ENVIRONMENTAL EARTH SCIENCES
CONTAMINATION RESOLVED

31 March 2019

**Shellharbour City Council**
PO Box 155
Shellharbour Square
Shellharbour City Centre NSW 2529

Attention: **Courtney Williams** Waste Manager | **Dianne Tierney** Waste Manager

Dear Courtney and Dianne,

**February 2019 Quarterly Environmental Monitoring – Dunmore Recycling and Waste Disposal Depot, Dunmore, New South Wales.**

## 1.0 Introduction

Environmental monitoring is undertaken on a quarterly basis at the Dunmore Recycling Waste Disposal Depot, Dunmore, NSW (the site), in accordance with Environment Protection Licence (EPL) No. 5984. The monitoring includes sampling groundwater bores, a leachate pond, surface water bodies, a dust gauge and landfill gas at the landfill surface to detect any potential impacts of land filling activities on the environment.

## 2.0 Scope of works

On 13 February 2019, groundwater, surface water, leachate, gas and dust samples were collected in and around the site.

Groundwater samples were collected from nine monitoring bores (BH1c, BH2, BH3, BH4, BH13, BH14, BH16, BH20 and BH20s). At BH10, only the standing water level (SWL) was measured and no sample was taken. Surface water was collected from the leachate pond (LP1), three on site retention ponds (SWP1, SWP2, and SWP4) and Rocklow Creek at four points (SWC2, SWC_Up, SWC_Down and SWC_Down_2). Sampling was not taken at BH19 as the blockage encountered during the August monitoring round was still present. No sample was collected from BH15 as the access point was overgrown with trees and presented a potential WHS risk to field staff. No sample was taken at SWP5 as the retention pond was dry. Sampling locations are shown on Figure 1 (Attachment 1).

A dust gauge bottle was collected to the north of the site (DDG) and a gas walkover of all site buildings and the landfill cap was also undertaken. Landfill gas was measured in the field using a Inspectra Laser Unit (ILU) and a GA5000 Landfill Gas Analyser (GA5000).

## 3.0 Field measurements

Prior to purging, monitoring bores were measured for SWL. During sampling, field measurements were taken including pH, electrolytic conductivity (EC), oxidation/reduction potential (ORP), dissolved oxygen and temperature. Colour and odour of water samples were also noted. Field measurements recorded for each location are presented in Table 1 (Attachment 2).

All sampling was undertaken in accordance with Environmental Earth Sciences NSW (2011) *Soil, Gas and Groundwater sampling manual.*

## 4.0 Laboratory analysis

The following analyses were undertaken for site groundwater and surface water during the February 2019 monitoring event:

- groundwater – ionic balance (pH, total dissolved salts (TDS), sodium, calcium, potassium, magnesium, fluoride, chloride, ammonium, sulfate, bicarbonate, phosphate and nitrate), total organic carbon (TOC), biological oxygen demand (BOD), total and soluble iron, and soluble manganese;
- surface water (SWC_Up, SWC_Down and SWC_Down_2) – ionic balance, total and soluble iron, turbidity, nitrate, ammonium and bicarbonate;
- surface water (SWC2) – ammonium, nitrate, bicarbonate and total and soluble iron;
- surface water SWP1, SWP2 and SWP4 – ionic balance, total and soluble iron and turbidity;
- additional analyses for SWP4 – TOC and BOD; and
- leachate tank (LP1) – ionic balance, TOC, BOD, total and soluble iron, soluble manganese, turbidity, faecal coliforms and E.*Coli*.

Water samples and the dust sample were sent to Sydney Analytical Laboratories (SAL) for inorganic chemical analyses and to Sonic Healthcare for faecal coliforms and *Escherichia coli* (*E.Coli*) counts. All laboratories are NATA accredited for the methods used.

The inorganic laboratory results for groundwater and surface water are shown in Table 2 and Table 3 (Attachment 2). Calculated ratios of principal ions are presented in Table 4 (Attachment 2).

## 5.0 Results and discussion

### 5.1 Groundwater flow

Inferred groundwater contours from the February 2019 standing water level (SWL) measurements are illustrated in Figure 2 (Attachment 1). These were calculated using SWLs from surveyed bores. Groundwater flow direction was towards Rocklow Creek in a southerly direction similar to previous monitoring events.

Cumulative rainfall for November 2018 (91.2 mm), December 2018 (49.2 mm), January 2019 (102.6 mm) and February 2019[1] (29.6 mm) was 272.6 mm *(BOM – Albion Park Wollongong Airport weather station)* and slightly below 1999-2019 mean rainfall for this period of the year. Groundwater levels increased at all monitoring wells. The average of the measured standing water levels throughout the site have increased by ~0.10 mAHD from 0.70 mAHD in November 2018 to ~0.80 mAHD.

## 5.2 Groundwater

### 5.2.1 Groundwater sampling locations impacted by leachate

Field and laboratory results from the February 2019 sampling round, specifically from bores BH1c, BH2, BH3, BH4, BH20 and BH20s displayed chemistry that can be related to leachate impact with high levels of potassium, ammonium and nitrate. Leachate interaction is demonstrated by elevated concentrations of non-native potassium ($K^+$), ammonium ($NH_4^+$-N) and nitrate ($NO_3^-$) relative to native sodium ($Na^+$), calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$). This comparison is known as the leachate to non-leachate (L/N) ratio.

An L/N ratio >10 may be indicative of leachate impact depending on the combination with other indicators such as odour, colour, BOD and bicarbonate whereas a significant impact is likely to correspond with a ratio of >20 (Table 4, Attachment 2).

Bore BH1c is located near the old unlined landfill cell and intercepts leachate within the cell. As such the chemical signature of this bore has historically contained elevated leachate indicators in comparison to other monitoring bores (Schoeller plot BH1 a/b/c, Attachment 3). This continued during the current monitoring event and the groundwater was found to have a brown tinge, and leachate odour noted in combination with elevated TDS (4020 mg/L), $K^+$ (240 mg/L) [resulting in low Ca/K – 1.14] and $NH_4^+$-N (355 mg/L) concentrations. The very low levels of dissolved oxygen (0.19 ppm, Table 1) and presence of soluble $Fe^{2+}$ (2.9 mg/L) indicate an anaerobic environment and biochemical demand in response to microbial respiration. BOD has fluctuated since the bore was installed, ranging from 830 mg/L to 6 mg/L. BODs have remained at similar levels (6-8 mg/L) since August 2016 with a trend of small increases up to the February 2019 BOD concentration of 26 mg/L. Further evidence of microbial activity and respiration of nitrogen species in groundwater is elevated $HCO_3^-$ resulting in a low Cl/$HCO_3^-$ ratio of 0.43 (Table 4). This suggests some degradation of the leachate plume, and the organic nitrogen species therein, has occurred in this monitoring bore.

Bore BH2 is located down gradient from the old unlined landfill cell. Historically elevated levels of $NH_4^+$-N indicate some leachate impact at this location. $NH_4^+$-N concentration at BH2 showed an increasing trend since 2010 and reached its historical maximum in August 2017 and November 2017 (49 mg/L in both months). $NH_4^+$-N concentration decreased slightly in the February 2019 monitoring round to a level of 39 mg/L (down from 44 mg/L in November 2018). Bicarbonate ($HCO_3^-$), $Na^+$ and $Mg^{2+}$concentrations in groundwater have shown an increasing trend since February 2008 (Table 2, Schoeller plot BH2, Attachment 3). Calcium ($Ca^{2+}$) concentrations slightly decreased whilst potassium ($K^+$) slightly increased since the last monitoring round (Table 2, Schoeller plot BH2, Attachment 3). These two ions (and chlorine ($Cl^-$)) have generally followed the same trend observed in February 2019 monitoring round since September 2015. Low oxygen and negative redox (Table 2) continue to suggest microbial respiration and therefore degradation of the leachate is occurring at this location. Additionally, a leachate odour was noted.

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[1] Up until 13 February 2019 (date of sample event)

Groundwater from bore BH3 reported a decrease in concentration of native ions ($Na^+$, $Mg^{2+}$ and $Ca^{2+}$. Non-native nitrogen species decreased in February 2019 with $NH_4^+$-N concentration falling to 19 mg/L from 29 mg/L in November 2018. $NO_3^-$ recorded a reduction in concentration to 56 mg/L following an increase by an order of magnitude in August 2018 (7.5 mg/L in May 2018 to 78 mg/L in August 2018). Over this monitoring period concentrations of $HCO_3^-$ decreased whilst $K^+$ increased slightly. The L/N ratio (51.94 %) had increased slightly since the November 2018 monitoring round (47.60 %) despite the decrease in non-native nitrogen species and due to the low TDS (<1000 mg/L) the L/N ratio must be used with some caution. It was reported and verified during the drilling of BH3 that old unconfined waste dumps were in the vicinity of bore BH3 (outside the designated cells near bore BH2). In the previous monitoring report, it was suggested that elevated nitrogen species concentrations and a proportional increase of L/N ratio was due to the relatively high rainfall recorded in October and November 2018 and subsequent leaching of nitrogen species from the overlying unconfined waste in the vicinity of BH3 through the soil profile and into groundwater. Elevated L/N ratios after significant rainfall has been observed over the historical data range. The best example of this trend was observed during the August 2013 monitoring round, which was undertaken following a cumulative rainfall of 390.2 mm for May, June and July comparative to the 198.5 mm mean rainfall for 1999-2018 for that period. BH3's historic peak L/N ratio (208.90%) was recorded that monitoring round. In the absence of significant rainfall periods it is expected that nitrogen species in groundwater at BH3 will continue to decrease.

Bore BH20 is located down gradient of the landfill, leachate ponds and shallow old landfill. This bore was positioned to assess the chemical characteristics on the boundary of the landfill site. Field observations at bore BH20 recorded a negative redox (-112 mV) with clear groundwater and no odour. The L/N ratio (22.12%) in the February 2019 round had decreased from the November 2018 value (29.92%) but was still considered significantly elevated. The TDS remained relatively low (815 mg/L) making the L/N susceptible to natural variations or fluctuations in chemistry. Chemical characteristics of the bore show groundwater is low in $Na^+$, with a moderate Ca/K and K/TDS ratio (Table 4). Ammonium levels remained elevated at 21 mg/L however other landfill indicators were low or absent.

Bore BH20s is located directly adjacent to BH20 but at a shallower depth – *screened intervals of BH20 and BH20s are 6.0-9.0 mBGL and 1.5-4.5 mBGL respectively*. Similarly, this bore was positioned to compare the chemical characteristics on the boundary of the landfill site in order to locate potential transport pathways to Rocklow Creek. In February 2019, field measurements at bore BH20s recorded a negative redox (-210 mV), indicative of a reducing environment. Groundwater was clear, and no odour was detected. $NO_3^-$ concentrations decreased significantly from 105 mg/L in November 2018 to 33 mg/L in February 2019. The decrease in $NO_3^-$ led to a decrease in L/N ratio (70.46%), however this value was still elevated and is indicative of potentially high leachate impact at this site. TDS is relatively low (800 mg/L) making the L/N susceptible to natural variations or fluctuations in chemistry. Chemical characteristics of the bore show groundwater was low in $Na^+$, with a moderate Ca/K and K/TDS ratio (Table 4). As observed within BH3, the relatively high rainfall in October and November 2018 may have impacted the nitrogen species within BH20s, causing leaching of nitrogen species from the soil into the groundwater, resulting in elevated $NO_3^-$ concentrations. Ammonium levels (0.1 mg/L) have decreased significantly since May 2018 (1.0 mg/L) and remain lower than those seen at the deeper BH20 bore. It was previously thought that high nitrate levels in this shallower bore location was indicative of nitrification throughout the soil profile, however, continued monitoring at this location will be necessary to determine potential leachate transport pathways to Rocklow Creek.

#### 5.2.2 Remaining groundwater sampling locations

During the November 2018 monitoring round, ionic chemistry indicated that bores BH4, BH13, BH14 and BH16 only displayed slight to no leachate influence. Chemical composition of each of these bores has been depicted in Schoeller plots in Attachment 3.

The L/N ratio at bore BH4 showed a slight decrease in the February 2019 round (9.59%) — in November 2018 monitoring round the L/N ratio was 10.94%. The L/N ratio at this location had not previously exceeded 10% since February 2003. Relatively stable $NH_4^+$-N levels had been recorded up until August 2018, however, the November 2018 monitoring round recorded almost double this (16.0 mg/L). This round, $NH_4^+$-N levels decreased to 6.70 mg/L, however there was a sharp increase in nitrite ($NO_2^-$) from 0.13 mg/L to 9.6 mg/L, indicative of the nitrification process and transformation of $NH_4^+$-N to $NO_2^-$. The presence of nitrite should be investigated in down-gradient bores such as BH20 and BH20s during the next monitoring round to determine the migration pathways and rates of nutrients. BH4 is placed on the border of an historic shallow landfill site and down gradient of landfilling activities. This area should be continually monitored to determine water quality in this area.

Bore BH13 is in close proximity to a former night soil area (Figure 1). A slight residual leachate influence has been apparent at this location in the past. Analysis of chemical data from the February 2019 monitoring round shows a decrease of L/N ratio of 10.49% from 19.88% in November 2018. The previously elevated L/N ratios seen in August and November 2018 were attributed to the increased concentrations of $NO_3^-$ 26 mg/L and 32 mg/L, respectively) from 0.22 mg/L in May 2018. Large fluctuations in $NO_3^-$ have previously been observed in the historic data, however, chemical composition of the groundwater has generally remained consistent since monitoring began in 2002 (Schoeller plot BH13, Attachment 3).

The L/N ratio at bore BH14 remained stable in the February 2019 round (5.47%) — in November 2018 monitoring round the L/N ratio was 5.38 % at this location. $NO_3^-$ concentration remained stable at low levels however $NO_3^-$ levels have been historically high at this location. $NH_4^+$-N concentrations increased slightly from 0.90 to 1.70 mg/L however remain below the site criteria of 1.88 mg/L. Bore BH14 is strategically placed down gradient of landfilling activities and should be continually monitored to determine the water quality in this area given its history of leachate impact.

Bore BH16 is located in a swampy area with groundwater field observations recording a light brown colour and a minor leachate odour. The sampled redox potential indicates a reducing environment (-225 mV), which may have an influence on the historical dominance of NH4+-N over $NO_3^-$. This round $NH_4^+$-N concentrations decreased slightly to 0.1 mg/L from 0.2 mg/L. Groundwater sampling in February 2019 indicated limited to no leachate impact at BH16 despite a slightly elevated L/N ratio of 15.56%. Bore BH16 is located close to a drainage channel where offsite impacts can readily influence the chemical characteristics of the shallow groundwater and should continue to be monitored for fluctuations.

#### 5.2.3 Groundwater site criteria exceedances

$NH_4$-N concentrations above threshold levels (1.88 mg/L) (ANZECC, 2000) were reported in groundwater from bores BH1c (355 mg/L), BH2 (39 mg/L), BH3 (19 mg/L), BH4 (6.7 mg/L) and BH20 (21 mg/L). Nitrate ($NO_3^-$) was reported above guideline thresholds (10.6 mg/L) (ANZECC, 2000) at BH3 (56 mg/L) and BH20s (33 mg/L).

### 5.3 Surface water monitoring

During the February 2019 monitoring round, samples from Rocklow Creek (SWC2, SWC_Up, SWC_Down and SWC_Down_2) and three surface water ponds (SWP1, SWP2, and SWP4) were collected. Results of surface water analysis (Table 2 and Table 3) indicate that concentrations of ions were within the historical ranges. As surface water ponds are intended to retain any surface water migrating towards Rocklow Creek, the detection of chemical constituents that may be associated with landfill leachate are expected.

$NH_4^+$-N levels detected at SWP1 were below detection (<0.10 mg/L) which has decreased significantly since a concentration of 3.50 mg/L was recorded in November 2018. Ongoing minor leachate impact has been indicated by consistent L/N ratios > 10% and < 20%. Elevated concentrations of soluble iron and a negative redox potential are indicative of a reducing environment which may have contributed to historical low levels of dissolved oxygen and the production of $NH_4^+$-N.

Surface water sampled at SWP2 showed little to no leachate impact. The surface water pond collects runoff from around the site and potential impacts from site activities are often observed. $NH_4^+$-N concentration remained low at 0.20 mg/L however, fluctuating NH4+-N is common at this location with previous monitoring events ranging between 0.01 and 15 mg/L. $NO_3^-$ concentrations were below the limit of detection (0.10 mg/L). All chemical parameters at this location are within historical ranges.

$NH_4^+$-N concentration at SWP4 was below the limit of detection (<0.10 mg/L). The defined site trigger level of 1.88 mg/L was exceeded in May 2018 (2.60 mg/L). $NO_3^-$ levels also decreased to below the limit of detection from 8.0 mg/L in November 2018. The decrease in $NH_4^+$-N and $NO_3^+$ concentrations is indicative of the natural process of nitrification by which $NH_4^+$-N naturally attenuates. All chemical parameters at this location are within historical ranges.

The four surface water creek sites SWC2, SWC_Up, SWC_Down and SWC_Down_2 (Figure 2) were also sampled during the November 2018 sampling event. SWC_Down_2 is still a relatively new sampling location which was established in order to detect potential leachate impacts to Rocklow Creek originated from the eastern portion of the site (Environmental Earth Sciences NSW, 2017). SWC_Up, SWC_Down and SWC_Down_2 had high concentrations of TDS (>25,000 mg/L), notably $Na^+$ and $Cl^-$ (Table 2); this is due to the tidal nature of these waters and differentiates them from landfill groundwater / surface water.

The low nutrient and L/N ratios within Rocklow Creek indicated that there was no leachate impact within Rocklow Creek. All surface water creek sampling sites (SWC2, SWC_Up, SWC_Down and SWC_Down_2) had concentrations of $NH_4^+$-N and $NO_3^-$ below the ANZECC (2000) guidelines. All four sites will continue to be monitored to ensure leachate is not impacting upon the Rocklow Creek.

## 5.4 Monitoring of Leachate Tanks

The chemistry of leachate water at the Dunmore Recycling and Waste Disposal Depot is significantly different when compared to the surface and groundwater chemistry of non-leachate influenced bores. This is demonstrated through comparison of chemical data presented in Table 2. In particular TDS, BOD, TOC, $Na^+$, $NH_4^+$-N, $K^+$, $HCO_3^-$, $PO_4^{3-}$ and total iron concentrations are generally elevated in leachate pond water compared to other monitoring bores (Schoeller Plot LP1, Attachment 3). Ionic ratios (Table 4) such as low Ca/K (0.40) and high Na/Ca and L/N ratios represent landfill leachate chemical characteristics. These chemical characteristics have been relatively stable over the past 10 years of monitoring.

Laboratory analysis detected *faecal coliforms* and *E.Coli* during this round with concentrations of 170 CFU/100 ml and 140 CFU/100mL respectively (Table 3). Fluctuation in these concentrations in leachate tanks are common and thus dermal contact with these waters should continue to be avoided due to historic levels of elevated concentrations and the corresponding health concerns relating to high microbial counts.

### 5.5 Quality assurance/quality control

For quality assurance and quality control the following precision and reliability measures were calculated. The charge balance difference between the summed total of anions against cations (milli-equivalent units) was in the range of 0.33% to 4.05%. The results are a good indication that all major cations and anions present in the groundwater have been analysed and accounted for, providing confidence in the laboratory results obtained.

Field and laboratory practices were further evaluated by comparing the difference between field and laboratory pH and field measured electrical conductivity (EC) against laboratory total dissolved salts (TDS). The range of most relative percent difference (RPD) of field to laboratory pH measurements was between 0.37 % and 12.99%. The relationship between the field determined EC and laboratory measured TDS relationship ranged between 0.53 and 0.85.

RPDs between the intra-laboratory duplicate and the primary sample taken at bore BH13 were all within the acceptable RPD criteria. Thus, the data is considered reliable (Table 6).

### 5.6 Gas monitoring

Landfill gas was measured in the field using a Inspectra Laser Unit (ILU) and a GA5000 Landfill Gas Monitor (GA5000). Measurements were taken within and around all buildings in a 250 m radius from the current landfill cell as well as across the landfill cap (gas walkover grids of the February 2019 round are presented in Figure 3).

All readings were below the site-specific criteria outlined in EPL no. 5984 as the NSW EPA (2013) reporting threshold of 1.00 % v/v $CH_4$ within onsite buildings and therefore pose no direct risk. One reading on the landfill cap was recorded above the threshold concentration for closer investigation and potential action (500 ppm or 0.05 % v/v, NSW EPA [2013], Table 5). This reading was recorded at the base of one of the exhaust vents on the landfill cap and will be further investigated in the next monitoring round to determine if corrective action is required, for example additional capping material around the base of the vent. Continued monitoring with both the GA5000 and ILU will be undertaken at quarterly monitoring events.

### 5.7 Dust

Dust deposition levels to the north of the site were 1.7 g/m$^2$/month total solids, which is below the accepted level of 4 g/m$^2$/month (Australian Standards AS3580.10.1 and AS2724.1). Dust deposition levels are within historical ranges and will continue to be monitored to assess the closest sensitive receptor, houses located to the north-west of site.

## 6.0 Conclusion and recommendations

Groundwater behaviour across the site since the commencement of quarterly monitoring in 1992 has been generally consistent. As the plume beneath the site is relatively stable, changes in leachate behaviour into the future are not expected to be significant. Changes to site conditions such as stockpile locations, new landfill cells, new retention ponds and other earth works could potentially impact leachate behaviour on site.

The February 2019 monitoring round found a general decrease in L/N ratios at leachate impacted groundwater sampling locations due to decreases in nitrogen species concentrations, particularly at BH2, BH3, BH13, BH20 and BH20s.

Assessment of monitoring bores closest to Rocklow Creek, BH20 and BH20s, has detected the presence of leachate indicators despite the Rocklow Creek samples (SWC-Up, SWC-Down and SWC_Down_2), showing no affect. Although the historical data sets of these new bore locations are relatively limited, it appears that on-site activities are not significantly impacting Rocklow Creek. Surface water monitoring indicated that on site activities have had limited impact on water quality at locations SWP1, SWP2, SWP4 and SWP5. Assessment of Rocklow Creek sampling locations (SWC2, SWC-Up, SWC-Down and SWC_Down_2) reported no concentrations of $NH_4^+$-N and $NO_3^-$ above the ANZECC (2000) trigger value.

Gas concentrations detected at all buildings assessed on site were below guidelines and therefore no action was required. One gas concentration reading across the landfill cap was above the threshold criteria for further investigation and potential action and will be further assessed in the next monitoring round. Landfill gas exceedances were also recorded in May 2017 and as such it is recommended that monitoring continue with a FID or Inspectra Laser Unit and GA5000 Landfill Gas Monitor.

Depositional dust monitoring results continued to be below guidelines (Australian Standards AS3580.10.1 and AS2724.1) and will continue to be monitored to assess the impact that dust poses on nearby residential areas.

## 7.0 Limitations

This letter report has been prepared by Environmental Earth Sciences NSW ABN 109 404 006 in response to and subject to the following limitations:

1. The specific instructions received from Shellharbour City Council;
2. The specific scope of works set out in PO117559 issued by Environmental Earth Sciences NSW for and on behalf of Shellharbour City Council;
3. May not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Environmental Earth Sciences NSW (which consent may or may not be given at the discretion of Environmental Earth Sciences NSW);
4. This report comprises the formal report, documentation sections, tables, figures and appendices as referred to in the index to this report and must not be released to any third party or copied in part without all the material included in this report for any reason;
5. The report only relates to the site referred to in the scope of works being located at Dunmore Recycling and Waste Disposal Depot located at Buckleys Rd Dunmore, NSW ("the site");
6. The report relates to the site as at the date of the report as conditions may change thereafter due to natural processes and/or site activities;
7. No warranty or guarantee is made in regard to any other use than as specified in the scope of works and only applies to the depth tested and reported in this report,
8. Fill, soil, groundwater and rock to the depth tested on the site may be fit for the use specified in this report. Unless it is expressly stated in this report, the fill, soil and/or rock may not be suitable for classification as clean fill if deposited off site;
9. This report is not a geotechnical or planning report suitable for planning or zoning purposes; and
10. Our General Limitations set out at the back of the body of this report.

Should you have any further queries, please contact us on (02) 9922 1777.

On behalf of
**Environmental Earth Sciences NSW**

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## 8.0 References


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NSW Environment Protection Authority (2016). *Environmental guidelines: Solid Waste Landfills.*

# ENVIRONMENTAL EARTH SCIENCES GENERAL LIMITATIONS

## Scope of services
The work presented in this report is Environmental Earth Sciences response to the specific scope of works requested by, planned with and approved by the client. It cannot be relied on by any other third party for any purpose except with our prior written consent. Client may distribute this report to other parties and in doing so warrants that the report is suitable for the purpose it was intended for. However, any party wishing to rely on this report should contact us to determine the suitability of this report for their specific purpose.

## Data should not be separated from the report
A report is provided inclusive of all documentation sections, limitations, tables, figures and appendices and should not be provided or copied in part without all supporting documentation for any reason, because misinterpretation may occur.

## Subsurface conditions change
Understanding an environmental study will reduce exposure to the risk of the presence of contaminated soil and or groundwater. However, contaminants may be present in areas that were not investigated, or may migrate to other areas. Analysis cannot cover every type of contaminant that could possibly be present. When combined with field observations, field measurements and professional judgement, this approach increases the probability of identifying contaminated soil and or groundwater. Under no circumstances can it be considered that these findings represent the actual condition of the site at all points.

Environmental studies identify actual sub-surface conditions only at those points where samples are taken, when they are taken. Actual conditions between sampling locations differ from those inferred because no professional, no matter how qualified, and no sub-surface exploration program, no matter how comprehensive, can reveal what is hidden below the ground surface. The actual interface between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from that predicted. Nothing can be done to prevent the unanticipated. However, steps can be taken to help minimize the impact. For this reason, site owners should retain our services.

## Problems with interpretation by others
Advice and interpretation is provided on the basis that subsequent work will be undertaken by Environmental Earth Sciences NSW. This will identify variances, maintain consistency in how data is interpreted, conduct additional tests that may be necessary and recommend solutions to problems encountered on site. Other parties may misinterpret our work and we cannot be responsible for how the information in this report is used. If further data is collected or comes to light we reserve the right to alter their conclusions.

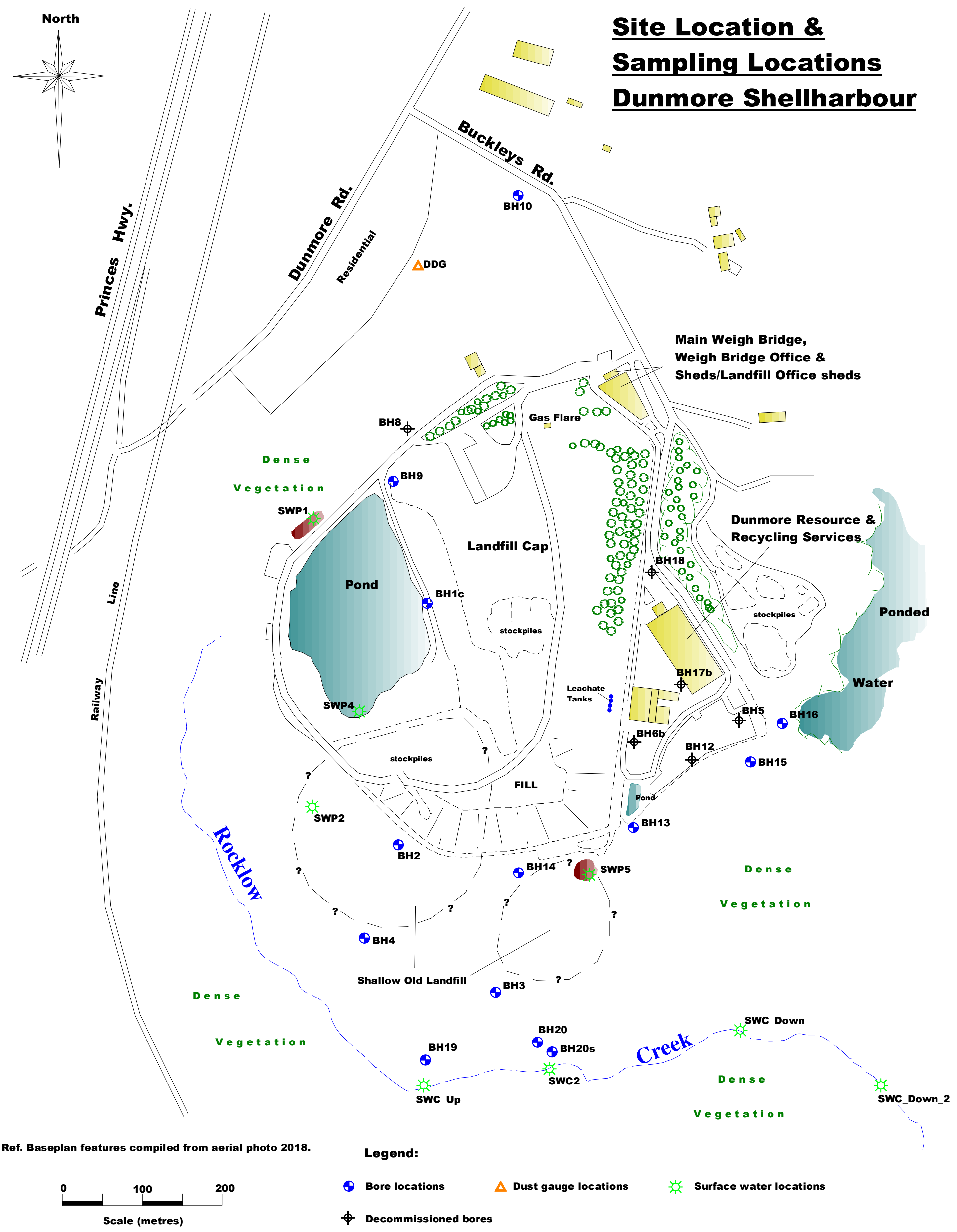
## Obtain regulatory approval
The investigation and remediation of contaminated sites is a field in which legislation and interpretation of legislation is changing rapidly. Our interpretation of the investigation findings should not be taken to be that of any other party. When approval from a statutory authority is required for a project, that approval should be directly sought by the client.

## Limit of liability
This study has been carried out to a particular scope of works at a specified site and should not be used for any other purpose. This report is provided on the condition that Environmental Earth Sciences NSW disclaims all liability to any person or entity other than the client in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by any such person in reliance, whether in whole or in part, on the contents of this report. Furthermore, Environmental Earth Sciences NSW disclaims all liability in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by the client, or any such person in reliance, whether in whole or any part of the contents of this report of all matters not stated in the brief outlined in Environmental Earth Sciences NSW's proposal number and according to Environmental Earth Sciences general terms and conditions and special terms and conditions for contaminated sites.

To the maximum extent permitted by law, we exclude all liability of whatever nature, whether in contract, tort or otherwise, for the acts, omissions or default, whether negligent or otherwise for any loss or damage whatsoever that may arise in any way in connection with the supply of services. Under circumstances where liability cannot be excluded, such liability is limited to the value of the purchased service.

# ATTACHMENT 1 FIGURES

# Site Location & Sampling Locations Dunmore Shellharbour

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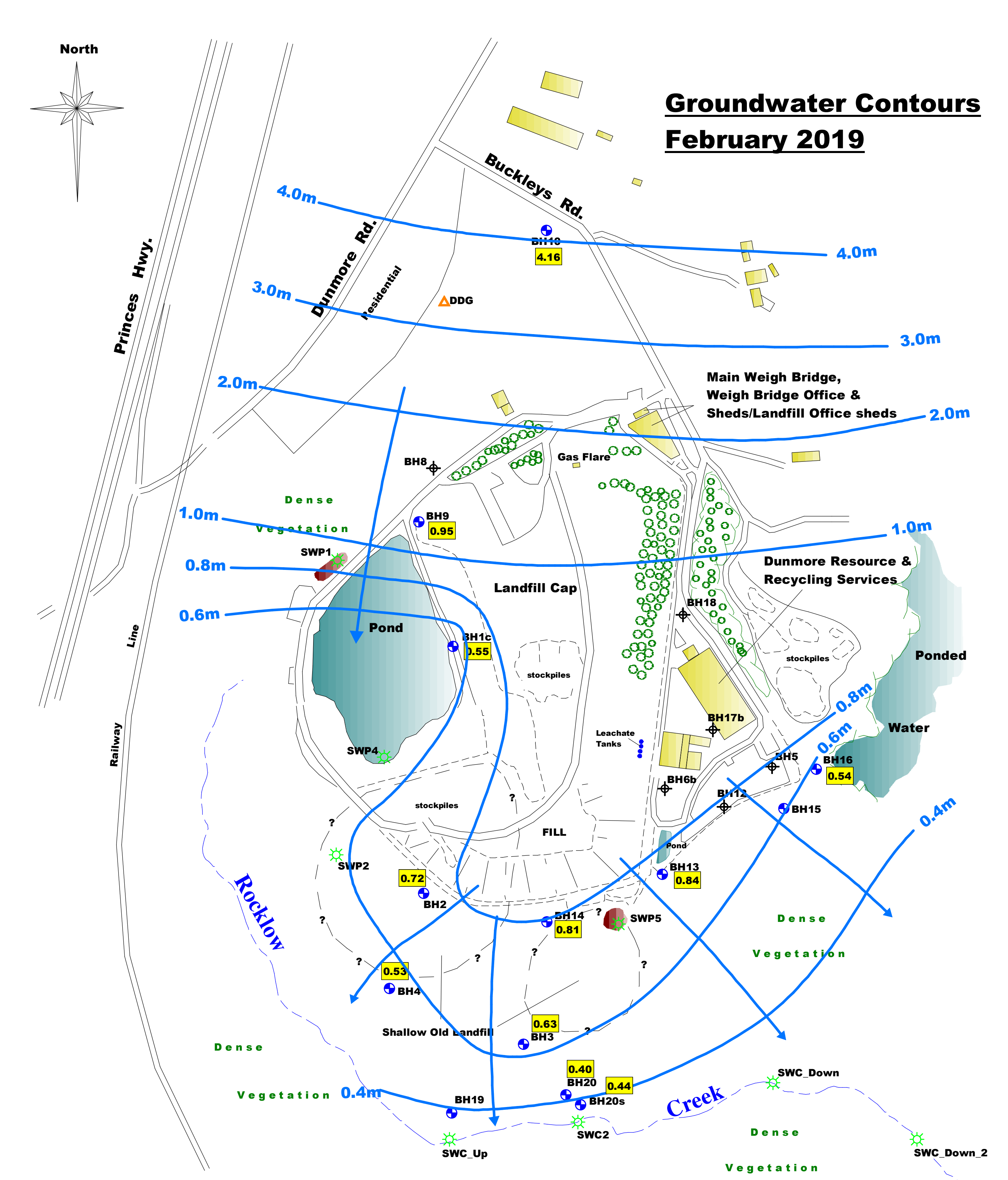
|---|---|---|---|---|
| ENVIRONMENTAL EARTH SCIENCES CONTAMINATION RESOLVED | Title: Site Plan & Sampling Locations | | | |
| | Location: Buckleys Road, Dunmore, Shellharbour, NSW | | | |
| Client: Shellharbour City Council | Job No. 118077 | | Date: August 2018 | Figure 1 |
| | Drawn by: TRJ | Proj. Man. LV | Scale: As shown | |




Ref. Baseplan features compiled from aerial photo 2018.

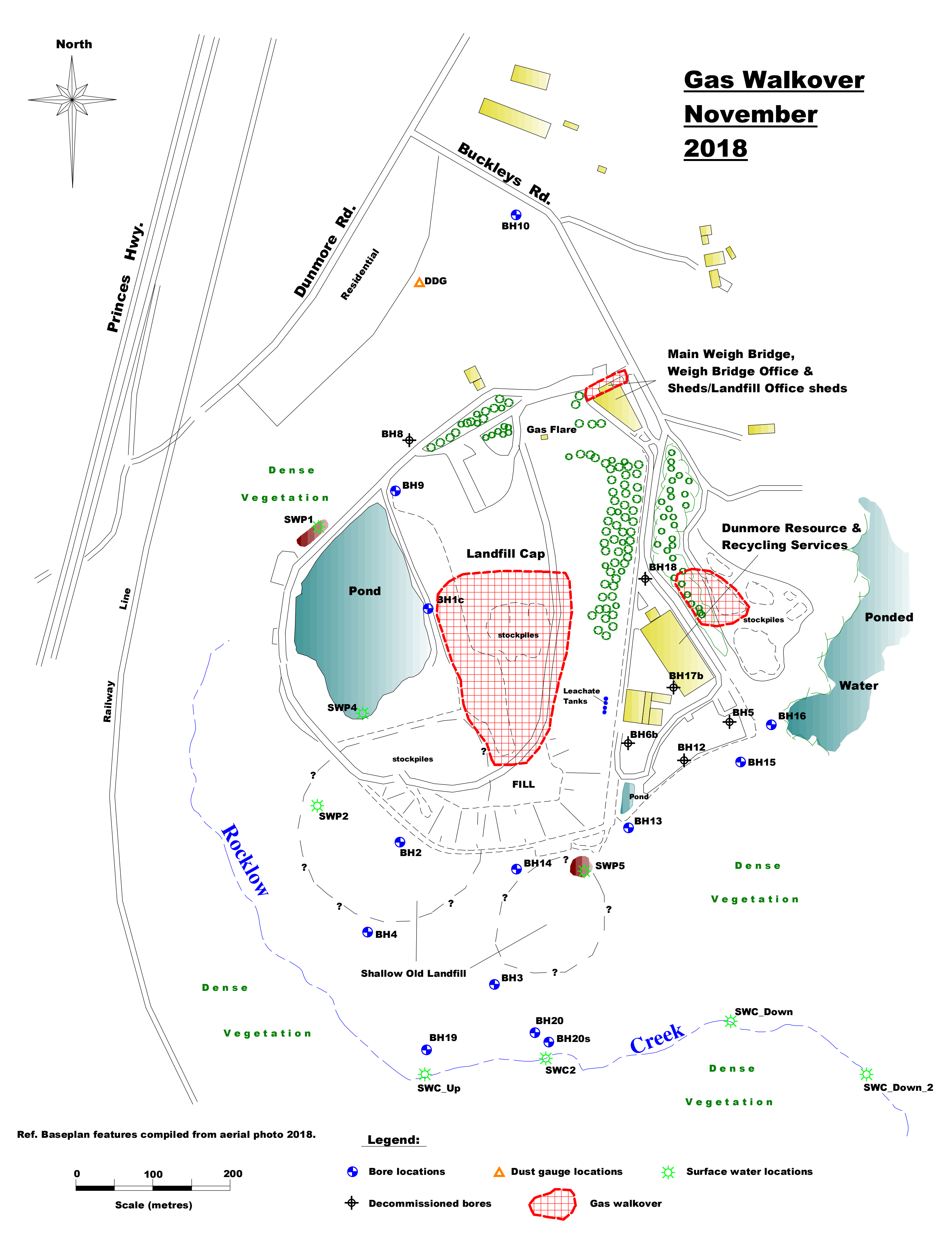
0 100 200

Scale (metres)

**Legend:**

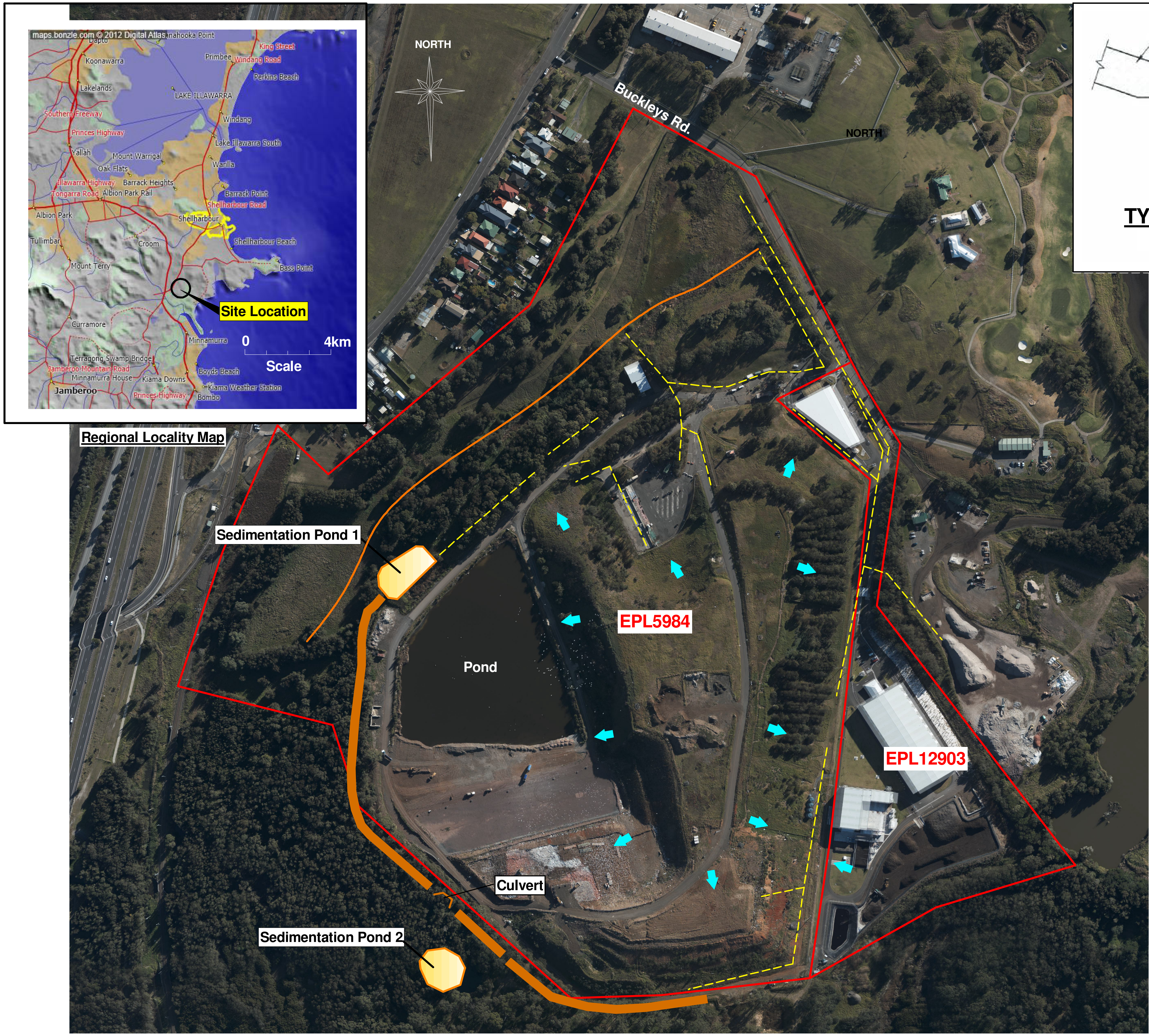
- Bore locations
- Dust gauge locations
- Surface water locations
- Decommissioned bores
- 3.0m Inferred groundwater contour (m AHD)
- Inferred flow direction
- 0.35 SWL (standing water level m AHD)

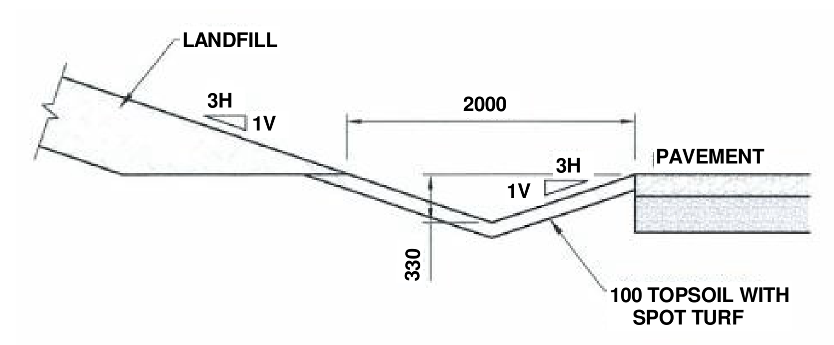
| | |
|---|---|
| ENVIRONMENTAL EARTH SCIENCES<br>CONTAMINATION RESOLVED | Title: Groundwater Contours - February 2019 |
| | Location: Buckleys Road, Dunmore, Shellharbour, NSW |
| Client: Shellharbour City Council | Job No. 118109 · Date: 6 March 2019 · Drawn by: TRJ · Proj. Man. MN · Scale: As shown · Figure 2 |




ENVIRONMENTAL EARTH SCIENCES
CONTAMINATION RESOLVED

| | | | |
|---|---|---|---|
| Title: Gas Walkover | | | |
| Location: Buckleys Road, Dunmore, Shellharbour, NSW | | | |
| Client: Shellharbour City Council | Job No. 118077 | Date: August 2018 | Figure 3 |
| | Drawn by: TRJ | Proj. Man. LV | Scale: As shown |




**TYPICAL SECTION OF OPEN DRAIN**

SCALE 1:50

Legend:

- licence boundary
- levee bank
- drainage layout
- approx. stormwater diversion drain
- approx. stormwater flow direction

0 100 200

Scale

Ref. Based on updated aerial photograph 2018.

| ENVIRONMENTAL EARTH SCIENCES | Title: Surface Water Runoff | |
|---|---|---|
| | Location: Dunmore Recycling & Waste Disposal Depot, Shellharbour | |
| Client: Shellharbour City Council | | Job number: 118109 |
| Drawn by: TRJ | Scale: As shown | Source: See Ref. |
| Proj Man: EG | Date: Nov 2018 | Figure 4 |

# ATTACHMENT 2 TABLES

## TABLE 1 FIELD MEASUREMENTS – FEBRUARY 2019

| Sample | SWL | SWL | pH | EC | ORP | Temp. | DO | Colour | Odour |
|---|---|---|---|---|---|---|---|---|---|
| **Units** | mAHD | Dip (m) | - | mS/cm | mV | ºC | ppm | - | - |
| **BH1c** | 0.554 | 3.4 | 7.01 | 7.3 | -175 | 26 | 0.17 | Light brown | Leachate |
| **BH2** | 0.717 | 4.075 | 7.01 | 3.15 | -167 | 23.5 | 0.26 | Light brown / yellow | Leachate |
| **BH3** | 0.634 | 3.13 | 7.38 | 1.37 | -108 | 19.3 | 2.84 | Clear | None |
| **BH4** | 0.529 | 4.49 | 7.15 | 1.7 | -157 | 19.8 | 0.13 | Clear | Mild sweet / leachate odour |
| **BH10** | 4.161 | 0.63 | - | - | - | - | - | - | - |
| **BH13** | 0.835 | 4.46 | 7.05 | 1.57 | -51 | 21.2 | 0.29 | Clear | Slight leachate |
| **BH14** | 0.805 | 4.91 | 6.84 | 2.15 | -74 | 21 | 0.3 | Clear | None |
| **BH16** | 0.54 | 0.84 | 7.11 | 0.39 | -225 | 20.7 | 0.69 | Light brown | Sulfuric / Leachate |
| **BH20** | 0.4 | 2.37 | 7.31 | 1.23 | -112 | 20.3 | 0.14 | Clear | None |
| **BH20s** | 0.44 | 2.33 | 7.38 | 1.36 | -210 | 18.8 | 0.15 | Clear | None |
| **LP1** | - | - | 8.07 | 14.79 | -110 | 26.3 | 0.58 | Black | Leachate |
| **SWC2** | - | - | 7.24 | 46.25 | -148 | 21 | 0.96 | Clear | None |
| **SWC-Up** | - | - | 7.14 | 44.34 | -253 | 21.5 | 0.46 | Clear | None |
| **SWC-Down** | - | - | 7.25 | 42.85 | -50 | 21.2 | 1.77 | Clear | None |
| **SWC_DOWN_2** | - | - | 7.37 | 46.25 | -29 | 21.3 | 1.94 | Clear | None |
| **SWP1** | - | - | 8.2 | - | - | 25 | - | Brown tinge | None |
| **SWP2** | - | - | 8.39 | 2.15 | -151 | 25.7 | 6.13 | Very light brown | Slight sulfuric |
| **SWP4** | - | - | 9.1 | 2.34 | -64 | 26.7 | 9.87 | Very light brown | None |
| **SWP5** | - | DRY | | | | | | | |

**Notes:**
1. SWL Standing Water Level, measured to the top of the monument or casing; RL – reference level;
2. - not measured;
3. N/A = Not applicable
4. DO = dissolved oxygen;
5. ORP = electron activity; and
6. EC= electrolytic conductivity

## TABLE 2 WATER LABORATORY RESULTS – FEBRUARY 2019

| Sample | pH | TDS mg/L | Na mg/L | Ca mg/L | K mg/L | Mg mg/L | $NH_4$-N mg/L | Cl mg/L | F mg/L | $NO_3$ mg/L | $NO_2$ mg/L | $SO_4$ mg/L | $HCO_3$ mg/L | $PO_4$ mg/L | TOC mg/L | BOD mg/L | Sol. Mn mg/L | Sol. Fe mg/L | Tot. Fe mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BH1c** | 7.4 | 4020 | 695 | 140 | 240 | 105 | **355** | 820 | 0.25 | 0.1 | | 13 | 3250 | 0.15 | 175 | 25 | 0.16 | **2.9** | 15 |
| **BH2** | 7.2 | 1790 | 340 | 195 | 52 | 73 | **39** | 450 | 0.26 | 0.1 | | 130 | 1150 | 0.1 | 64 | 2 | 0.47 | **3.2** | 13 |
| **BH3** | 6.8 | 730 | 61 | 125 | 32 | 20 | **19** | 185 | 0.11 | **56** | | 75 | 290 | 0.12 | 13 | 5 | 0.18 | 0.11 | 3 |
| **BH4** | 7.1 | 1060 | 135 | 170 | 26 | 37 | **6.7** | 210 | 0.1 | 0.1 | 9.6 | 140 | 575 | 0.1 | 19 | 2 | 0.22 | 0.17 | 5.1 |
| **BH13** | 7.3 | 975 | 100 | 185 | 30 | 40 | 1 | 105 | 0.22 | 3.1 | | 195 | 625 | 0.1 | 23 | 3 | 0.26 | 0.29 | 1.2 |
| **BH14** | 7.2 | 1360 | 215 | 210 | 24 | 57 | 1.7 | 245 | 0.44 | 0.66 | | 78 | 1000 | 0.1 | 27 | 2 | 0.36 | **0.32** | 5.4 |
| **BH16** | 7.5 | 245 | 29 | 22 | 11 | 21 | 0.1 | 48 | 0.34 | 0.1 | | 35 | 135 | 0.1 | 10 | 9 | 0.09 | 0.25 | 2.6 |
| **BH20** | 7.1 | 815 | 43 | 150 | 30 | 38 | **21** | 150 | 0.13 | 0.1 | | 220 | 355 | 0.34 | 19 | 2 | 0.1 | 0.06 | 1.7 |
| **BH20s** | 7.6 | 800 | 45 | 110 | 105 | 41 | 0.1 | 67 | 0.12 | **33** | | 200 | 445 | 0.1 | 17 | 2 | 0.1 | 0.05 | 0.11 |
| **LP1** | **8.1** | 8870 | 1490 | 120 | 590 | 100 | **1070** | 1840 | 0.77 | 0.1 | | 110 | 7170 | 29 | 695 | 130 | 0.42 | **3** | 48 |
| **SWC2** | | | | | | | 0.6 | | | 0.1 | 0.33 | | 185 | | | | | 0.13 | 0.38 |
| **SWP1** | 7.2 | 325 | 47 | 42 | 11 | 16 | 0.1 | 66 | 0.15 | 0.1 | | 12 | 230 | 0.1 | | | | **2.3** | 47 |
| **SWP2** | **8.1** | 1290 | 290 | 79 | 36 | 58 | 0.2 | 360 | 0.15 | 0.1 | | 185 | 510 | 0.1 | | | | 0.05 | 0.15 |
| **SWP4** | **9** | 1270 | 325 | 44 | 25 | 61 | 0.1 | 390 | 0.3 | 0.1 | | 320 | 210 | 0.1 | 38 | 4 | | 0.11 | 0.46 |
| **SWC-UP** | 7.3 | 35200 | 10700 | 445 | 500 | 1250 | 0.2 | 19100 | 0.45 | 0.1 | | 2490 | 235 | 0.1 | | | | 0.15 | 0.28 |
| **SWC-DOWN** | 7.3 | 36500 | 11400 | 430 | 475 | 1220 | 0.1 | 20600 | 0.46 | 0.1 | | 2510 | 230 | 0.1 | | | | 0.11 | 0.25 |
| **SWC_DOWN_2** | 7.3 | 36800 | 11600 | 440 | 480 | 1240 | 0.1 | 20600 | 0.47 | 0.1 | | 2520 | 210 | 0.1 | | | | 0.1 | 0.23 |
| **ANZECC 2000** | 6.5-8.0 | - | - | - | - | - | 1.88* | - | - | 10.6# | - | - | - | - | - | - | - | 0.3 | - |

**Notes:**

1. results and guidelines are expressed in mg/L
2. SWC_Do – SWC_Down;
3. - not analysed;
4. guidelines levels from ANZECC (2000) – *Australian and New Zealand guidelines for fresh and marine water quality for the protection of aquatic ecosystems*;
5. * - guideline from freshwater trigger values as total $NH_4$-N at different pH values - Table 8.3.7 of ANZECC (2000) - based on average laboratory pH of 7.3 from pH values presented above;
6. # - # - based on the recalculated trigger value for freshwater, Hickey 2013; and
7. values above the guidelines are **bolded**.

## TABLE 3 SURFACE WATER RESULTS – FEBRUARY 2019

| Sample | $NH_4$-N | $HCO_3$ | Sol. Fe | Tot Fe | FCs | E. Coli |
|---|---|---|---|---|---|---|
| **Units** | mg/L | mg/L | mg/L | mg/L | CFU/100ml | CFU/100ml |
| **LP1** | **1070** | 7170 | **3** | 48 | 170 | 140 |
| **SWC2** | 0.6 | 185 | 0.13 | 0.38 | - | - |
| **SWC-UP** | 0.2 | 235 | 0.15 | 0.28 | - | - |
| **SWC-Down** | 0.1 | 230 | 0.11 | 0.25 | - | - |
| **SWC_DOWN_2** | 0.1 | 210 | 0.1 | 0.23 | - | - |
| **SWP1** | 0.1 | 230 | **2.3** | 47 | - | - |
| **SWP2** | 0.2 | 510 | 0.05 | 0.15 | - | - |
| **SWP4** | 0.1 | 210 | 0.11 | 0.46 | - | - |
| **ANZECC 2000** | 1.88* | - | $0.3^{\#}$ | - | - | - |

**Notes:**

1. - = not analysed;
2. FCs = faecal coliforms;
3. E. Coli = Escherichia coli;
4. guidelines levels from ANZECC (2000) – Australian and New Zealand guidelines for fresh and marine water quality for the protection of aquatic ecosystems;
5. * = guideline from marine trigger values as total $NH_4$-N at different pH values - Table 8.3.7 of ANZECC (2000) - Table 8.3.7 of ANZECC (2000) - based on average laboratory pH of 7.3 from pH values presented in Table 1;
6. # = interim indicative working level presented in section 8.3.7 of ANZECC 2000 (based on Canadian derived guidelines); and
7. values above the guidelines are **bolded.**

## TABLE 4 RATIOS OF PRINCIPAL IONS – FEBRUARY 2019

| Bore | Na/Cl | Na/Ca | Mg/Ca | Ca/K | $Cl/SO_4$ | $Cl/HCO_3$ | K/TDS (%) | L/N (%) |
|---|---|---|---|---|---|---|---|---|
| BH1c | 1.31 | 4.33 | 1.24 | 1.14 | 85.47 | 0.43 | 5.97 | 63.31 |
| BH2 | 1.17 | 1.52 | 0.62 | 7.32 | 4.69 | 0.67 | 2.91 | 14.98 |
| BH3 | 0.51 | 0.43 | 0.26 | 7.62 | 3.34 | 1.10 | 4.38 | 51.94 |
| BH4 | 0.99 | 0.69 | 0.36 | 12.75 | 2.03 | 0.63 | 2.45 | 12.40 |
| BH13 | 1.47 | 0.47 | 0.36 | 12.03 | 0.73 | 0.29 | 3.08 | 10.49 |
| BH14 | 1.35 | 0.89 | 0.45 | 17.07 | 4.26 | 0.42 | 1.76 | 5.47 |
| BH16 | 0.93 | 1.15 | 1.57 | 3.90 | 1.86 | 0.61 | 4.49 | 15.56 |
| BH20 | 0.44 | 0.25 | 0.42 | 9.75 | 0.92 | 0.73 | 3.68 | 22.12 |
| BH20s | 1.04 | 0.36 | 0.61 | 2.04 | 0.45 | 0.26 | 13.13 | 70.46 |
| LP1 | 1.25 | 10.82 | 1.37 | 0.40 | 22.66 | 0.44 | 6.65 | 97.08 |
| SWP1 | 1.10 | 0.98 | 0.63 | 7.45 | 7.45 | 0.49 | 3.38 | 10.67 |
| SWP2 | 1.24 | 3.20 | 1.21 | 4.28 | 2.64 | 1.21 | 2.79 | 8.50 |
| SWP4 | 1.29 | 6.44 | 2.29 | 3.43 | 1.65 | 3.20 | 1.97 | 5.86 |
| SWC-UP | 0.86 | 20.96 | 4.63 | 1.74 | 10.39 | 139.89 | 1.42 | 4.04 |
| SWC-DOWN | 0.85 | 23.11 | 4.68 | 1.77 | 11.12 | 154.16 | 1.30 | 3.64 |
| SWC_DOWN_2 | 0.87 | 22.98 | 4.65 | 1.79 | 11.08 | 168.84 | 1.30 | 3.62 |

Notes:

1. % indicates ratios are presented in percentage in that column; and
2. L/N = leachate/non-leachate ratio ; [(K + NH4 + NO3 + NO2)/(Ca + Mg + Na)] x 100.

# TABLE 5 SUMMARY OF GAS ANALYSIS – FEBRUARY 2019

| Location | GA 5000 V/V% | ILU V/V% |
|---|---|---|
| Landfill cap | 0.5 | **0.48** |
| Main weigh bridge, weigh bridge office and landfill office sheds | 0 | 0.00025 |
| Dunmore Resource & Recycling Services | 0 | 0.00026 |
| GUIDELINES | 1.25 % v/v / 0.05 % v/v | 1.25 % v/v / 0.05 % v/v |

**Notes:**

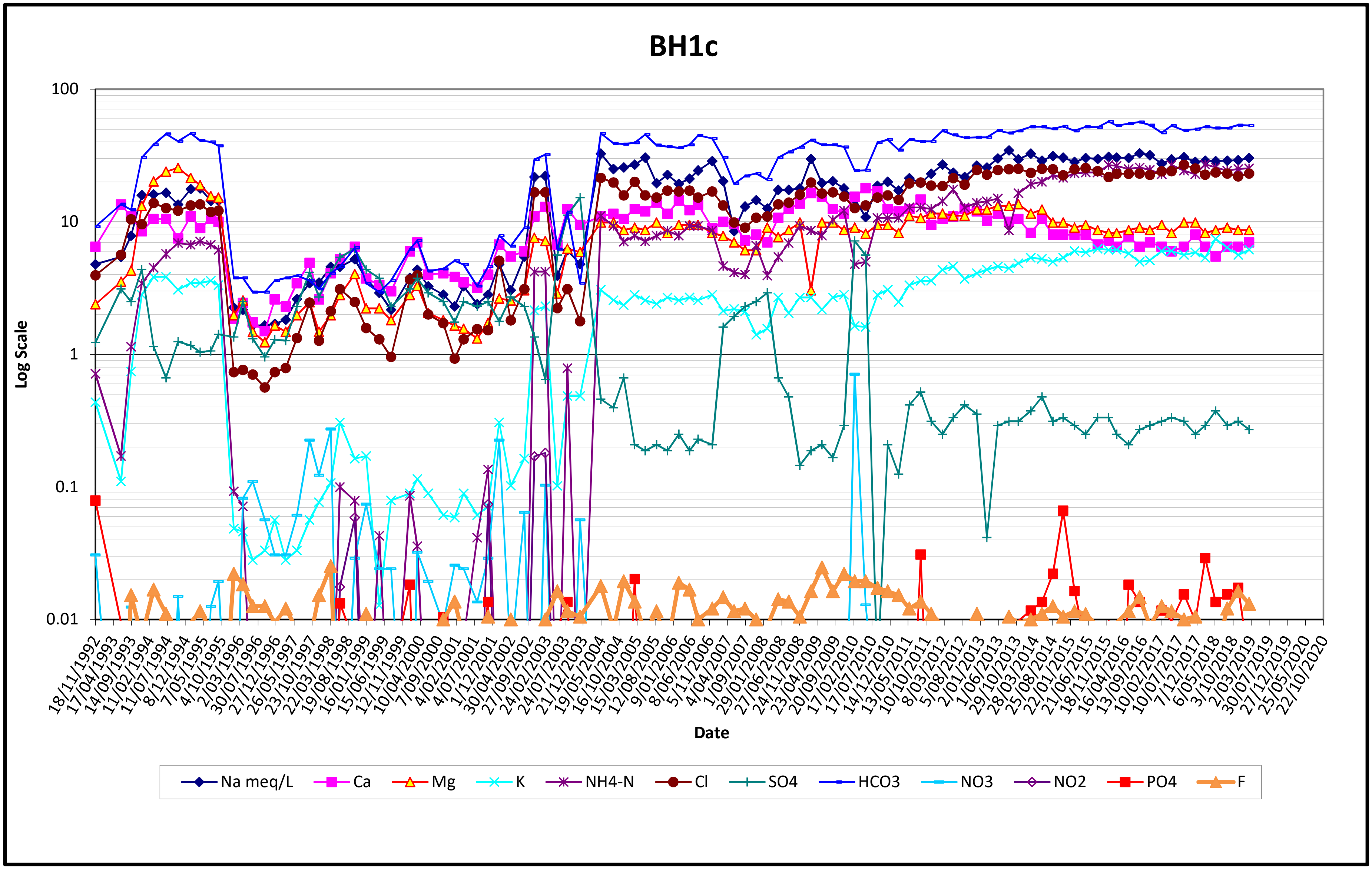
1. results and guidelines are expressed in V/V %;
2. Guidelines are as per the NSW EPA (1996) reporting accumulation value of 1.25 % v/v $CH_4$; and surface emission trigger value (500 ppm or 0.05 % v/v); and
3. values above the guidelines are **bolded**.

## TABLE 6 QA/QC – FEBRUARY 2019

| Analytes | BH13 | FD1 | RPD(%) |
|---|---|---|---|
| **pH** | 7.30 | 7.50 | 2.70 |
| **TDS** | 975 | 965 | 1.03 |
| **Na+** | 100 | 105 | 4.88 |
| **Ca++** | 185 | 180 | 2.74 |
| **Mg++** | 40 | 41 | 2.47 |
| **K+** | 30 | 32 | 6.45 |
| **NH4-N** | 1 | 1.2 | 18.18 |
| **Cl-** | 105 | 105 | 0.00 |
| **SO4--** | 195 | 190 | 2.60 |
| **HCO3-** | 625 | 640 | 2.37 |
| **NO3-** | 0.05 | 0.05 | 0.00 |
| **PO4---** | 0.1 | 0.1 | 0.00 |
| **F-** | 0.22 | 0.23 | 4.44 |
| **BOD** | 1 | 1 | 0.00 |
| **Fe.D** | 0.29 | 0.26 | 10.91 |
| **Fe.T** | 1.2 | 1.2 | 0.00 |
| **Mn.D** | 0.26 | 0.25 | 3.92 |
| **TOC** | 3 | 2 | 40.00 |

**Notes:**
1. results are expressed in mg/L;
2. RPD – Relative Percentage Difference
3. NA - not analysed;
4. values requiring further investigation are **bolded**.

# ATTACHMENT 3 SCHOELLER PLOTS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Ca
Mg
K
NH4-N
Cl
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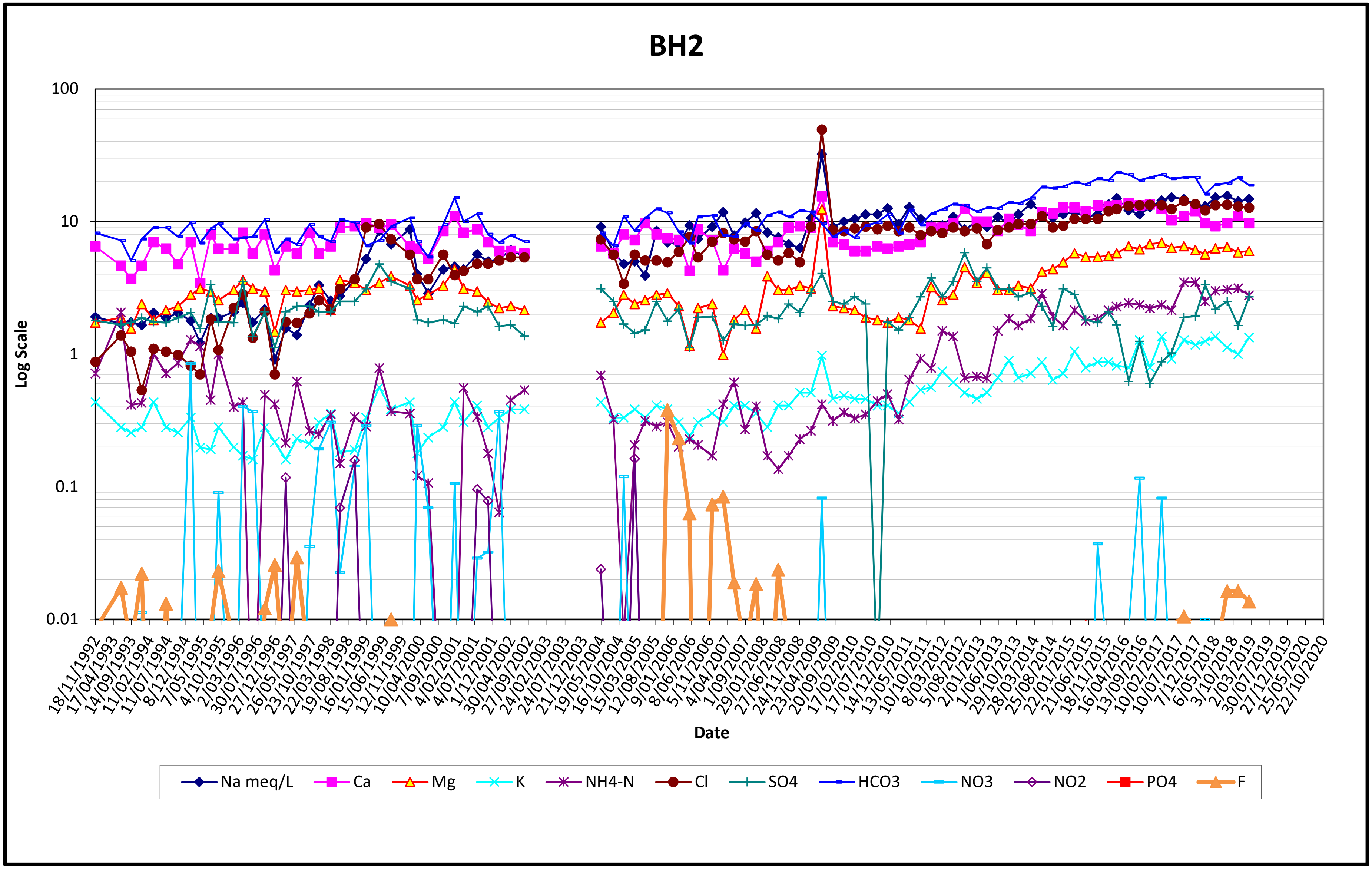
HCO3
NO3
NO2
PO4
F



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Log Scale
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Na meq/L
Ca
Mg
K
NH4-N
Cl
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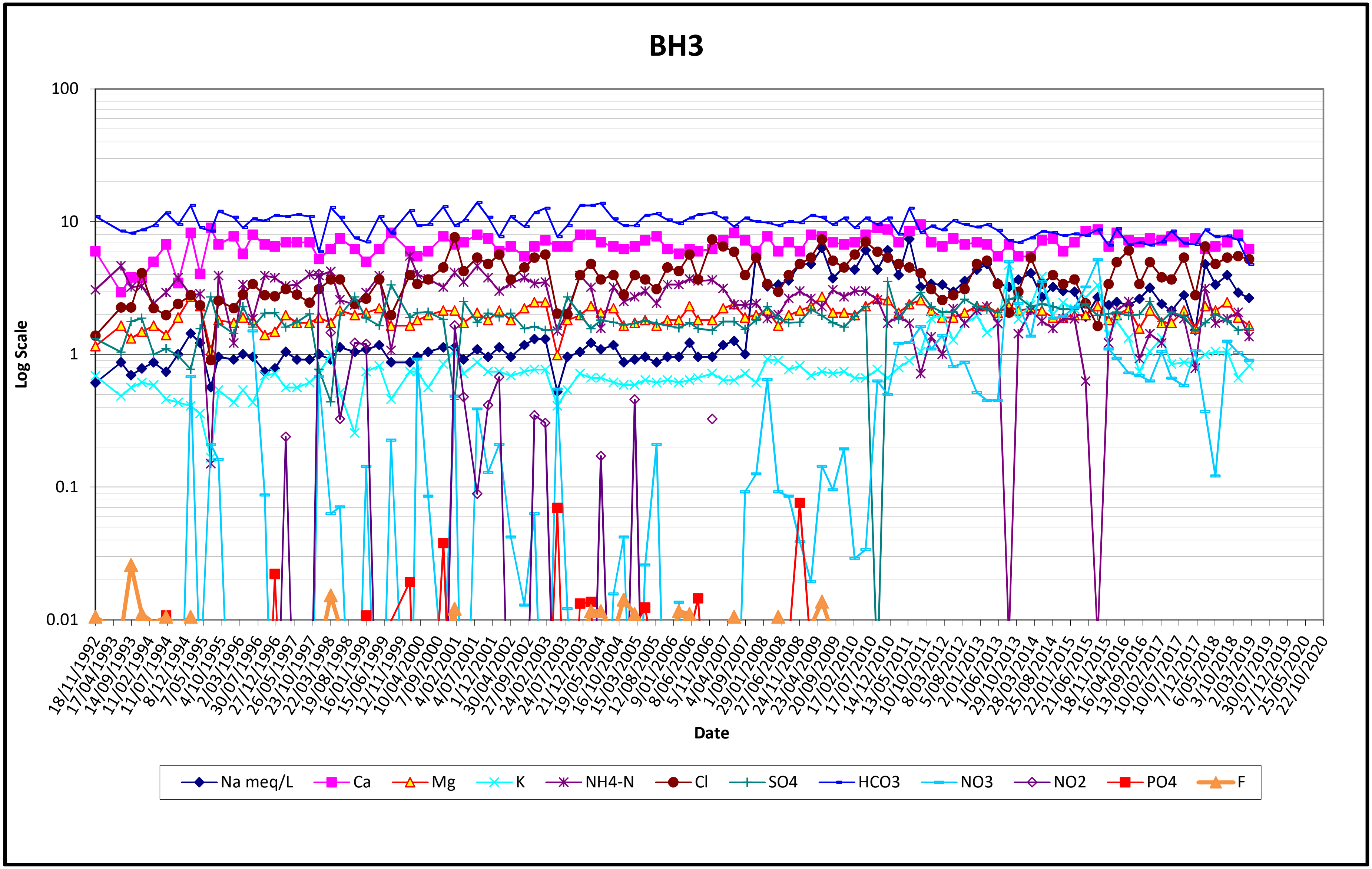
HCO3
NO3
NO2
PO4
F



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Mg
K
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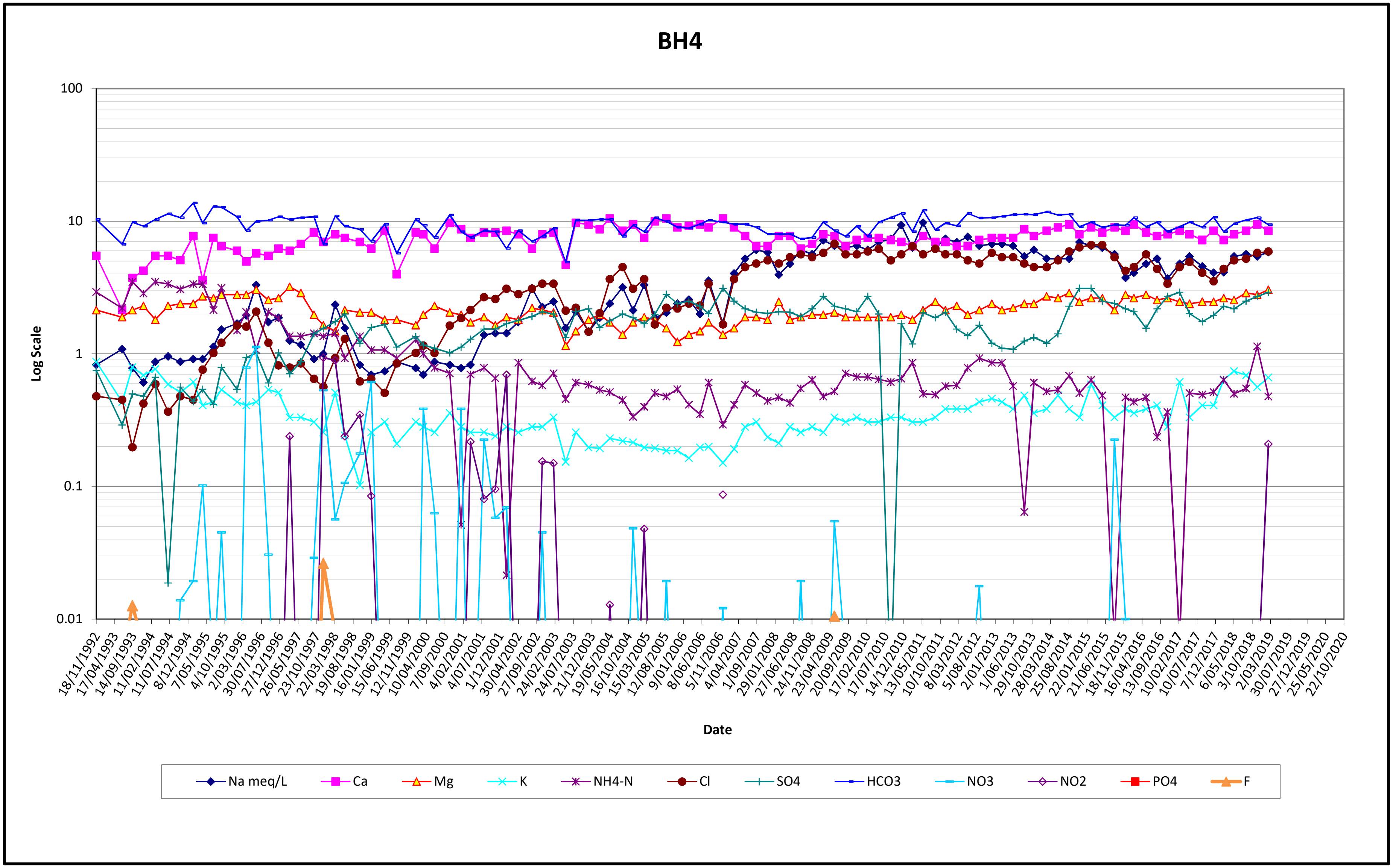
NO3
NO2
PO4
F



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Mg
K
NH4-N
Cl
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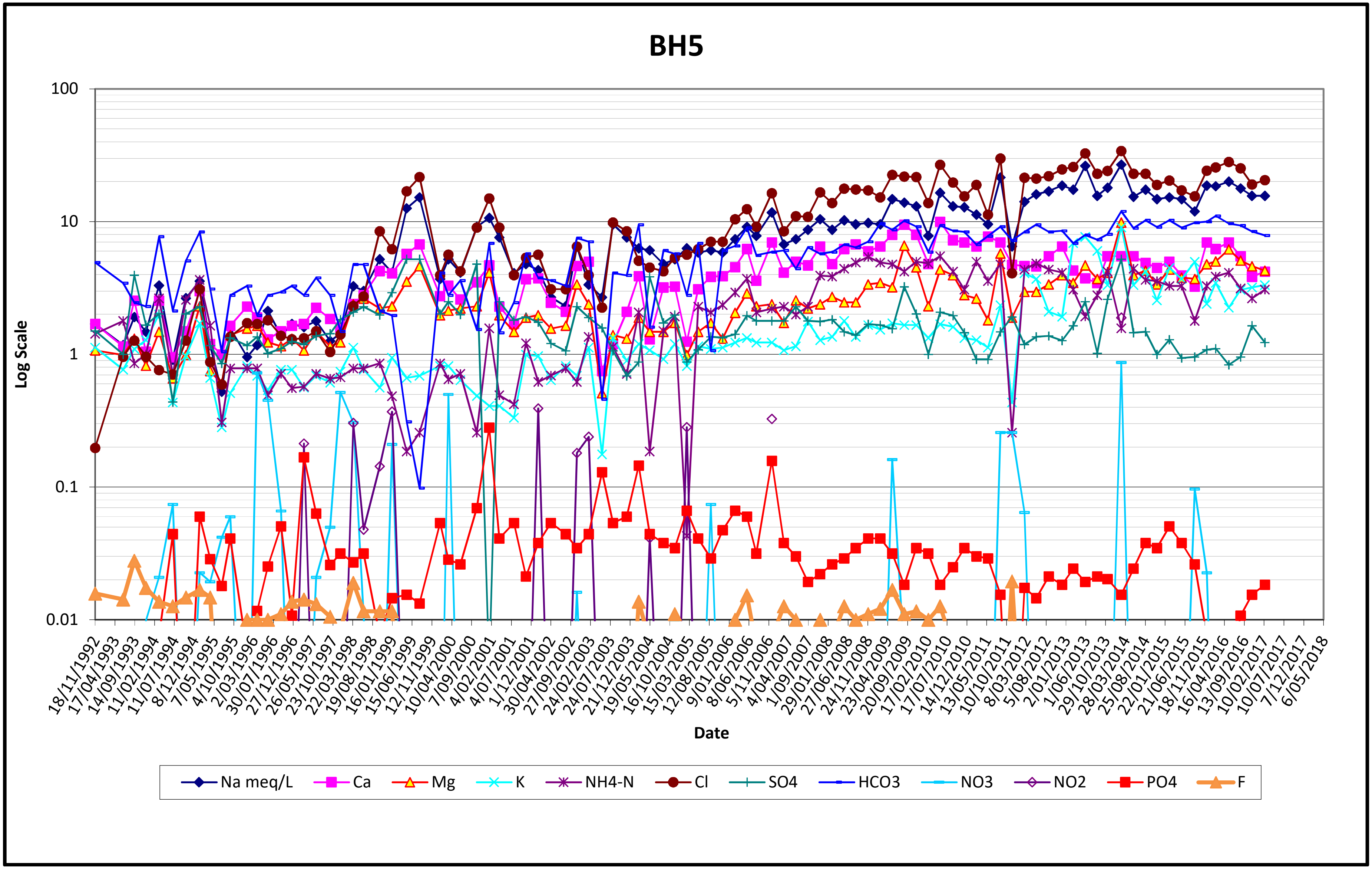
NO3
NO2
PO4
F



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7/12/2017
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PO4
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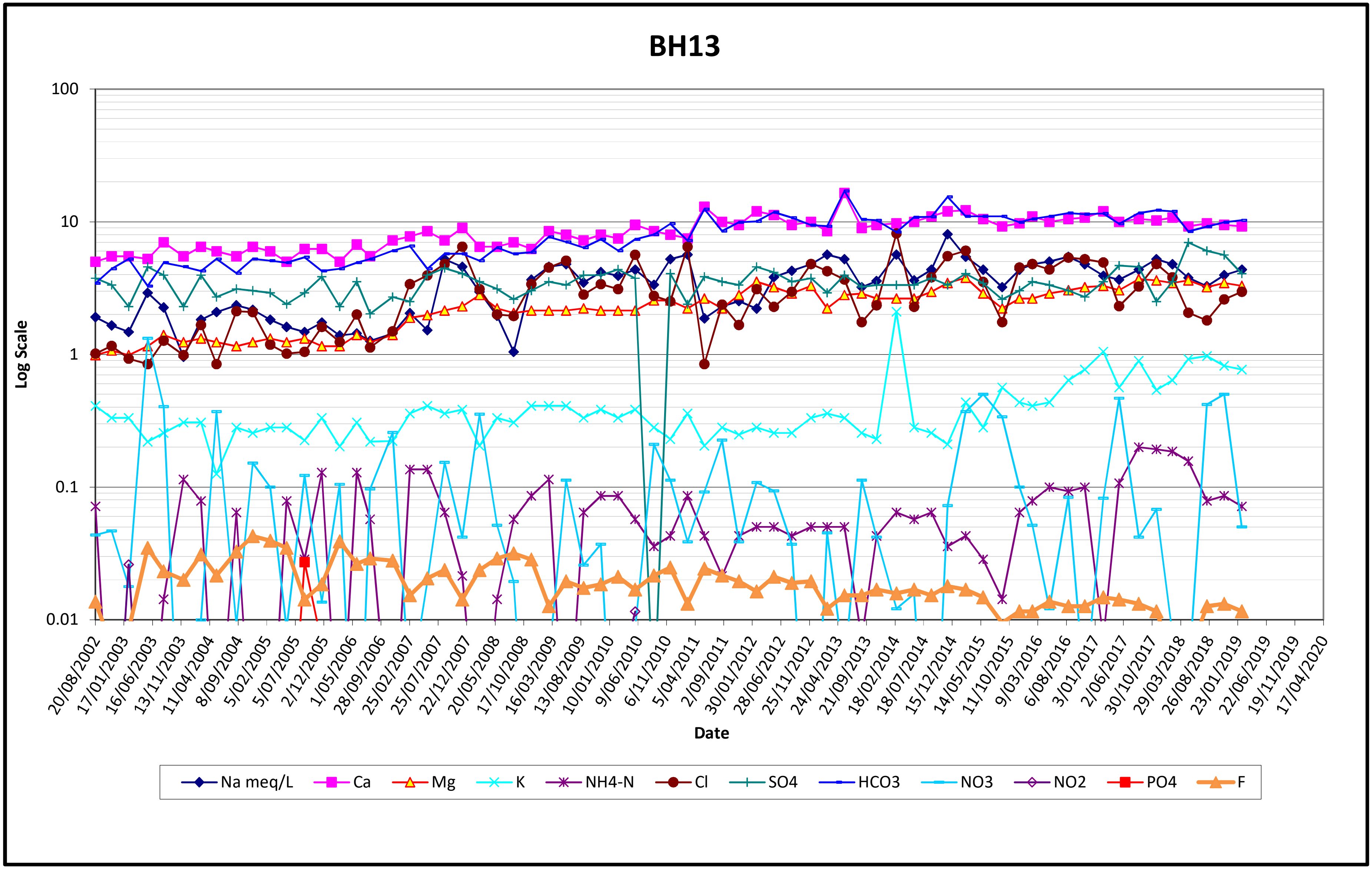

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19/11/2019
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NO2
PO4
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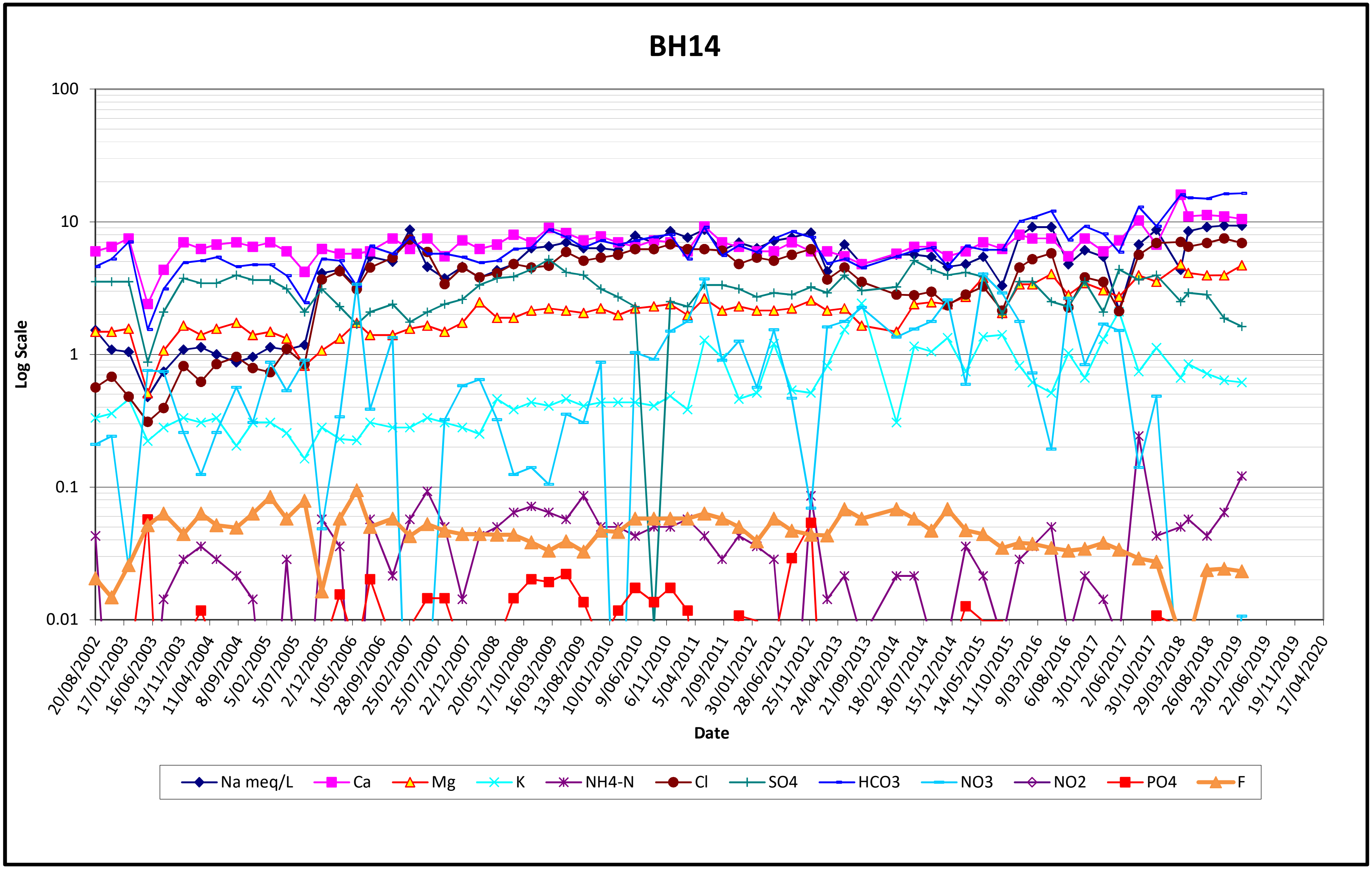
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6/08/2016
3/01/2017
2/06/2017
30/10/2017
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26/08/2018
23/01/2019
22/06/2019
19/11/2019
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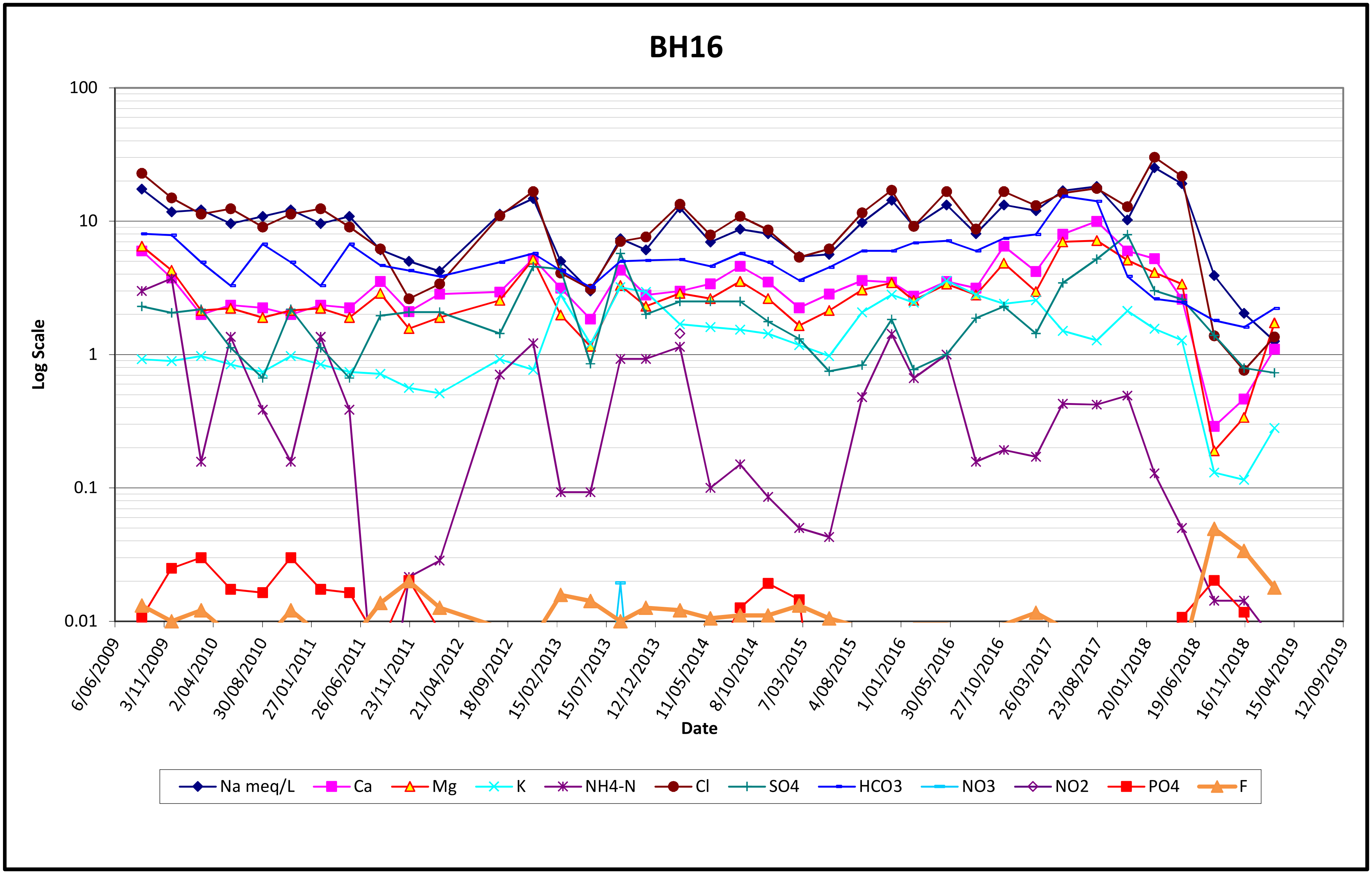
F



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0.01
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8/10/2014
7/03/2015
4/08/2015
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15/04/2019
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Ca
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SO4
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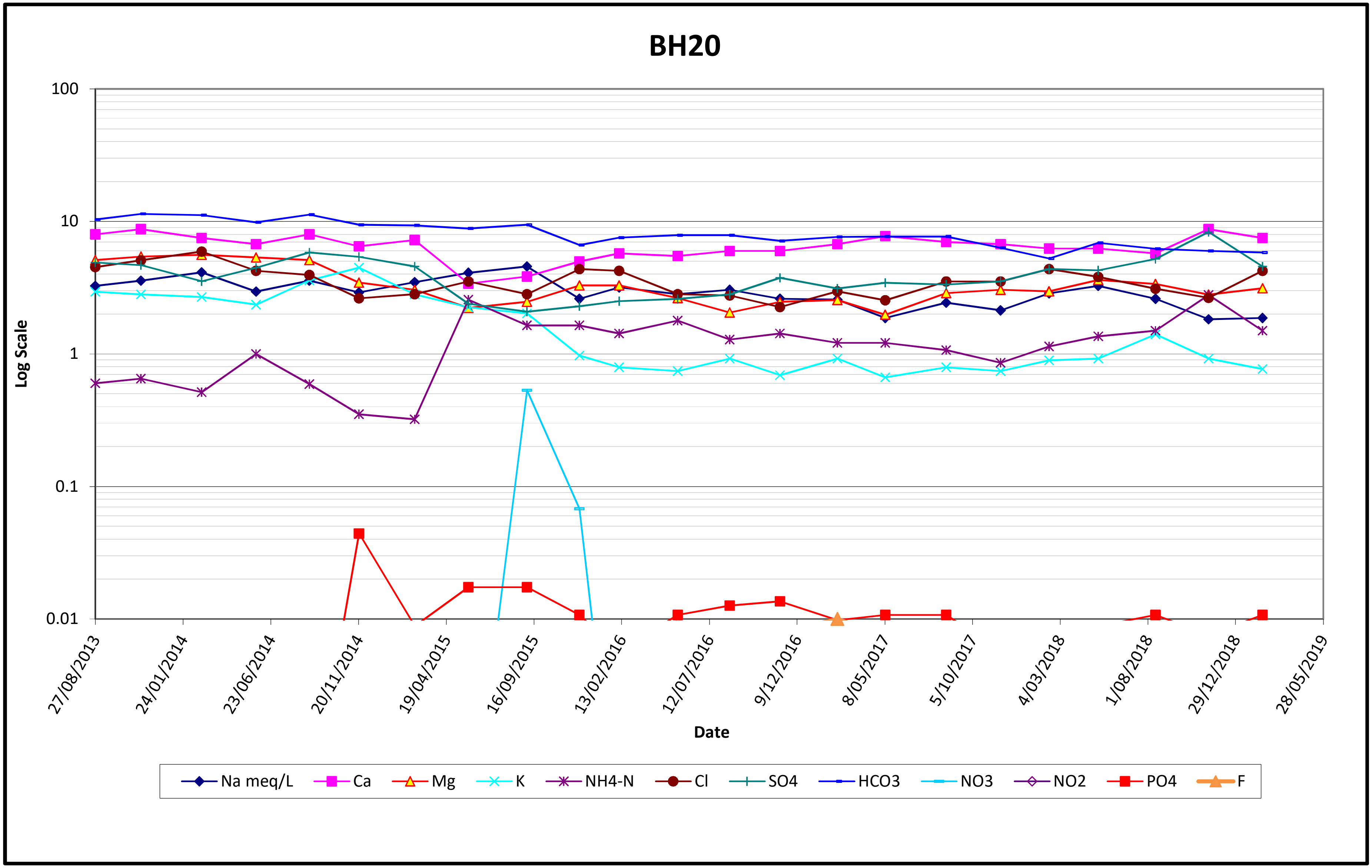
NO2
PO4
F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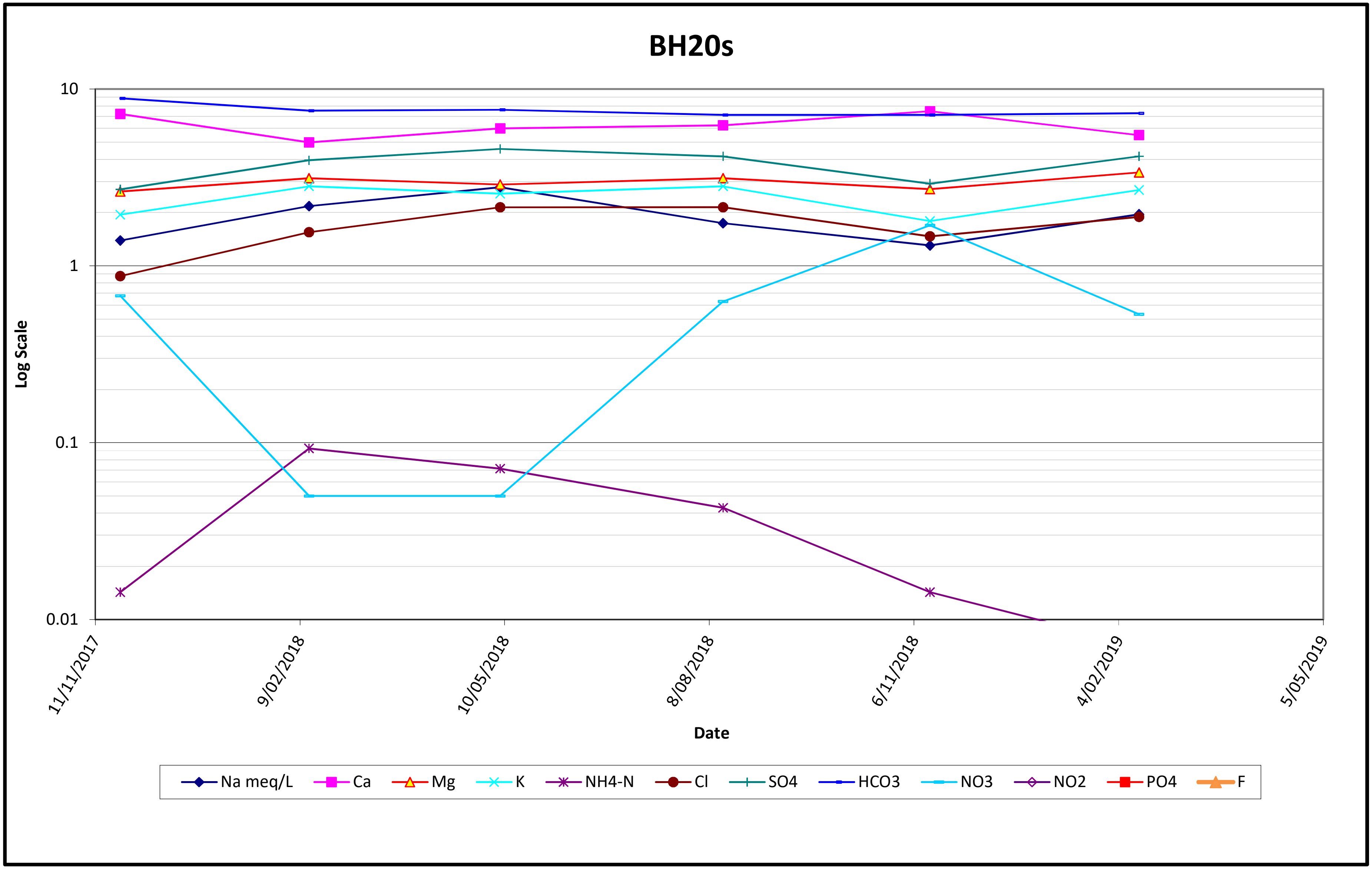
NO2
PO4
F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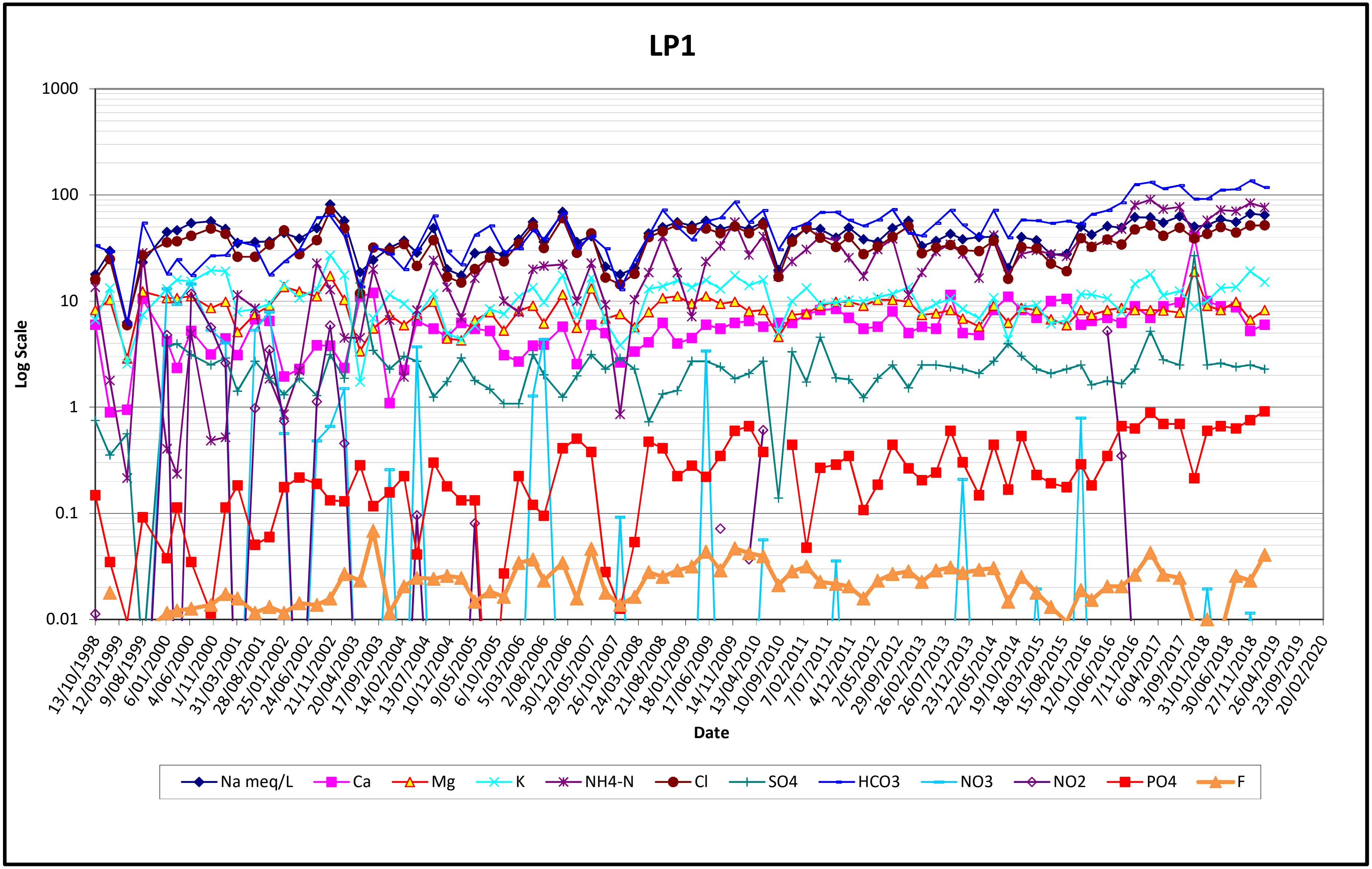

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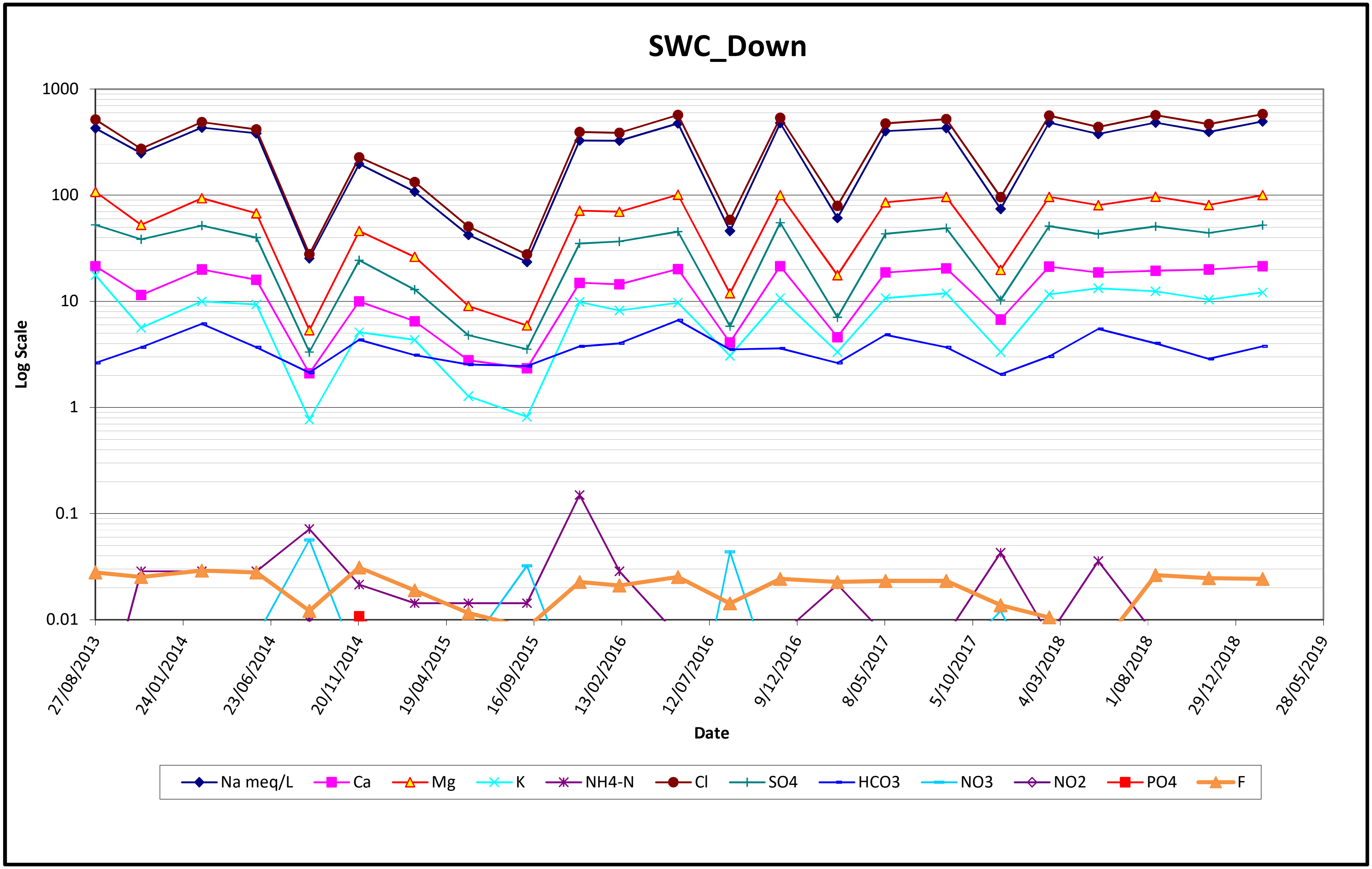

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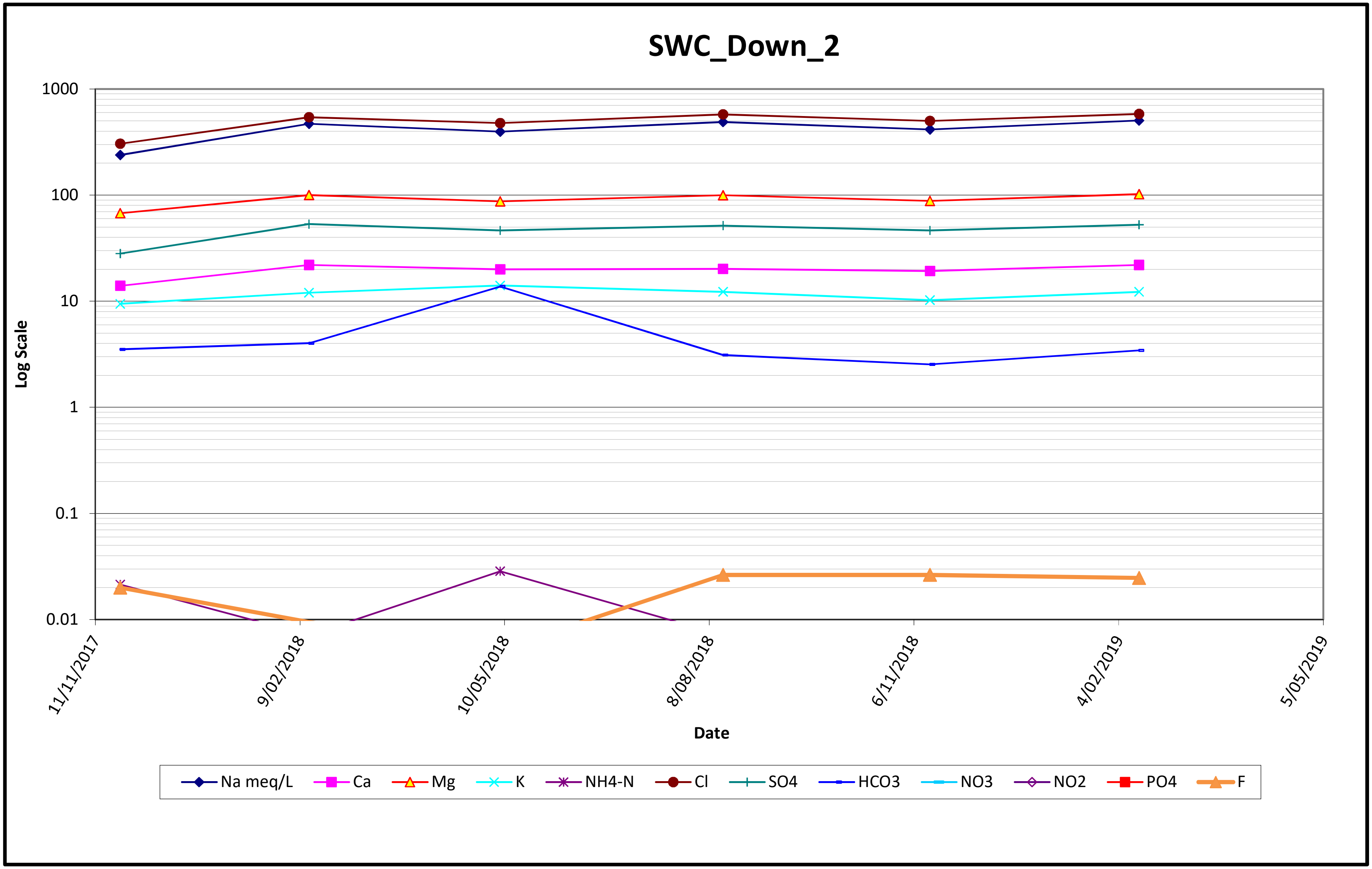
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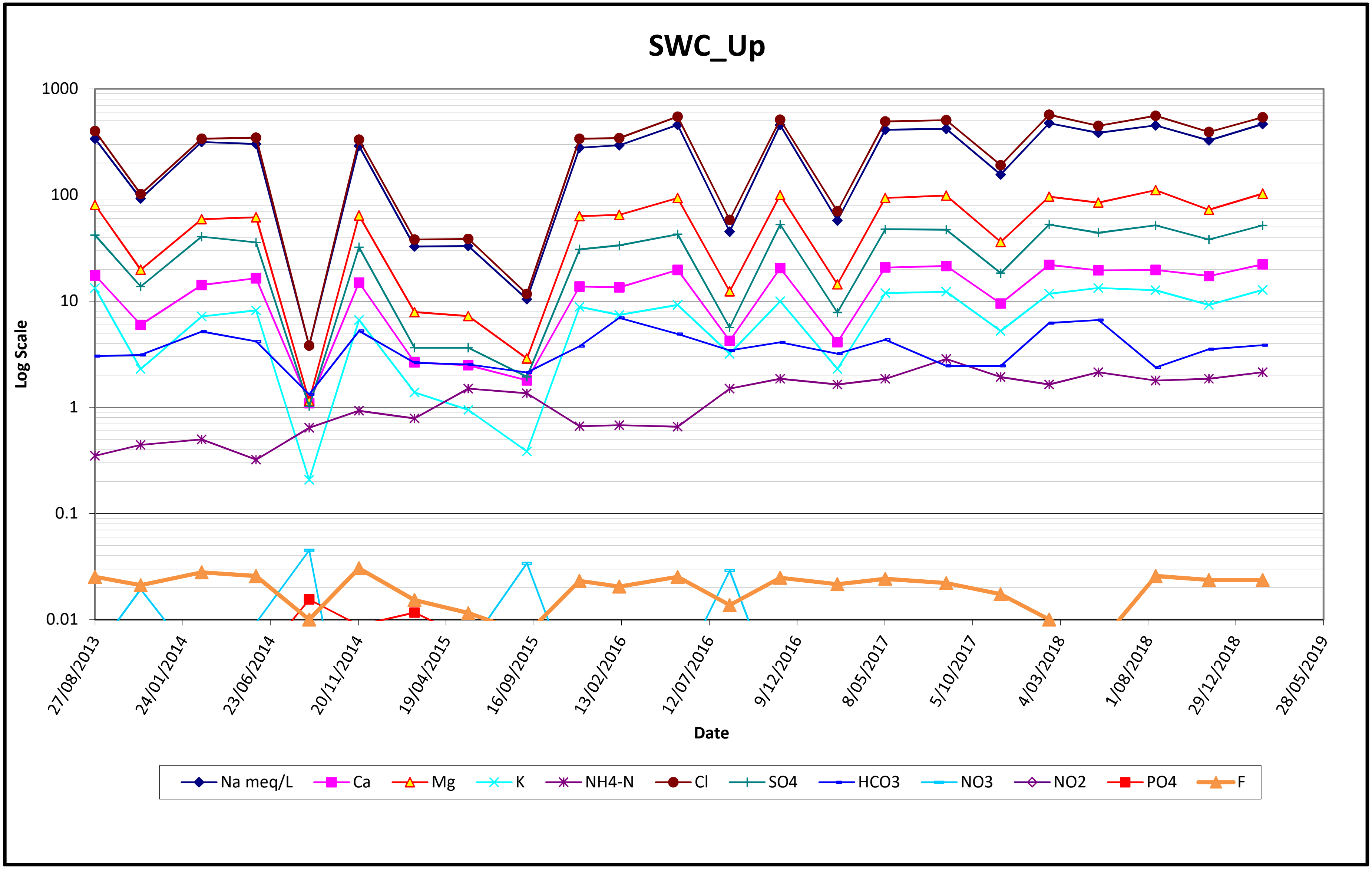

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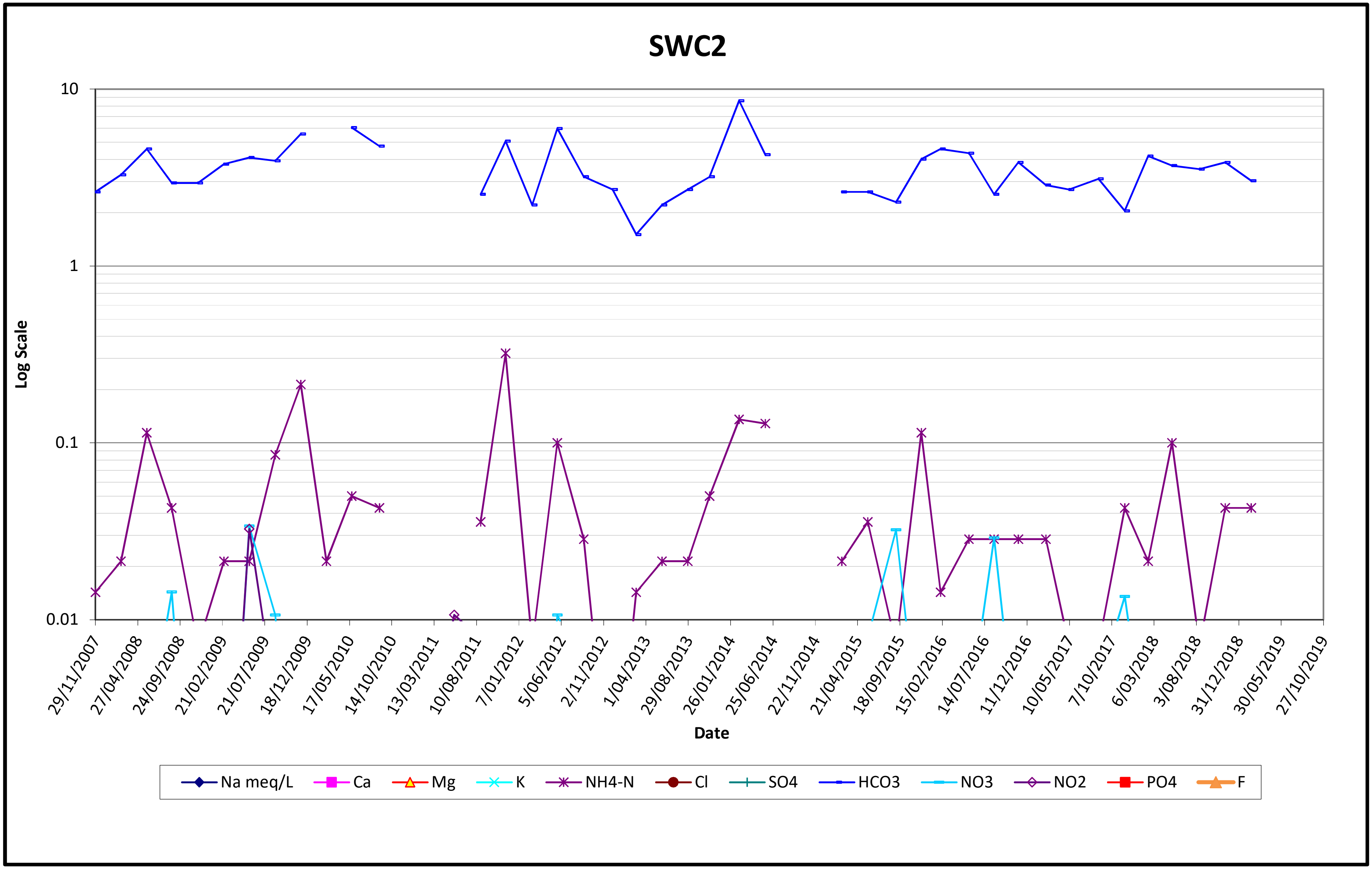

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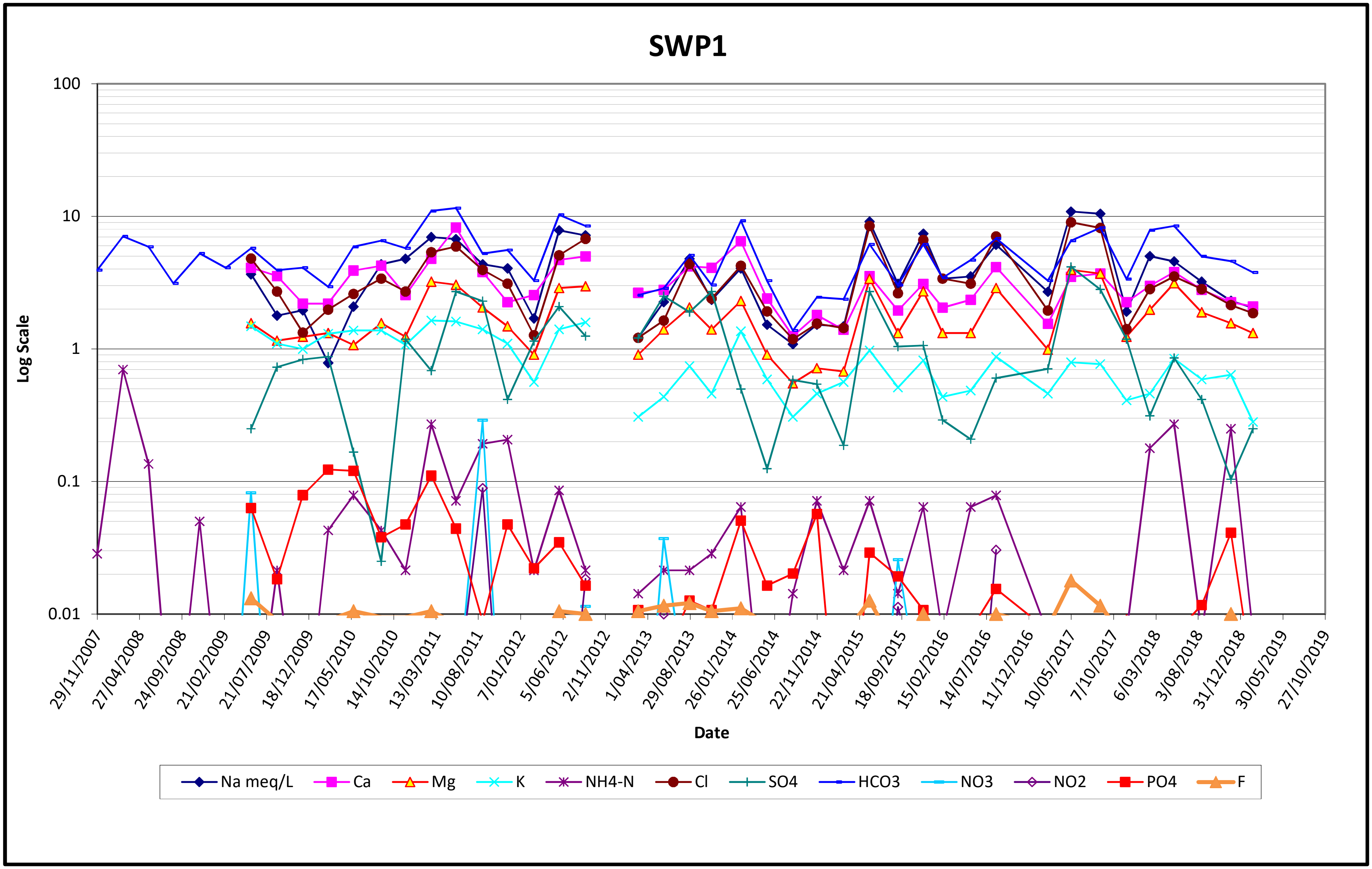
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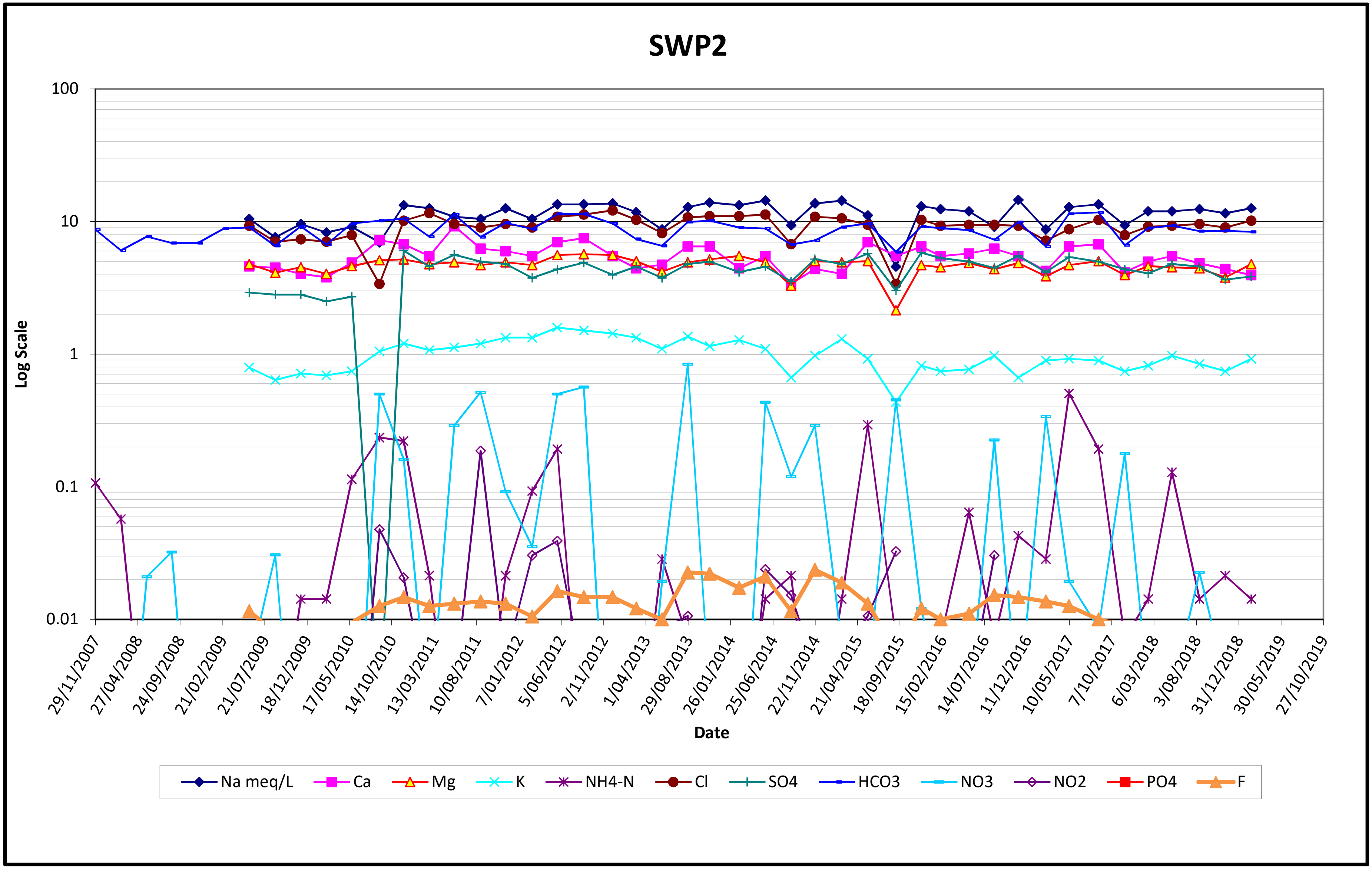
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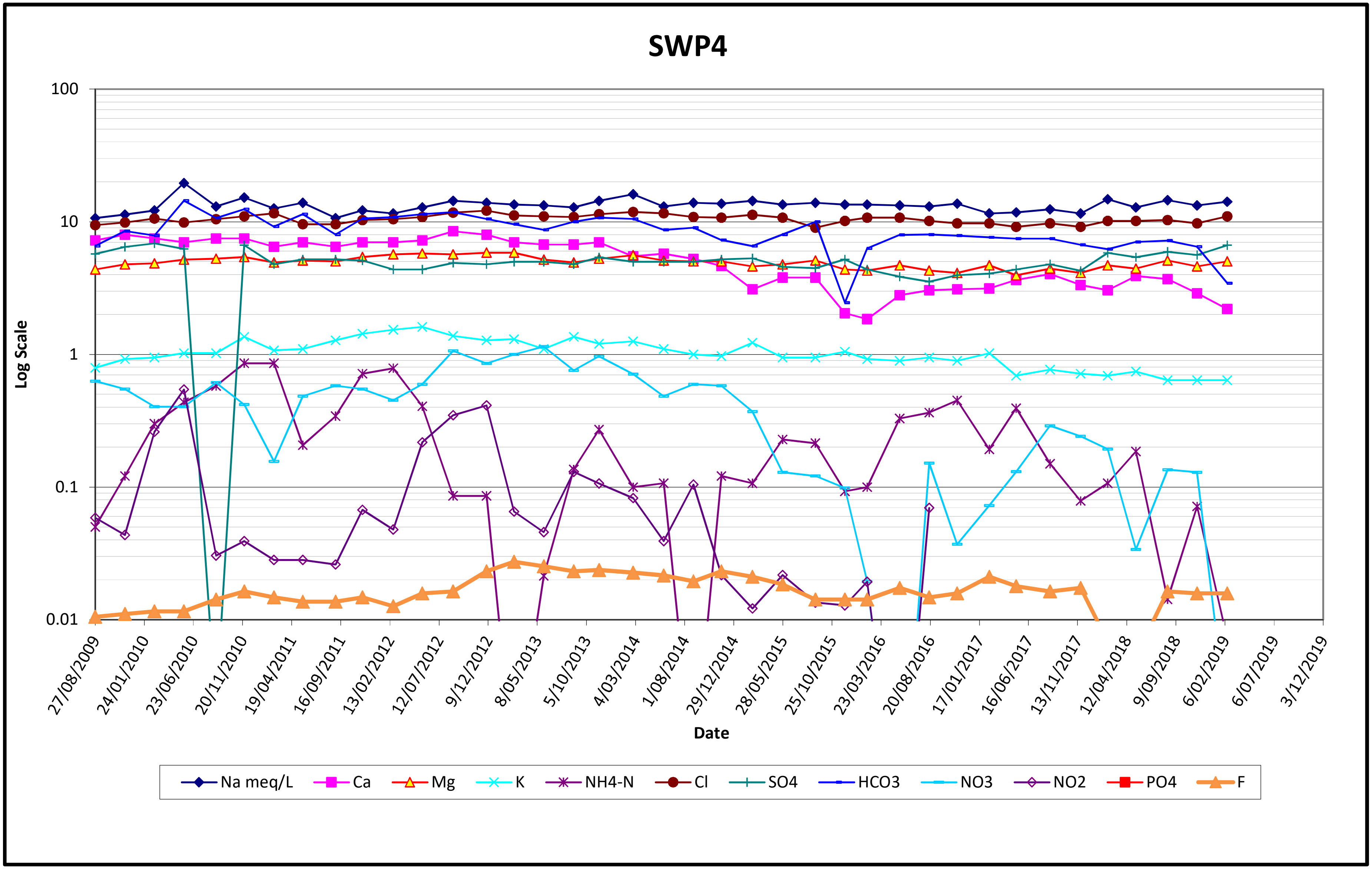
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Date
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