



28 June 2016

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,

May 2016 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 landfilling activities on the environment.

2.0 Scope of works

The quarterly May 2016 monitoring round was undertaken on 18 and 19 May 2016. During the May 2016 monitoring round groundwater, surface water, leachate, gas and dust samples were collected in and around the site.

Groundwater samples were collected from 15 monitoring bores (BH1c to BH6 and BH12 to BH20) while three bores (BH8-10) were measured for standing water level (SWL) only. Surface water was collected from the leachate pond (LP1), four on site retention ponds (SWP1, SWP2, SWP4 and SWP5) and Rocklow Creek (SWC2, SWC_UP and SWC_Down). 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 (Figure 3). Landfill gas was measured in the field using an Inspectra Laser Unit (ILU) and a GA5000 Landfill Gas Analyser (GA5000).



3.0 Field measurements

Prior to purging, monitoring bores were measured for standing water level (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 undertaken was 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 May 2016 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 (SWC2, SWC_Up and SWC_Down) – total and soluble iron, turbidity, nitrate, nitrite, ammonium and bicarbonate;
- surface water SWP1, SWP2, SWP4, SWP5, SWC_Up and SWC_Down – ionic balance, total and soluble iron and turbidity;
- additional analyses for SWP4, SWC_Up and SWC_Down – TOC and BOD; and
- leachate pond – ionic balance, TOC, BOD, total and soluble iron, soluble manganese, turbidity, faecal coliforms, *E.Coli*, TPH, PAH, Phenols and BTEX.

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). Both 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 May 2016 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 (Environmental Earth Sciences NSW, 2010, 2011b, 2012b, 2013, 2014, 2015 and 2016).

Accumulative rainfall for February, March and April 2015-2016 was 66.2 mm with all three months receiving lower than average rainfall (2-40 mm range) (*BOM – Albion Park weather station*). In comparison to the last monitoring period in February 2016, standing groundwater levels decreased by 0.01 – 0.28 m across the site in all bores except for bores



BH3, BH5, BH18 and BH19, which increased by 0.03 to 0.35m. Previous monitoring results have shown that bores BH19 and BH20 appear to be tidally influenced from the adjacent Rocklow Creek which results in fluctuating SWLs in comparison to the other bores. All groundwater levels are still within historic levels.

Relative groundwater levels for bores BH19 and BH20 have not been included in the construction of the groundwater contours (Figure 2 – Attachment 1) as previous results have highlighted issues with the survey data.

5.2 Groundwater

5.2.1 Groundwater sampling locations impacted by leachate

Field and laboratory results from the May 2016 sampling round, specifically from bores BH1c, BH3, BH5, BH15, BH16 and BH20, displayed chemistry that can be related to leachate impact. This 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 at a ratio of >20 (BH1c, BH3, BH5, BH15, BH16 and BH20) as shown in Table 4 (Attachment 1).

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, Attachment 3). This continued during the current monitoring event and the groundwater was found to have a dark amber colour and putrescible waste odour noted in combination with elevated TDS (4,120 mg/L), K^+ (225 mg/L) [resulting in low Ca/K – 1.34] and NH_4^+-N (350 mg/L) concentrations. The absence of oxygen (negative redox, Table 1) and presence of soluble Fe^{2+} indicate a high chemical or biological demand in response to microbial respiration. It is noted that BOD has fluctuated since the bore was installed, ranging from 830 mg/L to 15 mg/L. BOD increased from 15 mg/L in November 2015 to 160 mg/L in the next two monitoring rounds (February 2016 and May 2016). Further evidence of microbial activity is elevated HCO_3^- resulting in a low Cl/ HCO_3^- ratio of 0.42 suggesting microbial respiration (Table 4). This suggests some degradation of the leachate plume has occurred in this monitoring bore.

Groundwater from bore BH3 showed a reduction in nitrate (45 mg/L) and increasing concentrations of ammonium (35 mg/L) in comparison to the February 2016 monitoring round. This change has been associated with a reduction in oxygen and a negative ORP (-87 mV) resulting in NO_3^- converting to NH_4^+-N . The groundwater was moderately fresh (TDS, 1305 mg/L) and clear with suspended organic particulates. No odour was noted during sampling. The L/N ratio was similar to the February 2016 event at 58.4, however due to the low TDS content of the water the L/N ratio must be used with some caution. Long term trends (since 1992) show that K^+ concentrations have generally had an increasing trend since February 2011. Nitrogen species (NO_3^- , NO_2^- and NH_4^+-N) have remained within historical levels.

Commensurate with previous monitoring events, leachate indicators in the groundwater from BH3 are elevated and above levels found at the up-gradient bores BH2 and BH14. These results suggest the presence of waste dumps in the vicinity of bore BH3 outside the



designated cells near bores BH2 and BH14. This was confirmed during installation of bore BH3, as shallow waste was encountered during drilling.

Bore BH5's groundwater was brown in colour, with a slight putrescible waste odour and a highly negative redox (Table 1). A dominance of $\text{NH}_4^+\text{-N}$ over NO_3^- is further evidence of a highly reducing environment. In comparison to historical data, leachate indicators have remained relatively stable (Schoeller plot BH5, Attachment 3). Leachate impact is also demonstrated by an elevated K/TDS ratio compared to other non impacted sites (Table 4). A K/TDS ratio $>4\text{-}10$ indicates elevated potassium in relation to the other dissolved analytes. It is likely that the ongoing influence at bore BH5 is contributed to a leachate plume originating from several possible sources, including a previous overspill of the leachate ponds, the former unlined landfill cell and organic waste stockpiling activities.

Bore BH15 displayed an elevated L/N ratio which can be largely associated with a high K^+ concentration (730 mg/L) compared to non leachate influenced sites with $\text{K}^+ < 50$ mg/L (Schoeller plot BH15, Attachment 1). $\text{NH}_4^+\text{-N}$ is also elevated at 210 mg/L, compared to other non-impacted locations at the site, which is consistent with previous monitoring rounds. Bore BH15 is located near a drainage line with the groundwater bearing zone <0.5 m below the ground surface. Groundwater therefore has the potential to be influenced from local onsite and offsite works and surface water. Activities such as stockpiling of mulch material have been undertaken up-gradient of bore BH15 and it is possible that runoff from these stockpiles is also influencing the water chemistry. Field observations of a negative redox (negative ORP) and amber coloured water are indicative of a reducing environment. This reducing environment promotes reactions, which in turn results in the dominance of $\text{NH}_4^+\text{-N}$ and the elevated levels of soluble Mn^{2+} (0.44 mg/L) and Fe^{2+} (17 mg/L). In addition, bore BH15 is located within a swampy environment where microbiological activity drives reducing reactions that can result in naturally high levels of leachate indicators such as organic carbon, $\text{NH}_4^+\text{-N}$ and HCO_3^- .

Bore BH16 is located in a swampy area with groundwater field observations recording an amber colour and a strong leachate odour. Recorded ORP indicates a highly reducing environment (-224 mV) resulting in the dominance of $\text{NH}_4^+\text{-N}$ over NO_3^- . These results are consistent with nearby bores BH5 and BH16. Over the past four monitoring rounds $\text{NH}_4^+\text{-N}$ concentrations have exceeded the ANZECC (2000) criteria and the L/N ratio has also been in excess of 20. The combination of elevated ammonium (14 mg/L), L/N ratio (37) and relatively high K/TDS ratio (9.5) indicate that groundwater at bore BH16 is leachate impacted. Stockpiles of organic waste in close proximity to bore BH16 could be influencing the groundwater chemical characteristics. Bores BH16 and BH15 are located close to a drainage channel where offsite impacts can readily influence the chemical characteristics of the shallow groundwater.

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, and slight yellow colour of the groundwater. The L/N ratio was consistent with results from the last monitoring round (26.1) with $\text{NO}_3^- < 0.1$ mg/L and $\text{K}^+ 29$ mg/L. However, the TDS was 705 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 were elevated at 20 mg/L however other landfill indicators were low or absent.

5.2.2 Remaining groundwater sampling locations

During the May 2016 monitoring round, ionic chemistry indicated that bores BH2, BH4, BH6b, BH12, BH13, BH14, BH17, BH18 and BH19 only displayed slight to no leachate



influence. Chemical composition of each of these bores has been depicted in Schoeller plots in Attachment 3.

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. May 2016, NH_4^+ -N concentrations (34 mg/L) exceeded the ANZECC (2000) trigger levels. Bicarbonate (HCO_3^-), Na^+ , Cl^- , Ca^{2+} , Mg^{2+} , K^+ and NH_4^+ -N concentrations in groundwater have all been increasing since January 2008, with the change in ammonium concentrations having an uncharacteristically steep gradient (Table 2, Schoeller plot BH2, Attachment 3). No oxygen, negative redox and an elevated soluble Fe^{2+} and BOD (Table 2) suggest microbial respiration and therefore degradation of the leachate is occurring at this location.

Bore BH4 showed little to no leachate influence based on field observations such as clear/slightly green water, neutral pH, and a mild H_2S odour. Groundwater chemistry, such as relatively low K^+ and nitrogen species (in comparison to leachate affected bores) and a high Ca/K ratio of 21.5 also indicate limited leachate influence. During the May 2016 monitoring round NO_3^- was not detected and NH_4^+ -N at 6.6 mg/L exceeded the ANZECC (2000) trigger levels. The historical chemical composition of the groundwater has remained relatively stable since monitoring began in 1992 (Schoeller plot BH4, Attachment 3). This site is located down gradient of the unlined old landfill cell and will continue to be monitored to assess any potential leachate migration towards Rocklow Creek.

Groundwater from BH6b had no odour, was amber in colour and has an L/N ratio of 8.49, suggesting a slight leachate impact. It is likely that any influence of leachate at bore BH6b is due to its proximity to the unlined landfill cell (Figure 1). The water within bore BH6b has a TDS of 1,090 mg/L, meaning the L/N ratio is sensitive to minor changes in chemistry and therefore reducing the effectiveness of the ratio. Limited nitrogen species were detected however a NH_4^+ -N result of 7.8 mg/L could indicate minor though diminishing leachate impact. All analytes were within historical ranges. No oxygen, negative redox and an elevated soluble Fe^{2+} and BOD (Table 2) suggest microbial respiration and therefore degradation of the leachate is occurring at this location. Ongoing earth works/ mulching activities associated with green waste stockpiles have been noted in proximity to bore BH6b since May 2014. Changes to the physical conditions around bore BH6b may influence groundwater chemistry.

Field observations for bore BH12 indicated the groundwater at this location was clear with no odour. Stockpiling of green waste has been observed at nearby locations. Pertinent chemical indicators at this site showed a high Ca/K ratio (12.4) and moderately low L/N ratio (10.25) both suggesting limited to slight leachate influence. This bore will continue to be monitored as it is situated hydraulically down gradient of the leachate ponds and landfill (Figure 1).

Bore BH13 is located 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 May 2016 monitoring round shows no indication that the groundwater in this bore is currently impacted by leachate. The chemical composition of the groundwater has remained consistent since monitoring began in 2002 (Schoeller plot BH13, Attachment 3). Further monitoring will help to monitor any trends which develop at this location.

In May 2016 the L/N ratio at bore BH14 fell below 10 for the first time since the December 2012 monitoring round. Generally, most groundwater constituents at bore BH14 have remained within historical ranges (Schoeller plot BH14, Attachment 3). As previously noted surface water pond SWP3, directly up gradient of bore BH14, has been completely filled and



is operating as a new landfill cell (Figure 2). Groundwater conditions appear unchanged with results showing an oxygenated environment, where NO_3^- was the dominant N species. The concentration of NH_4^+ -N remained below the ANZECC 2000 trigger value for 95% protection of aquatic ecosystems. Nitrate (NO_3^-) concentrations were still above the trigger value and similar to bore BH3, which is directly down hydraulic gradient of bore BH14. Both locations may therefore be influenced by similar sources. This bore is strategically placed down gradient of landfilling activities and should be continually monitored to determine the water quality in this area.

Bore BH17 is located adjacent to and across-hydraulic gradient of the leachate ponds. Water chemistry and field observations displayed limited influence from landfill leachate. Ammonium concentration in groundwater (11 mg/L) exceeded ANZECC (2000) trigger levels although no other leachate indicators were prominent, suggesting limited leachate impact. A negative ORP and elevated dissolved iron suggests that microbial activity is occurring within this bore.

Minor leachate influence was noted at bore BH18 (Table 4). The ionic constituents of bore BH18 were stable compared with historic levels. Concentrations of NH_4 -N at this location (3.8 mg/L) exceeded the ANZECC (2000) trigger levels (1.88 mg/L).

Bore BH19 is a relatively new monitoring bore located on the south west boundary of the site. Field observations included a negative ORP and grey colour. Groundwater chemical characteristics support a limited leachate influence with an L/N ratio less than 10 and a high Ca/K ratio. Bore BH19 is down gradient of current sand dredging activities and unlined landfill cells. NH_4 -N at this location (7.6 mg/L) exceeds the ANZECC (2000) trigger levels (1.88 mg/L). Bore BH19 is positioned to detect any potential leachate migration to the south west of site and will continue to be monitored.

Ammonium levels were found elevated in the groundwater across the entire site with bores BH1c (350 mg/L), BH2 (34 mg/L), BH3 (35 mg/L), BH4 (6.6 mg/L), BH5 (58 mg/L), BH6b (7.8 mg/L), BH12 (13 mg/L), BH15 (210 mg/L), BH16 (14 mg/L), BH17 (11 mg/L), BH18 (3.8 mg/L), BH19 (7.6 mg/L) and BH20 (25 mg/L) above threshold levels. Nitrate was also found above guidelines (ANZECC 2000) in samples from bores BH3 (45 mg/L), and BH14 (12 mg/L).

5.3 Surface water monitoring

A water sample was taken from the sediment pond located in the south east portion of the site. This surface water sample (SWP5) is to replace the water quality sample SWP3 taken from Pond 3 which has been filled. Results of surface water analysis (Table 2 and Table 3) for samples collected from Rocklow Creek (SWC2, SWC_Up and SWC_Down) and four surface water ponds (SWP1, SWP2, SWP4 and SWP5) confirm that concentrations of ions are within a range similar to previous monitoring rounds. This has been depicted in the Schoeller plots provided in Attachment 3.

As these 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. At SWP1, SWP2, SWP4 and SWP5, a slightly elevated K/TDS ratio (2.2 to 6.3) and a slightly elevated L/N ratio (6.9 to 18.3) indicate the possibility of a slight leachate influence.

Location SWP1 has a low TDS level (500 mg/L) and as such caution must be applied when comparing ratios (Table 4) as low concentrations of native ions can have skewed ratios even when there is minimal to no actual impact from leachate present. Nitrate and ammonium



concentration do not exceed the ANZECC (2000) trigger values, indicating minor to no leachate impacts at SWP1 during this current sampling round. Continued monitoring at SWP1 will provide indication of potential leachate impacts on site surface water.

Surface water sample SWP2 showed no indicators of leachate impact. The surface water pond collects runoff from around the site and potential impacts from site activities are often observed. Both ammonium and NO_3^- were at low levels (0.9 mg/L and 0.13 mg/L) during this sampling round. This fluctuation in nitrate is common at this location with previous monitoring events fluctuating between 1 and 30 mg/L. Ammonia and nitrate are below the ANZECC 2000 trigger values. All chemical parameters at this location are within historical ranges.

Surface water sample SWP4 displayed ammonium levels of 4.6 mg/L which is above the defined trigger value and may indicate leachate influence or catchment affect. All chemical parameters at this location are within historical ranges. This location should continue to be monitored for any fluctuations in chemical composition indicating a more prominent leachate impact.

As previously discussed (Environmental Earth Sciences NSW, 2012a) SWP3 has been filled with large rocks and boulders (0.3 – 1.0 m in diameter), lined with plastic and is now being used as a new landfill cell.

SWP5 was sampled from the sediment dam located directly down gradient of the previous surface water pond SWP3. Surface water displayed low TDS (205 mg/L) which suggests that the water within SWP5 is mainly rainfall and not influenced by groundwater. Low levels of K (13 mg/L) and low levels of $\text{NH}_4^+\text{-N}$ (<0.1 mg/l) at this location indicate that there is no leachate influence.

The surface water sample from Rocklow Creek, SWC2, had low levels of $\text{NH}_4^+\text{-N}$ (0.4 mg/L) and low levels of NO_3^- (0.18 mg/L) which is consistent with previous sampling results. These are within the ANZECC 2000 trigger value for 95% protection of freshwater ecosystems. All chemical parameters at this location are within historical ranges.

The two surface water creek sites SWC_Up and SWC_Down were also sampled during the May 2016 sampling event. These two sites are up- and down-gradient of the established SWC2 site and help assess leachate impacts within Rocklow Creek. SWC_Up and SWC_Down had a TDS range of 34,700 – 35,200 mg/L and are dominated by Na^+ and Cl^- (Table 2) differentiating themselves 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. Both SWC_Up and SWC_Down had low concentrations of $\text{NH}_4^+\text{-N}$ and NO_3^- which did not exceed the ANZECC (2000) trigger value for 95% protection of freshwater ecosystems. Levels detected at all Rocklow Creek locations, are within historical levels established since monitoring was commenced.

5.4 Leachate Pond monitoring

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 for groundwater from the various bores and the leachate pond presented in Table 2. In particular TDS, TOC, $\text{NH}_4^+\text{-N}$, K^+ , and PO_4 concentrations are generally elevated in leachate pond water compared to other monitoring bores (Schoeller plot Leachate, Attachment 3). Ionic ratios (Table 4) such as low Ca/K (<0.70) 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 for faecal coliforms and *E.Coli* showed counts of 260 CFU/100ml for faecal coliforms and 260 CFU/100ml for *E.Coli* (Table 3). These results are low and below historical values. However as precaution dermal contact with these waters should be avoided due primarily to health concerns relating to 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 between the summed total of anions against cations (milli-equivalent units) was in the range of 0.04% to 1.84%. 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 0.00% and 9.39%. The relationship between the field determined EC and laboratory measured TDS relationship ranged between 0.06 and 1.81. The majority of data is within the TDS/EC typical range of 0.5 to 0.9.

The analysis of the intra-laboratory duplicate taken at bore BH18 showed a maximum RPD of 7.4%. The data is therefore considered reliable (Table 6).

5.6 Gas monitoring

Landfill gas was measured in the field using an 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.

Readings taken from around the main weigh bridge station during the May 2016 round considered specific points most likely to accumulate landfill gas. All readings were below the NSW EPA (1996) reporting threshold of 1.25 % v/v CH₄ within onsite buildings and therefore pose no direct risk. No landfill gas was detected with the GA5000. Continued monitoring with both the GA2000 and ILU will be undertaken at quarterly monitoring events.

Over a 30 minute period the remaining site sheds (Figure 3) were tested utilising the GA5000. All readings were below the NSW EPA (1996) reporting threshold of 1.25 % v/v CH₄ within onsite buildings and pose no direct risk.

Sampling across the landfill cap consisted of walking a grid pattern and taking readings every minute. All readings were below the threshold concentration for closer investigation and potential action (500 ppm or 0.05 % v/v, NSW EPA [1996], Table 5).

5.7 Dust

Dust deposition levels to the north of the site were 0.4 g/m²/month total solids, which is below the accepted level of 4 g/m²/month (Australian Standards AS3580.10.1 and AS2724.1). Dust deposition levels to the north of site 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 generally 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.

Assessment of monitoring bores BH4, BH13, BH17b, BH18, BH19, BH20 and sampling locations along Rocklow Creek indicates minimal leachate impact. It is likely that on site activities are not significantly impacting upon Rocklow Creek.

Leachate influenced groundwater appears to be moving down gradient from bore BH5 and it is possible that it is influencing water quality at bores BH15 and BH16. Bores BH15 and BH16 may also be influenced by runoff from mulching activities. It is important to note that these bores are located in/or near swampy environments or near heavily vegetated areas. Heavily wooded areas to the south can also have a natural attenuation effect on leachate impacted water. This would further inhibit its rate of migration and should continue to limit its extent of impact on Rocklow Creek.

Surface water monitoring indicated that on site activities have had minimal impact on water quality at locations SWP1, SWP2 and SWP4. The new surface water pond 5 (SWP5) indicated fresh water (TDS 295 mg/L) and is most likely predominantly rainfall and surface water runoff. No leachate indicators were observed at this new site.

Assessment of Rocklow Creek sampling locations (SWC2, SWC_Down and SWC_Up) showed detectable concentrations of $\text{NH}_4\text{-N}$. These values did not exceed the ANZECC (2000) trigger value for 95% protection of freshwater ecosystems ($\text{NH}_4\text{-N}$ 1.88 mg/L based upon a pH of 7.3 and 10.6 mg/L NO_3^-). The May 2016 monitoring of Rocklow Creek found nitrogen as $\text{NH}_4\text{-N}^+$ and NO_3^- to be within historic concentration ranges at all other locations.

Gas concentrations detected at the weighbridge station and all buildings assessed on site were below guidelines and no action was required to be taken. Future monitoring with an ILU and GA5000 will continue with special attention to buildings located near the weighbridge station.

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 if any 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 PO109055 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

- Australian Government – Bureau of Meteorology – www.bom.gov.au – *Weather Station Albion Park Post office – 068000.*
- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia (ARMCANZ) (2000). *Australian and New Zealand guidelines for fresh and marine water quality.*
- AS/NZS 3580.10.1:2003 (R2014). *Methods for sampling and analysis of ambient air - Determination of particulate matter - Deposited matter - Gravimetric method.*
- AS/NZS 2724.1:1984. *Ambient air – Particulate matter, Determination of deposited matter expressed as insoluble solids, ash, combustible matter, soluble solids and total solids.*
- Hickey C. W (2013). *NIWA Updating nitrate toxicity effect on freshwater aquatic species.*
- Environmental Earth Sciences NSW (2012a). *Quarterly Environmental Monitoring – Dunmore Recycling and Waste Disposal Depot, Dunmore, New South Wales, August 2012; report number 110031_August12.*
- Environmental Earth Sciences NSW (2012b). *Environmental Monitoring at the Dunmore Recycling and Waste Depot, Dunmore, New South Wales – Annual Report September 2011 to August 2012; report number 110031_Annual_2012.*
- Environmental Earth Sciences, (2011a) *Soil, gas and groundwater sampling manual.*
- Environmental Earth Sciences NSW (2011b). *Environmental Monitoring at the Dunmore Recycling and Waste Depot, Dunmore, New South Wales; Annual Report September 2010 to August 2011; report number 110031_Annual_2011.*
- Environmental Earth Sciences NSW (2010). *Environmental Monitoring at the Dunmore Recycling and Waste Depot, Dunmore, New South Wales; Annual Report September 2009 to August 2010; report number 110031_Annual_2010.*
- NSW Environment Protection Authority (1996). *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.

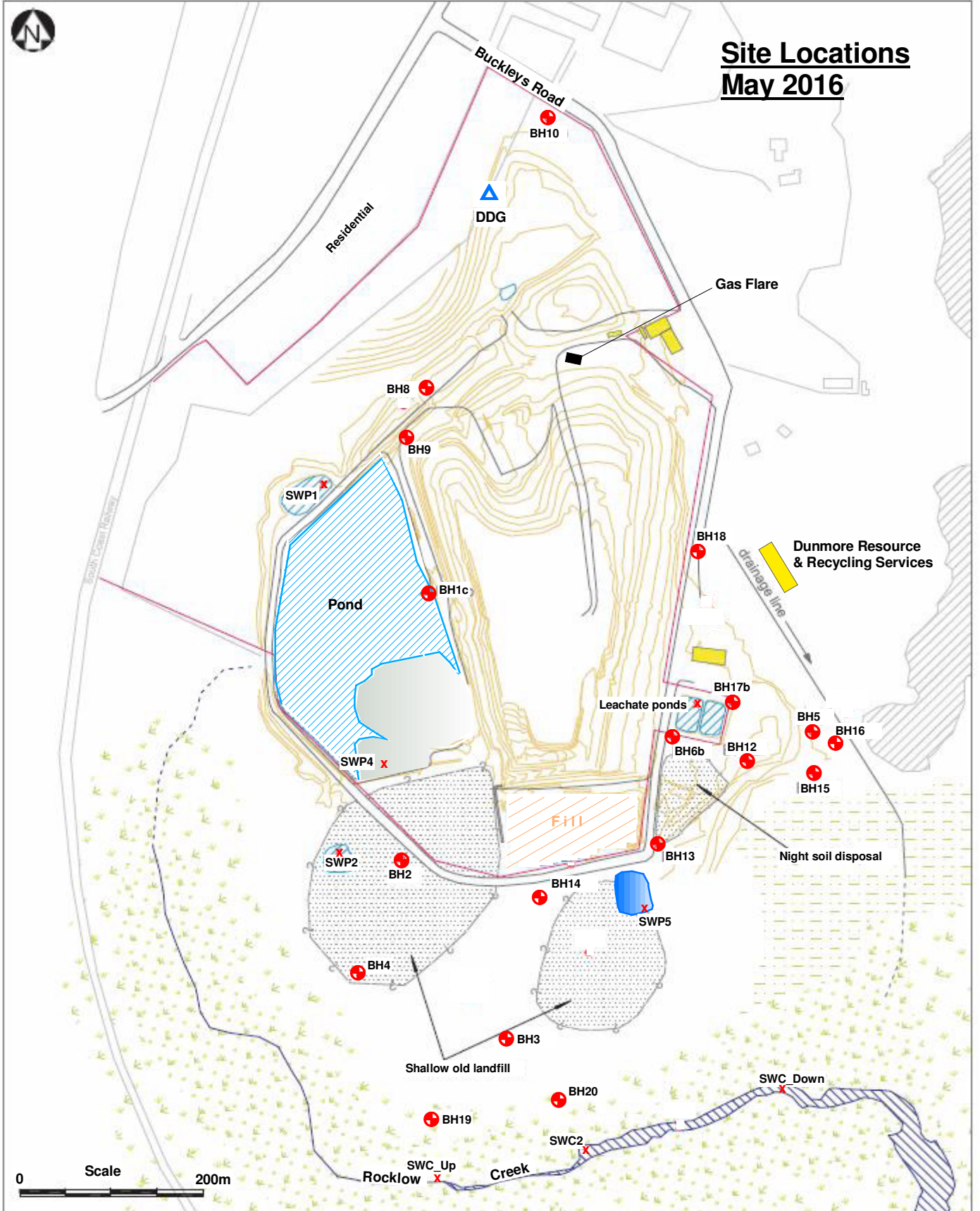
Limit of liability

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 Locations May 2016



Legend:

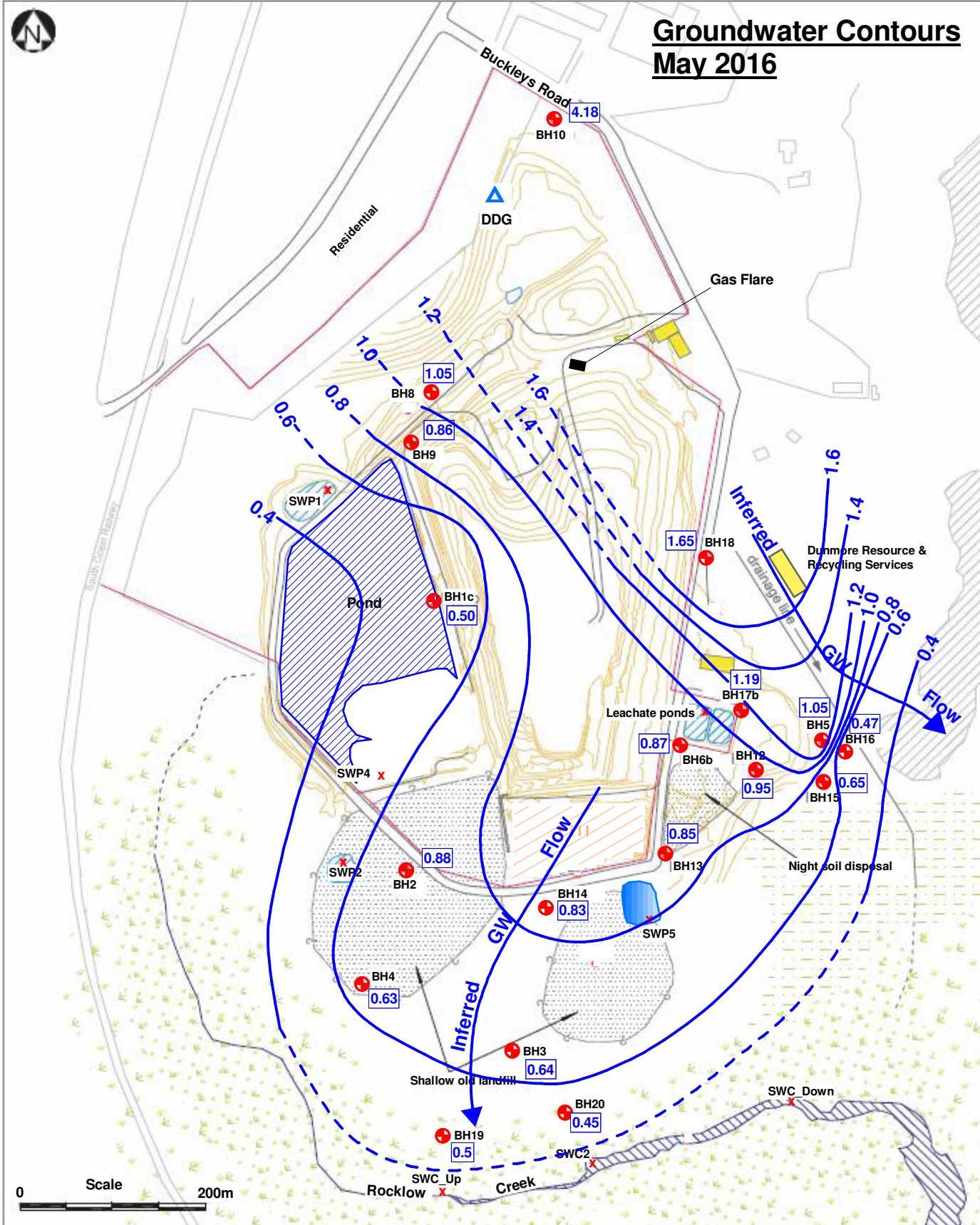
- + Borehole locations
- x Surface water locations
- ▲ DDG Dust gauge location
- Water
- Buildings

	Title: Site Locations	
	Location: Buckleys Road, Dunmore, NSW	
Client: Shellharbour City Council	Job number: 112096	
Drawn by: TRJ	Scale: As shown	Figure 1
Proj Man: DF	Date: May 2016	

Note: Based on aerial photo dated 1 Sept. 2010



Groundwater Contours May 2016



Legend:

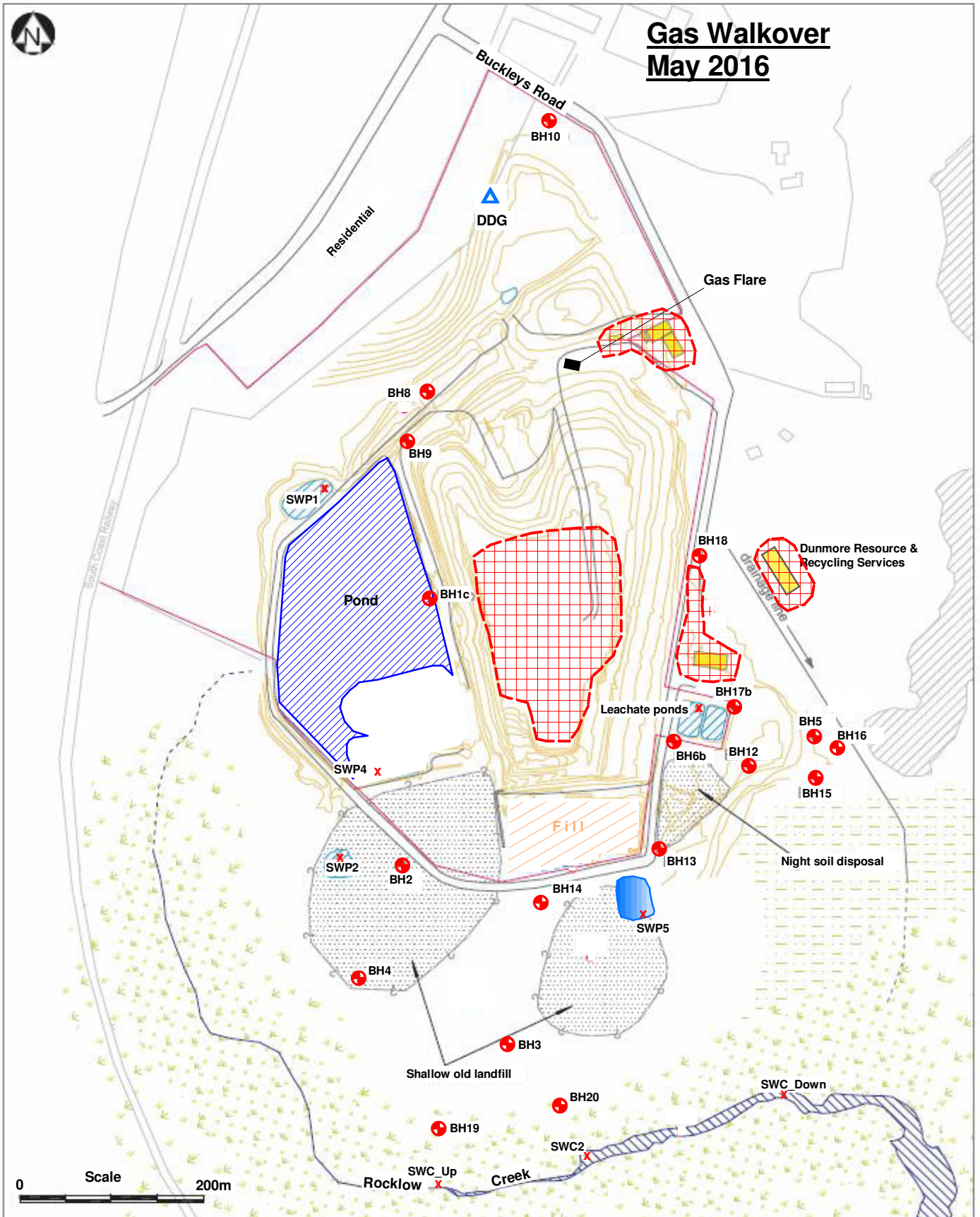
- Borehole locations
- x Surface water locations
- ▲ DDG Dust gauge location
- ~ Inferred groundwater contour (m AHD)
- Water
- Buildings
- 1.55 Standing water level
- Flow direction

Note: Based on aerial photo dated 1 Sept. 2016

	Title: Inferred Groundwater Contours - May 2016	
	Location: Buckleys Road, Dunmore, NSW	
Client: Shellharbour City Council	Job number: 112096	
Drawn by: TRJ	Scale: As shown	Figure 2
Proj Man: DF	Date: May 2016	



Gas Walkover May 2016



Legend:

- Borehole locations
- Surface water locations
- DDG Dust gauge location
- Gas walkover
- Water
- Buildings

Note: Based on aerial photo dated 1 Sept. 2016

	Title: Gas Walkover	
	Location: Buckleys Road, Dunmore, NSW	
Client: Shellharbour City Council	Job number: 112096	
Drawn by: TRJ	Scale: As shown	Figure 3
Proj Man: DF	Date: May 2016	

ATTACHMENT 2 TABLES

TABLE 1 FIELD MEASUREMENTS – MAY 2016

Sample	SWL	SWL	pH	EC	ORP	Temp.	DO	Colour	Odour
Units	mAHD	Dip (m)	-	µS/cm	mV	°C	%	-	-
BH1c	0.50	3.45	6.91	6012	-175.8	27.5	5.5	Dark amber	Strong leachate
BH2	0.76	4.03	6.84	3033	-127	21.5	0.9	Amber	Slight H ₂ S
BH3	0.64	1.22	7.32	1305	-87	19.4	7.3	Clear with black pieces	None
BH4	0.63	4.39	7.2	1763	-131	19.4	0	Slightly green	Slight H ₂ S
BH5	1.30	1.22	6.79	3535	-157.3	19.2	0	Brown	Slight leachate
BH6b	0.87	4.29	6.9	2119	-157.1	21.2	0.1	Amber	None
BH8	1.05	4.37	-	-	-	-	-	-	-
BH9	0.86	5.35	-	-	-	-	-	-	-
BH10	4.18	0.61	-	-	-	-	-	-	-
BH12	0.95	3.295	6.95	3005	-136	23.8	0	Clear	None
BH13	0.85	4.45	6.97	1631	-92	21.6	0.5	Clear	None
BH14	0.83	4.89	7.17	1844	-50	20.4	1.4	Clear	None
BH15	0.65	0.76	6.86	5398	-93.6	17.7	11	Brown/Amber	None
BH16	0.47	0.91	6.45	2941	-2235	17.8	39.9	Amber	Very strong leachate
BH17	1.19	4.34	6.42	3054	-127.7	21.2	2.6	Amber	None
BH18	1.65	1.5	6.81	3662	-205	19.8	2.5	Light amber	None
BH19	0.50	4.69	7.48	2132	-126.4	19.2	1.2	Grey	None
BH20	0.45	3.25	7.54	1141	-177.6	19.5	0	Light yellow	Slight odour
LP1	-	-	8.41	7776	-50.3	19.2	19.5	Dark brown	No odour
SWC2	-	-	7.45	33301	51.8	16.4	43.3	Clear	None
SWC_Up	-	-	7.43	36200	56.2	15.5	35	Clear	None
SWC_Down	-	-	7.35	19500	78.5	15	47.8	Clear	None
SWP1	-	-	7.69	787	-124.5	13.7	6	Brown/Light brown	None
SWP2	-	-	7.72	2045	-123.9	14.5	10.7	Clear	Slight H ₂ S
SWP4	-	-	8.08	1953	-81	17.2	16.9	Brown	None
SWP5	-	-	8.06	373	-18.2	16.5	66.1	Dark brown/Dark green	None

- 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 – MAY 2016

Sample	pH	TDS	Na	Ca	K	Mg	NH ₄ -N	Cl	F	NO ₃	NO ₂	SO ₄	HCO ₃	PO ₄	TOC	BOD	Sol. Mn	Sol. Fe	Tot. Fe
BH1c	7.2	4120	695	155	225	105	350	815	0.22	<0.1	-	10	3350	0.58	175	160	0.33	4.2	11
BH2	7.0	1870	280	275	31	79	34	465	0.15	0.53	-	30	1380	<0.1	54	110	0.55	5.9	13
BH3	7.4	915	54	145	52	27	35	215	0.13	45	-	94	410	<0.1	15	26	0.13	0.14	2.1
BH4	7.2	890	110	165	15	34	6.6	200	<0.1	<0.1	-	75	555	<0.1	18	33	0.16	0.92	4.3
BH5	6.8	2060	460	140	88	75	58	1000	0.14	<0.1	-	40	590	0.12	37	200	0.31	1.6	5.2
BH6b	6.9	1090	170	160	23	33	7.8	270	<0.1	<0.1	-	82	590	<0.1	27	43	0.33	5.0	17
BH12	7.0	1740	220	280	44	56	13	525	0.16	<0.1	-	335	470	<0.1	23	48	0.43	4.4	16
BH13	7.1	945	115	200	17	35	1.4	155	0.26	0.75	-	160	670	<0.1	22	6	0.23	0.16	2.5
BH14	7.3	1100	210	150	20	49	0.7	205	0.66	12	-	120	735	0.28	22	5	0.15	0.06	0.90
BH15	6.9	4220	465	185	730	80	210	1410	0.22	<0.1	-	170	1540	0.61	265	86	0.44	17	20
BH16	6.7	1470	305	71	140	41	14	590	0.18	<0.1	-	48	435	0.15	82	66	0.12	0.90	5.4
BH17	6.4	1880	335	180	31	80	11	560	<0.1	<0.1	-	385	450	<0.1	35	48	0.45	35	57
BH18	7.2	2120	475	170	44	81	3.8	720	0.29	<0.1	-	86	955	0.34	34	19	0.32	0.26	1.5
BH19	7.3	1050	120	190	16	41	7.6	260	<0.1	0.13	-	98	575	<0.1	19	41	0.07	0.17	28
BH20	7.7	705	65	110	29	32	25	100	0.18	<0.1	-	125	480	0.34	17	27	0.06	0.06	1.3
LP1	8.3	6080	1170	140	415	100	525	1350	0.39	<0.1	240	85	4360	11	390	310	0.31	2.1	2.8
SWC2				-	-	-	0.4	-	-	0.18	-	-	265	-	-	-	-	0.05	0.16
SWC_UP	7.3	34700	10500	395	360	1140	0.3	19400	0.48	0.18	-	2050	300	<0.1	-	-	-	0.02	0.18
SWC_Do	7.5	35200	10900	405	380	1230	0.1	20200	0.48	<0.1	-	2180	405	<0.1	-	-	-	0.03	0.15
SWP1	7.0	410	81	47	19	16	0.9	110	0.16	<0.1	<0.1	10	285	0.24	-	-	-	0.60	3.1
SWP2	7.8	1390	275	115	30	59	0.9	335	0.21	0.13	0.13	240	525	<0.1	-	-	-	0.05	0.10
SWP4	7.9	1340	305	56	35	57	4.6	380	0.33	<0.1	<0.1	185	485	<0.1	37	29	-	0.06	0.31
SWP5	7.7	205	45	18	13	8.3	<0.1	27	0.20	<0.1	-	22	170	<0.1	-	-	-	0.06	0.49
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 NH₄-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 – MAY 2016

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	525	4360	2.1	2.8	260	260
SWC2	0.4	265	0.05	0.16	-	-
SWC_UP	0.3	300	0.02	0.18	-	-
SWC_Down	0.1	405	0.03	0.15	-	-
SWP1	0.9	285	0.60	3.1	-	-
SWP2	0.9	525	0.05	0.10	-	-
SWP4	4.6	485	0.06	0.31	-	-
SWP5	<0.1	170	0.06	0.49	-	-
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 NH₄-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 – MAY 2016

Bore	Na/Cl	Na/Ca	Mg/Ca	Ca/K	Cl/SO ₄	Cl/HCO ₃	K/TDS (mg/L)	L/N (mg/L)
BH1B	1.31	3.91	1.12	1.34	110.43	0.42	5.46	60.21
BH2	0.93	0.89	0.47	17.30	21.00	0.58	1.66	10.34
BH3	0.39	0.32	0.31	5.44	3.10	0.90	5.68	58.41
BH4	0.85	0.58	0.34	21.46	3.61	0.62	1.69	6.99
BH5	0.71	2.86	0.88	3.10	33.87	2.92	4.27	21.63
BH6b	0.97	0.93	0.34	13.57	4.46	0.79	2.11	8.49
BH12	0.65	0.68	0.33	12.41	2.12	1.92	2.59	10.25
BH13	1.14	0.50	0.29	22.95	1.31	0.40	1.80	5.47
BH14	1.58	1.22	0.54	14.63	2.31	0.48	1.82	8.00
BH15	0.51	2.19	0.71	0.49	11.24	1.58	17.30	128.77
BH16	0.80	3.74	0.95	0.99	16.65	2.33	9.52	36.93
BH17	0.92	1.62	0.73	11.33	1.97	2.14	1.65	7.06
BH18	1.02	2.44	0.79	7.54	11.34	1.30	2.08	6.59
BH19	0.71	0.55	0.36	23.17	3.59	0.78	1.52	6.76
BH20	1.00	0.52	0.48	7.40	1.08	0.36	4.11	26.09
LP1	1.34	7.29	1.18	0.66	21.52	0.53	6.83	66.67
SWP1	1.14	1.50	0.56	4.83	14.90	0.66	4.63	13.83
SWP2	1.27	2.08	0.85	7.48	1.89	1.10	2.16	6.91
SWP4	1.24	4.75	1.68	3.12	2.78	1.35	2.61	9.48
SWP5	2.57	2.18	0.76	2.70	1.66	0.27	6.34	18.26
SWC_UP	0.83	23.17	4.76	2.14	12.82	111.30	1.04	3.00
SWC_Do	0.83	23.46	5.01	2.08	12.56	85.85	1.08	3.03

Notes:

1. SWC_Do – SWC_Down;
2. ratios presented in percentage milli-equivalents/litre (meq/L) unless otherwise indicated; and
3. L/N = leachate/non-leachate ratio (mg/L); $[(K + NH_4 + NO_3 + NO_2)/(Ca + Mg + Na)] \times 100$.

TABLE 5 SUMMARY OF GAS ANALYSIS – MAY 2016

Location	GA 2000 V/V%	LIU V/V%
Office / main Weigh Bridge	0.0	0.0124
Landfill Cap	0.0	0.00000
Office Demountables	0.0	0.00000
Recycle shop	0.0	0.00000
Large storage shed	0.0	0.00000
Second weigh bridge	0.0	0.00000
Buildings off site	0.0	0.00000
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 CH₄; and surface emission trigger value (500 ppm or 0.05 % v/v); and
3. values above the guidelines are **bolded**.

TABLE 6 QA/QC – MAY 2016

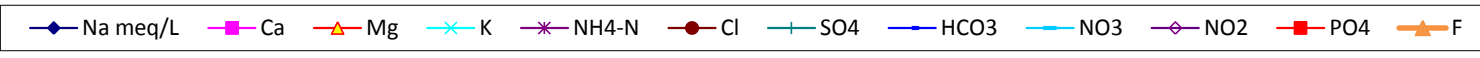
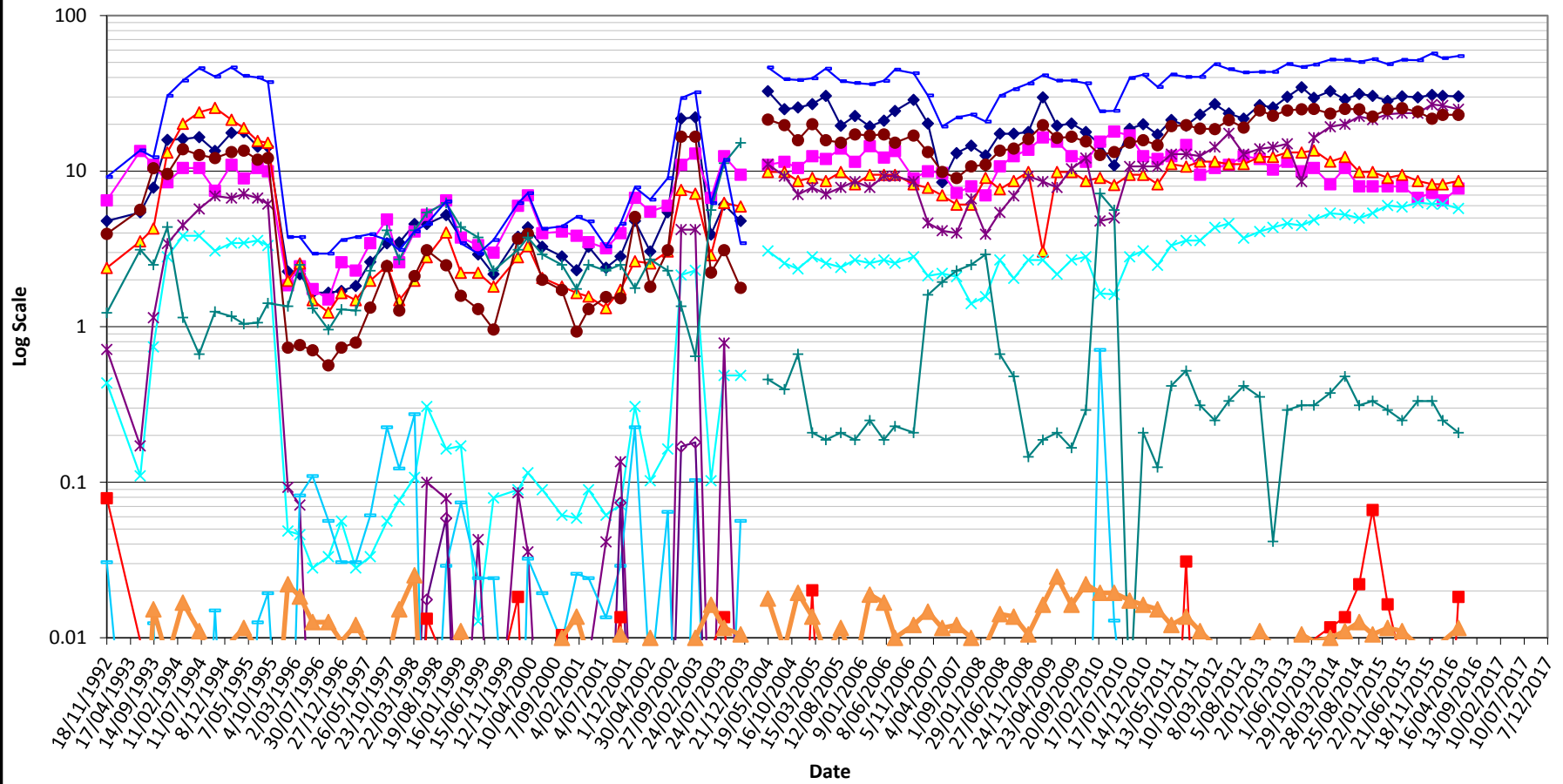
Analytes	BH18	FD1	RPD (%)
pH	7.1	7.2	1.4
TDS	2090	2120	1.4
Na+	470	475	1.1
Ca ²⁺	170	170	0.0
K ⁺	43	44	2.3
Mg ²⁺	81	81	0.0
NH ₄ -N	3.7	3.8	2.7
Cl ⁻	735	720	2.1
F ⁻	0.29	0.29	0.0
NO ₃ ⁻	<0.1	<0.1	NC
SO ₄ ²⁻	80	86	7.2
HCO ₃ ⁻	940	955	1.6
PO ₄ ³⁻	0.32	0.34	6.1
TOC	33	34	3.0
BOD	20	19	5.1
Mn. Dissolved	0.32	0.32	0.0
Fe. Dissolved	0.28	0.26	7.4
Fe. Total	1.4	1.5	6.9

Notes:

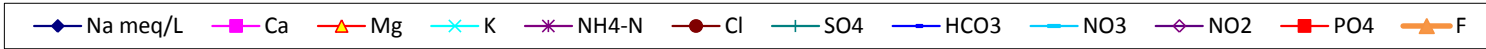
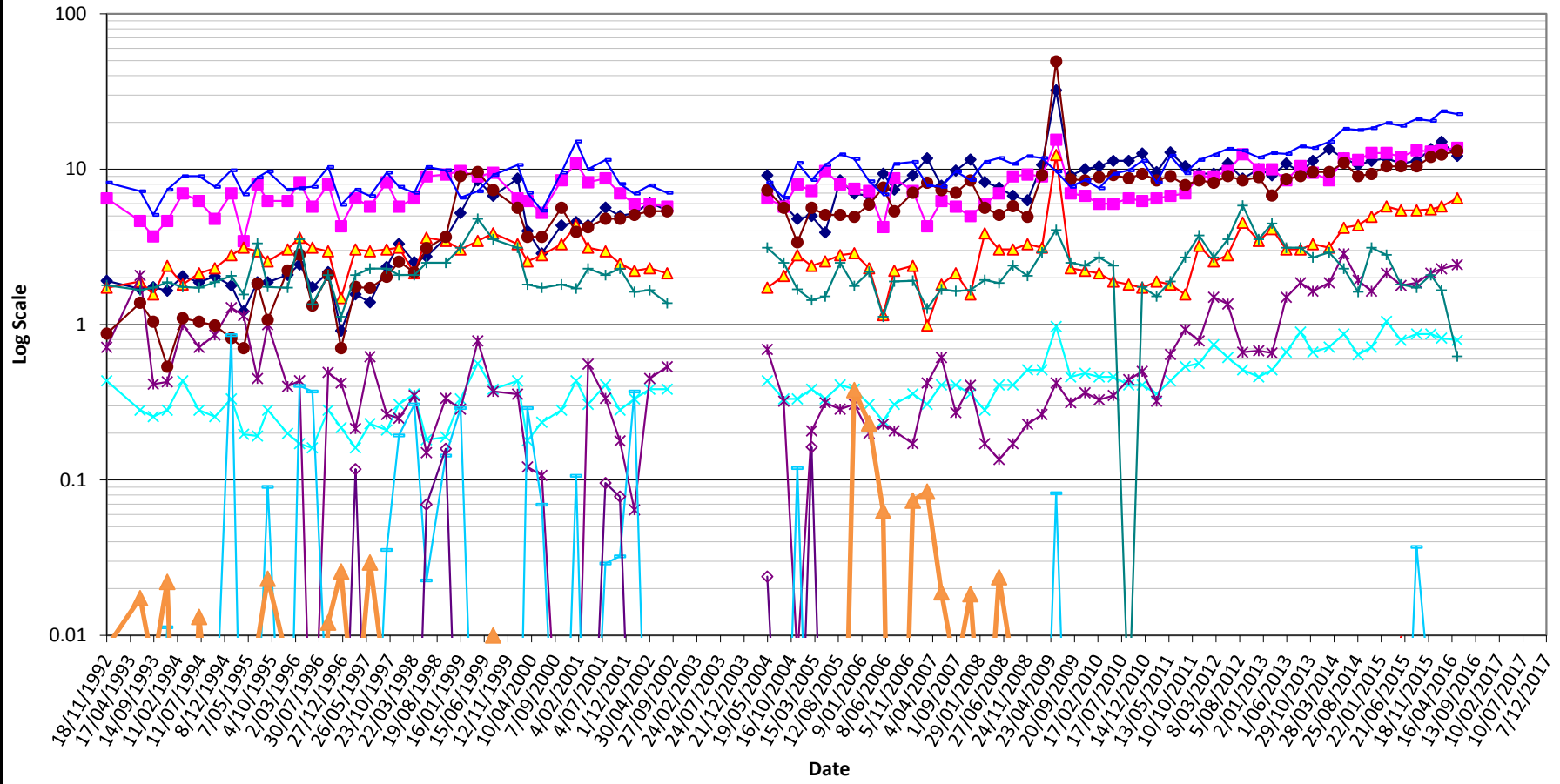
1. results are expressed in mg/L;
2. RPD – Relative Percentage Difference
3. NA - not analysed;
4. values requiring further investigation are **bolded**.

ATTACHMENT 3 SCHOELLER PLOTS

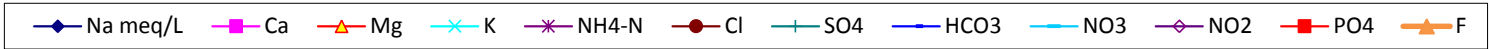
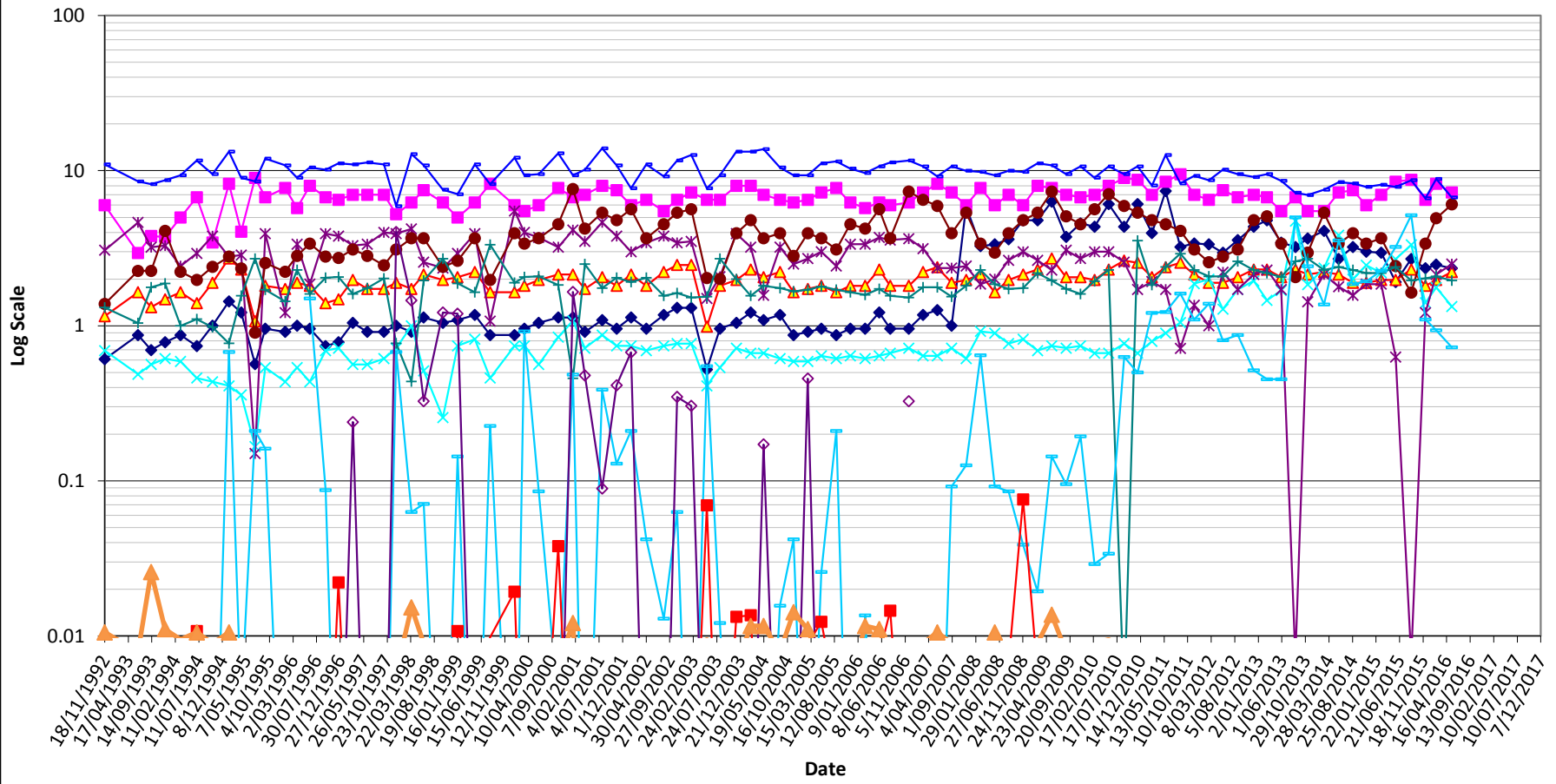
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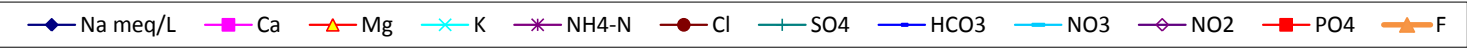
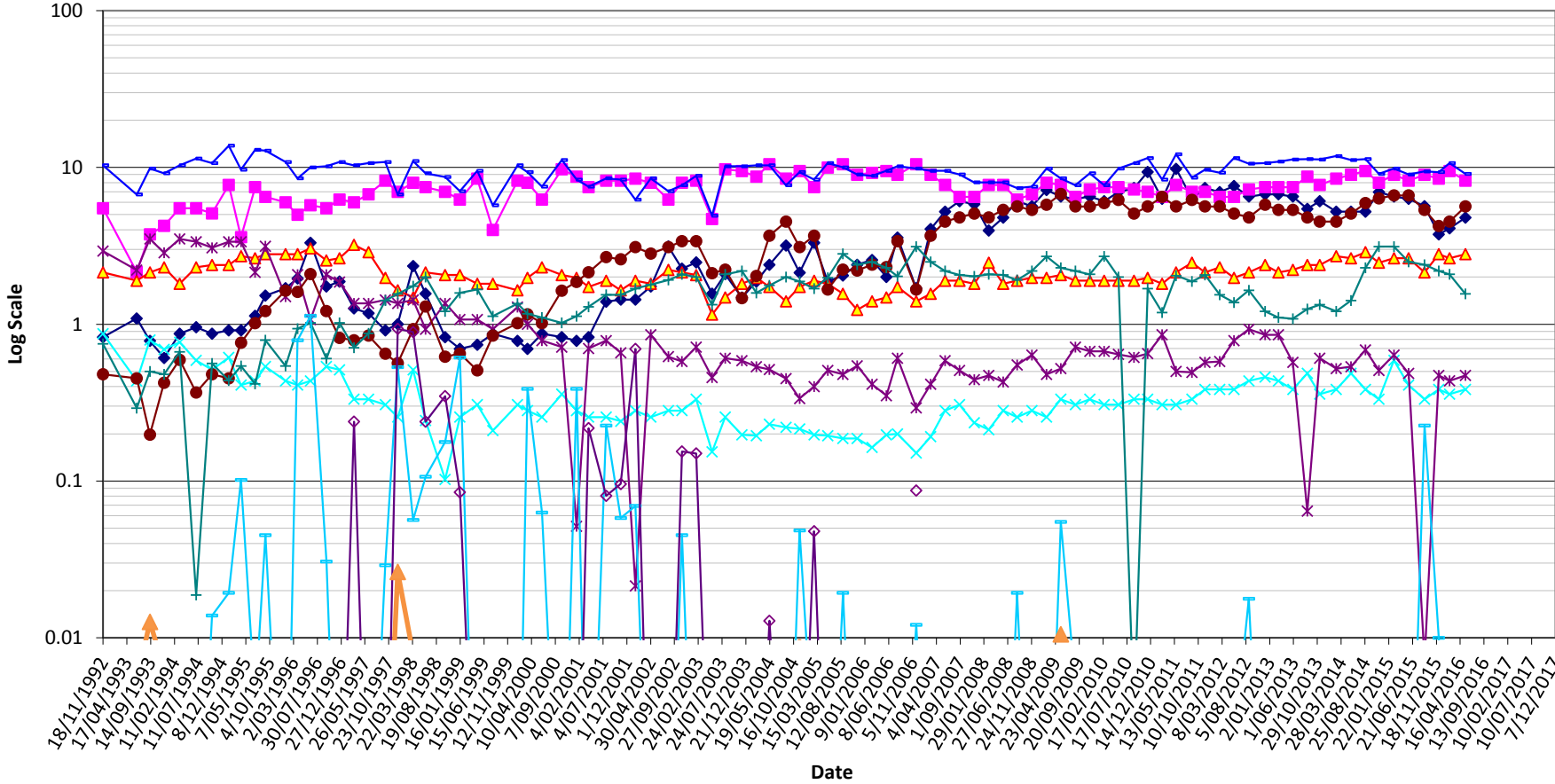
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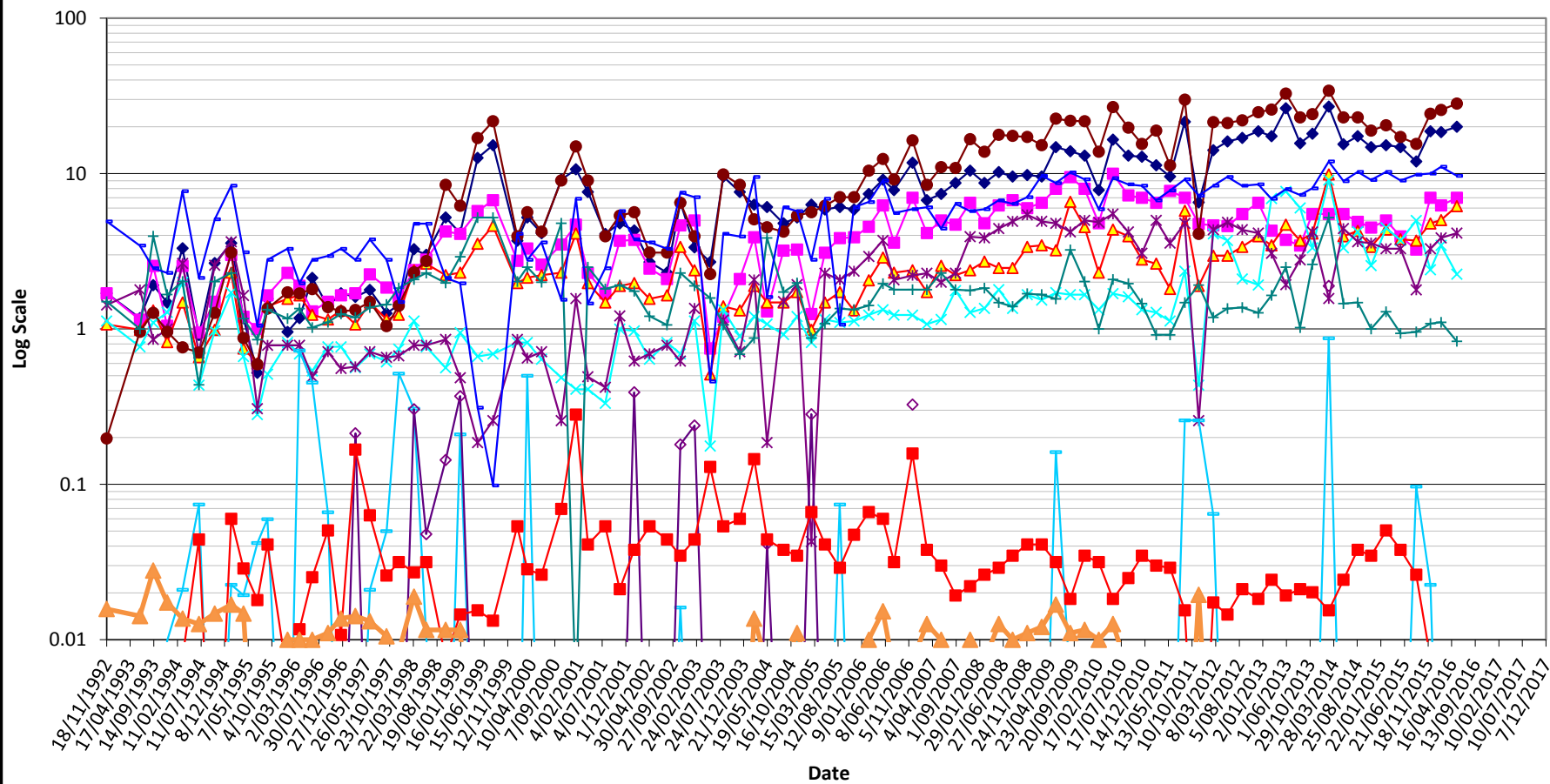
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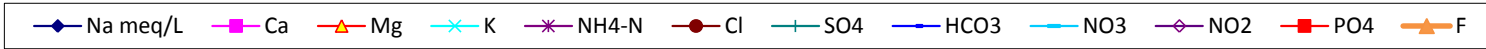
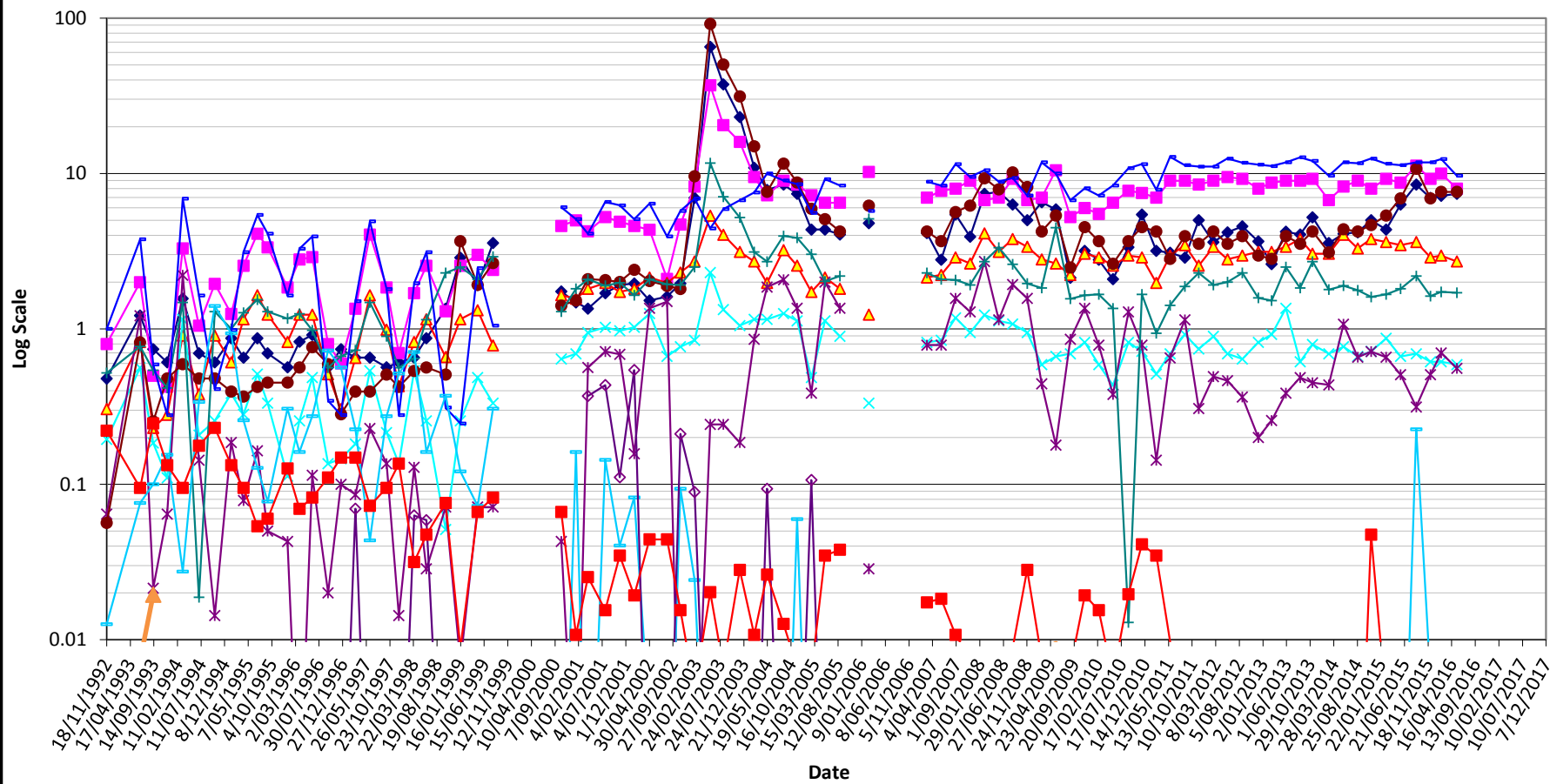
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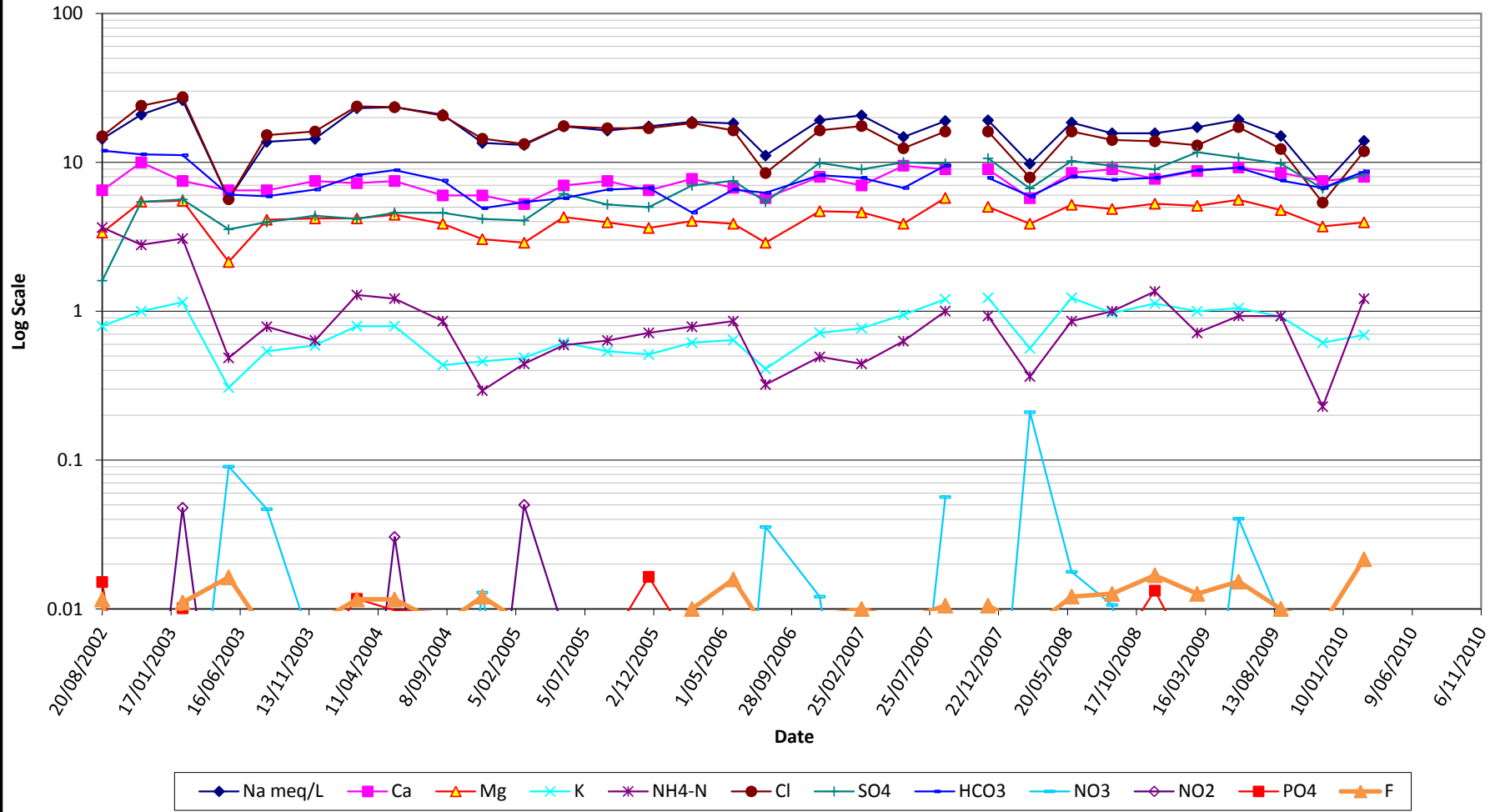
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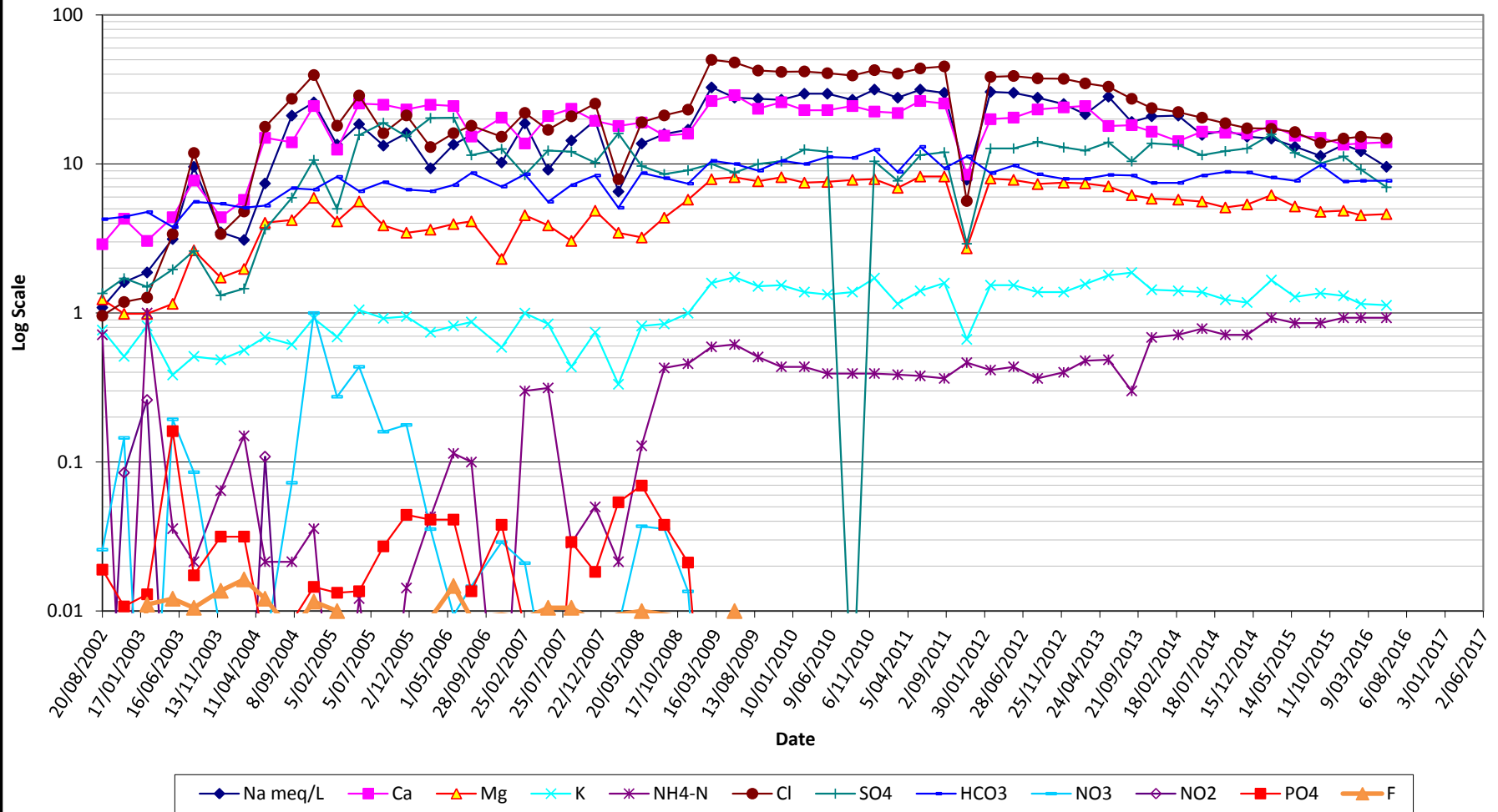
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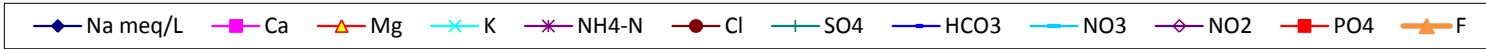
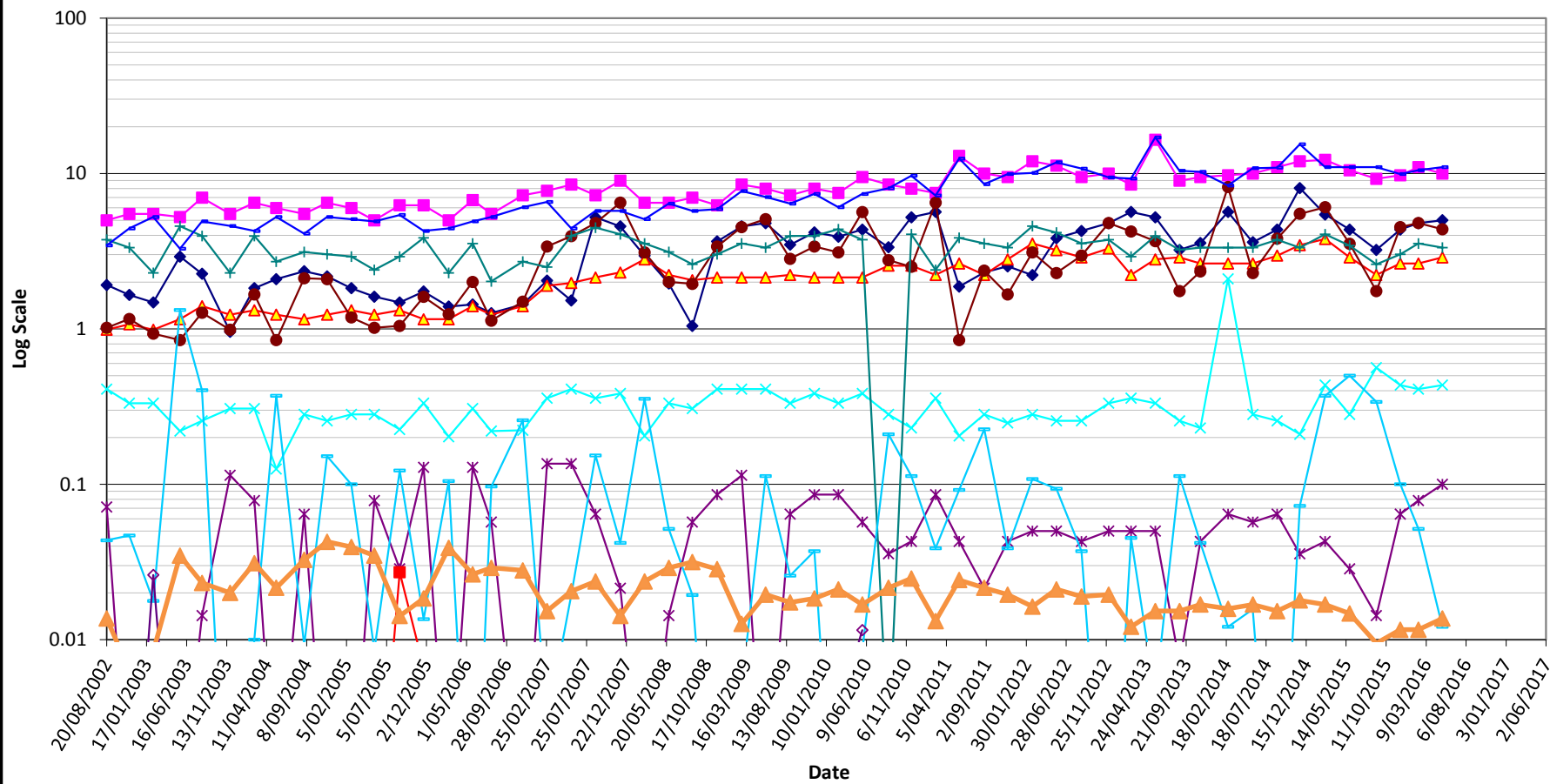
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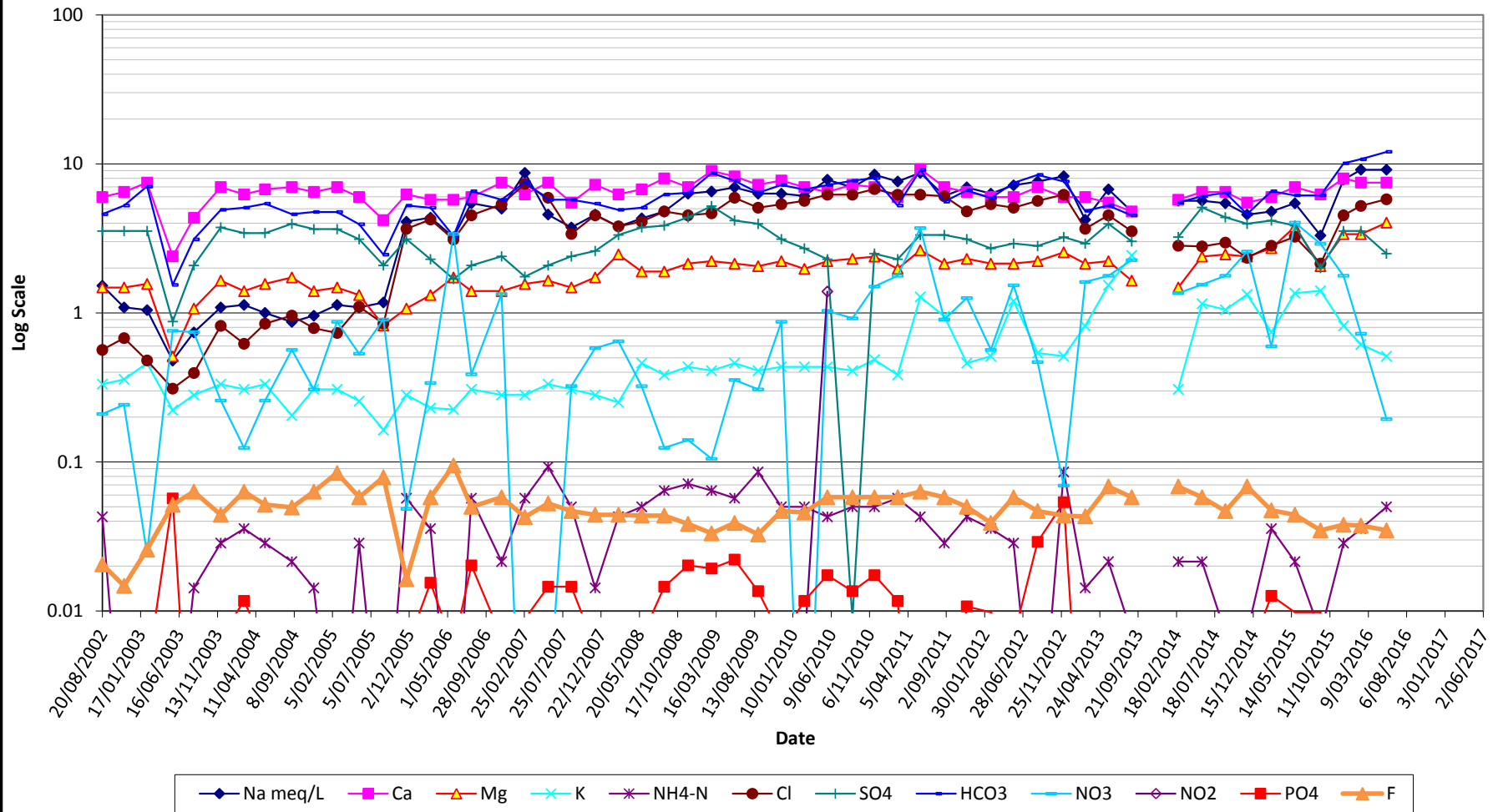
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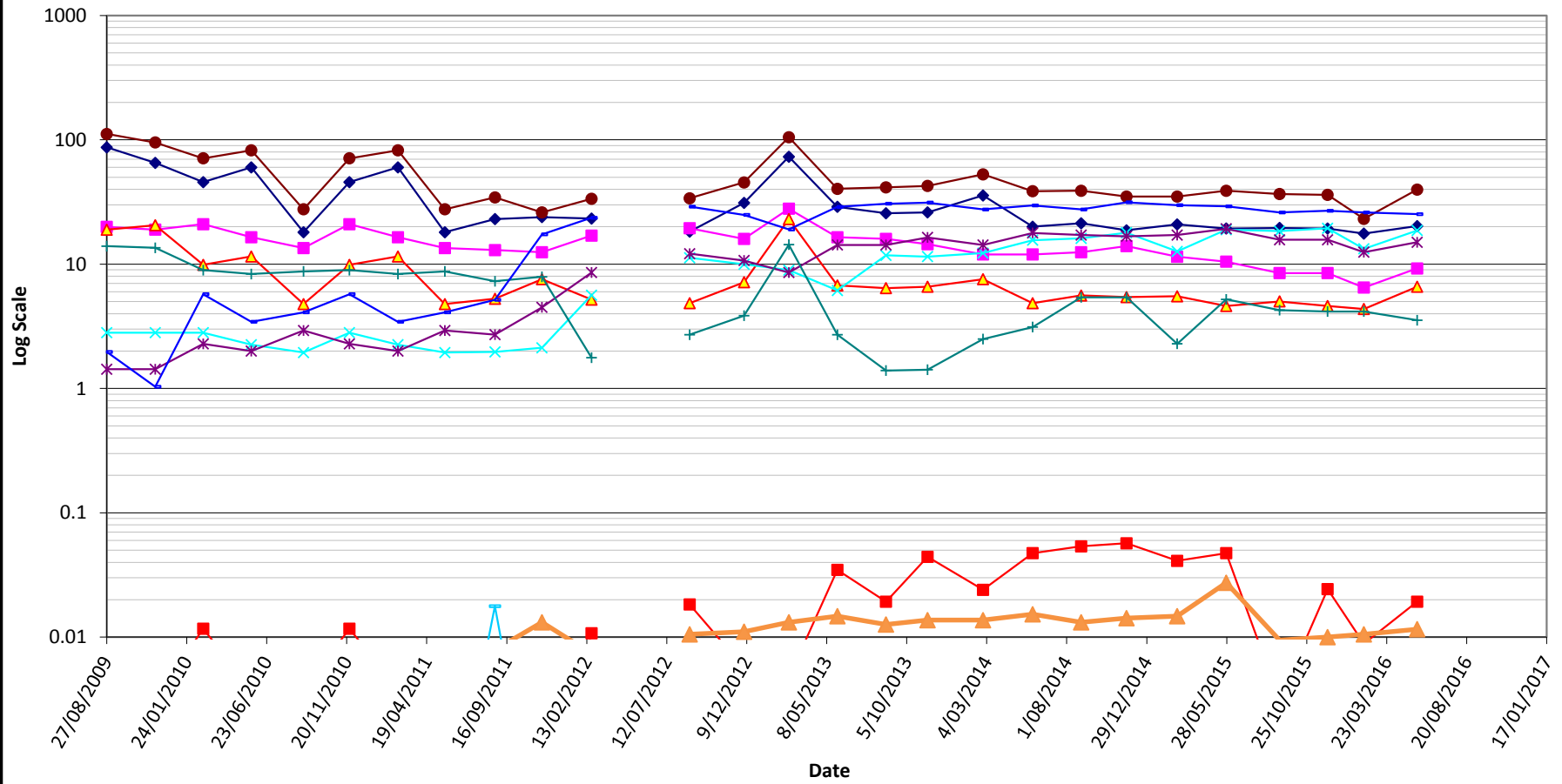
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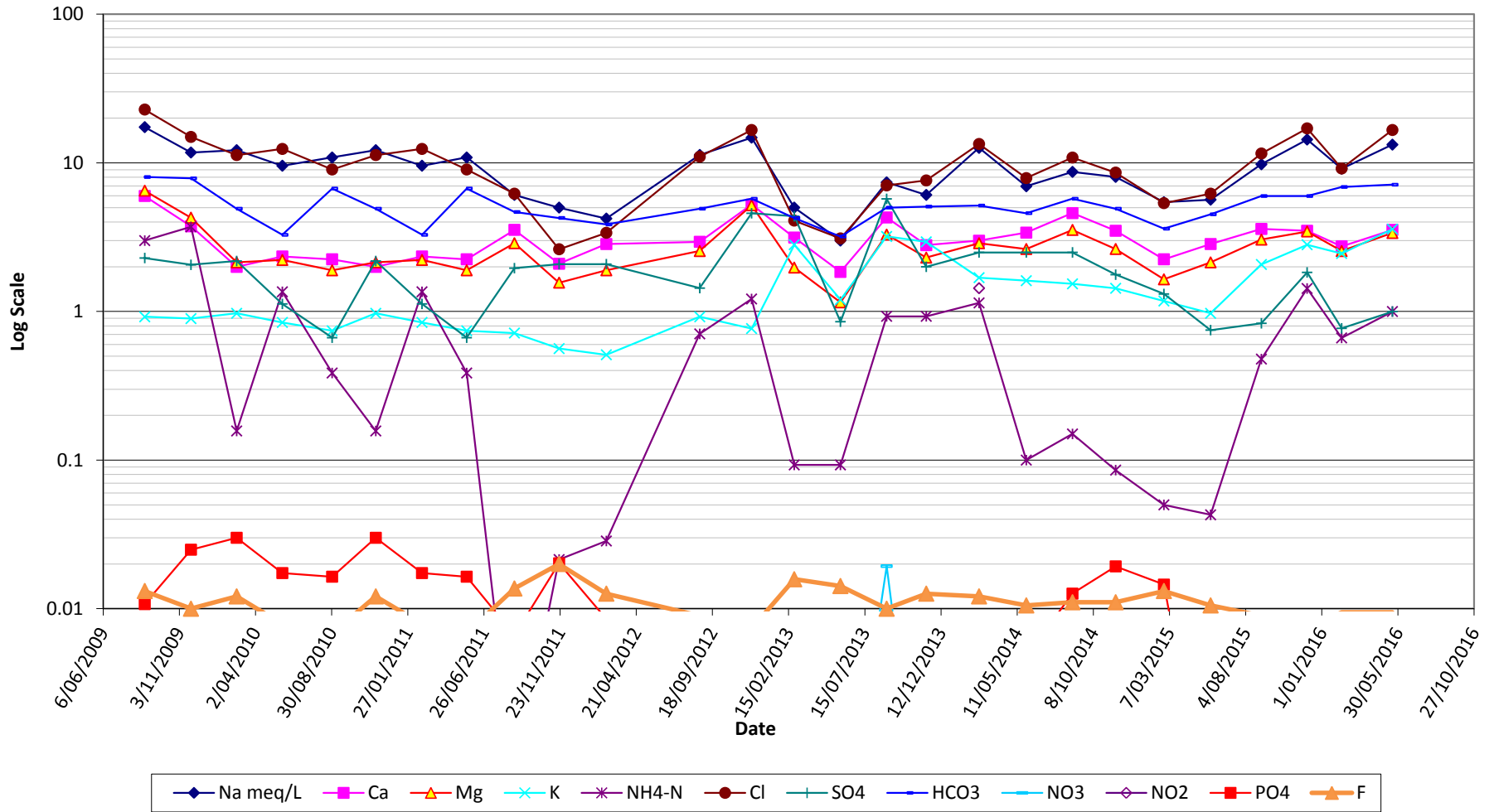
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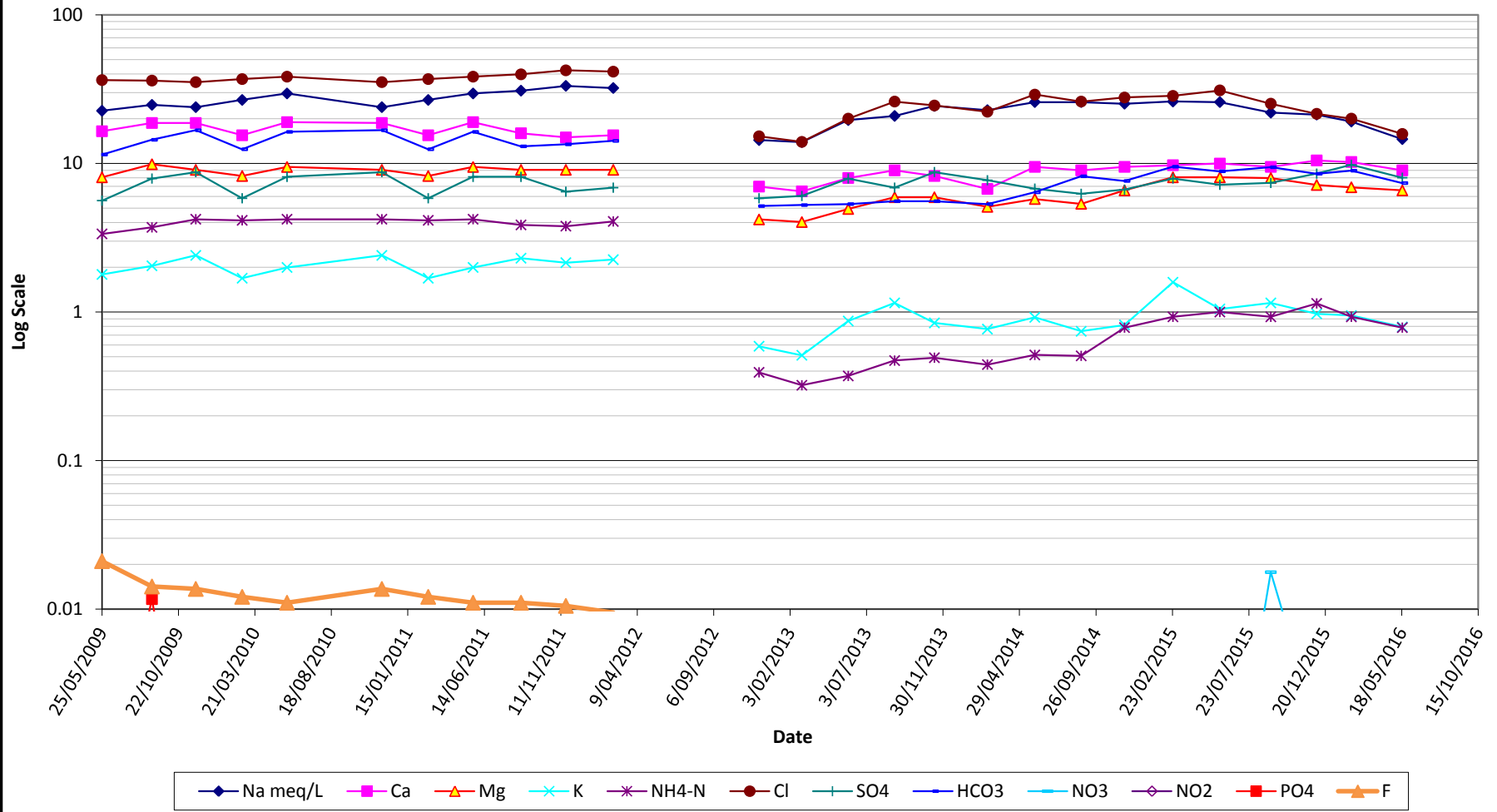
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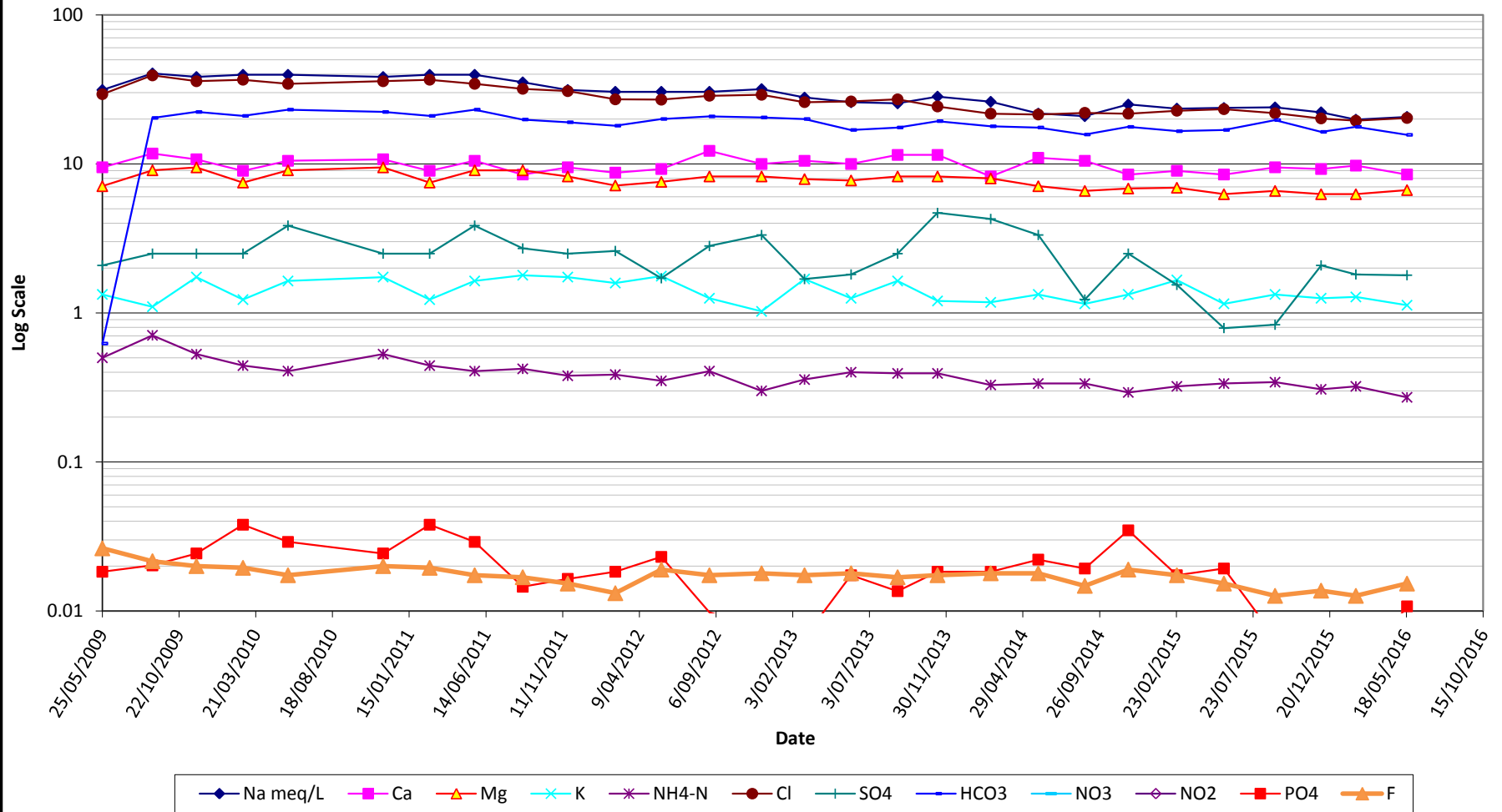
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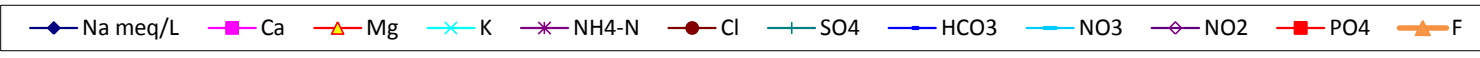
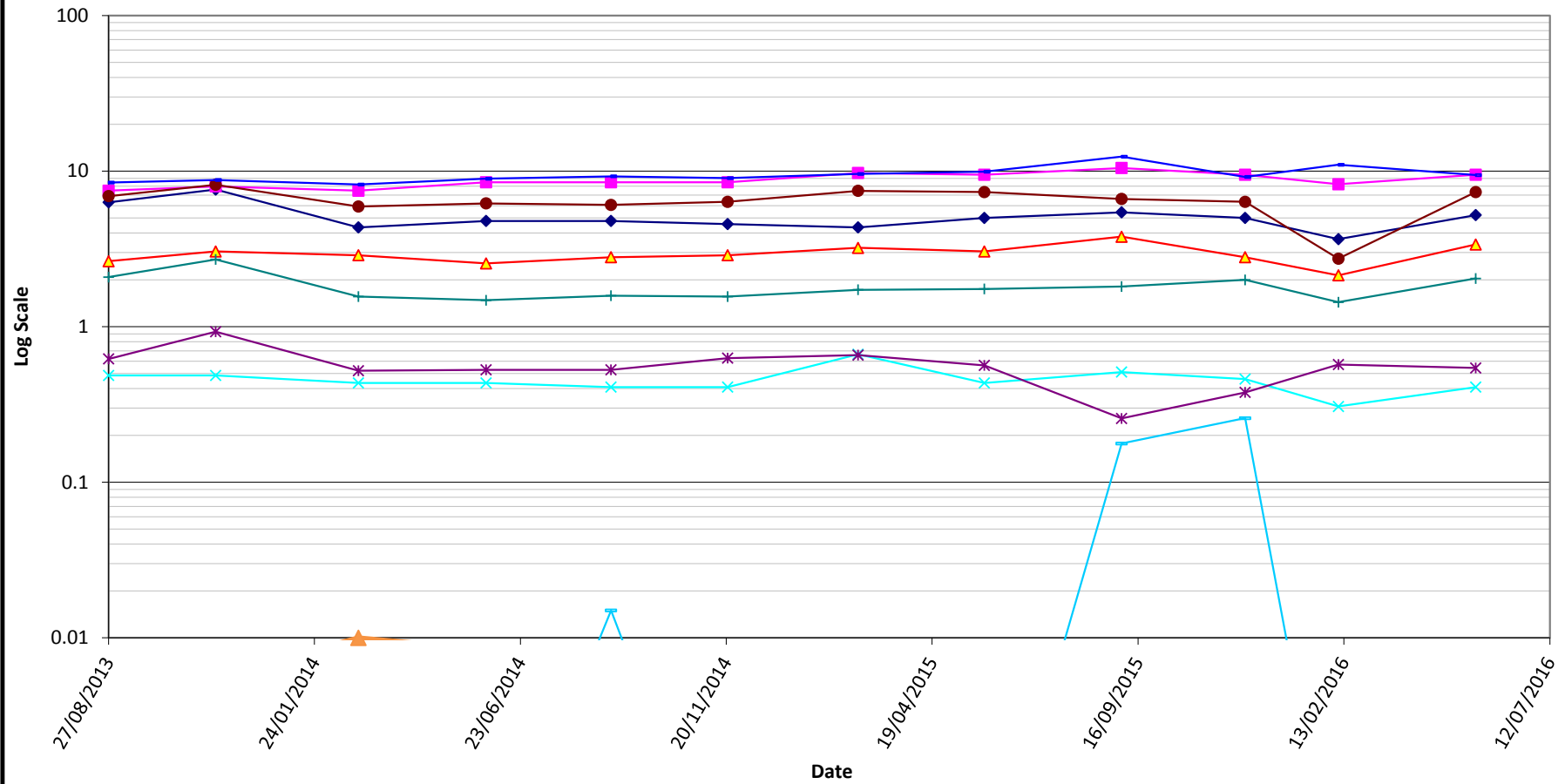
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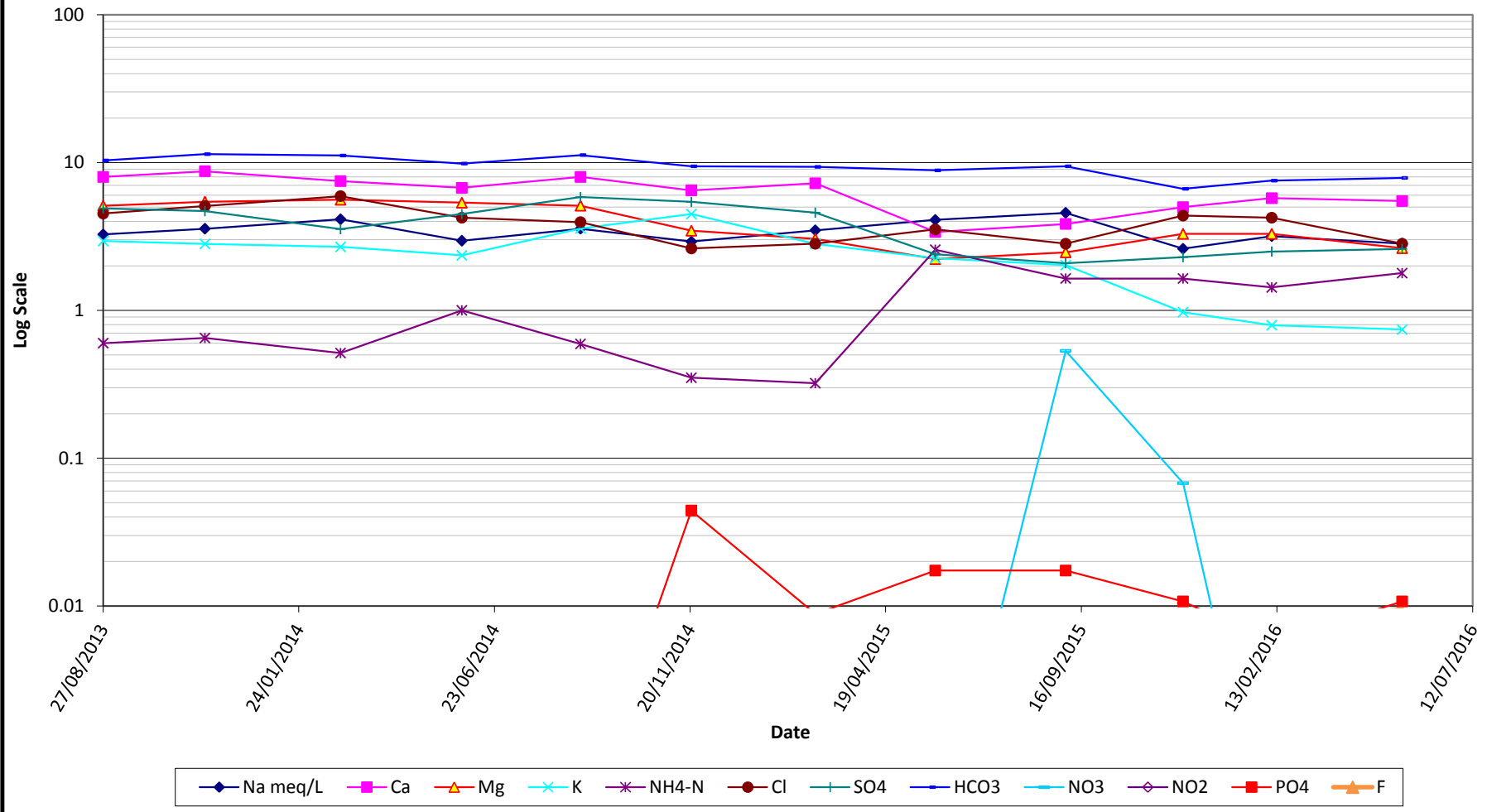
BH18



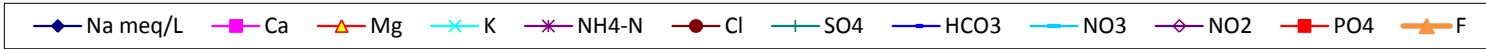
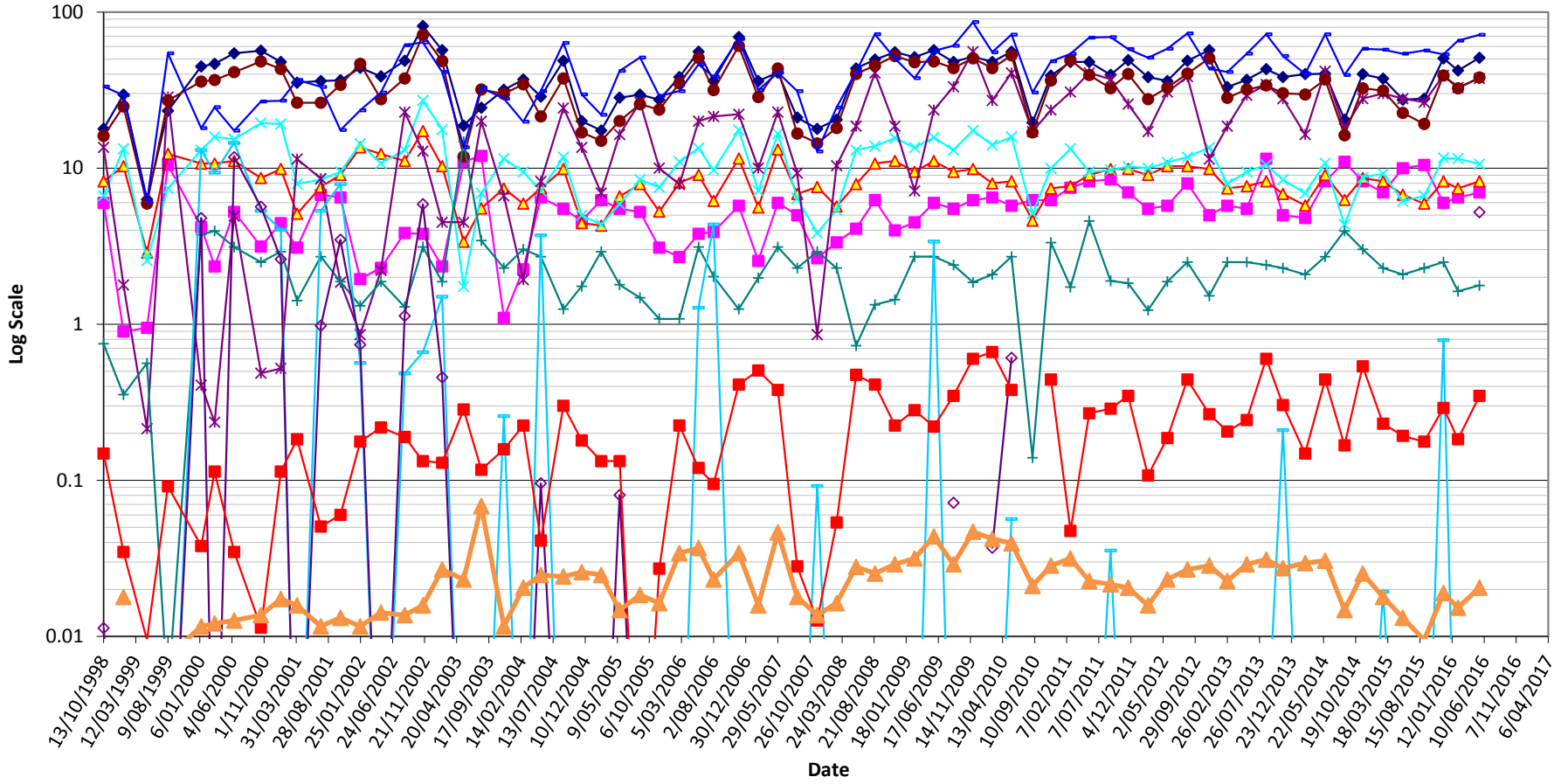
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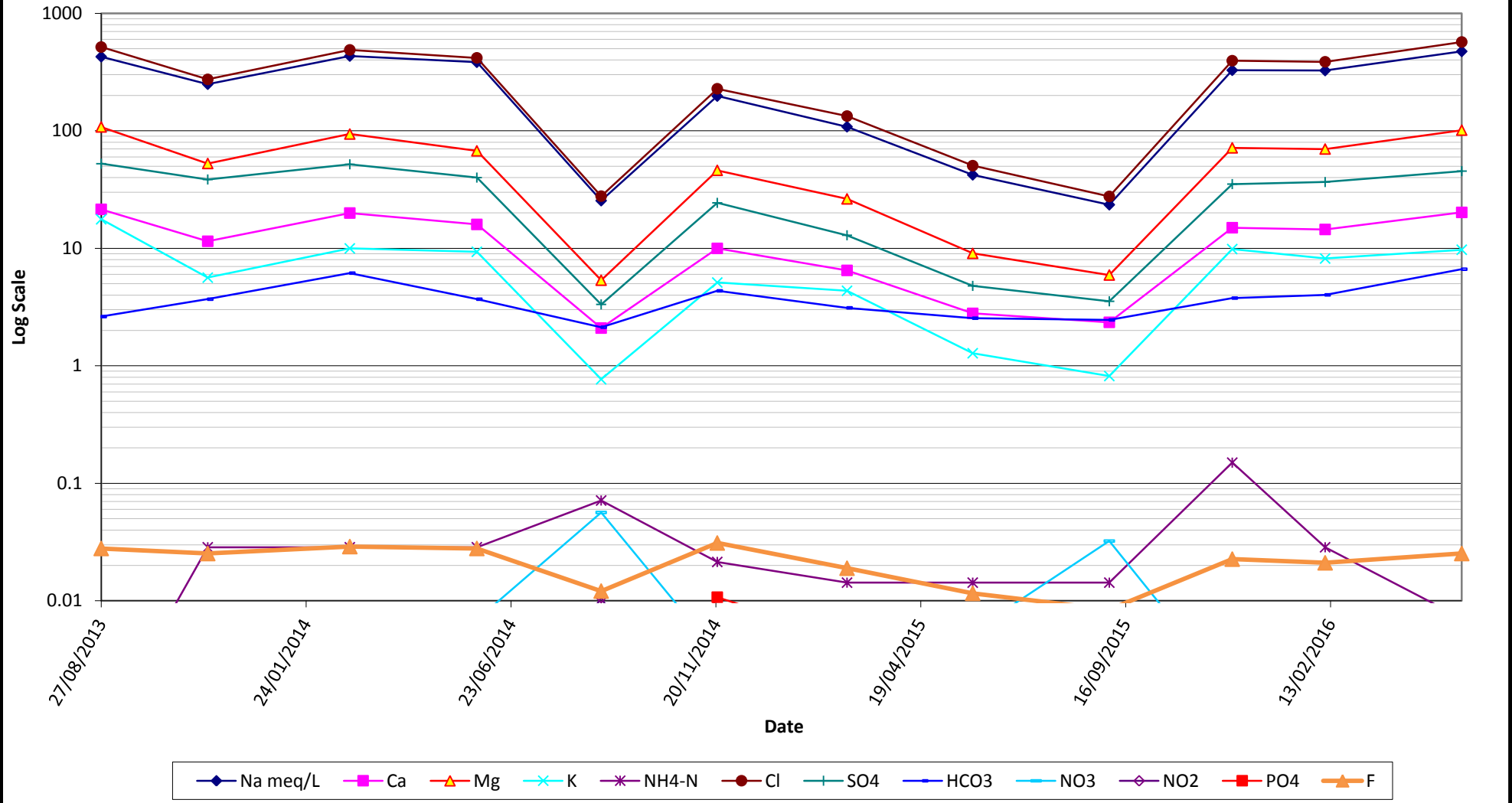
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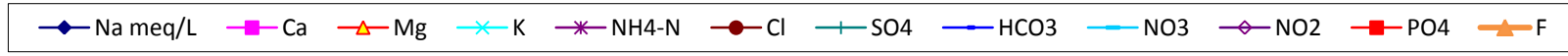
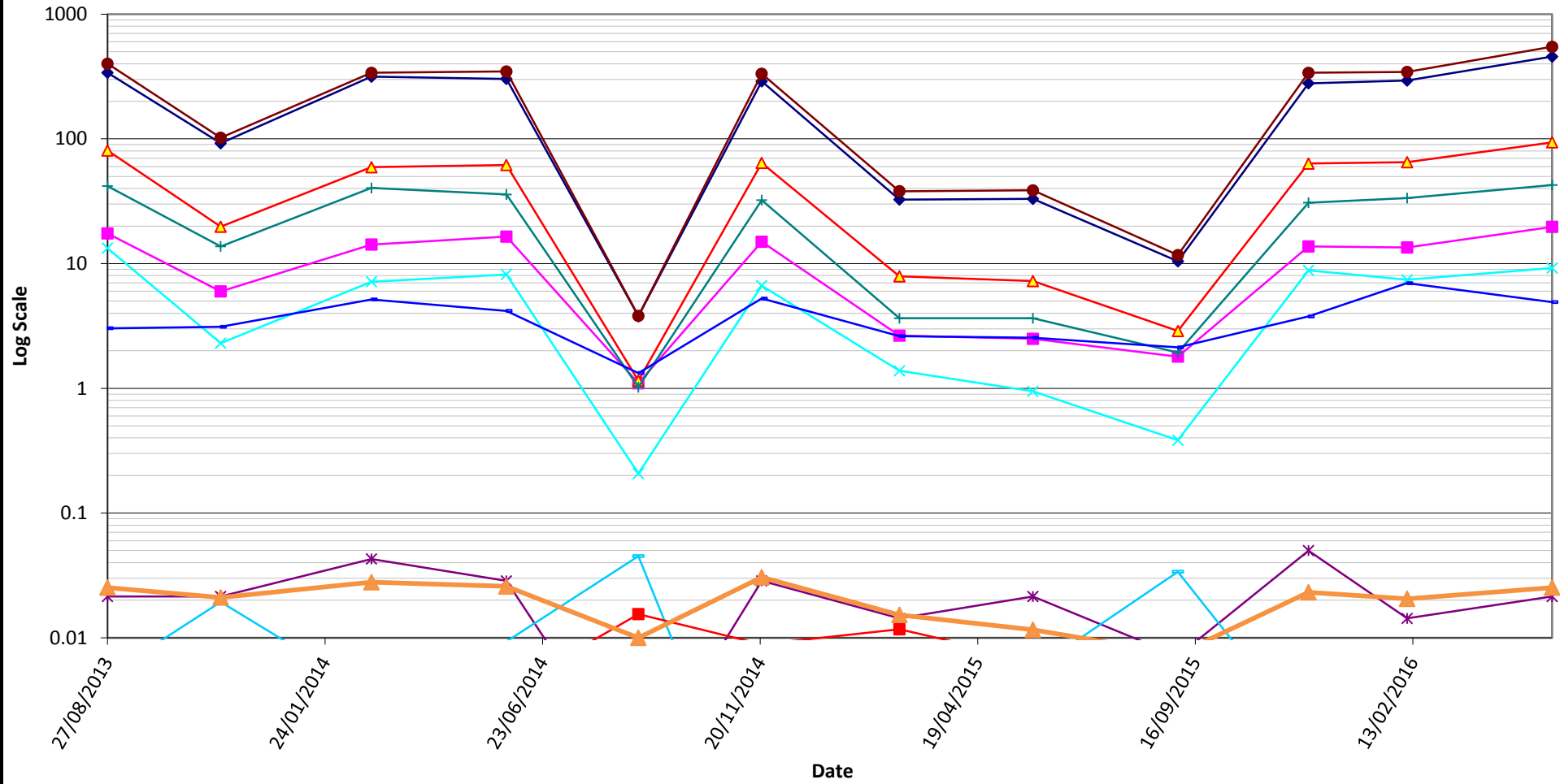
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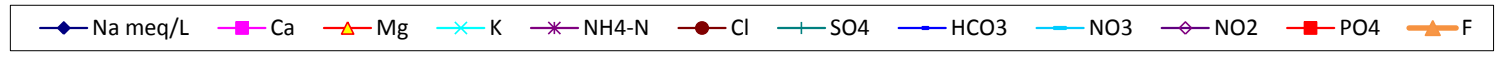
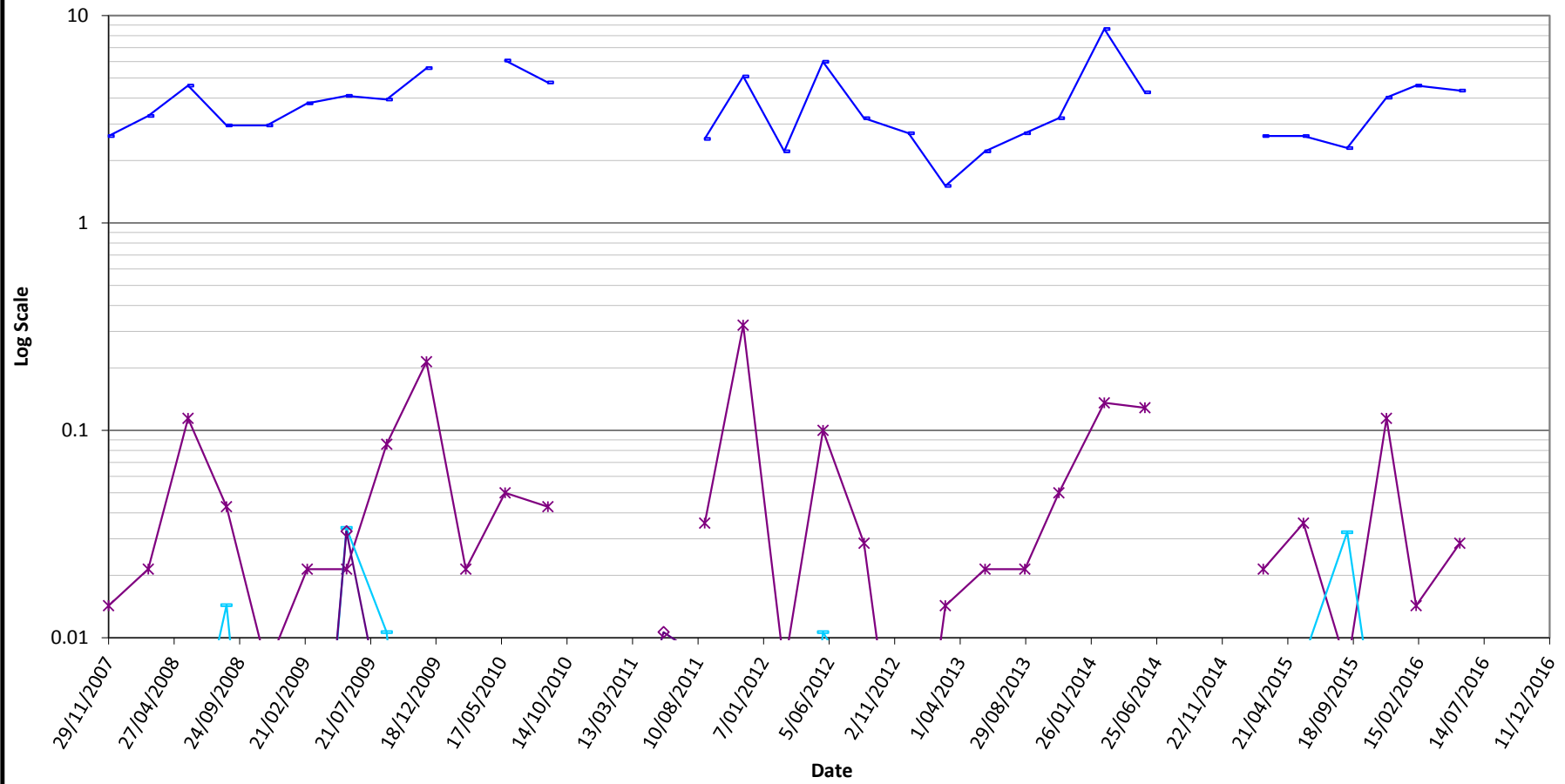
SWC_Down



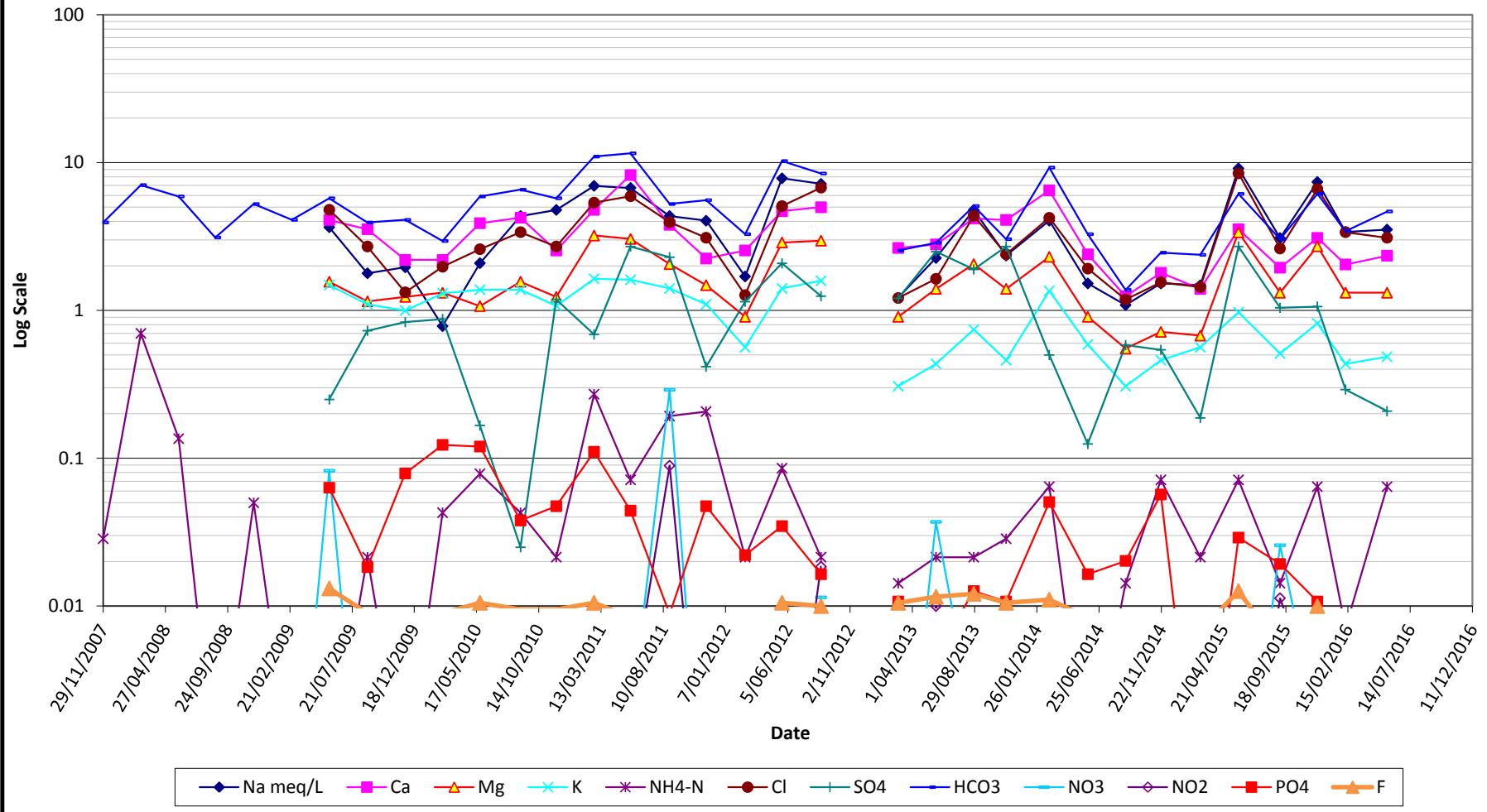
SWC_Up



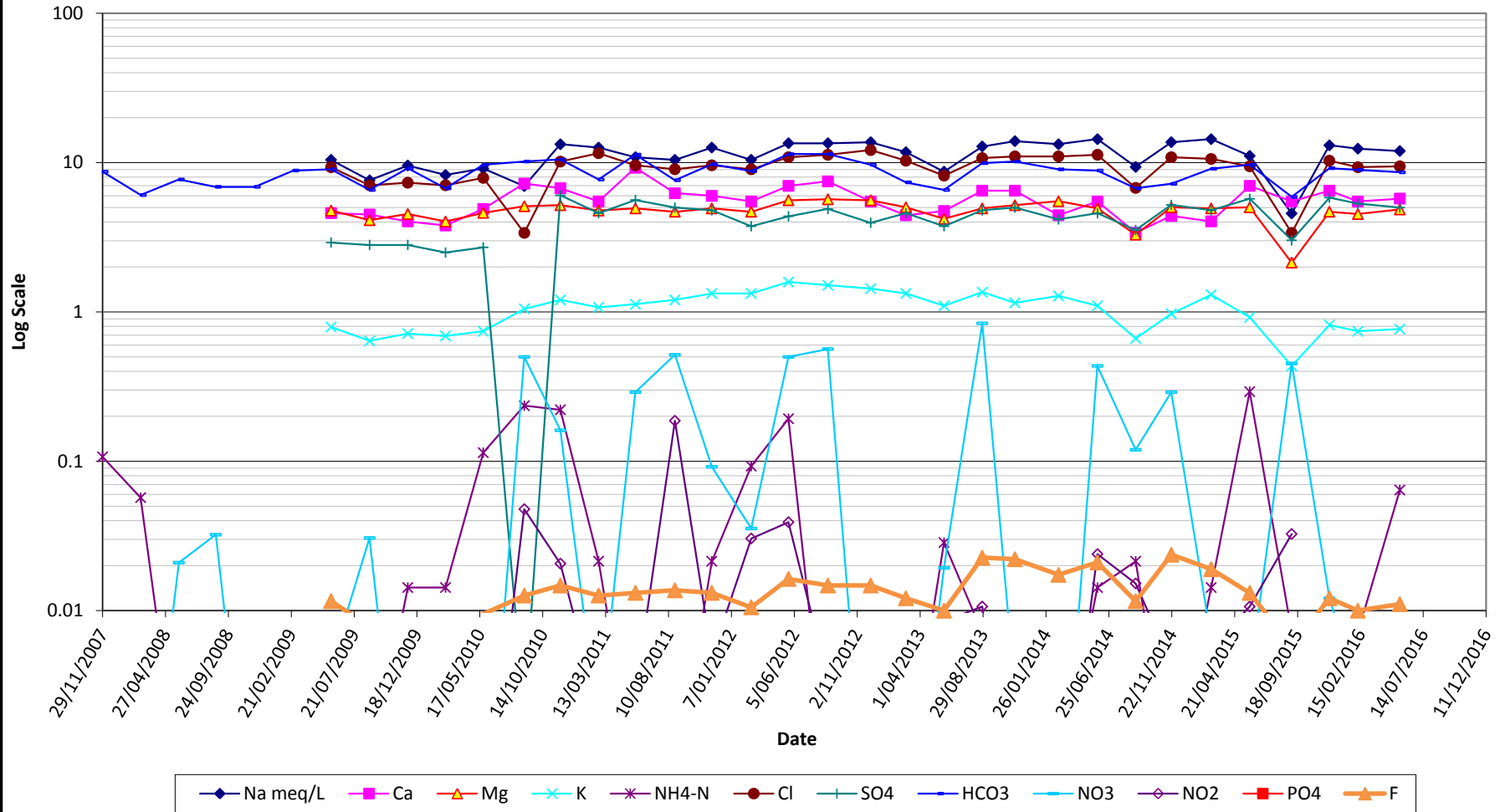
SWC2



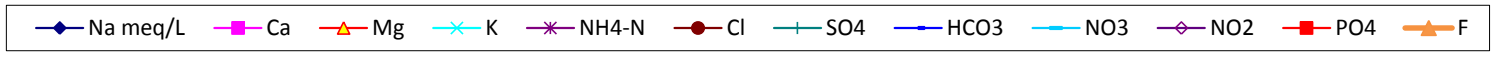
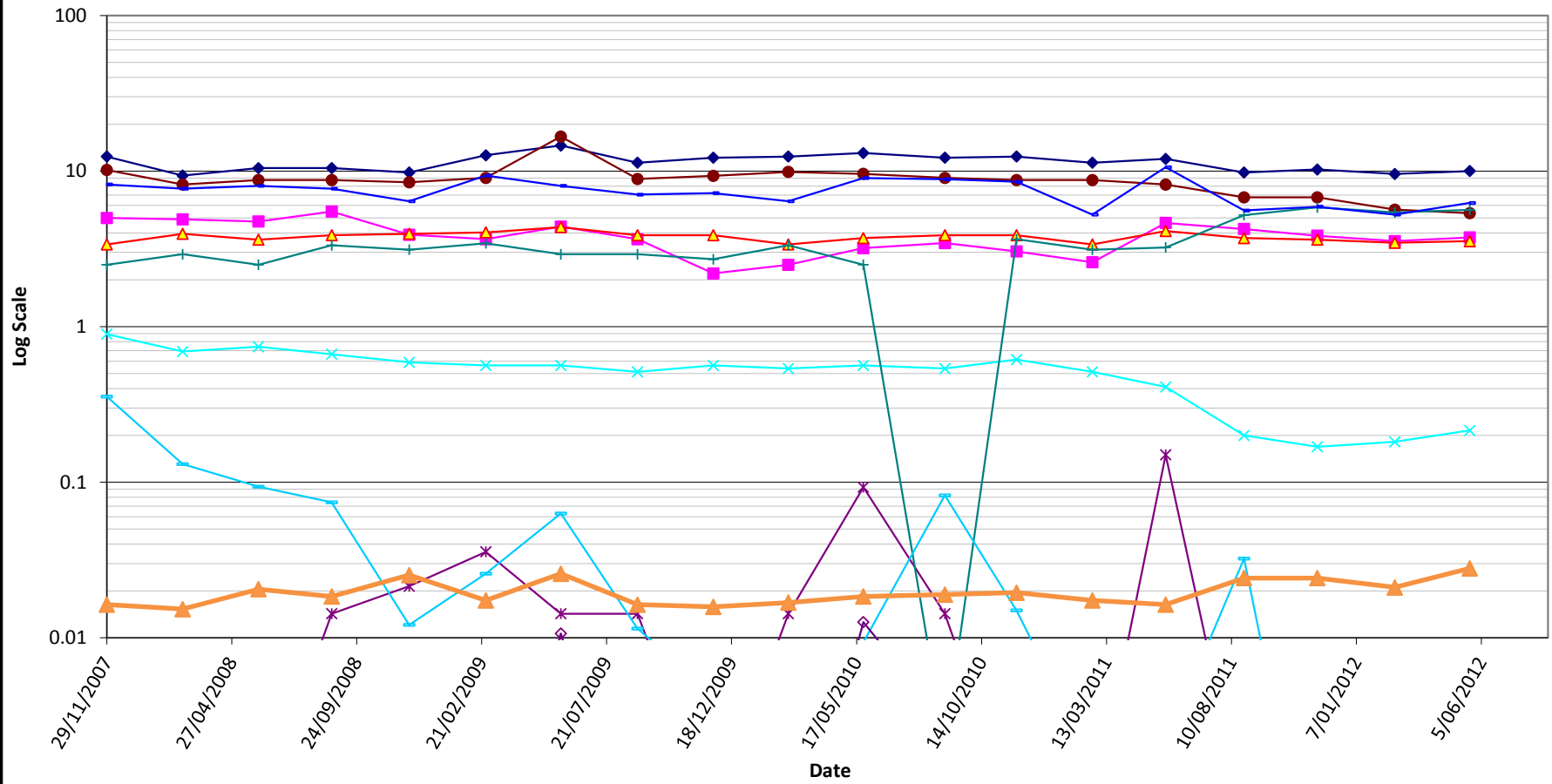
SWP1



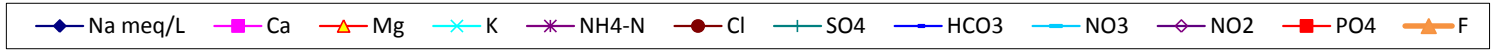
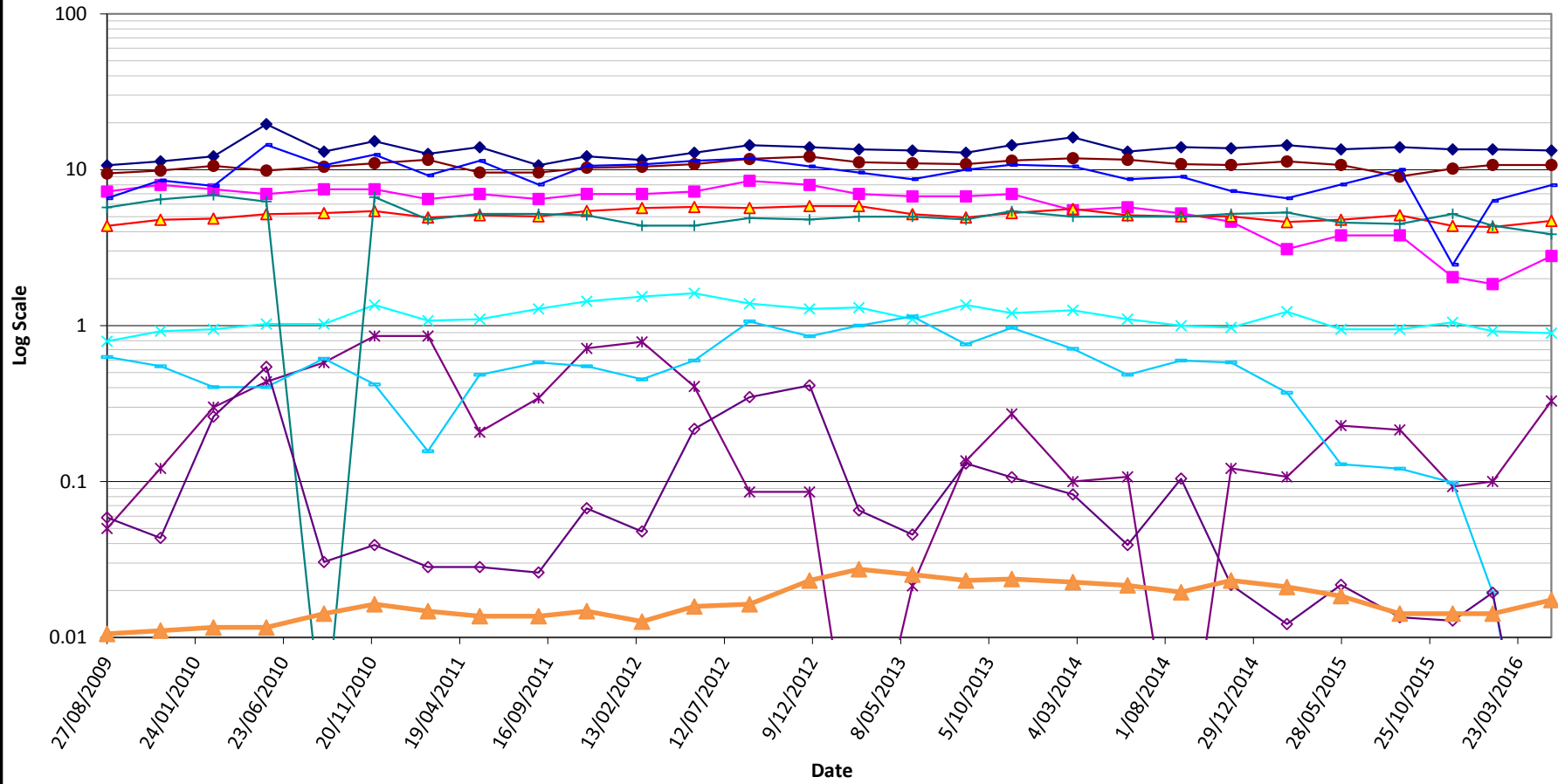
SWP2



SWP3



SWP4



SWP5

