

# Appendix C Arup Desk Study

Sartorial Spirits  
**A-Dhann United Downs**  
Desk Study of Ground Conditions

Issue | 20 December 2019

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 270838

**Ove Arup & Partners Ltd**  
1 West Regent Street  
Glasgow G2 1RW  
United Kingdom  
[www.arup.com](http://www.arup.com)

**ARUP**

# Contents

---

	Page
<b>Executive Summary</b>	<b>1</b>
<b>1 Introduction</b>	<b>5</b>
1.1 Proposed Development	5
1.2 Appointment and Scope of Works	5
1.3 Limitations	6
<b>2 The Site</b>	<b>7</b>
2.1 Data sources	7
2.2 Site location	7
2.3 Surrounding land use	8
2.4 Current land use	9
2.5 Topography	9
2.6 Geology and Ground Conditions	9
2.7 Ground Stability & Infilled Ground	12
2.8 Hydrogeology	15
2.9 Hydrology	17
2.10 Flooding	18
2.11 Discharge Consents	19
2.12 Contaminated Land Register and Pollution Incidents	20
2.13 Landfill and Waste Management Facilities and Permitting History	21
2.14 Contemporary Trade Directory Entries & Points of Interest	24
2.15 Ecology & Sensitive Land uses	25
2.16 Radon Gas	25
2.17 Unexploded Ordnance	25
2.18 Site history	26
<b>3 Landfill Construction and Design</b>	<b>31</b>
3.1 General Landfill Layout	31
3.2 Capping Design	33
3.3 Hydrogeological Risk Assessments	35
3.4 Leachate Management and Monitoring	40
3.5 Landfill Gas Management	41
3.6 Gas Monitoring	41
3.7 Settlement monitoring	61
3.8 Surface Water Management	63
<b>4 Risk Evaluation and Summary</b>	<b>65</b>
4.1 Methodology	65

## References

## Appendices

### Appendix A

A3 Format Figures

### Appendix B

United Downs Landfill Select Drawings from Suez Recycling and Recovery Limited

### Appendix C

Cornwall Consultants Ltd., Regulated Mining Search: Metalliferous Minerals, 28 October 2019

### Appendix D

Unexploded Bomb Risk Map

### Appendix E

Settlement Monitoring Data

## Executive Summary

---

A double still distillery is proposed to be constructed on the land adjacent to the United Downs Deep Geothermal Power (UDDGP) project. The intention of the development is to make use of waste heat, direct heat or a combination of both from the UDDGP project.

Ove Arup and Partners Ltd. (Arup) have been appointed to produce documentation to address issues associated with locating a distillery at the site. The site has formerly been impacted by historical metalliferous mining activity, and more recently used as a landfill.

### Landfill and Landfill Gas

United Downs Landfill operated between 1974 and 2010, following which restoration works were undertaken by means of capping and planting. Deposited wastes anticipated some 10-12m in thickness beneath the site comprising largely non-hazardous materials.

Currently the landfill is under the control of Cornwall Council and consists of several distinct features including:

- Capping layer,
- Leachate management system,
- Surface water management system,
- Monitoring network, and
- Gas collection system and energy generation

Settlement is a common issue with landfills. The extent of settlement is considered relatively mature (i.e. most primary settlement has likely occurred) and is currently settling under self-weight as a result of ongoing creep within the landfill mass. From review of available data, the landfill may settle another 2 to 6 m and broadly at a rate of 0.1 mm per year (although available data is limited and difficult to draw clear conclusions). In addition, there should be an expectation of variation of this rate across the settlement.

However, where structures are planned, any additional loading imposed on the landfill mass from these planned structures will result in additional settlement and increase the overall rate of ongoing settlements with time (unless designed appropriately).

The issues associated with settlements of the landfill beneath the structures could be mitigated by use of piled foundations, which would penetrate below the landfill and transfer the additional loads to the underlying materials, hence avoiding any significant additional loading of the landfill materials themselves. Raft foundations may also be possible and should be evaluated further, particularly in light of the risks associated with development above the former mine workings.

There are however significant issues associated with the historical mine workings which need to be considered when assessing the feasibility of foundation design options.

## Mine Workings

The initial review has indicated that an extensive network of mine workings is present beneath the site, with workings from original ground surface to some 300m below ground surface recorded. Access to the workings was from vertical shafts, some 60 of which have been identified within the site area. On the basis of the information received, it appears that prior to the upfilling of the site to its current level, most of these shafts were abandoned without any formal treatment (i.e. without any in-filling or stabilisation). In addition, given the age of the mine workings, there are potentially undocumented mine workings at or close to the original ground surface (i.e. linear excavations where mineral deposits were mined).

Both the shallow workings and the mine entries associated with them present a significant subsidence hazard for the site, and the associated risks would need to be considered as part of any development proposals taken forward.

Obviously, with this level of geotechnical issue, the easiest path forward would be to site the structures outside of the mine workings hazard zones, allowing for a suitable exclusion zone around the areas of hazard identified. However, we recognise the challenge of this given the relatively large footprint of the mine workings and the number of mine entries indicated to be present.

Based on the available information that we have reviewed is that it is unlikely to be feasible to fully characterise the extent of the mining features beneath the site with available site investigation methods. Furthermore, it is unlikely to be economically viable to fully stabilise or treat the mine workings and mine entries within the site.

## Other Considerations

The proposed development will need to consider any potential impacts associated with the wider environmental setting, particularly given the existing impacts associated with the landfill and mine workings. For example, the proposed development will need to be developed such that it does not degrade the existing groundwater or surface water regimes or impact the existing landfill management system.

A radon survey will be necessary, although the mitigation of radon will likely already be covered using gas intrusion preventative measures (such as gas barriers).

## Implications for Development

To develop the site in its currently location, a risk-based approach could would need to be considered. However, shifting the site location, should also be considered to minimise its location in relation to both the landfill and mine

workings. Information provided in this document can be used to identify option locations.

An example of a reasonable scope of further work would broadly include the following stages:

1. **Desk Study:** While our initial desk study has included review of the information available to us, some additional information is known to be held by the Environment Agency and site owner that has not yet been received. The desk study should compile any other available information to allow a conceptual model of ground conditions to be developed.
2. **Hazard Zoning:** Identified hazards should be classed according to relative level of risk that they may pose, and then the project Masterplan can be reviewed and updated to avoid areas of the greatest risk.
3. **Ground Investigation:** While we note that a ground investigation (GI) is unlikely to fully characterise the ground hazards and risks, it would be necessary to undertake some intrusive GI to inform the geotechnical design. The scope of GI should be defined following the detailed desk study assessment.
4. **Design:** Any structures within the site should where possible be located a sufficient distance away from known mine entries and shallow mine workings. Treatment of the areas of greatest hazard should be performed where it is not possible to avoid them. Given the uncertainty in the extent of the mine workings, the design should incorporate measures to mitigate the risks of potential mining related subsidence (e.g. designing foundation slabs to span or cantilever potential subsidence features). Roads and open areas accessible to the public are also likely to require additional measures such as incorporation of high-strength geogrids to mitigate the risks to the public associated with sudden mining related subsidence by temporarily spanning any voids that may migrate to the ground surface.
5. **Construction:** During construction, subsidence issues may arise which need to be addressed. Thus, a more significant amount of contingency (both in project cost and schedule) should be allowed for, than at a more conventional site. The designer would need to work closely with the contractor to develop a reasonable contingency to allow safe construction.
6. **Maintenance & Monitoring:** On-going monitoring (such as settlement monitoring) will be needed to identify issues before significant impacts occur. In addition, a level of maintenance should be expected to deal with potential mining subsidence during operation.

While the above does present a possible mechanism to develop the site, the costs for such an approach should be expected to be significantly greater than they would be for a typical development of this nature (even if this were only a landfill). In addition, we would expect that maintenance of the site and contingency costs may be difficult to evaluate for this type of risk, thus cost overruns could become a problem.

The findings of this review should be discussed with the project architect along with local contractors to seek feedback on construction methods.

This report also provides a detailed description of the history of the landfill, known extent of the mineworks, and a high-level evaluation of the risks identified during this review. Whilst the risk evaluation documents the primary issues identified in this review, it is possible that additional issues may be found during the course of project development. Given the inherent uncertainty of the subsurface environment and the potential for changes to the proposed project, the risk evaluation should be considered to be a 'living document' and should be reviewed and revised as necessary at each project phase.



# 1 Introduction

## 1.1 Proposed Development

A double still distillery is proposed to be constructed on the land adjacent to the United Downs Deep Geothermal Power (UDDGP) project (Figure 1). The intention of the development is to make use of waste heat, direct heat or a combination of both from the UDDGP project.

The distillery infrastructure is planned to include maltings, grain silos, water management facilities, biome warehouses, offices, accommodation, a visitor centre, and parking. In addition, there are also plans for a geothermally heated spa facility, implementation of CO<sub>2</sub> recovery and storage from fermentation, and development of a hydrogen fuel making and storage plant for hydrogen powered vehicles, including electric car charging points.

The location proposed is on the northern part of the United Downs Landfill that is now closed and due to enter its aftercare phase in the near future (see Appendix A, Figure A 1). The history of the landfill is discussed in detail below and select drawings from the former operator, Suez Recycling and Recovery Limited (Suez) are provided in Appendix B.



Figure 1. Site Vicinity Map.

## 1.2 Appointment and Scope of Works

Ove Arup and Partners Ltd. (Arup) have been appointed to produce documentation to address the following associated with locating a distillery at this site:

- High-level geotechnical feasibility and risk mitigation, including an assessment of risk to site occupants and visitors in relation to the site's history as
  - A former landfill site; and
  - Abandoned copper mines; and
- High-level methane (and other landfill) gas risk mitigation, including an assessment of risk to site occupants and visitors, as well as operation of a distillery from a liability perspective (i.e. risk of explosion and to health).

This report presents the findings of the desk-based work that has been undertaken and the results of the above assessments

### 1.3 Limitations

This report has been prepared on behalf of Santorial Spirits Limited. While this report provides information related to geotechnical and geoenvironmental conditions and risks, it is not intended to provide design information. This report has been developed from information described and referenced in this report. Arup is not responsible for the accuracy of the work provided by others. In addition, Arup takes no responsibility for the level of risk identified in this document or for the identified mitigation measures associated with those risks. As noted in this report, additional work is required to adequately characterise the risks identified in this document and to develop appropriate mitigation measures.

## 2 The Site

---

This section identifies the site location, its context in the wider United Downs area and provides a summary of the general condition and history of the area to support the development of a ground conditions model for the site. This section also serves to identify the environmental setting of the site and associated features that may impact future development.

### 2.1 Data sources

This review has been undertaken based on the following sources of information:

- Historic Ordnance Survey mapping and environmental data obtained from Landmark [1];
- Aerial Photographs obtained from Historic England Archives [13];
- Geological Information published by the British Geological Survey [10], [12];
- Previous reports pertaining to the site's operation as a landfill, provided by the current site owners (as of June 2019), Cornwall Council (referenced separately where applicable); and
- Data obtained from the Environment Agency and Cornwall Council.

### 2.2 Site location

The site is located to the south east of Redruth in Cornwall at NGR 174170, 41290 (Figure 1). The site comprises some 9.69 hectares of land located in the north of the United Downs Landfill, which ceased filling operations in 2010. The site (and the landfill) lie in an area of known historical mining activities, which is evident from the surrounding landscape.

The main access route into the site is from the east; an un-named B-road runs along the eastern boundary, with direct access into the site area, through the current United Downs recycling centre/civic amenity site. Sparry Lane and an un-named track form the western site boundary also grant access to the site, leading from Carharrack in the west and United Road in the north. There is no external access into the site from the north or south, albeit the southern site boundary comprises an internal haul road associated with the wider United Downs Landfill site.

The site location is shown on Figure 1, Figure 2, and Figure A 1 (in Appendix A) in the context of the United Downs landfill area.



Figure 2. Site Location Map.

## 2.3 Surrounding land use

United Downs Industrial Park borders the site to the north, separated from the site by a vegetation buffer. The industrial park includes, within 50m of the site, a cleaning services supplier, Cornish welding supplies, a fibre glass depot, an alloy wheel refurbishment services, a book publisher, and most notably the United Downs Deep Geothermal Power plant.

The Geothermal power plant, under operation by Geothermal Engineering Limited, comprises two deep geothermal wells; one for production and one for injection, drilled to depths of some 2,000 and 5,000 m targeting the Porthtowan fault zone some 800m to the south west of the site. Water is to be pumped from the production well, fed through a heat exchanger and then re-injected into the ground to pick up more heat from the granite in a continuous cycle. Energy derived from the heat exchanger is planned to be used to generate electricity via a binary type of geothermal plant.

The southern site boundary is formed from an existing internal access road associated with the United Downs Landfill, which leads from Sparry Lane in the west, to a perimeter track in the east. The wider United Downs Landfill predominates the land to the south and west of the site area. Beyond the landfill in the west, the land comprises woodland, scrub and open fields. To the east, beyond

the un-named B-road, an area of partially vegetated mining spoils extends towards a raceway track.

Figure A 2 in Appendix A illustrates the surrounding and current land use.

## 2.4 Current land use

The site forms part of the wider United Downs Landfill. The landfill site was operational from 1974, with final waste filling undertaken in an extension area in 2010 (the extension area is located to the south of the proposed development site). Capping and restoration works have been undertaken since closure of the landfill.

The west and central parts of the development site comprise capped, largely vegetated and restored landfill cells. In the east, the site is occupied by the existing engine sheds of the Combined Landfill Project (CLP) landfill gas control system, beyond which a generator and the site car park and offices are present. The existing United Downs Civic Amenity Site is present in and along the eastern boundary of the site.

An internal haul road runs almost east to west across the central site area, which meanders around the existing CLP engine compound. Overgrown vegetated areas are present along the northern site boundary and in the west of the site.

## 2.5 Topography

The topography of the site is influenced by historic landfilling activities and subsequent landfill capping works. The most recent topographical survey was undertaken at the site in 2019 and has been supplied by Cornwall Council (Figure A 3 in Appendix A).

The site is at its highest elevation in its centre, where it reaches 108 m above ordnance datum (AOD), sloping to some 103 mAOD along its northern boundary and some 105 mAOD to the southern boundary. A more noticeable gradient is to the west, where the current surface level is some 80 mAOD where Sparry Lane meets the site boundary. The existing CLP engine compound lies at an elevation of between 96 to 98 mAOD, with the carpark and site office at similar level. In the eastern site reaches, the existing civic amenity site lies at an elevation of some 93 mAOD.

To the south of the landfill site, ground level is some 50 mAOD, indicative of the topographical influence of the landfilling works.

The existing topography of the site indicates that levelling will likely be required to facilitate the construction of any new buildings. Proposed levelling works are anticipated to comprise filling as opposed to cut, which would likely impact the engineered cap of the landfill site.

## 2.6 Geology and Ground Conditions

The site is located within the United Mines Landfill and as such, shallow ground conditions beneath the site will be dominated by deposited wastes. A review of

both Ordnance Survey (OS) maps prior to landfill operations and the most recent topographical survey for the site indicates that landfilling has raised the ground by some 8 to 10 across the site. This excludes the thickness of any deposited mining spoils beneath the site.

The geology of the site (below the deposited waste materials) has been reviewed from geological maps, digital geological datasets, and from historical borehole data obtained through the British Geological Survey. A summary of the geological conditions beneath the site is presented below and shown on Figure A 4.

### 2.6.1 Superficial Geology

The British Geological Survey 1:50,000 series Sheet 352 (1990) “Falmouth: Solid and Drift Geology” [12] indicates superficial deposits to be absent beneath the site.

The BGS Geoindex 1:50,000 scale Digital Geology mapping shows an area of made ground in the southwestern area of the site, but this does not cover the entire site area or wider United Downs landfill as would be expected. Upon review of historic OS plans (discussed further in Section 2.18), this area of made ground corresponds to the locale of a historical chemical works, which at the turn of the 19<sup>th</sup> century was labelled “Trevince Works, Arsenic and Tin”. The made ground may therefore comprise by-products and wastes associated with these works.

The BGS define Made Ground in their ‘Artificial Ground’ dataset as “man-made deposits such as embankments and spoil heaps on the natural ground surface”. It is anticipated that such deposits cover much of the site area, from both landfilling and earlier mining activities.

### 2.6.2 Bedrock Geology

The BGS Geoindex 1:50,000 scale Digital Geology mapping shows the site is underlain by the Devonian Mylor Slate Formation, comprising hornfelsed slate and siltstone, known locally as “Killas Mudstones” [2].

Hornfelsing is likely attributable to Carboniferous/Permian intrusion of the Carnmenellis Granite which outcrops at surface approximately 1.2 km west of the site. A small area of slate and siltstone (not hornfelsed) is shown in the east of the site beneath the civic amenity centre.

West-southwest to east-northeast trending felsite dykes of Permian age are shown along the northern site boundary and to the south of the site. Three west-southwest to east-northeast trending mineral veins are also shown within the site and a fourth mineral vein is shown immediately north of the site.

The vein minerals within the bedrock strata have been extensively mined both beneath the site, and in the wider local area for copper, iron, arsenic and zinc sulphides. The principle mines in the locale of the site are the: Consolidated, Wheal Jane, Mount Wellington, East Jane, Poldice and United Mines [2].

A number of mines in the locale of the site, including the Consolidated and United Downs mines (beneath the site area) drain to the County Adit [2], which runs

north to south, crossing the western site area. An extensive underground system of horizontal tunnels, reportedly up to 30 km in length discharges water from the local mining areas to the Carnon River, some 3km north east of site [2].

Further details of the mining undertaken on and in the locale of the site are presented in Section 2.7.

### 2.6.3 Historic Boreholes (British Geological Survey)

The BGS online collection of historic boreholes [11] contains four borehole records within the site boundary (SW74SW51 to SW74SW54). All boreholes are from an investigation undertaken by ‘Cornwall Mining & Tin Ltd’ in 1977 and 1978. Borehole depths within the site area range from 125 m below ground level (mbGL) to 189 mbGL and all include a section of ‘open-hole’ drilling from surface to depths of between 20 and 34 mbGL.

The strata recovered from the open-hole drilling are not recorded on the logs. The logs are hand-written scans and much of the text is illegible, however it is apparent that coring of bedrock started at the base of the open-holed sections, with bedrock described variously as schist, spotted slate/shale, mineralised ‘killas’ (local terminology for clay-slate), ‘vein-quartz’, and ‘QVK’ (quartz-veined killas).

The bedrock is typically described as being ‘moderately well bedded’ and relict bedding varies in orientation from 5° to 63° (relative to core) but is most commonly noted between 20° and 30°.

Lamination and schistosity is also recorded at several locations at angles between 30° and 56° to the core. Veinlets of quartz and sulphide are recorded throughout the core, with no apparent trend in orientation and varying from 15° to 90° in relation to the core.

The boreholes appear to have been undertaken for the purpose of mineral resource exploration and the logs contain notes on the presence of mineral lodes within the rock. Lodes and elvan are recorded as indicated in Table 1.

Table 1. BGS Borehole Data

BGS Borehole ID	Borehole Number	Depth From (mbGL)	Depth To (mbGL)	Description
SW74SW51	77/5	71.15m	78.75m	Lode, weak lode and elvan
		132.75m	133.30m	Elvan
SW74SW52	77/7	70.4m	71.5m	Weak lode
		73.0m	74.0m	Weak lode
		97.4m	110.85m	Lode and weak lode
SW74SW53	77/8	53.75m	54.2m	Weak lode
		121.97m	122.38m	Elvan
		133.0m	136.13m	Lode
		138.8m	139.0m	Lode

BGS Borehole ID	Borehole Number	Depth From (mbGL)	Depth To (mbGL)	Description
		145.5m	146.0m	Weak lode
		165.5m	166.42m	Weak lode
SW74SW54	77/9	32.66m	35.0m	Lode and weak lode
		123.28m	134.95m	Lode, weak lode and elvan

Evidence of historic mine workings was recorded as indicated in Table 2.

Table 2. Historic Mine Working Summary

BGS Borehole ID	Borehole Number	Depth From (mbGL)	Depth To (mbGL)	Description
SW74SW52	77/7	10.0m	11.6m	“Old workings: Water returns lost, rods crusted with ochre”
SW74SW53	77/8	49.8m	63.4m	“Core [text illegible] and ochre-stained, 53.4m-53.95m: Cavity. Suspected old workings”

Two additional boreholes from the 1977 and 1978 investigation are present some 22m north of the site and present similar findings to the four boreholes within the site area, however no evidence of mine workings is recorded at these locations.

## 2.7 Ground Stability & Infilled Ground

Information on ground stability was included in the obtained Envirocheck Report for the site [1]<sup>1</sup>. This includes records on extractive industries, collapsible and compressible ground stability hazards, and hazards associated with mining and quarrying. It should be noted that the summary of ground stability hazards presented by the Envirocheck Report does not necessarily present a true reflection of risks, as recorded features can be missed from datasets. Unrecorded features can present additional hazards.

### 2.7.1 Ground Stability Hazards – BGS Classifications

The British Geological Survey have supplied the Landmark Envirocheck report with the following classifications for the geological formations mapped on site:

- Collapsible Ground Stability Hazards: Very Low hazard potential;
- Compressible Ground Stability Hazards: Very low hazard potential to ‘No Hazard’;
- Ground Dissolution Stability Hazards: No Hazard;
- Landslide Ground Stability Hazards: Very Low hazard potential;
- Running Sand Ground Stability Hazards: No Hazard; and

<sup>1</sup> Due to the size of the Envirocheck report, its contents have not been appended. The information can be provided electronically.



- Shrinking or Swelling Clay Ground Stability Hazards: No Hazard.

**The BGS classifications presented above are based on mapped geology only, and the list does not include hazard ratings for unmapped materials – such as landfill waste or mine workings unidentified by the BGS.** Both landfill waste and mine workings are known to be present at the site, and both can present a significant compressible ground hazard.

## 2.7.2 Ground Stability – Mining

### Envirocheck Report

The Envirocheck report shows the site to be within a ‘Potential Mining Area’ associated with a number of historic copper and tin ore mines, and an area of Mining Instability with evidence for the latter stated to be ‘Conclusive Metalliferous Mining’.

The list of mines potentially associated with the site and its surrounding area is extensive. Generally summarised from the Envirocheck report and available mining reports from the area [3] these include the following;

**United Mines:** These workings are located directly beneath the site and the wider site area and comprise the Poldory, Whiteworks, Wheal Clifford, Ale and Cakes, Cupboard Hill and Wheal Squire Mines. It is anticipated these connect to the Great County Adit in the western site area.

**Great Consolidated Mines:** These workings are largely located to the immediate north of the site and include Wheal Fortune, Wheal Lovely, Wheal Virgin and Wheal Girl mines, in addition to numerous others.

Together, the mines above are known as the “Clifford Amalgamated Mines”. To the east of the River Carnon the Modern Wheal Jane collection of mines is present.

The Potentially Contaminative Industrial Uses (Extractive Industries) dataset supplied within the Envirocheck report shows eight shafts within the A-Dhann site between 1855 and 1909. 17 No. additional shafts from the same period are shown within 100m of the site boundary. This dataset also records eight instances of ‘Unspecified Deposited Material’ within the site between 1855 and 1909 (likely associated with the build-up of mining spoil at the surface). An additional 5No. areas of ‘Unspecified Deposited Material’ are shown between 1909 and 1915.

From plans supplied by Envirocheck, there are two Recorded Mineral Sites and five Man Made Mining Cavities within 250m of the site boundary to the south. (these classifications may be subject to positional inaccuracy due to incomplete data, as historic mines are understood to be present beneath the site itself).

## Cornwall Consultants Mining Study

Cornwall Consultants Ltd were commissioned by Arup to undertake a mining search for the A-Dhann site [9] (with the full report provided in Appendix C). The study has concluded the site to have a **High Risk** associated with metalliferous minerals beneath the site and has recommended that further actions be taken.

The following executive summary was provided by Cornwall Consultants Ltd:

*“Our research indicates multiple former mine shafts; lode outcrops and surface workings within the site. Most of the identified features are not believed to have been permanently secured or information is sparse. We strongly believe that the property could be affected by subsidence related to historic metalliferous mining and we are unable to confirm or dismiss this without further assessment.”*

*“The Mining Search provides an assessment of the subsidence risk presented to the property from historic metalliferous mining. The report findings are based on factual information from maps, plans and records in Cornwall Consultants Ltd private archive, the results of relevant on-site investigations, as well as commercially available datasets. This information has been interpreted by experts to reasonably predict the existence; location and likelihood of unrecorded mine workings.”*

Key findings of the Mining Study can be summarised as follows:

- The site is situated within an area of extensive historic metalliferous mining activity. Extensive underground workings exist beneath the entire site; however most are at sufficient depth not to present a direct risk of subsidence to the surface.
- The site is entirely covered by raw/partly processed mine waste of variable thickness, comprising mixed rock debris.
- The research has identified early surface workings on many of the mineral lode outcrops, although further such workings (unrecorded) are likely to exist. Surface workings can cause subsidence problems particularly if they are connected to underground workings.
- There may be as many as 60 mineshafts within the boundary of the site. A small number (less than 5) were assessed and treated in the 1980s. Any mineshafts for which remediation records are not available are assumed to remain unsecured and cannot be considered to be in a stable state.
- The eastern half of the site lies within the Mineral Safeguarding Areas associated with two strategic mine shafts or designated metalliferous minerals.

Figure 3 and Figure 4 provide extracts showing the extent of identified mine workings at the site. The Study recommends that a Mining Investigation is undertaken to further assess the risks to the property.

Additional information on the general history and typical characteristics of metalliferous mining in the South West region is provided in the Mining Study, which is included as Appendix C to this report.

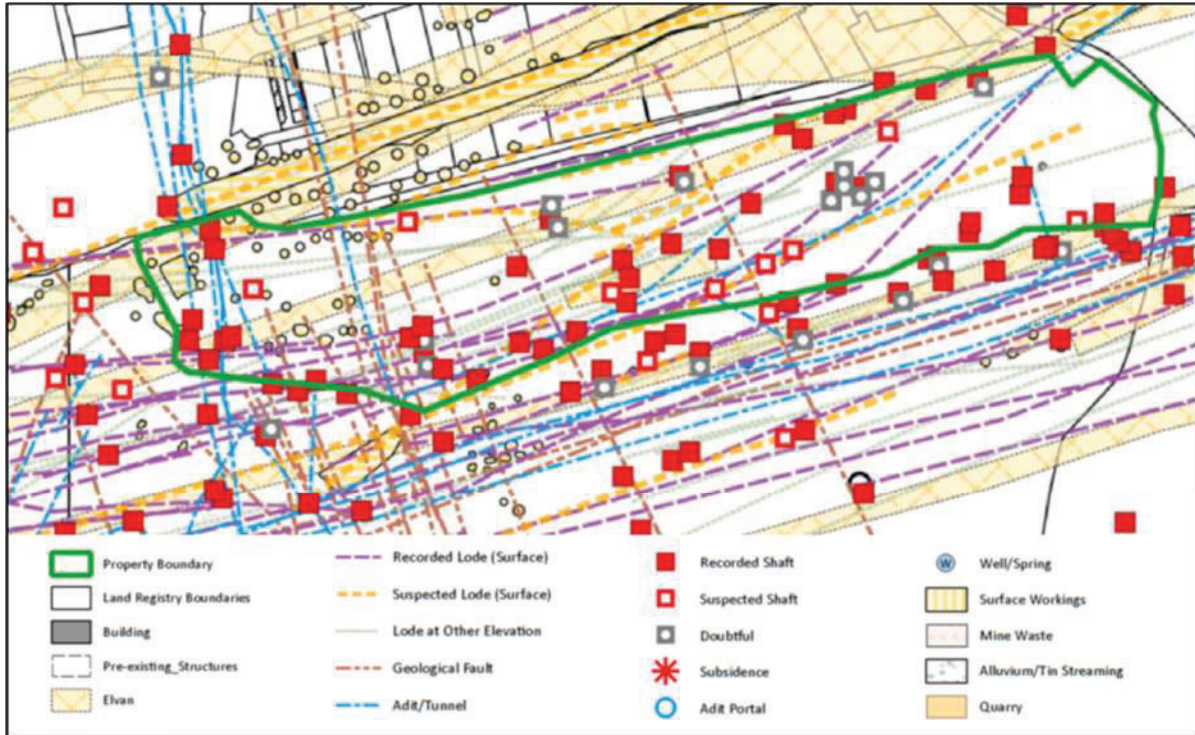


Figure 3. Documented Surface and Shallow Mining Features [9].

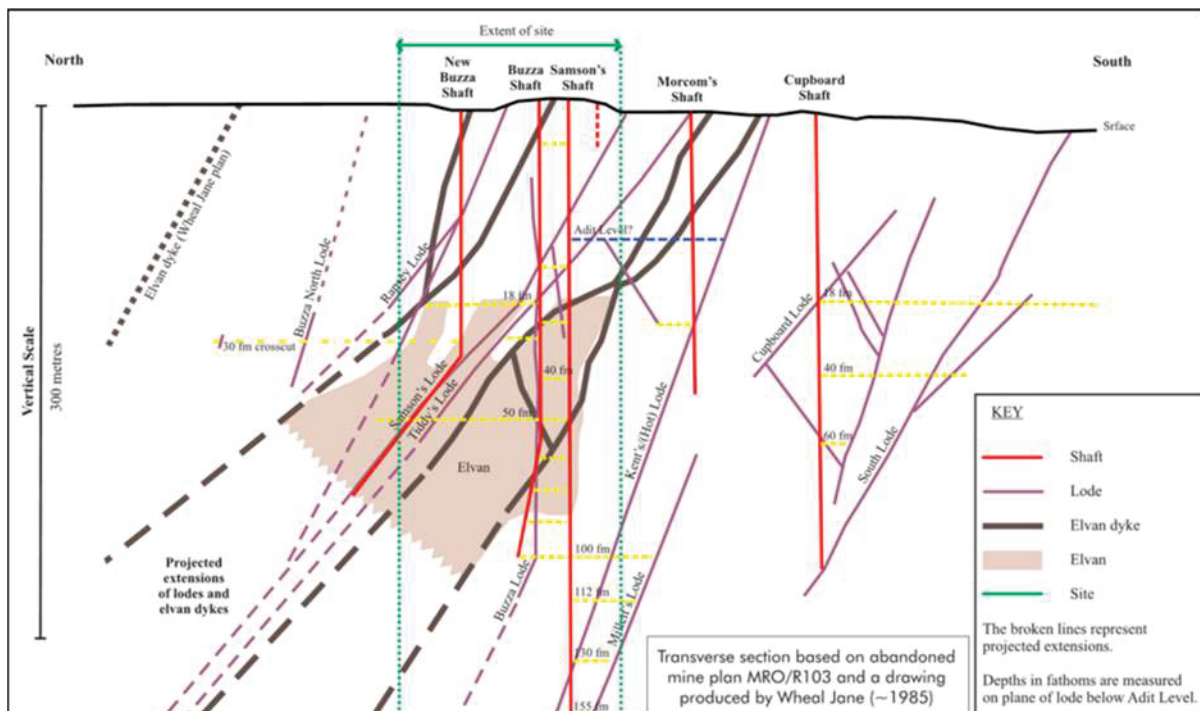


Figure 4. Cross Section of 'Samson's Shaft' [9].

## 2.8 Hydrogeology

Bedrock at the site has been classed by the Environment Agency (EA) to be a High Vulnerability Secondary A Aquifer, with well-connected fractures for bedrock flow.

The Killas rocks are reported to have a low primary porosity and a high secondary porosity caused by fractures, faults, and weathering which provide storage and limited groundwater flow [2]. The strata are also reported to have been subject to extensive alteration via weathering which has decomposed rock fragments to a clay like material, which has potential for infilling fractures in rock, causing a reduction in permeability [2].

Based on monitoring undertaken at the United Downs landfill in 2018, and as reported in the 2018 annual report for the landfill [2], groundwater below the site and wider landfill area is presumed to flow in a northerly direction.

Groundwater flow in the locale of the site is reportedly dominated by the County, Wellington, and Wheal Jane adits [2]. A conduit/tunnel system is believed to be hydraulically connected to the site providing a preferential route for groundwater flow in a north easterly direction with discharge of groundwater and mine water into the River Carnon just below Twelveheads Village (Figure 5) [2].

A more detailed description of local groundwater flow conditions is detailed below in Section 3.3.

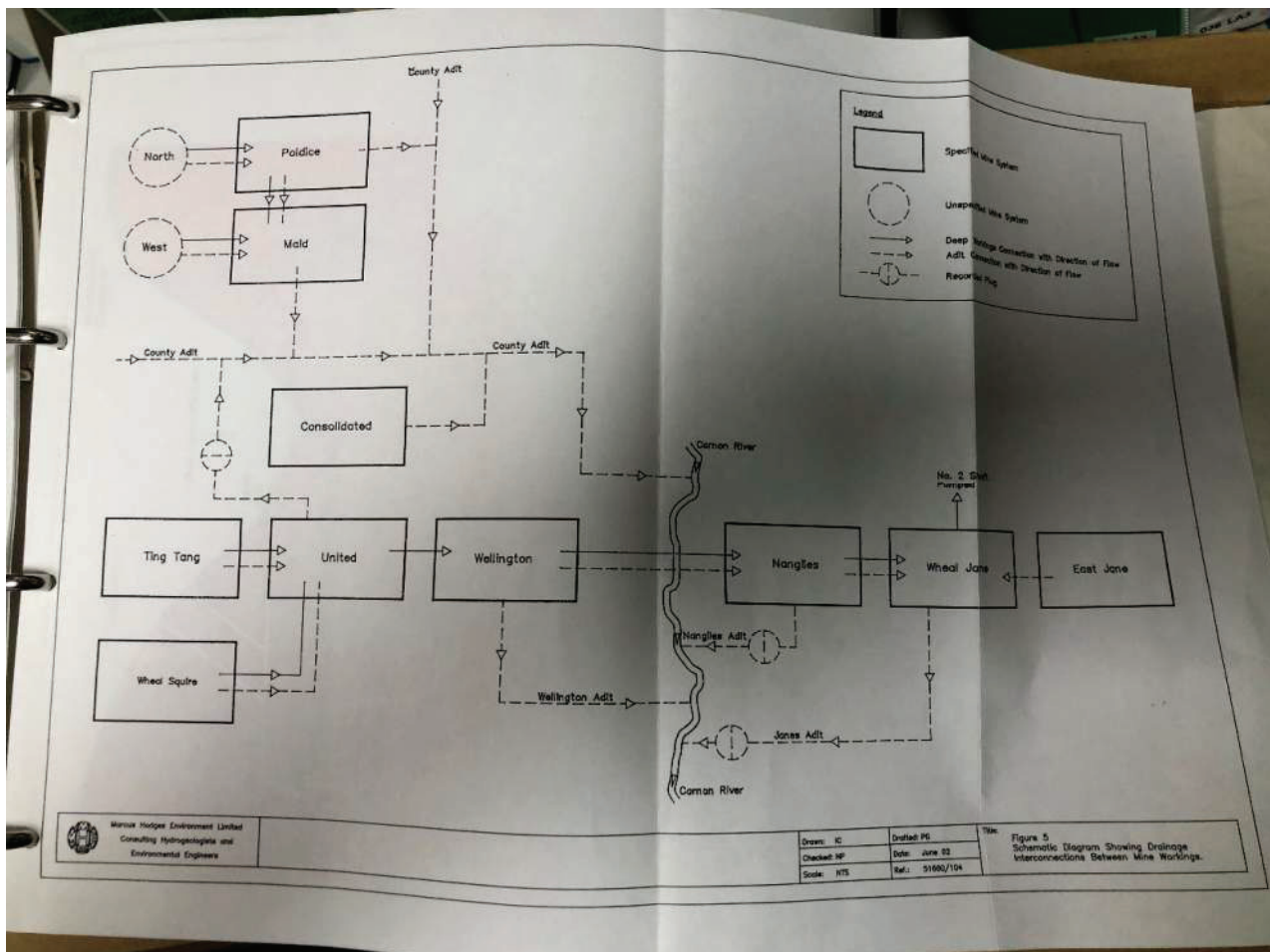


Figure 5. Process & Instrumentation Diagram of Drainage Connections between Mineworkings [8].

A Source Protection Zone (SPZ) is present some 1.5km to the south west of the site area (consisting of both SPZ-1 and SPZ-2 zones. Associated with this, a

licensed groundwater abstraction well, with a low abstraction rate of 2.3m<sup>3</sup> per day and 795m<sup>3</sup> per year, is listed in roughly the same area, with abstracted water used for agriculture.

Further groundwater abstractions for domestic and agricultural uses are listed 1.2km and 1.5km to the west of the site. One of the abstractions pertains to the abstraction of groundwater from a mining adit whilst the other is from a well.

The secondary A aquifer beneath the site, the surrounding groundwater abstractions and SPZs, and the reported network of subsurface tunnels will require consideration with respect to the future development of the site, and the potential creation of preferential pathways for contaminant migration.

## 2.9 Hydrology

There are no identifiable natural surface water features within the site boundary, however drainage features associated with the landfill are present. The site lies within the surface water catchment of the Hicks Mill Stream.

There a number of surface water features located around the perimeter of the wider landfill area, notably on the western and southern boundaries (and beyond) comprising the Hicks Mill Stream and some of its un-named tributaries. The main course of the Hicks Mill Stream is located some 800m to the south of the site and has been classed as River Quality B, with a flow less than 0.31 cubic metres per second (cumecs).

An attenuation pond ('Sparry Lane Pond') is located at the western boundary of the United Mines Landfill Site. This pond is fed by two un-named minor watercourses which appear to collect run-off from the western and south-western areas of the landfill, and by a stream which collects water from the Carharrack catchment. Water collected in the attenuation pond is transferred to the southeast via a rising main, is culverted beneath the leachate treatment plant and discharges to a tributary of the Hicks Mill Stream.

Due to the topography of the site and wider landfill area, surface waters drain southwards to the Hicks Mill Stream at 50mAOD. The Hicks Mill stream and the local mine adits flow to the east and support the River Carnon, which is some 1.3km to the east of the site area at its closest point.

The most recent annual monitoring report for the landfill site (from 2018) [2] by the EA states that with respect to surface water features in the locale of the "*Rivers and streams vary within this area in character and water quality. Some suffer from poor water quality due to leached minerals and metals from mine workings or from agricultural run-off*".

The United Downs Landfill has a permitted abstraction license for the use of surface waters from an un-named tributary of Hicks Mill Stream located on the western boundary of the main landfill area, some 250m to the south west of the site. The license is for abstracted water to be used in dust suppression works, and records show the license for this has been held by both Sita Cornwall Ltd and Suez UK Environment Ltd, with the most recent license dated from 2016; after filling operations at the site had ceased.

A further water abstraction license is listed as held by Suez UK Environment Ltd pertaining to the abstraction of surface water from the Gwenapp stream some 900m to the south of the site area, for use in dust control works. The most recent permit for this abstraction is also dated 2016.

Wheal Maid Mine has a license for the abstraction of water from a river (anticipated to be the Carnon River) north of the site, for use in industrial processing at an abstraction rate of some 180m<sup>3</sup> per day. The current status of the license is unknown.

## 2.10 Flooding

A review of the flood risk on the site has been undertaken from flood maps provided in the obtained Envirocheck report [1].

### 2.10.1 Rivers or Seas

There is no risk identified to the site from flooding or extreme flooding from rivers or seas without defences.

### 2.10.2 Other Surface Water Flooding

A review of the Environment Agency Surface Water map [1] indicates that within the site, there are a number of surface water features which have a Low (1,000 year) return risk of flooding. On the southern site boundary, corresponding to historical mining features, a small area is also identified which has a high – 30year return risk of flooding. An extract of the reviewed plan is presented as Figure 6.

These surface water features within the site area are not shown on reviewed current hydrology plans or OS maps for the site, however they roughly correspond to some historic mining features (which would have been backfilled with waste). It is not anticipated that such surface water features remain within the site area, in its present form; particularly following landfilling and capping restoration works. Consequently, it is anticipated that the EA map pertains to site features prior to infilling of the site area with waste (Figure 6).

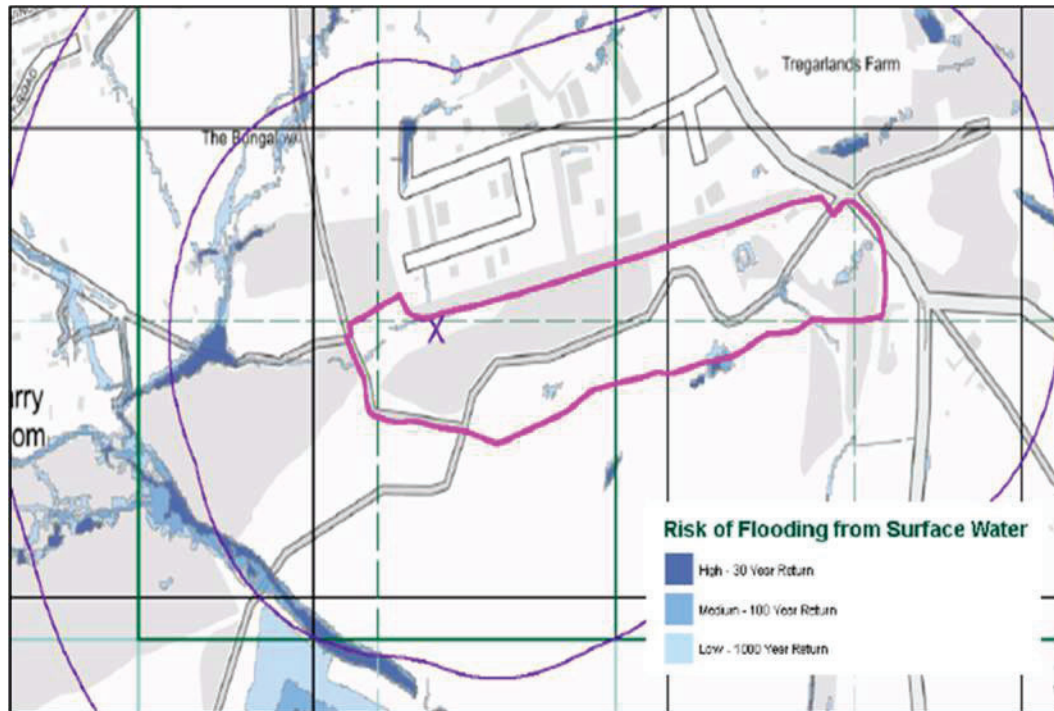


Figure 6. EA Surface Water Flood Plan.

### 2.10.3 Groundwater Flooding

The site has been classed as having limited potential to flood from groundwater. However, the land to the immediate west (10m from the site boundary) has been identified to have potential to flood a property situated below ground level with groundwater. The Envirocheck report shows that 200m to the west of the site and 500m to the south, there is potential for flooding to occur at surface from groundwater.

Due to the landfill construction and leachate management, the risk of shallow groundwater within the site area is considered to be low.

## 2.11 Discharge Consents

A review of the obtained Envirocheck report [1] indicates that there are no discharge consents within the site area, and none are listed within the wider Landfill site. A review of discharge consents within 500m of the site boundary is provided below.

- A revoked consent (1995) is listed for the discharge of trade effluent/site drainage from a motor manufacturer located within the United Downs Industrial Park some 340m to the north of the site. The receiving water has not been named.
- A consented soakaway is registered to the same motor manufacturers as above, for trade effluent and site drainage, dated 2012. The soakaway is located some 360m north of the site, within the United Mines Industrial park.

- A discharge consent for final/treated effluent into an un-named stream is licensed to a trade centre (not motor vehicles) within the United Mines Industrial Park some 420m north of the site.
- A further soakaway consent is listed some 440m to the south east of the site pertaining to treated effluent from a domestic property.
- A discharge consent is held by South West Water for storm sewage overflow into an un-named stream from storm tanks on the sewage network located just off Sparry Lane, some 500m west of the site area.
- A number of discharge consents are held by the waste water treatment works located some 500m to the south of the site, largely for storm water overflow into nearby surface water features (i.e. the un-named tributaries of the Hicks Mill Stream).

The presence of soakaways in the locale of the site indicate that shallow ground conditions must be such as to enable infiltration and the draining of water.

## 2.12 Contaminated Land Register and Pollution Incidents

A review of the obtained Envirocheck report [1] indicates the following pollution incidents to have occurred on, and in the near vicinity of the site area.

- One Category 3 minor incident<sup>2</sup> is recorded to have occurred within the site area, comprising the discharge of unspecified “chemicals” into a surface water feature. The incident occurred in 1991, and no further details have been provided.
- In September 1993 surface water run-off (attributed to weather conditions) from an area of the refuse tip entered a freshwater stream some 58m south east of the site. This was classed by the Environment Agency as a Category 2 Significant Incident.
- In January 1993 a Category 3 minor incident was recorded some 370m to the south of the site, on the wider landfill perimeter and pertained to surface water run-off from the landfill to a surface water feature (also listed as weather attributable).

No further pollution incidents to controlled waters are recorded within 500m of the site area. The incidents listed above are not anticipated to have significantly impacted or had any long-term impact on the site area.

The Envirocheck report lists the following Substantiated Pollution Incidents to have occurred within 500m of the site:

- In September 2008 and April 2009, Category 2 significant incidents to air were recorded some 470m north of the site, pertaining to landfill odour.

---

<sup>2</sup> The EA defines pollution incidents as Category 1 for ‘major’, 2 for ‘significant’ and 3 for ‘minor’. More information can be found at the EA’s website:  
<https://www.gov.uk/government/organisations/environment-agency>



Numerous other reports of landfill odour have been recorded over 500m from the site area, largely concentrated to the north west of the site, the most recent dated 2009. It is noted that further refuse tips and infilled land are present to the north west of the site area.

### **2.12.1 Planning Hazardous Substance Consents**

Only one application for a hazardous substance consent is listed within 1km of the site area, pertaining to Flo Gas UK Ltd located in the United Downs Industrial Estate some 116m north east of the site area. The application was for the handling/storage of liquified extremely flammable gas (including LPG) and natural gas (whether liquified or not) and is dated 2003. The Flo Gas premises is currently listed as inactive.

## **2.13 Landfill and Waste Management Facilities and Permitting History**

Landfilling operations at the Site commenced in 1974 under Waste Management Licence (WML) 20530 issued to former operators CES, dated 24 November 1993. Pollution Prevention and Control (PPC) Permit, reference BK2429IG, was issued on the 18 August 2004 to CES, superseding the landfilling aspects of WML 20530, and later transferred to SITA on 3 November 2006 (transfer reference MP3439MH). The Site was then regulated under Environmental Permit MP3439MH/V004 (the Permit), and three Permit variations were granted between 2009 and 2017 (V005 to V007). An application to transfer the Permit to Cornwall Council was made on 19th June 2019, reference EPR/UP3035QX/T001, and the transfer was completed on 2nd September 2019.

### **2.13.1 On-Site**

The existing United Mines Landfill is a licensed waste management facility, which ceased filling operations in 2010.

Within the obtained Envirocheck report, the licence for the site is listed as effective, and the site categorised as landfilling of great than 10 tonnes per day (T/D) with a capacity of greater than 25,000 tonnes excluding inert waste. The site is a Local Authority Recorded Landfill (and is now under the remit of the Local Authority having been passed over following closure by Suez). Local Authority records indicate the site accepted domestic, commercial, trade, special wastes (primary asbestos and oil).

The Environment Agency records show the site to be registered to County Environmental Services Ltd in 1992 and 1998 with a “very large” input rate of greater than 250,000 tonnes per year. Authorised wastes at the site are listed to have included (but not limited to); ammonia, arsenic, cadmium, barium, copper and chromium compounds, cyanides, organic and other acids, polyester resins, synthetic adhesive wastes, lead/acid batteries, mercury compounds, various forms of asbestos, difficult – non-specific wastes, toxic and special wastes, fuels, oils, and greases, tar, bitumen, and asphalts and solid putrescible wastes. Prohibited

wastes include animal waste and carcasses, clinical wastes, drums of greater than 25 litres capacity, large volumes of liquid wastes, and waste which would produce leachate unsuitable for treatment.

The most recent permit pertaining to the site area is an Integrated Pollution Permit and Control, granted to Suez Recycling and Recovery, dated August 2018. The activity is listed as waste landfilling greater than 10T/D with capacity greater than 25,000 tonnes excluding inert wastes and disposal of less than 50 T/D of non-hazardous waste involving biological treatment.

The 2018 permit supersedes those historically listed, which included a 2006 permit which, in addition to the waste above, permitted the deposition of combustion wastes; waste derived fuel greater or equal to 3MW but less than 50MW.

### 2.13.2 Civic Amenity Site

The existing household waste amenity site is listed as being operated by Suez Recycling and Recovery UK Ltd, with the license issued in 1994, and being last modified in 2016. The civic amenity site remains open and operational in the eastern site area.

County Environmental Services Ltd are also listed as having operated the civic amenity site, with EA records indicating the maximum input to the site was recorded as “small” equal to or greater than 10,000 and less than 25,000 tonnes per year. The license for this site, under Environmental Services is dated 1997, with the site permitted to receive garden and household wastes, vehicle parts, and waste from private dwellings. Clinical waste, commercial and industrial waste and toxic wastes were prohibited at the site.

In 1994 (the license for which has been superseded), the civic amenity site was a registered waste transfer site, with the same input rates as above, however with a more varied authorised waste list, which, in addition to the above, included contaminated rubbish bags and sacks, solid putrescible wastes, denatured paints, oils and greases, non-toxic metal compounds, polymeric materials, tar, bitumen, pitch and asphalt. Prohibited wastes included difficult wastes and domestic pet carcasses.

### Prosecutions Relating to Authorised Processes

The United Downs Landfill site was reportedly prosecuted in January 2002 for the contravening of the conditions of its waste management licence, under the EPA90 Prosecution Act. The site was found guilty of contravening their license and fined. No further details on this event have been provided.

There are no other prosecutions listed within 500m of the site area.

### 2.13.3 Surrounding Waste Management Facilities

#### Historical Landfill Sites

North Tresamble Farm located some 855m to the south of the site is listed as a historic landfill which accepted inert, industrial, commercial and household waste. The site is listed to have operated from 1980 to 1982. A further landfill is registered some 849m to the south east of the site, at Tresamble, Gwennap. The landfill closed in 1984, however little else is known as to the nature of the site.

Pound Caravan Site located some 900m to the north west of the site, now licensed to Cornwall County Council is listed as a historical landfill site which previously accepted inert, commercial and household waste. A further historical landfill is listed in the same locale, located at “Wheal Jewell Gypsy site”. Both sites are also, under the Local Authority Landfill register, listed to have accepted mine fill contaminated with heavy metals.

#### Waste Disposal, Transfer and Treatment Facilities

A number of waste facilities are recorded in the locale of the site, particularly within the United Mines Industrial Park to the north of the site area. Those within 500m of the site area are listed below

- A metal recycling facility and scrapyards is located some 270m to the north of the site, within the United Mines Industrial Park. The site is a registered waste treatment and disposal site. The original license for the site was issued in 1992 and was modified in 2005; the site is listed as operational (as far as is known) and is authorised to accept batteries, petrol, scrap metal, vehicle parts and waste oil. Prohibited wastes include clinical wastes, flammable solvents, hazardous wastes, flammable materials, noxious and explosive wastes, radioactive and special wastes, and food and vegetable matter.
- A further operational scrapyards is located some 290m north of the site, extending to some 360m north towards United Road. The site has a license for the physical treatment of waste and metal recycling, with a maximum waste input rate of “very small” – less than 10,000 tonnes per year. The most recent license for the site is dated 2003 and was initially issued in 1992. Authorised wastes at the site include vehicles, parts and equipment and scrap metal. Special wastes and transformers are prohibited at the site.
- A former metal recycling site and scrapyards was located within the United Downs Industrial Park some 380m north of the site, however the license for this site was revoked in 2016. Prior to closure, the site operated as a scrapyards with a maximum input rate of less than 10,000 tonnes per year. The site operated from 1993 and was authorised to accept batteries, petrol, waste oils and scrap metal. This site is likely to be in the same premises as that above, under different ownership.
- A further waste management facility for end of life vehicles is located within the industrial park some 400m north of the site. The license for the site was issued in 2004, however its current status is unknown. Potentially related to

this was a vehicle depollution facility, located in close proximity to the end of life vehicle site. The license for this site was issued in 2012 however has now been surrendered.

- An active mixed metal recycling site is located some 400m north of the site, at Heather bank, along United Road. The site is also operated as a scrapyards accepting mechanical plant, scrap metal, and vehicles, at a rate of no more than 10,000 tonnes per year. The site has been in operation since 1996.
- A registered waste transfer site was located to the immediate north of United Road, within the United Downs Industrial Park some 400m north of the site area. The site accepted “very small” volumes of waste, less than 10,000 tonnes per year, comprising paper and cardboard from domestic and commercial and industrial premises. Hazardous wastes. Highly flammable materials, liquid and noxious wastes and explosive materials were prohibited at the site. The licence for the site was dated 1991 however is recorded to have lapsed or been surrendered.

## 2.14 Contemporary Trade Directory Entries & Points of Interest

The civic amenity site in the eastern site area is currently listed as a trade directory entry. In addition, a tank is listed on the southern central site boundary, alongside a shaft. A further shaft is listed in the north western site area. No further ‘Points of Interest’ are listed in the Envirocheck report as being within the site area. A further shaft is however annotated in the landfill area to the south of the site, and an “industrial feature” classed as energy production is located almost in the centre point of the landfill, pertaining to the landfill gas system at the site. There are far more shafts than those depicted on the Envirocheck Industrial Map anticipated beneath the site and in its immediate locale.

There are numerous trade entries for premises in the locale of the site area, most of which pertain to units within the United Downs Industrial Park, located to the north of the site.

A list of the premises nearest the site, within 150m, is provided below;

- An active distribution services – of unknown type (34m north);
- An inactive aggregates supplier (34m north);
- An inactive horticultural equipment manufacturer (34m north);
- An inactive mechanical engineers’ firm (81m north);
- An active powder coater for vehicles (91m north);
- An inactive car repairs and conversion specialists (90m north);
- An inactive furniture manufacturer (66m north);
- The inactive Flo Gas gas suppliers (96m north);
- An active glass fibre manufacturer (105m north); and
- An active cleaning materials and equipment firm (106m north).

In addition to the above, an active car breakdown and recovery services, a garage services, an active car paint and lacquer manufacturers, plus various other recycling scrap metal, fuel merchants and distributor premises are located within the industrial park.

## 2.15 Ecology & Sensitive Land uses

The site lies in a nitrate vulnerable zone.

The land surrounding the site; immediately alongside the eastern site boundary and some 500m from the northern, western and south western boundary, is classed a World Heritage Site.

Wheal Maid Lagoon, at Gwennap is listed under the Environmental Protection Action (1990) Part II A Section 78C (1) as a Designated Special Site.

A Grade II listed building, the Eldons Engine House, is located on the eastern site boundary.

## 2.16 Radon Gas

A review of the Health Protection Agency's Indicative Atlas of Radon in England and Wales shows that the site is within an area of elevated radon potential, and that more than 30% of homes in the 1km grid square around the A-Dhann site are estimated to be at or above action level. This rating represents the highest radon potential within the 1km grid square and is not necessarily representative of the radon potential of specific geological conditions beneath a specific site or address. The igneous felsite dykes adjacent to the A-Dhann site are a potential source of radon, and Radon Protection Measures may therefore be necessary for the proposed development.

## 2.17 Unexploded Ordnance

An Unexploded Bomb (UXB) Risk Map has been obtained from ZeticaUXO (see Appendix D). The map shows the A-Dhann site to be located in an area that experienced a low intensity of bombing during the second world war, corresponding to less than 15 bombs per 1,000 acres (around 4,000,000 m<sup>2</sup>). The closest town is Redruth, which is also shown as having experienced a low intensity of bombing. Other nearby towns include Truro and Falmouth, which are indicated as having 'Moderate' and 'High' bombing densities respectively.

The site itself is in a predominantly rural setting and is not within an area that is known to have been heavily bombed, nor is it situated near any known war-time strategic installations that could have been priority targets for enemy aircraft. The site is not known to have been used for any historical military activities, and there is no evidence of bombing at the site on the available post-war historical mapping. No information has been reviewed which indicates any UXB materials or military waste may have been accepted at the Landfill.

Therefore it is unlikely that any further risk assessment or mitigation measures will be required with regards to Unexploded Ordnance.

## 2.18 Site history

The history of the site and its immediate surround has been researched from available historical maps and aerial photographs obtained from Historic England Archives. A general summary of the historical development of the site is summarised below and is presented on Figure A 5a, b, and c.

Table 3. Historical Site Review

Date	On-Site	Off-Site
1880	The site is annotated within the disused tin and copper United Mines. The site and its immediate surround have been subject to clear mining activities. 3No. shafts are annotated in the western site area, 2No. are annotated in the central site area, and 1No. is shown in the eastern site area. An access track forms the western site boundary, running from the north outside of the site area the track forks, with one branch running along the southern site boundary, until the eastern site area, where it transects the east of the site, meandering around shafts and some small buildings. Some 5No. shafts and a chimney are located on the eastern section of the southern site boundary whilst a further two shafts are shown in and along the north eastern boundary. The entire surface of the site is worked, showing as spoils, tailings and pits.	A further 8No. shafts are annotated within a 100m radius of the site boundary, across the mining landscape, with numerous other shafts located further afield. To the east, the present day un-named B-road is present running from the north and forking to the south east and south west some 70m from the site boundary. The south east fork of the road runs through some small holdings and fields, although much of the land around the area is dominated by mining. A chemical works is shown some 200m to the immediate south west of the site area, alongside a tin steam works. Mining dominates the landscape around the site, with the Great Consolidated Mine (tin and copper), located some 500m to the north.
1908	All shafts located within the site area are now labelled disused. Spoil heaps and pits remain across the site area. The chimney on the eastern section of the southern boundary is no longer shown, and all previously observed buildings in the east appear to have been demolished.	The shafts across the landscape surrounding the site are now also annotated as dis-used. The 1908 O.S plans show more shafts (annotated dis-used) within 100m radius of the site than the earlier 1880- plans, particularly to the immediate south west of the site. The chemical works is now annotated as the “Trevince Works, Arsenic and Tin”, to the immediate south of which “Arsenic Works Woods” is annotated. An engine house is shown some 175m to the north east of the site area and an old clay pit is annotated some 100m to the north west. The surrounding landscape remains dominated by mining features.
1951 (vertical aerial images)	Site appears largely unvegetated, likely due to extensive cover of mining spoil. Track shown through centre of site.	Further unvegetated areas likely due to mining spoil to south of site

Date	On-Site	Off-Site
1963	There has been little change to the site area and it remains dominated by past mining activities. "Old Shafts" is annotated across the area of the site. A pond is shown in the central eastern site area, alongside a former shaft.	The chemical works to the south west is now annotated as "works". The engine house to the north east is no longer shown.
1964, 1967 and 1969 (vertical aerial images)	Site becoming more vegetated, however presence of mining activities still notable. Possible depressions visible around old shafts.	Sewage works shown on 1967 aerial images, 500m south of the site boundary
1970	The site is shown to be occupied by scrub and small shrubs and furze. Some small buildings are shown along the western site boundary. The access track along the southern site boundary remains, and now branches in the eastern site area. Disused shafts remain annotated across the site area. The 1974 O.S plan shows contours within the site area; the central point of the site seems to lie at an elevation of 100mAOD.	The landscape around the site remains dominated by dis-used shafts, with spoils now overgrown by scrub, rough pasture and furze. A go-kart track has been constructed 200m to the east, whilst some buildings have been constructed along the un-named B-road to the south of the site area. Tregarlands Farm is located some 150m north of the site. To the south west, the arsenic and tin chemical works is no longer shown, however Arsenic Works Wood remains annotated. On the 1974 O.S plan, a sewage works is shown to have been constructed some 500m south of the site boundary.
1981	There has been little change to the site area and its immediate surroundings.	
1982 (vertical aerial images)	There has been little change to the site area and its immediate surroundings.	Evidence of waste placement in 'Area A' in the west of the United Mines Landfill Site

Date	On-Site	Off-Site
1988	<p>The site and wider area to the south is labelled as United Mines Waste Disposal site, with the land to the immediate south annotated as a refuse tip. A few shafts remain annotated within the site area, indicating that filling has not started in this area. The small collection of buildings remains in the far western site area. Some earthworks are visible along the northern site boundary, with the ground appearing to slope towards the north. In the east of the site a small patch of land is annotated as “RG Sc Heath” alongside the pond and an old shaft. A “waste recycling centre” is shown in the present-day location of the civic amenity site. A small engine house is shown on the north eastern site boundary, alongside a chimney which is outside the site area.</p>	<p>To the immediate north of the site United Downs Industrial Estate is under construction. The un-named B-road alongside the eastern site boundary has an elevation annotation of 96.5mAOD.</p>
1991-1994	<p>There has been little change to the site. Notably, the 1:10,000 1993 plan shows that tipping of refuse has been undertaken across the wider united downs landfill site, and appears to come up to the access track which forms the southern site boundary. The 100mAOD contour is still shown within the central site area, further indicating that no filling has been undertaken within the site area, to the north of the access track. Only one small shed like building remains on the western site boundary. The waste recycling site remains in the eastern site area and some upfilling / waste deposition appears to have been undertaken around it, again, south of the access road which crosses the site in this eastern area. The pond remains shown alongside the outline of the former shaft.</p>	<p>There has been little change to the surrounding site area, Tregarlands Farm remains to the north, and works are ongoing at the United Downs Industrial Park; with the addition of some depot units.</p> <p>Significant landfilling has been undertaken to the immediate south of the site, extending towards Arsenic Wood. The landfill area extends over the site of the former chemical works. A drain is seen to truncate and separate the area of filling from Arsenic wood.</p>
1995 (oblique aerial photo)	<p>Side slopes of Phase C (Phase 3) and Phase 4A (Phase D – Area A) visible on aerial image. Cells appear not to have been filled at this point. Phase 1 and Phase B (Phase 2) appear to have already been filled. (see Figure 7).</p>	<p>Further development at the Industrial Park to the north of the site</p>
2000	<p>The entire site area is now shown to have been subject to infilling, with the exception of a small area in the east, separated from the waste by a drain. There has been slight amendment to the access tracks crossing the site area to accommodate the filling works. The recycling facility remains in the eastern site area. The small shed remains on the western boundary of the site.</p>	<p>The United Downs industrial park has been subject to further expansion to the north. To the south the landfill extends to Arsenic Wood (the separator drain remains) and the sewage works.</p>



Date	On-Site	Off-Site
2006	The site and wider area to the south remains annotated as United Mines Waste Disposal site. The existing site offices appear to have been constructed in the east of the site area, to the immediate west of the drain which remains annotated. Some internal works tracks are evident within the site area in addition to some lines anticipated to be subsurface utilities, extending southwards to the wider site area.	There has been little change to the wider site area.
2019	The present-day access track within the site area is well defined, the area above which is annotated as vegetated. Further vegetation is apparent between the recycling site and the site offices.	To the north, United Downs Industrial Park has expanded, and almost all plots are occupied. To the immediate south, the wider landfill area appears partially vegetated, with well-defined tracks, and some surface drainage features. The existing leachate treatment tanks are now shown alongside Arsenic Woods to the south, to the west of the sewage works. A sewage pumping station is now also shown on the south western site boundary of the landfill area, alongside arsenic woods.

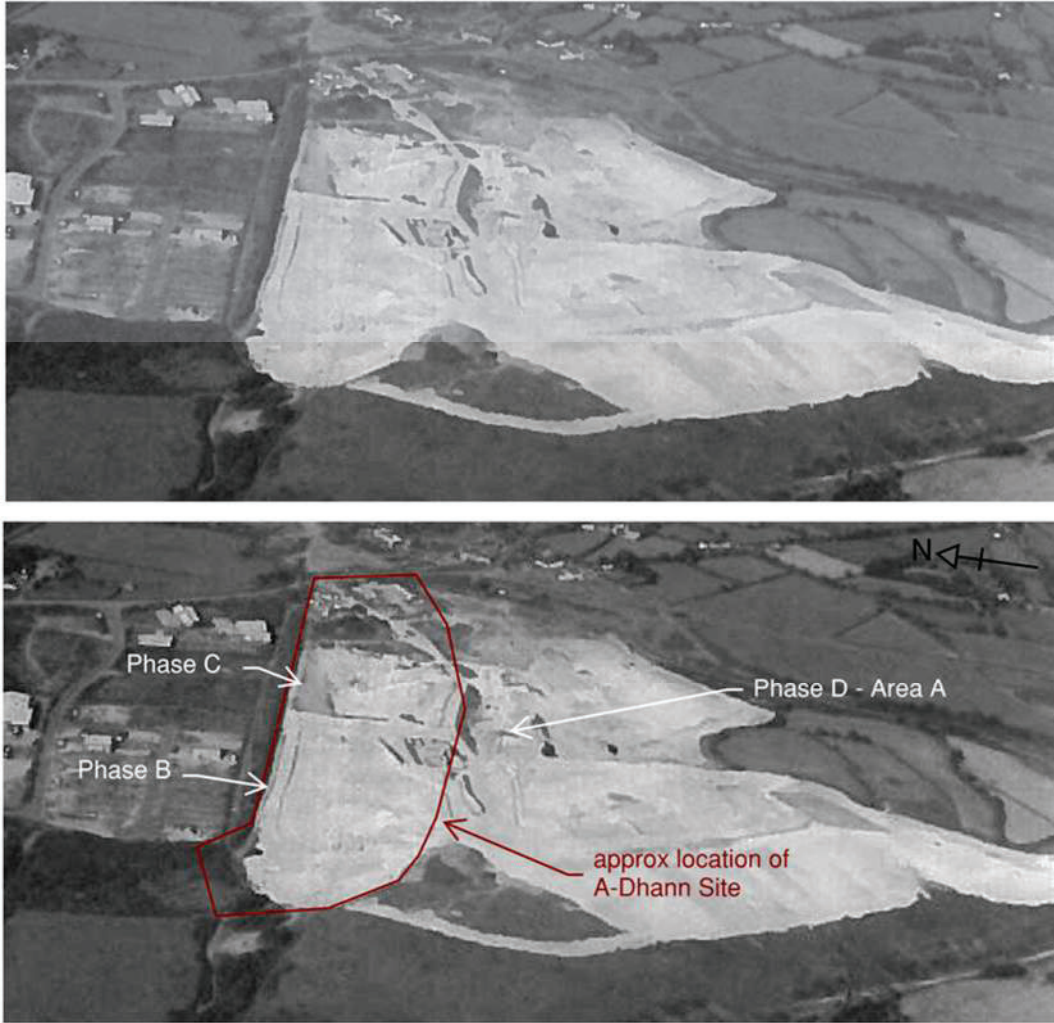


Figure 7. Oblique Aerial Image (1995) – Original (top image) and Annotated (bottom image).

## 3 Landfill Construction and Design

---

### 3.1 General Landfill Layout

The site area lies in the north of the United Mines Landfill facility as shown on Figure A 1. The landfill site is constructed in an area of extensive historical mine workings, excavated mine spoil and mine shafts.

The landfill is now closed, and comprises a total area of approximately 45Ha, with the A-Dhann development site occupying some 9.69Ha of this area (around 22%). The wider landfill site is divided into two distinct areas: 1) dilute and attenuate, and 2) the extension area; these areas are summarised as follows:

1. Phases A to D cover around 30Ha and are located in the older unlined part of the landfill and were operated under the principle of “dilute and attenuate”. This area was operational between 1974 (by Cornwall County Council) and July 2005. The current study site lies within this landfill area.
2. Phases 1 to 4 cover around 15Ha and are located in the “extension area” with fill cells engineered and comprising of a full mineral liner, artificial basal liner and a leachate drainage blanket. Phases 3 and 4 “piggy back” over Phase A. Landfilling commenced in the extension area in May 2005 and putrescible waste deposition ceased in this area on 31 October 2010. The extension area was licensed to accept up to a maximum of 250,000 tonnes per year of inert and non-hazardous waste. The fields of the extension area (Boswell, Arsenic Wood and Dump Field) are “reclaimed”, comprising of mine spoil and overburden with imported topsoil.

Both areas originally consisted of 4 phases (No’s 1 to 4), however for clarity, the older dilute and attenuate cells were subsequently referred to as Phases A to D in several reports prepared for the site. Phase A was sub-divided into 3 ‘areas’ (A to C) and Phase D into 2 ‘areas’ (A and B).

The extension area covers an area of around 11Ha but was partially ‘piggybacked’ over Phase A (largely the southern half of Area A and the northern half of Area B), giving a total Site area of approximately 36Ha. Originally 4 single-cell phases were planned, though Phases 3 and 4 were later sub-divided into 2; Phases 3A, 3B, 4A and 4B respectively. Phase 4B was ultimately not constructed.

The landfill plan supplied within the annual monitoring report (Figure 8) shows the A-Dhann site to comprise Phase B and Phase C and the northern fringes of Phase D Area B, Phase D Area A, and Phase A Area C. In the eastern site area, no landfill phases are shown, rather the existing United Mines Offices, the gas compound, and the civic amenity site are present.

A review of the landfill base plan (Figure 9), show the original labelling of the older landfill cells, with the A-Dhann site comprising Phase 2, Phase 3, the northern area of Phases 4a and 4b and a small area of Phase 1. The eastern site area remains outside the landfill cell layout.

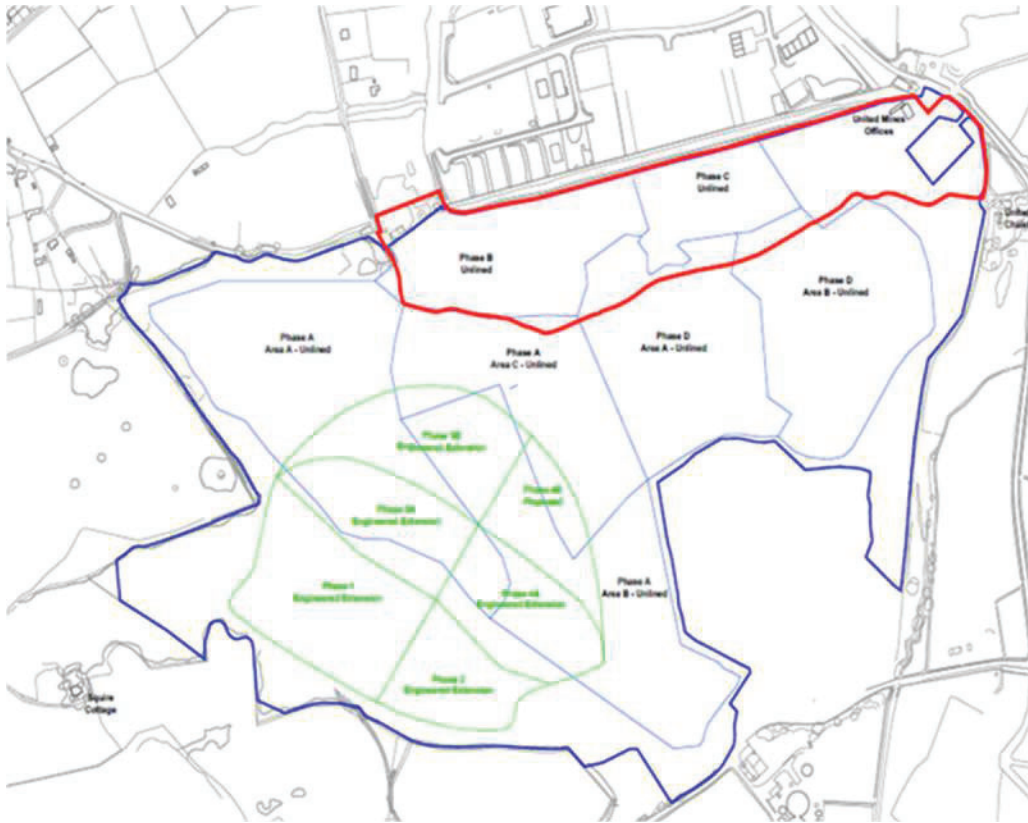


Figure 8. Landfill Areas [2].



Figure 9. Landfill Cell Base Plan (Drawing Utm-LCD-0316-01-A3).

## 3.2 Capping Design

Capping of the landfill was completed between 1999 and 2012. A review of the capping boundaries across the landfill has been undertaken, and these are presented on Figure A 6 in Appendix A. Note the capping phases do not correspond with the waste cell phases.

The capping phases of the older landfill area are referred to as numbers not letters. A summary of the capping build-up across the proposed A-Dhann development site is provided below in Table 4, as taken from the supplied capping plan (Utm-CAP-0316-01). The wider landfill area capping details have also been provided for reference.

Table 4 shows that across the A-Dhann development site, the landfill cap comprises a minimum of 0.1m (up to 0.3m) of site processed material placed above the waste, overlain by either a geosynthetic clay liner or a linear low-density polyethylene liner, overlain in turn by a 0.3m thick protection layer.

From restoration details, a minimum of 0.55m of subsoil has been placed over the protection layer, subsequently covered with topsoil. In some areas, to enable tree planting, some 1m of subsoil has been placed.

No Certified Quality Audit (CQA) report or references (or EA approval correspondence) has been provided or reviewed with respect to the capping works undertaken for the phases located within the A-Dhann site.

CQA records are however listed as available for the other capped phases within the wider landfill area (Phase 4/04 + horse lane, Phase 4/05, Extension Phase 1, Extension Phase 2/A, Extension Phase 2/B, Extension Phase 3A/3B, Extension Phase 4, and Phase 1/12). The CQA report for the Extension Phase 2 capping has been received.

No details as to how the engineered capping phases are tied together across the A-Dhann site and the wider landfill area have been provided or reviewed, however overlapping and jointing of either Geosynthetic Clay Liner (GCL) GCL or Linear Low-Density Polyethylene (LLDPE) is anticipated to have occurred.

Table 4. United Mines Landfill Capping Works

Cap / Restoration Phase ID and date	Area Capped m <sup>2</sup>	Capping Barrier	Restoration	Area of A-Dhann Site
<b>A-Dhann Development Site</b>				
Phase 1/01 & 4A/01  2001	56,800	0.1m site processed material, GCL, 0.3m site processed material <50mm	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Comprises western extremities of the site

Cap / Restoration Phase ID and date	Area Capped m <sup>2</sup>	Capping Barrier	Restoration	Area of A-Dhann Site
Phase 4/12* 2012	19,000	0.3m site processed regulating layer, 1mm LLDPE, 0.3m protection layer	0.55m subsoil, 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Small parcel in western site area.
Phase 2 * 1999	16,000	0.3m site processed material <20mm, GCL, 0.3m site processed material.	0.7m subsoil and 0.15m topsoil.	Comprises northern central area of site
Phase 3 1999	16,000	0.3m site processed material <20mm GCL 0.3m site processed material	0.7m subsoils & 0.15m topsoil	Comprises southern central area of site
Phase 4B/05 2005	20,200 (TBC)	0.1m site processed material, 1mm LLDPE, 0.3m site processed material	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Comprises eastern site area, alongside un-capped areas; gas compound, offices & CA site.
<b>Wider Landfill Area</b>				
Phase 4 2000	12,000	0.1m site processed material, 1mm Lapped HDPE, geotextile, 0.5m site processed material <50mm	0.3m subsoils & 0.15m topsoil	Not applicable
Phase 1/02 & 4A/02 2002	48,700	0.1m site processed material, GCL, 0.3m site processed material <50mm	0.55m subsoils & 0.15m topsoil's	Not applicable
Phase 4B/03 2003	20,372	0.1m site processed material, 1mm LLDPE, 0.3m site processed material	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable
Phase 4B/04 + horses Lane 2004	13,000 (TBC)	0.1m site processed material, 1mm LLDPE, 0.3m site processed material	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable
Ext - Phase 1 2006	10,000	0.3m site processed regulating layer, 1mm LLDPE, 0.3m protection layer	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable

Cap / Restoration Phase ID and date	Area Capped m <sup>2</sup>	Capping Barrier	Restoration	Area of A-Dhann Site
Ext - Phase 2 2007	5,000	0.3m site processed regulating layer, 1mm LLDPE, 0.3m protection layer	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable
Ext - Phase 2 2008	4,500	0.3m site processed regulating layer, 1mm LLDPE, 0.3m protection layer	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable
Ext - Phase 3A/3B 2009	25,000	0.3m site processed regulating layer, 1mm LLDPE, 0.3m protection layer	0.55m subsoil & 0.15m topsoil, locally subsoil 1050mm in tree planting areas	Not applicable

### 3.3 Hydrogeological Risk Assessments

Under the requirements of its permit, the United Downs Landfill site has been subject to numerous Hydrogeological Risk Assessments to ensure the level of risk presented to underlying groundwater from landfilling activities met the terms of the groundwater regulations current at the time of permit issue.

The following HRA reports have been received and reviewed as part of this study

- United Mines Landfill Site HRA Review July 2007 Sita / Suez [4];
- United Mines Landfill Site HRA Review August 2013 Sita / Suez [5]; and
- Technical Note: United Mines Landfill HRA Addendum January 2018 ESI [6].

The above list of received documents does not include all Hydrogeological Risk Assessments undertaken for the site, which can be summarised as follows, as taken from [5].

The original Conceptual Site Model (CSM) was presented by Aspinwall & Company (1999), as part of an Environmental Statement; a requirement of the planning application for the then proposed extension to the landfill site.

Marcus Hodges Environment (MHE) subsequently produced a Regulation 15 Water Quality Risk Assessment (MHE, 2002), following the failure of the Aspinwall report to fully address the Groundwater Regulations, as part of the IPPC application. This is regarded as the first 'true' HRA for the Site.

A second HRA was later produced by WS Atkins (2003) in response to a Schedule 4 notice which required further analysis of the Site, using the existing Risk Assessment model to ensure the design fulfilled the requirements of the Groundwater Regulations 1988 and the EU Landfill Directive.

Later, a collective HRA review (HRAR) of the MHE and WS Atkins HRA's was undertaken by SITA in June 2007 (SITA, 2007) following acquisition of the Site in 2006. A further HRA review (HRAR) was undertaken in 2013, to incorporate additional data gathered since the 2007 HRAR.

The 2018 ESI HRA Addendum was prepared in response to a Schedule 5 Notice in November 2017, which related to an application by SUEZ to vary the Environmental Permit for the landfill.

### 3.3.1 Hydrogeological Conceptual Site Model Summary

The original Conceptual Site Model (CSM) was presented by Aspinwall & Company in May 1999, as part of the Environmental Statement for the proposed landfill extension, a summary is presented below, as taken from the 2007 and 2013 HRA reports [4] [5]. The most recent 2018 HRA Addendum for the site identified no significant change to the conceptual site model since this time.

The CSM prepared for the site showed, as per previous sections, geology beneath the landfill to comprise Devonian Mylor Slate Formation, of siltstones and slates with occasional sandstones. The extension area of the landfill was proved to be underlain by up to 3m of mine spoil comprising cobbles, gravels and sand in a clay matrix. Beneath the spoil, the upper 6 to 8m of the bedrock was noted to be weathered. Similar mining spoils and weathered bedrock are anticipated beneath the A-Dhann development site.

Six recorded mine shafts were noted beneath the site of the landfill extension with additional shallow mine workings. Two further mineshafts were revealed by site investigations in this area. As per the mining and historical review, mine shafts and shallow mine workings are also expected beneath the A-Dhann site.

A number of mine drainage adits are present beneath and in the locale of the wider landfill site. Notable adits are the County Adit, Mount Wellington Adit, Nangiles Adit and Wheal Jane Adit. Water levels in the Wheal Jane Adit are controlled by pumping and this water is treated prior to discharge to the River Carnon.

If water levels within the Wheal Jane Adit are allowed to rise then discharge of acid mine water from the Nangiles Adit can occur to the River Carnon and ultimately to the Fal Estuary [4].

The Mount Wellington and Wheal Jane mine workings are interconnected and drain the strata below the United Mines Landfill site. The County Adit is the largest adit system and drains workings to the north of the United Mines landfill site. The southern limb of this system (the Cross County Adit) has been reported to run south to north below the older area of the United Mines Landfill site. A review of relevant mine plans indicates that this adit is expected to be present beneath the western area of the A-dhann site.

The 2013 HRA [3] included a schematic representation of the adit system draining the strata below the landfill, as shown below:



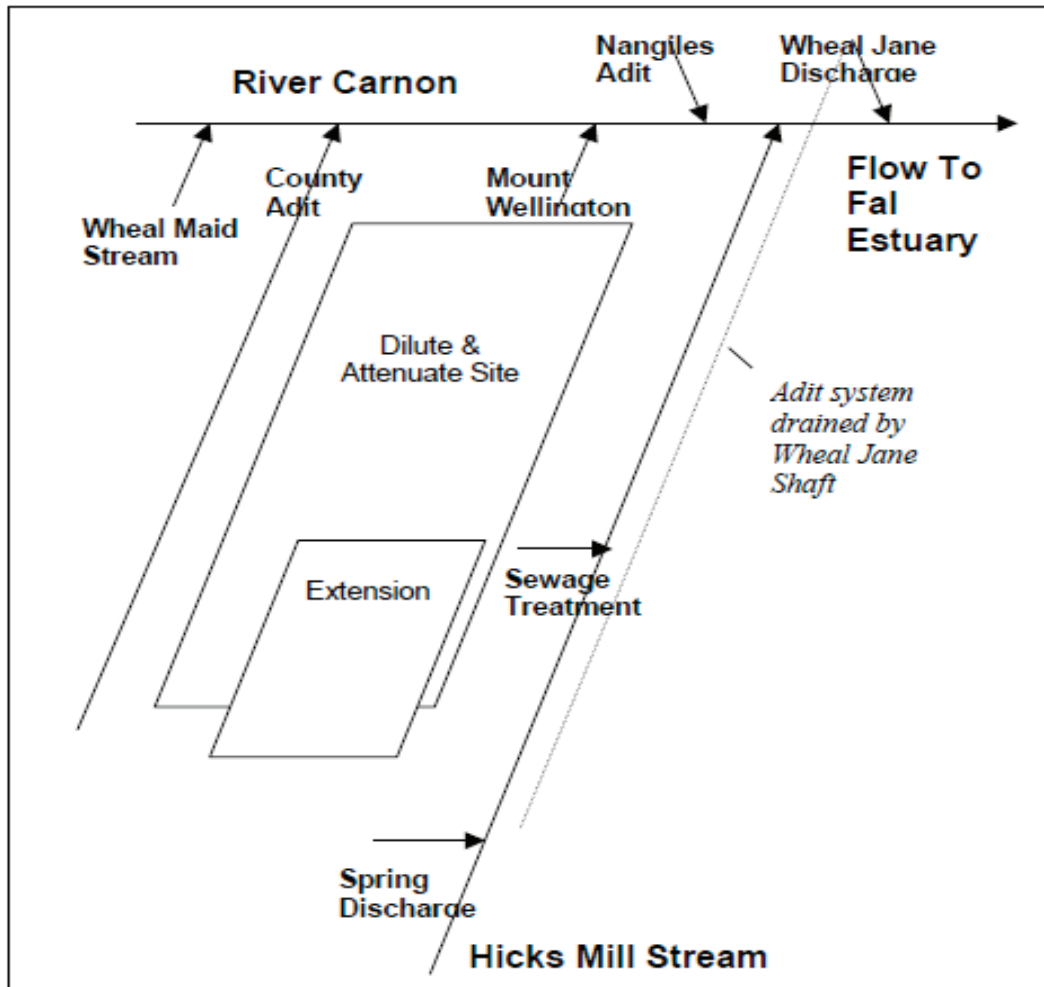


Figure 10. Schematic Illustration of the Subsurface Drainage System including Adit.

Due to the low primary permeability of the Killas, most bedrock groundwater flow is believed to take place through fractures with higher flows associated with fault zones. Infilling of rock fractures by clay is anticipated within the bedrock. The bedrock is classified by the Environment Agency as a Secondary A aquifer, however groundwater quality is reportedly poor due to elevated concentrations of cadmium, iron, manganese, lead, zinc, nickel and arsenic [5].

Groundwater flow beneath the United Mines landfill is dominated by the County, Mount Wellington and Wheal Jane adits, the resultant groundwater flow is in a north / north easterly direction. The landfill lies within the catchment of the Hicks Mill Stream to the south of the landfill but the base of the stream lies above recorded groundwater levels to the south of the site, and therefore it is inferred that the stream is not fed by base flow [5]. Groundwater is believed to flow preferentially into mine workings rather than the stream (Figure 11). A schematic cross section prepared for the landfill site (which includes the A-Dhann site area) as part of the HRA reviews, is presented as Figure 12 on the following page.

The 2007 HRA stated that Groundwater quality up gradient of the site is characterised by low pH (4.1 to 6.4), low conductivity, elevated metal concentrations and variable and elevated concentrations of ammoniacal nitrogen. Sewer leakage to the west of the site was believed to influence groundwater

quality in the vicinity. Mine water quality from the pumped Wheal Jane shaft has even lower pH (3.2 to 3.8), elevated ammoniacal nitrogen, BOD, chloride and very high metal concentrations. Total Organic Carbon and potassium concentrations were low. Historical monitoring data of the Wheal Jane discharge was characterised by elevated ammoniacal nitrogen and it was therefore deduced this was not a result of contamination by leachate. Elevated ammoniacal nitrogen readings were obtained downstream in the River Carnon prior to waste disposal at United Mines landfill site. Generally, groundwater beneath the landfill site was already considered “polluted” by historical mining activities.

Groundwater monitoring undertaken at the site in 2012, from the locations shown in the extract below, was used to create inferred groundwater flow contours as part of the 2013 HRA. The contour plot created for groundwater beneath the landfill as part of the 2013 HRA is shown below as Figure 11; which indicates that the A-Dhann site is likely to receive groundwater flow from the north east, and also the south and south eastern landfill area.



Figure 11. Groundwater Contours and Flow Directions per 2013 HRA [5].

SCHEMATIC CROSS SECTION B-B TO SHOW HYDROGEOLOGY  
SCALE @ A1 1:1000

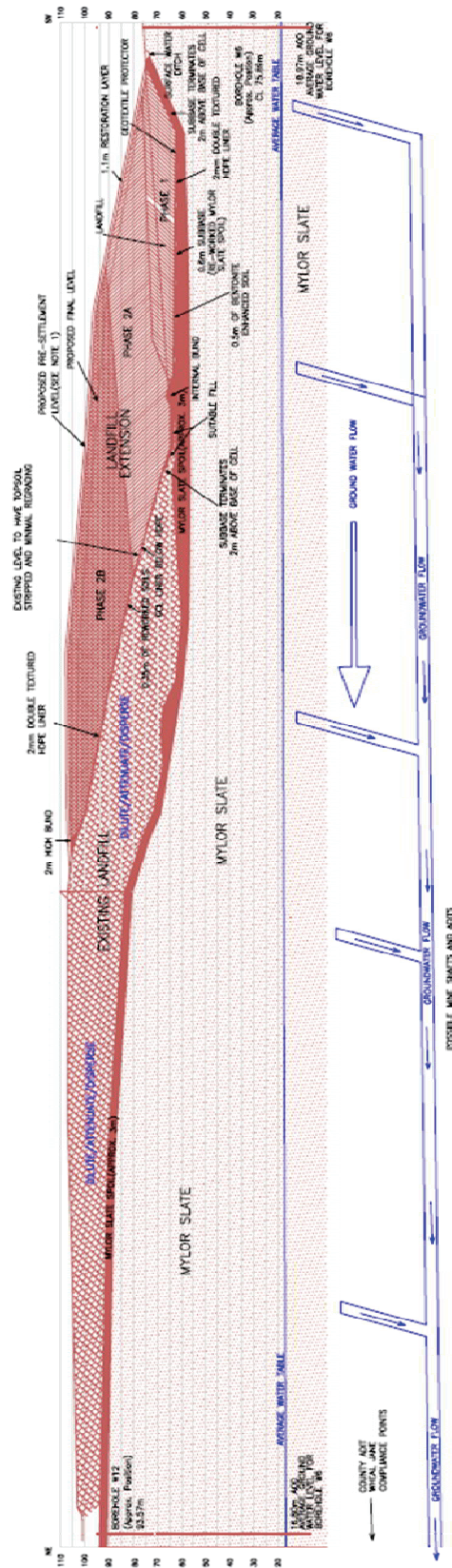


Figure 12. Hydrogeological Conceptual Schematic (per 2007 HRA) [4].

### 3.4 Leachate Management and Monitoring

Leachate level and quality monitoring has been undertaken across the United Downs Landfill site in accordance with the landfill permit and the Monitoring Management Plan, which has not been reviewed or received as part of this report.

Leachate levels are assumed to be controlled via a system of gas extraction leachate treatment and disposal (however at the time of this report, the Leachate Management Plan had not been received).

Collected leachate is pumped to the leachate treatment plant located in the southern area of the United Downs Landfill site, some 500m south of the A-Dhann site area. Treated leachate subsequently discharges to a sewer under a trade effluent consent, which in turn discharges to the South West Water Sewage Treatment Plant at Lanner St Day.

The most recent annual monitoring for the landfill (2018 [2]) indicates that the leachate treatment plant has reduced operational performance, with a total volume of 13,762m<sup>3</sup> of leachate being removed from the landfill site for the 2018 annual monitoring period (10,292m<sup>3</sup> via the south west water outlet and 3,470m<sup>3</sup> removed by tanker for offsite disposal). At the time of preparation of the 2018 annual monitoring report, Suez were reportedly updating the landfill sites treatment plant with the aim of reducing reliance on future tankering of leachate from the site area [2].

The extension area of the landfill – which is engineered and has a basal liner, is subject to leachate monitoring from several borehole locations on a quarterly basis, as required by the landfill permit. The compliance limits for leachate levels vary between 1.5m and 0.5m above the cell base. For the 2018 period, through ongoing active management of leachate, all leachate levels within the landfill extension area (to the south of the A-Dhann site) were compliant, except for two locations. The annual monitoring report states however that the non-compliances were largely indicative of monitoring well construction – with a well being installed 0.5m above the cell base, which makes compliance with 0.5m above the cell base leachate levels impractical to achieve

For the older are of the landfill, and the A-Dhann development site, there are no compliance limits applied to leachate levels in wells.

A review of the leachate wells within the Dilute and Attenuate Area of the landfill indicates that 4No. wells are located within or just outside the A-Dhann site area; UN/L003, UN/L004, UN/L005 and UN/1006, as shown on Figure A 7.

The monitored 2018 leachate levels for wells located within and in the immediate locale of the A-Dhann site are presented in Table 5.

Table 5. 2018 Monitored Leachate Levels below and in the locale of the A-Dhann site

Monitoring Point	Min (mAOD)	Mean (mAOD)	Max (mAOD)	Range (m)
UN/L003	83.88	85.08	86.77	2.89
UN/L004	89.14	89.51	89.7	0.56
UN/L005	89.19	89.38	89.51	0.32
UN/L006	90.37	91.76	93.51	3.19

### 3.5 Landfill Gas Management

The Permit requires the operator of the United Mines Landfill Site to collect landfill gas and to use this to produce energy. If the landfill gas cannot be used to produce energy, the Permit states that the operator shall use appropriate measures to flare or treat the gas in accordance with an approved landfill gas management plan.

Management of landfill gas at the United Mines Landfill Site is subcontracted to CLP Envirogas. In-waste gas extraction wells are connected to two 1003kW landfill gas engines in the gas utilisation compound, and an enclosed ground-flare is used when the engines are unavailable [2].

The layout of the Gas Extraction System for the United Mines Landfill Site is shown on Figure A 7 (from Drawing 5876.SURV.D01, 'As-built Buried/Enhanced Gas Infrastructure' in Appendix B [14]). Individual gas wells are generally connected to one of a number of manifold points around the site, although it should be noted that there are a large number of gas wells shown on the layout drawing which do not appear to be connected to the rest of the system. The manifolds are connected to a series of 180mm, 250mm and 315mm diameter buried gas pipes with dewatering points and valves.

The United Mines Landfill Sites Gas Utilisation Compound is located in the north of the site and is within the boundary of the A-Dhann development. The as-built gas infrastructure drawing suggests that the pipework enters the gas utilisation compound at two entry points, in the north and southeast of the compound.

The density of gas extraction well and associated infrastructure appears to be less concentrated in the northern part of the A-Dhann site (relative to other areas of the landfill). While there is no reason provided in the documents reviewed, this may indicate a reduced rate of methane production in this area.

### 3.6 Gas Monitoring

Gas monitoring at the United Mines Landfill Site is undertaken in accordance with the Environmental Permit and the Monitoring Management Plan (MMP).

Gas monitoring is undertaken in the form of:

- In-waste Gas Analysis;
- Perimeter Gas Monitoring;

- Trace Gas Analysis at the inlet to the landfill gas compound;
- Point Source Emissions to Air (from gas engines and flare);
- Surface Emissions Monitoring; and
- Void Pathway Monitoring.

The Permit requirements and results of landfill gas monitoring are discussed in the remaining subsections to this section below.

### 3.6.1 In-Waste Gas Monitoring

#### In-Waste Gas Monitoring Strategy

It is understood that the in-waste gas monitoring system has been designed and implemented to facilitate the evaluation of when sufficient gas (quality and quantity) is produced by the landfill, to allow collection and extraction to commence. The in-waste gas wells are routinely monitored to provide information on the behaviour and efficiency of the gas extraction system. Ingress of oxygen into the landfill is also assessed from the monitoring results and is used to determine when actions need to be taken to address the oxygen ingress.

The most recently available version of the Permit (EPR/MP3439MH/V007) [15] states that in-waste gas boreholes are required to be monitored monthly, until gas extraction commences in a particular cell.

The Environmental Monitoring Report from 2016 [16] includes results for approximately 215 no. in-waste gas monitoring “IDs”, and readings appear to have been taken once per month. The 2017 and 2018 reports [17][2] do not include detailed data for the in-waste gas monitoring, however a brief summary of exceedances is provided.

The 2016 monitoring report states that the in-waste monitoring locations are shown on a figure included within the 2016 report, however only the perimeter monitoring locations are indicated. Some of the monitoring IDs appear to correspond with the labelled wells shown on the as-built gas infrastructure drawing (5876.SURV.D01) [14]. It is unclear what the other monitoring ID’s (not shown on the drawing) relate to. As such, the precise location of all in-waste gas monitoring wells cannot be verified, and the location of some of the results is unknown.

The annual environmental monitoring reports (2016 to 2018) state the following from the environmental Permit with regards to in-waste gas monitoring:

- Where the oxygen level exceeds 5% or the addition of carbon dioxide and methane concentration percentages is less than 80%, an assessment of air ingress into the system shall be undertaken; and
- Where the concentration of carbon monoxide exceeds 100ppm, then further investigation shall be undertaken.

The results of in-waste gas monitoring are also assessed against Suez own criteria (from their Gas Field Balancing and Gas System Inspection Procedure):

- Where oxygen concentrations exceed 3%, investigations are undertaken; and
- Where carbon monoxide concentrations exceed 75ppm, investigations are undertaken.

### **In-Waste Gas Monitoring Results (2016 to 2018)**

A review of oxygen concentrations and balance gas criteria was undertaken after each monitoring round during the 2016 to 2018 monitoring events. Investigations and actions including further rebalancing and assessment work were performed by Suez to ensure oxygen ingress was kept to a minimum.

The annual monitoring reports from 2016, 2017, and 2018 provide the following with regards to exceedances of in-waste gas monitoring criteria:

- In 2018, there were no exceedances of the carbon monoxide threshold.
- In 2017, six breaches of the carbon monoxide threshold occurred at two locations (UGW00074 and UGW00076), from a total of 3,864 readings collected during this period. However, the two wells where exceedances were recorded are not shown to be within the A-Dhann site (Note that it was not stated which of the CO thresholds was exceeded, or what the recorded concentrations were).
- Exceedances identified during 2016 are not summarised within the report, however raw monitoring data is provided as Appendix D to the 2016 report and summarised in Table 6 below.

The as-built gas infrastructure drawing (Figure 09) shows 44 no. gas wells to be located within the A-Dhann site (excluding the Perimeter Monitoring Boreholes), and these are listed in the table below. Available data from the 2016 monitoring results is summarised in Table 6.

Table 6. In-Waste Gas Monitoring Results (2016): Exceedances highlighted

Well ID	Corresponding ID (assumed) from 2016 results appendix	Number of monitoring visits		Flow m <sup>3</sup> /hr	CH <sub>4</sub> Flow m <sup>3</sup> /hr	CH <sub>4</sub> (%) range		CO <sub>2</sub> (%) range		O <sub>2</sub> (%) range		CO (ppm) range	
		No. Visits recording Gas Concentrations	No. Visits Recording Flow Rates	Max	Max	Min	Max	Min	Max	Min	Max	Min	Max
1612													
GW52													
GW106	UGW00106	12	3	2	1.3	0	63.2	1.9	25.9	0	20.6	0	1
GW55													
GW105	UGW00105	12	3	2	0	0	30.7	1.3	16.4	2.3	20.6	0	2
GW107													
GWSP1	UGW00SP1	12	0			0	65.6	1.9	29	0	20.8	0	0
GW440	UGW00440	12	0			22.3	78.1	10.8	31.6	0.1	14.2	0	0
GWA13	UGW00A13	4	0			3.2	60.3	14.9	32.2	0	12.7	0	0
GW438	UGW00438	11	0			4.1	65.9	4	35.1	0.2	18.9	0	5
GW543	UGW00543	11	0			0	34.4	1.7	22.3	2.2	20.3	0	9
GW545	UGW00545	12	0			44.9	64.8	27.5	37.3	0	0.4	0	1
GWE15	UGW00E15	11	0			9	53.8	5.4	24.6	1.9	16.8	0	2
GWE26													
GWE14	UGW00E14	12	0			29.7	68.3	17	37	0	10.1	0	1
GWE16	UGW00E16	12	0			0.4	56.9	7.4	30	2.9	17.4	0	7



Well ID	Corresponding ID (assumed) from 2016 results appendix	Number of monitoring visits		Flow m <sup>3</sup> /hr	CH <sub>4</sub> Flow m <sup>3</sup> /hr	CH <sub>4</sub> (%) range		CO <sub>2</sub> (%) range		O <sub>2</sub> (%) range		CO (ppm) range	
		No. Visits recording Gas Concentrations	No. Visits Recording Flow Rates	Max	Max	Min	Max	Min	Max	Min	Max	Min	Max
GWM24	UGW00M24	12	0			0.1	71.6	2.1	99.1	0.2	20.6	0	4
GWM21	UGW00M21	12	0			0.3	67	2.1	34.4	1.4	19.2	0	3
GWM10	UGW00M10	12	0			0.5	4.5	3.7	13	13.8	20	0	14
GWD3A	UGW00D3A	12	0			5.1	54.6	4.1	34.5	1.3	16.5	0	4
GWM11													
GW516	UGW00516	12	0			55.8	69.8	28.3	34.1	0	2.6	0	2
GWM5													
GW509	UGW00509	12	0			0	72.3	0.7	27.8	0.2	21.2	0	3
GWM4	UGW00M04	12	0			0.2	44.1	1.2	19.8	6.8	21.5	0	1
GWM9	UGW00M09	12	0			0.1	40.6	3.8	28.7	0	20.5	0	1
GWM2	UGW00M02	12	0			1.1	41	1.8	21.8	5.8	20.3	0	9
GW508	UGW00508	12	0			5.4	49.6	11.8	26.6	0.8	13.4	0	4
GW1634 (obscured on drawing by 1622)													
1622													
BH1													
GW104	UGW00104	12	3	2	0	0	24.6	0.8	18.7	0.3	20.9	0	0

Well ID	Corresponding ID (assumed) from 2016 results appendix	Number of monitoring visits		Flow m <sup>3</sup> /hr	CH <sub>4</sub> Flow m <sup>3</sup> /hr	CH <sub>4</sub> (%) range		CO <sub>2</sub> (%) range		O <sub>2</sub> (%) range		CO (ppm) range	
		No. Visits recording Gas Concentrations	No. Visits Recording Flow Rates	Max	Max	Min	Max	Min	Max	Min	Max	Min	Max
GW103	UGW00103	12	3	22	3.1	14.2	54.6	18.7	27.9	0	0.4	0	1
GW519	UGW00519	12	2	2	0	0	26.3	2.3	27.8	3.2	20.6	0	1
GW705	UGW00705	12	5	22	8.8	22.6	46.1	21.9	29.4	0	0.8	0	1
GW518A	UGW0518A	11	3	2	0	0	26.6	1.8	14.1	0	20.9	0	5
GW102	UGW00102	12	4	17	1.2	6.2	69	9.9	27.8	0	13.3	0	1
GW101	UGW00101	12	4	17	4.1	1.1	59.8	3.7	29.7	0	19.3	0	4
GW100	UGW00100	12	3	2	0	0	59	1.4	30.5	0	20.7	0	3
GW517	UGW00517	12	3	2	0.2	8	36.5	6	21.9	2.4	13.7	0	0
GW750	UGW00750	12	1	2	0	0	24.2	1.4	20.4	2.5	20.8	0	0
GW501	UGW00501	12	1	2	0.1	0.2	28.5	0.8	23.8	0.1	21	0	0
GW500	UGW00500	12	1	2	0.4	1.8	43	7.8	33	0	13.7	0	1
GW751	UGW00751	12	1	2	0.1	1	35.4	5.5	27.3	0	16.7	0	2

## Notes:

- Well IDs are based on the as-built gas infrastructure drawing 5876.SURV.D01 (Appendix A).
- Greyed cells indicate no data available.
- Coloured cells indicate elevated oxygen concentrations.

In addition to the gas wells listed above, there are also ten gas wells shown within the A-Dhann site which are labelled as 'Unknown', for which results cannot be found.

The results show that no exceedances of the Carbon Monoxide thresholds (75ppm and 100ppm) were recorded in any of the in-waste gas monitoring wells within the A-Dhann site during 2016.

The results show that the oxygen thresholds (3% and 5%) were exceeded in 40 out of 44 in-waste gas monitoring wells in the A-Dhann site during 2016; and in total, 230 out of 395 oxygen readings were greater than 5%, with an additional 19 readings recording oxygen concentrations between 3% and 5%. In three wells (UGW00M02, UGW00M04, UGW00M10), all 12 no. monthly oxygen readings were recorded above the upper threshold of 5%.

All wells (with the exception of UGW00516) also failed to meet the minimum combined concentration of methane and carbon dioxide during one or more monitoring visits in 2016. In accordance with the Permit, an investigation should have taken place to assess oxygen ingress into the landfill system, however it is not known whether this occurred or whether any specific remedial actions were taken to address potential oxygen ingress.

## 3.6.2 Perimeter Gas Monitoring

### Perimeter Gas Monitoring Strategy

In 2018, gas concentrations were monitored in 111 no. perimeter points, in accordance with the Permit and the Monitoring Management Plan. Of these 111 no. perimeter monitoring points, seven are located within the A-Dhann site boundary and a further 30 no. are located above the northern boundary of the A-Dhann site, as shown on Figure A 7.

During 2016 and 2018, the Permit required monthly monitoring of Carbon Dioxide and Methane in the Perimeter landfill gas monitoring boreholes around the United Mines Landfill Site, and the compliance limits for these gases varied by location in relation to off-site receptors. The Permit also requires that Oxygen concentrations, Atmospheric Pressure and Differential Pressure are also monitored in the perimeter boreholes on a monthly basis, however there are no compliance limits for these parameters. A Permit Variation was issued in 2018, and updated carbon dioxide action levels were set.

Compliance Limits / Action Levels for Carbon Dioxide were removed in August 2018 under Permit Variation EPR/MP3439MH/V007, however the Permit still required that Carbon Dioxide was monitored on a monthly basis in the perimeter locations. The Permit Variation Application also sought to reduce the frequency of perimeter gas monitoring from Monthly to Quarterly, however this was considered unacceptable by the Environment Agency at the time, and monthly monitoring has continued. The 2018 monitoring report has screened the perimeter monitoring results against the compliance limits that were in place prior to the variation being issued in August 2018.

In some perimeter boreholes, particularly to the north east of the United Mines site, the gas wells appear to have been monitored more frequently than once per month.

### **Perimeter Gas Monitoring Results (2016 to 2018)**

Monitoring results are presented in the Annual Monitoring Reports as Time-Series Concentration Graphs, with detailed monitoring results tables not provided. The time-series charts show that none of the perimeter wells (with the exception of G62 and G121) within or around the A-Dhann site recorded Methane concentrations above the compliance limit of 1%, and that maximum concentrations in the majority of wells were not more than 0.5%. The results for Carbon Dioxide readings were more variable, and the compliance limits for CO<sub>2</sub> in individual perimeter wells are also variable.

A list of Perimeter Gas Monitoring wells shown on the Gas Infrastructure Layout Drawing (5876.SURV.D01) as being potentially applicable to the A-Dhann site, along with their compliance limits and a summary of results for Carbon Dioxide are presented in Table 7 below. As the data from 2016 and 2017 is only presented in the monitoring reports in the form of charts, the 'Max' readings and the number of exceedances presented below have been approximated from the charts as detailed results are not available.

Results for Methane concentrations in wells G62 and G121 are presented in Table 8. These were the only perimeter wells near the A-Dhann site which recorded methane concentrations above the compliance limit of 1% during the 2016 to 2018 monitoring periods.

Table 7. Perimeter CO<sub>2</sub> Gas Monitoring Results between 2016 and 2018 (see notes at end).

Well ID	ID (assumed) from monitoring reports		ID from Permit: Table S3.5 (assumed)	Location (in relation to A-Dhann site)	Carbon Dioxide (% v/v) - 2018			Carbon Dioxide (% v/v) - 2017			Carbon Dioxide (% v/v) - 2016		
	2016 / 2017	2018			Action Leve	Max	No. > Limit	Limit	Max	No. > Limit	Limit	Max	No. > Limit
GP17				Off-site. NW									
GP14				On-site. NW									
GP12	UN/G12	UNMI/G012	G12	On boundary. N/NE	4.9	2.5		3.8	<3.8		3.8	<3.8	
GP13	UN/G13	UNMI/G013	G13	On boundary. N/NW	4.9	3.1		3.8	<3.5		3.8	<3.5	
GP146	UN/G146	UNMI/G146	G146	Off-site. N	4.2	0.9		3.8	<1		3.8	<1	
GP11	UN/G11	UNMI/G011	G11	Off-site. N	3.8	1.7		3.8	<2		3.8	<2	
W12				Off-site. N									
GP145	UN/G145	UNMI/G145	G145	Off-site. N	3.8	2.0		3.8	<2		3.8	<2	
GP8	UN/G08	UNMIG008	G08	Off-site. N	3.8	0.6		3.8	<1		3.8	<1	
GP9	UN/G09	UNMI/G009	G09	Off-site. N	3.8	1.0		3.8	<1		3.8	<1.	
GP10	UN/G10	UNMI/G010	G10	Off-site. N	3.8	0.8		3.8	<1		3.8	<1	
GP144	UN/G144	UNMI/G144	G144	Off-site. N	3.8	1.7		3.8	<1		3.8	<1.5	
GP7	UN/G07	UNMI/G007	G07	Off-site. N	3.8	0.7		3.8	<1		3.8	<1	
GP143	UN/G143	UNMI/G143	G143	Off-site. N	3.8	1.4		3.8	<1		3.8	<1	
GP4	UN/G04	UNMI/G004	G04	Off-site. N	3.8	0.7		3.8	<0.5		3.8	<0.5	
GP5	UN/G05	UNMI/G005	G05	Off-site. N	3.8	0.3		3.8	<3		3.8	<3	

Well ID	ID (assumed) from monitoring reports		ID from Permit: Table S3.5 (assumed)	Location (in relation to A-Dhann site)	Carbon Dioxide (% v/v) - 2018			Carbon Dioxide (% v/v) - 2017			Carbon Dioxide (% v/v) - 2016		
	2016 / 2017	2018			Action Level	Max	No. > Limit	Limit	Max	No. > Limit	Limit	Max	No. > Limit
GP6	UN/G06	UNMI/G006	G06	Off-site. N	3.8	0.9		3.8	<3		3.8	<3	
GP142	UN/G142	UNMI/G142	G142	Off-site. N	3.8	1.3		3.8	<1		3.8	<1	
GP141	UN/G141	UNMI/G141	G141	Off-site. N	3.8	1.7		3.8	<1.5		3.8	<2	
GP3	UN/G03	UNMI/G003	G03	Off-site. N	3.8	1.6		3.8	<1.5		3.8	<2	
GP140	UN/G140	UNMI/G140	G140	Off-site. N	3.8	2.4		3.8	<1		3.8	<2	
GP139	UN/G139	UNMI/G139	G139	Off-site. N	7.0	5.8		3.8	<7		3.8	<4	
GP138	UN/G138	UNMI/G138	G138	Off-site. N	3.8	4.6	4	3.8	<4.5	2	3.8	<1.5	
GP2	UN/G02	UNMI/G002	G02	Off-site. N	3.8	3.0		3.8	<3		3.8	<3	
GP137	UN/G137	UNMI/G137	G137	Off-site. N	4.1	3.4		3.8	<3.8		3.8	<3.8	
W13A				Off-site. N									
W13				Off-site. N									
GP1	UN/G01	UNMI/G001	G01	Off-site. N	4.1	2.1		3.8	<3		3.8	<3.5	
GP136	UN/G136	UNMI/G136	G136	Off-site. N	3.8	2.0		3.8	<1.5		3.8	<2	
GP135	UN/G135	UNMI/G135	G135	Off-site. N	5.1	2.0		3.8	<3		3.8	<3	
GP134	UN/G134	UNMI/G134	G134	Off-site. N	2.2	1.8		1.5	<1.5		1.5	<1	
GP133	UN/G133	UNMI/G133	G133	Off-site. N	8.9	2.2		1.5	<6	most	1.5	<8	all
GP132	UN/G132	UNMI/G132	G132	Off-site. N	5.9	4.9		1.5	<7	some	1.5	<5	some
GP131	UN/G131	UNMI/G131	G131	Off-site. N	5.0	4.1		1.5	<5	some	1.5	<4	most
GP130	UN/G130	UNMI/G130	G130	Off-site. N	8.3	15.8	some	1.5	<12	all	1.5	<11	most

Well ID	ID (assumed) from monitoring reports		ID from Permit: Table S3.5 (assumed)	Location (in relation to A-Dhann site)	Carbon Dioxide (% v/v) - 2018			Carbon Dioxide (% v/v) - 2017			Carbon Dioxide (% v/v) - 2016		
	2016 / 2017	2018			Action Level	Max	No. > Limit	Limit	Max	No. > Limit	Limit	Max	No. > Limit
GP129	UN/G129	UNMI/G129	G129	Off-site. N	7.0	5.2		1.5	<6	most	1.5	<5	most
GP128	UN/G128	UNMI/G128	G128	Off-site. N	4.9	3.0		1.5	<3	some	1.5	<3.5	most
GP127	UN/G127	UNMI/G127	G127	On-site. NE	5.7	3.5		1.5	<3	some	1.5	<5	some
GP126				On-site. NE									
GP125	UN/G125	UNMI/G125	G125	On-site. E/NE	7.6	6.1	1	1.5	<6	most	1.5	<6	most
GP124				On-site. E/NE									
GP123	UN/G123	UNMI/G123	G123	On boundary. E	4.7	2.3	0	1.5	<2	1	1.5	<8	some
GP122	UN/G122	UNMI/G122	G122	On boundary. E	7.4	5.4	0	1.5	<5	some	1.5	<4.5	some
GP121	UN/G121	UNMI/G121	G121	On boundary. SE	7.1	4.1	0	1.5	<4.5	some	1.5	<9	most
GP62	UN/G62	UNMI/G062	G62	Off-site. SE	10.0	3.1	0	1.5	<16	most	1.5	<20	Most

## Notes:

- Well IDs are based on the as-built gas infrastructure drawing 5876.SURV.D01 (Appendix A).
- Greyed cells indicate no data available.
- Limits for 2018 obtained from Appendix E of 2018 Annual Monitoring Report; Limits for 2017 obtained from Table 4 of the 2017 Annual Monitoring Report; Limits for 2016 obtained from Table 4 of the 2016 Annual Monitoring Report.
- Coloured cells indicate exceedances.

Table 8 - Perimeter Methane Gas Monitoring Results between 2016 and 2018 (see notes at end).

Well ID	ID (assumed) from monitoring reports		ID from Permit: Table S3.5 (assumed)	Location (in relation to A-Dhann site)	Methane (% v/v) - 2018			Methane (% v/v) - 2017			Methane (% v/v) - 2016		
	2016 / 2017	2018			Limit	Max	No. > Limit	Limit	Max	No. > Limit	Limit	Max	No. > Limit
GP121	UN/G121	UNMI/G121	G121	On boundary. SE	1	<0.5		1	<0.5		1	<4	1 out of 24
GP62	UN/G62	UNMI/G062	G62	Off-site. SE	1	2.2	1	1	<4	5 out of 17	1	<4	13 out of 20

Notes:

- Well IDs are based on the as-built gas infrastructure drawing 5876.SURV.D01 (Appendix A).
- Coloured cells indicate exceedances.