Tarbolton Landfill – Report

Monitoring plan and update of potential for environmental impacts resulting from consolidated ash waste deposition and lack of operational management

Scottish Environment Protection Agency (SEPA)

August 2018

Non-Technical Summary

The company operating Tarbolton Landfill in Ayrshire entered liquidation and there has been no operational management at the site since mid-June 2018. SEPA have recently qualitatively assessed the risks to the environment[1]. This assessment identified some further work would be beneficial, notably with respect to landfill gas and to a lesser extent surface water. This report presents the latest data and findings which considers the potential effects from the absence of operational site management. The evidence produced has been used to update the risk assessment (Table 1).

SEPA carried out a programme of gas monitoring to further assess the risk of landfill gas migration and to look for evidence of sub-surface fires within the landfill. No definitive signs of lateral landfill gas migration from the landfill site towards receptors were identified, however several areas have been identified which will be subject to further monitoring. No evidence of sub-surface fires within the waste mass has been identified.

Leachate level monitoring shows that the leachate levels are stable. However, the weather during the monitoring period was predominantly drier than average and it is unclear to what extent this has led to this stabilisation of the levels. Levels are expected to rise in response to increased rainfall as we move into autumn and winter. Continued monitoring of leachate levels will be undertaken. An increase in leachate levels on site may be expected to increase the frequency and magnitude of leachate outbreaks occurring due to the lack of operational management at the site.

The main areas of note with surface leachate outbreaks are those at the edges of the site as these have the clearest pathway into the water environment. The lack of active leachate management is impacting on the water environment, particularly via the leachate outbreaks. However, the magnitude of the impact does not appear to have changed significantly since the previous assessment.

This is confirmed by the surface water monitoring as the concentration of the landfill indicator chemicals, ammoniacal nitrogen, chloride and electrical conductivity readings are relatively stable downstream of the landfill in the Water of Fail.

Since the last assessment a new receptor has been identified. Potentially farm animals could enter water courses downstream of the landfill and drink affected water. Overall, here is a low risk to farm animals from ingesting contaminated surface water. However, there is a predicted theoretical risk for manganese. Further, assessments are underway to determine the actual level of risk in this case (section 3.5.2).

Overall, the landfill is having an environmental impact and the lack of ongoing management has to some extent led to increases in the risk of harm occurring. These increased risks have not led to additional impacts so far and the ongoing monitoring is planned to ensure that the impact of the site is well understood.

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

Table 1 Updated 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 Update	**Impact increased due to landfill gas from lack of operational management.**	**Low**	**Low**	**No immediate concerns related to landfill gas migration however periodic monitoring recommended, to ensure continued protection of local receptors.**
Air	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.
Ground-water	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.
	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.
Surface Water Update	**Surface water quality impact increased due to lack of operational management.**	**Moderate**	**Moderate/High**	**Currently, data suggest no further deterioration due to the continuing localised impact on the quality of surrounding surface water.**
	Impact on farm animals drinking contaminated surface water	**Very Low**	**Low/Moderate**	**Risk will increase with significantly higher leachate flows entering the Biggary Burn (Section 3.5.2)**

Media	**Risk type**	**Current Risk Assessment**	**Future Risk Assessment - lack of operational management**	**Comments**
Surface Water	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.
	Impact on fishery water quality and other receptors.	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.

Bold entries denote updates or additions from Table 1; Investigation into the potential for environmental impacts resulting from consolidated ash waste deposition and lack of operational management

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1.0 Introduction

This report presents the findings of the ongoing investigation by SEPA into the potential risks to the water environment and other receptors at Tarbolton landfill.

The aim of these investigations was to refine the assessment of 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:

- Undertaking a landfill gas monitoring programme to collect additional environmental data to confirm the results of the site operator monitoring and provide additional information once the boreholes were sealed.
- Interpretation of the results of the SEPA monitoring undertaken since the first assessment
- Update and refine the qualitative risk assessment of potential risks to the water environment and other receptors
- Development of recommendations regarding further monitoring to refine our understanding of the future risks and to aid future action in relation to the site.

This report presents an updated assessment of the environmental risk posed by the site based on the additional evidence collected following an initial assessment by SEPA in July 2018[2]. The risk assessment has been updated in light of this new data (Table 1).

Since June 2018, there has been a lack of operational management at the site. As would be the case with any unmanaged landfill, the absence of management is likely to present an increased risk to the environment. As part of the risk assessments made, we have made an estimate of the potential additional risks to the environment from 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). The ongoing monitoring is required to assess the developing impacts due to the lack of operational management at the landfill site.

This report has not presented all of the site information and background information regarding the site and its setting. This is available in the preceding report.

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

2.0 Air quality

2.1 Landfill gas monitoring

SEPA report[2] made recommendations to assess the developing impacts due to the lack of operational management at Tarbolton landfill.

SEPA designed and carried out a programme of landfill gas monitoring to assess the current risk of landfill gas migration. Gas sampling taps were reinstalled in the 12 perimeter gas boreholes followed by 4 rounds of gas monitoring. In addition, methane and hydrogen sulphide walkover surveys were carried out at positions covering the landfill's perimeter, and at other targeted locations (e.g. based on observations of gas bubbling or leachate breakout).

A further risk associated with landfills is the development of sub-surface fires in the landfill waste mass itself. A key indicator of such fires is the presence of carbon monoxide in the gas generated within the landfill. Therefore the landfill gas manifolds, which link to areas of the landfill waste mass, were monitored for carbon monoxide.

2.2 Perimeter gas borehole monitoring

The 12 perimeter boreholes (shown in Figure 1) were monitored on a weekly basis between 12 July 2018 and 02 August 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[3]. The atmospheric pressure was measured using the GA5000's internal barometer which is verified against readings from a UKAS-calibrated barometer[4].

SEPA Permit PPC/A/1000105 defines the following perimeter borehole trigger levels for landfill gas concentrations at Tarbolton Landfill: Methane '>1%' and Carbon dioxide '>1.5%'[5]. 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, the Health and Safety Executive[6] recommend that, in areas accessible to humans, action is needed to prevent the oxygen falling below 18% v/v at atmospheric pressure.

The stable landfill gas concentration and atmospheric pressure results for Tarbolton Landfill were recorded on 12 July 2018, 20 July 2018, 26 July 2018 and 02 August 2018 (for tabulated results see Appendix A Table A1). Methane and carbon dioxide concentrations were below the trigger level concentrations, stipulated in SEPA permit PPC/A/1000105, on each occasion, with the exception of boreholes GWS3, GWD5 and GWD6. For information, on each monitoring occasion borehole GWD1 was flooded and no measurements could be taken.

[3] SEPA Procedure ES-NFC-WP-002, Determination of oxygen, methane and carbon dioxide in landfill gas using a landfill gas monitor
[4] SEPA Procedure ES-NFC-WP-021, Use and Verification of Field Barometers for Accredited Methods
[5] 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
[6] Guidance Note EH40: Occupational Exposure Limits 2002, Health and Safety Executive (2002)

Borehole GWD5 exceeded the carbon dioxide trigger level concentration on 20 July 2018 and 02 August 2018. Boreholes GWS3 and GWD6 also exceeded the carbon dioxide trigger level concentration on 02 August 2018. The exceedances were, however, all limited to 1.5 - 2.5% v/v carbon dioxide which is relatively low. This level of carbon dioxide in the perimeter boreholes may be due to landfill gas migration or from another non-landfill related source; it is not possible to say definitively. However the fact that they were not accompanied by elevated concentrations of methane gives reassurance that the gas within these boreholes currently indicates a low risk of landfill gas migration.

SPEA will continue to undertake monthly perimeter gas borehole monitoring continue in line with the PPC permit condition.

2.3 Methane walkover survey

Perimeter methane surveys were undertaken using a calibrated laser methane detector (TDL-500, SEPA equipment ref. QP-00286) on 12 July 2018, 20 July 2018, 26 July 2018 and 02 August 2018.

The perimeter methane surveys involved sampling the air near to the perimeter boreholes and at locations in between (Figure 2), here termed ‘spot samples’ and prefixed ‘SS’. The methane measurements, summarised in Appendix A Table A2, were taken at ground level unless stated otherwise. GPS coordinates for all sampling points were recorded on a high precision GPS (Trimble Geoxh 6000 series, SEPA equipment ref. QP-00267).

For information, the average background atmospheric methane concentration expected for the UK in 2017 was approximately 1.9 ppm[7].

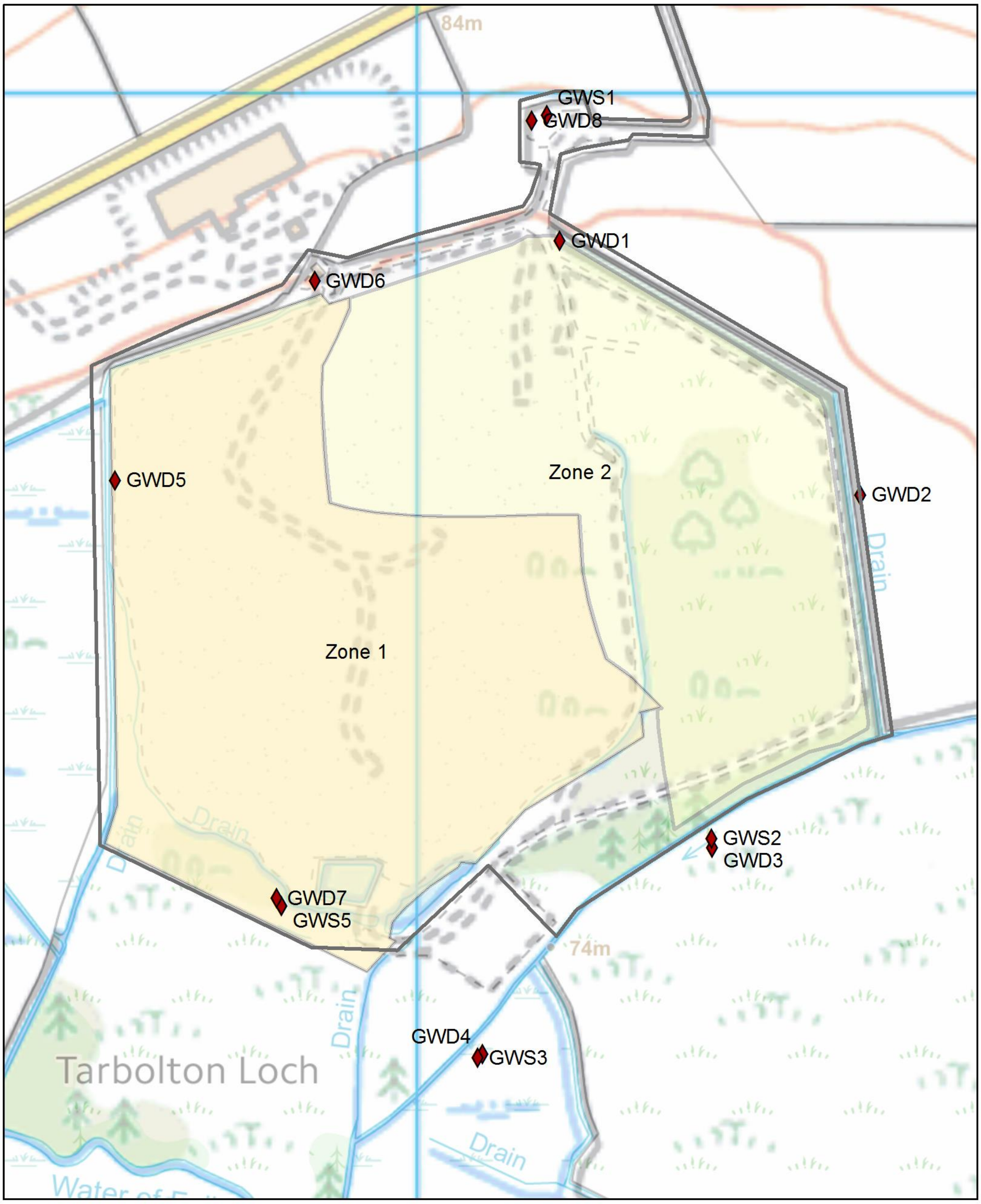
For the purposes of this report, spot sample methane measurements less than 100 ppm (0.01 %) are considered to be informative but are not discussed further. They will however be used as a comparison to any future perimeter methane walkover monitoring, to indicate whether perimeter site conditions are deteriorating.

Methane concentrations of 700 ppm in the vicinity of borehole GWS5 on 20 July 2018 and 100 ppm near to borehole GWD7 on 26 July 2018 indicate that methane was elevated in these areas, however the gas readings within the boreholes on the same days were below the detection limit of the GA5000 analyser. GWS5 and GWD7 are situated next to each other on the southern perimeter, south west and downslope from a leachate lagoon. It is recommended that walkover methane monitoring be continued in this area to assess whether these are isolated occurrences or an area requiring further action in relation to landfill gas migration.

Generally spot samples were below the limit of detection (5 ppm) of the methane detector around the perimeter of the landfill, with the exception of spot samples SS2, SS4, SS5, SS12, SS13, SS19 and SS20. Of these spot samples SS12, SS13 and SS20 are in areas overlying the landfill waste mass and therefore are not of concern in relation to lateral landfill gas migration.

[7] http://agage.eas.gatech.edu/data_archive/agage/gc-md/monthly/MHD-gcmd.mon

Figure 1 Perimeter borehole locations at the Tarbolton Landfill site



N

0 0.0375 0.075 1:3,209 0.15 km

0 0.015 0.03 0.06 Miles

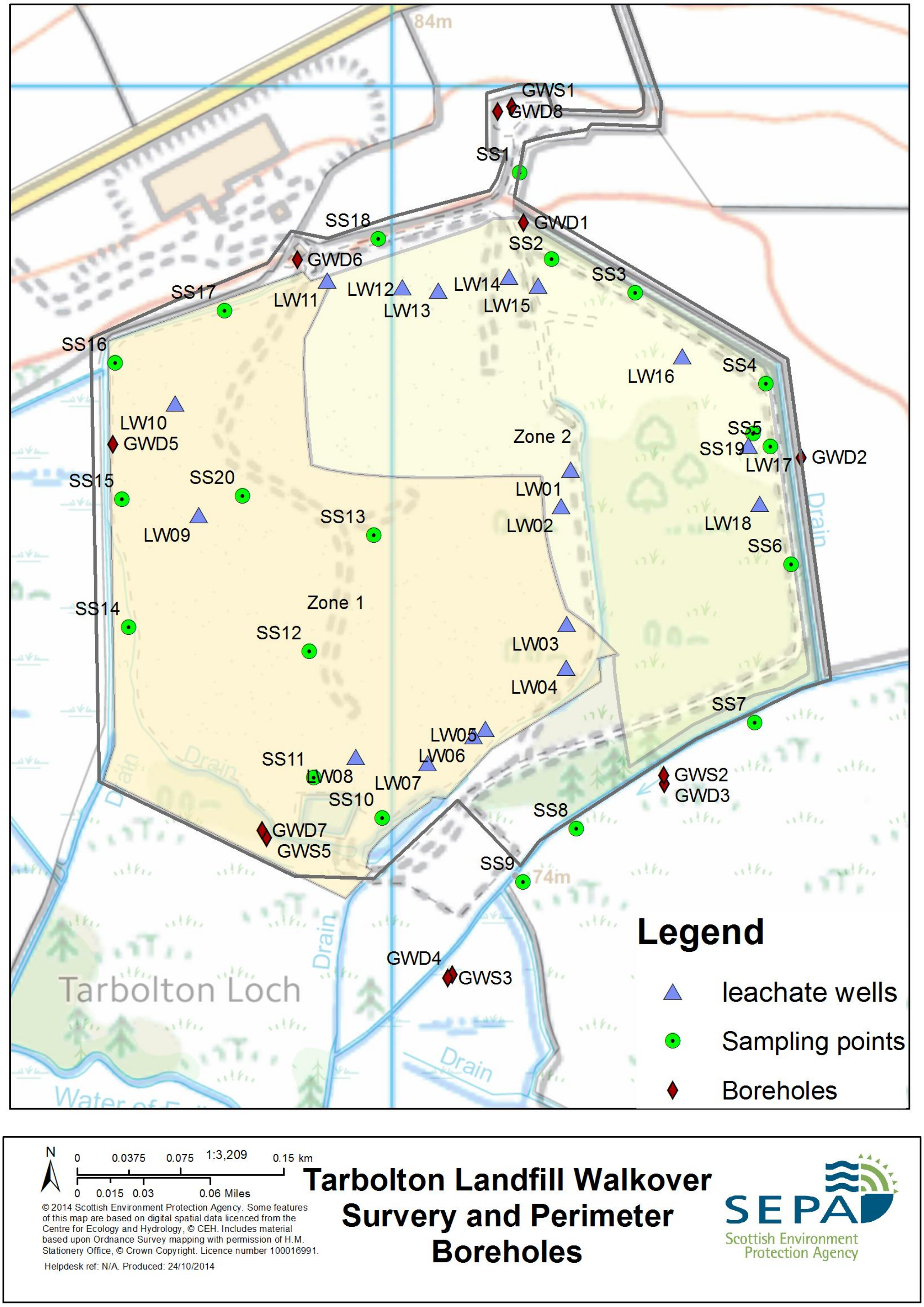
Tarbolton Landfill Perimeter Boreholes

© 2014 Scottish Environment Protection Agency. Some features of this map are based on digital spatial data licenced from the Centre for Ecology and Hydrology, © CEH. Includes material based upon Ordnance Survey mapping with permission of H.M. Stationery Office, © Crown Copyright. Licence number 100016991.

Helpdesk ref: N/A. Produced: 24/10/2014

SEPA Scottish Environment Protection Agency

Figure 2 Walkover survey locations at the Tarbolton Landfill site



SS2 is in an area of interest due to contamination from a leachate breakout. The methane measurements taken in this area were overlying leachate-contaminated, waterlogged soil.

On three of the four monitoring occasions methane was measured at levels between 750 and 55000 ppm. On 26 July 2018 a methane concentration of 55000 ppm (5.5 %) was recorded, which is noteworthy as this is above the lower explosive limit of methane. From visual observation, it is currently understood that the leachate contamination has been caused by leachate running down from the landfilled area resulting in contamination, which is in turn responsible for the elevated methane levels, rather than from lateral, sub-surface landfill gas migration. Unfortunately, due to the waterlogged nature of this part of the site, the nearby borehole GWD1, which is well positioned to monitor sub-surface methane levels, was also flooded and therefore could not be monitored for landfill gas.

SS5 was identified as an area of interest, during the site visits, due to bubbles of gas observed to be rising in a puddle at this location. Over the course of the investigation period this puddle became progressively cloudier and developed a strong leachate smell. The methane measurements taken overlying this puddle ranged from 50 ppm to 159 000 ppm (15.9%). The nearby borehole GWD2, which is drilled to a depth of approximately 4.80 m, contained methane at below the detection limit of the GA5000 analyse on all three occasions, therefore indicating that this may be a localised area of methane generation. SS4 which lies 45m to the north of this position had a slightly elevated methane measurement of 20 ppm, whilst SS6, 85m to the south, had a reading below 5 ppm.

The areas in and around spot sample positions SS2 and SS5 will continue to be monitored, in addition to the area around boreholes GWD7 and GWS5.

2.4 Hydrogen sulphide walkover survey

Perimeter and on-landfill hydrogen sulphide walkover surveys were undertaken using a calibrated Rae Systems Multirae Lite (PGM6208, SEPA equipment ref. QP-00380) to establish if there were any areas of interest in relation to hydrogen sulphide. The walkover surveys were undertaken on 12 July 2018, 20 July 2018, 26 July 2018 and 02 August 2018.

The Multirae is a personal safety device which measures indicative hydrogen sulphide concentrations ranging from 0 to 100 ppm. The Multirae was set to measure continuously (one-minute averages) over the course of each monitoring visit.

GPS coordinates for all sampling points were recorded on a high precision GPS (Trimble Geoxh 6000 series, SEPA equipment ref. QP-00267).

No detectable concentrations of hydrogen sulphide were measured around the perimeter of the landfill. Similarly, during the walkover on the landfill waste mass taking in areas proximate to each leachate well location, no detectable concentrations of hydrogen sulphide were measured with the exception of the area immediately proximate to leachate well LW12, which was measured on the 26 July 2018 to have a hydrogen sulphide concentration of 0.8 ppm. This concentration is above the odour threshold for hydrogen sulphide (0.008 ppm) but below both the UK 8 hour workplace exposure limit of 5 ppm or the short-term (15-minute) exposure limit of 10 ppm[8]. This level of hydrogen sulphide represents a very low risk to members of the public outwith the site's boundary as it is in a very localised area

[8] EH40/2005 Workplace Exposure Limits. Second edition (2011)

immediately proximate to the leachate well; the levels dilute to non-detectable levels within a distance of several metres.

2.5 Gas manifold survey

Sub-surface fires within a landfill can be caused by damaged or poorly functioning gas collection systems that permit air to be drawn into the waste. The flare, however, is not currently operating and therefore air ingress is minimised. As a precaution, the gas composition was monitored across the existing network of gas collection wells, via the gas manifolds. These manifolds take in gas from the individual in-waste landfill gas wells. The presence of a subsurface fire would be indicated by high levels of carbon monoxide.

Carbon monoxide is a gas produced as a by-product during incomplete combustion and is not thought to be produced as a result of chemical reactions within a landfill site during the degradation process. A trigger limit of 100 ppm is often used, if levels exceed this further investigation should be initiated[9].

The two gas manifolds were monitored on 03 August 2018 using a calibrated Geotech GA5000. The atmospheric pressure was measured using the GA5000's internal barometer which is verified against readings from a UKAS-calibrated barometer[10].

The highest concentration of carbon monoxide was measured at 17 ppm, which is below the custom and practice 100 ppm trigger thus indicating that at the time of monitoring, there were not considered to be any subsurface fires in the areas of the landfill connected by gas lines to the manifolds. Landfill gas measurements, including indicative measurements of hydrogen sulphide and carbon dioxide, can be found in Appendix A Table A3.

Although not currently operational, the level of oxygen within the gas collection system is noteworthy. Many landfill gas operators use a trigger level of 5 % oxygen at the gas well when operating a gas collection system[9]. 6 of the 13 gas lines monitored on 03 August 2018 had oxygen levels in excess of 5 %.

As long as the flare and gas extraction system is not turned on the risk of sub-surface fires is assumed to be lower, however, whilst the site is not operational, the gas manifold survey will be repeated on a six monthly basis, with further, more intensive investigations being initiated if levels are found to exceed 100 ppm.

2.6 Risks to receptors

Based on the perimeter gas borehole surveys, the methane and hydrogen sulphide walkover surveys reported here and the risk assessment completed previously[2], there is currently considered to be a low risk to receptors posed by lateral landfill gas migration from Tarbolton Landfill.

It is assumed, however, that the landfill will continue to produce landfill gas many years into the future, and therefore, monitoring is required to assess the level of lateral gas migration. This monitoring should, as a minimum, include monthly perimeter gas borehole monitoring in line with the PPC permit condition, along with targeted perimeter methane surveys which focus on areas of interest.

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[9] The Management of Landfill Gas, Landfill Gas Industry Code of Practice (March 2012)
[10] SEPA Procedure ES-NFC-WP-021, Use and Verification of Field Barometers for Accredited Methods

Based on the gas manifold survey reported here there are no signs of sub-surface, in-waste fires, which could damage the landfill infrastructure thereby potentially increasing the risk to receptors. This landfill gas survey should be repeated on a six monthly basis.

2.7 Landfill gas risk assessment summary

Summary of findings: The perimeter gas borehole monitoring indicated slightly elevated levels of carbon dioxide in 3 of the 12 perimeter boreholes but no elevated levels of methane. Based on this, there are no immediate concerns relating to lateral landfill gas migration from the site. Two areas on the northern and eastern perimeter of the landfill were found to have elevated levels of methane in the ambient air at ground level, however these were localised to areas overlying surface leachate breakouts from the landfill. Occasional elevated levels of methane in the ambient air at ground level were also measured on the southern perimeter, near boreholes GWD7 and GWS5. The hydrogen sulphide survey did not identify any areas of concern on or around the perimeter of the landfill. No elevated levels of carbon monoxide, which could indicate the presence of sub-surface fires, were measured in the landfill's gas collection system manifolds.

Risk Assessment: Low

Further Work: Continuation of monthly perimeter gas borehole monitoring in line with the PPC permit condition, along with targeted perimeter methane surveys which focus on areas of interest. Six monthly landfill gas (including carbon monoxide) survey of the gas collection system. If perimeter borehole or walkover survey carbon dioxide or methane levels increase a review of the monitoring programme should be undertaken. If carbon monoxide levels are found in the gas collection system, actions will be required to investigate further and mitigate risk.

3.0 Water environment

3.1 Leachate levels

Leachate at the site is monitored via 18 leachate wells, LW1-LW18. The location of each of the leachate installations is shown in Appendix B Figure B1. Leachate wells LW1-LW10 monitor Zone 1 of the site[11]. Leachate wells LW11-LW18 monitor Zone 2.

Leachate levels were formerly managed by pumping to maintain heads below permitted levels. However, leachate extraction ceased in May 2018. Leachate levels at the site were monitored monthly by the site operator up until this date. SEPA have monitored leachate levels weekly from the end of June to the beginning of August.

The leachate elevation and head levels are shown for Zone 1 (Appendix B Figure B2 & Figure B3 respectively) and for Zone 2 of the landfill (Appendix B Figure B4 & Figure B5 respectively). Leachate levels in both Zone 1 and Zone 2 have been stable since May 2018. An updated topographic survey is required to confirm the cap level of the leachate wells, particularly LW2 where very elevated levels have been recorded throughout 2018. LW1 has collapsed and is no longer monitored. Although the leachate management system has not been in operation in recent months, the observed stable leachate levels recently recorded are considered to be the result of reduced rainfall in summer 2018. A return to normal rainfall levels is expected to result in increased leachate heads through winter 2018 and beyond.

The Tarbolton landfill permit (PPC/A/1000105) limits leachate head levels to less than 2 m. These are exceeded at a number of wells and have been for some time since 2017 (Appendix B Figure 3 and 5). The base of the leachate collection system in the fully lined cells in Zone 2 is understood to be around 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 the current and historic monitoring. This is consistent with the observation of leachate outbreaks locally around the perimeter of Zone 2 and elsewhere on the site. Over time, if unmanaged, it is likely that an increase in both the number and volume of intermittent and continuous discharges of leachate to nearby watercourses will occur with an associated increase in the rate of infiltration to groundwater. This may then have an increased impact on the water environment over and above that already associated with landfilling activity.

3.2 Leachate lagoons

The three leachate lagoons at the site were sampled on the 25 July 2018. These are located to the south of the site (Appendix B Figure B6). Two of these lagoons are known to be unlined. The two unlined lagoons displayed an orange ochreous appearance (Appendix B Figure B7) and were also noted as being over capacity. The leachate in the third lagoon, which is understood to be lined, was black in colour (Appendix B Figure B7) and is understood to be the primary collection point for water pumped from leachate wells. During the site visits in May 2018 water was observed on the surface of the ground surrounding the lagoons in a number of places. In June 2018, the leachate breakout areas and the extent of ponding around the lagoons were assessed using a handheld GPS on site, the positions and extents are shown in Figure 6 (Appendix B). The permit requires a 200 mm freeboard, or gap, between the surface of the lagoon and the bank to mitigate this overtopping risk.

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

Samples collected, in July 2018, from the lagoons indicate that the lined lagoon has higher concentrations of contaminants than either of the unlined lagoons (Appendix B Table B1). The concentration of ammoniacal nitrogen in the lined lagoon is within the ranges encountered during the routine leachate monitoring carried out by the operator (2009-2017). The range of median values was 26 mg/l (LW9) to 1535 mg/l (LW12)[12]. Similarly, the pH values are typical of leachate encountered at this site. Relatively low levels of total petroleum hydrocarbons (TPH) were encountered in all three lagoons. The results from the two unlined lagoons are very similar to one another with the exception of suspended solid results (Appendix B Table B1).

3.3 Surface leachate discharges to drainage ditches

The surface leachate breakout on the site in Zone 2 has been sampled and analysed in July 2018. This was carried out to refine the risks to surface water from the leachate pooling on the site and entering drainage ditches which drain into surface waters around the site. Samples were taken from three main areas (Appendix B Figure B8).

- Three samples were taken from pipes feeding the east drainage ditch which then joins the Biggary Burn. An example of one of the pipes is shown in Appendix B Figure B9.
- Samples were taken from the east drainage ditch which then enters the Biggary Burn. Samples were also taken up and downstream of the confluence with the Biggary Burn.
- Finally, sampling was also carried out in a drainage ditch in the south east of the site. This area drains through the site running in a south westerly direction and leaving the site to the south near the leachate lagoons and joining the Biggary Burn more or less to the south of the leachate lagoons (Appendix B Figure B8).

The sampling was carried out to assess the inputs to the Biggary Burn from two drainage ditches in Zone 2 running across the site exiting to the south and also along the eastern flank of the site.

3.3.1 Leachate discharges from pipes into the eastern drainage ditch

The concentrations encountered in the samples from discharge pipes was similar to the unlined leachate lagoons in terms of the concentration of ammoniacal nitrogen and pH (Appendix B Table B2). The discharge from Pipe 2 exhibited lower concentrations than Pipes 1 and 3, which had broadly similar concentrations.

The concentrations of metals exhibited a markedly different pattern which was dependant on the metal concerned. Some metals, such as cadmium, nickel and arsenic, showed broadly similar concentrations from all three pipes, while the concentrations of iron, aluminium and manganese were higher in Pipe 2 (Appendix B Table B3). The variations described are consistent with the range of concentrations recorded in leachate wells in May 2018. The values recorded are also within the range of values encountered from the leachate quality monitoring carried out at the site.

[12] Table C5 Page 83 from Investigation into the potential for environmental impacts resulting from consolidated ash waste deposition and lack of operational management

Figure 3 Concentration of ammoniacal nitrogen in on-site drains and the Biggary Burn, sampled 25 and 26 July 2018

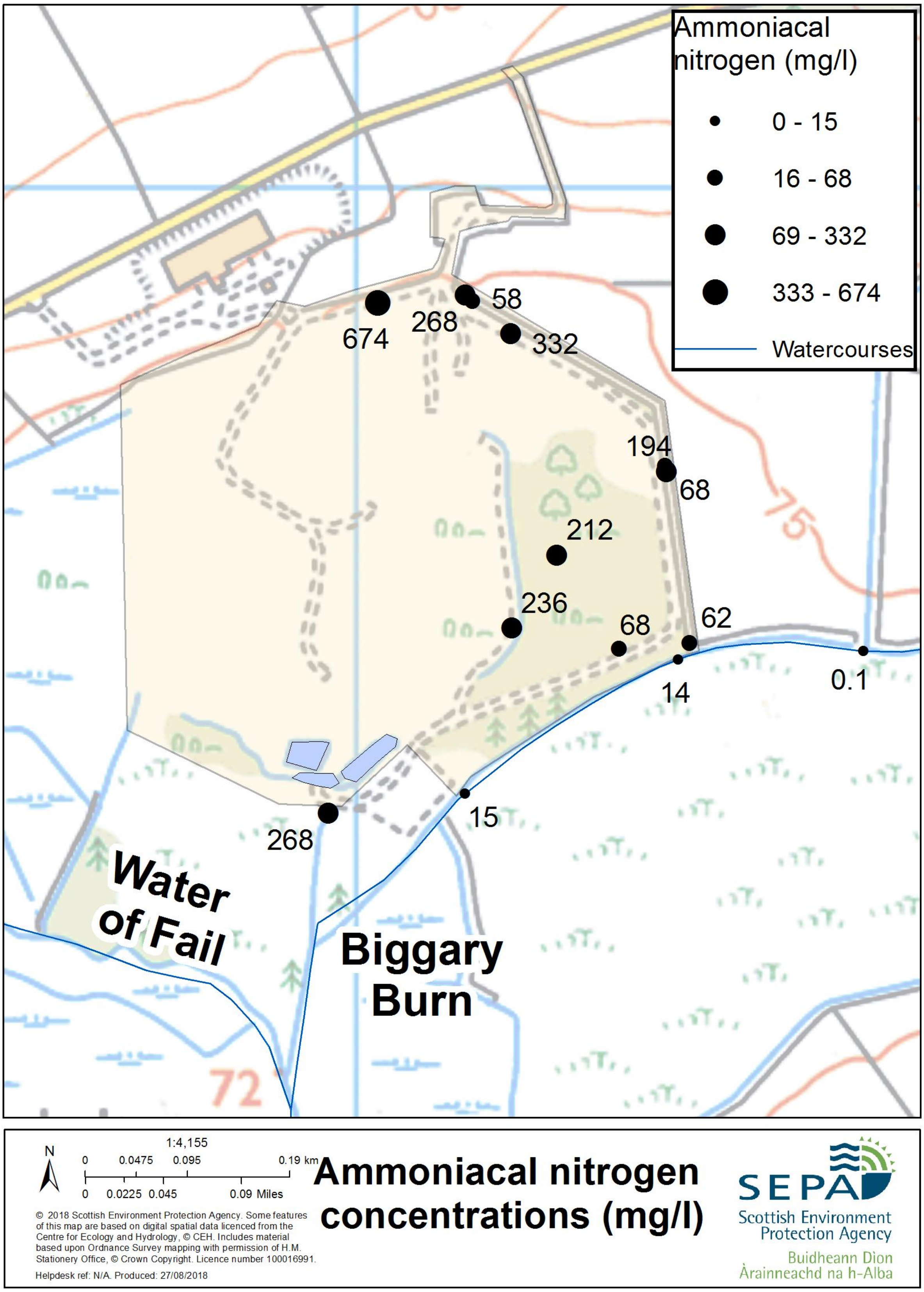
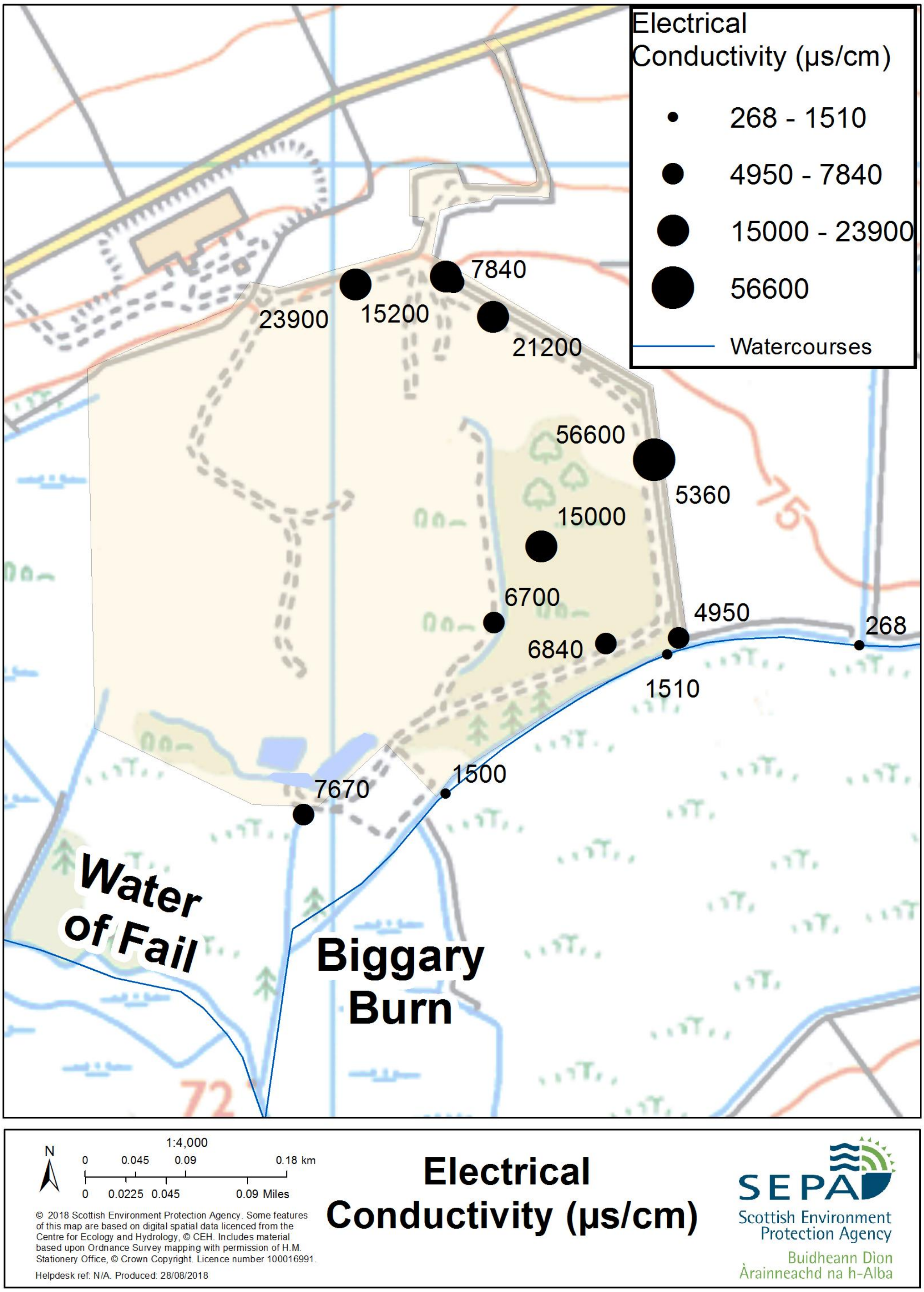


Figure 4 Electrical conductivity readings in on-site drains and the Biggary Burn, sampled 25 and 26 July 2018



3.3.2 Eastern drainage ditch and Biggary Burn

The concentrations in the eastern ditch for landfill indicator chemicals are shown in Table B4 (Appendix B) and Table B5 for metals (Appendix B). Values are highest at Site 1 for landfill indicator chemicals; ammoniacal nitrogen was 674 mg/l and electrical conductivity was 23,900 µs/cm. The values generally fall from this high level along the eastern field drain towards the confluence with the Biggary Burn (Sites 2 to 4); typically electrical conductivity was 5,000 µs/cm and ammoniacal nitrogen was 60 mg/l. However, an extremely high electrical conductivity was recorded 10 m from one of these typical concentrations with a value of 56,600 µs/cm (ammoniacal nitrogen was 194 mg/l) (Site 3). The cause of this is unknown but may reflect the inherent spatial variability of the drainage ditch. The concentrations of ammoniacal nitrogen and electrical conductivity readings are also shown spatially (Figure 3 and Figure 4 respectively). Within the Biggary Burn the concentrations of these indicators were much lower upstream of the landfill (Site 5) as compared to those downstream (Sites 6 and 7).

In contrast, the metals show quite different spatial patterns in the drainage ditch depending on the metal concerned (Appendix B Table B5). Despite this variation between metals, the overall concentrations are relatively high in the drainage ditch and also in the Biggary Burn (Sites 1 to 4 and 6, 7). The concentrations downstream of the drainage ditch in the Biggary Burn are considerably higher than those upstream (Site 5) for all metals except aluminium and vanadium. Samples from the field drain near the confluence taken on two consecutive days showed large fluctuations in the concentrations of some metals including aluminium and iron. This may be indicative of the inherent variation in the composition of the leachate derived material into the surface water environment (Appendix B Table B5). The composition of the landfill indicator compounds is far less variable in this context (Appendix B Table B4).

3.3.2 South eastern drainage ditch

Sampling was also carried out to the south east of the site. This area drains through the site running in a south westerly direction and leaving the site to the south near the leachate lagoons and joining the Biggary Burn more or less to the south of the lagoons (Appendix B Figure B8). The first sample was from a ditch near the track to the south east corner of the site (ref 559398). The composition of this sample is similar to the typical samples from the east field drain (ref 559244) (Appendix B Table B6 and Table B7).

The other samples form a transect. The first of these is in the middle of the site (559396) and showed the highest electrical conductivity measurement (Appendix B Table B6). The other two sites were fairly similar but the site downstream of the lagoon had higher levels of contamination and electrical conductivity (559388). The concentrations of metals was again specific to the metal to some degree but generally reflected this pattern (Appendix B Table B7). This most likely reflects the breakouts in the area around the lagoons and in this area of the site. The concentrations of ammoniacal nitrogen and electrical conductivity readings are also shown spatially (Figures 3 and 4 respectively).

Comparing the results from this input (559388) to the Biggary Burn to the East field drain (559244) clearly shows that the electrical conductivity and the concentrations of ammoniacal nitrogen exceed those from the field drain (Appendix B Table B8). The concentration of iron was lower in the samples from the east field drain. Arsenic and manganese were more or less the same for both locations. All of the other metals were higher in the east field drain (Appendix B Table B9).

These results show that the concentrations of metals and landfill indicator chemicals are significant and are high enough to lead to a downgrade in water quality in the surrounding surface waters. The monitoring results from the surface water drains and ditches feeding the Biggary Burn show significant concentrations of pollutants are entering the burn.

3.4 Groundwater

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. No new data has been collected since the previous risk assessment; further information will be presented in subsequent reporting.

3.5 Surface water

Sampling was carried out at various locations on Water of Fail (Appendix B Table 10 and Figure B10). Samples were analysed for a range of parameters associated with landfill site inputs. The access to water courses has been severely hampered by the growth of vegetation along the banks of the Water of Fail and the Biggary Burn. This has reduced safe access for sampling and at the current time a limited number of sampling points can be routinely taken. These are highlighted in bold in (Appendix B Table 10). The discontinuity in sampling regimes mean that it is not practical to compare the concentrations in different places from different times.

3.5.1 Surface water quality

The limited access has meant that the surface water monitoring programme has been curtailed in terms of the number of sites visited. The initial assessment used three sites (ref 554743, 554744, and 554745 in appendix Table B10). At the moment three sites are used routinely but only one of these was used in the initial assessment (ref 554745). These are all on the Water of Fail. The initial assessment concluded that it was likely that the site (ref 554743) on the Water of Fail, 50 meters upstream of the confluence was to some extent impacted by the landfill and that the comparison between this site and the site downstream of the confluence was assessing the inputs from the landfill to the Biggary Burn rather than the impact of the landfill *per se*. To address this we have monitored further upstream of the landfill (ref 122046) (Appendix B Table 10).

Figure 5 shows the distribution of ammoniacal nitrogen concentrations. Upstream of the landfill the concentration is around 0.2 (mg/l). The site just before the Biggary Burn confluence (ref 554743) recorded a result of 3.1 mg/l in May 2018. For reference, the site downstream of the confluence (ref 554745) recorded a result of 4.6 mg/l in May 2018. The subsequent sampling from this site has shown lower concentrations more similar to the site downstream (ref 122048) that had an average result of 1.3 (mg/l) (Figure 5). These results suggest that the landfill is having an impact on the ammoniacal nitrogen concentration in the Water of Fail (Appendix B Table 11).

In contrast, when comparing results for ammoniacal nitrogen with electrical conductivity a slightly different pattern emerges (Figure 6). The results of this sampling show that at the most upstream site (ref 122046) the electrical conductivity reading is around 500 (µs/cm); the site just before the Biggary Burn confluence (ref 554743) is very similar at 508 (µs/cm) prior to the inclusion of this site. The site downstream of the confluence (ref 554745) recorded a result of 607 (µs/cm). The most downstream site (ref 122048) has an average result of 615 (µs/cm). A similar pattern is evident for chloride concentrations. This suggests that there may be another source of ammoniacal nitrogen between this upstream point and the sampling point upstream of the Biggary Burn confluence (Appendix B Table B11).

Figure 5 Concentration of ammoniacal nitrogen from the Water of Fail

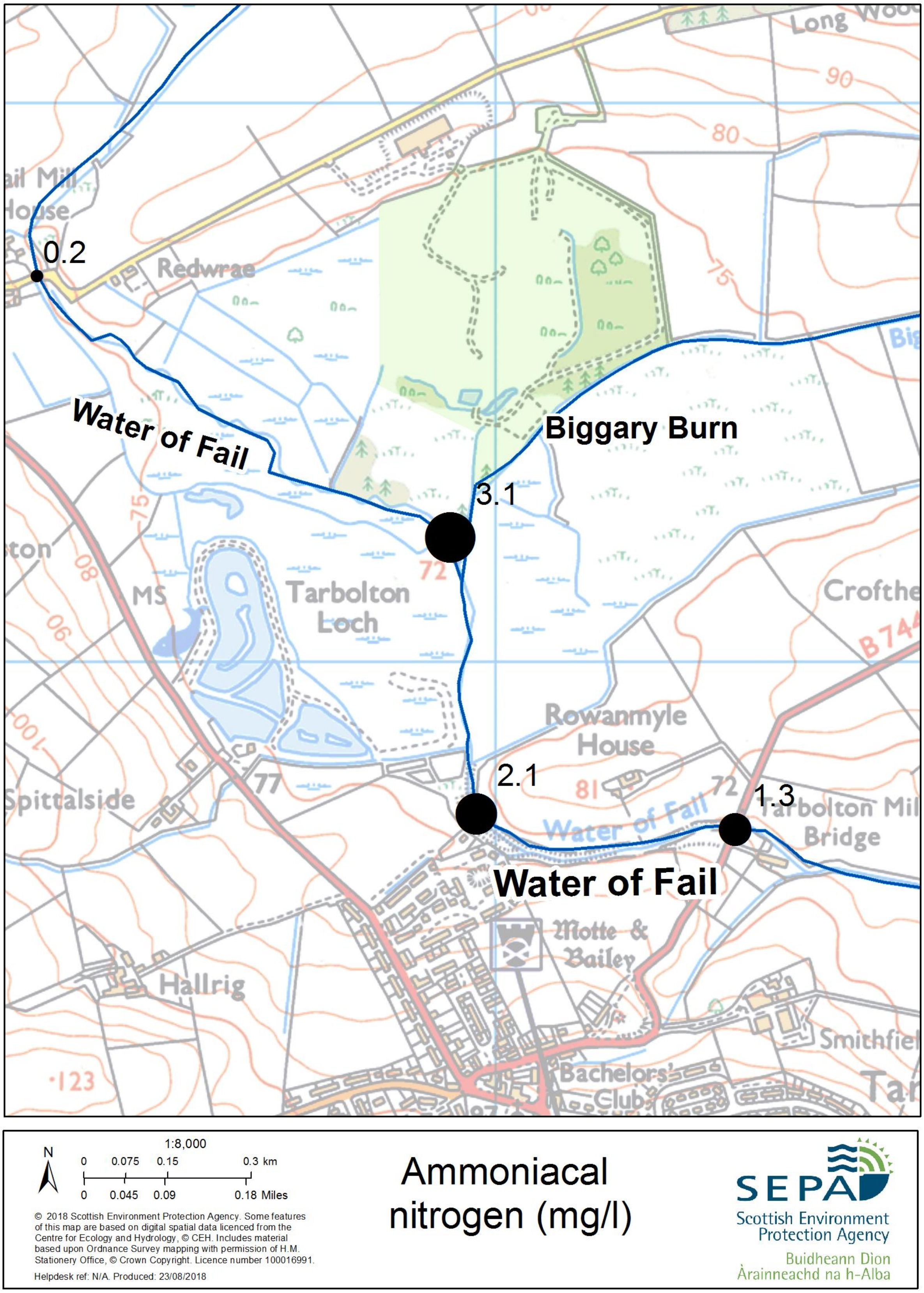
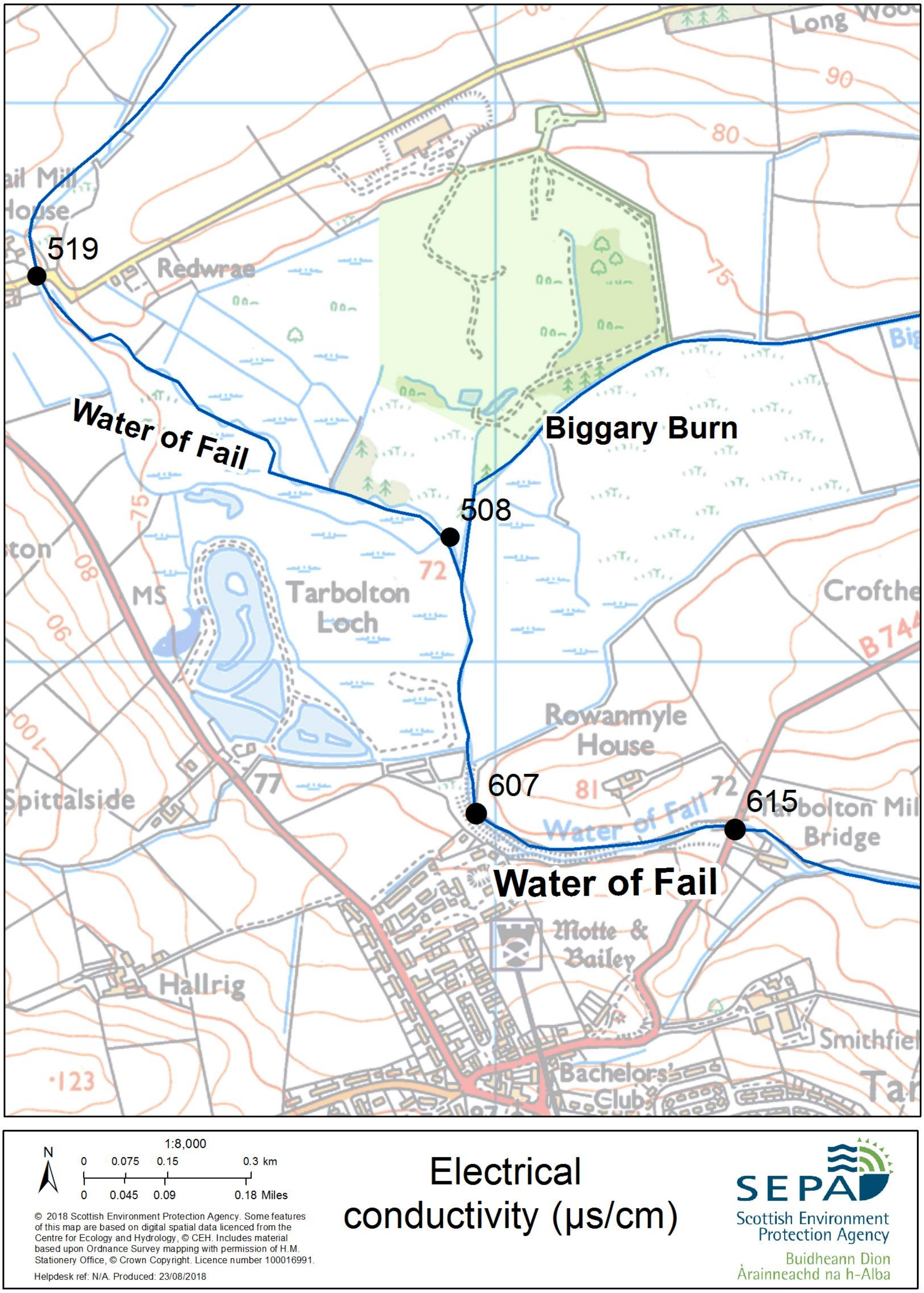


Figure 6 Electrical conductivity readings from the Water of Fail



The main mitigation against environmental harm is dilution which is limited in the Biggary Burn and the Water of Fail. The Q95 flow in the Biggary Burn,150 m downstream of the confluence with the Eastern field drain, is estimated at 0.004 (m^3/s). For the Water of Fail, immediately upstream of the confluence of the Biggary Burn, the Q95 flow is estimated at 0.04 (m^3/s). The respective values for the means flows are 0.02 and 0.3 (m^3/s). This represents a dilution factor of about 10 between the Biggary Burn and the Water of Fail.

Comparing the data from May with that obtained recently there is no obvious deterioration in the Water of Fail downstream of the landfill with respect to ammoniacal nitrogen and electrical conductivity (Appendix B Figure B11).

3.5.2 Risk to farm animals

The risk to farm animals drinking contaminated water in the environment is not routinely assessed. A preliminary assessment has been made here by comparing the concentrations observed in the Biggary Burn and Water of Fail to limits[13] published by the Food and Agriculture Organization of the United Nations (FAO). These are shown in Appendix B Table B12 for electrical conductivity and Appendix B Table B13 for 14 toxic compounds which include metals, metalloids, fluoride, nitrate and nitrite. There is no limit set for any form of ammoniacal nitrogen.

The results of the risk assessment are shown in Appendix B Table B14. This table is split into two areas. The first is the drainage ditch to the east of the site and points along the Biggary Burn. The second is the Water of Fail. The quality observed in the ditch to the east of the site before the confluence with the Biggary Burn is just below limit of suitability for drinking water based on the electrical conductivity. From immediately downstream of the confluence with this ditch, the water in the Biggary Burn and Water of Fail is satisfactory for farm animals for all constituents except manganese.

The limit FAO suggest for manganese protective of livestock exposure via drinking water is based on that for human drinking water, since data are not available to derive a value for livestock. This limit is breached at all sampling points along the Biggary burn and the Water of Fail. The limit is set at 0.05 mg/l based on acceptability to consumers rather than health impacts. The health derived human limit is 0.4 mg/l14. Further research is required to refine this limit to take into account differences in body mass and amount of water consumed. At the current time, the samples from the Biggary Burn and Water of Fail are below this human health based limit of 0.4 mg/l.

This risk should be minimised in two ways: diffuse pollution General Binding Rules15 that state that livestock should be kept away from water courses should be enforced; if this is not the case, available dilution in the Biggary Burn and Water of Fail mean that at present there is no risk from livestock drinking the water.

3.6 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

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[13] Water quality for agriculture; FAO IRRIGATION AND DRAINAGE PAPER 29 Rev. 1 (ISBN 92-5-102263-1). Chapter 6 "Water Quality for Livestock and poultry"

[14] Manganese in Drinking-water

[15] Reducing the risk of water pollution: Diffuse pollution general binding rules explained

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 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 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.

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. As far as SEPA are aware, there are no downstream drinking water abstractions.

The risk to livestock consuming contaminated water is currently low. However, if the volume of leachate entering surface waters increases then this risk will obviously increase, especially as the main mitigation is dilution which is limited. Therefore, additional monitoring will be undertaken to assess the developing impacts to the quality of surface water and ecosystems associated with the lack of operational management at the landfill.

3.7 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.

The risk to farm animals from drinking contaminated surface waters is currently low. The risk from manganese needs further assessment. The manganese limit used appears to be overly conservative.

Risk Assessment: Moderate (surface waters) to low (farm animals).

Further Work: Catchment walk to assess relative importance of inputs. Additional surface water monitoring at additional locations to assess potential future risks due to the lack of operational management. Refine risk assessment limits for farm animals drinking contaminated water. Carry out additional leachate and groundwater monitoring to continue to assess the impact of the landfill.

4.0 Conclusions

The risk assessment findings are summarised in Table 1 at the start of this report.
The key conclusions from the SEPA investigation are:

- Based on the available evidence, the landfill gas risk is 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.

5.0 Actions and recommendations

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

- 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.

The specific actions are listed in Table 3. The data collected will be used to update and refine the risk assessments already made (Table 1). During the course of the monitoring detailed, unusual results will be flagged and investigated appropriately. Depending on the nature of the result, this might be resampling, an investigation into the validity of the analysis. The risk assessments will be reviewed as new data becomes available. All results will be reported appropriately, including an updated risk assessment and a review of the monitoring plan if required.

Table 3 Ongoing monitoring plan to support the assessment of risk from Tarbolton Landfill following the deposition of consolidated ash waste and lack of operational management

Media	Frequency	Review of Monitoring Requirements
Landfill gas (perimeter boreholes)	Monthly	Review in 3 months (Nov 2018).
Methane walkover survey (perimeter areas of concern)	Monthly	Review in 3 months (Nov 2018).
Landfill gas (in-waste/gas manifolds)	6 monthly	Review in 6 months (Feb 2019).
Surface water	Weekly	Review end of Sep 2018.
Catchment Walk	Once Scheduled for Sep 2018	None
Groundwater Quality	Quarterly	Review in 1 Year (Aug 2019)
Groundwater Levels	Quarterly	Review in 3 months (Nov 2018).
Leachate well Quality	Two Months	Review in 6 months (Feb 2019).
Leachate well Levels	Monthly	Review in 1 Year (Aug 2019)
Trade Effluent Discharge	This is required quarterly (permit) but is not covered at the moment.	

[+] Mostly field measurements but samples will be taken as appropriate

Appendix A Air quality tables

Table A1 SEPA landfill gas measurements of perimeter boreholes at Tarbolton Landfill

Borehole	Date	Methane (% v/v)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Atmospheric Pressure (mbar)
GWD1	12/07/2018	-	-	-	-
	20/07/2018	-	-	-	-
	26/07/2018	-	-	-	-
	02/08/2018	-	-	-	-
GWD2	12/07/2018	< 0.3	< 0.3	19.9	1015
	20/07/2018	< 0.3	0.5	20.5	1004
	26/07/2018	< 0.3	0.7	18.6	1005
	02/08/2018	< 0.3	0.7	19.5	1013
GWD3	12/07/2018	< 0.3	0.3	20.6	1015
	20/07/2018	< 0.3	1.0	20.5	1004
	26/07/2018	< 0.3	< 0.3	19.6	1004
	02/08/2018	< 0.3	1.4	19.8	1013
GWD4	12/07/2018	< 0.3	0.4	20.3	1016
	20/07/2018	< 0.3	1.1	20.2	1005
	26/07/2018	< 0.3	1.0	18.0	1005
	02/08/2018	< 0.3	0.7	20.1	1013
GWD5	12/07/2018	< 0.3	0.9	19.3	1016
	20/07/2018	< 0.3	2.1	20.0	1004
	26/07/2018	< 0.3	1.4	18.8	1006
	02/08/2018	< 0.3	2.5	19.5	1013
GWD6	12/07/2018	< 0.3	< 0.3	19.7	1016
	20/07/2018	< 0.3	0.8	19.8	1004
	26/07/2018	< 0.3	1.0	18.3	1006
	02/08/2018	< 0.3	2.1	19.7	1008
GWD7	12/07/2018	< 0.3	< 0.3	20.3	1016
	20/07/2018	< 0.3	0.3	> 20.9	1004
	26/07/2018	< 0.3	0.4	19.0	1006
	02/08/2018	0.4	1.2	20.1	1013
GWD8	12/07/2018	< 0.3	< 0.3	20.7	1013
	20/07/2018	< 0.3	0.3	> 20.9	1002
	26/07/2018	< 0.3	0.4	19.4	1002
	02/08/2018	< 0.3	0.5	19.7	1011
GWS1	12/07/2018	< 0.3	< 0.3	> 20.9	1012
	20/07/2018	< 0.3	0.4	> 20.9	1003
	26/07/2018	< 0.3	0.5	19.8	1002
	02/08/2018	< 0.3	0.6	19.9	1010
GWS2	12/07/2018	< 0.3	< 0.3	20.6	1015
	20/07/2018	< 0.3	0.5	20.6	1004
	26/07/2018	< 0.3	0.4	19.4	1005
	02/08/2018	< 0.3	0.4	20.2	1013
GWS3	12/07/2018	< 0.3	< 0.3	20.3	1016
	20/07/2018	< 0.3	0.8	20.1	1005
	26/07/2018	< 0.3	0.5	18.3	1005
	02/08/2018	< 0.3	1.5	18.9	1014
GWS5	12/07/2018	< 0.3	< 0.3	20.6	1016
	20/07/2018	< 0.3	< 0.3	21.7	1004
	26/07/2018	< 0.3	< 0.3	19.2	1006
	02/08/2018	< 0.3	< 0.3	20.9	1014

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 each monitoring occasion the borehole GWD1 was flooded and no measurements could be taken.

Table A2 SEPA walkover methane measurements from the landfill's perimeter and at selected 'spot sample' locations

Location	Methane (ppm)				Comments
	12/07/2018	20/07/2018	26/07/2018	02/08/2018	
GWD1	<5	10	12	<5	
GWD2	20	<5	<5	9	
GWD3	<5	18	<5	<5	
GWD4	<5	<5	<5	<5	
GWD5	<5	<5	<5	<5	
GWD6	<5	<5	<5	<5	
GWD7	<5	<5	100	<5	
GWD8	<5	<5	<5	<5	
GWS1	<5	<5	<5	<5	
GWS2	<5	20	<5	<5	
GWS3	<5	<5	<5	<5	
GWS5	<5	700	13	<5	
SS1	<5	-	-	-	
SS2	<5	*5000	*55000	*750	*Above bubbling puddle / leachate breakout. Near GWD1.
SS3	<5	-	-	-	
SS4	20	-	-	-	
SS5	29000	Not measured	50	159000	Above bubbling puddle / leachate breakout. Near GWD2.
SS6	<5	-	-	-	
SS7	<5	-	-	-	
SS8	<5	-	-	-	
SS9	<5	-	-	-	
SS10	<5	-	-	-	
SS11	<5	-	-	-	
SS12	1000	-	-	-	Near in-waste gas well. On landfill waste mass (i.e. not on perimeter).
SS13	6000	-	-	-	Near broken landfill gas pipe connection. On landfill waste mass (i.e. not on perimeter).
SS14	<5	-	-	-	
SS15	<5	-	-	-	
SS16	<5	-	-	-	
SS17	<5	-	-	-	
SS18	<5	-	-	-	
SS19	200	-	-	-	Small hole/fissure in landfill capping soil proximate to leachate well LW17
SS20	1000	-	-	-	At gap in liner near leachate well LW09. On landfill waste mass (i.e. not on perimeter).

Note: 1% v/v methane = 10000 ppm methane. SS denotes 'Spot Sample'. Laser methane detector zero has 5ppm tolerance, hence readings below 5ppm should be considered below detection limit

Table A3 Gas measurements at the two Tarbolton Landfill gas manifolds and the non-operational gas flare

Gas Manifold Line	Date	Methane	Carbon Dioxide	Oxygen	Carbon Monoxide	Hydrogen Sulphide	Atm. Pressure
		% v/v	% v/v	% v/v	ppm	ppm	mb
M1A	03/08/2018	39.2	14.6	9.2	3	310	1012
M6	03/08/2018	35.0	13.3	10.2	6	372	1013
M4	03/08/2018	> 50	25.3	0.2	14	954	1013
MA2	03/08/2018	> 50	22.0	0.9	17	703	1013
MA7	03/08/2018	20.4	7.6	13.6	15	171	1014
MA8	03/08/2018	17.5	5.7	13.6	11	46	1015
MA9	03/08/2018	> 50	16.0	0.6	11	51	1015
MA10	03/08/2018	16.2	5.7	14.3	8	15	1015
MA1	03/08/2018	17.2	5.6	14.5	7	82	1015
M210	03/08/2018	> 50	26.6	0.4	5	35	1013
M211	03/08/2018	> 50	26.5	0.7	6	36	1013
M212	03/08/2018	49.7	24.2	0.3	5	167	1013
M218	03/08/2018	> 50	25.4	0.5	7	75	1013
Flare	03/08/2018	0.1	0.4	20.6	4	12	1016

Appendix B Surface water tables and graphs

Table B1 Concentration of chemicals in the three leachate lagoons, sampled 25 July 2018

Chemical	Lined lagoon	Unlined Lagoon 1	Unlined Lagoon 2
Ammoniacal Nitrogen (mg/l)	625.8	252.4	208.34
pH (pH Units)	7.5	8	7.9
Cyanide (mg/l)	<0.1	<0.1	<0.1
sulphate (mg/l)	29.3	<8.28	<8.28
Sulphide (mg/l)	1.45	<0.1	<0.1
Suspended soilids (mg/l)	300	213	97
Biohemical Oxygen Demand (mgO_2/l)	<450	<65	<50
Settled Biohemical Oxygen Demand (mgO_2/l)	<450	<50	<40
Chemical Oxygen Demand (mgO_2/l)	3230	584	499
Settled Chemical Oxygen Demand (mgO_2/l)	3240	522	431
TPH(C_{10}-C_{40}) (mg/l)	0.69	0.23	0.3
TPH(C_8-C_{10}) (mg/l)	0.05	0.04	0.06
TPH(C_8-C_{40}) (mg/l)	0.74	0.26	0.35

Note that the reported analysis was carried out by Scottish Water. Settled BOD or COD as the name suggests is the analysis of the sample after the sample has been left to settle for one hour. The liquid portion is then analysed.

Table B2 Concentration of landfill indicator chemicals in the three pipes discharging into the eastern boundary field drain, sampled 25 July 2018

Determinand	Discharge pipe (1) to East field drain (Ref 559390)	Discharge pipe (2) to East field drain (Ref 559391)	Discharge pipe from cell 3 lagoon to East field drain (Ref 559392)
Ammoniacal Nitrogen (mg/l)	268	57.8	332
pH (pH Units)	7.2	7.1	7.6
Chloride (mg/l)	4,780	2,070	6,530
Electrical conductivity (25°C) (µS/cm)	15,200	7,840	21,200

Table B3 Concentration of total metals in the three pipes discharging into the eastern boundary field drain, sampled 25 July 2018

Determinand	Discharge pipe (1) to East field drain (Ref 559390)	Discharge pipe (2) to East field drain (Ref 559391)	Discharge pipe from cell 3 lagoon to East field drain (Ref 559392)
Aluminium (µg/l)	134	1,950	449
Arsenic (µg/l)	<20	<20	24.2
Cadmium (µg/l)	5.58	5.05	7.94
Chromium (µg/l)	72.2	122	438
Copper (µg/l)	56.9	227	275
Iron (µg/l)	1,690	48,900	2,020
Lead (µg/l)	37.1	118	108
Manganese (µg/l)	1,950	4,400	2,240
Nickel (µg/l)	129	198	185
Vanadium (µg/l)	8.73	26	62.9
Zinc (µg/l)	198	443	732

Table B4 Concentration of landfill indicator chemicals in the eastern boundary field drain and Biggary Burn, sampled as indicated

Determinand	Site 1	Site 2	Site 3	Site 4	Site 4	Site 5	Site 6	Site 7
	u/n w/c at track, N of Tarbolton Landfill (Ref 559389)	East field drain, 180m u/s of Biggary Burn conf, Tarbolton Landfill (Ref 559393)	East field drain, 170m u/s of Biggary Burn conf, Tarbolton Landfill (Ref 559397)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Biggary Burn, u/s of field drain conf, E of Tarbolton Landfill (Ref 101299)	Biggary Burn,d/s of field drain conf, E of Tarbolton Landfill (Ref 559245)	Biggary Burn at footbridge, 250m d/s of East field drain conf (Ref 559394)
Ammoniacal Nitrogen (mg/l)	674	67.7	194	52.5	61.6	0.1	14.1	14.7
pH (pH Units)	7.9	7.9	7	8	8	8	8.03	7.5
Chloride (mg/l)	7,350	1,530	21,400	1,270	1,350	17	361	364
Electrical conductivity (25°C) (µS/cm)	23,900	5,360	56,600	4,490	4,950	268	1,510	1,500
Sampled	25-Jul-18	25-Jul-18	25-Jul-18	25-Jul-18	26-Jul-18	26-Jul-18	26-Jul-18	25-Jul-18

Table B5 Concentration of total metals in the eastern boundary field drain and Biggary Burn, sampled as indicated

Determinand	Site 1	Site 2	Site 3	Site 4	Site 4	Site 5	Site 6	Site 7
	u/n w/c at track, N of Tarbolton Landfill (Ref 559389)	East field drain, 180m u/s of Biggary Burn conf, Tarbolton Landfill (Ref 559393)	East field drain, 170m u/s of Biggary Burn conf, Tarbolton Landfill (Ref 559397)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Biggary Burn, u/s of field drain conf, E of Tarbolton Landfill (Ref 101299)	Biggary Burn,d/s of field drain conf, E of Tarbolton Landfill (Ref 559245)	Biggary Burn at footbridge, 250m d/s of East field drain conf (Ref 559394)
Aluminium (µg/l)	336	983	1,120	1,820	997	3,580	2,420	433
Arsenic (µg/l)	23.5	<20	<40	<20	<20	<2.0	3.08	<20
Cadmium (µg/l)	0.626	1.76	7.15	1.65	1.44	0.058	0.503	0.415
Chromium (µg/l)	171	54.2	16.5	52.8	73.2	5.3	21.8	13.7
Copper (µg/l)	44.5	51.3	218	64.1	43.7	3.86	19.7	14
Iron (µg/l)	5,140	3,930	24,700	6,610	3,890	5,930	6,170	2,030
Lead (µg/l)	20.5	42.7	38.9	70.2	37.1	3.96	25	12.8
Manganese (µg/l)	1,350	874	9,500	699	696	151	316	275
Nickel (µg/l)	116	46.6	111	44.4	42.7	5.5	14	12.8
Vanadium (µg/l)	86.6	9.91	11.9	14.9	9.23	8.14	6.24	4.52
Zinc (µg/l)	90.6	160	195	209	164	14.5	71.6	49.4
Sampled	25-Jul-18	25-Jul-18	25-Jul-18	25-Jul-18	26-Jul-18	26-Jul-18	26-Jul-18	25-Jul-18

Table B6 Concentration of landfill indicator chemicals in on site drains leading to the Biggary Burn, sampled 25 July 2018

Determinand	Leachate at track, SE of Tarbolton Landfill (Ref 559398)	U/T of Biggary Burn, u/s of track, SE of Tarbolton Landfill (Ref 559396)	U/T of Biggary Burn at track, SE of Tarbolton Landfill (Ref 559395)	d/s of leachate lagoons, S of Tarbolton Landfill (Ref 559388)
Ammoniacal Nitrogen (mg/l)	67.5	212	236	268
pH (pH Units)	7.5	7.8	7.9	8
Chloride (mg/l)	2,080	4,680	1,460	1,660
Electrical conductivity (25°C) (µS/cm)	6,840	15,000	6,700	7,670

Table B7 Concentration of total metals in on site drains leading to the Biggary Burn, sampled 25 July 2018

Determinand	Leachate at track, SE of Tarbolton Landfill (Ref 559398)	U/T of Biggary Burn, u/s of track, SE of Tarbolton Landfill (Ref 559396)	U/T of Biggary Burn at track, SE of Tarbolton Landfill (Ref 559395)	U/T of Biggary Burn, d/s of leachate lagoons, S of Tarbolton Landfill (Ref 559388)
Aluminium (µg/l)	1,870	728	87.2	1,120
Arsenic (µg/l)	<20	<20	<20	<20
Cadmium (µg/l)	<0.400	0.571	<0.400	<0.400
Chromium (µg/l)	11.7	23.6	7.28	10.3
Copper (µg/l)	13.4	82	<3.50	8.47
Iron (µg/l)	6,220	7,120	4,550	10,400
Lead (µg/l)	8	21.9	<2.00	14.5
Manganese (µg/l)	1,440	1,740	394	504
Nickel (µg/l)	35.8	87.6	25.6	32.4
Vanadium (µg/l)	7.92	5.93	<4.00	6.94
Zinc (µg/l)	29.5	177	<19	37

Table B8 Comparison of landfill indicator chemicals from site drains leading to the Biggary Burn

Determinand	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	U/T of Biggary Burn, d/s of leachate lagoons, S of Tarbolton Landfill (Ref 559388)
Ammoniacal Nitrogen (mg/l)	52.5	61.6	268
pH (pH Units)	8	8	8
Chloride (mg/l)	1,270	1,350	1,660
Electrical conductivity (25°C) (µS/cm)	4,490	4,950	7,670
Sampled	25-Jul-18	26-Jul-18	25-Jul-18

Table B9 Comparison of total metals from site drains leading to the Biggary Burn

Determinand	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref 559244)	U/T of Biggary Burn, d/s of leachate lagoons, S of Tarbolton Landfill (Ref 559388)
Aluminium (µg/l)	1,820	997	1,120
Arsenic (µg/l)	<20	<20	<20
Cadmium (µg/l)	1.65	1.44	<0.400
Chromium (µg/l)	52.8	73.2	10.3
Copper (µg/l)	64.1	43.7	8.47
Iron (µg/l)	6,610	3,890	10,400
Lead (µg/l)	70.2	37.1	14.5
Manganese (µg/l)	699	696	504
Nickel (µg/l)	44.4	42.7	32.4
Vanadium (µg/l)	14.9	9.23	6.94
Zinc (µg/l)	209	164	37
Sampled	25-Jul-18	26-Jul-18	25-Jul-18

Table B10 Surface water sampling locations

Map Reference*	Code	Sampling Point Description	National Grid Reference	Temporal SEPA data range
2	559244	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf	NS 43310 28577	July 2018
1	101299	Biggary Burn, u/s of field drain conf, E of Tarbolton Landfill Ayr	NS 43472 28570	July 2018
3	559245	Biggary Burn, d/s of field drain conf, E of Tarbolton Landfill Ayr	NS 43300 28562	July 2018
4	559394	Biggary Burn at footbridge, 250m d/s of East field drain conf (Ref 559394)	NS 43102 28438	July 2018
5	554744	Biggary Burn, 50m upstream of Water of Fail confluence (SW4)	NS 42947 28226	Spring 2018
6	**122046**	**Water of Fail at Fail Toll**	**NS 42180 28690**	**1976 to 2006 Summer 2018**
7	554743	Water of Fail, 50m upstream of Biggary Burn confluence (SW3)	NS 42920 28223	Spring 2018
8	**554745**	**Water of Fail, upstream of Red Rose Way (SW5)**	**NS 42967 27728**	**Spring & Summer 2018**
9	**122048**	**Water of Fail at Willie's Mill**	**NS 43430 27700**	**1976 to 2006 Summer 2018**

* Number refers to marker in Appendix B Figure 10

Table B11 Surface water sample results

Determinand	Location name	Average	Minimum	Maximum	Count
Ammoniacal nitrogen (mg/l)	Water of Fail at Fail Toll (ref 122046)	0.2	0.1	0.3	4
Ammoniacal nitrogen (mg/l)	Water of Fail, 50m u/s of Biggary Burn conf (ref 554743)	3.1			1
Ammoniacal nitrogen (mg/l)	Water of Fail, u/s of Red Rose Way (ref 554745)	2.1	1.0	4.6	7
Ammoniacal nitrogen (mg/l)	Water of Fail at Willie's Mill (ref 122048)	1.3	0.7	1.8	3
Chloride (mg/l)	Water of Fail at Fail Toll (ref 122046)	44	42	48	4
Chloride (mg/l)	Water of Fail, 50m u/s of Biggary Burn conf (ref 554743)	47			1
Chloride (mg/l)	Water of Fail, u/s of Red Rose Way (ref 554745)	64	49	72	7
Chloride (mg/l)	Water of Fail at Willie's Mill (ref 122048)	68	63	72	3
Electrical Conductivity (µS/cm)	Water of Fail at Fail Toll (ref 122046)	519	494	538	4
Electrical Conductivity (µS/cm)	Water of Fail, 50m u/s of Biggary Burn conf (ref 554743)	508			1
Electrical Conductivity (µS/cm)	Water of Fail, u/s of Red Rose Way (ref 554745)	607	560	653	7
Electrical Conductivity (µS/cm)	Water of Fail at Willie's Mill (ref 122048)	615	553	656	3
pH (pH units)	Water of Fail at Fail Toll (ref 122046)	7.9	7.8	8.1	4
pH (pH units)	Water of Fail, 50m u/s of Biggary Burn conf (ref 554743)	7.7			1
pH (pH units)	Water of Fail, u/s of Red Rose Way (ref 554745)	7.9	7.7	8.3	7
pH (pH units)	Water of Fail at Willie's Mill (ref 122048)	7.8	7.7	7.9	3

Table B12 Effect of electrical conductivity on quality of drinking water for farm animals.

Electrical Conductivity (µS/cm)	Rating	Remarks
<1500	Excellent	Usable for all classes of livestock and poultry.
1500 – 5000	Very Satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhoea in livestock not accustomed to such water; watery droppings in poultry.
5000 – 8000	Satisfactory for Livestock	May cause temporary diarrhoea or be refused at first by animals not accustomed to such water.
	Unfit for Poultry	Often causes watery faeces, increased mortality and decreased growth, especially in turkeys.
8000 – 11000	Limited Use for Livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for Poultry	Not acceptable for poultry.
11000 – 16000	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16000	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: Water quality for agriculture; FAO IRRIGATION AND DRAINAGE PAPER 29 Rev. 1 (ISBN 92-5-102263-1)

Table B13 Acceptable limits for toxic components for drinking water for farm animals including footnotes as published.

Constituent	Upper Limit (mg/l)
Aluminium	5
Arsenic	0.2
Beryllium[1]	0.1
Boron	5
Cadmium	0.05
Chromium	1
Cobalt	1
Copper	0.5
Fluoride	2
Lead[2]	0.1
Manganese[3]	0.05
Mercury	0.01
Nitrate + Nitrite (as N)	100
Nitrite (as N)	10
Selenium	0.05
Vanadium	0.1
Zinc	24

1 Insufficient data for livestock. Value for marine aquatic life is used here.
2 Lead is accumulative and problems may begin at a threshold value of 0.05 mg/l.
3 Insufficient data for livestock. Value for human drinking water used.
Source: Water quality for agriculture; FAO IRRIGATION AND DRAINAGE PAPER 29 Rev. 1 (ISBN 92-5-102263-1)

Table B14 Risk assessment for quality of drinking water to farm animals from the various sampling points on the surface ditch to the East of the landfill site, the Biggary Burn and the Water of Fail

Parameter	Limit (mg/l)	Field drain, E of Tarbolton Moss Landfill, u/s of Biggary Burn conf (Ref		Biggary Burn,d/s of field drain conf, E of Tarbolton Landfill (Ref 559245)		Biggary Burn at footbridge, 250m d/s of East field drain conf (Ref 559394)		Biggary Burn, 50m u/s of Water of Fail conf (Ref 554744)		Water of Fail, 50m u/s of Biggary Burn conf (Ref 554743)		Water of Fail, u/s of Red Rose Way (Ref 554745)		Water of Fail at Willie's Mill (Ref 122048)	
		Concentration	% of limit	Concentration	% of limit	Concentration	% of limit	Concentration	% of limit	Concentration	% of limit	Concentration	% of limit	Concentration	% of limit
Electrical Conductivty (µs/cm)	5000	4,720	94	1,510	30	1,500	30	1,049	21	508	10	607	12	615	12
Magnesium	250	na	na	23.3	9	na	na	19.9	8	14	6	15.5	6	na	na
Aluminium	5	1.41	28	2.42	48	0.433	9	0.185	4	1.7	34	0.949	19	na	na
Arsenic	0.2	0.02	10	0.003	2	0.02	10	0.001	1	0.001	1	0.001	1	na	na
Cadmium	0.05	0.002	4	0.0005	1	0.0004	1	0.00006	<1	0.00005	<1	0.00004	<1	na	na
Chromium	1	0.063	6	0.022	2	0	1	0.003	<1	0.003	<1	0.002	<1	na	na
Copper	0.5	0.054	11	0.02	4	0.014	3	0.004	1	0.007	1	0.005	1	na	na
Fluoride	2	na	na	na	na	na	na	0.158	8	0.171	9	0.178	9	na	na
Lead	0.1	0.054	54	0.025	25	0.013	13	0.002	2	0.001	1	0.001	1	na	na
Manganese	0.05	0.698	1,396	0.316	632	0.275	550	0.302	604	0.298	596	0.274	548	na	na
Mercury	0.01	na	na	na	na	na	na	0.000005	<1	0.000005	<1	0.00001	<1	na	na
Nitrate + Nitrite (as N)	100	4.17	4	1.59	2	na	na	2.92	3	9.8	10	3.63	4	3.48	3
Nitrite (as N)	10	na	na	0.294	3	na	na	0.158	2	0.084	1	0.157	2	0.252	3
Vanadium	0.1	0.012	12	0.006	6	0.005	5	0.002	2	0.003	3	0.003	3	na	na
Zinc	24	0.187	1	0.072	<1	0.049	<1	0.01	<1	0.014	<1	0.012	<1	na	na

Red highlight average concentration measured is > 75 % of the limit
Orange highlight average concentration measured is > 50 % of the limit
na denotes no data
Values are average of 2018 data

Figure B1 Map showing position of leachate wells at the Tarbolton Landfill site

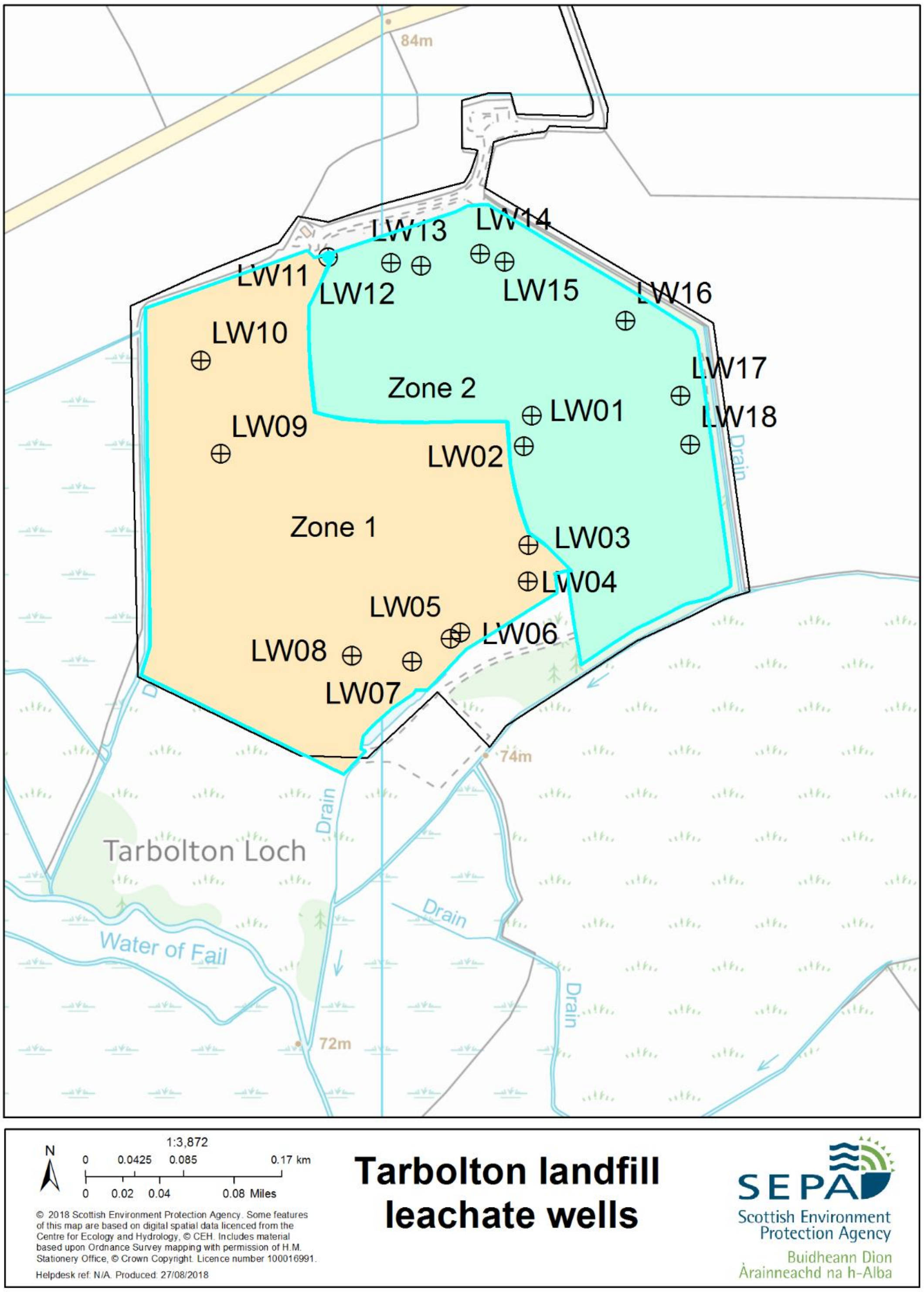
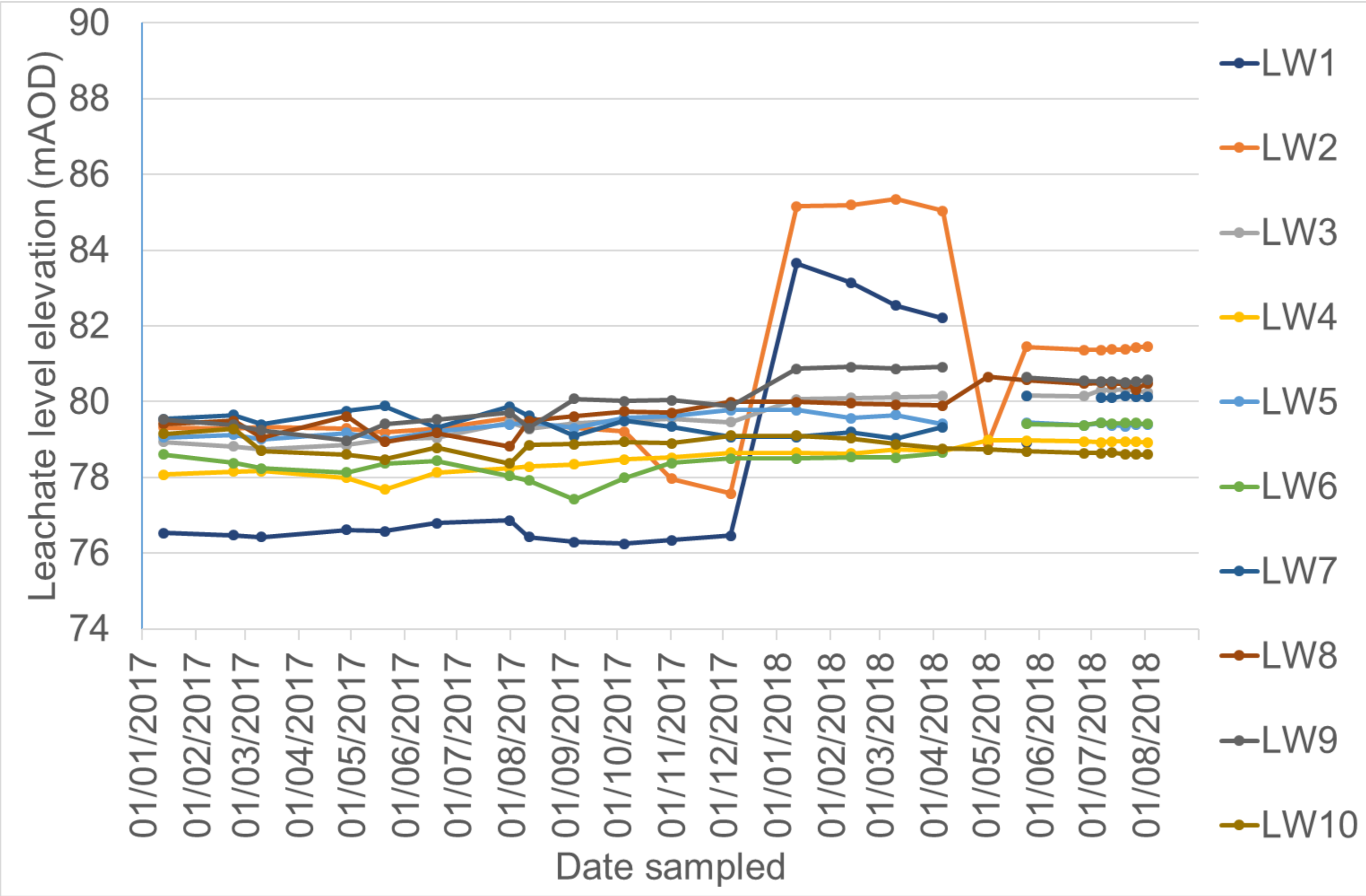
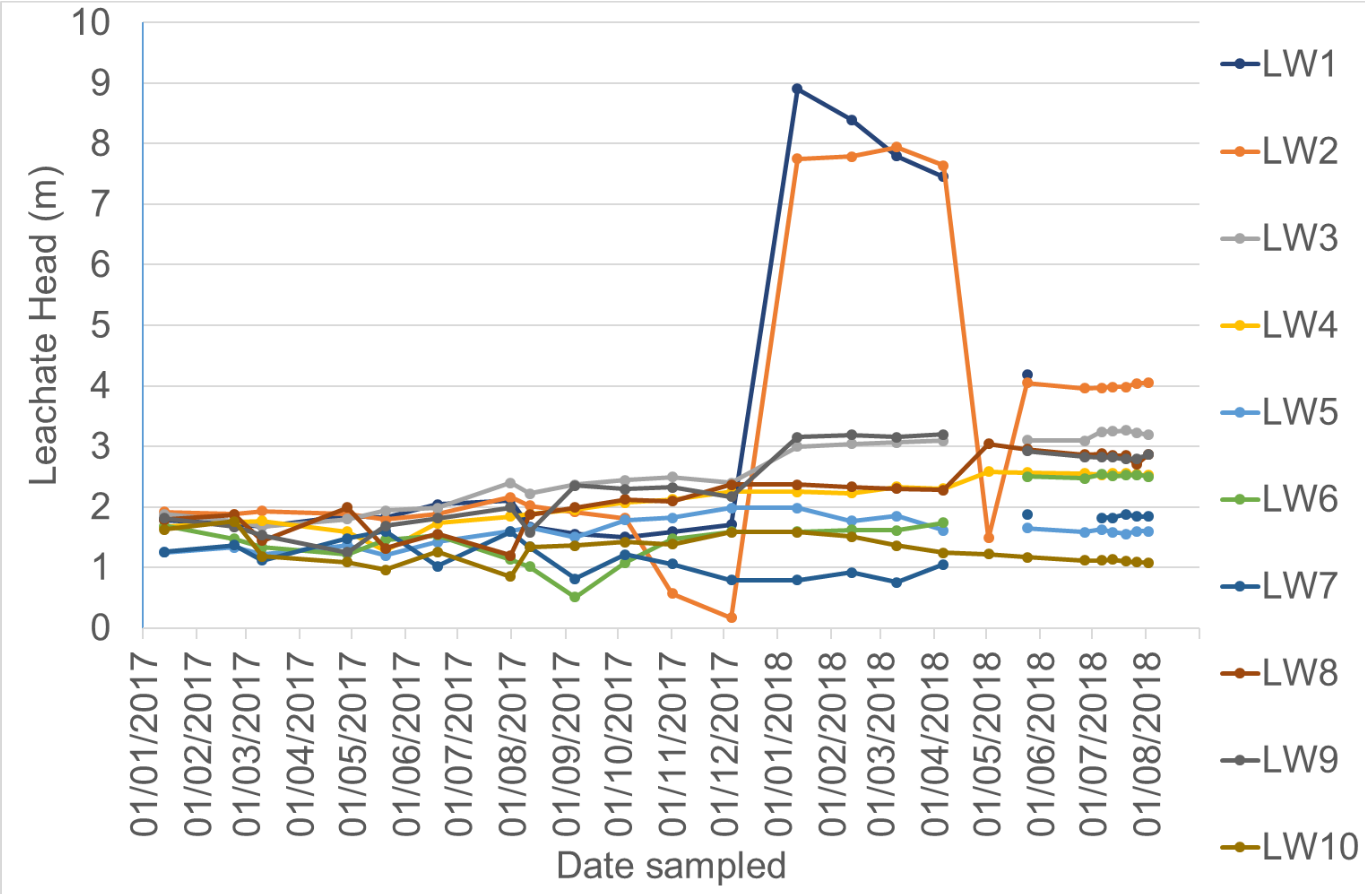


Figure B2 Zone 1 Landfill leachate levels for 2017-2018



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. LW1 is considered unsafe to sample and monitoring has ceased at this point.

Figure B3 Zone 1 Landfill leachate head levels for 2017-2018



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. LW1 is considered unsafe to sample and monitoring has ceased at this point.

Figure B4 Zone 2 Landfill leachate levels for 2017-2018

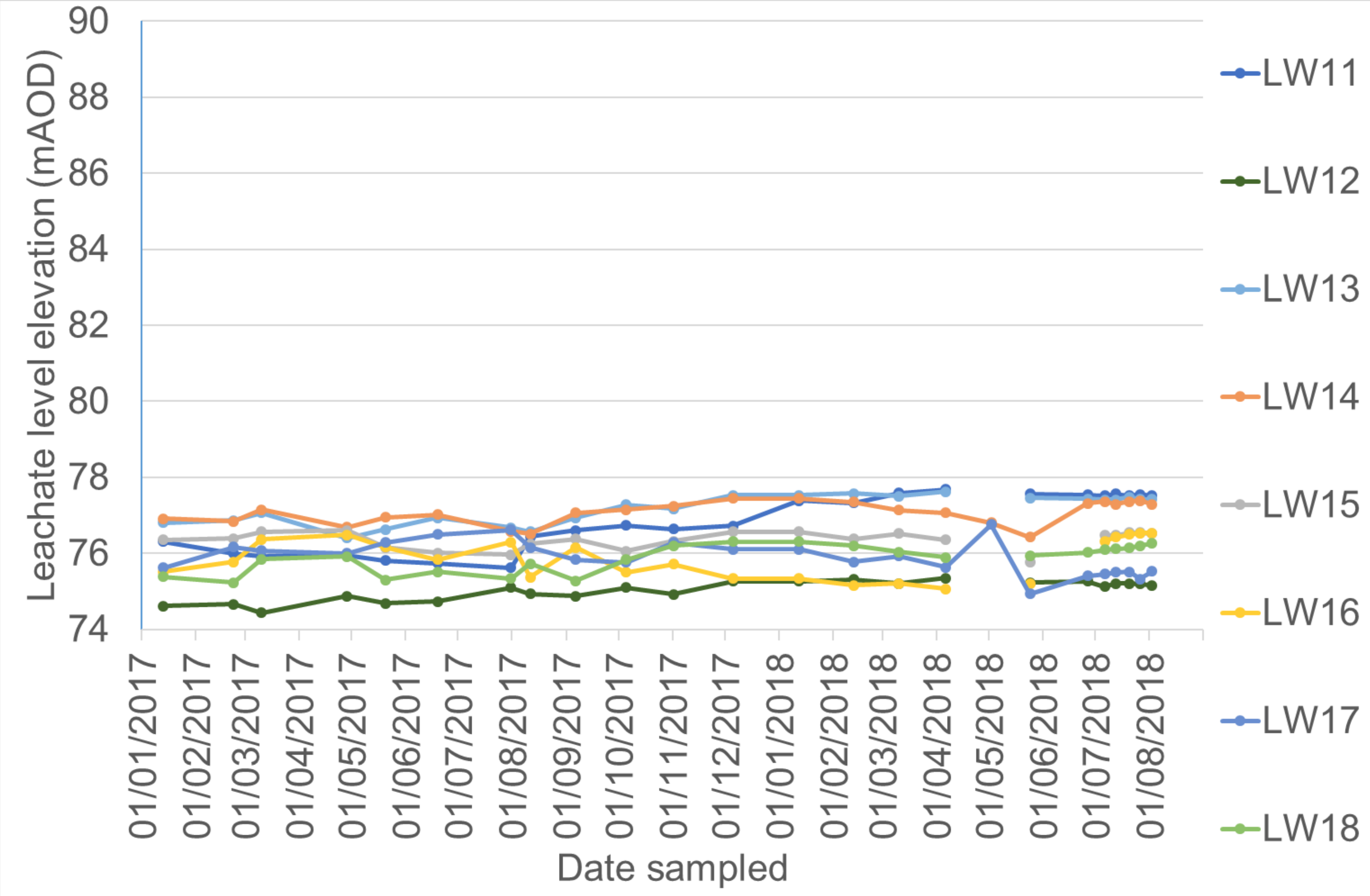


Figure B5 Zone 2 Landfill leachate head levels for 2017-2018

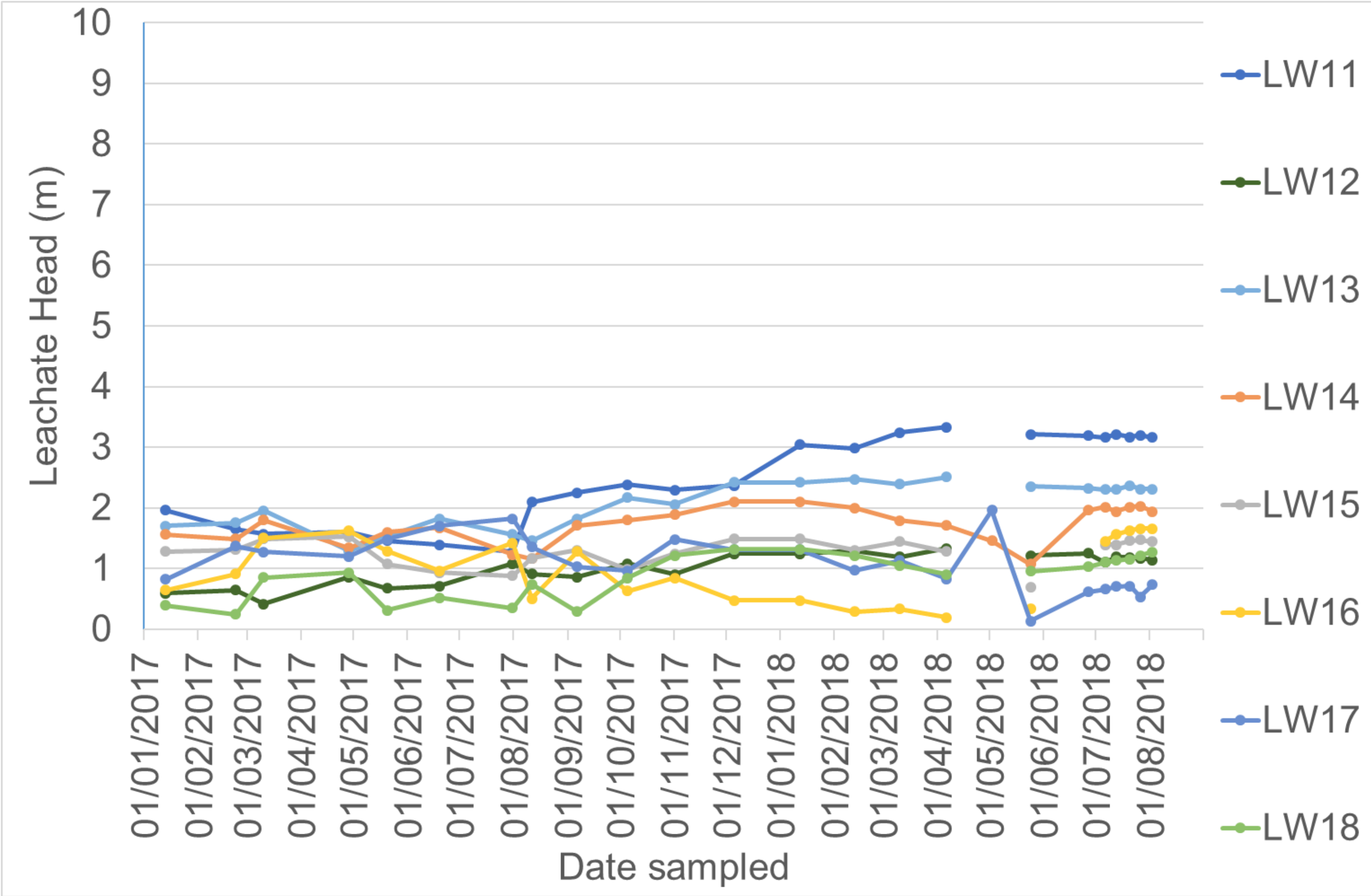


Figure B6 Extents of leachate breakouts at the lagoons and other areas of the site as of 18 June 2018

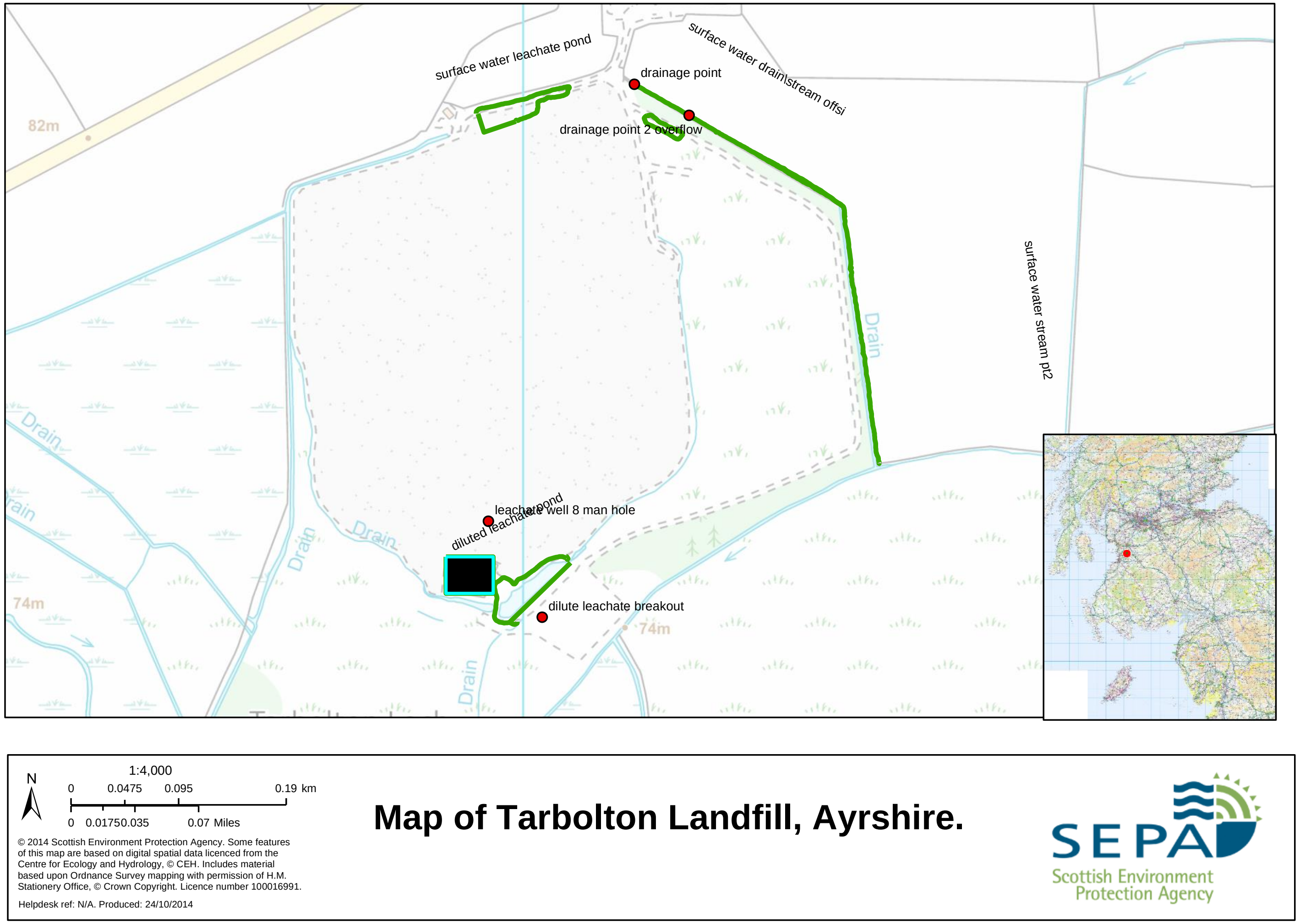


Figure B7 Photograph of leachate lagoons at Tarbolton Landfill site

Figure B8 Map showing monitoring sampling points for leachate and surface water samples. Leachate pond are also shown.

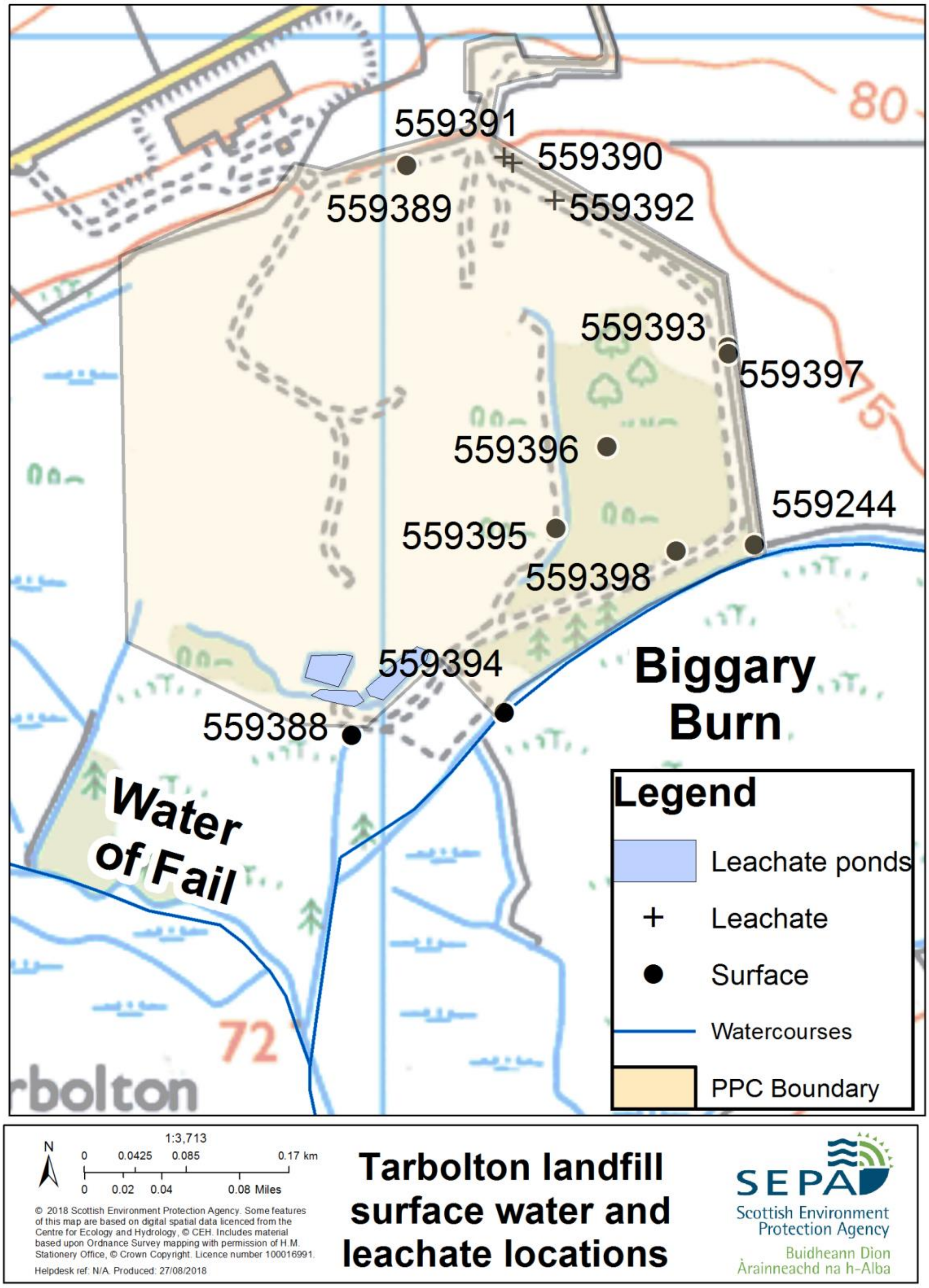


Figure B9 Photograph of surface water ditch showing one of the discharge pipes

Figure B10 Map of surface water locations shown in Table B10.

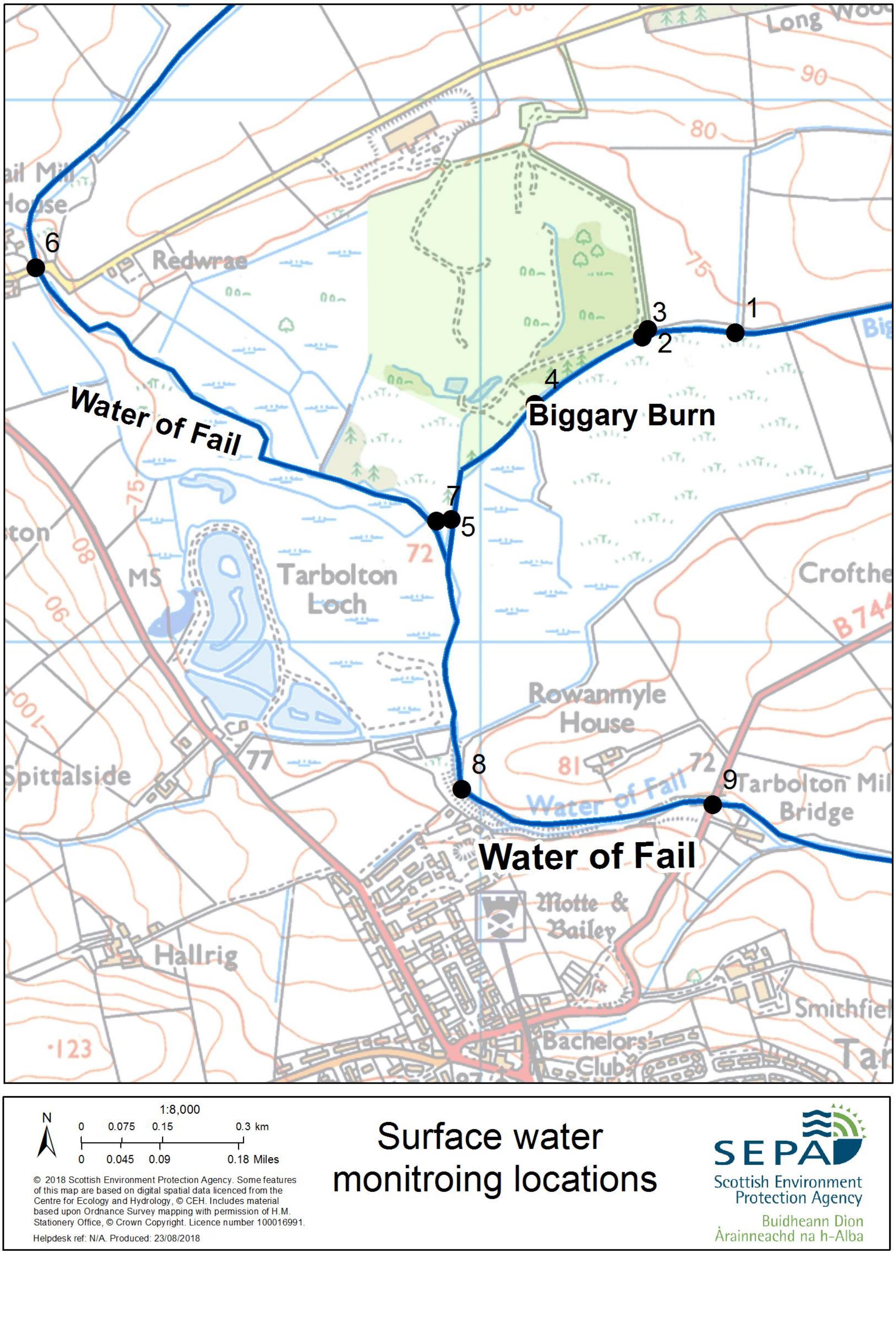


Figure B11 Trends in Ammoniacal nitrogen (mg/l) and electrical conductivity (µs/cm) in the Water of Fail downstream of Tarbolton Landfill (ref 554745)