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FINAL

# HYDROGEOLOGICAL RISK ASSESSMENT
# FOR
# NANT-Y-GWYDDON LANDFILL SITE
# GELLI, RHONDDA, SOUTH WALES

Prepared for
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**HYDROGEOLOGICAL RISK ASSESSMENT REPORT**
**NANT-Y-GWYDDON LANDFILL SITE**
**GELLI, RHONDDA, SOUTH WALES**

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# NANT-Y-GWYDDON LANDFILL SITE
# GELLI, RHONDDA, SOUTH WALES

## 1.0 REPORT CONTEXT

### 1.1 Introduction

1.1.1 In June 2003 Encia Consulting Limited (ECL) was commissioned by Amgen Rhondda Limited (ARL) to act as specialist hydrogeological consultants, in relation to the production of a Hydrogeological Risk Assessment for the Nant-y-Gwyddon Landfill Site.

1.1.2 Although the Site is now closed and a PPC Permit for continued operation is therefore not required, the Site remains a licensed Waste Management facility, regulated by the Environment Agency (the Agency) in accordance with the Waste Management Licensing Regulations 1994 (hereinafter referred to as the 1994 Regulations), and the Landfill (England and Wales) Regulations 2002 (hereinafter referred to as the 2002 Regulations).

1.1.3 Therefore, the Agency requires that a retrospective Regulation 15 Risk Assessment be completed, as a pre-requisite for consideration of a Closure Plan for the Site and, although the Site ceased receiving waste for disposal in March 2002, the approval of the latter would enable the Site to be considered definitively closed and to thereby enter its aftercare phase.

1.1.4 This Risk Assessment follows the production by ECL of a Desk Study/Initial Appraisal (Phase 1) Report in January 2004 (ref. AM5465/1/1), which should be read in conjunction with this Risk Assessment.

1.1.5 Although this report has been produced to satisfy the requirements of the 1994 Regulations, it has, nonetheless, been compiled with reference to the Environment Agency's most-recent guidance on the subject (produced in connection with the transposition into UK Legislation of the Landfill Directive[1]).

1.1.6 The main reference document, *"Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels"* (EA, April 2003), is hereinafter referred to by its Document Reference number (LFTGN01).

1.1.7 The Registered Office of the Licence Holder is:

Amgen Rhondda Limited
Bryn Pica
Llwydcoed
Aberdare
CF44 0BX

### 1.2 Site Location

1.2.1 The Nant-y-Gwyddon Landfill Site is located at Ordnance Survey National Grid Reference (NGR) SS 980 940, approximately 1.6 km to the north-west of Tonypandy, in an elevated position above the Rhondda Fawr valley, as shown on the Site Location Plan (**Drg. No. AM5465/2/001**).

[1] European Landfill Directive (1999/31/EC), which has been implemented by the Landfill (England and Wales) Regulations 2002, made under the Pollution Prevention and Control Act 1999.

1.2.2 Access to the Site is via the locked gate at the bottom of the purpose-built access road, at the Gelli Civic Amenity site, off the B4223 (Nant-y-Gwyddon Road), at NGR SS 9782 9468.

1.2.3 The address of the Site is:

Nant-y-Gwyddon Landfill Site
c/o Gelli Civic Amenity Site
Nant-Y-Gwyddon Road
Gelli, Pentre
CF41 7TL

1.2.4 The Initial Appraisal Report (AM5465/1/1 - hereinafter referred to as the Phase 1 Report) also contains the detail of the geographical and environmental context within which the Site is situated.

1.2.5 The landfill site boundary comprises an area of approximately 24 ha and consists of 3 main areas:

- **Phase 1 Landfill** – Containing approximately 1.25 million $m^3$ of waste in an area of approximately 9 ha. This area has now been fully remediated with the construction of an engineered geocomposite capping layer and drainage measures.
- **Phase 2** – The 3.5 ha area historically referred to as Phase 2, previously consisted of an engineered barrier system (liner) and leachate storage facility. These have now been removed and the restored area now consists of gently sloping grassland and a small surface water lagoon and associated drainage.
- **Site Offices, Weighbridge, Car Park and Landfill Gas Compound** – These are located adjacent to the site entrance.

## 2.0 ENVIRONMENTAL AND LEGISLATIVE CONTEXT

### 2.1 Introduction

2.1.1 The Conceptual Model for this Regulation 15 Risk Assessment is therefore based on the findings of the Phase 1 Report, which is itself based upon information provided by the Licence Holder, and obtained from a variety of Public Domain sources, including the following:

- The extant Waste Management Licence, Working Plan, Planning Application, and Planning Consent.
- Previous Site Investigation Reports (see Section 4 of the Phase 1 Report).
- BGS Geological Map (1:50,000 scale, Sheet 231, Drift edition, published in 1979).
- The Landmark Information Group's "Envirocheck" Report (see Appendix B of the Phase 1 Report).
- The Environment Agency website.

2.1.2 Much of this information has already been presented in the Phase 1 Report, and is not repeated unless significantly updated.

2.1.3 The conceptual hydrogeological site model is summarised in **Section 3.0** herein, which should be read in conjunction with the Phase 1 Report.

## 2.2 Environmental Setting

### *Site History*

2.2.1 The lower slopes of the Rhondda Valleys have experienced a large degree of industrial activity throughout the 19th and 20th Centuries.

2.2.2 Large-scale commercial mining commenced in this part of the Rhondda Fawr Valley in the 1860's in the following collieries:

- Llwynypia Colliery (formerly Glamorgan) Est. 1866
- Gelli Colliery Est. 1869
- Cambrian Colliery Est. 1873
- Eastern Colliery Est. 1873

2.2.3 The majority of works recorded in these seams took place prior to 1940. Some mining activity did take place beneath Blaen Clydach (via the Cambrian Colliery) from the 1950's onwards, up until 1962. In addition to which, the No.1 Rhondda Rider (No.1 RR), No.1 Rhondda (No.1 R), and Daren Rhestyn seams also appear to have been exploited for domestic use (trial adits and small spoil heaps litter the hillside at or around the level of outcrop of these coal seams).

2.2.4 A detailed Site History was presented in Table 1 of the Phase 1 Report, based on the Envirocheck Report (Appendix B therein).

### *Environmental Sensitivity*

2.2.5 The Envirocheck Report, compiled by the Landmark Information Group, includes a search on Sensitive Land Uses, including all known locally, nationally, and internationally designated sites, up to 2 km from the Site. This search confirmed the absence of any SPAs, SACs, or NNRs. However, it has highlighted the presence of one SSSI (Craig Pont-Rhondda) and one Local Nature Reserve (Glyncornel) within 1km of the Site. Both of these relate to an area of predominantly ancient oak woodland (the only one left in South Wales), which is approximately 500 metres east of the Site and, therefore, overlap to a significant extent.

2.2.6 In addition, although carrying no formal conservation status, much of the land adjacent to the Site is managed by the Forestry Commission and forms part of the Clydach Vale Country Park.

2.2.7 The above information is summarised on **Drg. No. AM5465/2/002**.

## 2.3 Previous Work

2.3.1 The Site has been subject of a great deal of previous work (including desk studies, as well as non-intrusive and intrusive site investigations). This has been summarised in **Table 1**, below:

2.3.2 All of the above were reviewed as part of the *"Regulation 15 – Initial Appraisal of Nant-y-Gwyddon Landfill Site"*, which was produced by ECL in January 2004. Since that time, additional site investigation work has been undertaken, which included the following:

- Geophysical investigation of leachate levels within the existing landfill;
- Drilling of replacement and/or additional leachate monitoring wells;
- Drilling of 10 new boreholes around the perimeter of the completed Phase 1.

2.3.3 This most recent work (see **Appendix A**) has yielded additional geological and hydrogeological information, which is reflected in the revised Site Layout Plan and Hydrogeological Cross Sections (**Drg. Nos. AM5465/2/003** and **AM5465/2/005** respectively).

**Table 1: Summary of Previous Work Undertaken**

| Year | Details |
|---|---|
| 1982 | Wimpey Laboratories Investigation: 7 No. boreholes and 14 No. trial pits. |
| 1984 | *"Report on the Hydrogeological Survey of a Proposed Waste Disposal Tip Site"*, Sir William Halcrow & Partners (April 1984): This investigation represents the best initial assessment of ground conditions at the Nant-y-Gwyddon Site, along with early recommendations for the engineering design of the landfill. |
| 1986 | Rhondda Borough Council Investigations: 45 No. trial pits. |
| 1990 | Exploration Associates Investigation, on behalf of Sir William Halcrow & Ptnrs (Bund Stability Assessment). |
| 1993 | Working Plan for WML Application, produced for RBC, by WS Atkins. |
| 1995 | Integral Geotechnique Investigation of Upper and Lower Gelli Tips for Mid-Glamorgan County Council. |
| 1997 | *"Stability Assessment of Inert Bund and Associated Slopes at Nant-y-Gwyddon Landfill Site"*, David P Smith (March 1997): 6 No. trial pits dug and an additional piezometer installed.<br>*"Review of Landfill Gas and Leachate Management at the Nant-y-Gwyddon Landfill Site, Rhondda, South Wales"*, CL Associates (April 1997): This report, commissioned by Rhondda Borough Council, formed part of an environmental audit of the Nant-y-Gwyddon Landfill Site. It was requested by the Environment Agency Wales as part of a modification of the Site's waste management licence. Many recommendations were made most of which have now been implemented.<br>*"Report on the Health of the Residents Living Near the Nant-y-Gwyddon Landfill Site Using Routinely Available Data"*, University of Wales; College of Medicine (exact date unknown). |
| 1998 | *"Investigation into Odour Problems at Nant-y-Gwyddon Landfill Site, South East Wales"*, Entec (January 1998): Although this investigation was mostly concerned with landfill gas emissions it contains useful information regarding waste inputs and the composition of certain industrial waste. In particular calcium sulphate filter cake accepted into the waste in large volumes during 1995-1996.<br>*"Review of Remediation Proposals"*, Babtie Group (August 1998): Concluded that insufficient detail was available to provide proper assessment of proposals.<br>*"Contract Remediation and Capping Works"*, CL Associates (September 1998): Full specification document, following on from the incomplete Draft version that was reviewed by Babtie, as above.<br>*"The Events Occurring on the 26 March 1997 in the Vicinity of Nant-y-Gwyddon Landfill Site, S.E. Wales"*, Entec (November 1998): Report commissioned by the Environment Agency, in order to assess the provenance and significance of the (hydrogen sulphide) odour complaints from residents of Clydach Vale and Blaen Clydach on the above date.<br>*"Installation of Groundwater Monitoring Apparatus at Nant-y-Gwyddon Landfill Site, Gelli, South Wales"*, CL Associates (November 1998): Factual Report on intrusive site investigations, including borehole logs and initial groundwater monitoring data (7 days only). |
| 1999 | *"Outline Phase 1 Audit at Nant-y-Gwyddon Landfill Site"*, Golder Associates (May 1999): Desk Study only. |
| 2000 | *"Nant-y-Gwyddon Landfill Site – Stability Desk Study"*, Arup (June 2000). This desk study contains a good assessment of the hydrogeological factors affecting the Nant-y-Gwyddon Landfill Site, including mining history. |
| 2001 | *"Nant-y-Gwyddon, Inert Monitoring Standpipes - Factual Report on Ground Investigation"*, Exploration Associates (March 2001): Work commissioned by Arup, including intrusive site investigation procedures (i.e. a single borehole was advanced), together with the geological and subsequent laboratory (analytical) information obtained. (A single borehole log with a water strike recorded, and analytical results for COD, Ammoniacal Nitrogen, and Volatile Fatty Acids only).<br>*"Nant-y-Gwyddon Inert Bund – Stability Assessment"* Arup (March 2001): A geotechnical assessment of the eastern face of the progressively restored landfill only. Report Ref.: 556767/08.<br>*"Health and Safety Issues at Nant-y-Gwyddon"*, Entec (May 2001): Report commissioned by ARL, in order to obtain independent verification of the suitability of the hazardous gas monitoring at the Site, both in terms of working practices and the health and safety of the surrounding population.<br>*"Independent Investigation Nant-y-Gwyddon Landfill Site"*, David W Purchon (December 2001): This Report was commissioned by the National Assembly for Wales, and included (as Appendix 9): *"A Review of the Hydrogeological Investigations at Nant-y-Gwyddon Landfill Site, S. Wales"*, BGS (2001): The latter was commissioned, to determine the suitability of the Site with reference to the guidance available at that time, and to carry out a one-off monitoring exercise utilising ARL's current environmental monitoring installations. |
| 2002 | *"Public Health Investigations at the Nant-y-Gwyddon Landfill"*, US Dept. of Health (December 2002): An evaluation of the Environmental Health Assessment Process. |
| 2003 | *"Nant-y-Gwyddon Landfill Site - Waste Characterisation Survey – Phase 1 Report"*, Encia (May 2003): Report commissioned by ARL, in order to address concerns of local residents over questions regarding the nature of the wastes deposited at the Site. |

## 2.4 Legislative Context

2.4.1 Regulation 15 of the WML Regulations 1994 (as amended) includes the following requirements:

> (1) *Where a waste regulation authority proposes to issue a waste management licence authorising—*
>
> > *(a) any disposal or tipping for the purpose of disposal of a substance in list I which might lead to an indirect discharge into groundwater of such a substance;*
> > *(b) any disposal or tipping for the purpose of disposal of a substance in list II which might lead to an indirect discharge into groundwater of such a substance;*
> > *(c) a direct discharge into groundwater of a substance in list I; or*
> > *(d) a direct discharge into groundwater of a substance in list II,*
>
> *the authority shall ensure that the proposed activities are subjected to prior investigation.*
>
> (2) *The prior investigation referred to in paragraph (1) above shall include examination of the hydrogeological conditions of the area concerned, the possible purifying powers of the soil and sub-soil and the risk of pollution and alteration of the quality of the groundwater from the discharge and shall establish whether the discharge of substances into groundwater is a satisfactory solution from the point of view of the environment.*
>
> (3) *A waste management licence shall not be issued in any case within paragraph (1) above until the waste regulation authority has checked that the groundwater, and in particular its quality, will undergo the requisite surveillance.*

2.4.2 It is therefore considered that the Phase 1 Desk Study Report (January 2004) and the quantitative risk assessment summarised in this Report are sufficient to demonstrate that the Licence Holder has complied fully with the requirements for both prior investigation and requisite surveillance.

2.4.3 With regard to **Regulation 15 paragraphs (1)** and **(2)**, the hydrogeological conceptual model for the Site is presented in **Section 4.0** of this Report, which should be read in conjunction with the January 2004 Phase 1 Report.

2.4.4 With regard to **Regulation 15 paragraph (3)**, insofar as it relates to the proposed transfer of the Site to post-closure status, it is considered that, combined with the Phase 1 Report, this present document demonstrates that the Site is in compliance with the 1994 Regulations.

# 3.0 CONCEPTUAL MODEL

## 3.1 Landfill Characterisation

### *Site Engineering*

3.1.1 The Site was engineered as a containment facility in the late 1980's (Phase 1) and early 1990's (Phase 2). The site now incorporates a protective landfill cap and systems for the management of leachate and landfill gas. These features include an extensive network of landfill gas extractor wells and leachate monitoring wells, and a leachate extraction measures (see drawing **AM5465/2/003** for further illustration).

3.1.2 At the time of its construction, the Site was considered to have been a model of best practice; utilising the latest containment technology. The Working Plan (referenced in Section 4.4 of the 1997 CL Associates Report), states that the engineered basal liner is composed of the following:

- 300mm graded colliery spoil (drainage and protection layer[2]) over;
- 2.5mm rough (finished) HDPE membrane laid on;
- 300mm graded colliery spoil (drainage and protection layer[2]) over;
- excavated and recompacted ground (where fissures had been cement-grouted or concreted dependant on size).

3.1.3 For the purposes of LandSim modelling, this Site has been assumed to have an HDPE flexible membrane liner (FML) plus 300mm of processed colliery spoil. This is considered to be representative of a reasonable worst case assessment of the basal lining system at the site.

3.1.4 Construction of a fully engineered and CQA'd landfill cap was completed at the site in September 2005. The redundant landfill infrastructure (i.e. basal lining and leachate collection system) in the Phase 2 area was removed and the area restored.

3.1.5 The capping system at the site consists of the following components, constructed in accordance with the Construction Quality Assurance (CQA) methods specified by the Environment Agency:

- 300 mm restoration layer (100 mm grading) over;
- 400 mm restoration layer (150 mm grading) over;
- 300 mm protection layer (20 mm grading) over;
- Geo-synthetic drainage layer with above cap drainage system laid on;
- 1 mm thick Geomembrane Cap (textured LLDPE) laid on;
- Geo-synthetic drainage layer with beneath cap landfill gas and leachate drainage system laid on;
- 200 mm foundation layer (20 mm grading) over;
- regulated / re-profiled landfill surface.

3.1.6 The remediation of the phase 2 area (not containing landfill waste) was completed in summer 2006 with the removal of the large leachate attenuation lagoons located within this area of the site. The lining material forming these lagoons was removed (and disposed off-site) and the area in-filled to leave a shallow surface water lagoon.

3.1.7 **Section 5.2** herein, contains more detail regarding these matters.

### *Waste Types Deposited*

3.1.8 The Nant-y-Gwyddon Site was the point of disposal for a mixture of municipal (household), commercial and non-hazardous industrial wastes, during the period 1988 – 2002.

3.1.9 More detailed descriptions, as compiled by the EA, for the Nant-y-Gwyddon Remediation Sub-group Committee, are presented in **Table 2**, below:

---

[2] The drainage layers above and below the HDPE were constructed using collector drains, in no-fines granular surround with a geotextile wrap, connected via pre-cast concrete ring chambers to the leachate and surface water outfalls respectively. **<u>However, both systems are now directed to the leachate collection system.</u>**

## 3.2 Hazard Generation Potential

3.2.1 Leachate is generated when contaminants within the deposited waste are leached out of the waste materials by percolating liquids. Water is the main cause of the leachate hazard and is derived from the following main sources at the Nant-y-Gwyddon Landfill Site:

- Wastes that had a high moisture content at the time they were deposited;
- Rainwater that entered the Site whilst it was operational; and
- Minimal infiltration of rainwater through the engineered cap post-closure.

3.2.2 It is highly probable that leachate generated within the landfill, derived from the above mixture of wastes that have been deposited at the Site, will contain a variety of List I and List II substances at a concentration that, were they to be released into the hydrosphere, would represent an environmental hazard.

**Table 2: Description of Accepted Waste Types**

| Waste Type | Description |
|---|---|
| Household/ Domestic waste | These are the waste arisings predominantly from domestic properties. By definition these will include a very wide range of wastes that can arise in the home such as cleaning agents, pharmaceuticals, etc. |
| Commercial waste | Waste arising from shops and offices is defined as commercial waste. This waste stream will include packaging, food waste, paper and plastic although other |
| Industrial waste | Industrial waste is the material thrown out from any factory or other similar type of business. This material can contain almost anything but here refers to waste that is considered as being dry non-hazardous industrial waste. |
| Inert wastes | Wastes coming from green field developments are usually defined as 'inert', e.g. soils, sub-soils, stone, brick, etc. Although they do possess some chemical characteristics, these are not usually significant and are limited to parts that will |
| Civic Amenity waste | This is similar to household waste but collected from civic amenity sites. This waste is more controlled and does not have the same level of undesirable waste products as household waste. |
| Filter cake | Here filter cake refers to waste products from the treatment of trade effluent at the L'Oreal and Purolite factories. This material is rich in sulphur and thought to be the cause of the levels of hydrogen sulphide in the landfill gas. |

3.2.3 However, the exact extent to which List I and List II substances will remain in the leachate will depend on many factors such as pH, redox, anaerobic or aerobic states, the presence of sulphide, and/or volatilisation of organic compounds into landfill gas. Nevertheless, it would be imprudent to suggest that List I and List II substances would not be present in the leachate. It must also be taken into account that, in the long term, conditions in the landfill will change so that a substance present in the leachate at one time may not be at another, and vice versa.

3.2.4 There are currently three locations (**L5**, **L5a**, and **LPS1**) from which ARL take leachate samples for laboratory analysis. **L5a** is a leachate inspection manhole and, using this; samples are taken from the basal leachate drainage system. Leachate samples taken from the pumping station and holding tank are identified as monitoring points **LPS1** and **L5** respectively.

3.2.5 A significant amount of leachate quality data was also generated from the leachate attenuation lagoons situated in phase 2 (monitoring ID **LL01**) prior to their removal in June 2006. More detailed descriptions of each of the monitoring points (including their respective locations) can be found in the Phase 1 Report and is presented in drawing no. AM5465/2/003.

3.2.6 Monitoring of Leachate quality has shown the presence of typically 'lower than UK average' concentrations of List I and List II substances, this is considered to be a reflection of the exposed location, high incident precipitation, and long period of uncapped operation of the Site.

3.2.7 Leachate sampled at **L5a** has consistently yielded the highest concentrations of most leachate contaminantion. Therefore, for the purposes of characterising the Source Term for the LandSim models, only **L5a** data has generally been used, to best reflect the nature of fresh leachate emerging from the base of the landfill.

3.2.8 A statistical summary of all of the **L5a** data is provided in **Table 3**, below.

3.2.9 However, it is not considered feasible or necessary to model the behaviour of all of the potential contaminants of concern listed above. Therefore, based on this data, the Source Term has been derived using data from L5a only (see **Section 6.1** herein for details).

**Table 3: Statistical Summary of Fresh Leachate Quality Data**

| Determinand | Total No. of Samples | No. at/below MRVs | No. of Positive Results | Min | Mean | Max | Std. Dev. |
|---|---|---|---|---|---|---|---|
| Alkalinity | 39 | 0 | 39 | 650 | 1929 | 7200 | 1139 |
| Ammoniacal Nitrogen | 47 | 0 | 47 | 22.9 | 245 | 730 | 162 |
| Benzene (µg/l) | 8 | 7 | 1 | 0.47 | 0 | 0.47 | |
| BOD | 45 | 10 | 35 | 2 | 58 | 823 | 138 |
| COD | 47 | 0 | 47 | 126 | 511 | 1490 | 363 |
| Cadmium | 22 | 16 | 6 | 0.001 | 0.0057 | 0.02 | 0.0079 |
| Calcium | 17 | 0 | 17 | 101 | 149.2 | 223 | 32.4 |
| Chloride | 46 | 0 | 46 | 20.1 | 648 | 1030 | 209 |
| Chromium | 20 | 5 | 15 | 0.009 | 0.030 | 0.19 | 0.046 |
| Conductivity (µs/cm) | 49 | 0 | 49 | 1430 | 4897 | 8090 | 1482 |
| Copper | 15 | 6 | 9 | 0.008 | 0.0198 | 0.07 | 0.020 |
| Ethylbenzene (µg/l) | 3 | 2 | 1 | 0.24 | 0.2400 | 0.24 | |
| Formaldehyde | 20 | 0 | 20 | 0.34 | 2.32 | 19.74 | 4.26 |
| Iron | 15 | 0 | 15 | 0.26 | 14.6 | 64.86 | 20.7 |
| Lead | 15 | 12 | 3 | 0.01 | 0.03 | 0.07 | 0.035 |
| Magnesium | 17 | 0 | 17 | 67.4 | 82.3 | 101 | 8.16 |
| Manganese | 4 | 0 | 4 | 0.61 | 0.828 | 1.05 | 0.193 |
| Nickel | 15 | 0 | 15 | 0.02 | 0.0473 | 0.1 | 0.0198 |
| Nitrate | 25 | 1 | 24 | 0.43 | 15.97 | 43.7 | 10.29 |
| Nitrite | 25 | 1 | 24 | 0.11 | 0.751 | 1.66 | 0.433 |
| pH | 49 | 0 | 49 | 7.1 | 7.64 | 8.4 | 0.270 |
| Phosphate | 6 | 2 | 4 | 0.2 | 0.45 | 0.7 | 0.208 |
| Phosphorus | 7 | 1 | 6 | 0.11 | 1.66 | 7 | 2.65 |
| Potassium | 17 | 0 | 17 | 139 | 251 | 399 | 78.9 |
| Sodium | 16 | 0 | 16 | 188 | 470 | 796 | 158.4 |
| Sulphate | 15 | 2 | 13 | 60 | 171 | 385 | 101.1 |
| Sulphide | 12 | 4 | 8 | 0.03 | 1.5 | 10.8 | 3.77 |
| Suspended Solids | 20 | 0 | 20 | 8 | 444 | 2260 | 634.0 |
| TOC | 34 | 1 | 33 | 12.8 | 111.8 | 408 | 86.5 |
| TON | 25 | 0 | 25 | 1.58 | 19.7 | 65 | 15.6 |
| Toluene (µg/l) | 7 | 6 | 1 | 0.1 | 0.1 | 0.1 | |
| Trichloroethene (µg/l) | 6 | 5 | 1 | 1 | 1.0 | 1 | |
| Xylene (µg/l) | 8 | 7 | 1 | 0.79 | 0.8 | 0.79 | |
| Zinc | 15 | 3 | 12 | 0.06 | 0.256 | 1.25 | 0.325 |

All values are quoted in mg/l unless stated otherwise.

3.2.10 The Hydrogeological Conceptual Model produced for this Site, on the basis of all the information summarised and/or referred to above, is set out in the sub-sections that follow, and is summarised in **Table 4**, below.

3.2.11 The Input Parameters and Justifications used in the LandSim (version 2.5.14) modelling described herein are summarised in the Table in **Appendix B**. Whereas, an example of the LandSim Set-up file thus generated is presented in **Appendix C**. (Please note that the only difference between the model simulations is the duration of the Management Control Period – see **Section 5.3** herein for details).

## 3.3 Potential Contaminant Transport Pathways

3.3.1 The pathways considered in this risk assessment, along which potential hazards could migrate, are as follows:

- Water emerging from the containment system in place (the engineered basal liner), which includes a flexible membrane liner (FML), although this discharge is subject to a Trade Effluent Discharge Consent);
- Lateral movement of groundwater within adjacent geological strata;

- Vertical and (then) lateral flow of groundwater (predominantly through fractures) in underlying strata; and
- The Nant-y-Gwyddon stream, which is partly spring-fed.

**Table 4: Summary of Conceptual Hydrogeological Model of Site**

| Component | Comment/Description |
|---|---|
| Hazard | Leachate, containing List I and II substances, within all parts of the Site (that is now closed).<br>The Site was fully engineered, using the most up-to-date techniques available at the time of construction and was designed to provide liner performance equivalent to at least 1 metre of clay with a maximum hydraulic conductivity of $1x10^{-9}$ m/s.<br>Since closure, 100% of the landfilled area has now been permanently capped using an LLDPE membrane and covered with restoration soils. |
| Source | During its Operational lifetime, which was shorter than that allowed for in the original design of the Site), it received a mixed input of waste including:<br>▪ Household/ Domestic waste<br>▪ Commercial Waste<br>▪ Industrial Waste<br>▪ Inert wastes<br>▪ Civic Amenity waste<br>▪ Filter Cake Waste<br>(See Table 2 for details). |
| Pathways | 1. Unsaturated Coal Measures strata.<br>2. Groundwater within Coal Measures Strata.<br>3. Nant-y-Gwyddon stream. |
| Receptor | 1. Groundwater beneath the landfill.<br>2. The Nant-y-Gwyddon stream.<br>3. The Afon Rhondda Fawr. |
| Compliance Points | For List I substances the Compliance Point is the point of entry to groundwater, which is therefore the water table beneath the Site.<br>For List II substances the Compliance Point is the nearest significant receptor in the direction of groundwater flow.<br>In the absence of any specific groundwater receptor this has been taken to be Borehole NG111, at the north-eastern corner of the Site, adjacent to the old leachate collection tank, and at least 400 metres from the landfilled area. |

## 3.4 Potential Receptors

3.4.1 The receptors considered in this assessment, which would be at risk from any fugitive leachate emissions from the landfill, are as follows:

- the Nant-y-Gwyddon stream (as above); which is a pathway to
- the Afon Rhondda Fawr; and
- groundwater resources within the underlying Coal Measures strata.

3.4.2 With regard to the latter, following a literature review, it has been concluded that it is highly probable that all groundwater percolating laterally and/or vertically through the Coal Measures strata on which the Site is founded contributes to baseflow in either the Nant-y-Gwyddon or Afon Rhondda Fawr. Therefore, any potential contribution to more distant, regional, groundwater resources has been discounted.

## 3.5 Compliance Points

3.5.1 For **List I** substances, the Compliance Point is the point of entry to groundwater, which is therefore the water table beneath the Site. .

3.5.2 For **List II** substances the Compliance Point should be the nearest significant receptor in the direction of groundwater flow. However, in the absence of groundwater abstraction boreholes in the area, and the probable 100% contribution of groundwater to the baseflow in nearby surface water features, the Compliance Point has been taken to be the borehole on the downgradient perimeter of the WML area (i.e. NG111), which is 400 metres from the eastern edge of the landfill.

# 4.0 SITE CHARACTERISATION

## 4.1 Hydrology

4.1.1 The Site is located near the watershed separating the Rhondda Fawr and Clydach valleys. Therefore, no part of the Site is within the EA's Indicative Floodplain for the Rhondda Fawr (see http://www.environment-agency.gov.uk/maps/info/floodmaps/).

4.1.2 This part of the Rhondda valley receives a high annual rainfall (the long-term average annual total precipitation for the Site is over 1900 mm), most of which leaves the surface water catchment, via a network of tributary rivers and streams, in the Avon Rhondda Fawr (which typically exhibits a high intensity-short duration response to rainfall events).

4.1.3 The Nant-y-Gwyddon stream (a small tributary of the Afon Rhondda Fawr) is fed by clean surface water drainage from within the area of the licensed landfill.

4.1.4 It has been shown that a large proportion of the groundwater passing beneath the Nant-y-Gwyddon site, enters into the Nant-y-Gwyddon stream via a number of spring located on the valley side. These are typically associated with the outcrop location of the No. 1 Rhondda and No. 1 Rhondda Rider coal seams – the main aquicludes retaining groundwater beneath the site.

4.1.5 Under the EA's General Quality Assessment (GQA) Scheme, the water quality of the Afon Rhondda Fawr, in common with all surface water features designated as "Main River" across all of England and Wales, is regularly monitored and annual targets for improvement set (where necessary).

4.1.6 Over the last ten years, the adjacent reach of the Afon Rhondda Fawr has been generally classified as Grade A (the highest possible rating). However, since this classification has been the same at points both upstream and downstream of its confluence with the Nant-y-Gwyddon stream, the impact of the latter is clearly insignificant, in terms of both quantity and quality.

## 4.2 Surface Water Quality

4.2.1 ARL currently monitor the quality of surface water at seven locations on or around the Myndd-y-Gelli/Llwynypia Mountain

4.2.2 The surface water monitoring points **SW1**, **SW5**, **SW6**, and **SW8** are within the immediate vicinity of the landfill site and located along the Nant-y-Gwyddon stream:

- **SW5** (the site fire lagoon) - Surface water collecting at the western margin of the site is conveyed by drainage ditches to this point (sampling now discontinued).
- **SW6** (upper Nant-y-Gwyddon stream) - The majority of the surface water collected from the area surrounding the landfill is discharged into the stream here. It has been documented that site drainage at this location was susceptible to leachate contamination, particularly during the early operation of the site. Strict surface water discharge consent conditions now exist for site drainage discharged to the Nant-y-Gwyddon stream at this location.
- **SW8** (middle Nant-y-Gwyddon) - Located half way down the stream to determine the impact of the groundwater component of the total flow downstream of this point.
- **SW1** (lower Nant-y-Gwyddon) – located approximately 750 m up stream of the confluence of the Nant-y-Gwyddon stream with the Avon Rhondda Fawr.

4.2.3 In addition, there are three more distant surface water monitoring points (**SW2**, **SW3**, and **SW4**), which are located as follows:

- **SW4** (Glyncornel Nature Reserve Lake) – Located just upstream of the lake in a small spring. Tracer tests have shown that 80% of the groundwater passing below the landfill emerges on the lower slopes of the Rhondda Fawr Valley, some of which feed into this lake.
- **SW2** (Nant-y-Clydach Fach) – This stream flows in a south-easterly direction through the Clydach Vale Country Park and is also fed by groundwater from the Main Aquifer above the No.1 RR coal seam.
- **SW3** (Cwm Cae Dafydd Tributary) – This tributary originates on the south-western margin of the licensed Site, flows south through the village of Cwm Clydach, and into the Nant Clydach (a major tributary of the Rhondda Avon Fawr).

4.2.4 As part of the process of compiling this Regulation 15 Risk Assessment report, the statistical analysis of surface water quality data presented in the Phase 1 Report has been thoroughly updated and revised.

4.2.5 **Table 5**, below, presents a statistical summary of potential contaminants in the surface water at Nant-y-Gwyddon, compared to the relevant standards (as defined in the Phase 1 Report). Exceedances of this standard are presented in brackets within the Positive Results column alongside the column with the total number of samples analysed for each determinand over the entire monitoring period.

***List II and other Non-Listed Substances***

4.2.6 Surface water sampled within the four main watercourses surrounding the Nant-y-Gwyddon site is considered to be of general good quality. Table 5 and 6 (below) presents annual average concentrations (2006 and 2005, respectively), calculated for 22 key Water quality determinands and compares them to statutory water quality thresholds (e.g. Drinking Water Standard – DWS).

4.2.7 There has been an improvement in surface water quality monitored in 2006 when compared with 2005. This is particularly noticeable in relation to ammoniacal nitrogen ($NH_4$ as N) concentrations reported at all monitoring locations, but is most pronounced at SW 6.

4.2.8 Of the 22 water quality determinands presented in Table 5, it can been seen that only 1 failed (marginally) its respective water quality standard (i.e. Iron at SW 6 annual average value for 2006 1.08 mg/l, compared to Environmental Quality Standard (EQS) of 1.0 mg/l).

4.2.9 With regards to $NH_4$ concentrated reported at SW 6, the improvement in water quality in 2006 reflects the remediation work carried out at the site during 2005 and subsequent restoration work in 2006. This can be clearly attributed to removal of the leachate / surface water drainage infrastructure in the phase 2 area and the subsequent remediation of the phase 1 under-drainage system.

**Table 5: Annual Averages for Surface Water Quality Determinands monitored at Nant-y-Gwyddon in 2006.**

| Water Quality Determinand | Units | EAL | | Surface Water Monitoring Point | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW8 |
| Alkalinity (as $CaCO_3$) | mg/l | - | - | 94.5 | 11.2 | 52.6 | 56.7 | - | 60.2 | 118.3 |
| Ammonia (as N) | mg/l | DWS | 0.5 | 0.4 | 0.3 | 0.3 | 0.4 | - | 0.3 | 0.4 |
| BOD | mg/l | | | 1.3 | 1.6 | 1.3 | 1.3 | - | 1.3 | 1.3 |
| Cadmium | mg/l | DWS | 0.005 | 0.0005[1] | 0.0005[1] | 0.0005[1] | 0.0005[1] | - | 0.0005[1] | 0.0005[1] |
| Calcium | mg/l | DWS | 250 | 25.3 | 6.2 | 17.8 | 18.2 | - | 20.1 | 32.2 |
| Chloride | mg/l | DWS | 250 | 10.5 | 6.9 | 6.9 | 11.3 | - | 3.5 | 12.2 |
| Chromium | mg/l | DWS | 0.05 | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | - | 0.005[1] | 0.005[1] |
| COD | mg/l | - | - | 18.9 | 18.8 | 18.8 | 18.9 | - | 30.0 | 18.9 |
| Copper | mg/l | DWS | 2 | 0.005[1] | 0.005[1] | 0.005 | 0.006 | - | 0.005[1] | 0.005[1] |
| EC @ 20°C | µS/cm | DWS | 1500 | 413 | 80 | 200 | 220 | - | 191 | 561 |
| Iron | mg/l | EQS | 1 | 0.1 | 0.05 | 0.25 | 0.05 | - | **1.08** | 0.10 |
| Lead | mg/l | DWS | 0.01 | 0.005[1] | 0.005 | 0.005[1] | 0.005[1] | - | 0.006 | 0.005 |
| Magnesium | mg/l | DWS | 50 | 26.7 | 2.0 | 10.4 | 12.0 | - | 11.4 | 41.3 |
| Nickel | mg/l | DWS | 0.02 | 0.005[1] | 0.005[1] | 0.004[1] | 0.005[1] | - | 0.005[1] | 0.005[1] |
| Nitrate (as $NO_3$) | mg/l | DWS | 50 | 1.1 | 0.9 | 0.7 | 0.8 | - | 0.7 | 1.2 |
| Nitrite (as $NO_2$) | mg/l | DWS | 0.1 | 0.1[1] | 0.1[1] | 0.1 | 0.1 | - | 0.1 | 0.1 |
| PH | - | DWS | 5.5-9.5 | 8.2 | 7.1 | 7.8 | 7.9 | - | 7.9 | 8.2 |
| Potassium | mg/l | DWS | 12 | 7.9 | 0.7 | 2.1 | 1.8 | - | 5.1 | 12.1 |
| Sodium | mg/l | DWS | 200 | 13.3 | 4.8 | 6.5 | 9.5 | - | 5.2 | 19.8 |
| Sulphate | mg/l | DWS | 250 | 92.5 | 8.8 | 27.8 | 29.3 | - | 35.3 | 160.0 |
| TOC | mg/l | - | - | 1.8 | 1.0 | 0.9 | 1.0 | - | 0.6 | 1.7 |
| Zinc | mg/l | DWS | 5 | 0.011 | 0.013 | 0.013 | 0.013 | - | 0.034 | 0.009 |

**Table 6: Annual Averages for Surface Water Quality Determinands monitored at Nant-y-Gwyddon in 2005.**

| Water Quality Determinand | Units | EAL | | Surface Water Monitoring Point | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW8 |
| Alkalinity (as $CaCO_3$) | mg/l | - | - | 91.6 | 17.6 | 76 | 54.7 | 58.8 | 227 | 132 |
| Ammonia (as N) | mg/l | DWS | 0.5 | **0.68** | **0.51** | **0.52** | **0.51** | 0.46 | **30.0** | **0.61** |
| BOD | mg/l | | | 1.0[1] | 1.8 | 1.0 | 1.2 | 1.1 | 3.4 | 1.1 |
| Cadmium | mg/l | DWS | 0.005 | 0.0006 | 0.0005[1] | 0.0005[1] | 0.0005[1] | 0.005[1] | 0.005[1] | 0.005[1] |
| Calcium | mg/l | DWS | 250 | 28 | 13 | 19 | 19 | 29 | 14 | 33 |
| Chloride | mg/l | DWS | 250 | 11 | 7 | 7 | 10 | 8 | 62 | 13 |
| Chromium | mg/l | DWS | 0.05 | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] |
| COD | mg/l | - | - | 20 | 21 | 20 | 22 | 70 | 94 | 21 |
| Copper | mg/l | DWS | 2 | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | 0.008 | 0.005[1] | 0.006 |
| EC @ 20°C | µS/cm | DWS | 1500 | 360 | 104 | 174 | 209 | 177 | 767 | 476 |
| Iron | mg/l | EQS | 1 | 0.30 | 0.06 | 0.25 | 0.09 | 0.71 | 0.39 | 0.21 |
| Lead | mg/l | DWS | 0.01 | 0.001 | 0.006 | 0.006 | 0.005[1] | 0.008 | 0.005[1] | 0.005[1] |
| Magnesium | mg/l | DWS | 50 | 29.3 | 2.5 | 10.9 | 13.3 | 4.9 | 6.6 | 43.5 |
| Nickel | mg/l | DWS | 0.02 | 0.005 | 0.005[1] | 0.005[1] | 0.005[1] | 0.005[1] | 0.009 | 0.005[1] |
| Nitrate (as $NO_3$) | mg/l | DWS | 50 | 2.2 | 1.2 | 1.3 | 1.7 | 1.0 | 1.2 | 2.7 |
| Nitrite (as $NO_2$) | mg/l | DWS | 0.1 | 0.13 | 0.1[1] | 0.1[1] | 0.1[1] | 0.1[1] | 0.1[1] | 0.1 |
| PH | - | DWS | 5.5-9.5 | 8.1 | 7.7 | 7.8 | 8.0 | 7.8 | 7.7 | 8.1 |
| Potassium | mg/l | DWS | 12 | 7.7 | 0.6 | 1.8 | 1.5 | 1.9 | 2.0 | 10.9 |
| Sodium | mg/l | DWS | 200 | 13.5 | 4.9 | 4.9 | 7.5 | 3.1 | 3.7 | 16.8 |
| Sulphate | mg/l | DWS | 250 | 95.5 | 11.8 | 27.0 | 28.0 | 28.7 | 31.0 | 155.5 |
| TOC | mg/l | - | - | 2.5 | 3.1 | 1.3 | 1.2 | 3.9 | 22.7 | 3.0 |
| Zinc | mg/l | DWS | 5 | 0.008 | 0.019 | 0.023 | 0.011 | 0.032 | 0.050 | 0.014 |

Note 1: Substance not detected above minimum reporting value.

### *List I Substances*

4.2.10 Between 2002 and 2004, no sample from any monitoring location yielded a detectable concentration of cadmium above the laboratory detection limit (MRV) of 0.005mg/l and, since the MRV was lowered to either 0.0005mg/l or 0.001mg/l (in March 2004), 8 detectable cadmium concentrations of 0.001mg/l (five times less than the UK DWS) have been reported for **SW2**, **SW4**, **SW5**, **SW6**, and **SW8**. Whereas **SW1** and **SW3** have never reported any detectable concentrations of cadmium.

4.2.11 No positive results have been reported for any of the 6 surface water samples taken and analysed for mercury on 16/06/2003 (i.e. all samples reported non-detectable concentrations at or below the 0.05mg/l MRV).

4.2.12 Analysis has been performed on a suite of VOCs (those present within the filter cake material deposited at the Site between 1995 and 1997), as required by the Site Licence/Working Plan.

4.2.13 77 surface water samples have been analysed for 1,2-dichloroethane, but none has yielded a detectable concentration above MRVs (of 2μg/l between 2002 and 2003, and 0.4μg/l between 2004 and 2005).

## 4.3 Geology

4.3.1 The Rhondda Valley is positioned in the centre of the South Wales Coalfield; an area in which the mineral reserves contained within a 5000 metre-thick cyclical sequence of mudstones, siltstones (shales), sandstones, and coal seams, have been extensively exploited.

4.3.2 Surface geology has been strongly influenced by glaciation, which impacted the area in excess of 10,000 year ago. Therefore, in addition to scouring-out characteristic "U-shaped" valleys, the lower flanks of Myndd-y-Gelli and Llwynypia Mountain have been covered with thin layers of boulder clay and sand and gravel.

4.3.3 Elsewhere, periglacial activity has caused the creation of thick "head" deposits, which have resulted in numerous shallow landslides on steeper slopes. In addition, small patches of peat, up to 20m thick, occur in areas of poor drainage.

4.3.4 Using both published and site investigation data, the strata underlying the Nant-y-Gwyddon Landfill Site have been determined as being part of the Carboniferous Upper Coal Measures (UCM) sequence. The Rhondda and Llynfi beds, which make up Myndd-y-Gelli and Llwynypia Mountain, consist of cyclical (coarsening-upward) sequences of mudstone, siltstone, sandstone, and coal.

4.3.5 Dipping in a south-easterly direction (at approximately 7°), these beds are contained within a large down-faulted block, bounded by two significant NNE-SSW trending faults; namely the Dinas Fault (to the west) and the Cymer Fault (to the east). Mining records have proven that the strata within this fault block are consistent in both thickness and inclination. See Section 7 of the Phase 1 Report for more detail.

## 4.4 Hydrogeology

4.4.1 The area of land on which the Nant-y-Gwyddon Landfill Site is located is designated as being underlain by a Minor Aquifer (as per the EA's Policy and Practice for the Protection of Groundwater (1998)), but is covered by soils with a low leaching potential (see the *Envirocheck Report* in the Phase 1 Report).

4.4.2 Based on the information available on the EA's website, it has been determined that the Site is not within the source protection zone (SPZ) of any abstraction licensed for public water supply. However, there is a Licenced Abstraction within 1 km of the Site, held by Welsh Water (Dwr Cymru), which relates to two points on the Nant Cesig stream, less than 1200 metres to the north-west of the perimeter of the landfill, which are shown on **Drg. No. AM5465/2/002**. Although these points are not currently used for supply, the licenses remain in force and, as such, they are afforded all the statutory protection that such a licence entails.

4.4.3 The local Environmental Health Department has confirmed that there are no known private (domestic) water supplies for individual properties, or groups of properties, within the vicinity of the Site, except for that at Bwllfa Farm (NGR SS 9704 9415), which is also shown on **Drg. No. AM5465/2/002**.

4.4.4 The Hydrogeological conceptual site model thus derived for Nant-y-Gwyddon identifies two groundwater bodies beneath the landfill site that could be at risk from any fugitive emissions of leachate from the Site. These have been identified as follows:

- The Upper Aquifer – Previous investigation have indicated seasonal groundwater retained above a siltstone/mudstone aquiclude located approximately 25 to 30m above the No.1 RR coal seam.

- The Main Aquifer – Groundwater retained above the No.1 RR coal seam (and associated argillaceous horizons), between 28 and 35 metres below the base of the landfill. Various springs located at the level of the outcrop of the No.1 RR coal seam (eastern slope of Myndd-y-Gelli/Llywnypia Mountain) are thought to represent the discharge points for this aquifer, issuing into various sensitive receptors.

- The Lower Aquifer - Groundwater retained above the No.1 R coal seam (which is approximately 40 metres below the No.1 RR) and which is also associated with spring discharges on the lower slopes of the Afon Rhondda Fawr valley.

4.4.5 The boreholes that have been used to monitor the Upper Aquifer are as follows:

- Boreholes **NG105**, **NG106**, **NG107**, and **NG108** (dry), proven (see Section 4.5 below) to be located hydraulically upgradient of the landfill.
- Borehole **NG104**, proven to be downgradient of the landfill.

4.4.6 The boreholes that have been used to monitor the Main Aquifer (above the No.1 RR coal seam) are as follows:

- Boreholes **GW94** and **NG109** (dry), proven to be upgradient of the landfill.
- Boreholes **GW96**, **GW97**, **NG101**, and **NG110**, proven to be downgradient of the landfill.

4.4.7 The borehole that has been used to monitor the Lower Aquifer (between the No.1RR and No.1 R coal seams), is as follows:

- Borehole **NG111**, proven to be downgradient of the landfill.

4.4.8 In addition to the above, in April 2005, ten new boreholes (**BH1** to **BH10**) were drilled around the perimeter of the landfill to improve the scope of the groundwater monitoring infrastructure available at Nant-y-Gwyddon:

- Boreholes **BH1**, **BH3**, **BH4**, and **BH9** were drilled/installed to monitor the Upper Aquifer (although **BH1** and **BH3** have generally been dry).
- Boreholes **BH2**, **BH5**, **BH6**, **BH7**, **BH8**, and **BH10** were drilled/installed to monitor the Main Aquifer above the No.1 RR coal seam.

4.4.9 **Drawings AM5465/2/004** and **AM5465/2/005** illustrate this information in plan view and cross-sectional view respectively.

## 4.5 Groundwater Levels

4.5.1 Groundwater levels have been monitored using boreholes **GW94**, **GW96**, **GW97**, and **NG101** to **NG107** inclusive from September 2000 to date. Monitoring of groundwater levels within boreholes **NG108** to **NG111** inclusive, commenced following their installation in November 2004. Monitoring of all the new boreholes commenced after their installation in May 2005.

4.5.2 **Table 7**, below, provides a statistical summary of all available groundwater level data, with the mean values highlighted in bold text, and the boreholes sorted by both aquifer, and their location in relation to the landfill.

**Table 7 – Statistical Summary of Groundwater Levels Data**

| Aquifer | Borehole | Location | Min | Mean | Max | Std | Count |
|---|---|---|---|---|---|---|---|
| Upper Aquifer | NG 105 | Upgradient | 332.9 | **335.08** | 343.9 | 1.59 | 60 |
| | NG 106 | | 335.7 | **338.11** | 340.1 | 1.17 | 59 |
| | NG 107 | | 333.0 | **336.59** | 341.6 | 2.32 | 57 |
| | NG 108 | | DRY | | | | |
| | BH1 | | DRY | | | | |
| | BH3 | | DRY | | | | |
| | BH4 | Adjacent | 326.3 | **326.58** | 326.9 | 0.27 | 5 |
| | BH9 | | 322.4 | **322.92** | 323.5 | 0.45 | 6 |
| | BH10 | | 311.3 | **312.37** | 312.9 | 0.69 | 8 |
| | NG 104 | Downgradient | 318.4 | **320.02** | 325.6 | 1.64 | 59 |
| Main Aquifer | GW 94 | Upgradient | 318.2 | **329.97** | 334.2 | 2.45 | 61 |
| | NG 109 | | DRY | | | | |
| | BH2 | | 297.0 | **299.86** | 303.0 | 2.71 | 5 |
| | NG 101 | Adjacent | 285.8 | **290.08** | 307.5 | 3.02 | 51 |
| | BH5 | | 294.3 | **295.48** | 296.6 | 1.03 | 8 |
| | GW 96 | Downgradient | 253.3 | **267.74** | 284.5 | 6.60 | 61 |
| | GW 97 | | 266.1 | **275.32** | 297.4 | 8.83 | 53 |
| | NG 110 | | 262.3 | **266.08** | 276.2 | 4.36 | 14 |
| | BH6 | | 281.8 | **283.04** | 284.8 | 0.93 | 7 |
| | BH7 | | 275.5 | **279.35** | 290.8 | 5.75 | 6 |
| | BH8 | | 275.6 | **275.89** | 276.3 | 0.25 | 7 |
| Lower Aquifer | NG 111 | Downgradient | 227.6 | **233.69** | 247.6 | 6.72 | 10 |

NB All units are in maOD unless stated

4.5.3 Groundwater levels in immediate proximity to the landfill appear to be constant, at between 326maOD (**BH4**) and 323maOD (**BH9**), which would imply that groundwater is indeed being intersected and controlled by the underliner drainage layer.

4.5.4 **NG101**, an older borehole monitoring the Main Aquifer below the landfill, has yielded an average recorded groundwater level of approximately 290maOD, whereas the new borehole **BH5** has yielded a similar average value of approximately 295maOD. However, the difference in levels being recorded in these two boreholes (the western-most being consistently about 5m lower) is believed to be due to both the west-to-east hydraulic gradient between them.

4.5.5 Borehole **NG111** yields the lowest groundwater levels of any of those monitored (typically 234maOD), having penetrated below the No.1 R coal seam.

4.5.6 Taken together, all of the above confirms the established view that the UCM can be considered as a multi-layer aquifer; with sandstone layers (more readily able to transmit water) separated by less permeable strata.

4.5.7 On this basis, the data also confirms the easterly flow of groundwater at all levels within the UCM sequence.

4.5.8 Finally, where groundwater is retained in the "Upper Aquifer" (above mudstone and/or siltstone bands that are themselves approximately 20 metres above the No.1 RR coal seam) the groundwater monitoring data indicates that:

- This groundwater is being effectively removed by the underliner drainage blanket;
- Groundwater in the Main Aquifer (discharging to springs downstream of the Site) is typically separated from that above by approximately 25 metres of unsaturated strata; and
- Groundwater retained above the No.1 R coal seam (discharging to springs on the lower slopes of the Afon Rhondda Fawr valley) is similarly separated from that above, by approximately 40 metres of unsaturated strata (including the No.1 RR coal seam).

4.4.10 **Drawing AM5465/2/005** illustrate this information in cross-sectional view.

## 4.6 Groundwater Quality

4.6.1 For the purposes of determining the nature of background groundwater quality, as for surface water quality data, the statistical analysis of groundwater quality data presented in the Phase 1 Report has been thoroughly updated and revised.

4.6.2 The significant features of this analysis of the data (summarised below) should be read in conjunction with **Table 8**, which follows. It should be noted that the latter, differentiates upgradient and downgradient data for both the Upper and Main Aquifers.

***List II and other Non-Listed Substances***

4.6.3 All major ion concentrations (for calcium, chloride, magnesium, potassium, sodium, and sulphate) are low, which is indicative of groundwater that has been relatively recently derived from rainfall.

4.6.4 Ammoniacal nitrogen concentrations upgradient of the landfill were below MRVs in 70% of samples taken from the Upper Aquifer and in 72% of samples taken from the Main Aquifer. Nevertheless, in both aquifers, in excess of 60% of samples that yielded a positive result were above the DWS limit of 0.39 mg/l (i.e. 0.5 mg/l as ammonium [$NH_4^+$]).

4.6.5 Nitrate and nitrite (both as N) have been detected in variable proportions of samples, although not generally in excess of DWS limit values. The mean nitrate concentration calculated for the Main Aquifer downgradient of the landfill is less than a third of the DWS value of 11.3 mg/l (i.e. 50 mg/l as $NO_3$), whereas a single positive result for nitrite (less than 1% of samples analysed) yielded a concentration of 0.09 (three times the DWS limit) upgradient of the landfill in the Upper Aquifer.

4.6.6 Iron has been detected in the majority of samples, which is consistent with the accepted characteristic of groundwater within Coal Measures strata.

4.6.7 Copper and zinc have not exceeded DWS Limits in any groundwater samples analysed. However, whereas mean concentrations have exceeded applicable Freshwater EQS limits (28µg/l and 500µg/l respectively) upgradient of the landfill mean downgradient concentrations have not exceeded these limits.

4.6.8 The other toxic metals (chromium, lead, and nickel) have been detected in variable proportions of groundwater samples: Of 71 samples of groundwater from the Upper Aquifer upgradient of the landfill analysed for chromium concentrations, 12 (17%) yielded positive results, which included 3 (4%) exceedances of the 0.05mg/l DWS limit. Similarly, for lead, out of 63 samples, 14 (22%) positive analytical results have included 3 (5%) exceedances of the 0.02mg/l DWS limit. Whereas, for nickel, out of 63 samples, 39 (62%) positive analytical results have included 20 (32%) exceedances of the 0.02mg/l DWS limit.

**Table 8: Aquifer-Specific Upgradient and Downgradient Groundwater Quality Statistics**

| Determinand | DWS | Total No. of Samples | No. at/below MRVs | Count of Positive Results | Min | Mean | Max | Std. Dev. | No. of Samples >DWS | Total No. of Samples | No. at/below MRVs | Count of Positive Results | Min | Mean | Max | Std. Dev. | No. of Samples >DWS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Nant-y-Gwyddon Groundwater Quality Statistics for the Upper Aquifer** | | | | | | | | | | | | | | | | | |
| | | **Upper Aquifer - Upgradient Boreholes (NG105, NG106 and NG107)** | | | | | | | | **Upper Aquifer - Downgradient Borehole (NG104)** | | | | | | | |
| Ammonia as N | 0.39 | 181 | 126 | 55 | 0.05 | 0.53 | 2 | 0.46 | 33 | 63 | 49 | 14 | 0.07 | 0.69 | 2.4 | 0.62 | 11 |
| Arsenic | 0.01 | 6 | 0 | 6 | 1 | 5.3 | 22.1 | 8.256 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | 0 |
| Benzene | 0.001 | 20 | 20 | 0 | 0 | | 0 | | 0 | 7 | 7 | 0 | 0 | | 0 | | 0 |
| Cadmium | 0.005 | 82 | 55 | 27 | 0.0002 | 0.003 | 0.009 | 0.003 | 8 | 30 | 26 | 4 | 0.001 | 0.005 | 0.007 | 0.003 | 2 |
| Calcium | 250 | 63 | 0 | 63 | 5.51 | 16.3 | 60.7 | 10.3 | 0 | 22 | 0 | 22 | 3.5 | 6.8 | 27.7 | 5.2 | 0 |
| Chloride | 250 | 107 | 51 | 56 | 2 | 8.3 | 49.6 | 7.06 | 0 | 39 | 20 | 19 | 3 | 5.5 | 8 | 1.4 | 0 |
| Chromium | 0.05 | 71 | 59 | 12 | 0.005 | 0.03 | 0.08 | 0.03 | 3 | 25 | 22 | 3 | 0.02 | 0.027 | 0.04 | 0.012 | 0 |
| Copper | 2 | 63 | 37 | 26 | 0.005 | 0.034 | 0.23 | 0.052 | 0 | 22 | 16 | 6 | 0.006 | 0.018 | 0.04 | 0.014 | 0 |
| Iron | 0.2 | 63 | 13 | 50 | 0.01 | 14.7 | 146 | 27.9 | 47 | 22 | 5 | 17 | 0.18 | 9.8 | 74.9 | 20.4 | 16 |
| Lead | 0.01 | 63 | 49 | 14 | 0.005 | 0.018 | 0.08 | 0.023 | 3 | 22 | 18 | 4 | 0.005 | 0.019 | 0.05 | 0.021 | 2 |
| Magnesium | 50 | 63 | 0 | 63 | 2.2 | 5.78 | 25.5 | 4.08 | 0 | 22 | 0 | 22 | 2.02 | 3.77 | 9.62 | 1.8 | 0 |
| Manganese | 0.05 | 36 | 5 | 31 | 0.002 | 2.34 | 9.69 | 2.39 | 30 | 12 | 0 | 12 | 0.05 | 1.05 | 7.71 | 2.2 | 10 |
| Mercury | 0.001 | 6 | 5 | 1 | 0.07 | 0.07 | 0.07 | | 1 | 1 | 1 | 0 | 0 | | 0 | | 0 |
| Nickel | 0.02 | 63 | 24 | 39 | 0.005 | 0.043 | 0.22 | 0.049 | 20 | 22 | 8 | 14 | 0.005 | 0.013 | 0.05 | 0.014 | 2 |
| Nitrate (as N) | 11.3 | 120 | 63 | 57 | 0.11 | 1.02 | 9.42 | 1.37 | 0 | 42 | 26 | 16 | 0.3 | 0.74 | 1.5 | 0.359 | 0 |
| Nitrite (as N) | 0.03 | 119 | 118 | 1 | 0.09 | 0.09 | 0.09 | | 1 | 43 | 43 | 0 | 0 | | 0 | | 0 |
| Phosphorus | 2.2 | 22 | 14 | 8 | 0.12 | 0.57 | 1.2 | 0.3 | 0 | 8 | 7 | 1 | 0.19 | 0.19 | 0.19 | | 0 |
| Potassium | 12 | 63 | 5 | 58 | 0.5 | 1.84 | 9.6 | 1.75 | 0 | 22 | 2 | 20 | 0.6 | 1.42 | 4.29 | 0.941 | 0 |
| Sodium | 200 | 63 | 0 | 63 | 3 | 6.9 | 23.8 | 3.7 | 0 | 22 | 0 | 22 | 3 | 5.1 | 10 | 1.67 | 0 |
| Sulphate | 250 | 63 | 9 | 54 | 4.2 | 30.5 | 120 | 29.2 | 0 | 22 | 0 | 22 | 10 | 16.8 | 35 | 5.8 | 0 |
| Zinc | 5 | 60 | 19 | 41 | 0.005 | 0.091 | 0.56 | 0.114 | 0 | 21 | 5 | 16 | 0.01 | 0.043 | 0.17 | 0.044 | 0 |
| **Nant-y-Gwyddon Groundwater Quality Statistics for the Main Aquifer** | | | | | | | | | | | | | | | | | |
| **Determinand** | **DWS** | **Main Aquifer - Upgradient Borehole (GW 94)** | | | | | | | | **Main Aquifer - Downgradient Boreholes (GW96, GW97, and NG110)** | | | | | | | |
| Ammonia as N | 0.39 | 65 | 47 | 18 | 0.06 | 0.67 | 2.5 | 0.62 | 12 | 120 | 89 | 31 | 0.06 | 0.84 | 5.4 | 0.87 | 22 |
| Arsenic | 0.01 | 66 | 48 | 19 | 1.06 | 1.67 | 3.5 | 1.62 | 13 | 121 | 90 | 32 | 1.06 | 1.84 | 6.4 | 1.87 | 23 |
| Benzene | 0.001 | 9 | 8 | 1 | 0.002 | 0.002 | 0.002 | | 1 | 18 | 17 | 1 | 0.0005 | 0.0013 | 0.002 | 0.0011 | 1 |
| Cadmium | 0.005 | 29 | 22 | 7 | 0.001 | 0.0023 | 0.007 | 0.0024 | 1 | 52 | 40 | 12 | 0.001 | 0.003 | 0.007 | 0.0026 | 2 |
| Calcium | 250 | 22 | 0 | 22 | 2.46 | 7.27 | 14 | 2.78 | 0 | 43 | 0 | 43 | 1.9 | 32.5 | 311 | 47.1 | 1 |
| Chloride | 250 | 40 | 19 | 21 | 5 | 8 | 12 | 2 | 0 | 78 | 20 | 58 | 4 | 20.5 | 70 | 13.2 | 0 |
| Chromium | 0.05 | 25 | 15 | 10 | 0.007 | 0.0236 | 0.13 | 0.038 | 1 | 47 | 44 | 3 | 0.008 | 0.024 | 0.059 | 0.021 | 1 |
| Copper | 2 | 22 | 14 | 8 | 0.01 | 0.019 | 0.03 | 0.0095 | 0 | 43 | 35 | 8 | 0.005 | 0.0236 | 0.12 | 0.033 | 0 |
| Iron | 0.2 | 22 | 4 | 18 | 0.01 | 41.4 | 121 | 40.7 | 17 | 43 | 10 | 33 | 0.06 | 10.5 | 146 | 22.1 | 31 |
| Lead | 0.01 | 22 | 15 | 7 | 0.006 | 0.031 | 0.061 | 0.022 | 5 | 43 | 33 | 10 | 0.005 | 0.0368 | 0.14 | 0.0534 | 3 |
| Magnesium | 50 | 21 | 0 | 21 | 1.54 | 5.03 | 9.45 | 1.84 | 0 | 43 | 0 | 43 | 0.2 | 17.6 | 172 | 25 | 2 |
| Manganese | 0.05 | 11 | 0 | 11 | 0.56 | 0.778 | 1.07 | 0.197 | 11 | 21 | 2 | 19 | 0.002 | 0.571 | 6.86 | 1.25 | 13 |
| Mercury | 0.001 | 2 | 2 | 0 | 0 | | 0 | | 0 | 3 | 2 | 1 | 0.23 | 0.23 | 0.23 | | 1 |
| Nickel | 0.02 | 22 | 13 | 9 | 0.007 | 0.019 | 0.04 | 0.011 | 3 | 43 | 33 | 10 | 0.005 | 0.022 | 0.1 | 0.025 | 3 |
| Nitrate (as N) | 11.3 | 44 | 32 | 12 | 0.08 | 0.83 | 2.5 | 0.645 | 0 | 87 | 36 | 51 | 0.3 | 3.55 | 10.3 | 3.1 | 0 |
| Nitrite (as N) | 0.03 | 44 | 44 | 0 | 0 | | 0 | | 0 | 87 | 87 | 0 | 0.1 | 0.1 | 0.1 | | 0 |
| Phosphorus | 2.2 | 8 | 2 | 6 | 0.2 | 2.58 | 9 | 3.31 | 2 | 14 | 9 | 5 | 0.1 | 0.257 | 0.6 | 0.17 | 0 |
| Potassium | 12 | 22 | 1 | 21 | 0.87 | 2.02 | 4.61 | 1.21 | 0 | 43 | 3 | 40 | 0.38 | 3.14 | 13.3 | 2.17 | 1 |
| Sodium | 200 | 22 | 0 | 22 | 2 | 6.9 | 25.8 | 5.4 | 0 | 43 | 0 | 43 | 2.29 | 13.1 | 48 | 9.6 | 0 |
| Sulphate | 250 | 22 | 0 | 22 | 7 | 13 | 31 | 5.28 | 0 | 43 | 0 | 43 | 5.88 | 28.2 | 85.2 | 17.5 | 0 |
| Zinc | 5 | 22 | 13 | 9 | 0.006 | 0.055 | 0.09 | 0.034 | 0 | 41 | 25 | 16 | 0.007 | 0.047 | 0.31 | 0.078 | 0 |

All data quoted in mg/l

***List I Substances***

4.6.9 Benzene has been detected in <5% (1 out of 22) samples both up- and downgradient of the landfill, in each case from samples recovered from the Main Aquifer, which is adjacent to the No.1 RR Coal Seam. **Since benzene is a major component of coal[3], these results are considered to reflect a natural characteristic of groundwater in Coal Measures strata.**

4.6.10 Cadmium has been detected in a variable proportion of groundwater samples from the two aquifers; both up- and downgradient of the landfill. However, by far the highest proportion of positive results (34%) has been obtained for the Upper Aquifer upgradient of the landfill. **Therefore, these results are also considered to reflect a natural characteristic of ambient groundwater.**

4.6.11 Mercury has been detected (at concentrations above DWS limits) on 2 out of 6 occasions for which it has been analysed, one of which was from an upgradient borehole in the Upper Aquifer. **Therefore, this is also cannot be considered to be related to the presence of the landfill.**

## 5.0 RISK ASSESSMENT METHOD

### 5.1 The Nature of the Risk Assessment

5.1.1 Given that the landfill may represent a potential hazard to local surface water and/or groundwater resources, a risk assessment, based on prior investigation, is required in order to comply with Regulation 15 of the 1994 Regulations. Nevertheless, the risk assessment undertaken and presented herein has also been undertaken in accordance with the latest guidance, issued in pursuance of compliance with the 2002 Regulations.

5.1.2 As set out within LFTGN01, the appropriate complexity of assessment for a Site should be determined from the potential risks presented by the Site, which are linked to the nature of potential hazards, the sensitivity of the surrounding environment, degree of uncertainty, and likelihood of a risk being realised. There are essentially two levels of complexity:

- **Simple risk assessments** should be carried out where feasible source-pathway-receptor linkages are identified, or in preparation for conducting a more complex assessment, and where either:
  - It is clear from the conceptual model and the risk screening that the hazards are relatively low and the environmental setting is sufficiently insensitive to negate the possibility of significant impacts (e.g. sites on low permeability strata remote from abstractions and surface waters); or
  - The potential source, pathway and receptor terms can all be defined with sufficient certainty so as to be confidently represented by conservative inputs, models and assumptions, e.g. a single homogenous source of in-house waste, well-defined flow characteristics and directions etc.

3 See http://www.nsc.org/library/chemical/benzene.htm

- **Complex risk assessments** should be carried out where complete source-pathway-receptor linkages are present and where either:

  - ➢ The Site setting is sufficiently sensitive to warrant detailed assessment, e.g. on permeable strata (e.g. Major Aquifer); within a Source Protection Zone; or close to surface water bodies; or
  - ➢ There is uncertainty relating to any of the source, pathway or receptor terms, e.g. variable leachate quality, or an undefined groundwater flow pattern that cannot be overcome by the adoption of conservative inputs or assumptions.

5.1.3 Given the nature of the Site, and its environmental setting, it has been agreed that it is necessary to complete a complex risk assessment to support the application for the Site to be granted post-closure status. This has therefore required the use of the latest version of the Environment Agency's preferred assessment tool; the probabilistic landfill liner performance assessment software; LandSim version 2.5.14.

## 5.2 Review of Technical Precautions

5.2.1 Landfill waste disposal at Nant-y-Gwyddon was terminated approximately 9 years before the anticipated completion date and, therefore, the Site is comprised of a completed phase (Phase 1) containing approximately 1.4 million cubic metres of waste, adjacent to an unused second phase (Phase 2), the basal engineering for which has now been removed and the area restored.

5.2.2 Landfill Gas and Leachate management systems at the Site are maintained by ARL staff, in order to protect the environment from any potential harm that could arise from the production of leachate and landfill gas at the Site.

***Landfill Gas Management***

5.2.3 Landfill gas (LFG) production at Nant-y-Gwyddon is controlled using an active gas extraction and flaring system. This consists of approximately 40 vertical gas extraction wells evenly spaced across the landfilled area. Fugitive LFG emissions are further limited through the presence of the engineered capping layers (i.e. final).

5.2.4 Landfill gas collected from the landfill is pumped to landfill gas power generation compound situated adjacent to the site office. Currently the power generation scheme at the site consists of 650kW Jenbacher Landfill Gas Generation Set and 400m$^3$/hr gas extraction plant and high temperature enclosed flare.

5.2.5 The pressure in this extraction system is regulated using control vales at the wells or one of four manifold systems.

***Leachate Management***

5.2.6 Landfill engineering at Nant-y-Gwyddon is based on the principle of total containment. The engineered barrier system (basal liner) is described (by WS Atkins in the 1993 Working Plan) as consisting of:

- 300 mm graded colliery spoil and protective mat over a 2.5 mm HDPE membrane laid on 300 mm graded colliery spoil with sub-liner drainage and protective mat over excavated and re-compacted ground.

- Collector drains containing no-fines granular material and protected by a geotextile wrap, are connected to the appropriate leachate and surface water outfalls, via a series ducts constructed from pre-cast concrete rings.

5.2.7 Following the cessation of waste disposal activities, the most effective means of limiting the production of leachate is the construction of a suitably engineered cap over the waste. Currently the whole waste surface at Nant-y-Gwyddon is covered by a permanent LLDPE engineered cap.

5.2.8 Infiltration through this cap is considered to be no more than 5% of the incident precipitation; the remainder being either evaporated or redirected to the Nant-y-Gwyddon stream via the surface water management system on-site (see below).

5.2.9 The reduced infiltration rate has been assumed (rather than 10% and 20%) because of the steeps slopes (giving rise to greater run-off) that make-up nearly half the surface area of the completed landfill).

5.2.10 Leachate reaching the base of the waste mass is collected by the above-liner, leachate drainage system, which consists of a series of Herring Bone drains, which direct leachate (under the influence of gravity) through the inert bund (retaining the eastern margin of phase 1) to the leachate holding tank. From this location, leachate is conducted directly to the local foul sewer network, via a 1.5 km pipeline, at a consented rate of 6 litres per second.

5.2.11 Leachate that is actively removed from west side of Phase 1 (inside Jones' Bund) is pumped to the holding tank via an underground pipeline. Since the remediation of the site in 2005, volumes of leachate produced from both these sources have reduced significantly compared to those values measured previously.

### *Groundwater Management*

5.2.12 Reports issued in 1999 (Babtie Group and Golder Associates) appear to suggest that there was an underliner drainage blanket, although earlier reports (and the Working Plan for the Site) indicate that the engineered barrier is made up of an FML sandwiched between protective layers of processed colliery spoil within which there are a network of drainage pipes. These are designed to relieve any potential for the build-up of external groundwater pressure within the sandstone that overlies the No.1 RR coal seam.

5.2.13 Groundwater emerging from beneath the untipped Phase 2 is directed via the surface water management system, to the Nant-y-Gwyddon stream, whereas that emerging from beneath the completed Phase 1 is transferred to the leachate management system.

5.2.14 The Nant-y-Gwyddon stream is monitored in order to detect any evidence of leakage from the landfill (into this groundwater collection system, or any other adjacent strata, for which, in all cases, the stream is considered to be the common ultimate receptor).

### *Surface Water Management*

5.2.15 The majority of the clean surface water drainage generated within the Site boundary is discharged directly into the Nant-y-Gwyddon stream, and is regulated by the Environment Agency, by means of a Discharge Consent issued to ARL (Consent No. AN0308301).

5.2.16 However, due to the natural topography of the Site, surface water drainage from the 2 ha area to the west of the Site haulage road (adjacent to Phase 2) is discharged to the Cwm Caedafydd watercourse at the south-western margin of the Site (Consent No. AN0320901 issued to ARL in June 2002).

5.2.17 ARL are also required to manage surface water drainage generated in the recently-worked area of the Gelli Tips.

5.2.18 Discharge volumes associated with this area are minimal and a single settlement lagoon is employed prior to the discharge of any water to the Nant-y-Gwyddon stream.

5.2.19 This discharge is also regulated by a surface water Discharge Consent (No. AN0308201).

## 5.3 Proposed Assessment Scenarios

5.3.1 LFTGN01 states that a "*hydrogeological risk assessment must be carried out for the whole lifecycle of the landfill, i.e. from the start of the operational phases until the point at which the landfill is no longer capable of posing an unacceptable environmental risk. This must include consideration of the proposed technical precautions in conjunction with any natural geological barriers. Different scenarios must be considered, to assess the hydrogeological risks at different stages of the landfill's lifecycle. Plausible external influences, failure scenarios and accidents must also be considered.*"

5.3.2 For the reasons set out in **Section 5.1**, above, this risk assessment has been undertaken using LandSim version 2.5.14, which allows for the assessment of the performance of the landfill over its entire lifecycle, by simulating the degradation of the engineering and/or the cessation of management control, with the passage of time.

5.3.3 The software therefore enables the quantitative assessment of any probable discharges from the landfill over the longer-term, arising from any or all of the following:

- The cessation of the control of leachate levels within the waste;
- The degradation of the FML;
- The degradation of the LLDPE Cap; and
- The declining source term.

5.3.4 Therefore, using a single model (NYG05), the simulations used in this risk assessment, which are identical apart from the duration of the Management Control Period (MCP), are as follows:

- NYG05-020 20 Year MCP
- NYG05-030 30 Year MCP
- NYG05-060 60 Year MCP
- NYG05-150 150 Year MCP
- NYG05-400 400 Year MCP
- NYG05-K20 20,000 Year MCP

5.3.5 However, these simulations have not allowed for the beneficial effects of recirculating treated leachate and, due to the changes in the software, the Cation Exchange Capacity of clay liners. The latter is a measure of the time-limited ability of clay minerals in particular to remove certain cations (positively-charged ions) from leachate (such as ammonium $NH^{4+}$) as it passes.

## 5.4 The Priority Contaminants to be Modelled

### *Determination of Environmental Assessment Limits (EALs)*

5.4.1 Before probabilistic modelling of landfill liner performance using LandSim can be undertaken, it is necessary to critically review all the environmental monitoring data available, select significant contaminant species, and define Environmental Assessment Levels (EALs), as set out below.

5.4.2 Compliance with the Groundwater Regulations 1998 requires that the landfill will not result in any discernible discharges of List I substances to groundwater and will not cause pollution of groundwater by List II substances. EALs are an important part of this assessment, in that they provide both an indication of groundwater sensitivity as well as providing compliance criteria (i.e. to determine the point at which monitoring results may indicate that non-compliant discharges have occurred).

5.4.3 With regard to List I substances, EALs are the concentrations at which they would become "discernible" in groundwater, for which purpose it is assumed that none is present in groundwater beneath the Site.[4]

5.4.4 Therefore, (with reference to Appendix 7 of the Agency's Guidance on "*Hydrogeological Risk Assessments for Landfills*" (LFTGN01), March 2003), the selection of appropriate EALs is based on likely acceptable Minimum Reporting Values (MRVs):

5.4.5 With regard to List II substances in groundwater, in order to derive EALs for those contaminants that are present within the leachate, it is necessary to determine what could be regarded as "pollution".

5.4.6 To this end, background groundwater quality data must be compared with the appropriate WQS for groundwater (i.e. the UK's DWS (SI 2000/3184) and EALs determined in accordance with the advice given in Section 2.5 of LFTGN01. Therefore, it is first necessary to determine what background groundwater quality is.

5.4.7 Using the upgradient data for the Upper Aquifer, and removing all List I substances, those non-List I substances for which no DWS limit value has been defined, and any for which only very limited data is available, potential EALs have been derived for the remaining substances as 110 to 120% of the maximum observed value reported to-date.

5.4.8 The results of this process are presented in **Table 9**, below, and it will be noticeable that some of these potential EALs are above their respective DWS limit values (shown in **bold** type)[5]:

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[4] Although benzene, cadmium, and mercury have occasionally been detected in groundwater, none of these results can be attributed to the presence of the landfill. (See Appendix B for details).

[5] Whereas, Environment Agency guidance (Section 2.5 of LFTGN01) suggests that the determination of EALs may not be appropriate for substances that frequently appear to exceed the least stringent appropriate WQS in background groundwater quality data, or if the potential EALs derived exceed the appropriate WQS.

**Table 9: Derivation of Site-Specific EALs for Substances in Groundwater**

| Potential Contaminant | Statistical Summary of Boreholes Upgradient of Upper Aquifer | | | | | DWS | >DWS | Potential EAL |
|---|---|---|---|---|---|---|---|---|
| | Min | Mean | Max | SD | Count | | | |
| Ammonia (as N) | 0.05 | 0.53 | 2 | 0.46 | 55 | 0.39 | 33 | **2.2** |
| Calcium | 5.51 | 16.3 | 60.7 | 10.3 | 63 | 250 | 0 | 70 |
| Chloride | 2 | 8.3 | 49.6 | 7.06 | 56 | 250 | 0 | 60 |
| Chromium | 0.005 | 0.030 | 0.08 | 0.03 | 12 | 0.05 | 3 | **0.09** |
| Copper | 0.005 | 0.034 | 0.23 | 0.052 | 26 | 2 | 0 | 0.25 |
| Iron | 0.01 | 14.7 | 146 | 27.9 | 50 | 0.2 | 47 | **161** |
| Lead | 0.005 | 0.018 | 0.08 | 0.023 | 14 | 0.01 | 3 | **0.09** |
| Magnesium | 2.2 | 5.78 | 25.5 | 4.08 | 63 | 50 | 0 | 30 |
| Manganese | 0.002 | 2.34 | 9.69 | 2.39 | 31 | 0.05 | 30 | **10.7** |
| Nickel | 0.005 | 0.043 | 0.22 | 0.049 | 39 | 0.02 | 20 | **0.24** |
| Nitrate (as N) | 0.11 | 1.02 | 9.42 | 1.37 | 57 | 11.3 | 0 | 10.4 |
| Potassium | 0.5 | 1.84 | 9.6 | 1.75 | 58 | 12 | 0 | 10.6 |
| Sodium | 3 | 6.9 | 23.8 | 3.7 | 63 | 200 | 0 | 30 |
| Sulphate | 4.2 | 30.5 | 120 | 29.2 | 54 | 250 | 0 | 150 |
| Zinc | 0.005 | 0.091 | 0.56 | 0.114 | 41 | 5 | 0 | 0.62 |

5.4.9 However for the purpose of quantitative assessment using LandSim 2.5.14, it is considered more important to select potential List II contaminant species with reference to their likely presence in leachate; the differences in leachate and groundwater concentrations; and their toxicity and persistence in the environment (see Table 3.2 in LFTGN01)

5.4.10 Consequently, the following EALs are proposed:

- Ammonia (as N) 2.2 mg/l
- Chloride 60 mg/l
- Chromium 0.09 mg/l
- Copper 0.25 mg/l
- Lead 0.09 mg/l
- Nickel 0.24 mg/l
- Zinc 0.62 mg/l

***Selection of Contaminant Species for Modelling Purposes***

5.4.11 Because of the lengthy operational history of the landfill at Nant-y-Gwyddon, there is no site-specific data on ambient groundwater quality that pre-dates the deposition of waste on the Site. However, from analysis of the data that is available, there is no indication of any adverse trends in the results for any of the determinands for which analysis has routinely been made.

5.4.12 There is a considerable body of data for cadmium, which has been analysed as part of the routine monitoring of the Site, in accordance with the requirements of the extant Waste Management Licence for the Site.

5.4.13 Given all of the above, the potential leachate constituent species chosen (based upon their potential solubility, resistance to retardation and/or biodegradation, and for bioaccumulation) for modelling using LandSim (for which the results are presented in **Section 6.6** of this report), are as shown in **Table 10**, below:

**Table 10: List of Contaminants of Concern to be Included in LandSim Model**

| List I | List II |
|---|---|
| Cadmium | Ammoniacal Nitrogen |
| | Chloride (Not Listed) |
| | Chromium |
| | Copper |
| | Lead |
| | Nickel |
| | Zinc |

## 5.5 Justification for Methodology Used

5.5.1 The conceptual hydrogeological site model encompasses all aspects of the hydrological cycle insofar as they impinge upon the potential ability of the Site to affect the external hydrosphere.

5.5.2 As stated in **Section 5.1**, it is accepted that a complex, quantitative, risk assessment is necessary and that the Environment Agency's probabilistic landfill liner performance assessment software, LandSim version 2.5.14, is the appropriate risk assessment tool.

# 6.0 RISK ASSESSMENT CALCULATIONS AND RESULTS

## 6.1 Model Parameterisation

### *Source Term*

6.1.1 Having selected the above species for modelling purposes, and derived EALs for the non-List I substances, the LandSim modelling requires the definition of the Source Term, using the data summarised in **Table 3**.

6.1.2 The Source Term is therefore as shown in **Table 11**, below:

**Table 11: Source Term Parameterisation in LandSim**

| Contaminant of Concern | Probability Density Function |
|---|---|
| Ammonia as N. | LOGTRIANGULAR (23,245,730) |
| Cadmium | LOGTRIANGULAR (0.001,0.006,0.02) |
| Chloride | LOGTRIANGULAR (20,648,1030) |
| Chromium | LOGTRIANGULAR (0.009,0.03,**0.26**)* |
| Copper | LOGTRIANGULAR (0.008,0.02,**0.09**)** |
| Lead | LOGTRIANGULAR (0.007,0.03,0.07) |
| Nickel | LOGTRIANGULAR (0.02,0.05,0.1) |
| Zinc | LOGTRIANGULAR (0.06,0.26,1.25) |

6.1.3 However, it should be noted that, in pursuance of a worst-case scenario, the data used here is based upon the results obtained from **L5a** alone, for the reasons stated previously, with the exception of those cases, highlighted in bold above, where **L5**(*) or **LL01**(**) have yielded higher peak concentrations

### *Background Groundwater Quality*

6.1.4 Background Groundwater Quality, has been determined using the data summarised in **Table 7**, above.

6.1.5 The Background Groundwater Quality is therefore as shown in **Table 12**, below:

**Table 12: Background Groundwater Quality in LandSim**

| Contaminant of Concern | Probability Density Function |
|---|---|
| Ammonia as N. | LOGTRIANGULAR (**0.065**,**0.67**,**2.5**) |
| Cadmium | LOGTRIANGULAR (**0.001**,0.003,0.009) |
| Chloride | LOGTRIANGULAR (**5**,8,50) |
| Chromium | LOGTRIANGULAR (**0.007**,0.03,**0.13**) |
| Copper | LOGTRIANGULAR (**0.01**,0.034,0.23) |
| Lead | LOGTRIANGULAR (**0.006**,**0.031**,0.08) |
| Nickel | LOGTRIANGULAR (**0.007**,0.043,0.22) |
| Zinc | LOGTRIANGULAR (**0.006**,0.091,0.56) |

6.1.6 However, it should be noted that, in pursuance of worst-case assumptions, the borehole reporting the highest value has been used in each and every case, for all minimum, mean, and/or maximum values. As such, the values used here are those derived from the groundwater monitoring boreholes located upgradient of the landfill, as follows:

- Numbers in **bold** type have been derived from the **Main Aquifer** (Borehole **GW94**); and
- All other values have been derived from the Upper Aquifer (Boreholes NG105, NG106, and NG107).

***Unsaturated Zone Thickness***

6.1.7 For the purposes of modelling the performance of the landfill liner using LandSim, the thickness of the Unsaturated Zone, which is of fundamental importance in determining predicted concentrations at the point of entry into groundwater, has been derived as follows:

- The depth of the No.1 RR coal seam and the range of depths to groundwater in boreholes **BH2** and **BH7** (see Drawing **AM5465/2/002**), provide the best indication of the depth to groundwater in the Main Aquifer beneath the landfill.
- In **BH2**, the base of the Main Aquifer is at 296.5maOD, whereas in **BH7** it is at 269maOD.
- In **BH2**, groundwater has been observed to be at 300maOD +/- 3m, whereas in **BH7** it has been observed to be at 280maOD +/- 5m.
- Based on information compiled by Ove Arup and Partners (Arup), in an earlier investigation of the Site (see **Arup Drawing No. WSKN04**), the base of the landfill is understood to range from 346maOD (in the south-west) to 310maOD (in the north-east).
- Therefore, the groundwater in the Main Aquifer beneath the south-west corner of the landfill is between 43 and 49 metres below the liner, whereas in the north-east corner of the landfill it is between 25 and 35 metres below the liner.
- Therefore the minimum distance is 25m and the maximum distance is 49m; with a most likely value of 38m (assuming the slopes on both the water table and the landfill liner to be constant).
- All of the above pre-supposes that any groundwater moving through fissure systems in the Upper Aquifer, which does come into contact with the underliner drainage blanket (although all such fissures are believed to have been grouted or cemented prior to construction of the landfill), is being removed and discharged, via the leachate collection system, into the foul sewer.

**Table 13: Qualitative Assessment of Accidents and their Consequences**

| Potential Accident | Likelihood of Occurrence | Implications of Occurrence | Consequence of Occurrence | Likelihood of Non-Compliance with the Groundwater Regulations 1998 |
|---|---|---|---|---|
| Flooding | Very Unlikely<br>*(Due to the elevated situation of the Site).* | Site inundated<br>Increased leachate heads<br>Increased leachate leakage<br>Reduced attenuation potential<br>Surface water discharge | Significant | Possible |
| Subsidence | Unlikely<br>*(See Coal Mining Report from the Coal Authority).* | Potential breach of engineered containment<br>Increased leachate leakage<br>Reduced attenuation potential | Severe | Probable |
| Landslide | Very Unlikely<br>*(Because of CQA of the Site and absence of history of local earthquakes etc).* | Possible breach of engineered containment<br>Increased leachate leakage<br>Reduced attenuation potential | Significant | Fairly Probable |
| Fire | Unlikely<br>*(None of these can be completely discounted, but all possible precautions will be taken to prevent them, in accordance with Amgen Rhondda's WP and PRP*).* | Potential damage to geomembrane<br>Derogation of leachate management system<br>Loss of overall management control | Significant | Fairly Probable |
| Explosion | | Potential breach of engineered containment<br>Derogation of leachate management system<br>Increased leachate leakage<br>Reduced attenuation potential | Severe | Probable |
| Containment Breach | | Increased leachate leakage<br>Reduced attenuation potential | Significant | Probable |

*** WP = Working Plan. PRP = Policy, Rules, and Procedures.**

6.4.3 However, given that it is considered either 'unlikely' or 'very unlikely' that any of the accident scenarios considered might actually occur, additional quantitative assessment of the potential events is not considered necessary at this time.

## 6.5 Leachate Leakage

6.5.1 On the assumption that, irrespective of how well they are engineered, all landfills will leak (to some extent), the guidance published on the requirements for an HRA states that it must "*establish whether the predicted discharge from the landfill complies with the requirements of the Groundwater Regulations... for each of the considered scenarios... and must include (assessment of) both List I and List II Substances*".

6.5.2 This Section of the assessment considers whether the predicted discharge from the Site complies with the requirements of the Groundwater Regulations 1998

6.5.3 With regard to the use of LandSim 2.5.14 and, in particular, the consequential variation of leachate levels and landfill leakage in the longer-term, the predictions of the simulation for the whole Site are as shown in **Table 14**, below.

***General Comments***

6.1.8 A full presentation of these – and all other - input parameters, and their derivation and/or justification, is contained in tabular form in **Appendix B**.

## 6.2 Sensitivity Analysis

6.2.1 In accordance with the guidance on the Use of the Management Control Feature in LandSim 2.5, issued by the Environment Agency in March 2004, the multi-phase LandSim model developed in connection with this HRA (see **Appendix C**), has been run in a number of simulations to investigate the sensitivity of the results to variation of this parameter. These simulations, for which *all* the setup *and* results files are contained on the CD-ROM in **Appendix D**, are as identified in **Section 5.3**, above.

6.2.2 Apart from this, LandSim is a probabilistic model that deals with parametric uncertainty by using probability density functions (PDFs) to define ranges of possible input values for each parameter required. This, combined with the selection of randomly-chosen parameter values over a large number of realisations, then gives rise to a large range of outcomes, which enable results to be quoted in terms of their probability of occurrence. It is therefore not considered necessary to conduct any other formal analysis of sensitivity to uncertainty or variation in any modelled parameters.

## 6.3 Model Validation

6.3.1 Groundwater and Surface Water monitoring data collected to-date, including regular sampling and analysis of background water quality within the underlying Coal Measures groundwater quality, has not yielded any evidence of significant adverse environmental effects that can be attributed to the presence of the Site.

6.3.2 However, given that the licence for this Site has not yet been surrendered, this conclusion is of course open to revision in the light of ongoing monitoring, and the Environment Agency will be advised of any such changes.

## 6.4 Accidents and their Consequences

6.4.1 In this context, accidents are considered to be unintentional incidents that might reasonably be anticipated to occur, but which are unforeseeable in terms of the timing of their occurrence. However, the process of evaluating environmental risks must include the consideration of the likelihood of such accidents as well as the resulting harm. It is therefore considered most appropriate to assess the consequences of accidents by qualitative means in the form of a risk matrix, as presented in **Table 13**, below.

6.4.2 This assessment indicates that:

- It has been determined to be either "fairly probable" or "probable" that any potential accident (scenario considered) would result in the Site's non-compliance with the requirements of the Groundwater Regulations 1998, owing to resultant potential increases in discharges of List I and List II substances into the environment.
- The prevention of accidents occurring is therefore a key part of the ongoing management strategy for the Site. Consequently, there is an emphasis on ensuring that robust and workable procedures and action plans are in place to prevent such occurrences.

**Table 14: Comparison of 95th Percentile Predicted Leachate Leakage Rates ($m^3$/day)**

| Head of Leachate | Duration of Management Control Period | Time to Surface Water Breakout (Years) | Once Maximum Head (Breakout Level) Reached | |
|---|---|---|---|---|
| | | | Initial[1] | Final[2] |
| 1 | 20 | 311 | 68.07 | 396.1 |
| | 30 | 312 | 68.06 | 396.0 |
| | 60 | 312 | 69.60 | 395.1 |
| | 150 | 312 | 68.46 | 393.8 |
| | 400 | 420 | 134.9 | 405.7 |
| | 20,000 | N/A | 384.15 | |

Notes:
1. Initial value is earliest point after cessation of management control (variable).
2. Final value is post-degradation of all engineered containment systems (> 1000 years).
3. Maximum head possible assumed to be 5m i.e. the height of the inert bund

6.5.4 In LandSim 2.5.14, these predictions generally relate to the fact that, following the cessation of management control; it will take approximately 300 years for leachate breakout to occur (when modelled Leachate heads equate to the elevation of the lowest point on the perimeter of the Inert Bund, assumed to be 5m, along the northern and eastern sides of the landfill). However, in the 20,000-year model, where the management control equals the model simulation period, leachate leakage at the end of the simulation is otherwise limited only by the natural balance between water ingress and egress through the engineered cap and basal liner respectively.

6.5.5 More than a five fold increases in leakage rates over the longer-term (from <70 $m^3$/day to approximately 400 $m^3$/day), have a significant effect upon the contaminant concentrations predicted, which are discussed in the following Sections of this report. However, these predictions also serve to demonstrate that the computations made by the software based on the parameters entered are indeed hydraulically consistent.

6.5.6 Notwithstanding the fact that there has been no indication to-date that the presence of the Site is having any significant adverse environmental impact, the probabilistic landfill liner performance (i.e. contaminant transport) modelling carried out as part of this HRA, does allow certain conclusions to be reached. The modelling data - and the inferences made from them - are set out below.

## 6.6 Emissions to Groundwater

### *List I Substances*

6.6.1 This HRA must demonstrate that the technical precautions will "*prevent substances in List I from entering groundwater*". Consequently, it must consider whether there is likely to be a discernible discharge of List I substances to groundwater.

6.6.2 Cadmium is the only List I substance routinely analysed and detected in groundwater. However, it is not detected in 70-80% of samples analysed (depending on location).

6.6.3 Of the List I substances for which analysis has been undertaken, cadmium is the only one for which positive results are routinely obtained. Therefore, notwithstanding an allowance for its presence in groundwater upgradient of the landfill at all levels within the UCM stratigraphy, this is the sole List I substance incorporated into the LandSim model.

6.6.4 **Table 15**, below, presents the resultant 95th Percentile predictions for maximum cadmium concentrations at the base of the unsaturated zone, immediately prior to entry to groundwater in the strata beneath the Site.

**Table 15: 95th Percentile Predicted Peak Concentrations of Cadmium (List I Substance) at Base of Unsaturated Zone**

| 95th Percentile Predicted Concentrations for List I Substances (mg/l) and Peak (Years) (unless negligible) | | | | | | | |
|---|---|---|---|---|---|---|---|
| List I Substance | MRV* (mg/l) | Duration of Management Control Period (Years) | | | | | |
| | | 20 | 30 | 60 | 150 | 400 | 20,000 |
| Cadmium | 1.0E-04 | 0.0108 (28) | 0.013 (35) | 0.013 (39) | 0.014 (63) | 0.016 (95) | 4.12E-04 (929) |

* Discernable Concentration in clean Groundwater

6.6.5 These results must be viewed in the context of the ambient concentrations of cadmium in groundwater both up- and downgradient of the landfill. Therefore, it is not relevant to compare the results against the MRV stated for clean groundwater in LFTGN01. Furthermore, since this Site has been - and shall continue to remain – regulated under 1994 Regulations it is not necessary to prove compliance with the 2002 Regulations.

6.6.6 Nevertheless, given the presence of cadmium upgradient of the landfill, in compliance with the Groundwater Regulations 1998, it can be demonstrated that the Site is not giving rise to discernable discharges of cadmium into groundwater.[6].

***List II Substances***

6.6.7 This HRA must demonstrate that the technical precautions will *"limit the introduction of List II substances into groundwater so as to avoid pollution"*. In order to achieve this, in relation to groundwater passing under the site and to the downgradient borehole **NG110**, which has been treated as the Compliance Point, the following factors are required to be considered:

- The presence of any such List II substances in groundwater considered to be hydraulically upgradient of the Site;
- The probable concentrations on leachate emerging from the base of the liner (engineered phases); and
- The potential for natural attenuation processes to reduce any resultant contaminant plume to below EALs before it reaches the Compliance Point.

6.6.8 With regard to the former, boreholes NG105, NG106, and NG107, monitoring the Upper Aquifer, have been taken as monitoring background groundwater quality upgradient of the site. With regard to the latter two points, these have been addressed through the LandSim modelling that has been undertaken and the results of which, in so far as they relate to List II substances, are presented in **Table 15** below.

6.6.9 No polluting discharge is predicted for ammonia, copper, and lead in any of the MCP scenarios, above that concentration currently experienced in background groundwater quality. A slight discharge of zinc, above background concentrations, is predicted for the 400-year MCPs, with no discharge predicted in the remaining scenarios. Slight discharges of chloride, chromium, and nickel are predicted for all MCPs, although these concentrations are all below the given EAL for each determinand.

6.6.10 Taking into account the above, none of these predicted concentrations should cause pollution of groundwater.

[6] The other anomalous List I substances detected in groundwater downgradient of the landfill, but not detected in leachate, are discussed within the updated environmental monitoring summary in **Appendix B**

**Table 16: 95th Percentile Predicted Peak Concentrations of Non-List I Substances**

| **95th Percentile Predicted Peak Concentrations for Non-List I Substances at the Base of the Unsaturated Zone** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Substance** | **Source Term Concentration (mg/l)** | **Duration of Management Control Period (Years)** | | | | | |
| | | **20** | **30** | **60** | **150** | **400** | **20,000** |
| Ammonia | LOGTRIANGULAR (23,245,730) | 242.5 (28) | 198.6 (6) | 193.1 (6) | 192.1 (6) | 185.5 (6) | 335.4 (116) |
| Chloride | LOGTRIANGULAR (20,648,1030) | 302.8 (5) | 302.7 (5) | 292.1 (5) | 293.1 (5) | 296.3 (5) | 365.2 (7) |
| Chromium | LOGTRIANGULAR (0.009,0.03,0.26) | 0.2 (28) | 0.193 (32) | 0.164 (28) | 0.179 (28) | 0.138 (28) | 0.026 (377) |
| Copper | LOGTRIANGULAR (0.008,0.02,0.09) | 5.9E-04 (1379) | 5.9E-04 (1381) | 3.3E-04 (1381) | 1.7E-04 (1849) | 8.6E-04 (380) | 1.9E-06 (20,000) |
| Lead | LOGTRIANGULAR (0.007,0.03,0.07) | 2.2E-05 (2048) | 2.1E-05 (2041) | 3.4E-06 (2264) | 1.4E-05 (1534) | 2.1E-04 (1855) | 5.4E-09 (20,000) |
| Nickel | LOGTRIANGULAR (0.02,0.05,0.1) | 0.2 (28) | 0.187 (32) | 0.179 (28) | 0.169 (28) | 0.136 (53) | 0.0238 (379) |
| Zinc | LOGTRIANGULAR (0.06,0.26,1.25) | 0.254 (232) | 0.256 (231) | 0.334 (116) | 0.834 (210) | 0.626 (210) | 0.00232 (2282) |
| **95th Percentile Predicted Peak Concentrations for Non-List I Substances at the Off-site Compliance Point** | | | | | | | |
| **Substance** | **Chosen EAL** | **Duration of Management Control Period (Years)** | | | | | |
| | | **20** | **30** | **60** | **150** | **400** | **20,000** |
| Ammonia | 2.2 | NPDP | NPDP | NPDP | NPDP | NPDP | NPDP |
| Chloride | 55 | 48.9 (6) | 48.9 (6) | 54.6 (7) | 59.2 (7) | 49.2 (7) | 50.4 (9) |
| Chromium | 0.09 | 0.0793 (12) | 0.079 (14) | 0.079 (14) | 0.079 (13) | 0.086 (679) | 0.089 (755) |
| Copper | 0.25 | NPDP | NPDP | NPDP | NPDP | NPDP | NPDP |
| Lead | 0.09 | NPDP | NPDP | NPDP | NPDP | NPDP | NPDP |
| Nickel | 0.24 | 0.125 (9) | 0.126 (9) | 0.127 (11) | 0.129 (565) | 0.136 (9) | 0.131 (924) |
| Zinc | 0.62 | NPDP | NPDP | NPDP | NPDP | 0.292 (1134) | NPDP |

All units are mg/l with Time in years in parentheses (where appropriate).
NPDP – No Polluting Discharge Predicted
EAL – This is the observed maximum value + 10%

6.6.11 The concentration of List II Substances at the base of the unsaturated zone has been presented in **Table 16** to show the concentration of the substance as it enters the underlying geological strata.

6.6.12 The predicted concentrations of both copper and lead are very low and well below their respective leachate source term concentrations, due to the fact that they are both highly retarded substances in the environment.

6.6.13 The predicted peak concentrations of ammonia, chloride, chromium, and zinc are all well below the maximum value stated within the leachate source term, with (apart from ammonia and chloride) a relatively high retardation value, meaning they should not present a significant risk to groundwater.

6.6.14 Predicted peak concentrations of nickel at the base of the unsaturated zone were above the maximum value associated with the leachate source term. However, this is still below the EAL assigned for a discharge to groundwater and therefore any emissions containing nickel should not present a risk to groundwater.

6.6.15 It is therefore considered that, with the benefit of all the previous work undertaken, this Site is capable of complying with the Groundwater Regulations, insofar as it should not cause discernable pollution of groundwater by List II substances.

### 6.7 Hydrogeological Completion Criteria

6.7.1 It is assumed that the conditions required for the likely acceptability of surrender of the Waste Management Licence for this Site would be satisfied only when the Site could be shown (by risk assessment based on all observational data up to that time) to no longer have the potential to cause damage to, or deterioration of, the environment and/or risk to human health.

6.7.2 With regard to potential impact on ground and surface water, this means that it will be necessary to then show, using all data available at the time, that the Site can comply with the requirements of the Groundwater Regulations 1998.

## 7.0 REQUISITE SURVEILLANCE

### 7.1 Monitoring Schedules

7.1.1 Regulation 15 (3) of the WML Regulations 1994 as amended states that:

*A waste management licence shall not be issued in any case within paragraph (1) above until the waste regulation authority has checked that the groundwater, and in particular its quality, will undergo the requisite surveillance.*

7.1.2 Therefore, in accordance with the conditions of the extant Waste Management Licence, ARL have undertaken environmental monitoring on in-situ landfill gas generation, flare stack emissions, ambient air quality; leachate levels and quality; groundwater levels and quality; and surface water quality.

7.1.3 The on- and off-site monitoring points are shown on the drawings included with the Phase 1 Report.

7.1.4 The Environmental Monitoring Schedule for the Nant-y-Gwyddon Site is as presented in **Table 17**, below.

### 7.2 Rationale

7.2.1 This schedule was drawn up - and approved by the Environment Agency - based on best practice at the time, taking account of site-specific conditions and the overall perception of the environmental sensitivity of the Site.

**Table 17: Revised (Updated) Environmental Monitoring Schedule**

| Media | Interval | Sampling Points | Determinands monitored |
|---|---|---|---|
| LANDFILL GAS | Monthly | Perimeter - GMBH01, 02, 03A, 03B, 04, 05, 06, 07, 08, NYG1, 2, 3, 4, 5, 6, 7, 8, 9, 10. | Carbon Dioxide, Methane, Oxygen, Carbon Monoxide, Hydrogen Sulphide, Pressure, Relative Pressure, Temperature. |
| | | Gas Field - GW1A, 3, 4, 10, 11, 26, 27, 32, 33, 35, 36, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, S, T, U, V, GWSI24, GWSI29, GWSI30, GWMH59, | Carbon Dioxide, Methane, Oxygen, Carbon Monoxide, Hydrogen Sulphide, Barometric Pressure, Temperature. |
| LEACHATE | Weekly | LMP1a, LMP1b, LMP6, LMP7, LMP8 | Level |
| | Monthly | L5, L5a, LPS1 | Alkalinity, Ammoniacal Nitrogen, BOD, COD, Chloride, Electrical Conductivity, Formaldehyde, pH, Suspended Solids, TOC. |
| | Quarterly | | Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Nickel, Potassium, Sodium, Zinc, Sulphide, Nitrite, Nitrate, TON, Phosphate, Phenols, 1,1,1,-Trichloroethane, 1,2,-Dichloroethane, Carbon Tetrachloride, Benzene, Trichloroethene, Toluene, Tetrachloroethene, Ethyl Benzene, M&P Xylene, O-Xylene, Styrene, Total Xylenes, Sulphate Waste, Chloride Waste. |
| GROUNDWATER | Monthly | GW94, GW96, GW97, NG101, NG104, NG105, NG106, NG107, NG108, NG109, NG110, NG111, NYG1, 2, 3, 4, 5, 6, 7, 8, 9, 10. | Level. Alkalinity, Ammoniacal Nitrogen, BOD, COD, Chloride, Electrical Conductivity, Formaldehyde, pH, Nitrite, Nitrate, Suspended Solids, TOC. |
| | Quarterly | | 1,1,1-Trichloroethane, 1,2-Dichloroethane, Benzene, Cadmium, Calcium, Carbon Tetrachloride, Chromium, Copper, Ethyl Benzene, Iron, Lead, Magnesium, M&P Xylene, Nickel, O-Xylene, Phenol, Phosphate, Potassium, Sodium, Styrene, Sulphate, Sulphide, Toluene, TON, Tetrachloroethene, Trichloroethene, Total Xylene, Zinc. |
| | Annually | | 2 Methyl prop-I-ol, Acetone, Acetonitrile, Acrylonitrile, Anionic Detergents, Arsenic, Butan-1-ol, Butan-2-ol, Dimethoxymethane, Ethanol, Ethyl acetate, Ethyl acrylate, Manganese, Mercury, Methanol, Methyl ethyl ketone, n-propanol, Propan-2-ol, TON. |
| SURFACE WATER | Monthly | SW1, SW2, SW3, SW4, SW5a, SW6, SW8. | Alkalinity, Ammoniacal Nitrogen, BOD, COD, Chloride, Electrical Conductivity, Dissolved Oxygen, Formaldehyde, pH, Suspended Solids, TOC. |
| | Quarterly | | 1,1,1-Trichloroethane, 1,2-Dichloroethane, Benzene, Cadmium, Calcium, Carbon Tetrachloride, Chromium, Copper, Ethyl Benzene, Iron, Lead, Magnesium, M&P Xylene, Nickel, Nitrate, Nitrite, O-Xylene, Phosphate, Potassium, Sodium, Styrene, Sulphate, Sulphide, Toluene, TON, Tetrachloroethene, Trichloroethene, Total Xylene, Zinc. |
| | Annually | | 2 Methyl prop-I-ol, Acetone, Acetonitrile, Acrylonitrile, Anionic Detergents, Arsenic, Butan-1-ol, Butan-2-ol, Dimethoxymethane, Ethanol, Ethyl acetate, Ethyl acrylate, Manganese, Mercury, Methanol, Methyl ethyl ketone, n-propanol, Propan-2-ol, TON. |

N.B.: SW5 was removed during October 2005 and is no longer available for sampling, monitoring ID SW5a is now used for the monitoring of the surface water lagoon created in the phase 2 area.

# 8.0 CONCLUSIONS AND RECOMMENDATIONS

## 8.1 General Conclusions

8.1.1 The overall site sensitivity of the Site has been assessed to be low on the grounds that:

- the Site is not located on a Major Aquifer;
- the Site is not located in a groundwater SPZ; and
- there are no downgradient licensed groundwater abstractions in the vicinity.

8.1.2 The only plausible pollutant (source – pathway – receptor) linkage is that relating to the potential for leachate reaching the water table beneath the site to be diluted in groundwater passing beneath the Site, which contributes to the flow of the Nant-y-Gwyddon stream, which then discharges into the Afon Rhondda Fawr.

8.1.3 In addition, it must be emphasised that there is between 10 and 30 metres of unsaturated material beneath the Site, which provides extensive scope for natural attenuation of leachate from the Site;

8.1.4 The results of the groundwater monitoring carried out at the Site to-date indicate that the groundwater around the Nant-y-Gwyddon Site is typical of the hydro-geochemistry of the Coal Measures, which have been affected by extensive underground mining of coal seams.

8.1.5 With regard to surface water quality monitoring in the vicinity of the Site, the key features of the data are considered to be as follows:

- The landfill site is situated at the head of the Nant-y-Gwyddon valley and as such it is difficult to comment on the impact the landfill is having on the surface water as there is no up and down gradient comparison.
- The surface water is of generally good quality (especially in the more distant surface water monitoring points), except for a few slightly elevated concentrations of List II metals, most probably due to the extensive history of coal mining in the area leading to a mine water signature in the surface water.
- SW5 and SW6 yielded more slightly elevated concentrations in the surface water, possibly due to it receiving surface water run off from the hard standing areas of the landfill site.

8.1.6 **Appendix D** to this Report contains all relevant environmental monitoring data relied upon and graphs produced (in electronic form on a CD-ROM).

## 8.2 Compliance with the Landfill (England and Wales) Regulations 2002

8.2.1 Notwithstanding the above, the results of this risk assessment have established that the Site poses a potential hazard to near-surface groundwater and/or surface water quality.

8.2.2 Consequently, arrangements have been made to collect the leachate and/or any contaminated surface water runoff that is generated by the Site.

8.2.3 Therefore, the Site complies with the requirements of the Waste Management Licensing Regulations 1994 and the 2002 Regulations.

## 8.3 Compliance with the Groundwater Regulations 1998

8.3.1 The results of this risk assessment have established the following:

- the Site poses a potential hazard to ground and surface water quality; and
- it therefore falls within the scope of the Groundwater Regulations 1998.

8.3.2 However, this risk assessment has demonstrated that, with the completion of the capping of the site, all practical steps have now been taken to limit the potential for the Site to have and adverse impact on the surrounding environment.

8.3.3 This assessment therefore constitutes the *'prior investigation'* that must be carried out prior to any consideration being given to the transfer of the Site, under the 1994 Regulations, to post-closure status.

***Potential Discharges of List I Substances***

8.3.4 In accordance with the findings of this risk assessment, it has been determined that the combination of the engineered containment in place and the natural attenuation capacity (and thickness) of the unsaturated zone beneath the landfill, is sufficient to prevent any discharges of List I substances from reaching groundwater.

8.3.5 Setting aside the potential consequences of unremedied accident or emergencies, which have been adequately dealt with in **Section 5.5**, above, this conclusion has been reached as a result of having taken into consideration the following:

- Given the provisions of the leachate monitoring and management procedures, allied with action plans and emergency action plans, the only way in which leachate could escape from the Site prior to the end of the Management Control Period, would be as a consequence of a catastrophic failure of the leachate management systems.
- However, it is anticipated that permanent cessation of leachate management control will only be allowed when a future risk assessment, based on all operational data then available, demonstrates that the (by then degraded and diluted) leachate present within the Site no longer represented an environmental hazard.

8.3.6 Therefore, with regard to the prevention of discernable discharges of List I substances, it is concluded that the design and operational performance of the Site complies with the requirements of the Groundwater Regulations 1998.

***Potential Pollution by List II Substances***

8.3.7 Based on all of the investigative work carried out to-date, there is no evidence – either from observational data – or groundwater modelling predictions – to suggest that groundwater passing beneath the Site is being impacted by leachate migration from the Site. On the contrary, there is clear evidence to show that the groundwater quality is poor and that the dilution rates involved make such impacts insignificant and/or probably undetectable.

8.3.8 Therefore, with regard to the avoidance of pollution of the environment with List II substances, it is concluded that the operational performance of the Site complies with the requirements of the 2002 Regulations.

## 9.0 REFERENCES

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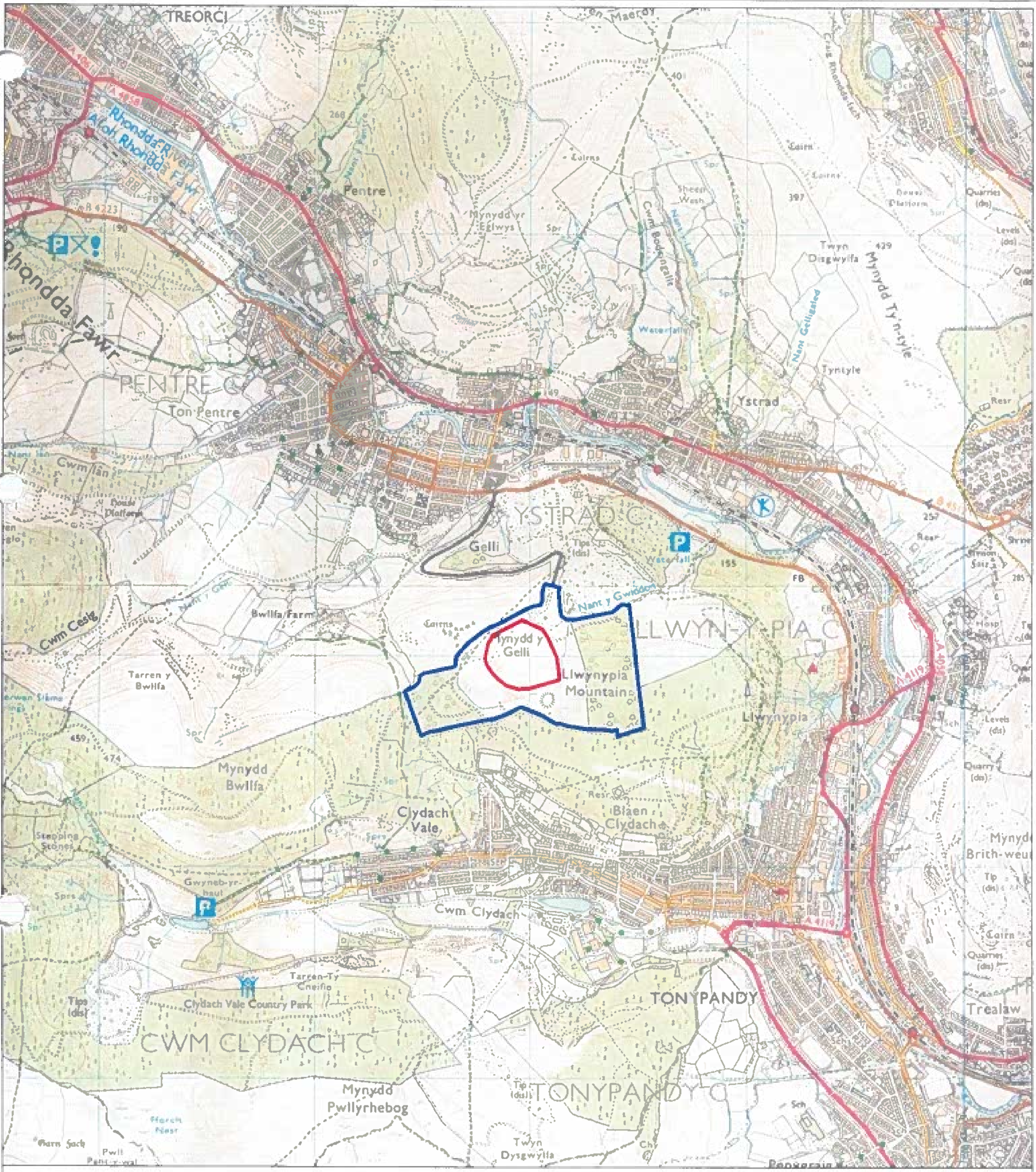
TERRADAT, "*Resistivity Tomography to Characterise Landfill Internal Structure*", March 2004.

Drawings






KEY

LIMIT OF WASTE DISPOSAL

WML BOUNDARY

ENCIA

ENCIA CONSULTING LIMITED
ENCIA HOUSE, AUDBY LANE
WETHERBY, WEST YORKSHIRE
TEL: - 01937 589955
FAX: - 01937 544760

JOB TITLE

Hydrogeological

NANT-Y-GWYDDON LANDFILL SITE
HYDROLOGICAL RISK ASSESSMENT

| REV. | DESCRIPTION | DATE |
|---|---|---|

AMGEN Rhondda

AMGEN RHONDDA
NANT-Y-GWYDDON LANDFILL SITE
NANT-Y-GWYDDON ROAD
GELLI
MID-GLAMORGAN
CF41 7TL

DRAWING TITLE

SITE LOCATION PLAN

| DRAWN | SIGNATURE | DATE | STATUS |
|---|---|---|---|
| S.T | | 1/2/06 | FOR COMMENT ☐ FOR APPROVAL ☐ |
| APPROVED | SIGNATURE | DATE | |
| L.F. | | 25/06/07 | DRAFT ☐ FINAL ☑ |

| SCALE | SHEET | DRAWING NO. |
|---|---|---|
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