5
91
90.5
90
89.5
89
88.5
88
87.5
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL15 Graph
3
2.5
2
1.5
1
0.5
0
89.6
89.4
89.2
89
88.8
88.6
88.4
88.2
88
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

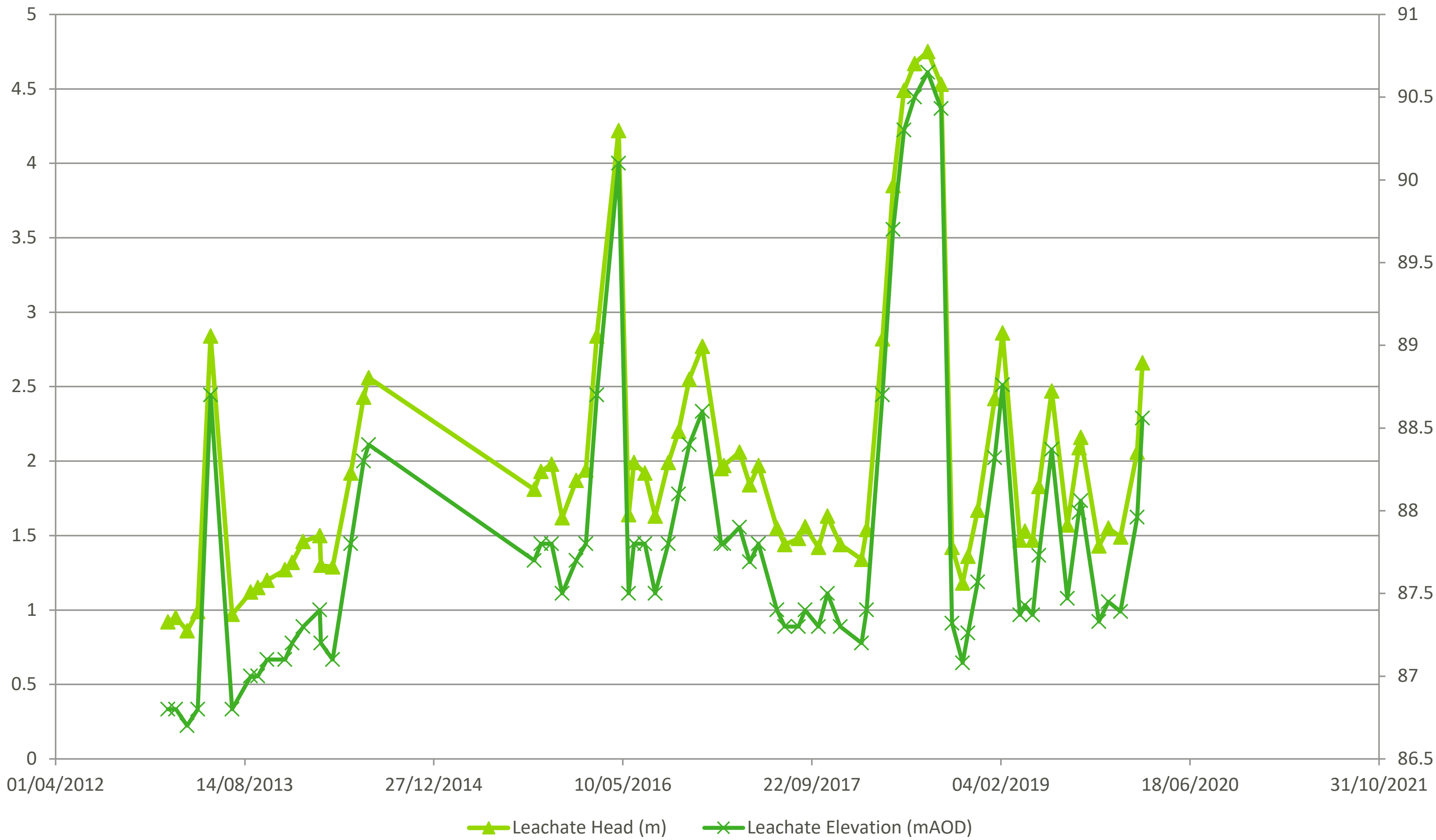

Elsenham; ELSEL16 Graph
10
9
8
7
6
5
4
3
2
1
0
100
98
96
94
92
90
88
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

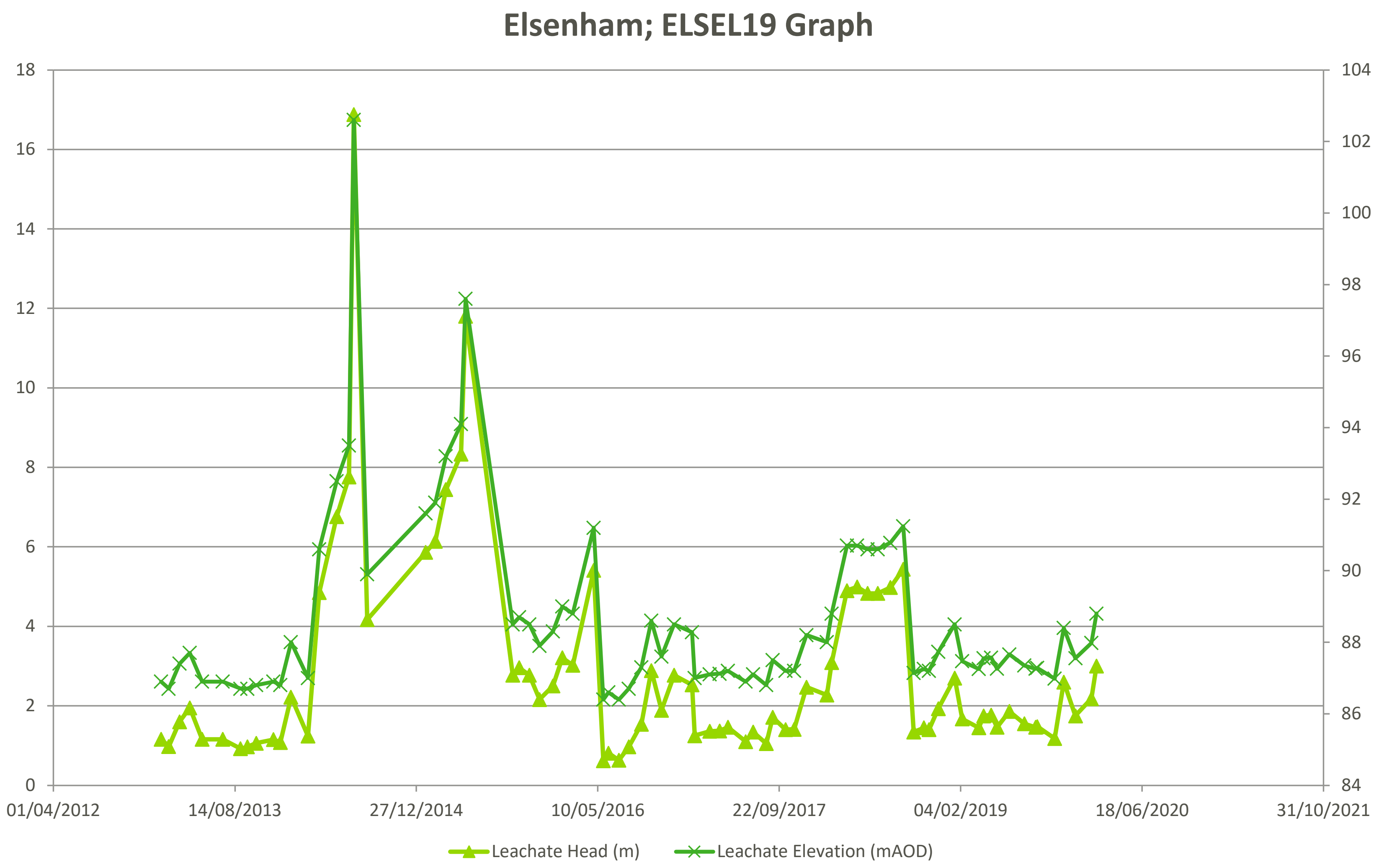
GOLDER

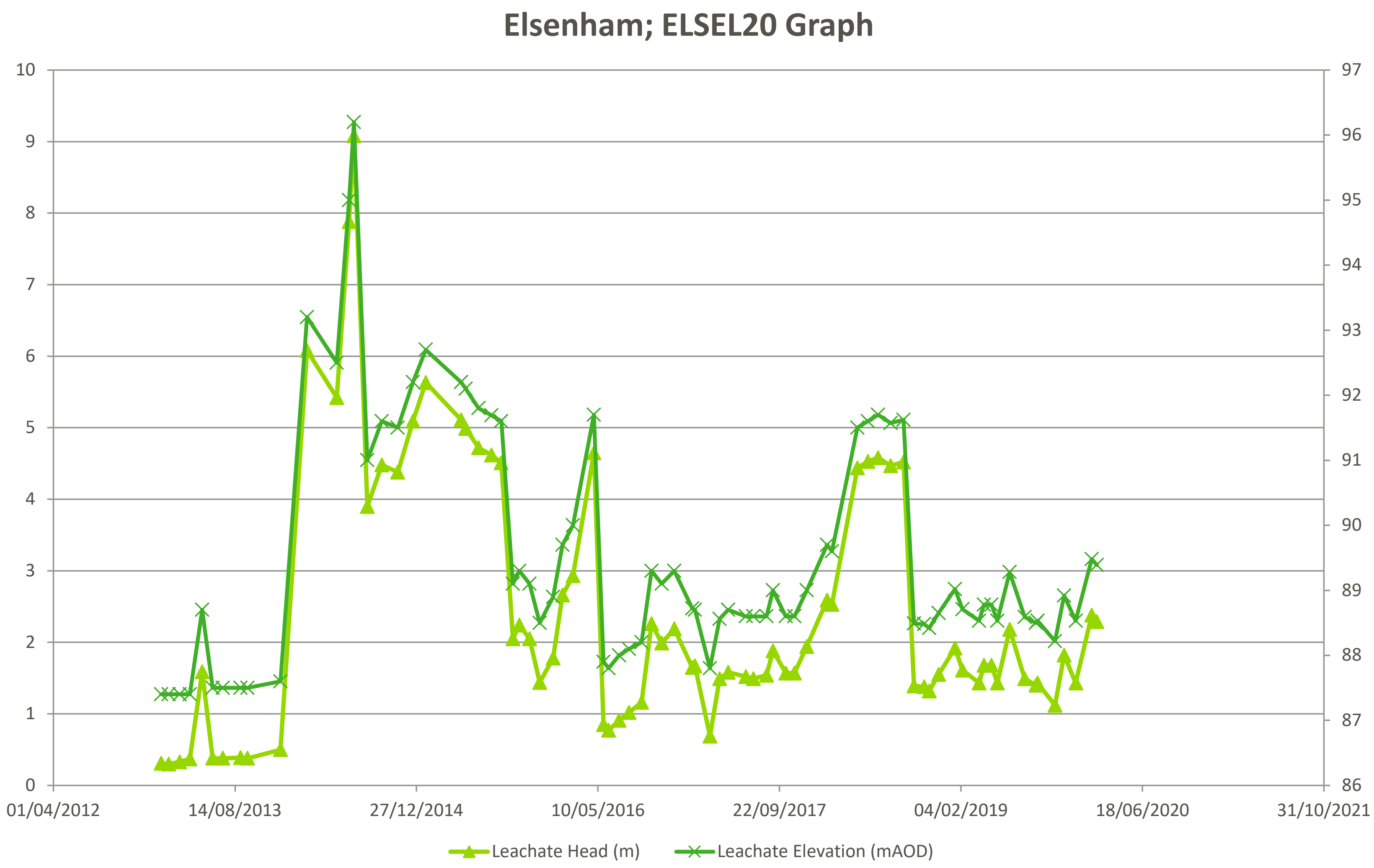

Elsenham; ELSEL17 Graph
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
90.5
90
89.5
89
88.5
88
87.5
87
86.5
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

GOLDER

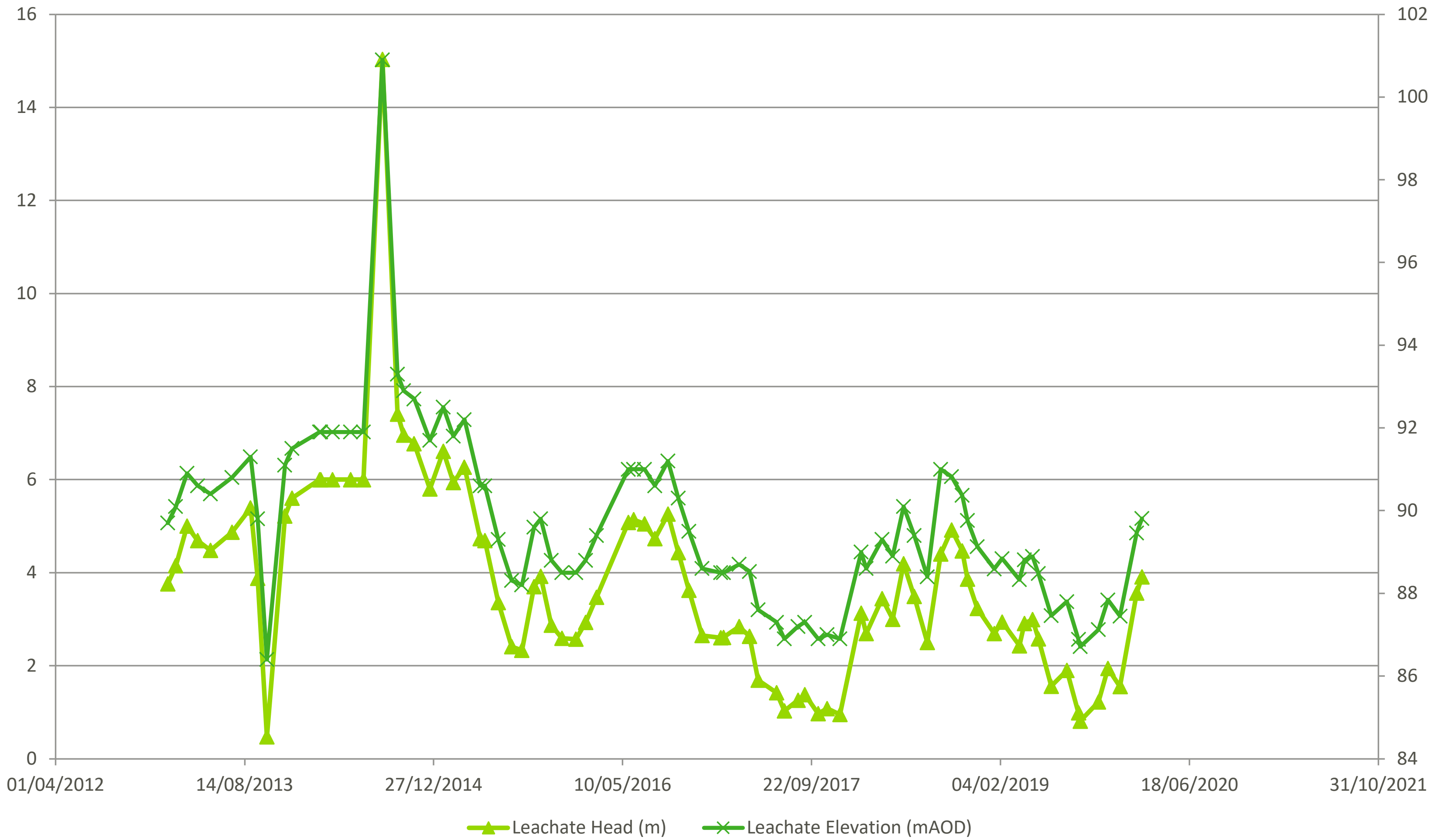
Elsenham; ELSEL18 Graph

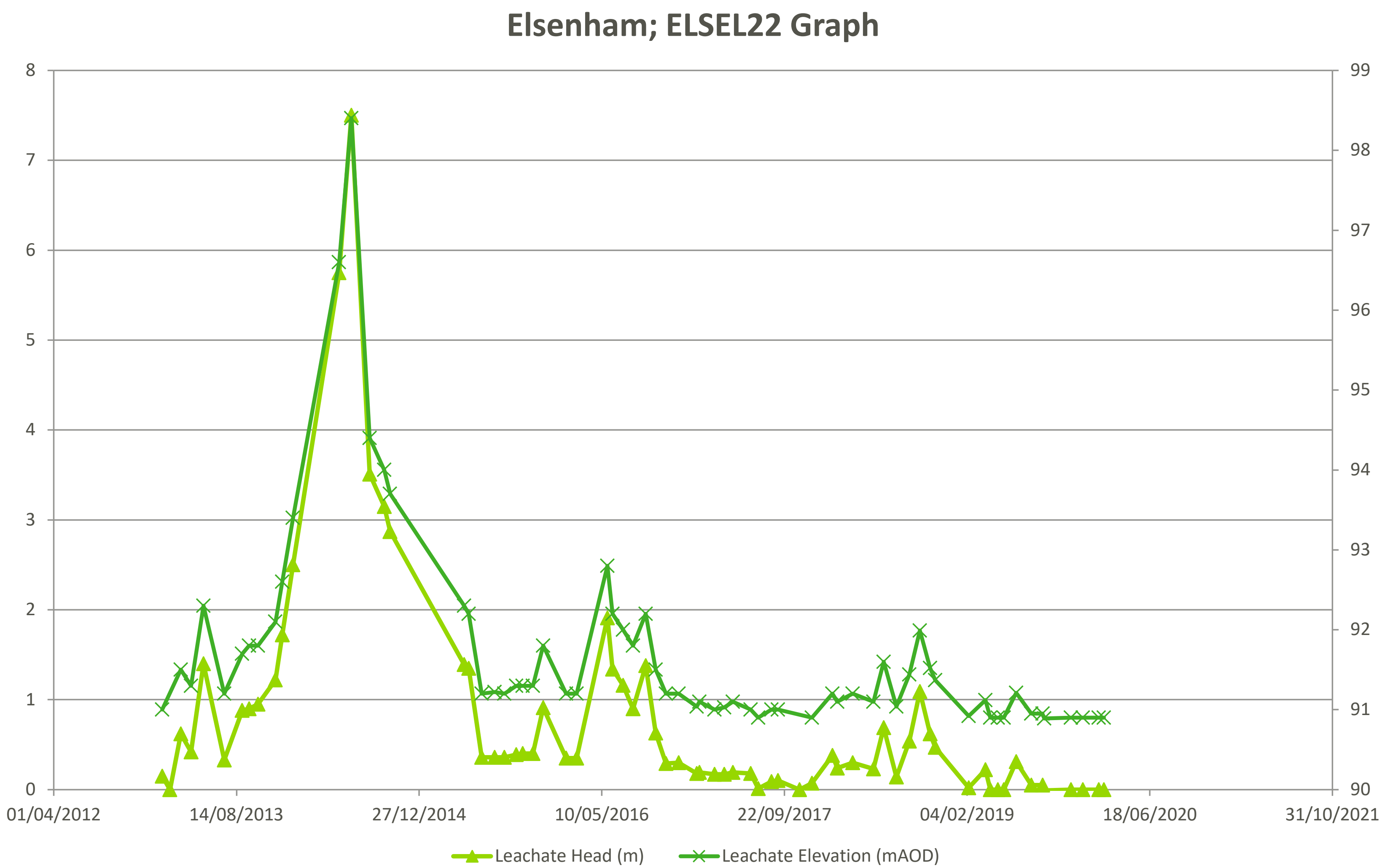



Elsenham; ELSEL19 Graph
18
16
14
12
10
8
6
4
2
0
104
102
100
98
96
94
92
90
88
86
84
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

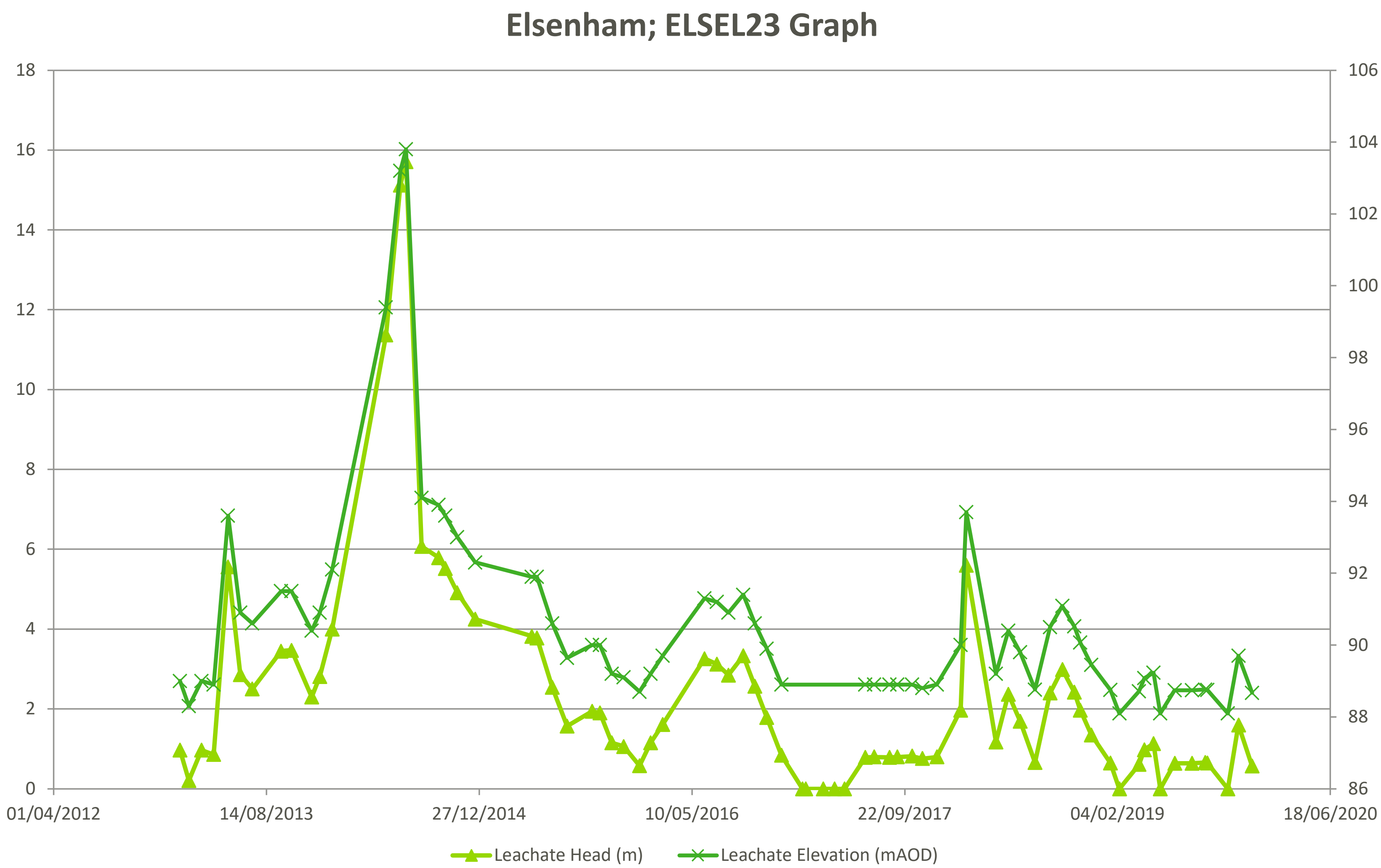

Elsenham; ELSEL20 Graph
10
9
8
7
6
5
4
3
2
1
0
97
96
95
94
93
92
91
90
89
88
87
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

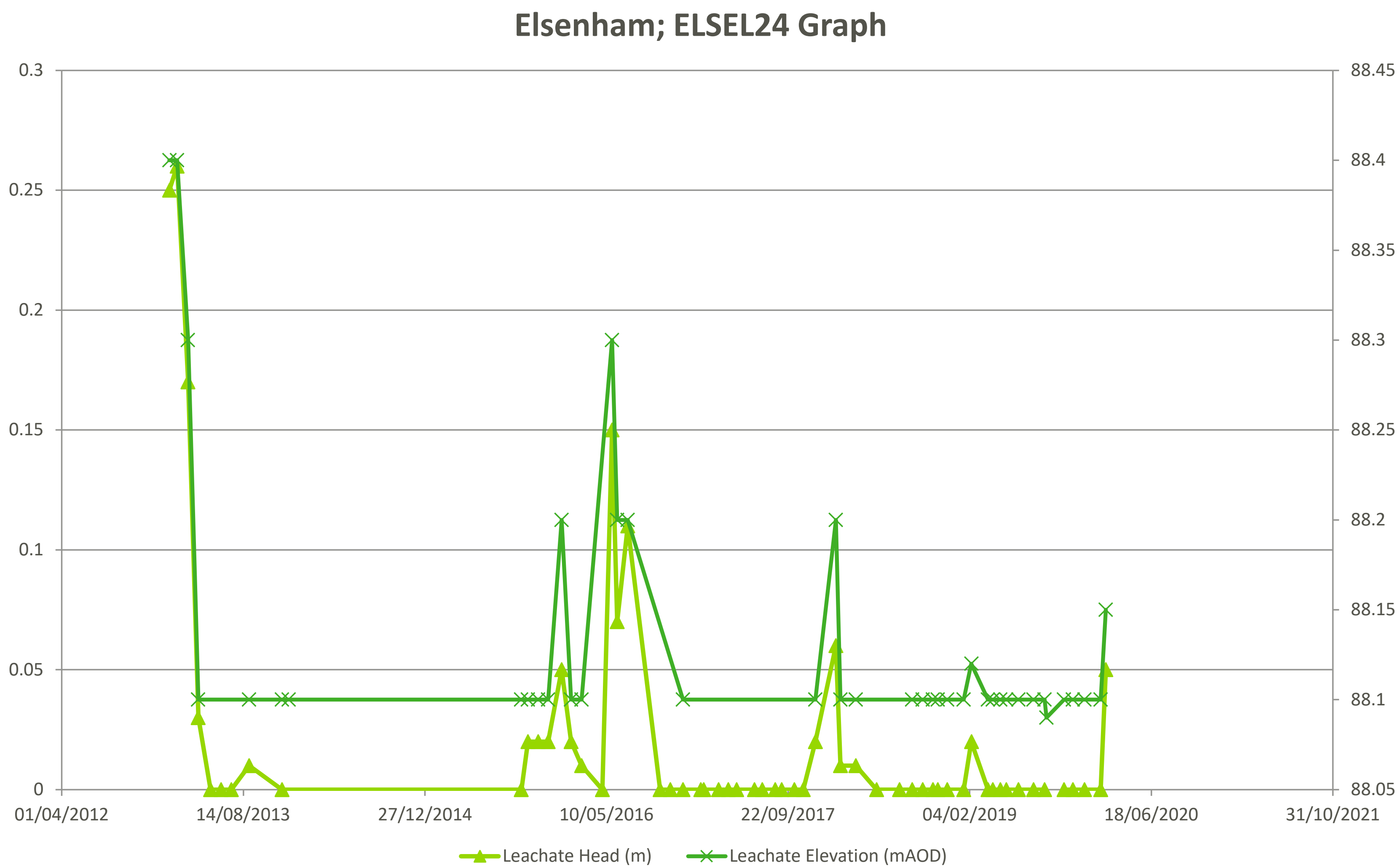
Elsenham; ELSEL21 Graph

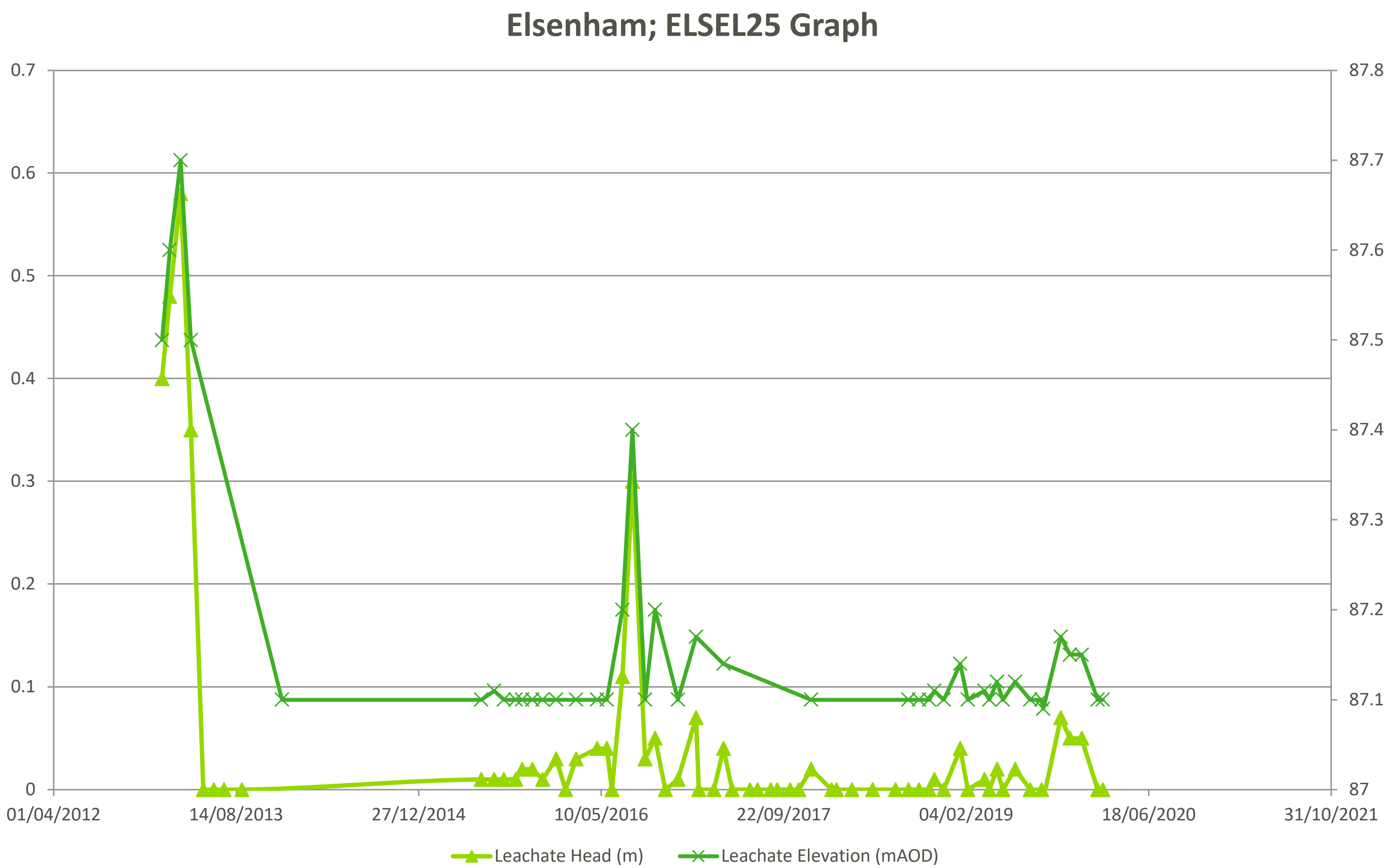


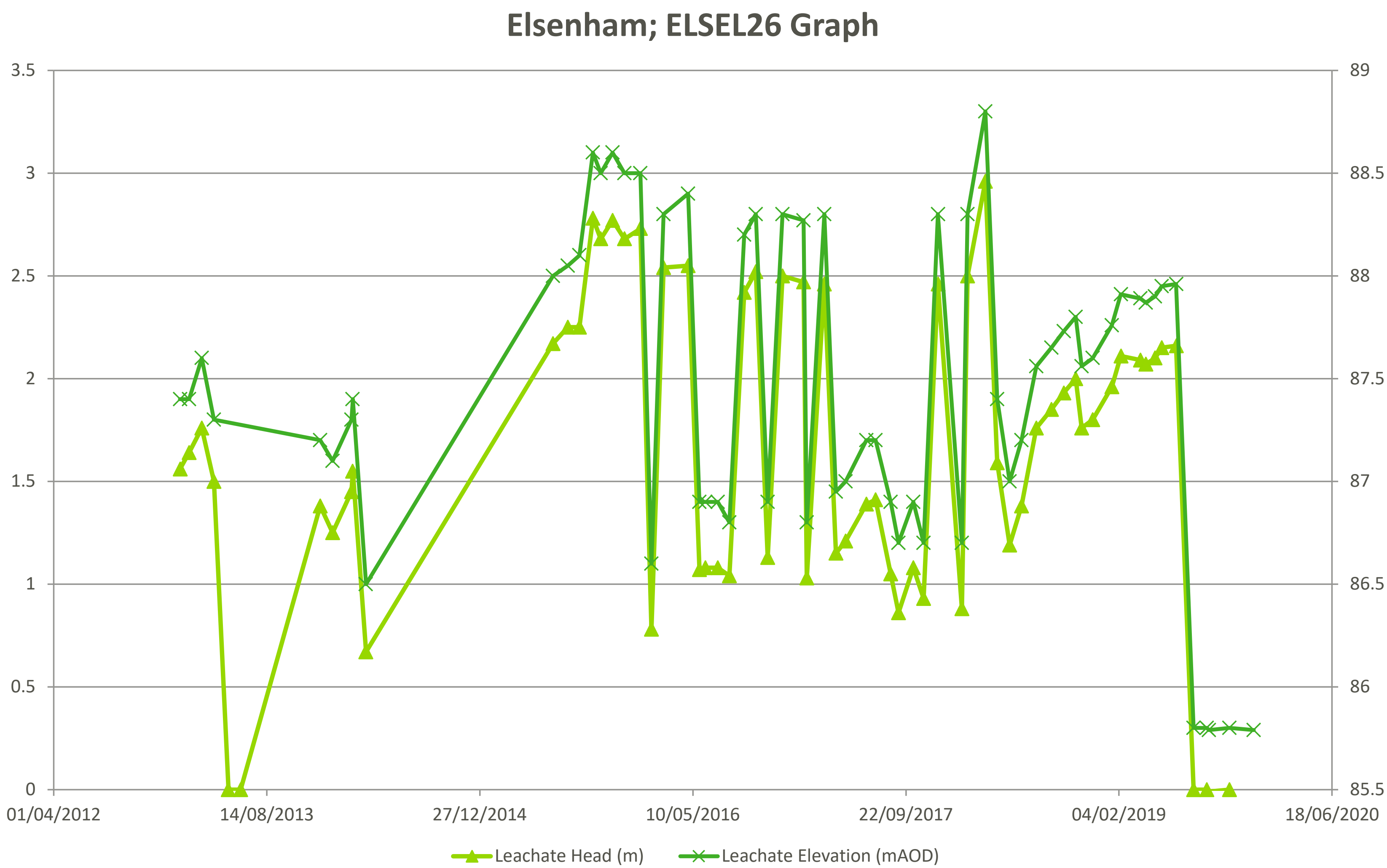

Elsenham; ELSEL22 Graph
8
7
6
5
4
3
2
1
0
99
98
97
96
95
94
93
92
91
90
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)

GOLDER

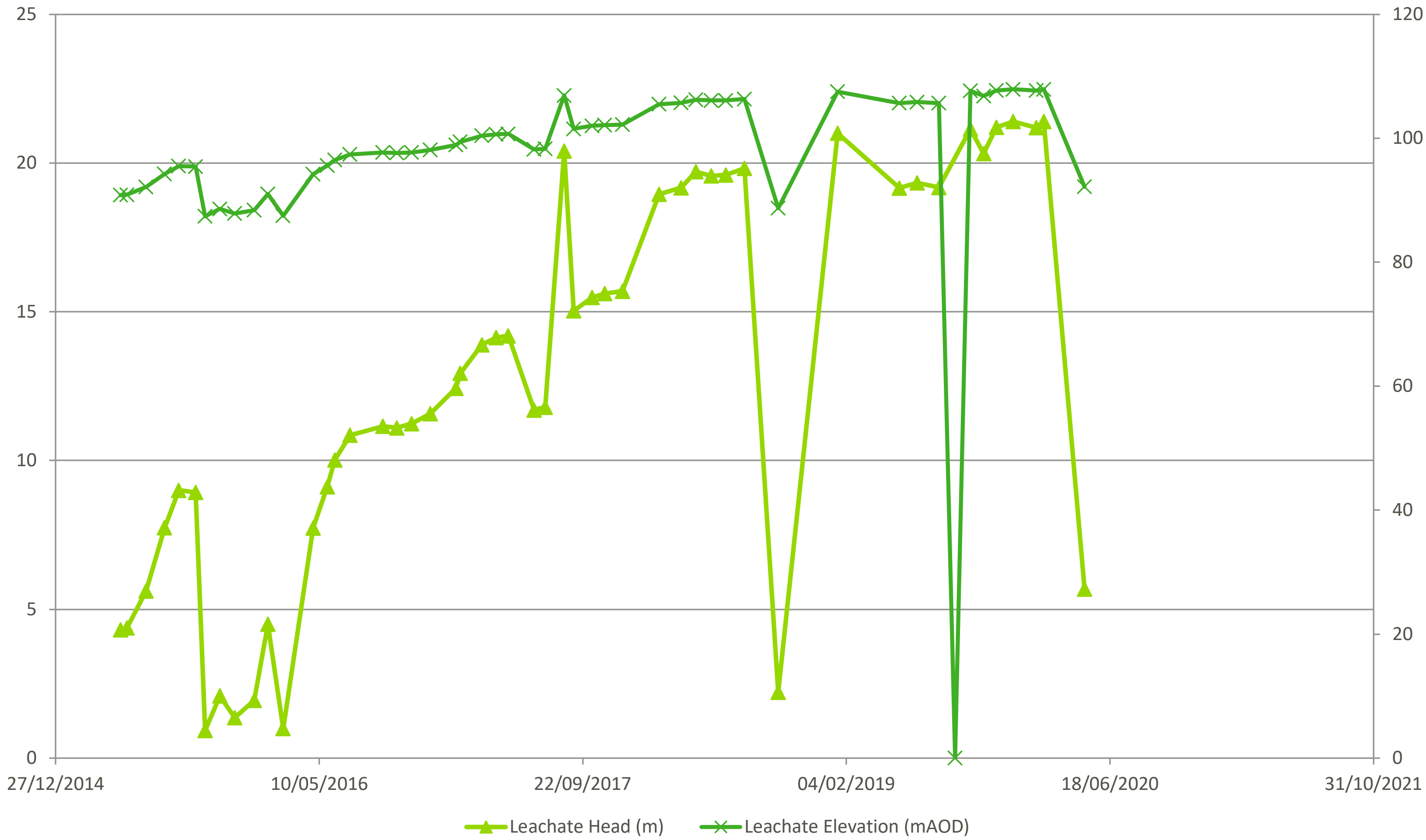

Elsenham; ELSEL23 Graph
18
16
14
12
10
8
6
4
2
0
106
104
102
100
98
96
94
92
90
88
86
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL24 Graph
0.3
0.25
0.2
0.15
0.1
0.05
0
88.45
88.4
88.35
88.3
88.25
88.2
88.15
88.1
88.05
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL25 Graph
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
87.8
87.7
87.6
87.5
87.4
87.3
87.2
87.1
87
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Leachate Head (m)
Leachate Elevation (mAOD)


Elsenham; ELSEL26 Graph
3.5
3
2.5
2
1.5
1
0.5
0
89
88.5
88
87.5
87
86.5
86
85.5
01/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
Leachate Head (m)
Leachate Elevation (mAOD)

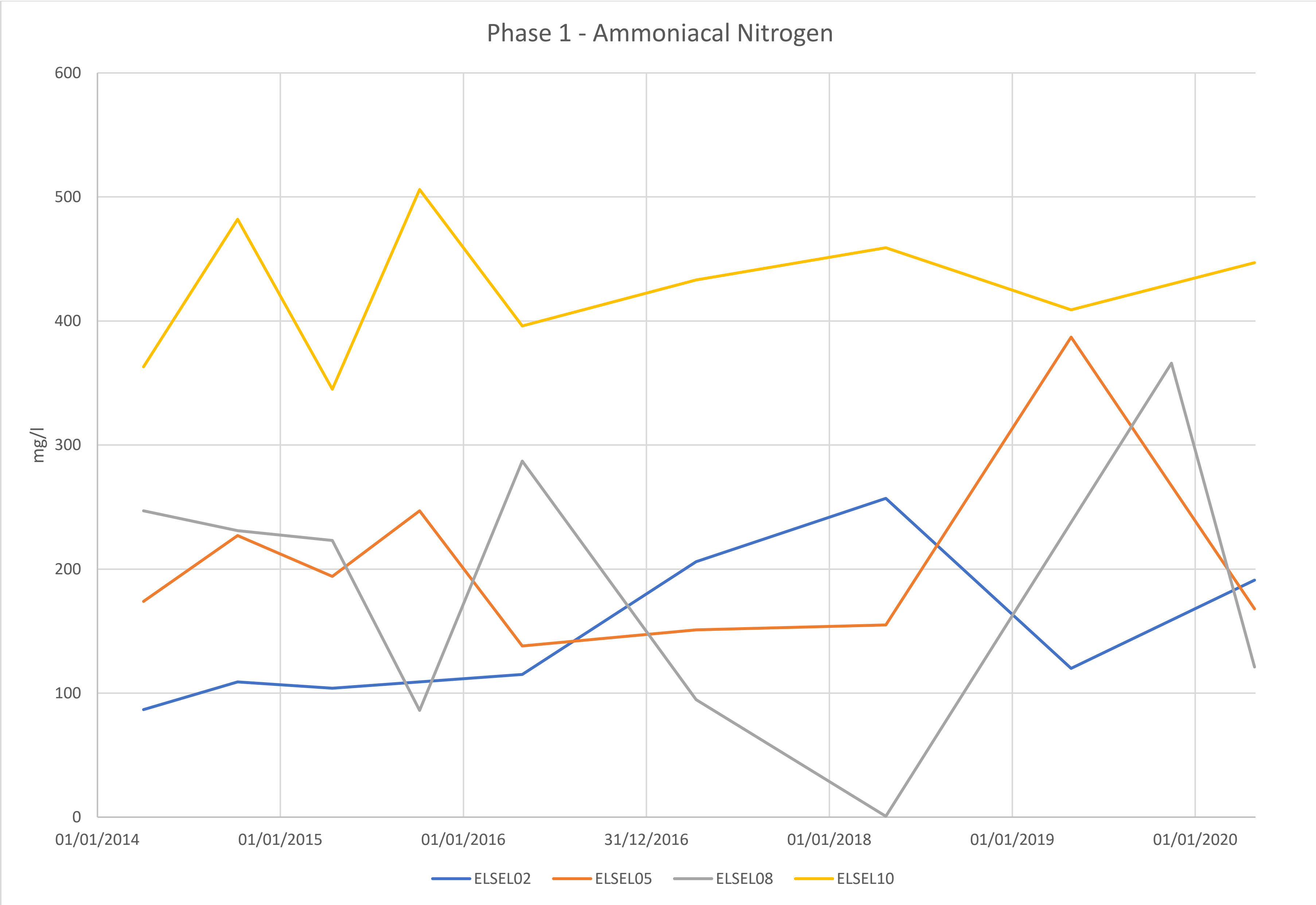
Elsenham; ELSEL27 Graph

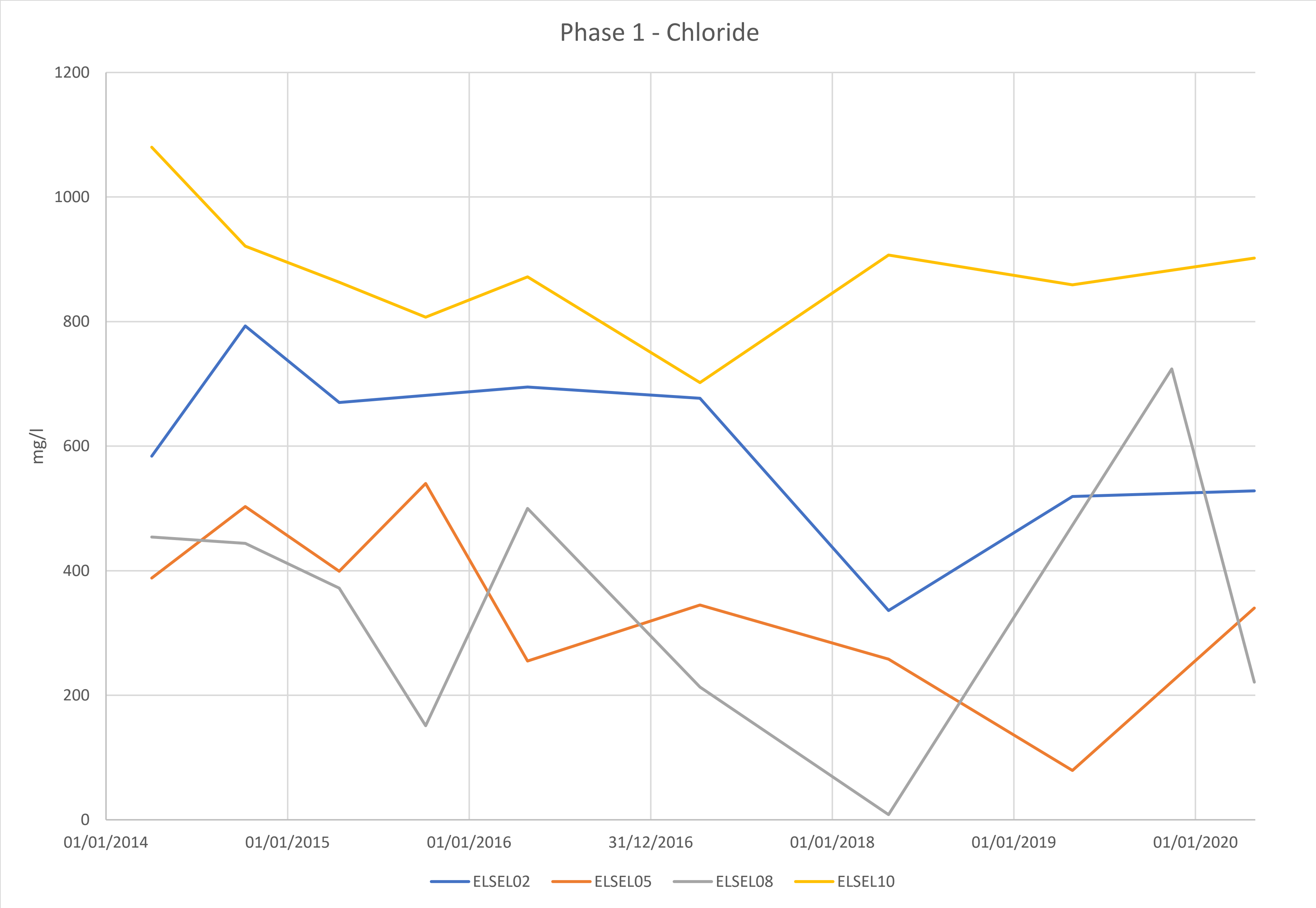


GOLDER

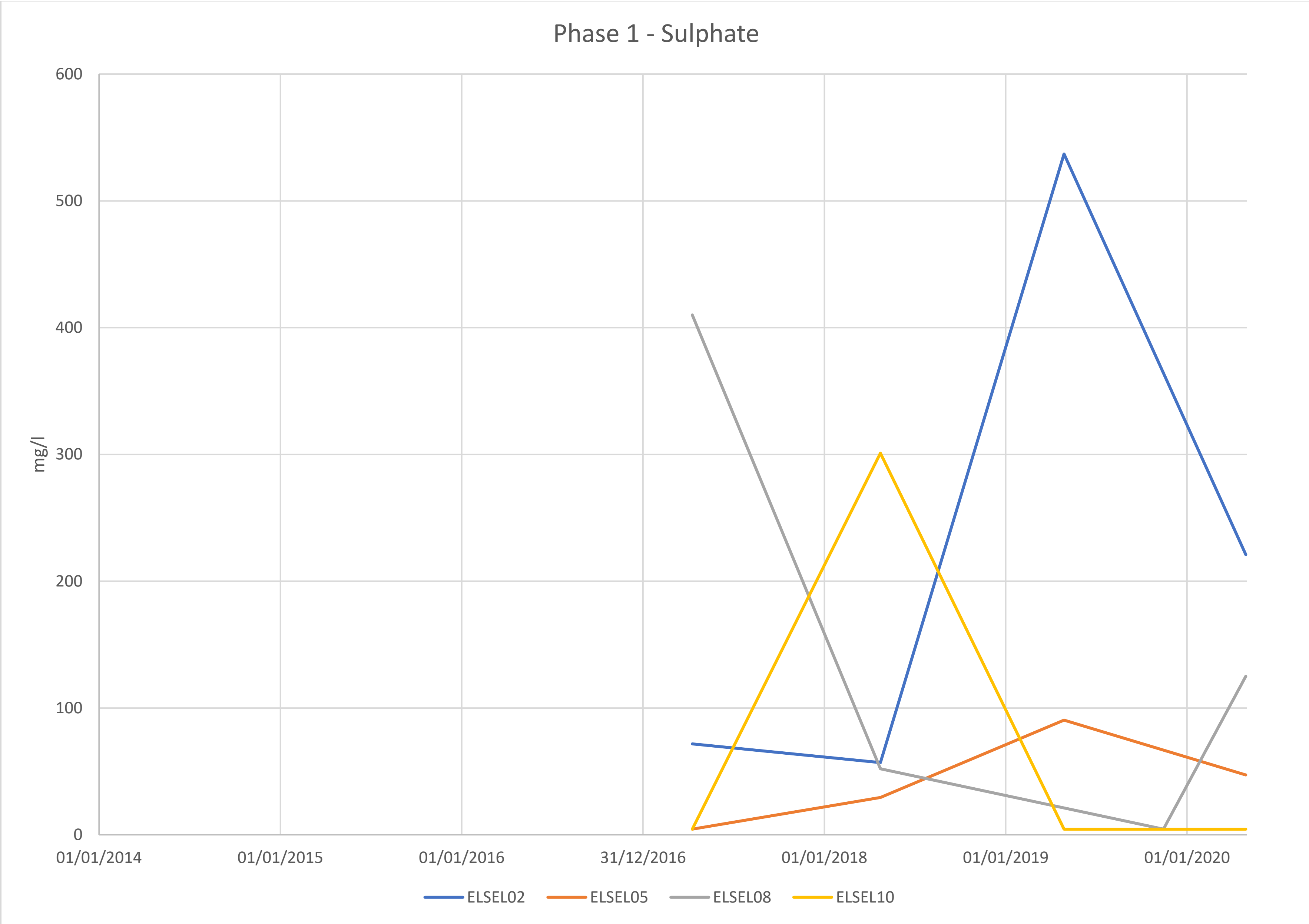
APPENDIX B

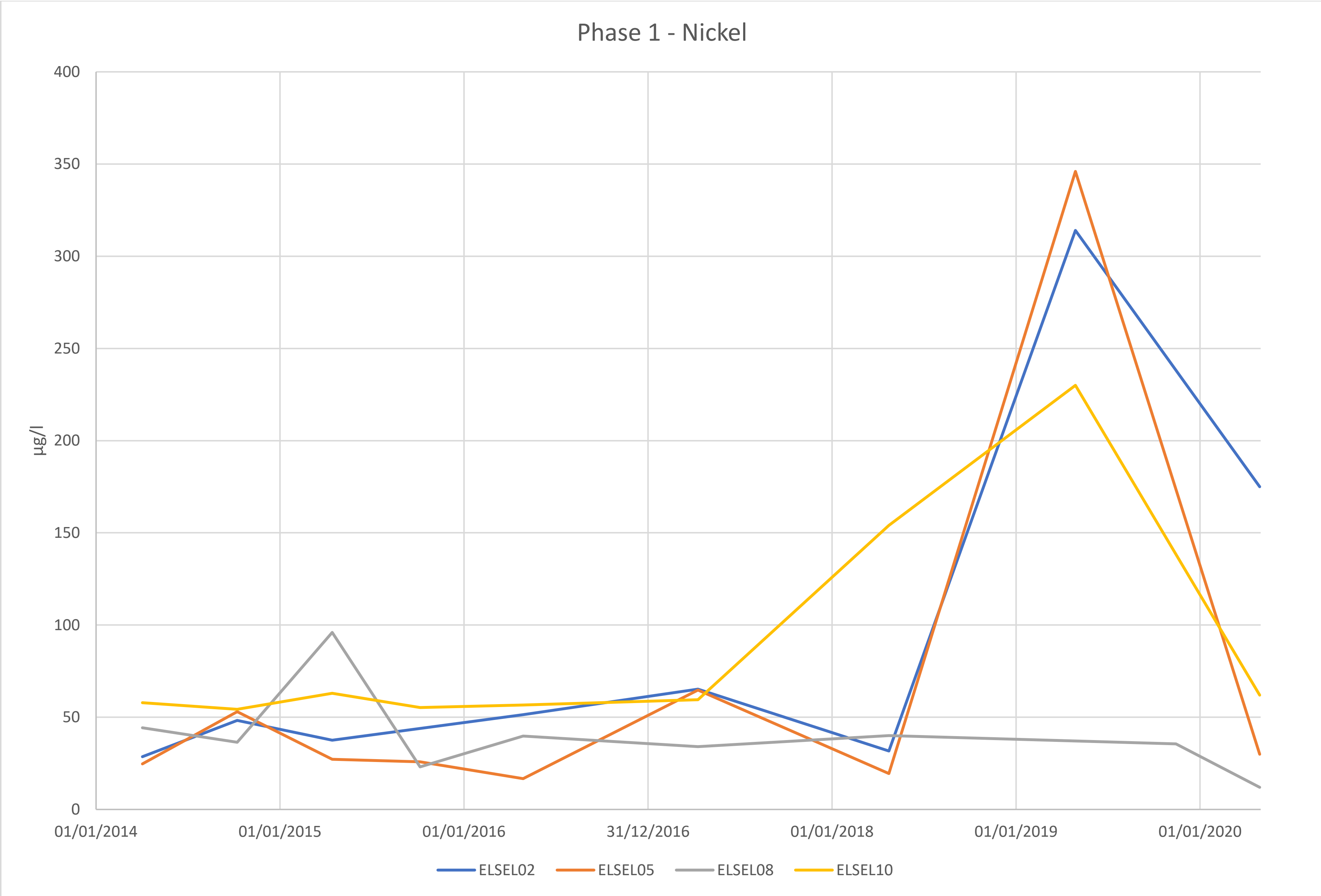
Leachate Quality

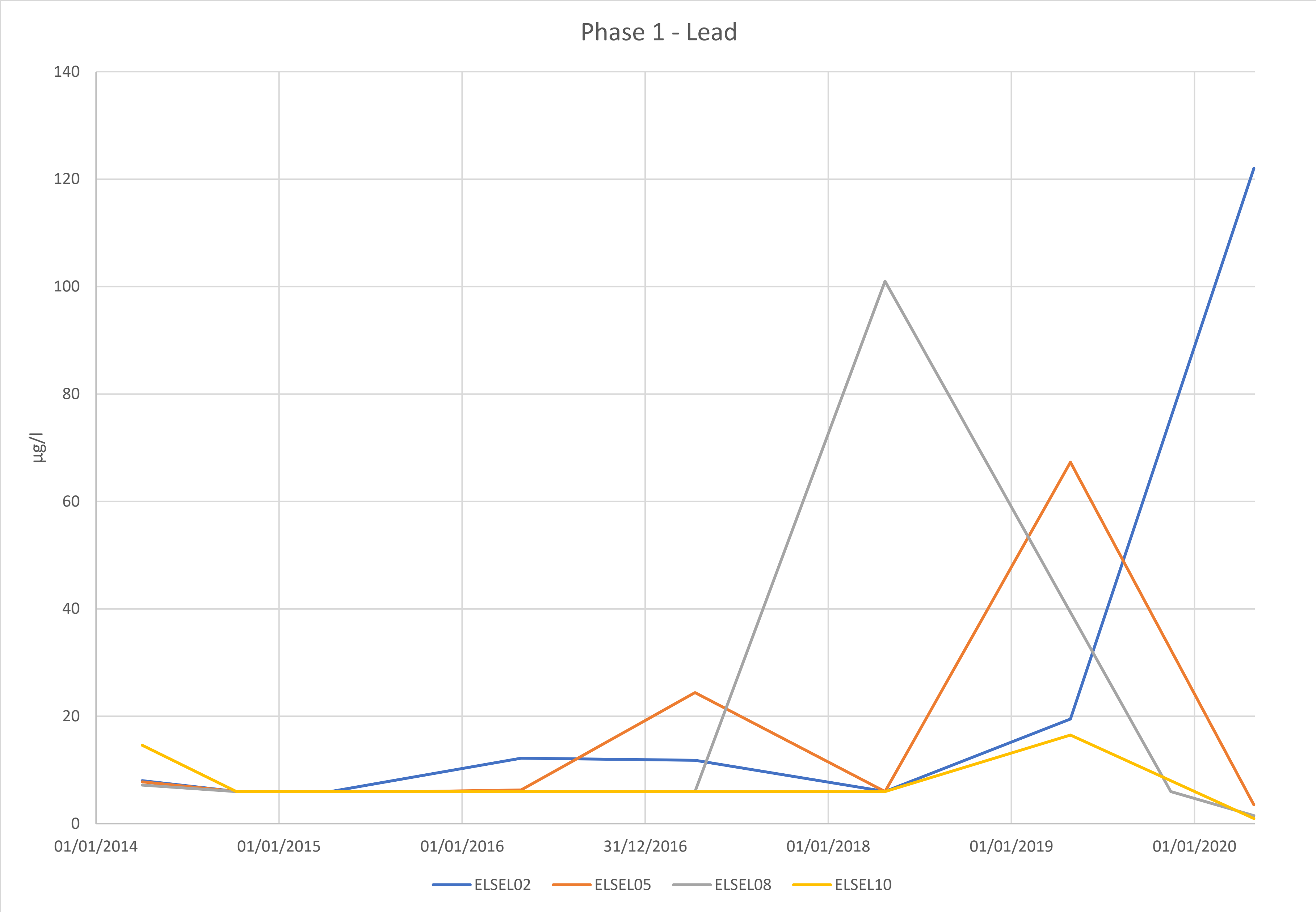

Phase 1 - Ammoniacal Nitrogen
mg/l
600
500
400
300
200
100
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



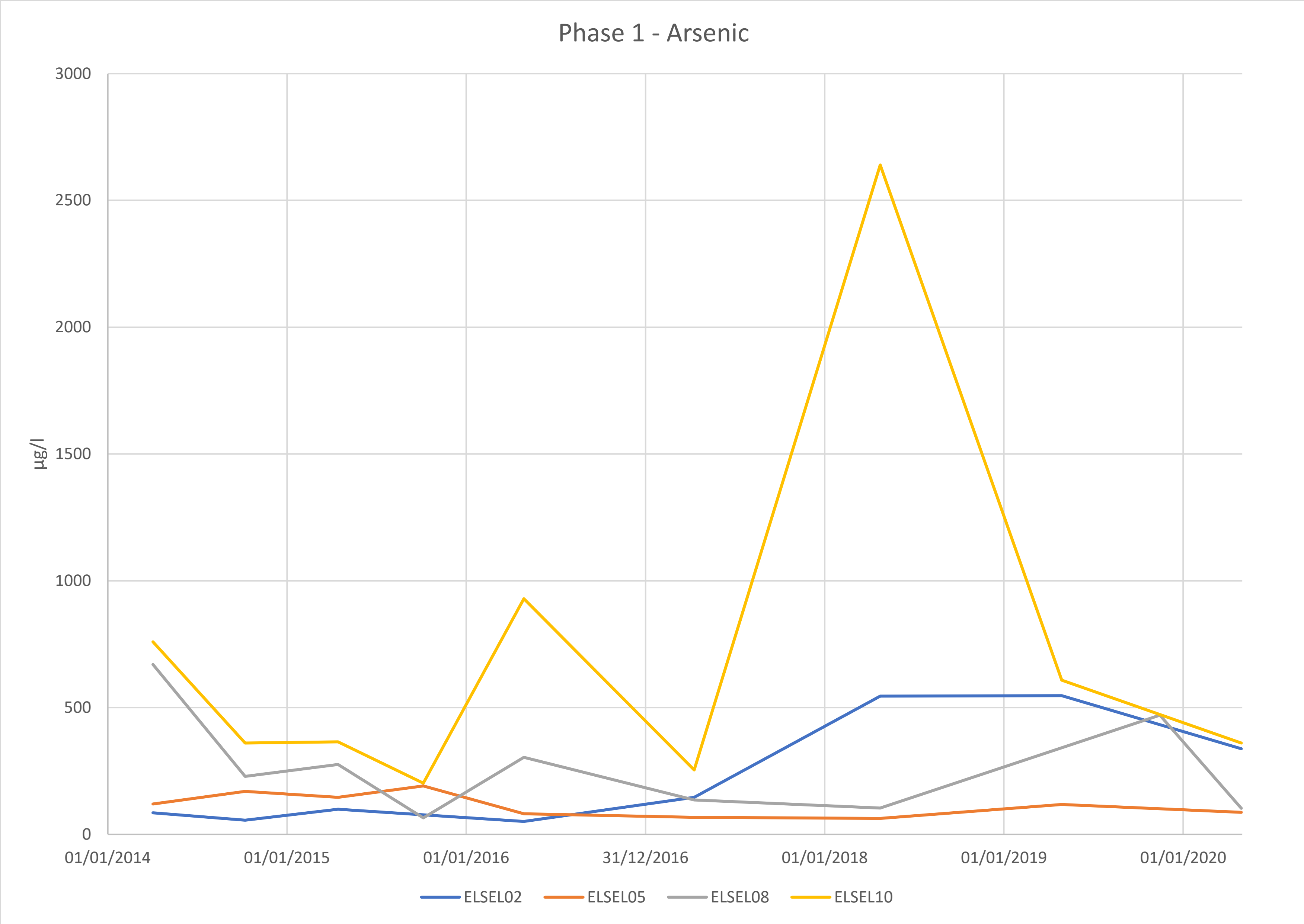
Phase 1 - Chloride
mg/l
1200
1000
800
600
400
200
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10


Phase 1 - Sulphate
600
500
400
300
200
100
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10

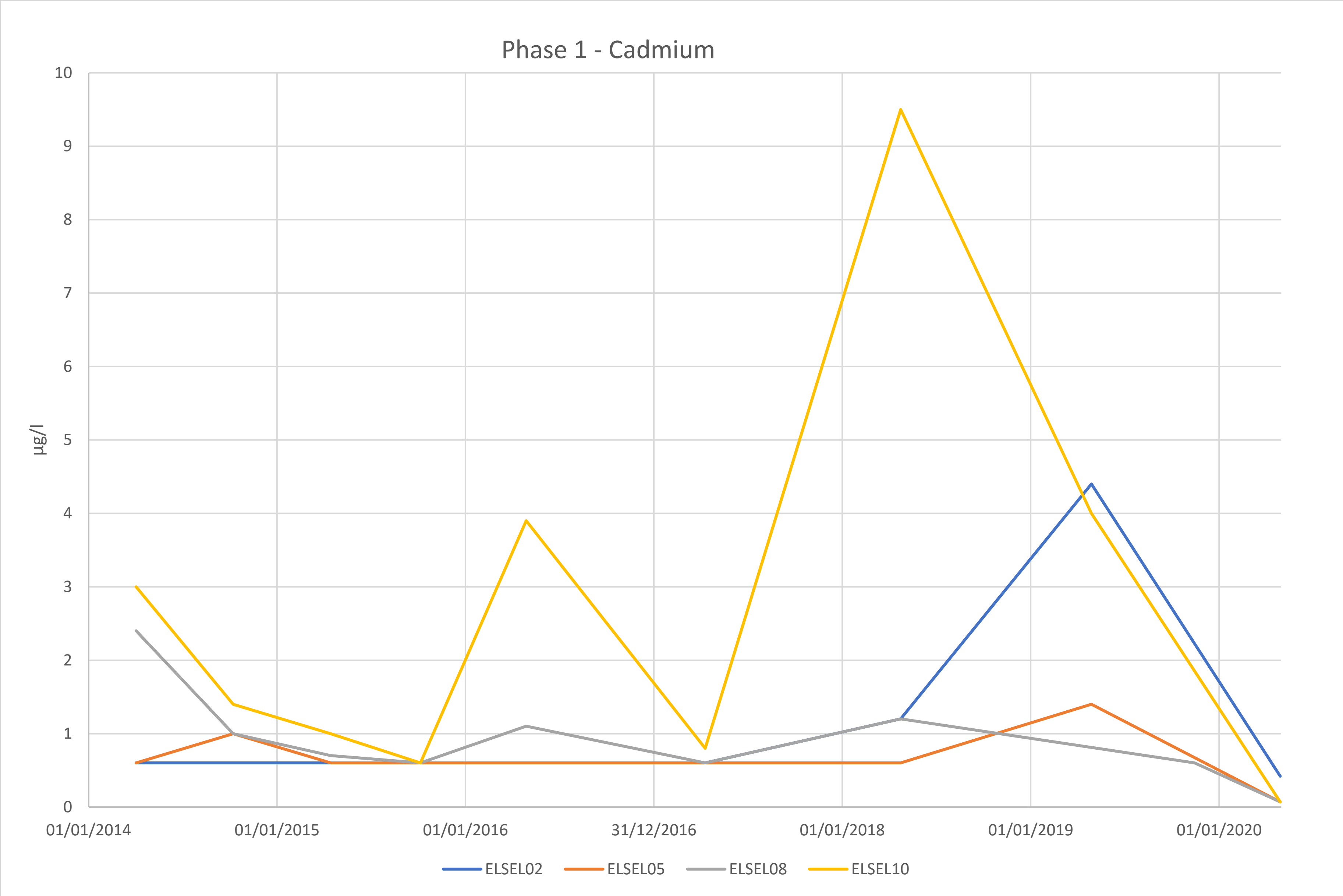

Phase 1 - Nickel
µg/l
0
50
100
150
200
250
300
350
400
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



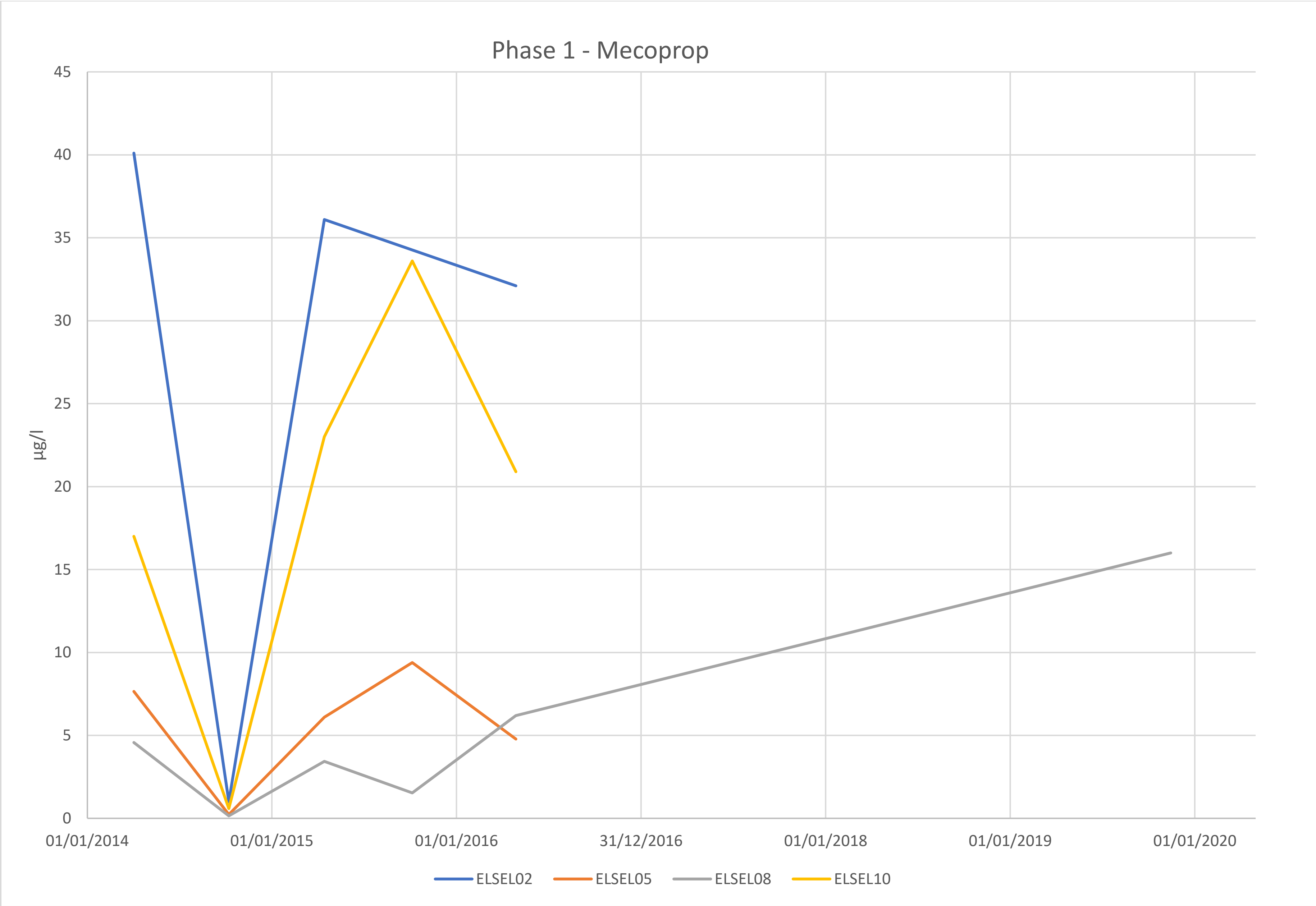
Phase 1 - Lead
140
120
100
80
60
40
20
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



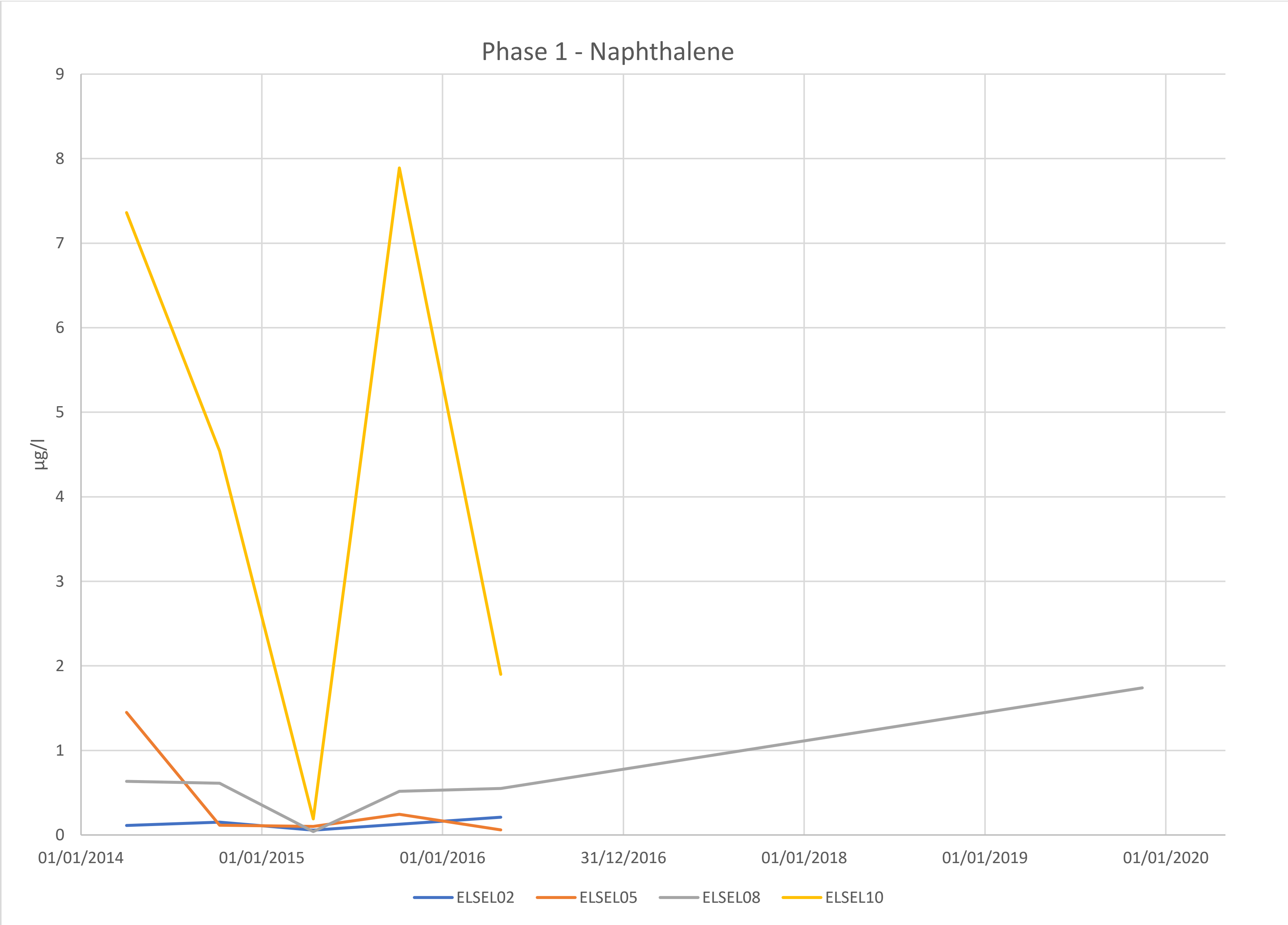
Phase 1 - Arsenic
µg/l
3000
2500
2000
1500
1000
500
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



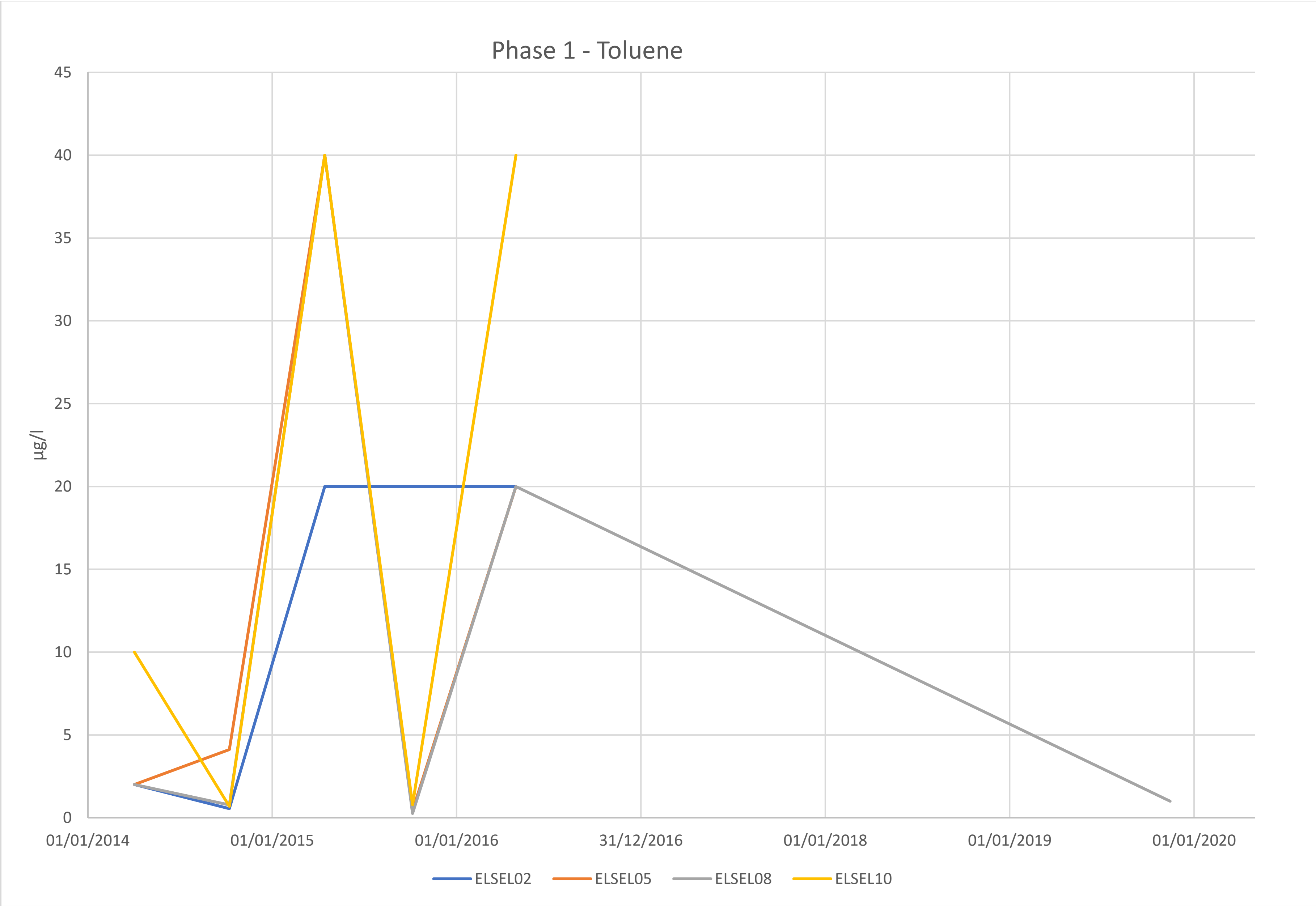
Phase 1 - Cadmium
10
9
8
7
6
5
4
3
2
1
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10

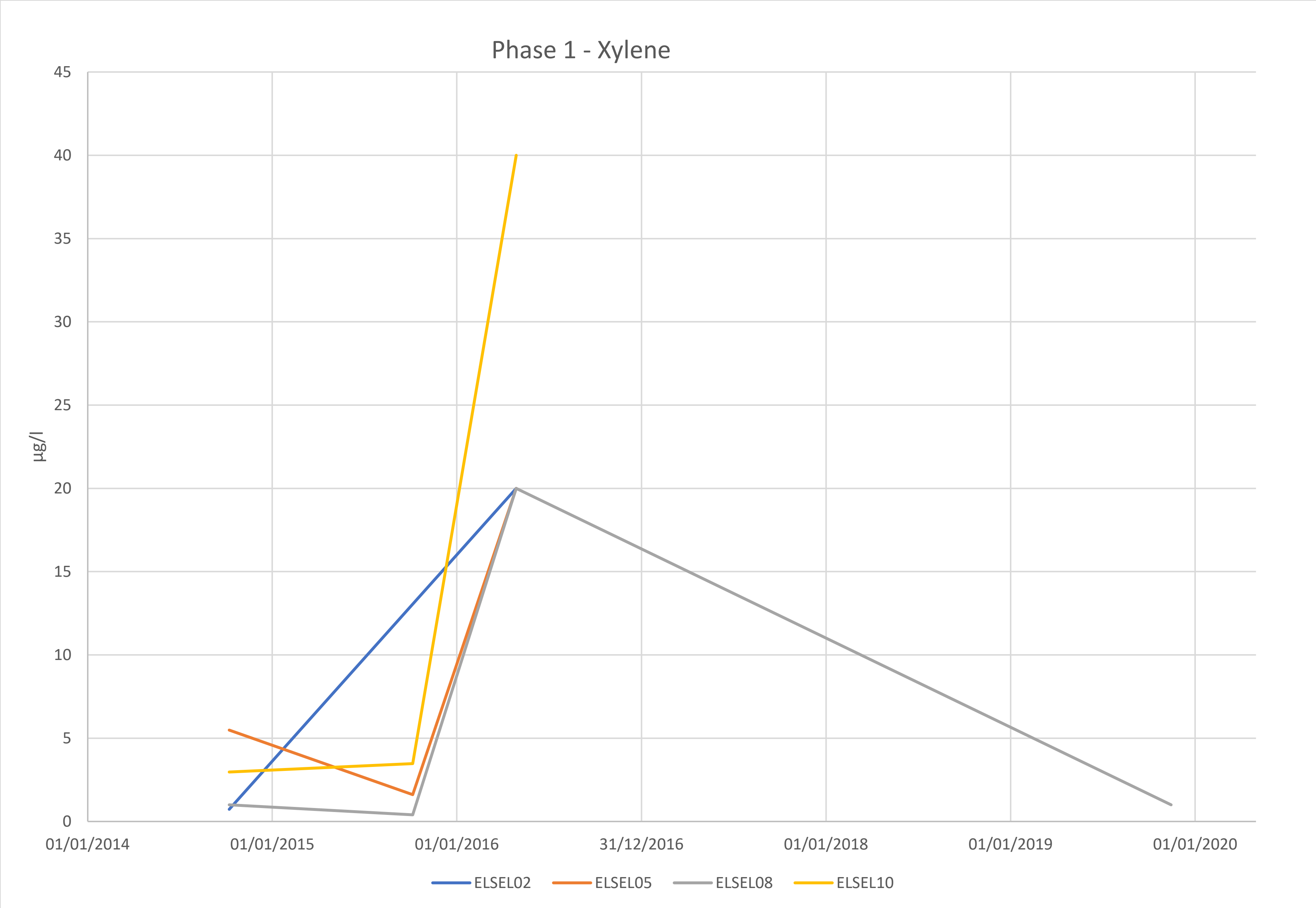


Phase 1 - Mecoprop
µg/l
45
40
35
30
25
20
15
10
5
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10

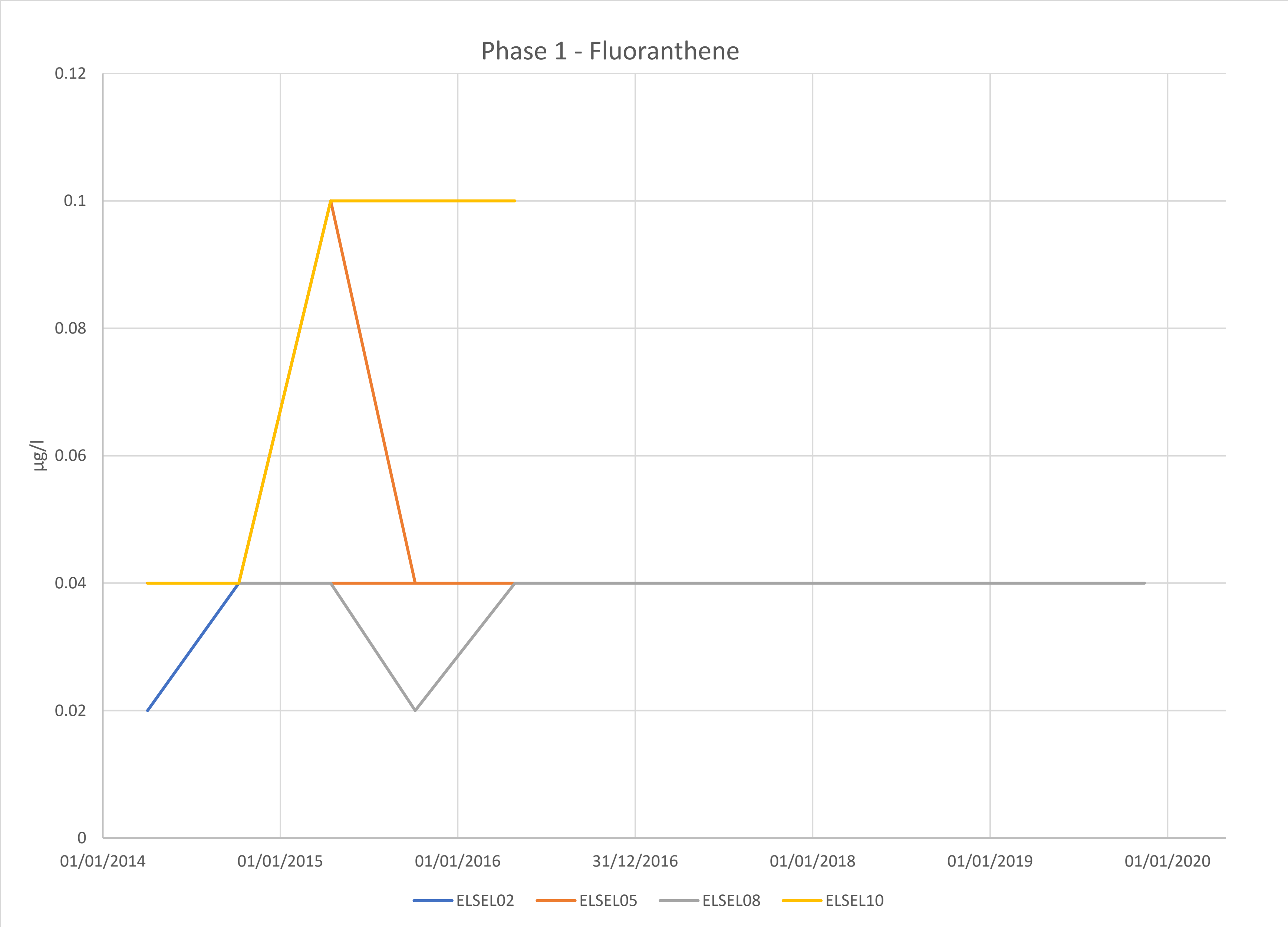


Phase 1 - Naphthalene
µg/l
0
1
2
3
4
5
6
7
8
9
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10

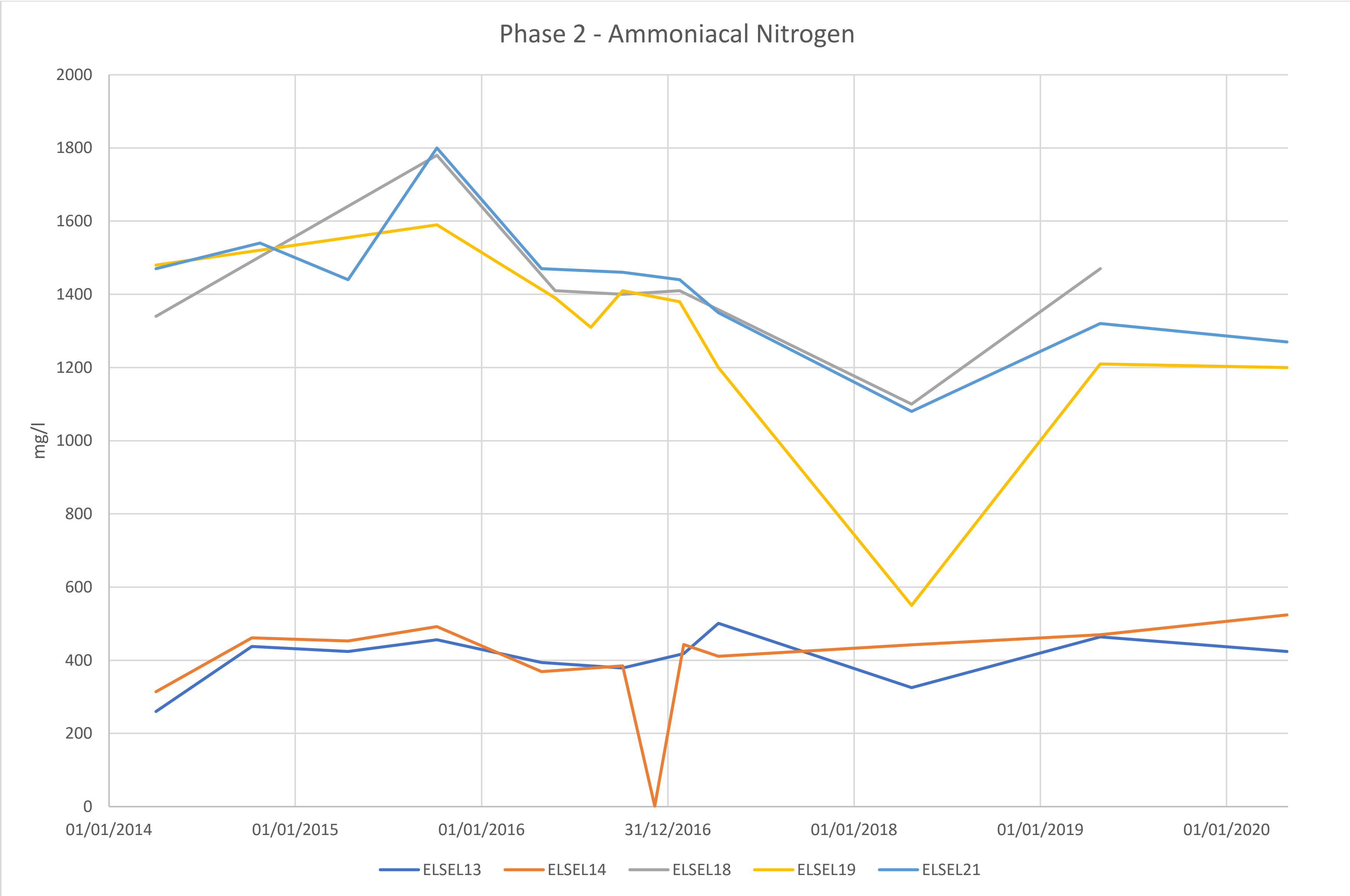

Phase 1 - Toluene
µg/l
45
40
35
30
25
20
15
10
5
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



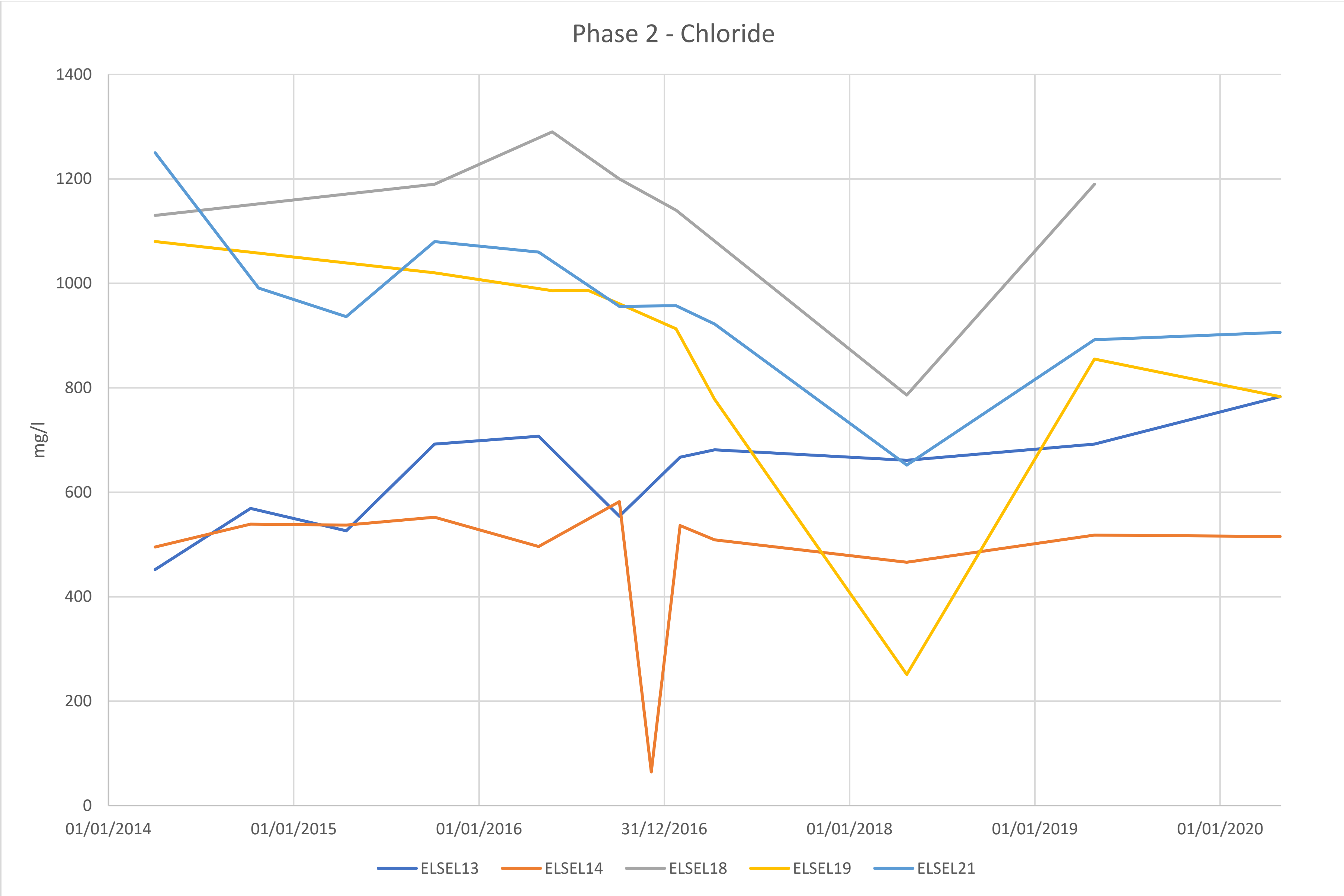
Phase 1 - Xylene
45
40
35
30
25
20
15
10
5
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



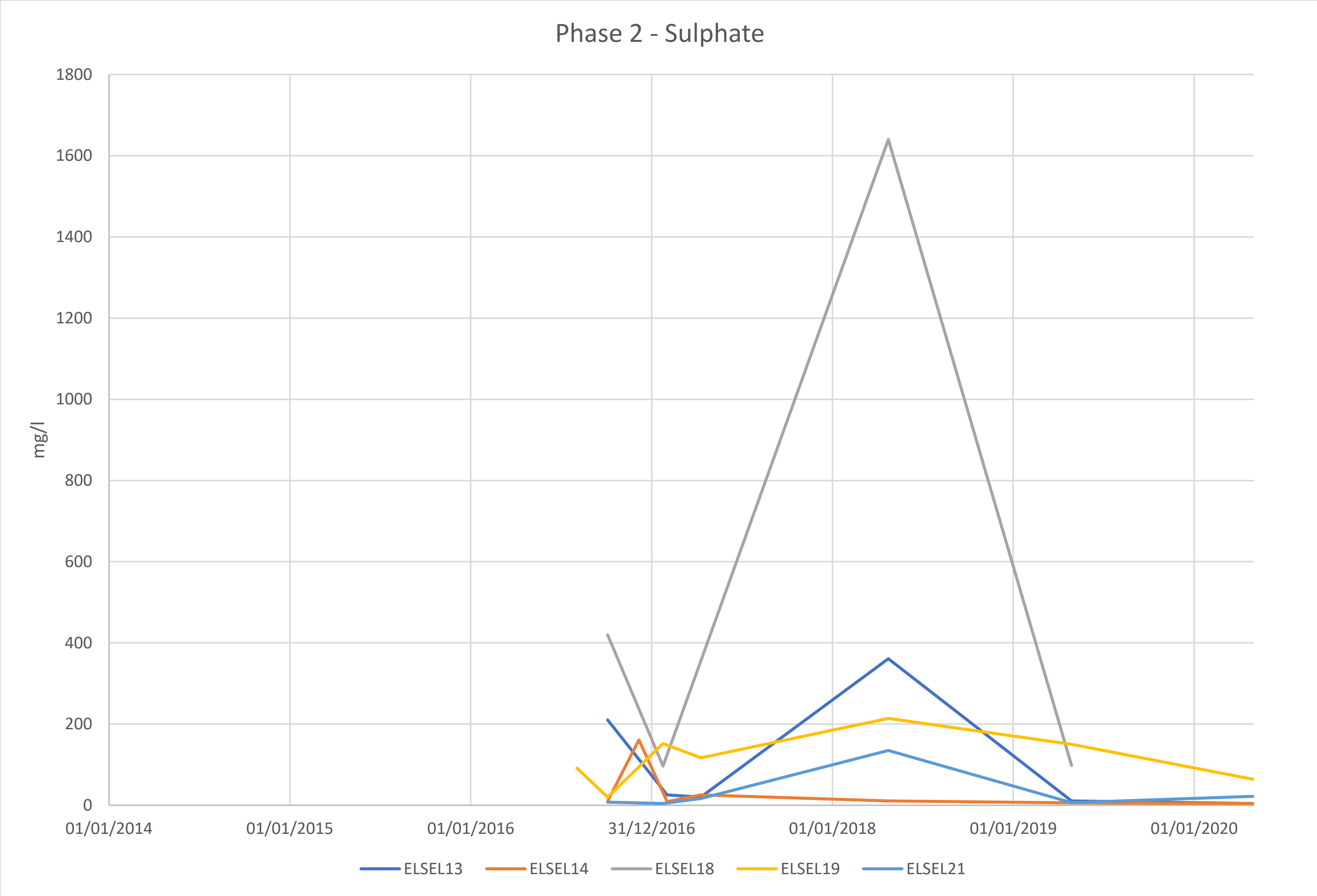
Phase 1 - Fluoranthene
µg/l
0.12
0.1
0.08
0.06
0.04
0.02
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL02
ELSEL05
ELSEL08
ELSEL10



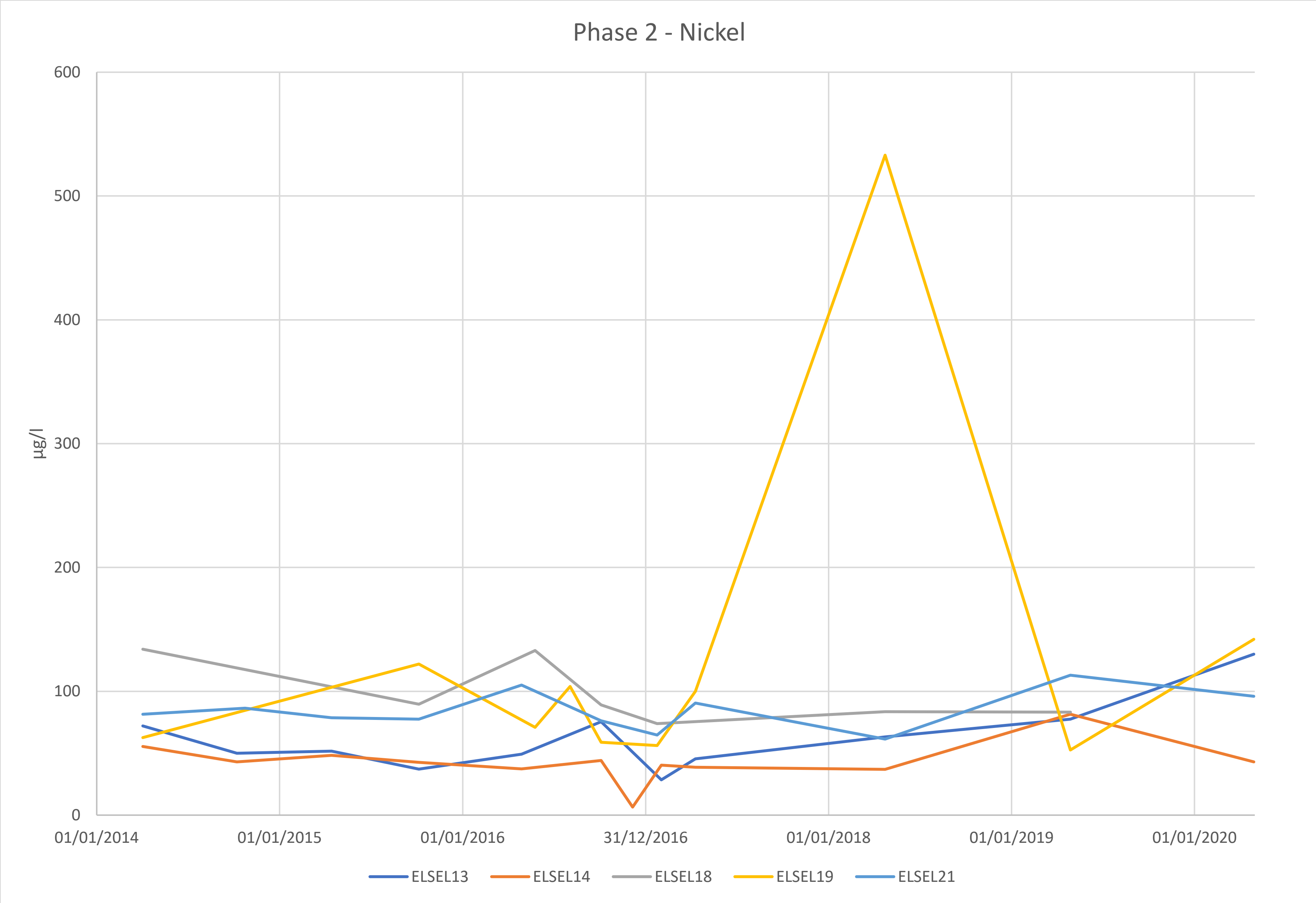
Phase 2 - Ammoniacal Nitrogen
mg/l
2000
1800
1600
1400
1200
1000
800
600
400
200
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



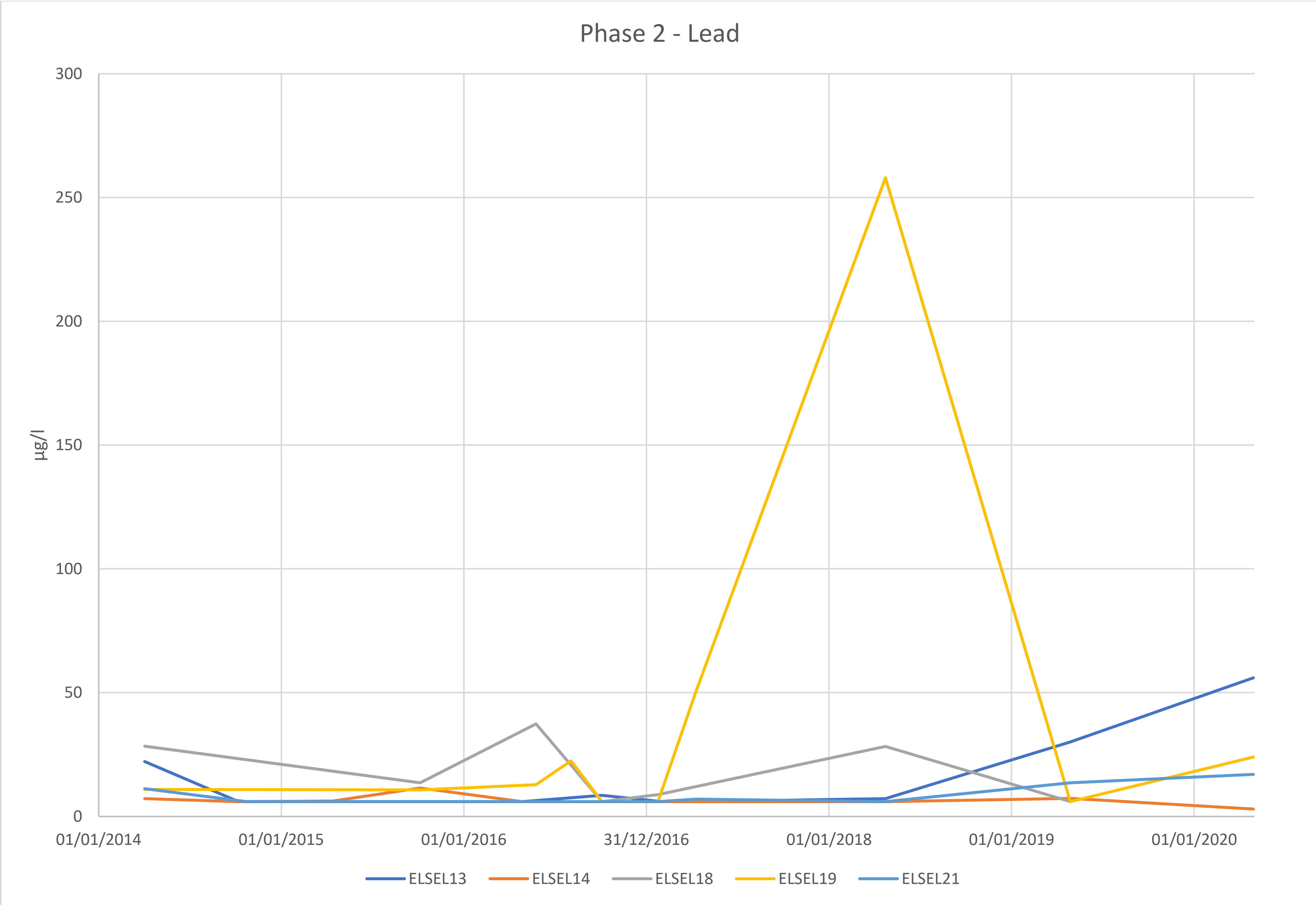
Phase 2 - Chloride
1400
1200
1000
800
600
400
200
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



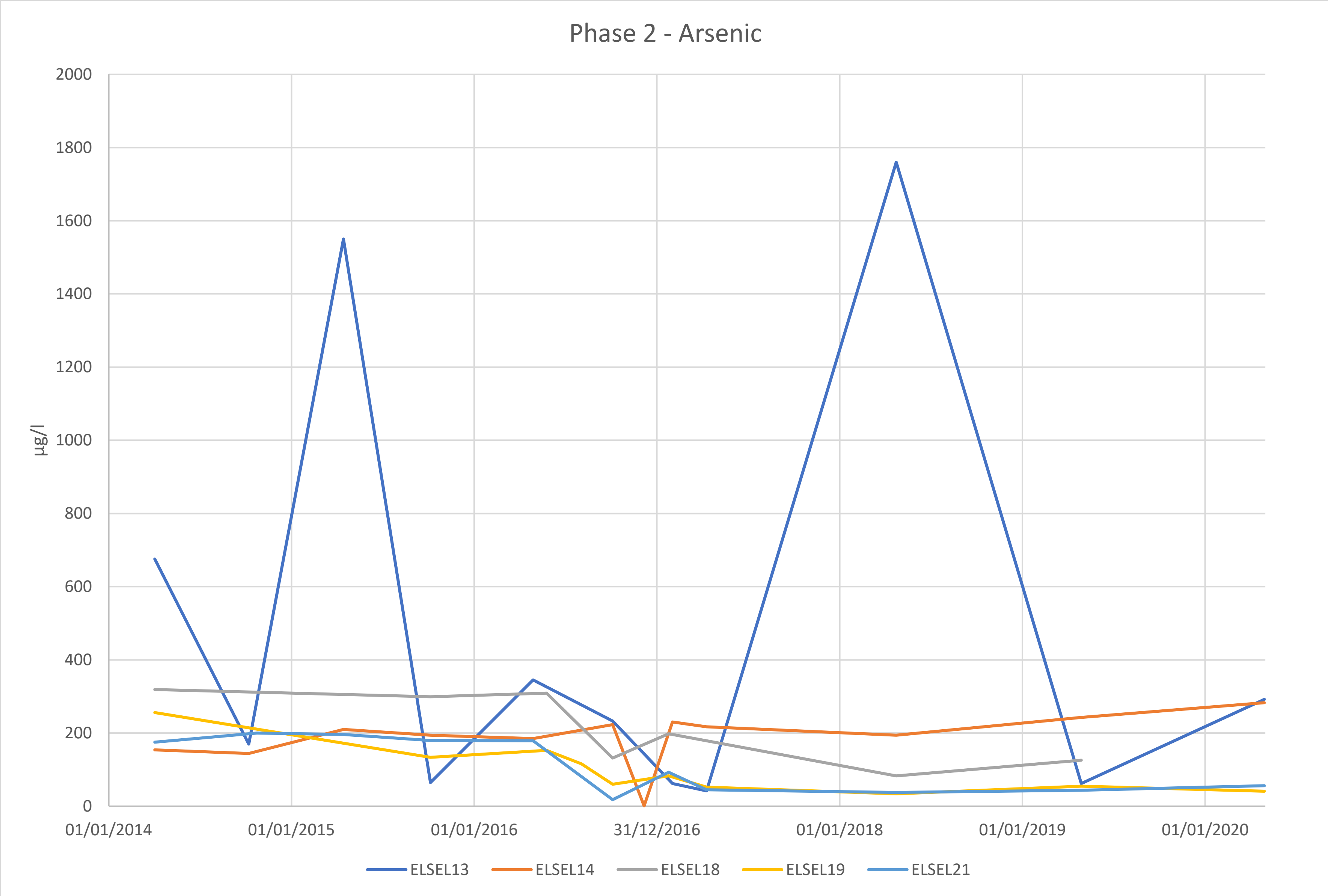
Phase 2 - Sulphate
mg/l
1800
1600
1400
1200
1000
800
600
400
200
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



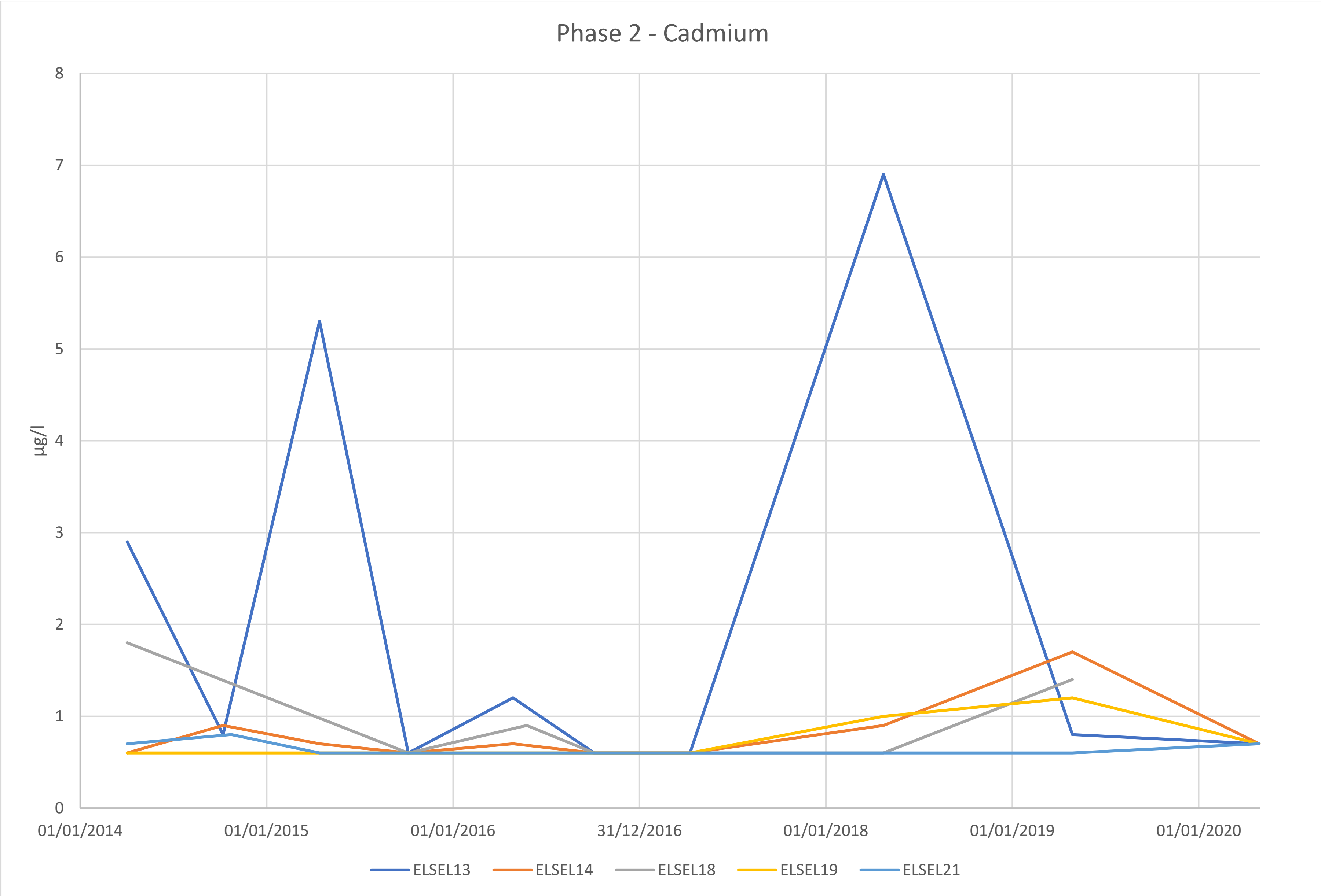
Phase 2 - Nickel
600
500
400
300
200
100
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



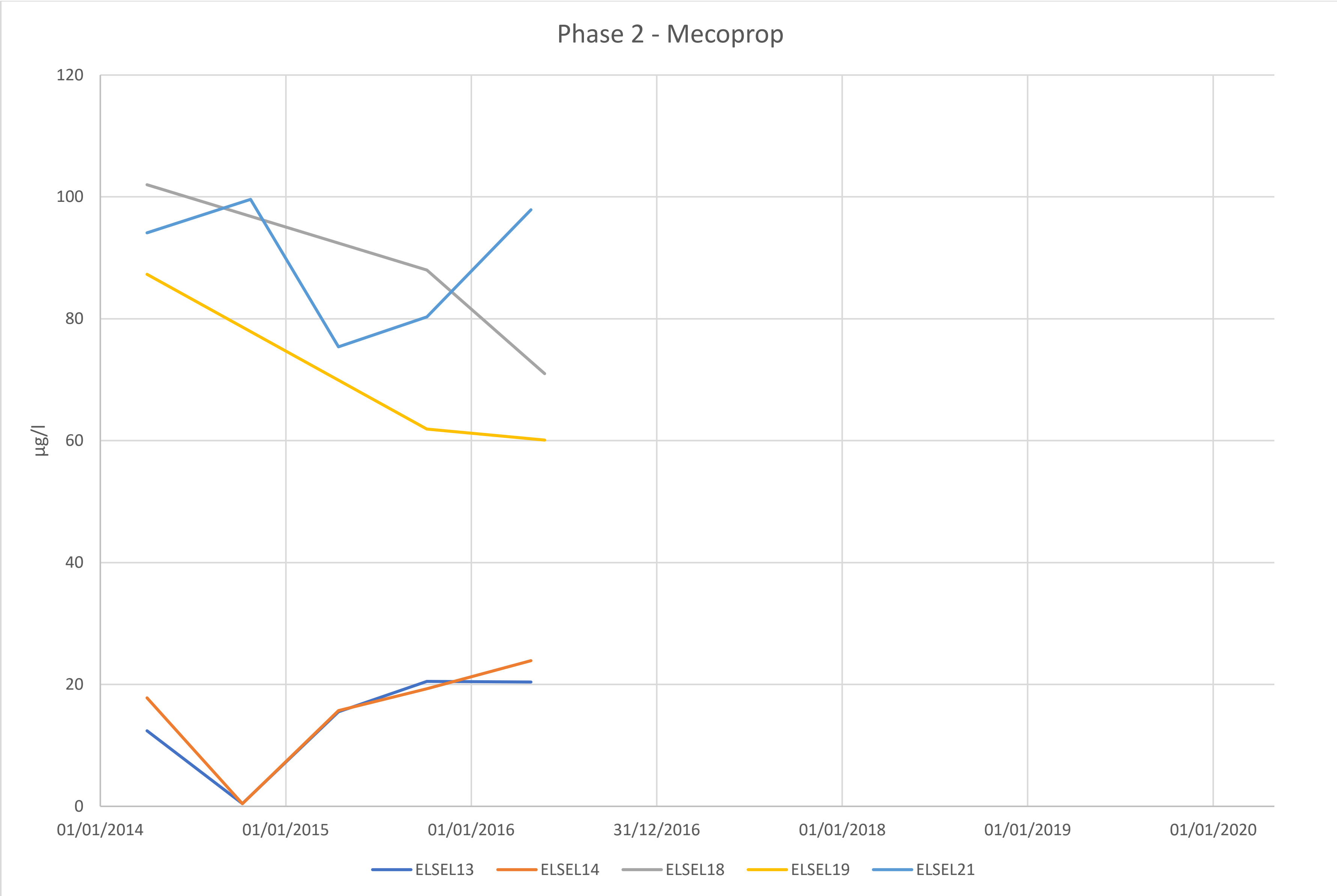
Phase 2 - Lead
300
250
200
150
100
50
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21

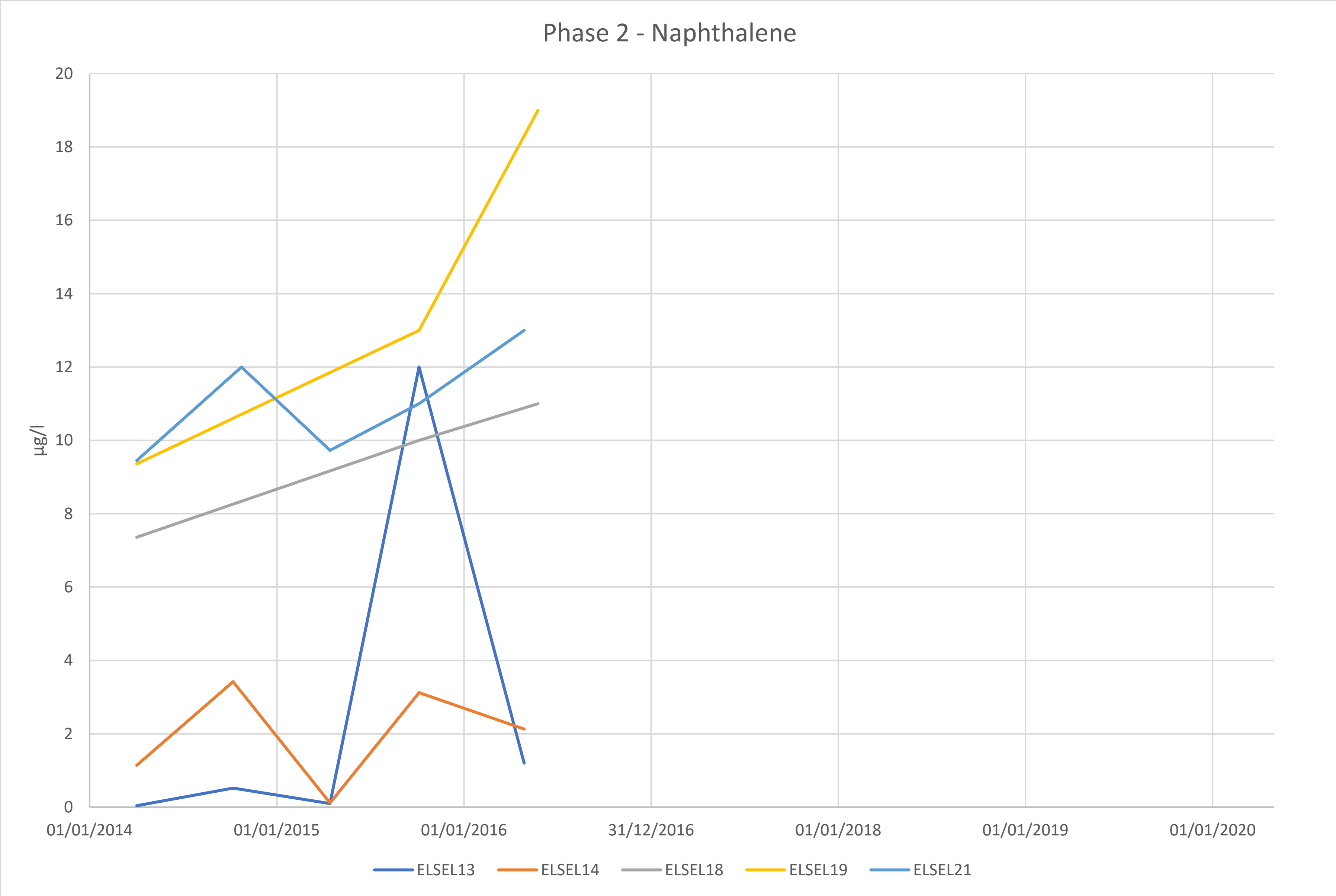


Phase 2 - Arsenic
µg/l
2000
1800
1600
1400
1200
1000
800
600
400
200
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



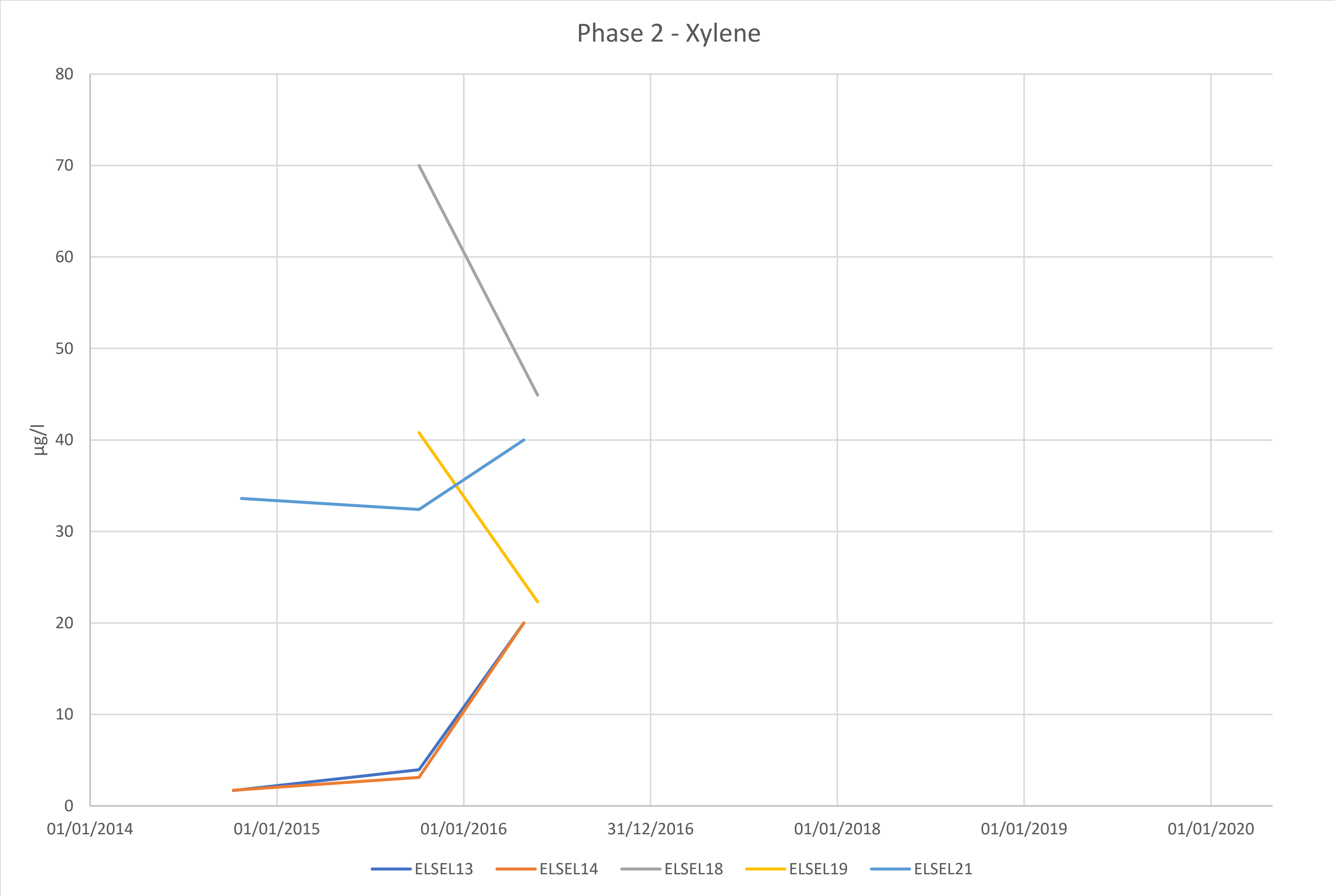
Phase 2 - Cadmium
µg/l
8
7
6
5
4
3
2
1
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21

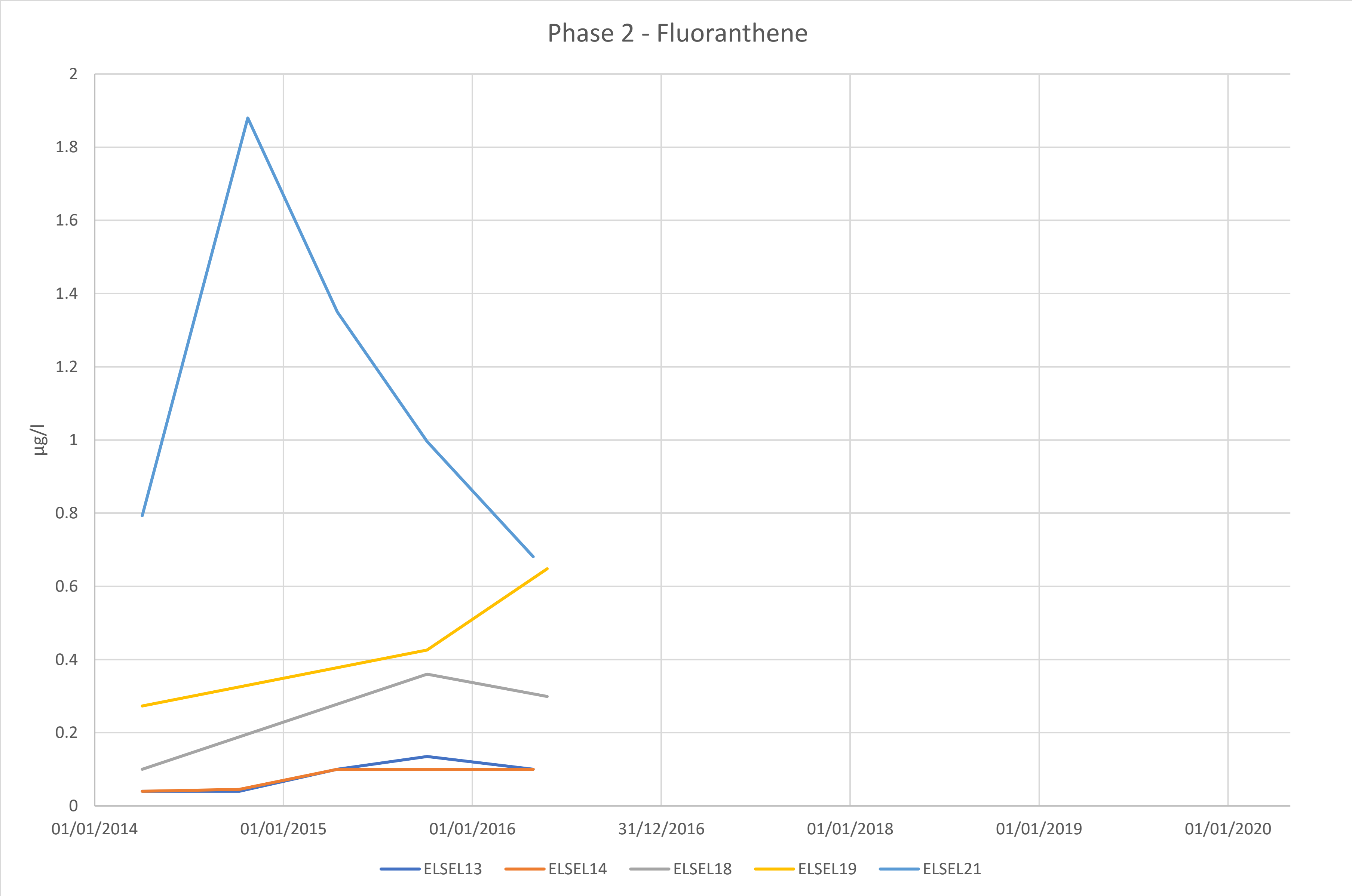

Phase 2 - Mecoprop
µg/l
120
100
80
60
40
20
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21

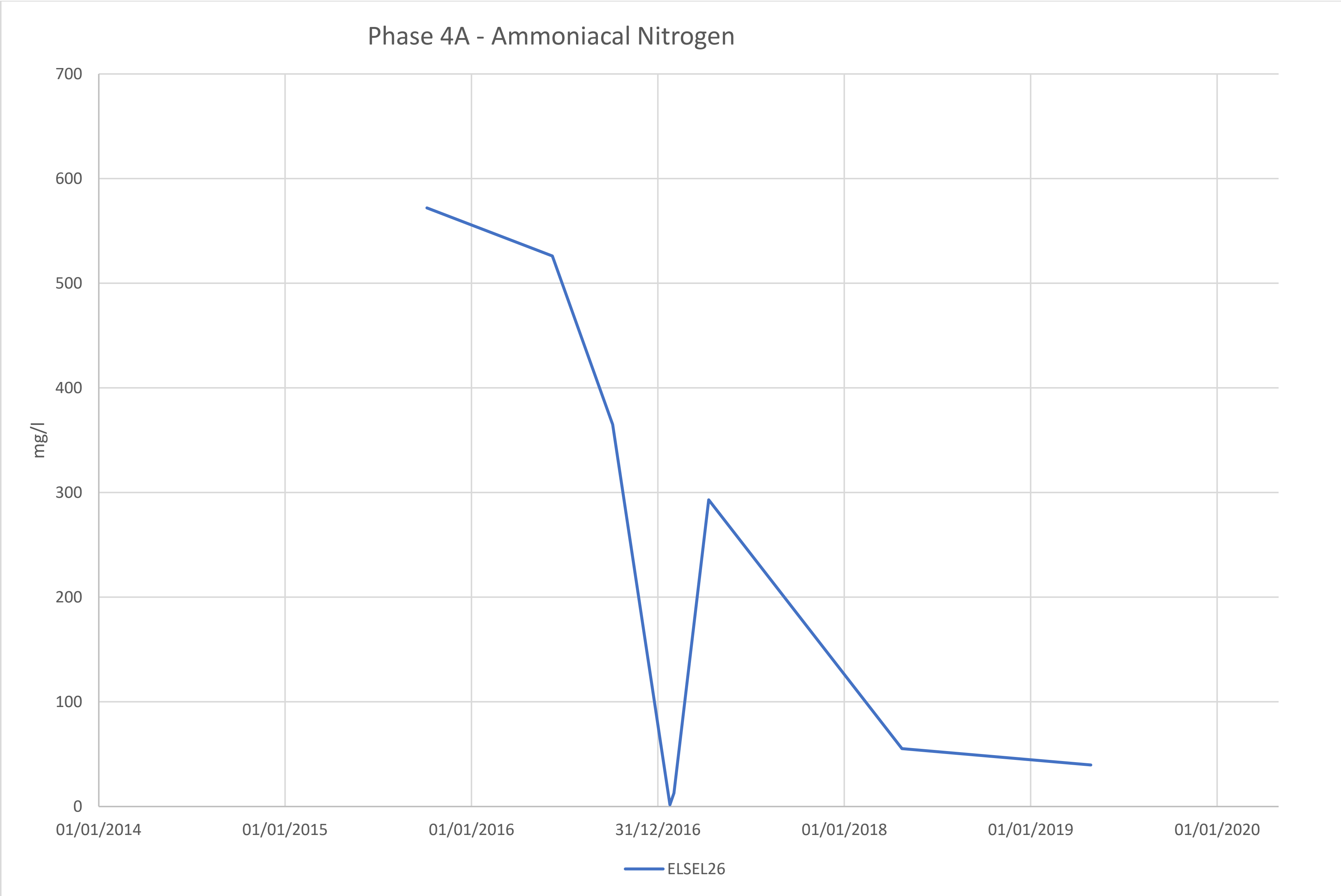


Phase 2 - Naphthalene
µg/l
20
18
16
14
12
10
8
6
4
2
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21

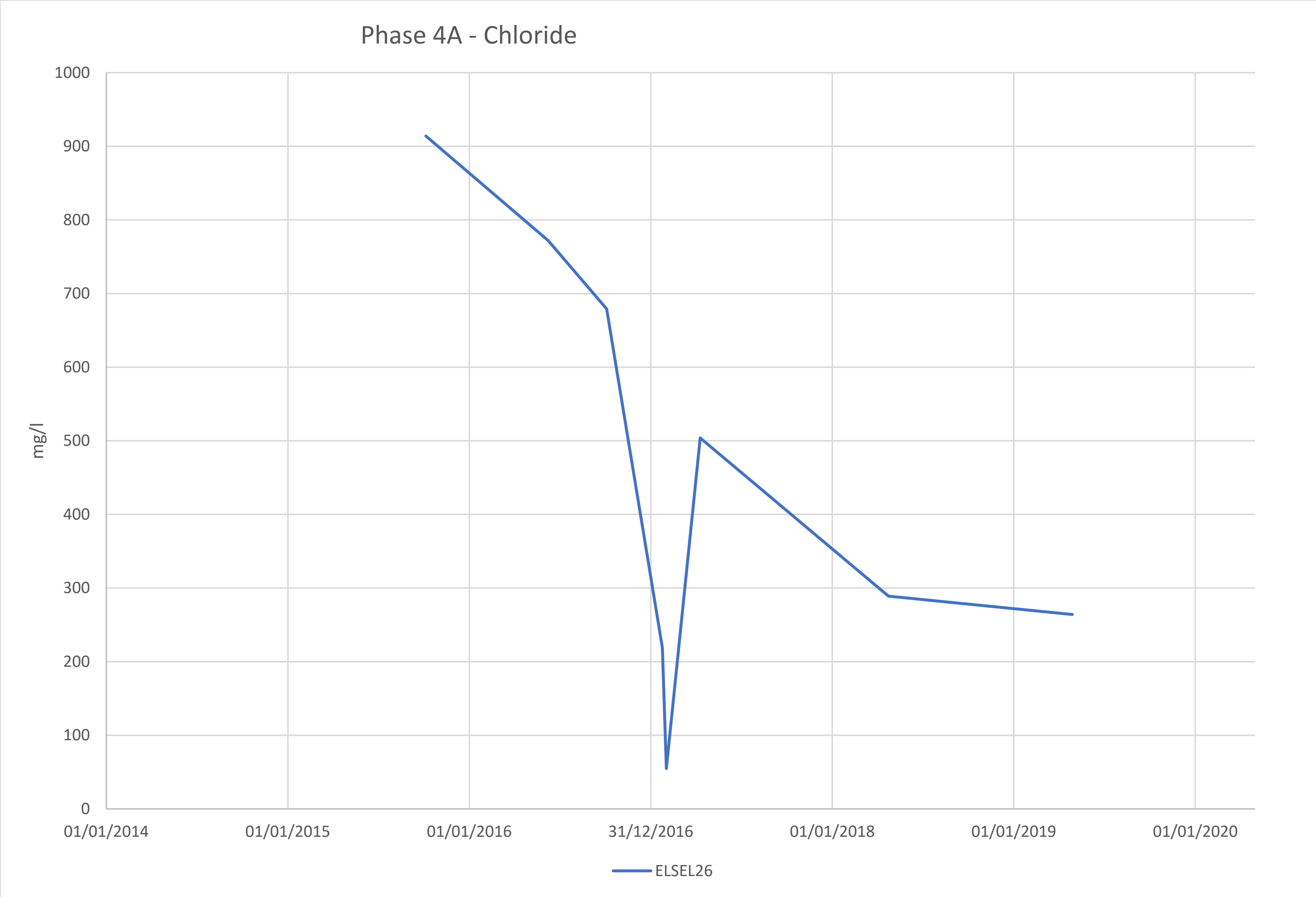
Phase 2 - Toluene
µg/l
90
80
70
60
50
40
30
20
10
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21


Phase 2 - Xylene
µg/l
80
70
60
50
40
30
20
10
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21

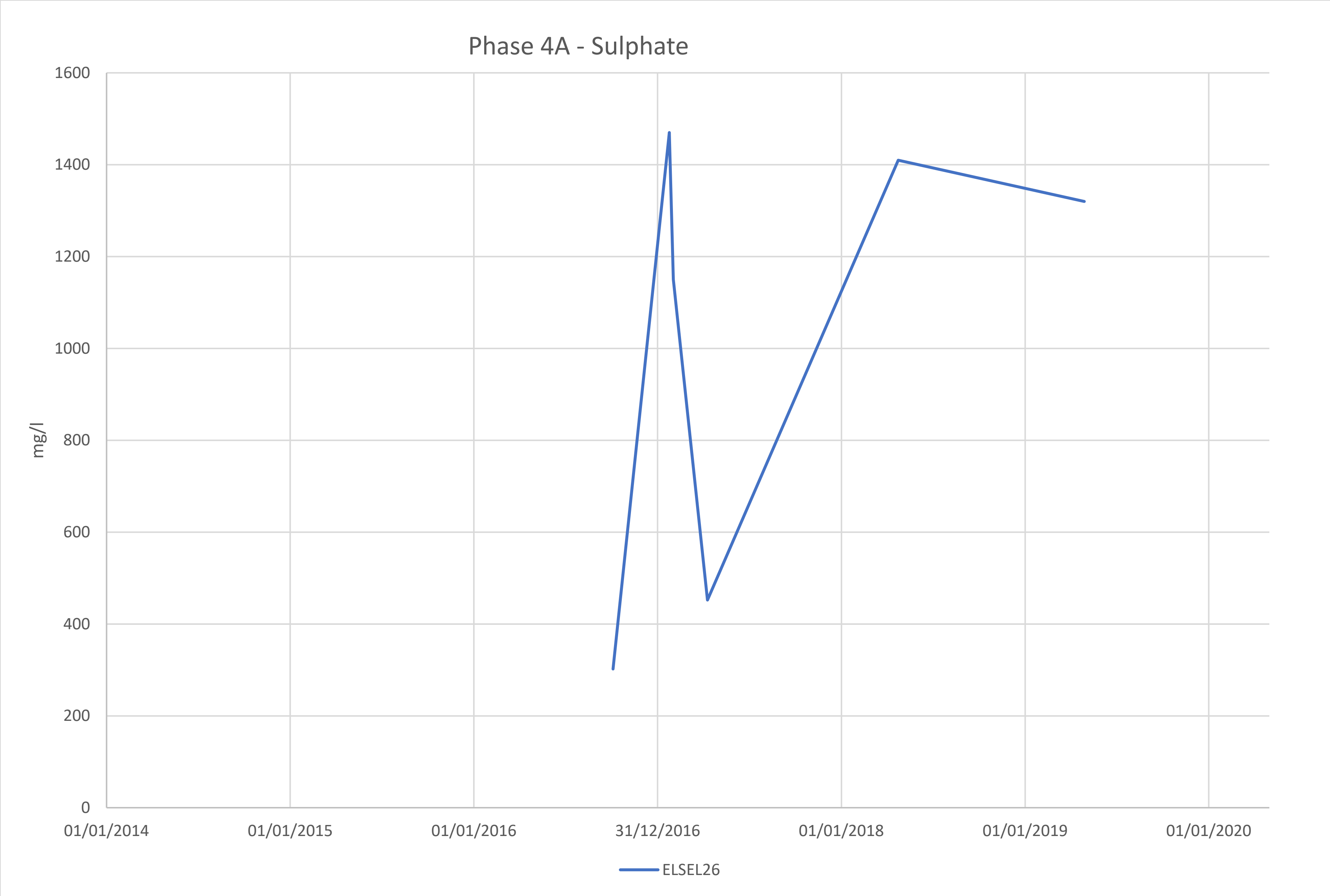

Phase 2 - Fluoranthene
µg/l
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL13
ELSEL14
ELSEL18
ELSEL19
ELSEL21



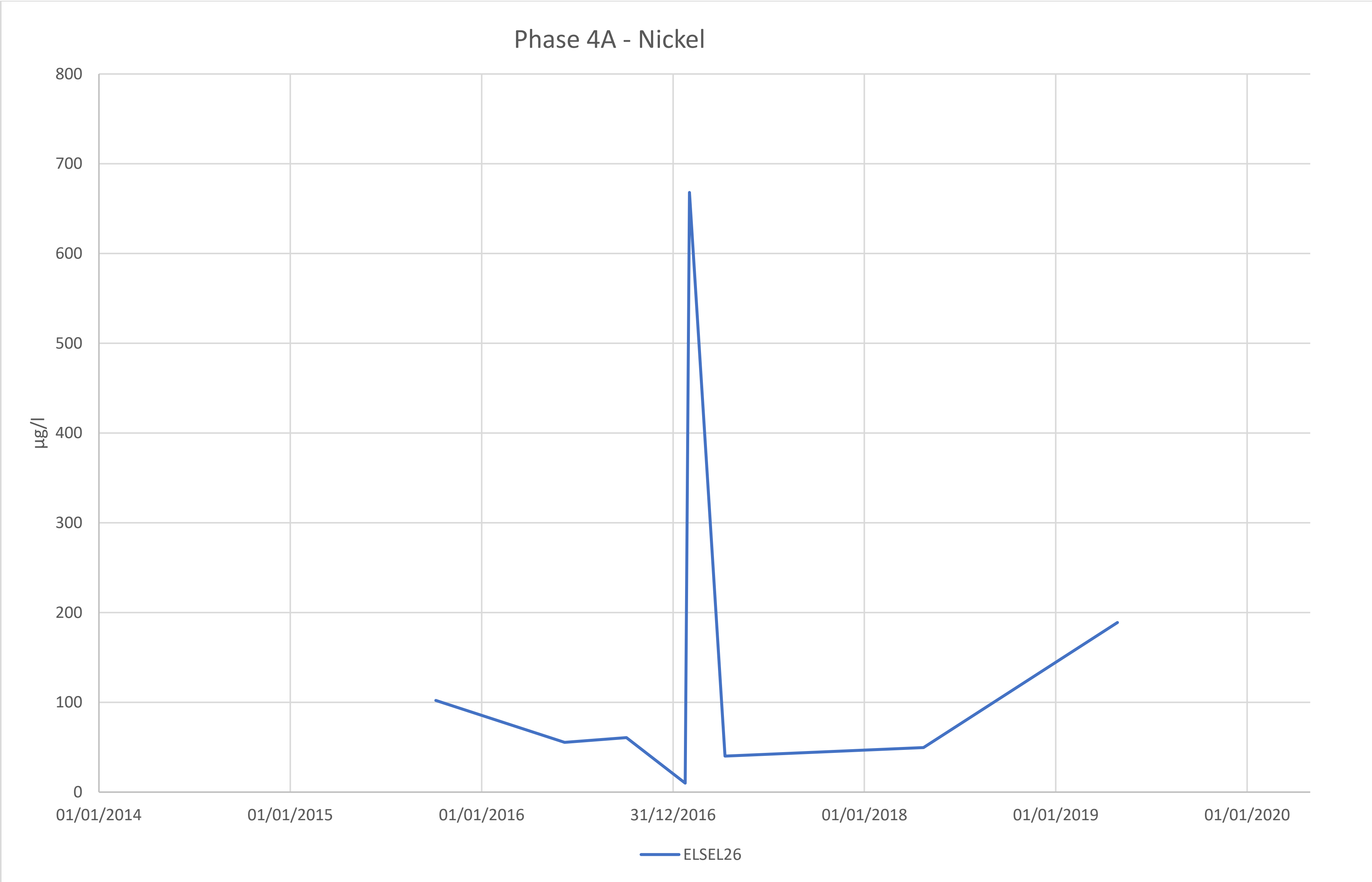
Phase 4A - Ammoniacal Nitrogen
mg/l
700
600
500
400
300
200
100
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



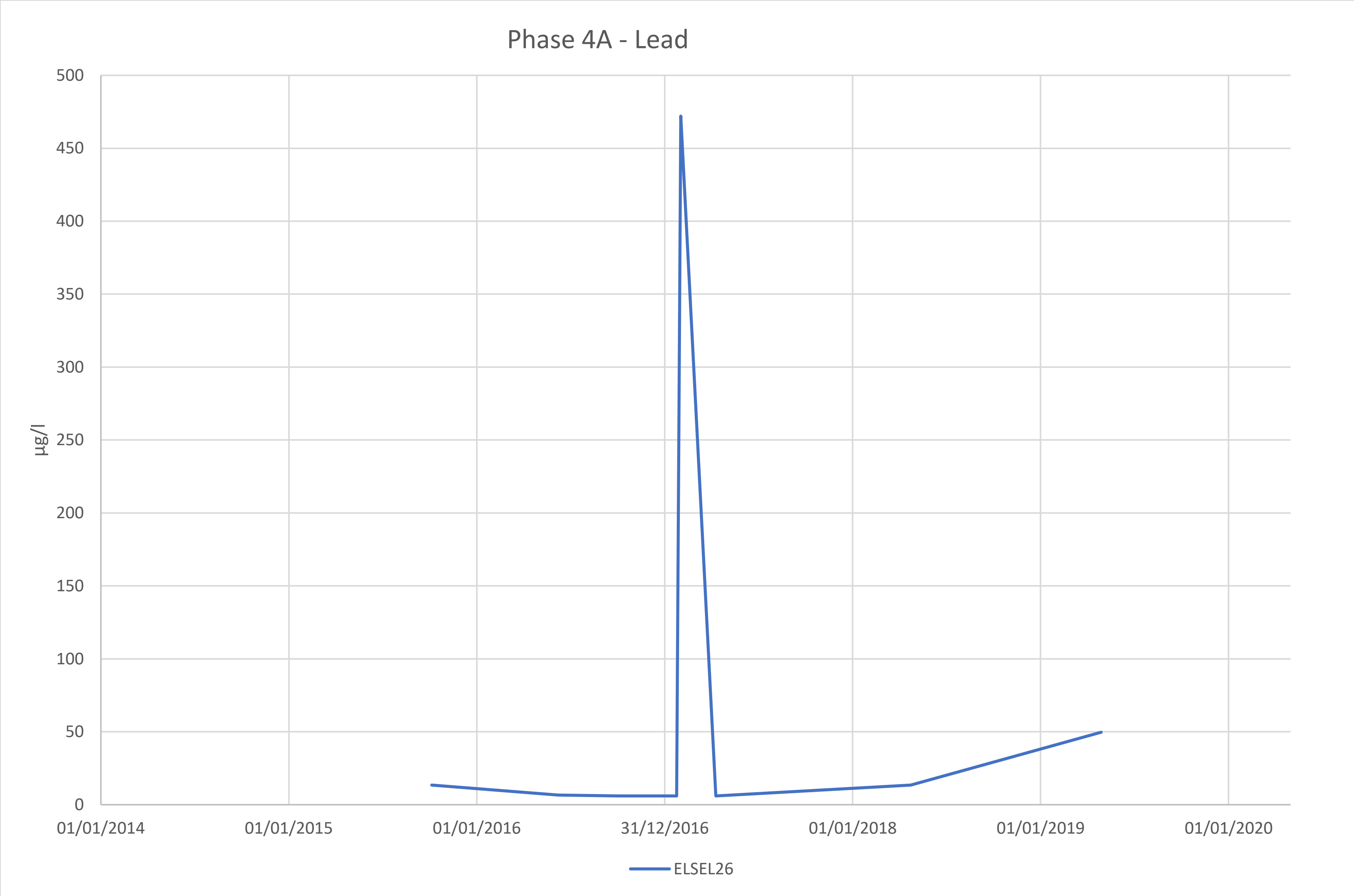
Phase 4A - Chloride
1000
900
800
700
600
500
400
300
200
100
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



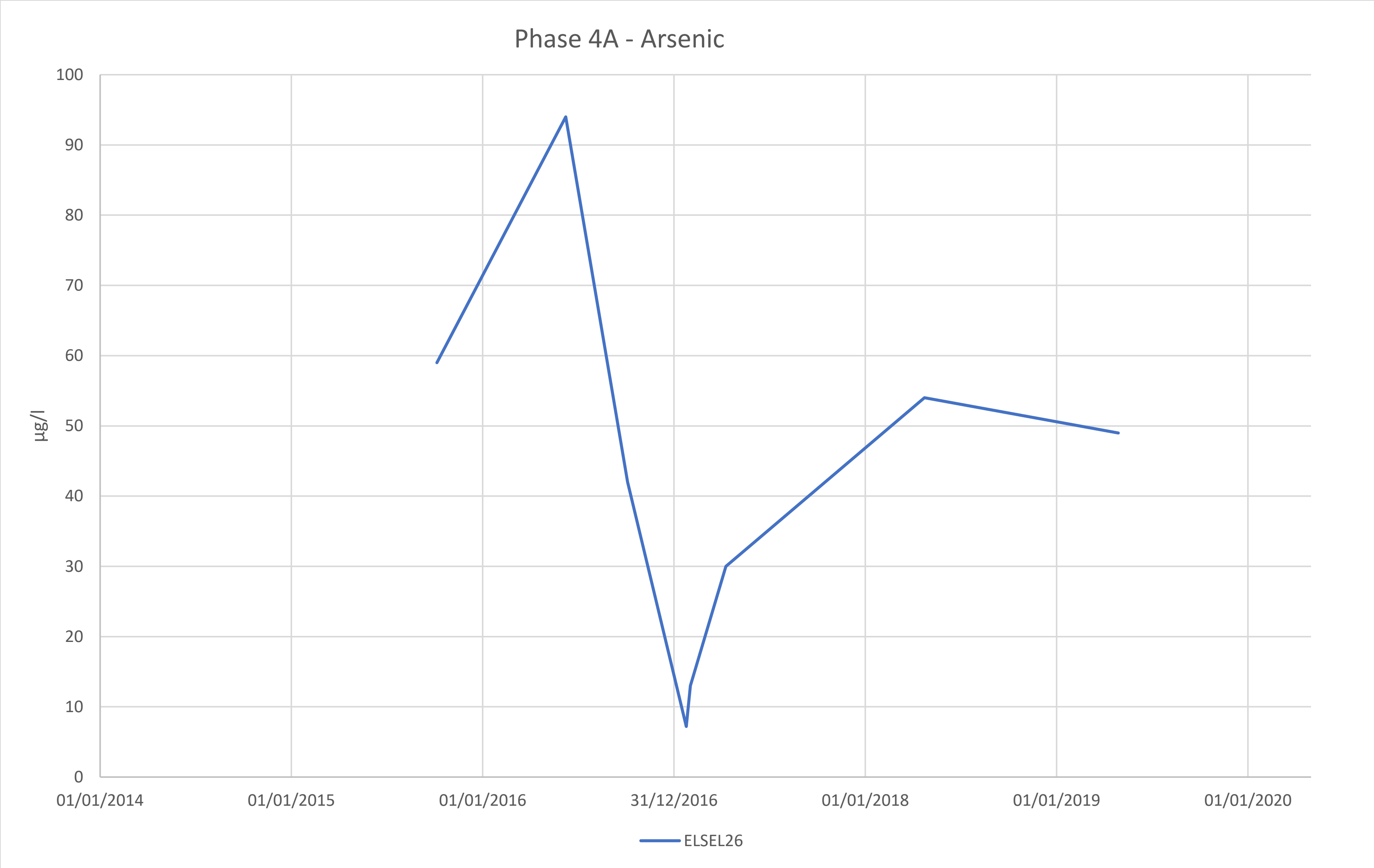
Phase 4A - Sulphate
1600
1400
1200
1000
800
600
400
200
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



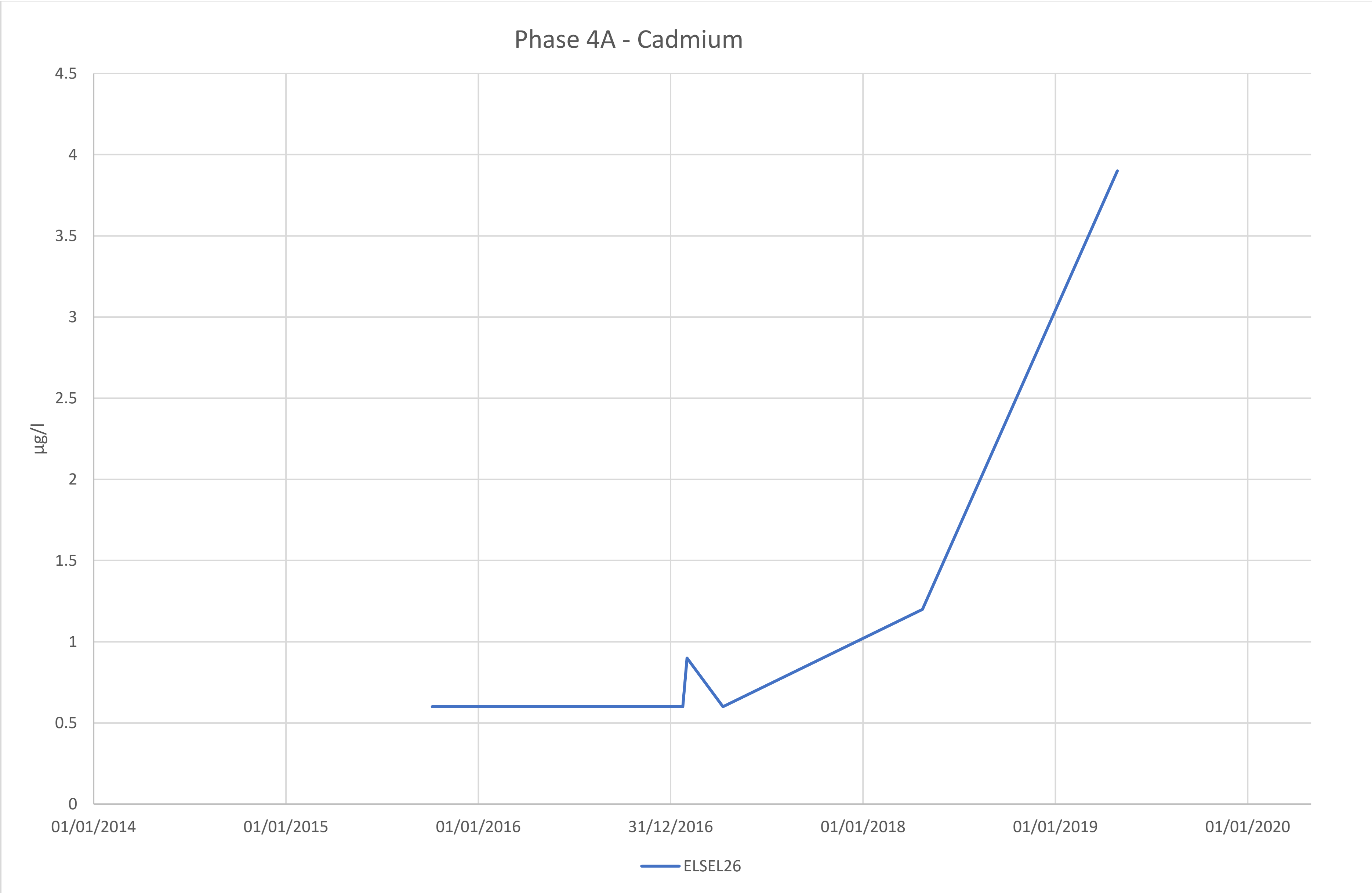
Phase 4A - Nickel
800
700
600
500
400
300
200
100
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



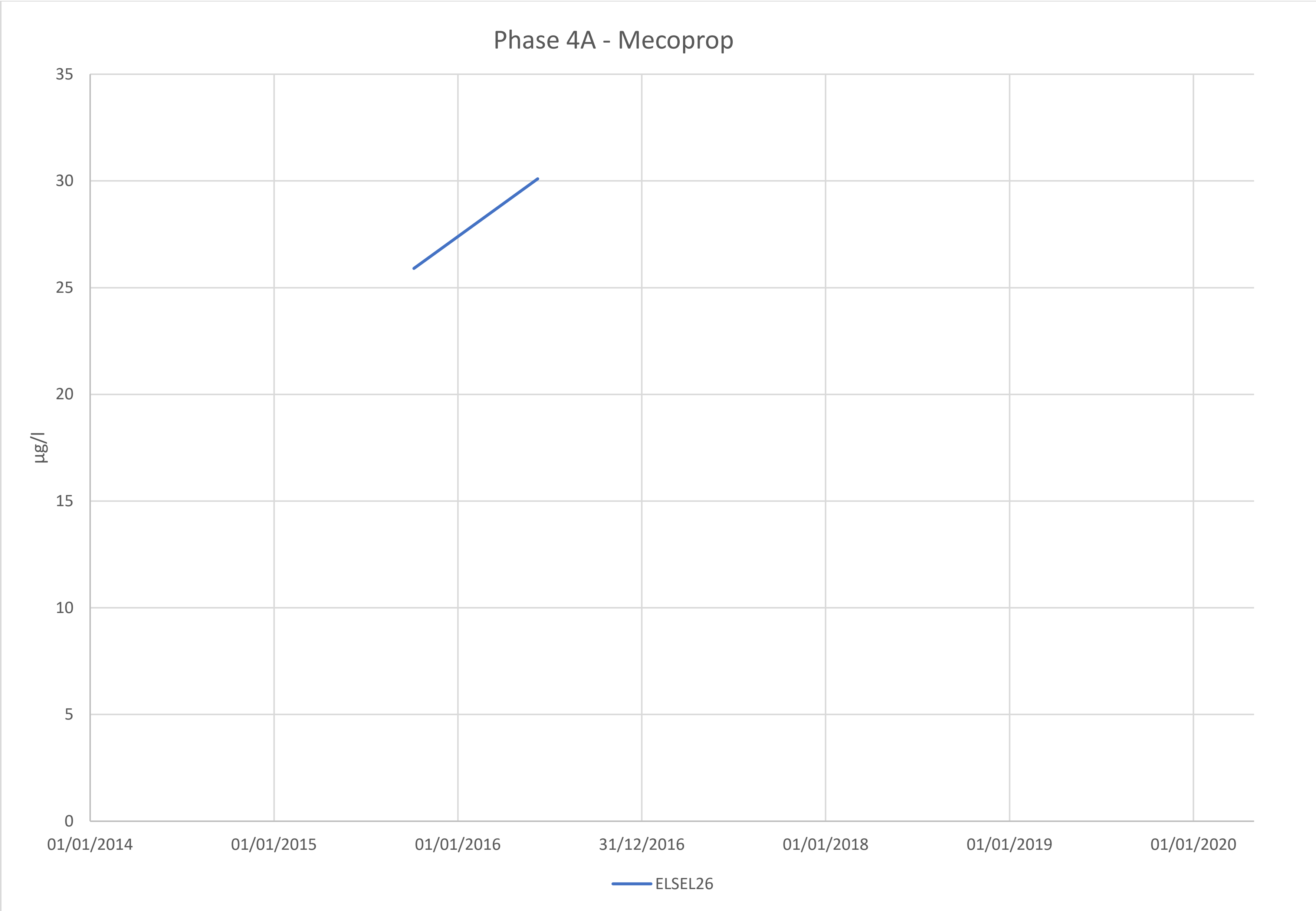
Phase 4A - Lead
µg/l
500
450
400
350
300
250
200
150
100
50
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



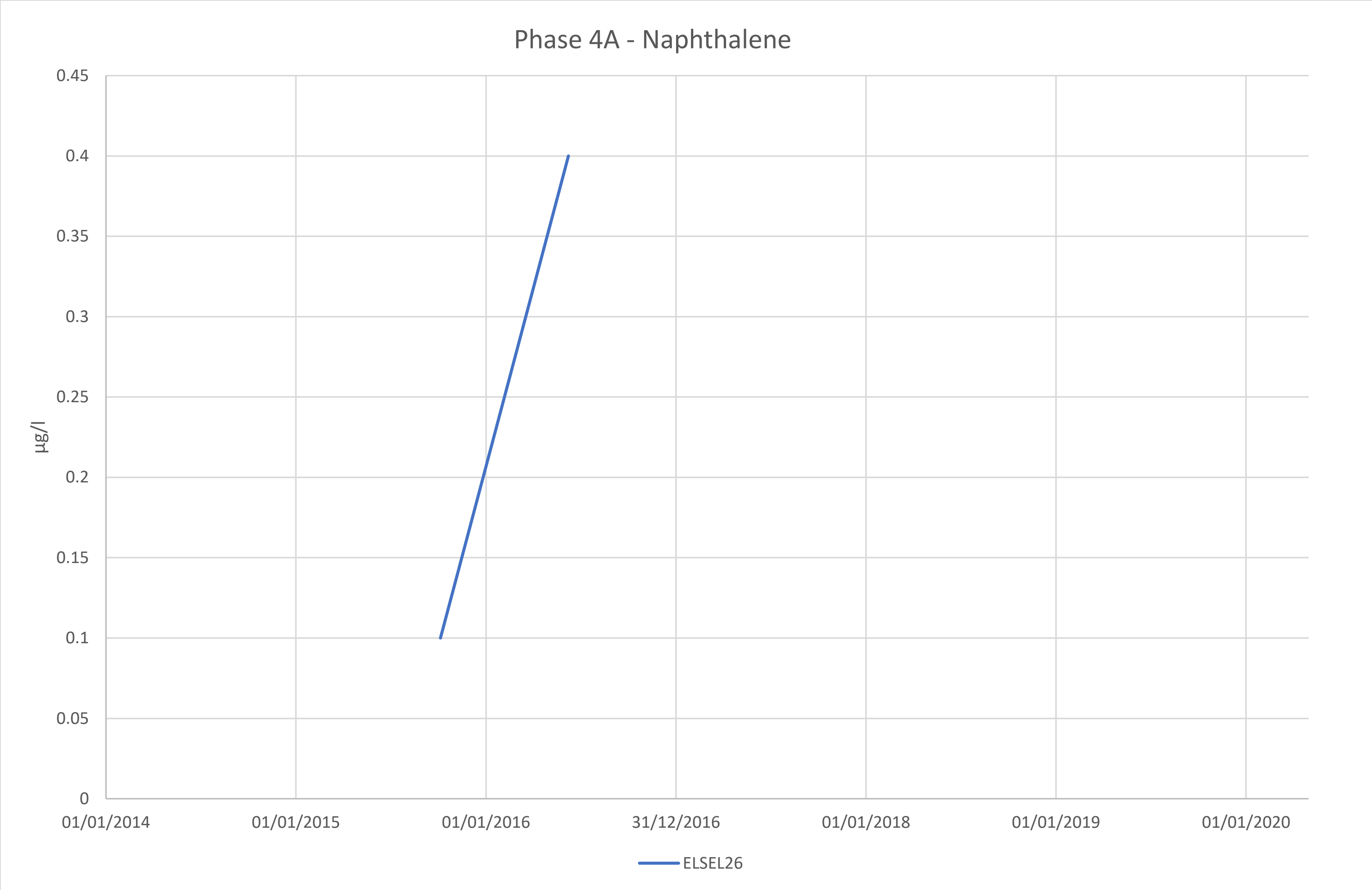
Phase 4A - Arsenic
100
90
80
70
60
50
40
30
20
10
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



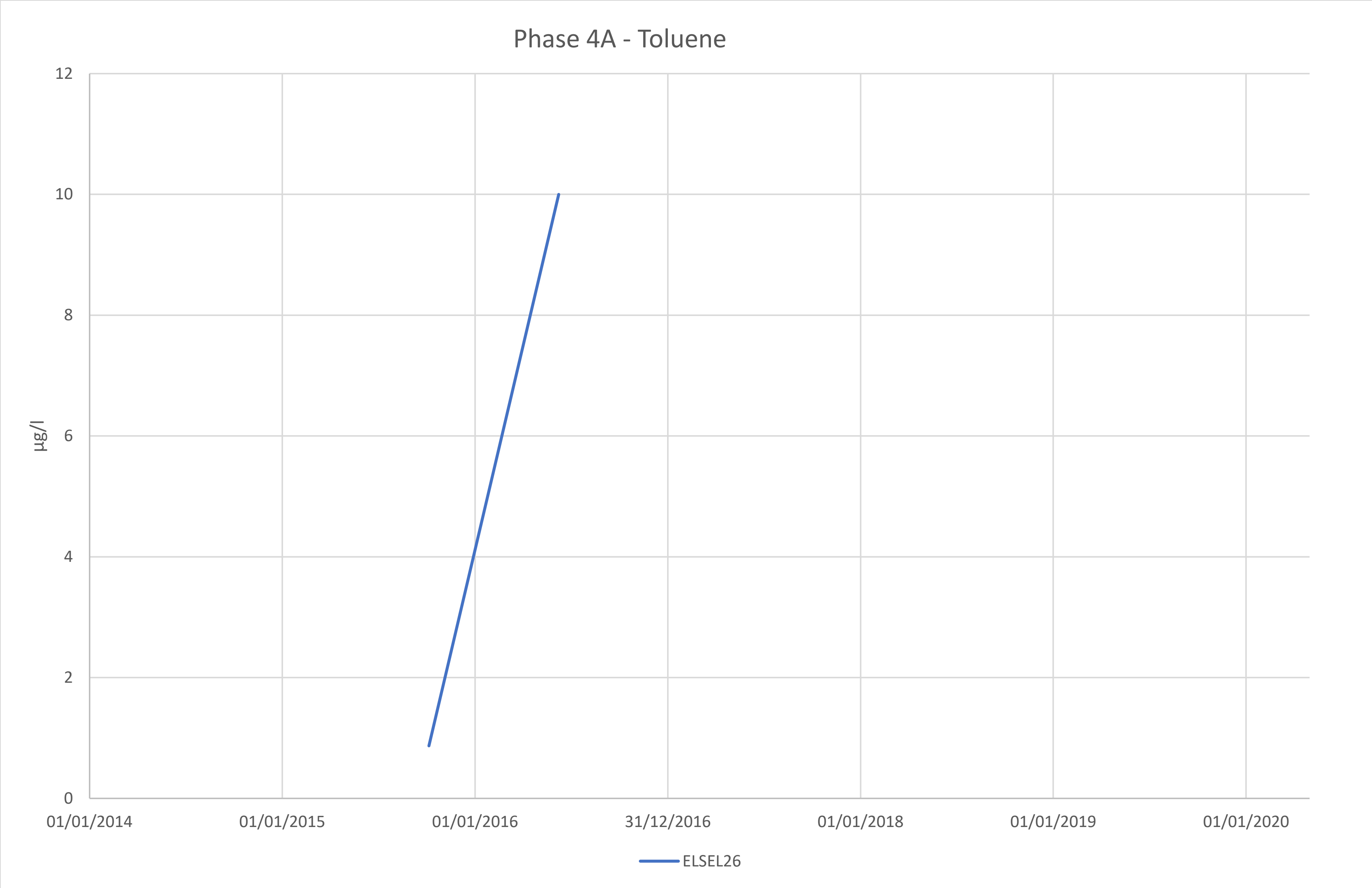
Phase 4A - Cadmium
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



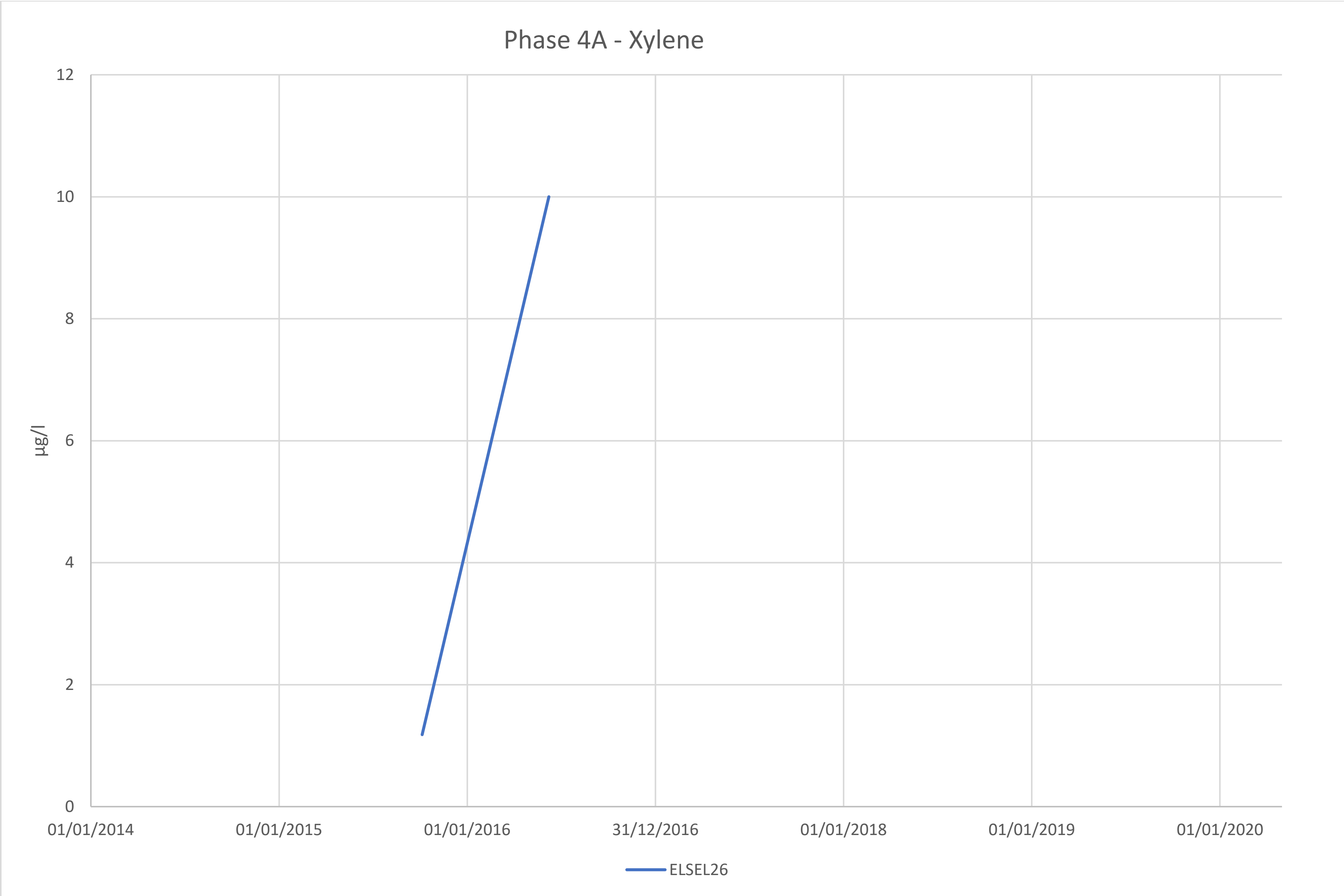
Phase 4A - Mecoprop
35
30
25
20
15
10
5
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26

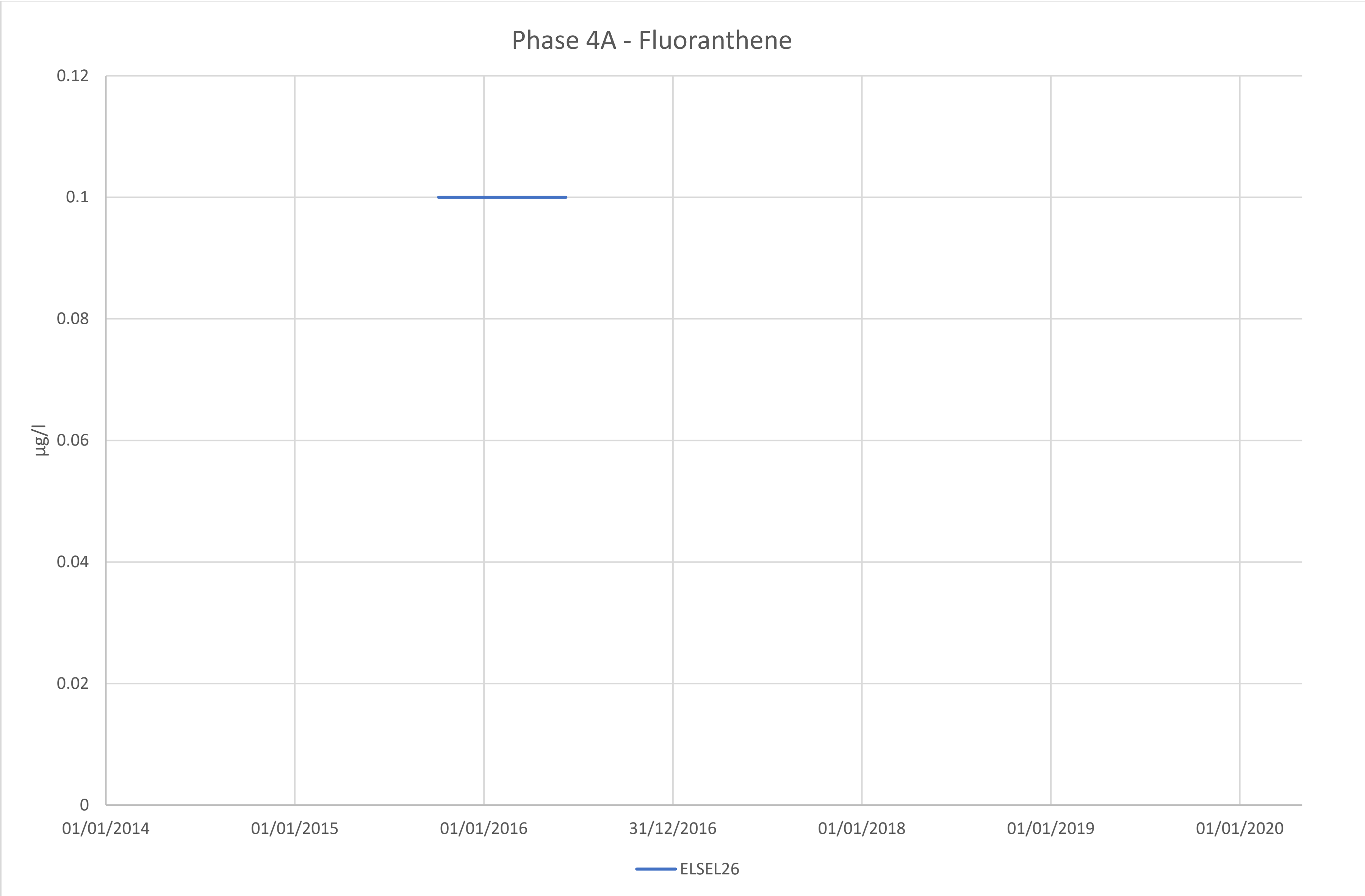


Phase 4A - Naphthalene
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26

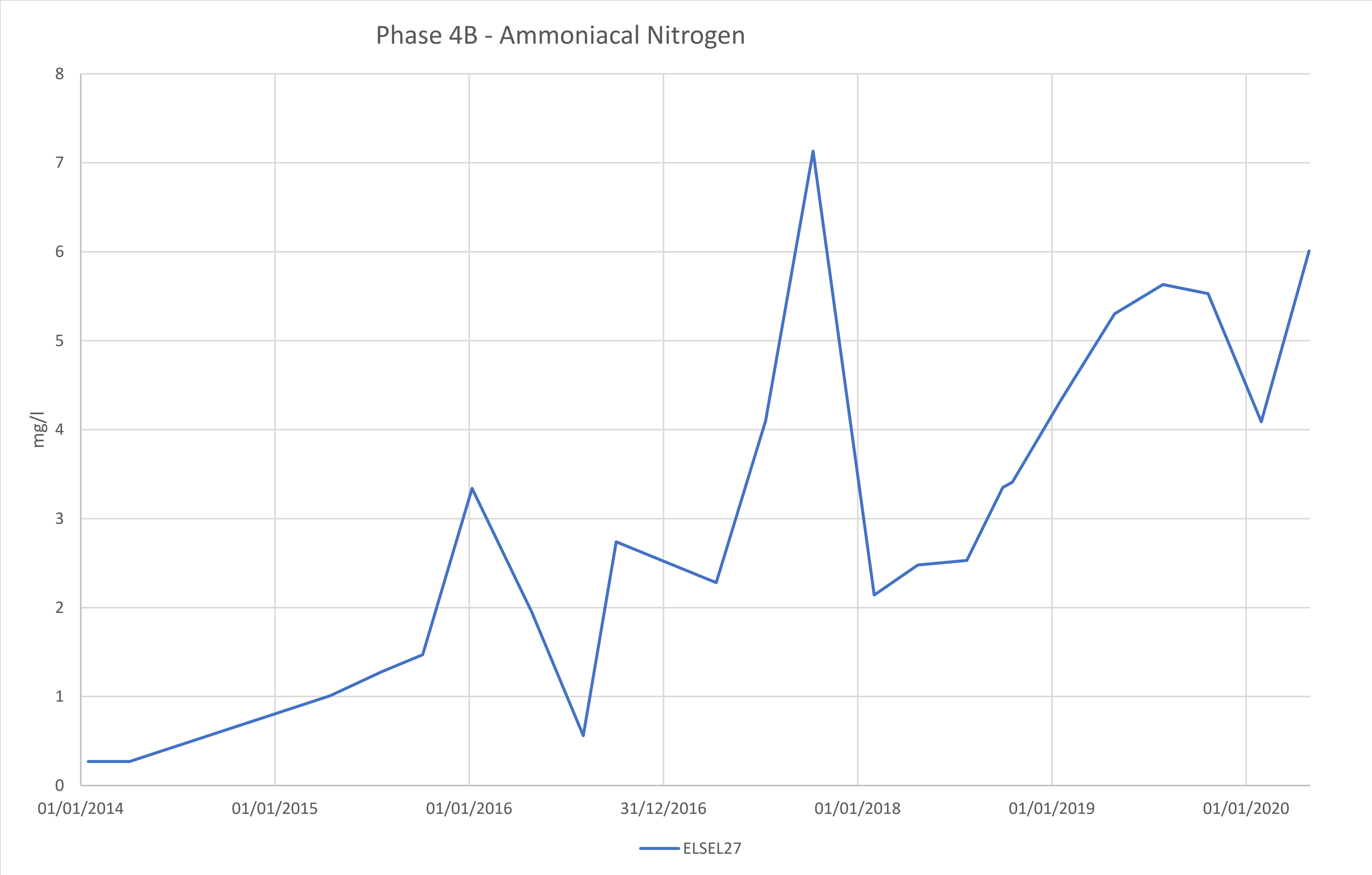


Phase 4A - Toluene
µg/l
12
10
8
6
4
2
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26


Phase 4A - Xylene
12
10
8
6
4
2
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26

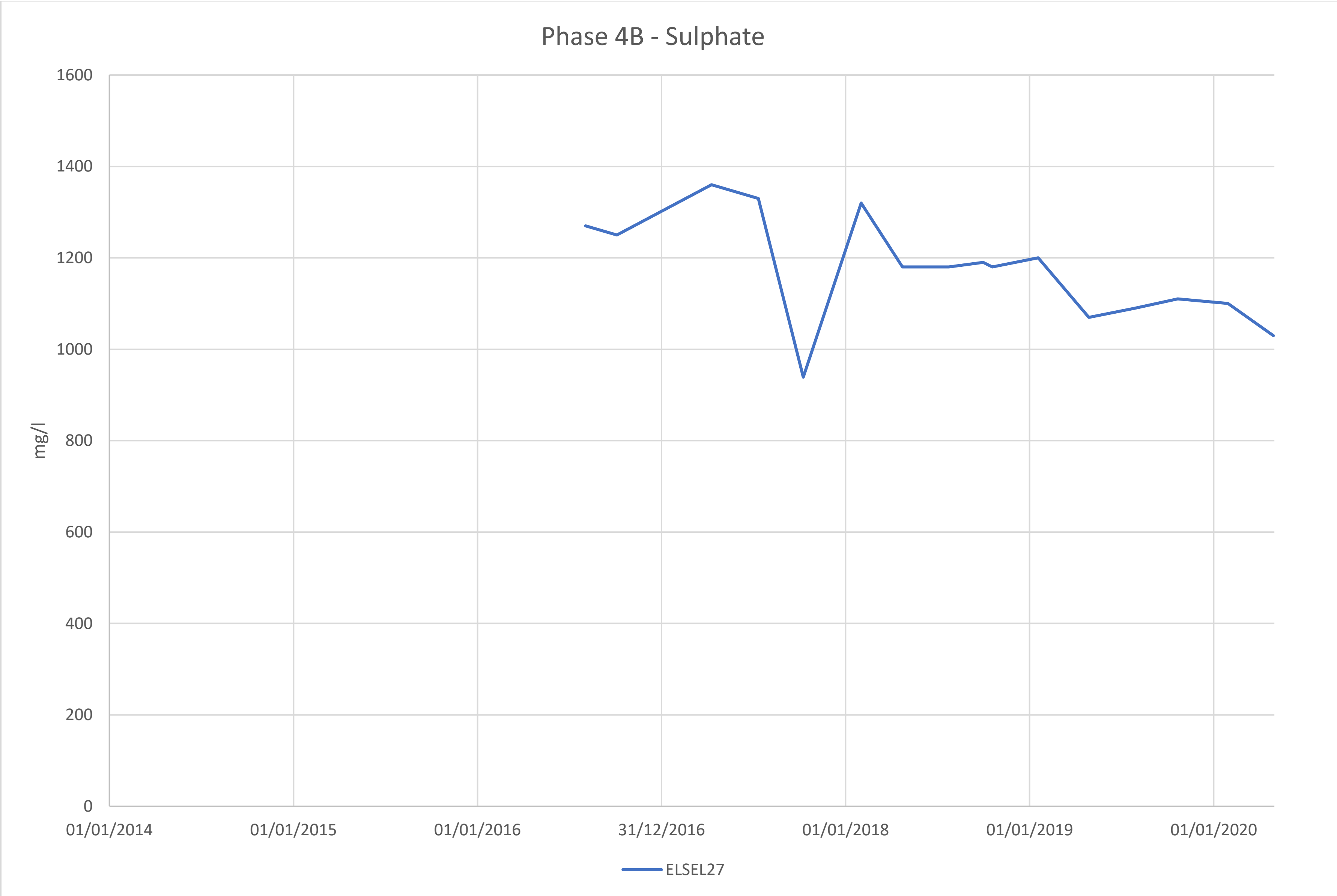


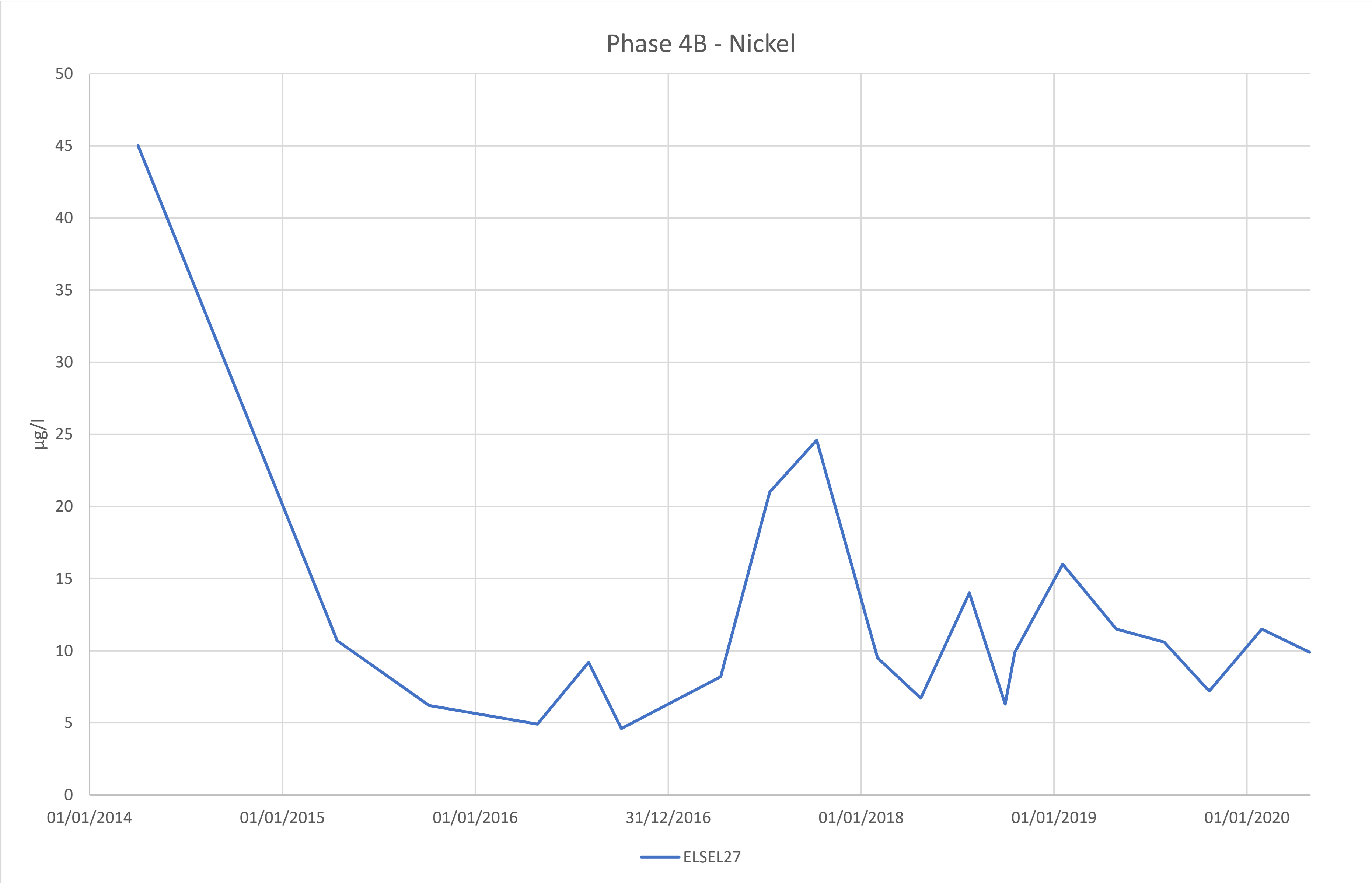
Phase 4A - Fluoranthene
0.12
0.1
0.08
0.06
0.04
0.02
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL26



Phase 4B - Ammoniacal Nitrogen
mg/l
8
7
6
5
4
3
2
1
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

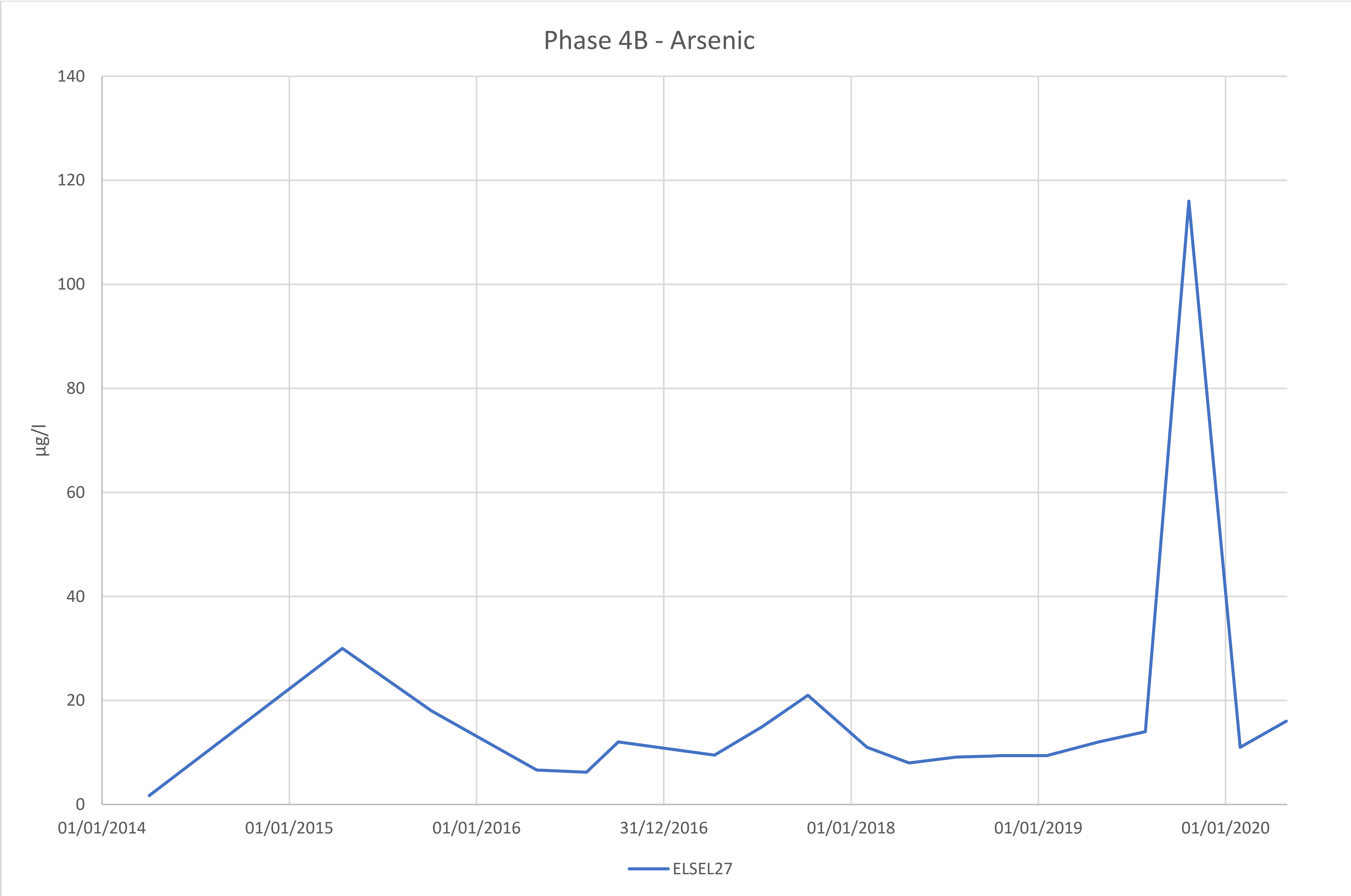
Phase 4B - Chloride
600
500
400
300
200
100
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

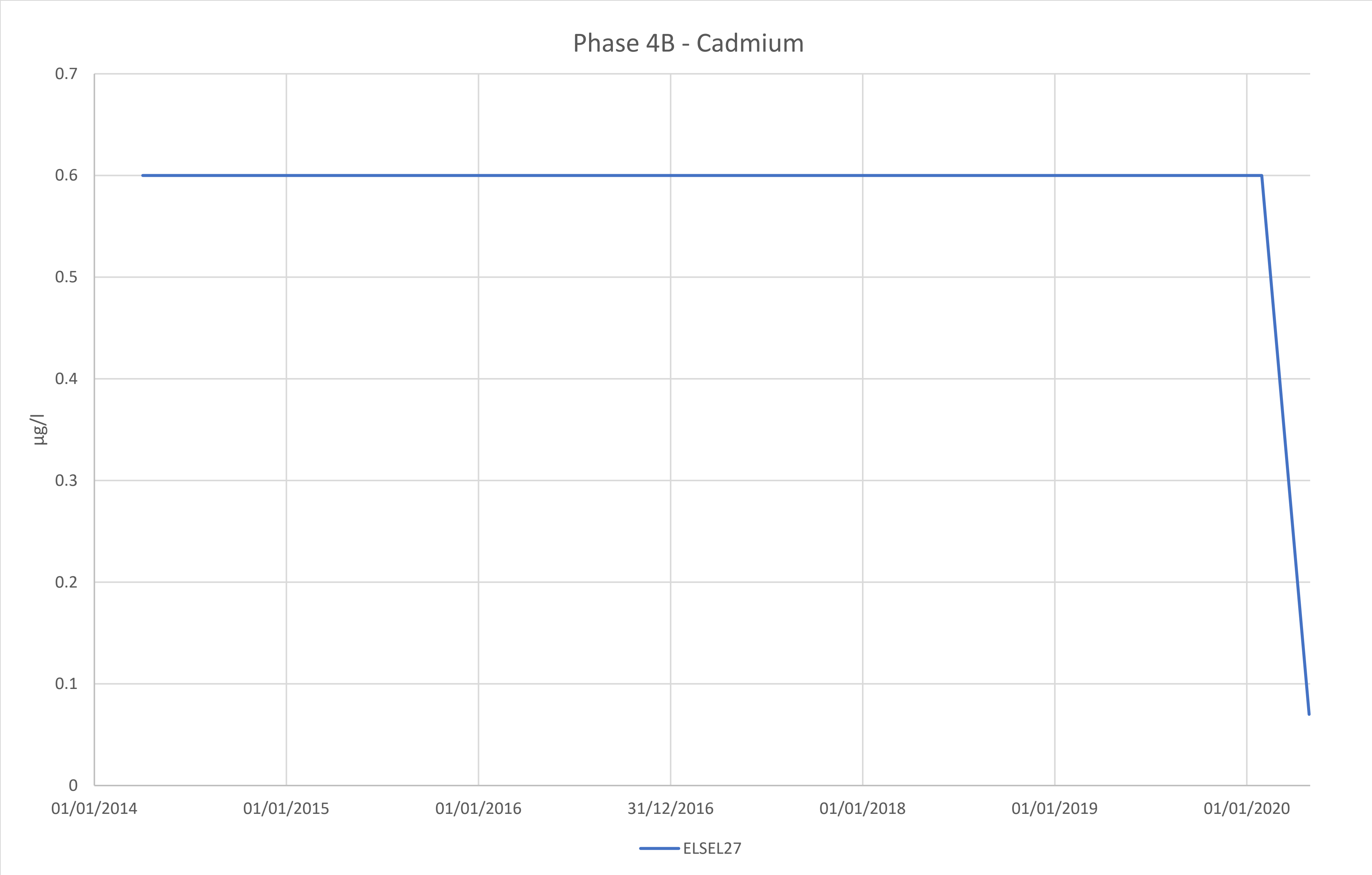

Phase 4B - Sulphate
1600
1400
1200
1000
800
600
400
200
0
mg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

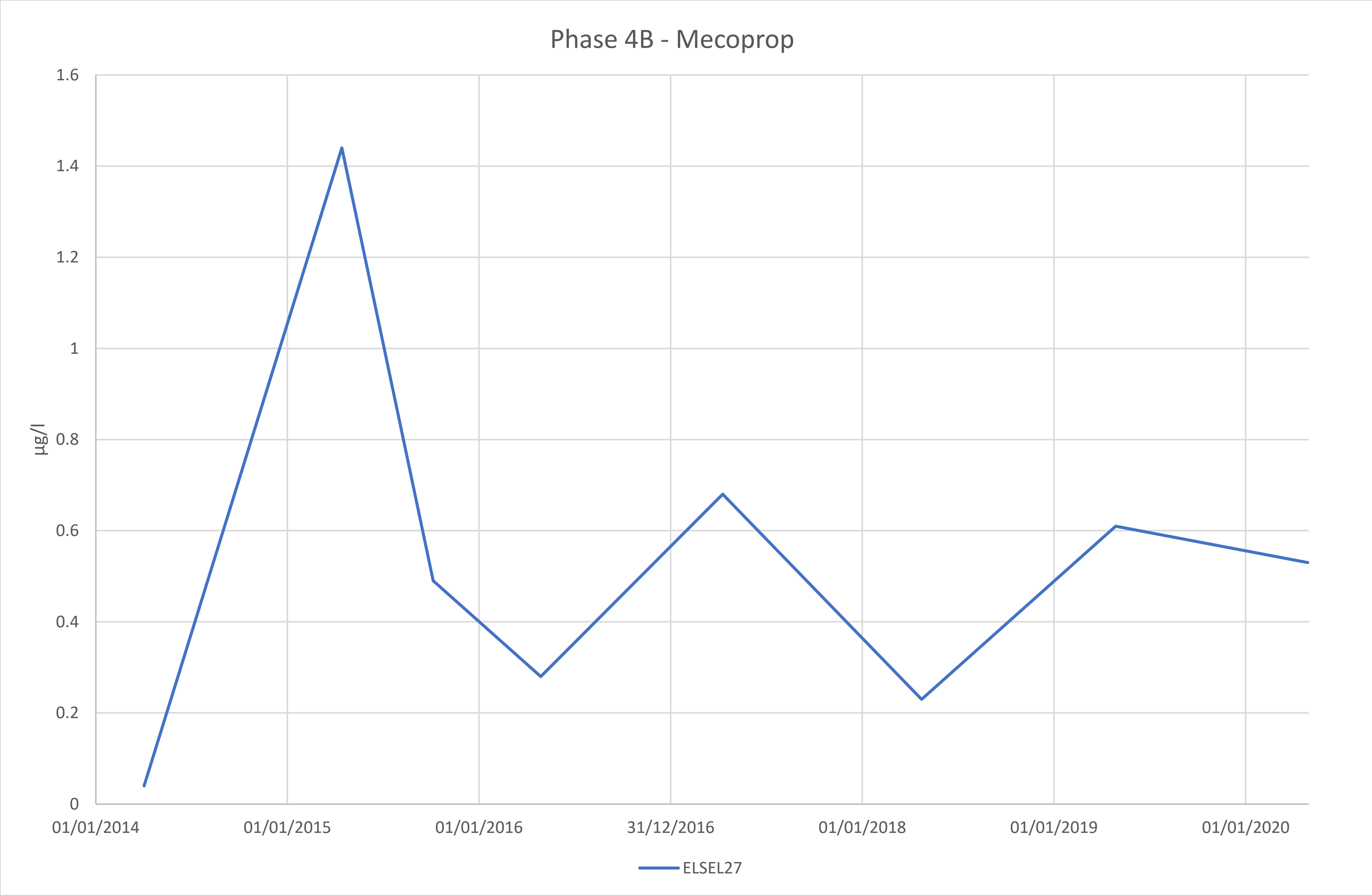


Phase 4B - Nickel
µg/l
50
45
40
35
30
25
20
15
10
5
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

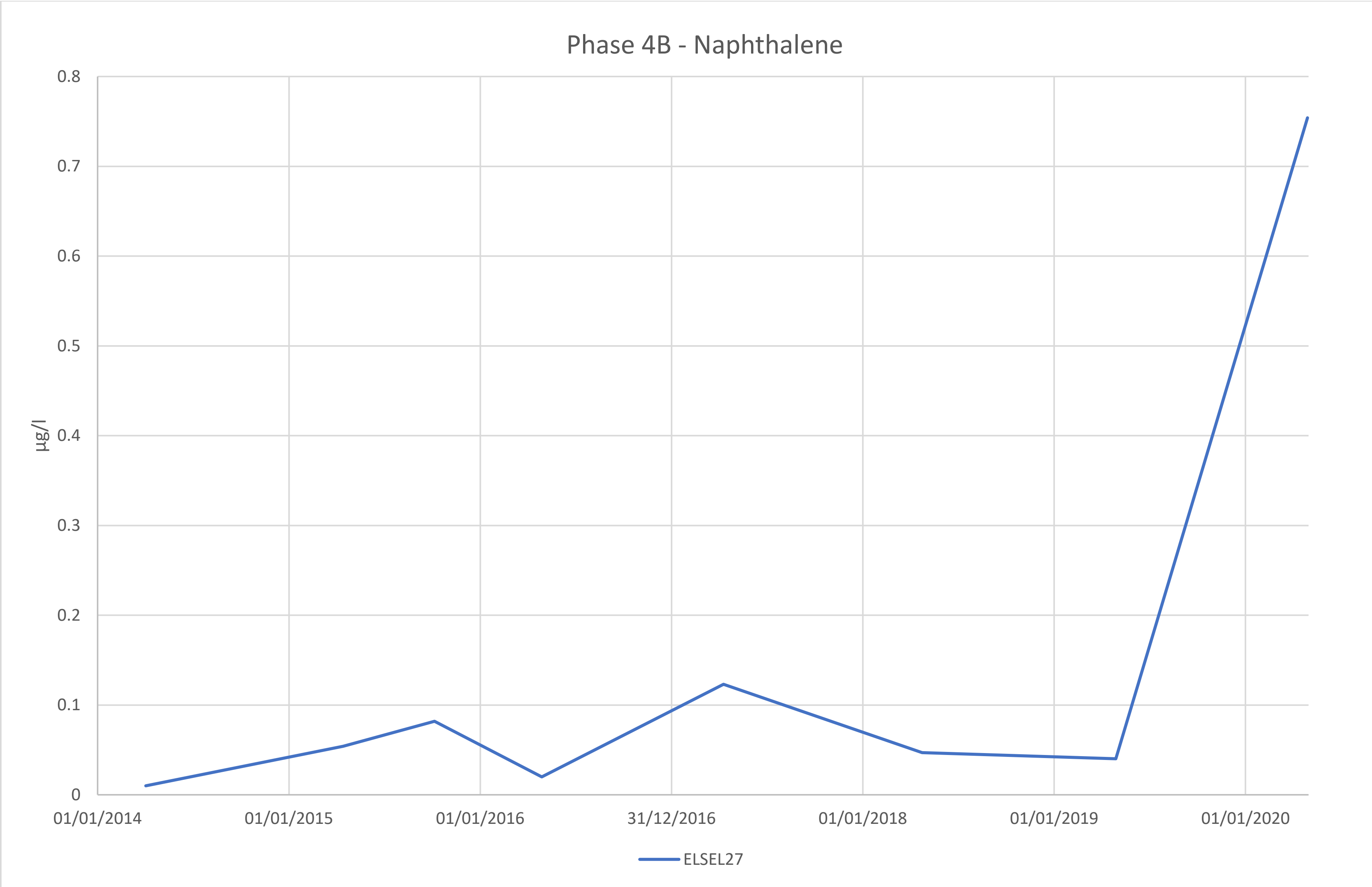
Phase 4B - Lead
25
20
15
10
5
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27


Phase 4B - Arsenic
140
120
100
80
60
40
20
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

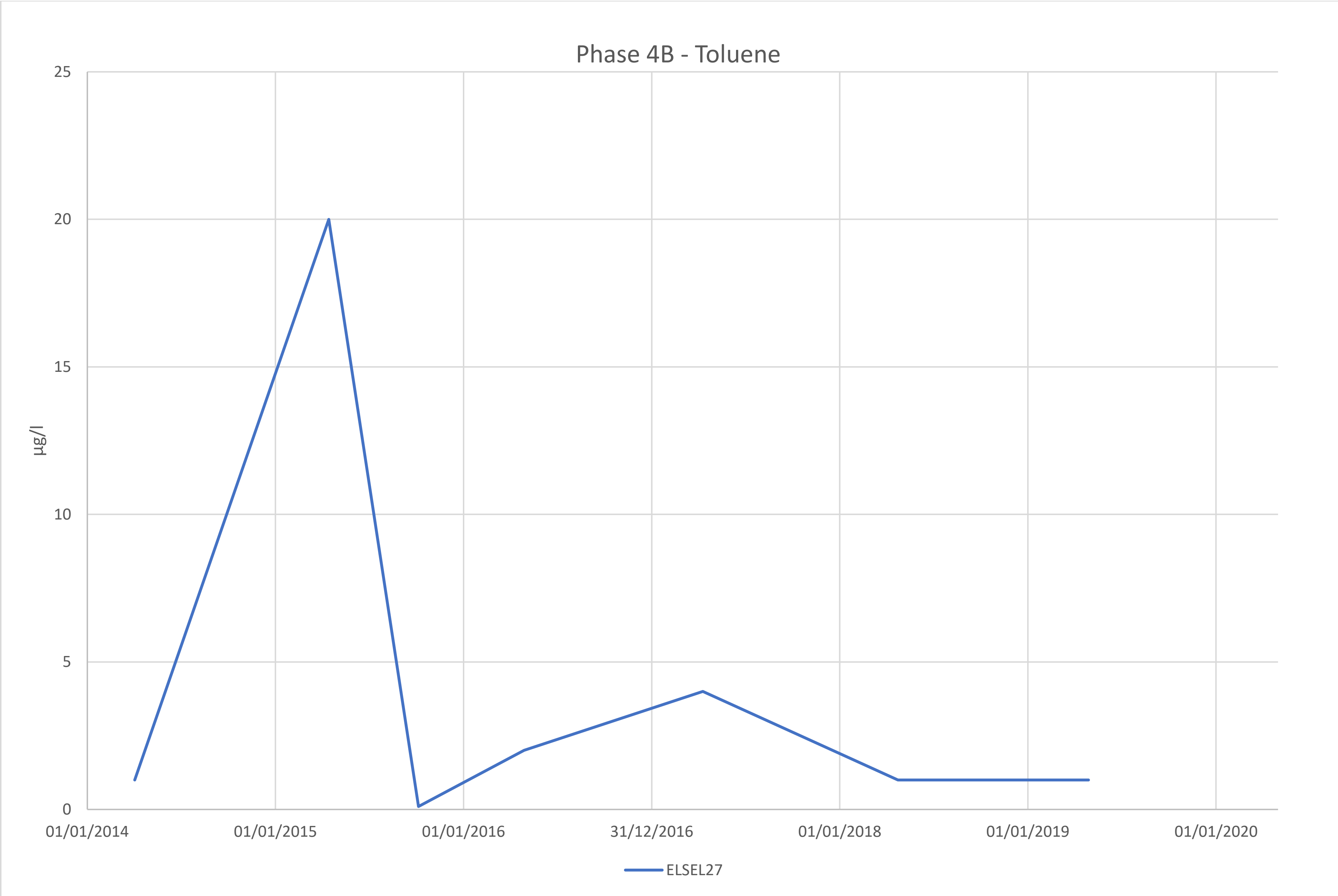

Phase 4B - Cadmium
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27



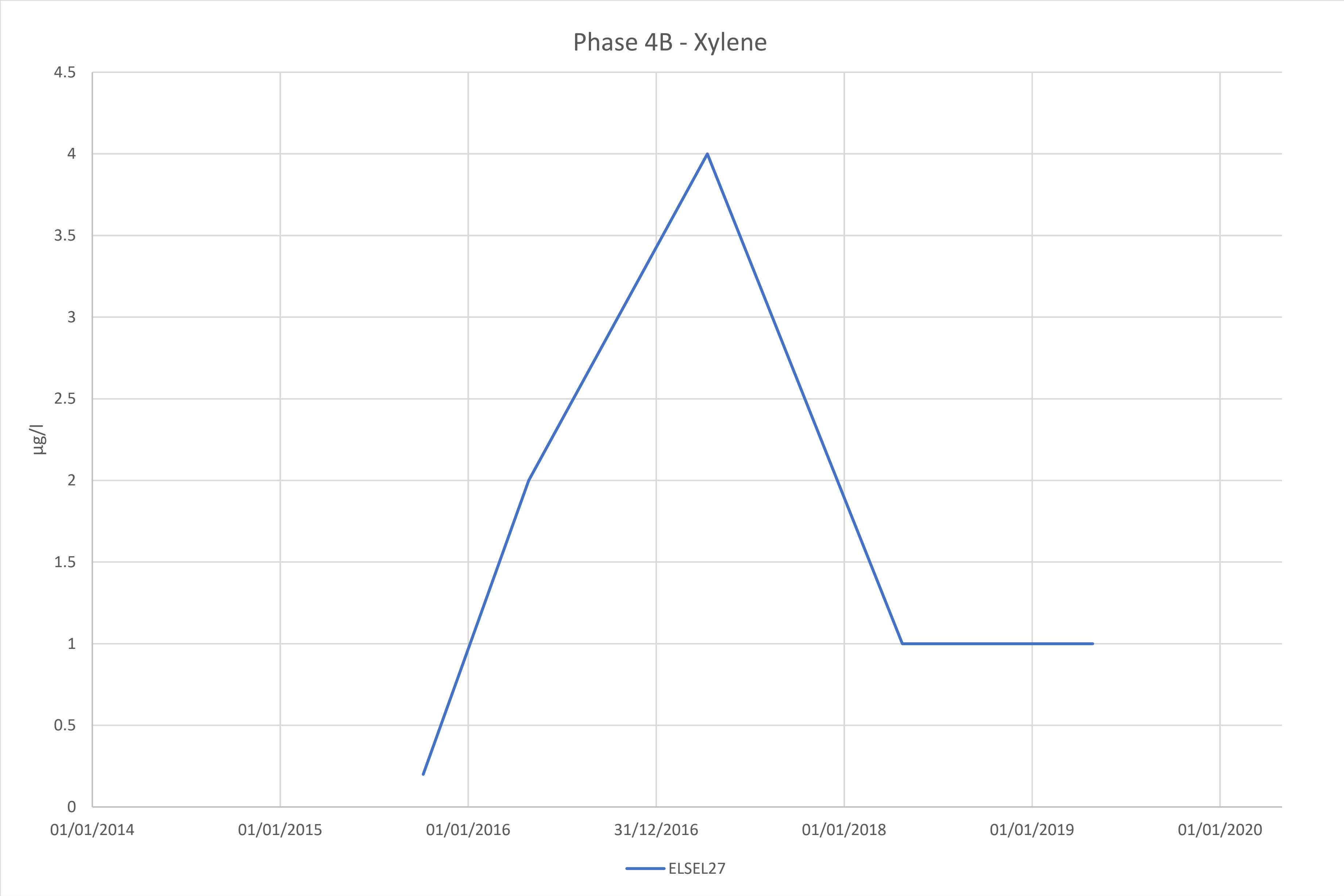
Phase 4B - Mecoprop
µg/l
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27



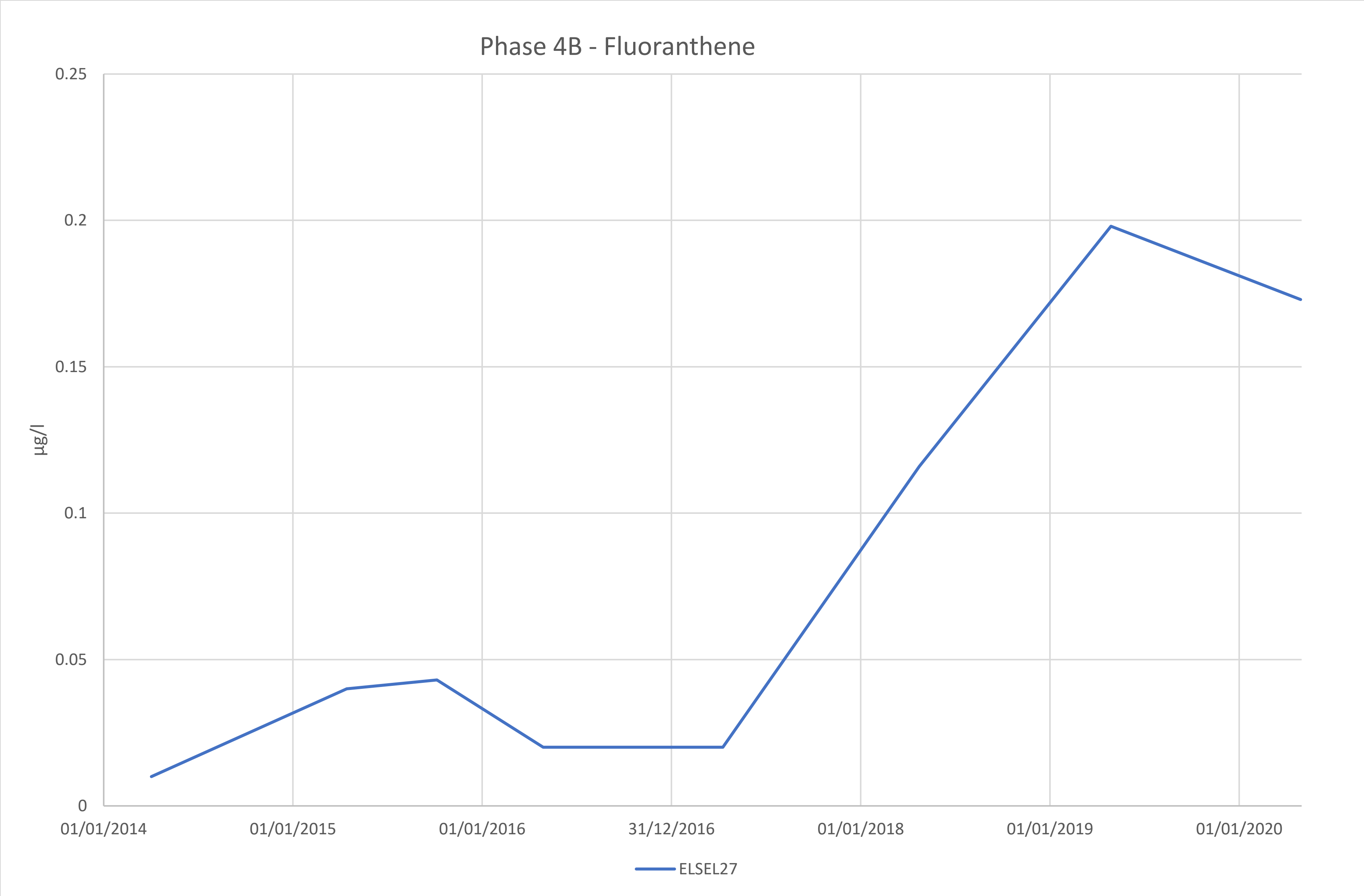
Phase 4B - Naphthalene
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27



Phase 4B - Toluene
25
20
15
10
5
0
µg/l
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27



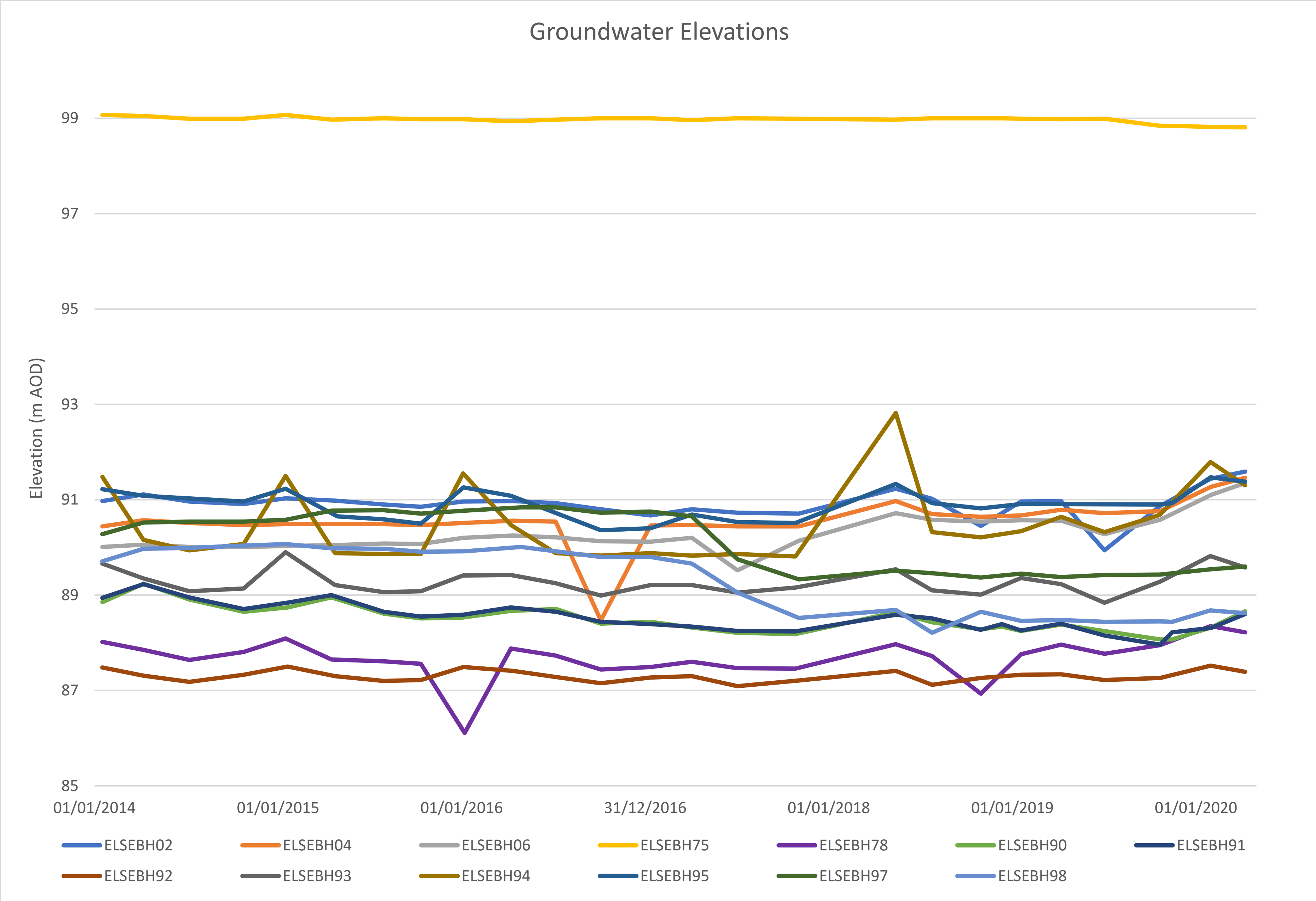
Phase 4B - Xylene
µg/l
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

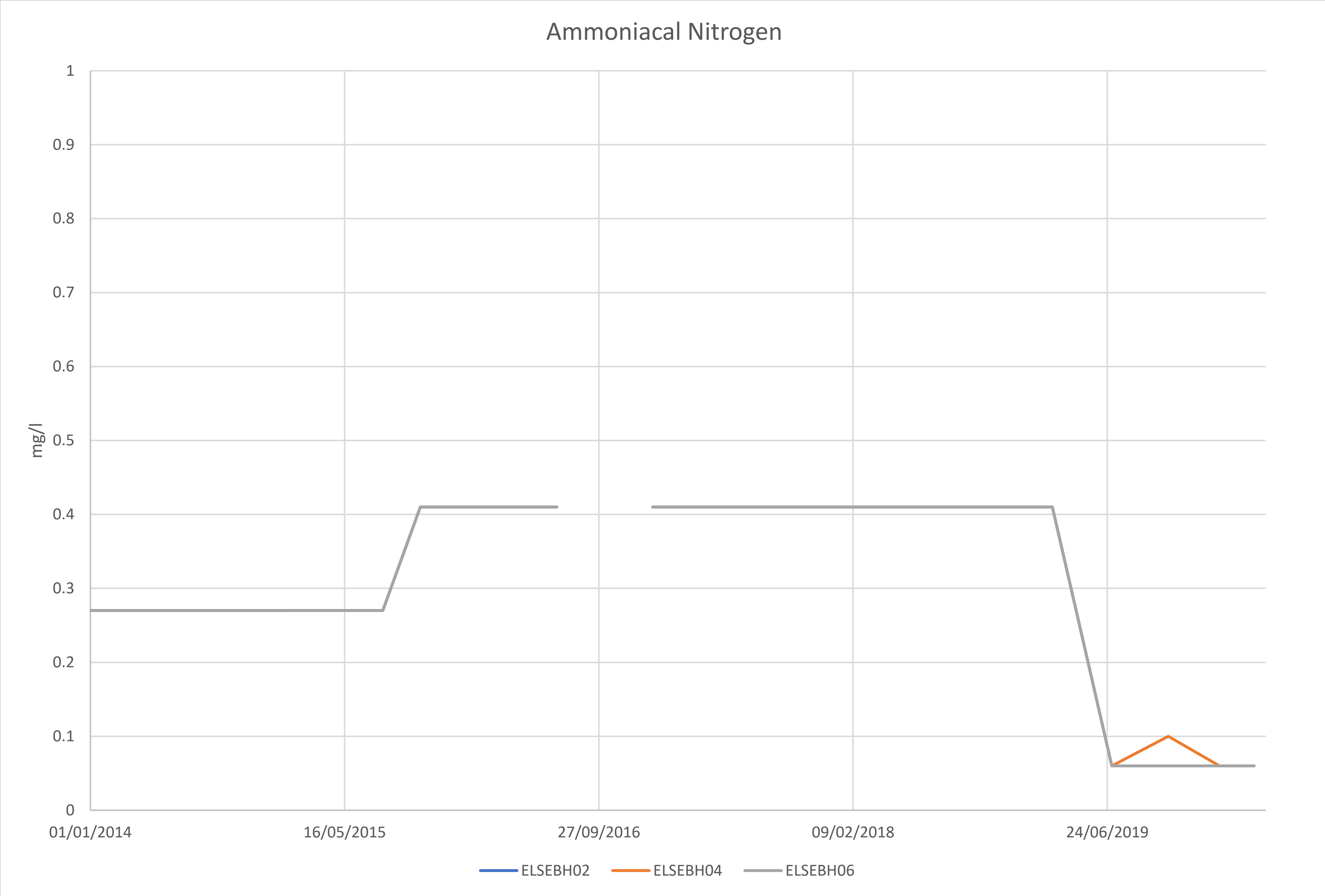


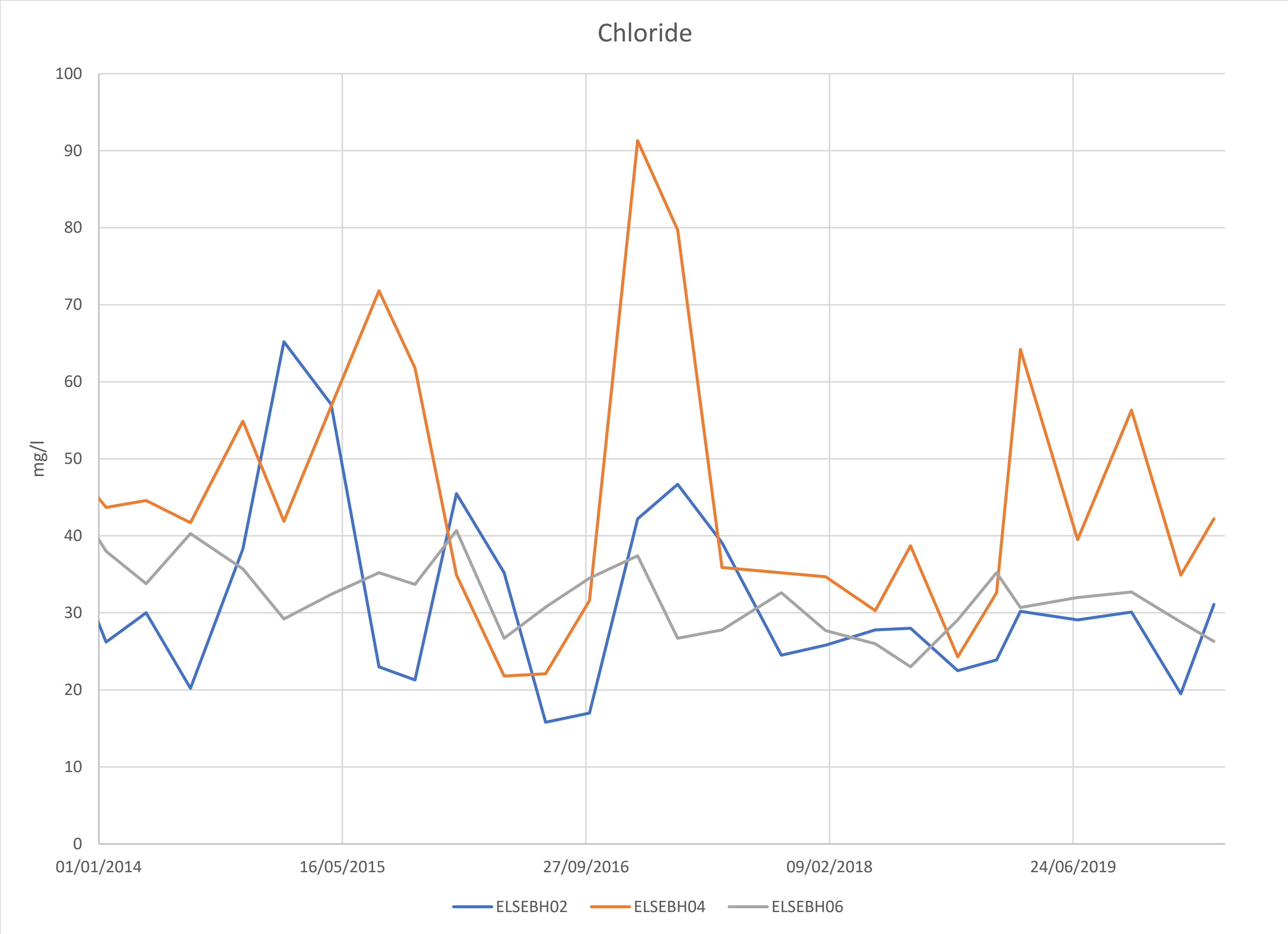
Phase 4B - Fluoranthene
µg/l
0.25
0.2
0.15
0.1
0.05
0
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEL27

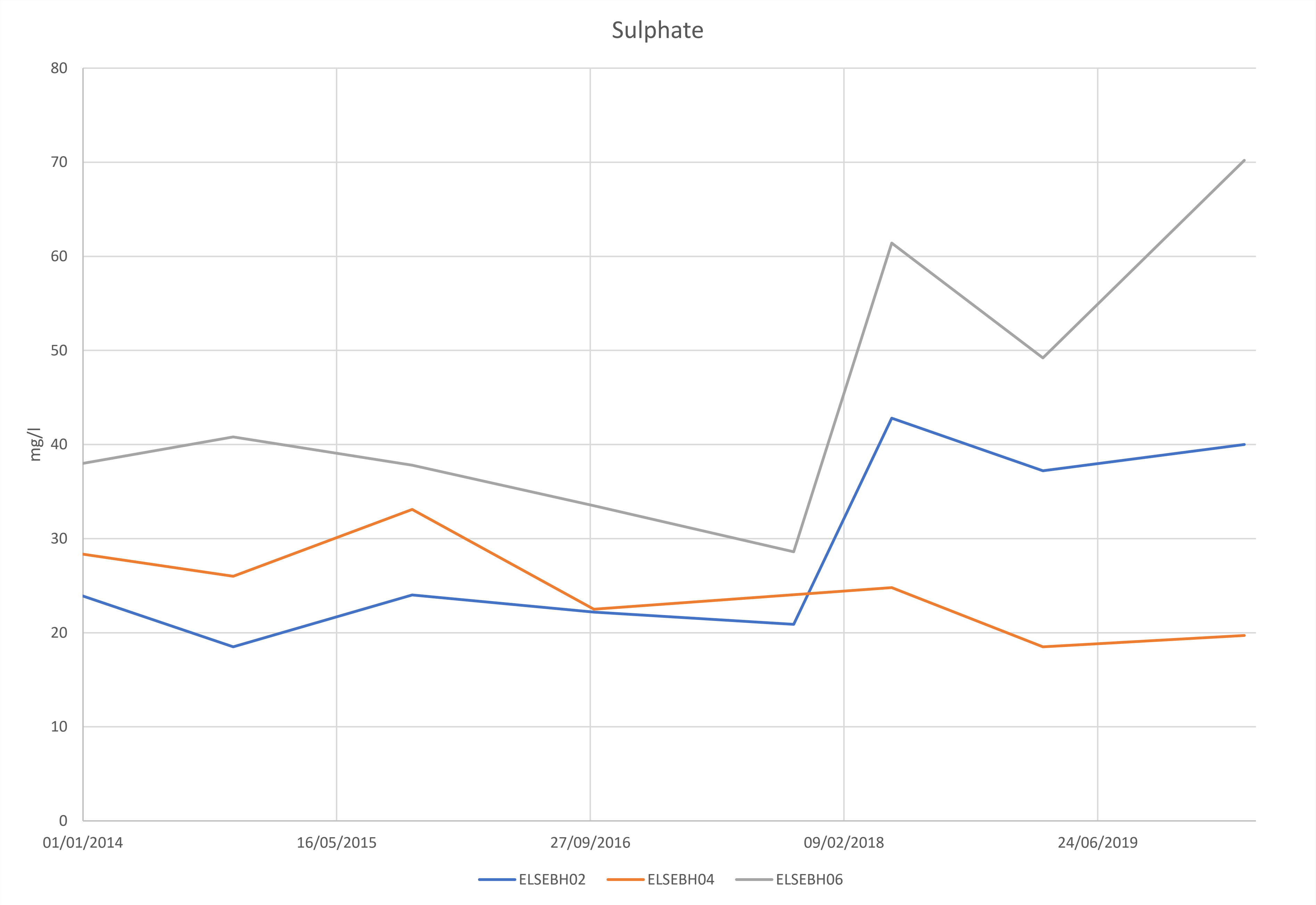
APPENDIX C

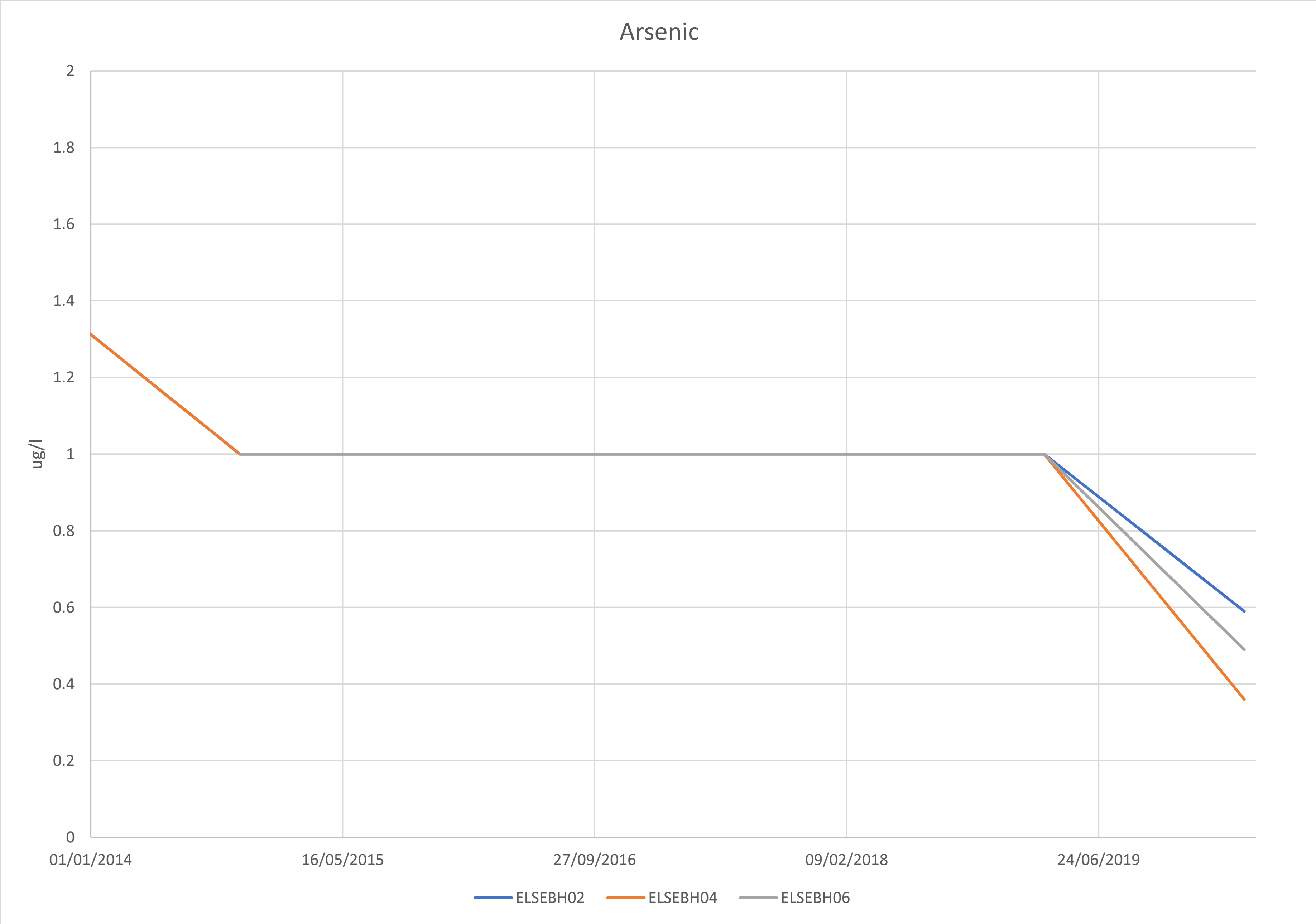
Groundwater Elevation and Quality

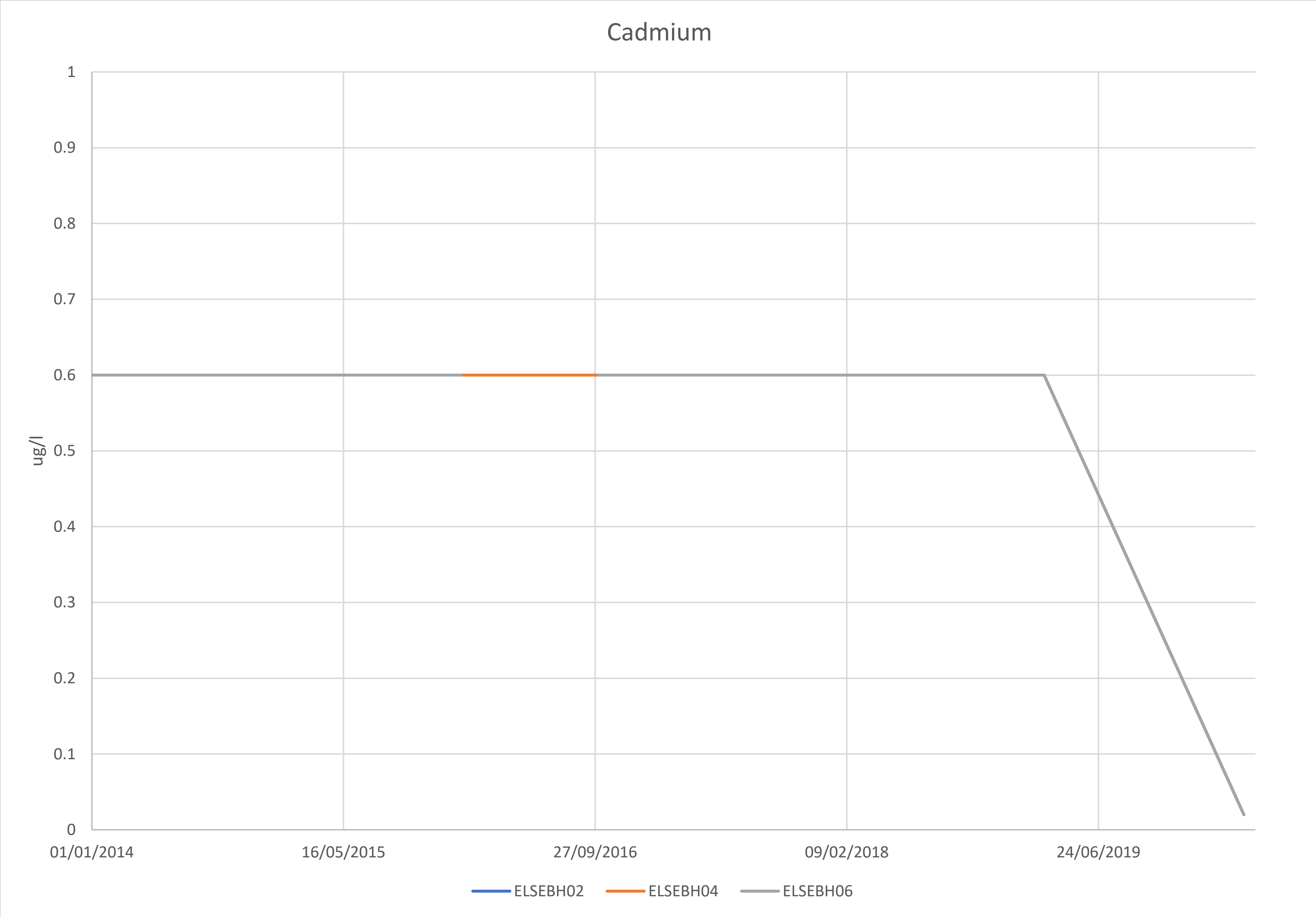

Groundwater Elevations
Elevation (m AOD)
99
97
95
93
91
89
87
85
01/01/2014
01/01/2015
01/01/2016
31/12/2016
01/01/2018
01/01/2019
01/01/2020
ELSEBH02
ELSEBH04
ELSEBH06
ELSEBH75
ELSEBH78
ELSEBH90
ELSEBH91
ELSEBH92
ELSEBH93
ELSEBH94
ELSEBH95
ELSEBH97
ELSEBH98

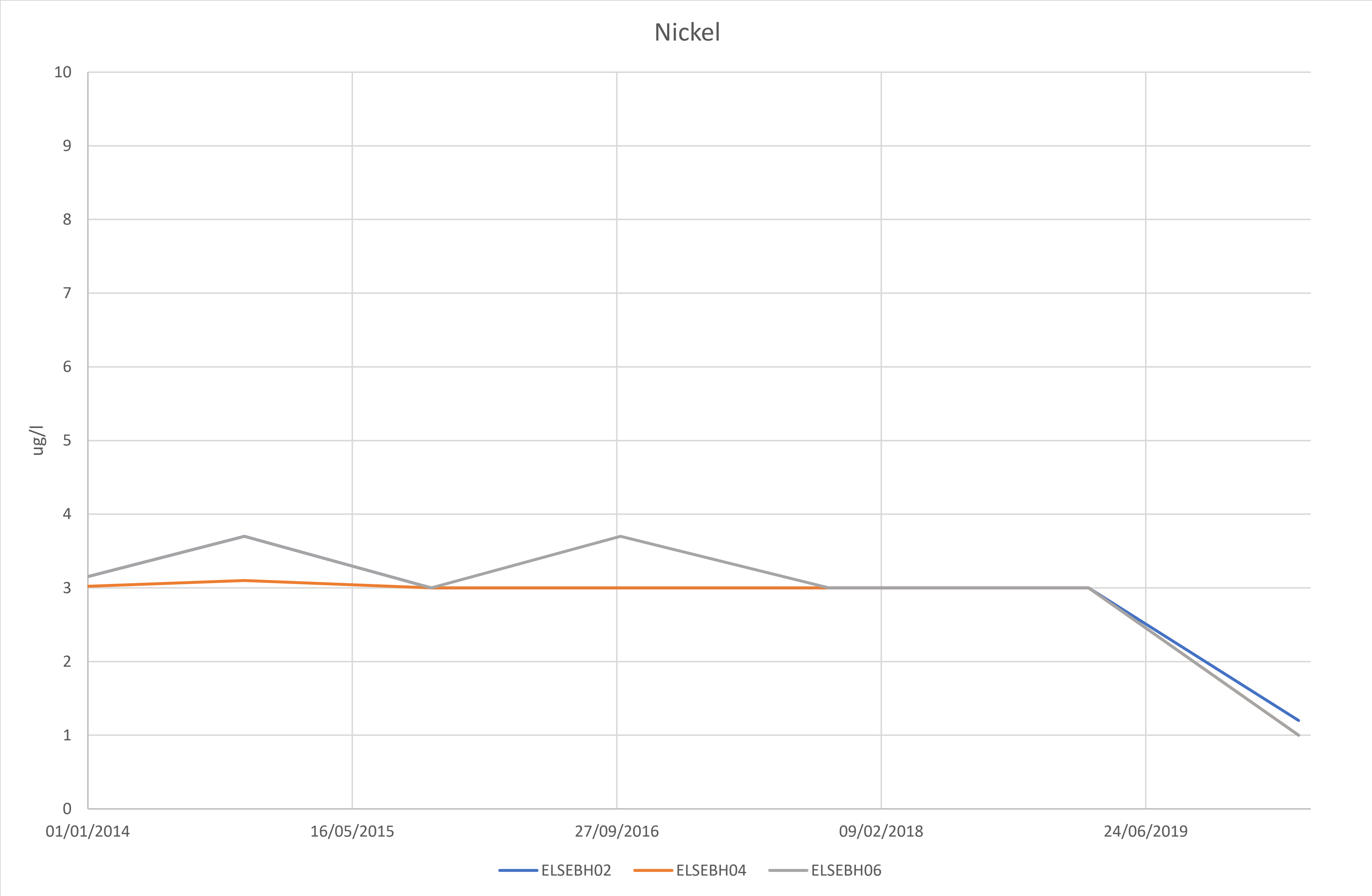

Ammoniacal Nitrogen
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

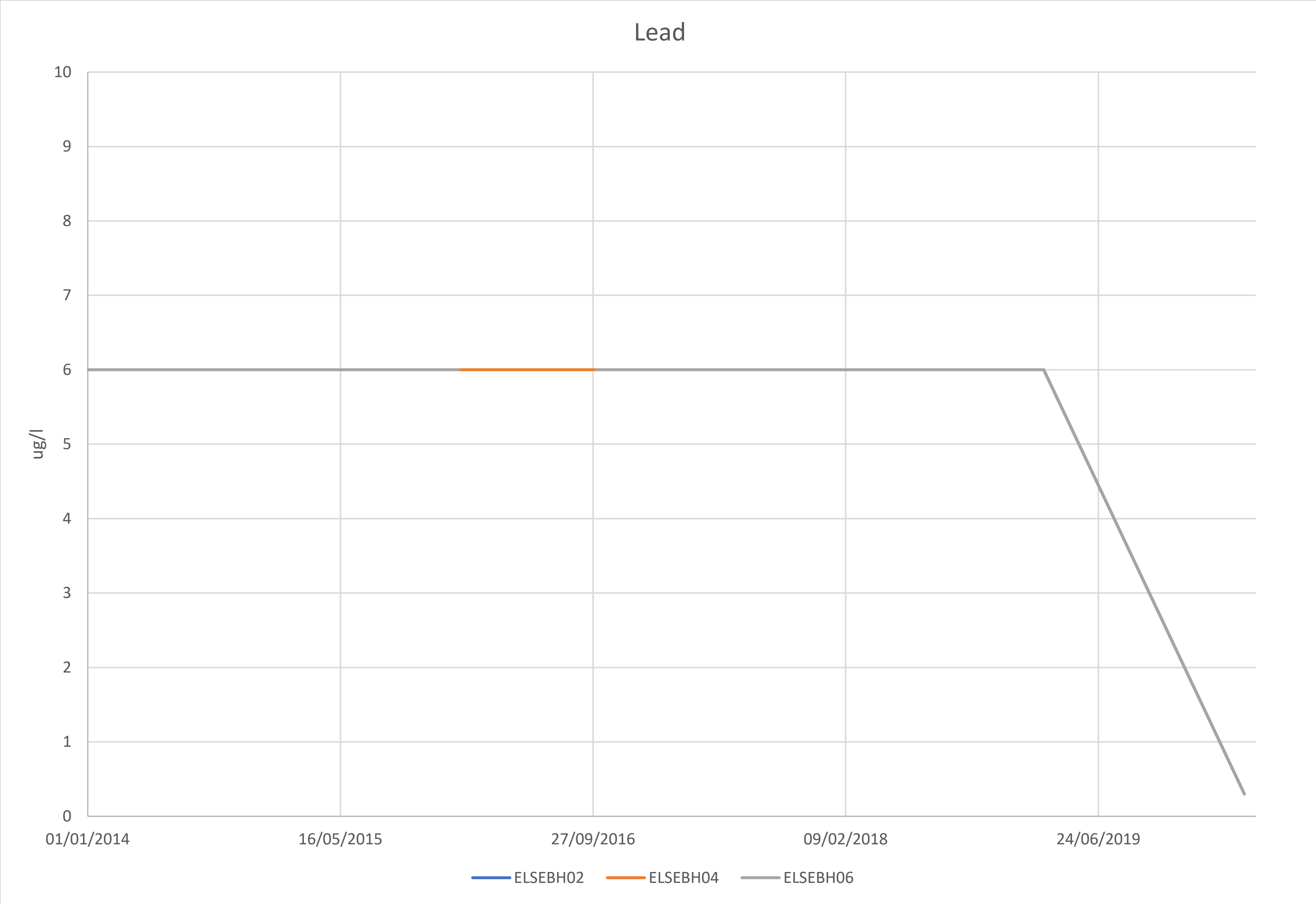

Chloride
100
90
80
70
60
50
40
30
20
10
0
mg/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06


Sulphate
mg/l
80
70
60
50
40
30
20
10
0
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

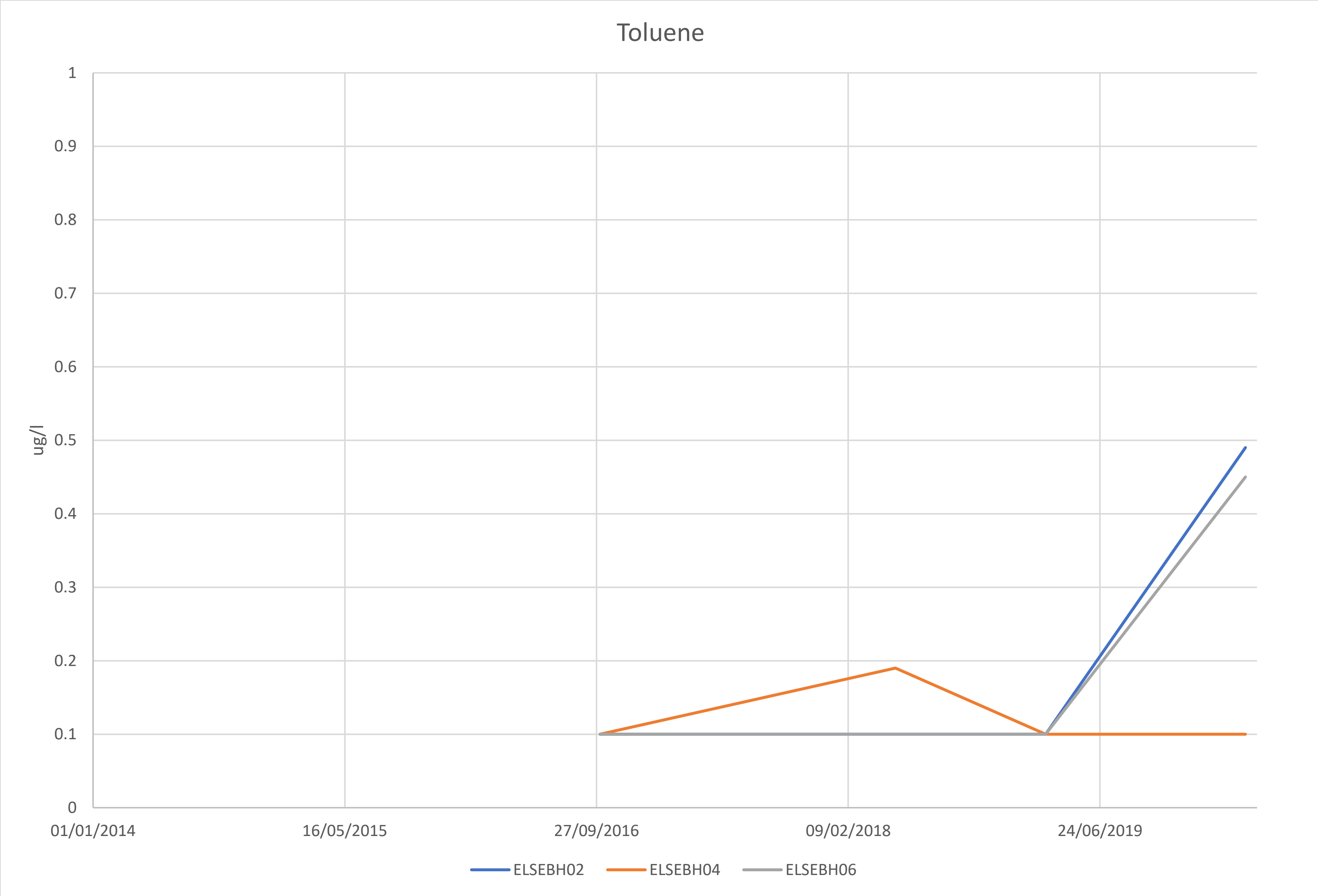

Arsenic
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ug/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

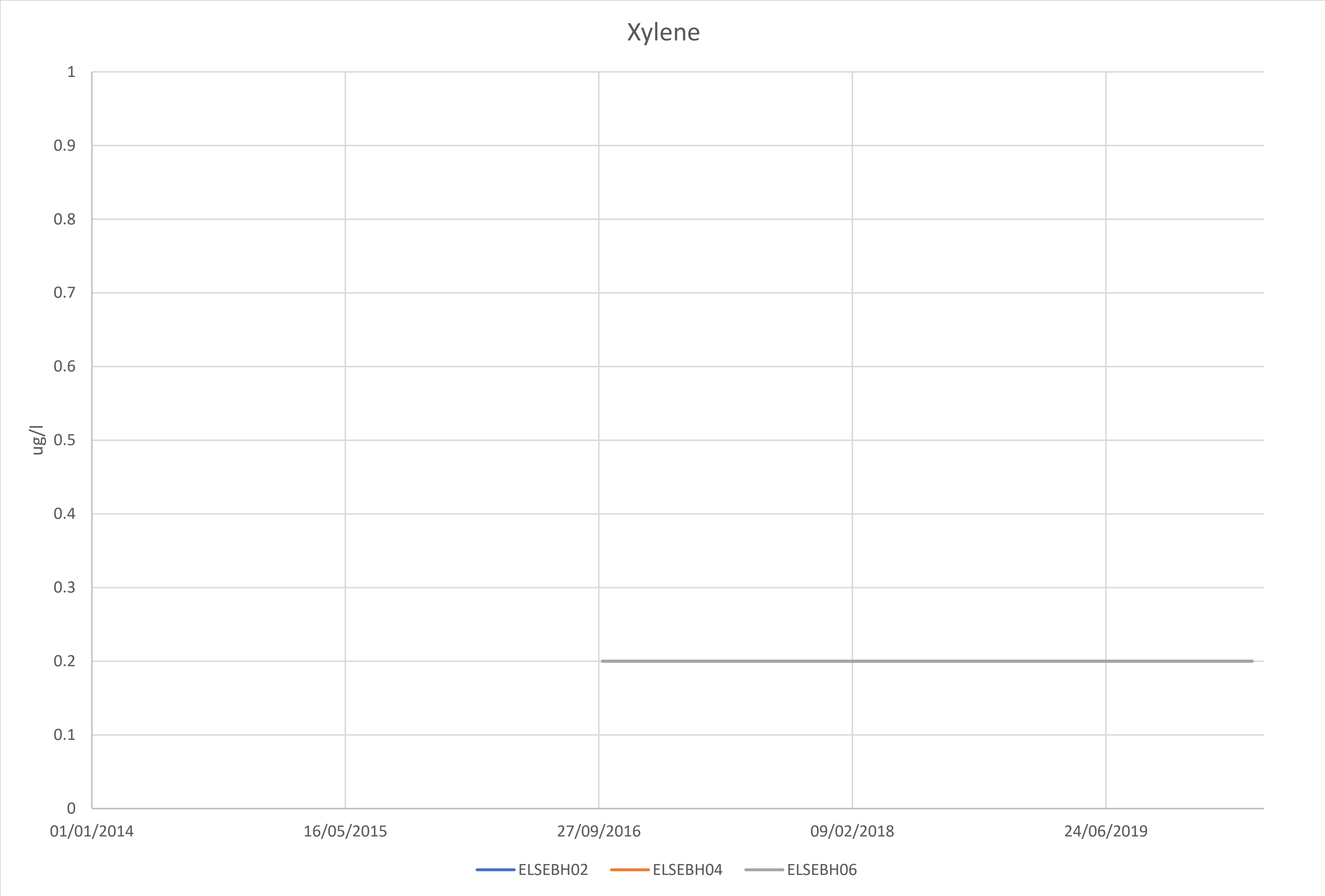

Cadmium
ug/l
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06


Nickel
10
9
8
7
6
5
4
3
2
1
0
ug/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06



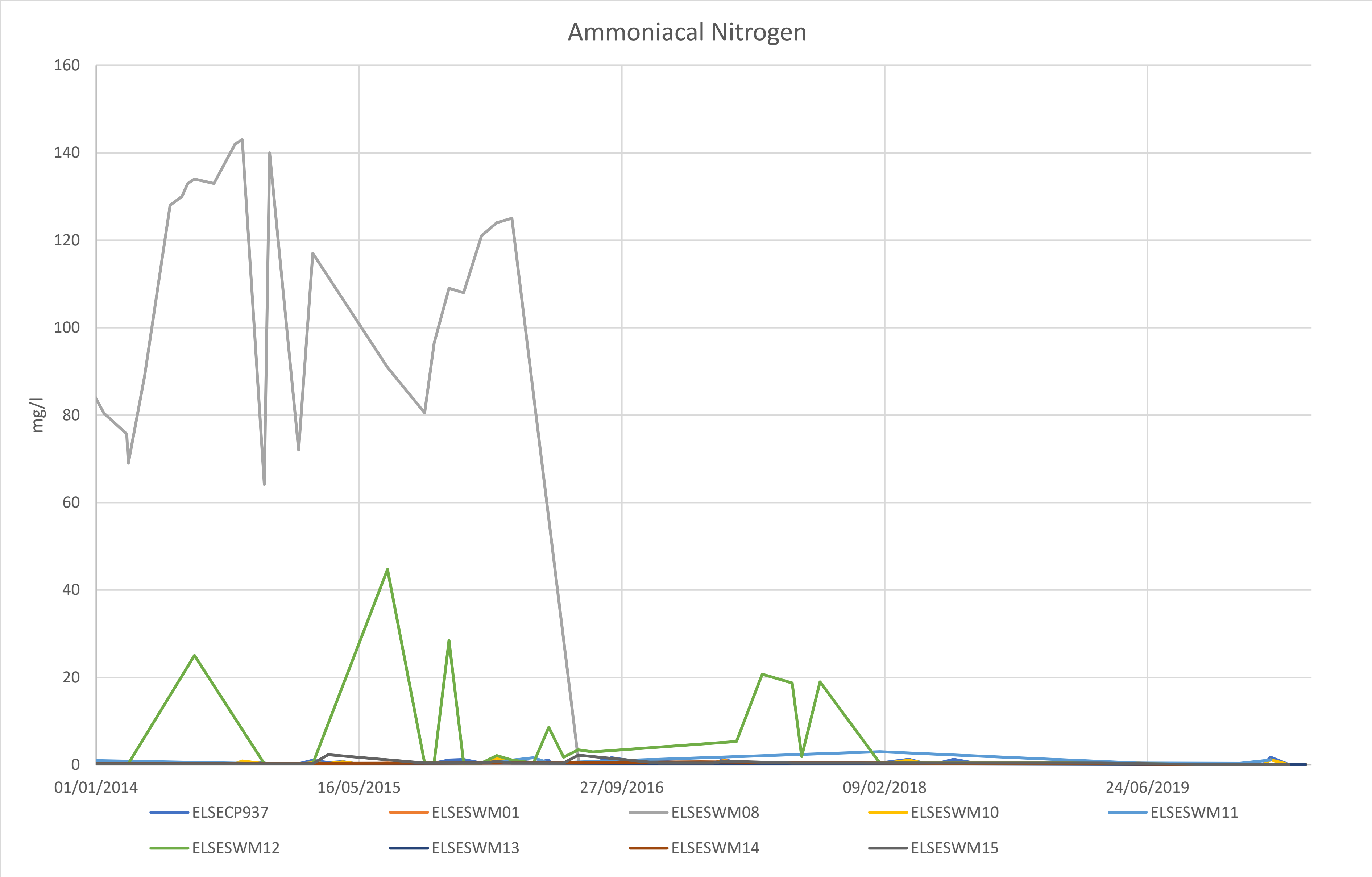
Lead
10
9
8
7
6
5
4
3
2
1
0
ug/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

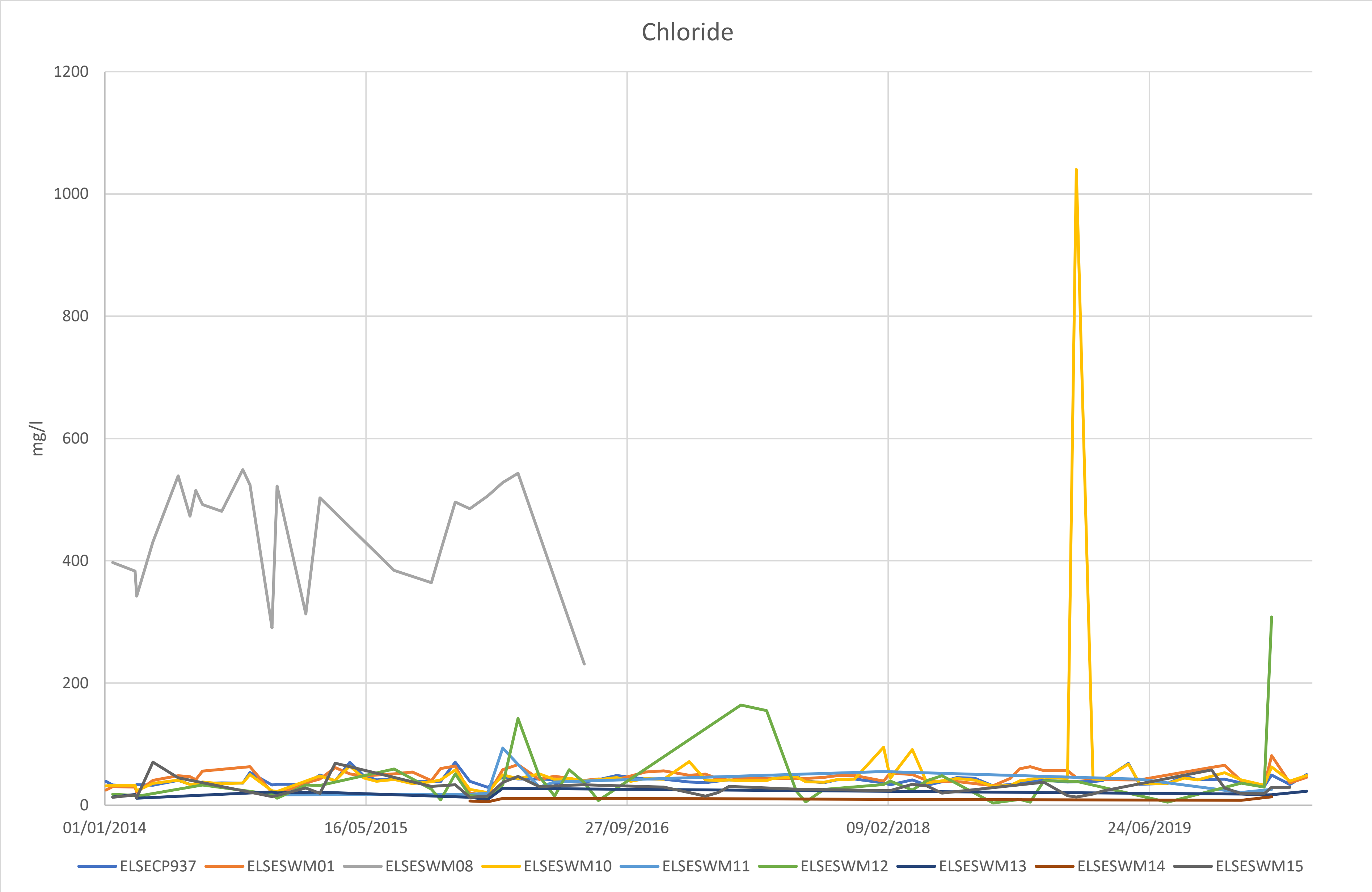

Toluene
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

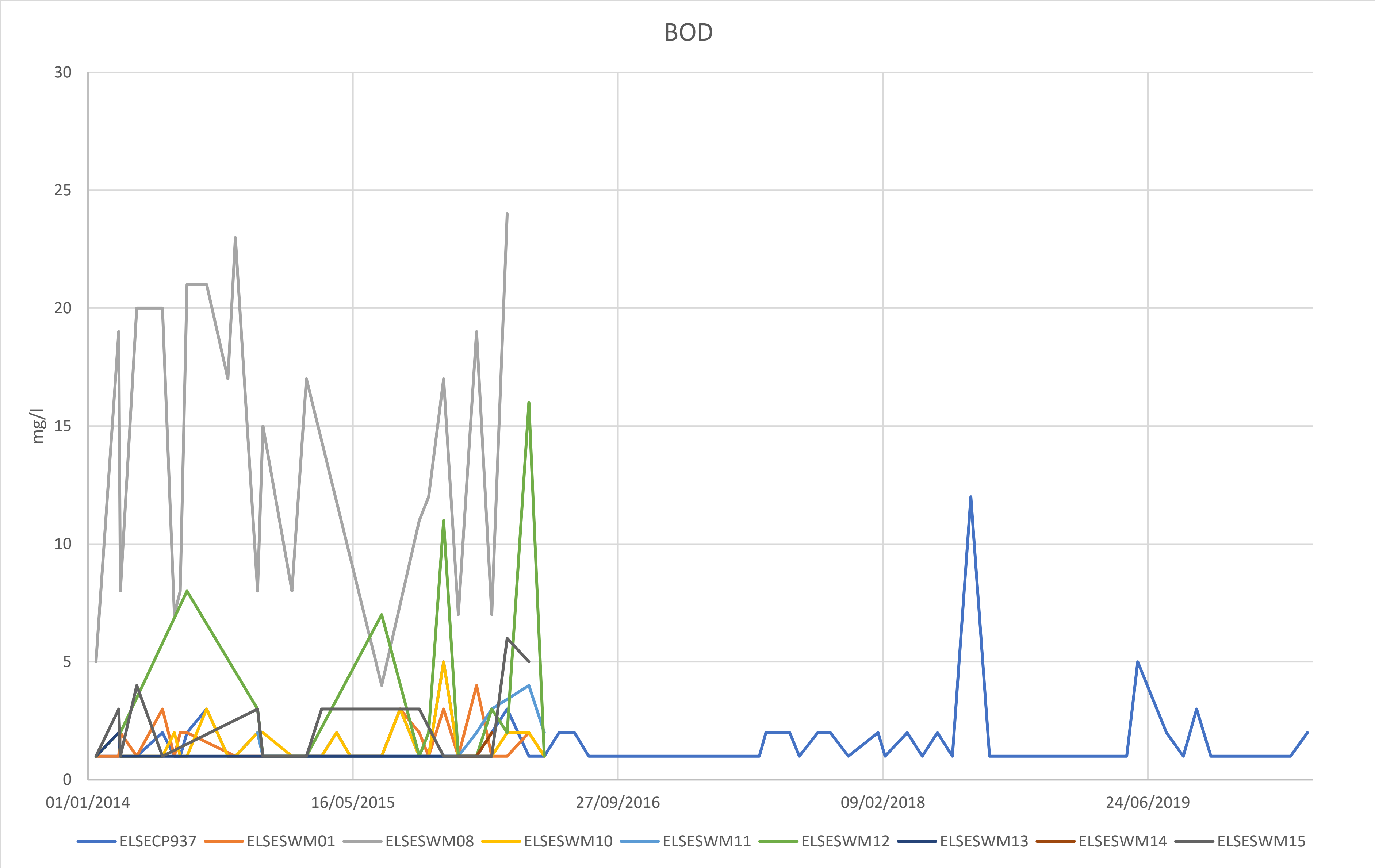

Xylene
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSEBH02
ELSEBH04
ELSEBH06

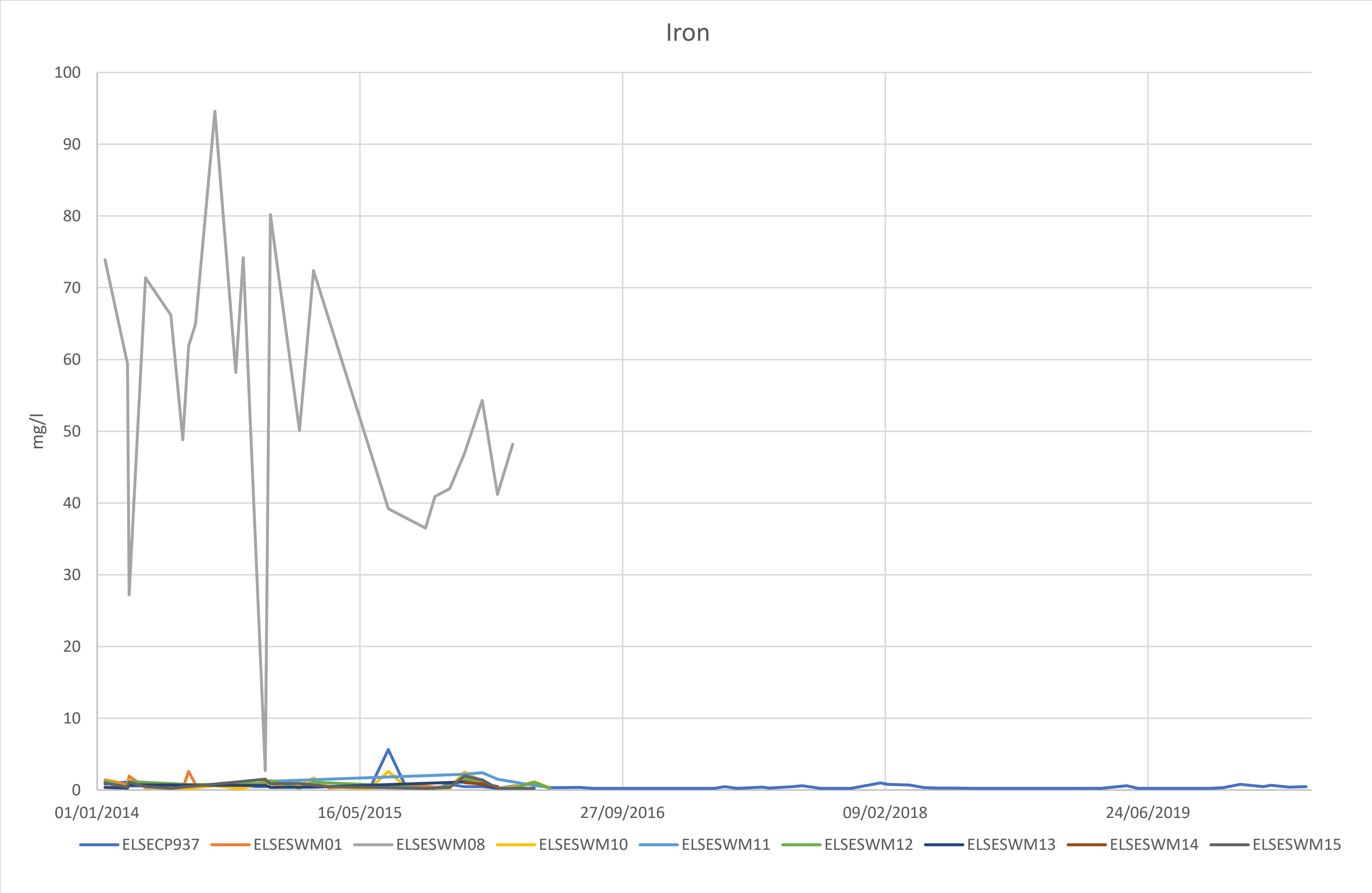
APPENDIX D

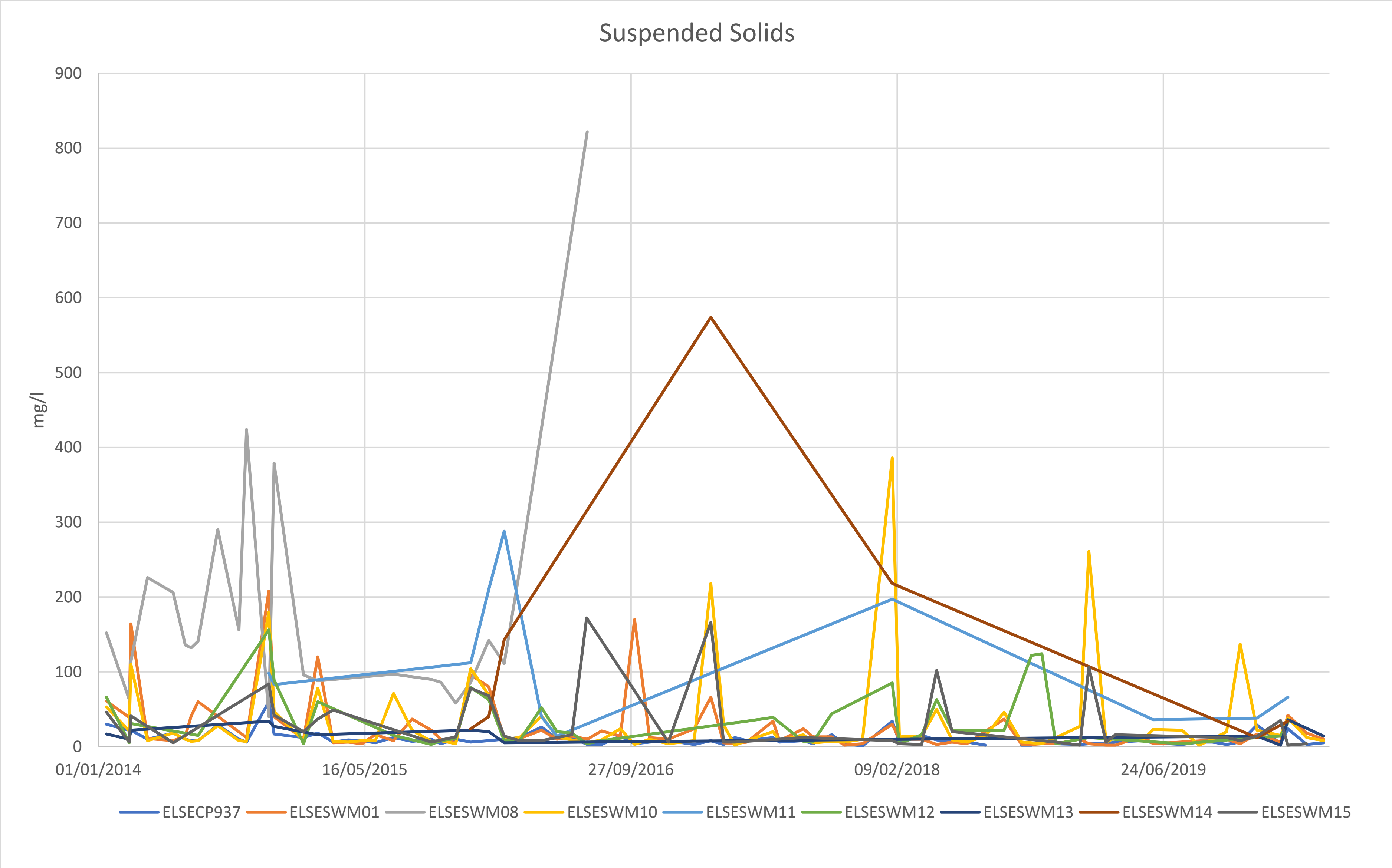
Surface Water Quality

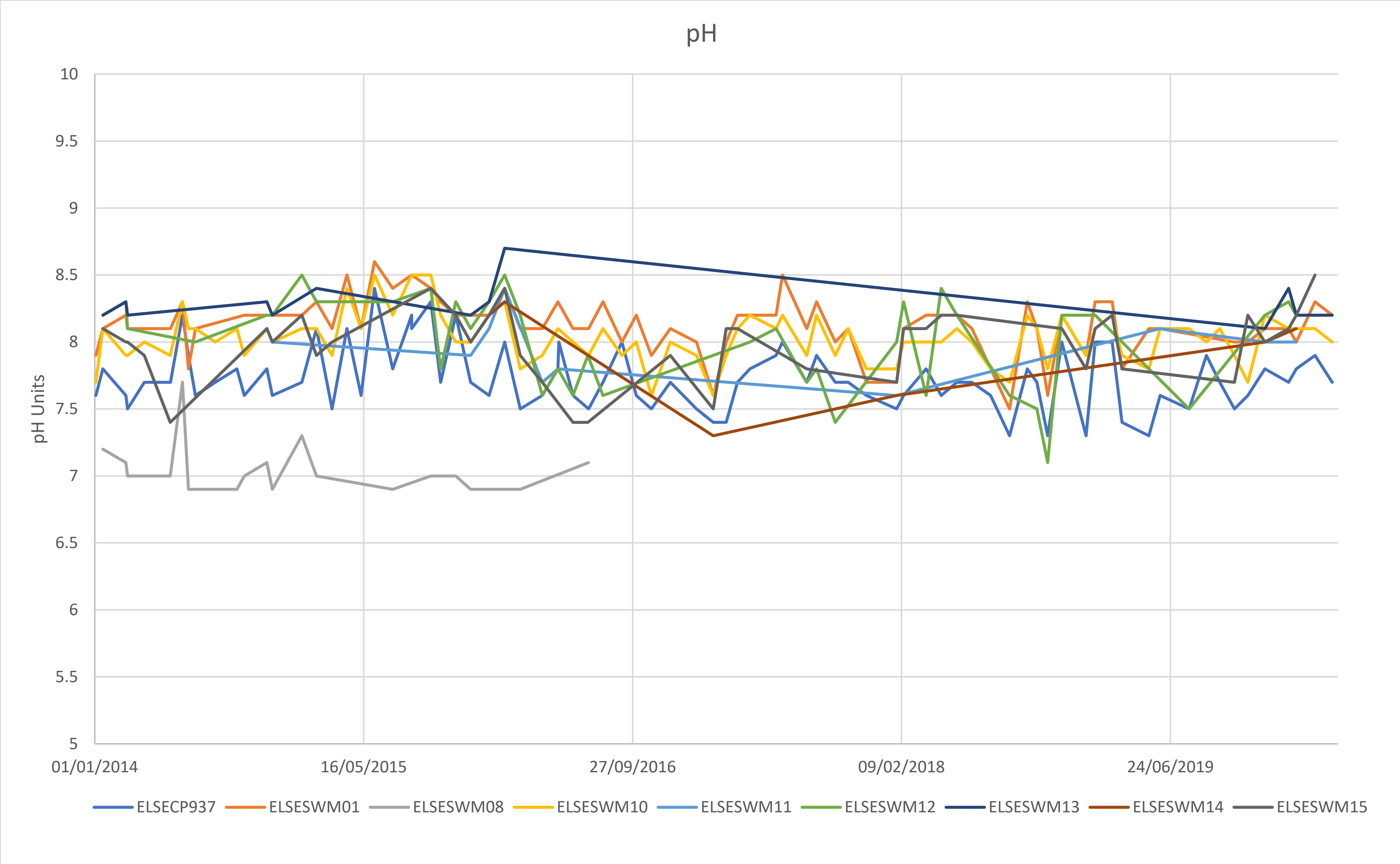

Ammoniacal Nitrogen
160
140
120
100
80
60
40
20
0
mg/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15

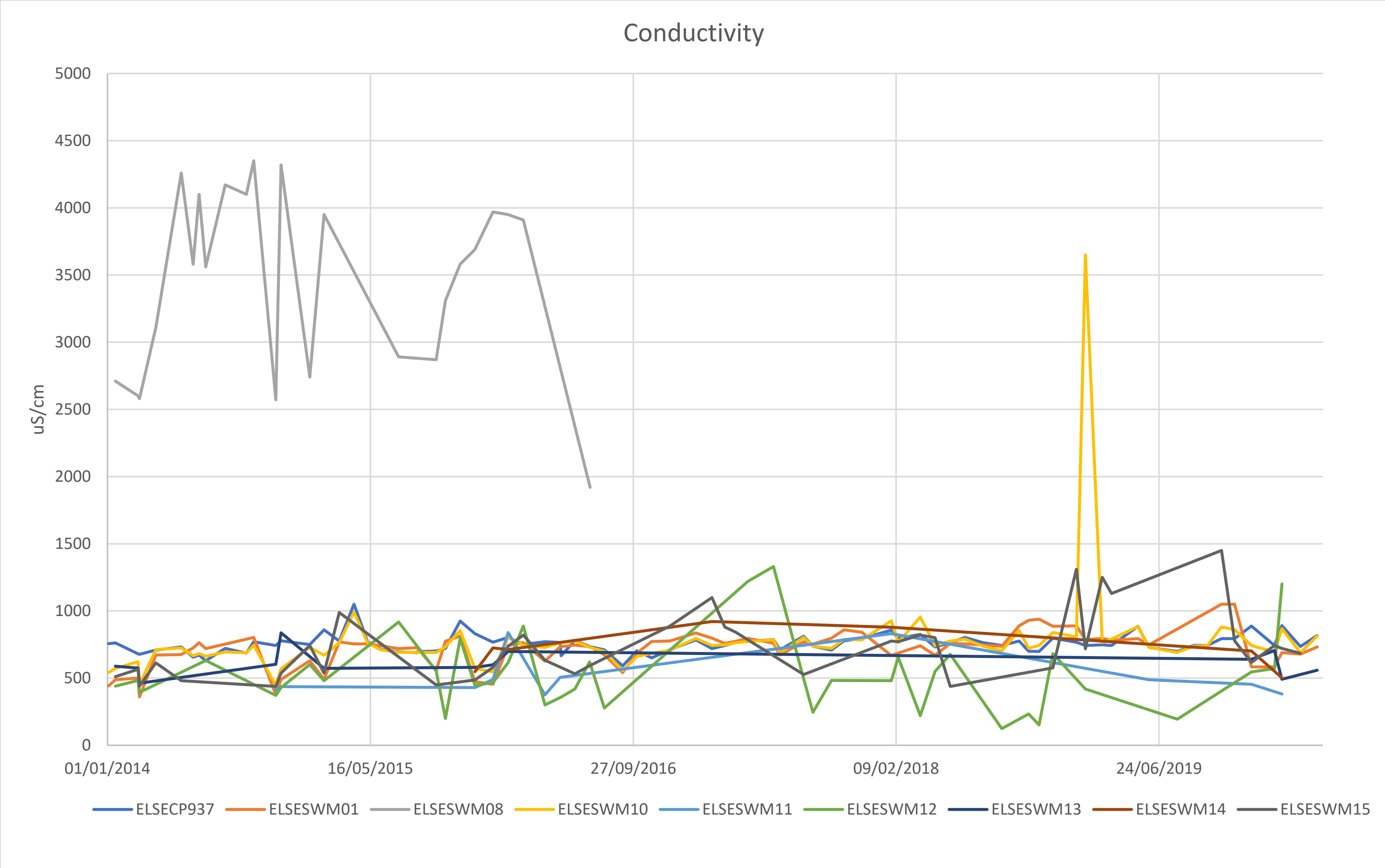

Chloride
1200
1000
800
600
400
200
0
mg/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15


BOD
mg/l
30
25
20
15
10
5
0
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15


Iron
mg/l
100
90
80
70
60
50
40
30
20
10
0
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15


Suspended Solids
900
800
700
600
500
400
300
200
100
0
mg/l
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15


pH
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
pH Units
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15

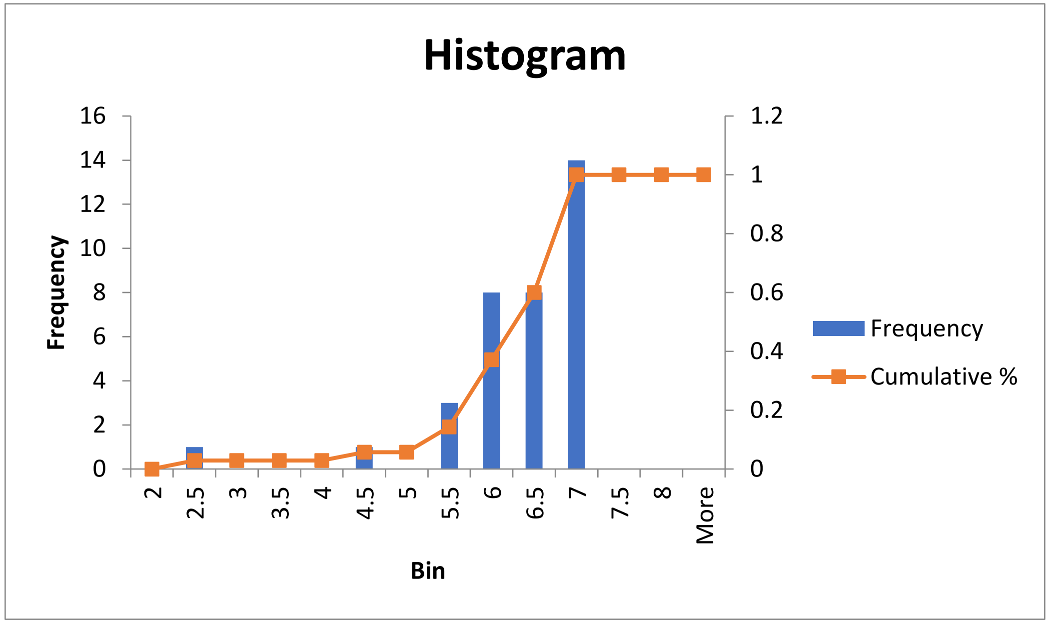

Conductivity
uS/cm
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/2014
16/05/2015
27/09/2016
09/02/2018
24/06/2019
ELSECP937
ELSESWM01
ELSESWM08
ELSESWM10
ELSESWM11
ELSESWM12
ELSESWM13
ELSESWM14
ELSESWM15

APPENDIX E

Derivation of Probability Density Functions

Phase 1
Chloride

Column1	
Mean	540.27143
Standard Error	45.85922
Median	519
Mode	#N/A
Standard Deviation	271.3068
Sample Variance	73607.381
Kurtosis	-0.846774
Skewness	0.0125115
Range	1071.7
Minimum	8.3
Maximum	1080
Sum	18909.5
Count	35



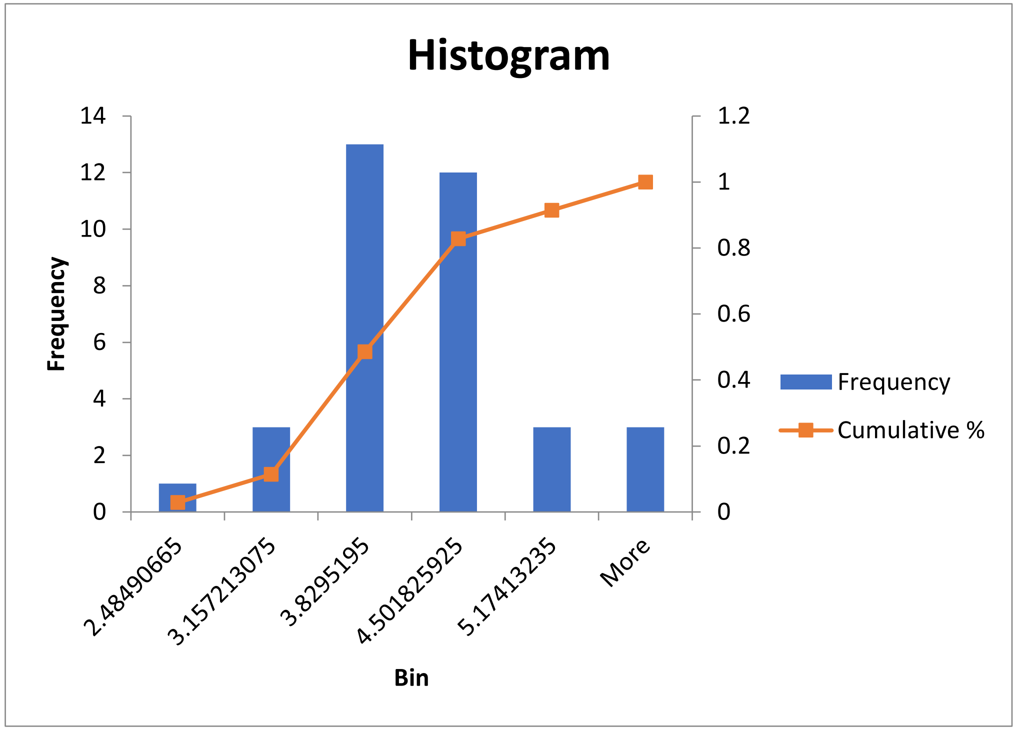
Bin	*Frequency*	*Cumulative %*
2	0	0.00%
2.5	1	2.86%
3	0	2.86%
3.5	0	2.86%
4	0	2.86%
4.5	1	5.71%
5	0	5.71%
5.5	3	14.29%
6	8	37.14%
6.5	8	60.00%
7	14	100.00%
7.5	0	100.00%
More	0	100.00%

LogTri(8.3,1075,1080)

Nickel

Column1	
Mean	71.808571
Standard Error	13.310034
Median	48.3
Mode	#N/A
Standard Deviation	78.743225
Sample Variance	6200.4955
Kurtosis	5.7948106
Skewness	2.4903579
Range	334
Minimum	12
Maximum	346
Sum	2513.3
Count	35

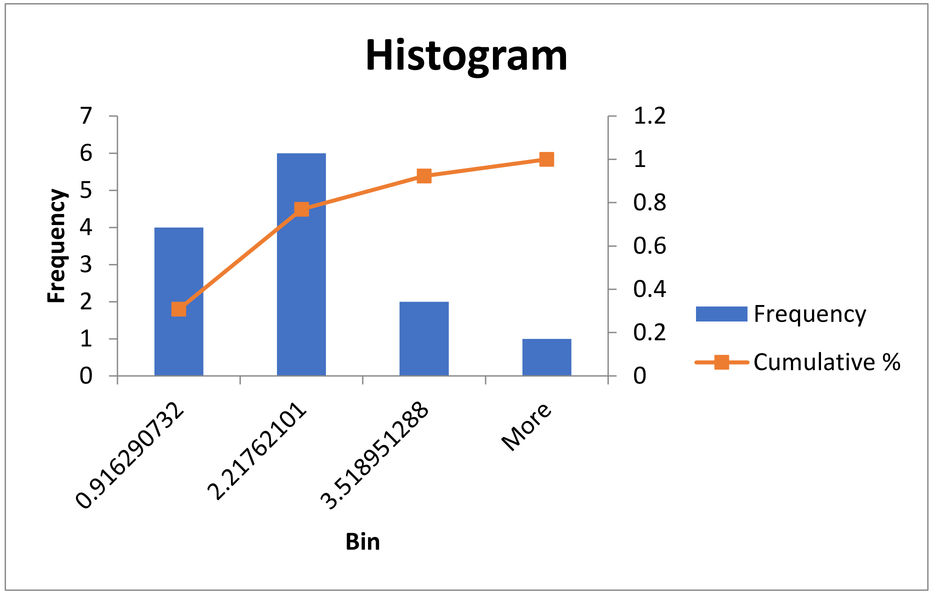
Bin	Frequency	Cumulative %
2.48490665	1	2.86%
3.157213075	3	11.43%
3.8295195	13	48.57%
4.501825925	12	82.86%
5.17413235	3	91.43%
More	3	100.00%



LogTri(0.012,0.046,0.346)

Phenol

Column1	
Mean	17.555385
Standard Error	9.1184929
Median	7.5
Mode	7.5
Standard Deviation	32.877194
Sample Variance	1080.9099
Kurtosis	11.255385
Skewness	3.2892282
Range	121.5
Minimum	2.5
Maximum	124
Sum	228.22
Count	13



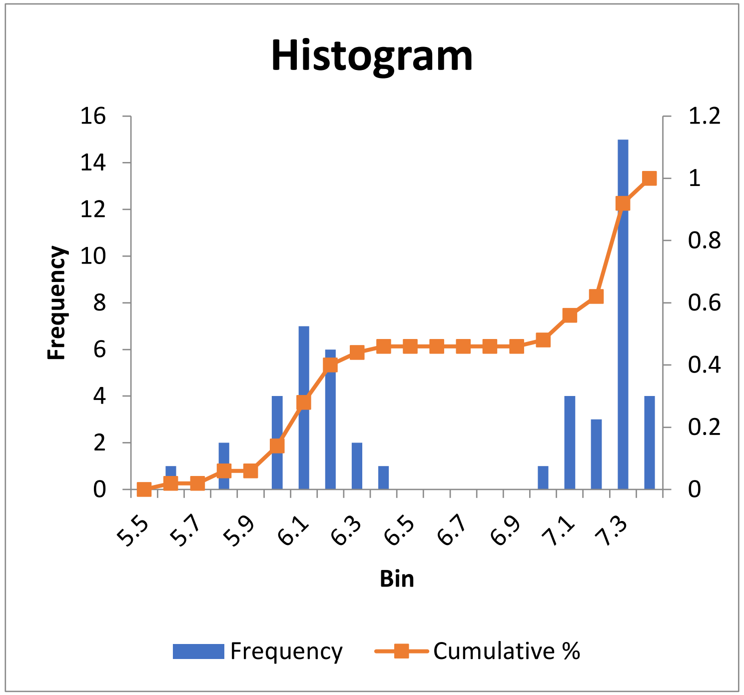
Bin	*Frequency*	*Cumulative %*
0.916290732	4	30.77%
2.21762101	6	76.92%
3.518951288	2	92.31%
More	1	100.00%

LogTri(0.0025,0.009,0.124)

Phase 2
Ammoniacal Nitrogen

Column1	
Mean	931.73569
Standard Error	72.571378
Median	1100
Mode	1470
Standard Deviation	518.2633
Sample Variance	268596.85
Kurtosis	-1.687394
Skewness	-0.021119
Range	1798.48
Minimum	1.52
Maximum	1800
Sum	47518.52
Count	51

Bin	*Frequency*	*umulative %*
5.5	0	0.00%
5.6	1	2.00%
5.7	0	2.00%
5.8	2	6.00%
5.9	0	6.00%
6	4	14.00%
6.1	7	28.00%
6.2	6	40.00%
6.3	2	44.00%
6.4	1	46.00%
6.5	0	46.00%
6.6	0	46.00%
6.7	0	46.00%
6.8	0	46.00%
6.9	0	46.00%
7	1	48.00%
7.1	4	56.00%
7.2	3	62.00%
7.3	15	92.00%
More	4	100.00%

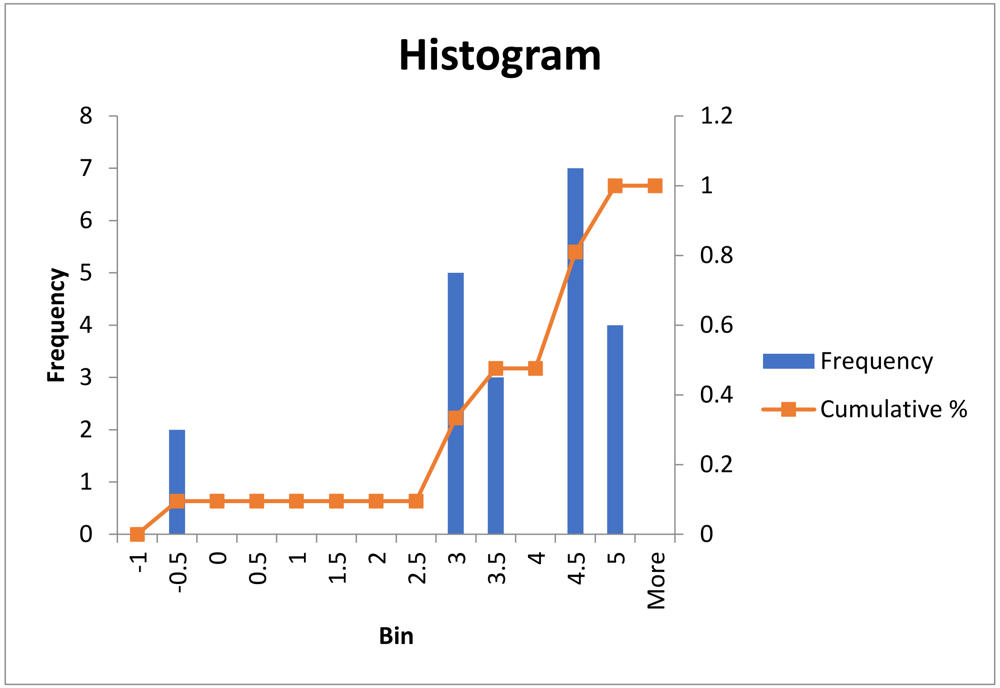


LogTri(1.52,1480,1800)

MCPP

Column1	
Mean	50.665714
Standard Error	8.1030668
Median	60.1
Mode	#N/A
Standard Deviation	37.132917
Sample Variance	1378.8535
Kurtosis	-1.785408
Skewness	0.060905
Range	101.57
Minimum	0.43
Maximum	102
Sum	1063.98
Count	21

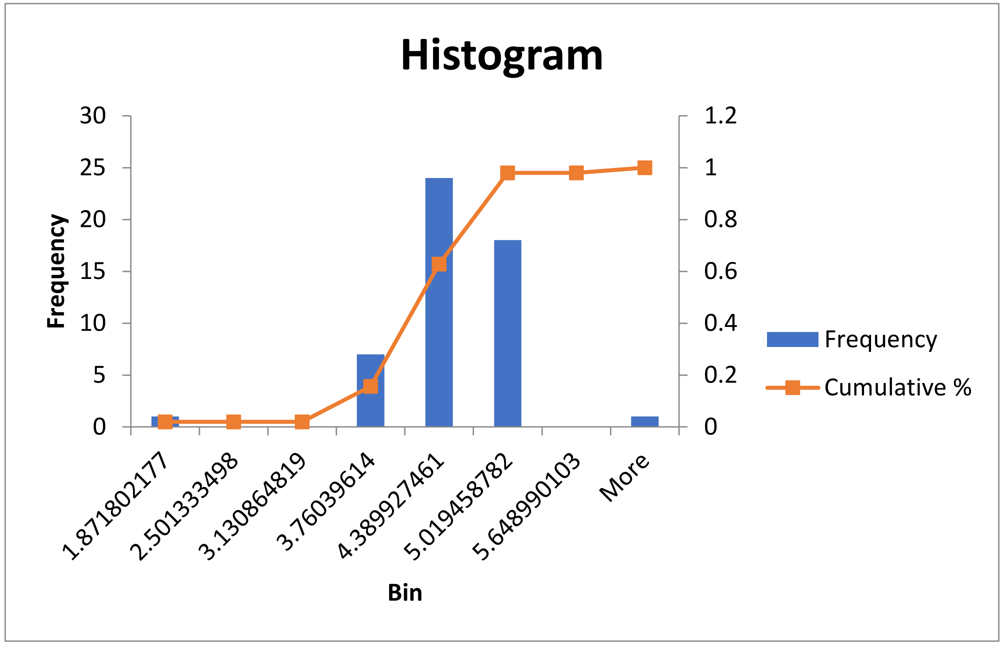
Bin	Frequency	Cumulative %
-1	0	0.00%
-0.5	2	9.52%
0	0	9.52%
0.5	0	9.52%
1	0	9.52%
1.5	0	9.52%
2	0	9.52%
2.5	0	9.52%
3	5	33.33%
3.5	3	47.62%
4	0	47.62%
4.5	7	80.95%
5	4	100.00%
More	0	100.00%



LogTri(0.00043,0.09,0.102)

Nickel

Column1	
Mean	80.723529
Standard Error	9.9648215
Median	72
Mode	77.5
Standard Deviation	71.163059
Sample Variance	5064.181
Kurtosis	33.700851
Skewness	5.3082681
Range	526.5
Minimum	6.5
Maximum	533
Sum	4116.9
Count	51

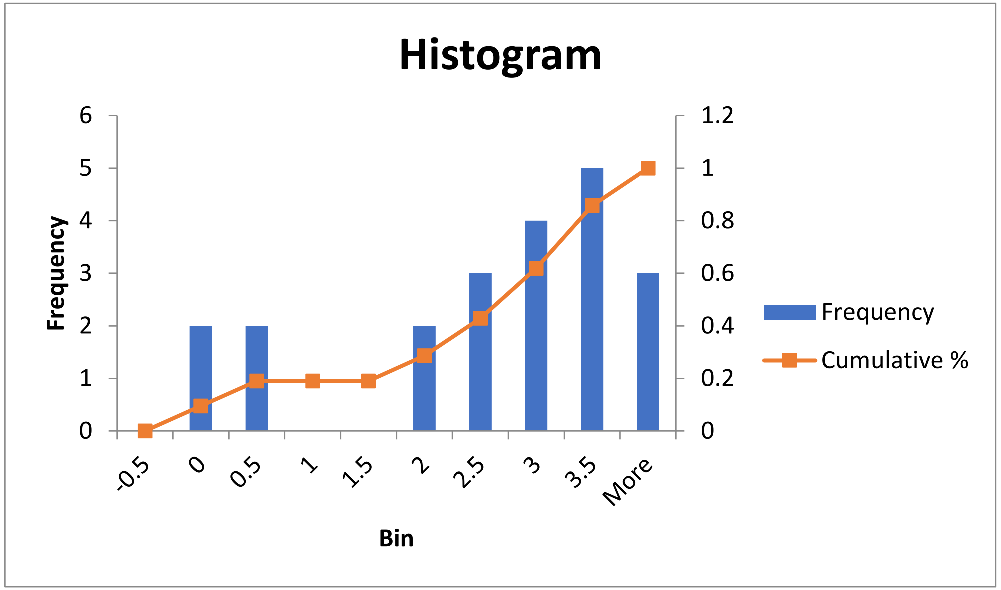


Bin	Frequency	Cumulative %
1.871802177	1	1.96%
2.501333498	0	1.96%
3.130864819	0	1.96%
3.76039614	7	15.69%
4.389927461	24	62.75%
5.019458782	18	98.04%
5.648990103	0	98.04%
More	1	100.00%

LogTri(0.0065,0.0806,0.533)

Toluene

Column1	
Mean	17.69381
Standard Error	2.828112
Median	20
Mode	20
Standard Deviation	12.960037
Sample Variance	167.96256
Kurtosis	-1.398809
Skewness	0.1282204
Range	39.19
Minimum	0.81
Maximum	40
Sum	371.57
Count	21

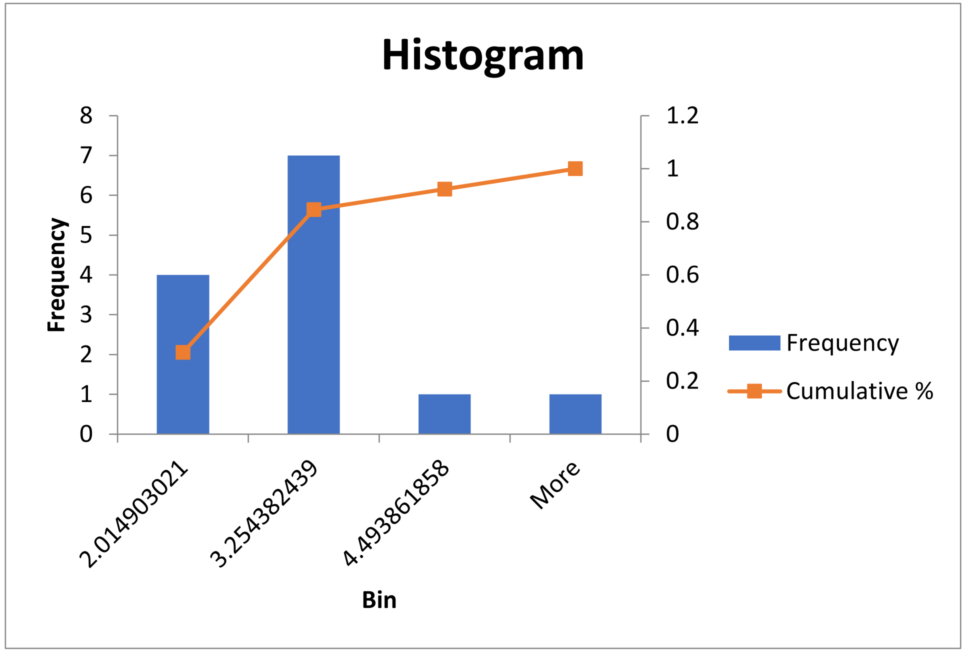


Bin	*Frequency*	*Cumulative %*
-0.5	0	0.00%
0	2	9.52%
0.5	2	19.05%
1	0	19.05%
1.5	0	19.05%
2	2	28.57%
2.5	3	42.86%
3	4	61.90%
3.5	5	85.71%
More	3	100.00%

LogTri(0.00082,0.033,0.04)

Phenol

Column1	
Mean	42.423077
Standard Error	22.373709
Median	25
Mode	25
Standard Deviation	80.669554
Sample Variance	6507.5769
Kurtosis	12.535989
Skewness	3.5149934
Range	301.5
Minimum	7.5
Maximum	309
Sum	551.5
Count	13

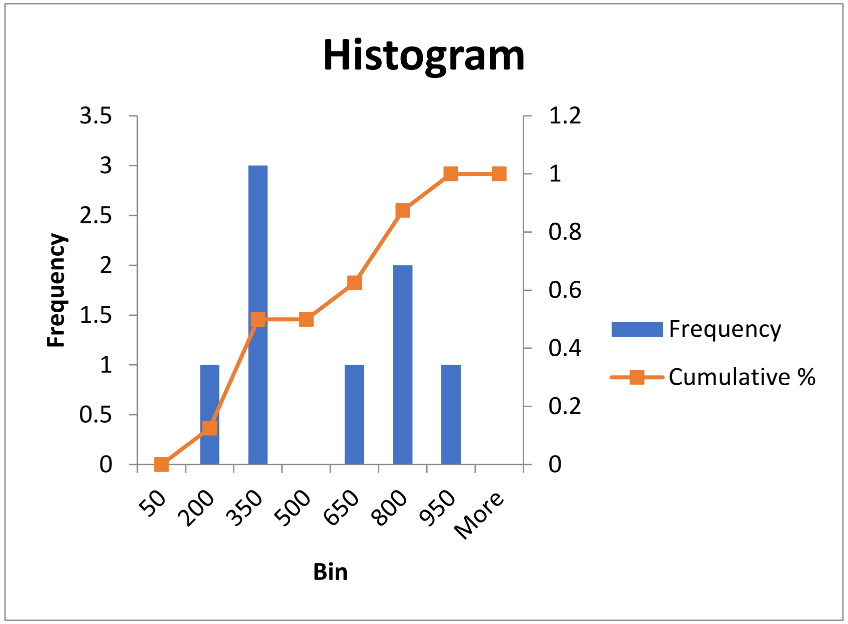


Bin	*Frequency*	*Cumulative %*
2.014903021	4	30.77%
3.254382439	7	84.62%
4.493861858	1	92.31%
More	1	100.00%

LogTri(0.0075,0.026,0.309)

Phase 4A
Chloride

Column1	
Mean	461.9875
Standard Error	107.16888
Median	396.5
Mode	#N/A
Standard Deviation	303.11936
Sample Variance	91881.344
Kurtosis	-1.383627
Skewness	0.2578007
Range	859.1
Minimum	54.9
Maximum	914
Sum	3695.9
Count	8

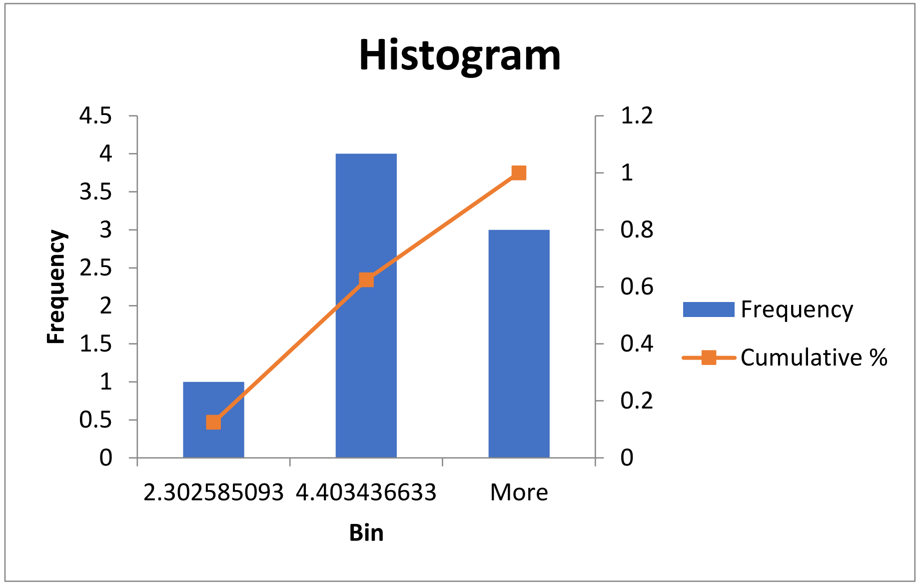


Bin	*Frequency*	*Cumulative %*
50	0	0.00%
200	1	12.50%
350	3	50.00%
500	0	50.00%
650	1	62.50%
800	2	87.50%
950	1	100.00%
More	0	100.00%

Tri(54.9,800,914)

Nickel

	Column1
Mean	146.8375
Standard Error	76.854206
Median	58
Mode	#N/A
Standard Deviation	217.37652
Sample Variance	47252.551
Kurtosis	6.5358724
Skewness	2.5114983
Range	658
Minimum	10
Maximum	668
Sum	1174.7
Count	8



Bin	Frequency	Cumulative %
2.302585093	1	12.50%
4.403436633	4	62.50%
More	3	100.00%

LogTri(0.01,0.0817,0.668)

Phenol

	Column1
Mean	7.5
Standard Error	0
Median	7.5
Mode	#N/A
Standard Deviation	#DIV/0!
Sample Variance	#DIV/0!
Kurtosis	#DIV/0!
Skewness	#DIV/0!
Range	0
Minimum	7.5
Maximum	7.5
Sum	7.5
Count	1

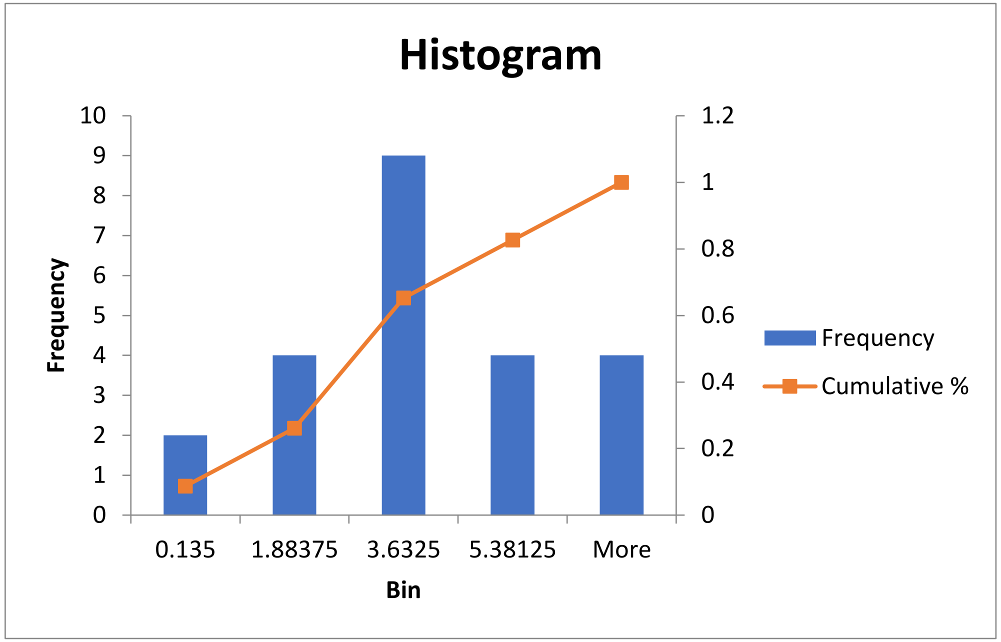
Single(0.0075)

Phase 4B
Ammoniacal Nitrogen

Column1	
Mean	3.083913
Standard Error	0.4066758
Median	2.74
Mode	0.135
Standard Deviation	1.9503484
Sample Variance	3.803859
Kurtosis	-0.655469
Skewness	0.3206139
Range	6.995
Minimum	0.135
Maximum	7.13
Sum	70.93
Count	23

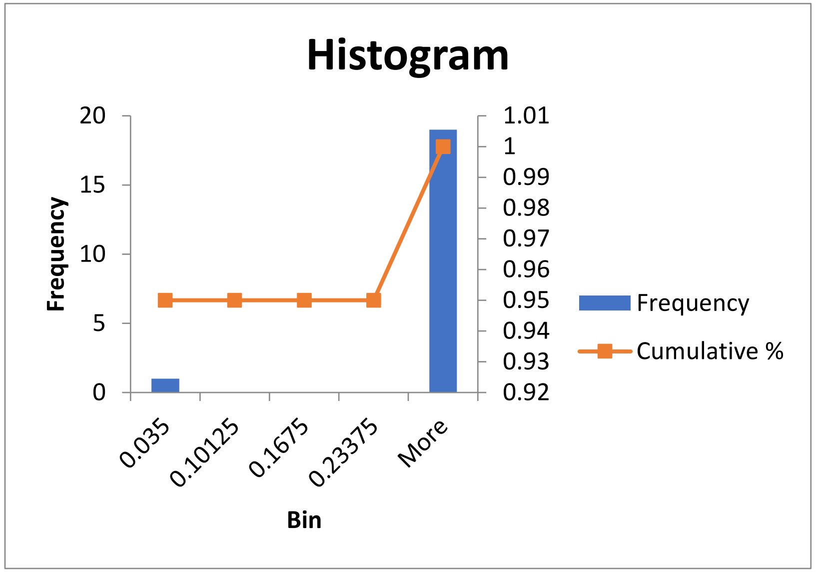
Bin	*Frequency*	*Cumulative %*
0.135	2	8.70%
1.88375	4	26.09%
3.6325	9	65.22%
5.38125	4	82.61%
More	4	100.00%

Tri(0.135,3.63,7.13)



Cadmium

	Column1
Mean	0.28675
Standard Error	0.01325
Median	0.3
Mode	0.3
Standard Deviation	0.0592558
Sample Variance	0.0035113
Kurtosis	20
Skewness	-4.472136
Range	0.265
Minimum	0.035
Maximum	0.3
Sum	5.735
Count	20

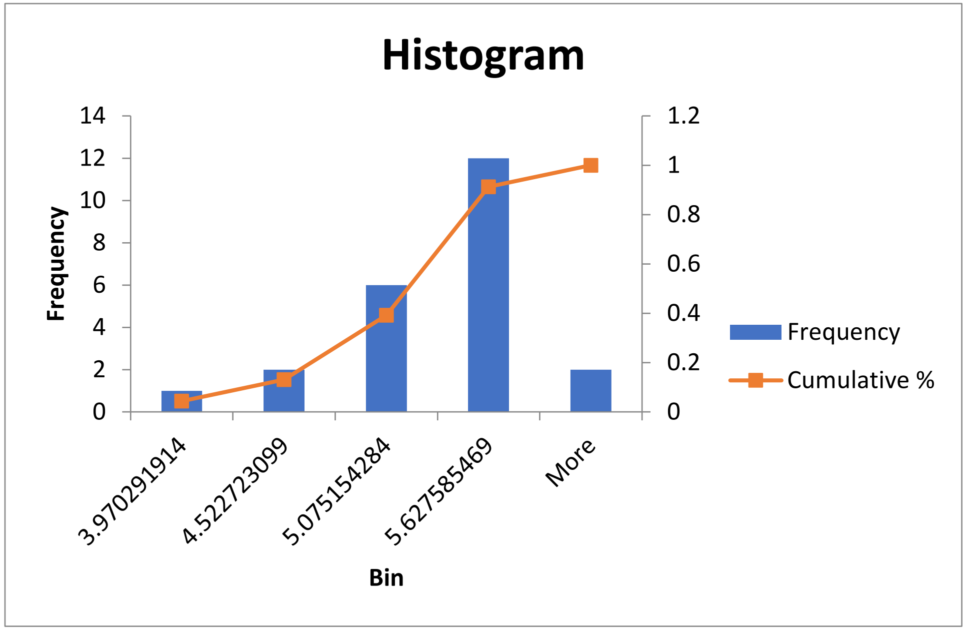


Bin	*Frequency*	*Cumulative %*
0.035	1	95.00%
0.10125	0	95.00%
0.1675	0	95.00%
0.23375	0	95.00%
More	19	100.00%

Tri(3.5E-5, 3E-4, 3E-4)
Not detected above LOD

Chloride

Column1	
Mean	186.11739
Standard Error	22.072121
Median	175
Mode	265
Standard Deviation	105.85417
Sample Variance	11205.106
Kurtosis	3.2253874
Skewness	1.7044928
Range	430
Minimum	53
Maximum	483
Sum	4280.7
Count	23

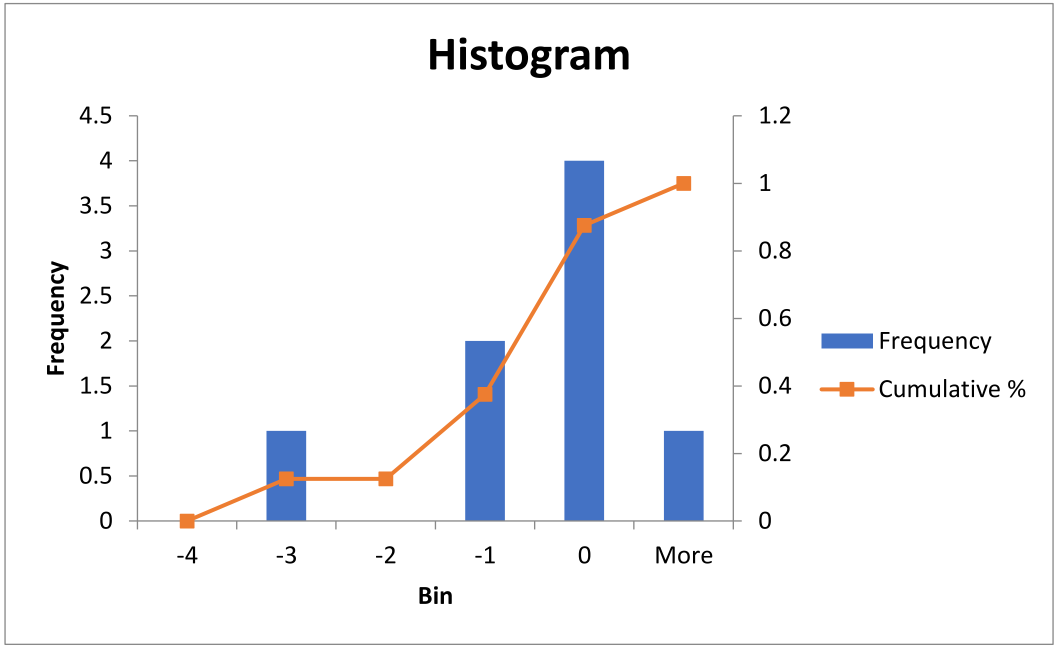


Bin	*Frequency*	*Cumulative %*
3.970291914	1	4.35%
4.522723099	2	13.04%
5.075154284	6	39.13%
5.627585469	12	91.30%
More	2	100.00%

LogTri(53,278,483)

MCPP

Column1	
Mean	0.535
Standard Error	0.1506533
Median	0.51
Mode	#N/A
Standard Deviation	0.426112
Sample Variance	0.1815714
Kurtosis	2.9465879
Skewness	1.3861746
Range	1.42
Minimum	0.02
Maximum	1.44
Sum	4.28
Count	8



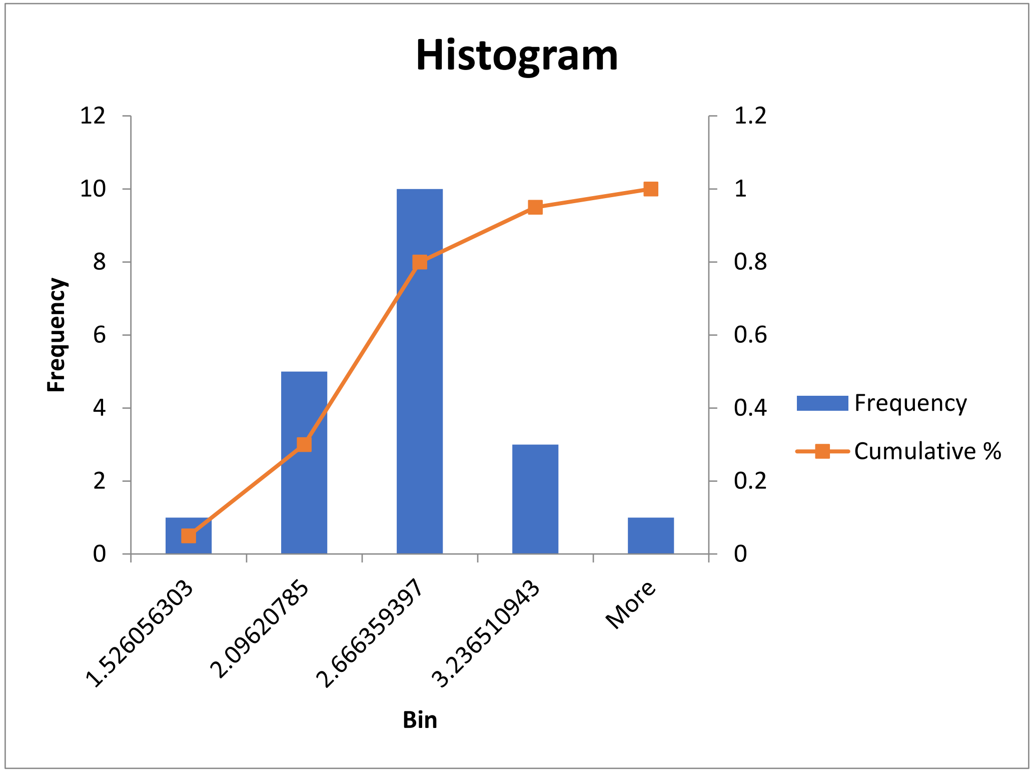
Bin	*Frequency*	*Cumulative %*
-4	0	0.00%
-3	1	12.50%
-2	0	12.50%
-1	2	37.50%
0	4	87.50%
More	1	100.00%

LogTri(2E-5,0.001,0.00144)

Nickel

	Column1
Mean	12.375
Standard Error	2.0582808
Median	9.9
Mode	9.9
Standard Deviation	9.2049114
Sample Variance	84.730395
Kurtosis	8.2627261
Skewness	2.6548248
Range	40.4
Minimum	4.6
Maximum	45
Sum	247.5
Count	20

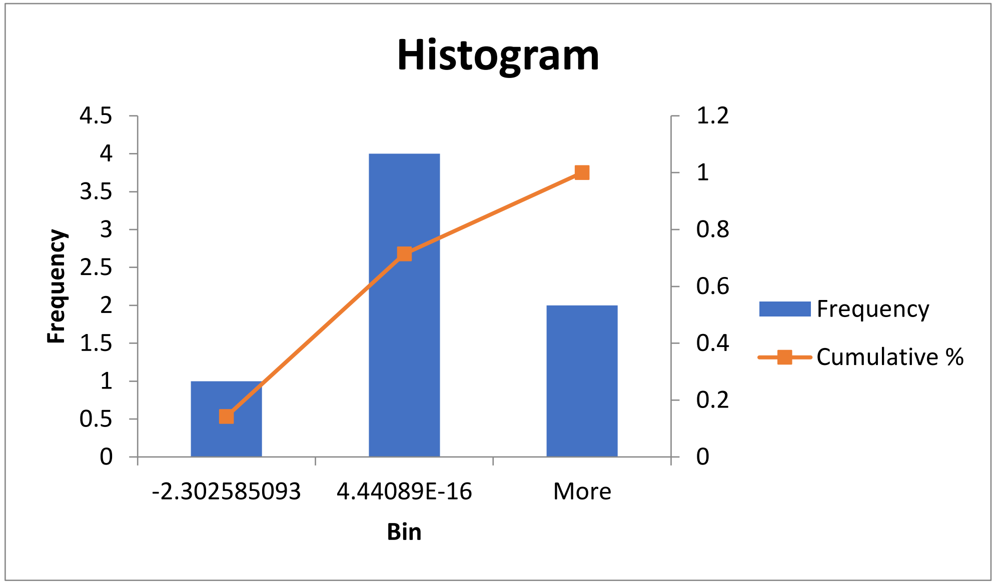
Bin	*Frequency*	*Cumulative %*
1.526056303	1	5.00%
2.09620785	5	30.00%
2.666359397	10	80.00%
3.236510943	3	95.00%
More	1	100.00%



LogTri(0.0046,0.014,0.045)

Toluene

Column1	
Mean	2.0857143
Standard Error	1.3390524
Median	0.5
Mode	0.5
Standard Deviation	3.5427995
Sample Variance	12.551429
Kurtosis	6.3279986
Skewness	2.4906193
Range	9.9
Minimum	0.1
Maximum	10
Sum	14.6
Count	7

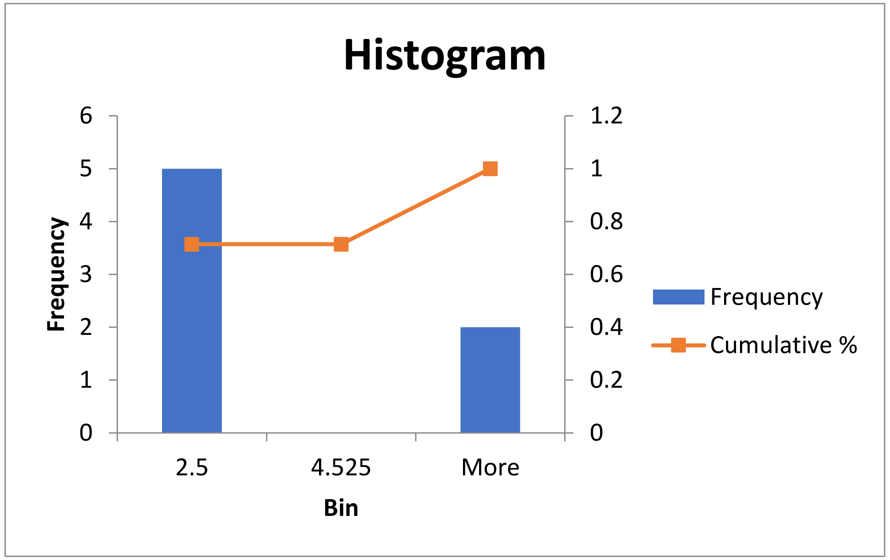


LogTri(0.0001.0.001.0.01)

Phenol

	Column1
Mean	3.6085714
Standard Error	0.7165407
Median	2.5
Mode	2.5
Standard Deviation	1.8957886
Sample Variance	3.5940143
Kurtosis	-0.768117
Skewness	1.2411509
Range	4.05
Minimum	2.5
Maximum	6.55
Sum	25.26
Count	7

Bin	Frequency	Cumulative %
2.5	5	71.43%
4.525	0	71.43%
More	2	100.00%



Tri(0.0025,0.0025,0.00655)

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