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Hydrogeological Risk Assessment Review for LLanddulas Landfill, Conwy

Contents

Disclaimer

1. Introduction

LLanddulas Landfill is permitted to 3C Waste Limited, a company name of FCC Environment. It operates under environmental permit reference EPR/BU0800IZ/V011, 2016. The site is permitted to take non-hazardous waste. The last review of the Hydrogeological Risk Assessment (HRA) of the site was undertaken by FCC in 2013 and a further 6 year review is now required.

This report seeks to review the hydrogeological conditions of the site and whether there have been any significant changes in the last six years. The assessment will determine whether the site remains compliant with the conditions of its environmental permit and the Environmental Permitting Regulations. This review assesses the last years of environmental monitoring data together with information contained in the following reports:

- SLR: 2003: LLanddulas Phases 1 and 3, Hydrogeological Risk Assessment. Report reference 4D-197-187/HRA;
- SLR: 2003: Llanddulas Landfill, Phase 2 and 3A. Hydrogeological Risk Assessment. Report 4D-197-126/HRA.
- SLR: 2007: Llanddulas Landfill, North Wales, Hydrogeological Risk Assessment Review. Report reference 404-0197-00552;
- SLR: 2008: Llanddulas Landfill, Conwy, North Wales, Permit Variation Application, Hydrogeological Risk Assessment. Report reference 404-0197-00529/HRA;
- SRL: 2008: Llanddulas Landfill Permit Variation Application, Environmental Setting and Installation Design. Report reference 404-197-00529/ESID;
- FCC: 2013: Llanddulas Landfill, Conwy, Hydrogeological Risk Assessment Review.

2. The Site

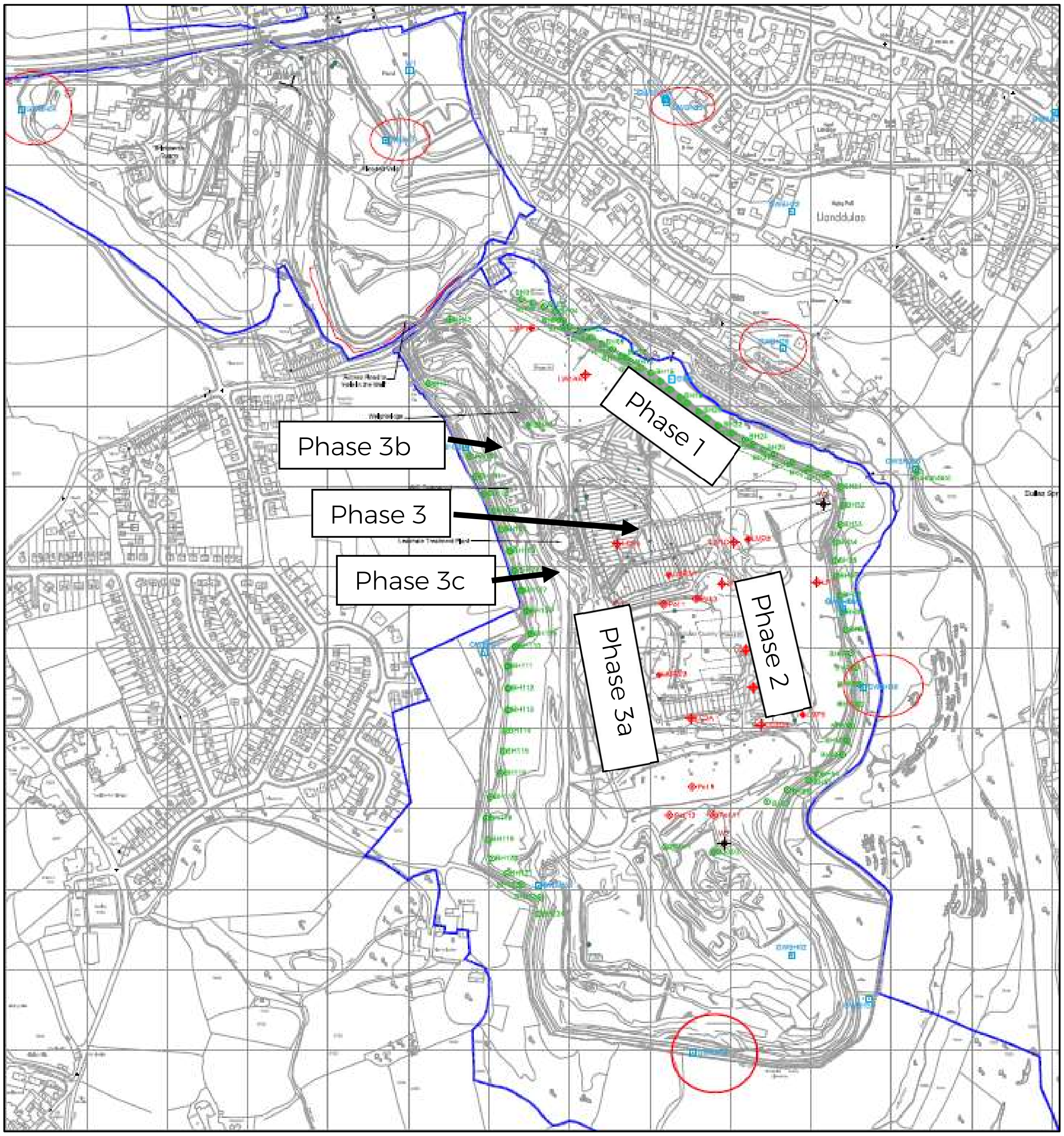
2.1. Location

The site is located on Abergele Road, Llanddulas, Conwy, North Wales, LL22 8HP. It lies to the southwest of Llanddulas village and approximately 2km east of Colwyn Bay, centred on National Grid Reference SH 904 775.

The position of the site is on a hill side which falls steeply towards the coast. Ground levels in the south are around 180m AOD. These fall to the north, with the site entrance being around 120m AOD. The River/Afon Dulas is located approximately 350m east of the site and ground levels drop sharply to approximately 25m AOD along the course of the river.

To the northeast of the site is Llanddulas village and holiday chalets. To the northwest is a further area of quarrying. It contains lagoons that are understood to be used as a source of water for dust suppression. The west of the site is bordered by fields and then further housing, with Plas Farm to the southwest. South of the site is largely agricultural land. The land to the east is wooded as it falls to the Afon Dulas. A Site Plan is presented as Figure 1.

Figure 1: Site Plan (taken from FCC MEPP, Drawing 122M264, 2014)



2.2. Environmental Setting

The site is approximately 600m south of the North Wales Coast and the Liverpool Bay Special Protection Area (SPA). There is a SSSI: Llanddulas Limestone and Gwrych Castle Wood directly east of the site, designated as such based on the limestone grassland, heath and woodland communities. Other environmental features are summarised in Table 1.

Table 1: Local Environmental Features

Receptor	Nature of receptor	Distance from site
Residential/Work-Place/Amenity - up to 250 m	Llanddulas chalet park Residential Plas Farm Residential	50m to NE 150m west 200m SW 200m east
Residential/Work-Place/Amenity - Between 250 and 1000 m	Coast	600m N
Habitats		
Habitats Directive sites	Liverpool Bay SPA	750m north
CROW Act 2000 sites	Llanddulas Limestone and Gwrych Castle Wood SSSI Mynydd Marian SSSI	Adjacent to east 750m west
Other habitat sites	None	
Groundwater		
Aquifer	Clwyd Limestone Group	
Groundwater protection zone	No	
Groundwater abstractions	None licensed within 2km Private: Gwymp Mill Private: Bodhyfryd Hall	 500m SE 500m NE
Surface Water		
Nearest surface water	Afon Dulas, Class A	350m east
Direct runoff from site?	No	
Surface water abstractions	None known	
Wells and springs		
Wells	NGR: SH910 768	500m SE
Springs	Dulas Spring: NGR SH909 777	350m east
Air quality management zone	No	
Flood risk	Not affected by flooding from rivers or sea	

2.3. Site History

In 2003 the northern half of Llanddulas Landfill, comprising phases 1 and 3, were operated under Waste Management Licence No CBC 06. Phases 2 and 3a in the southern half of the site, were separated from the northern half by an inert bund running east to west and were regulated under a separate waste management licence CBC 08. The 2007 HRA reported that the two licences were consolidated in to one permit in 2004.

A valley feature is referred to in the 2008 ESID. This is the area around the east west trending Llysfaen Fault, originally filled with inert waste. The 2008 permit variation sought to vary the waste types to non-hazardous in the western portion. The variation was not successful and final restoration in this area will continue to be inert.

The site in its current state is reaching completion and only part of Phase 3A remains to be capped. Work still remains to infill the valley feature around the Llysfaen Fault.

3. Geology and Hydrogeology

3.1. Geology

3.1.1. Site Geology

The British Geological Survey geology of Britain viewer indicates the western part of the site to be underlain by Glacial Till. No superficial deposits are recorded for the eastern and southeastern areas. A narrow band of Alluvium forms the base of the Afon Dulas valley to the east. The underlying solid geology is recorded as being the Clwyd Limestone Group, of Carboniferous age. The limestones are reported to dip approximately 15 degrees to the north-north-east.

There are two faults which affect the site, the most significant of which is the LLysfaen fault, which separates the north half of the site from the south. It trends approximately east to west at the southern boundary of Phases 1 and 3. The Plas Farm fault also trends east to west close to the southern boundary of the site.

3.2. Hydrogeology

The Carboniferous Limestone is designated as a principal aquifer. Flow within the aquifer is governed by faults and fractures. Tracer tests have been carried out on the west of the site (BH6), in the vicinity of the Llysfaen Fault to investigate flow paths. Results show a direct connection to Dulas Spring to the east of the site. Further tests on the base of the quarry also showed an impact on Dulas Spring, but travel appears to have been more diffuse than from BH6.

Groundwater levels are monitored in 17 boreholes. The environmental permit divides them in to upstream and downstream as follows:

Upstream: GW1, GW2, GWBH32, GWBH33, GWBH34, GWBH35
Downstream: GWBH04, GWBH06R,GWBH07, GWBHs22 to 28 and GWBH36.
Groundwater levels since 2011 are presented in Figures 2 and 3.

Figure 2: Groundwater Levels Upgradient Boreholes

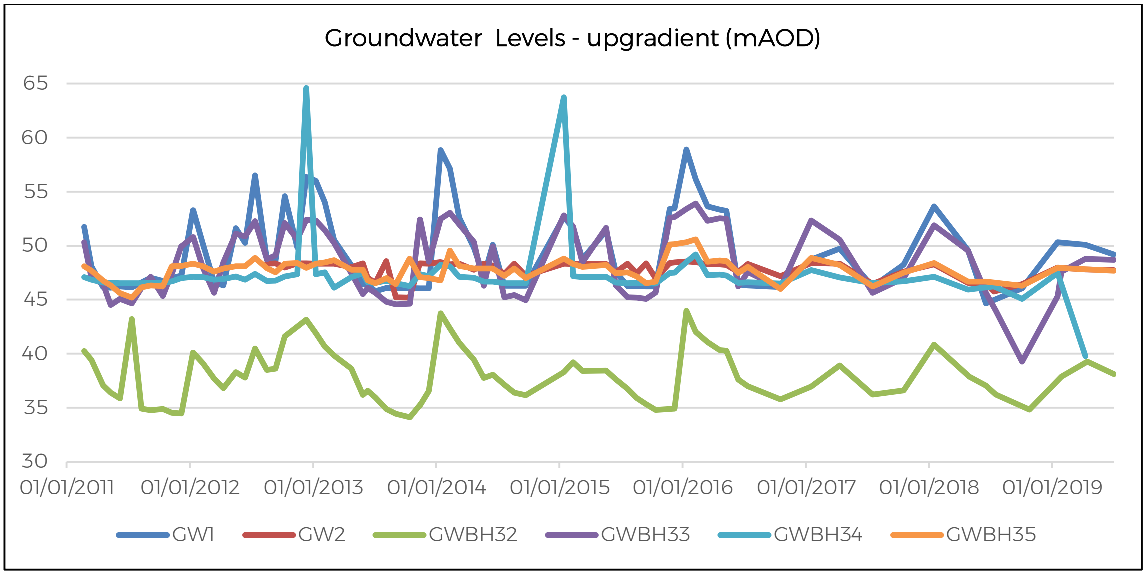
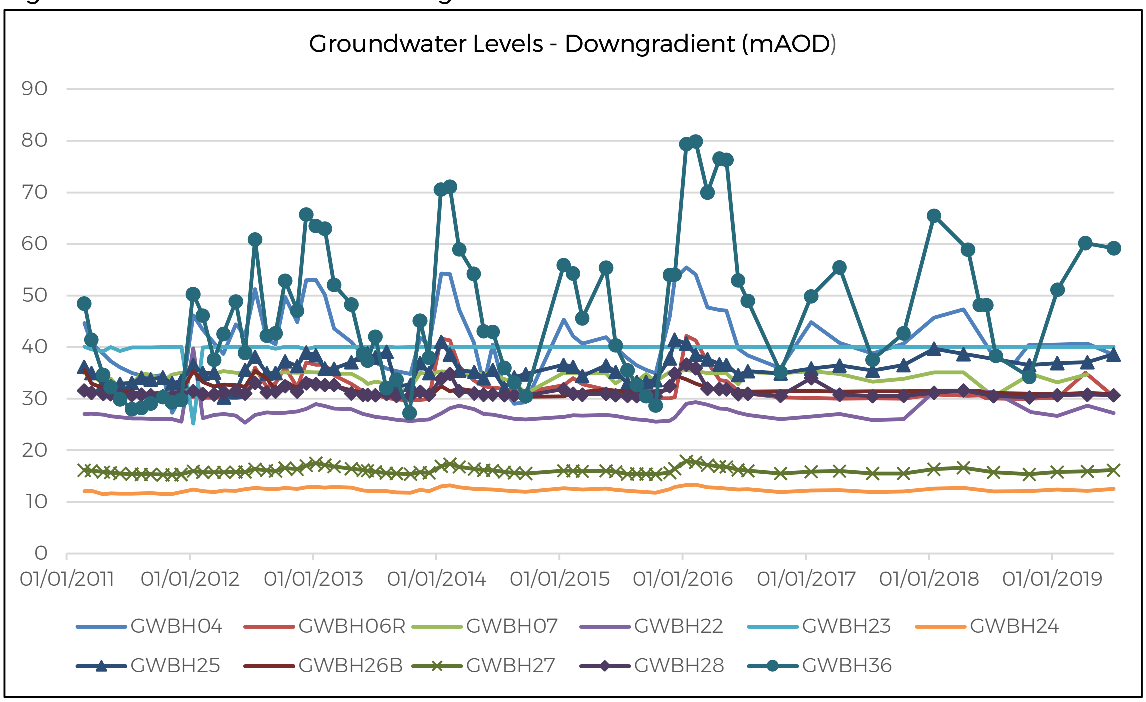


Figure 3: Groundwater Levels Downgradient Boreholes



The graphs of groundwater levels show an approximate average of 45m AOD upgradient and 35m AOD downgradient. Seasonal borehole responses differ and reflect the fact that boreholes intersect different fissure/fracture systems, some of which have greater connectivity with the aquifer as a whole. GWBH23 appears to be permanently flooded. GWBH36 shows annual fluctuations up to 50m. It is interesting to note that in the 2008 ESID groundwater fluctuations of the order of 50m were reported for GWBH06R. Data for the last 10 years shows fluctuations are much reduced in this borehole at around 10m.

Cell bases in Phase 1 are between 110 and 115mAOD. In Phase 2 levels vary between 86 and 90m AOD. Phase 3 levels are between 96.5 and 98m AOD and in Phase 3A levels are around 89.5mAOD. The 2003 HRA reported the unsaturated zone below the site to be more than 30m thick.

Data from 2004 was used to derive a range of hydraulic gradients between 0.016 and 0.037. Hydraulic gradients used in the 2007 assessments of the site were approximately 0.033 for Phase 1 and 3. For Phase 2 and 3A a value of around 0.006 was used.

The 2007 HRA reports there to be no licensed abstractions in the vicinity of the site. The nearest licensed abstraction is reported to be at a distance of 9km. The 2008 ESID reports private abstractions at Gwymp Mill (NGR SH 909 768) approximately 500m southeast of the site and at Bodhfryd Hall (NGR SH 906 782) approximately 500m northeast of the site.

3.3. Hydrology

The closest surface water course is the Afon Dulas, which flows from south to north approximately 350m east of the site. The 2008 ESID describes the river quality as Class A, (very good) for 2006. It had previously been Class C in 2000 – 2002. There is no direct discharge to the river. Site surface water is dealt with by a number of infiltration basins.

There are a number of wells and springs along the course of the Afon Dulas including wells to the south east of the site on the eastern side of the river, approximate National Grid Reference SH910 768 and a spring directly east on the western/landfill side of the river at approximate National Grid Reference SH909 777. This is Dulas Spring as discussed above. Flow at the spring at recorded by v-notch weir as between 3 and 60 l/s.

4. Review of Conceptual Hydrogeological Site Model

4.1. Source

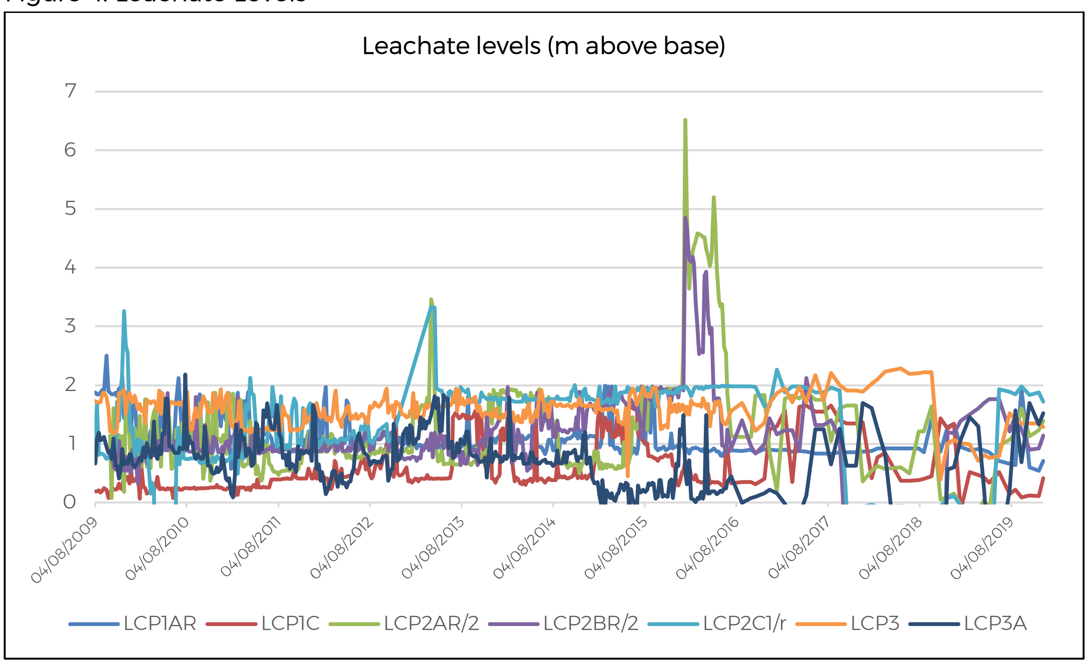
4.1.1. Leachate Level

The control of leachate level in a particular cell is affected by the nature of the leachate drainage system. In Phase 3 both leachate pipes and gravel were installed, with a basal gradient of 1 in 50. In Phase 1 the leachate drainage is reported to be less well developed. Phase 2 and 3A are assumed to incorporate a gravel drainage blanket of permeability not less than 1 x 10^{-3} m/s and pipework, with a fall of not less than 1 in 50, as modelled in the HRA.

The 2003 HRA modelled leachate heads of up to 2m above the cell base for Phase 1 and 3. For Phase 2 and 3A up to a 5m head of leachate was modelled. The current leachate compliance limit is 2m above the cell base. Higher leachate heads – up to 10 m in Phase 2 and 3A and up to 20m in Phase 1 and 3, were modelled in the 2007 HRA.

At a meeting with the Environment Agency on 1 August 2019 it was reported that leachate levels were 100% compliant. Figure 4 illustrates that apart from very occasional spikes leachate levels are very consistent across the site and well controlled to 2m above base, or less.

Figure 4: Leachate Levels



Leachate is treated in a leachate treatment plant adjacent to Phase 3 and from there it is sent to sewer.

4.1.2. Leachate Quality
4.1.2.1. HAZARDOUS SUBSTANCES

The original source term was defined by SLR in 2003, who modelled mecoprop and mercury as hazardous substances. In 2018 the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) reassessed substances and mecoprop is no longer considered as hazardous, however, lead, previously assessed as a non-hazardous substance, is now considered as hazardous by JAGDAG.

This assessment considers the hazardous substances mercury and lead within the leachate. Concentrations from January 2013 to date are summarised in the tables below.

Table 2: Leachate Lead Concentrations (mg/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	20	20	20	20	20	19	27
n>LOD	6	4	1	2	5	9	4
Min	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Mean	0.010	0.013	0.010	0.011	0.014	0.016	0.011
Max	0.021	0.04	0.01	0.036	0.063	0.037	0.036

Table 3: Leachate Mercury Concentrations (ug/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	20	20	20	20	20	18	27
n>LOD	1	1	2	3	2	1	2
Min	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mean	0.011	0.015	0.066	0.115	0.116	0.123	0.089
Max	0.03	0.065	1	1	1	1	1

Table 4 compares the recent data with that from previous HRAs.

Table 4: Comparison of Hazardous Substances between Reviews

	Original HRA		1st Review		2013 HRA			2019 HRA		
	Min	Max	Min	Max	Min	Mean	Max	Min	Mean	Max
Lead (mg/l)	0.002	12	0.0025	0.097	0.0005	0.0097	0.163	<0.001	0.012	0.063
Mercury (ug/l)	0.1	110	0.05	1.8	<0.01	0.14	1.59	<0.005	0.076	1

The data shows that hazardous substance concentrations have decreased since the 2013 HRA and are significantly lower than the original source term.

4.1.2.2. NON-HAZARDOUS POLLUTANTS

SLR, 2003 modelled ammoniacal nitrogen and chloride as non-hazardous pollutants. Also considered in 2003 were copper, zinc and lead. The key non-hazardous pollutants assessed for this review are ammoniacal nitrogen, chloride and mecoprop. An assessment of copper and zinc is also included to determine whether there continues to be sufficient concentration of each to assess in future HRA reviews.

Table 5: Leachate Ammoniacal Nitrogen Concentrations (mg/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	20	20	20	20	20	19	27
Min	38.6	568	844	1140	1230	1110	1320
Mean	281	1071	1441	1614	1991	1520	2255
Max	559	1480	2740	2120	2720	2490	3090

Table 6: Leachate Chloride Concentrations (mg/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	20	20	20	20	20	19	27
Min	191	1870	1710	2380	1930	1250	361
Mean	964	2538	2584	3177	3159	1801	2243
Max	2550	3130	4480	3720	4300	2770	2730

Table 7: Leachate Copper Concentrations (dissolved mg/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	5	5	5	6	6	2	6
n>LOD	5	3	4	4	5	1	5
Min	0.019	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mean	0.271	0.043	0.019	0.022	0.086	0.146	0.041
Max	0.909	0.135	0.042	0.047	0.288	0.282	0.171

Table 8: Leachate Zinc Concentrations (dissolved mg/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	5	5	5	6	6	2	6
n>LOD	5	5	5	6	6	2	6
Min	0.068	0.033	0.047	0.036	0.069	0.063	0.024
Mean	0.343	0.127	0.1272	0.070333	0.260333	0.244	0.1015
Max	1.131	0.433	0.319	0.117	0.731	0.425	0.221

Table 9: Leachate Mecoprop Concentrations (ug/l)

	LCP1AR	LCP1C	LCP2AR	LCP2BR	LCP2C1	LCP3	LCP3A
n	20	20	20	20	20	18	27
n>LOD	19	20	20	20	20	18	26
Min	0.12	0.3	18.16	19.51	21.22	16.42	2.69
Mean	22	56	67	72	82	57	78
Max	93.7	232	193.33	170	204	183.93	264

Table 10: Comparison of Non-Hazardous Pollutants between Reviews

	Original HRA		1st Review		2013 HRA			2019 HRA		
(mg/l)	Min	Max	Min	Max	Min	Mean	Max	Min	Mean	Max
NH4-N	4	2860	0.03	3200	2	1611	4010	38.6	1453	3090
Chloride	37	8700	6	8700	516	2703	4440	191	2352	4480
Copper*	0.002	10.6	0.002	0.72	-	-	-	0.01	0.09	0.91
Zinc*	0.00225	1950	0.04	1.22	-	-	-	0.024	0.18	1.13
MCPP	0.05	0.189	0.0041	0.254	<0.00002	0.043	0.153	0.00012	0.062	0.264

'* dissolved concentrations from 1st review onwards

The assessment of data for non-hazardous pollutants indicates that concentrations of ammoniacal nitrogen, chloride and mecoprop have decreased in the older cells, but not so noticably in more recent cells. The result is that the average values for the site as a whole remain fairly consistent with the original source term. Figure 4 presents a graph of ammoniacal nitrogen concentrations in leachate for the last 10 years. Figure 5 presents data for chloride in leachate. Copper and zinc concentrations remain low and fairly similar to the concentrations at the time of the first review. It is noted that the earlier 2003 source term gives much higher concentrations and this is thought to be a result of using data for total rather than dissolved metals. It is concluded that these two parameters are not the best indicators of leachate quality for future HRA reviews.

Figure 4: Ammoniacal nitrogen concentrations in leachate

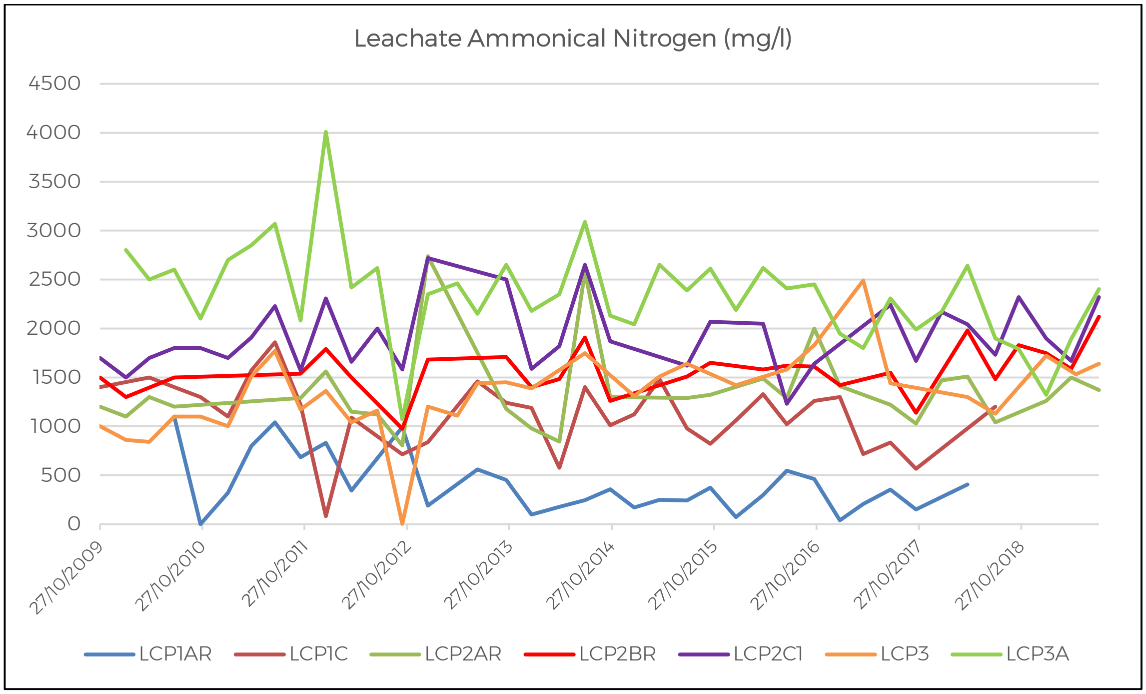
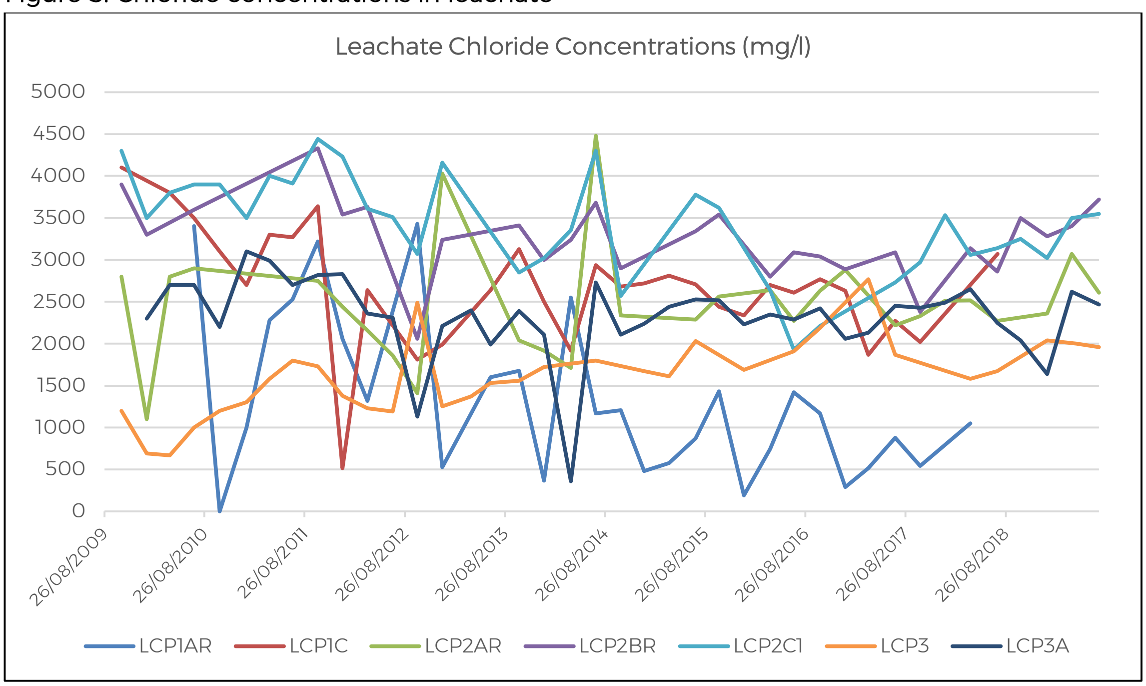


Figure 5: Chloride concentrations in leachate



4.2. Pathways

4.2.1. Landfill Containment

The wastes have been placed within engineered containment, more than 30m above the saturated zone of the limestone aquifer. Seepage from each phase will first pass through the engineered basal liner, allowing some attenuation. The migration pathway through the sidewall liner is only likely to occur if there is significant perched leachate acting against the sidewall.

The landfill has been engineered such that Phases 1A and 1B have a 1m thick silty clay liner. Phase 1C has a composite liner. Modelling within the original HRA confirmed that the composite liner should have a minimum 1m thickness of clay and a maximum permeability of 1 x 10^{-9} m/s. The artificial sealing layer is welded high density polyethylene. Capping has comprised a 1mm liner low density polyethylene (LLDPE) liner. This is reported in the 2007 HRA to have replaced the original proposed cap design of a geosynthetic clay liner (GCL).

The 2008 ESID describes sidewall containment to be as follows:

Phase 1 – potential silt liner, although details unclear;
Phase 2 – sloped batters to 115m AOD, where the top of a geomembrane liner terminates;
Phase 3A – side slopes at 1 in 2.5, with anchored geosynthetic materials.

4.2.2. Unsaturated zone

The unsaturated zone is considered in previous HRAs to be more than 30m thick. A review of average groundwater levels for the last 10 years confirms this to be the case. Borehole 36, which is southeast of Phase 2 has fluctuations in groundwater levels of up to 50m. This suggests it intersects fissures which have poor connectivity with the rest of the aquifer. However, even at its highest levels there would still be 5-10m of unsaturated zone below Phase 2.

Previous risk assessment models have assumed that there is dilution in the aquifer, but no attenuation in the unsaturated zone, due to the potential for rapid fissure flow.

4.3. Receptors

The 2007 HRA reports there to be no licensed abstractions in the vicinity of the site. The nearest licensed abstraction is reported to be at a distance of 9km. There are private abstractions reported 500m to the southeast and 500m to the northeast. For risk assessment purposes the receptor for hazardous substances has been assumed to be the groundwater in the Carboniferous limestone directly beneath the site. For non-hazardous pollutants the receptor is taken to be the groundwater at the downgradient boundary of the site. The principal direction of groundwater migration from the downgradient boundary of the site will be northeastwards towards the sea.

5. Hydrogeological Risk Assessment

5.1. Numerical Modelling

5.1.1. Justification for Modelling Approach and Software

The original risk assessment was carried out using Landsim 2 to determine the impact form basal seepage. The model was updated in 2007 to take into account the items below:

- Different background groundwater chemistry;
- Higher leachate heads, up to 10 m in Phase 2 and 3A and up to 20m in Phase 1 and 3;
- A different assessment of hydraulic gradient;
- Changing leachate quality.

Changes were found to be acceptable.

5.1.2. Model Parameterisation

Leachate levels have been assessed in section 4.1. This shows levels being very consistently being maintained at or below 2m above the base across the site. The current quality of the leachate has been assessed in section 4.2. The leachate generally remains within previously modelled ranges, with some determinands showing a decline, particularly in earlier cells.

Landfill containment engineering has been undertaken in line with recommendations in earlier HRAs. On the basis of the above, no further quantitative modelling is required.

5.2. Emissions to Groundwater

5.2.1. General

Background groundwater quality for Phase 1 and 3 is reported in 2007 to be represented by borehole GW25. Background groundwater quality for Phase 2 and 3A is assumed to be represented by borehole 36 and Dulas Spring. Now that landfilling has progressed into Phases 2 and 3A these monitoring locations do not appear to be best placed to represent background conditions, which should be in locations upgradient.

As described in section 3.2, groundwater levels are monitored in the following positions:

Upstream: GW1, GW2, GWBH32, GWBH33, GWBH34, GWBH35
Downstream: GWBH04, GWBH06R, GWBH07, GWBHs22 to 28 and GWBH36.

Trigger levels are assigned to the following boreholes:

GWBH4, GWBH7, GWBH23, GWBH25, GWBH34, GWBH35, GWBH36.

Of these boreholes GWBH34 and GWBH35 are upgradient. It is unclear why they have, therefore, been assigned trigger levels. The chemistry of both the up and downgradient boreholes is assessed below to determine whether there has been any impact since 2013. It should be noted that there has been no data for GWBH26B after 2016. It is understood the borehole generally has too little water to sample. It also appears to be in the site of a new housing development, which has affected its performance as an indicator of landfill activity.

5.2.2. Hazardous Substances

Lead

There is no trigger level for lead within the permit but lead is assessed as a key determinand in the leachate, so it is also considered within the groundwater. Concentrations are presented in Table 11. Borehole data is coded as shown below so it is easy to identify which boreholes are upgradient and which have trigger levels.

GWBH	Borehole is upgradient
GWBH	Trigger level applies
GWBH	Upgradient with trigger level

Table 11: Groundwater Lead Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	35	55	57	41	56	55
n>LOD	0	19	1	1	1	0
Min	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mean	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Max	<0.001	0.008	0.004	0.001	0.003	<0.001
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	56	56	55	29	57	56
n>LOD	0	0	0	0	0	1
Min	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mean	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Max	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	55	54	53	54	56	
n>LOD	2	11	0	4	22	
Min	<0.001	<0.001	<0.001	<0.001	<0.001	
Mean	<0.001	0.001	<0.001	<0.001	0.003	
Max	0.004	0.004	<0.001	0.003	0.032	

The data shows very few results above detection limit. There was one exceedance of the UKDWS of 10mg/l in GWBH36, but this happened in 2014 and has not been repeated since. Boreholes GWBH02 and GWBH33 are both upgradient and have noticeably more exceedances of the detection limit for lead than many downgradient boreholes, suggesting this is a feature of the natural groundwater chemistry.

Mercury

Table 12: Groundwater Mercury Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	36	57	59	42	57	57
n>LOD	5	1	36	16	2	6
Min	<5.00E-06	<5.00E-06	6.00E-06	9.00E-06	<5.00E-06	<5.00E-06
Mean	2.86E-05	1.90E-05	2.42E-05	5.88E-05	2.06E-05	2.13E-05
Max	1.10E-04	1.00E-04	1.00E-04	4.00E-04	1.00E-04	1.00E-04
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	58	58	57	31	58	58
n>LOD	1	4	5	12	17	19
Min	<5.00E-06	<5.00E-06	<5.00E-06	1.00E-05	<5.00E-06	<5.00E-06
Mean	1.88E-05	1.90E-05	1.97E-05	2.48E-05	5.59E-05	3.30E-05
Max	1.00E-04	1.00E-04	1.00E-04	1.00E-04	9.00E-04	4.00E-04
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	57	57	53	54	56	
n>LOD	5	6	18	2	7	
Min	<5.00E-06	<5.00E-06	<5.00E-06	<5.00E-06	<5.00E-06	
Mean	2.24E-05	2.08E-05	3.03E-05	1.62E-05	1.93E-05	
Max	1.00E-04	1.00E-04	5.90E-04	1.00E-04	1.00E-04	

The trigger level for mercury is 0.01ug/l ie 1e-5 mg/l. In most boreholes with trigger levels the maximum value recorded is 1e-4mg/l. This is reflective of the higher limit of detection that has been used on occasion, rather than an exceedance. GWBH34 records a slightly higher maximum concentration, however this borehole is in an upgradient position and is not, therefore, indicative of leachate contamination.

Tributyl tin and trifuralin

Trigger levels for these two substances still remain on the permit although it has been recommended that they were removed at the time of the 2008 HRA review. There have been no occurrences of trifuralin above detection limit since 2013. There was one occurrence of tributyl tin at 0.00322 mg/l in GWBH36 during 2015, but no subsequent results above detection limit, suggesting that this is an anomaly. It is recommended that these determinands are removed from the monitoring suite.

5.2.3. Non-hazardous Pollutants

Ammoniacal nitrogen

Data for ammoniacal nitrogen is presented in Table 13 below.

Table 13: Groundwater Ammoniacal Nitrogen Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	34	55	57	40	55	55
n>LOD	21	25	32	25	31	37
Min	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mean	0.06	0.02	0.16	0.03	0.05	0.18
Max	1	0.2	3.8	0.4	0.6	2.4
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	56	56	55	28	56	56
n>LOD	46	33	25	26	34	28
Min	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mean	0.05	0.03	0.03	6.70	0.04	0.02
Max	0.5	0.01	0.3	40.3	0.5	0.12
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	55	55	51	52	54	
n>LOD	40	27	32	19	30	
Min	<0.01	<0.01	<0.01	<0.01	<0.01	
Mean	0.03	0.014	0.05	0.02	0.03	
Max	0.4	0.08	0.6	0.18	0.4	

The trigger level for ammoniacal nitrogen is 1mg/l. The trigger level has been exceeded in GWBH04. This occurred once in July 2017 and once in July 2018. This borehole is downgradient to the northwest, whereas the direction of groundwater flow is generally considered to be to the northeast. It is, however, downgradient of the open quarry and lagoons to the north of the landfill. It is possible the increases are associated with slight stagnation of the lagoons in the summer months.

Chloride

Table 14: Groundwater Chloride Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	36	57	59	42	57	56
n>LOD	36	57	59	42	57	56
Min	7	11	20	67	49	60
Mean	24.03	13.86	0.16	128.07	86.19	67.43
Max	52	20	58	187	129	80
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	57	56	56	28	57	57
n>LOD						
Min	69	97	12	52	20	31
Mean	75.07	142.12	19.54	60.17	42.42	44.35
Max	83	97	51	70	53	69
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	57	57	53	54	56	
n>LOD						
Min	34	15	17	13	15	
Mean	37.54	32.11	21.58	21.30	69.70	
Max	54	44	27	69	111	

The trigger level for chloride is 250mg/l. There are no exceedances of the trigger level in any borehole.

Mecoprop

Table 15: Groundwater Mecoprop Concentrations (ug/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	35	57	59	41	57	56
n>LOD	7	6	2	2	3	0
Min	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mean	0.03	0.03	0.02	0.02	0.02	<0.02
Max	0.11	0.24	0.03	0.03	0.03	<0.06
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	57	57	56	29	57	57
n>LOD	0	2	3	0	2	2
Min	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mean	<0.02	<0.02	<0.02	<0.03	<0.02	<0.02
Max	<0.07	0.11	0.1	<0.2	0.11	0.14
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	57	57	53	54	56	
n>LOD	0	1	2	2	2	
Min	<0.02	<0.02	<0.02	<0.02	<0.02	
Mean	<0.02	<0.02	<0.02	<0.02	<0.02	
Max	<0.1	0.02	0.02	0.04	0.02	

The trigger level for mecoprop is 0.04ug/l. In the boreholes to which trigger levels are assigned there is one exceedances in GWBH25 out of 56 samples. The highest concentration of 0.24ug/l is recorded in GWBH02 upgradient. The results appear to be indicative of background groundwater quality.

Phenol

Table 16: Groundwater Phenol Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	16	26	28	13	26	26
n>LOD	1	0	0	0	1	1
Min	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mean	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Max	0.002	<0.1	<0.1	<0.0005	0.0007	0.0016
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	27	27	26	9	26	27
n>LOD	1	1	1	1	2	0
Min	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mean	<0.0005	0.0042	<0.0005	<0.0005	<0.0005	<0.0005
Max	0.0043	0.0005	0.0016	2.3769	0.0014	<0.1
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	25	25	22	22	24	
n>LOD	0	2	1	0	0	
Min	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Mean	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Max	<0.1	0.001	0.0006	<0.1	<0.1	

The trigger level for phenol is 0.5ug/l. It is noted that there has been a limit of detection of 0.1mg/l on one occasion for most boreholes. This is the highest concentration recorded in the boreholes with trigger levels and will also have affected the mean concentration. Very few results are recorded above the LOD.

Potassium

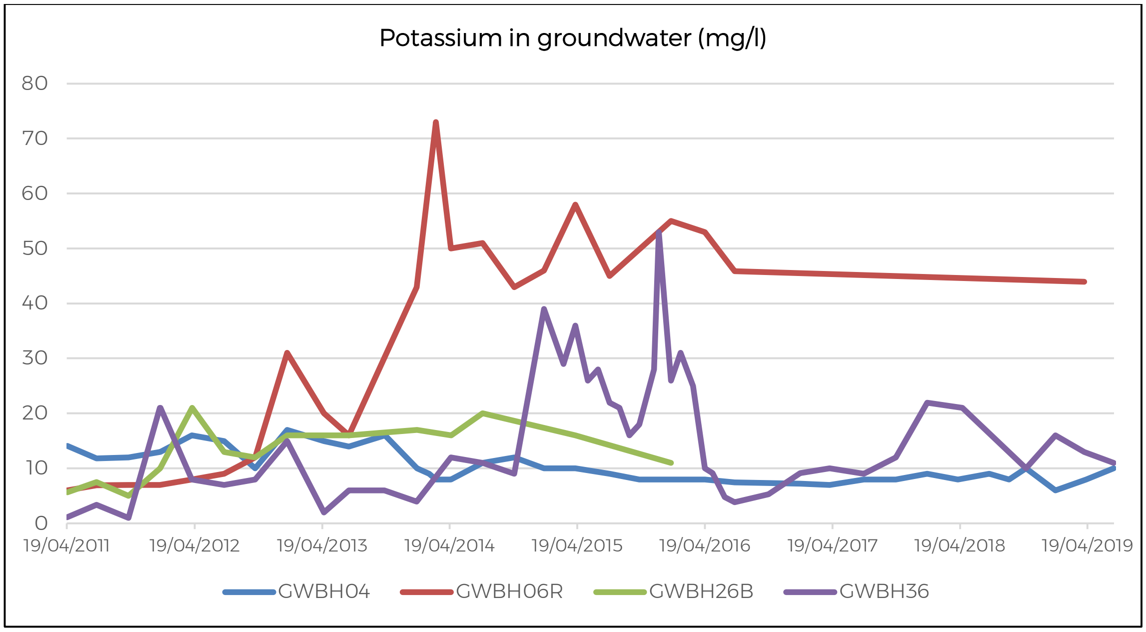
In the 2013 HRA there appeared to be a rise in the concentration of potassium in certain boreholes. The data below is reviewed to determine whether this is still the case. The trigger level for potassium is 12mg/l.

Table 17: Groundwater Potassium Concentrations (mg/l)

	GWBH01	GWBH02	GWBH04	GWBH06R	GWBH07	GWBH22
n	15	26	32	15	27	26
n>LOD	10	26	32	15	27	26
Min	1	1	6	16	3	2
Mean	1.20	1.49	9.44	44.93	4.38	2.49
Max	4	3	17	73	10	5
	GWBH23	GWBH24	GWBH25	GWBH26B	GWBH27B	GWBH28
n	27	27	26	8	27	27
n>LOD	27	27	13	8	26	2
Min	1	2.5	<1	11	<1	<1
Mean	1.75	3.48	1.23	16.00	2.29	1.00
Max	2	9	3	20	3	1
	GWBH32	GWBH33	GWBH34	GWBH35	GWBH36	
n	26	26	24	23	37	
n>LOD	26	26	24	23	37	
Min	2	1.3	2.6	1	2	
Mean	3.26	2.80	3.26	2.42	17.01	
Max	14	4	4	13	53	

For boreholes with trigger levels there are exceedances in GWBH04 downgradient and GWBH35 upgradient. There are also exceedances in GWBH36 downgradient. To understand the potassium concentrations further Figure 6 plots concentrations in selected boreholes, the same as for those reviewed in the 2013 HRA. There is a noticeable decline in concentrations in GWBH36B since 2016 and GWBH06R since 2014.

Figure 6: Groundwater potassium concentrations (mg/l)



Borehole GWBH04 has been compliant since 2014. GWBH06R is not assigned trigger levels and is monitored less frequently than other boreholes. This is understood to do with insufficient water on some sample rounds. Borehole GW26B is understood to be close to an area of housing development and has not been sampled since 2016. This is also understood to be due to lack of water, potentially affected by the building works. GWBH36 is the borehole which shows the greatest seasonal fluctuations in groundwater levels, of up to 50m. This is indicative of lack of connectivity of fissures/fractures with the rest of the aquifer.

Concentrations in GWBH36 do now appear to be declining. The peak in concentrations occurred shortly after the construction of the compost area in the southwest of the site. The CQA of the concrete base took place between December 2013 and March 2014. The concrete associated with the new housing development close to GW26B may also account for the rise in potassium concentrations associated with this borehole.

5.3. Emissions to Surface Water

5.3.1. General

The site has a consented discharge point W1 in the quarry void north of the landfill. The quality of the discharge to the Irish Sea is monitored at this point, with emission limits for BOD, ammoniacal nitrogen, suspended solids, pH and visible oil and grease. The permit also requires monitoring of the Afon Dulas up and downgradient of the site and at the Dulas

Spring. The spring has weekly and monthly monitoring suites, with hazardous substances required annually. The river has monthly and quarterly suites.

Table 18 summarises the monitoring data for W1.

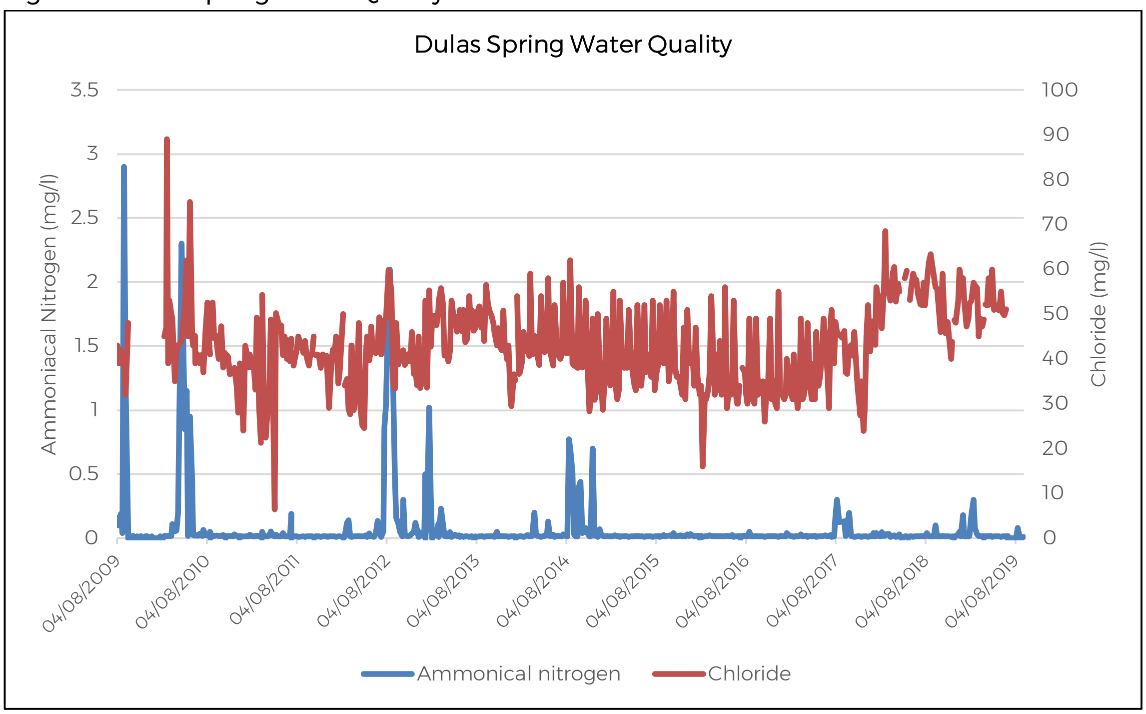
Table 18: W1 Surface Water Quality (mgl)

	pH	NH4-N	BOD	SS
Trigger	>6 <9	5	15	50
n	82	82	82	82
Min	7.2	0.01	<1	<5
Mean	7.97	0.27	2.93	14.33
Max	9.2	4.3	35.6	129

The above table shows the maximum values exceed the permitted limits, but mean values are much lower than the limit. A review of the data indicates the exceedances have only taken place once for each determinand and appear to be anomalous data.

Figure 7 presents the ammoniacal nitrogen and chloride data for the Dulas Spring.

Figure 7: Dulas Spring Water Quality



The data shows small fluctuations in chloride concentrations. There have been occasional peaks in ammoniacal nitrogen concentrations. Since 2014 concentrations have remained below 0.5mg/l. Figures 8 and 9 presents water quality information up and downgradient on the Afon Dulas.

Figure 8: Afon Dulas Chloride (mg/l)

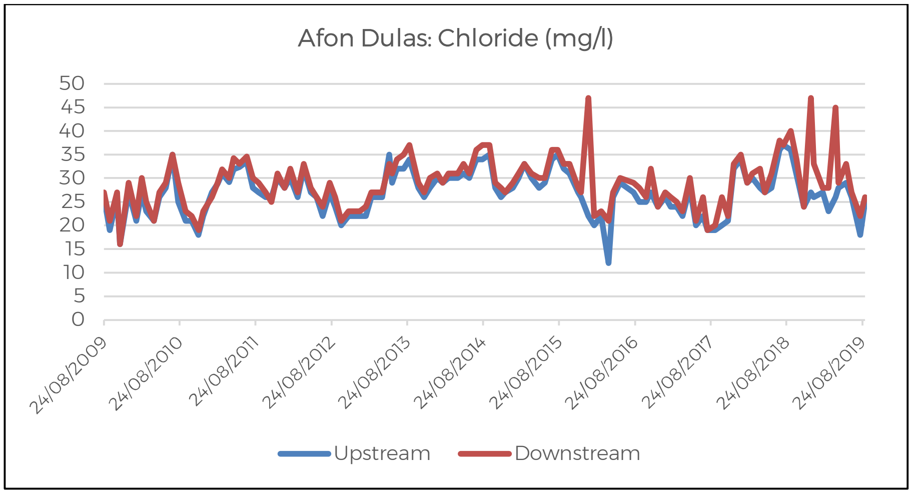
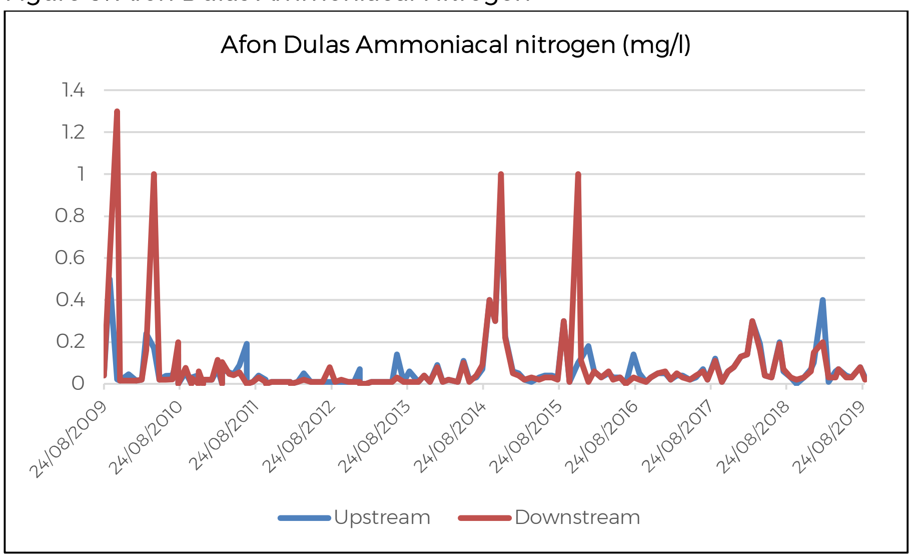


Figure 9: Afon Dulas Ammoniacal Nitrogen



The graphs of water quality in the Afon Dulas show very little difference up and down gradient given that the downgradient position is some distance north of the landfill and north of the Abergele Road. There have been new housing developments between the landfill and the downgradient sampling position and given this is also downgradient of a main road, there are many other potential influences on the water quality.

5.4. Review of Technical Precautions

The landfill containment measures at Llanddulas Landfill have progressed in line with previous risk assessment models. There have been no new areas of landfill lining since the 2013 HRA review. Some capping works have taken place in the last six years and there only remains part of Phase 3A left to cap.

Leachate is removed from containment cells for treatment in the on site treatment plant adjacent to Phase 3, before discharge to sewer. Leachate level monitoring shows good compliance with the environmental permit limit of 2m above the landfill base.

No further design changes are currently proposed in the area of the Llysfaen Fault.

The current technical precautions are considered to be in line with the environmental permit and functioning as intended.

6. Requisite Surveillance

6.1. Monitoring Objectives

At the time of the 2013 HRA the monitoring requirements of the environmental permit were above those of the EA's Regulatory Position Statement 156 (RPS) for landfill monitoring. The permit has since been modified to meet some of the requirements of the RPS.

6.2. Monitoring Frequency and Determinands

The RPS allows annual monitoring of leachate quality in non-operational cells. At present the environmental permit requires quarterly leachate quality in all wells. This could be reduced in all cells that have a complete permanent cap. The cells where capping is not wholly complete are Phase 3A and Phase 2A, B & C.

The RPS also allows leachate level monitoring to be reduced from monthly to quarterly in non-operational cells. It is proposed that this reduced frequency is applied to future monitoring.

Groundwater monitoring in the current environmental permit is required quarterly. In accordance with the RPS only a limited monitoring suite is required quarterly. Other determinands can be measured annually. Table 18 sets out the proposed reduction in groundwater monitoring in line with the RPS, with the inclusion of mecoprop annually, as this has been used as a key determinand within the HRA.

Table 18 – Reduced groundwater monitoring in line with RPS 156.

Monitoring point reference/description	Parameter	Monitoring frequency	Monitoring standard or method
Up gradient MEPP	Water level, electrical conductivity, chloride, ammoniacal nitrogen, pH	Quarterly	As specified in Appendix 6 of Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003) and Horizontal Guidance Note H1 – Environmental Risk Assessment for permits, Annex J, version 2, April 2010)
	total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel, zinc, manganese, mecoprop	Annually	
	Hazardous substances	Annually for first six years of operation	
Down or cross gradient MEPP	Water level, electrical conductivity, chloride, ammoniacal nitrogen, pH	Quarterly	As specified in Appendix 6 of Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003) and Horizontal Guidance Note H1 – Environmental Risk Assessment for permits, Annex J, version 2, April 2010)
	total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel, zinc, manganese, mecoprop	Annually	After the initial 6 year monitoring period for hazardous substances, if the results of quarterly or annual monitoring suggest an increase in contamination, the operator shall also undertake a full hazardous substances screen.
	Hazardous substances detected in the leachate	Annually for first six years of operation then every two years	

Tributyl tin and trifuralin are not considered significant as indicators of landfill leachate. It was requested at the time of the 2013 HRA that these substances be removed from the table of trigger levels. This request is repeated.

No changes are proposed to the current surface water monitoring regime.

7. Summary and Conclusions

Llanddulas Landfill is reaching completion. There are parts of Phase 3A, Phase 2C and Phase 2B left to cap and a small area of temporary cap on Phase 2A. There is also the remaining restoration in the area of the fault, east to west across the centre of the site. Landfill containment has been undertaken in line with risk-assessed design.

Leachate levels are well managed and leachate continues to be treated by the on-site plant.

A review of leachate quality indicates leachate strength is within the original modelled source term and is declining in some cells. Leachate quality monitoring continues to be above the requirement of RPS156 in the closed cells of the site and this could be reduced from quarterly to annual analysis. Leachate level monitoring could be reduced from monthly to quarterly.

A review of copper and zinc concentrations in the leachate indicates that these two determinands are not good indicators of whether the leachate remains compliant with the original source term. The original leachate source term appears to have been based on total metal concentrations, whereas subsequent monitoring has been for dissolved concentrations. The dissolved concentrations are low.

It is proposed that groundwater quality monitoring is reduced in line with the recommendations of RPS156. Mecoprop, as a key determinand in the risk assessments, would be added annually. Tributyl tin and trifuralin are considered to be no longer required for inclusion in the groundwater monitoring suite. It is recommended that trigger levels for these two substances is removed from the environmental permit.

Trigger levels are assigned to upgradient boreholes GWBH34 and GWBH35. It is not clear why this is the case as trigger levels are usually assigned to downgradient boreholes. It is recommended that trigger levels are removed from these two boreholes.

Groundwater monitoring does not indicate contamination from landfill leachate. An increase in potassium in certain boreholes was noted at the time of the 2013 HRA. A review of development activities both on and off the site suggests this may be associated with concreting works both in the area of the composting site and in adjacent housing developments. Concentrations have declined noticeably in GWBH36.

The site is considered to be compliant with the environmental permit and with the principles of the Environmental Permitting Regulations.

REFERENCES

1. FCC: 2013: Llanddulas Landfill, Conwy, Hydrogeological Risk Assessment Review.
2. SLR: 2003: LLanddulas Phases 1 and 3, Hydrogeological Risk Assessment. Report reference 4D-197-187/HRA;
3. SLR: 2003: Llanddulas Landfill, Phase 2 and 3A. Hydrogeological Risk Assessment. Report 4D-197-126/HRA.
4. SLR: 2007: Llanddulas Landfill, North Wales, Hydrogeological Risk Assessment Review. Report reference 404-0197-00552;
5. SLR: 2008: Llanddulas Landfill, Conwy, North Wales, Permit Variation Application, Hydrogeological Risk Assessment. Report reference 404-0197-00529/HRA;
6. SRL: 2008: Llanddulas Landfill Permit Variation Application, Environmental Setting and Installation Design. Report reference 404-197-00529/ESID;

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