Tarbolton Landfill – Report

Investigation into the potential for environmental impacts resulting from consolidated ash waste deposition and lack of operational management

Scottish Environment Protection Agency (SEPA)

July 2018

Non-Technical Summary

Tarbolton Landfill in Ayrshire has accepted consolidated ash waste. This waste can have hazardous properties and the landfill site may not have been authorised to accept it. In addition, the operator company has entered liquidation and there has been a lack of operational management at the site since mid-June 2018. SEPA have undertaken an investigation to assess the potential risks to the water environment and to human health posed by the deposition of consolidated ash waste. This investigation also considers the potential effects of a lack of operational management of the site. This report presents the findings of this investigation.

All non-hazardous landfill sites operate with some degree of environmental impact. This is particularly the case for landfill sites that include unlined phases, which were more commonplace prior to the introduction of more stringent standards through the Landfill Directive.. The monitoring results indicate the site has a water quality impact similar to many other landfill sites in Scotland, particularly those sites with unlined phases or operational management failures.

A conceptual site model has been developed based on a desk study. SEPA used this information to plan an initial monitoring programme designed to collect environmental data, to confirm the results of the site operator monitoring and to provide additional information that was not previously available. This initial monitoring programme has provided a snapshot of conditions at the site in spring 2018.

Based on the spring 2018 monitoring results and the lack of operational management at the site, current risks to the environment and human health have been qualitatively assessed using a Source-Pathway-Receptor approach. The risk assessment results are presented in Table 1 on the following page. Our qualitative risk assessment has graded the risk from Very Low through to High. This is to enable easy comparison and ranking of the relative risks to the different receptors.

Dust and particulate matter monitoring by SEPA indicated that there is a very low risk of dust blowing from site towards local residences. This was further confirmed by low dust deposition and soiling levels (measuring dust arriving both vertically and horizontally) at the local residences. The levels of the inhalable fractions of dust measured at the same local residences were not of concern in relation to Scottish Air Quality Objectives and Defra's Daily Air Quality Index.

Landfill gas monitoring by SEPA is ongoing but has been constrained to date by the condition of the operator's monitoring wells. Further work by SEPA is planned to improve the gas monitoring infrastructure at the site to aid future gas monitoring. Based on the current factors, the risk to human health due to migration of landfill gas is assumed to be low.

There are no known private water abstractions in the vicinity of the landfill. There is a fishery to the southwest of the landfill. The fishery ponds are upgradient of groundwater flow near the landfill and are clay are lined which will limit any groundwater inflow. They are fed by a watercourse which is not downstream of the landfill. We consider that the

fishery is not linked by the water environment to the landfill and the potential risk is considered to be very low. The key environment receptors are the Water of Fail, the Biggary Burn, and groundwater. SEPA monitoring has confirmed that elevated concentrations of contaminants associated with the landfill, such as ammoniacal nitrogen and metals, are present in the groundwater and the Biggary Burn. Following the recent suspension of leachate management, leachate levels are rising. This will increase the frequency and flows of leachate outbreaks, which will increase the impact on the water environment. Further monitoring will be required to assess the significance of these outbreaks.

A continued lack of operational management will increase the risk of additional impact to the environment. Further environmental monitoring is recommended to assess the developing impacts due to the lack of operational management at the landfill site.

Table 1 Qualitative risk assessment for Tarbolton Landfill following the deposition of consolidated ash waste and lack of operational management

Media	Risk type	Current Risk Assessment	Future Risk Assessment - lack of operational management	Comments
Air	Human health impact due to dust from lack of operational management.	**Very Low**	**Very Low**	The risk is unlikely to increase, particularly where the site is not operational. No further monitoring required. No elevated levels of windblown dust from the site, and most receptors lie upwind. See section 4 for more detail.
	Human health impact increased due to landfill gas from lack of operational management.	**Low**	**Low**	Gas sampling points need to be adequately maintained so that future risks can be fully characterised. See section 5 for more detail.
Ground-water	Human health impact increased due to lack of operational management.	**Very Low**	**Very Low**	Available evidence suggests that no private water supplies in the area are sourced from surface water or groundwater. See section 3.3 for more detail.
	Groundwater quality impact increased due to lack of operational management.	**Low/Moderate**	**Moderate**	There are groundwater impacts but the scale of impact is similar to other landfill sites with unlined phases elsewhere in Scotland. High pH leachate could compromise site liner integrity but there is no evidence to support this at present. Increasing leachate heads are expected to increase the risk to groundwater. See section 6.5 for more detail.
Surface Water	Surface water quality impact increased due to lack of operational management.	**Moderate**	**Moderate/High**	Currently, data suggest the landfill is having a localised impact on the quality of surrounding surface water. See section 6.6 for more detail.
	Ecology impact due to landfill impact on water quality.	**Low**	**Low/Moderate**	Invertebrate data suggest that there is currently no obvious impact due to the landfill. See section 6.6 for more detail.

Media	Risk type	Current Risk Assessment	Future Risk Assessment - lack of operational management	Comments
	Impact on fishery water quality and human health from consuming the fish.	**Very Low**	**Very Low**	No evidence of a water environment connection to the landfill. The fishery is upgradient of groundwater flow near the landfill and the ponds are clay lined, limiting any groundwater ingress. The ponds are fed from a stream to the southwest of the fishery, which is not downstream of the landfill area. See section 3.4 for more detail.

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1.0 Introduction

This report presents the findings of an investigation by SEPA into the potential risks to human health and the water environment at Tarbolton landfill.

The original aim of this investigation by SEPA was to assess if there are additional risks to the environment over and above those assessed as acceptable at permit determination as a result of Tarbolton Landfill site having potentially accepted an unauthorised waste type.

The objectives of this SEPA investigation included:

- Development of a conceptual site model based on existing environmental data available for the site, including review of data collected by the site operator as required by the site permit
- Undertaking a monitoring programme in Spring 2018 to collect additional environmental data to confirm the results of the site operator monitoring and provide additional information that was not previously available
- Interpretation of the results of the SEPA monitoring programme
- Qualitative risk assessment of potential risks to the water environment and human health
- Development of recommendations regarding further works to refine our understanding of the predicted future risks and to aid future regulatory action in relation to the site.

The report presents an overall assessment of the environmental risk currently posed by the site based on all available evidence at the time of writing. The risk assessment is based on previous monitoring data (both operator and SEPA monitoring), site observations and knowledge of landfill operations and impacts.

Currently (July 2018), there is a lack of operational management at the site. This is likely to present an increased risk to the environment. This would be the case with any unmanaged landfill site. Therefore, SEPA have also estimated the potential additional risks to the environment as a result of a lack of operational management at the site. This future risk assessment is an estimate and is predictive; that is, the assessment of risk, particularly over the longer term, depends on a number of variables (including climatic conditions, any intermittent management of the site or any infrastructure works that are undertaken). Further work will be required over time to assess the developing impacts due to the lack of operational management at the landfill site.

2.0 Site background

The Tarbolton Landfill site is located 1.5 kilometres north of the village of Tarbolton, 11 kilometres north east of Ayr. See Figure 1.

Tarbolton Landfill is authorised by SEPA under the Pollution Prevention and Control (PPC) regulatory regime[1] as a non-hazardous landfill. The permit (PPC-A-100105) was originally granted on 22 January 2007. There have been three subsequent variations to the permit: 30 July 2007, 3 October 2008 and 8 March 2018.

The PPC installation comprises two main zones (Figure 2):

- Zone 1, which is partially lined and dates from the 1970s.
- Zone 2, which is fully lined and dates from 2007.

Although described in the permit and in this report as a landfill, note that Tarbolton is in reality a “land raise” as waste deposition has been predominantly above the original ground level. The landfill is around 20 m high.

Zone 1 covers the south and west of the PPC installation area (approximately 60% of the footprint of the site). This zone was previously authorised under a Waste Management Licence (WML-W-20006), prior to issue of the PPC permit. However, landfilling in this zone has occurred at least since 1972 when conditional planning permission for waste deposition was granted. This zone comprises ten phases. Zone 1 is understood to be partially lined but the exact lateral extent and engineering standards of the lining system in Zone 1 is uncertain. The WML permit included a requirement for a basal lining system. However, prior to the WML being issued, the conditions attached to the 1993 planning permission (P/90/1173 granted 12 May 1993) for landfill site extension also include a requirement for landfill cells to be lined. Thus, it is assumed that waste deposition since the mid 1990s has been within lined cells. Zone 1 is partially capped (approximately 75% of the surface); the current capping is predominantly on the sides with the central area remaining uncapped.

Zone 2 covers the north and east of the PPC installation area (approximately 40% of the footprint of the site). This zone comprises six cells, of which four have been constructed and have accepted waste, the fifth is partially constructed and the sixth has not yet commenced. The Zone 2 cells partially piggyback onto the older waste in Zone 1. The Zone 2 cells have a fully engineered basal lining system. Zone 2 is currently not capped (there is a small portion of capping in place on part of Cell 1 but this is in poor condition).

Landfill gas arises from the breakdown of biodegradable waste. Methane (CH_4), a core component of landfill gas, is a highly potent greenhouse gas as well as being potentially flammable. In some circumstances, landfill gas has the potential to migrate laterally through the ground. Landfill gas can also generate unpleasant odours. There is landfill gas collection and conveyance infrastructure in Zone 1 but this is in poor condition. There is no landfill gas collection/extraction infrastructure in Zone 2; the

[1] Pollution Prevention and Control (Scotland) Regulations 2012

majority of landfill gas arising here is likely to be passively venting to atmosphere. Cessation of flaring in Zone 1 is unlikely to have a significant net effect. It is likely that the majority of gas generated in Zone 1 is passively venting to atmosphere.

Leachate is a potentially polluting liquid which results from rainwater percolating through landfilled waste. Leachate accumulates in the sealed base of the landfill site and is intermittently pumped out to be collected, treated and discharged to the environment. There are leachate extraction wells in both Zone 1 and Zone 2. When leachate extraction is occurring, leachate is pumped to a lined lagoon in the south west of the site, mixed with water extracted from two adjacent unlined lagoons to provide a degree of dilution, and subsequently discharges to a Scottish Water sewer via pumping. There are limits on the strength of leachate which can be discharged to sewer imposed by Scottish Water.

There are perimeter drains around the western and eastern sides of the installation. The perimeter drains collect site run-off from the completed cells. Additionally the perimeter drains intercept leachate from the unlined phases in Zone 1. The perimeter drains flow into the Biggary Burn. Leachate outbreaks have occurred in the past; leachate outbreaks are uncontrolled discharge from the side of the landfill. Observations by SEPA staff during site visits suggest the frequency of outbreaks and the flows involved has recently worsened.

Tarbolton landfill is authorised to accept 2.5 million tonnes of waste in total. There is reported to be around 4 years of remaining void space at present.

The site is authorised to accept:

- Municipal Waste which fulfils the Waste acceptance criteria in paragraphs 1 and 3 of Schedule of the 2003 Regulations[2]
- Non-Hazardous Waste of any other origin which fulfils the Waste acceptance criteria in paragraphs 1 and 3(b) of Schedule 2 of the 2003 Regulations
- Inert Waste.

The site management plan specifies the waste types deemed acceptable for disposal; this includes a list of relevant European Waste Catalogue (EWC) codes. The site management plan also sets out the waste acceptances procedures that should be used to determine whether a particular waste is suitable for disposal in this landfill.

Tarbolton Landfill Limited informed SEPA that the site has accepted consolidated ash waste for a period of around 20 years. The ash is mixed with liquids, including drilling mud, to help stabilise it. The consolidated ash waste contains a number of metals, petroleum hydrocarbons and polychlorinated biphenyls (PCBs). The consolidated ash waste potentially contains substances that have hazardous properties.

[2] Landfill (Scotland) Regulations 2003

There is the additional possibility that waste was deposited on the site prior the 1970s. Anecdotal evidence suggests that made ground, possibly including waste, may extend beyond the footprint of the current landfill.

It is important to note that all non-hazardous landfill sites operate with some degree of environmental impact. This is particularly the case for landfill sites that include unlined phases. The licensing process aims to restrict such environmental impacts to those which are considered acceptable.

Figure 1 - Location of Tarbolton Landfill

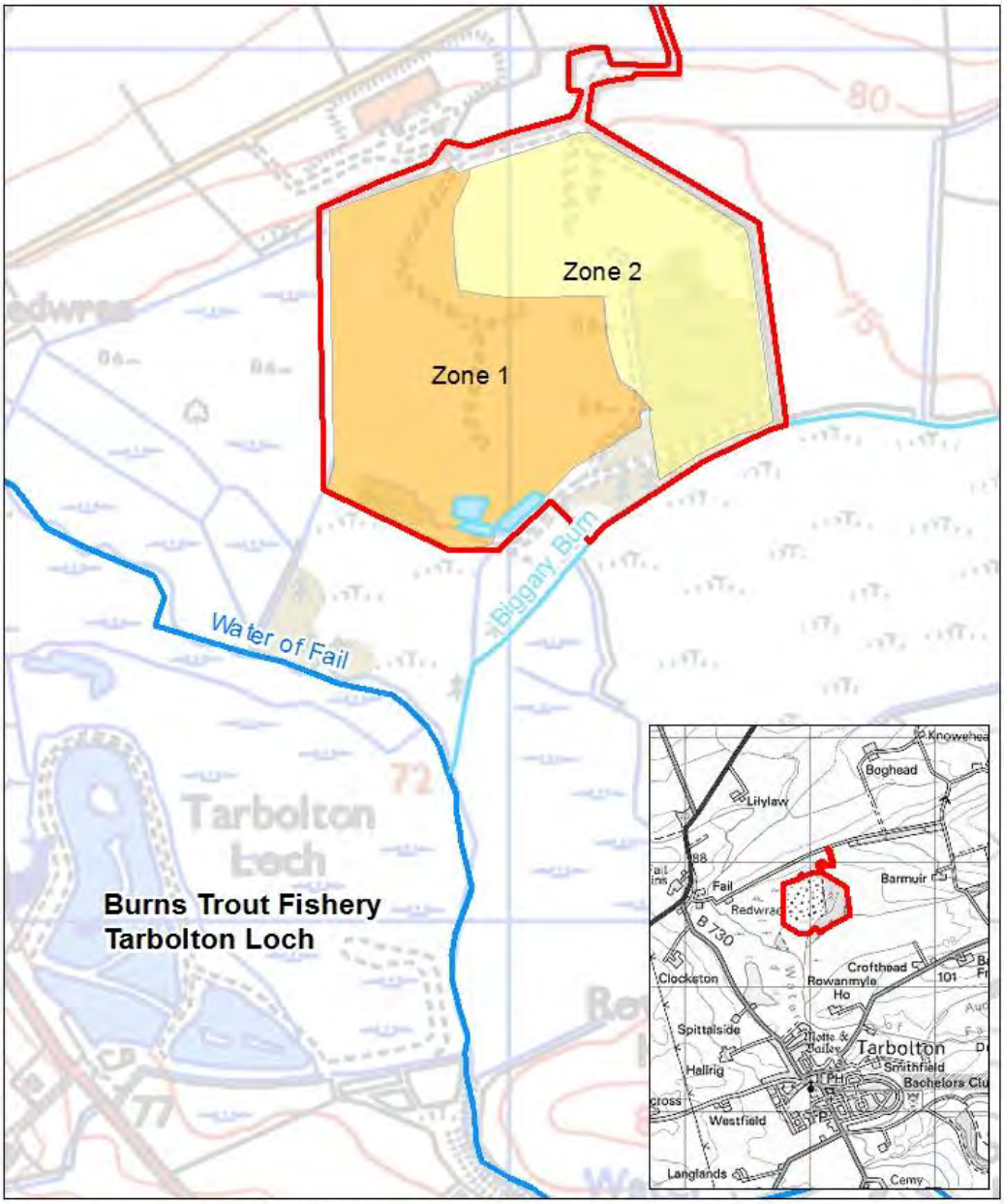

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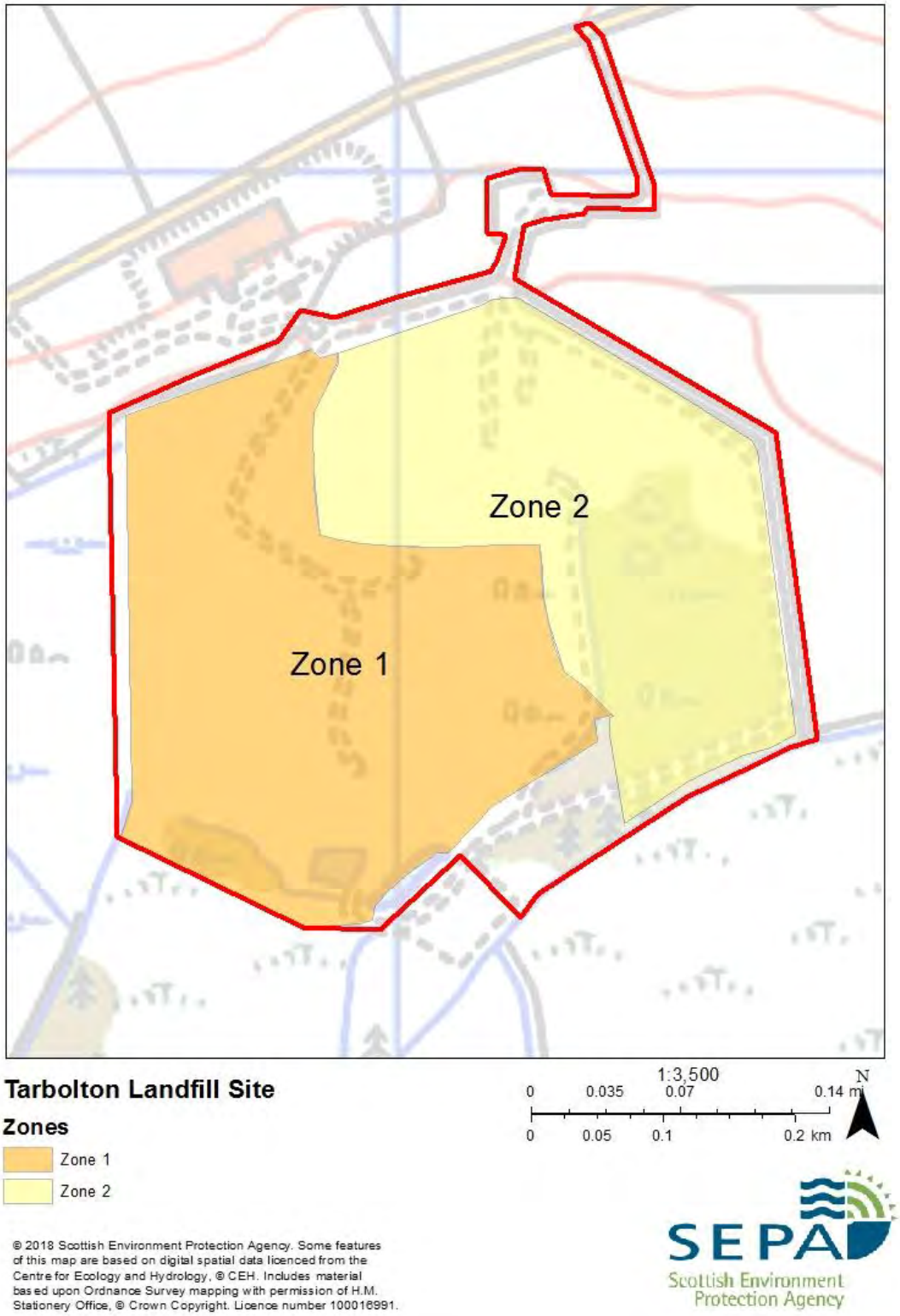
Figure 2 - Tarbolton Landfill showing Zones 1 and 2[3]

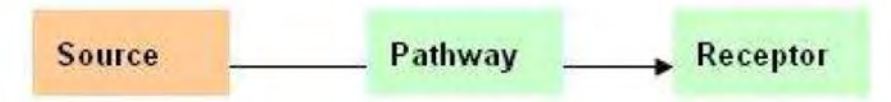


[3] Note that Zone 2 piggybacks over Zone 1 along the boundary between the two zones.

3.0 Site setting and identification of sources, pathways and receptors

3.1 Source pathway receptor methodology

We have used the source-pathway-receptor methodology to assess the range of pathways and receptors that need to be considered. This is a generally accepted procedure for assessing risks from potentially polluting inputs.



Characterisation of the environmental setting of the site informs our understanding of the existence of, and linkage between, these components.

Figure 3 shows the sources, pathways and receptors that have been identified at Tarbolton Landfill.

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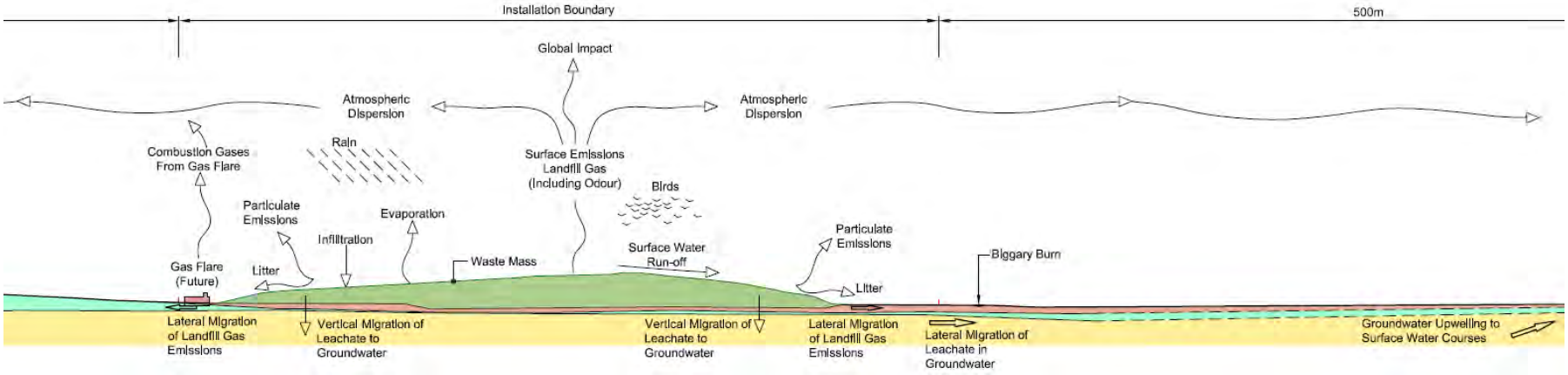
Figure 3 – Sources, Pathways and Receptors at Tarbolton Landfill[4]



Source
Landfill Waste Mass
Unauthorised Waste Deposition

Pathway
Air
Leachate
Surface Runoff
Landfill liner leakage
Groundwater in the superficial deposits
Groundwater in the bedrock

Receptor
Human Health (landfill gas and dust)
Surface Water Quality
Surface Water Ecology
Groundwater in the superficial deposits
Groundwater in the bedrock
Private Water Supplies and other abstractions

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[4] Conceptual Model, Environmental Setting and Installation Design Report, Tarbolton No. 2 Landfill, January 2005.

3.2 Air quality

Local air quality and human receptors are potentially at risk from surface emissions of dust, which may contain inhalable fractions (including PM_{10} and $PM_{2.5}$)[5] and from landfill gas. Most air quality receptors are about 800m to the south of the site, in Tarbolton village. Wind roses, based on data from Prestwick Airport, show that winds likely to affect these receptors are infrequent.

Humans are identified as a key receptor. Risks posed by air quality and landfill gas impacts from the landfill are discussed further in sections 4 and 5.

3.3 Geology and hydrogeology

The site is located on the Mauchline groundwater body (150502). The superficial deposits at the site are peat which overlies glacial till. The peat ranges in thickness from 2.2m to 8.3m and the glacial till from 0.5m to 3.9m. During construction of the landfill, the peat was locally removed due to geotechnical considerations. The bedrock underlying the site consists of the Mauchline Sandstone. There is limited connection to any groundwater deeper than the Mauchline Sandstone.

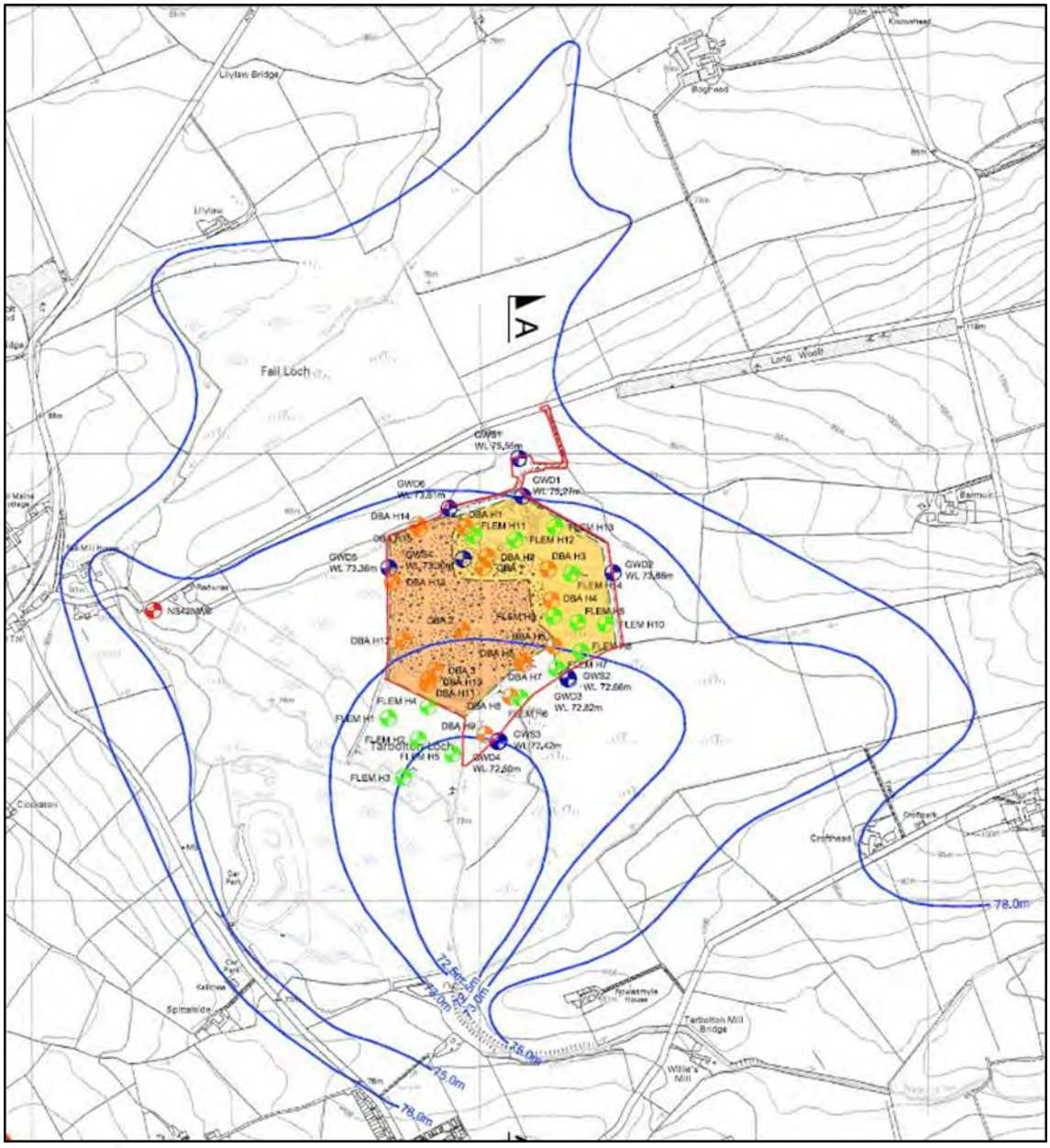
The sandstone bedrock aquifer has potential for use for water supply. Drinking water supplies are an extremely sensitive receptor but there are no known groundwater abstractions within 2 km.

The groundwater flow is generally to the south beneath the landfill. Groundwater is likely to provide flow to surface waters. The groundwater levels are likely to be influenced by surface topography. The groundwater level contours in Figure 4 are based on interpretation of the available water level data, from September 2004, and surface topography. The groundwater level data available for the site show little variation over time.

Groundwater is identified as a key receptor. Risks to groundwater are discussed further in Section 6.5.

[5] See Glossary for definition

Figure 4 - Groundwater level contours at Tarbolton Landfill site and in the immediate vicinity[6]



3.4 Surface water

There are a number of surface water features in the vicinity of the site. In general, the surface waters around the site flow to the Biggary Burn and the Water of Fail. The watercourses are likely to receive baseflow from groundwater.

The Water of Fail is silty and canalised throughout its upper reaches which creates a poor habitat for many aquatic invertebrates. The Water of Fail is a Water Framework Directive (WFD) water body (ID 10426[7]). The WFD classification of the Water of Fail is “bad” and has

[6] Tarbolton PPC Application HRA- Drawing Number 76.0265/PP/15. Note site boundary indicated on this figure is not consistent with current PPC installation boundary as defined in permit. See Figure 1 for correct installation boundary.
[7] Water Environment Hub

been at this state since 2010. The main driver for this are ecological impacts; status due to ammonium was previously “bad” but is now “moderate”. Classification monitoring sites are approximately 5 km downstream of the landfill site near the confluence with the River Ayr near Failford. Typically, classification sites are chosen to represent the overall state of the water body rather than site-specific impacts.

In addition, Burns Trout Fishery is located to the south west of Tarbolton Landfill. Information provided to SEPA by the fishery operator has confirmed that the fishery ponds are clay-lined. The ponds are fed from a watercourse to the southwest of the fishery, which is not downstream of Tarbolton landfill, and then discharge into the Water of Fail. Based on this information together with the interpreted groundwater flow regime (see Section 3.3), the fishery is not considered to be downgradient of the Tarbolton landfill.

There are no licensed abstractions from surface water for water supply[8] downstream of the landfill. There are no known private water abstractions from surface water within 2km of the landfill. The surface water courses may be used for informal recreation.

Surface waters are identified as a key receptor. Risks to surface waters are discussed further in section 6.6.

[8] The licenses downstream of the site relate to water usage in hydropower generation.

4.0 Air quality

Ash has the potential to form dust and suspended particulate matter. This may pose a risk to human health.

4.1 Dust monitoring

SEPA conducted onsite and offsite dust monitoring around Tarbolton Landfill over the period 9 February to 4 April 2018.

The purpose of this investigation was to measure dust and suspended particulate matter levels[9] in the vicinity of the landfill site, to assess whether the site itself was acting as a significant source of dust and suspended particulate matter in the area, and to establish if levels of dust and suspended particulate matter in the area were of concern. See the glossary for definitions of dust and particulate matter.

Figure 5 shows the monitoring locations used in this investigation. The offsite monitoring locations were selected as they represented the most often downwind, and hence potentially most impacted receptor (Offsite Location B) and the most populous area (Offsite Location C), respectively. Offsite Location B was sited at a residence to the east of the landfill site, whilst Offsite Location C was positioned to the south, at the edge of Tarbolton village. Onsite Locations a, b and c were situated on the western, eastern and southern boundaries of the landfill, respectively, to investigate dust blowing over the boundary of the landfill towards the receptors (Table 2).

[9] These are defined in the Technical Guidance Note M17, *Monitoring Particulate Matter in Ambient Air around Waste Facilities, Environment Agency*, Version 2, July 2013

Figure 5 - Monitoring locations for air quality assessments

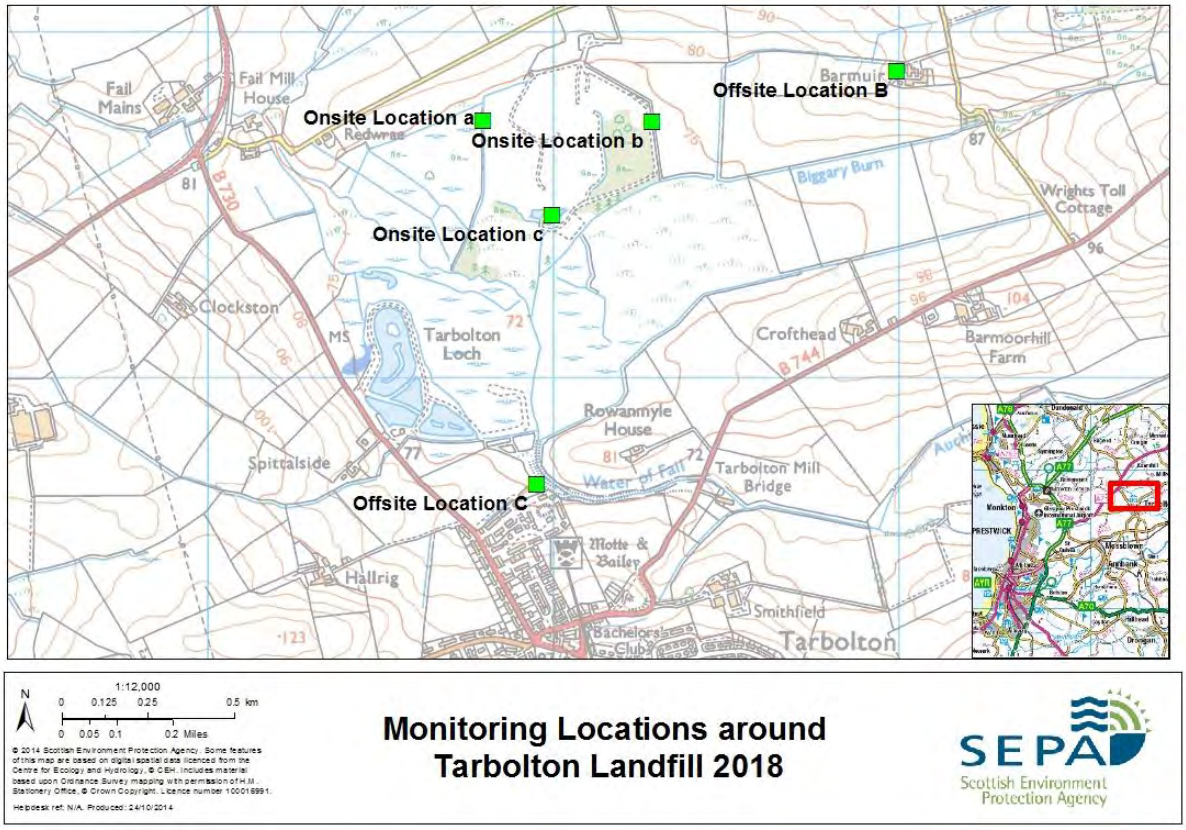


Table 2 – Dust monitoring equipment Locations

Site	Equipment	NGR[10]
Offsite Location B	Osiris, Sticky Pad, Weather Station	NS 43994 28888
Offsite Location C	Osiris, Sticky Pad	NS 42952 27694
Onsite Location a	DustScan	NS 42798 28746
Onsite Location b	DustScan	NS 43287 28743
Onsite Location c	DustScan	NS 42997 28472

Notes: *Small case letters are used to indicate positions on the landfill site boundary. Upper case letters are used to identify offsite receptors. The boundary positions (Onsite Locations a, b and c) were selected to be approximately in line between the active tipping area and the identified offsite receptors (Offsite Locations A, B and C). Offsite Location A, however, was not monitored due to it being in an upwind position considering the prevailing south westerly wind, and therefore is not identified in Figure 5.*

[10] National Grid Reference

4.1.1 Suspended particulate matter (PM_{10} and $PM_{2.5}$) at receptors

PM_{10} and $PM_{2.5}$ suspended particulate fractions were measured at two residential areas close to the site at Offsite Locations B & C.

Turnkey Osiris airborne particle monitors, certified as indicative ambient particulate monitors for PM_{10} in the range 0 to 100 µg/m^3/-, were deployed[11] from 26 February 2018 to 4 April 2018.

The main health concern related to PM_{10} and $PM_{2.5}$ is the potential effect from inhalation. Air Quality Objectives[12] (AQO) are in place for the protection of human health for PM_{10} and $PM_{2.5}$ (Table B1 in Appendix B). Defra's Daily Air Quality Index[13] (DAQI) also provides an index and banding level system for PM_{10} and $PM_{2.5}$ concentrations (Table B2 in Appendix B).

Figures B1 and B2 in Appendix B present indicative 24 hour average PM_{10} concentrations for Offsite Locations B and C. The dashed lines indicate the monitoring period average (blue) and the AQO values for indicative[14] comparison based on the available data. Offsite Location B displays a data gap from 7 to 20 March 2018 due an Osiris pump failure. Offsite Location C has a data gap from 18 to 20 March 2018 due to a power supply failure.

The indicative 24 hour average PM_{10} concentrations measured during the monitoring period were below the 50 µg/m^3 AQO level, with a maximum concentration of 14 µg/m^3 and 15 µg/m^3, measured at Offsite Locations B and C, respectively. These concentrations are both within the lowest index and banding of the DAQI. The monitoring period PM_{10} average (excluding data gaps) for Offsite Location B was 7 µg/m^3 and for Offsite Location C was 6 µg/m^3. These values are lower than the annual average PM_{10} AQO concentration of 18 µg/m^3, and are not considered to be of concern. The average PM_{10} concentration at Auchencorth Moss, Penicuik (rural background site) over the corresponding period was 6 µg/m^3 indicating that the PM_{10} concentrations are similar to this rural background reference location.

The indicative 24 hour average $PM_{2.5}$ concentrations measured during the monitoring period, with a maximum concentration of 11 µg/m^3 and 13 µg/m^3, measured at Offsite Locations B and C, respectively are both within the lowest banding of the DAQI. The monitoring period $PM_{2.5}$ average (excluding data gaps) for Offsite Locations B and C was 5 µg/m^3. Again, these concentrations are lower than the annual average $PM_{2.5}$ AQO concentration of 10 µg/m^3, and are not considered to be of concern.

[11] SEPA procedure ES-NFC-WP-031 Measurement of total suspended particulate, PM_{10}, $PM_{2.5}$ and PM_1 using an Osiris monitor

[12] http://www.scottishairquality.co.uk/air-quality/standards

[13] http://www.scottishairquality.co.uk/air-quality/daqi

[14] Indicative only given the monitoring equipment used and given there is data for a 5 week monitoring period rather than the standard 12 months used for official comparison by a reference method or equivalent technique.

Hourly average PM_{10} concentrations measured during the monitoring period are shown in Figure B3 in Appendix B. Data from the rural background reference site at Auchencorth Moss[15] have been included for comparison.

Generally, the PM_{10} concentrations at both locations follow similar trends. The similar concentrations measured at both locations, concurrently, indicate an absence of a localised, influencing PM_{10} source. There is a single period on 5 March 2018 where the PM_{10} concentrations differ noticeably - Offsite Location B shows a spike in PM_{10} not seen at Offsite Location C, however this coincides with winds from an easterly direction which rules out the source being the landfill as it lies to the west.

Flux monitoring (measuring the horizontal passage of dust past a point) was carried out at the site boundary and both deposition (measuring the vertical passage of dust to a surface or the ground) and flux monitoring was carried out at receptors. A 'dust soiling' method was used at both boundary and receptors which involved measuring the Effective Area Coverage (%EAC) rather than the weight of the dust as would be typical with a 'mass' method.

4.1.2 Dust monitoring at site boundary

DustScan DS100 gauges[16] were used to measure horizontal dust flux at three locations, close to the boundary of the site (Onsite Locations a, b and c). These locations were chosen to help identify any dust transport 'pathway' from the site to offsite locations.

The DustScan DS100 is a directional dust sampler that collects dust in horizontal flux from 360° around the sampling head using a sticky pad, to determine the direction(s) from which dust has blown. The gauge consists of a 1.6 m freestanding post, with a cylindrical monitoring head fitted to the top; a north-facing alignment peg ensures directional consistency.

The DustScan sampling cylinders were deployed on 9 February to 26 February 2018, and from 12 March to 4 April 2018. Measurement cylinders were sent to DustScan for analysis to determine absolute area coverage (%AAC) and dust soiling (see below) or effective area coverage (%EAC), expressed as percentages, for individual 15° segments. These data have been used to compare against dust annoyance risk values (Table B3 in Appendix B). Deployments over 14 days provide indicative results only.

Results for all three boundary locations (Figure B4 and Figure B5 in Appendix B) indicate a 'very low' dust impact risk from all wind directions. Visual inspection noted little dust to be present on the DustScan dust collection sheets. This indicates that during the periods of monitoring (9 to 26 February 2018, and from 12 March to 4 April 2018), little or no dust was found to be blowing from the site, over the site boundary, at the three positions selected.

[15] Source http://www.scottishairquality.co.uk/latest/site-info?site_id=ACTH&view=statistics

[16] SEPA Procedure ES-NFC-WF-046, *Use of DustScan DS100 dust gauge*

4.1.3 Dust soiling at offsite receptors

Sticky Pad dust monitors were deployed[17] at Offsite Locations B and C from 26 February 2018 to 4 April 2018.

The sticky pad method measures horizontal and vertical soiling. It is based on the principle of exposing a piece of white adhesive paper for a period of days. Dust particles stick to the paper and the dust soiling coverage is measured using a reflectometer. The results are expressed as the percentage effective area coverage per day (%EAC/day). Beaman and Kingsbury[18] provide guideline typical levels for differing environment types (Table B4 in Appendix B), and custom and practice complaint thresholds, which are dependent on the colour of the dust (Table B5 in Appendix B).

The sticky pad results (Table B6 in Appendix B) indicate that deposition rates at both Offsite Locations B and C, were all below 0.4% EAC/day which is below the custom and practice 'possible complaints' level. Again, visual inspection noted little dust to be present on the sticky pad sheets upon collection.

This indicates that dust deposition and dust flux soiling rates at the two offsite receptor locations were low during the monitoring period, 26 February to 4 April 2018.

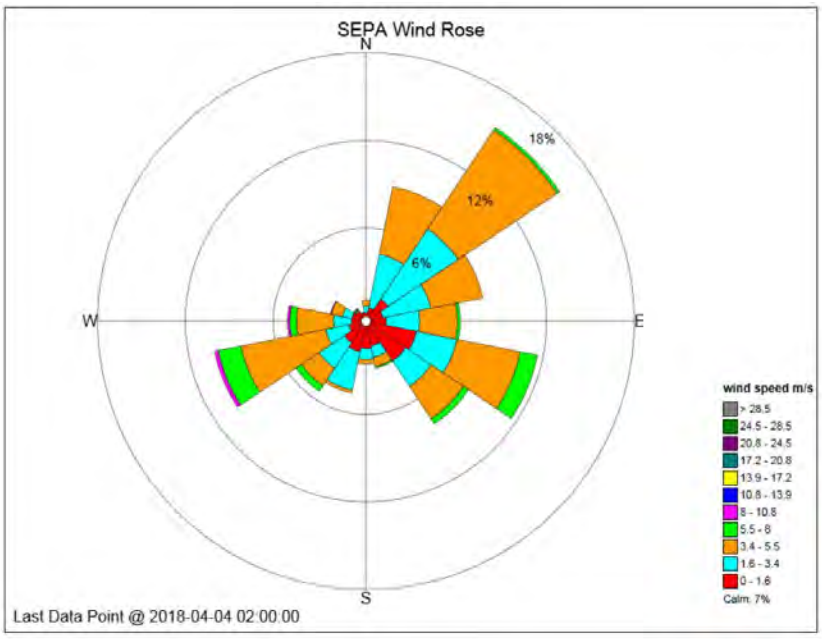
Taking the sticky pad results in combination with the DustScan results, it can be concluded that during the period from 12 March to 4 April 2018 little dust was blowing from site towards the offsite monitoring positions or being deposited at the offsite monitoring positions.

4.1.4 Meteorology

A weather station was deployed at Offsite Location B for the period 26 February to 4 April 2018 to measure wind direction and wind speed. The windrose for the exposure period (Figure 6) shows that the wind blew from most directions during the monitoring period, but was predominantly from a north easterly direction. The prevailing wind direction in this area is south westerly.

Figure 6 - Windrose - 26 February to 4 April 2018

[17] SEPA Procedure ES-NFC-WP-007, *Use of Sticky Pads for dust deposition*
[18] *Beaman, A.L. & Kingsbury, R.W.S.M. (1981), "Assessment of nuisance from deposited dust particulates using a simple and inexpensive measuring system", Clean Air, Vol.11, No.2, pp.77-81*


SEPA Wind Rose
N
E
S
W
18%
12%
6%
wind speed m/s
> 28.5
24.5 - 28.5
20.8 - 24.5
17.2 - 20.8
13.9 - 17.2
10.8 - 13.9
8 - 10.8
5.5 - 8
3.4 - 5.5
1.6 - 3.4
0 - 1.6
Calm: 7%
Last Data Point @ 2018-04-04 02:00:00

4.2 Interpretation of air and dust monitoring results

Landfilling activities which have the potential to produce dust and suspended particulate matter include:

- movement of waste on- and off-site
- handling, storage and processing of waste
- plant traffic both on- and off-site
- plant used to burn landfill gas, including gas flares or engines
- dust generated from the surface of the landfill

Dust and suspended particulate matter generated by an emission source onsite and released to the air, will spread out from the source and be carried on the wind away from the site. The impacts of dust released from a non-elevated source (i.e. close to the ground) will decrease with distance, due to dispersion and dilution[19].

The dust and suspended particulate matter investigations reported here were limited in scope. It is important to understand that they were undertaken over a period of approximately 5 weeks each, during the winter-early spring when dust is generally suppressed by damp and precipitation. The landfill site was however operational.

Since vehicle / waste movement operations and gas flaring are dust, $PM_{2.5}$ and PM_{10} producing activities it is assumed that Tarbolton Landfill when non-operational will generally produce less dust, $PM_{2.5}$ and PM_{10} than when operational. Fugitive dust and particulate matter releases from the surface of the landill and the site haul roads may increase during drier periods.

The majority of the ash deposited on the landfill is contained within the body of the waste mass, and as such is not subject to resuspension by wind or mechanical disturbance and therefore represents a very low risk in terms of forming airborne dust and suspended particulate matter.

4.3 Summary of air and dust monitoring results

Results indicated that during the monitoring period:-

- Indicative PM_{10} and $PM_{2.5}$ concentrations measured at the offsite monitoring locations were below Scottish Air Quality Objective (AQO) concentrations and within the lowest banding of Defra's Daily Air Quality Index (DAQI).

- Tarbolton Landfill was not identified as a significant source of PM_{10} or $PM_{2.5}$ to the ambient air monitored at the offsite receptors.

- Boundary dust flux monitoring and offsite / receptor dust deposition monitoring did not identify elevated levels of dust being blown over the site boundary towards the offsite / receptor monitoring locations.

[19] *Impact on Health of Emissions from Landfill Sites*, Health Protection Agency, ISBN 978-0-85951-704-1, 2011

4.4 Air quality risk assessment summary

Summary of findings: Suspended particulate matter concentrations and dust soiling levels at the investigated receptors were not of concern during the period of monitoring. Boundary dust flux monitoring did not identify elevated levels of dust being blown over the site boundary towards the offsite / receptor monitoring locations. These findings are based on a limited monitoring study.

The majority of the ash deposited on the landfill is contained within the waste mass, and as such is not subject to resuspension by wind or mechanical disturbance, and therefore represents a very low risk in terms of forming airborne dust and suspended particulate matter.

Risk Assessment: Very Low

Further Work: No further monitoring required, especially considering that the site is currently non-operational. SEPA will review the situation if concerns relating to dust emissions from site are received in the future.

5.0 Landfill gas

Landfill gas arises from the breakdown of biodegradable waste. Methane (CH_4), a core component of landfill gas, is a highly potent greenhouse gas. In some circumstances, landfill gas has the potential to migrate laterally through the ground. Landfill gas can also generate unpleasant odours.

5.1 Landfill gas monitoring

SEPA carried out landfill gas monitoring of the twelve perimeter boreholes (Figure 7) at Tarbolton Landfill on 2 May 2018 and 18 June 2018. The methane, carbon dioxide and oxygen measurements were carried out using a calibrated Geotech GA5000 instrument in accordance with SEPA's UKAS-accredited procedure[20]. The atmospheric pressure was measured using the GA5000's internal barometer which is verified against readings from a UKAS-calibrated barometer[21].

Methane and carbon dioxide concentrations recorded on 02 May 2018 and 18 June 2018 were below the trigger level concentrations stipulated in SEPA permit PPC/A/1000105 and oxygen concentrations were within the safe level of greater than 18% v/v[22] as set by the Health and Safety Executive. However, on both occasions all the boreholes were sampled as passive vents due to the absence of appropriate gas sealing caps and gas taps. Maintenance is required at all boreholes to establish gas tight seals and to provide suitable taps for gas sampling, as stipulated in the site PPC permit.

Table 3 details the stable landfill gas concentration results for Tarbolton Landfill.

[20] SEPA Procedure ES-NFC-WP-002, *Determination of oxygen, methane and carbon dioxide in landfill gas using a landfill gas monitor*
[21] SEPA Procedure ES-NFC-WP-021, *Use and Verification of Field Barometers for Accredited Methods*
[22] *Guidance Note EH40: Occupational Exposure Limits* 2002, Health and Safety Executive (2002)

Figure 7 - Perimeter Borehole Locations at the Tarbolton Landfill Site

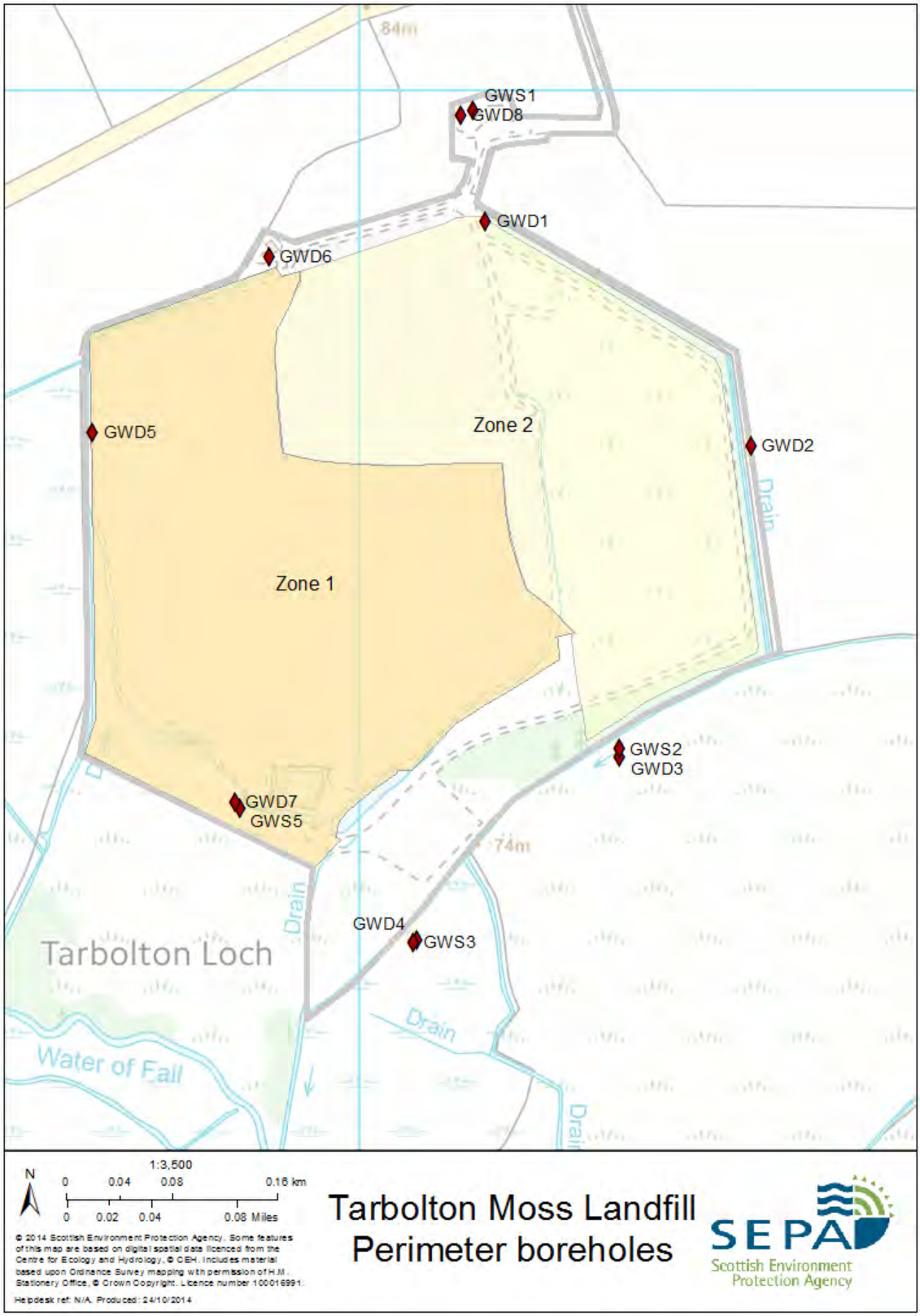


Table 3 - SEPA landfill gas measurements from the perimeter boreholes at Tarbolton Landfill on 2 May 2018 and 18 June 2018

Borehole Reference	Methane Stable (%)		Carbon Dioxide Stable (%)		Oxygen Stable (%)		Atmospheric Pressure (mbar)*	
	02/05/18	18/06/18	02/05/18	18/06/18	02/05/18	18/06/18	02/05/18	18/06/18
GWS1	<0.3	<0.3	<0.3	<0.3	20.5	>20.9	987	1004
GWD8	<0.3	<0.3	<0.3	<0.3	20.6	>20.9	988	1005
GWD1	N/A	<0.3	N/A	<0.3	N/A	>20.9	N/A	1005
GWD2	<0.3	<0.3	<0.3	<0.3	20.8	>20.9	992	1005
GWD3	<0.3	<0.3	0.3	<0.3	20.8	>20.9	992	1005
GWS2	<0.3	<0.3	<0.3	<0.3	20.9	>20.9	991	1005
GWD4	<0.3	<0.3	<0.3	<0.3	20.9	20.6	992	1005
GWS3	<0.3	<0.3	<0.3	<0.3	20.9	20.7	992	1005
GWS5	0.8	<0.3	0.3	<0.3	20.8	20.3	992	1005
GWD7	<0.3	<0.3	<0.3	<0.3	>20.9	20.5	992	1006
GWD5	<0.3	<0.3	<0.3	<0.3	>20.9	>20.9	993	1005
GWD6	<0.3	<0.3	<0.3	<0.3	>20.9	>20.9	992	1005

Notes: *The GA5000 was calibrated and linearity tested up to 50% methane, 40% carbon dioxide and 20.9% oxygen. Concentrations exceeding these have been reported as "greater than" (>) the upper calibration values. The GA5000's lower limit of detection for methane, carbon dioxide and oxygen is 0.3%, concentrations below this have been reported as "less than" (<) this value. On 02 May 2018 the borehole GWD1 was flooded and no measurements could be taken.*

Monitoring of perimeter boreholes support that lateral migration of gas is unlikely; trigger levels have not been breached in these boreholes previously.

SEPA Permit PPC/A/1000105 defines the following trigger levels for landfill gas concentrations: Methane '>1%' and Carbon dioxide '>1.5%'[23]. The trigger level for methane at this site is 1% v/v above agreed background concentrations (based on 20% of the Lower Explosive Limit). The trigger level for carbon dioxide is 1.5% v/v above the agreed background concentration based on the UK Occupational Exposure Standard. In addition, these standards from the *Health and Safety Executive*[24] recommend that, in areas accessible to humans, action is needed to prevent the oxygen falling below 18% v/v at atmospheric pressure**.**

[23] These trigger levels are in accordance with guidance levels stated in the 'Guidance on the management of landfill gas LFTGN03', Environment Agency / SEPA, September 2004

[24] *Guidance Note EH40: Occupational Exposure Limits* 2002, Health and Safety Executive (2002)

5.2 Risks to receptors

A review of the landfill gas data submitted by the operator between 2015 and 2017 shows that there had been no breaches of the trigger concentrations for the perimeter boreholes. However, it is not known if the landfill gas data collected by the operator were also sampled as passive vents.

The risk to human health due to landfill gas generated from the landfilled ash is assumed to be low, due to the lower organic content of the ash waste. However it is assumed that the waste mass, which contains non-inert waste, will continue to generate landfill gas.

Given that large areas of the site are uncapped and extraction and flaring has ceased it is likely that the majority of landfill gas is passively venting to atmosphere, as this is the preferential pathway. Passive venting of gas may increase the frequency of nuisance odour from the site.

Although landfill gas extraction and flaring on the site has ceased, the landfill gas extraction infrastructure on the site (located in part of Zone 1 only) is in poor condition and the cessation of extraction and flaring in itself is unlikely to present an increased risk to receptors.

Additional work is required to improve the reliability of the monitoring network and to assess the risk of lateral gas migration from site.

5.3 Landfill gas risk assessment summary

Summary of findings: A review of the landfill gas data submitted by the operator shows that there had been no breaches of the trigger concentrations for the perimeter boreholes although there is uncertainty on the reliability of this data. The levels of landfill gas measured in the perimeter boreholes at Tarbolton Landfill on 02 May 2018 and 18 June 2018 were below the trigger concentrations detailed in SEPA permit PPC/A/1000105 and are not considered to be harmful. However, on both occasions all the boreholes were sampled as passive vents. In considering both the potential for gas generation and that the likely preferential pathway is passive venting to atmosphere, it is considered that the risk to receptors as a result of landfill gas is low. However, further monitoring work is needed to establish whether landfill gas being generated onsite is migrating laterally.

Risk Assessment: Low

Further Work: Maintenance is required at all boreholes to establish gas tight seals and to provide suitable taps for gas sampling. SEPA are installing appropriate caps and gas sampling taps to this end, before commencing further landfill gas monitoring to fully assess the risk of lateral migration given the lack of operational management at the site.

6.0 Water environment

6.1 Preliminary assessment of water environment hazard posed by ash waste deposition

The suitability of waste material deposited in landfill is commonly assessed based upon the waste leachate composition compared to waste acceptance criteria (WAC). A Scottish Government Direction in 2005 outlined Criteria and Procedures for the Acceptance of Waste at Landfills in Scotland. (http://www.gov.scot/Topics/Environment/waste-and-pollution/Waste-1/17103/landfilldirection)

Tarbolton Landfill has been accepting treated ash waste for around twenty years. As part of the treatment process the ash waste has been blended with offshore drilling mud. No leachate testing has been undertaken on the ash waste deposited at Tarbolton. This presents difficulties and uncertainty when assessing the potential risks to the water environment due to the ash waste deposition within the landfill.

Solid chemical composition testing has been undertaken both on the source of the ash waste (DERL) and on samples collected directly from ash deposited in the landfill (SEPA 2014 Samples), these are summarised in Table C1 in Appendix C**.** In addition, documents submitted by C&P Environmental[25] indicate that the consolidated ash waste deposited contains concentrations of total petroleum hydrocarbons (TPH). As no leachate testing is available the ash waste cannot be compared to WAC for a non-hazardous landfill.

Also shown in Table C1 in Appendix C are composition values for typical Scottish soils and pulverised fuel ash (PFA). Comparison between these and the ash waste composition has been used as an initial screening of risk to identify if the ash constituent concentrations are elevated. As no leachate testing is available, indicative pulverised fuel ash (PFA) leachate contents, as outlined in BRE509 have been considered to further inform potential risks.

Pulverised fuel ash is a by-product of coal power energy production and is used when mixed with cement grouts to fill subsurface voids in ground stabilisation techniques. As such detailed testing information is available on the leachability of PFA grout. The ash waste at Tarbolton is not directly comparable with PFA grout stabilisation, however, the materials are considered to be sufficiently similar to be used as an analogue, particularly in the absence of any other leachate data from the Tarbolton ash waste.

Contaminants may also be derived from the drilling mud used as part of the ash waste stabilisation process.

The following potential water environment risks are highlighted;

- The pH of the ash waste at 11-12.2 is elevated. Placement of waste with elevated pH could present issues for the integrity of the landfill liner.
- The waste has the potential to produce leachate containing elevated concentrations of eco-toxic metals such as cadmium, arsenic, nickel and zinc.
- Total petroleum hydrocarbons (TPH) and poly chlorinated biphenyls (PCBs) were also identified in the waste.

[25] Summary of the assessment of treated ash waste from William Tracey into Tarbolton Landfill site, C & P Environmental, 17 August 2017

- Owing to the ash having been consolidated with offshore drilling muds, the waste has the potential to contain Naturally Occurring Radioactive Materials (NORM).

Discharge of leachate from the landfill with this composition would present significant concerns for the quality of the surrounding water environment.

6.2 Water environment monitoring

Leachate, groundwater and surface water monitoring was undertaken by the site operator at Tarbolton Landfill. This monitoring is a requirement of the site permit (PPC-A-1000105) issued by SEPA.

Some historic monitoring at the site has, on occasion, also been undertaken by SEPA.

In response to the reports of the site having received treated ash waste SEPA undertook a review of all available site environmental monitoring information from site monitoring reports between 2009 and 2017. A preliminary assessment of the potential impacts to the water environment and recommendations for further investigation by SEPA was undertaken and used to inform field works.

Site visits were undertaken on 02/05/2018, 03/05/2018 and 10/05/2018 by SEPA Field Chemistry and Water Resources Unit staff to collect environmental data to confirm the results of the site operator monitoring and provide additional information that was not available during the preliminary assessment stages. The SEPA monitoring programme included analysis of parameters associated with the consolidated ash waste that have not previously been routinely monitored by the operator.

The site operator monitoring results have been compared with those collected by SEPA to provide an updated water environment risk assessment.

6.2.1 Leachate monitoring network

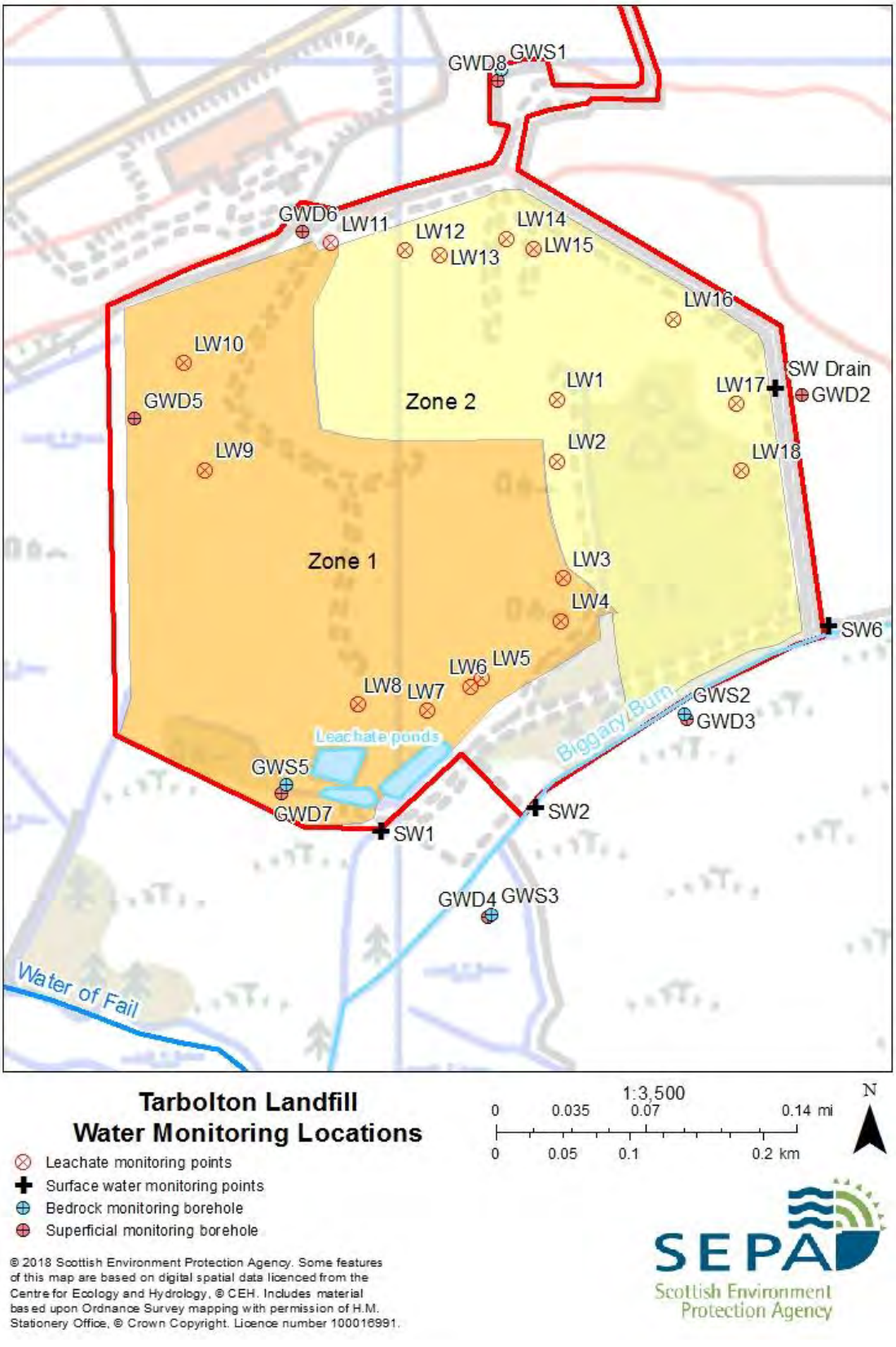
Leachate at the site is monitored via 18 leachate wells, LW1-LW18 (Figure 8). In addition the leachate authorised discharge is also monitored. The locations of each of the leachate installations are shown on Figure 8. Leachate wells LW1-LW10 monitor Zone 1 of the site[26]. Leachate wells LW11-LW18 monitor Zone 2.

SEPA collected leachate samples from leachate wells LW2, LW4, LW8, LW10, LW14 and LW17 on the 03/05/2018. The leachate management and pumping system was not operational at the time of sampling.

The majority of the analysis was undertaken by SEPA's laboratory. A number of organic and radiological substances were analysed by a commercial laboratory. These include hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Summary results are presented in Appendix C.

[26] LW1 and LW2 are located where Zone 2 piggybacks onto Zone 1.

Figure 8 - Tarbolton leachate, groundwater and surface water monitoring locations



Note: Surface water monitoring points SW3, SW4 and SW5 are located to south and are shown in Figure A1 in Appendix A

6.2.2 Groundwater monitoring network

Groundwater monitoring is undertaken by the site operator using 12 boreholes[27] surrounding the landfill waste mass (Figure 8).

Table 4 below outlines the borehole installation details.

- Boreholes named 'GWD' are installed to target groundwater in the shallow superficial deposits (although the response zone generally also penetrates into the sandstone below)
- Boreholes named 'GWS' are installed to target groundwater in the bedrock sandstone deposits.
- Three boreholes, GDW1, GWD8 and GWS1, are positioned upgradient of the landfill.
- GWD1 is partially installed into made ground and is located in close proximity to the landfill waste mass. Samples recovered from GWD1 are unlikely to be representative of the natural background groundwater chemistry upgradient of the landfill.
- GWD8 and GWS1 are preferred as upgradient monitoring locations.

Samples of groundwater have been recovered by the site operator on a monthly basis between 2009 and 2017[28] from the monitoring network at the landfill:

- Samples have been analysed for a range of common landfill monitoring parameters including pH, COD, BOD, ammoniacal nitrogen and chloride.
- Metals and selected major ions analysis is undertaken on samples 4 times per year.
- A limited number of samples have been analysed for hydrocarbons and other organic contaminants in 2009-2011.

SEPA collected and analysed groundwater samples from GWS1, GWS2, GWS3, GWS5, GWD2, GWD3, GWD4, GWD7 and GWD8 on 10 May 2018. These locations were selected to give adequate coverage of the quality of both upgradient and downgradient groundwater quality to inform the risk assessment. Several locations were not monitored, for example GWD1, GWD5 and GWD6, as they are located in very close proximity to the waste mass and may not provide representative groundwater samples.

Samples of groundwater were recovered from monitoring boreholes after they were purged of three times the calculated well volume. The majority of the analysis was undertaken by SEPA's laboratory. A number of organic and radiological substances were analysed by a commercial laboratory. These include hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Summary results are presented in Appendix D.

[27] There is an additional borehole (GWS4) which is not currently in use.
[28] Monitoring data for the year 2014 is not available

Where relevant the monitoring results have been compared to standard assessment limit values to indicate if there has been an impact on groundwater quality:

- Resource protection values, RPVs, apply to non-hazardous substances in groundwater, are based on dissolved concentrations and indicate the concentrations at which the quality of groundwater is considered to have been degraded.
- Minimum reporting values, MRV, apply to hazardous substances, which should be prevented from entering groundwater.

Table 4 - Groundwater monitoring installations at Tarbolton Landfill

Borehole	Ground Level (metres Above Ordnance Datum)	Plain Pipe (metres Below Ground Level)	Slotted Section (metres Below Ground Level)	Response Zone	Monitoring Location
GWD1	75.18	0.0-1.0	1.0-6.0	Made ground, clay and sandstone (weathered)	Upgradient
GWD2	73.49	0.0-1.0	1.0-7.0	Peat, clay and sandstone (weathered)	Downgradient of Zone 2
GWD3	73.35	0.0-2.5	2.5-5.5	Peat and clay	Downgradient of Zone 1 and 2
GWD4	72.86	0.0-2.5	2.5-8.5	Peat and clay	Downgradient of Zone 1 and 2
GWD5	73.61	0.0-1.0	1.0-6.0	Peat, gravel and sandstone (weathered)	Downgradient of Zone 1
GWD6	75.22	0.0-2.0	2.0-5.0	Clay sand and sandstone (weathered)	Upgradient of Zone 1
GWD7	No borehole log available				Downgradient of Zone 1
GWD8	No borehole log available				Upgradient
GWS1	79.61	0.0-11.5	11.5-17.5	Sandstone	Upgradient
GWS2	73.49	0.0-10.0	10.0-16.0	Sandstone	Downgradient of Zone 1 and 2
GWS3	72.94	0.0-14.5	14.5-20.5	Sandstone	Downgradient of Zone 1 and 2
GWS4[29]	76.12	0.0-11.0	11.0-17.0	Sandstone	Downgradient
GWS5	No borehole log available				Downgradient of Zone 1

[29] GWS4 is not currently in use as a monitoring borehole at the site.

Note: GWD7 and GWS5 were reported during the site visit to be installed into the waste and are also located in close proximity to an unlined leachate lagoon (see section 6.3).

6.2.3 Surface water monitoring network

Surface water monitoring is undertaken by the site operator at six locations surrounding the landfill waste mass and in nearby rivers and burns as shown in Figure A1 in Appendix A.

Surface water sampling has been undertaken quarterly between 2009 and 2016. Samples are monitored for a number of landfill indicator parameters including ammoniacal nitrogen, chloride, electrical conductivity and metals. Metals analysis was undertaken annually between 2009 and 2011. SW1 has been monitored once in May 2011.

SEPA collected samples from three of the six locations. The focus of the SEPA surface water sampling was to assess if the landfill is causing a Water Framework Directive water quality down grade in a baseline water body, the Water of Fail (Figure A1 in Appendix A). During the on-site investigations a drain to the east of the site was found to be visually impacted and an additional sample, SW Drain, was collected from this drain (Figure A1 in Appendix A), further explanation is provided in Section 6.6. The results are summarised in Appendix E.

Where relevant the monitoring results have been compared to standard assessment limit values to indicate if there has been an impact on water quality.

Environmental quality standard, EQS, values are used for surface water. In the case of some heavy metals these require additional assessment to calculate a bioavailable concentration from the dissolved metal concentrations. The values are designed to protect the most sensitive aquatic organisms from acute and chronic toxicity (lethal and sub-lethal effects), thereby imparting protection for populations and ecosystems. .

6.2.4 Metals sampling and analysis

SEPA analysed both total and dissolved metals in all samples recovered from the Tarbolton Landfill site. The site operator initiated monitoring record includes only total metals analysis.

Dissolved metal analysis is required for accurate assessment of contaminant concentrations against RPV, MRV and EQS values.

Total metal analysis includes all dissolved and solid metals within a sample, including any entrained sediment. As such samples containing high suspended solid concentrations can give high total metal concentrations even when the dissolved metal content in the water sample is comparatively low. This is important to note because water quality assessment limit values are based on environmental toxicity of metals which generally relate only to the dissolved, or in some cases estimated bioavailable, metal fraction (and not the total).

Dissolved metals analysis involves passing a sample through a <0.45µm filter prior to analysis. SEPA do this on a sub sample within the laboratory and not in the field at the time of sampling. This method does marginally increase the uncertainty in the result as redox changes and dissolution and precipitation reactions in the sample can alter the relative

proportion of dissolved and total metals prior to analysis. The use of a <0.45µm filter is generally accepted to provide an assessment of only the dissolved metal species contained within the sample, however, it should be noted that some very small solid metal particulates may pass through the filter.

6.3 Field observations

The site walkover and sampling investigations in May 2018 resulted in a number of observations about the site condition, waste and landfill engineering management practices and sampling procedures. These are outlined in the following sections.

6.3.1 Water and leachate management

The leachate head in the waste mass was not being actively managed at the time of the site visit (See section 6.4). Pipework and pumps associated with the leachate well network were present on site. However, the majority of the pipework was not connected to the pumps and the system was not in a condition to allow the leachate management system to be switched on without additional works (Figure 9).

Figure 9 - Leachate wells LW15 (top) and LW12 (bottom) at Tarbolton Landfill site.

The site visit involved an initial walkover with the site environmental consultant from Roche Environmental Ltd. There are three leachate lagoons at the site. Two of these lagoons are known to be unlined. The two unlined lagoons displayed an orange ochreous appearance (Figure 10) and were also noted as being over capacity (Figure 11); water was being discharged on to the ground surface surrounding the lagoons in a number of places (Figure 12). The leachate in the third lagoon, which is understood to be lined, was black in colour (Figure 13) and is understood to be the primary collection point for water pumped from leachate wells.

Verbal descriptions from the Roche Environmental Ltd representative indicated that historically the site leachate was managed by mixing the ochreous and black lagoon leachate waters together prior to discharge to the licensed discharge location to the south of the site (Figure A1 in Appendix A). It was reported that more recently the leachate was tankered for offsite disposal.

The elevation of the unlined lagoons is similar to nearby groundwater levels. Therefore, it is considered probable that the unlined lagoons are in direct hydraulic continuity with the shallow groundwater.

Currently (July 2018) there is no active leachate management at the site.

Figure 10 - Leachate lagoons at Tarbolton Landfill site

Figure 11 - Over topping of the eastern leachate lagoon at Tarbolton Landfill

Figure 12 - Flooding of the site path next to the eastern leachate lagoon by overtopped leachate and/or ponded run off

In addition to the areas next to the leachate lagoons the paths running around the east and south east area of the waste mass were also ponded with run off and/or leachate (Figure 13). In one location, between the eastern drain and eastern site track it appeared that a bund had been breached in an attempt to drain water off site (Figure 14).

In close proximity to the bund breach, the drain on the eastern edge of the site, next to GWD2, was observed as being orange in colour and the drain stream bed contained ochreous precipitates along it entire length (Figure 15). In response this location was added to the SEPA site sampling. See further discussion in 4.7 and 4.8.

Figure 13 - Water logging of the site track in the east-south east of the site

Figure 14 - Water logging along the east-south east site track, breached bund and water discharge off site

Figure 15 - Visually impacted drain to the east of the Tarbolton Landfill site

6.3.2 Waste material

The waste material deposited was observed exposed at the surface of landfill close to leachate well LW2 during the walk over. The waste was a mixture of household and/or commercial waste (wood, plastic and rubble) (Figure 16) with bands of grey, black and brown ashy material (Figure 17). This ash waste varied from a blocky coarse grained gravel with a vitreous, anthracite like appearance to a finer grey ash and coarse clinker of gravels and cobbles with an irregular shape (similar to burnt mine waste or metal slag) (Figures 17 and 18).

Figure 16 - Waste material consisting of wood, plastic, rubble and other household and/ or commercial waste materials

Figure 17 - Grey, black and brown bands of ash waste material exposed at surface at Tarbolton Landfill

Figure 18 - Ash waste and other waste materials exposed at surface at Tarbolton Landfill

6.3.3 Monitoring installations and sampling practices

The SEPA sampling and monitoring team were led to each of the borehole and leachate well installations by the Roche Environmental Ltd representative on 02/05/2018. The majority of the boreholes were labelled with stickers and indelible ink but at several locations the labels were faded and illegible. Roche Environmental used chalk to label each of the groundwater boreholes during the walkover. While all chalked borehole designations appeared to correlate with the site plans and borehole logs, the lack of labels suggests the potential for borehole samples to have been incorrectly labelled in the past or for neighbouring boreholes to be confused with one another, particularly if the sampling technician was not familiar with the site.

Several of the boreholes did not have secure top of pipe covers to protect against water ingress, accidental damage or vandalism (Figure 19).

The leachate wells had no consistent labelling method and during the walk over the Roche environmental representative marked several of the leachate well locations incorrectly in the first instance, before realising and rectifying the error (Figure 20). This further confirms the potential risk that samples previously recovered may not have been labelled and reported correctly.

One of the leachate wells, LW1, in the active area of the site was noted as having been damaged, presumably by site plant during waste disposal activities (Figure 21).

Groundwater monitoring boreholes GWS5 and GWD7 were reported to have been formed into the waste mass, in the incorrect location as the site manager was not present on site at the time of drilling. Furthermore, both boreholes are located in close proximity to one of the ochreous coloured lagoons which were reported to be unlined (Figure 10). This suggests the potential for the samples recovered from these boreholes to be heavily influenced by leachate seepage from the lagoon base. This factor reduces the confidence with which water samples from these boreholes can be considered representative of groundwater downgradient of the landfill.

SEPA enquired, during the walkover, about the sampling methods used during the regular site operator initiated monitoring. The responses provided by the Roche Environmental Ltd representative indicated that groundwater samples were commonly recovered from boreholes without appropriate purging having taken place. At some locations a small amount of purging was undertaken using the sampling pump. Where a bailer was used then one or two bail volumes was removed prior to sample recover. Neither of these methods would be sufficient to provide a representative groundwater sample recovered in line with best practice sampling techniques.

Figure 19 - Borehole GWD7

Note: The borehole has no top of pipe cap, protective cover, location label and is in close proximity to the unlined western lagoon

Figure 20 - Chalk marking used on leachate wells which otherwise have no permanent labelling

Figure 21 - Leachate well LW1

6.4 Leachate monitoring results

The leachate samples recovered by SEPA were analysed for common landfill indicators, metals, hydrocarbons, organics and PCBs. Summary results are displayed in tables and graphs in Appendix C. Where relevant the SEPA result has been compared to the site operator monitoring results (2009-2017). The leachate composition has also been compared in Table C2 in Appendix C to the 'UK Default Leachate Inventory and Concentrations' as defined within Landsim[30] additional parameters are also derived from literature values (Kjeldsen et al. 2002, Mukherjee et al. 2015). Provided for comparison in Table C3 in Appendix C are typical leachate composition values from waste at various breakdown stages at typical WML landfill sites[31].

6.4.1 Leachate levels

Leachate levels at the site were monitored monthly by the site operator up until May 2018. Leachate levels were formerly managed by pumping to maintain heads below permitted levels. However, leachate extraction was not occurring during the SEPA site visits in May and June 2018. SEPA have monitored leachate levels at the site in May and June 2018. The recent leachate level monitoring data is summarised in Table C4 in Appendix C.

The operator monitoring data for 2017 and 2018 is presented in Figure C1 in Appendix C. An increasing trend is observable from autumn 2017 onwards in the majority of locations (There is uncertainty regarding whether the observed trends in LW1 and LW2 are reliable owing to reported changes in cap level requiring confirmation by an updated topographic survey). This pattern is consistent with the visual evidence from SEPA staff site visits that the frequency and volume of leachate outbreaks has increased since autumn 2017.

Despite Zone 1 of the landfill being partially unlined, the leachate levels in Zone 1 are several metres higher than groundwater levels in the adjacent boreholes (typically 5-8m higher). This indicates that the waste, the partial lining system and/or the underlying near-surface geology are sufficiently low permeability to prevent the leachate from freely draining from the base of the partially lined phases. Instead mounding of leachate within the waste mass is occurring. This will result in lateral flow of leachate towards the perimeter drainage ditch along the western site boundary and towards the unlined lagoons in the south of the site. In addition, vertical migration of leachate downwards to the underlying groundwater is expected to be occurring.

Vertical leakage from Zone 2 of the landfill is anticipated to be less than from Zone 1 owing to the presence of a complete engineered liner system. However, it must be noted that even fully engineered liners experience basal leakage to some extent; engineered landfill liner systems are not completely impermeable barriers. Leachate levels in Zone 2 are above the groundwater levels in the adjacent boreholes (typically 2-5m higher). Thus there will be a downwards vertical gradient through the lining system. Leachate heads are a key control factor influencing the rate of basal leakage in engineered landfills.

The base of the leachate collection system in the fully lined cells in Zone 2 is understood (based on drawings submitted in 2006 in support of the PPC application) to be around

[30] Landsim Version 2.5, 2001-2008 Golder Associates

[31] Waste Management Paper No 26A, Landfill Completion, Department of the Environment 1993

75 mAOD with the top of the basal liner system in the perimeter bunding at 77 mAOD. This suggests that an overtopping risk exists once leachate levels exceed 77mAOD. This is equivalent to leachate heads in the lined cells exceeding 2m. Leachate levels in parts of Zone 2 have exceeded this threshold in late 2017 and 2018. This is consistent with the observation of leachate outbreaks locally around the perimeter of Zone 2.

Where leachate outbreaks occur due to leachate levels overtopping the basal liner system, this poses a risk both to surface water and groundwater. A proportion of the leachate outbreak will migrate to the perimeter drainage system via overland flow. The rest will infiltrate into the ground and migrate downwards into the shallow groundwater. The relative proportions migrating via each pathway may vary spatially depending on local variations in ground conditions and temporally in relation to prevailing weather conditions.

In addition to leachate outbreaks from the waste mass, there is visual evidence that intermittent overtopping of the leachate lagoons has also occurred. Similar to the leachate outbreaks, overtopping from the lagoons poses a risk to surface waters via overland flow and to groundwater via infiltration.

Currently (July 2018) active leachate management is not occurring. It is likely that leachate levels within the waste mass and the lagoons will continue to rise. The rate of rise in leachate levels will be dependent on weather conditions. The rise in leachate levels will increase the rate of downward and lateral migration of leachate and thus the associated risk of groundwater and surface water quality impacts.

Over time, if unmanaged, the increase in intermittent and chronic discharges of leachate to nearby watercourses and increase in rate of infiltration to groundwater may have an increased impact on the water environment over and above that already associated with landfilling activity.

Monitoring of leachate is recommended to assess the rise in leachate levels as well as the frequency and magnitude of leachate outbreaks occurring due to the lack of operational management at the site.

6.4.2 Landfill leachate indicator parameters

The ammoniacal nitrogen, chloride and electrical conductivity values with the SEPA monitoring results are largely similar to the site operator monitoring returns (Table C5 in Appendix C). Leachate concentrations within the Zone 1 are lower than those within the Zone 2, this difference is a consequence of the differences in engineering and time since waste deposition.

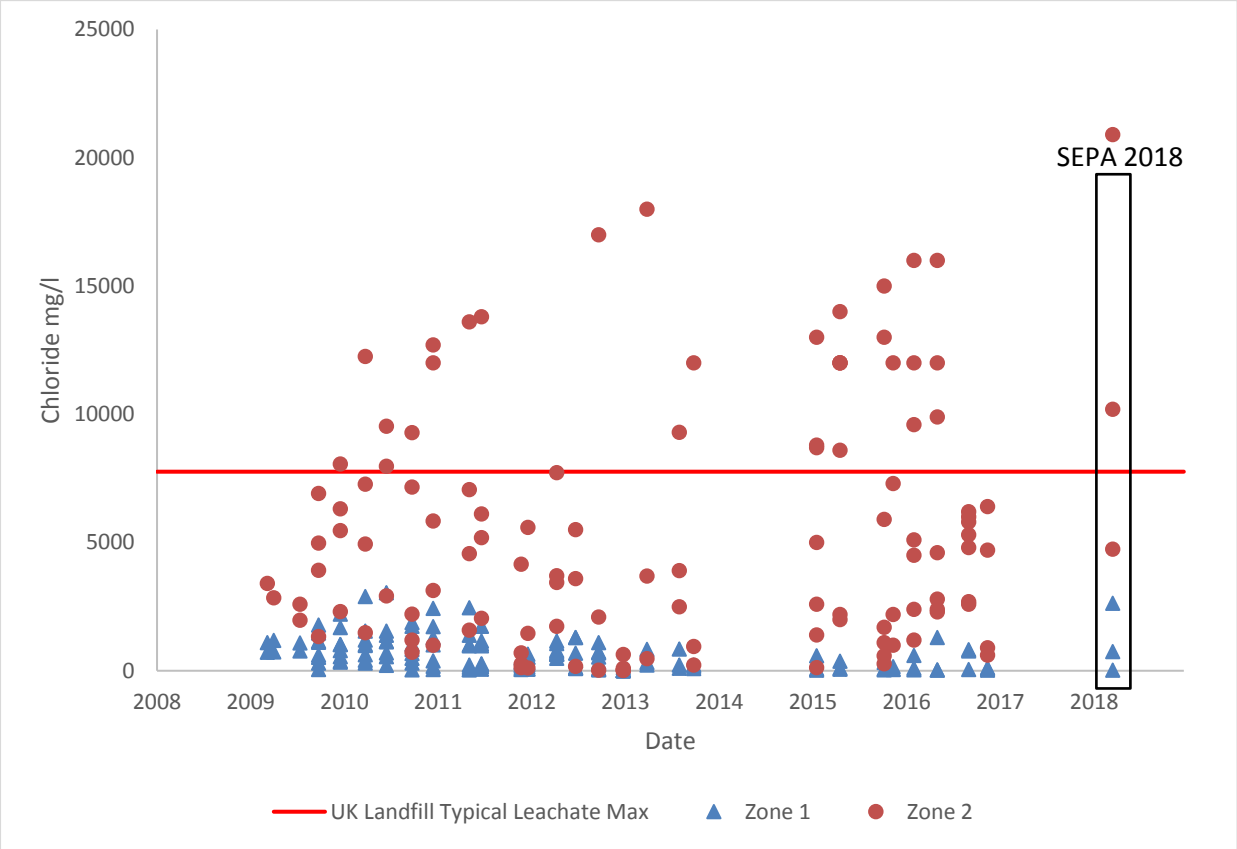
The leachate pH in SEPA samples (pH 6.96-7.56) is consistent with the site operator monitoring results (pH 6-8.4) and both are within the typical UK landfill leachate range (pH 4-9, Table C2 in Appendix C). As such, the potential risk of liner damage due to elevated ash waste pH is considered to be very low.

Ammoniacal nitrogen leachate concentrations in SEPA samples and the site monitoring results are within the typical UK landfill leachate range (Table C2 in Appendix C).

Chloride leachate concentrations within the Zone 2 are elevated compared to the typical UK landfill leachate (Landsim default inventory[32]). Leachate well LW17 contains the highest chloride concentrations recorded to date at the site (20900 mg/l). As shown in Figure 22, there is no indication of a rising trend or a significant change in the number of elevated chloride concentrations in the leachate since 2009.

In Zone 1, there is an indication of a declining trend in chloride concentrations, however, SEPA monitoring results are elevated compared to the more recent site operator monitoring results.

Figure 22 - Leachate chloride concentrations in Zone 1 and Zone 2 at Tarbolton Landfill

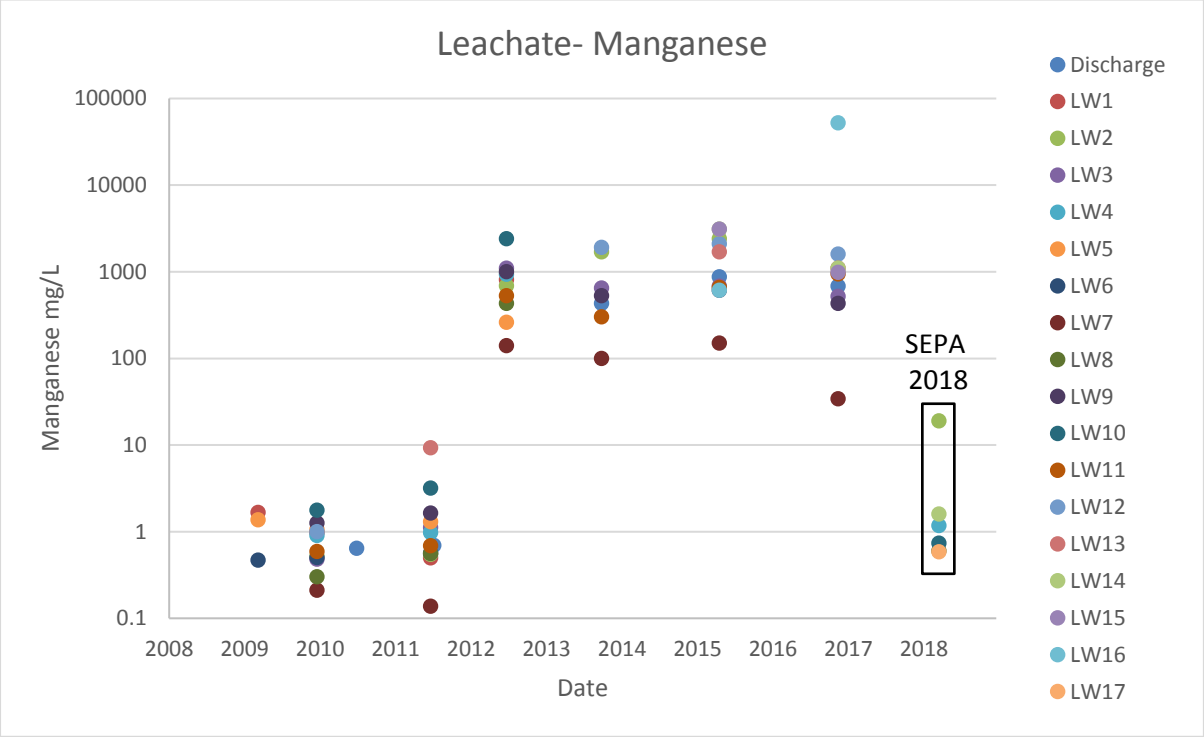


6.4.3 Metals

The SEPA sample results for metals (total) are generally at the lower end of the range identified in the site operator monitoring results (2009-2017) (Table C5 in Appendix C). SEPA results are generally similar to the 2009-2011 concentrations, whereas the metal concentrations between 2012 and 2016 are commonly 3 orders of magnitude higher than the 2009-2011 range. This pattern suggests that there may be a reporting error in the site results for this period, with microgram values (µg/l) having been reported as milligram values (mg/l) (Figure 23)

[32] Landsim Version 2.5, 2001-2008 Golder Associates

Figure 23 -Graph of total manganese concentrations in leachate at Tarbolton Landfill



The concentrations in the site monitoring results for manganese, nickel and chromium in the leachate are elevated (approximately 50% of values) compared to typical UK landfill leachate maximum values (Table C2 in Appendix C). Lead, iron and cadmium occasionally exceed the typical UK landfill leachate maximum values. (Some or all of these elevated concentrations may be related to the possible reporting error outlined above). However, the site operator monitoring data is for total metals whereas the Landsim inventory, from which the UK landfill leachate maximum values in Table C2 in Appendix C are taken, is for dissolved metals. Therefore the site operator monitoring data is conservative as under normal operating conditions only dissolved phase contaminants would be expected to migrate downwards into groundwater.

Dissolved metals from SEPA analysis of leachate identified above minimum reporting value, MRV, and resource protection value, RPV, concentrations of iron, manganese, nickel, chromium, zinc, arsenic, copper, aluminium and mercury (Table C6 in Appendix C). This indicates that there is a potential risk to groundwater quality from these metals.

Above EQS concentrations of iron, manganese, nickel, chromium, lead, zinc, arsenic, copper, aluminium and mercury were identified in the dissolved metal leachate results (Table C7 in Appendix C). This also indicates that there is a potential risk to surface water quality from these metals. (Note that some of the EQS values relate to a bioavailable or reactive concentration or a particular metal species in the case of chromium. However the dissolved concentrations suggest these EQS values are likely to be exceeded)

MRV, RPV and EQS values are not directly applicable to leachate as they indicate the concentration at which the quality of groundwater or surface water is considered to have

been degraded. However, the comparison here is useful to help inform potential risks from leachate migration to groundwater either directly from Zone 1 or through leachate liner migration in Zone 2, or surface outbreaks impacting on surface water. It should also be noted that surface outbreaks would discharge particulate matter as well as dissolved metals which would further increase the risk of impact to surface water quality.

Many of the above metals were noted to be present at elevated concentrations in the ash waste (Section 6.1). This suggests that the metal leachate content is, at least in part, sourced from the ash waste deposited in the landfill.

No Naturally Occuring Radioactive Materials (NORM) were detected in the landfill leachate.

6.4.4 Organic contaminants

In the SEPA analysis, comparatively low concentrations of BTEX, petroleum hydrocarbon, PAH and chlorinated hydrocarbons were identified in the Zone 2 leachate well samples (LW2, LW14, LW17) (Tables C8, C9, C10 in Appendix C). The maximum petroleum hydrocarbon concentrations identified in LW14 (VPH/EPH>C5-C44- 1328µg/l) are within the short chain hydrocarbon range and may therefore be subject to significant degradation and volatilisation prior to any potential impact on the groundwater environment.

Some very low concentrations of PAH and chlorinated hydrocarbons were identified in the Zone 1 leachate wells (LW4 and LW8).

The site operator monitoring results, while not directly comparable with the SEPA results, (as they are from samples of the discharge and not individual leachate wells) also indicate some low concentrations of BTEX and PAHs.

In general the concentrations of organic contaminants identified are considered to present a low risk to groundwater.

6.5 Groundwater

6.5.1 Landfill leachate indicator parameters and major ion chemistry

The concentrations of ammoniacal nitrogen, chloride and electrical conductivity in SEPA samples are largely consistent with the site operator monitoring results. SEPA samples generally record concentrations similar to the long term median.

Concentrations of ammoniacal nitrogen and chloride are elevated in downgradient groundwater compared to upgradient in both SEPA and the site monitoring results (Table D1 in Appendix D). Concentrations in groundwater sampled from superficial and bedrock monitoring installations are similar.

The ammoniacal nitrogen RPV, 0.39mg/l, is consistently exceeded in the majority of downgradient boreholes. The chloride RPV, 250mg/l, is exceeded in the downgradient borehole GWS5 on several occasions between 2015 and 2017.

In GWS5 there is an upward trend in ammoniacal nitrogen and chloride (Figure 24 and Figure 25). Variations in concentrations of ammoniacal nitrogen in GWD7 and chloride in

GWD6 are also observed (Figure 24 and Figure 25). All other locations show consistent concentrations of these contaminants (see Figures D1 and D2 in Appendix D).

Figure 24 - Ammoniacal nitrogen in groundwater in GWD7 and GWS5

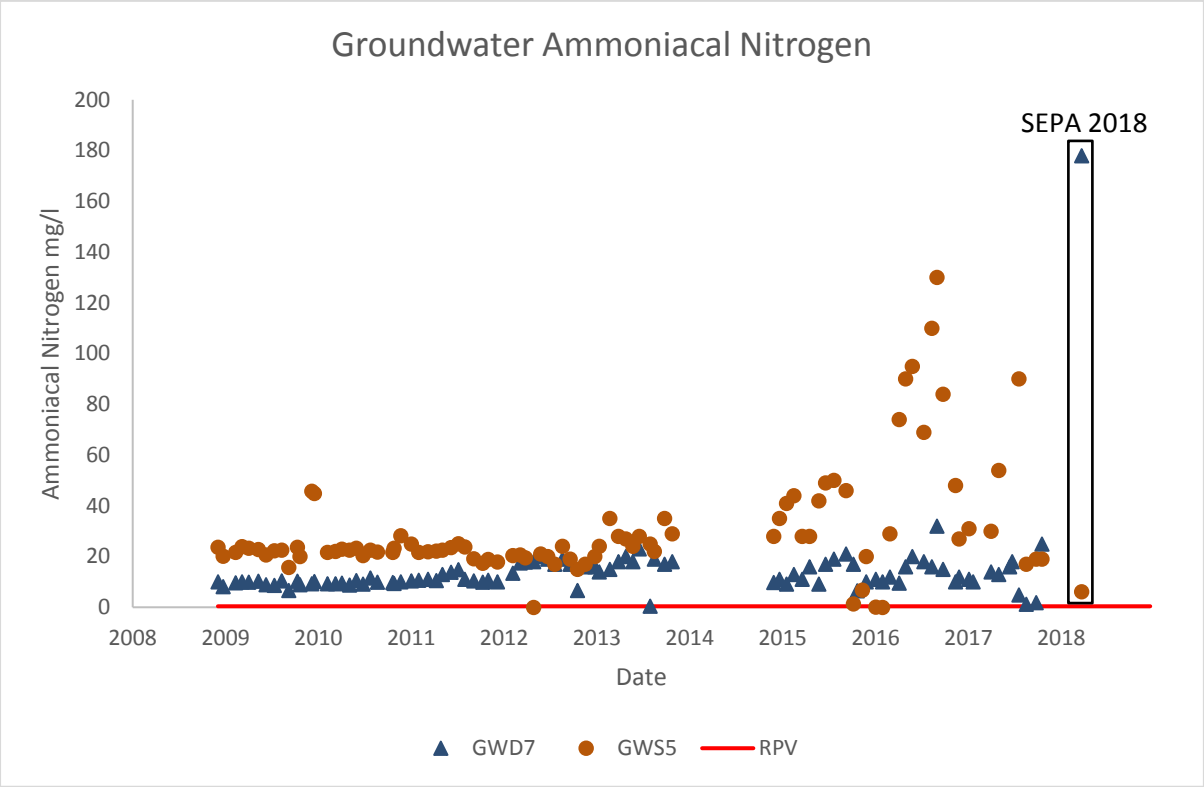
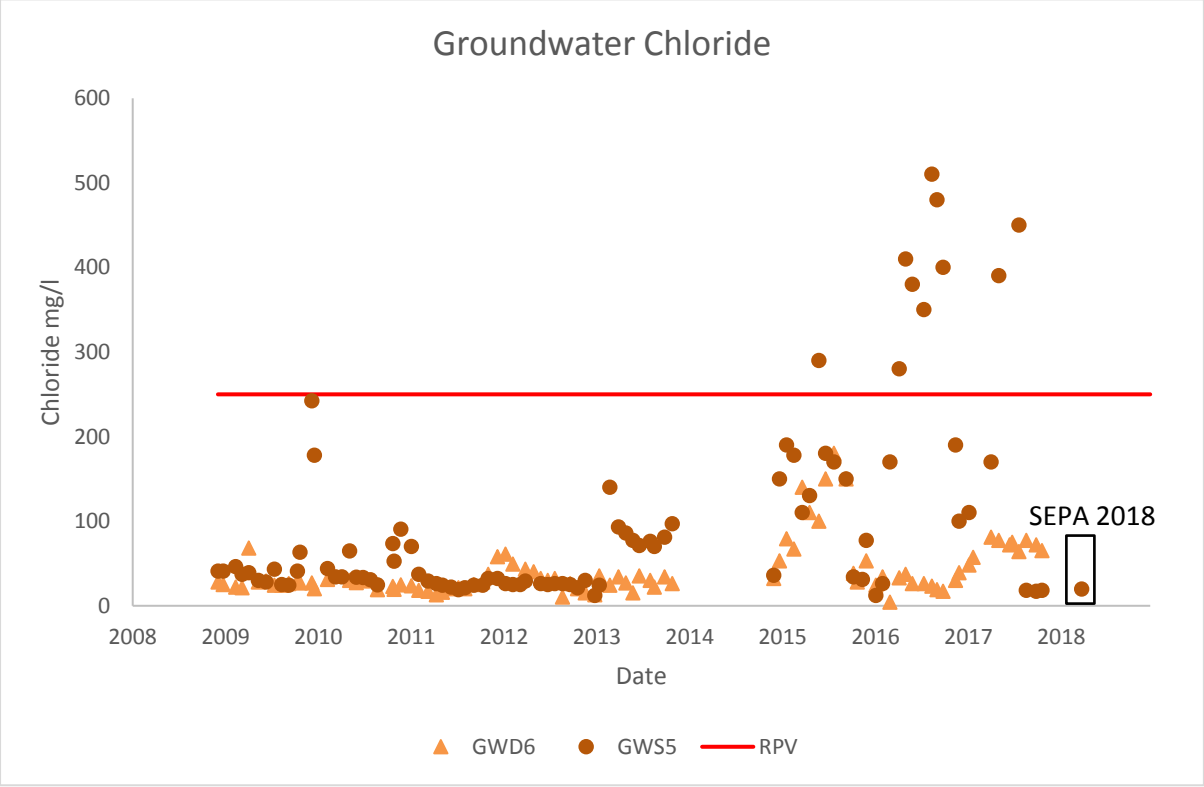


Figure 25 - Chloride in groundwater in GWD6 and GWS5



The pH of groundwater is generally in the circum-neutral range (pH 6-8) as would be expected in this geology.

SEPA samples of GWS5 and GWD7 are not consistent with the site operator monitoring results. The major ion chemistry results from these two boreholes are also not consistent with the site operator monitoring results. The reason for this is not clear. It may be due to the lack of management of the leachate levels in recent months resulting in a change in impact on groundwater at this location. However, it should also be noted that these boreholes are installed into waste and are located in close proximity to unlined and overtopping leachate lagoons. As such GWS5 and GWD7 may not provide water samples which are representative of the impact of the waste mass on downgradient groundwater.

The site operator monitoring results indicate a change in GWS5 and GWD7 in 2013 (see Figures 24 and 25); prior to this GWS5 and GWD7 provided consistent monitoring results. This should be investigated further by SEPA to inform the water environment risk and determine an accurate assessment of downgradient impact.

The major ion results, shown on Piper plots (Figures D3 to D6 in Appendix D), also demonstrate a change in the chemistry of GWS5 from a calcium bicarbonate type water consistent with the other downgradient samples in 2011 to a sodium bicarbonate type water but with an increase proportion of chloride, more consistent with the site leachate chemistry in 2016. The SEPA 2018 Piper plot indicates GWD7 as having a chemistry more consistent with the site leachate and GWS5 returning to calcium bicarbonate type water. The Piper plots also indicate that there have been changes in GWS5 and GWD7 which suggest that may now not provide reliable downgradient groundwater samples.

Groundwater results from other downgradient boreholes (excluding GWS5 and GWD7 due to the reasons above) identify moderately elevated concentrations of ammoniacal nitrogen which are similar to those recorded at other landfills in Scotland that also include unlined phases. The chloride concentrations in the other downgradient boreholes are similar to upgradient. This indicates is a low to moderate risk to groundwater quality from these contaminants.

It should be noted that the locations of the large majority of borehole monitoring installations at the site are not considered to be ideal, which complicates the interpretation of impacts on groundwater downgradient of the landfill. Several are installed in very close proximity to the waste mass (e.g. GWD6 and GWD1) or into the waste mass (e.g. GWS5 and GWD7). Other downgradient boreholes are located on the opposing side of a surface water from the landfill.

6.5.2 Metals

The concentrations of total metals in samples recovered by SEPA are generally consistent with the site operator monitoring results (Table D2 in Appendix D). Two notable exceptions are GWD8 and GWS5 which are elevated or at the upper limit of the 2009-2017 range. As with the leachate metal results there are order of magnitude difference in the concentrations recorded in some metals in 2009-2011 and those recorded in 2012-2016 (Figure D7 in Appendix D). However, unlike the leachate the results in the 2009-2011 are higher than those in 2012-2016. Also the same pattern is not as pronounced in iron or manganese concentrations (Figure D8 in Appendix D). Nevertheless, the step change in results suggest a laboratory or reporting issue and introduce doubts to the reliability of the results.

In general both SEPA and the site operator monitoring results indicate very elevated total metal concentrations in downgradient groundwater at the site. These include iron, manganese, chromium, nickel, zinc, aluminium, mercury and cadmium. The dissolved concentrations of metals, however, are consistently lower than the total concentrations across all SEPA samples. This difference is most notable where samples contain high suspended solid concentrations, e.g. GWD8 and GWS5 (Figure 26). This is commonly an indication that borehole installations may need to be redeveloped. At this site, however, the waste deposited, being predominantly ash waste, may result in groundwater being impacted by downward migration of leachate laden with sediment derived from fines fraction of the ash waste. This is likely to be most pronounced downgradient of Zone 1 where leachate migration is not fully constrained by a liner and landfill engineering.

The very high total metal content in groundwater is likely to occur only in close proximity to the landfill as downgradient migration in both bedrock and superficial aquifers of the high suspended solid metal fraction will be limited. It should be noted that changes in redox state in the leachate or groundwater could result in increased dissolution of the solid metal fraction and potentially increase the risk to groundwater quality. The lack of operational management of the leachate levels may increase leachate migration and result in increased risks.

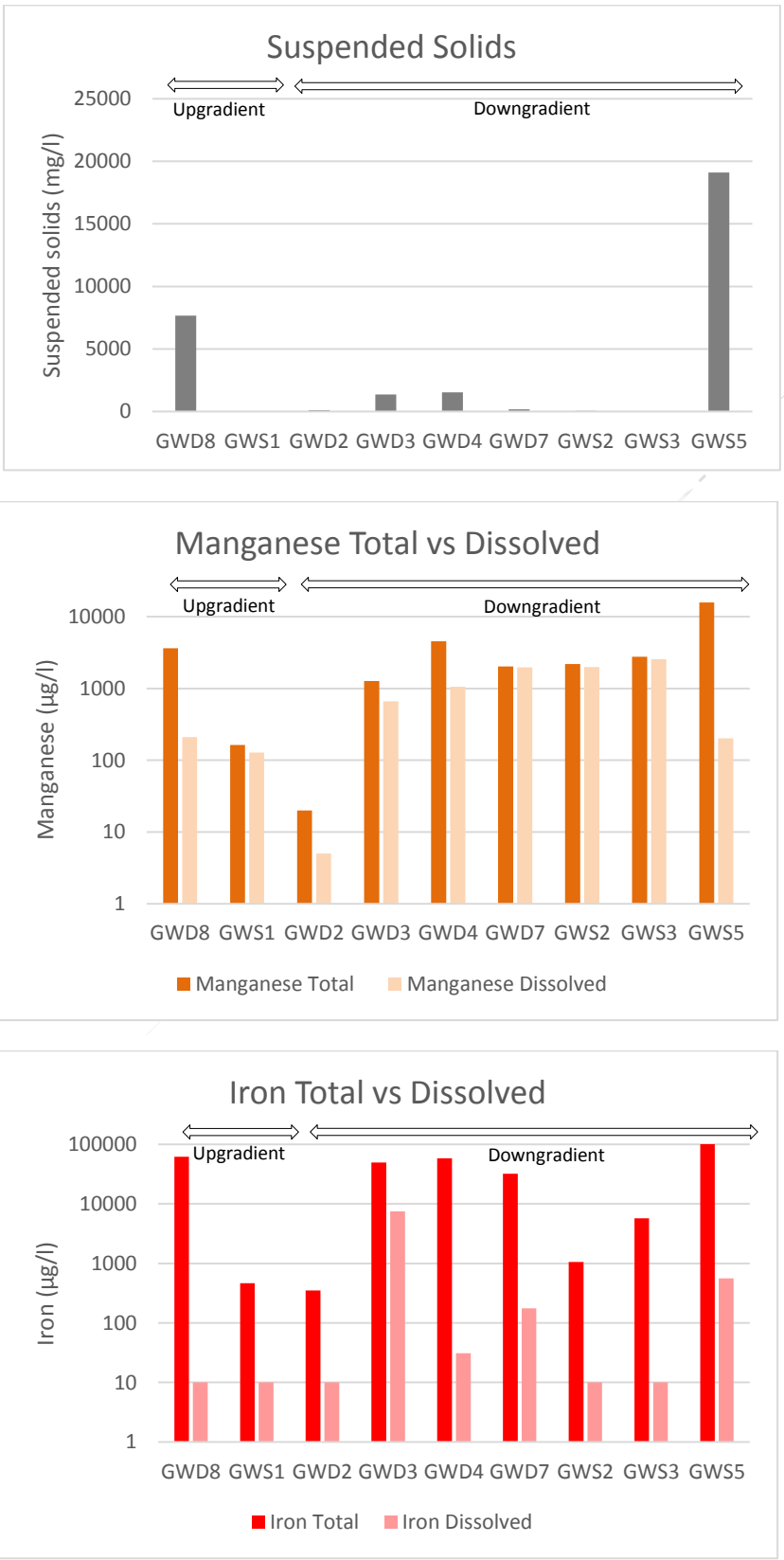
The conservative approach to monitor only total metals, used by the operator, may not be the most appropriate to accurately assess the risks from metals to groundwater quality at the site.

The dissolved metals in SEPA analysis indicates above RPV concentrations of manganese in the majority of samples and iron (GWD3), nickel (GWD7) and aluminium (GWD3) in one downgradient borehole (Table D3 in Appendix D). A similar association of above EQS concentrations of manganese, iron, nickel and aluminium is also recorded. EQS are not directly applicable to groundwater but indicate that the metal concentrations present in groundwater, if discharged to surface water via baseflow, would present a potential risk to surface water quality (dependent on dilution in surface water). The majority of the metals, with the exception of mercury, have higher dissolved concentrations in the downgradient boreholes than in the upgradient boreholes, which is consistent with the source of metals being the landfill. Mercury exceeds the MRV in both upgradient and downgradient boreholes, but with the highest concentrations recorded upgradient in GWD8, possibly suggesting an upgradient source. It is noted however that GWD8 was associated with high suspended solids and therefore doubts remain over the reliability of results from this location.

The groundwater metal exceedances recorded are consistent with the elevated metals concentrations recorded in the leachate (Tables C6 and C7 in Appendix C). They are also consistent with the metals detected in the ash waste (Table C1 in Appendix C) This also suggests the ash waste deposition is, at least in part, the cause of the groundwater quality impact associated with dissolved metals.

There is a low to moderate risk to downgradient groundwater from the dissolved metal concentrations. The concentrations identified in groundwater are generally in line with other landfill sites in Scotland that also have unlined phases.

Figure 26 - Total and dissolved iron and manganese and suspended solids in groundwater at Tarbolton



Note: the metal concentration axis has a logarithmic scale to allow comparison between total and dissolved concentrations. The relative proportion in the difference between total and dissolved differs for different metals, likely to be due to difference in metal geochemistry, however all show the same pattern.

6.5.3 Organic contaminants

SEPA groundwater samples were analysed for a suite of organic and hydrocarbon derived chemicals including; benzene, toluene, ethylbenzene, total xylenes (BTEX), extractable petroleum hydrocarbons (EPH) volatile petroleum hydrocarbons (VPH) chlorinated solvents, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). The results are provided in summary in Tables D4 to D6 in Appendix D.

Concentrations of short chain aliphatic hydrocarbons were identified in upgradient groundwater, none were identified downgradient. One PAH, acenaphthene was identified at 0.34µg/l in GWD7. It is unusual to identify one PAH in isolation. This PAH was identified in the leachate sampling from LW14 but there it was also associated with 3 other PAHs (Fluorene, Naphthalene and Phenanthrene). Acenaphthene is classified as a hazardous substance, however, the comparatively low concentration and isolated identification indicates a low risk to groundwater quality.

The site operator monitoring for organic substances is limited, however, for the results available the site and SEPA monitoring results are largely consistent. The site monitoring identified a number of PAHs in GWD1 in 2009-2011, however, as previously stated this upgradient borehole is located very close to the waste mass and is unlikely to provide reliable and representative results for the impact of the landfill on groundwater.

6.5.4 Groundwater risk assessment

There are two key pollutant linkages for groundwater: basal leakage and indirect leachate infiltration.

The first pollutant linkage to groundwater relates to vertical infiltration of leachate leaking downwards through the base of the landfill. This pollutant linkage exists at all landfill sites, particularly those which include unlined phases. Although this pollutant linkage has not been created by the consolidated ash waste deposition, the elevated inorganic contaminants, particularly metals, in the leachate due to the ash waste deposition may have increased the potential risk to groundwater posed by this linkage. If leachate heads within the waste mass are not actively managed, the potential risk associated with this linkage is likely to increase over the long-term.

The second pollutant linkage to groundwater relates to indirect infiltration of leachate into the ground around the landfill in the vicinity of leachate outbreaks and around the leachate lagoons. This pollutant linkage is associated with the lack of operational management rather than necessarily being related to consolidated ash waste deposition. Again, the lack of operational management means that the risk associated with this linkage is likely to increase over the long-term.

As well as being a receptor in its own right, groundwater also acts as a pathway to surface waters. Groundwater downgradient of the landfill may enter surface waters via baseflow. Thus, any increase in risks to groundwater would be expected to result in a consequent increase in risks to surface waters.

Ongoing groundwater monitoring is required to assess the developing impacts due to the lack of operational management at the landfill. Future groundwater quality analysis should

include both dissolved and total metals. The frequency of future groundwater monitoring can be lower than the frequency of surface water monitoring owing to the differences in the timescales over which the groundwater and surface water pathways operate.

Were operational site management to resume at the site in the future, it is recommended that monitoring boreholes GWS5 and GWD7 be replaced in a more suitable location further from the potential influence of the unlined lagoons.

6.5.5 Groundwater risk assessment summary

Summary of findings: Some downgradient impact on groundwater quality at Tarbolton would be expected because the landfill is partially unlined, even if there had been no ash waste deposition or lack of operational management. The newer phases of the landfill are lined, but protection of groundwater by the lining system has been adversely affected by the recent lack of operational management, particularly in relation to leachate management.

Elevated concentrations of ammoniacal nitrogen and chloride have been identified in a number of downgradient boreholes, however, there are doubts over the suitability of these monitoring locations. Other downgradient boreholes indicate a low to moderate impact on groundwater quality from ammoniacal nitrogen and chloride. These contaminants are unlikely to be associated with the ash waste deposition.

Metal concentrations differ markedly between total and dissolved fractions. Dissolved metals compared with groundwater quality assessment limit values (RPV and MRV) indicate downgradient impacts from iron, manganese and aluminium and nickel. These contaminants are likely to be sourced, at least in part, from the ash waste.

There is a low to negligible impact from organic contaminants in groundwater.

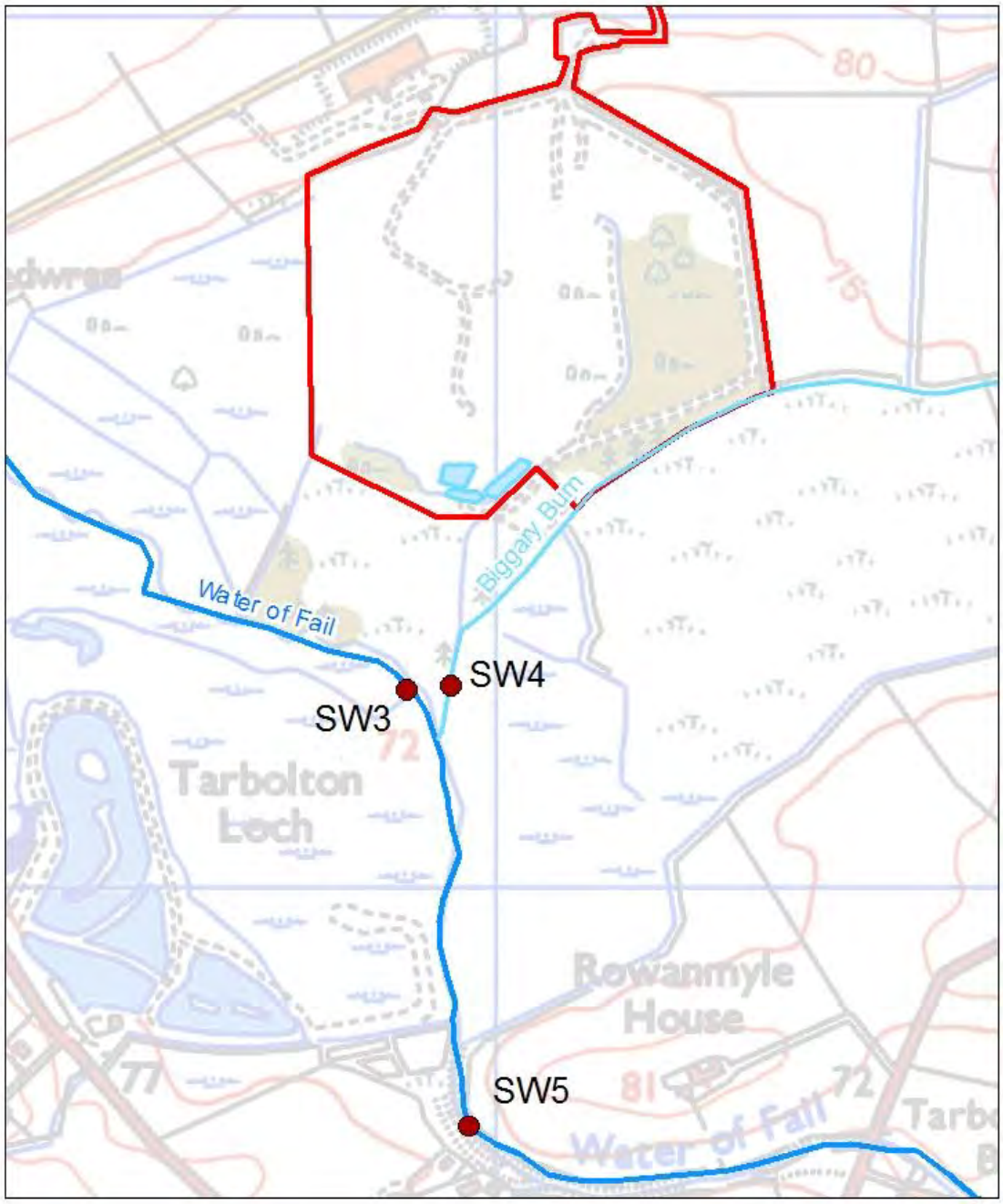
Risk Assessment: Low to moderate currently based on current observed impacts. If leachate levels are not actively managed, then there is potential for increased downward migration of leachate and impact on groundwater, increasing the risk to moderate.

Further Work: Ongoing groundwater monitoring is required to assess the developing impacts due to the lack of operational management at the landfill. Future groundwater quality analysis should include both dissolved and total metals.

6.6 Surface water

Sampling was carried out at three locations: one on the Biggary Burn and the other two were upstream and downstream of this Burn's confluence with the Water of Fail (see Figures 27 to 30 below and Table E1 in Appendix E). Samples were analysed for a range of parameters associated with landfill site inputs. Rainfall in the month preceding sampling was around 300% of the average for April based on data from Prestwick. Samples were analysed for a range of parameters associated with landfill site inputs.

Figure 27 - Surface water sampling sites near Tarbolton Landfill



Tarbolton Landfill
Surface Water Monitoring Locations

1:6,000
0 0.05 0.1 0.2 mi
0 0.075 0.15 0.3 km

N

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SEPA
Scottish Environment Protection Agency

Figure 28 - SW3 Water Of Fail 50 m upstream of confluence with the Biggary Burn

Figure 29 - SW4 Biggary Burn downstream of Tarbolton Landfill. 50 m upstream of confluence with the Water of Fail

Figure 30 - SW5 Water of Fail 500 m downstream of confluence with the Biggary Burn

6.6.1 Physico-chemical and inorganic parameters

The typical landfill indicators, electrical conductivity (Figure E1 in Appendix E), chloride (Figure E2 in Appendix E) and ammoniacal nitrogen (Figure E3 in Appendix E), were elevated in the Biggary Burn (SW4) as compared to the Water of Fail. The values from the point downstream of the confluence with the Biggary Burn (SW5) on the Water of Fail were elevated compared to the upstream site (SW3). For ammoniacal nitrogen, the difference between the Biggary Burn and the Water of Fail was almost an order of magnitude. Based on these results water quality classification is bad at all three locations (Table E2 in Appendix E). The same pattern was seen in the non-ionised ammonia results as well (Figure E4 in Appendix E). The results for the upstream location (SW3) may reflect additional inputs (e.g. diffuse pollution, domestic sewage, mining) not associated with the landfill on the Water of Fail but may also reflect indirect landfill influence via groundwater and the western perimeter drain.

Comparing the SEPA data to that from the operator shows that for the Water of Fail at both SW3 and SW5, the concentrations measured are comparable. However, for the Biggary Burn the electrical conductivity (Figure E1 in Appendix E) and concentrations of chloride (Figure E2 in Appendix E) and ammoniacal nitrogen (Figure E3 in Appendix E) are far higher than those measured previously by the operator.

Surface water electrical conductivity was measured in the field on the 2nd May 2018, the results of which are shown on Figure E5 (in Appendix E) compared to SEPA laboratory analysis results from 2018 and the 2016 operator average. These indicate elevated conductivity in surface waters in close proximity to the Tarbolton Landfill compared with the average 2016 operator monitoring results. In May 2018 the upstream conductivity in the Biggary Burn is within the expected range for a surface water, however, inputs from the eastern drain causes a significant increase in conductivity downstream (from 252 to

990 μS/cm). This is consistent with the visual impact in the eastern drain from a leachate breakout during the site walkover (See section 6.3.1 and Figure 14). The monitoring results indicate the breakout is a new feature likely related to rises in leachate levels (Section 6.4.1) and the recent lack of operational management at the site. The chloride and metals concentrations in the breakout and downstream (SW4) indicate it to be the primary source of impact on the Biggary Burn (Figure E6 and Figures E10 to E17 in Appendix E). Ammoniacal nitrogen results are more elevated in the Biggary Burn than in the breakout (Figure E8 in Appendix E), suggesting that there are other inputs, between the eastern drain and SW4, to the Biggary Burn from the landfill.

SEPA previously made chemical assessments on the Water of Fail based on data collected between 1997 and 2006. The four assessed sites, relative to the confluence of the Biggary Burn with the Water of Fail, are from around 1 km upstream to around 2.5 km downstream (the closest site is approximately 0.25 km downstream). Comparing these historical data with data from the recent monitoring campaign shows that levels of chloride and ammoniacal nitrogen are much higher now than they were a decade ago: upstream average concentration of ammoniacal nitrogen was 0.6 mg/l and 0.25 km downstream it was 0.8 mg/l, compared with 3.1 and 4.6 mg/l at SW3 and SW5 respectively; chloride concentrations were in the region 17 – 18 mg/l at all historical sites, compared with 47 and 61 mg/l at SW3 and SW5 respectively. These data show a marked increase, especially considering that SW5 is a further 250 metres downstream than the downstream point in the earlier data set.

Chemical oxygen demand (COD; mg/l) was higher in the Biggary Burn compared to the Water of Fail. The site downstream of the confluence, SW5, was slightly elevated in comparison with SW3 (Figure E9 in Appendix E).

Biochemical oxygen demand (BOD) was broadly similar at all three locations, but marginally higher in the Water of Fail compared to the Biggary Burn. Due to the limited data set and the relatively small size of this difference, these BOD results should only be considered indicative. Dissolved organic carbon (DOC) was elevated in the Biggary Burn compared to the Water of Fail.

Metal concentrations tended to be higher in the Biggary Burn than in the Water of Fail. With the exception of manganese, the environmental quality standards (EQS) were not breached at any of the locations. For manganese the EQS was breached in the Biggary Burn but not the Water of Fail (Table E2 in Appendix E). The relative proportion of dissolved metal to total metal concentrations was also higher in the samples from the Biggary Burn. The data for aluminium, cadmium, chromium, copper, lead, manganese, nickel and zinc are shown in Figure E10 through to Figure E17 (in Appendix E) respectively.

6.6.2 Organic chemicals

The monitoring plan included a range of organic chemicals which are associated with landfill sites. The monitoring has demonstrated that polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene and xylene (BTEXs) along with other volatile organic compounds and petroleum hydrocarbons were not detected at the surface water monitoring sites.

6.6.3 Surface water risk assessment

The design of the landfill site has created two pollutant linkages to surface waters. Firstly, the perimeter site drainage may intercept leachate leakage from the unlined phases within Zone 1 and allow contaminants to migrate into downstream watercourses. Secondly, leachate entering groundwater may subsequently impact on downgradient surface waters via baseflow. Although these pollutant linkages have not been created by the consolidated ash waste deposition, the elevated inorganic contaminants, particularly metals, in the leachate due to the ash waste deposition may have increased the potential risks posed by these existing linkages.

In addition to these pollutant linkages, the subsequent lack of operational management has resulted in contamination of surface water on site by leachate via overland flow. The surface water contaminated with leachate has the potential to escape from the site and enter nearby watercourses.

The surface leachate sample taken from near GWD2 contained relatively high amounts of ammoniacal nitrogen (Figure E5 in Appendix E) and chloride (Figure E6 in Appendix E). Electrical conductivity was also elevated (Figure E7 in Appendix E). This sample was from a surface leachate breakout which drains from the eastern side of the site to the Biggary Burn uspstream of the SW3 monitoring point.

The chemical monitoring in the Biggary Burn and Water of Fail has shown that there are some impacts on the surface water environment, particularly in the Biggary Burn. In particular, there are elevated concentrations of:

- Ammoniacal nitrogen
- Manganese

Based on the SEPA monitoring results, the site leachate and surface leachate within the site has the potential to cause harm to ecological receptors in the event of significant leachate breakout. The main mitigating factor, dilution in the Biggary Burn, in particular is limited. This is because of the Burn's typically small flow and what are already elevated concentrations. This could cause a failure of environmental standards in both the Biggary burn and potentially in the Water of Fail. Releases of heavy metals, which intrinsically are not subject to degradation, will add to the environmental load downstream of the site.

Overall, we consider that the risk to the aquatic ecosystem is low to moderate currently. The monitoring data have shown that chemical impacts are fairly localised and at a distance of 500 metres downstream, the signal from the landfill is dissipated. It is reasonable to expect some impact from a landfill with an unlined phase located in close proximity to surface waters.

This assessment concurs with the results of monitoring of invertebrate fauna in the Water of Fail up and downstream of the Biggary Burn confluence. This was carried out to assess potential ecological impacts of Tarbolton landfill. Water quality was found to be moderate above and below the confluence. Unfortunately, the Water of Fail is silty and canalised

throughout its upper reaches, which in itself causes poor invertebrate diversity. This fact could potentially mask any decline in ecology due to problems with water quality.

Given the lack of operational management to control leachate levels within the landfill, the risks to surface waters will potentially increase. Primarily this will relate to direct impacts on surface water quality and sediment loading via increased frequency / magnitude of leachate outbreaks or lagoon overtopping. There will also be a secondary indirect impact due to any increase in risks to groundwater quality.

In the short term, these pollutant linkages are likely to result in an increased risk of localised, short-term impacts on surface water quality. There is potential that, over time and if unmanaged, that intermittent and chronic discharges of leachate to nearby watercourses may have an increased risk of impact on water quality and ecology over and above that already associated with landfilling activity. The risk to human health from surface water exposure is considered to be low because, as far as SEPA are aware, there are no downstream drinking water abstractions. Risks from any occasional recreational use of the watercourse downstream of the site are also deemed low, since relevant exposure (by the oral route) is unlikely.

Additional monitoring is required to assess the developing impacts to the surface water quality and ecosystems associated with the lack of operational management at the landfill.

The final area of concern identified in the conceptual model is the Burns Trout Fishery. This series of ponds is located near the Water of Fail to the South west of the landfill site.

Information provided to SEPA by the fishery operator has confirmed that the fishery ponds are clay-lined, which will constrain groundwater ingress. The ponds are fed from a watercourse to the southwest of the fishery, which is not downstream of Tarbolton landfill, and then discharge into the Water of Fail. Based on this information together with the interpreted groundwater flow regime (see section 3.3), the fishery is not considered to be downgradient of the Tarbolton landfill. Therefore, the potential risk is considered to be very low.

6.6.4 Surface water risk assessment summary

Summary of findings: There are some localised impacts on the water environment due to the landfill. There are elevated concentrations of ammoniacal nitrogen and metals. The major pathway to surface waters is likely to be leachate entering surface water directly rather than via groundwater. Water quality impacts may have consequences for surface water ecosystems but these are already influenced by silt and canalisation.

Risk Assessment: Moderate (surface waters) to very low (fishery).

Further Work: Additional surface water monitoring including additional locations to assess potential future risks due to the lack of operational management.

7.0 Conclusions

The risk assessment findings are summarised in Table 1 at the start of this report.

The key conclusions from the SEPA investigation are:

- The monitoring results indicate the site poses a very low risk to human health from dust.
- Based on the available evidence, the landfill gas risk is also considered to be currently low.
- The monitoring results indicate the site has a water quality impact similar to many other landfill sites in Scotland, particularly those sites with unlined phases or operational management failures.
- There is currently no operational management taking place at the site. If this situation continues, then this will increase the risk of additional impact to the environment from the landfill, particularly for risks relating to leachate levels.

8.0 Actions and Recommendations

Based on the conclusions above, the following actions are underway by SEPA to assess the developing impacts due to the lack of operational management at Tarbolton landfill:

- Landfill gas monitoring points are to be sealed and appropriate gas sampling taps installed. Further landfill gas monitoring will be undertaken to further assess potential for landfill gas migration from the site.
- Additional monitoring of leachate levels and chemistry is being undertaken to assess the rise in leachate levels as well as the frequency and magnitude of leachate outbreaks.
- Further surface water monitoring, including at additional locations, will be undertaken to assess the impacts due to the lack of active leachate management.
- Ongoing groundwater monitoring of the site to assess the impacts due to the lack of active leachate management will be undertaken. Groundwater monitoring will be less frequent than surface water monitoring given the differences in relevant timescales for the groundwater pathways compared with the surface water pathways. Metals analysis should include both total and dissolved metals to aid risk characterisation.

If operational management of the site is resumed in the future, then a further recommendation is made:

- Replacing GWS5 and GWD7 as downgradient boreholes in a more suitable location further from the influence of the unlined lagoons.

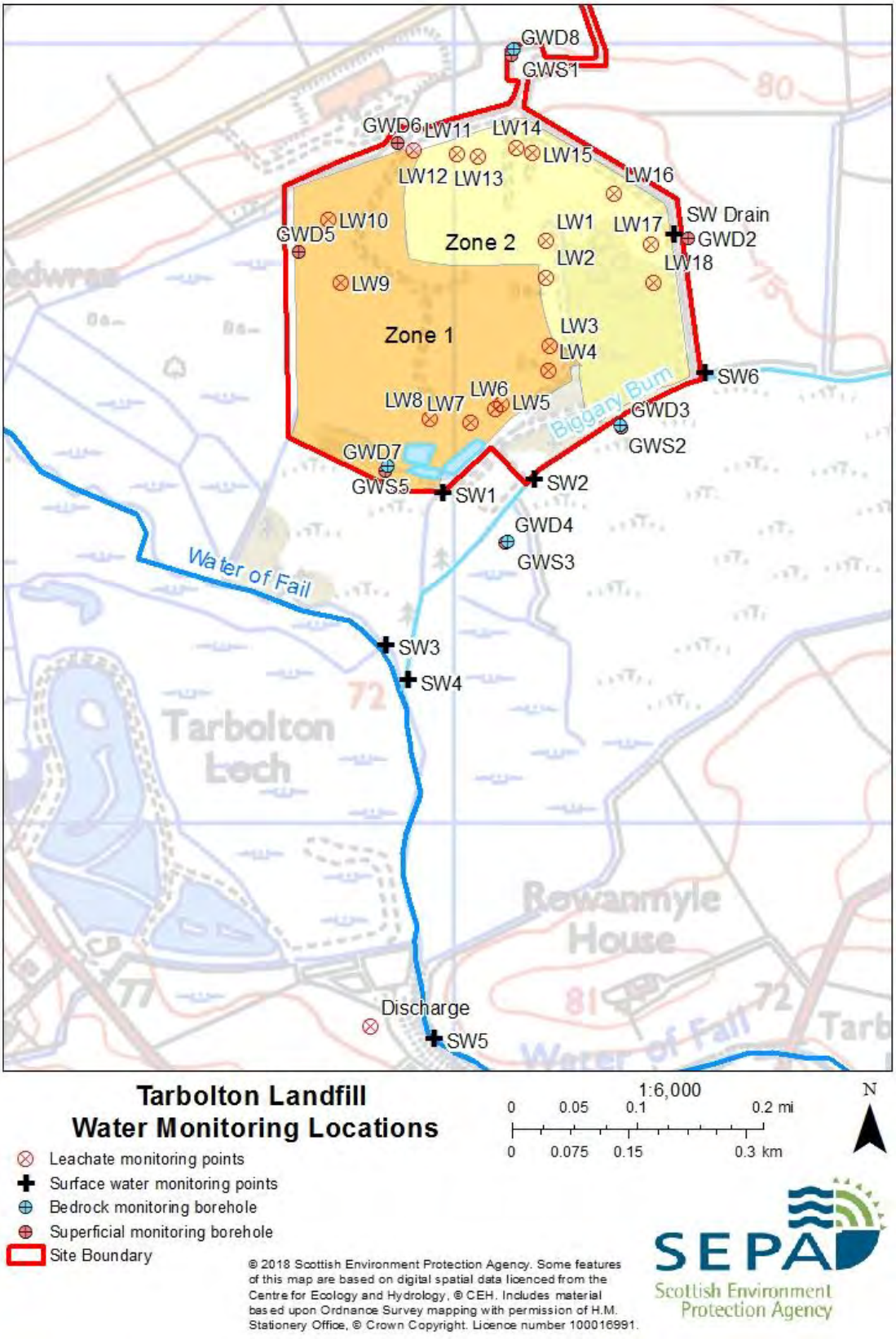
Glossary

Term		Explanation
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes	Group of volatile hydrocarbon compounds, commonly found in fuels such as petrol
DWS	Drinking water standard	Standards adopted by the Scottish Government and used by SEPA to define when water is fit for human consumption
Dust		Particulate matter in the size range 1-75 µm in diameter
EPH	Extractable petroleum hydrocarbons	Mixture of hydrocarbons, commonly found in fuels such as diesel
EQS	Environmental quality standard	Standards adopted by the Scottish Government and used by SEPA to protect aquatic ecosystems
Groundwater		Water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil
Leachate		Liquid formed when water infiltrates through waste, taking in soluble contaminants as it does
LOD	Limit of detection	The concentration above which it can be affirmed, with a stated level of confidence that a sample is different from a blank sample that does not contain the substance of interest
MRV	Minimum reporting value	Standards used to assess the potential for significant entry of hazardous substances into groundwater
Non-hazardous waste		Category of waste materials that do not meet the criteria for classification as either inert nor hazardous wastes
NORM	Normally occurring radioactive materials	Radioactive material found in the environment that is not man-made
PAH	Polycyclic aromatic hydrocarbon	Type of hydrocarbon compound
PCB	Polychlorinated biphenyl	Type of chlorinated organic compound
PM	Particulate matter	Airborne particulate matter made up of a collection of solid and/or liquid materials of various sizes
PM_{10}		The fraction of suspended particulate matter up to 10 µm aerodynamic diameter
$PM_{2.5}$		The fraction of suspended particulate matter up to 2.5 µm aerodynamic diameter

Term		Explanation
PPC	Pollution Prevention and Control	Regulatory regime under the Pollution Prevention and Control (Scotland) Regulations that covers certain industrial activities PPC is the principal regulatory regime for operational landfills
RPV	Resource protection value	Standards used to assess groundwater pollution by non-hazardous substances
Status		The physical, chemical or ecological condition of a water body, defined in accordance with the Water Framework Directive (WFD)
VPH	Volatile petroleum hydrocarbons	Mixture of volatile hydrocarbons, commonly found in fuels such as petrol
%V/V	% volume / volume	Percentage by volume
Waste		Materials which the holder discards or intends or is required to discard
Water body		A discrete geographical unit of surface water or groundwater defined for the purposes of river basin management planning in accordance with the Water Framework Directive (WFD)
WML	Waste Management Licence	Regulatory regime under the Waste Management Licensing (Scotland) Regulations that covers the treatment, storage and disposal of waste. Waste management licensing was principal regulatory regime for landfills prior to PPC.

Appendix A Maps and figures

Figure A1 - Tarbolton water environment monitoring locations



Appendix B Air quality tables and graphs

Table B1 - Scottish Air Quality Objectives (AQO)[33]

Pollutant	Time Period	Concentration	Date to be Achieved
PM_{10}	24 hour mean, not to be exceeded more than 7 times a year	50 µg/m^3	31 December 2010
	Annual Mean	18 µg/m^3	31 December 2010
$PM_{2.5}$	Annual Mean	10 µg/m^3	2020

Table B2 - Daily Air Quality Index[34]

Banding	Index	24 Hour Mean (µg/m^3)	
		PM_{10}	$PM_{2.5}$
Low	1	0-16	0-11
	2	17-33	12-23
	3	34-50	24-35
Moderate	4	51-58	36-41
	5	59-66	42-47
	6	67-75	48-53
High	7	76-83	54-58
	8	84-91	59-64
	9	92-100	65-70
Very High	10	>101	>71

[33] http://www.scottishairquality.co.uk/air-quality/standards
[34] http://www.scottishairquality.co.uk/air-quality/daqi

Table B3 - Directional Dust Assessment Matrix, Dust Impact Risk[35]

		AAC: dust coverage				
		Level 0: <80%/interval	Level 1: 80 to <95%/interval	Level 2: 95 to <99%/interval	Level 3: 99 to 100%/interval	Level 4: 100% over 45°/interval
EAC: dust soiling	Level 0: <0.5%/day	Very Low	Very Low	Very Low	Low	Medium
	Level 1: 0.5 to <0.7%/day	Low	Low	Low	Medium	High
	Level 2: 0.7 to <2.0%/day	Medium	Medium	Medium	High	High
	Level 3: 2.0 to <5.0%/day	High	High	High	High	Very High
	Level 4: ≥5%/day	Very High	Very High	Very High	Very High	Very High

Table B4 - Varying Effective Area Coverage with Situation[36]

%EAC/day	Situation
0.01	Rural
0.02	Suburban
0.3 - 0.4	Urban
0.5	Rural Summertime
0.8 - 1.0	Industrial

Table B5 - Percentage Effective Area Coverage Complaint Thresholds[37]

%EAC/day	Response
0.2	Noticeable
0.5	Possible Complaints
0.7	Objectionable
2.0	Probable Complaints
5.0	Serious Complaints

[35] Source: DustScan Ltd

[36] *Beaman, A.L. & Kingsbury, R.W.S.M. (1981), "Assessment of nuisance from deposited dust particulates using a simple and inexpensive measuring system", Clean Air, Vol.11, No.2, pp.77-81*

[37] *Beaman, A.L. & Kingsbury, R.W.S.M. (1981), "Assessment of nuisance from deposited dust particulates using a simple and inexpensive measuring system", Clean Air, Vol.11, No.2, pp.77-81*

Table B6 - Sticky pad results

Sampling Information				Result	
Site	**Deposition or Impact**	**Exposure Period (days)**	**Collection Date**	**%EAC/day**	**Analysis Date**
C	Impact (vertical pad)	14	12/03/2018	0.2	23-Apr-18
C	Deposition (horizontal pad)	14	12/03/2018	0.2	23-Apr-18
B	Impact	14	12/03/2018	0.2	23-Apr-18
B	Deposition	14	12/03/2018	0.4	23-Apr-18
C	Impact	23	04/04/2018	0.2	23-Apr-18
C	Deposition	23	04/04/2018	0.3	23-Apr-18
B	Impact	23	04/04/2018	0.1	23-Apr-18
B	Deposition	23	04/04/2018	0.3	23-Apr-18

Figure B1 – 24-hour average PM_{10} concentrations at Offsite Location B

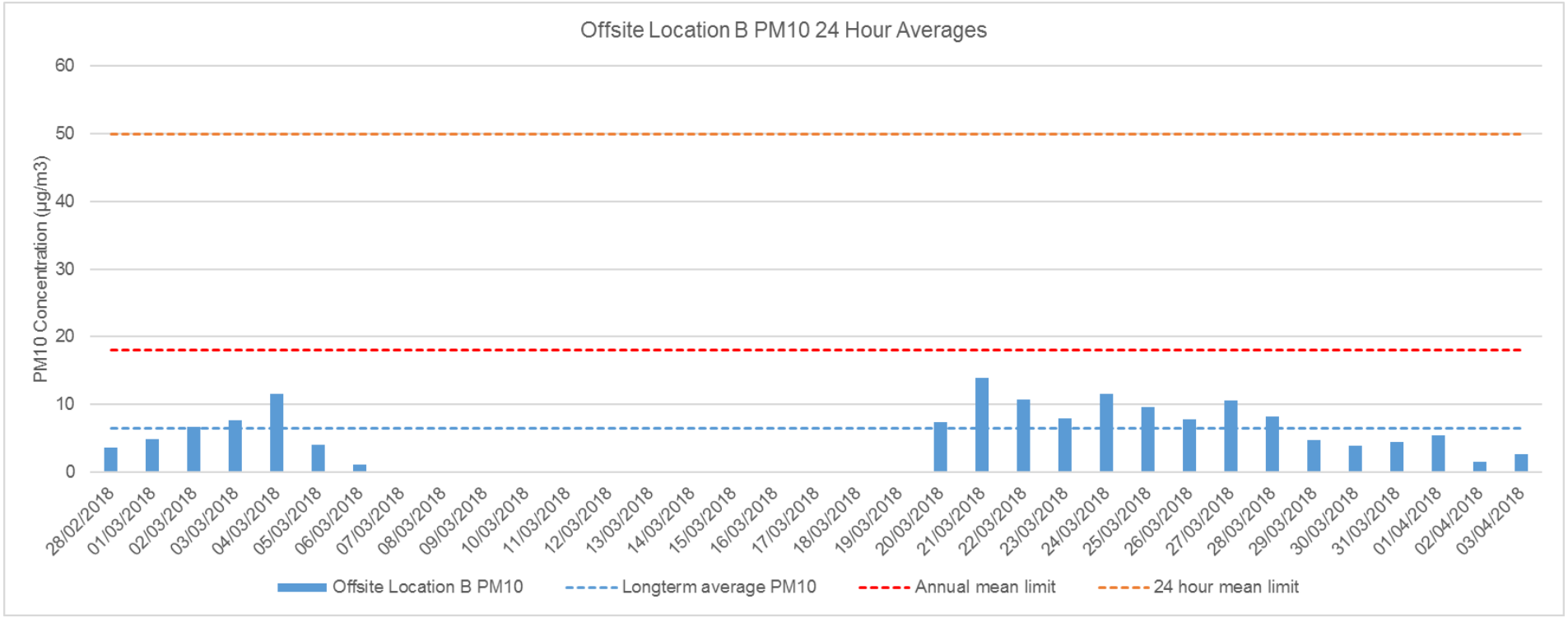


Figure B2 - 24-hour average PM_{10} concentrations at Offsite Location C

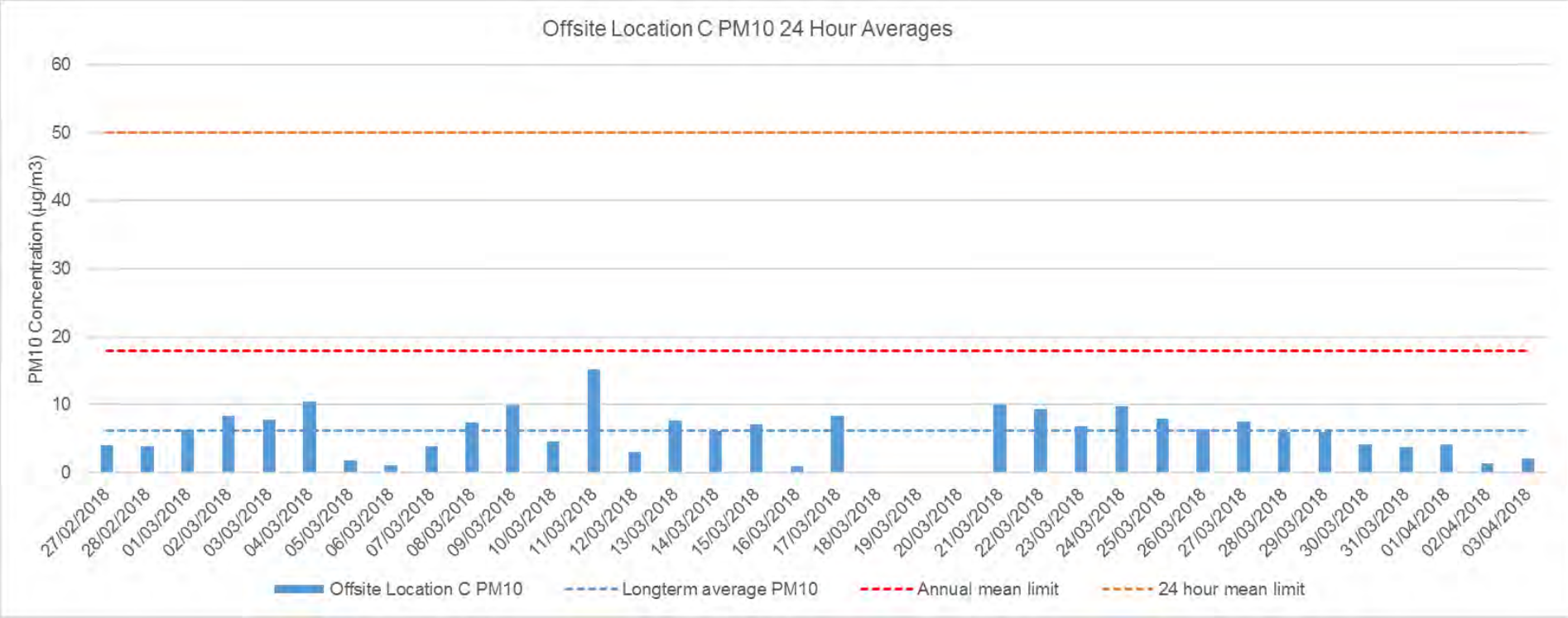


Figure B3 - Hourly average PM_{10} concentrations at Offsite Locations B and C

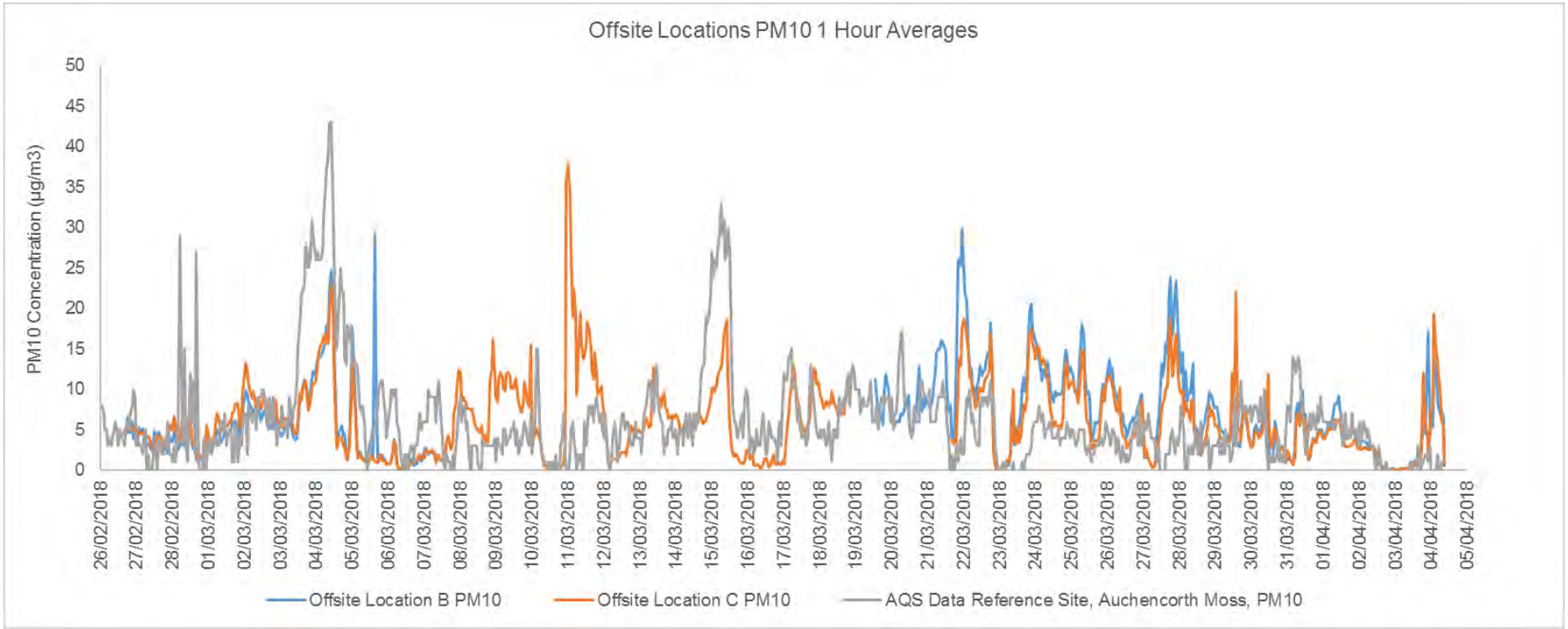


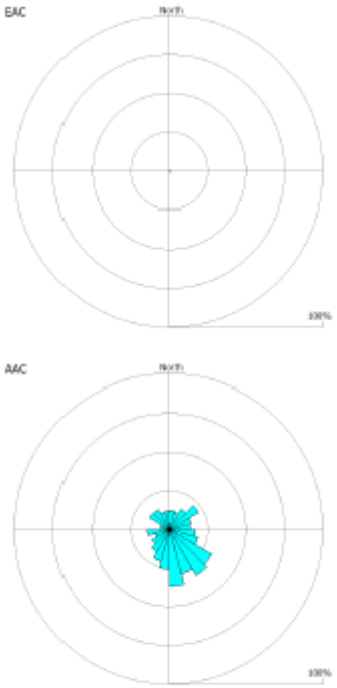
Figure B4 - DustScan Results from 9 to 26 February 2018

Client:	SEPA	**Site:**	Tarbolten Landfill
Point:	East (East)		
Date Out:	09-Feb-18	**Date In:**	26-Feb-18
Interval*:	17 days	**Our Ref:**	83811 / East / ZSEPATL

DIRECTIONAL DUST FLUX DATA

Effective Area Coverage (EAC%) / interval = 0.4
Absolute Area Coverage (AAC%) / interval = 17.8
Effective Area Coverage (EAC%) / day = 0.0
Absolute Area Coverage (AAC%) / day = 1.0

Segment	EAC% /Interval	AAC% /Interval	EAC% /Day	AAC% /Day	Dust Impact Risk
00°-15°	0.2	12.2	<0.1	0.7	N/A
15°-30°	0.2	11.7	<0.1	0.7	N/A
30°-45°	0.3	15.3	<0.1	0.9	N/A
45°-60°	0.6	21.9	<0.1	1.3	N/A
60°-75°	0.4	14.7	<0.1	0.9	N/A
75°-90°	0.3	13.8	<0.1	0.8	N/A
90°-105°	0.4	17.1	<0.1	1.0	N/A
105°-120°	0.4	19.3	<0.1	1.1	N/A
120°-135°	0.8	31.9	<0.1	1.9	N/A
135°-150°	0.9	34.4	<0.1	2.0	N/A
150°-165°	0.8	29.8	<0.1	1.8	N/A
165°-180°	1.1	36.8	<0.1	2.2	N/A
180°-195°	0.6	25.8	<0.1	1.5	N/A
195°-210°	0.6	21.2	<0.1	1.2	N/A
210°-225°	0.4	16.6	<0.1	1.0	N/A
225°-240°	0.3	13.2	<0.1	0.8	N/A
240°-255°	0.1	9.7	<0.1	0.6	N/A
255°-270°	0.3	14.9	<0.1	0.9	N/A
270°-285°	<0.1	5.5	<0.1	0.3	N/A
285°-300°	<0.1	6.5	<0.1	0.4	N/A
300°-315°	0.2	15.1	<0.1	0.9	N/A
315°-330°	0.2	14.8	<0.1	0.9	N/A
330°-345°	0.2	11.8	<0.1	0.7	N/A
345°-360°	0.2	12.0	<0.1	0.7	N/A



The rose diagrams represent the soiling (EAC) and presence (AAC) of dust for each 15 degree arc per sampling interval.

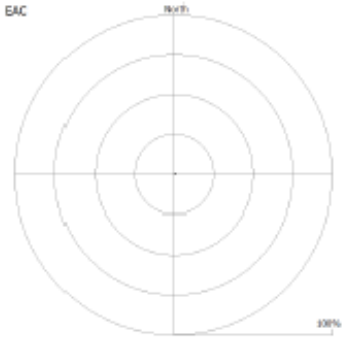
Figure B5 - DustScan Results from 12 March to 4 April 2018

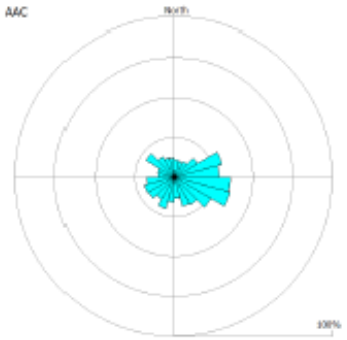
Client:	SEPA	**Site:**	Tarbolten Landfill
Point:	East (East)		
Date Out:	12-Mar-18	**Date In:**	04-Apr-18
Interval*:	23 days	**Our Ref:**	83814 / East / ZSEPATL

DIRECTIONAL DUST FLUX DATA

Effective Area Coverage (EAC%) / interval = 0.3
Absolute Area Coverage (AAC%) / interval = 18.8
Effective Area Coverage (EAC%) / day = 0.0
Absolute Area Coverage (AAC%) / day = 0.8

Segment	EAC% /Interval	AAC% /Interval	EAC% /Day	AAC% /Day	Dust Impact Risk
00°-15°	0.1	10.9	<0.1	0.5	N/A
15°-30°	0.1	10.1	<0.1	0.4	N/A
30°-45°	0.2	11.2	<0.1	0.5	N/A
45°-60°	0.3	17.0	<0.1	0.7	N/A
60°-75°	0.8	31.2	<0.1	1.4	N/A
75°-90°	0.6	28.4	<0.1	1.2	N/A
90°-105°	1.0	35.4	<0.1	1.5	N/A
105°-120°	0.9	36.7	<0.1	1.6	N/A
120°-135°	0.6	27.1	<0.1	1.2	N/A
135°-150°	0.3	20.2	<0.1	0.9	N/A
150°-165°	0.3	19.0	<0.1	0.8	N/A
165°-180°	0.2	13.6	<0.1	0.6	N/A
180°-195°	0.3	16.0	<0.1	0.7	N/A
195°-210°	0.4	20.4	<0.1	0.9	N/A
210°-225°	0.2	16.2	<0.1	0.7	N/A
225°-240°	0.3	19.1	<0.1	0.8	N/A
240°-255°	0.3	19.7	<0.1	0.9	N/A
255°-270°	0.3	17.8	<0.1	0.8	N/A
270°-285°	0.1	10.5	<0.1	0.5	N/A
285°-300°	0.1	11.4	<0.1	0.5	N/A
300°-315°	0.3	20.8	<0.1	0.9	N/A
315°-330°	0.2	14.7	<0.1	0.6	N/A
330°-345°	0.1	12.6	<0.1	0.5	N/A
345°-360°	0.1	11.9	<0.1	0.5	N/A





The rose diagrams represent the soiling (EAC) and presence (AAC) of dust for each 15 degree arc per sampling interval.

Appendix C Leachate and ash waste tables and graphs

Table C1 - Tarbolton ash waste composition - summarised composition of ash waste source 'DERL' and six ash samples recovered by SEPA from the landfill in 2014. Also summarised for comparison are Scottish soil median values (Paterson *et al*. 2011) and Pulverised Fuel Ash composition (BRE509 & Sear and Coombs 2001)

		DERL Results			SEPA 18/07/2014			SEPA 24/07/2014			Scottish Soil	Pulverised Fuel Ash	
Determinand	Unit	Filter	Bottom	Cyclone	TAR-WAS-01	TAR-WAS-02	TAR-WAS-03	TAR-WAS-04	TAR-WAS-05	TAR-WAS-06	Median	Min	Max
pH	mg/kg	11.6	11.8	11	12.2	12.2	12.2	12.1	12.1	12.1	-	-	-
Iron	mg/kg	-	-	-	20000	20000	20000	20000	20000	20000	24700	-	-
Manganese	mg/kg	420	960	1600	1700	1900	1700	1400	1500	1400	450	103	1555
Nickel	mg/kg	49	330	180	330	240	170	150	150	160	17	108	583
Lead	mg/kg	4600	270	1400	2500	5700	2500	2800	2800	2900	23	1	976
Zinc	mg/kg	-	-	-	7900	7700	7300	11000	10000	11000	48	148	918
Chromium (III)	mg/kg	-	-	-	170	160	150	240	230	250	-	-	-
Chromium (VI)	mg/kg	-	-	-	<2	<2	<2	<2	<2	<2	-	-	-
Chromium	mg/kg	120	170	170	170	160	150	240	230	250	41.2	97	192
Cadmium	mg/kg	47	3	14	19	20	19	15	16	16	-	0	4
Arsenic	mg/kg	42	16	20	100	100	89	190	180	200	-	40	109
Aluminium	mg/kg	26000	25000	110000	38000	37000	39000	29000	36000	32000	29000	-	-
Copper	mg/kg	5300	4600	22000	2200	2200	2400	1500	1700	1500	7.5	119	474
Mercury	mg/kg	12	<1	<1	<1	1	1	1	1	1	-	-	-
Selenium	mg/kg	-	-	-	<10	<10	<10	<10	<10	<10	-	4	162
Sulphates	%	-	-	-	4.5	4.6	4.7	3.8	4.2	4.1	-	-	-
PAH (Total)	mg/kg	0.3	<0.10	<0.10	-	-	-	-	-	-	-	-	-
PCB (sum of)	ng/kg	5578	445.5	421.5	-	-	-	-	-	-	-	-	-

Notes: values derived from; Geochemical Atlas for Scottish Topsoils, Edward Paterson, 2011, Macaulay Land Use Research Institute and BRE 509 Stabilising Mine Workings with PFA Grouts, Environmental Code of Practice, 2nd Edition, BRE Building Technology Group

Table C2 - Leachate summary results compared with landfill leachate typical values

Parameter	Units	Landfill Leachate Typical UK Values			Site Operator Leachate Monitoring 2009-2016					SEPA Leachate Monitoring 03/05/2018	
		Min	Likely	Max	Number	Min	Median	Max	Number> typical max	Min	Max
pH		4		9	295	6	7.5	8.4	0	6.96	7.56
Ammoniacal Nitrogen	mg/l	4.37	723	3640	294	0.06	372	2950	0	4.53	1020
Chloride	mg/l	36.6	2270	7760	294	3.3	973	8200	30	28.5	20900
Electrical Conductivity	µS/cm	2500		35000	296	520	7025	57500	23	664	53092
Iron (total)	mg/l	0.29	9.93	5530	71	0.04	31	20000	2	0.575	33.5
Manganese (total)	mg/l	0.08	0.78	324	67	0.138	260	52000	32	0.582	18.9
Nickel (total)	mg/l	0.00883	0.12	2.21	71	0.0062	7.9	570	37	0.0187	0.294
Lead (total)	mg/l	0.00957	0.13	1.02	40	0.002	0.125	500	7	0.00171	0.0514
Zinc (total)	mg/l	0.00225	0.165	208	63	0.002	6	140	0	0.0192	0.225
Chromium (total)	mg/l	0.00856	0.0647	1.75	70	0.002	0.653	1500	31	0.00742	0.781
Cadmium (total)	mg/l	0.0019	0.0101	0.105	17	0.0003	0.0008	0.13	1	0.000299	0.000299
Arsenic (total)	mg/l	0.000673	0.00484	1.31	8	0.005	0.0084	0.046	0	<0.02	0.174
Mercury (total)	mg/l	0.00004	0.00009	0.00195	-	-	-	-	-	<0.0095	0.0788
Benzene	µg/l	2	-	50	5	<0.1	0.17	1.06	0	<1.0	3.57
Toluene	µg/l	-	-	-	4	<0.1	0.36	4.83	-	<1.0	49.2
Ethyl Benzene	µg/l	-	-	-	3	<0.1	0.18	1.22	-	<1.0	14
Xylene	µg/l	-	-	-	3	<0.2	0.81	5.33	-	<3.0	65.4
PAH Total	µg/l	-	-	-	6	<0.04	0.75	3.16	-	<2	67.9
PCBs*	ng/l	-	-	-	-	-	-	40*	-	<0.01	<0.01
Mecoprop	µg/l	0.25	-	230	7	1.84	2.71	23.4	0	-	-

Notes: Landfill Leachate Typical UK Values sourced from 'Landsim UK Default Leachate Inventory and Concentrations' some additional parameters derived from 1).*Peter Kjeldsen , Morton A. Barlaz , Alix P. Rooker , Anders Baun , Anna Ledin & Thomas H. Christensen (2002) Present and Long-Term Composition of MSW Landfill Leachate: A Review, Critical Reviews in Environmental Science and Technology, 32:4, 297-336*, and 2). *Mukherjee, S., Mukhopadhyay, S., Hashim, M. A., & Sengupta, B. (2015). Contemporary environmental issues of landfill leachate: assessment & remedies. Critical Reviews in Environmental Science and Technology, 45(5), 472-590*. Mecoprop and benzene which are based on values at other Scottish Landfills.
*PCB values are provided from SEPA sample of the site leachate discharge on 13/05/1998

Table C3 - Typical composition of leachate from domestic waste at various stages of decomposition

Determinand	Fresh Wastes	Aged Wastes	Wastes with high moisture contents
pH	6.2	7.5	8.0
COD	23800	1160	1500
BOD	11900	260	500
TOC	8000	465	450
Volatile acids (as C)	5688	5	12
NH_3–N	790	370	1000
NO_3–N	3	1	1.0
Ortho–P	0.73	1.4	1.0
Cl	1315	2080	1390
Na	9601	300	1900
Mg	252	185	186
K	780	590	570
Ca	1820	250	158
Mn	27	2.1	0.05
Fe	540	23	2.0
Ni	0.6	0.1	0.2
Cu	0.12	0.03	—
Zn	21.5	0.4	0.5
Pb	0.40	0.14	

Note: Table is extract from Waste Management Paper No 26A, Landfill Completion, Department of the Environment 1993. All values in mg/l except pH.

Table C4 - Landfill leachate levels for 2017-2018

Well	Leachate Head on Base (m)				Leachate Level (mAOD)			
	Operator Data		SEPA Data		Operator Data		SEPA Data	
	2017	2018 (Jan – May)	May 2018	June 2018	2017	2018 (Jan – May)	May 2018	June 2018
LW1	1.50 – 2.11	4.18 – 8.90			76.25 – 76.86	78.93 – 90.15		
LW2	0.17 – 2.16	4.05 – 7.94	-3.4	3.96	77.57 – 79.56	81.45 – 89.56	78.89	81.36
LW3	1.68 – 2.46	3.00 – 3.10		3.09	78.74 – 79.55	80.06 – 85.05		80.15
LW4	1.28 – 2.25	2.23 – 2.57	2.58	2.55	77.68 – 78.65	78.63 – 80.18	78.98	78.95
LW5	1.20 – 1.98	1.61 – 1.98		1.58	79 – 79.78	79.41 – 80.90		79.38
LW6	0.51 – 1.69	1.59 – 2.50		2.47	77.42 – 78.60	78.50 – 80.93		79.38
LW7	0.79 – 1.60	0.75 – 1.88			79.07 – 79.88	79.03 – 82.42		
LW8	1.20 – 2.37	2.28 – 2.95	3.04	2.86	78.82 – 79.99	79.90 – 83.72	80.66	80.48
LW9	1.25 – 2.35	2.92 – 3.20		2.83	78.97 – 80.07	80.64 – 85.52		80.55
LW10	0.85 -1.76	1.17 – 1.58	1.22	1.12	78.37 – 79.28	78.69 – 83.59	78.74	78.64
LW11	1.27 – 2.38	2.98 – 3.33		3.19	75.62 – 76.73	77.33 – 80.54		77.54
LW12	0.41 – 1.24	1.19 – 1.33		1.25	74.43 – 75.26	75.21 – 80.32		75.27
LW13	1.29 – 2.42	2.35 – 2.51		2.32	76.40 – 77.53	77.46 – 82.73		74.43
LW14	1.16 – 2.10	1.07 – 2.10	1.46	1.96	76.51 – 77.45	76.42 – 80.46	76.81	73.31
LW15	0.88 – 1.52	0.69 – 1.49			75.96 – 76.60	75.77 – 78.37		
LW16	0.47 – 1.62	0.19 – 0.47			75.34 – 76.49	75.06 – 80.38		
LW17	0.82 – 1.82	0.13 – 1.31	1.96	0.61	75.62 – 76.62	74.93 – 78.16	76.76	75.41
LW18	0.24 – 1.32	0.90 – 1.32		1.03	75.23 – 76.31	75.89 – 77.39		76.02

Note: The field report (CHEM/2018/064) indicates that leachate levels were monitored on 2 April 2018. However, this is understood to be a typographical error as leachate levels were monitored at the same time as sample recovery on the 2 May 2018.

Table C5 - Summary results of common landfill indicator parameters in leachate; table displays the summarised site operator returns data from 2009-2017 compared with the single SEPA sampling round from selected leachate wells on 03/05/2018

Landfill Leachate Indicators		Zone 1 Landfill Leachate								Zone 2 Landfill Leachate									Discharge
		LW3	LW4	LW5	LW6	LW7	LW8	LW9	LW10	LW1	LW2	LW11	LW12	LW13	LW14	LW15	LW16	LW17	
Ammoniacal Nitrogen mg/l	Number	25	14	17	16	25	13	25	14	17	24	24	22	13	7	6	6	-	27
	Min	36	106	98.2	9.3	3.1	0.4	9	0.06	52.7	22	0.8	45	366	48	25	86	-	56
	Max	1330	687	516	790	939	751	390	163	1200	1850	2950	2500	2000	1100	1100	1400	-	1190
	Median	270	471.5	320	675	251	84.2	26	17.25	448	490	650	1535	720	470	505	930	-	148
	SEPA 2018	-	233	-	-	-	4.53	-	476	-	202	-	-	-	779	-	-	1020	-
Chloride mg/l	Number	25	14	17	16	25	13	25	14	17	24	82	22	13	7	6	6	-	27
	Min	100	3.3	4.9	8.6	7	8.2	8.5	6.4	263	8	22	22	100	280	590	2600	-	9.4
	Max	3040	1300	778	1190	1740	1390	770	729	3600	17000	7970	18000	16000	12000	12000	15000	-	7730
	Median	638	878	498	1015	527	163	125	64.5	1730	2350	3150	9415	8700	4500	4900	10950	-	670
	SEPA 2018	-	752	-	-	-	28.5	-	2630	-	4740	-	-	-	10200	-	-	20900	-
Electrical Conductivity µS/cm	Number	25	14	17	16	25	13	25	14	17	24	24	22	13	7	6	7	-	27
	Min	2600	2600	2510	718	520	719	700	1030	1840	1000	4600	3840	366	3610	590	11300	-	2670
	Max	18600	12000	9180	12100	17100	9350	6300	5840	15700	35000	36700	56900	57500	38700	12000	48600	-	36900
	Median	6150	6410	4940	9155	4690	2330	1420	1665	8400	9715	14000	31672	29500	17300	4900	38800	-	3660
	SEPA 2018	-	4857	-	-	-	664	-	11034	-	13115	-	-	-	27134	-	-	53092	-

Table C6 - Summary results of total metal concentrations in leachate monitored; table displays summarised site operator returns data from 2009-2017 compared with the single SEPA sampling round from selected leachate wells on 03/05/2018

Metals (total)		Zone 1 Landfill Leachate								Zone 2 Landfill Leachate									Discharge
		LW3	LW4	LW5	LW6	LW7	LW8	LW9	LW10	LW1	LW2	LW11	LW12	LW13	LW14	LW15	LW16	LW17	
Iron mg/l	Number	6	3	4	3	6	3	6	3	4	6	6	4	3	2	1	1	-	11
	Min	1.63	1.44	0.3	2.88	1.7	0.64	0.04	0.005	17.2	4.41	0.005	6.51	7.9	2700	470	980	-	2.92
	Max	1100	1500	420	20.8	1900	91	260	29	4200	540	2100	20000	15000	4400	470	980	-	700
	Median	240	15.84	26.8	18.02	75.5	16	23	3.73	71.235	66.75	975	2800	1500	3550	470	980	-	9.53
	SEPA 2018	-	8.07	-	-	-	12	-	27	-	33.5	-	-	-	5.63	-	-	0.575	-
Manganese mg/l	Number	6	3	4	3	6	3	6	3	4	6	6	4	3	2	1	1	-	5
	Min	0.48	0.9	1.06	0.47	0.138	0.3	1.26	1.77	0.499	0.52	0.59	1	9.296	1100	3100	610	-	0.644
	Max	1100	930	260	0.565	150	430	1000	2400	810	2400	940	2100	1700	3100	3100	610	-	870
	Median	585	0.972	1.3355	0.5	67	0.558	480	3.168	1.32	354.45	415	1750	1100	2100	3100	610	-	430
	SEPA 2018	-	1.17	-	-	-	0.601	-	0.736	-	18.9	-	-	-	1.6	-	-	0.582	-
Nickel mg/l	Number	6	3	4	3	6	3	5	3	4	6	6	4	3	2	1	1	-	11
	Min	0.063	0.0319	0.024	0.0864	0.204	0.025	0.0128	0.0062	0.0495	0.029	0.061	0.18	0.611	160	150	190	-	0.016
	Max	20	39	28	0.0959	170	13	24	15	69	64	51	570	510	190	150	190	-	25
	Median	13	0.033	0.0516	0.091	14.5	0.12	7.9	0.022	0.0628	8.075	22.5	225	110	175	150	190	-	0.0229
	SEPA 2018	-	0.0196	-	-	-	0.0187	-	0.045	-	0.029	-	-	-	0.203	-	-	0.294	-
Chromium mg/l	Number	6	3	4	3	6	3	6	3	4	6	6	4	3	2	1	1	-	11
	Min	0.047	0.034	0.011	0.03	0.057	0.01	0.005	0.002	0.013	0.0074	0.183	0.1	0.666	210	210	740	-	0.004
	Max	12	30	6.4	0.037	34	1.9	3.2	0.62	61	14	110	420	880	1500	210	740	-	9.4
	Median	2.65	0.037	0.025	0.035	0.76	0.033	0.705	0.005	0.0215	1.055	19.5	260	460	855	210	740	-	0.007
	SEPA 2018	-	0.0087	-	-	-	0.0127	-	0.0177	-	0.0074	-	-	-	0.781	-	-	0.311	-

Table C6 (continued)

Metals (total)		Zone 1 Landfill Leachate								Zone 2 Landfill Leachate									Discharge
		LW3	LW4	LW5	LW6	LW7	LW8	LW9	LW10	LW1	LW2	LW11	LW12	LW13	LW14	LW15	LW16	LW17	
Lead mg/l	Number	6	3	4	3	6	3	6	3	4	6	6	4	2	2	1	1	-	11
	Min	0.005	0.001	0.001	0.002	0.005	0.004	0.004	0.003	0.004	0.003	0.001	0.009	0.27	0.23	0.045	4.4	-	0.0005
	Max	0.41	0.045	0.13	0.009	0.71	0.045	0.045	0.045	2.7	0.26	0.94	1.8	0.45	7.3	0.045	4.4	-	0.045
	Median	0.045	0.005	0.0625	0.005	0.045	0.005	0.045	0.005	0.0155	0.0261	0.35	0.7725	0.36	3.765	0.045	4.4	-	0.01
	SEPA 2018	-	0.0017	-	-	-	0.0514	-	0.0058	-	0.0072	-	-	-	0.0115	-	-	0.0057	-
Zinc mg/l	Number	6	3	4	3	6	3	6	3	4	6	6	4	3	2	1	1	-	11
	Min	0.026	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.008	0.01	0.01	0.11	0.043	71.5	20	86.2	-	0.002
	Max	20	8.9	30	0.057	36	5.7	34.1	6	16	47	55.3	56	140	140	20	86.2	-	20
	Median	10.6	0.013	0.197	0.017	17.15	0.032	6.65	0.013	0.12	2.2185	11.45	16.305	58.4	105.75	20	86.2	-	0.054
	SEPA 2018	-	0.132	-	-	-	0.225	-	0.122	-	0.0192	-	-	-	0.0499	-	-	0.0822	-
Arsenic mg/l	Number	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
	Min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.005
	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.046
	Median	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0084
	SEPA 2018	-	<0.004	-	-	-	0.0038	-	<0.02	-	<0.02	-	-	-	0.0465	-	-	0.174	-
Cadmium µg/l	Number	6	3	4	3	5	3	6	3	4	5	6	4	3	2	1	1	-	11
	Min	<0.3	<0.3	<0.3	<0.3	<1	<0.3	<0.3	<0.4	0.4	<0.3	<0.1	0.7	<1	<30	<30	70	-	0.05
	Max	<30	<30	<30	<10	<30	<30	<30	<30	37	130	<30	60	<30	70	<30	70	-	15
	Median	-	-	-	-	-	-	-	-	0.8	15	-	32.5	-	42.5	-	70	-	0.4
	SEPA 2018	-	<0.08	-	-	-	0.3	-	<0.4	-	<0.4	-	-	-	<0.8	-	-	<0.8	-

Table C7 - Dissolved metal concentrations in leachate monitored by SEPA on 03/05/2018

Leachate Metals (dissolved)	Units	MRV/RPV	EQS	LW4	LW8	LW10	LW2	LW14	LW17
				Zone 1 Landfill Leachate			Zone 2 Landfill Leachate		
Iron (<0.45µm)	mg/l	0.2	1	**0.209**	0.032	**0.571**	0.108	**4.79**	0.029
Manganese (<0.45µm)	mg/l	0.05	0.123*	**1.18**	**0.405**	**0.629**	**18.3**	**1.64**	**0.626**
Nickel (<0.45µm)	µg/l	20	4*	19.6	3.31	**40.5**	**24.8**	**206**	**288**
Chromium (<0.45µm)	µg/l	50	3.4, 4.7Ŧ	7.36	0.657	10.9	6.95	**780**	**315**
Lead (<0.45µm)	µg/l	25	1.2*	<0.35	<0.35	2.14	<2.00	10.2	<4.00
Zinc (<0.45µm)	µg/l	-	10.9*	56.5	9.36	27	<19	28.5	<38
Arsenic (<0.45µm)	µg/l	10	50	2.15	<2.0	<20	<20	-	**177**
Cadmium (<0.45µm)	µg/l	0.1	0.08-0.25θ	0.021	0.016	<0.400	<0.400	<0.800	<0.800
Copper (<0.45µm)	µg/l	1	1*	0.48	**1.49**	<3.50	<3.50	<7.00	<7.00
Aluminium (<0.45µm)	µg/l	25	15α	<11.00	<11.00	<11.00	18.7	**310**	**129**
Mercury	µg/l	0.01	0.07	<0.0095	**0.0788**	<0.0095	**0.0197**	<0.0095	<0.0950

NOTES: Values in **BOLD** indicate concentrations above the RPV or MRV

Values which are shaded in grey are likely to be above EQS, however it should be noted that some EQS are based on bioavailable or reactive concentrations or specific chemical species. It is not possible to make direct comparison between EQS and leachate or groundwater concentrations. Therefore the above EQS vales highlighted are for indicative purposes only to inform assessment of potential risk.

* EQS is based on the bioavailable concentration

Ŧ chromium EQS is based on concentrations of Chromium VI and Chromium III

α aluminium EQS is based on reactive concentration

θ cadmium EQS based on five categories of surface water hardness

Table C8 - Results of petroleum hydrocarbon analysis in leachate monitored by SEPA at Tarbolton Landfill site on 03/05/2018

Petroleum Hydrocarbons	LW4	LW8	LW10	LW2	LW14	LW17
	Zone 1			Zone 2		
Benzene (µg/l)	<1.00	<1.00	<1.00	**1.64**	**2.91**	**3.57**
Toluene (µg/l)	<1.00	<1.00	<1.00	**1.22**	**18.1**	**49.2**
Ethyl Benzene (µg/l)	<1.00	<1.00	<1.00	**1.15**	**8.88**	**14**
Total Xylenes (µg/l)	<3.00	<3.00	<3.00	**5.88**	**26.2**	**65.4**
Aliphatic VPH >C5 - C6 (µg/l)	**15**	<20	<20	**59**	**286**	**630**
Aliphatic VPH >C6 - C8 (µg/l)	<10	<20	<20	<10	**833**	**260**
Aliphatic VPH >C8 - 10 (µg/l)	<10	<20	<20	**11**	**55**	**102**
Aliphatic VPH >C5 - C10 (µg/l)	**15**	<20	<20	**70**	**1174**	**992**
Aromatic VPH >C5 - C7 (µg/l)	<10	<20	<20	<10	<20	<20
Aromatic VPH >C7 - C8 (µg/l)	<10	<20	<20	<10	<20	**33**
Aromatic VPH >C8 - C10 (µg/l)	<10	<20	<20	<10	**39**	**44**
Aromatic VPH >C5 - C10 (µg/l)	<10	<20	<20	<10	**39**	**77**
VPH >C5 - C10 (µg/l)	**15**	<20	<20	**70**	**1213**	**1069**
Aliphatic EPH >C10 - C12 (µg/l)	<40	<20	<40	<40	<40	<200
Aliphatic EPH >C12 - C16 (µg/l)	<40	<20	<40	<40	<40	<200
Aliphatic EPH >C16 - C35 (µg/l)	<40	<20	<40	<40	<40	<200
Aliphatic EPH >C35 - C44 (µg/l)	<40	<20	<40	<40	<40	<200
Aliphatic EPH >C10 - C44 (µg/l)	<40	<20	<40	<40	<40	<200
Aromatic EPH >C10 - C12 (µg/l)	<40	<20	<40	<40	**115**	<200
Aromatic EPH >C12 - C16 (µg/l)	<40	<20	<40	<40	<40	<200
Aromatic EPH >C16 - C21 (µg/l)	<40	<20	<40	<40	<40	<200
Aromatic EPH >C21 - C35 (µg/l)	<40	<20	<40	<40	<40	<200
Aromatic EPH >C35 - C44 (µg/l)	<40	<20	<40	<40	<40	<200
Aromatic EPH >C10 - C44 (µg/l)	<40	<20	<40	<40	**115**	<200
EPH >C10 - C44 (µg/l)	<40	<20	<40	<40	**115**	<200
Aliphatic VPH/EPH >C5 - C44 (µg/l)	<40	<20	<40	**70**	**1174**	**992**
Aromatic VPH/EPH >C5 - C44 (µg/l)	<40	<20	<40	<40	**154**	<200
VPH/EPH >C5 - C44 (µg/l)	<40	<20	<40	**70**	**1328**	**992**

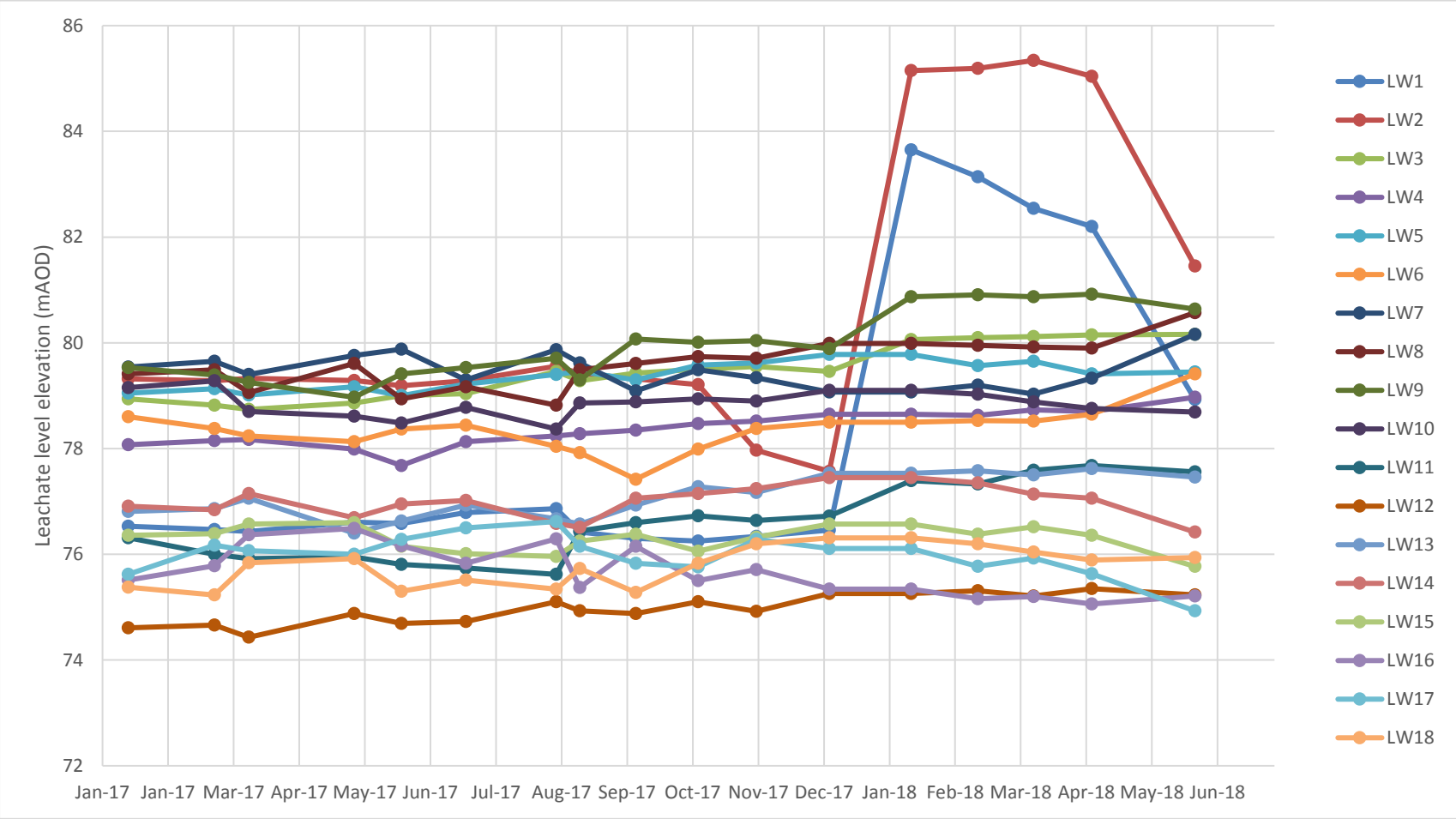
Table C9 - Results of PAH analysis in leachate monitored by SEPA on 03/05/2018

Polycyclic Aromatic Hydrocarbons	LW4	LW8	LW10	LW2	LW14	LW17
	Zone 1			Zone 2		
Acenaphthene (µg/l)	<0.2	<0.05	<0.5	<0.2	**5.1**	<1
Anthracene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (a) anthracene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (a) pyrene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (b) fluoranthene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (e) pyrene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (g,h,i) perylene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Benzo (k) fluoranthene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Chrysene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Dibenz (a,h) anthracene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Fluoranthene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Fluorene (µg/l)	<0.2	<0.05	<0.5	<0.2	**2.65**	<1
Indeno (1,2,3) cd pyrene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Naphthalene (µg/l)	<0.2	<0.05	<0.5	**0.263**	**62.3**	<1
Perylene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1
Phenanthrene (µg/l)	<0.2	<0.05	<0.5	<0.2	**2.24**	<1
Pyrene (µg/l)	<0.2	<0.05	<0.5	<0.2	<1	<1

Table C10 - Results of chlorinated hydrocarbon analysis in leachate monitored by SEPA on 03/05/2018

Chlorinated Hydrocarbons	LW4	LW8	LW10	LW2	LW14	LW17
	Zone 1			Zone 2		
1,3-Dichlorobenzene (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
1,4-Dichorobenzene (µg/l)	<1.00	**1.02**	<1.00	<1.00	<1.00	<1.00
1,2-Dichlorobenzene (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	**1.85**
Dichloromethane (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Chloroform (µg/l)	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250
1,1,1-Trichloroethane (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
1,2-Dichloroethane (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	**5.5**
Carbon tetrachloride (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Trichloroethene (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Tetrachloroethene (µg/l)	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00

Figure C1 - Landfill leachate levels for 2017-2018 based on operator returns data



Note that the reported leachate well cap elevations for LW1 and LW2 presented in the operator dataset vary during 2017 and 2018. The reported cap level for LW1 increased from 78.46 mAOD in January 2017 to 82.96 mAOD in August 2017 then to 90.15 mAOD in January 2018 (i.e. an overall increase in cap level of 11.69 m). The reported cap level for LW2 increased from 81.98 mAOD in 2017 to 89.56 mAOD in 2018 (i.e. an overall increase in cap level of 7.58 m). Therefore, there is uncertainty as to whether the major step-change in the data in January 2018 evident above is representative or whether it is simply an artefact of the monitoring reporting methodology. Roche Environment Ltd reported a new topographic survey of these wells is required.

Appendix D Groundwater tables and graphs

Table D1 - Summary results of common landfill indicator parameters in groundwater; table displays summarised site operator returns data from 2009-2017 compared with the single SEPA sampling round from selected groundwater boreholes on 03/05/2018

Landfill Leachate Indicators		GWD8	GWS1	GWD1	GWD2	GWD3	GWD4	GWD5	GWD6	GWD7	GWS2	GWS3	GWS5
		Upgradient			Downgradient								
Ammoniacal Nitrogen RPV=0.39mg/l	Number	94	93	93	85	93	95	94	91	94	92	89	90
	Min	<0.01	<0.01	<0.01	<0.01	<0.3	<0.015	<0.015	<0.01	0.49	<0.01	<0.015	<0.015
	Max	18	11	15	15	10	9.3	13	21	32	6.2	5.15	130
	Median	0.11	0.05	0.12	0.11	2.9	5.5	0.755	0.15	11	0.405	1.18	23.3
	No. >RPV	24	19	23	18	92	94	75	30	94	51	78	88
	%>RPV	26	20	25	21	99	99	80	33	100	55	88	98
	SEPA 2018	0.177	0.111	-	<0.024	3.38	5.12	-	-	178	0.396	1.04	6.17
Chloride RPV=250mg/l	Number	95	93	93	85	93	95	95	92	95	93	90	91
	Min	0.005	3	11	11	0.5	0.5	7	4	0.49	12	2.2	12
	Max	39	60	960	130	40	29	34	180	95	33	26	510
	Median	21	14	14	15	9	16	10	29.2	17	15	16	41
	No. >RPV	0	0	1	0	0	0	0	0	0	0	0	10
	%>RPV	0	0	1	0	0	0	0	0	0	0	0	11
	SEPA 2018	21.3	13.7	-	14.9	8.85	16	-	-	885	16.1	16.3	19.5
Electrical Conductivity DWS= 2500µS/cm	Number	95	93	93	85	93	95	95	92	95	93	90	91
	Min	339	279	244	238	6.3	7.1	6	6.6	6.8	3.8	4.5	56.4
	Max	622	453	470	600	454	815	1490	1360	638	611	558	3640
	Median	555	364	326	296	321	567	182	371.5	422	417	470	580
	No. >DWS	0	0	0	0	0	0	0	0	0	0	0	8
	%>DWS	0	0	0	0	0	0	0	0	0	0	0	9
	SEPA 2018	458	350	-	289	319	565	-	-	5020	391	465	313

Table D2 - Summary results of total metal concentrations in groundwater; table displays summarised site operator data from 2009-2017 compared with the single SEPA sampling round from selected groundwater boreholes on 03/05/2018

Metals (total) (µg/l)		GWD8	GWS1	GWD1	GWD2	GWD3	GWD4	GWD5	GWD6	GWD7	GWS2	GWS3	GWS5
		Upgradient			Downgradient								
Iron RPV=200µg/l	Number	25	25	27	23	26	26	25	24	25	25	25	25
	Min	2.75	<1	<0.6	2.75	43	2.75	2.75	45	76	0.00	0.00	24.00
	Max	35700	800	55460	50800	138000	61000	170000	123000	831000	4230	5830	425000
	Median	100	78	55	170	7275	390	37000	700	7000	89	210	8000
	No. >RPV	11	9	9	11	25	15	22	18	23	10	13	22
	SEPA 2018	61900	463	-	353	49800	58400	-	-	2030	1060	5730	382000
Manganese RPV=50µg/l	Number	27	26	27	22	26	27	27	26	27	27	27	27
	Min	0.11	0.11	1.19	0.11	280	380	93	46	1.50	580	2.10	<2.2
	Max	2820	250	2820	2820	2590	38300	7570	1590	21900	22000	2990	10300
	Median	48	89	93	43	836	1000	5600	290	384	1948	2399	1062
	No. >RPV	13	21	16	10	26	27	27	25	25	27	22	25
	SEPA 2018	3640	163	-	20	1270	4520	-	-	2030	2180	2760	15800
Nickel RPV=20µg/l	Number	29	26	30	25	26	27	29	28	30	27	25	26
	Min	<0.5	<0.5	<0.5	<0.5	0.61	<0.5	<0.5	0.89	<0.06	<0.5	<0.5	<0.6
	Max	130	6	109	109	151	93	69	55	673	5	4	490
	Median	3.0	0.5	1.8	0.9	6.1	1.0	1.6	3.1	4.5	0.5	1.0	3.7
	No. >RPV	9	0	10	3	1	7	3	6	12	0	0	4
	SEPA 2018	199	1	-	1	79	107	-	-	24	1	1	639
Chromium RPV=50µg/l	Number	27	26	27	23	26	27	27	26	27	27	27	27
	Min	<0.25	<0.2	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.2	<0.25
	Max	36	7	50	50	88	59	65	63	413	7	7	176
	Median	3.0	0.5	2.0	4.4	2.2	3.0	2.0	3.0	3.0	0.5	0.5	1.0
	No. >RPV	0	0	1	1	1	1	1	3	6	0	0	4
	SEPA 2018	50	<0.50	-	3	53	70	-	-	6	1	<0.50	348

Table D2 (continued)

Metals (total) (µg/l)		GWD8	GWS1	GWD1	GWD2	GWD3	GWD4	GWD5	GWD6	GWD7	GWS2	GWS3	GWS5
		Upgradient			Downgradient								
Lead RPV=25µg/l	Number	29	26	30	26	26	27	29	27	30	27	27	29
	Min	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
	Max	88	12	568	568	105	61	45	68	328	9	12	240
	Median	1.0	0.5	5.1	0.6	1.0	0.5	0.5	0.5	0.8	0.5	0.5	0.5
	No. >RPV	6	0	10	1	2	1	3	7	10	0	0	4
	SEPA 2018	87	0	-	1	33	38	-	-	5	1	<0.35	242
Zinc EQS=11.9µg/l	Number	27	26	27	23	26	27	27	26	27	27	27	27
	Min	<1	<1	<1	<1.3	<1	<1	<1	<1.3	<1.3	<1	<1.3	<1
	Max	140	138	2190	2010	230	504	179	150	942	207	70	625
	Median	8.2	4.4	22.5	6.0	10.5	16.0	12.9	16.2	22.0	4.0	2.6	12.0
	No. >RPV	11	5	19	8	13	14	15	15	17	4	4	14
	SEPA 2018	176	2	-	1	79	107	-	-	24	1	1	639
Arsenic RPV=10µg/l	Number	3	3	3	3	3	3	3	3	3	3	3	3
	Min	<1	<0.8	<1	<0.8	<1	2.00	<1	1.00	<1	<0.8	3.00	<0.8
	Max	5	1	7	1	2	16	7	11	43	1	12	2
	Median	4.8	0.5	6.4	0.5	1.8	16.0	6.9	9.0	13.0	0.5	10.0	0.5
	No. >RPV	0	0	0	0	0	2	0	1	2	0	2	0
	SEPA 2018	7	<2.0	-	<2.0	9	21	-	-	3	3	<2.0	44
Cadmium MRV=0.1µg/l	Number	9	8	10	6	9	10	9	10	10	8	10	9
	Min	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
	Max	1	0	3	0	1	8	2	1	3	0	1	1
	Median	0.015	0.015	0.028	0.015	0.040	0.040	0.015	0.045	0.040	0.040	0.028	0.040
	No. >RPV	1	0	2	0	1	3	1	3	2	2	2	1
	SEPA 2018	0.931	0.042	-	<0.015	0.463	0.945	-	-	0.043	0.037	<0.015	3.36

Note: Mercury is not included in the site monitoring record. Mercury results are available in SEPA monitoring below.

Table D3 - Results of total and dissolved metals analysis in groundwater in SEPA 2018 samples

Metals (Total and Dissolved)	Units	RPV/MRV	EQS	GWD8	GWS1	GWD2	GWD3	GWD4	GWD7	GWS2	GWS3	GWS5
				Upgradient		Downgradient						
Iron (<0.45µm)	µg/l	200	1000	<10	<10	<10	**7500**	31	175	<10	<10	**562**
Manganese (<0.45µm)	µg/l	50	123*	**210**	**128**	<5	**660**	**1050**	**1960**	**1990**	**2560**	**201**
Nickel (<0.45µm)	µg/l	20	4*	1.83	0.53	<0.35	5.1	2	**20.1**	<0.35	0.9	2.54
Chromium (<0.45µm)	µg/l	50	3.4, 4.7Ŧ	<0.50	<0.50	2.99	0.699	<0.50	3.46	<0.50	<0.50	<0.50
Lead (<0.45µm)	µg/l	25	1.2*	<0.35	<0.35	<0.35	0.981	<0.35	<0.35	<0.35	<0.35	<0.35
Zinc(<0.45µm)	µg/l	-	10.9*	<1.1	<1.1	<1.1	2.59	<1.1	<1.1	<1.1	<1.1	<1.1
Arsenic (<0.45µm)	µg/l	10	50	<2.0	<2.0	<2.0	<2.0	3.58	<2.0	<2.0	7.62	3.48
Cadmium (<0.45µm)	µg/l	0.1	0.08-0.25θ	<0.015	<0.015	<0.015	<0.015	<0.015	0.02	<0.015	0.015	<0.015
Copper (<0.45µm)	µg/l	1	1*	<0.15	<0.15	<0.15	0.981	<0.15	<0.15	<0.15	<0.15	<0.15
Aluminium (<0.45µm)	µg/l	25	15α	<11.00	<11.00	<11.00	**51.7**	<11.00	<11.00	<11.00	<11.00	<11.00
Mercury	µg/l	0.01	0.07	**0.277**	**0.0102**	<0.0095	<0.015	**0.0615**	<0.0095	<0.0095	**0.0263**	**0.077**
Suspended Solids (105°C)	mg/l			7670	21.1	98	1360	1520	163	61	13.2	19100

NOTES: Values in **BOLD** indicate concentrations above the RPV or MRV

Values which are shaded in grey are likely to be above EQS, however it should be noted that some EQS are based on bioavailable or reactive concentrations or specific chemical species. It is not possible to make direct comparison between EQS and leachate or groundwater concentrations. Therefore the above EQS vales highlighted are for indicative purposes only to inform assessment of potential risk.

* EQS is based on the bioavailable concentration

Ŧ chromium EQS is based on concentrations of Chromium VI and Chromium III

α aluminium EQS is based on reactive concentration

θ cadmium EQS is based on five categories of surface water hardness

Table D4 - Summary results of BTEX in groundwater; table displays summarised site operator returns data from 2009-2017 compared with the single SEPA sampling round from selected groundwater boreholes on 03/05/2018

BTEX		GWD8	GWS1	GWD1	GWD2	GWD3	GWD4	GWD5	GWD6	GWD7	GWS2	GWS3	GWS5
		Upgradient			Downgradient								
Benzene (µg/l)	Number	3	3	3	3	3	3	3	3	3	3	3	3
	Min	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max	0.130	<1	<1	<1	<1	<1	<1	<1	0.290	<1	<1	<1
	No. >LOD	1	0	0	0	0	0	0	0	1	0	0	0
	SEPA 2018	<1.00	<1.00		<1.00	<1.00	<1.00			<1.00	<1.00	<1.00	<1.00
Toluene (µg/l)	Number	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Min	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.140	<1	<1
	No. >LOD	0	0	0	0	0	0	0	0	0	1	0	0
	SEPA 2018	<1.00	<1.00		<1.00	<1.00	<1.00			<1.00	<1.00	<1.00	<1.00
Ethyl Benzene (µg/l)	Number	3	3	3	3	3	3	3	3	3	3	3	3
	Min	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	No. >LOD	0	0	0	0	0	0	0	0	0	0	0	0
	SEPA 2018	<1.00	<1.00		<1.00	<1.00	<1.00			<1.00	<1.00	<1.00	<1.00
Xylene (µg/l)	Number	3	3	3	3	3	3	3	3	3	3	3	3
	Min	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	Max	<2	<2	<2	0.200	<2	<2	<2	<2	<2	<2	<2	<2
	No. >LOD	0	0	0	1	0	0	0	0	0	0	0	0
	SEPA 2018	<3.0	<3.0		<3.0	<3.0	<3.0			<3.0	<3.0	<3.0	<3.0

Table D5 - Results of petroleum hydrocarbon analysis in groundwater in SEPA 2018 samples

Petroleum Hydrocarbons	GWD8	GWS1	GWD2	GWD3	GWD4	GWD7	GWS2	GWS3	GWS5
	Upgradient			Downgradient					
Aliphatic VPH >C5 - C6 (µg/l)	**14**	<10	<10	<10	<10	<10	<10	<10	<10
Aliphatic VPH >C6 - C8 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aliphatic VPH >C8 - 10 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aliphatic VPH >C5 - C10 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aromatic VPH >C5 - C7 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aromatic VPH >C7 - C8 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aromatic VPH >C8 - C10 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aromatic VPH >C5 - C10 (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10
VPH >C5 - C10 (µg/l)	**14**	<10	<10	<10	<10	<10	<10	<10	<10
Aliphatic EPH >C10 - C12 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aliphatic EPH >C12 - C16 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aliphatic EPH >C16 - C35 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aliphatic EPH >C35 - C44 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aliphatic EPH >C10 - C44 (µg/l)	<20	**15**	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C10 - C12 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C12 - C16 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C16 - C21 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C21 - C35 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C35 - C44 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
Aromatic EPH >C10 - C44 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
EPH >C10 - C44 (µg/l)	<20	**15**	<10	<10	<20	<10	<10	<20	<10
Aliphatic VPH/EPH >C5 - C44 (µg/l)	**14**	**15**	<10	<10	<20	<10	<10	<20	<10
Aromatic VPH/EPH >C5 - C44 (µg/l)	<20	<10	<10	<10	<20	<10	<10	<20	<10
VPH/EPH >C5 - C44 (µg/l)	**14**	**15**	<10	<10	<20	<10	<10	<20	<10

Table D6 - Results of PAH analysis in groundwater; table displays site operator returns data from 2009-2011 compared with the single SEPA sampling round from selected groundwater boreholes on 03/05/2018

PAHs		Acenaphthene	Acenaphthylene	Anthracene	Benzo (a) anthracene	Benzo (g,h,i) perylene	Benzo (a) pyrene	Benzo (b) fluoranthene	Benzo (k) fluoranthene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno (1,2,3) cd pyrene	Naphthalene	Phenanthrene	Pyrene
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
GWD8	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
GWS1	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GWD1	2009	<0.01	<0.01	<0.01	**0.03**	**0.04**	**0.05**	**0.06**	**0.02**	**0.03**	<0.01	**0.06**	<0.01	**0.04**	<0.01	<0.01	**0.05**
	2010	<0.01	<0.01	<0.01	<0.1	**0.161**	**0.173**	**0.216**	<0.09	<0.8	<0.04	**0.146**	<0.01	<0.12	<0.01	<0.03	**0.165**
	2011	<0.01	<0.01	**0.017**	**0.127**	**0.109**	**0.157**	**0.189**	**0.063**	**0.113**	**0.024**	**0.175**	**0.01**	**0.115**	**0.01**	**0.043**	**0.174**
GWD2	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GWD3	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
GWD4	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table D6 (continued)

PAHs		Acenaphthene	Acenaphthylene	Anthracene	Benzo (a) anthracene	Benzo (g,h,i) perylene	Benzo (a) pyrene	Benzo (b) fluoranthene	Benzo (k) fluoranthene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno (1,2,3) cd pyrene	Naphthalene	Phenanthrene	Pyrene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
GWD5	2009	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
	2010	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GWD6	2009	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
	2010	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GWD7	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	**0.344**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
GWS2	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03	<0.01	<0.01	<0.01	<0.01	<0.03
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
GWS3	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GWS5	2009	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	2010	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
	2011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SEPA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Figure D1 - Ammoniacal nitrogen concentrations in groundwater showing data from operator returns and SEPA 2018 monitoring

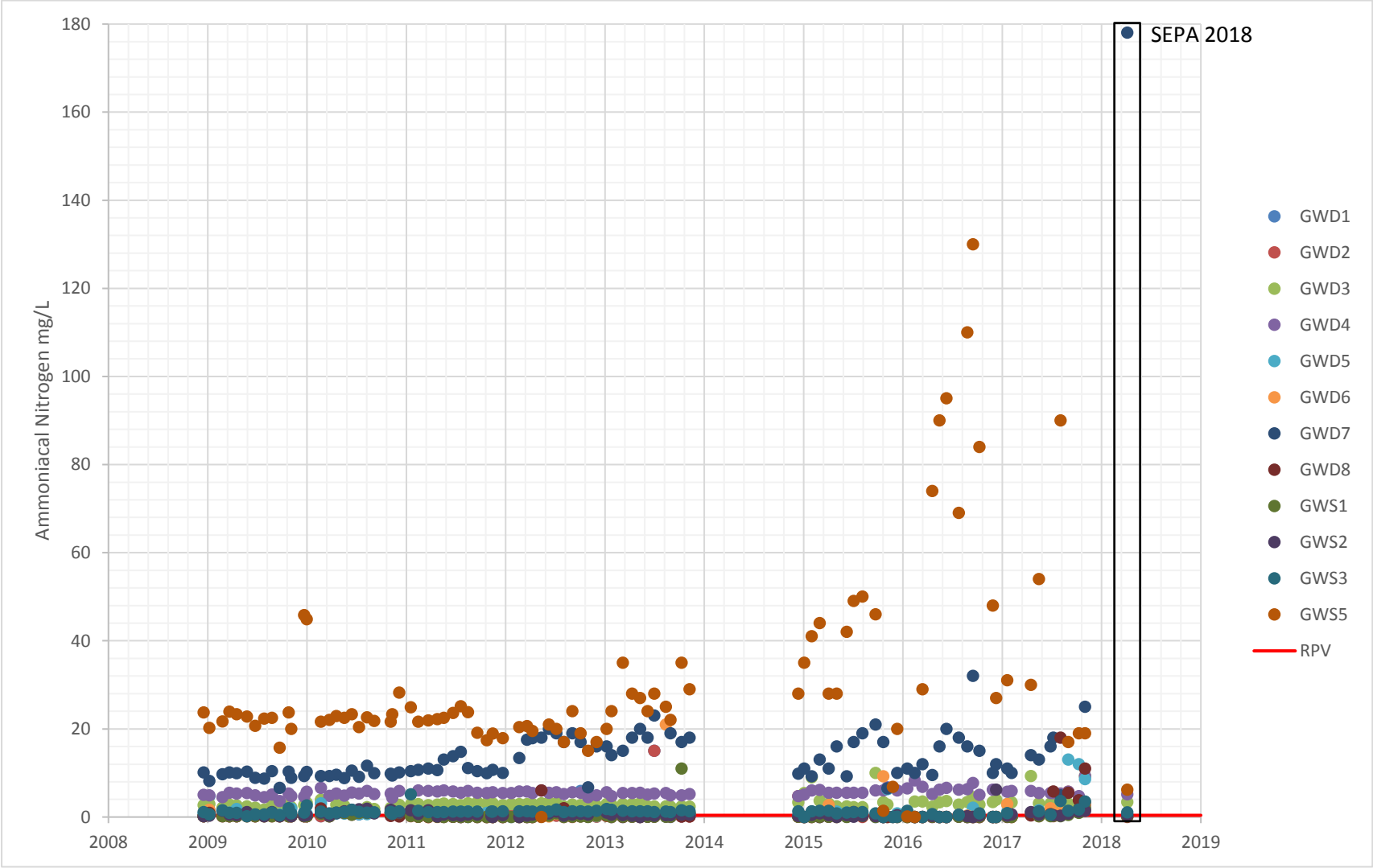


Figure D2 - Chloride concentrations in groundwater showing data from operator returns and SEPA 2018 monitoring

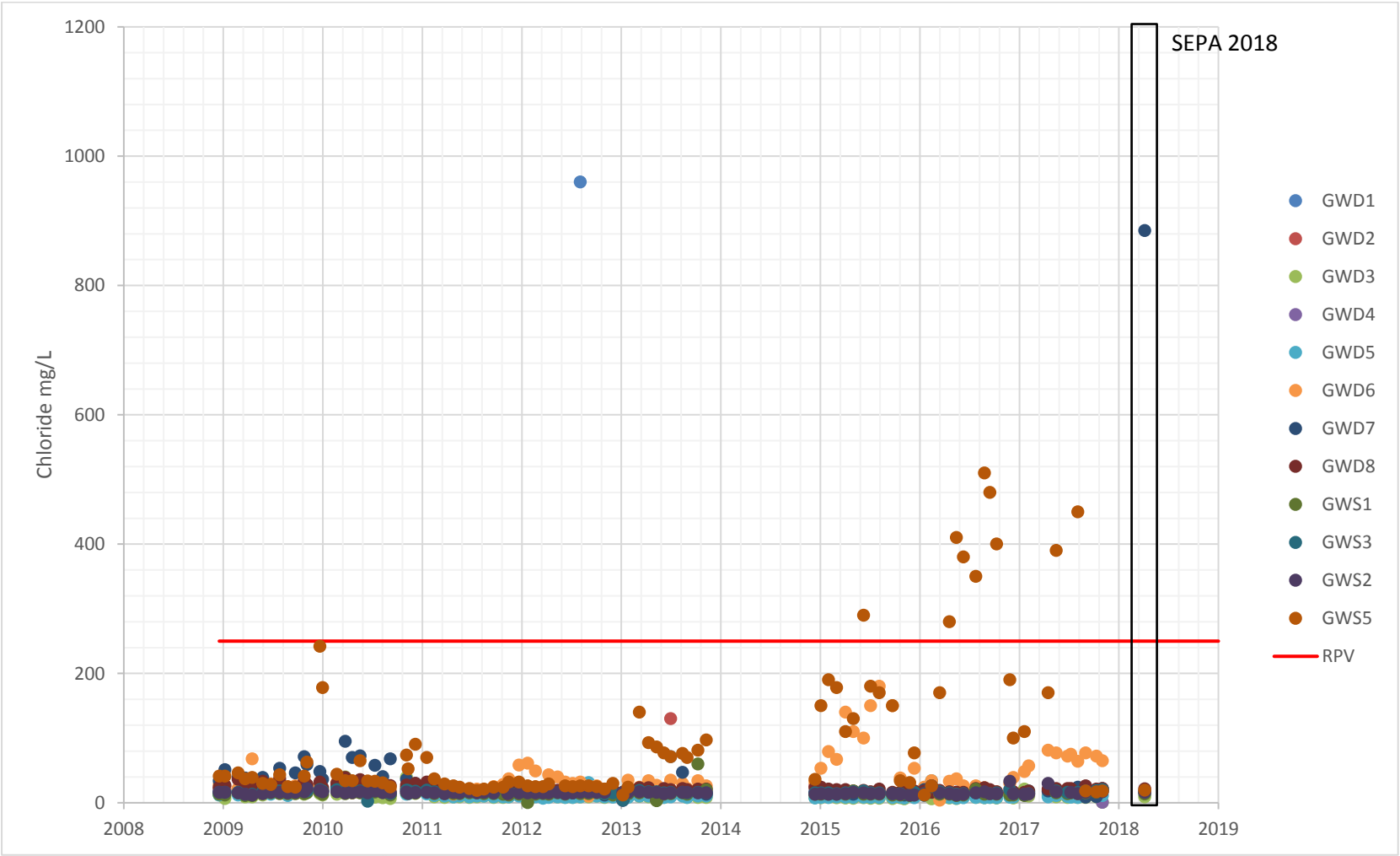


Figure D3 - Piper plot for 2011

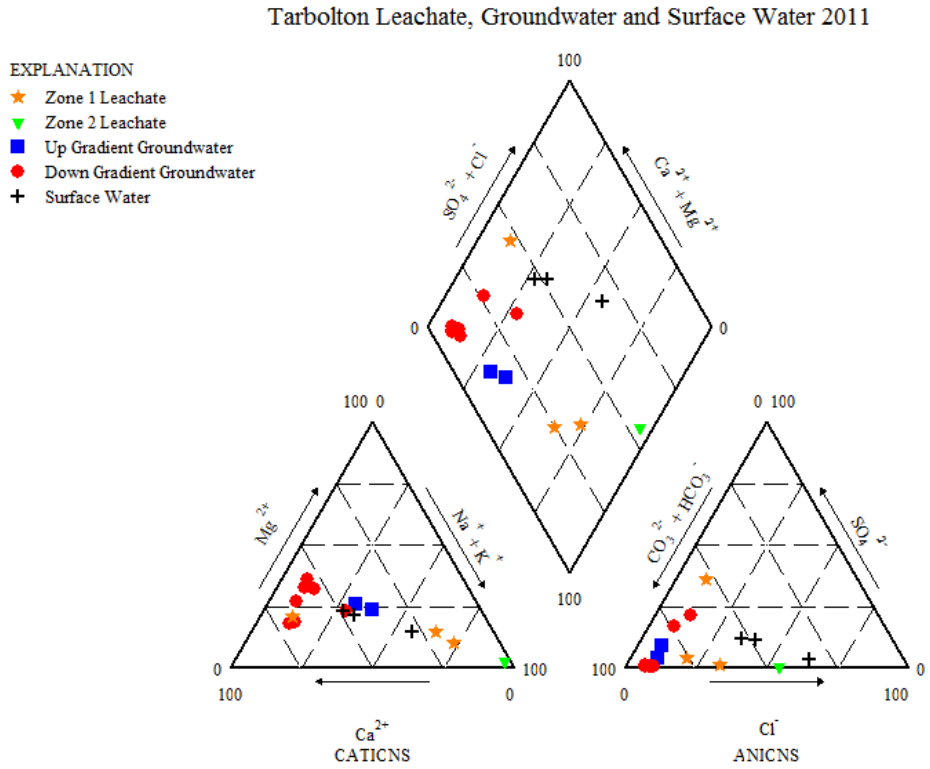


Figure D4 – Piper plot for 2015

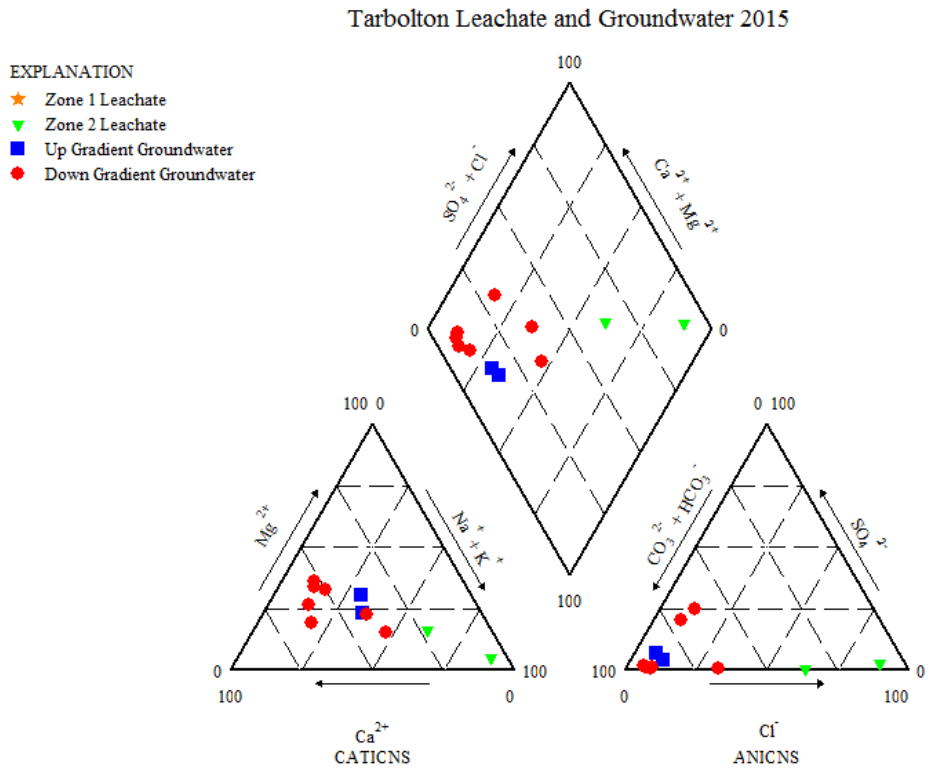


Figure D5 – Piper plot for 2016

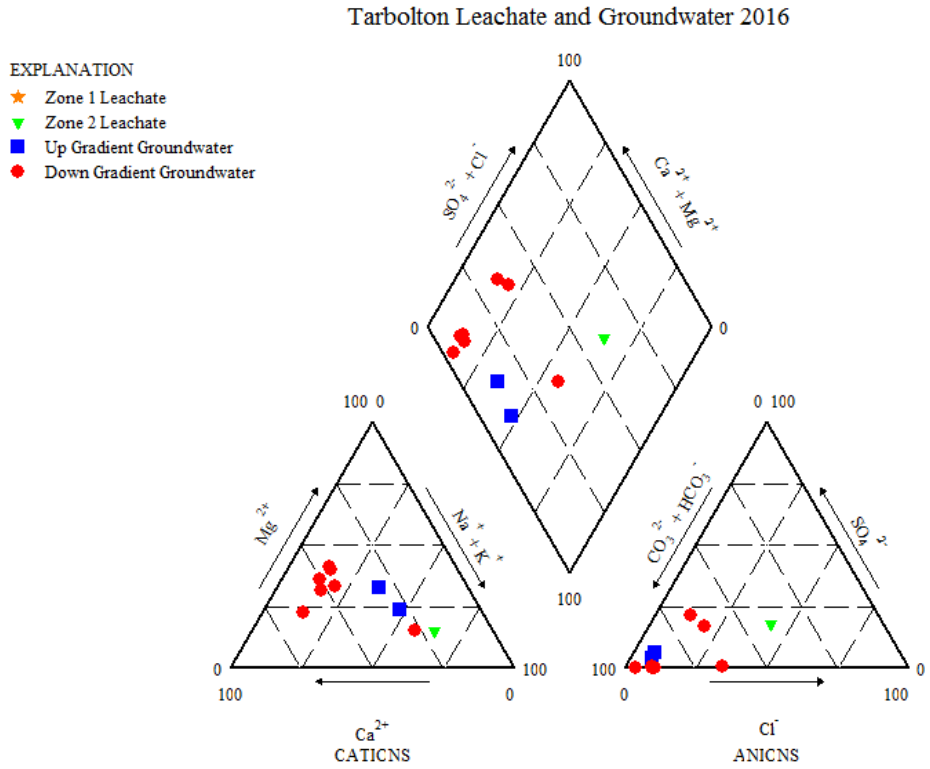


Figure D6 – Piper plot for 2018

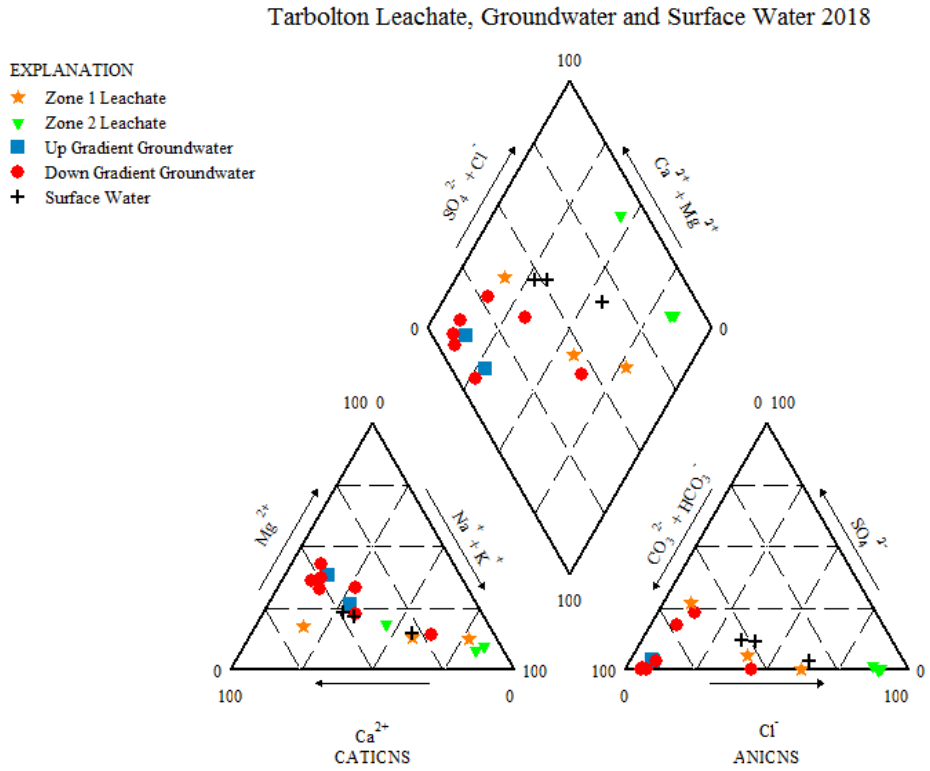


Figure D7 - Nickel (total) results in groundwater showing data from operator returns and SEPA 2018 monitoring

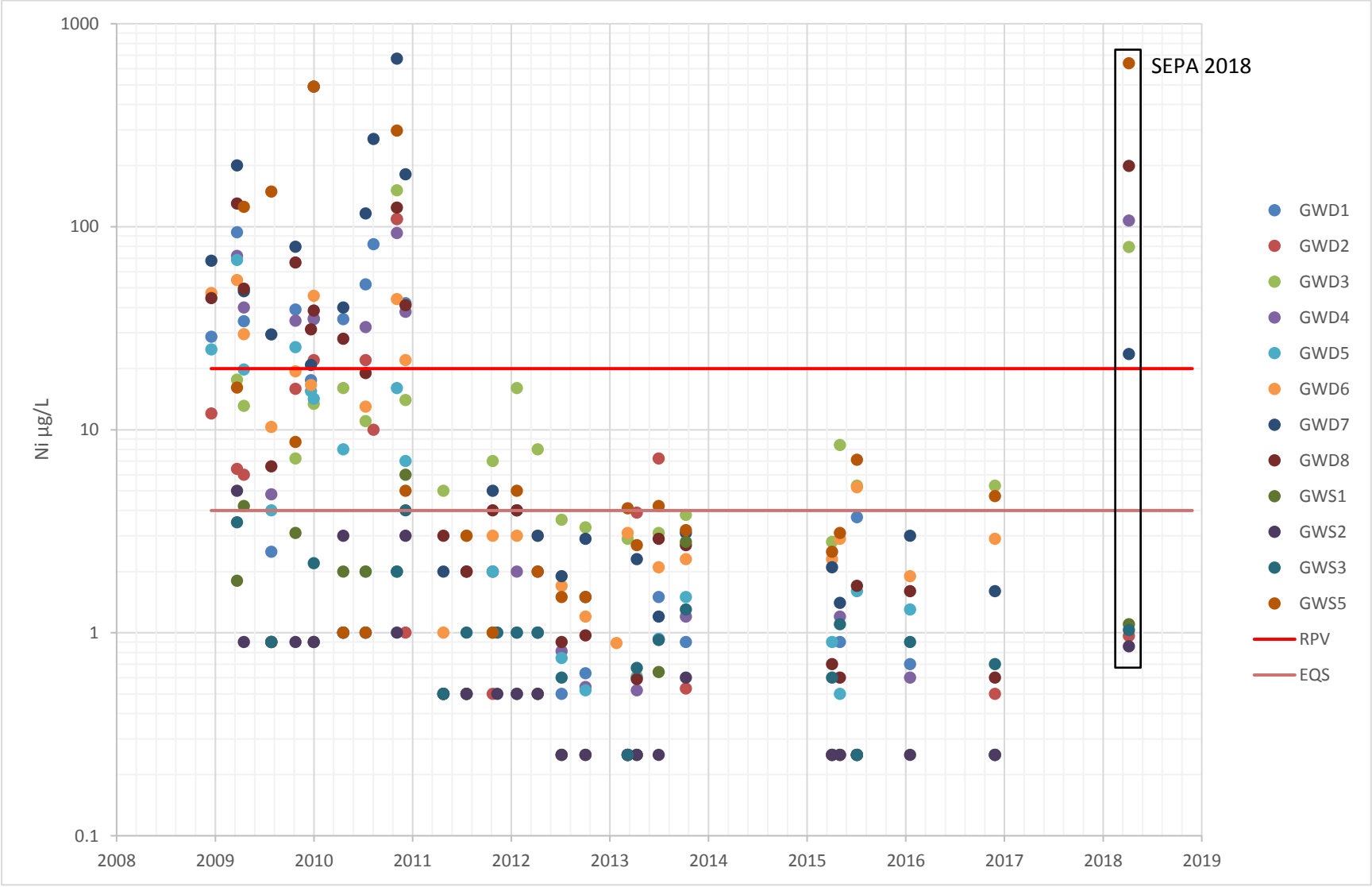
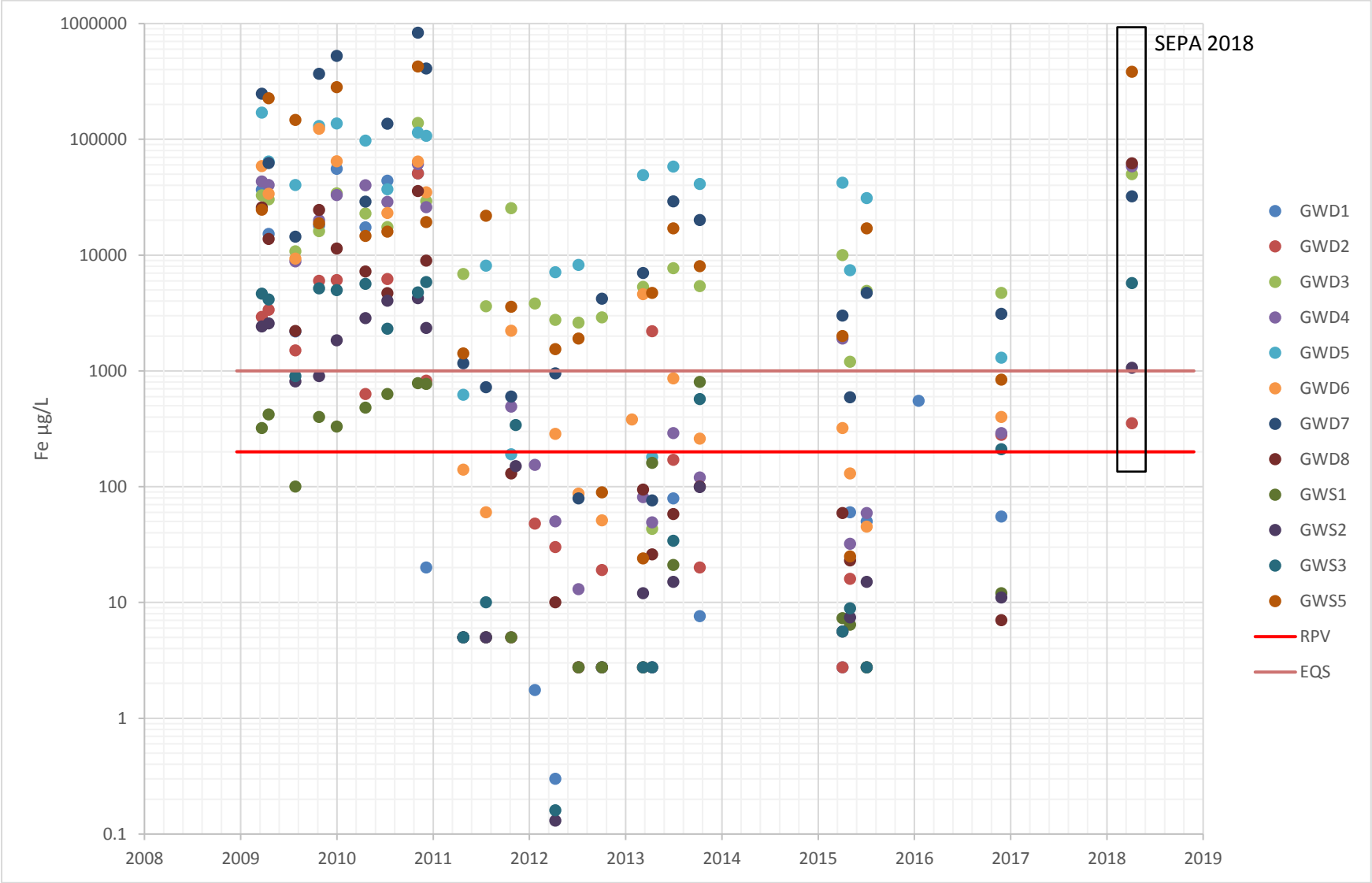


Figure D8 - Iron (total) results in groundwater showing data from operator returns and SEPA 2018 monitoring



Appendix E Surface water tables and graphs

Table E1 - Surface water sampling locations

Code	Sampling Point Description	National Grid Reference	Date Time	Distance from Confluence (metres, approx.)
SW3	Water of Fail, 50m upstream of Biggary Burn confluence	NS 42920 28223	02/05/2018 11:40	50 upstream
SW4	Biggary Burn, 50m upstream of Water of Fail confluence	NS 42947 28226	02/05/2018 11:30	50 upstream
SW5	Water of Fail, upstream of Red Rose Way	NS 42967 27728	02/05/2018 11:02	500 downstream

Table E2 - Summary of Water Framework Directive (WFD) surface water assessments – see also explanatory note following table

Code	Description	Determinand	Concentration	WFD Assessment	Risk Characterisation	Comments
SW3	Upstream Water of Fail	Ammoniacal Nitrogen (mg/l)*	3.06	**Bad**	2.8	
SW4	Biggary Burn		22.4	**Bad**	20.4	
SW5	Downstream Water of Fail		4.6	**Bad**	4.2	
SW3	Upstream Water of Fail	Biochemical Oxygen Demand (ATU) (mg/l)*	4.4	**Moderate**	0.73	
SW4	Biggary Burn		3.1	Good	0.51	
SW5	Downstream Water of Fail		5.2	**Moderate**	0.86	
SW3	Upstream Water of Fail	pH (pH units)+	7.71	High	0.7	
SW4	Biggary Burn		8.04	High	0.67	
SW5	Downstream Water of Fail		7.7	High	0.7	
SW3	Upstream Water of Fail	Reactive Phosphorus (mg/l)+	0.11	**Moderate**	0.73	
SW4	Biggary Burn		0.04	High	0.22	
SW5	Downstream Water of Fail		0.1	**Moderate**	0.65	
SW3	Upstream Water of Fail	Dissolved Arsenic (µg/l)	<2.00	Pass	0.04	
SW4	Biggary Burn		<2.00	Pass	0.04	
SW5	Downstream Water of Fail		<2.00	Pass	0.04	
SW3	Upstream Water of Fail	Dissolved Cadmium (µg/l)	0.02	Pass	0.08	Hardness 125 mg/l
SW4	Biggary Burn		0.06	Pass	0.24	Hardness 170 mg/l
SW5	Downstream Water of Fail		0.02	Pass	0.08	Hardness 125 mg/l
SW3	Upstream Water of Fail	Dissolved Chromium (µg/l)	<0.50	Pass	0.11	
SW4	Biggary Burn		3.59	Pass	0.76	
SW5	Downstream Water of Fail		0.58	Pass	0.12	
SW3	Upstream Water of Fail	Dissolved Copper (µg/l)	2.76	Pass	0.06	
SW4	Biggary Burn		3.84	Pass	0.28	
SW5	Downstream Water of Fail		2.87	Pass	0.06	
SW3	Upstream Water of Fail	Dissolved Iron (mg/l)	0.1	Pass	0.1	
SW4	Biggary Burn		0.13	Pass	0.13	
SW5	Downstream Water of Fail		0.1	Pass	0.1	

Table E2 (continued)

Code	Description	Determinand	Concentration	WFD Assessment	Risk Characterisation	Comments
SW3	Upstream Water of Fail	Total Mercury (µg/l)	<0.01	Pass	0.14	MAC[38] from 2015 directions used
SW4	Biggary Burn		<0.01	Pass	0.14	
SW5	Downstream Water of Fail		0.01	Pass	0.14	
SW3	Upstream Water of Fail	Dissolved Manganese (mg/l)	0.15	Pass	0.71	
SW4	Biggary Burn		0.43	**Fail**	3.5	
SW5	Downstream Water of Fail		0.16	Pass	0.74	
SW3	Upstream Water of Fail	Dissolved Nickel (µg/l)	3.4	Pass	0.18	
SW4	Biggary Burn		6.76	Pass	0.29	
SW5	Downstream Water of Fail		3.39	Pass	0.17	
SW3	Upstream Water of Fail	Dissolved Lead (µg/l)	<0.35	Pass	0.02	
SW4	Biggary Burn		1.34	Pass	0.06	
SW5	Downstream Water of Fail		<0.35	Pass	0.02	
SW3	Upstream Water of Fail	Dissolved Zinc (µg/l)	2.49	Pass	0.05	
SW4	Biggary Burn		8.48	Pass	0.09	
SW5	Downstream Water of Fail		3.16	Pass	0.06	
SW3	Upstream Water of Fail	1,2 Dichloroethane (µg/l)	<1.00	Pass	0.1	
SW4	Biggary Burn		<1.00	Pass	0.1	
SW5	Downstream Water of Fail		<1.00	Pass	0.1	
SW3	Upstream Water of Fail	Anthracene (µg/l)	<0.01	Pass	0.1	
SW4	Biggary Burn		<0.01	Pass	0.1	
SW5	Downstream Water of Fail		<0.01	Pass	0.1	
SW3	Upstream Water of Fail	Benzene (µg/l)	<1.00	Pass	0.1	
SW4	Biggary Burn		<1.00	Pass	0.1	
SW5	Downstream Water of Fail		<1.00	Pass	0.1	

[38] Maximum Allowable Concentration

Table E2 (continued)

Code	Description	Determinand	Concentration	WFD Assessment	Risk Characterisation	Comments
SW3	Upstream Water of Fail	Benzo-[a]-pyrene (µg/l)	<0.01	**Fail**	60	Standard protective of risks via the foodchain
SW4	Biggary Burn		<0.01	**Fail**	60	
SW5	Downstream Water of Fail		<0.01	**Fail**	60	
SW3	Upstream Water of Fail	Carbon tetrachloride (µg/l)	<1.00	Pass	0.08	
SW4	Biggary Burn		<1.00	Pass	0.08	
SW5	Downstream Water of Fail		<1.00	Pass	0.08	
SW3	Upstream Water of Fail	Chloroform (µg/l)	<0.25	Pass	0.1	
SW4	Biggary Burn		<0.25	Pass	0.1	
SW5	Downstream Water of Fail		<0.25	Pass	0.1	
SW3	Upstream Water of Fail	Trichloroethene (µg/l)	<1.00	Pass	0.1	
SW4	Biggary Burn		<1.00	Pass	0.1	
SW5	Downstream Water of Fail		<1.00	Pass	0.1	
SW3	Upstream Water of Fail	Tetrachloroethene (µg/l)	<1.00	Pass	0.1	
SW4	Biggary Burn		<1.00	Pass	0.1	
SW5	Downstream Water of Fail		<1.00	Pass	0.1	
SW3	Upstream Water of Fail	Dichloromethane (µg/l)	<1.00	Pass	0.05	
SW4	Biggary Burn		<1.00	Pass	0.05	
SW5	Downstream Water of Fail		<1.00	Pass	0.05	
SW3	Upstream Water of Fail	Fluoranthene (µg/l)	<0.01	**Fail**	1.6	Standard protective of risks via the foodchain
SW4	Biggary Burn		<0.01	**Fail**	1.6	
SW5	Downstream Water of Fail		<0.01	**Fail**	1.6	
SW3	Upstream Water of Fail	Naphthalene (µg/l)	<0.01	Pass	0.005	
SW4	Biggary Burn		<0.01	Pass	0.005	
SW5	Downstream Water of Fail		<0.01	Pass	0.005	
SW3	Upstream Water of Fail	Toluene (µg/l)	<1.00	Pass	0.01	
SW4	Biggary Burn		<1.00	Pass	0.01	
SW5	Downstream Water of Fail		<1.00	Pass	0.01	

Table E2 (continued)

Code	Description	Determinand	Concentration	WFD Assessment	Risk Characterisation	Comments
SW3	Upstream Water of Fail	Dieldrin (µg/l)	<0.01	Pass	1	Deemed not a relelvant substance in this case
SW4	Biggary Burn		<0.01	Pass	1	
SW5	Downstream Water of Fail		<0.01	Pass	1	
SW3	Upstream Water of Fail	Lindane (µg/l)	<0.02	Pass	1	Deemed not a relelvant substance in this case
SW4	Biggary Burn		<0.02	Pass	1	
SW5	Downstream Water of Fail		<0.02	Pass	1	

+ Risk characterisation calculated against moderate/poor boundary
* Assessed against value but standard is 90%ile
When a LOD (<) result has been recorded assumed that the concentration = the LOD

Explanatory Note for Table E2

The aim of the work carried out here is to assess the impact of Tarbolton Landfill on surface water receptors. The most appropriate method is to use the Environmental Quality Standards (EQS) associated with the Water Framework Directive classification scheme.

There are two types of EQS that could be applied to this assessment. The Maximum Allowable Concentration (MAC) is typically used in situations where there has been intermittent or short term exposure to the chemical. The alternative is the "annual average" EQS which is used to assess the potential for chronic effects following longer term exposure. Given that the exposure from the landfill to receptors is chronic then we consider that the most appropriate assessment is the annual average EQS. However, the EQS is normally used to assess a representative data set collected typically over or a year or more on a common statistical basis. In this instance, there is a single data point. It must be borne in mind that the assessments are indicative of potential impact rather than conclusive. Risk Characterisation ratios, the ratio of the measured concentration to the EQS, have been calculated. Values less than 1 indicate that the EQS has not been breached while values greater than 1 indicate that the EQS has been breached.

Details of the limits used are contained in the Directions issued to SEPA from the Scottish Government[39]. Bioavailable metal assessments were used to assess EQS compliance shown in Table E2 and were made using the UKTAG MBAT tool[40]. The calculated bioavailable concentrations are shown in the relevant figures above. For the bioavailable assessments, each site had a site specific standard calculated as pronounced differences were observed between the concentrations of supporting parameters in the Biggary Burn as compared to the Water of Fail.

The Environmental Quality Standards (EQS) for benzo-[a]-pyrene[41] and fluoranthene in water are set to protect wildlife and humans from the risk of exposure via fishery products owing to bioaccumulation up the food chain (protection of "direct" toxicity in ecology is implicit in this approach). A group of chemicals containing some PCBs have an EQS set in biota for the same protection goal, with no equivalent water EQS. Refer to main text in section 6.6 for further information on this assessment.

[39] The Scotland River Basin District (Standards) Directions 2014
The Scotland River Basin District (Standards) Amendment Directions 2015

[40] Rivers & Lakes - Metal Bioavailability Assessment Tool (M-BAT)

[41] For the group of priority substances of polyaromatic hydrocarbons, the biota EQS and corresponding AA-EQS in water refer to the concentration of benzo-[a]-pyrene, on the toxicity of which they are based. benzo-[a]-pyrene can be considered as a marker for the other PAHs, hence only benzo-[a]-pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water.

Figure E1 - Electrical conductivity in surface water showing data from operator returns and SEPA monitoring

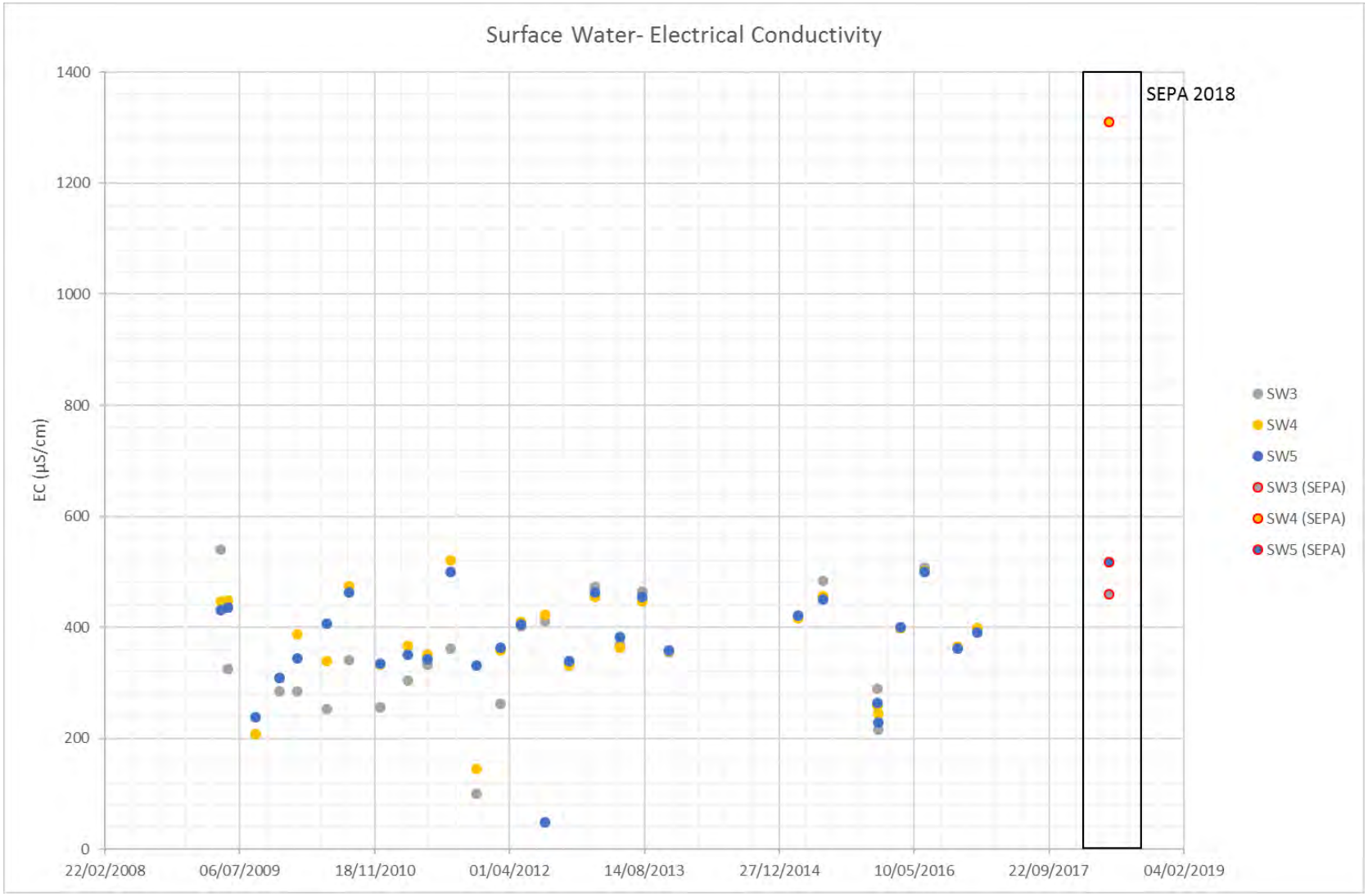


Figure E2 - Concentrations of chloride in surface water showing data from operator returns and SEPA monitoring

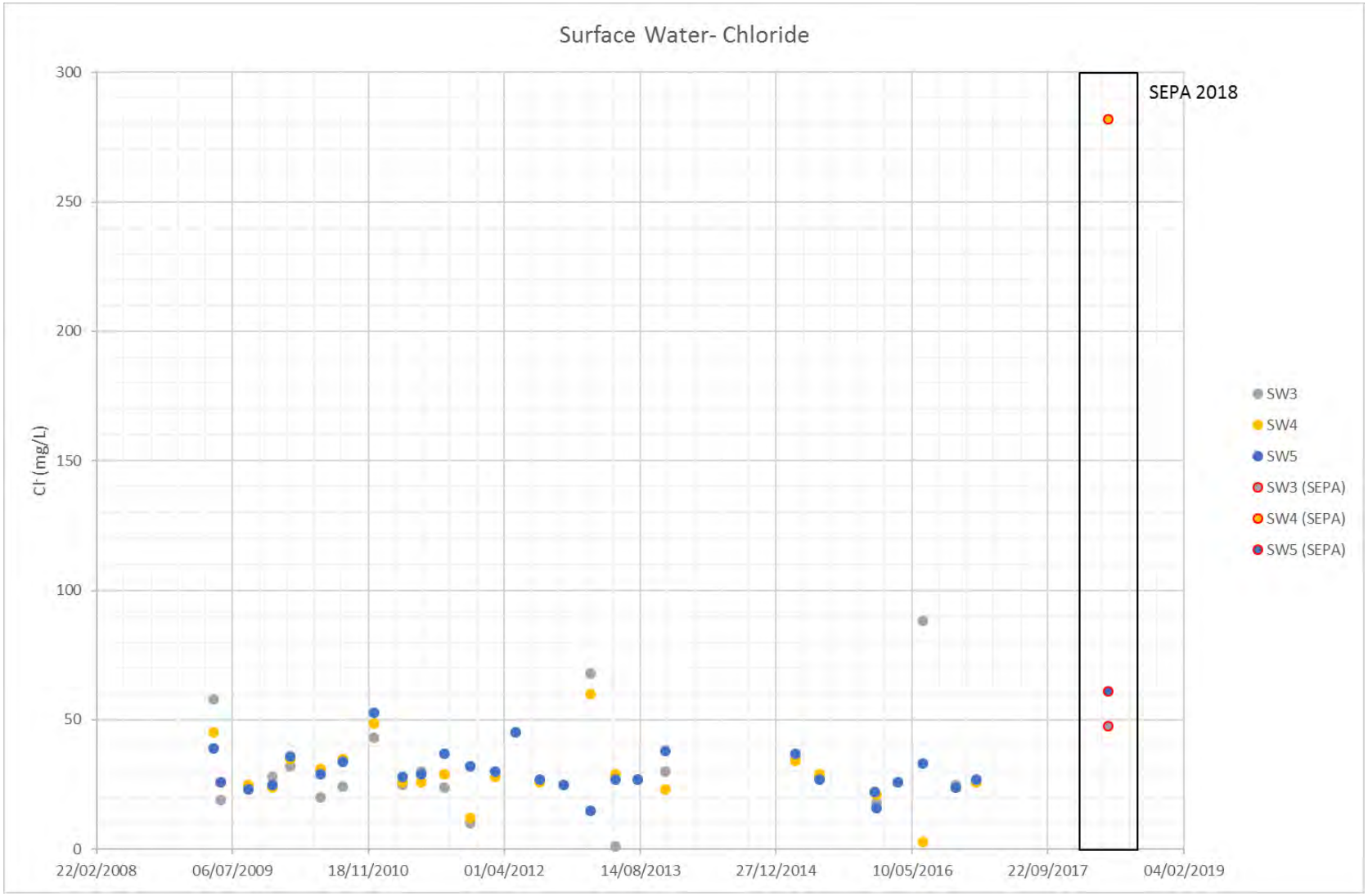


Figure E3 - Concentrations of ammoniacal nitrogen in surface water showing data from operator returns and SEPA monitoring

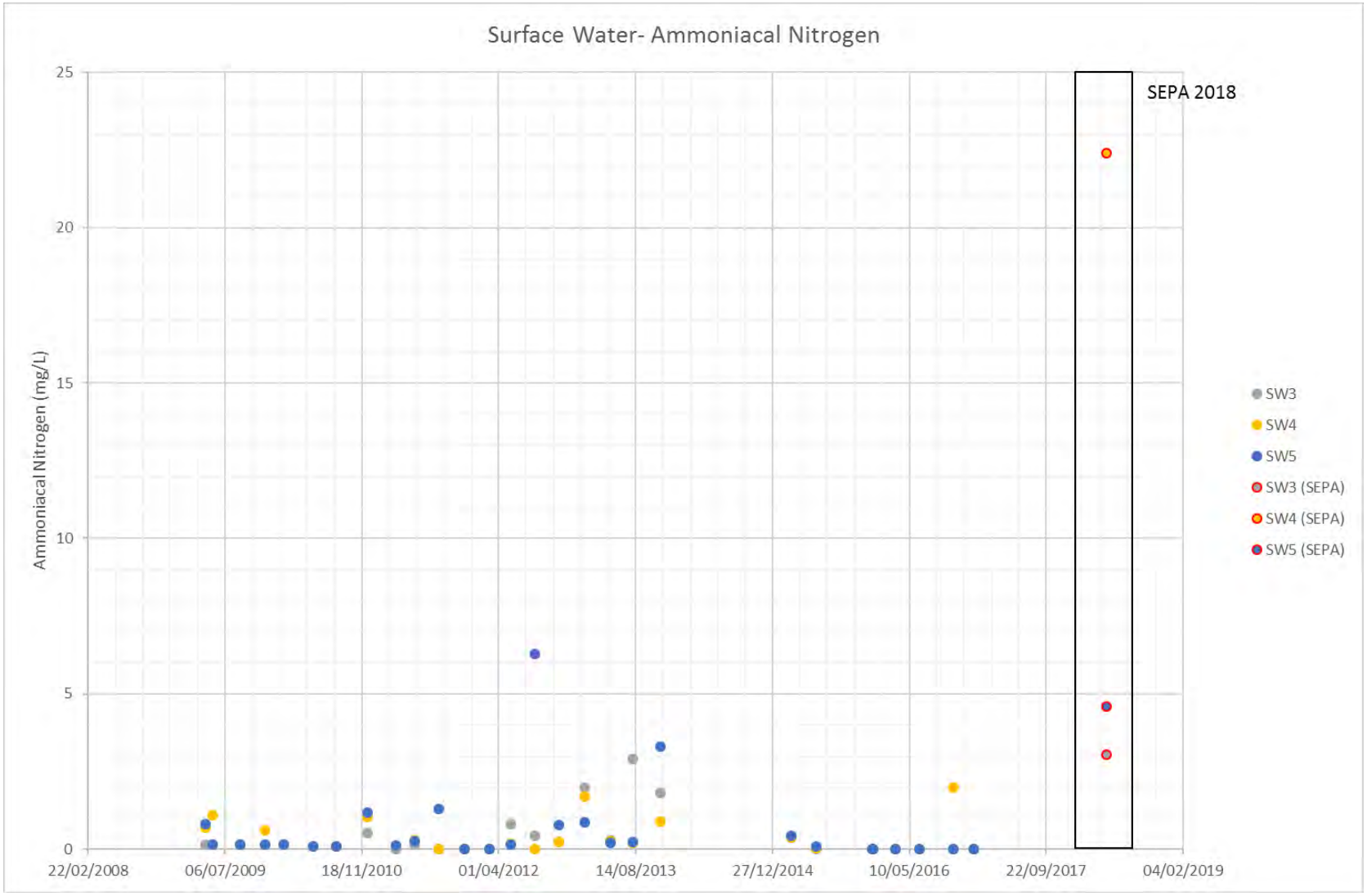


Figure E4 - Concentrations of nitrogenous species

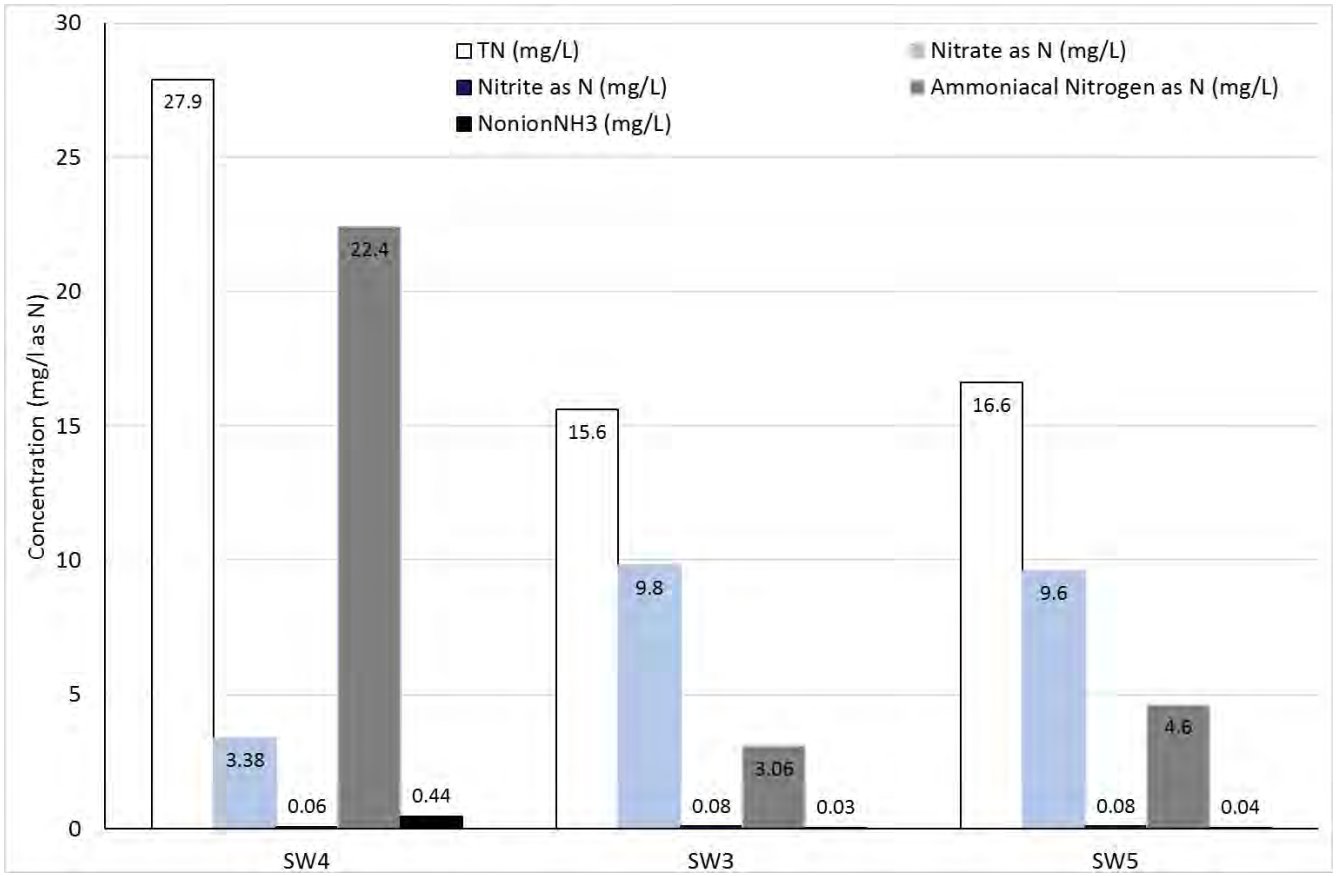


Figure E5 - Electrical conductivity in surface waters in proximity to the Tarbolton Landfill site

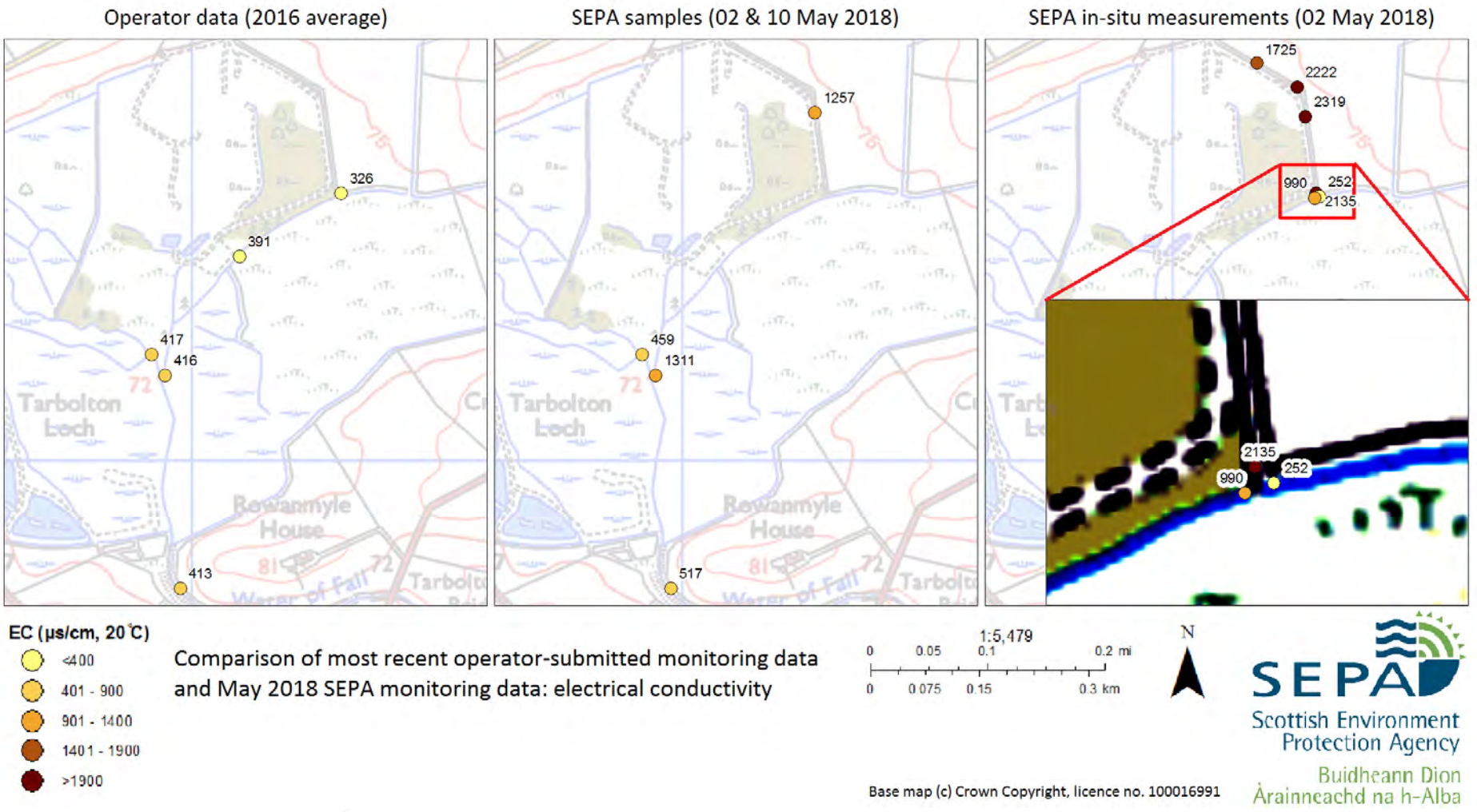


Figure E6 - Map of chloride concentrations in surface waters and leachate wells

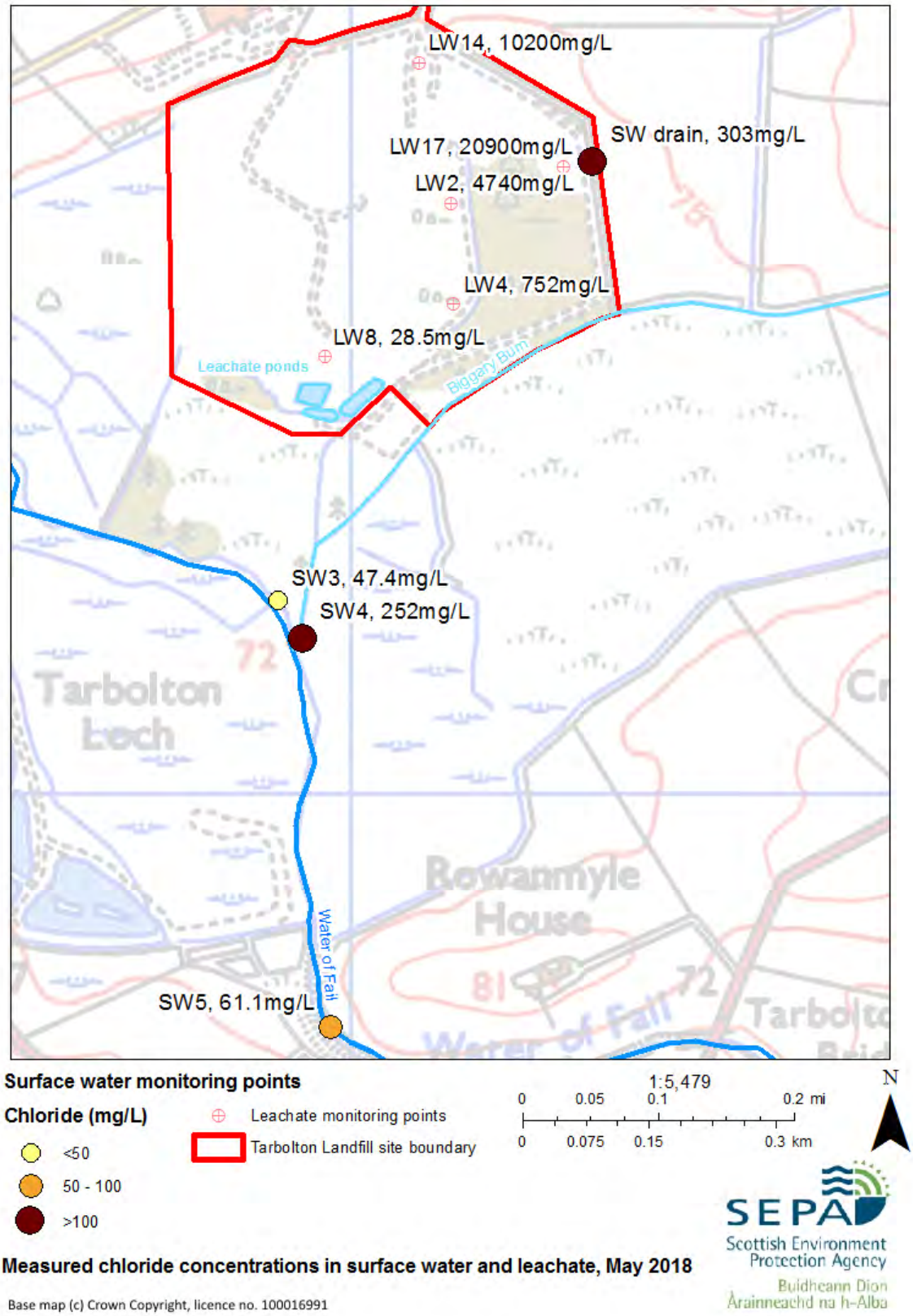


Figure E7 - Map of electrical conductivity of surface waters and leachate wells

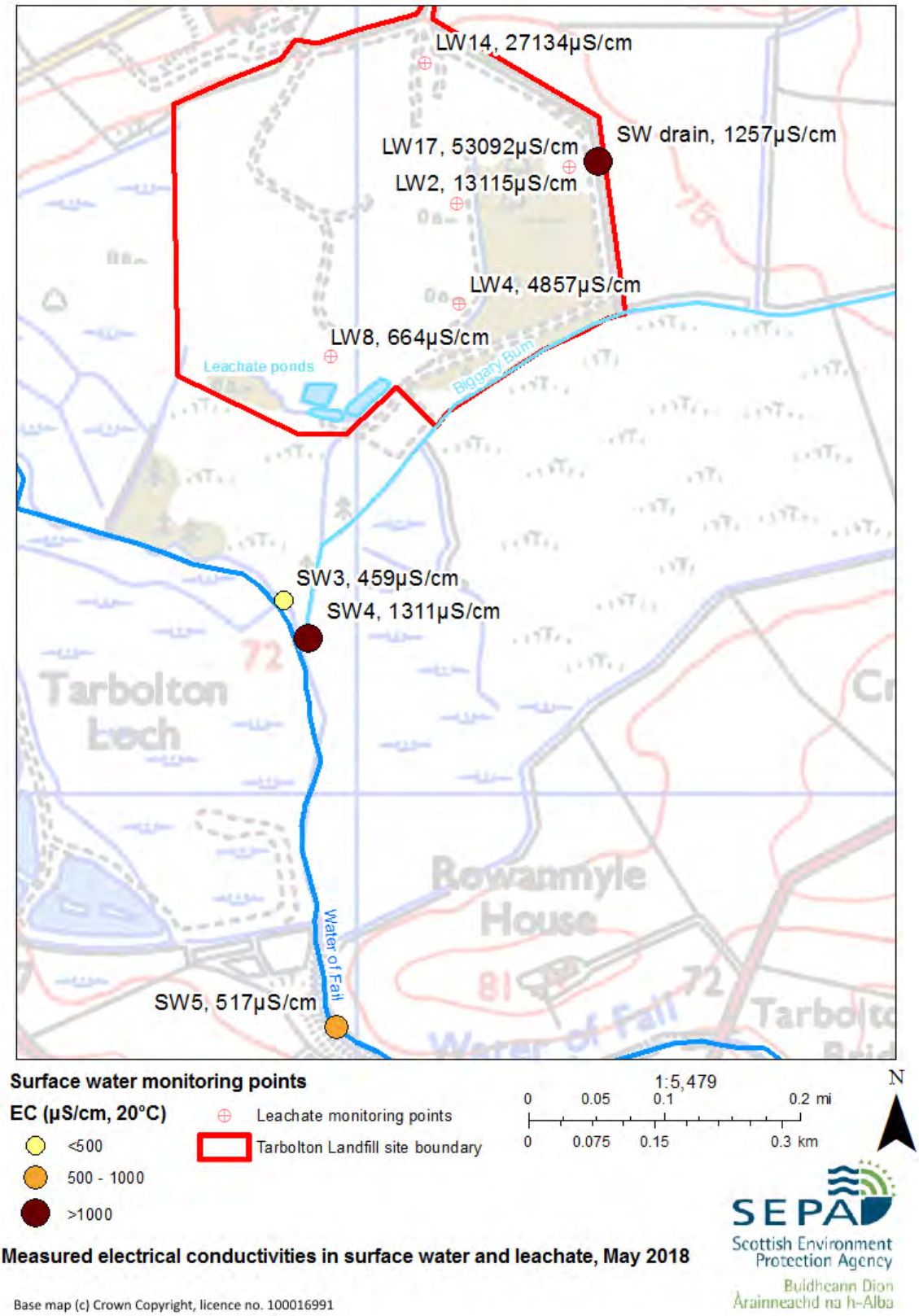


Figure E8 - Map of ammoniacal nitrogen concentrations in surface waters and leachate wells

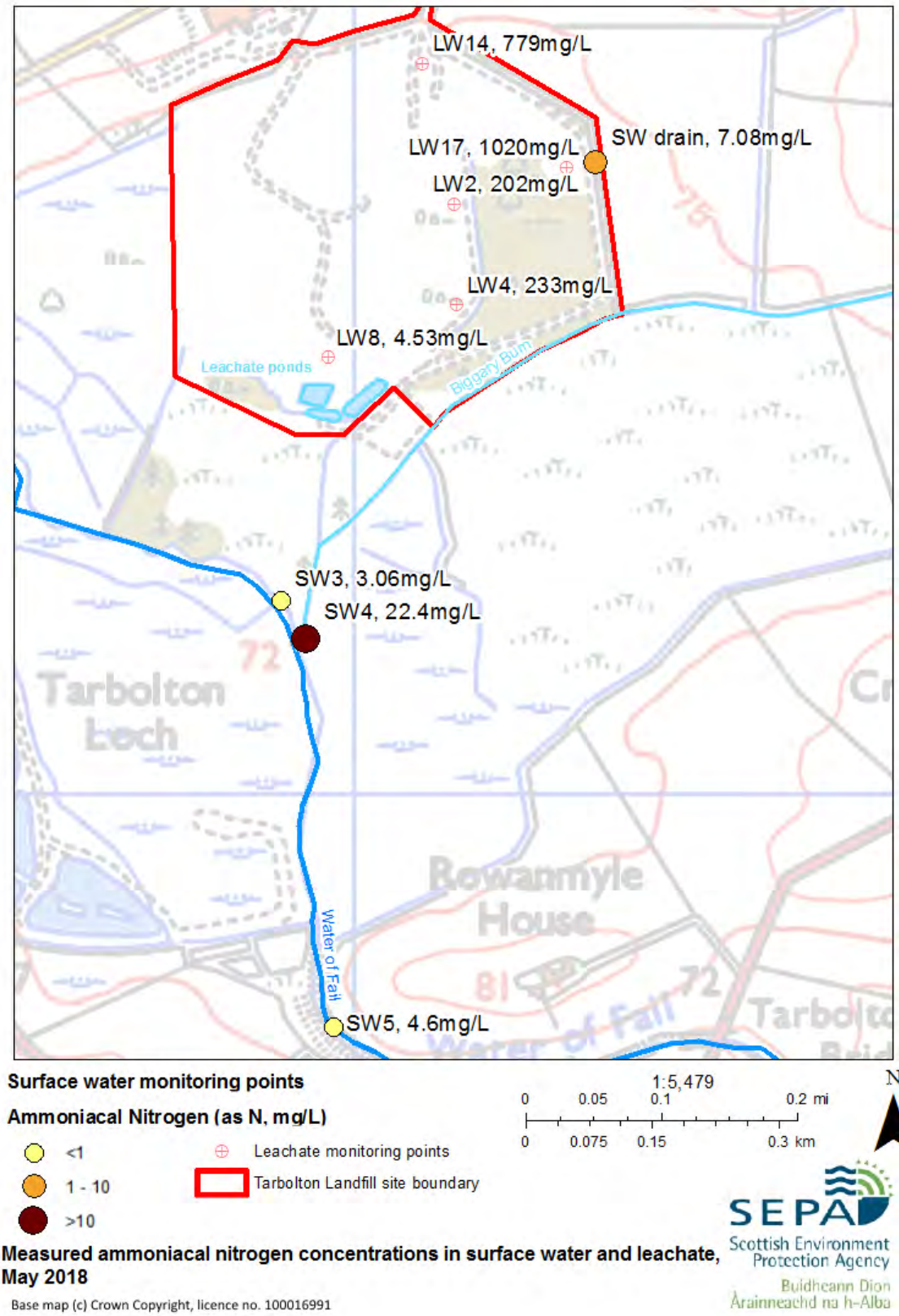


Figure E9 - Biochemical and Chemical Oxygen Demand

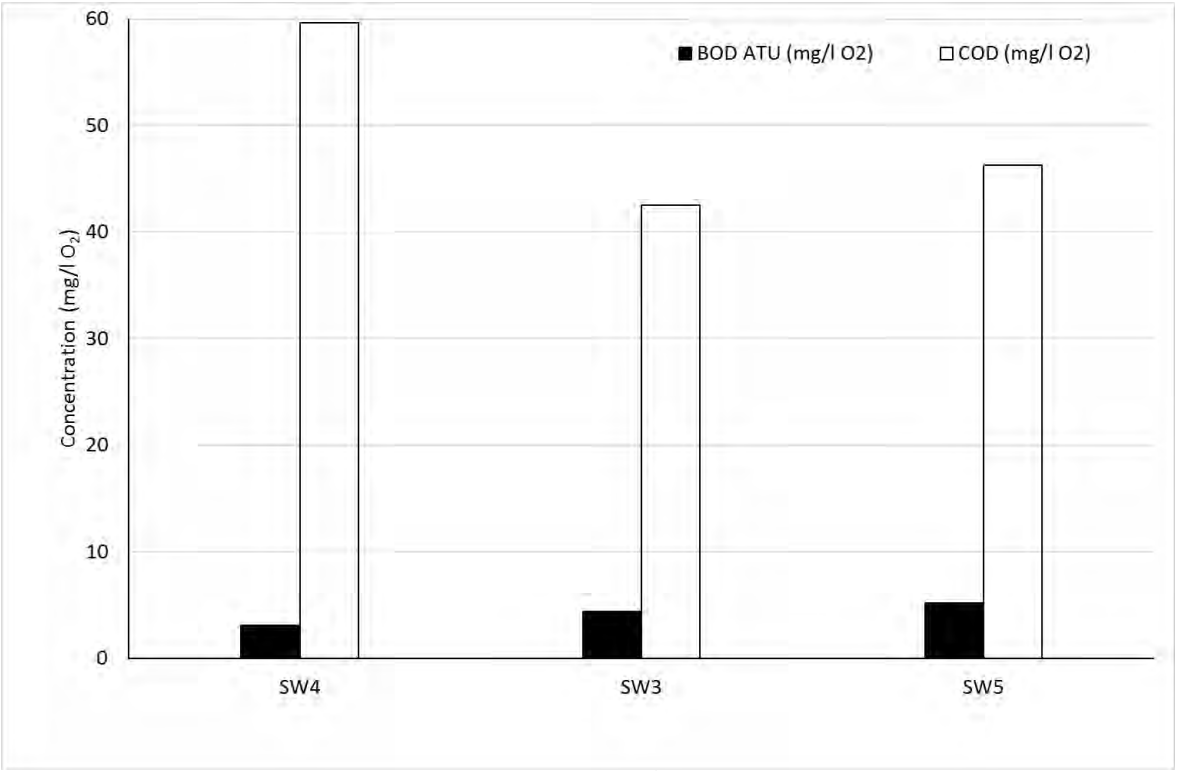


Figure E10 - Total and dissolved aluminium concentrations

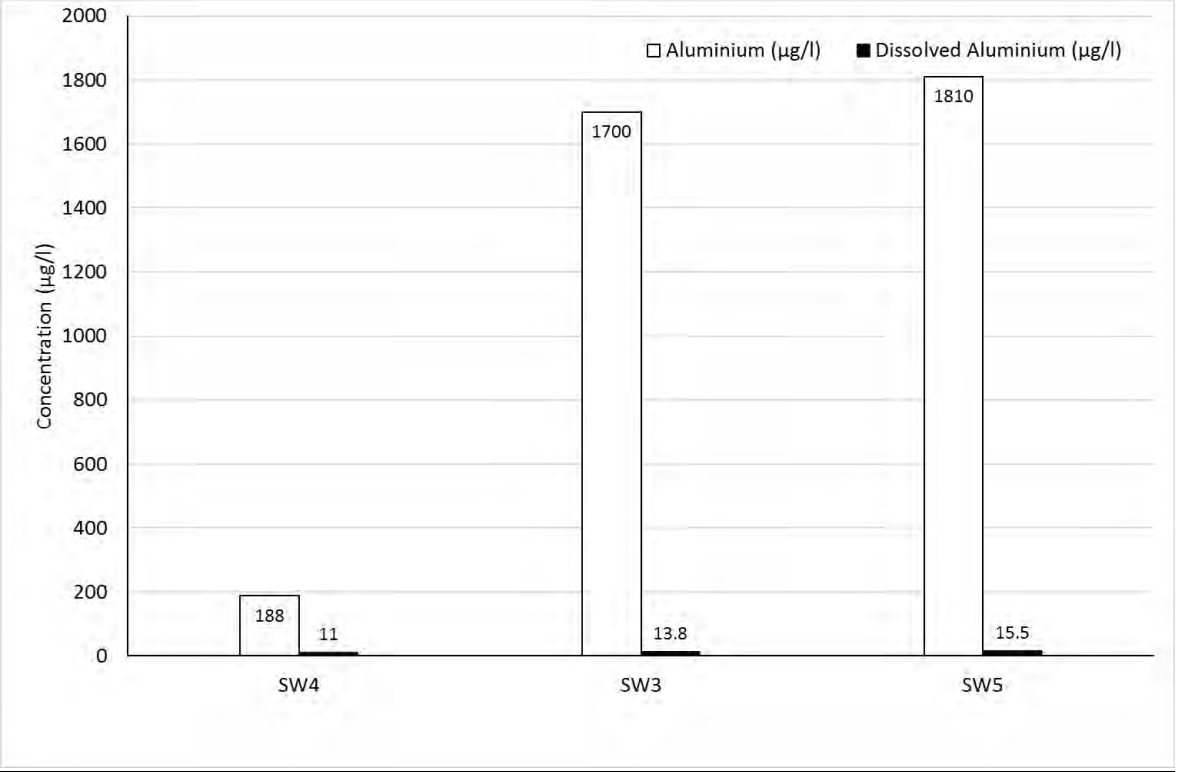


Figure E11 - Total and dissolved cadmium concentrations

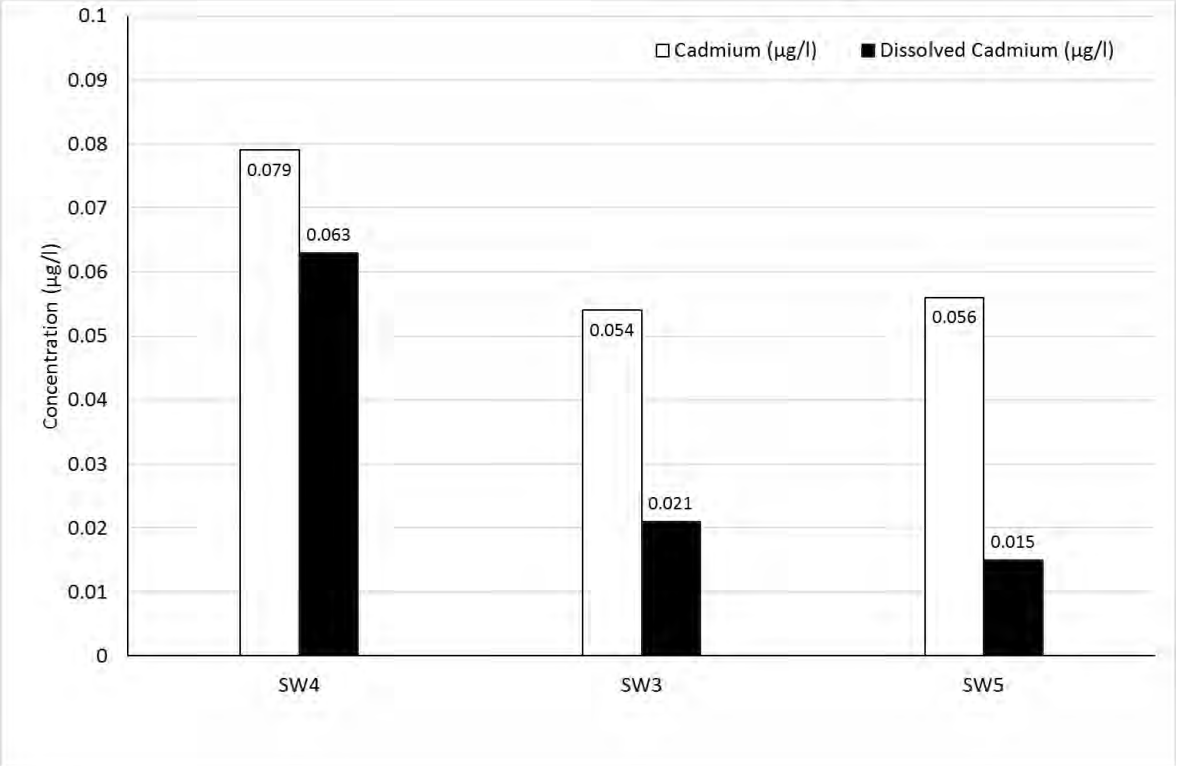


Figure E12 - Total and dissolved chromium concentrations

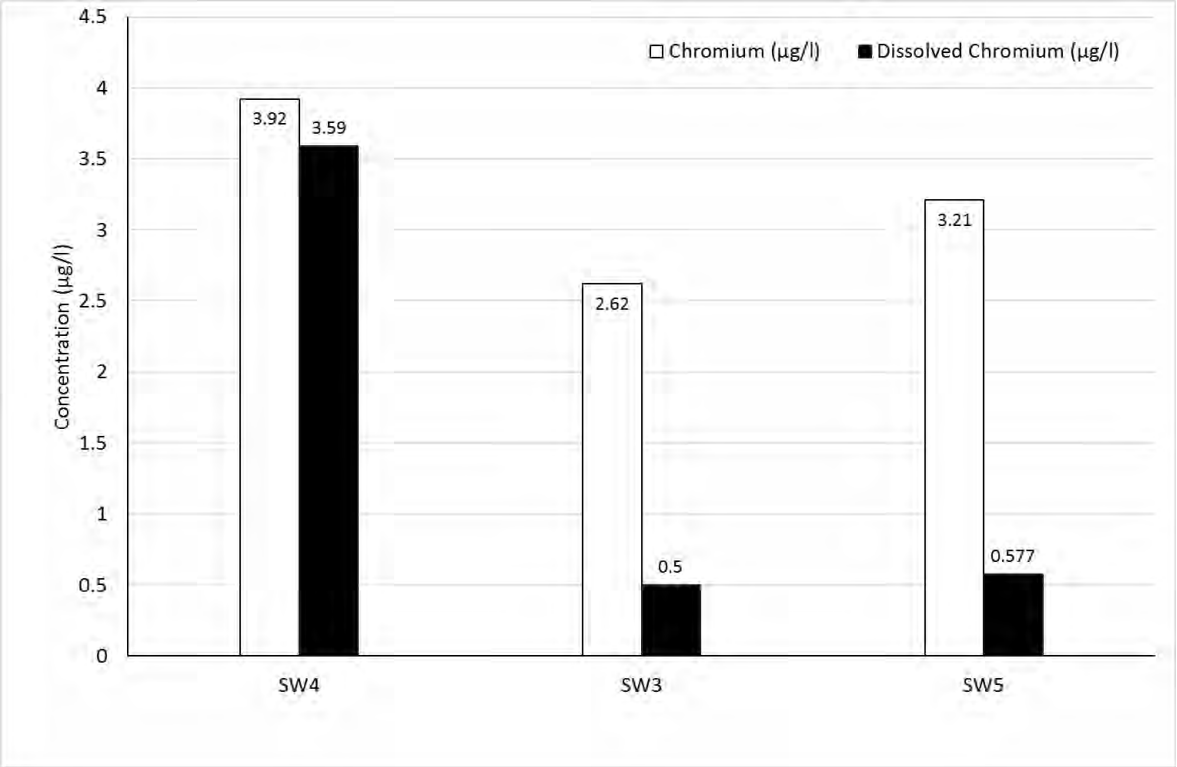


Figure E13 - Total, dissolved and bioavailable copper concentrations

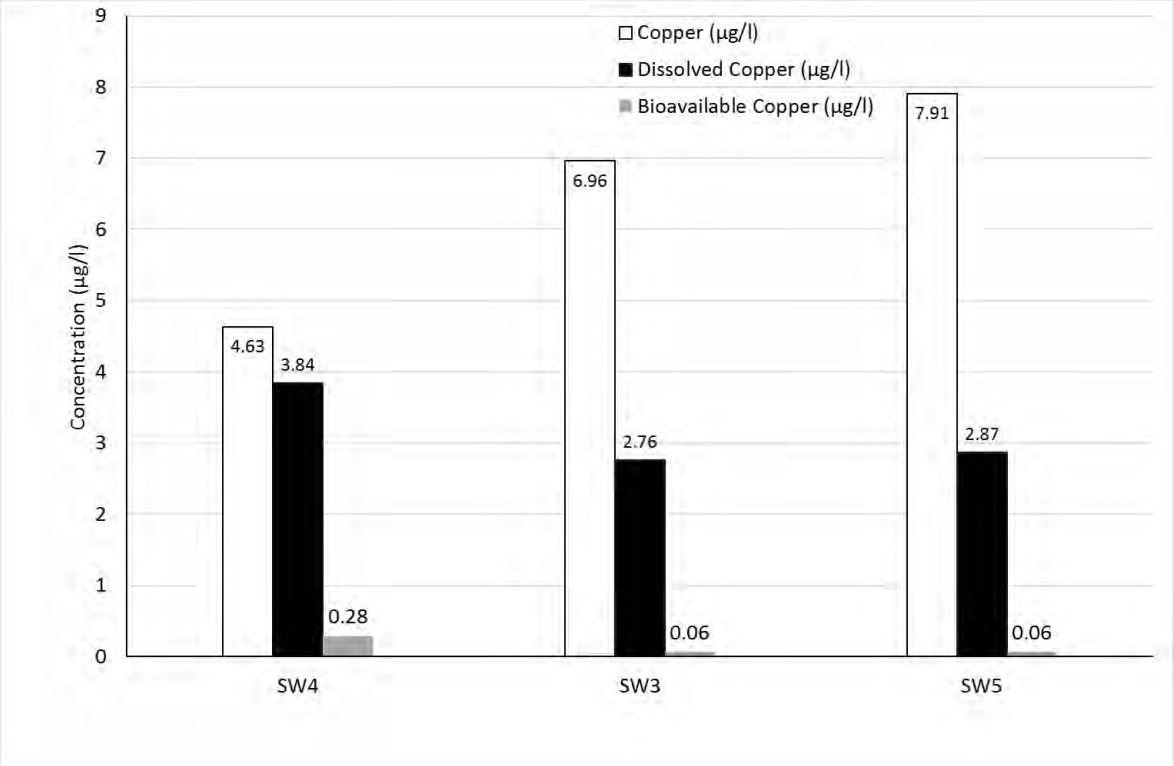


Figure E14 - Total, dissolved and bioavailable lead concentrations

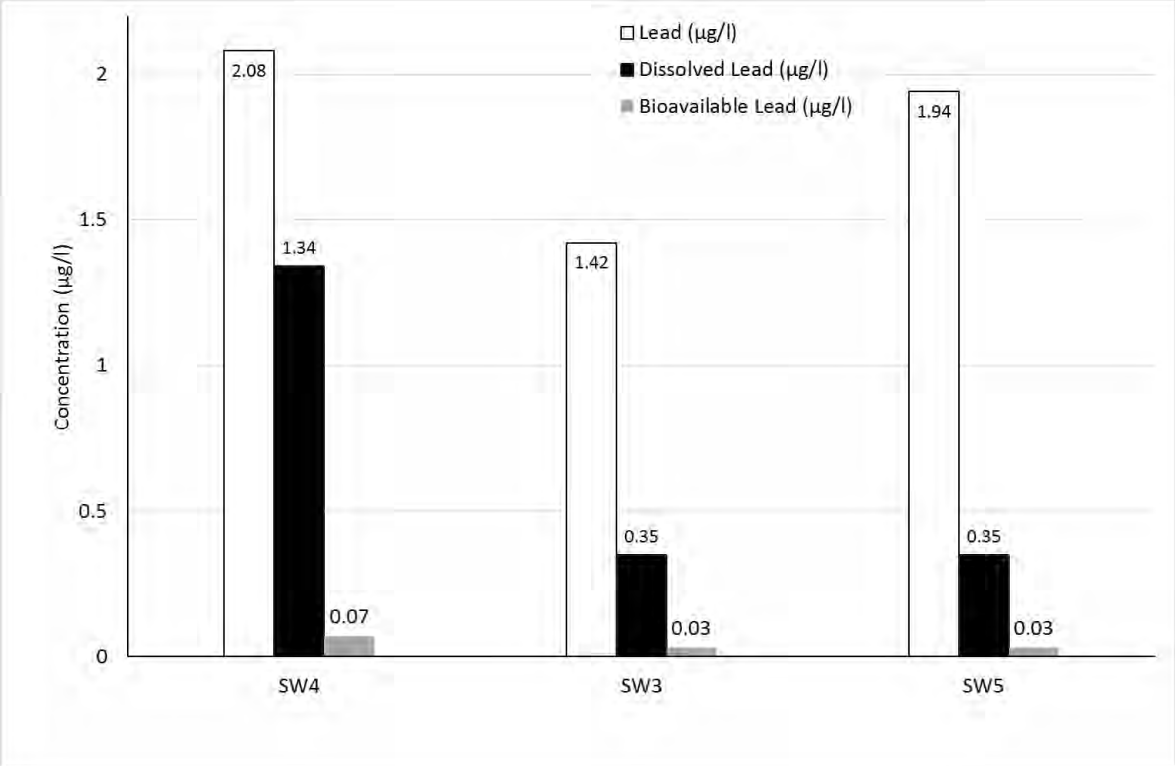
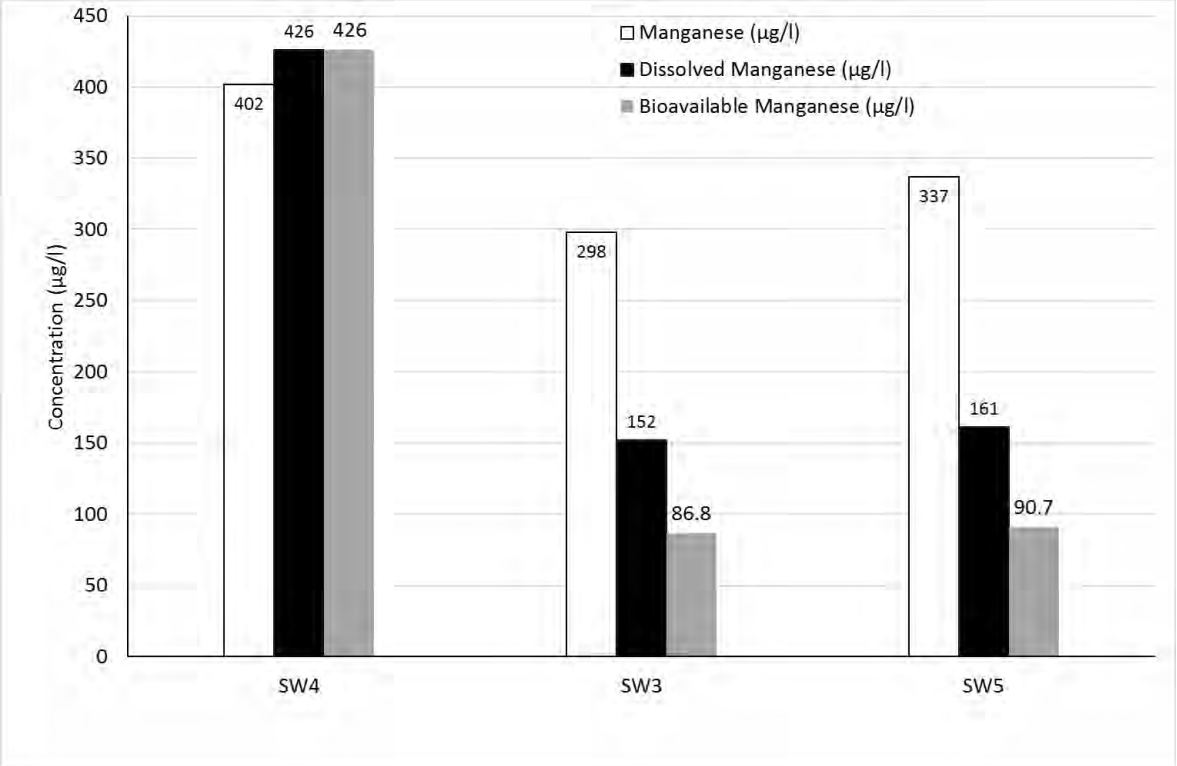


Figure E15 - Total, dissolved and bioavailable manganese concentrations



Note: The dissolved concentration is higher than the total. However, the discrepancy is within the analytical margin of error.

Figure E16 - Total, dissolved and bioavailable nickel concentrations

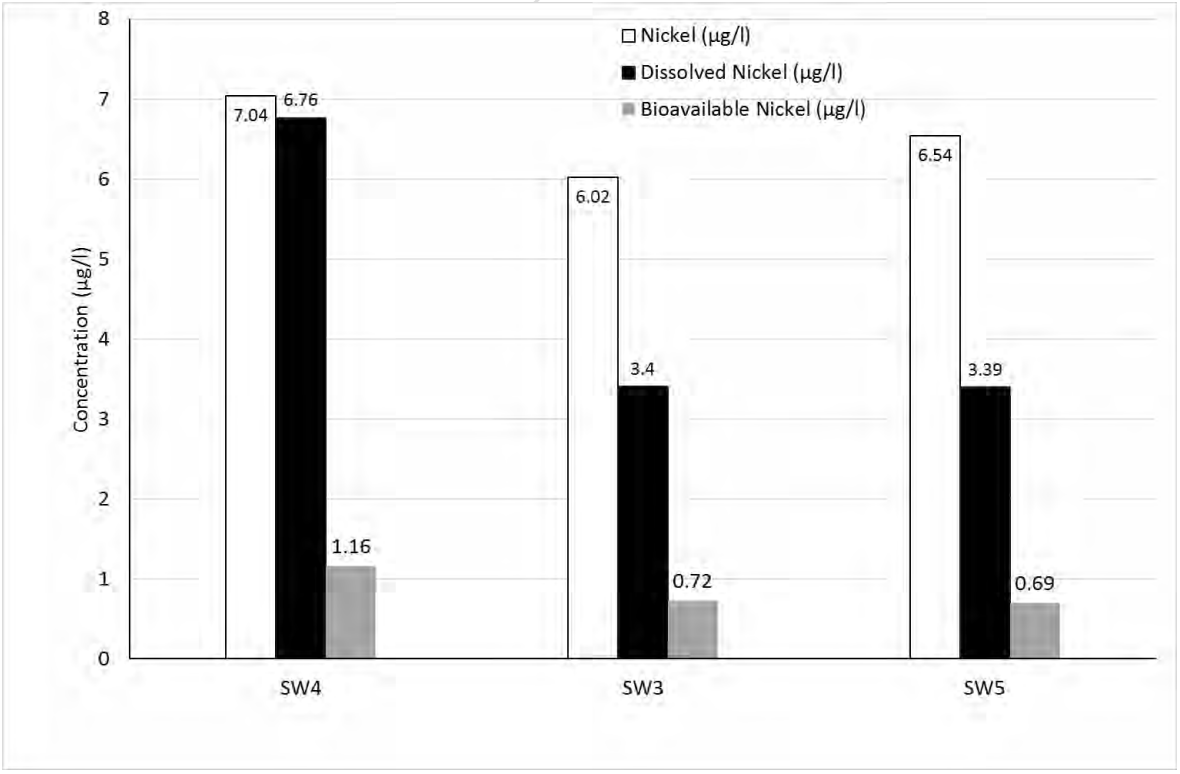
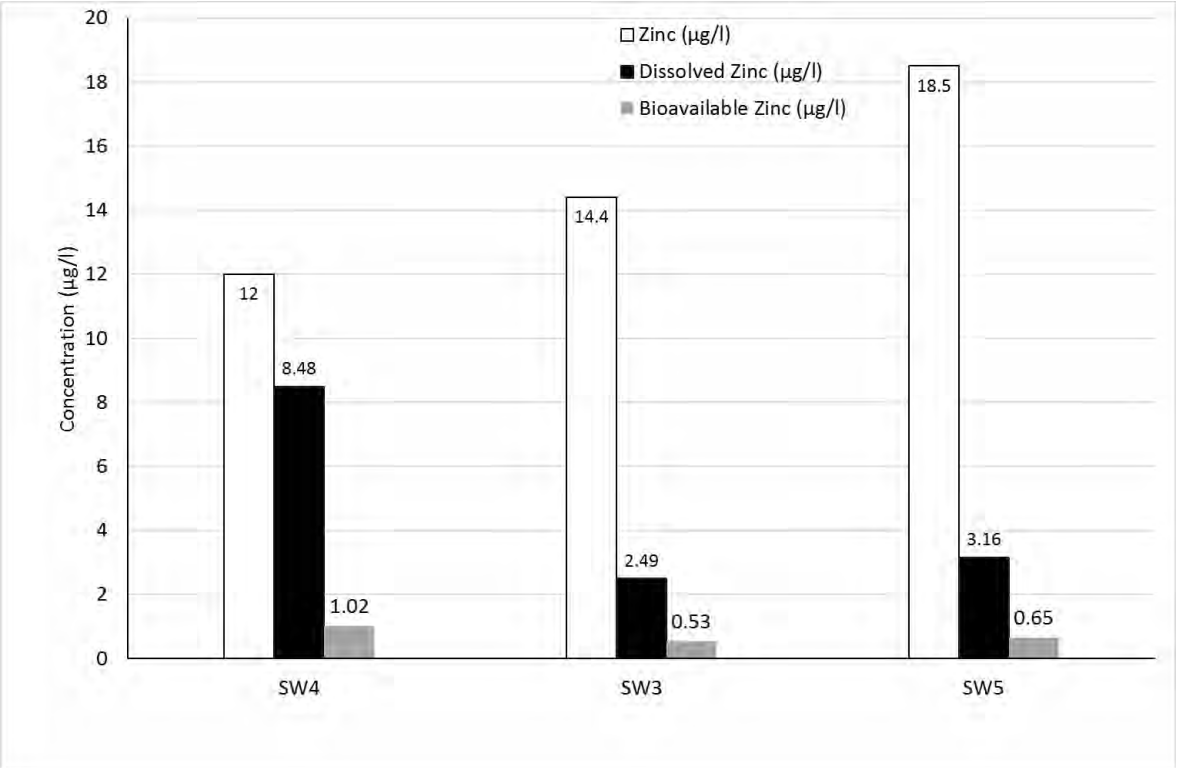



Figure E17 - Total, dissolved and bioavailable zinc concentrations