NANTYCAWS LANDFILL
PPC APPLICATION

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HABITATS RISK ASSESSMENT

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1.0 INTRODUCTION

1.1 Background

CWM Environmental Limited has retained SLR Consulting Limited (SLR) to prepare a PPC Permit Application in support of the further development of Nantycaws Landfill site, near Carmarthen.

This report provides additional information to support the PPC permit application in respect to potential risks to Habitats Sites. Habitats Sites are those that have been identified as being of importance to habitats or species that are rare or important in the European context. They are designated under the provisions set out by The Conservation (Natural Habitats &c.) Regulations 1994, known as "the Habitats Regulations". Those sites that are identified for the ornithological interest are known as Special Protection Areas (SPAs) and those designated for other fauna, flora and habitats as Special Areas of Conservation (SAC). Where such sites have been put forward for approval, but have not yet been fully designated, they are prefixed by a 'c' to show their 'candidate' status.

Ramsar sites are designated under the International Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention). Although the Ramsar designation does not in itself imply any statutory protection, for the purposes of this assessment the interest features of a Ramsar site are given the same status as other Habitats Sites, i.e. cSAC and SPA.

1.1.1 The Habitat Regulations

Regulation 50 of the Habitat Regulations states that competent authorities should, where consent has already been given for an activity to which Regulation 48 would normally apply, as soon as reasonably practicable review their decision, or consent, and shall affirm, modify or revoke it.

Regulation 48 of the Habitat Regulations states that:

"A competent authority, before deciding to undertake, or give any consent, permission or other authorisation for, a plan or project which -

a) is likely to have a significant effect upon a European site in Great Britain (either alone or in combination with other projects), and

b) is not directly connected with or necessary to the management of the site,

shall make an appropriate assessment of the implications for the site in view of that site's objectives."

In this instance it is the Environment Agency (EA) that is the competent Authority and the PPC application is seen as the opportunity to undertake a Regulation 50 review.

Regulation 48 also states that:

"A person applying for any such consent, permission or other authorisation shall provide such information as the competent authority may reasonably require for the purposes of the assessment".

This document provides detailed information on the proposal, the nearby Habitats Sites, and assesses the likelihood of there being significant effect upon the interest features of the Habitats Site as a result of the operations of the existing Nantycaws Landfill.

1.2 Assessment Aim

This report assesses the potential hazards identified to establish whether or not landfill operations associated with Nantycaws Landfill would affect the 'integrity' of the nearby Habitats Site. The integrity being defined as:

'the coherence of its ecological structure and function, across the whole area, that enables it to sustain the habitat, complex of habitats and/or the levels of populations of the species for which it is classified'.[1]

1.3 Approach

The assessment has been undertaken as a 4 stage approach, recommended by EA Guidance[2]. Each stage of the assessment is summarized in Table HABRA1 below. If, following Stage 2, the Coarse Risk Assessment, it becomes apparent that there are no pathways between the installation site and the habitats sites Stage 3 of the approach detailed below shall not be undertaken.

TABLE HABRA1 – THE STAGED APPROACH TO ASSESSMENT[2]

Stage 1	**General screening criteria.** Do any Habitats Sites fall within the zone of influence of the landfill site, i.e. within 2 km of an SPA, cSAC, or Ramsar or within 5km of an SPA where the activity has the potential to attract gulls or corvidae, or some other relevant hazard?
Stage 2	**Coarse risk assessment.** Identify the scope and pathways of potential hazards for each Habitat Site receptor identified.
Stage 3	**More detailed assessment of risk.** Consider the threats identified in combination and alone and examine potential to prevent or minimise an impact. This includes a risk rating assessment of the probability of an adverse effect occurring and the potential consequences upon the identified features of interest.
Stage 4	**Determination.** Conclusion on the significance of adverse effects upon the integrity of the Habitats Site.

1.3.1 Data Sources

To aid this process a number of sources of data and reference materials have been available for examination, these include:

[1] PPG 9 box C10

[2] Environment Agency (2003) Further Guidance applying the Habitats Regulations to Waste Management Facilities. (Version 52-02).

- Habitats Regulations Guidance Notes No.1-4 produced by English Nature in 1997 (these are also relevant in Wales as they refer to the Habitat Regulations which cover England, Wales and Scotland);
- Countryside Council for Wales citation documents for Afon Tywi/River Tywi cSAC associated SSSIs;
- cSAC citation documents for Afon Tywi/River Tywi cSAC;
- Information relating population size and distribution and autecology of Birds Directive Annex I species. JNCC website; and
- Nantycaws Landfill PPC Application – Environmental Setting and Installation Design (ESID) report. (SLR/4B-610-002/ESID) May 2004.

2.0 ASSESSMENT SCREENING

2.1 Stage 1: Identification of Habitats Sites

The first part of this assessment is to identify those Habitats Sites that are potentially affected by the landfill site.

Under Landfill Directive Regulatory Guidance Note 5[3] the Environment Agency (EA) sets out the rationale behind the requirements for further and more detailed assessments of risks upon Habitats Sites when they are located within 5km of the application site.

The EA has in this instance identified such Habitats Sites:

- The Afon Tywi/River Tywi cSAC, 3 km to the north-north-west; and
- The Bae Caerfyrddin ac Aberoedd/Carmarthen Bay and Estuaries cSAC, 14 km to the south-west.

Though the latter site is outside the usual 5km area of consideration it has been identified for further assessment in this instance as the installation is within the catchment area for this estuary.

2.2 Description of Habitats Sites and Interest Features Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC

2.2.1 Baseline Description

The Afon Tywi cSAC is a 363.45 hectare and is an actively eroding river across a floodplain of alluvium, glacial sands and gravels which extends from Llandovery to the confluence with the Afon Tâf and Pembrey Coast SSSI in Carmarthen Bay. It is designated for its species of international importance (Annex II species). Twaite shad (*Alosa fallax*) and otter (*Lutra lutra*) are the primary reason for the site selection, however the following additional Annex II fish species are qualifying features: sea lamprey (*Petromyzon marinus*), brook lamprey (*Lampetra planeri*), river lamprey (*Lampetra fluviatillis*), Allis shad (*Alosa alosa*) and bullhead (*Cottus gobio*).

Carmarthen Bay & Estuaries cSAC covers approximately 66,100 hectares and includes a variety of habitat types including sandbanks, estuaries, mudflats, sandflats, *Salicornia* saltmarsh and salt meadow. It is designated for its Annex I habitats (Sandbanks which are slightly covered by seawater all the time, estuaries, mudflats and sandflats not covered by seawater at low tide, large shallow inlets and bays, *Salicornia* and other annuals colonising mud and sand, and Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)) and for its Annex II species of international importance (Twaite shad). The following Annex II species are qualifying features although not the primary reason for the site selection: sea lamprey, river lamprey, Allis shad and otter.

[3] Landfill Directive, Regulatory Guidance Note 5 – Habitats Regulations & The Landfill Directive, Information and Guidance for Landfill Operators (version 1.1, December 2001). Environment Agency.

For the purpose of this baseline description, all habitats and interest features occurring within the cSAC boundaries are considered. However, the assessment will only consider those features identified as reasons for International designation.

2.3 Stage 2: Scope of potential hazards

This section provides outline detail of the application site to provide a context to the screening. This is then followed by the screening of all those potential risks from the site identified by the Environment Agency in the Risks Matrix. The screening exercise utilises information collected on the habitats sites and reports prepared on the installation site (ESID[4], HRA[5], NHRA[6], GRA[7]).

2.3.1 The Application Site

Nantycaws Landfill (Centred NGR SN 470 173) is located to the south of Nantycaws, approximately 6km north-north-west of Carmarthen, Wales. For details of current and future waste types accepted at the landfill and site layout see the ESID[4].

2.3.2 Coarse Screening Exercise

The Afon Tywi cSAC and the Carmarthen Bay & Estuaries cSAC are outside the 2km buffer zone of influence for the landfill site, as recommended by EA guidance. However, it was felt necessary by the Environment Agency to identify any particularly vulnerabilities through the scoping assessment.

All potential risks from the landfill were considered for potential significant effect on Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC. A preliminary assessment of the potential hazards has been developed in conjunction with the EA in the form of a Risks Matrix. This matrix identifies the main concerns that result from the proximity of this landfill site to the nearby Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC. The Risks Matrices for these sites are located in Appendix 1 of this report.

Further to this initial assessment, the range of potential impacts identified by the EA has been compared against thresholds which identify the need for further assessment. These thresholds identify pathways from Nantycaws landfill to potential receptors, i.e. Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC, and are based upon EA guidance (see Appendix 2). Where, through the absence of a clear pathway or through attenuation of potential impact through increasing distance, a hazard is shown to represent a negligible or inconsequential risk to potential receptor sites (Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC)

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[4] Nantycaws Landfill, Environmental Setting and Installation Design Report, SLR Consulting Ltd. May 2004. (Ref: SLR/4B/610/002/ESID)

[5] Nantycaws Landfill: PPC Application, Section B-Hydrogeological Risk Assessment. SLR Consulting Ltd, May 2004, (Ref: SLR/4B/610/002/HRA)

[6] Nantycaws Landfill: PPC Application, Nuisance and Health Risk Assessment SLR Consulting Ltd. May 2004. (Ref: SLR/4B/610/002/NHRA)

[7] Nantycaws Landfill: PPC Application, Section C-Landfill Gas Risk Assessment, SLR Consulting Ltd, May 2004 (Ref: SLR/4B/610/002/GRA)

then no further detailed risk assessment is considered necessary. This scoping risk assessment is shown in Table HABRA2.

HABRA2: SCOPING OF POTENTIAL RISKS TO AFON TYWI cSAC AND CARMARTHEN BAY & ESTUARIES cSAC ARISING FROM NANTYCAWS LANDFILL

Hazard	Emissions or activities associated with waste facility	Factors affecting the need for a detailed (Stage 3) risk assessment (See Appendix 2); refer to SLR/610/002/ESID.	Afon Tywi cSAC Stage 3 assessment required?	Carmarthen Bay & Estuaries cSAC Stage 3 assessment required?
Toxic Contamination	Toxic leachate	Though Afon Tywi cSAC is not, Carmarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill.	No	Yes
	Landfill gas	Afon Tywi and Carmarthen Bay & Estuaries cSACs are more than 0.5km away from Nantycaws Landfill.	No	No
	Landfill gas flare emissions	Afon Tywi and Carmarthen Bay & Estuaries cSACs are more than 1km away from Nantycaws Landfill.	No	No
	Surface waters	Though Afon Tywi cSAC is not, Camarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill but is not within 500m downstream.	No	No
	Contaminated dusts	Afon Tywi and Carmarthen Bay & Estuaries cSACs are more than 1km of Nantycaws Landfill in the prevailing wind direction.	No	No
Nutrient Enrichment	Nutrient rich leachate	Afon Tywi is not hydrologically linked to Nantycaws Landfill. Carmarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill.	No	Yes
	Surface water	Afon Tywi is not hydrologically linked to Nantycaws Landfill. Carmarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill but is not within 500m downstream.	No	No
	Dust	Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC are not within 1km of Nantycaws Landfill in the prevailing wind direction.	No	No
Habitat loss	Surface water	Afon Tywi is not hydrologically linked to Nantycaws Landfill. Carmarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill but is not within 500m downstream.	No	No
	Access/ Land encroachment	Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC are not adjacent to Nantycaws Landfill.	No	No
Siltation	Surface water	Afon Tywi is not hydrologically linked to Nantycaws Landfill. Carmarthen Bay & Estuaries cSAC is hydrologically linked to the Landfill but is not within 500m downstream.	No	No
Smothering	Dust	Afon Tywi and Carmarthen Bay & Estuaries cSACs are not within 1km of Nantycaws Landfill in the prevailing wind direction.	No	No
	Litter	Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC are not adjacent to Nantycaws Landfill.	No	No
Disturbance	Noise/Vibration	Afon Tywi and Carmarthen Bay & Estuaries cSACs are not within 1km of Nantycaws Landfil.	No	No
	Physical Access	Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC are not adjacent to Nantycaws Landfill.	No	No
	Pest species (gulls)	Only Afon Tywi cSAC is within 5km of Nantycaws Landfill but is not designated for its avifauna.	No	No

Predation/ Displacement	Rodents	Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC are more than 500m from Nantycaws Landfill and are not designated for their raptor interest.	No	No
	Gulls/Corvids	Only Afon Tywi cSAC is within 5km of Nantycaws Landfill but is not designated for its avifauna.	No	No

Following the further scoping (HABRA2) of those potential risks identified by the EA in their Risks Matrices for the Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC there are no issues to consider further for Afon Tywi, but the following issues are still considered to be potential hazards for Carmarthen Bay & Estuaries cSAC which therefore require further assessment and evaluation to comply with Regulation 50:

Carmarthen Bay & Estuaries cSAC

- Toxic contamination (toxic leachate); and
- Nutrient Enrichment (nutrient rich leachate).

It is however considered that the two potential risks identified (toxic leachate and nutrient rich leachate) do not pose a threat to the interest features of Carmarthen Bay & Estuaries cSAC, given the fact there is at least a 14km buffer between them. This would mean that any potential leachate escape would be greatly diluted by the time it reaches the cSAC.

3.0 CONCLUSIONS

CWM Environmental Limited has retained SLR to prepare a PPC Permit Application in support of the development of Nantycaws Landfill site, near Carmarthen, Wales.

Under Landfill Directive Regulatory Guidance Note 5 the EA sets out the rationale behind the requirements for further and more detailed assessments of risks upon Habitat sites when they are located within 5km of the application site. The EA has, in this instance, identified two such international designations:

- Afon Tywi/River Tywi cSAC; and
- Bae Caerfyrddin ac Aberoedd/Carmarthen Bay and Estuaries cSAC.

The Afon Tywi cSAC is a 363.45 hectare site which is a actively eroding river. It is designated for its species of international importance (Annex II species). At its nearest point it is 3km from Nantycaws Landfill.

Carmarthen Bay & Estuaries cSAC covers approximately 66,100 hectares and includes a variety of habitat types. It is designated for its Annex I habitats and for its Annex II species of international importance. At its nearest point it is 14km from Nantycaws Landfill.

A scoping assessment of the likely impact of the landfill site upon Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC has been undertaken using the following information:

- A Risks Matrix, a preliminary (Stage 2) assessment of the risks undertaken by the EA;
- Information on the design and control measures in place at the application site (ESID Report and Site Management Statement).

Though no development is completely free of impact, the magnitude and significance of this must be carefully considered as to whether or not it will significantly impact upon the attributes that define Favourable Conservation status within the Habitats Site assessed.

Assessment of the relative vulnerability of ecological receptors of international significance within Afon Tywi cSAC and Carmarthen Bay & Estuaries cSAC to the hazards identified by the EA Risks Matrix has shown that there are still some potential hazards which require further assessment and evaluation. It is, however considered that given the stand-off of 14km (downstream), to Carmarthen Bay & Estuaries cSAC Nantycaws Landfill does not pose a significant hazard to interest features of the cSAC.

HABRA APPENDIX 1

Name of European Site: Carmarthen Bay & Estuaries

Priority Status: Medium

	Risk	Toxic Contamination				Nutrient Enrichment				Habitat Loss				Siltation		Smothering			Disturbance			Predation/Displacement		
	Landfill associated Hazards	Toxic leachate	Landfill gas	Toxic wastes	Contaminated dusts	Nutrient rich leachate		Nutrient rich wastes		Monitoring boreholes, etc	Landfill gas	Explosive wastes	Land encroachment	Suspended solids	Mud	Dust from wastes	Dust from periphery	Dust/particles from vehicles	Noise/Vibration	Human presence	Visual	Rodents	Gulls/Corvidaes	Other birds attraced to site
	Landfill associated Pathways	Escape to groundwater/Escape to surface water/Discharge point	Leak to atmosphere/Escape through fissure	Offsite spillage/Escape to unlined area	Carried on vehicles off site/Aerial transmission	Discharge to groundwater	Discharge to surface water	Collection and discharge to surface waters	Run off from site surface to surface water	Construction and maintainence	Escape to atmosphere/Escape to landwater outside site	Explosion causing distribution of products to atmosphere	Physical take-up of habitat or buffer zone	Discharge to surface waters	Run off from surfaces/Run off from roads	Airborne from waste discharge area	Vehicular disturbance	Vehicles outside boundary	Through atmosphere to outside of site	People in or around landfill	Removal or change of visual signs on landfill site	Live in surrounding area. Attracted to site by biodegradable wastes. Move into surrounding area	Live in surrounding area. Attracted to site by biodegradable wastes. Move into surrounding area	Live in surrounding area. Attraced to site by biodegradable wastes. Move into surrounding area
SAC/Ramsar habitat groups																								
1.12	Estuarine and intertidal habitats	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#						
1.13	Submerged marine habitats	#		#	#	#	#	#	#					#	#									
SAC/Ramsar species groups																								
2.5	Anadromous fish	#		#	#									#	#									
2.9	Mammals of riverine habitats	#		#	#								#						#	#				
SPA/Ramsar bird species groups																								

Hazard
↳ Non-hazardous
↳ "

Q.

Name of European Site: River Tywi

Priority Status: High

Risk	Toxic Contamination				Nutrient Enrichment				Habitat Loss				Siltation		Smothering			Disturbance			Predation/Displacement		
Landfill associated Hazards	Toxic leachate	Landfill gas	Toxic wastes	Contaminated dusts	Nutrient rich leachate		Nutrient rich wastes		Monitoring boreholes, etc	Landfill gas	Explosive wastes	Land encroachment	Suspended solids	Mud	Dust from wastes	Dust from periphery	Dust/particles from vehicles	Noise/vibration	Human presence	Visual	Rodents	Gulls/Corvidae	Other birds attracted to site
Landfill associated Pathways	Escape to groundwater/Escape to surface water/Discharge point	Leak to atmosphere/Escape through fissure	Offsite spillage/Escape to unlined area	Carried on vehicles off site/Aerial transmission	Discharge to groundwater	Discharge to surface water	Collection and discharge to surface waters	Run off from site surface to surface water	Construction and maintenance	Escape to atmosphere/Escape to land/water outside site	Explosion causing distribution of products to atmosphere	Physical take-up of habitat or buffer zone	Discharge to surface waters	Run off from surfaces/Run off from roads	Airborne from waste discharge area	Vehicular disturbance	Vehicles outside boundary	Through atmosphere to outside of site	People in or around landfill	Removal or change of visual signs on landfill site	Live in surrounding area. Attracted to site by biodegradeable wastes. Move into surrounding area	Live in surrounding area. Attracted to site by biodegradeable wastes. Move into surrounding area	Live in surrounding area. Attracted to site by biodegradeable wastes. Move into surrounding area
SAC/Ramsar habitat groups																							
SAC/Ramsar species groups																							
2.5 Anadromous fish	#		#	#									#	#									
2.6 Non migratory fish and invertebrates of rivers	#		#	#									#	#									
2.9 Mammals of riverine habitats	#		#	#								#						#	#				
SPA/Ramsar bird species groups																							

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Ein cyf/Our ref:SV

Dr Andrea Wilcockson
Ecologist
SLR Consulting Ltd
Wheeley Ridge
Wheeley Road
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Worcestershire
B48 7DD

5 January 2004

Dear Dr Wilcockson

SO 082 207 near Mythyr Tydfil and SN 465 171 near Carmarthen

Thank you for your recent enquiry regarding sites within a 5km radius of the above grid references.

I have enclosed the documents requested for the SAC and SSSI sites which have been found to fall within these areas, please see the list over leaf. No SPA or Ramsar sites were found at this location.

If you should require any further information about these sites please contact our area offices at Cardiff or Aberystwyth.

Plas Gogerddan	Unit 7
Aberystwyth	Castleton Court
Ceredigion	Fortran Road
SY23 3EE	St Mellons
	Cardiff
	CF3 OLT
Tel: 01970 821100	02920 772400

As discussed before Christmas we do not hold Favourable Condition Tables.

Any enquiries about Scheduled and Ancient Monuments should be made to CADW and your first point of contact will be Karen Winn, Records Inspectorate on telephone number 02920 826172.

I trust that this information is sufficient for your needs.

Yours sincerely

S. Vaughan.

Sandra Vaughan
International Designations Team

Enc
SO 082 207
River Usk/Afon Wysg Reasons for recommendation and SAC map
Brecon Beacons/Brannau Bryceiniog Reason for recommendation and SAC map
Brecon Beacons SSSI citation and map
Talybont Reservoir SSSI citation and map
River Usk (Upper Usk) SSSI/Afon Wysg (Afon Wysg Uchaf) SddGA citation and map

SN465 171
Waun-Fawr SSSI citation and map 3.5km SSE wet pasture.
Mynydd Llangynderyn SSSI citation and map 3.5km SSE grassland.
Coedydd y Garn SSSI citation and map 4km SE. woodland.
Ynys Uchaf SSSI citation and map 2.5km SE flood plain mire
Gweunydd a Choed Pen-Ty (Pen-Ty Pastures and Wood) SSSI citation and map 0.5km W wetland grassland / wet semi-nat woodland
Allt Penycoed Stream Section SSSI citation and map ≙ 2.4km NW. Geological / + Stream.
Cwm yr Abbey Stream Section SSSI citation and map (Geo) 3.5km. NE
Afon Twyi citation and maps 1 – 16 3km NNW → River!
Bishops Pond SSSI citation and map – too far oxbow lake part of R. Tywi 4.2km. NW

Gofalu am natur Cymru - ar y tir ac yn y môr
Caring for our natural heritage - on land and in the sea

Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd

Site details

Country	Wales
Unitary Authority	Abertawe/ Swansea; Caerfyrddin/ Carmarthenshire; Penfro/ Pembrokeshire
Grid Ref*	SS357991
Latitude	51 40 00 N
Longitude	04 22 35 W
SAC EU code	UK0020020
Area (ha)	66101.16

* This is the approximate central point of the SAC. In the case of large, linear or composite sites, this may not represent the location where a feature occurs within the SAC.

General site character

Marine areas. Sea inlets (82.1%)
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins) (13.7%)
Salt marshes. Salt pastures. Salt steppes (4.1%)
Shingle. Sea cliffs. Islets (0.1%)

Boundary map and associated biodiversity information on the NBN Gateway.
Natura 2000 data form for this site as submitted to Europe (PDF *format, size 30kb*).

Location of Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd SAC

Annex I habitats that are a primary reason for selection of this site

1110 *Sandbanks which are slightly covered by sea water all the time*

Carmarthen Bay and Estuaries on the south coast of Wales includes the sandbank of Helwick Bank, a linear shallow subtidal sandbank that is unusual in being highly exposed to wave and tidal action. The animal communities found in and on the bank reflect these conditions, being tolerant of high levels of disturbance. Within Carmarthen Bay there are also several other smaller sandbanks in relatively shallow waters, which support a range of species (including bivalves, amphipods and worms), many of which spend most of their time wholly or partly buried in the sediment.

1130 Estuaries

Carmarthen Bay and Estuaries provides an example of a large estuarine site on the south coast of Wales, encompassing the **estuaries** of the Rivers Loughor, Tâf and Tywi (coastal plain estuaries) and the Gwendraeth (a bar-built estuary). These four estuaries form a single functional unit around the Burry Inlet, with important interchanges of sediment and biota. The estuaries of this site support a range of subtidal and intertidal sediments that grade from sand at the mouth to mudflats in the upper estuary. The fauna of the sediments varies, but includes communities with polychaete and oligochaete worms and areas with extensive cockle beds and other bivalve molluscs. This site has a range of undisturbed transitions to coastal habitats.

1140 Mudflats and sandflats not covered by seawater at low tide

Carmarthen Bay and Estuaries on the south coast of Wales includes extensive areas of intertidal **mudflats and sandflats**. Large areas of these intertidal flats are dominated by bivalves. In areas of fine sand cockles *Cerastoderma edule* are abundant, along with other bivalves, amphipods and worms. In muddier sediments the sand-gaper *Mya arenaria*, peppery furrow-shell *Scrobicularia plana* and mud-snail *Hydrobia ulvae* are also found in large numbers. The lower Loughor Estuary is one of the few places in the UK where the worm *Ophelia bicornis* has been found. There are also beds of the nationally scarce dwarf eelgrass *Zostera noltei*.

1160 Large shallow inlets and bays

Carmarthen Bay, off the south Wales coast is an extensive shallow bay. Throughout the bay physical conditions vary considerably. Salinity varies from low (at the estuaries) to fully marine, there are gradients in wave action from sheltered to exposed, and strong tides sweep exposed headlands whilst other areas are sheltered from currents. There is a wide range of seabed types, including mud, sand and rock, although the majority of the seabed is sandy. The sediment supports a large number of species, including bivalve molluscs, worms, burrowing urchins, brittlestars and sand-stars.

1310 *Salicornia* and other annuals colonising mud and sand

Carmarthen Bay and Estuaries in south Wales is selected as representative of pioneer glasswort *Salicornia* spp. saltmarsh in the south-west of the UK. It forms an integral part of the estuarine system, supporting extensive pioneer communities and contributing to a complete sequence of saltmarsh vegetation, including transitions to upper saltmeadow and to important sand dune habitats.

1330 Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)

This extensive site in south Wales has a complete sequence of saltmarsh vegetation, from pioneer vegetation through to upper saltmarsh transitions. The grazed saltmarshes include upper margins with sea rush *Juncus maritimus* and marsh-mallow *Althaea officinalis*, which are a particularly distinctive ecological feature of this site. The area is also important for transitions from saltmarsh to sand dune and other habitats.

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site

Not applicable.

Annex II species that are a primary reason for selection of this site

1103 Twaite shad *Alosa fallax*

Twaite shad ***Alosa fallax*** migrate though the waters of Carmarthen Bay and Estuaries cSAC to reach spawning sites in the Afon Tywi. The Taf-Tywi-Gwendraeth estuary is also an important nursery area for juveniles and it is likely that twaite shad feed in the inshore waters of Carmarthen Bay.

Annex II species present as a qualifying feature, but not a primary reason for site selection

1095 Sea lamprey *Petromyzon marinus*

1099 River lamprey *Lampetra fluviatilis*

1102 Allis shad *Alosa alosa*

1355 Otter *Lutra lutra*

Many designated sites are on private land: the listing of a site in these pages does not imply any right of public access.

 [- top -]

Afon Tywi/ River Tywi

Site details

Country	Wales
Unitary Authority	Caerfyrddin/ Carmarthenshire
Grid Ref*	SN687263
Latitude	51 55 12 N
Longitude	03 54 41 W
SAC EU code	UK0013010
Area (ha)	363.45

* This is the approximate central point of the SAC. In the case of large, linear or composite sites, this may not represent the location where a feature occurs within the SAC.

Location of Afon Tywi/ River Tywi SAC

General site character

Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins) (9%)
Salt marshes. Salt pastures. Salt steppes (2%)
Shingle. Sea cliffs. Islets (7%)
Inland water bodies (standing water, running water) (62%)
Bogs. Marshes. Water fringed vegetation. Fens (6%)
Heath. Scrub. Maquis and garrigue. Phygrana (4%)
Improved grassland (3%)
Broad-leaved deciduous woodland (7%)

Boundary map and associated biodiversity information on the NBN Gateway.
Natura 2000 data form for this site as submitted to Europe (PDF *format, size 30kb*).

Annex I habitats that are a primary reason for selection of this site

Not applicable

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site

Not applicable.

Annex II species that are a primary reason for selection of this site

1103 Twaite shad ***Alosa fallax***

A large spawning population of **twaite shad *Alosa fallax*** occurs in the Tywi, south Wales, and is considered to be self-sustaining. Spawning sites occur throughout the lower reaches of the river between Carmarthen and Llangadog, with most spawning occurring downstream of Llandeilo. Water quality and quantity are considered adequate to maintain this internationally vulnerable species, and there are no impassable obstructions along the migration route, though one weir at Manorafon may be an obstacle during low flow conditions. The presence of Llyn Brianne reservoir at the headwaters provides the potential to manipulate river flows to aid shad migration.

1355 Otter ***Lutra lutra***

The Afon Tywi is one of the best rivers in Wales for **otters *Lutra lutra***. There are abundant signs of otters and they are regularly seen on the river. The water quality is generally good and there is an ample supply of food. There are suitable lying-up areas along the river bank, but there few known breeding sites on the main river, although cubs have been seen.

Annex II species present as a qualifying feature, but not a primary reason for site selection

1095 Sea lamprey ***Petromyzon marinus***

1096 Brook lamprey ***Lampetra planeri***

1099 River lamprey ***Lampetra fluviatilis***

1102 Allis shad ***Alosa alosa***

1163 Bullhead ***Cottus gobio***

Many designated sites are on private land: the listing of a site in these pages does not imply any right of public access.

 [- **top** -]

CADW

Scheduled Ancient Monument Information

Prepared by: CADW Ancient Monuments Inspectorate	**Prepared for:** Andrea Wilcockson
Date: 12/01/2004	

SAM No	SAM Title	CAM File	Completed	Trad. NGR	NGR X	NGR Y
CM060	Group of Standing Stones NE of Llechdwnni	1254	Yes	SN432101	243200	210100
CM198	Is-Coed-Uchaf Standing Stone	2632	Yes	SN386123	238600	212300

100 fa/
100 fa/

CADW

Scheduled Ancient Monument Information

Prepared by: Cadw Ancient Monuments Inspectorate	Prepared for: Andrea Wilckson
Date: 12/01/2004	

SAM No	SAM Title	CAM File	Completed	Trad. NGR	NGR X	NGR Y	
CM272	Maesdulais Limekilns	6630	Yes	SN518144	251800	214400	1
CM273	Odyn Jac Limekilns	6632	Yes	SN502142	250200	214200	2
CM278	Garnbwll Limekiln	6644	Yes	SN498140	249800	214000	3

Scheduled + Ancient Monuments within 5Km radius of Carmarthen.

CADW

Scheduled Ancient Monument Information

Prepared by: CADW Ancient Monuments Inspectorate	**Prepared for:** Andrea Wilcockson
Date: 12/01/2004	

SAM No	SAM Title	CAM File	Completed	Trad. NGR	NGR X	NGR Y	
CM228	Round Barrow 200m SSW of Felin-Wen-Isaf	3510	Yes	SN461212	246120	221204	4
CM231	Merlins Hill Hillfort	3586	Yes	SN455215	245500	221500	5

CADW

Scheduled Ancient Monument Information

Prepared by: CADW Ancient Monuments Inspectorate	**Prepared for:** Andrea Wilcockson
Date: 12/01/2004	

SAM No	SAM Title	CAM File	Completed	Trad. NGR	NGR X	NGR Y	
CM042	Ffynnon-Newydd Standing Stones	1073	Yes	SN494211	249400	221100	6
CM043	Llech Ciste Standing Stone	1533	Yes	SN514283	251400	228300	too far.
CM151	Pen y Cnap Castle	1309	Yes	SN516213	251600	221300	7
CM157	Allt-y-Ferin Mound and Bailey Castle	1308	Yes	SN522232	252200	223200	too far.
CM201	Crugiau Round Barrows	2695	Yes	SN500285	250000	228500	too far.

CADW

Scheduled Ancient Monument Information

Prepared by: CADW Ancient Monuments Inspectorate	**Prepared for:** Andrea Wilcockson
Date: 12/01/2004	

SAM No	SAM Title	CAM File	Completed	Trad. NGR	NGR X	NGR Y	
CM061	Mynydd Llangyndeyrn Burial Chamber	1683	Yes	SN485132	248500	213200	8
CM122	Pen Celli Standing Stone	1385	Yes	SN439138	243900	213800	9
CM123	Clos-Teg Standing Stones	1384	Yes	SN455150	245500	215000	10
CM124	Banc y Bettws Castle Mound	1383	Yes	SN458154	245800	215400	11
CM191	Standing Stone NE of Halfway House	2581	Yes	SN452121	245200	212100	12
CM203	Mynydd Llangyndeyrn Round Cairns	2763	Yes	SN482132	248200	213200	13
CM227	Remains of Blast Furnace at Pont Henry	3485	Yes	SN474092	247400	209200	
CM240	Castell y Domen, Gwempa	3688	Yes	SN436126	243600	212600	14
CM277	Limekilns at Penymynydd, Pedair Heol	6641	Yes	SN439094	243900	209400	
CM316	Gwempa Standing Stone	7428	Yes	SN445111	244506	211128	15

DYFED COEDYDD Y GARN SSSI

Carmarthen District

Date of notification:	July 1988
National grid reference:	SN 511145
OS 1:50,000 Sheet No:	159
1:25,000 Sheet No:	SN51
Site area:	22.7 hectares (56.1 acres)

Description:

On the narrow outcrop of Carboniferous Limestone which surrounds the South Wales Coalfield a distinctive climax woodland, with a rich and varied ground flora, has developed. Such woodland is typically dominated by ash Fraxinus excelsior, with an admixture of wych elm Ulmus glabra, oak Quercus sp, sycamore Acer pseudoplanatus, crab apple Malus sylvestris subsp sylvestris and wild cherry Prunus avium. A well developed shrub layer exists with much hazel Corylus avellena, blackthorn Prunus spinosa and hawthorn Crataegus monogyna, together with the uncommon buckthorn Rhamnus cartharticus and spindle Euonymus europeaus. Coedydd y Garn is an outstanding example of this limestone woodland.

Along the main ridge, the woods occupy linear tors of limestone. The ground flora includes colourful vernal dominants such as wood anemone Anemone nemorosa, early dog-violet Viola reichenbachiana, lesser celandine Ranunculus ficaria and early-purple orchid Orchis mascula. Areas with a more blocky, pavement-like outcrop are characterized by dog's mercury Mercurialis perennis, soft shield-fern Polystichum setiferum, hart's-tongue Phyllitis scolopendrium and bryophyte mats. The uncommon toothwort Lathraea squamaria (a parasitic plant associated with hazel) also occurs here. Dry, exposed outcrops have an interesting flora which includes dwarf spurge Euphorbia exigua, wild thyme Thymus praecox, and wild basil Clinopodium vulgare. In such areas an assemblage of terrestrial molluscs that mostly require dry, calcareous conditions is to be found, typified by Candidula intersecta and the small species, Vallonia excentrica and Ceciliodes acicula, the latter most often enountered in nests of ants Lasius spp. The north-facing slopes of Coedydd y Garn include wet, flushed areas dominated by alder Alnus glutinosa and pedunculate oak Quercus robur, in addition to ash. Whilst some of the flushes that emanate from the limestone are predictably calcareous, others are more acidic, being derived from surface waters that pass through humus layers.

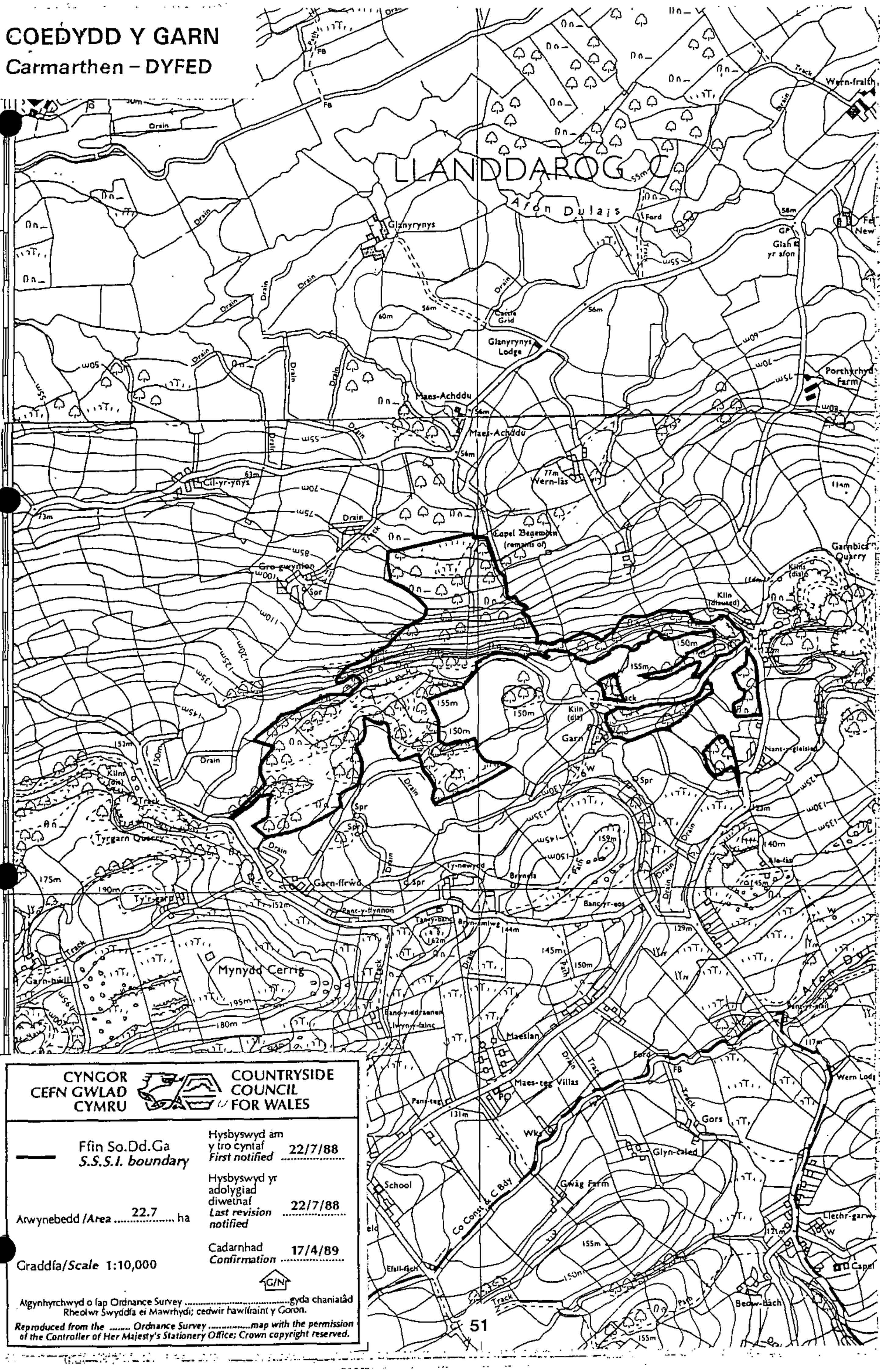
Throughout much of Coedydd y Garn the abundance of dead wood and the large areas of sunny wood-edge make the site ideal for a varied invertebrate fauna. Uncommon species include the bee chafer Trichius fasciatus (a scarabaeid beetle that mimics bees); glow worm Lampyris noctiluca (whose larvae depend on high mollusc densities) and, in the grassy clearing, the impressive brown and yellow robber-fly Asilus crabroniformis, a rare and endangered asilid which is predatory on other flies. Complementing these rare insects are other uncommon species such as the hoverflies, Arctophila fulva, Platycheirus tarsalis, Leucozona laternarius and Portevinia maculata and the marbled white Melanargia galathea and brimstone Gonepteryx rhamni butterflies. A wide variety of woodland birds occur at this site, including nesting pied flycatchers and redstarts.

Remarks:

Included within the boundary of the site is a roadside nature reserve containing one of two populations of green hellebore Helleborus viride known in the botanical vice county of Carmarthenshire.

COEDYDD Y GARN

Carmarthen – DYFED



CYNGOR CEFN GWLAD CYMRU — COUNTRYSIDE COUNCIL FOR WALES

Ffin So.Dd.Ga *S.S.S.I. boundary*

Hysbyswyd am y tro cyntaf *First notified* 22/7/88

Hysbyswyd yr adolygiad diwethaf *Last revision notified* 22/7/88

Arwynebedd /*Area* 22.7 ha

Cadarnhad *Confirmation* 17/4/89

Graddfa/*Scale* 1:10,000

G/N

DYFED
Carmarthen District

GWEUNYDD A CHOED PEN-TY
(PEN-TY PASTURES & WOOD) SSSI

Date of notification: January 1989

National Grid Reference: SN 483167

1:50,000 Sheet No: 159
1:25,000 Sheet No: SN 41

Site area: 9 .0 hectares (22.2 acres)

Description:

The site consists of two areas of unimproved herb-rich grassland linked by a wet semi-natural wood. This habitat complex is of outstanding botanical and entomological interest, supporting a number of uncommon species.

The sloping pasture south of the wood is on fairly acidic soils and is particularly notable for its huge population of meadow thistle Cirsium dissectum, a declining southern species that is characteristic of damp pastures found in parts of the Carmarthen Coalfield and elsewhere. Other uncommon and characteristic species that grow in this pasture are devil's-bit scabious Succisa pratensis, whorled caraway Carum verticillatum, saw-wort Serratula tinctoria, heath spotted-orchid Dactylorhiza maculata ssp. ericetorum and petty whin Genista anglica, together with at least six species of sedge Carex spp. The field margins, flushes and damp areas at the foot of the slope support a nationally recognised plant community characterised by purple moor-grass Molinia caerulea, tormentil Potentilla erecta and wild angelica Angelica sylvestris. Other representative species here include meadowsweet Filipendula ulmaria, greater bird's-foot-trefoil Lotus uliginosus and marsh-marigold Caltha palustris. The pasture also has some heathy areas with heather Calluna vulgaris, sheep's-fescue Festuca ovina, purple moor-grass, heath wood-rush Luzula multiflora, and heath spotted-orchid.

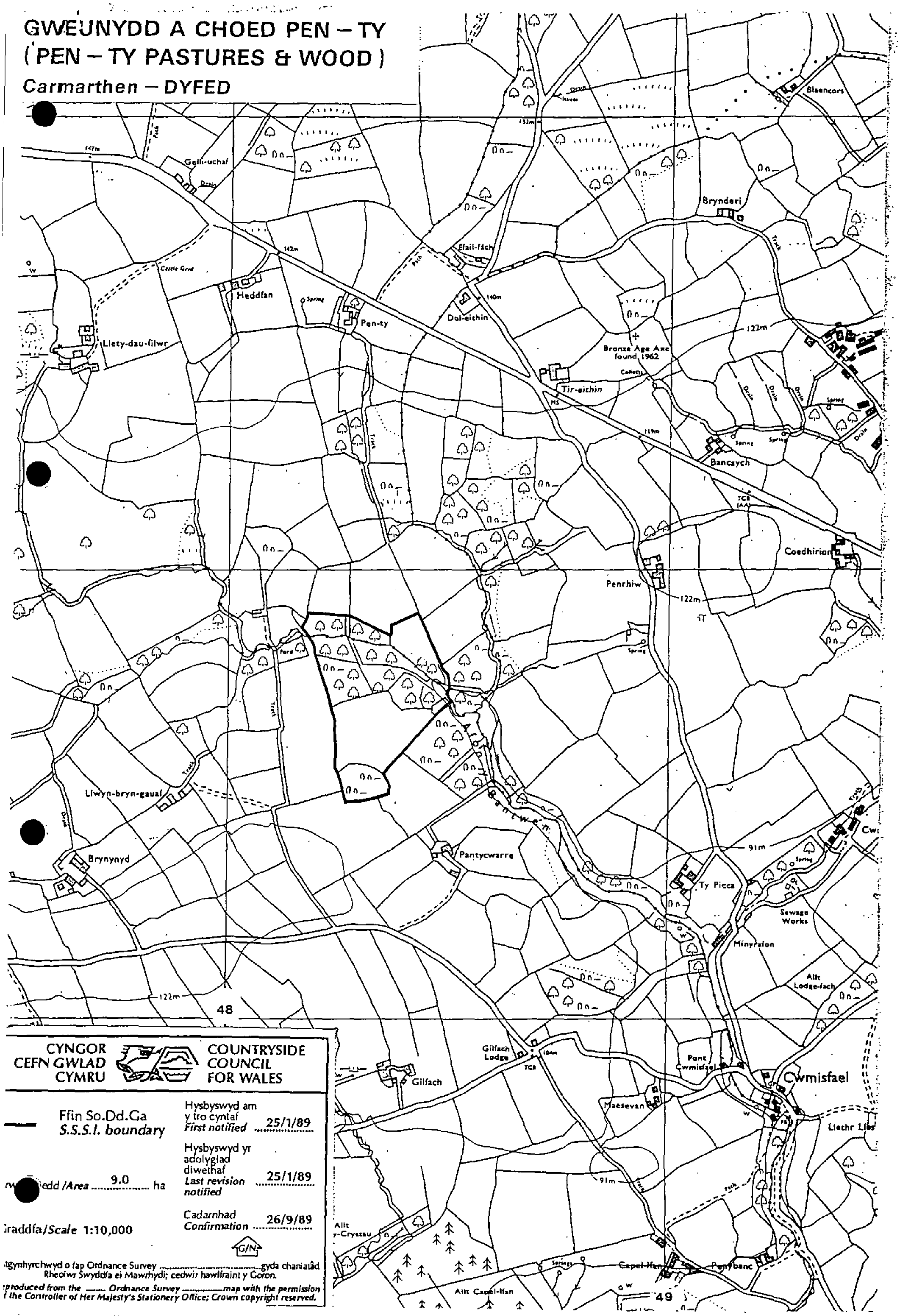
The pasture north of the wood supports a contrasting mesotrophic grassland community, with common bird's-foot-trefoil Lotus corniculatus, common knapweed Centaurea nigra, yarrow Achillea millefolium amongst Yorkshire-fog Holcus lanatus, sweet vernal-grass Anthoxanthum odoratum and crested dog's-tail Cynosurus cristatus. This enclosure, in conjunction with the adjacent woodland, is noteworthy for its invertebrate fauna, with twenty-four species of butterfly having been recorded, including localized and declining species such as marbled white Melanargia galathea, small blue Cupido minimus, silver-washed fritillary Argynnis paphia and brown hairstreak Thecla betulae. The sheltered, irregular woodland edge and hedgerows, with an abundance of young blackthorn Prunus spinosa, provide ideal conditions for the brown hairstreak, an uncommon autumn-flying butterfly. The southerly pasture supports the marsh fritillary butterfly Eurodryas aurinia and the small pearl-bordered fritillary Boloria selene, also the hoverfly, Arctophila fulva, which is a characteristic species of this type of grassland.

The wet woodland connecting these areas of pasture is dominated by alder Alnus glutinosa and ash Fraxinus excelsior, with a ground flora typified by yellow pimpernel Lysimachia nemorum, tufted hair-grass Deschampsia cespitosa and remote sedge Carex remota. Water avens Geum rivale occurs locally.

Remarks:

GWEUNYDD A CHOED PEN – TY
(PEN – TY PASTURES & WOOD)

Carmarthen – DYFED



CYNGOR CEFN GWLAD CYMRU — **COUNTRYSIDE COUNCIL FOR WALES**

Ffin So.Dd.Ga / *S.S.S.I. boundary*	Hysbyswyd am y tro cyntaf / *First notified* 25/1/89
Arwynebedd /*Area* 9.0 ha	Hysbyswyd yr adolygiad diweithaf / *Last revision notified* 25/1/89
Graddfa/*Scale* 1:10,000	Cadarnhad / *Confirmation* 26/9/89

G/N

Carmarthen District

Date of Notification:	April 1985
National Grid Reference:	SN 444181
O.S. 1:50,000 Sheet No:	159
1:25,000 Sheet No:	SN 41
Site area:	1.6 hectares (4 acres)

Description:

The most complete section in the Cwmffrwd Member of the Arenig Carmarthen Formation. This is the best exposure through the thick turbidite/shale sequence which makes up this unit, showing the base of the member and good sections in the underlying Pibwr mudstones. The latter shows changing trilobite faunas indicative of significant ecological changes related to water depth and oxygenation. An important site with ecologically and stratigraphically significant trilobite faunas and sediments.

In layman's terms, the interest of this site may be expressed more simply, and such a statement is provided below. This should not be taken as definitive and further information as to details of the interest can be obtained from the Nature Conservancy Council.

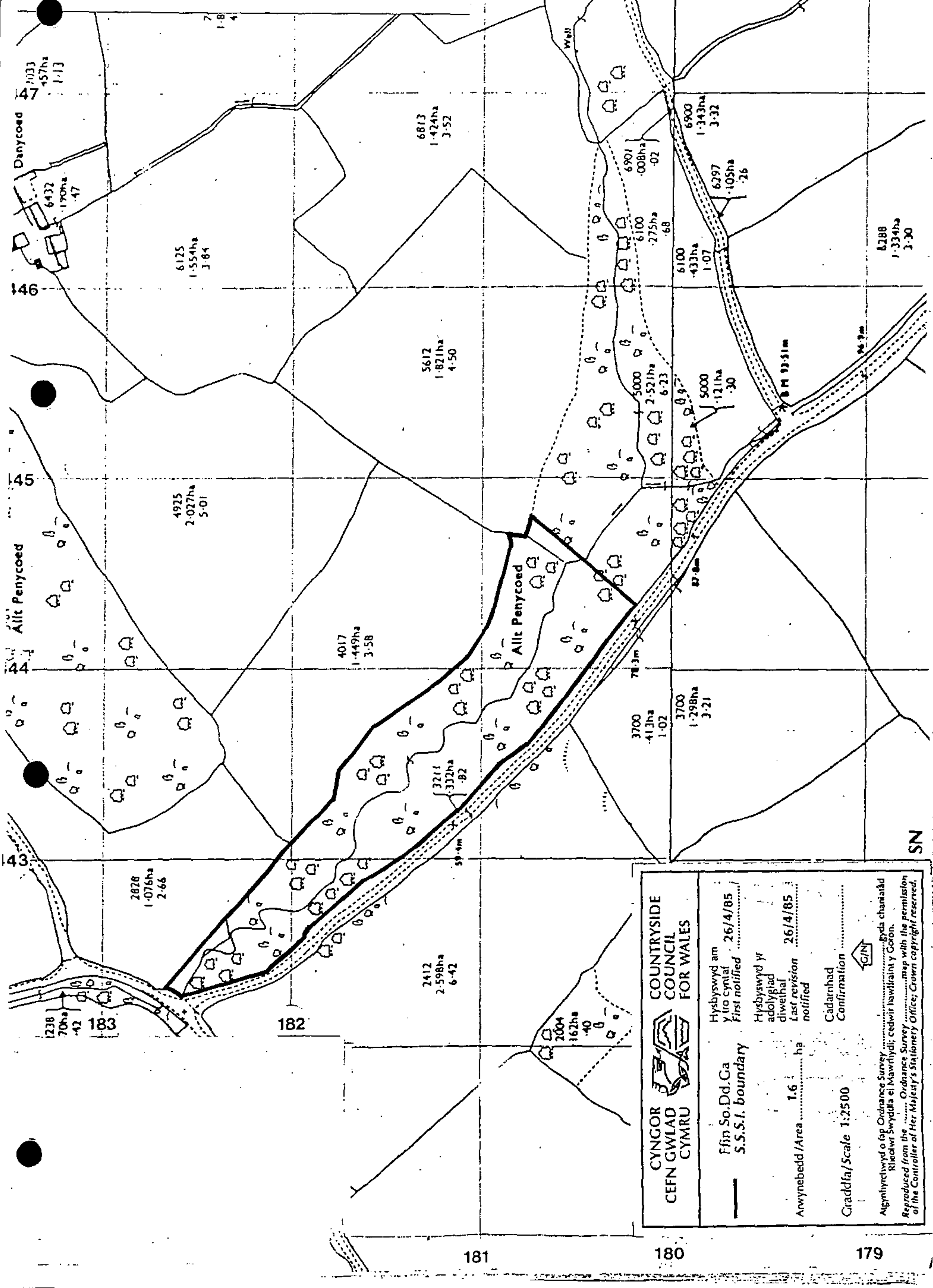
This stream section provides important exposure of a sequence of fossil-bearing sandstones and muds which were deposited in deep-water marine conditions some 500 million years ago. The fossilised remains of a new extinct group of sea-living arthropods, known as trilobites, have been recorded from this area and have helped geologists understand the conditions which existed on the sea bed during the period when sediment was accumulating. The rich fossil assemblage described from Allt Penycoed has also allowed geologists to compare this section with rocks of a similar age throughout South Wales and the rest of the British Isles.

Remarks:

This site has been selected as a result of the Nature Conservancy Council's Geological Conservation Review, a national survey and evaluation of sites of geological and physiographical interest (in progress).

ALLT PENYCOED STREAM SECTION.

Carmarthen — DYFED



DYFED | WAUN-FAWR SSSI

Carmarthen District

Date of Notification: August 1979 (renotified in 1983)

National Grid Reference: SN 497134

O.S. 1:50,000 Sheet No.: 159

1:25,000 Sheet No.: SN 41

Site Area: 5½ hectares (14 acres)

Description:

This enclosed wet pasture is a particularly diverse example of the sedge-rich heathy grasslands that are such a feature of the Carmarthen portion of the south Wales Coalfield.

The site occupies most of a small basin which is lined by shallow peat developed over clay. Parts are dominated by purple moor-grass (Molinia caerulea) and rushes (Juncus spp.), whilst the most species-rich areas are characterised by whorled caraway (Carum verticillatum) and up to eight species of sedges (Carex spp.).

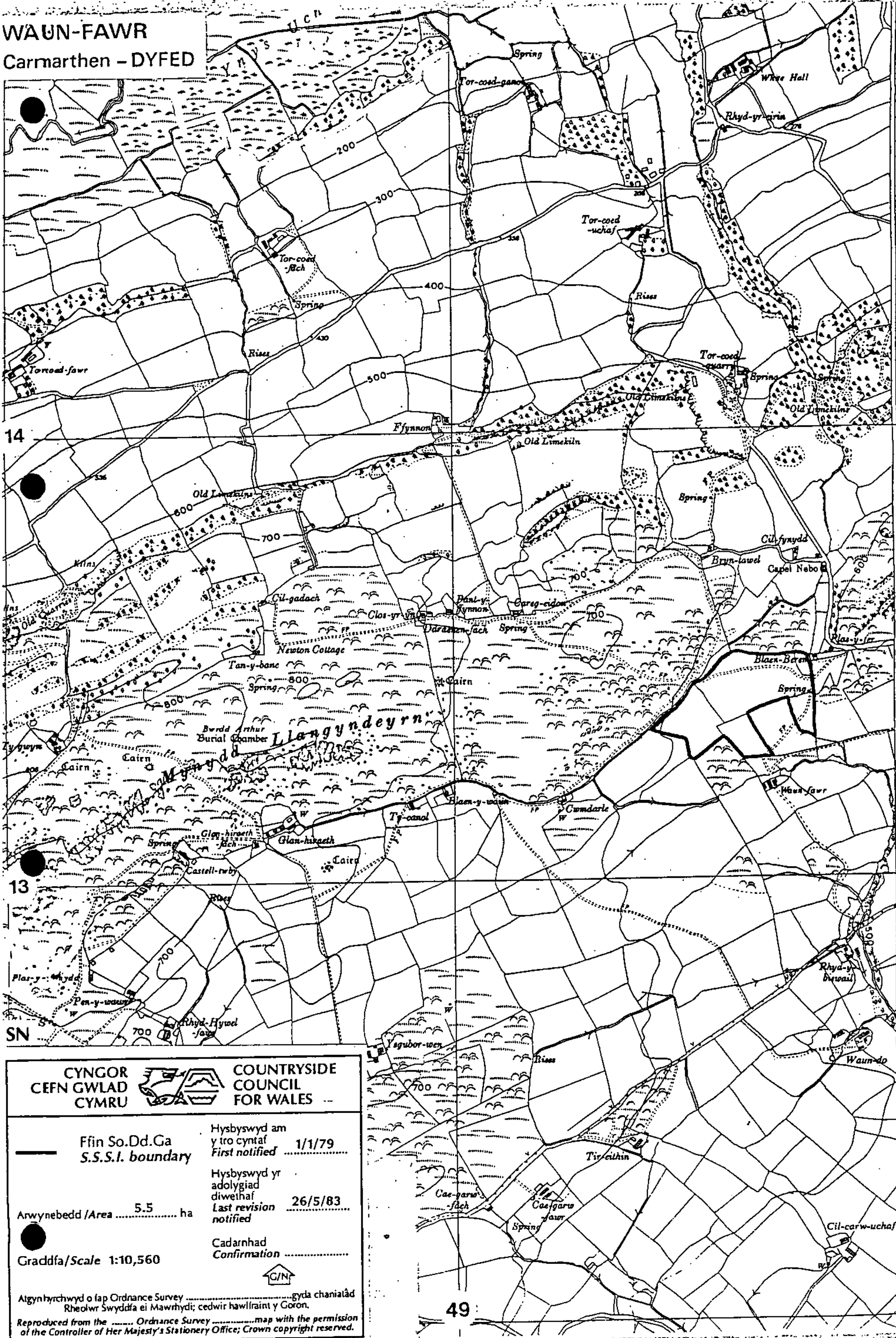
Notable plants of these more open swards are meadow thistle (Cirsium dissectum), devil's-bit scabious (Succisa pratensis) and quaking-grass (Briza media). Acidic flushes have the insect-eating common butterwort (Pinguicula vulgaris) and round-leaved sundew (Drosera rotundifolia), as well as many-stalked spike-rush (Eleocharis multicaulis), bog pimpernel (Anagallis tenella) heather (Calluna vulgaris), cross-leaved heath (Erica tetralix) and common cottongrass (Eriophorum angustifolium).

The marbled white butterfly (Melanargia galathea) has been recorded from the site, near its northernmost limits in Britain, and there is a strong colony of the scarce marsh fritillary butterfly (Euphydryas aurinia). The scarlet tiger moth (Callimorpha dominula) is also present.

Remarks:

Subject to a management agreement between the owner and the Nature Conservancy Council, under section 15 of the Countryside Act, 1968.

WAUN-FAWR
Carmarthen – DYFED



CYNGOR CEFN GWLAD CYMRU — COUNTRYSIDE COUNCIL FOR WALES

Ffin So.Dd.Ga
S.S.S.I. boundary

Hysbyswyd am y tro cyntaf / *First notified* 1/1/79

Hysbyswyd yr adolygiad diwethaf / *Last revision notified* 26/5/83

Arwynebedd /*Area* 5.5 ha

Cadarnhad / *Confirmation* ....

Graddfa/*Scale* 1:10,560

G/N

DYFED MYNYDD LLANGYNDEYRN SSSI

Carmarthen District

Date of Notification: March 1992

National Grid Reference: SN 486134

OS 1: 50,000 Sheet No: 159
1: 25,000 Sheet No: SN 41

Site Area: 85.2 hectares (210.5 acres)

Description:

An extensive area of common land lying at an altitude of about 250 metres (820 feet) on a ridge of Namurian Quartzite, situated near the village of Crwbin. The site exhibits a mosaic of semi-natural grassland, dry heath, mire and rock outcrops, and is notable as one of the larger upland semi-natural areas left in south-west Wales which, unlike most others, remains lightly grazed.

The structure of the ridge, which delineates the edge of the South Wales Coalfield, is dominated by the alternate succession of hard resistant beds of very pure ortho-quartzite, which form large expanses of dip-slopes dipping southwards. Softer strata of other sedimentary rocks have eroded to form elongate depressions in which, because of poor drainage, mire vegetation has developed over the predominantly acid soils.

The quartzite slopes and outcrops are sparsely clad by heathy vegetation with bell heather Erica cinerea, western gorse Ulex gallii, bilberry Vaccinium myrtilus and the uncommon upland ecotype of tormentil Potentilla erecta sub sp. strictissima. The wetter depressions are dominated by purple moor-grass Molinia caerulea, sharp-flowered rush Juncus acutiflorus, jointed rush J. articulatus and cross-leaved heath Erica tetralix, with devil's-bit scabious Succisa pratensis, wild angelica Angelica sylvestris and other species amongst mats of mosses and low vegetation. The devil's-bit scabious supports small colonies of the marsh fritillary butterfly Euphydryas aurinia, particularly on the bog in the south-east of the site. The forester moth Adscita statices also occurs.

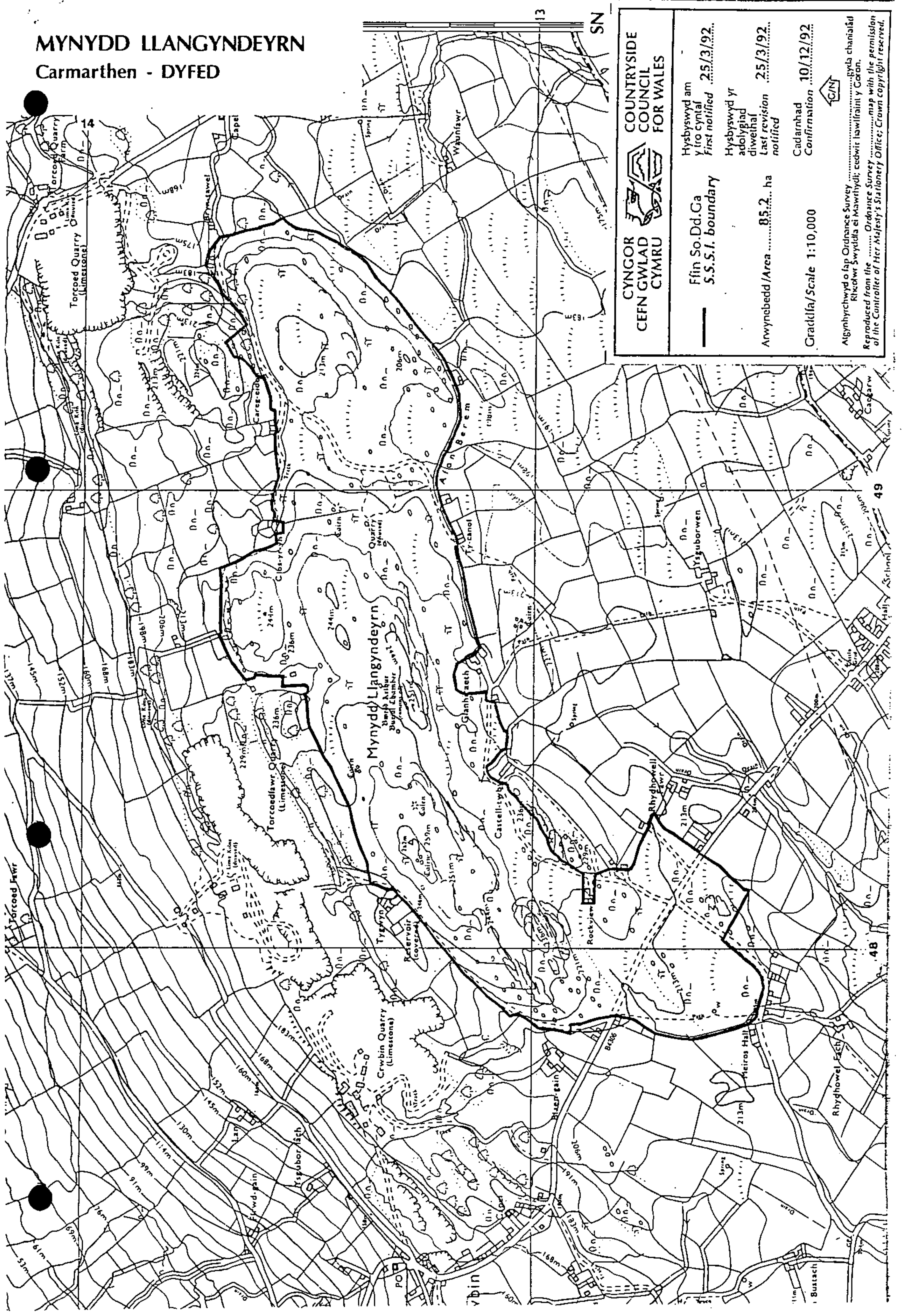
One large topographical depression holds an extensive mire with a good range of plant species which includes deergrass Trichophorum cespitosum, common cottongrass Eriophorum angustifolium, bogbean Menyanthes trifoliata, marsh St. John's-wort Hypericum elodes, royal fern Osmunda regalis, marsh cinquefoil Potentilla palustris, bog asphodel Narthecium ossifragum, cranberry Vaccinium oxycoccos and cross-leaved heath.

The site as a whole provides breeding habitat for a variety of birds, notably curlew, stonechat and grasshopper warbler.

Continued overleaf/

MYNYDD LLANGYNDEYRN

Carmarthen - DYFED



DYFED

BISHOP'S POND SSSI

Carmarthen District

Date of Notification: 1973 (renotified in 1983)

National Grid Reference: SN 445209

O.S. 1:50,000 Sheet No: 159

1:25,000 Sheet No: SN 42

Site Area: 5½ hectares (13½ acres)

Description:

This is the best example of an ox-bow lake in west Wales. It is especially notable for its reed sweet-grass (Glyceria maxima) swamp. This is a rare and distinctive vegetation type in Wales, largely confined to the Tywi valley and the coastal flats of south Wales.

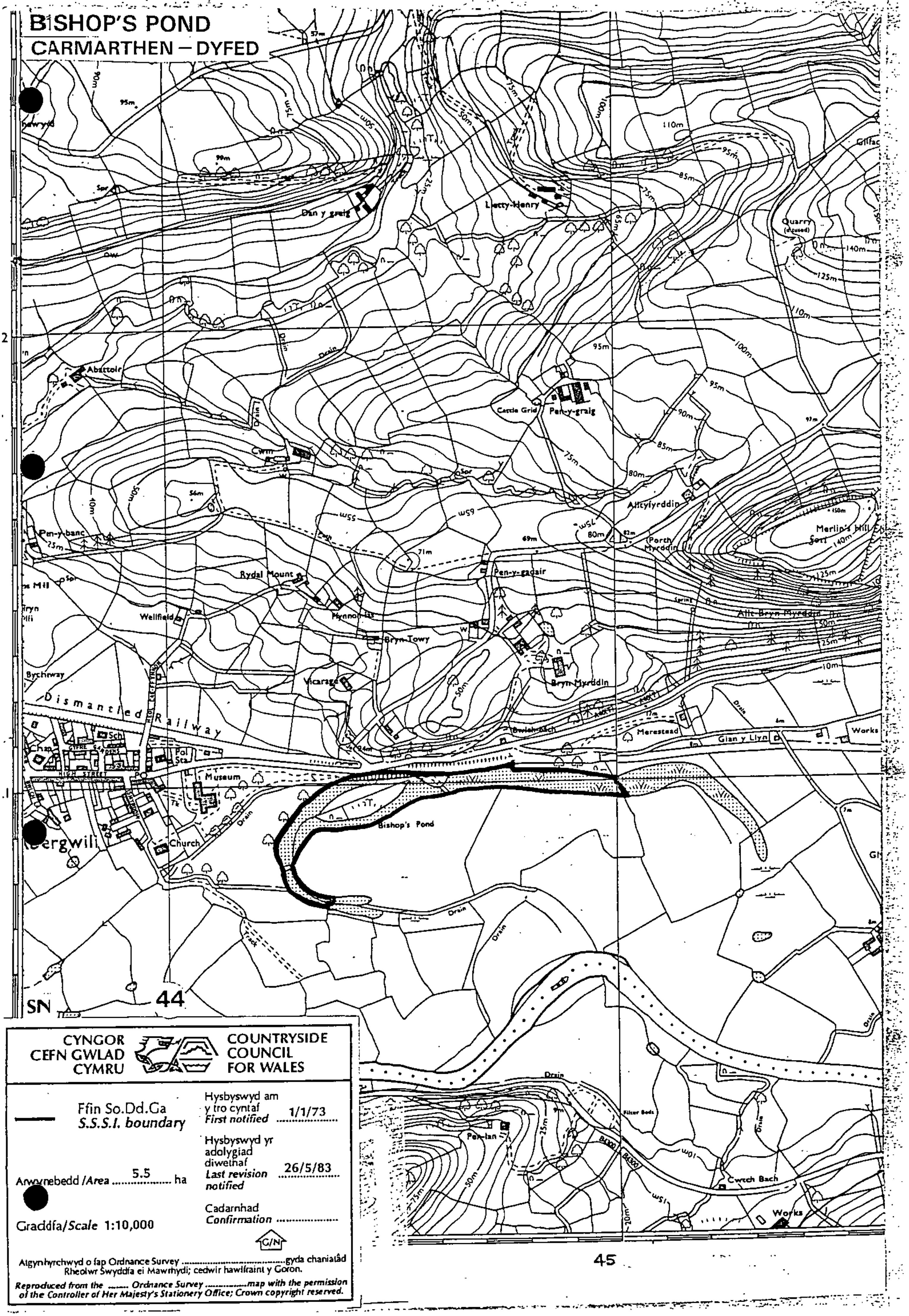
In summer, reed sweet-grass, along with some bladder-sedge (Carex vesicaria) and branched bur-reed (Sparganium erectum) surround pools of standing water dominated by yellow water-lily (Nuphar lutea). There is much water horsetail (Equisetum fluviatile) on the shallow margins of the pools. Because of the low summer water-table, the edges of the lake have more open vegetation with water-pepper (Polygonum hydropiper) and less common plants like northern yellow-cress (Rorippa islandica) and trifid bur-marigold (Bidens tripartita). Woodland or hedgerow trees border the lake and during the high winter water levels there is a large island at the western end.

Notable plant species recorded from the site include least bur-reed (Sparganium minimum) and unbranched bur-reed (S. emersum). Adder's-tongue (Ophioglossum vulgatum) grows on the bankside. As for its animal life, the site is locally important for breeding birds which include mute swan, mallard, coot, moorhen, dipper and kingfisher. Tench, pike, perch, roach, eels, three-spined stickleback and minnows are present, and the site appears to be an old traditional stocked coarse fishery.

Remarks:

Most of the site is managed as a nature reserve by the West Wales Naturalists' Trust. Part is owned by Dyfed County Council and the grounds of their Carmarthen Museum adjoin.

BISHOP'S POND
CARMARTHEN – DYFED



CYNGOR CEFN GWLAD CYMRU | COUNTRYSIDE COUNCIL FOR WALES

Ffin So.Dd.Ga
S.S.S.I. boundary

Hysbyswyd am y tro cyntaf
First notified 1/1/73

Hysbyswyd yr adolygiad diwethaf
Last revision notified 26/5/83

Arwynebedd /*Area* 5.5 ha

Cadarnhad
Confirmation ....

Graddfa/*Scale* 1:10,000

G/N

DYFED

CWM YR ABBEY STREAM SECTION SSSI

Carmarthen District

Date of Notification: April 1985

National Grid Reference: SN 501195

O.S. 1:50,000 Sheet No: 159

1:25,000 Sheet No: SN 51

Site area: 2.3 hectares (5.7 acres)

Description:

An outstanding Arenig faunal and stratigraphic locality. One of the key Carmarthen localities yielding well preserved trilobite faunas, in contrast to the normal situation where fauna is either sparse or greatly deformed by tectonism. Its common olenid trilobite faunas differ from other Arenig faunas in Wales and compare most closely with Arenig forms from Spitzbergen. This is the best section in the well known 'Peltura punctata Beds', now in part the Cwm yr Abbey Member of the Carmarthen Formation, with abundant Porterfieldia punctata. A key exposure in studies of trilobite faunas, their distribution and ecology.

In layman's terms, the interest of this site may be expressed more simply, and such a statement is provided below. This should not be taken as definitive and further information as to details of the interest can be obtained from the Nature Conservancy Council.

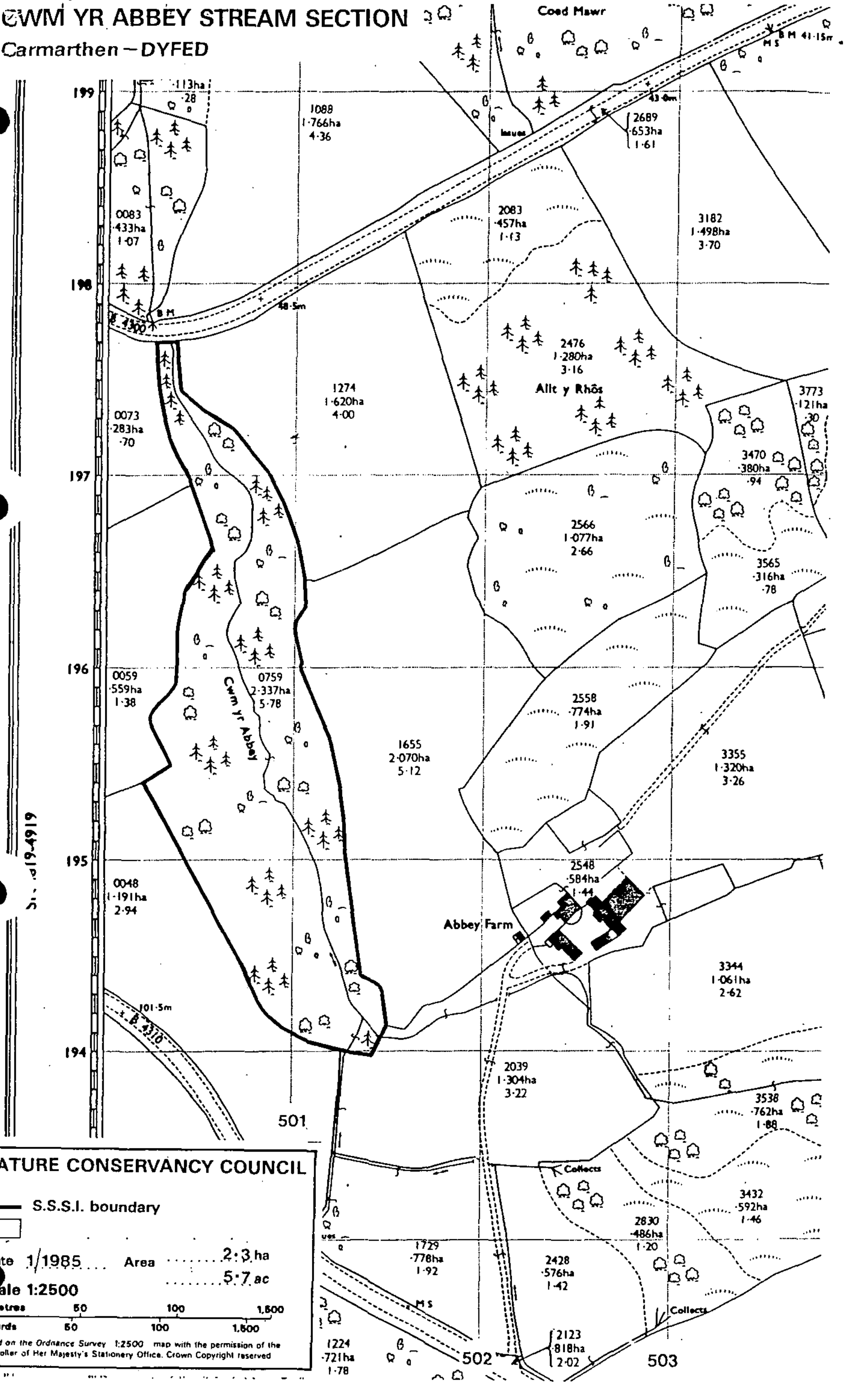
Cwm yr Abbey is one of the few localities in South Wales which has yielded well-preserved fossil specimens of a now extinct group of arthropods, known as trilobites. The rocks from which these fossil remains have been described are of considerable antiquity and since their deposition in deep water marine conditions some 500 million years ago they have been subjected to a great deal of folding and faulting. At most locations in South Wales these movements within the earth's crust have tended to destroy or deform the remains of the trilobite fossils, so Cwm yr Abbey assumes particular importance as a rare source of well-preserved specimens. Also of particular note is the fact that one of the trilobite forms described from Cwm yr Abbey shows great similarity to specimens described from Spitzbergen.

Remarks:

This site has been selected as a result of the Nature Conservancy Council's Geological Conservation Review, a national survey and evaluation of sites of geological and physiographical interest (in progress).

CWM YR ABBEY STREAM SECTION

Carmarthen – DYFED



DYFED

Carmarthen District

YNYS UCHAF SSSI
32WJK

Date of Notification: July 1987

National Grid Reference: SN 489149

O.S. 1:50,000 Sheet No: 159
1:25,000 Sheet No: SN 41

Site area: 15.7 hectares (38.8 acres)

Description:

A large area of flood plain mire located on the relatively base-enriched Old Red Sandstone soils of the Gwendraeth Fach valley, large expanses of the site being covered by a fenland-type plant community dominated by meadowsweet Filipendula ulmaria, marsh valerian Valeriana officinalis, marsh-marigold Caltha palustris, water horsetail Equisetum fluviatile and hemlock water-dropwort Oenanthe croccata. Ynys Uchaf is the only known locality in the Borough for tubular water-dropwort Oenanthe fistulosa. Small areas are more acidic with bladder-sedge Carex vesicaria and bogbean Menyanthes trifoliata. The southern edge of this site is fringed by a carr of alder Alnus glutinosa, ash Fraxinus excelsior and several species of willow Salix spp; below these trees greater tussock-sedge Carex paniculata forms imposing stands.

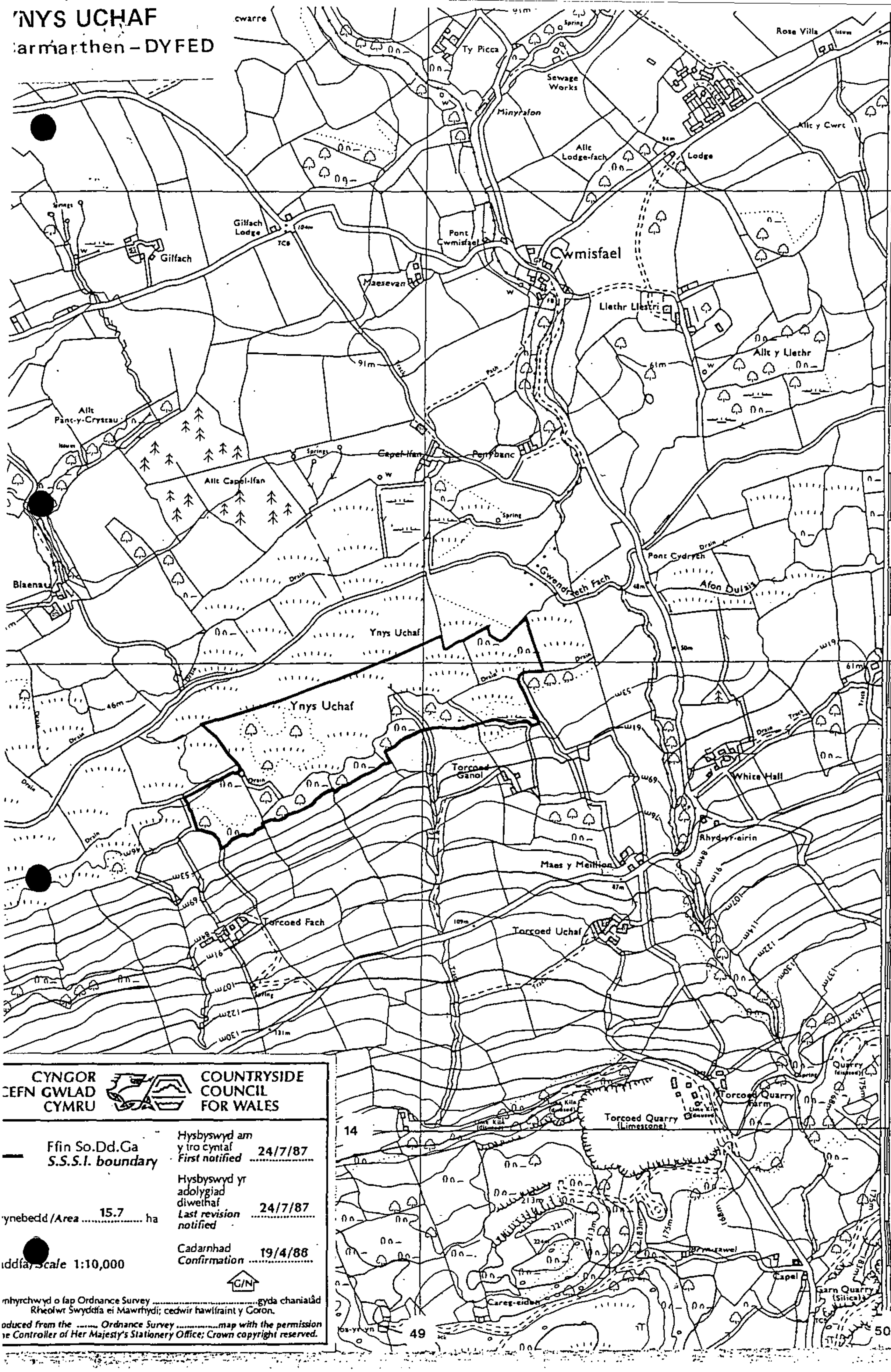
Water rail Rallus aquaticus is believed to breed and wildfowl, principally teal Anas crecca and mallard Anas platyrhynchos, frequent the site, especially during winter. The adjacent Gwendraeth Fach is rich in aquatic invertebrates and is regularly used by otters Lutra lutra who take advantage of the cover provided by the vegetation for resting.

Several notable invertebrates occur at Ynys Uchaf, including the brilliantly iridescent chrysomelid beetle Pilemostoma fastuosa, and also Phyllobrotica quadrimaculata, a beetle whose larvae feed on skullcap Scutellaria galericulata. The slender groundhopper Tetrix subulata, a small invertebrate related to the grasshoppers and which is very local in Wales, occurs on mossy areas.

Remarks:

'NYS UCHAF

:armarthen – DYFED



CYNGOR CEFN GWLAD CYMRU | COUNTRYSIDE COUNCIL FOR WALES

Ffin So.Dd.Ga
S.S.S.I. boundary

Hysbyswyd am y tro cyntaf
First notified 24/7/87

Hysbyswyd yr adolygiad diwethaf
Last revision notified 24/7/87

Cadarnhad
Confirmation 19/4/88

…ynebedd/*Area* 15.7 ha

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…mhyrchwyd o fap Ordnance Survey …… gyda chaniatâd Rheolwr Swyddfa ei Mawrhydi; cedwir hawlfraint y Goron.

…oduced from the …… Ordnance Survey …… map with the permission …e Controller of Her Majesty's Stationery Office; Crown copyright reserved.

CYNGOR CEFN GWLAD CYMRU
COUNTRYSIDE COUNCIL FOR WALES

CARMARTHENSHIRE — AFON TYWI

Local Planning Authority: Carmarthenshire County Council

Date of Notification:

National Grid Reference: SN 762348 - SN 355075

OS Maps:

	1:50,000 Sheet number:	146, 159
	1:10,000 Sheet number:	SN73 SE,SW
		SN72 NW
		SN62 NE,SE,SW
		SN52 SE,SW
		SN51 NE,NW
		SN42 SE,SW
		SN41 NW,SW
		SN31 NE,SE
		SN30 NE,NW

Site Area: 1249.5 ha

Description:

Afon Tywi Site of Special Scientific Interest extends downstream from Llandovery to the confluence with the Afon Tâf and Pembrey Coast SSSI in Carmarthen Bay. It is an actively eroding river meandering across a wide floodplain which is composed of alluvium, glacial sands and gravels. This has resulted in extensive shingle banks being formed. These are important for birds and invertebrates, and the river is also of special interest for its fish species and otters, and in its lower reaches for its saltmarsh vegetation.

GEOLOGY

The Afon Tywi from Llandovery to Carmarthen Bay (at Llanstephan - Ferryside) displays a varied geology and geomorphology. The course of the river is characteristic of a mature river valley. Over the 74 km from Llandovery down to the sea the river falls just 65 m. There is a tidal influence from Llanstephan up-stream to Bryn Myrddin. For the greater part, the river meanders over a flat valley floor, re-working previously deposited river sediments. Though rock sections are uncommon, the orientation of the river course indicates that it is controlled by features in the underlying solid geology, such as faults or folds in the rocks of the valley floor. Generally, ashes, sandstones and limestones gives rise to solid areas of river bed. The areas of shale and mustone are occupied by glacial till or river alluvium. These latter desposits are frequently exposed in small river cliffs, displaying evidence of the historical development of the river basin.

FLORA

Submerged aquatic plants present in stretches of moderate flow in the river channel include the sporadic occurrence of water crowfoot Ranunculus penicillatus ssp. penicillatus and water starwort species Callitriche hamulata, stagnalis and platycarpa.

Characteristic vegetation of the exposed gravel shoals include unstable communities which are subject to periodic inundation. Species such as yellow cresses Rorippa spp., water forget-me-knot Myosotis scorpioides and water pepper Polygonum hydropiper, are widespread and frequent. Grasses such as reed canary-grass Phalaris arundinacea, marsh foxtail Alopecurus geniculatus and creeping and common bents Agrostis spp. occur on more stable areas of shingle where gorse Ulex spp. and willows Salix spp. are becoming established. These areas of scrub also provide important overwintering sites for shingle invertebrates and rest areas for otters.

Marginal vegetation consists mainly of reed canary-grass Phalaris arundinacea, reed sweet-grass Glyceria maxima with branched bur-reed Sparganium erectum occurring occasionally.

Much of the river bank is subject to active erosion and the species composition, often dominated by tall ruderals and ephemerals reflects this. Species such as rosebay willow herb Chamerion angustifolium, nettle Urtica dioca, creeping thistle Cirsium arvense and marsh ragwort Senecio aquaticus are dominant along much of the banks with common knapweed Centaurea nigra and yarrow Achillea millefolia common. However, extensive areas of Indian balsam Impatiens gladulifera and to a lesser extent Japanese knotweed Fallopia japonica occur in the lower reaches.

Tree cover is sparse along the banks of the Afon Tywi, the adjacent floodplain dominated mainly by intensive dairy farming with improved grassland running down to the river. Spate river conditions make fencing impractical with the result that there is little tree regeneration. Existing trees comprise mainly of alder Alnus glutinosa, common sallow Salix cinerea and common osier Salix viminalis. Where areas of deciduous woodland have been retained, the dominant species are alder A. glutinosa, ash Fraxinus excelsior, willow Salix spp. and sycamore Acer pseudoplatanus.

Below Carmarthen, but especially in the lowest reaches of the river, a diverse range of saltmarsh communities covering over 150 hectares has developed. These range from transitional low marsh communities at the lowest levels merging into extensive areas of common saltmarsh-grass Puccinellia maritima saltmarsh communities including the thrift Armeria maritima sub-community. A rayed sea aster Aster tripolium community is also present with extensive areas of at least three red fescue Festuca rubra communities. At the top of the saltmarsh in some places are well developed examples of sea rush Juncus maritimus saltmarsh including the scarcer parsley water-dropwort Oenanthe lachenalii sub-community.

There are also important transitions to wet grassland, freshwater mire and dune. The richest areas are normally ungrazed or lightly grazed. Morfa Uchaf is particularly important in this respect with a rich variety of associations including two forms of innundation grassland, one with a dense stand of slender spike-rush Eleocharis uniglumis.

MAMMALS

Otter Lutra lutra is widespread along the river where appropriate bankside cover is available, and water voles Arvicola terrestris have also been recorded.

FISH

The Afon Tywi is used by both twaite and allis shad, Alosa fallax and A. alosa. This river is one of only four rivers in England and Wales, known to date, in which the twaite shad breeds. Shad are regulary seen and sometimes caught by local fishermen. Much of the river habitat is considered suitable for shad spawning with the main areas between Carmarthen and Llanegwad, with spawning also reported further upstream near Manordeilo.

The river also supports an excellent population of sea trout Salmo trutta trutta, which is why the Afon Tywi is recognised as one of the premier sea trout fisheries in the United Kingdom. Atlantic salmon Salmo salar, the eel Anguilla anguilla, the river lamprey Lampetra fluviatillis and the sea lamprey Petromyzon marius are other migratory fish present. Non migratory fish include the brown trout Salmo trutta fario and the bullhead Cottus gobbio.

BIRDS

The Afon Tywi, downstream of Llandovery, meanders through a wide gravel-based flood plain, with generally sparse bankside tree cover and this supports an important breeding bird community. A particular feature is its extensive areas of shingle banks providing suitable breeding habitat for little ringed plover Charadrius dubius. The Afon Tywi is the most important river in the UK for this species and holds approximately 4-5% of its total population (in 1997). Active bank erosion is another feature of the river providing nesting sites for kingfishers Alcedo atthis and a significant population of sand martins Riparia riparia, the Afon Tywi catchment holds between 1 and 2% of its British breeding population. Common sandpiper Actitus hypoleucs also breeds along the Afon Tywi. Mute swan Cygnus olor breeds along the slow flowing reaches whilst occasional reaches of faster flowing riffles with bankside tree cover, provide habitat for dipper Cinclus cinclus and grey wagtail Motacilla cinerea, but these species are generally scarce along the Afon Tywi.

Small numbers of overwintering white-fronted geese Anser. albifrons have been recorded on adjacent flood plains. The tidal reaches provide important feeding grounds for a diverse assemblage of estuarine birds including black-tailed godwit Limosa limosa, oystercatcher Haematopus ostralegus and curlew Numenius arquata.

INVERTEBRATES

The Afon Tywi supports an important assemblage of river invertebrates including beetles (Coleoptera), true flies (Diptera), dragonflies (Odonata), spiders (Araneae) and molluscs (Mollusca). The main invertebrate interest on the Afon Tywi is found on the extensive shingle banks. The fauna includes national rarities such as the 5-spot ladybird Coccinella quinquepunctata, the click beetle Negastrius sabulicola, the ground beetle Lionychus quadrillum and the predatory shingle fly Tachydromia acklandi. The nationally scarce wolf spider Arctosa cinerea is also found on the shingle banks.

The Afon Tywi additionally supports populations of the nationally scarce club-tailed dragonfly Gomphus vulgatissimus, especially where the river is slow flowing and there is bankside scrub or woodland to provide shelter for the maturing adults.

The nationally scarce freshwater pearl mussel Margaritifera margaritifera has also been recorded from the lower reaches of the river.

Remarks:

Part of the Afon Tywi is within the Dinefwr district of the Tir Cymen scheme.

The site incorporates land previously notified as part of Gweunydd Dryslwyn SSSI.

Afon Tywi abuts the Dinefwr Estate, Creigiau Llansteffan, Craig Ddu-Wharley Point Cliffs and Pembrey Coast SSSIs.

Afon Tywi is a possible Special Area of Conservation (SAC).

Afon Tywi abuts onto the Burry Inlet candidate SAC.

The site supports the following habitats and species listed in the EC Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora:

Common otter Lutra lutra - Annex II and IV
Allis shad Alosa alosa - Annex II and V
Twaite shad Alosa fallax - Annex II and V
Atlantic Salmon Salmo salar - Annex II and V
Bullhead Cottus gobio - Annex II and V
Sea Lamprey Petromyzon marinus - Annex II
River Lamprey Lampetra fluviatilis - Annex II and V
Freshwater Pearl Mussel Margaritifera margaritifera - Annex II and IV

Otter and freshwater pearl mussel are listed under Schedule 5 of the Wildlife and Countryside Act 1981, (as amended).

HABRA APPENDIX 2

1.0 INTRODUCTION

Under the requirements of the Landfill Directive Regulatory Guidance Note 5[1] the Environment Agency (EA) sets out the rationale behind the requirements for further and more detailed assessments of risks upon "European Sites", these being;

- Special Protection Areas (SPAs);
- Special Conservation Areas (SACs);
- candidate Special Conservation Areas (cSACs); and
- Ramsar sites.

Waste activities are assessed for potential impacts where the facility falls within 2km of a European Site and/or the activity could attract gulls and corvids and falls within 5km of an SPA or Ramsar site, or any other site which may be susceptible to disturbance or predation by these pests.

The EA has identified seven general categories of hazard that have the potential to cause impacts to protected sites. Examples of waste activities and emissions that have the potential to lead to these hazards are listed under each general category below:

- *Toxic Contamination*: landfill gas, landfill gas flare emissions, leachate, surface water and dust;
- *Nutrient Enrichment*: surface water, leachate and dust;
- *Habitat Loss or physical damage*: surface water, physical access (litter collection, environmental monitoring, emergency access and remedial schemes);
- *Siltation*: surface water;
- *Smothering*: dust and litter
- *Disturbance*: noise, gulls & corvids (including bird-scaring techniques), physical access (litter collection, environmental monitoring, emergency access and remedial schemes); and
- *Predation*: gulls, corvids and rats.

By considering the specific activities of a waste operation it is possible to highlight any potential hazard-pathway-receptor links that could have an effect upon the interest features of European Sites can be undertaken. The EA has created a generic sensitivity matrix for key European habitat and species interest features to the identified hazards, and their associated activities, which is shown in Table Appendix2/1.

This sensitivity matrix has been devised by the EA in conjunction with English Nature and the Countryside Council for Wales. Though a similar matrix has not been devised by Scottish Natural Heritage at this time it is anticipated that those sensitive receptors outlined in Table Appendix 2/1 are sufficient to guide appropriate assessments within Scotland where required.

[1] Landfill Directive, Regulatory Guidance Note 5 – Habitats Regulations & The Landfill Directive, Information and Guidance for Landfill Operators (version 1.1, December 2001). Environment Agency.

Table Appendix 2/1 is taken from Appendix 6 of the Habitats Regulations and is indicative of the generic matrix used by the EA to produce Sensitivity Risk Matrices specific to individual European Sites.

TABLE 1 - WASTE MANAGEMENT SENSITIVITY MATRIX

	Hazard (and the emissions or activities which may give rise to the hazard at waste sites)	Toxic contamination (Leach, LFG, LFG flare, SW, dust)	Nutrient enrichment (Leach, SW, dust)	Habitat loss (SW, Access)	Siltation (SW)	Smothering (Dust, Litter)	Disturbance (Access, Noise, Gulls)	Predation (Gulls)
SPA /Ramsar bird species groups	3.10 *Birds of open sea and offshore rocks*							
	3.9 Birds of estuarine habitats	3	3	3		3	3	3
	3.8 Birds of coastal habitats	3	3	3		3	3	3
	3.7 Farmland Birds			3		3	3	3
	3.6 Birds of lowland freshwaters & their margins	3	3	3	3	3	3	3
	3.5 Birds of lowland dry grassland			3		3	3	3
	3.4 Birds of lowland wet grassland	3		3	3	3	3	3
	3.3 Birds of lowland heaths & brecks			3		3	3	3
	3.2 Birds of woodland & scrub			3		3	33	3
	3.1 *Birds of uplands*			3			3	3
SAC/Ramsar species groups	2.12 Marine mammals	3						
	2.11 Coastal plants			3		3		
	2.10 Amphibia	3	3	3	3	3	3	
	2.9 Mammals of riverine habitats	3	3	3	3		3	
	2.8 Mammals wooded habitats					3	3	
	2.7 Invertebrates of wooded habitats			3		3		
	2.6 Non-migratory fish and invertebrates of rivers	3	3	3	3	3		
	2.5 Anadromous fish	3	3		3			
	2.4 * Liverworts		3	3		3		
	2.3Vascular plants,grassland		3	3		3		
	2.2 Vascular plants, lower plants and invertebrates, wet habitats	3	3	3	3	3		
	2.1 Vascular plants of aquatic habitats	3	3					
SAC/Ramsar habitat groups	1.13.Submerged marine habitats	3	3		3			
	1.11 *Coastal habitats sensitive to abstraction	3	3	3	3	3		
	1.12 Estuarine and intertidal habitats	3	3	3		3		
	1.10 * Coastal habitats		3	3		3		
	1.9 * Upland	3	3	3		3		
	1.8 * Dry heathland habitats	3	3	3		3		
	1.7 * Dry Grassland	3	3	3		3		
	1.6 * *Dry woodlands*	3	3	3		3		
	1.5.*.Standing waters not acidification sensitive	3	3		3			
	1.4 *Standing Waters acidification sensitive	3	3		3			
	1.3 Riverine habitats	3	3		3			
	1.2 * Bogs and wet habitats, acidification sensitive	3	3	3	3	3		
	1.1 * Fens and wet habitats not acidification sensitive	3	3	3	3	3		

KEY TO HAZARDS: Leach = leachate, LFG = Landfill gas, LFG Flare = landfill gas flares or engines, SW = surface water discharges, dust = dust / particulate emissions, Access = physical access, Litter = windborne debris, Noise = noise emissions, Gulls = gulls, corvids, rats & other predatory vermin

NOTES TO TABLE APPENDIX 2/1: *The matrix is not comprehensive and is based on the judgement of staff in the EA, EN and CCW. There may be other hazards and* sensitivities, which will vary according to circumstances. 3 Indicates that at least one of the features in the group is potentially sensitive to the hazard, and the likely exposure of the interest feature to the hazard should be assessed. This should be an exploration of the hazard – pathway- receptor links. Qualifying features have been grouped to facilitate sensitivity assessment. * indicates that the group contains priority habitats or species. Possible impacts associated with these hazards are discussed in Section 2 of this Appendix.

2.0 WASTE MANAGEMENT HAZARDS: EXTENT, IMPACT AND CONTROL

This section considers the waste management activities and the potential risks they pose to European sites. The guidance offered in this section is based on the Environment Agency's recent guidance[2] and other published sources. The information provided in the following sections has been used to guide the scoping exercise undertaken in Section 2 of the Habitats Risk Assessment (Coarse Risk Assessment).

The guidelines presented seek to identify a threshold within which a potential hazard is likely to affect the interest features of a European Site and would therefore require further detailed assessment, i.e. where the risk to the European Site can be identified as neither negligible nor inconsequential. Where it can be clearly shown that there is no pathway for a particular hazard to have an effect upon the interest features of a European Site then these hazards would not normally be considered for further detailed assessment.

Where a hazard requires either control mechanisms, engineering solutions, specific mitigation or management that are not pre-requisites of existing waste management regulation, e.g. Landfill Regulations 2002 and Groundwater Regulations 1998, then it is likely to be necessary to undertake a detailed assessment. There remains a risk that the management systems or controls may fail or cease to operate in the future thus presenting a degree of risk to the European Site.

The following section outlines general guidance for each general hazard category identified by the EA. These are:

- Toxic contamination;
- Nutrient enrichment;
- Habitat Loss or physical damage;
- Siltation;
- Smothering;
- Disturbance; and
- Predation.

2.1 Toxic Contamination

Toxic contamination comprises emissions from waste activities which could be toxic or harmful to the flora and fauna of European Sites.

The sensitivity of habitats and species to toxic contamination may be reflected in a direct effect upon species, either through poisoning or phytotoxic reactions or through indirect effects. An indirect toxic effect may result through the transmission of toxins to higher trophic levels through consumption of prey species or other food sources. Toxic contamination of a single species may destabilize food webs and ultimately cause a shift in community composition towards more pollution tolerant species. Table Appendix 2/1

[2] Environment Agency (2003) Habitats Directive: Work Instruction Appendix 6 - Technical and procedural issues specific to waste management facilities.

highlights those International interest features that are considered to be sensitive to toxic contamination.

Existing regulatory controls (Landfill Regulations 2002 and Groundwater Regulations 1998) ensure that waste sites designed and constructed since 2002 have engineering and system controls in place to prevent many potentially toxic effects occurring outside the installation boundary. Where these systems are in place then the potential effects upon European Sites are likely to be negligible. In particular situations; i.e. where these conditions are not met by a waste site; where it is considered that consequences of a failure of these systems could have a severe effect upon a European site; and where a European interest feature is considered to be especially sensitive further more detailed assessment of risks would be undertaken.

The following section considers the specific waste management activities that could cause toxic contamination: leachate, landfill gas, landfill gas flare emissions, surface water and contaminated dust.

2.1.1 Leachate

Leachate can escape from a waste site and, if it enters surface or groundwater, can pollute water down gradient. Therefore a pathway for possible effects of toxic leachate upon European Sites only occurs where they are hydrologically linked and down gradient of the waste site. Any effects upon European Sites that are up gradient, or in different surface water catchments, to a waste site would be considered negligible or inconsequential.

Pre-requisite permit conditions, under the Groundwater Regulations 1998 and Landfill Regulations 2002, require:

- the prevention of discharges of polluting substances (List I and List II) to groundwater;
- appropriate collection and treatment of leachate; and
- provision of barrier systems, or containment.

These permit conditions mean that potentially toxic effects of leachate upon a European Site from a waste site designed and constructed since 2002 are likely to be negligible.

2.1.2 Landfill Gas

Landfill gas can occur outside the perimeter of waste sites accepting biodegradable wastes where engineering has been below modern standards. Toxic gases may have negative effects upon plants or soil fauna. EA guidance suggests that effects are unlikely beyond a 0.5 km radius. Any effects of landfill gas from waste sites that do not accept biodegradable waste; or are more than 0.5 km away from a European Site are likely to be negligible or inconsequential.

Under the Landfill Regulations 2002, landfill gases must be collected and treated from biodegradable landfill sites. These permit conditions mean that any potential effects of landfill gas upon a European Site from a biodegradable waste site designed and constructed since 2002 are likely to be negligible.

2.1.3 Landfill gas flare emissions

Landfill gas flares and utilisation engines can emit toxic gases, including SO_x, NO_x, hydrocarbons, CO, HCl etc. EA guidance suggests that the volume of exhaust gases are likely to be small in comparison to other combustion facilities and effects at European Sites more than 1 km away are likely to be negligible or inconsequential.

2.1.4 Surface Water

Surface waters may be contaminated by wastes, leachate, construction materials or chemicals used on site resulting in a toxic discharges down stream. EA guidance suggests that effects may be dispersed throughout the downstream catchment, although are most likely to manifested within a few hundred metres of the waste facility. Therefore the effects of contaminated surface waters upon European Sites greater than 500m downstream are likely to be negligible or inconsequential. Where the consequences of a discharge to surface waters could have a severe effect upon a European site, for instance where sensitive aquatic interest features are present downstream, further more detailed assessment of risks would be undertaken.

2.1.5 Contaminated dusts

The effects of toxic contamination of plants, invertebrates and other fauna through dust deposition will depend upon the prevailing wind direction and particle size. Larger particles (>30 μm) will mostly deposit within 100m of the source and small particles (<10μm) can travel up to 1km from the source. Therefore the effects of contaminated dusts upon European Sites greater than 1 km in the direction of prevailing winds are likely to be negligible or inconsequential.

2.2 Nutrient Enrichment

Nutrient enrichment comprises the addition of nutrients arising from activities associated with landfill operations. Nutrient enrichment can result in modifications to the floral composition of a site, directly affecting protected habitats and species of flora or indirectly affecting protected species dependant on the vegetation.

The sensitivity of European interest features to nutrient enrichment are summarised in Table Appendix 2/1. Habitats with naturally low nutrient status support plant species adapted to a nutrient-limited environment and are considered to be especially sensitive, e.g. coastal shingle and saltmarsh and the sensitivity of wetland habitat, such as bog, to aerial deposition[3].

The following section considers the specific waste management activities that could cause nutrient enrichment: leachate, surface water and dust.

[3] JA Lee (1998) Unintentional Effects with Terrestrial Ecosystems. Ecological Effects of Sulphur and Nitrogen Pollution. Journal of Ecology Vol. 86: No 1, pp 1-12.

Existing regulatory controls (Landfill Regulations 2002 and Groundwater Regulations 1998) ensure that waste sites designed and constructed since 2002 have engineering and system controls in place to prevent many potentially enriching effects occurring outside the installation boundary. Where these systems are in place then the potential effects upon European Sites are likely to be negligible. In particular situations; i.e. where these conditions are not met by a waste site; where it is considered that consequences of a failure of these systems could have a severe effect upon a European site; and where a European interest feature is considered to be especially sensitive further more detailed assessment of risks would be undertaken.

2.2.1 Leachate

As described in Section 2.1.1, leachate can escape from a waste site and, if it enters surface or groundwater, can pollute water down gradient. Any effects of nutrient enrichment upon European Sites that are up gradient, or in different surface water catchments, to a waste site are likely to be negligible or inconsequential. Permit conditions controlling leachate within waste sites designed and constructed since 2002 are likely to reduce possible enrichment effects to negligible levels.

2.2.2 Surface Water

As described in Section 2.1.2, surface waters may become nutrient enriched through operations within a waste installation and result in discharges down stream. The effects of nutrient enriched surface waters upon European Sites greater than 500m downstream are likely to be negligible or inconsequential. Where the consequences of a discharge to surface waters could have a severe effect upon a European site, for instance where nutrient sensitive aquatic interest features are present downstream, further more detailed assessment of risks would be undertaken.

2.2.3 Contaminated dusts

As described in Section 2.1.5, the effects of toxic contamination of plants, invertebrates and other fauna through dust deposition will depend upon the prevailing wind direction and particle size. The effects of nutrient enrichment through dust deposition upon European Sites greater than 1 km in the direction of prevailing winds are likely to be negligible or inconsequential.

2.3 Habitat Loss

Habitat loss involves the direct destruction or physical take-up of vegetation, either directly through physical encroachment, land-take or erosion; or indirectly through localised increases in access (inc. monitoring, litter collection, emergency access and remedial schemes) associated with landfill operations; or habitat change such as a lowering of water levels leading to drying of wetland habitats.

Habitat loss can result in the direct loss of individuals or populations of plant or animal species. It may also cause other populations to become demographically unstable or unsustainable, due to loss of prey species or habitat niches for different life history stages.

International interest features that are considered sensitive to habitat loss are summarised in Table Appendix 2/1.

The EA has identified the erosive action of surface waters and physical access to European Sites as part of the operation of a waste installation as potential activities that could cause habitat loss.

2.3.1 Surface Water

The physical passage of water may cause scouring and erosion of bed and bank habitats if flow dynamics are altered by the activity or engineering resulting from the operation of a waste installation. EA guidance suggests that erosion would only manifested within a few hundred metres downstream of the installation boundary and therefore the effects upon European Sites occurring either upstream or downstream and beyond 500m are likely to be negligible or inconsequential.

2.3.2 Physical Access

Physical access would only be an issue where a waste activity directly impinges upon a European Site. Therefore the potential effects upon European Sites not immediately adjacent to a waste installation are likely to be negligible or inconsequential.

2.4 Siltation

Siltation comprises the deterioration of habitat arising through the deposition of sediment from surface water. Siltation can have resultant impacts upon both floral and faunal assemblages and can impact upon populations dependant upon these species.

Siltation may have an effect upon wetland habitats and water levels that could lead to a reduction in the capacity of those habitats to function. Silt could smother wetland vegetation or cause a blockage of wetland drainage that may have an adverse affect upon the functioning of the wetland. Siltation may lead to the drying of ponds or other wetland habitats that are necessary for internationally important species to complete their lifecycle.

Silt can smother or block the feeding and respiratory organs of marine animals and reduce light penetration of the water column. This may reduce primary productivity of shallow waters, or reduce the effectiveness of birds that forage for invertebrates or fish using visual clues. International interest features that are considered sensitive to siltation are summarised in Table Appendix 2/1.

The EA has identified that the effects of silt-laden surface run-off discharged as part of the operation of a waste installation could cause siltation downstream. EA guidance suggests that siltation would only manifested within a few hundred metres downstream of the installation boundary and therefore the effects upon European Sites occurring either upstream or downstream and beyond 500m are likely to be negligible or inconsequential.

2.5 Smothering

Smothering, through the deposition of dust or litter can result in the deterioration of habitats of international importance. The sensitivity of habitats and species to smothering is summarised in Table Appendix2/1.

2.5.1 Dust

Where large amounts of dust are deposited on vegetation over a long time scale (a full growing season for example) there may be some adverse effects upon the plants' photosynthesis, respiration and transpiration. Furthermore, it can lead to phytotoxic gaseous pollutants penetrating the plants[4] (see Section 2.1.5). The overall effect would be a decline in plant productivity. The amounts of dust deposited and its effects are also dependent upon weather conditions as in wet weather less dust will be generated and that which has been deposited upon foliage is likely to be washed off. Bryophytes and lichens may be more susceptible to dust deposition than higher plants.

As described in Section 2.1.5, the effects of dust deposition will depend upon the prevailing wind direction and particle size. The effects of dust smothering upon European Sites greater than 1 km in the direction of prevailing winds are likely to be negligible or inconsequential.

2.5.2 Litter

Due to the large size of the majority of litter only European sites that are immediately adjacent to a waste installation are considered to be susceptible to litter smothering. The effects of litter smothering upon European Sites that are not adjacent to the waste installation are likely to be negligible or inconsequential.

2.6 Disturbance

Disturbance is classified as any activity which may result in a species deviating from normal, preferred behaviour. The effects of disturbance upon species are complex, because species show differing responses to disturbance and in many cases they are able to habituate to low levels of disturbance. In general, the proximity to source, intensity, duration and frequency of any disturbance are the main factors that will affect the severity of an impact.

Different types of disturbance could potentially affect a number of species of conservation interest. Disturbance is generally associated with mammals and birds of international importance, because habitat interest features (e.g. wetlands, dry heath, woodlands) and other fauna (e.g. invertebrate and amphibians) are not considered sensitive to visual, human presence and noise disturbances related to the activities of the landfill site.

Generally speaking, secretive or shy bird species are likely to be more vulnerable to noise, visual, human or pest disturbance. For example, an analysis of the responses of waders and wildfowl to disturbance found that a passive, low-level and continuous disturbance is likely to lead to habituation and active, high level and continuous disturbance is likely to lead to the

[4] Farmer, A. M. (1993) *The Effects of Dust on Vegetation – A Review.* Environmental Pollution, 79: pp.63-75.

displacement of many bird species from the disturbed area, leaving only very tolerant species[5]. The sensitivity of interest features to disturbance is summarized in Table Appendix 2/1.

EA guidance suggests that noise and/or visual disturbance; disturbance associated with increased numbers of pest species (such as crows and gulls); or the use of non-specific bird scaring techniques may have disturbance effects upon protected species.

Disturbance to habitats is also considered as a potential risk, whereby access to European Sites causes a physical disturbance, through trampling etc.

2.6.1 Noise and Visual intrusion

EA guidance suggests that noise and visual intrusion is most likely to be relevant where the waste activity or access routes are within or immediately adjacent to a European Site. Theoretical calculations of noise levels from standard operating equipment at waste facilities (e.g. compactors, trucks, etc) show that increased noise would be attenuated to background levels of 45 dB $_{\text{Aeq 1hr}}$ (average noise levels experienced over 1 hour) within 500m. Research has shown that intense noise sources, such as busy roads, may cause disturbance up to 1km away[6]. Therefore, in the majority of waste management facilities, the effects of noise and visual disturbance upon European Sites would be considered negligible or inconsequential at distances greater than 500 m from the installation boundary or access roads.

Further detailed assessment of noise disturbance would be considered where an intense noise source was identified as likely to occur on a regular basis within a European Site at levels above the World Health Organisation guidelines[7] of 55 dB $_{\text{Aeq 1hr}}$. For instance, the use of noise cannons as bird scaring techniques, would usually be considered for further assessment where a European Site was within 1km of the facility.

2.6.2 Pest species

EA guidance suggests that negative effects of disturbance effects due to pest species is most likely in the vicinity of breeding bird colonies. Waterfowl populations, including migratory wintering birds are considered sensitive to disturbance in both feeding and roosting areas. Terns are considered particularly sensitive to disturbance at breeding sites.

Excessive disturbance can result in reduced food intake and/or increased energy expenditure. This disturbance can be especially damaging during winter months when energy expenditure is high and intake is low.

Gulls usually breed and roost at flat-lying coastal sites, although they are likely to travel anywhere between 25 and 60 km daily for foraging, and therefore the potential impacts of

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[5] Hill, D. *et al.* (1997) Bird Disturbance. Improving the quality and utility of disturbance research. Journal of Applied Ecology. 34, 275-288, BES

[6] Reijnen, Foppen, Veebaas (1997) Disturbance by traffic of breeding birds: evaluation of the effect and consideration in planning and managing road corridors. Biodiversity and Conservation 6, pp 567-581

[7] WHO "Environmental Health Criteria 12: Noise" as referred to in Mineral Planning Guidance 11: The control of Noise at Surface Mineral Workings (1998).

predation resulting from gulls attracted to a waste facility are likely to be wide ranging. SPA and Ramsar sites that have been designated for breeding and migratory bird populations that are within 5km of a waste installation that accepts biodegradable and putrescible wastes are considered for further detailed assessment.

2.6.3 Physical Access

Physical access causing a trampling disturbance effect would be limited to waste facilities that directly impinge or are immediately adjacent to a European Site. Therefore the potential effects of physical access upon European Sites greater than a 100m away from a waste installation are likely to be negligible or inconsequential.

2.7 Predation/Displacement

Waste facilities that accept biodegradable and putrescible wastes have the potential to attract vermin, including gulls, corvids and rodents. Predation and displacement resulting from these pests in the vicinity are most likely to have a negative effect upon birds of international importance. The sensitivity of interest features to predation and displacement are summarised in Table Appendix 2/1.

The EA consider that gulls, corvids and rodents have the potential to cause predation and displacement within European Sites.

2.7.1 Vermin

The home range of brown rat is related to the availability of food, with high concentrations of individuals centred upon and rarely moving far from important food sources. The average home range is reported to be about 0.5km although transient males have been known to travel much further, with a maximum recorded journey of 3.3km[8]. The effects of predation from rodents upon interest features of European Sites are likely to be negligible or inconsequential where distances from the waste facility are greater than 500 m from the installation boundary.

In addition, there is a small risk of raptor species being accidentally poisoned through the use of chemical vermin control. Where raptors that could forage upon such species comprise an interest feature of a European Site further detailed assessment may be necessary.

2.7.2 Predation and Displacement by Gulls and Corvidae

Gulls usually breed and roost at flat-lying coastal sites, although they are likely to travel anywhere between 25 and 60 km daily for foraging, and therefore the potential impacts of predation resulting from gulls attracted to a waste facility are likely to be wide ranging. Where a facility accepts biodegradable wastes and therefore has the potential to attract gulls or corvidae; further, detailed assessment would be undertaken where European sites that are designated for their bird populations occur within 5km.

[8] Corbett *et al* (1991) The Handbook of British Mammals. Third Edition

Various control measures can be implemented to reduce the possible effects of birds attracted to waste sites; although these measures are implemented, and will be assessed, on a case by case basis.

3.0 CONCLUSION AND SUMMARY TABLE

The previous section defines thresholds where the further detailed assessment of a potential hazard posed by the operation of a waste facility would be required to assess the impacts upon a European nature conservation site. These thresholds have been defined by a thorough review of existing guidance and published literature related to the activities of waste facilities. The thresholds defined act as guidance only and where any doubt exists as to whether a potential hazard may require further assessment, the precautionary principle has been applied and further assessment undertaken. Only where effects upon European Sites can be shown to be negligible or inconsequential is a potential hazard not considered further by the Habitats Risk Assessment.

Table Appendix 2/2 below provides a quick reference to the thresholds defined in Section 2 of this Appendix. Refer to the text for the reasoning behind the definition of thresholds presented.

TABLE APPENDIX 2/2. THRESHOLDS FOR EUROPEAN SITES REQUIRING FURTHER ASSESSMENT

Hazard	Emissions or activities associated with waste facility	Thresholds for European Sites requiring further assessment
Toxic Contamination	Toxic leachate	Where European Site is hydrologically linked and occurs downstream or down hydrological gradient.
	Landfill gas	Where European Site occurs less than 0.5 km from waste facility.
	Landfill gas flare emissions	Where European Site occurs less than 1 km from waste facility.
	Surface waters	Where European Site is hydrologically linked and occurs downstream of waste facility.
	Contaminated dusts	Where European Site occurs less than 1 km away in the direction of the prevailing wind.
Nutrient Enrichment	Nutrient rich leachate	Where European Site is hydrologically linked and occurs downstream or down hydrological gradient.
	Surface water	Where European Site is hydrologically linked and occurs downstream of waste facility.
	Dust	Where European Site occurs less than 1 km away in the direction of the prevailing wind.
Habitat loss	Surface water	Where European Site is hydrologically linked and occurs within 500m downstream of waste facility.
	Access/ Land encroachment	Where European Site is immediately adjacent to the waste facility.
Siltation	Surface water	Where European Site is hydrologically linked and occurs within 500m downstream of waste facility.
Smothering	Dust	Where European Site occurs less than 1 km away in the direction of the prevailing wind.
	Litter	Where European Site is immediately adjacent to the waste facility.
Disturbance	Noise/Vibration	Where European Site designated for faunal interest is within 500 m – 1km of the waste facility boundary.
	Physical Access	Where European Site is immediately adjacent to or within 100m of the waste facility.
	Pest species (gulls)	Where a European Sited designated for avian interest is within 5km of a waste facility accepting putrescible waste.
Predation/ Displacement	Rodents	Where a European Site designated for faunal interest is within 500m of a waste facility accepting putrescible waste. Except where the European site is designated for populations of raptors, where further assessment would be required for sites within 5 km.
	Gulls/Corvids	Where a European Sited designated for avian interest is within 5km of a waste facility accepting putrescible waste.

HYDROGEOLOGICAL RISK ASSESSMENT

SECTION B

SECTION B

HYDROGEOLOGICAL RISK ASSESSMENT

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1.0 INTRODUCTION

1.1 Report Context

SLR Consulting Limited (SLR) has been appointed by the CWM Environmental Limited (CWM) to prepare a PPC Permit Application in support of Phase 2 of their Nantycaws Landfill facility, c.8km east of Carmarthen at NGR SN470171 (Drawing No. ESID1). The landfill site is currently operated under Licence Number 34144.

The Nantycaws Landfill site layout is shown in Drawing No. ESID2.

Nantycaws Landfill Phase 2 comprises 5 engineered containment Cells (Cells 1 to 5 inclusive). The site is currently licensed to accept domestic, industrial and commercial wastes, in addition to difficult and special wastes.

Waste disposal operations are currently occurring within Cell 4. Cell 5 is yet to be developed. To date, Cells 1, 2 and 3 have been completed, although only part of Cell 1 has been finally capped, with the remaining areas of these Cells being temporarily capped.

Under the transitional provisions of the Landfill (England and Wales) Regulations 2002, the site has been classified as a landfill for hazardous waste changing to non-hazardous waste. However, it is proposed that for the PPC Application, the site will operate as a non-hazardous facility. This PPC Permit Application relates to operations within the existing site and the full development of Cells 1 to 5.

This report sets out the Hydrogeological Risk Assessment that has been prepared in support of this application. The proposed installation design and the site's setting are detailed within the Environmental Setting and Installation Design Report[1], which should be read in conjunction with this document.

1.2 Conceptual Hydrogeological Site Model

The conceptual hydrogeological site model is presented both in Table HRA1 and Drawing No. HRA1. The model demonstrates the following:

- The site comprises Cells 1 to 5. The development of the site has followed the principle of engineered containment.
- The site is effectively a landraise. It is located in a rural area and has been developed on agricultural land.

[1] SLR Consulting Ltd, 2004, *Nantycaws Landfill, Environmental Setting and Installation Design*, Ref: 4B-610-002/ESID

- The base and sides of the landfill have a composite lining system, comprising HDPE, and GCL (the artificial sealing liner) and underlain by an engineered geological barrier/attenuation layer comprising reworked, locally sourced, Glacial Drift, placed to a maximum permeability of 1 x 10^{-9}m/sec and ranging in thickness between 1m (Subcell 1A in Cell 1, 0.25 to 0.3m (Subcells 1B to 1F, and Cells 2, 3 and 4) and 0.5m in the future Cell 5. All elements of landfill construction are subject to independent Construction Quality Assurance (CQA).

- The bases of the current and remaining landfill cells lie on a thin horizon of in situ Glacial Drift. This is of variable thickness, and may be locally absent. Although typically represented by stiff Boulder Clay, it also contains more granular horizons that are water bearing. These horizons are laterally discontinuous, and may be in hydraulic connection with the underlying Devonian bedrock.

- The bases of Cells lie typically close to the potentiometric surface within the underlying Devonian bedrock. Discrete seepages are also present that are associated with localised groundwater in the Glacial Drift. A groundwater underdrainage system has therefore been installed below all Cells. This system comprises a series of collection drains which drain under gravity to the south, and with finger drains extending up to individual seepages. Currently the groundwater management system discharges to surface water ditches that drain to the Afon Y Bantwen.

- In the longer term provision may be made to seal up these drainage pipes, once landfilling has been completed. This is likely to result in inward hydraulic gradients into parts of the landfill Cells.

- The site is located in a groundwater discharge area, which provides baseflow to adjacent surface water ditches and streams along the perimeter and to the immediate south of the site.

The receptors that have been used within this assessment are as follows:

- For **List I Substances**, the potential receptor has been assumed to be the groundwater directly beneath the landfill site (prior to any dilution occurring); and

- For **List II Substances**, the potential receptor has been assumed to be the groundwater in the Devonian bedrock aquifer at the downstream boundary of the site (Drawing No. HRA1).

TABLE HRA1: SUMMARY OF CONCEPTUAL HYDROGEOLOGICAL MODEL

Hazard	Source	Potential Primary (Unsaturated) Pathways	Potential Secondary (Saturated) Pathways	Potential Receptors	Compliance Point
• Leachate generated within Cells 1 to 5. • Cells 1 to 5 have/will accept a range of commercial, industrial and domestic wastes. • The site therefore represents a potential hazard to ground and surface water resources as it has potential to contain List I and List II Substances. • The development falls within the scope of the Groundwater Directive.	• Nantycaws Landfill site is being developed using the principal of engineered containment.	• The primary pathway is via downward vertical leachate migration within the basal engineered lining system (artificial sealing liner), underlying engineered clay geological barrier / attenuation layer and in situ Glacial Drift. • Following cessation of leachate management there is potential for leachate levels to rise, with migration through the engineered sidewall geological barrier. • Following cessation of local underdrainage, inward hydraulic gradients into the site could potentially develop.	• Groundwater flow within the Devonian bedrock aquifer to the south.	• For List I Substances – the groundwater directly beneath or adjacent to the site (prior to dilution). • For List II Substances – the groundwater at the downstream site boundary within the Devonian bedrock. • The surface water ditches and streams immediately adjacent to the site.	• For List I and List II Substances – groundwater at the downstream site boundary within the Devonian bedrock. • Groundwater quality would be determined in downstream monitoring boreholes.

2.0 HYDROGEOLOGICAL RISK ASSESSMENT

2.1 The Nature of the Hydrogeological Risk Assessment

As set out within Section 1.2, Nantycaws Landfill represents a potential hazard to ground and surface water resources. Consequently, this development has to comply with the requirements of the Groundwater Regulations, 1998, and additional risk assessment work is required.

As set out within the regulatory technical guidance[2], 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);
- 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.

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

- The site setting is sufficiently sensitive to warrant detailed assessment e.g. on highly permeable strata, or close to a large groundwater abstraction; 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 can not be overcome by the adoption of conservative inputs or assumptions.

Given the nature of the Nantycaws Landfill and the site's environmental setting, it is considered appropriate to carry out a complex risk assessment.

[2] Environment Agency, March 2003, *Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels.*

2.2 The Proposed Assessment Scenarios

2.2.1 Lifecycle Phases

It is recognised that the hydrogeological risk assessment must assess compliance with the requirements of the Groundwater Regulations, 1998, throughout the lifecycle of the landfill i.e. from the start of the operational Cells until the point at which the landfill no longer is capable of posing an unacceptable environmental risk.

The different stages of the landfill's lifecycle have been conceptualised and shown on Drawing No. HRA1 and in Table HRA2. A conceptualisation of how different aspects of the technical precautions will perform during the lifecycle of the landfill is also presented. In addition, an indication of how the different technical precautions are modelled within the quantitative assessment is also provided.

TABLE HRA2: HYDROGEOLOGICAL RISK ASSESSMENT SCENARIOS

Scenario	Landfill Source	Landfill Cap[3]	Drainage System	Engineered Liner[4]
	Assumed Function & Parameter	**Assumed Operation and Parameter**	**Assumed Operation and Parameter**	**Assumed Operation and Parameter**
Operational /Active Management (Present - c.30yrs)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source term	No landfill cap during landfilling Infiltration rate specified as average annual rainfall: 1250 +/- 120mm (Normal Distribution) Following capping with geomembrane: 50 +/-10mm (Normal Distribution)	Active Management Leachate Leachate Head Ranging between 0 and 3m, based on slope of cells' floor and sidewall height	Composite engineered liner Cells 1 to 4: HDPE (with CQA) underlain by GCL and 0.25 to 1.0m of engineered clay, with the following permeability distribution: Min: $5x10^{-11}$, $1 x10^{-10}$, $1 x10^{-9}$m/s (Log Triangular Distribution) Cell 5: HDPE (with CQA and leak detection) underlain by GCL and 0.5m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, $1 x10^{-10}$, $1 x10^{-9}$m/s (Log Triangular Distribution)
Post Closure (c.30+ yrs)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source term	Capped with geomembrane and with increasing degradation: 50 +/-10mm (Normal Distribution)	No leachate management	Composite engineered liner Cells 1 to 4: HDPE (with CQA) with increasing defects and underlain by GCL and 0.25 to 1.0m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, $1 x10^{-10}$, $1 x10^{-9}$m/s (Log Triangular Distribution) Cell 5: HDPE (with CQA and leak detection) with increasing defects and underlain by GCL and 0.5m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, $1 x10^{-10}$, $1 x10^{-9}$m/s (Log Triangular Distribution)

[3] Assumed that landfill cap will function as designed up until approximately 250 years. Following that period it has been assumed that is degrades until approximately 1000 years, when final infiltration is equal to effective rainfall.
[4] Assumed that the basal liner will function as designed until approximately 150 years. The number of defects in the basal liner set to double very 100 years thereafter.

TABLE HRA2 (Cont): HYDROGEOLOGICAL RISK ASSESSMENT SCENARIOS

Scenario	Landfill Source	Landfill Cap[5]	Drainage System	Engineered Liner[6]
	Assumed Function & Parameter	**Assumed Operation & Parameter**	**Assumed Operation & Parameter**	**Assumed Operation & Parameter**
Long Term Post Closure (c.1000+ years)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source term	Geomembrane cap assumed non-functional. Infiltration equal to effective rainfall: 600 +/-60mm Normal Distribution	No leachate management	Cells 1 to 5 HDPE assumed to be non-functional. GCL and 0.25 to 1.0m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, $1 x10^{-10}$, $1 x10^{-9}$m/s (Log Triangular Distribution

[5] Assumed that landfill cap will function as designed up until approximately 250 years. Following that period it has been assumed that is degrades until approximately 1000 years, when final infiltration is equal to effective rainfall.

[6] Assumed that the basal liner will function as designed until approximately 150 years. The number of defects in the basal liner set to double very 100 years thereafter.

2.2.2 Accidents and their Consequences

Accidents are considered unintentional incidents that could reasonably occur, which are unforeseeable in terms of their time of occurrence. The process of evaluating environmental risks should therefore include the consideration of the potential impact of accidents as well as the resulting harm.

A qualitative risk assessment of the potential impacts of accidents and resulting damage to engineered management systems is presented in Table HRA3[7]. This also considers the likelihood of the accidents occurring and the magnitude of the consequences of such accidents and failures[8]. This assessment indicates that:

- It has been determined to be either "fairly probable" or "probable" that the consequence of the considered potential accidents would be the site's non-compliance with the requirements of the Groundwater Regulations, 1998, owing to the potentially increased discharge of List I and List II Substances into the environment;

- The prevention of the accidents from occurring is key to the ongoing management of Nantycaws Landfill. Consequently, this places the emphasis on having robust and workable procedures and actions in place in order to prevent them from occurring. More details relating to these procedures are presented within the site's Environmental Management System (EMS).

Given the nature of the outcome, i.e. non-compliance is either "fairly probable" or "probable" following the occurrence of an accident, additional quantitative assessment of the potential events is not considered necessary.

[7] This qualitative assessment has been carried out using the terms and methodology set out within "Environment Agency, November 2002, Draft Guidance on the Management of Landfill Gas".

[8] Given that this risk assessment tests the compliance of the proposed development with the requirements of the Groundwater Regulations, 1998, it is considered appropriate that the magnitude of the consequences should be related to the potential for non-compliance.

TABLE HRA3: QUALITATIVE ASSESSMENT OF ACCIDENTS AND THEIR CONSEQUENCES

Potential Accidents	Likelihood of Occurrence	Implications of Occurrence	Consequence of Occurrence	Likelihood of Non-compliance with the Groundwater Regulations, 1998.
Flooding	Unlikely	• Site inundated • High leachate heads with increased leakage through liner • Potential over-topping of control systems • Reduced attenuation potential	Severe	Probable
Subsidence	Very Unlikely	• Potential breach of the engineered containment • Increased leachate leakage • Reduced attenuation potential	Severe	Probable
Landslides	Extremely Unlikely	• Possible breach of the engineered containment, although this would depend upon the location of the landslide • Increased leachate leakage • Reduced attenuation potential	Significant	Fairly Probable
Fires	Somewhat Unlikely	• Potential breach of the geomembrane and degradation of the leachate management system • Increased leachate leakage	Significant	Fairly Probable

TABLE HRA3 (Cont.): QUALITATIVE ASSESSMENT OF ACCIDENTS AND THEIR CONSEQUENCES

Potential Accidents	Likelihood of Occurrence	Implications of Occurrence	Consequence of Occurrence	Likelihood of Non-compliance with the Groundwater Regulations, 1998.
Explosions	Unlikely	• Potential breach of the engineered containment and degradation of the leachate management system • Increased leachate leakage • Reduced attenuation potential	Severe	Probable
Major Breach of Installation Liner	Unlikely	• Increased leachate leakage • Reduced attenuation potential	Significant	Probable

2.2.3 The Priority Contaminants to be Modelled

The selection of the priority contaminants that have been included within this risk assessment is based on a detailed review of:

- analysis of List I, List II and general substances within the Nantycaws Landfill leachate;
- published data including LandSim defaults and a study by Knox *et.al* (2000)[9] of Trace of Organic Substances in Landfill Leachate of potential leachate quality.

Time series plots for electrical conductivity, chloride and ammoniacal nitrogen are included within Appendix ESID17[10].

The criteria for selecting the priority List I substances to be modelled were:

- those substances present within the Nantycaws leachate at concentrations significantly elevated above their respective Environment Agency Lower Reporting Levels (LRL); and
- the substances most likely to be present in leachate derived from domestic (non-hazardous) landfills as identified by Knox *et al* (2000).

The substances that have been selected for detailed assessment are identified below.

Parameter	**Characteristics**
List I Substances	
Mecoprop	An acid herbicide, with relatively high mobility.
Diethyl phthalate	A hydrocarbon (VOC).
Dichloromethane	A hydrocarbon (VOC).
4-Methylphenol	A hydrocarbon.
Cadmium	A heavy metal.
List II Substances	
Ammoniacal Nitrogen	Exhibits a very high risk factor[11] and common association with landfill leachate, including the Nantycaws leachate.
General Substances	
Chloride	Even though it has a low risk factor, it is typically elevated landfill leachate. It is also a useful contaminant to model as it acts in a conservative manner.

[9] Knox K., *et. al.*, October 2000: *The Occurrence of Trace Organic Compounds in Landfill Leachates and their Removal during On-site Treatment.* Proc. Waste 2000 Conference, Stratford-upon-Avon

[10] SLR Consulting Ltd, 2004, *Nantycaws Landfill, Environmental Setting and Installation Design*, Ref: 4B-610-002/ESID

[11] The very high risk factor reflects the typically very high concentrations in leachate in comparison to the very low Drinking Water Standard (applicable to groundwater) and Environmental Quality Standard (applicable to sensitive surface water environments) for ammoniacal nitrogen.

2.2.4 Determination of Environmental Assessment Limits (EALS)[12]

Compliance with the Groundwater Regulations, 1998, requires that the landfill will not result in discernible discharges of List I substances entering the groundwater and will not cause pollution of groundwater by List II Substances.

With regards to List I Substances, the appropriate Environmental Assessment Limits (EALs) are the levels at which they become "discernible". With regards to the priority List I Substances that are considered within this assessment the Minimum Reporting Values (MRV's)[13] are considered appropriate:

- 0.04µg/l is considered to be appropriate for mecoprop;
- 1µg/l is considered to be appropriate for 4-methylphenol, diethyl phthalate and dichloromethane, as there are no recommended MRV's for these substances;
- 0.1µg/l is considered to be appropriate for cadmium.

With regards to List II Substances, in order to determine both the sensitivity of the groundwater within the vicinity of Nantycaws Landfill and an indication of what could be regarded as "pollution", the approach adopted was to identify the most appropriate groundwater EALs for the contaminants that are present within the leachate. EALs are important as they provide both an indication of groundwater sensitivity as well as target values for the risk estimation process associated with the risk assessment phase of the project.

The EALs that are considered appropriate for Nantycaws Landfill site are derived within Table HRA4, presented below. In order to provide the greatest level of protection, the appropriate EAL for each considered contaminant was determined to be the most stringent applicable standard, except where background groundwater quality exceeds the specified standards. The standards that were considered to be appropriate for Nantycaws Landfill were the Drinking Water Standards (DWSs) and the Environmental Quality Standards (EQSs)[14].

Water quality data from the existing groundwater quality monitoring boreholes upgradient of the site (NACW008 and NACW227) were used to determine appropriate EALs.

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[12] An EAL can be defined as a water quality standard that is defined by UK Regulations (e.g. Water Supply (Water Quality) Regulations 1989), EU Directives (e.g. Drinking Water Directive (80/778/EEC)) or another relevant source (e.g. non-statutory Environmental Quality Standards).

[13] Environment Agency, March 2003, *Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels.*

[14] These were determined to be appropriate after considering Figure 3.1, Determination of Target Concentrations in Groundwater. Environment Agency, October 1999, *Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources*, R&D P20.

TABLE HRA4: DERIVATION OF ENVIRONMENTAL ASSESSMENT LIMITS

Substance	Maximum Concentration in Background Groundwater (NACW008 and NACW227) (mg/l)	UK Drinking Water Standard (mg/l)	Environmental Quality Standard (mg/l)	Resultant EAL (mg/l)
Ammoniacal-N	5.5	0.39	0.015	5.5
Chloride	26	250	250	250

2.3 Numerical Modelling

2.3.1 Justification for Modelling Approach and Software

The hydrogeological risk assessment has been carried out using conservative assumptions regarding the pathways and receptors. The risk assessment has focussed on the functioning of the containment system and attenuative properties of the mineral lining system.

The Environment Agency's LandSim2.5.14 software was used to provide an estimate of the potential risks associated with the existing and proposed development. This software was used for the following reasons:

- It uses Monte Carlo (stochastic) techniques and so allows a probabilistic appreciation of the landfill's performance;
- It provides a consistent approach to the estimation of hydrogeological risks in respect to landfills and groundwater;
- It provides an audited and verified code that is widely accessible;
- It aids comprehensive reporting of input values, assumptions and results;
- The model provides a good indication of the potential leakage rates. This is important as the installation's compliance with the requirements of the Groundwater Regulations, 1998, depends significantly upon the functioning of the containment system;
- It allows appreciation of performance of the landfill development through differing Cells of the landfill development. (see Section 2.4.2, Table HRA2 and Drawing HRA1);
- It allows the estimation of the potential attenuation of contaminants through the mineral element of the liner and underlying unsaturated and vertical pathways; and
- It allows the dilution and attenuation of List II Substances within the aquifer's saturated zone.

The stochastic model has been constructed for this risk assessment to assess potential leakage rates and impacts to the Devonian bedrock aquifer. Throughout this assessment the acceptable probability of an undesirable outcome occurring has been set at the 95%ile confidence level.

In addition, the 95%ile is commonly selected as a reasonable worst case, against which it is acceptable to make decisions taking into account the assumptions and limitations of the modelling process.

2.3.2 Model Parameterisation

The nature of all of the input parameters used, together with the appropriate probability distributions used to describe them are presented in the following:

- Table HRA2: which outlines how certain management systems would operate with time, and the appropriate probability density functions;
- Drawing No HRA1: provides an indication of the variation of input parameters as well as the site's conceptual model; and
- Appendices HRA1-3: contain both electronic and hard copies of the models and parameters used for this assessment.

Parameter values were determined from information directly measured at site wherever possible. If no site data were available, conservative parameter values were taken from authoritative sources or after previous SLR experience at similar sites. Unless certain alternative distributions were apparent (such as uniform, normal, lognormal), triangular distributions were used throughout the modelling process. Log triangular distributions were also used to parameterise leachate concentrations.

With regards to the potential leakage of leachate from the development and the potential dilution of this leachate within the aquifer, there are two key elements: the permeability of the lining system and groundwater flow within the Devonian bedrock.

- The ***permeability of the lining system*** for all Cells – site CQA data indicates that the engineered clay permeability meets the minimum acceptable requirements of $1x10^{-9}$ m/s;
- The ***groundwater flow in the Devonian bedrock*** - the horizontal hydraulic conductivity of the Devonian bedrock (log triangular distribution – min: $1x10^{-6}$, mode:$1x10^{-4}$, max:$1x10^{-3}$ m/s) and thickness of the formation (uniform distribution 5, 15m) have been chosen after review of boreholes logs, lithological descriptions, data for the Nantycaws area and Environment Agency aquifer classification as a 'Minor Aquifer'.

The above elements of the risk assessment are particularly critical to the compliance of the proposed development with the requirements of the Groundwater Regulations, 1998.

2.4 Emissions to Groundwater

This section of the assessment considers whether the predicted discharge from the proposed development complies with the requirements of the Groundwater Regulations, 1998. Electronic and hard copies of all of the models, parameterisation details and model results are presented within Appendices HRA1 - 3.

2.4.1 List I Substances

The hydrogeological risk assessment must demonstrate that the technical precautions would "*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.

Table HRA5 presents the simulated maximum List I Substance resultant concentrations at the base of the mineral liners of Cells 1 to 5. The resultant concentrations reflect the degree of decay and retardation each substance undergoes as it passes through the geological barrier/attenuation layer represented by the engineered clay component of the basal lining system.

TABLE HRA5: LIST I SUBSTANCE - RESULTANT CONCENTRATIONS AT THE BASE OF THE MINERAL LINER (PRIOR TO DILUTION)

Determinand	Maximum Concentration Specified in Leachate Source Term (mg/l)	Highest Resultant Concentration at 95%ile Confidence Level (mg/l)		Discernible Concentration (mg/l)
		Cell 1 to 4	Cell 5	
Cadmium	Cell 1 to 5: 0.105	$<1x10^{-6}$	$<1x10^{-6}$	$1x10^{-4}$
Mecoprop	Cells 1 – 4: 0.033 Cell 5: 0.140	$<2x10^{-5}$	$<1x10^{-6}$	$4x10^{-5}$
Diethyl phthalate	Cells 1 – 4: 0.022 Cell 5: 0.044	$<1x10^{-6}$	$<1x10^{-6}$	$1x10^{-3}$
Dichloromethane	Cells 1 – 4: 0.033 Cell 5: 0.066	$<1x10^{-6}$	$<1x10^{-6}$	$1x10^{-3}$
4-Methylphenol	Cells 1 – 4: 0.063 Cell 5: 0.125	$<1x10^{-6}$	$<1x10^{-6}$	$1x10^{-3}$

Notes:
1. The 95%ile resultant concentrations presented are the highest resultant simulated concentration for the whole landfill lifecycle.
2. Graphs showing resultant concentrations are shown in Appendix HRA3.

Table HRA5 demonstrates that the resultant concentrations are lower than those that have been determined to be discernible. Consequently, it is considered that the modelling has demonstrated that there would be no discernible discharges of List I Substances into the Devonian bedrock groundwater.

2.4.2 List II Substances

Table HRA6, overleaf, presents a summary of the simulated resultant concentrations of List II Substances at the downstream site boundary.

Table HRA6 demonstrates that:

- Full development of Nantycaws Landfill is shown to have little influence on groundwater quality in the Devonian bedrock. Resultant groundwater concentrations at the downstream site boundary are below the respective EALs.
- Consequently, it is considered that Nantycaws Landfill site will have negligible effect on the Devonian bedrock groundwater quality.
- The modelling has demonstrated that the discharge of List II Substances would be sufficiently limited so as to avoid pollution.

TABLE HRA6: LIST II SUBSTANCE - MAXIMUM RESULTANT CONCENTRATIONS AT THE DOWNSTREAM COMPLIANCE POINT (DEVONIAN BEDROCK)

Determinand	Maximum Background Groundwater Concentration (mg/l)	Highest Resultant Concentration at 95%ile Confidence Level (and year of peak) (mg/l)	EAL (mg/l)
Ammoniacal-N	5.5	5.44 (500 to 850 years)	5.5
Chloride	26	67 (150 years)	250

Notes:

1. The 95%ile concentrations presented are the highest resultant simulated concentration for the whole landfill lifecycle.
2. Graphs showing resultant concentrations are shown in Appendix HRA3.
3. Combined resultant water quality at the downstream site boundary represents water quality at the 'compliance point'.

2.5 Review of Technical Precautions

The hydrogeological risk assessment has demonstrated that the proposed development of Nantycaws Landfill complies with the requirements of the Groundwater Regulations, 1998.

A series of essential and technical precautions have been identified as part of the hydrogeological risk assessment and are detailed below.

2.5.1 Capping

The site should continue to be capped with a low permeability membrane cap in order to limit potential water infiltration.

2.5.2 Lining Design

The existing and proposed basal lining systems have been shown by the risk assessment to prevent a discernable discharge of List I Substances to groundwater and prevent pollution by List II Substances.

2.5.3 Leachate Drainage System

The leachate drainage systems should be used to manage leachate levels as considered in this assessment.

2.5.4 Leachate Control

It is essential that leachate elevations are maintained within the range of heads assumed in the assessment. Post closure leachate heads have been assumed to rise to the tops of the sidewall bunds.

The leachate inventory needs to be maintained within the distributions used in this assessment.

2.5.5 Groundwater Management

Local groundwater ingress / seepage relief drains should be used to manage any water encountered during landfill construction works.

2.5.6 Leak Detection System

This should be carried out on the HDPE artificial sealing liner to be installed within Cell 5. Any defects should be repaired and retested prior to waste acceptance.

2.6 Hydrogeological Completion Criteria

With regards to the conditions when Permit Completion will be attained, it is proposed that these would be satisfied when the site no longer has the potential to cause damage to or deterioration of the environment and risk to human health i.e. it no longer poses a potential risk to the environment or human health.

The risk assessment modelling has shown that following cessation of active control of leachate (c.60 years from start of landfilling) Nantycaws Landfill complies with the requirements of the Groundwater Regulations, 1998.

The essential elements of the post closure scenario are as follows:

- Leachate heads have been modelled on the assumption that there is no active control of leachate elevations.
- Maximum leachate heads are modelled.
- The results of the scenario suggest that the site remains compliant with the requirements of the Groundwater Regulations, 1998.
- This modelling therefore suggests that the site could comply with the requirements of the Groundwater Regulations, 1998, following the cessation of active leachate management and the saturation of the waste. Consequently, this suggests that this element of landfill management and control will not be the limiting factor in determining the site's ultimate time to completion.

3.0 REQUISITE SURVEILLANCE

3.1 The Risk Based Monitoring Scheme

The Groundwater Regulations (1998) require that 'requisite surveillance' is undertaken of leachate, groundwater and surface water.

Environmental monitoring is a crucial element of the risk assessment process as it:

- Allows for validation of the risk assessment;
- Can confirm whether risk management options are meeting their desired aims; and
- Provides a warning mechanism if adverse impacts are found.

Control and trigger levels form the basis for assessing groundwater monitoring data at landfill sites.

Control levels are specific assessment criteria relating to groundwater or other relevant parameters and are used to determine whether a landfill is performing as designed. They are levels that are intended to draw attention of site management and the Agency to the development of adverse, or unexpected, trends in the monitoring data. Such trends may results from failure of site engineering or management, or from variations between actual conditions and those assumed within the conceptual model. Control levels should be treated primarily as an early warning system to enable appropriate investigative or corrective measures to be implemented, particularly where there is potential for a trigger level to be breached.

A well-planned method of assessment, agreed between the operator and the Environment Agency, will help to both protect the environment and thereby avoid breaches of trigger levels, and provide clarity and avoid ambiguity when trigger level conditions are breached.

Control levels should therefore:

- Highlight variations between the conceptual model (i.e. assumed behaviour) and observed conditions;
- Identify unambiguous adverse trends which are indicative of leachate impacts;
- Allow for variation in natural water quality from baseline conditions; and
- Give sufficient time to take corrective or remedial action **before** trigger levels are breached.

Trigger levels are specific compliance levels, or regulatory standards. They are defined as criteria at which potential, or risk of future, significant adverse environmental effects and/or breaches of legislation have occurred. Such effects would be consistent with the groundwater having been polluted.

3.2 Leachate, Groundwater and Surface Water Monitoring Schedule

The proposed leachate, groundwater and surface water monitoring schedule is set out within Table HRA7, while the proposed control and trigger levels are presented within Tables HRA8 and HRA9.

Groundwater control and trigger levels have been set for List I substances which will be assessed at all downstream monitoring boreholes annually.

Trigger and control levels for List II substances have been set for the downstream monitoring points.

With regards to the intervals between control level and trigger level testing, it is proposed that comparison of monitoring data with control levels should be carried out each time monitoring data are collected. The monitoring frequency should be increased when there appears to be a danger of the trigger levels being breached, or when there is a rapidly rising trend towards this point. When an adverse trend or breach of a control level is indicated by the monitoring results, contingency actions should be implemented, within pre-specified response times, as agreed with the Environment Agency.

TABLE HRA7: PROPOSED LEACHATE AND GROUNDWATER AND SURFACE WATER MONITORING SCHEDULE

A. Leachate

Locations	Frequency	Measurement and Analytical Suite
Leachate Abstraction Points	Monthly	Leachate level, Electrical Conductivity (Elect. Cond), Chloride (Cl), Ammoniacal-N (NH_4-N), pH
	Quarterly	As monthly plus: Total Alkalinity (CaCO3) (tot alk), Magnesium (Mg), Potassium (K), Total Sulphates (SO_4), Calcium (Ca), Sodium (Na), BOD, COD, TOC, TON, Manganese (Mn), Iron (Fe), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn), Nickel (Ni), Mecoprop, Diethyl phthalate, Dichloromethane, 4-Methylphenol and Cadmium.
	Annual	Monitoring Point Base, List I Screen[21]
Leachate Monitoring Points	Monthly	Leachate Level
	Annual	Monitoring Point Base

[21] Given the uncertainty about the possible range of List I Substances that may be present within the landfill leachate, a combination of six different analytical methods is required for the List I Substance screening exercise as follows: (i) GCMS scan for volatiles; (ii) GCMS scan for semi-volatiles; (iii) derivitised GCMS scan for semi-volatiles; (iv) extraction of organotin compounds; (v) reduction of mercury compounds; and (vi) solution of cadmium compounds.

B. Groundwater

Locations	Frequency	Measurement and Analytical Suite
Groundwater monitoring boreholes: **Devonian bedrock** Upstream NACW219, NACW008 and NACW227 NACW221 Downstream NACW212, NACW205 and BH5/02, NACW203 Groundwater underdrainage discharge from all cells.	Monthly Quarterly Annual	Water level, Electrical Conductivity (Elect. Cond.), Chloride (Cl), Ammoniacal-N (NH_4-N), pH As monthly plus: Total Alkalinity (CaCO3) (tot alk), Magnesium (Mg), Potassium (K), Total Sulphates (SO_4), Calcium (Ca), Sodium (Na), Nitrates (NO3-N), Nitrites (NO2-N), Phosphates (PO4), TON, Manganese (Mn), Iron (Fe), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn), Nickel (Ni) Monitoring Point Base Downstream monitoring points only: Targeted List I Suite based on List I substances identified in leachate above LRL's.
All groundwater monitoring boreholes	Monthly Annual	Water level Monitoring Point Base

C. Surface Water

Locations	Frequency	Measurement and Analytical Suite
Upstream Ditch at SW203 Downstream Ditch at SW201, SW202 and SW204	Monthly Quarterly Annual	Water Level, Temperature (Temp), Electrical Conductivity (EC), pH, Ammoniacal-N (NH_4-N), Chloride (Cl) As monthly plus: total Alkalinity ($CaCO_3$) (tot Alk), Magnesium (Mg), Potassium (K), Zinc (Zn), Copper (Cu), Cadmium (Cd), Nickel (Ni), Iron (Fe), Lead (Pb), Chromium (Cr), total Sulphates (SO_4), Calcium (Ca), Manganese (Mn), Sodium (Na), TOC, TON, Ionic Balance List I Leachate Screen (same as groundwater screening).

TABLE HRA8: LEACHATE CONTROL AND TRIGGER LEVELS

Component of Monitoring Programme	Description
Compliance Locations	All landfill Cells: - Leachate Head – Leachate Monitoring Points - Leachate Quality – Composite leachate sample from Cells 1 to 5 for List II Substances. - Separate leachate samples from Cells 1 & 2 sump, and Cells 3 & 4 and Cell 5 sump for List I Substances.
Appropriate Control and Trigger Levels	<u>Leachate Head</u> Control Level: Cells 1 & 2 sump – 2.5m above base of sump Cells 3 & 4 sump – 2.3m above base of sump Cell 5 sump – 1.5m above base of cell Trigger Level: Cells 1 & 2 sump – 3.0m above base of sump Cells 3, 4 & 5 sump – 2.8m above base of sump Cell 5 sump – 2.0m above base of cell (Note: base of sump is 1m below base of Cells 1, 2 and 4) <u>Leachate Quality</u> • Control levels have been set at 80% of the maximum concentrations assumed within the hydrogeological risk assessment (see below): List I Substances / Cells 1 to 4 / Cell 5 Mecoprop: 0.026mg/l / 0.112mg/l Diethyl phthalate: 0.017mg/l / 0.035mg/l Dichloromethane: 0.026mg/l / 0.053mg/l 4-Methylphenol: 0.050mg/l / 0.101mg/l Cadmium: 0.084mg/l / 0.084mg/l List II Substances / Cells 1 to 5 Ammoniacal-N: 2,912mg/l Chloride: 15,200mg/l • Trigger levels have been set at the maximum concentrations assumed within the hydrogeological risk assessment: List I Substances / Cells 1 to 2 / Cell 5 Mecoprop: 0.033mg/l / 0.140mg/l Diethyl phthalate: 0.022mg/l / 0.044mg/l Dichloromethane: 0.033mg/l / 0.066mg/l 4-Methylphenol: 0.063mg/l / 0.126mg/l Cadmium: 0.105mg/l / 0.105mg/l List II Substances / Cells 1 to 5 Ammoniacal-N: 3,640mg/l Chloride: 19,000mg/l

TABLE HRA9: GROUNDWATER CONTROL AND TRIGGER LEVELS

Component of Monitoring Programme	Description
Compliance Locations	List I and List II Substances – Devonian bedrock RL1, RL2 and replacement for RL3.
Appropriate Control and Trigger Levels	<u>Control Levels</u> • List I Substances. The Groundwater Regulations (1998) prohibit the entry of List I Substances into groundwater. It is not practicable to derive control levels for List I substances in groundwater that can be measured by analytical methods. Control is provided by leachate management and landfill construction protocols. • List II Substances. Increasing trend in groundwater concentrations and four successive exceedences of List II Control Levels. Control levels have been set at 80% of the EAL's. <u>List II Substances</u> Ammoniacal-N: 4.4mg/l Chloride: 200mg/l <u>Trigger Levels</u> Increasing trend in groundwater concentrations and four successive exceedences of Trigger Levels. <u>List I Substances</u> – set at MRVs: Mecoprop: 0.00004mg/l Diethyl phthalate: 0.001mg/l Dichloromethane: 0.001mg/l 4-Methylphenol: 0.001mg/l Cadmium: 0.0001mg/l <u>List II Substances</u> – The relevant EAL: Ammoniacal-N: 5.5mg/l Chloride: 250mg/l

4.0 CONCLUSIONS

4.1 Compliance with the Landfill Regulations, 2003

The results of this risk assessment have established the following:

- The proposed development poses a potential hazard to ground and surface water quality. Consequently, arrangements must be made to collected any contaminated water and leachate that is generated by the site;

- Control and trigger levels have been determined in order to ensure the adequate protection of ground and surface water resources.

4.2 Compliance with the Groundwater Regulations, 1998

The results of this risk assessment have established the following:

- The proposed development poses a potential hazard to ground and surface water quality. Consequently, it falls within the scope applicability of the Groundwater Regulations, 1998.

- This assessment forms the "prior investigation" that must be carried out for this type of development.

- The technical precautions included in the site design prevent the discernible discharge of List I Substances in groundwater throughout the site's lifecycle.

- The existing technical precautions also limit the introduction of List II Substances into groundwater to avoid pollution throughout the site's lifecycle.

- The following essential and technical precautions have been identified as part of the hydrogeological risk assessment:

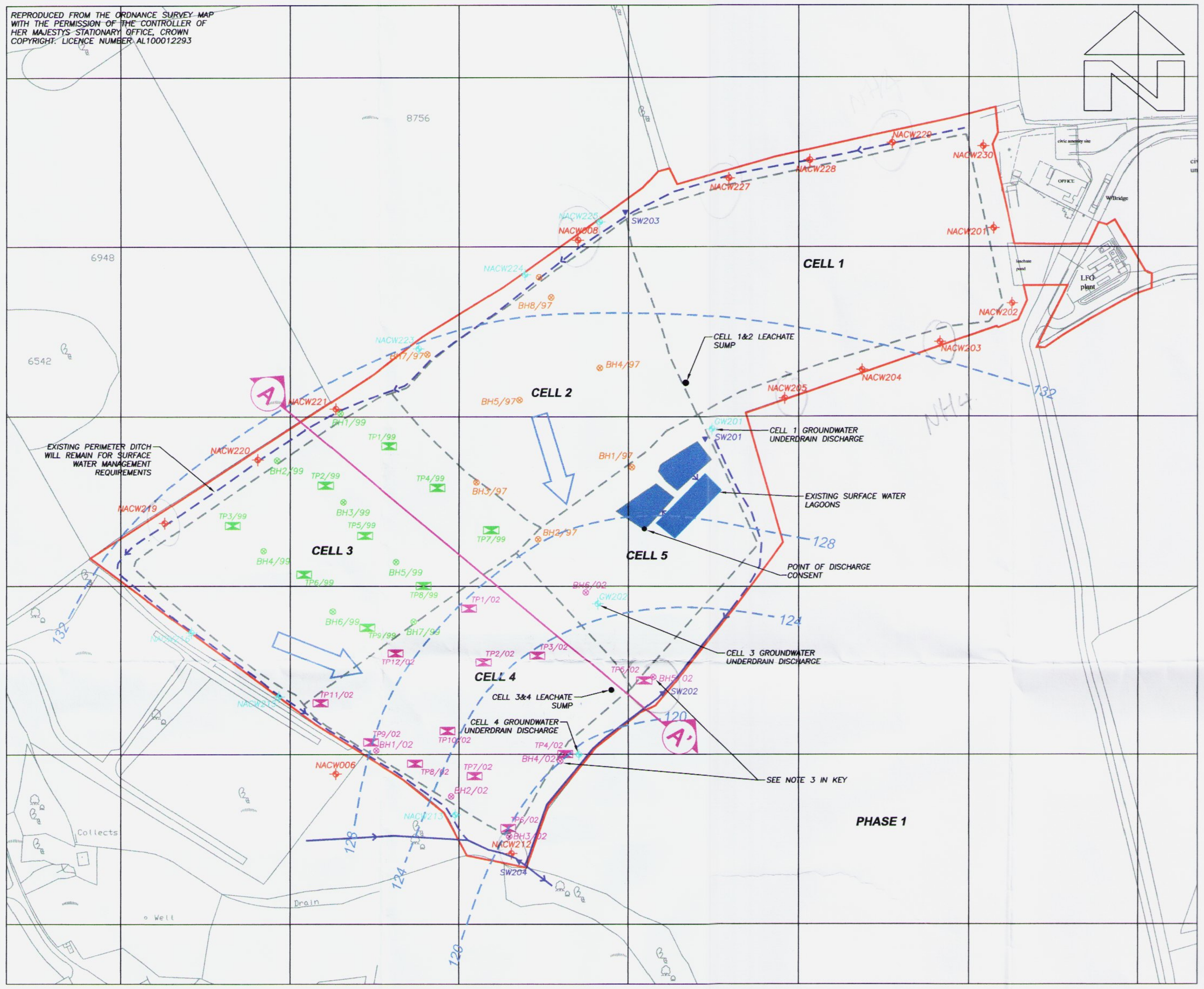
  - Maintenance of leachate elevations to within the heads assumed for this assessment and set as trigger/compliance levels;

  - Maintenance of the leachate inventory within the parameters; and

  - A risk-based programme of leachate and groundwater monitoring and the implementation of control and trigger levels.

The site therefore complies with these relevant requirements of the Groundwater Regulations, 1998.

DRAWINGS

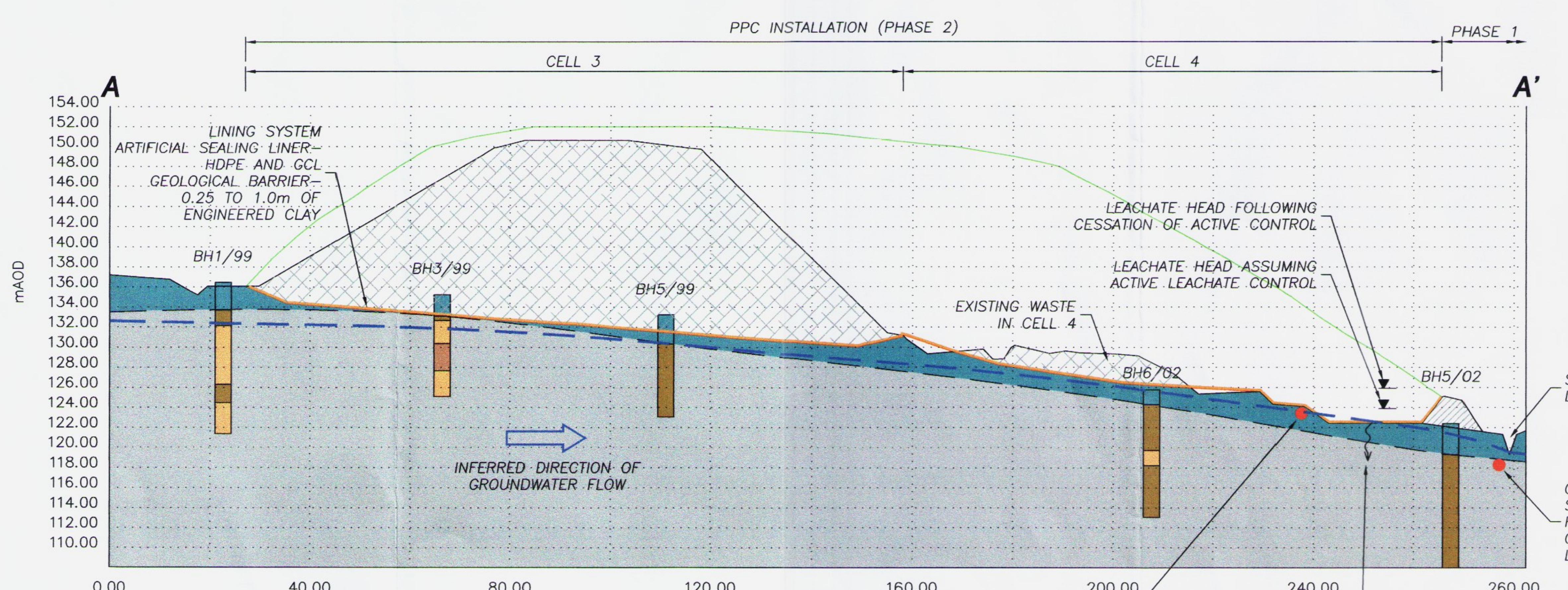


SITE PLAN

SCALE 1:2500

HYDROGEOLOGICAL RISK ASSESSMENT SCENARIOS

Scenario	Landfill Source Assumed Function & Parameter	Landfill Cap Assumed Operation and Parameter	Drainage System Assumed Operation and Parameter	Engineered Liner Assumed Operation and Parameter
Operational /Active Management (Present - c.30yrs)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source term	No landfill cap during landfilling Infiltration rate specified as average annual rainfall: 1250 +/- 120mm (Normal Distribution) Following capping with geomembrane: 50 +/-10mm (Normal Distribution)	Active Management Leachate Leachate Head Ranging between 0 and 3m, based on slope of cells floor and sidewall height	Composite engineered liner Cell 1 to 4: HDPE (with CQA) underlain by GCL and 0.25 to 1.0m of engineered clay, with the following permeability distribution: Min: $5x10^{-11}$, 1 $x10^{-10}$, 1 $x10^{-9}$m/s (Log Triangular Distribution) Cell 5: HDPE (with CQA and leak detection) underlain by GCL and 0.5m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, 1 $x10^{-10}$, 1 $x10^{-9}$m/s (Log Triangular Distribution)
Post Closure (c.30+ yrs)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source term	Capped with geomembrane and with increasing degradation: 50 +/-10mm (Normal Distribution)	No leachate management	Composite engineered liner Cells 1 to 4: HDPE (with CQA) with increasing defects and underlain by GCL and 0.25 to 1.0m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, 1 $x10^{-10}$, 1 $x10^{-9}$m/s (Log Triangular Distribution) Cell 5: HDPE (with CQA and leak detection) with increasing defects and underlain by GCL and 0.5m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, 1 $x10^{-10}$, 1 $x10^{-9}$m/s (Log Triangular Distribution)
Long Term Post Closure (c.1000+ years)	Based on leachate quality from the completed landfill Cells at Nantycaws site and LandSim defaults, with declining source	Geomembrane cap assumed non-functional. Infiltration equal to effective rainfall: 600 +/-60mm Normal Distribution	No leachate management	Cells 1 to 5 HDPE assumed to be non-functional. GCL and 0.25 to 1.0m of engineered clay with the following permeability distribution: Min: $5x10^{-11}$, 1 $x10^{-10}$, 1 $x10^{-9}$m/s (Log Triangular Distribution



NOTE: BOREHOLES HAVE BEEN EXTRAPOLATED ONTO THE CROSS SECTION

SECTION A-A'

SCALE
VERTICAL 1:500
HORIZONTAL 1:1000

NOTES

1. ALL BOREHOLE POSITIONS ARE APPROXIMATE.
2. LOCATION OF BOREHOLES DERIVED FROM GEOTECHNOLOGY SITE INVESTIGATION REPORTS (1999/2002)
3. FLOWING ARTESIAN CONDITIONS WITHIN BOREHOLES BH4/02 & BH5/02 REFLECT CONFINED AQUIFER CONDITIONS ASSOCIATED WITH THE GLACIAL DRIFT, AND GROUNDWATER FLOW PATHS WITHIN SANDSTONE UNITS (BH4/02) AND POSSIBLE FRACTURE ZONE/FAULT AT DEPTH BELOW THE MARL BEDROCK (BH5/02).

KEY – PLAN

- GROUNDWATER MONITORING BOREHOLE
- OTHER EXISTING BOREHOLES (EITHER GAS OR GROUNDWATER UNDERDRAINAGE POINTS)
- PREVIOUS BOREHOLES FOR PHASE 2 CELL 2

GEOTECHNOLOGY (1999) SITE INVESTIGATION
- BOREHOLES
- TRIAL PITS (22/4/99)

GEOTECHNOLOGY (2002) SITE INVESTIGATION
- BOREHOLES
- TRIAL PIT (12/5/02)

- STREAM/DRAINAGE DITCH
- SURFACE WATER SAMPLING POINT
- INFERRED GROUNDWATER CONTOURS (mAOD) (08/08/02)
- INFERRED GROUNDWATER FLOW DIRECTION

KEY – SECTION

BOREHOLE
BH 1/99

GEOLOGY
- GLACIAL DRIFT
- MARL
- SANDSTONE
- SANDSTONE & SILTSTONE

LOWER OLD RED SANDSTONE

- WASTE
- PRE-SETTLEMENT RESTORATION LEVEL
- FORMATION LEVEL
- INFERRED POTENTIOMETRIC SURFACE
- INFERRED GROUNDWATER FLOW DIRECTION

Revision	Issue Date	Issue By	Comments
0	MAY 2004	DM	

CWM ENVIRONMENTAL

Site: NANTYCAWS LANDFILL SITE
Project: PPC APPLICATION
Drawing: **Conceptual Hydrogeological Site Model & Risk Assessment Scenarios**
Date: MAY 2004
Scale: AS SHOWN
Drawing No. HRA1

Rev 0 MAY 04 DM 4B.610.002 NCHRA1CSM&RAS0 4B/MG

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HRA APPENDIX 1

HRA APPENDIX 2

THE DERIVATION AND NATURE OF PARAMETERS USED IN THE RISK ASSESSMENT

A: LANDFILL SOURCE

Item	Value/Description	Source/Derivation
Infiltration in to Open Waste during Operational Period (mm/year)	1,250 ± 120 (Normal Distribution)	As a worst case this assumes that all rainfall is able to enter the waste mass during the operational phases of the landfill.
Effective Precipitation through restored landfill clay cap (mm/annum)	50 ± 10 (Normal Distribution)	Typical accepted values for final restored landfill clay cap.
Effective Infiltration during Long Term Post Closure Period (mm/year)	600 ± 60 (Normal Distribution)	The geomembrane cap can be expected to have degraded sufficiently so that infiltration through the landfill cap will be equivalent to effective precipitation, which is estimated at 50% of annual rainfall.
Start of Geomembrane Cap Degradation (years from end of waste disposal)	250 (Single Value)	LandSim V2.5 Default.
End of Geomembrane Cap Degradation (years from end of waste disposal)	1000 (Single Value)	LandSim V2.5 Default.
Final Waste Thickness (m)	Cell 1A: Min: 7 Most Likely: 13 Max: 16 (Triangular Distribution) Cells 1B-F, Cell 2, Cell 3 inclusive: Min: 2 Most Likely: 18 Max: 22 (Triangular Distribution) Cell 4: Min: 2 Most Likely: 14 Max: 22 (Triangular Distribution) Cell 5: Min: 4 Most Likely: 14 Max: 22 (Triangular Distribution)	Based on current site and proposed scheme.
Waste Porosity (%)	Min: 20 Most Likely: 35 Max: 50 (Triangular Distribution)	Based on types of accepted wastes.
Waste Field Capacity (fraction)	Min: 0.20 Most Likely: 0.30 Max: 0.35 (Triangular Distribution)	Based on types of accepted wastes & LandSim defaults.

A (cont.): LANDFILL SOURCE

Item	Value/Description	Source/Derivation
Waste Density (kg/l)	Min: 0.6 Max: 0.7 (Uniform Distribution)	Based on types of accepted wastes.
Landfill Cap & Basal Area (Ha)	Base / Cap Cell 1A: 0.39 / 0.40 Cells 1B-F, 2 & 3: 5.80 / 5.84 Cell 4: 1.56 / 1.64 Cell 5: 1.0 / 1.1 (Single Values)	As built / proposed scheme.
Head of Leachate when Surface Water Breakout Occurs (m)	Cell 1A: 3 Cells 1B-F, 2 & 3: Min: 1 Max:3 Cell 4: 1.8 Cell 5: 2.0 (Single Values and Uniform Distribution)	Values based on as built / proposed scheme elevations.
End of Filling (years from start of waste disposal)	Cell 1A: 1 Cells 1B-F, 2 & 3: 7 Cell 4: 8 Cell 5: 10 (Single Values)	Based on site existing and proposed scheme.
Duration of Management Controls (years from start of waste disposal)	Cell 1A: 40 Cells 1B-F, 2 & 3: 39 Cell 4: 33 Cell 5: 31 (Single Values)	Based on existing and proposed scheme and assuming 10 years of landfilling, followed by 30 years of management control (proposed scheme).
Time Offset (years)	Cell 1A: 0 Cells 1B-F, 2 & 3: 1 Cell 4: 7 Cell 5: 8 (Single Values)	Based on site existing and proposed scheme.
Leachate Head on Basal Liner (m)	Min / Max Cell 1A: 0.5 / 3 Cells 1B-F, 2 & 3: 0.5 / 3 Cell 4: 0.5 / 2.0 Cell 5: 0.5 / 2.0 (Uniform Distribution)	Based on site design and taking into account the basal gradient of the cells.
Artificial Sealing Liner (Composite Basal Lining System comprising HDPE underlain by GCL).		
HDPE Membrane Defects (per Ha)	Pin Holes (0-5mm^2) Cells 1 to 4 / Cell 5 Min: 0 / 0 Mode: 25 / 13 Max: 25 / 13 Holes (5-100mm^2) Min: 0 / 0 Mode: 5 / 3 Max: 5 / 3 Tears (100-10,000mm^2) Min: 0 / 0 Mode: 0.1 / 0.1 Max: 2 / 1 (Triangular Distribution)	Assuming CQA for all cells. Leak detection survey assumed for Cell 5 only, and any necessary repairs are undertaken prior to waste deposition, as per LandSim V2.5 defaults.

A (cont.): LANDFILL SOURCE

Item	Value/Description	Source/Derivation
Geological Barrier/Attenuation Layer		
Engineered Clay Liner – Thickness (m)	Cell 1A: 1.0 Cells 1B-F, 2 & 3: Min: 0.25, Most Likely: 0.30, Max: 0.30 Cell 4: 0.3 Cell 5: 0.5 (Single Values and Triangular Distribution)	Site Design and CQA data for Nantycaws site.
Onset of HDPE Liner Degradation (years since filling commenced)	150 (Single Value)	LandSim 2.5 default.
Time for Area of Defects to Double (years)	100 (Single Value)	LandSim 2.5 default.
Engineered Clay Liner – Hydraulic Conductivity (m/s)	Min: 5×10^{-11} Most Likely: 1×10^{-10} Max: 1×10^{-9} (Log Triangular Distribution)	Based on permeability test data for the Boulder Clay at the site.
Moisture Content (fraction)	Min: 0.01 Max: 0.20 (Uniform Distribution)	Expected range for effective porosity of the clay liner. These values have been utilised for clay at other landfill sites, with the agreement of the EA.
Engineered Clay Liner - Total Organic Carbon (%)	Min: 0.1 Max: 1.0 (Uniform Distribution)	Assumed values, bearing in mind the shallow depth of the Glacial Boulder Clay sourced on site for the lining system.
Engineered Clay Liner – Density (kg/l)	Min: 1.8 Max: 2.0 (Uniform Distribution)	Typical values based on SLR experience.
Degradation Half Life (years)	Min / Max Mecoprop 0.07 / 0.5 Diethyl phthalate 0.077 / 0.62 Dichloromethane 0.077 / 0.3 4-Methylphenol 0.027 / 0.077 Ammoniacal – N not applicable Cadmium not applicable Chloride not applicable (Uniform Distribution)	Parameters based on published values including Howard et. al. (1991): Handbook of Environmental Degradation Rates.
Retardation (Kd) (l/kg)	Min / Max Cadmium 1.6 / 1,500 Ammoniacal – N 2 / 10 (Uniform Distribution)	LandSim default values.
Partition to Organic Carbon (Koc) (l/kg)	Min / Max Mecoprop 20 / 60 (Uniform Distribution) Diethyl phthalate 123 Dichloromethane 50 4-Methylphenol 49 (Single Values)	Based on published values including values previously accepted by the EA and internet web pages.

Note: No GCL in the composite liner or longitudinal dispersivity in the clay geological barrier/attenuation layer assumed as a worst case.

B: LEACHATE QUALITY

Item	Value/Description	Source/Derivation
Ammoniacal-N (mg/l)	Min: 4.37 Most Likely: 723 Max : 3,640 (Log Triangular Distribution)	Data based on combination of leachate data for site and LandSim defaults as worst case.
Chloride (mg/l)	Min: 1,010 Most Likely: 8,920 Max : 19,000 (Log Triangular Distribution)	
Cadmium (mg/l)	Min: 0.0019 Most Likely: 0.0101 Max : 0.105 (Log Triangular Distribution)	
Mecoprop (mg/l)	Cells 1 to 4 Min: 0.001 Most Likely: 0.0115 Max : 0.033 (Log Triangular Distribution) Cell 5 Min: 0.001 Most Likely: 0.022 Max : 0.140 (Log Triangular Distribution)	Distributions are based on actual site data. Mecoprop distribution for Cell 5 is based on Knox *et. al.* (2000) as a worst case. Worst case maximum concentrations has been assumed for Cell 5, by doubling the measured leachate concentrations for diethyl phthalate and dichloromethane. Also the most likely and maximum concentrations have been doubled for 4-Methylphenol.
Diethyl phthalate (mg/l)	Cells 1 to 4 Min: 0.0001 Most Likely: 0.002 Max : 0.022 (Log Triangular Distribution) Maximum concentration doubled for Cell 5: 0.044	
Dichloromethane (mg/l)	Cells 1 to 4 Min: 0.0001 Most Likely: 0.003 Max : 0.033 (Log Triangular Distribution) Maximum concentration doubled for Cell 5: 0.066	
4-Methylphenol (mg/l)	Cells 1 to 4 Min: 0.0001 Most Likely: 0.024 Max : 0.063 (Log Triangular Distribution) Cell 5 Min: 0.0001 Most Likely: 0.048 Max : 0.125 (Log Triangular Distribution)	

C: UNSATURATED PATHWAYS IN THE GLACIAL DRIFT BELOW THE LANDFILL

Item	Value/Description	Source/Derivation
Thickness (m)	Min: 0 Max: 1.5 (Uniform Distribution)	Range takes account of the variable thickness below the landfill site.
Moisture Content/ Effective Porosity (fraction)	Min: 0.01 Max: 0.20 (Uniform Distribution)	Expected range based on lithological description of the Boulder Clay.
Hydraulic Conductivity (m/s)	Min: 1×10^{-11} Most Likely: 1×10^{-9} Max : 1×10^{-6} (Log Triangular Distribution)	Expected range based on lithological description of the Boulder Clay.
Total Organic Carbon (%)	Min: 0.0 Max : 1.0 (Uniform Distribution)	Assumed values, bearing in mind the shallow depth and nature of the Glacial Boulder Clay below site
Engineered Clay Liner – Density (kg/l)	Min: 1.6 Max: 2.0 (Uniform Distribution)	Typical values based on SLR experience for Glacial Drift strata.
Degradation Half Life (years)	Min Max Mecoprop 0.07 0.5 Diethyl phthalate 0.077 0.62 Dichloromethane 0.077 0.3 4-Methylphenol 0,5 1.0 Ammoniacal – N 3.5 60 Cadmium not applicable Chloride not applicable (Uniform Distribution)	Parameters based on published values including Howard et. al. (1991): Handbook of Environmental Degradation Rates. Ammoniacal-N based on Erskine (2000), with maximum value increased to assume worst case conditions within Boulder Clay.
Retardation (Kd) (l/kg)	Min Max Cadmium 0 1,500 Ammoniacal – N 0 10 (Uniform Distribution)	LandSim default values and reflecting variable Glacial Drift strata.
Partition to Organic Carbon (Koc) (l/kg)	Min Max Mecoprop 20 60 (Uniform Distribution) Diethyl phthalate 123 Dichloromethane 50 4-Methylphenol 49 (Single Values)	Based on published values including values previously accepted by the EA and internet web pages.

Note: No dispersion assumed within the unsaturated zone as a worst case.

D: GEOLOGICAL PATHWAY WITHIN DEVONIAN BEDROCK AQUIFER

Item	Value/Description	Source/Derivation
Hydraulic Conductivity (m/s)	Min: 1×10^{-6} Most Likely: 1×10^{-4} Max : 1×10^{-3} (Log Triangular Distribution)	Values based on lithological description, permeability test data for site boreholes and EA aquifer classification as a 'Minor Aquifer'.
Mixing Zone Thickness (m)	Min: 5 Max: 15 (Uniform Distribution)	Based on site borehole information and topography.
Pathway Width (m)	Cell 1A: 50 Cells 1B-F, 2 & 3: 450 Cell 4: 150 Cell 5: 100 (Single Values)	Existing / proposed scheme and assuming that the compliance point is the downgradient (southern site boundary)
Pathway Length (m)	Min Max Cell 1A: 85 155 Cells 1B-F, 2 & 3: 155 305 Cell 4: 5 155 Cell 5: 45 155 (Uniform Distribution)	Width of pathway perpendicular to groundwater flow within the Frodingham Ironstone.
Regional Hydraulic Gradient (m/m)	Min: 0.02 Most Likely: 0.05 Max: 0.08 (Triangular Distribution)	Based on groundwater level monitoring data at the Nantycaws site.
Pathway Porosity (fraction)	Min: 0.05 Max: 0.20 (Uniform Distribution)	Expected range based on lithological description of the Devonian Bedrock.
Ammoniacal – N Degradation Half Life (years)	6 (Single Value)	Based on Erskine (2000)

Notes
1. No retardation assumed.
2. Degradation for ammoniacal nitrogen only.

E: BACKGROUND GROUNDWATER QUALITY- FRODINGHAM IRONSTONE

Item	Value/Description	Source/Derivation
Ammoniacal-N (mg/l)	Min: 0.01 Max : 5.5 (Uniform Distribution)	Range based on site specific monitoring data for upgradient monitoring boreholes GW008 and GW227
Chloride (mg/l)	Min: 7 Max : 26 (Uniform Distribution)	

HRA APPENDIX 3

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

4-Methylphenol	Non-Volatile
c (l/kg): 0.2919	m (l/kg): 0.0298

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Mecoprop	UNIFORM(0.07,0.5)
Diethylphthalate	UNIFORM(0.077,0.62)
Dichloromethane	UNIFORM(0.077,0.3)
4-Methylphenol	UNIFORM(0.027,0.077)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(3.5,60)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Mecoprop	UNIFORM(0.07,0.5)
Diethylphthalate	UNIFORM(0.077,0.62)
Dichloromethane	UNIFORM(0.077,0.3)
4-Methylphenol	UNIFORM(0.027,0.077)

Aquifer Pathway:

Ammoniacal_N	SINGLE(6)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Mecoprop	SINGLE(1e+009)
Diethylphthalate	SINGLE(1e+009)
Dichloromethane	SINGLE(1e+009)
4-Methylphenol	SINGLE(1e+009)

ckground Concentrations of Contaminants

units in milligrams per litre

Ammoniacal_N	UNIFORM(0.01,5.5)
Chloride	UNIFORM(7,26)

Phase: Cell 1A

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,10)
Infiltration to waste (mm/year):	NORMAL(1250,125)
Infiltration to grassland (mm/year):	NORMAL(600,60)
End of filling (years from start of waste deposit):	1
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 40

Cell dimensions

Cell width (m):	63
Cell length (m):	63
Cell top area (ha):	0.4
Cell base area (ha):	0.3969
Number of cells:	1
Total base area (ha):	0.3969
Total top area (ha):	0.4
Head of Leachate when surface water breakout occurs (m)	SINGLE(3)
Waste porosity (fraction)	TRIANGULAR(0.2,0.35,0.5)
Final waste thickness (m):	TRIANGULAR(7,13,16)
Field capacity (fraction):	TRIANGULAR(0.2,0.3,0.35)
Waste density (kg/l)	UNIFORM(0.6,0.7)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants
All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(4.37,723,3640) *Data are spot measurements of Leachate Quality*
Cadmium	LOGTRIANGULAR(0.0019,0.0101,0.105) *Substance to be treated as List 1*
Chloride	LOGTRIANGULAR(1010,8920,19000) *Data are spot measurements of Leachate Quality*
Mecoprop	LOGTRIANGULAR(0.001,0.0115,0.033) *Substance to be treated as List 1*
Diethylphthalate	LOGTRIANGULAR(0.0001,0.002,0.022) *Substance to be treated as List 1*
Dichloromethane	LOGTRIANGULAR(0.0001,0.0033,0.033) *Substance to be treated as List 1*
4-Methylphenol	LOGTRIANGULAR(0.0001,0.0241,0.0627) *Substance to be treated as List 1*

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.5,3)

Justification for Specified Head
Unjustified value

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Unjustified value

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	UNIFORM(1.8,2)
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(1e-020)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5e-011,1e-010,1e-009)

Justification for Composite: Clay or BES Substrate Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Dichloromethane: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(50)
4-Methylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(49)
Fraction of Organic Carbon (fraction)	UNIFORM(0.001,0.01)

Justification for Liner Kd Values by Species

Unjustified value

Glacial Drift pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0,1.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Pathway Density (kg/l):	UNIFORM(1.6,2)

Justification for Unsat Zone Geometry

Unjustified value

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(1e-011,1e-009,1e-006)

Justification for Unsat Zone Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m): SINGLE(1e-020)

Justification for Unsat Zone Dispersion Properties

Unjustified value

Retardation parameters for Glacial Drift pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0,10)
Cadmium	UNIFORM(0,1500)
Chloride	SINGLE(0)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(20,60)
Diethylphthalate: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(123)
Dichloromethane: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(50)
4-Methylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(49)

Fraction of Organic Carbon (fraction)	UNIFORM(0.001,0.01)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(85,155)
Pathway width (m):	SINGLE(50)

Phase: Cell 1, Cell 2, Cell 3

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,10)
Infiltration to waste (mm/year):	NORMAL(1250,125)
Infiltration to grassland (mm/year):	NORMAL(600,60)
End of filling (years from start of waste deposit):	7
Start of cap degradation (years from end of waste deposit):	*250*
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 39

Cell dimensions

Cell width (m):	400
Cell length (m):	145
Cell top area (ha):	5.84
Cell base area (ha):	5.8
Number of cells:	1
Total base area (ha):	5.8
Total top area (ha):	5.84
Head of Leachate when surface water breakout occurs (m)	UNIFORM(1,3)
Waste porosity (fraction)	TRIANGULAR(0.2,0.35,0.5)
Final waste thickness (m):	TRIANGULAR(2,18,22)
Field capacity (fraction):	TRIANGULAR(0.2,0.3,0.35)
Waste density (kg/l)	UNIFORM(0.6,0.7)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(4.37,723,3640)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0019,0.0101,0.105)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(1010,8920,19000)
	Data are spot measurements of Leachate Quality
Mecoprop	LOGTRIANGULAR(0.0001,0.0115,0.033)
	Substance to be treated as List 1
Diethylphthalate	LOGTRIANGULAR(0.0001,0.002,0.022)
	Substance to be treated as List 1
Dichloromethane	LOGTRIANGULAR(0.0001,0.0033,0.033)
	Substance to be treated as List 1
4-Methylphenol	LOGTRIANGULAR(0.0001,0.0241,0.0627)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.5,3)

Justification for Specified Head
Unjustified value

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Unjustified value

Liner installed under CQA	
Design thickness of clay (m):	TRIANGULAR(0.25,0.3,0.3)
Density of clay (kg/l):	UNIFORM(1.8,2)
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(1e-020)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5e-011,1e-010,1e-009)

Justification for Composite: Clay or BES Substrate Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Dichloromethane: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(50)

4-Methylphenol: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(49)
Fraction of Organic Carbon (fraction)	UNIFORM(0.001,0.01)

Justification for Liner Kd Values by Species

Unjustified value

Glacial Drift pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0,1.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Pathway Density (kg/l):	UNIFORM(1.6,2)

Justification for Unsat Zone Geometry

Unjustified value

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1e-011,1e-009,1e-006)

Justification for Unsat Zone Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m):	SINGLE(1e-020)

Justification for Unsat Zone Dispersion Properties

Unjustified value

Retardation parameters for Glacial Drift pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0,10)
Cadmium	UNIFORM(0,1500)
Chloride	SINGLE(0)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(20,60)
Diethylphthalate: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(123)
Dichloromethane: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(50)
4-Methylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(49)

Fraction of Organic Carbon (fraction)	UNIFORM(0,0.01)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(155,305)
Pathway width (m):	SINGLE(450)

Phase: Cell 4

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,10)
Infiltration to waste (mm/year):	NORMAL(1250,120)
Infiltration to grassland (mm/year):	NORMAL(600,60)
End of filling (years from start of waste deposit):	8
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 33

Cell dimensions

Cell width (m):	125
Cell length (m):	125
Cell top area (ha):	1.64
Cell base area (ha):	1.5625
Number of cells:	1
Total base area (ha):	1.5625
Total top area (ha):	1.64
Head of Leachate when surface water breakout occurs (m)	SINGLE(1.8)
Waste porosity (fraction)	TRIANGULAR(0.2,0.35,0.5)
Final waste thickness (m):	TRIANGULAR(2,14,22)
Field capacity (fraction):	TRIANGULAR(0.2,0.3,0.35)
Waste density (kg/l)	UNIFORM(0.6,0.7)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(4.37,723,3640)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0019,0.0101,0.105)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(1010,8920,19000)
	Data are spot measurements of Leachate Quality
Mecoprop	LOGTRIANGULAR(0.001,0.0115,0.033)
	Substance to be treated as List 1
Diethylphthalate	LOGTRIANGULAR(0.0001,0.002,0.0219)
	Substance to be treated as List 1
Dichloromethane	LOGTRIANGULAR(0.0001,0.0033,0.0323)
	Substance to be treated as List 1
4-Methylphenol	LOGTRIANGULAR(0.0001,0.0241,0.0627)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.5,2)

Justification for Specified Head
Unjustified value

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Unjustified value

Liner installed under CQA

Design thickness of clay (m):	SINGLE(0.3)
Density of clay (kg/l):	UNIFORM(1.8,2)
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(1e-010)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5e-011,1e-010,1e-009)

Justification for Composite: Clay or BES Substrate Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Dichloromethane: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(50)

4-Methylphenol: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(49)
Fraction of Organic Carbon (fraction)	UNIFORM(0.001,0.01)

Justification for Liner Kd Values by Species

Unjustified value

Glacial Drift pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0,1.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Pathway Density (kg/l):	UNIFORM(1.6,2)

Justification for Unsat Zone Geometry

Unjustified value

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1e-011,1e-009,1e-006)

Justification for Unsat Zone Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m):	SINGLE(1e-020)

Justification for Unsat Zone Dispersion Properties

Unjustified value

Retardation parameters for Glacial Drift pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0,10)
Cadmium	UNIFORM(0,1500)
Chloride	SINGLE(0)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(20,60)
Diethylphthalate: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(123)
Dichloromethane: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(50)
4-Methylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(49)
Fraction of Organic Carbon (fraction)	UNIFORM(0,0.01)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(5,155)
Pathway width (m):	SINGLE(150)

Phase: Cell 5

Infiltration Information

Cap design infiltration (mm/year):	NORMAL(50,10)
Infiltration to waste (mm/year):	NORMAL(1250,130)
Infiltration to grassland (mm/year):	NORMAL(600,60)
End of filling (years from start of waste deposit):	10
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration

Unjustified value

Duration of management control (years from the start of waste disposal): 31

Cell dimensions

Cell width (m):	100
Cell length (m):	100
Cell top area (ha):	1.1
Cell base area (ha):	1
Number of cells:	1
Total base area (ha):	1
Total top area (ha):	1.1
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	TRIANGULAR(0.2,0.35,0.5)
Final waste thickness (m):	TRIANGULAR(4,14,22)
Field capacity (fraction):	TRIANGULAR(0.2,0.3,0.35)
Waste density (kg/l)	UNIFORM(0.6,0.7)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(4.37,723,3640)
	Data are spot measurements of Leachate Quality
Cadmium	LOGTRIANGULAR(0.0019,0.0101,0.105)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(1010,8920,19000)
	Data are spot measurements of Leachate Quality
Mecoprop	LOGTRIANGULAR(0.001,0.022,0.14)
	Substance to be treated as List 1
Diethylphthalate	LOGTRIANGULAR(0.0001,0.002,0.044)
	Substance to be treated as List 1
Dichloromethane	LOGTRIANGULAR(0.0001,0.0033,0.066)
	Substance to be treated as List 1
4-Methylphenol	LOGTRIANGULAR(0.0001,0.0482,0.125)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.
Head on EBS is given as (m): UNIFORM(0.5,2)

Justification for Specified Head
Unjustified value

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Unjustified value

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	UNIFORM(1.8,2)
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(1e-020)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 13
Holes:	Minimum 0, Maximum 3
Tears:	Minimum 0, Most Likely 0.1, Maximum 1

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5e-011,1e-010,1e-009)

Justification for Composite: Clay or BES Substrate Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):

Dichloromethane: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(50)

4-Methylphenol: Calculated kd

Partition to Organic Carbon ml/g	SINGLE(49)
Fraction of Organic Carbon (fraction)	UNIFORM(0.001,0.01)

Justification for Liner Kd Values by Species

Unjustified value

Glacial Drift pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0,1.5)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.01,0.2)
Pathway Density (kg/l):	UNIFORM(1.6,2)

Justification for Unsat Zone Geometry

Unjustified value

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(1e-011,1e-009,1e-006)

Justification for Unsat Zone Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m):	SINGLE(1e-020)

Justification for Unsat Zone Dispersion Properties

Unjustified value

Retardation parameters for Glacial Drift pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0,10)
Cadmium	UNIFORM(0,1500)
Chloride	SINGLE(0)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(20,60)
Diethylphthalate: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(123)
Dichloromethane: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(50)
4-Methylphenol: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(49)

Fraction of Organic Carbon (fraction) UNIFORM(0,0.01)

Justification for Kd Values by Species

Unjustified value

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(45,155)
Pathway width (m):	SINGLE(100)

pathway parameters

No Vertical Pathway

Devonian Aquifer pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	UNIFORM(5,15)

Justification for Aquifer Geometry

Unjustified value

Pathway regional gradient (-):	TRIANGULAR(0.02,0.05,0.08)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1e-006,0.0001,0.001)
Pathway porosity (fraction):	UNIFORM(0.05,0.2)

Justification for Aquifer Hydraulics Properties

Unjustified value

Pathway longitudinal dispersivity (m):	SINGLE(1e-020)
Pathway transverse dispersivity (m):	SINGLE(1e-020)

Justification for Aquifer Dispersion Details

Unjustified value

Retardation parameters for Devonian Aquifer pathway

Modelled as aquifer pathway.

No retardation values used in this simulation.

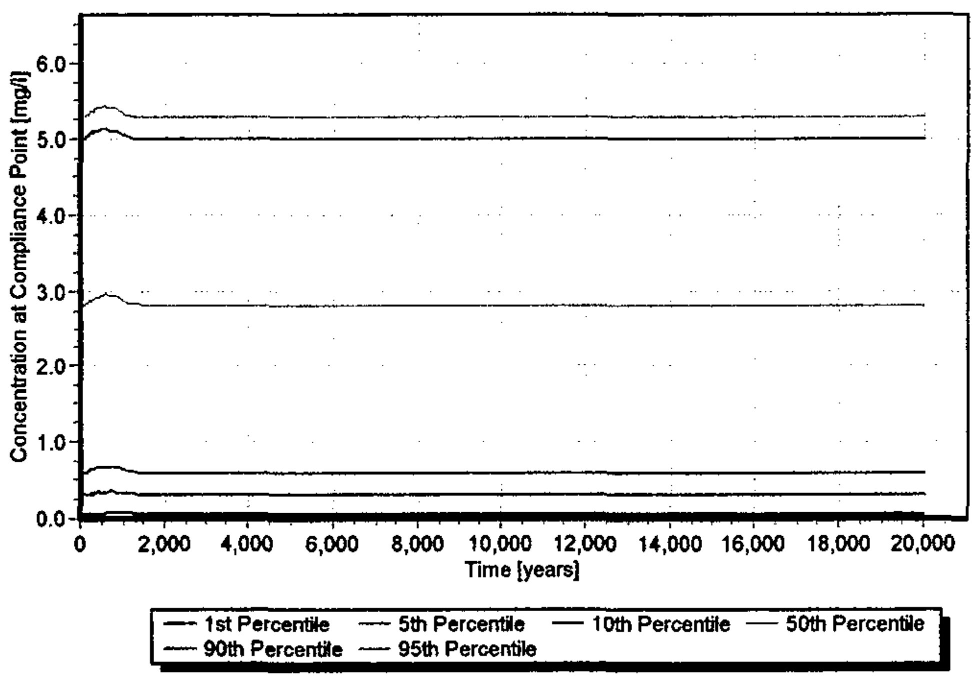
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Ammoniacal_N Concentration at Compliance Point [mg/l]



\Nantycaws HRA April V 1.0.sim

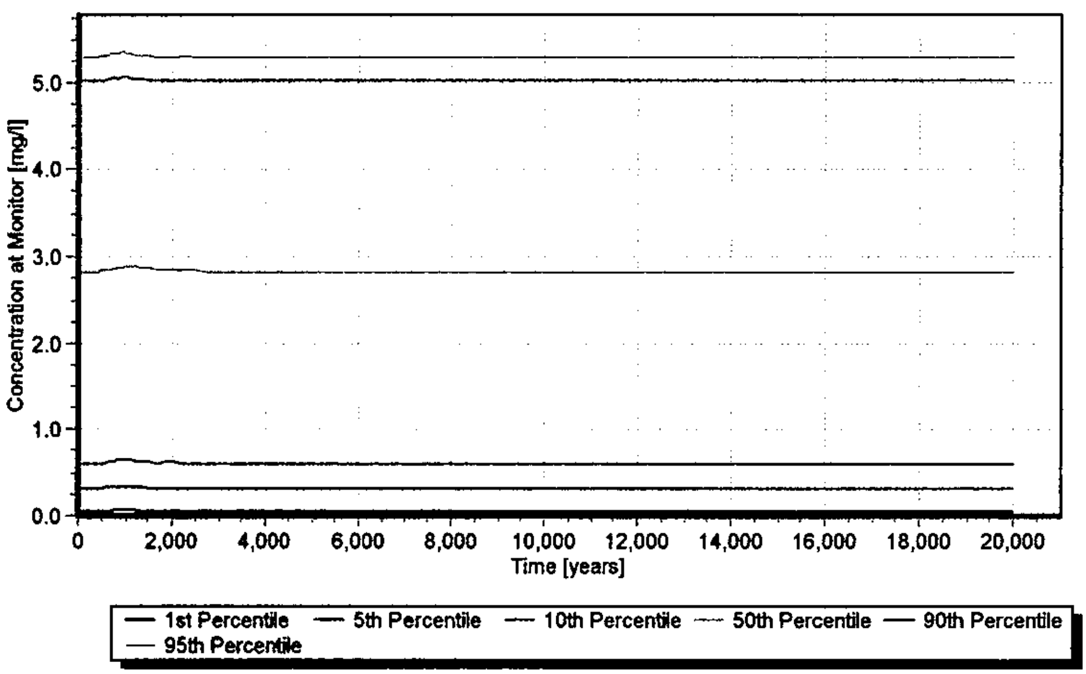
18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Ammoniacal_N Concentration at Monitor [mg/l]



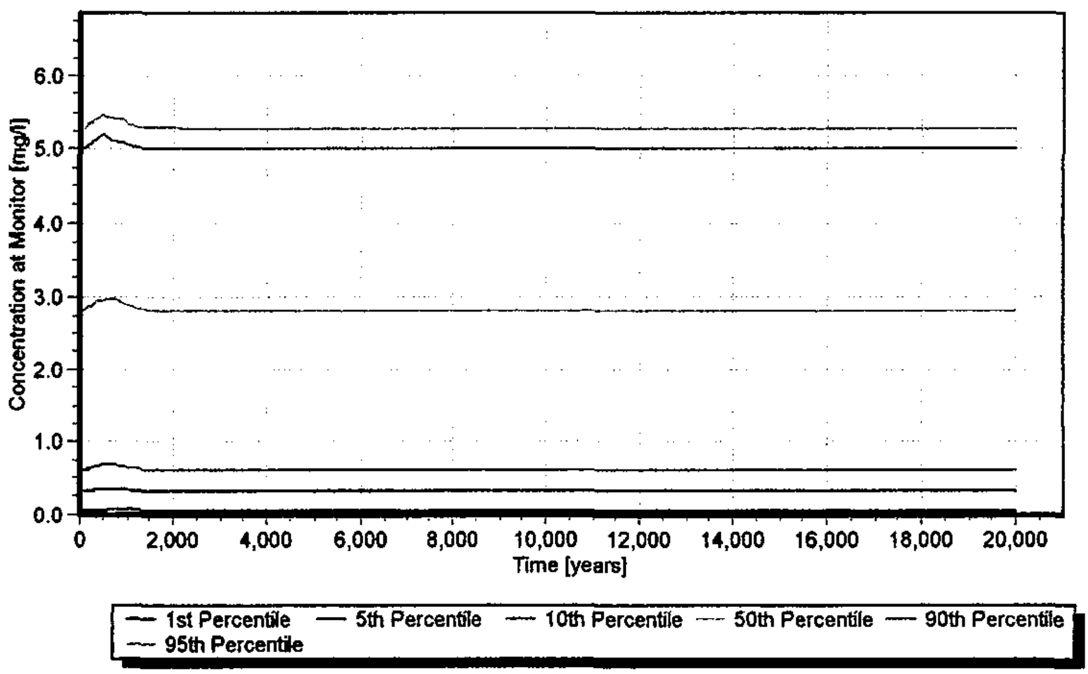
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Ammoniacal_N Concentration at Monitor [mg/l]



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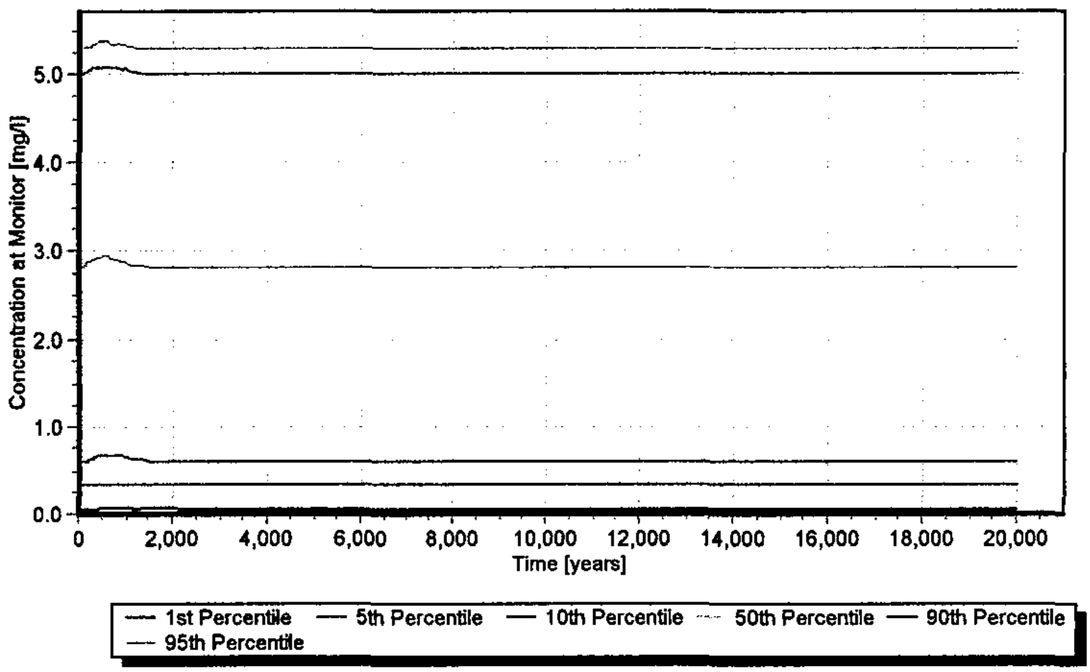
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Ammoniacal_N Concentration at Monitor [mg/l]



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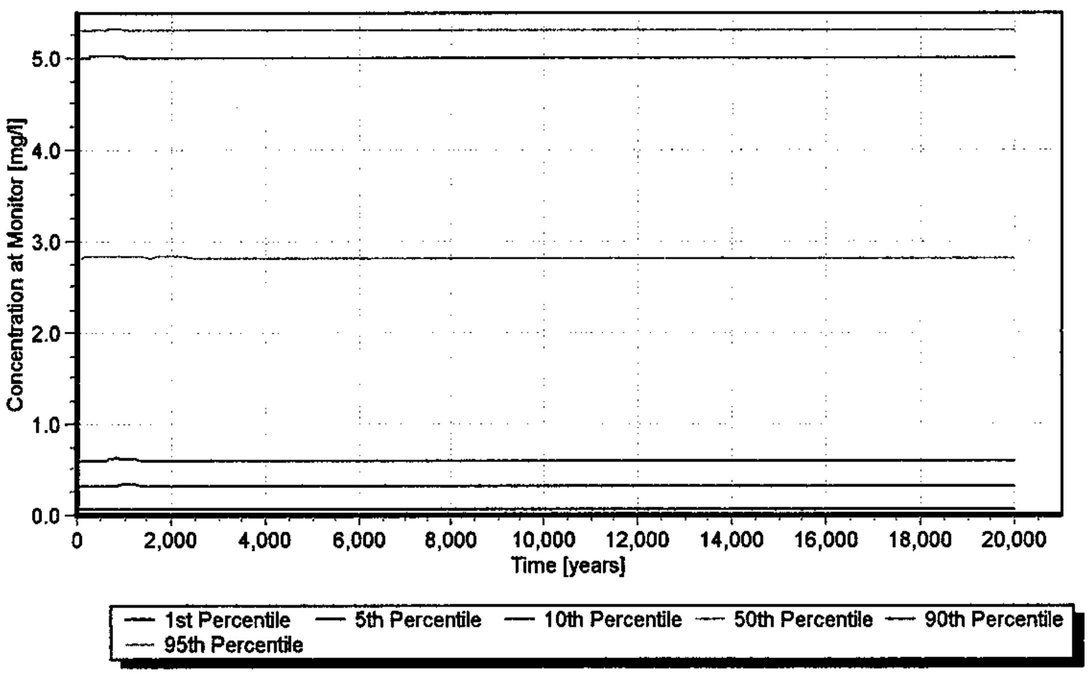
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Ammoniacal_N Concentration at Monitor [mg/l]



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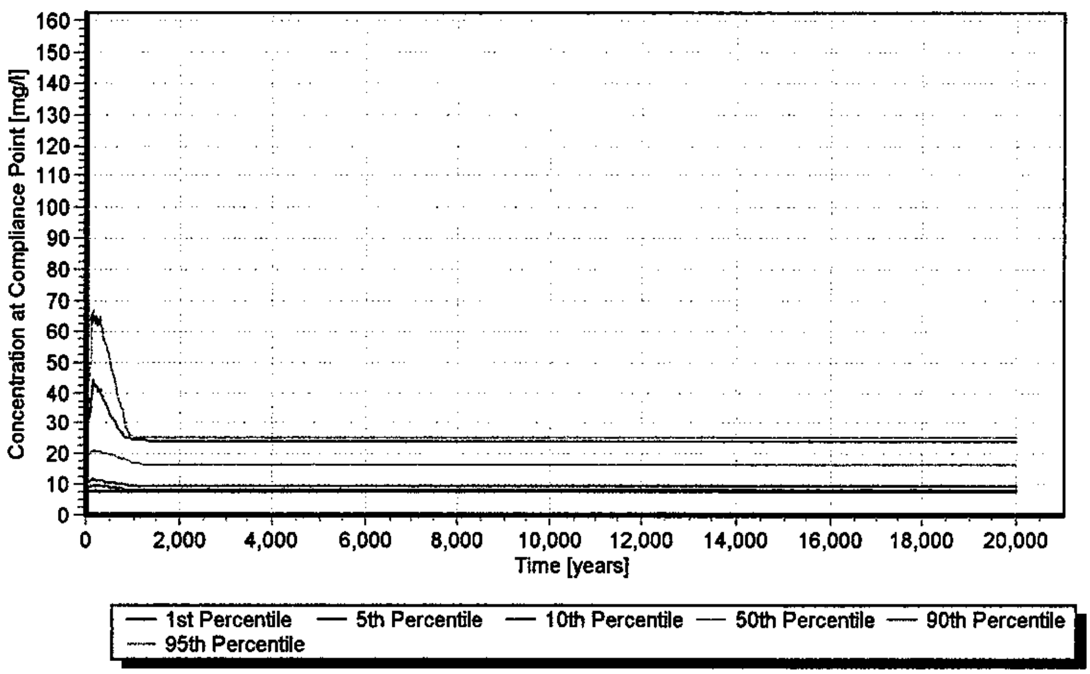
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Chloride Concentration at Compliance Point [mg/l]



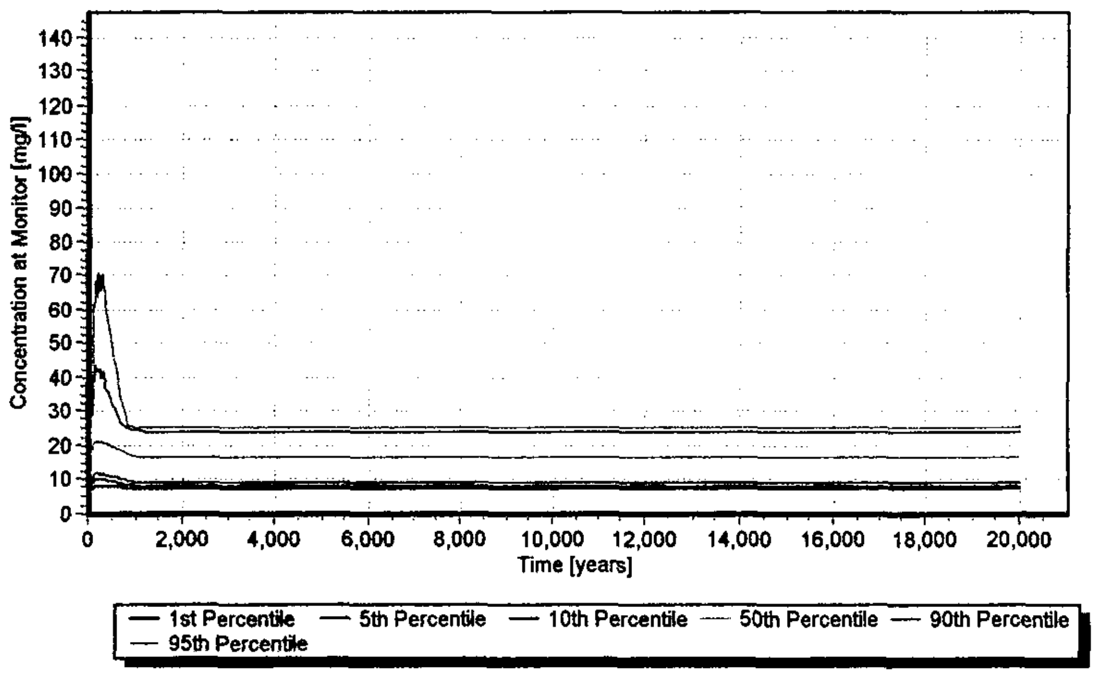
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Chloride Concentration at Monitor [mg/l]



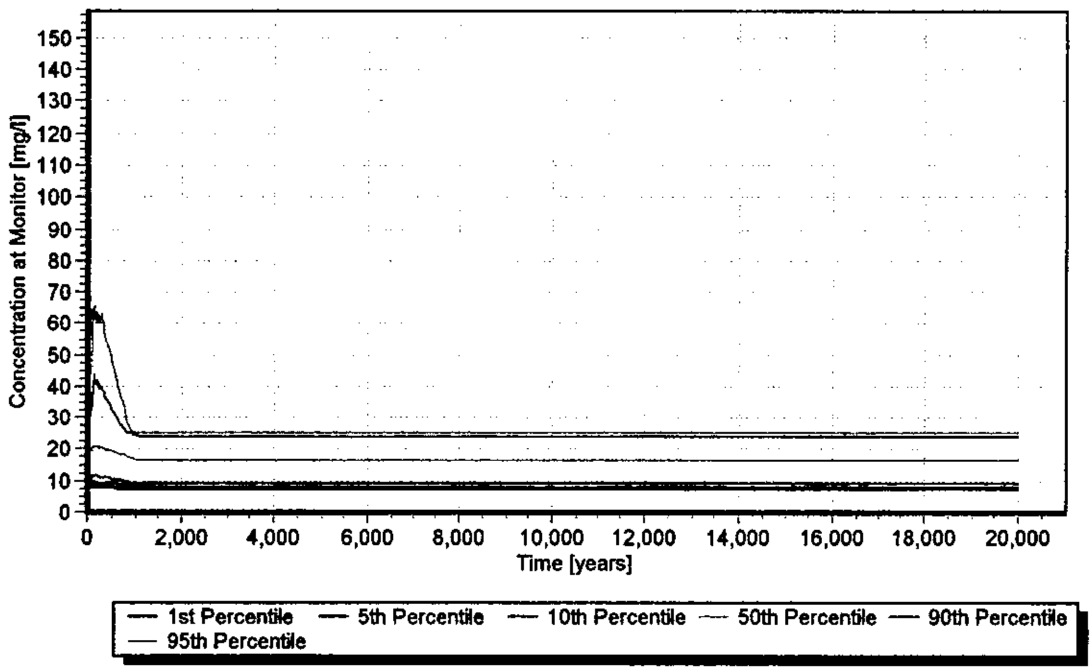
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer: CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Chloride Concentration at Monitor [mg/l]



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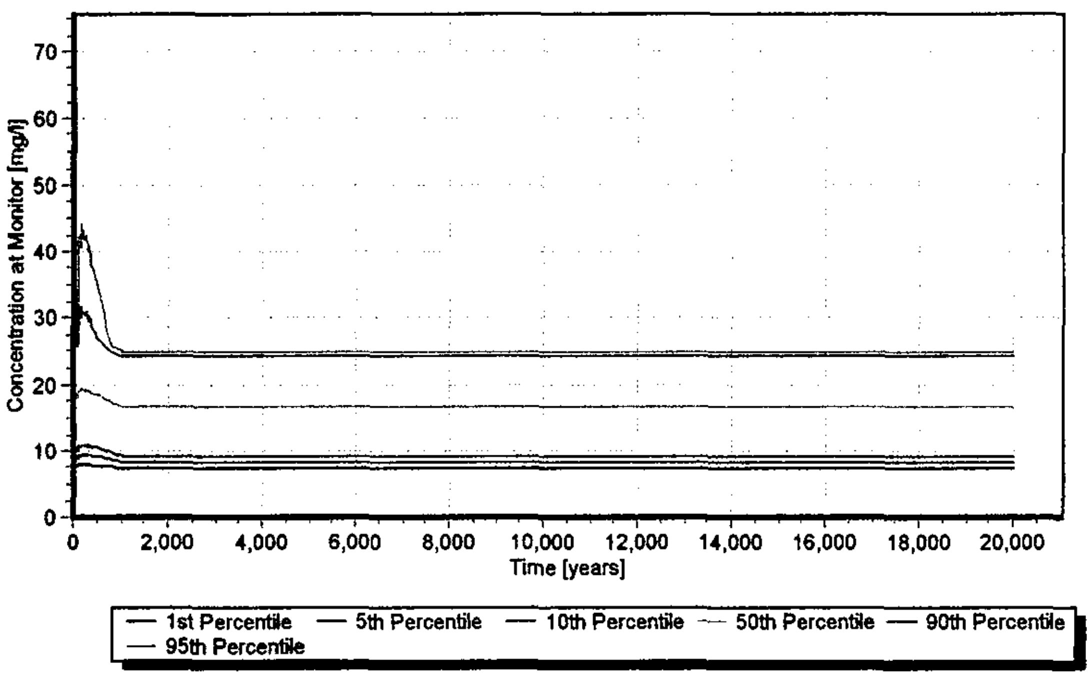
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Chloride Concentration at Monitor [mg/l]



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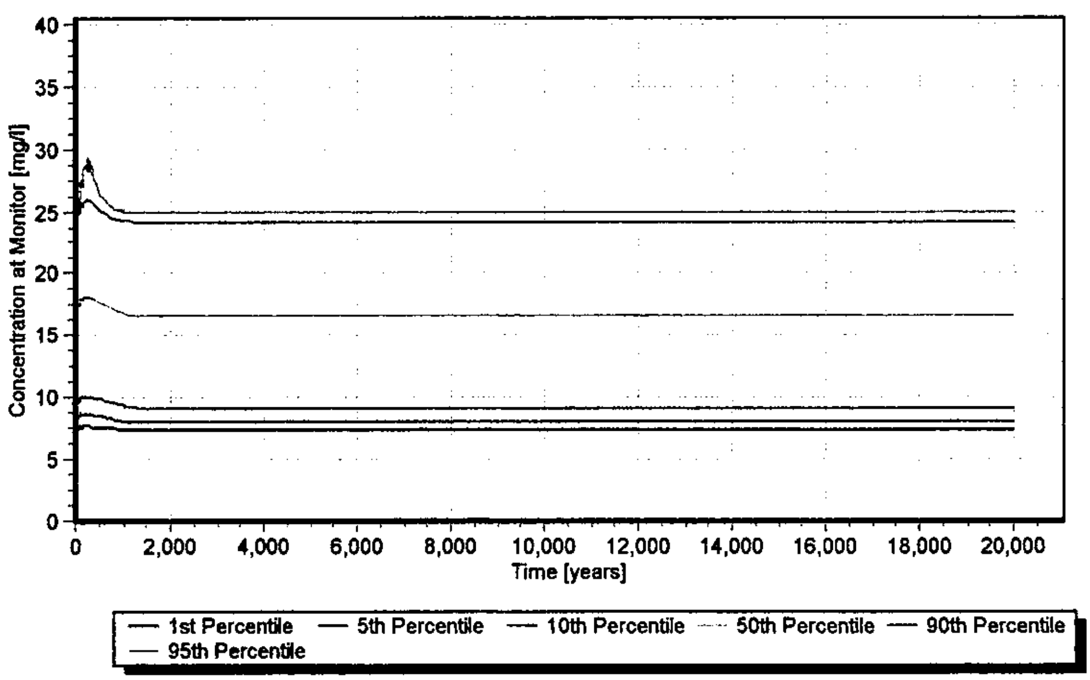
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Chloride Concentration at Monitor [mg/l]



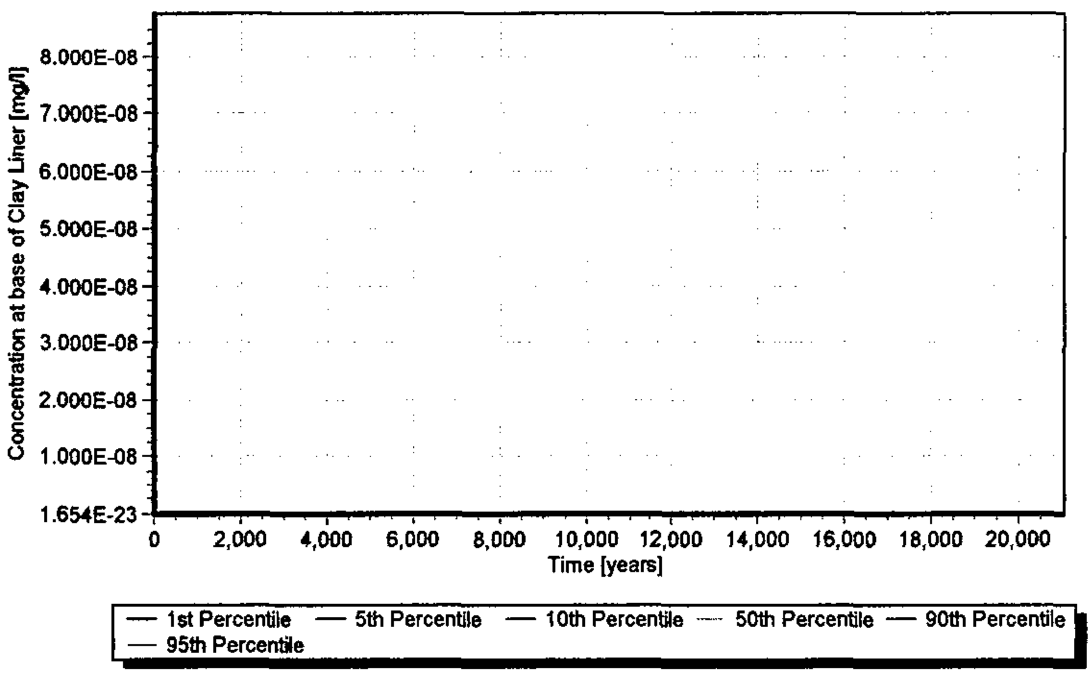
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Cadmium Concentration at base of Clay Liner [mg/l]



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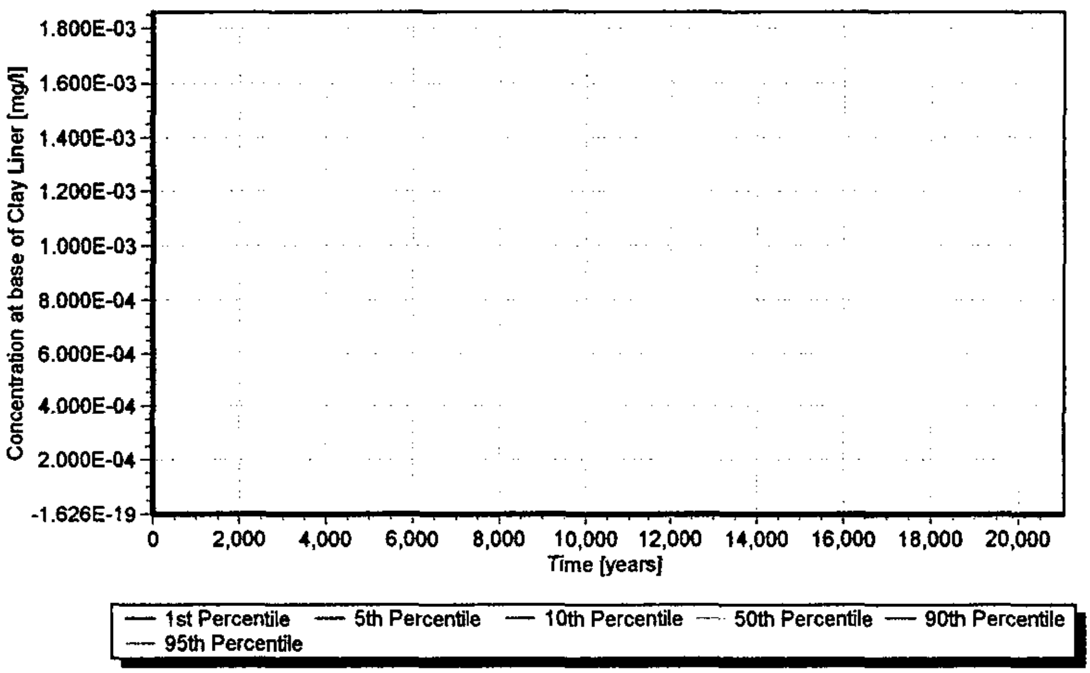
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Cadmium Concentration at base of Clay Liner [mg/l]



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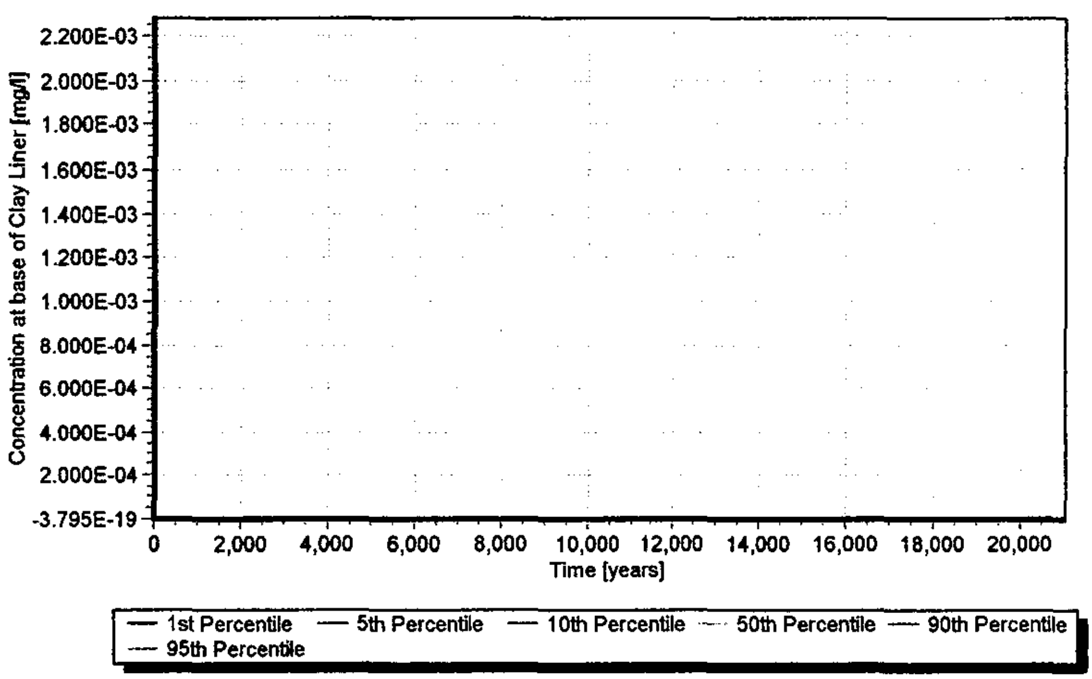
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Cadmium Concentration at base of Clay Liner [mg/l]



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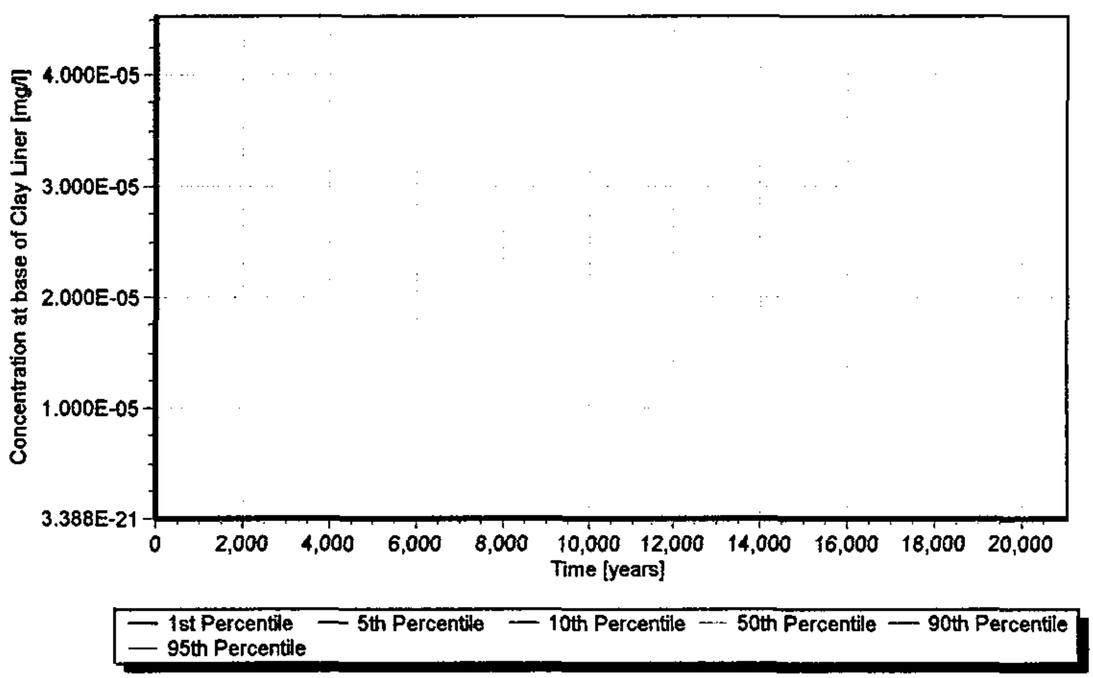
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Cadmium Concentration at base of Clay Liner [mg/l]



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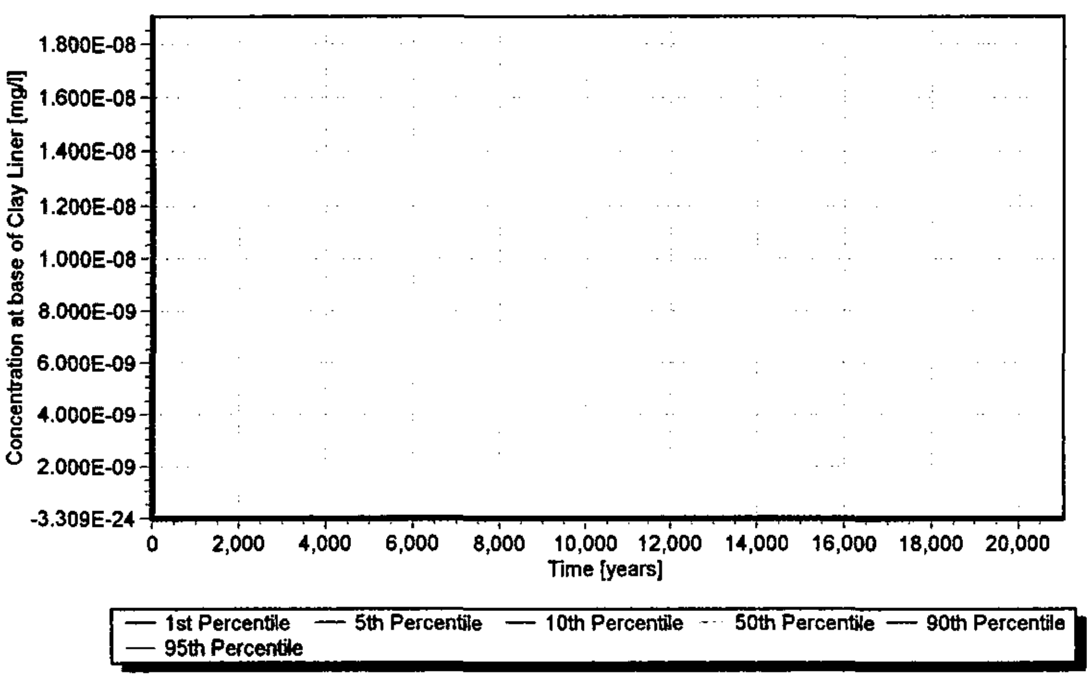
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Mecoprop Concentration at base of Clay Liner [mg/l]



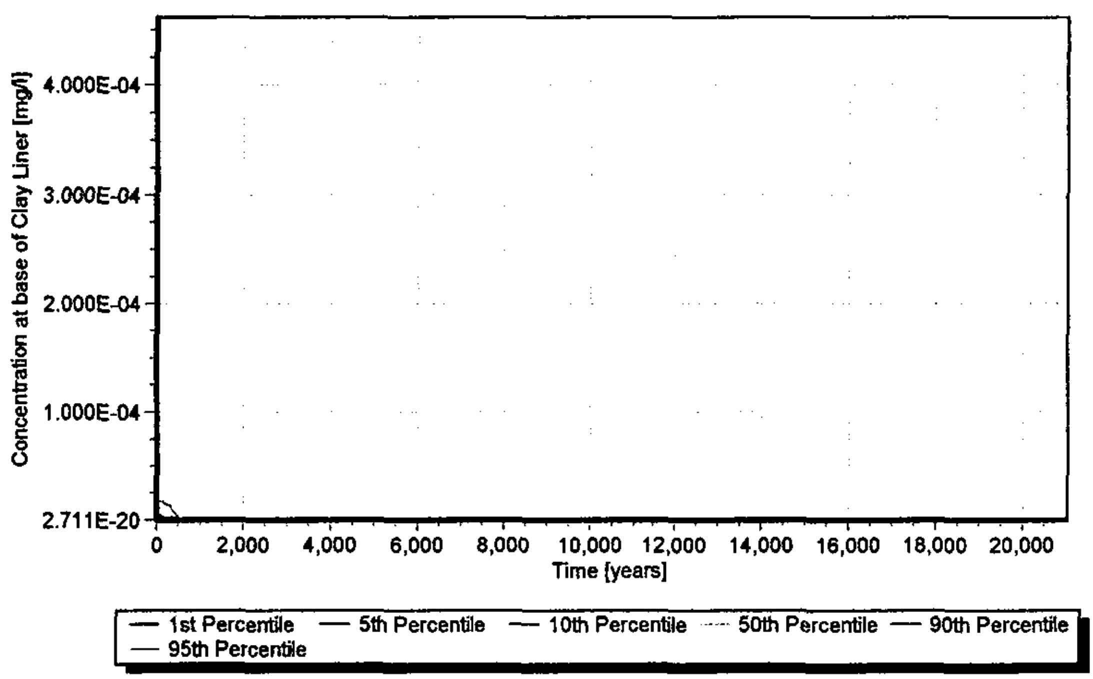
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Mecoprop Concentration at base of Clay Liner [mg/l]



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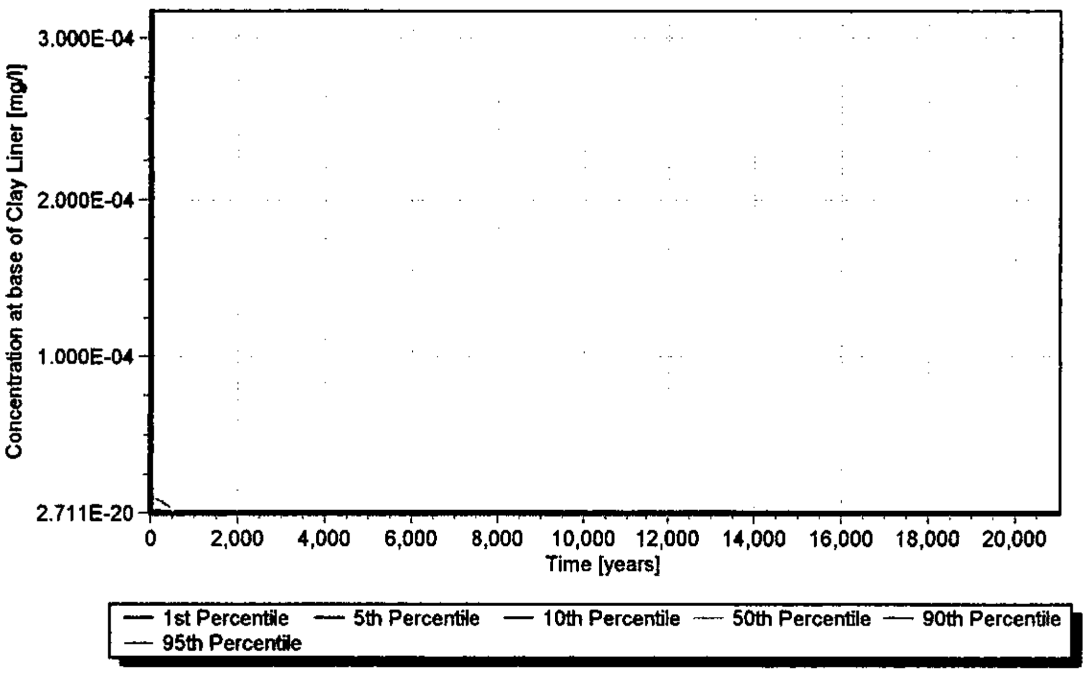
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Mecoprop Concentration at base of Clay Liner [mg/l]



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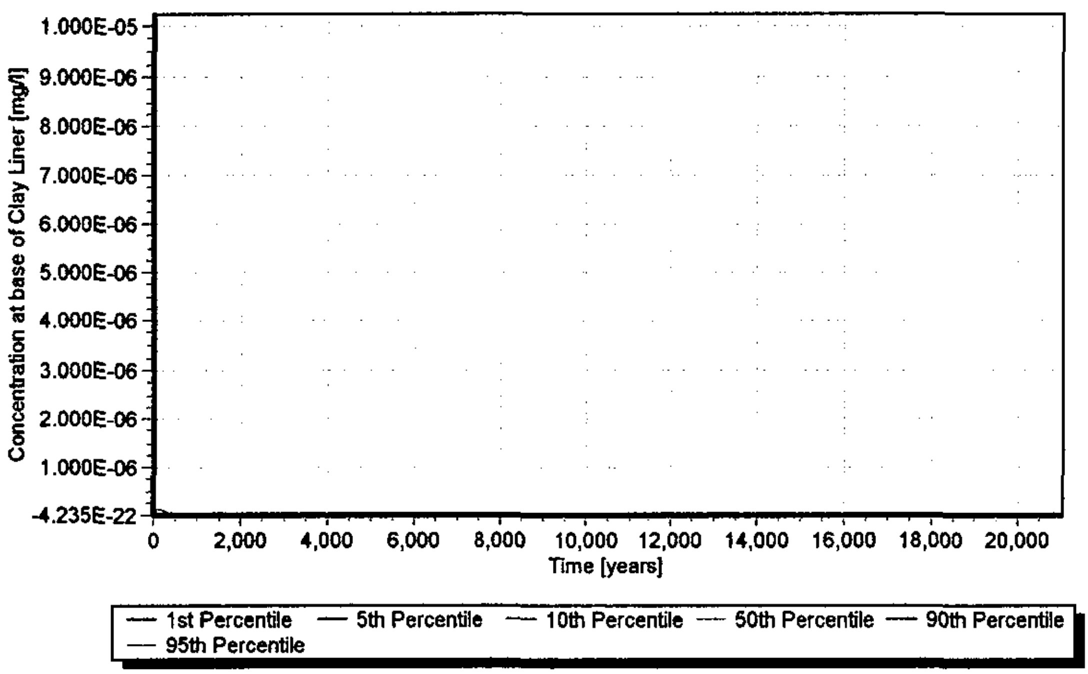
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Mecoprop Concentration at base of Clay Liner [mg/l]



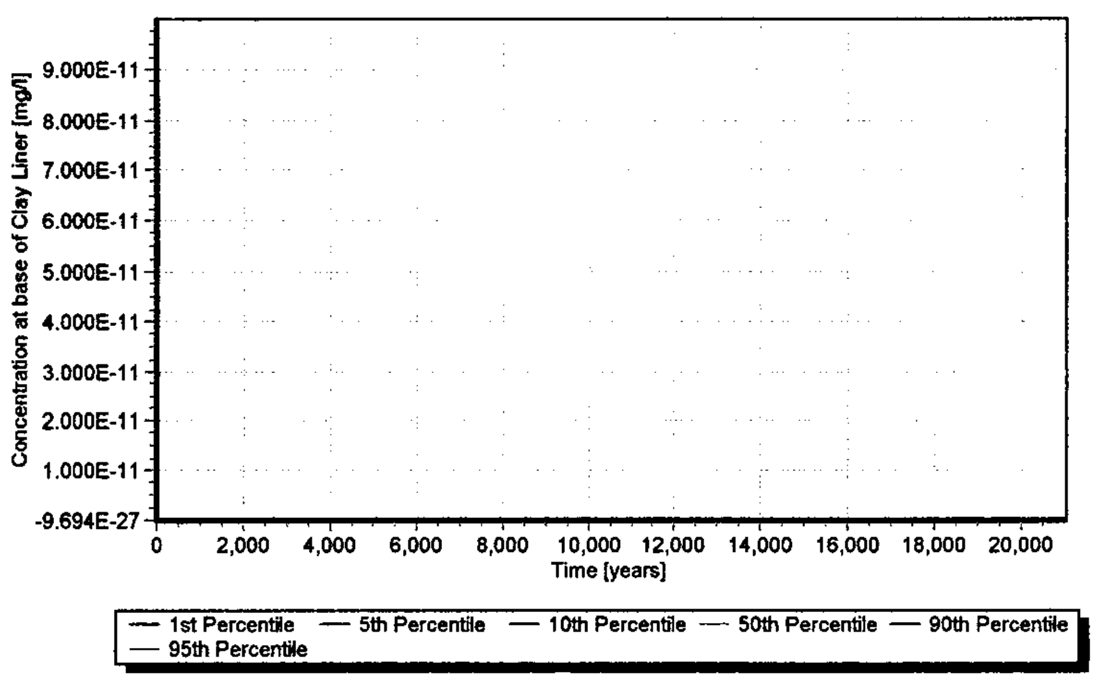
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Diethylphthalate Concentration at base of Clay Liner [mg/l]



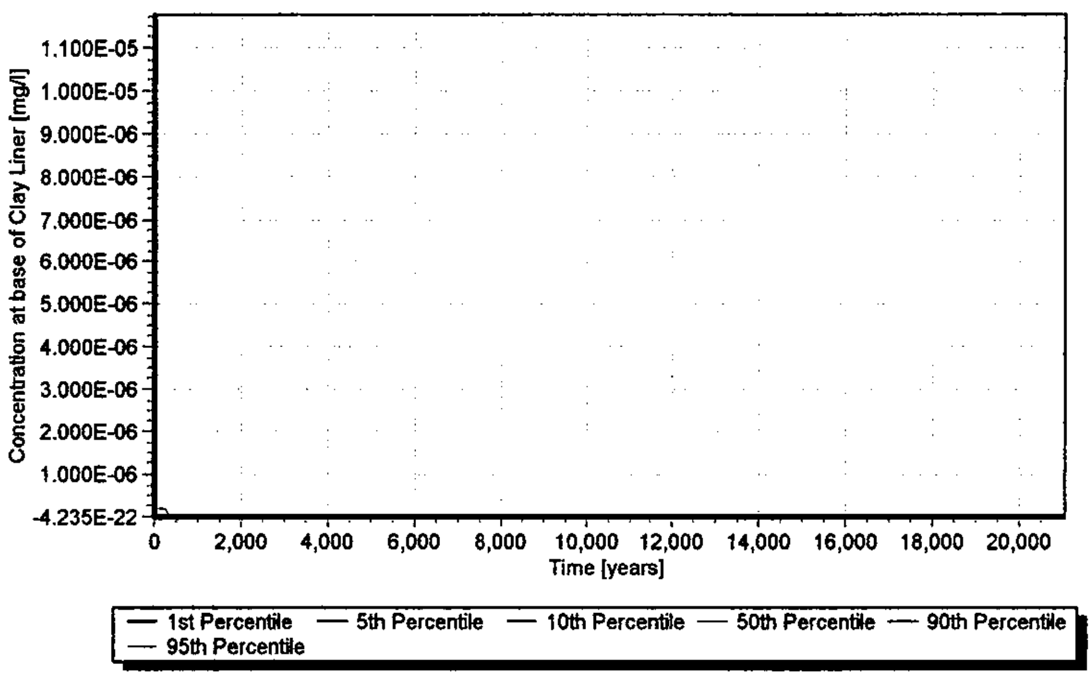
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Diethylphthalate Concentration at base of Clay Liner [mg/l]



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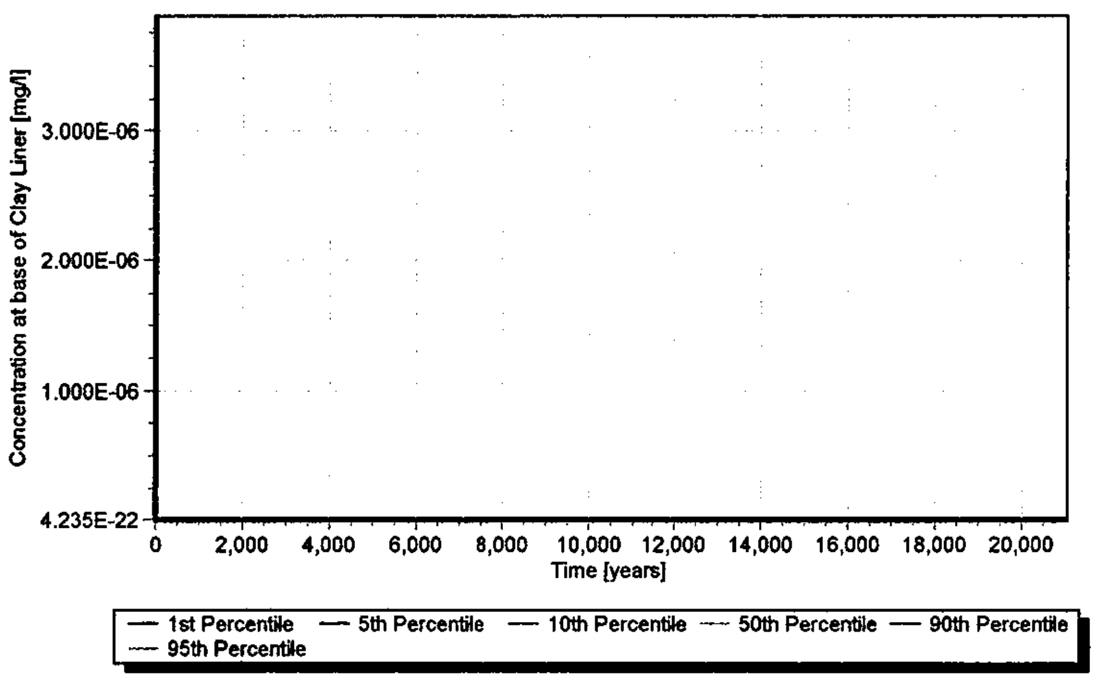
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Diethylphthalate Concentration at base of Clay Liner [mg/l]



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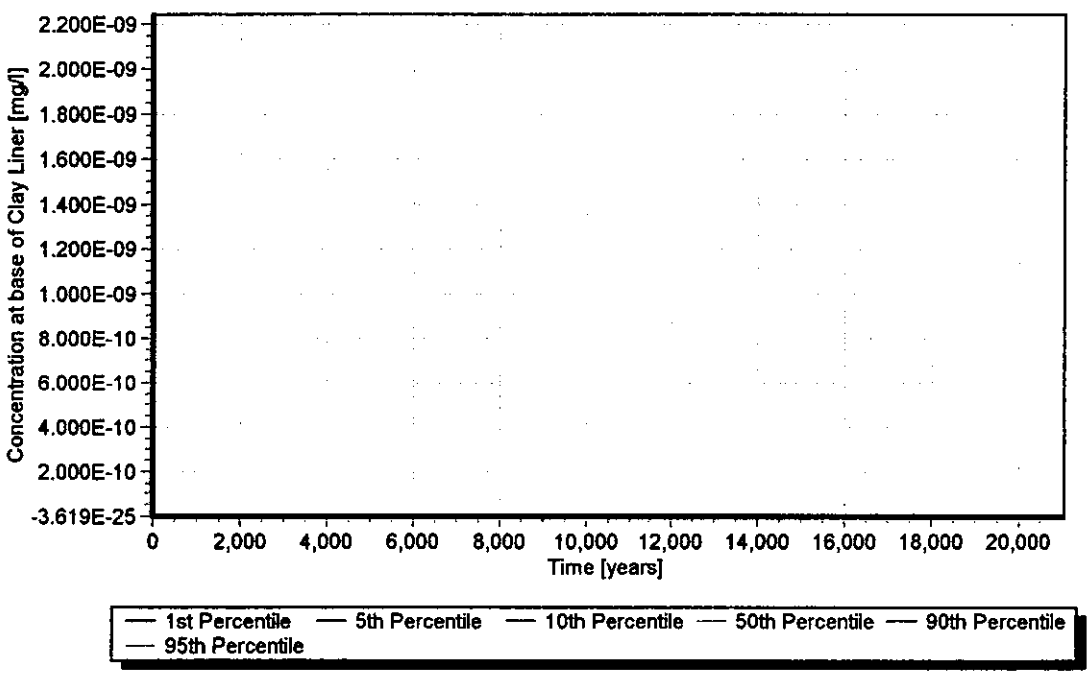
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Diethylphthalate Concentration at base of Clay Liner [mg/l]



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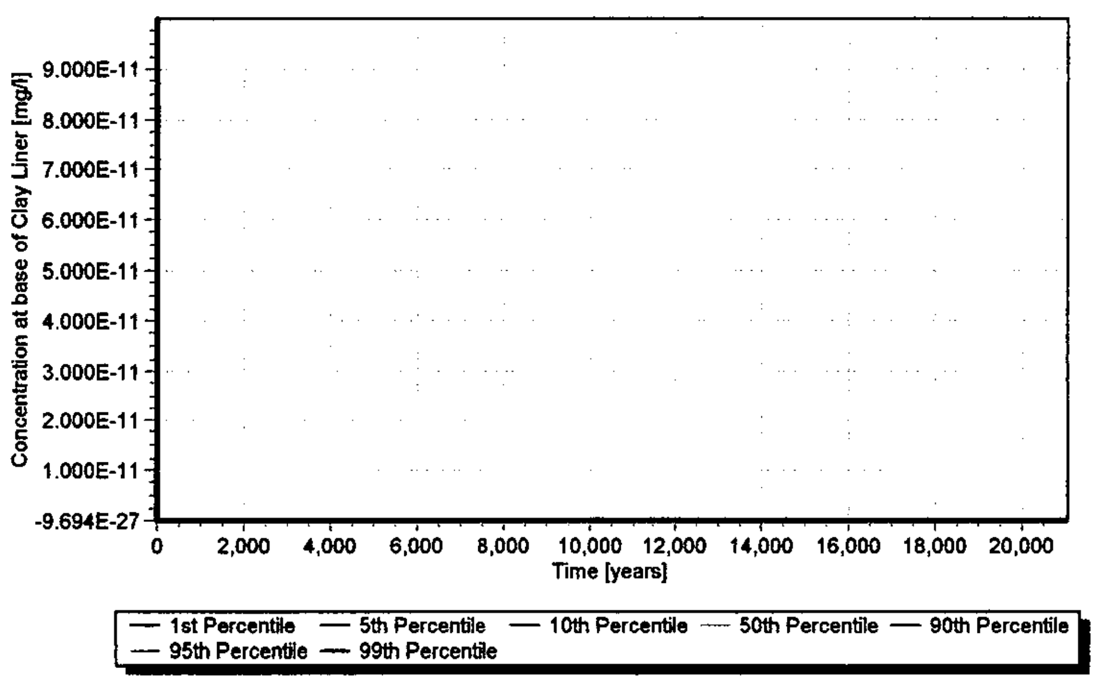
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, Dichloromethane Concentration at base of Clay Liner [mg/l]



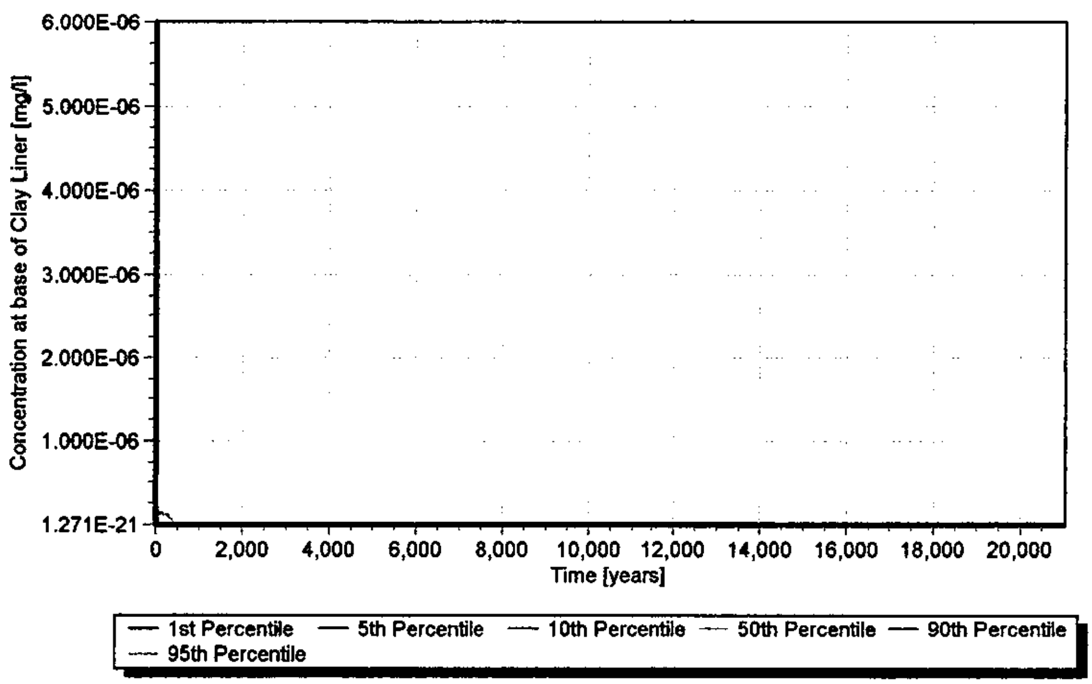
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, Dichloromethane Concentration at base of Clay Liner [mg/l]



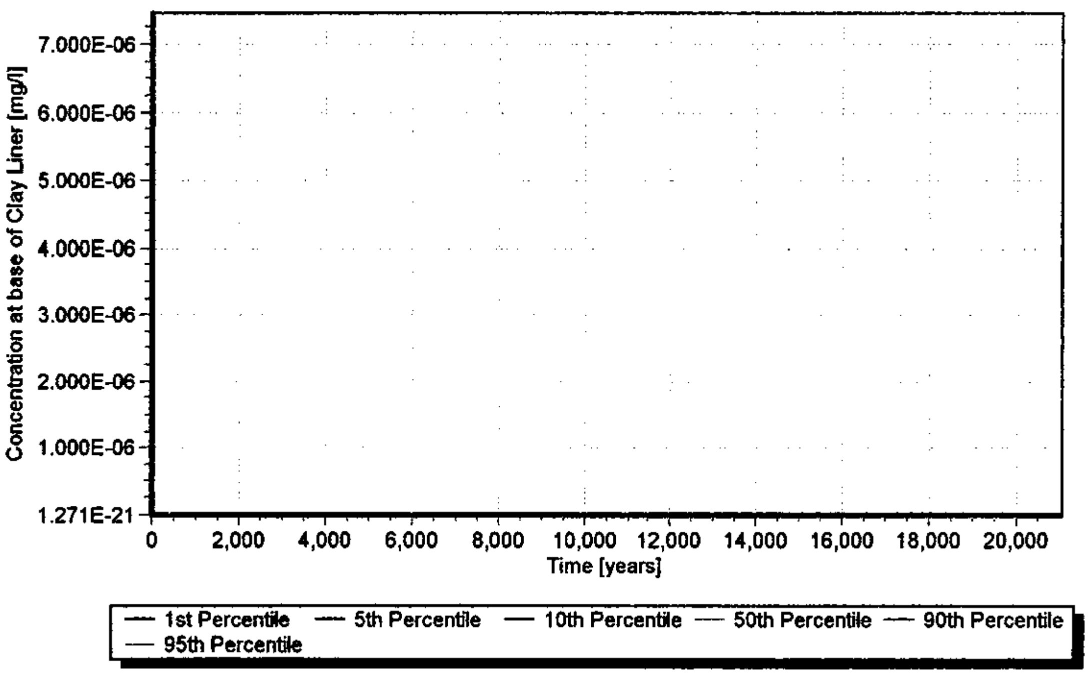
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, Dichloromethane Concentration at base of Clay Liner [mg/l]



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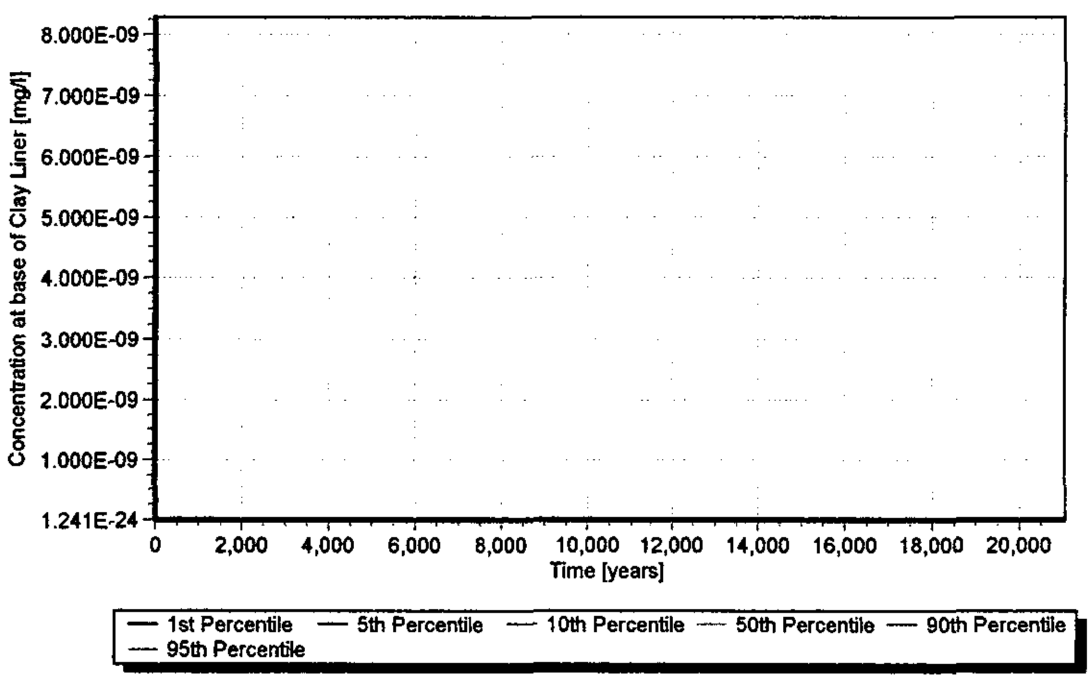
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, Dichloromethane Concentration at base of Clay Liner [mg/l]



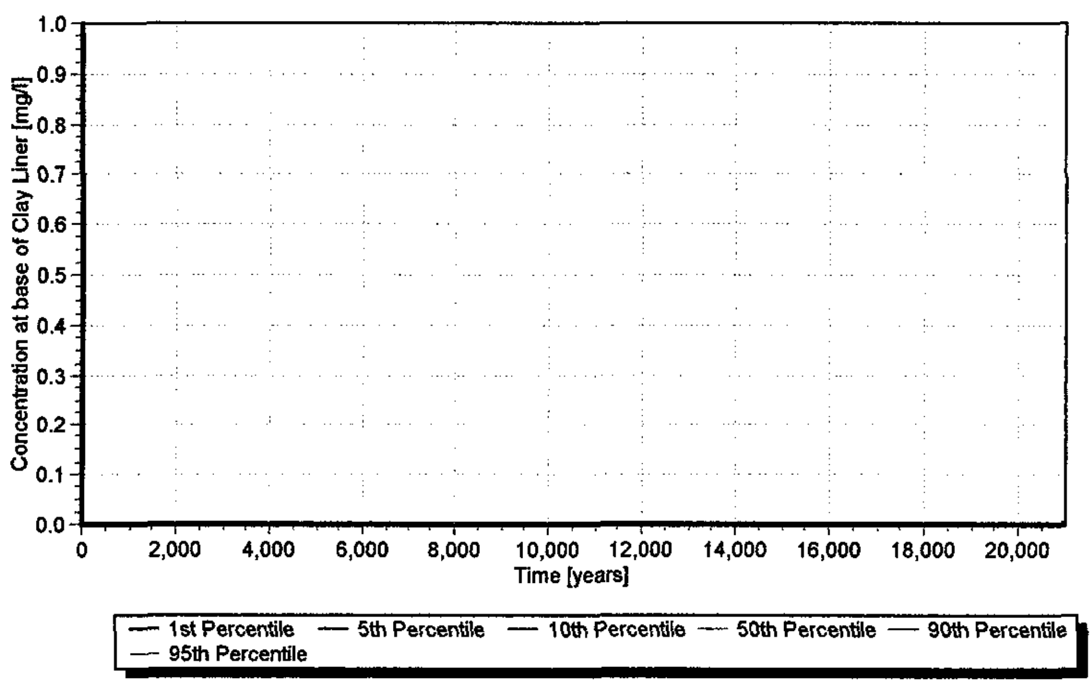
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1A, 4-Methylphenol Concentration at base of Clay Liner [mg/l]



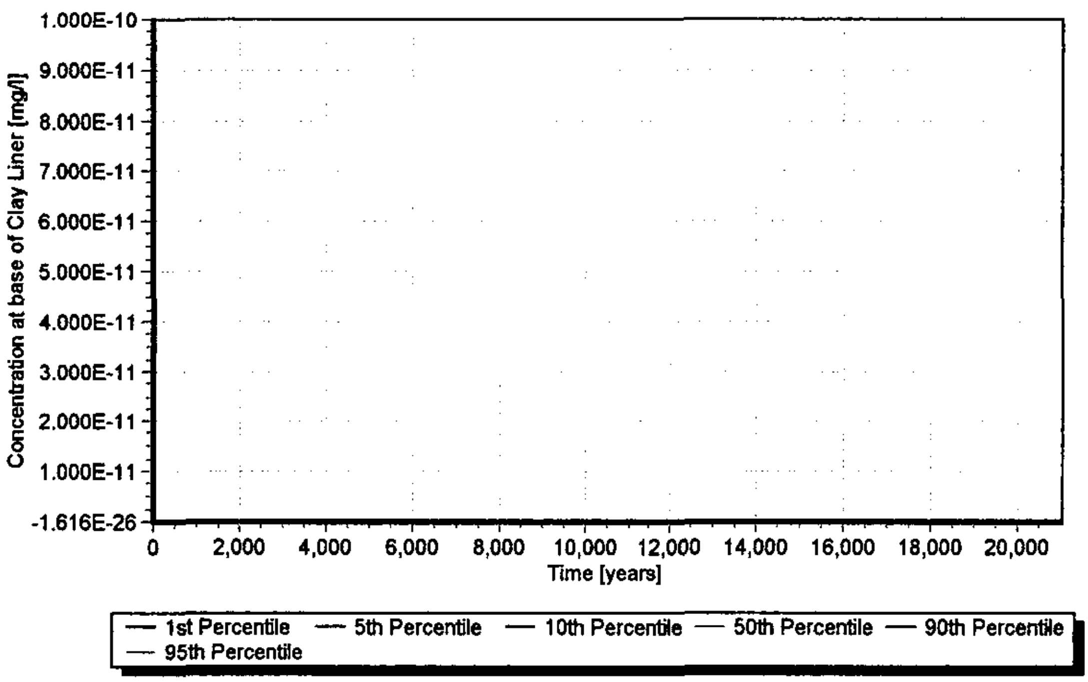
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 1, Cell 2, Cell 3, 4-Methylphenol Concentration at base of Clay Liner [mg/l]



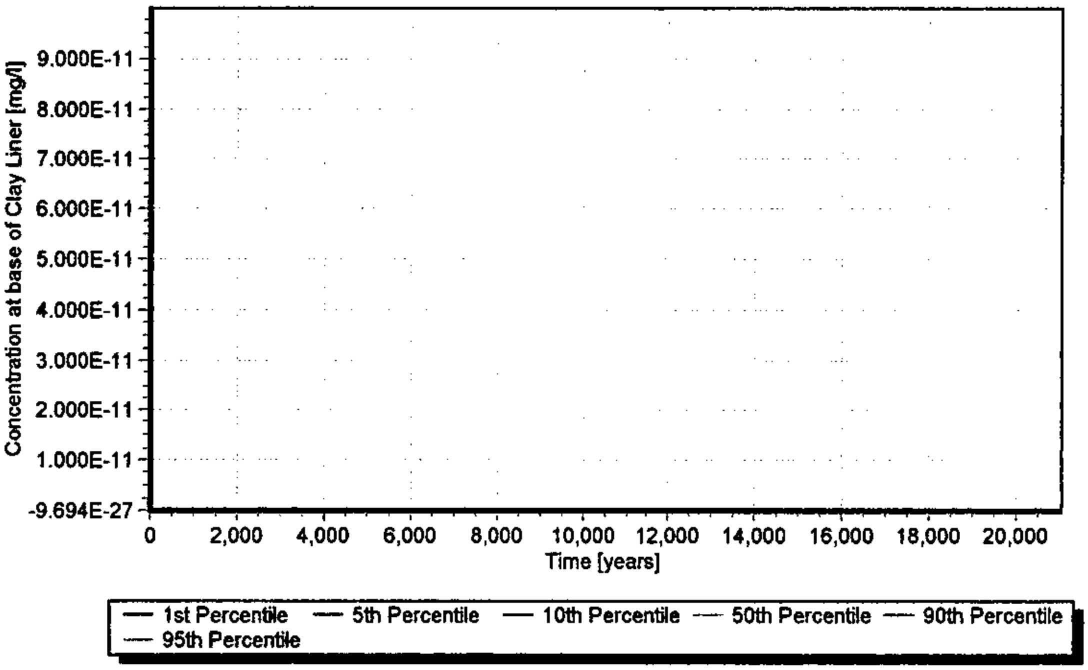
\Nantycaws HRA April V 1.0.sim 18/04/2004 06:21:06

LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 4, 4-Methylphenol Concentration at base of Clay Liner [mg/l]



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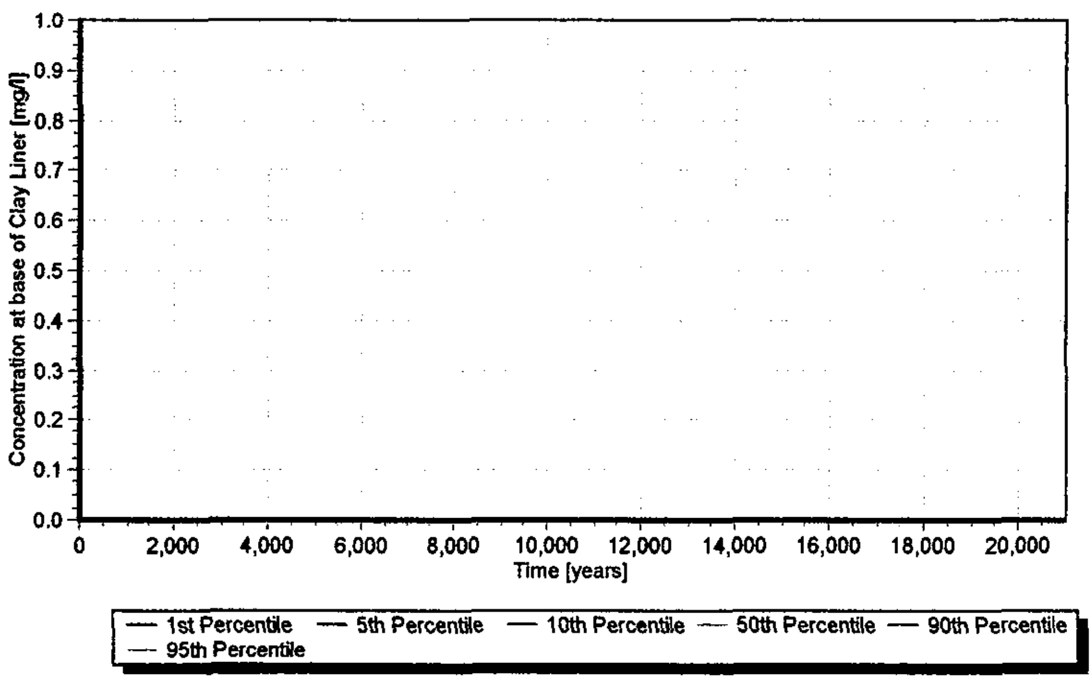
LandSim Version 2.5

Project Name: Nantycaws Landfill Site

Customer:CWM Environmental Limited

Results: Cell 5, 4-Methylphenol Concentration at base of Clay Liner [mg/l]



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STABILITY RISK ASSESSMENT

SECTION C

SRA with NW.

SECTION C:

STABILITY RISK ASSESSMENT

TABLE OF CONTENTS

DRAWINGS

TABLES

APPENDICES.

EXECUTIVE SUMMARY

This Stability Risk Assessment has been undertaken in support of the PPC Application by CWM Environmental (CWM) for the further development of Nantycaws Landfill Site near Carmarthen, Carmarthenshire.

The assessment considered the relationship of the proposed engineering works that are necessary to extend the life of the landfill and the effect of the waste stream together with the local geology and hydrogeology on the liner and hence the stability of various landfill components.

The assessment has followed the technical guidance issued by the Environment Agency and has addressed the specific stability issues in relation to:

- Basal sub-grade stability.
- Side slope sub-grade stability
- Basal liner stability.
- Side slope stability and integrity.
- Waste mass stability and,
- Capping stability and integrity.

The relevant findings of the Environmental Setting and Installation Design Report have been used in the development of a conceptual site stability model. Geotechnical design data have been interpreted from various ground investigations and reports made available by CWM.

The proposed works comprise the construction of an engineered and contained landfill cell to extend the capacity of the existing facility. The cell will abut existing landfill cells and the new waste will be integral with the existing waste, consequently there will be no new side slope lining. The base of the landfill will be constructed on either Glacial Till or Red Marl.

The maximum pre-settlement capping gradients are 1V:2.8H and the temporary waste slope gradients have been modelled at 1V:2.8H.

Limit equilibrium analysis has been used to assess the sub-grade and waste mass stability. Finite difference analysis confirmed the stability analysis and was used to assess the integrity of the components to the lining system. A closed-form analysis has been used to determine the stability and integrity of the capping system.

The findings of the stability risk assessment and stability analysis are:

- The basal sub-grade of the landfill cell will be formed in Glacial Till or Red Marl; regional groundwater potentiometric head is close to or above the proposed base of the landfill. Analysis has shown that mitigation drainage measures will be required to prevent basal heave. Such measures will include gravel filled drainage trenches and drainage geotextile blanket.

- The stability of the waste mass has been assessed for two of the threes modes of potential failure normally considered:
  - Mode 1 – critical slip surfaces passing solely through the waste.
  - Mode 2 – critical slip surfaces passing through the waste and along the minimum interface within the basal liner.
  - Mode 3 – critical slip surface passing down the side slope liner and along the critical basal liner interface – not applicable.
- The stability of Modes 1 and 2 was assessed to be acceptable with factors of safety greater than the minimum acceptable of 1.3.
- Mode 3 was deemed to be not applicable as no side slope liner exists within the scope of the assessment.
- Finite difference modelling has indicated that the integrity of the geosynthetics within the basal lining system will be maintained.
- The analysis of the capping system indicates acceptable factors of safety for all the proposed pre-settlement restoration slopes.
- The stability of the geosynthetic cap under the influence of construction plant has been shown to be adequate for gradients shallower than 1V:4H, with factors of safety greater than the minimum required.

1.0 INTRODUCTION

1.1 Report Context

As part of the PPC Permit Re-application for Nantycaws Landfill Site, SLR has undertaken a geotechnical Stability Risk Assessment, this section describes the manner in which the assessment has been carried out and presents the overall findings of the work.

The relevant background information describing the site setting (including geological, geotechnical and engineering information, site monitoring data and development proposals) are detailed within the Environmental Setting and Installation Design[1] (ESID) Report and is not repeated here.

The method adopted for this Stability Risk Assessment generally follows the principles outlined in the Environment Agency R&D Technical Report P-385[2] and, while not constituting official EA Guidance, from hereon referred to as 'The Guidance'. Where additional analytical techniques have been used, these are described within the text.

1.2 Conceptual Stability Site Model

The conceptual stability site model (Drawing No SRA 1) has been developed from the information contained within the ESID Report[1], which, in summary, indicates that:

- The development comprises five cells in two phases; the first three cells are partially restored, Cell 4 is operational and Cell 5 is yet to be developed.
- The geology of the site comprises Glacial Till (drift) overlying the Red Marls and Green Beds of Devonian age.
    - The upper levels of the Glacial Till is weathered to depths between 0.3m and 1.5m and is described as soft to firm slightly sandy silty clay with variable amounts of fine to coarse gravel.
    - The unweathered Glacial Till is generally firm to stiff sandy silty clay with varying amounts of cobbles and boulders. The material was proven to a maximum depth of 6.25m.
    - The Red Marl (Old Red Sandstone) was identified in all exploratory holes at depths between 0.5m and 4.2m. The strata is typically described as weak to moderately strong, fresh to slightly weathered fine grained marl.
    - Sandstone was encountered in some of the exploratory holes and was described as moderately weak to moderately strong, fresh to slightly weathered fine grained sandstone.
    - The inferred dip of the strata is between 20° and 40° to the south and no faults appear to cross the site.

- The development of Cell 5 is to the southeast of Cell 2 and the northeast of Cell 4 as indicated on Drawing SRA 1.

- The proposed development of Cell 5 will be adjacent to two existing landfill cells and will be integral with the existing cells. In effect the development will be a land raise with little or no excavation and no side slope sub-grades or liners.

- The base of the proposed landfill is below the potentiometric elevation of the artesian groundwater in the underlying Red Marl.

- The landfill will be developed to achieve engineered containment, utilising:

  - A composite basal lining system comprising a 0.5m thick, low permeability mineral basal liner (Artificial Geological Barrier) overlain by a 6mm Geosynthetic Clay Liner (GCL), a 2mm thick textured HDPE geomembrane, geotextile protector and granular leachate drainage system.

  - The final waste levels within Cells 1 to 4 will be covered with a granular regulation layer, a 1mm VFPE liner and 1m of restoration soils. The final waste levels within Cell 5 will be covered with a granular regulation layer, a 1mm VFPE liner and 1m of restoration soils.

- Leachate levels are to be maintained within a 2m zone above the top of the basal liner.

The following sections provide further details of the principal components of the landfill development.

1.2.1 Basal Sub-Grade Model

The basal sub-grades for all cells will be constructed in the Glacial Till and possibly the Red Marl at elevations between +123mAOD to +128mAOD. The proposed gradient of the base of the cell will be 1V:28H, falling to a leachate collection system.

1.2.2 Side Slopes Sub-Grade Model

The development will be essentially above ground and will abut, and be integral with the waste in the existing landfill cells. Hence there will be no side slope sub-grades and no side slope liner.

1.2.3 Basal Lining System Model

The basal lining system will comprise, from top to bottom, the following elements:

- 300mm thick free draining leachate drainage blanket.

- Geotextile protection layer.

- 2mm thick textured HDPE membrane.

- 6mm thick needle punched GCL.
- 0.5m thick engineered mineral liner constructed from site won, low permeability clay. The clay will be placed and compacted to achieve a maximum permeability of $1x10^{-9}$m/s.
- Underliner geotextile drainage blanket (GPT5 or similar)
- Gravel filled drainage trenches to control groundwater and facilitate construction.

The basal lining system will extend up the side slopes of the cell bunds and tie into the existing basal lining system where appropriate.

1.2.4 Side Slopes Lining System Model

The development will be essentially above ground and will abut and be integral with the waste in the existing landfill cells. Hence there will be no side slope sub-grades and no side slope liner.

1.2.5 Waste Mass Model

The site will be developed on the principle of engineered containment and will be permitted to receive non-hazardous municipal, commercial and industrial wastes, together with inert wastes.

The waste shall be placed in line with the pre-settlement restoration levels at a maximum gradient of approximately 1V:2.8H to a maximum elevation of 152mAOD.

1.2.6 Capping System Model

The design capping system for Cell 5 comprises, from top down:

- 1.0m thick restoration soil, 1.5m thick in areas of tree planting.
- Protection geotextile with integral drainage (GPT5 or similar).
- 1.0mm thick textured VFPE geomembrane.
- 300mm granular regulation layer is placed in contact with waste.

Above the crest of the void, the waste shall be placed in line with the pre-settlement restoration levels. The maximum gradient is approximately 1V:2.8H over a vertical height of 14m; elsewhere the gradients are shallower and the maximum pre-settlement elevation is approximately +152mAOD.

2.0 STABILITY RISK ASSESSMENT

Each of the principal components of the conceptual stability site model has been considered and the various elements of that component have been assessed with regard to stability.

The principal components considered are:

- Basal sub-grade (Table SRA 1).
- Basal lining system (Table SRA 2)
- Waste (Table SRA 3)
- Capping system (Table SRA 4).

2.1 Risk Screening

Issues relating to stability and integrity (as defined in Part B of the PPC Application Form for the Landfill Sector) for each principal component of the proposed development has been subject to a preliminary review to determine the need to undertake further detailed geotechnical analysis. The following sections present the results of the screening exercise.

2.1.1 Basal Sub-Grade Screening

The stability and deformability of the basal sub-grade will be ensured during construction and in the long term by appropriate design of the components in Table SRA 1, below.

Table SRA 1 Stability/Integrity Components of Basal Sub-Grade

Excessive Deformation	Compressible Sub-grade	The sub-grade comprising Glacial Till is considered effectively incompressible in relation to the imposed stress from the waste mass.
	Basal Heave	The underlying potentiometric head is at an approximate elevation between +122 and 130mAOD and falls to the south. The potentiometric head is approximately coincident or above the basal sub-grade, hence the possibility of heave from high groundwater levels will be assessed. It is not possible to predict likely groundwater inflows therefore monitoring should be carried out and a groundwater pressure relief system installed comprising gravel filled trenches.
	Cavities in Sub-grade	CQA procedure during excavations and subsequent placement and compaction of the basal sub-grade will eliminate the risk of near surface voids being present.
Filling on Waste	Compressible Waste	Not applicable
	Cavities in Waste	Not applicable

2.1.2 Side Slopes Sub-Grade Screening

The side slopes to the proposed Cell 5 will be formed by removing the temporary capping to the adjacent Cells 2 and 4 and making the new waste integral with the existing waste. Hence there is no requirement to assess a side slope sub-grade; the stability of the existing waste slope and the waste mass as a whole will be considered in Section 2.1.5.

2.1.3 Basal Lining System Screening

The controlling factors that influence the stability and integrity of the basal lining system are given in Table SRA 2, below.

Table SRA 2 Stability /Integrity Components of Basal Lining System

Mineral only	Stability and Integrity	Not applicable
	Compressible sub-grade	Not applicable
	Cavities	Not applicable
	Basal heave	Not applicable
Geosynthetic/ clay liner	Stability and Integrity	In terms of potential for movements along the basal lining system, the development of the landfill void will result in the generation of temporary waste slopes. The presence of temporary slopes may result in instability within the waste and the basal lining system. Since this issue is largely dependant upon the geometry of the waste mass, this aspect of the stability review is covered under Section 2.1.5, Waste Mass Stability.
	Compressible sub-grade	The limited thickness and comparatively low compressibility of the Glacial Till in the basal sub-grade will not be significant and no further assessment is considered necessary.
	Cavities	CQA of sub-grade preparation and liner construction should eliminate any risks associated with the presence of near-surface cavities. The potential for deeper voids/cavities to be of significance has been discussed and screened out in the basal sub-grade screening exercise (Table SRA 1).
	Basal heave	The hydrostatic pressures in the underlying Red Marl and sandstones are high and calculations are required to confirm acceptable levels of stability. A basal drainage system will be installed to reduce the risk of basal heave and to facilitate construction.

2.1.4 Side Slope Lining System Screening

The side slopes to the proposed Cell 5 will be formed by removing the temporary capping to the adjacent Cells 2 and 4 and making the new waste integral with the existing waste. Hence there will be no side slope liner and no requirement to assess the stability. The stability of the liner on the slopes of the inter-cell bunds will be considered in Section 2.1.5.

2.1.5 Waste Mass Screening

The controlling factors that influence the stability of the waste mass are presented in Table SRA 3 below:

The leachate control system will be designed to maintain the fluid level at between 1.5m (assessment) and 2.0m (compliance) above the top of the basal liner.

Table SRA 3 Stability/Integrity Components of Waste Mass

Failure wholly in waste	Stability		The stability of the future temporary waste slopes has been considered further. Existing waste slopes are currently standing at a gradient of about 1V:2.2H and will be considered as part of the side slope assessment. Leachate re-circulation only occurs within completed and capped phases away from active landfilling. In these areas, the waste mass is confined and as such, leachate re-circulation does not affect the stability of the confined waste mass. In the case of unconfined (temporary) waste faces, the stability of the unconfined waste mass will not be affected by leachate re-circulation; however, a r_u value of 0.1 has been adopted to represent the effect of several inputs which could increase pore fluid pressure within the waste.
Failure involving liner and waste	Mineral only	Stability	Not applicable
		Integrity	Not applicable
	Geosynthetic / mineral	Stability	The development of the void will result in the generation of a number of temporary waste slopes, in the short term. The presence of temporary slopes may result in instability of the waste and the underlying lining system. The stability of the waste mass and the underlying lining system is therefore considered further within this report. Leachate re-circulation only occurs within completed and capped phases away from active landfilling. In these areas, the waste mass is confined and as such, leachate re-circulation does not affect the stability of the confined waste mass. For temporary waste slopes, the potential influence of leachate re-circulation and other factors on stability has been modelled by the adoption of a r_u value of 0.1 within the waste.
		Integrity	This aspect of the side slope and basal lining system performance needs to be assessed for the potential build-up of tension within the basal lining geosynthetics.

In terms of waste settlement and its potential effects on leachate and gas collection/control systems, there is no specific discussion within TR1 or TR2 on methods of analysis. This issue is considered largely to be an operational consideration and can be addressed by conservative design or development of mitigation plans at detailed design stage. It is not therefore considered to require further assessment at this stage.

Leachate Collection System

Leachate collection from the base of Cell 5 will be provided by a leachate collection pipe installed within the gravel leachate drainage blanket. All basal pipework will be designed for a maximum 6% deflection to resist the static forces of the waste. Leachate will be extracted and monitored using telescopic vertical risers. The use of telescopic risers reduces the load imposed by waste settlement on the riser and hence the foundation pad, therefore it is considered that the stability of the underlying foundation is not required

Gas Collection System

Active gas extraction will be provided by gas extraction wells installed within the waste mass and connected to gas carrier mains. The effectiveness of the extraction system will be affected by differential settlement of the waste leading to low spots along the gas carrier mains across previously filled areas. These low spots can lead to collection of condensate which in turn will lead to blockages in the collection system.

To minimise the effect of waste settlement on the effectiveness of the gas collection system, gas extraction mains will be installed to suitable gradients across filled areas and condensate sumps will be installed at strategic locations. These measures will ensure that the effectiveness of the collection system will not be affected by settlement of the waste mass.

2.1.6 Capping System Screening

The controlling factors that influence the stresses in the capping system are given in Table SRA 4, below.

Table SRA 4 Stability Components of Capping Lining System.

Mineral Cap	Stability	Pre-settlement slope gradient	Not applicable
	Integrity	Compressible waste	Not applicable
		Slope deformation	Not applicable
		Construction	Not applicable
		Cavities in waste	Not applicable
Geosynthetic /mineral	Stability	Pre-settlement slope gradient	Stability of the lining system requires assessment with regard to interface shear strengths. In terms of the potential influence of gas pressures on the capping stability, gas extraction will be undertaken at the site. This effectively controls gas pressures under the cap and eliminates the potential for any significant pressure to build up beneath the capping system. It is therefore considered that the issue of gas pressure beneath the cap does not require further assessment.
	Integrity	Compressible waste	No external factors will be present to cause anything other than deformations normally associated with waste settlement. Further investigation is not considered to be required.
		Slope deformation	No external factors will be present to cause anything other than deformations normally associated with waste settlement. This aspect is therefore not considered to require further assessment.
		Construction	The potential affects of construction plant activity on the cap during placement of restoration soils should be considered as geosynthetics are to be used in the capping system.
		Cavities in waste	It is proposed that the final waste surface be graded and inspected prior to placement of the regulation layer. This practice will eliminate the potential for near-surface cavities to be present, and this issue does not therefore require further assessment.

2.2 Lifecycle Phases

This aspect of the assessment identifies the critical phases during the development of the landfill.

The landfill will be developed in a single phase across the full width of the base of the void. The temporary waste slope formed will be incorporated into the pre-settlement waste profile and waste will be placed to achieve the formation levels. The most critical condition, with respect to waste and lining system stability will occur at the end of filling to the proposed pre-settlement levels. To ensure the Stability Risk Assessment fully addresses the key issues throughout the life of the landfill, the following operational factors are considered:

- The temporary end of construction condition for the existing waste mass and basal / intercell bund sub-grades.

- The long-term final settled waste profile (for long-term integrity analysis of the lining system).

2.3 Data Summary

The following geotechnical data are required as input for the analyses undertaken for this Stability Risk Assessment:

- Material unit weight.
- Shear strength of soils, rock and waste.
- Elastic and compressibility properties of soils, rock and waste.
- Elastic properties of interfaces.
- Properties of structural elements, if used, to represent geosynthetics within the basal and side slope lining systems in finite different analysis.

A number of boreholes have been sunk on the site, however, there are no effective stress shear strength properties and only limited undrained shear strength data for the materials that will be encountered.

Where no direct measurement for a particular property is available, reference has been made to the borehole logs, published data and relevant experience from within SLR in the same or similar materials. In particular, specific reference has been made to the work of Trenter[3] with regard to the engineering properties of Glacial Till.

2.4 Selection of Appropriate Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action, which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses). However, consideration must also be given to analyses, which do not report factors of safety directly. For example, a finite difference analysis of tension within a basal lining system would not usually indicate overall 'failure' of the model even though the tension could be high enough to indicate a failure of the *integrity* of the lining system. In such cases, it is necessary to define an upper limit for tension and to express the factor of safety as the ratio of allowable tension to actual tension.

Prior to determining appropriate factors of safety for the various components of the model, it is necessary to identify key 'receptors' and evaluate the consequences in the event of a failure (relating to both stability and integrity). Consideration of the following receptors is required:

- Groundwater
- Property - relating to site infrastructure, third party property
- Human beings (i.e. direct risk)

The Factor of Safety adopted for each component of the model would be related to the consequences of a failure.

2.4.1 Factor of Safety for Basal Sub-Grade

The determination of the factor of safety for slope stability of the sub-grade is not applicable in this case since this component of the Stability Risk Assessment has been screened out.

The proposed minimum factor of safety against basal heave is 1.3.

2.4.2 Factor of Safety for Side Slope Sub-Grade

A factor of safety is not required for this component as it has been screen out of the assessment in Section 2.1.2.

2.4.3 Factor of Safety for Basal Lining System

A factor of safety of 1.3 is considered appropriate when using conservative peak shear strength parameters. Where reduced shear strength parameters are adopted (for example, for very long term conditions, involving the 'fully-softened' or residual shear strength of the basal liner clay), it is considered that the factor of safety could be reduced to a value greater than unity, in accordance with the advice given in the Guidance.

The risk of failure of the lining system will be assessed in terms of an acceptable tension induced in the lining system geosynthetics resulting from waste deformations.

Where there is a risk of excess groundwater accumulating within the underliner drainage system, analysis will be presented to show the necessary waste level to maintain a factor of safety of 1.3 against basal heave of the liner.

2.4.4 Factor of Safety for Side Slope Lining System

A factor of safety is not required for this component as it has been screened out of the assessment in Section 2.1.4.

2.4.5 Factor of Safety for Waste Mass

The waste shear strength parameters presented within the Guidance are considered conservative and can be considered to already include an element of partial factoring. Therefore, it is considered appropriate to adopt a factor of safety of 1.2 if adopting these shear strength parameters in combination with the Traditional Approach (Section 2.2.4 of the Guidance).

2.4.6 Factor of Safety for Capping System

A minimum factor of safety of 1.3 is considered appropriate and has been adopted where peak shear strength conditions are applied for the pre-settlement slopes. A factor of safety greater than unity is considered appropriate where residual shear strengths are applied.

2.5 Justification for Modelling Approach and Software

In order to perform a comprehensive Stability Risk Assessment, the components of the landfill development, as previously described in Section 1.2 of this document, have to be considered not only individually but in conjunction with one another where relevant. Any analytical techniques adopted for such an assessment should adequately represent all of the considered scenarios (i.e. the different modelled phases of the lifecycle) for both confined and unconfined conditions (where appropriate). The methodology and the software should also achieve the desired output parameters for the assessment (e.g. determination of limit equilibrium factor of safety or calculation of tension within liner components).

The analytical methods used in this Stability Risk Assessment include:

- Limit equilibrium stability analyses for the derivation of factors of safety for the toe bund and the pre-settlement waste slopes.
- Finite difference analyses for the determination of geosynthetic tension within the basal liner system.
- Closed-form analyses for the capping stability analysis.

The limit equilibrium analyses have been undertaken using the package STABLE Version 7.5 (MZ Associates, 1995). The Bishop[4] slip-circle and Morgenstern-Price[5] non-circular methods of analysis have been used.

The proprietary software FLAC, Version 4.0 (Itasca Consulting Group Inc, 2000) has been used for the basal lining system assessment. This is a two dimensional explicit finite difference programme which simulates the behaviour of structures built of soil, rock or other materials that may undergo plastic flow when their yield limits are reached. Materials are represented by elements, or zones, which form a grid that is adjusted by the user to conform to the shape/cross section of the object (in this case, slopes) being modelled. FLAC was originally developed for geotechnical and mining engineers undertaking studies of the behaviour of geological and similar materials and is therefore well suited for application to the Nantycaws Landfill lining system assessment.

The FLAC programme has been used to demonstrate a suitable analytical technique for side slopes in the Guidance. The authors of the software specifically state that the finite difference approach is more suitable for such analyses than the finite element method.

The capping stability assessment was undertaken using the methods proposed by Jones and Dixon[6] and Jones and Pine[7]. The equations developed by these authors were input into Microsoft Excel spreadsheets for processing. The analysis of the effects of construction plant on the geomembrane component of the capping system was undertaken using the method proposed by Kerkes[8] and the equations developed were input into Microsoft Excel spreadsheets for processing.

2.6 Justification of Geotechnical Parameters Selected for Analysis

The following section presents a justification for the various parameters used in the stability analyses based on the following criteria:

- An assessment of the quality and relevance of the site specific data.
- An assessment of the suitability of non site specific data where used.
- Methods for the derivation of the parameters adopted.

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component of the landfill cell in Table SRA 5, the values in parenthesis are the fully softened shear strength values. The interface parameters are presented in Table SRA 6.

The geotechnical parameters for limit equilibrium analysis include the shear strength and unit weight of each material within the model plus porewater or gas pressure assumptions. Shear strength has largely been defined using the effective shear strength parameters of cohesion, (c'), and the angle of shearing resistance, (ø'), although the undrained shear strength of clay (s_u) has been adopted where appropriate (i.e. for short-term conditions).

For the FLAC modelling, effective stress shear strength parameters are used, but with the addition of the elastic properties of the materials (bulk modulus, K, and shear modulus, S) or interfaces (shear stiffness, Ks, and normal stiffness, Kn). Unit weight is not applied for interfaces. Where structural elements have been used to represent geosynthetics, the shearing resistance along the edge of the element, $ø_s$, has been assumed to be equal to the shear strength of the interface that it crosses such that the presence of the element does not influence the strains along the interface. The other material parameters input for the structural elements were the Young's modulus, E, the yield strength, Y, the cross sectional area, A, and the perimeter, P. The properties of the geosynthetic has been adapted to those used on site based on the manufacturer's specification and the modelling experience of SLR.

There are no site specific effective stress shear strength parameters available for the site. Therefore geotechnical index properties measured on samples recovered from the adjacent Cell 4 at Nantycaws have been used to deduce appropriate effective stress shear strength parameters for use in the stability analysis. The relationship between plasticity index and the effective angle of internal friction (ø') quoted in Trenter[3] has been used to assess likely ranges in effective strength parameters.

2.6.1 Parameters Selected for Basal Sub-Grade Analysis

The applicable analyses for the basal sub-grade are:

- The potential for basal heave resulting from high hydrostatic groundwater pressures in the underlying Red Marl.

The potential for basal heave is dependent upon the bulk density of the Glacial Till, the depth to the free body of water and the hydrostatic head that exists within the free body of water.

The preliminary design parameters are presented in Table SRA 5.

2.6.2 Parameters Selected for Side Slopes Sub-Grade Analysis

An assessment of the stability is not required for this component as it has been screened out of the assessment in Section 2.1.2.

2.6.3 Parameters Selected for Basal Liner Analysis

The key parameter required for the basal lining system analysis (undertaken as part of the Waste Mass Analysis) is the angle of shearing resistance of the critical interface present. The critical interface is considered to occur between the GCL and the underlying clay liner; the interface parameters used in the analysis are presented in Table SRA 5.

The parameter values adopted for the basal lining system geosynthetics do not significantly influence the modelling results. The nominal parameter values adopted for the structural element used to represent a geomembrane within FLAC were E=120e6, Y=29e3, $\varnothing_s=12^o$ $A=1.002m^2$ and P=2.004m. These parameters were based upon the typical manufacturer's data.

2.6.4 Parameters Selected for Side Slope Liner Analyses

An assessment of the stability is not required for this component as it has been screen out of the assessment in Section 2.1.4.

2.6.5 Parameters Selected for Waste Analysis

In terms of waste strength, SLR adopts conservative values of effective shear strength parameters as derived from a study of geotechnical properties of municipal waste by Van Impe and Bouazza[9], these values being backed up in later work by Kavazanjian *et al*[10] and later confirmed in a research summary by Jotisankasa[11].

The values for c' and ø' adopted throughout the modelling were 5kPa and 25^o, respectively. The unit weight of the waste was taken as $11kN/m^3$, a value slightly higher than that generally adopted ($10kN/m^3$). This is based upon experience gained from some of SLR's most recent modelling and stability work.

2.6.6 Parameters Selected for Capping Analysis

The shear strength of the interfaces present within the capping system has been adopted from the values reported in the Guidance.

In summary, the geotechnical parameters selected for the required analysis are presented below in Table SRA 5 and the interface parameters in Table SRA 6.

Table SRA 5 Geotechnical Design Parameters (Stability)

Material	Bulk Unit Weight γ (kN/m³)	Undrained Shear Strength s_u (kPa)	Effective cohesion c' (kPa)	Angle of Shearing Resistance ø' (o)	Bulk Modulus K (MPa)	Shear Modulus S (MPa)	Typical Description
Top soil	16		0	30	-	-	Organic rich loosely placed top soil. No compaction.
Protector Soil (capping)	19		0	30	-	-	Sourced from site.
Drainage media	18		0	35	-	-	Course free draining granular
Waste	11		5	25	0.16	0.08	
Clay liner	20	>50	0 (0)	24 (16)	12	6	Remoulded firm to stiff Boulder Clay.
Glacial Boulder Clay	20	>50	0	24	-	-	Firm to stiff Boulder Clay.
Red Marl	21	>50	20	45	-	-	Moderately weak reddish brown fine grained Marl and Sandstone.

Table SRA 6 Interface Design Parameters

Interface	Peak		Post Peak Strength*	
	c' (kPa)	ø'	c' (kPa)	ø'
HDPE liner/geotextile	2	26	0.5	13
Geotextile/gravel drainage	0	25	0	22
HDPE membrane / GCL	0	25	0	20
GCL / Mineral liner	0	20	0	14
Waste/regulation layer (capping)	0	25	0	20
Protector (drainage) layer / VFPE membrane (capping)	2	26	0.5	22
Restoration soil / protector layer (capping)	0	26	0	22

* Fully softened or residual, as appropriate

2.7 Analyses

Details of the various Stability Risk Assessment analyses undertaken for the site are presented in the following sections.

2.7.1 Basal Sub-Grade Analysis

No slope stability analyses have been undertaken for this component since the need to do so have been eliminated in the screening process, as described in Section 2.1.1.

The proposed basal sub-grade elevation of the proposed Cell 5 will be +123m to +128mAOD; the potentiometric groundwater level within the underlying Red Marl is in the region of 122-130m AOD. Where the Glacial Till forms the basal sub-grade there is the potential for hydrostatic uplift of the sub-grade. Previously, during cell construction works, cells have been excavated to similar formation levels and basal heave has been experienced.

The factor of safety against basal heave is calculated from the formula presented below:

$$FoS = \frac{t.\gamma_{clay}}{U}$$

where:

t	=	thickness of clay between water bearing stratum and sub-grade elevation (for Cell 5, basal elevation 127mAOD and top of water bearing stratum +125m AOD, therefore 2m of clay to resist uplift).
FoS	=	Factor of safety (to be >1.3)
U	=	Hydrostatic uplift pressure (top of water bearing stratum +125mAOD and potential groundwater levels of +130m AOD, a 5m head of water (50kPa) is assumed to exist).
γ_{clay}	=	Density of clay (20 kN/m^3)

$$FoS = \frac{2 \times 20}{50} = 0.80$$

The calculated factor of safety against basal heave is less than unity and is therefore unacceptable. The necessary additional drainage measures required to alleviate the hydrostatic uplift pressures and hence the potential basal heave are discussed in Section 2.8.1.

2.7.2 Side Slope Sub-Grade Analysis

No slope stability analysis has been undertaken for this component since the need to do so have been eliminated in the screening process as described in Section 2.1.2.

2.7.3 Basal Liner Analysis

The basal heave analysis for the sub-grade (Section 2.7.1) concluded that sub-grade drainage would be required to prevent basal heave. Further analysis is required for the liner to determine the thickness of waste required to balance hydrostatic pressures that will build up in the under-liner drainage system.

The same conditions have been assumed as for the sub-grade analysis.

The assumed density of the waste and the required factor of safety of 1.3 results in a linear relationship between hydrostatic uplift and waste mass, determined from the following equation:

$$t = \frac{FoS.U}{\gamma_{waste}}$$

where:

t	=	thickness of waste required to balance the hydrostatic uplift
FoS	=	Factor of safety (1.3)
U	=	Hydrostatic uplift pressure (with minimum basal levels of 127m AOD, and potential groundwater levels of +130m AOD, a 3m head of water (30kPa) is assumed to exist on the underside of the liner).
γ_{waste}	=	Density of waste (11 kN/m^3)

With the potential uplift pressure equivalent to 3m head of water theoretically being present in some areas of the base of the landfill site, the equation below demonstrates that a waste thickness of 6 metres would be required (including a factor of safety of 1.3) to balance the uplift pressure.

$$t = \frac{1.3 \times 30}{11} = 3.5m \text{ of waste}$$

2.7.4 Side Slope Liner Analysis

No slope stability analysis has been undertaken for this component since the need to do so have been eliminated in the screening process as described in Section 2.1.4.

2.7.5 Waste Analysis

In considering the stability of the waste mass, the stability and integrity of the lining system must also be addressed, as they are intrinsically linked, therefore three potential modes of failure have been considered here, namely:

- **Mode 1** - Critical Slip Surfaces passing solely through the waste. The Mode 1 analysis was extended for this site to assess the local stability at the toe of the waste slope in Cell 5 to include the toe bund and drainage ditch that runs along the south-eastern boundary of Cell 5.
- **Mode 2** - Critical Slip Surfaces passing through the waste and along the basal lining system.
- **Mode 3** – Critical Slip Surfaces passing down through the side slope liner and along the basal lining system. It should be noted that Mode 3 is not applicable for this site as a side slope liner has been screened out in Section 2.1.4 and the junction between the old and new waste is assumed to be integral with no weak interface.

The analysis has considered the stability of the components in terms of circular and non-circular 2-D limit equilibrium using the computer program STABLE. Typical stability analysis outputs are presented in Appendix SRA 1.

Whilst it has been assumed that the leachate head on the base of the landfill is controlled to a maximum level of 2m, within the body of the waste, pore fluid pressures may exist. Pore fluid pressure is the combined effect of water and gas pressures. The distribution of pore fluid pressure varies within the waste mass due to a number of factors, including; under drainage, nature of the waste, presence of perched water tables and the presence of a gas extraction system. In order to model the pore fluid pressures in the waste mass, the analysis has assumed that the pore water pressures within the waste will either:

- simply reflect the basal leachate level, or
- be represented by a pore water pressure ratio (r_u) of 0.1 to allow for pore fluid pressures to build up within the waste mass above the basal leachate level. The interface between the waste and the clay liner is always assumed to have a pore water pressure equal to the assumed leachate level.

Waste Mass Stability

The results of the Mode 1 analyses are presented in Table SRA 7 below. The calculated factors of safety are for critical slip surfaces that pass solely through the waste, assuming a circular slip plane and effective stress parameters.

Table SRA 7 Summary of Waste Stability Analysis for Mode 1

Figure	File	Method	Pore Pressure Ratio r_u	Factor of Safety	Comments
A1-1	NTCM1BB	Drained Circular	0	1.854	Acceptable (FOS >1.2)
A1-2	NTCM1BC	Drained Circular	0.1	1.743	Acceptable (FOS >1.2)
A1-3	NTCM1BD	Drained Circular	0	1.459	Acceptable (FOS >1.3)

Cases A1-1 and A1-2 (Table SRA 7) assessed the stability of the waste mass where failure surfaces were modelled wholly within the waste. The analysis was used to assess the reduction in the factor of safety between the anticipated effective stresses for varying pore fluid pressure conditions within the waste mass. As can be seen the factor of safety exceeds the acceptable level as determined in Section 2.4.5, for all cases considered.

Case A1-3 considered the drained stability of the toe of the waste where it is retained by a toe bund and is immediately adjacent to a 2.5m deep drainage ditch. The concern was that the presence of the drainage ditch could compromise the overall stability of the waste mass. As can be seen, the presence of the ditch does reduce the factor of safety although not to critical levels and the stability is considered to be acceptable.

Mode 2 considers a potential failure mechanism that passes through the waste and along the basal lining system. The worst case for this mode of failure is considered to be as indicated by Section BB' on Drawing SRA 1 where the stability of a 22m high waste mass with a gradient of 1V:3H has been analysed. Both peak and fully softened shear strength parameters for the interface between the GCL and the mineral liner have been considered in the analysis. The interface shear strength between the GCL and the mineral liner is considered to be the critical interface and parameters are presented in Table SRA 6.

A 2m head of leachate in the base of the landfill has been assumed and therefore the effective stress at the interface between the drainage blanket and the clay liner has been calculated accordingly. The pore fluid pressures in the waste previously assumed for the investigation of Mode 1, (failure solely within the waste) have been applied to the waste only, for the investigation of Mode 2. Output drawings from STABLE, detailing the slope profiles and the critical slip planes for each scenario analysed for Mode 2, are presented in Appendix 1.

The factors of safety reported for peak and residual shear strengths of the basal liner under the two pore water pressure regimes are presented in Table SRA 8, below.

Table SRA 8 Summary of Waste Stability Analysis for Mode 2

Figure No.	File	Method	Pore Pressure Ratio r_u	ø' (°)	c' (kPa)	FoS	Comments
A1-4	NTCM2A	Drained Non-circular	0	20	0	2.002	Peak shear strength of basal liner interface. Acceptable (FOS >1.2)
A1-5	NTCM2B	Drained Non-circular	0.1	20	0	1.928	Peak shear strength of basal liner interface. Acceptable (FOS >1.2)
A1-6	NTCM2C	Drained Non-circular	0	14	0	1.574	Residual shear strength of basal liner interface. Acceptable (FOS >1.0)
A1-7	NTCM2D	Drained Non-circular	0.1	14	0	1.5	Residual shear strength of basal liner interface. Acceptable (FOS >1.0)

Cases A1-4 and A1-5 assume the interface angle of shearing resistance along the critical interface in the base of the landfill is at its peak, with a value of 20°. The stability analysis demonstrated that the factor of safety for this scenario is drops from 2.002 to 1.928 as the pore water pressure ratio (r_u) value rises, which are both considered to be acceptable.

Cases A1-6 and A1-7 assume that the critical interface on the base of the landfill is at residual value, with an angle of shearing resistance of 14°. Since residual values have been assumed for the critical interface, the allowable factor of safety has been reduced to greater than unity, in line with the recommendations made in the Guidance. The analysis has demonstrated that the calculated factor of safety is greater than unity for both cases.

Confined Basal Lining System Geosynthetics Integrity

This aspect of the basal lining system needs to be assessed for long terms conditions. The key area requiring analysis is the degree of tension induced within the basal geosynthetics as a result of long term deformation of the waste mass towards the critical outer waste slope i.e. the 22m high slope formed at a pre-settlement inclination of 1V:3H as analysed in the limit equilibrium stability analysis above.

A finite difference FLAC model has been used for the determination of basal geosynthetics integrity. The key elements of the modelling exercise undertaken are summarised below:

- The FLAC grid incorporates an inclined left hand side at a sufficient distance from the free waste slope (at the right hand side of the model) to ensure that deformation of the free waste slope could take place without being influenced by the fixed left hand edge of the model.

- The base of the model is inclined at 1V:22H and is fixed in the x and y directions along the lower boundary since this essentially represents a non-moveable boundary.

- The bottom row of elements within the model represents the clay liner element of the basal lining system. While realistic geotechnical properties are assigned to this layer, the modelling results are not influenced significantly by the presence of the clay.

- The waste mass is modelled above the clay liner. An interface was placed between the basal clay and the waste in order to represent the critical interface (i.e. the interface with the lowest shear strength) present within the basal lining system. In accordance with the limit equilibrium modelling, this interface was assigned an angle of shearing resistance of 14^{o}, representing residual conditions.

- The shear strength of the basal interface was taken as being low in order to examine the potential for this condition to actually be present as a result of shear displacements along the interface. This is undertaken to avoid the need to model a strain-softening interface. This is a conservative approach that ensures that the maximum potential displacements are induced along the base of the model beneath the free waste slope.

- A structural element was placed along the interface between the basal clay and the waste. This element is present to represent a geosynthetic within the basal lining system.

- The stiffness properties of the waste have been selected such that the maximum long term waste settlement is 20% of the full depth.

- It is considered important to model a realistic sequence of events when examining the behaviour of the basal lining system. Therefore, the waste elements have been modelled as being placed in discrete lifts, approximately 2m thick.

The drawings relating to the FLAC analysis are presented in Appendix SRA1. Figure A1-8 presents the overall layout of the FLAC model used for the analysis. Figure A1-9 presents the deformed FLAC grid, while Figure A1-10 indicates the displacements of the waste mass, effectively demonstrating a settlement of just over 20%.

Tension induced within the structural element of the model are reported as being a maximum of 200kN (Figure A1-11). This level of tension is well below the yield strength of any of the geosynthetics present within the basal lining system, and a high factor of safety against yield can be deduced. The reported relative displacements along the basal interface are reported as being less than 6.5mm (Figure A1-12). This degree of shear displacement is not sufficient to allow the peak shear strength of any of the possible interfaces present to be exceeded, and essentially confirms that the modelling approach is conservative.

2.7.6 Capping Analysis

The maximum pre-settlement slope for the landfill cap is designed at about 1V:2.8H (~19°) over a vertical height of 14m; the maximum vertical height above the edge of the landfill is approximately 30m. The capping will be designed to reduce the potential for low shear strength interfaces to be present which could result in low factors of safety.

The design provides for 1.0m or 1.5m of mixed cover soil over a protection geotextile that incorporates drainage measures. The impermeable barrier is provided by a 1mm thick textured VFPE geomembrane which overlies a granular gas drainage / regulating layer which is in contact with the waste.

The design reduces the ability for pore water pressures to build up within the system, therefore a low parallel submerged ratio, as defined by Jones and Dixon[6], can be used.

The analysis has been undertaken following the guidance in TR2 and is presented in Appendix SRA 2; Figure A2–1 gives guidance on the forces and parameters used in the analysis.

The results of the capping stability analysis are presented in Table A2–1 of Appendix SRA 2. When adopting the peak shear strength for the various liner interfaces, and a parallel submerged ratio of 0.15, the minimum reported factor of safety is 1.30; for assumed residual shear strength conditions the minimum factor of safety reported is 1.09. The analysis has been undertaken for 1m of restoration soil as this will be the worst case condition and stability will improve if the restoration layer is increased to 1.5m.

An analysis has been completed to determine the steepest slopes that construction plant could operate on without causing instability. The stability of a 1V:4H capping slope under the influence of construction plant operations has been assessed using the procedure proposed by Kerkes[8] and is presented in Table A2-2 Appendix SRA 2.

The analysis shows that a factor of safety of 1.3 against rupture of the geomembrane assuming residual shear strength conditions at restoration soil to geomembrane interface. The analysis has been undertaken assuming 8kN/m limiting tension in the geomembrane and a typical unit of plant for such work. The calculated factor of safety is 1.3 which is considered acceptable.

2.8 Assessment

2.8.1 Basal Sub-Grade Assessment

Assessment of the basal sub-grade formation in the Glacial Till has indicated that basal heave induced by the high groundwater potentiometric pressure in the Red Marl will occur unless specific drainage measures are installed.

The additional drainage measures in the basal sub-grade will comprise will comprise gravel filled trenches to the full depth of the Glacial Till at a horizontal spacing of about 15m. The basal sub-grade and drainage trenches will be overlaid with a drainage geotextile to accommodate possible seepages between the trenches.

2.8.2 Side Slope Sub-Grade Assessment

Consideration of the stability of the side slope sub-grade has been eliminated from the assessment by the screening process.

2.8.3 Basal Liner Assessment

The stability of the basal sub-grade will be acceptable provided that the groundwater is controlled to ensure that it is kept below the basal sub-grade elevation. Analysis has shown that 3.5m of waste will be required to balance the predicted excess hydrostatic pressures to prevent disruption to the liner. Therefore the basal drainage system should be maintained and kept operational until at least 3.5m of waste has been placed across the full width of the cell.

2.8.4 Side Slope Liner Assessment

Consideration of the stability of the side slope liner has been eliminated from the assessment by the screening process.

2.8.5 Waste Assessment

Waste Mass Stability

This Stability Risk Assessment incorporates an analysis of the basal liner stability since this component will play a role in waste mass stability, but would not be subject to potential instability mechanisms if the waste mass were not present.

The stability of the maximum waste slope height (Modes 1 and 2) have been assessed and have been found to attain the factors of safety discussed in Section 2.4.5.

The stability of the waste slopes has been assessed for a gradient of 1V:2.8H where factors of safety greater than the required minimum where determined for peak and post peak strength parameters.

As the waste settles with time, the factor of safety will increase and the conclusion is that the proposed pre-settlement temporary waste slopes are considered satisfactory.

Confined Side Slope Liner Integrity

The FLAC finite difference modelling indicated that the tension induced within the basal lining system geosynthetics below the critical free waste slope will be insignificant.

2.8.6 Capping Assessment

The assessment of the stability of the capping system demonstrated that a satisfactory factor of safety could be achieved for the steepest sections of the proposed restoration cap for the pre-settlement contours. The assessment also demonstrated that no tension would develop within the capping system.

The analysis for construction plant has shown, for the plant considered, that it should not operate on slopes steeper than 1V:4H, therefore plant should not operate on the locally steeper areas. The locally steep areas occur around the perimeter of the site and it is recommended that a temporary cap is provided until such time as settlement within the waste mass has reduced the gradient to 1V:4H or the cell is capped and placement of the restoration soils is delayed until shallower gradients are attained.

3.0 MONITORING

3.1 The Risk Based Monitoring Scheme

Based upon the foregoing Stability Risk Assessment, a simple risk-based monitoring scheme is considered appropriate for the future development of the landfill. The monitoring is limited to normal CQA control during construction.

3.1.1 Basal Sub-Grade Monitoring

The temporary control of groundwater is important to the initial stability of a number of components of the landfill, therefore monitoring will be required to provide warning of the on-set of potentially critical conditions. Cell 5 of the proposed scheme will be at +127m AOD, this base level is below the potentiometric head in the underlying Red Marl and a groundwater monitoring / management system will be required.

3.1.2 Side Slope Sub-Grade Monitoring

Monitoring of this component is not required since it has been eliminated from consideration by the screening process (Section 2.1.2).

3.1.3 Basal Lining System Monitoring

Monitoring during construction will comprise CQA to ensure compliance with the construction specification.

No additional instrumentation is deemed as being required during construction or post closure.

3.1.4 Side Slope Lining System Monitoring

Monitoring during construction will comprise CQA to ensure compliance with the construction specification.

No additional instrumentation is deemed as being required during construction or post closure.

3.1.5 Waste Mass Monitoring

No specific monitoring required for the waste stream other than to record waste elevation across the cell for the purpose of ensuring waste mass stability.

Leachate level and gas monitoring will be undertaken as part of the permit compliance requirement.

3.1.6 Capping Monitoring

Monitoring during construction will comprise construction quality assurance to ensure compliance with the construction specification.

No instrumentation required during construction or post closure.

4.0 REFERENCES

1 Nantycaws Landfill Environmental Setting and Installation Design Report, prepared for CWM Waste Management Limited by SLR Consulting, Report Ref. 4B-610-002-ESID, May 2004.

2 Jones, D.R.V. & Dixon, N. (2002) Stability of landfill lining systems, R&D Technical Reports P1-385/TR1 and TR2, Environment Agency.

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4 Bishop, A.W., (1965), 'The use of the slip-circle in the stability analysis of slopes' Geotechnique

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7 Jones, D.R.V. & Pine, R.J., 'Design of inclined geosynthetic lining systems for vertical landfill expansion' Proc. 8th Int. waste Management and Landfill Symposium, 2001.

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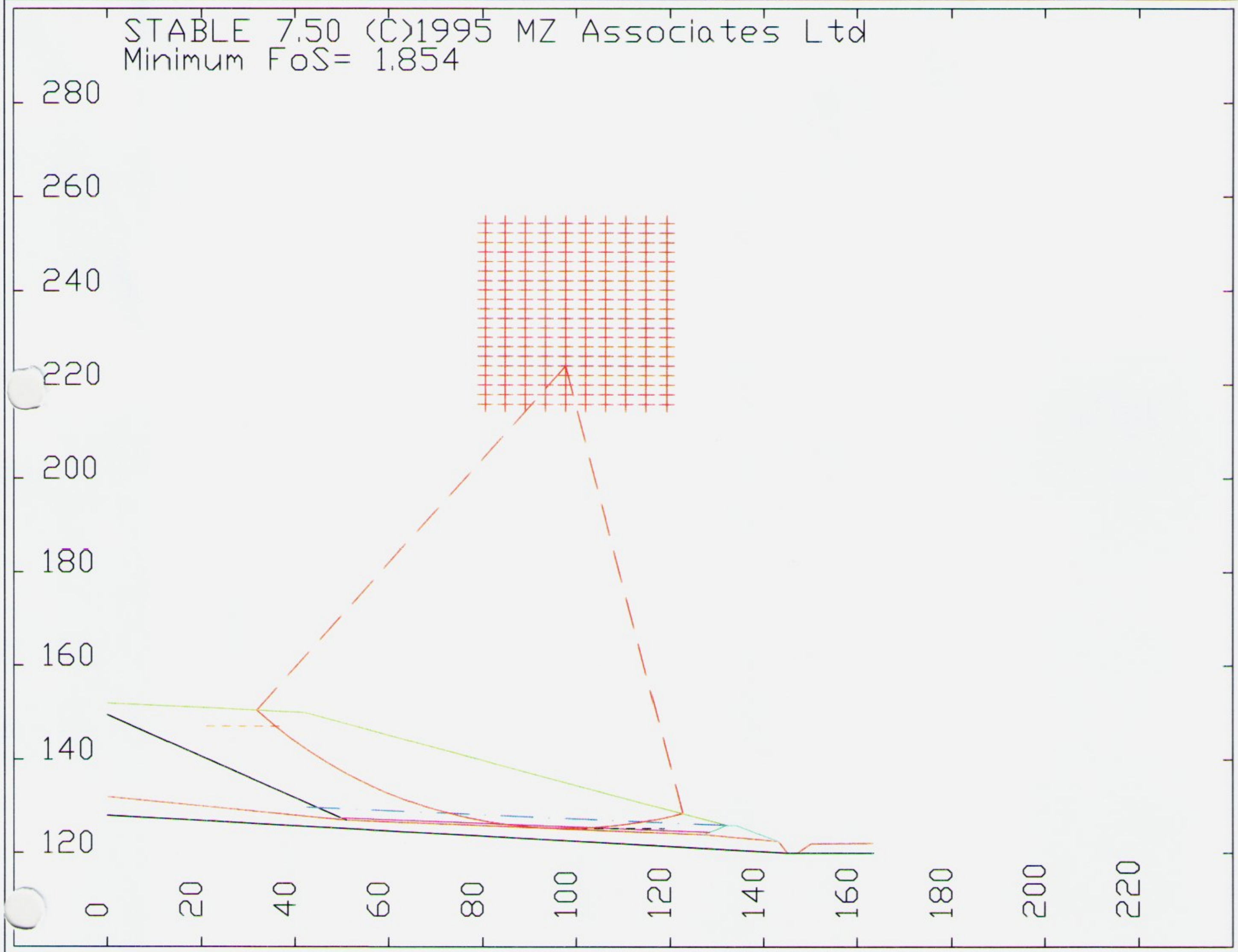
10 Kavazanjia, E., Matasovic, N., Bonaparte, R. & Schmertmann, G.R. (1995), "Evaluation of MSW properties for seismic analysis". Proc. Geo-environment 2000, ASCE Special Geotechnical Publication, pp 1126-1141.

11 Jotisankasa, A., "Evaluating the Parameters that Control the Stability of Municipal Solid Waste Landfills", Master of Science Dissertation, University of London, September 2001.

DRAWINGS

SRA APPENDIX 1



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Title: Nant y Caws Mode 1

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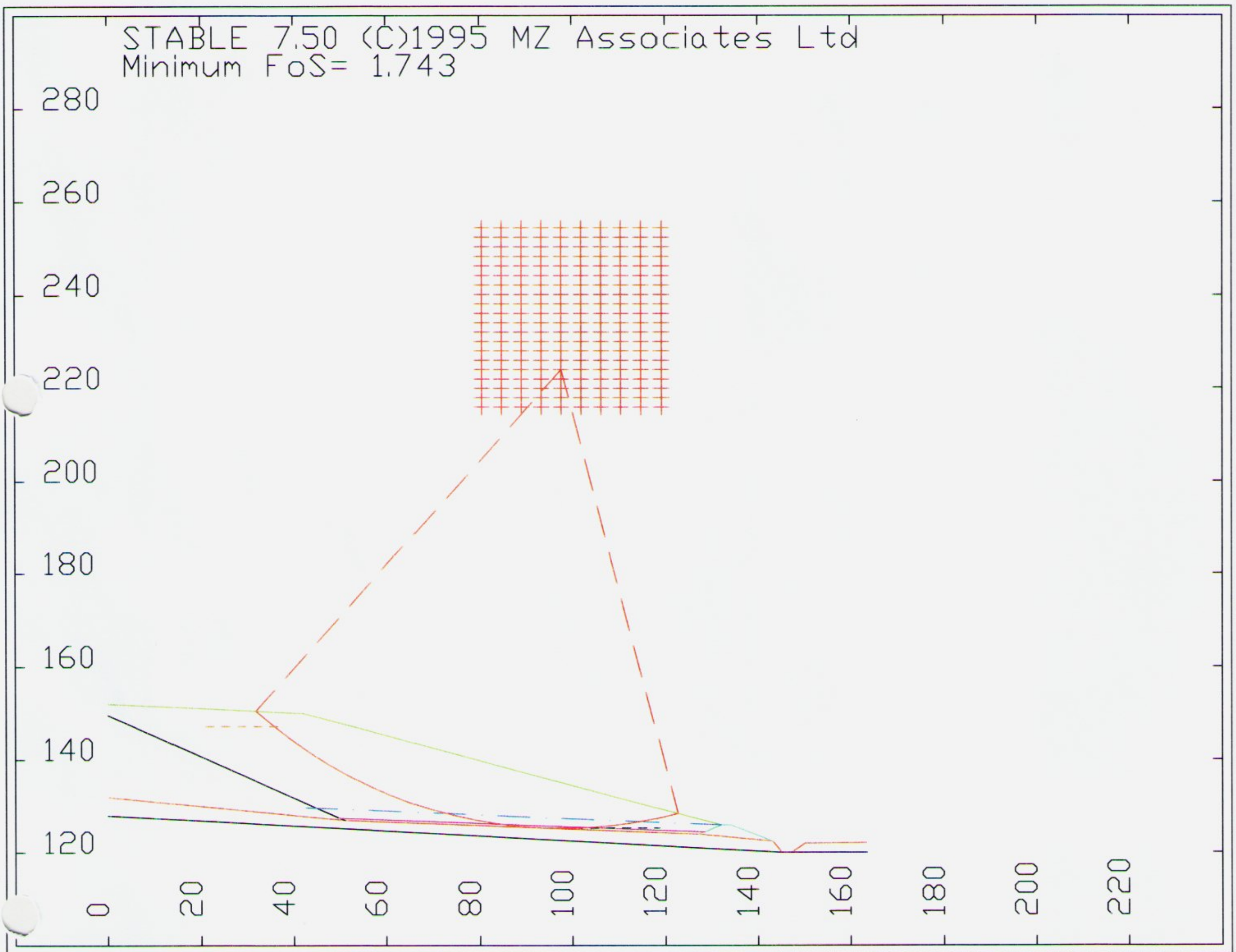
Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-1
Appendix No.	1



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Title: Nant y Caws Mode 1

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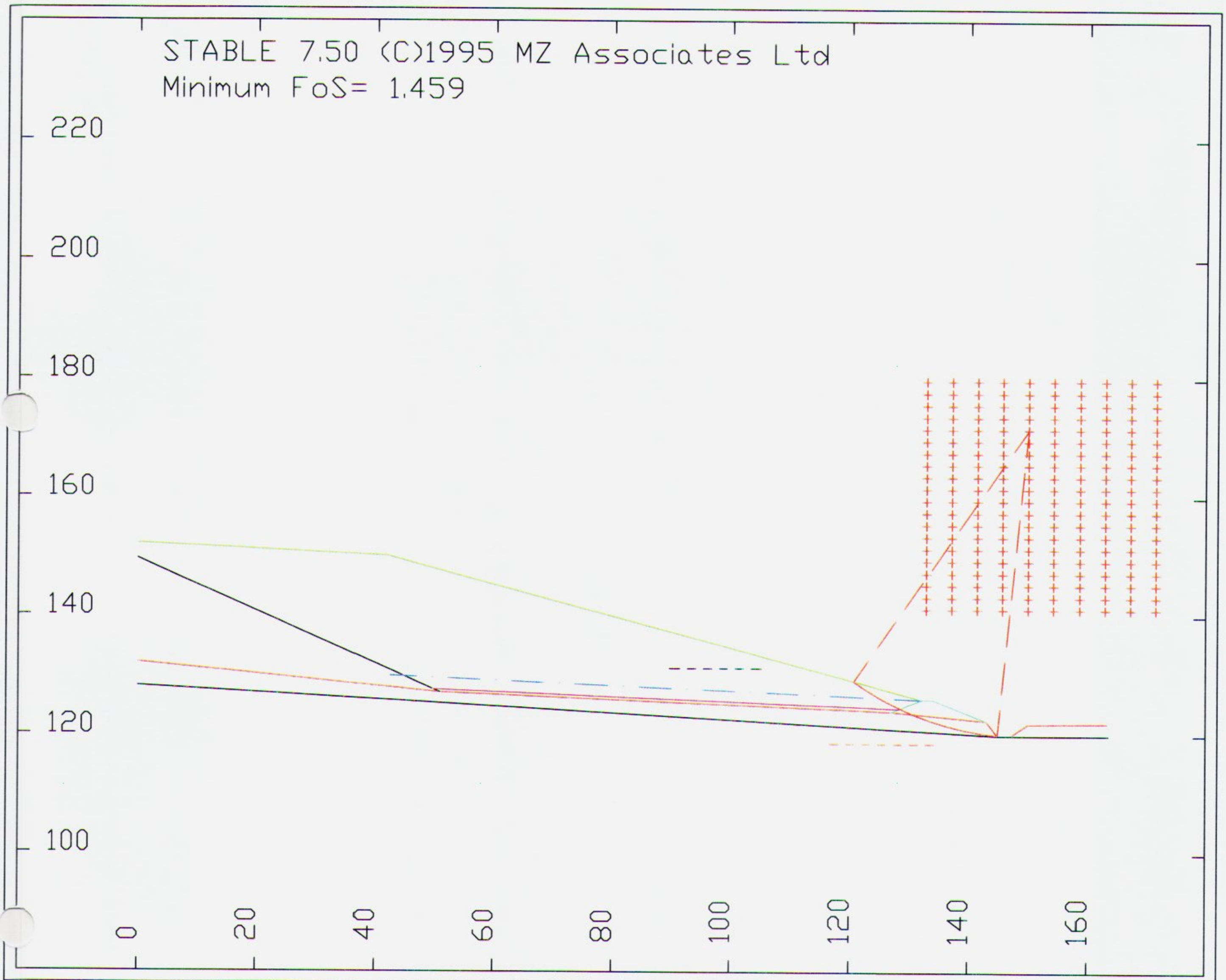
SLR

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-2
Appendix No.	1



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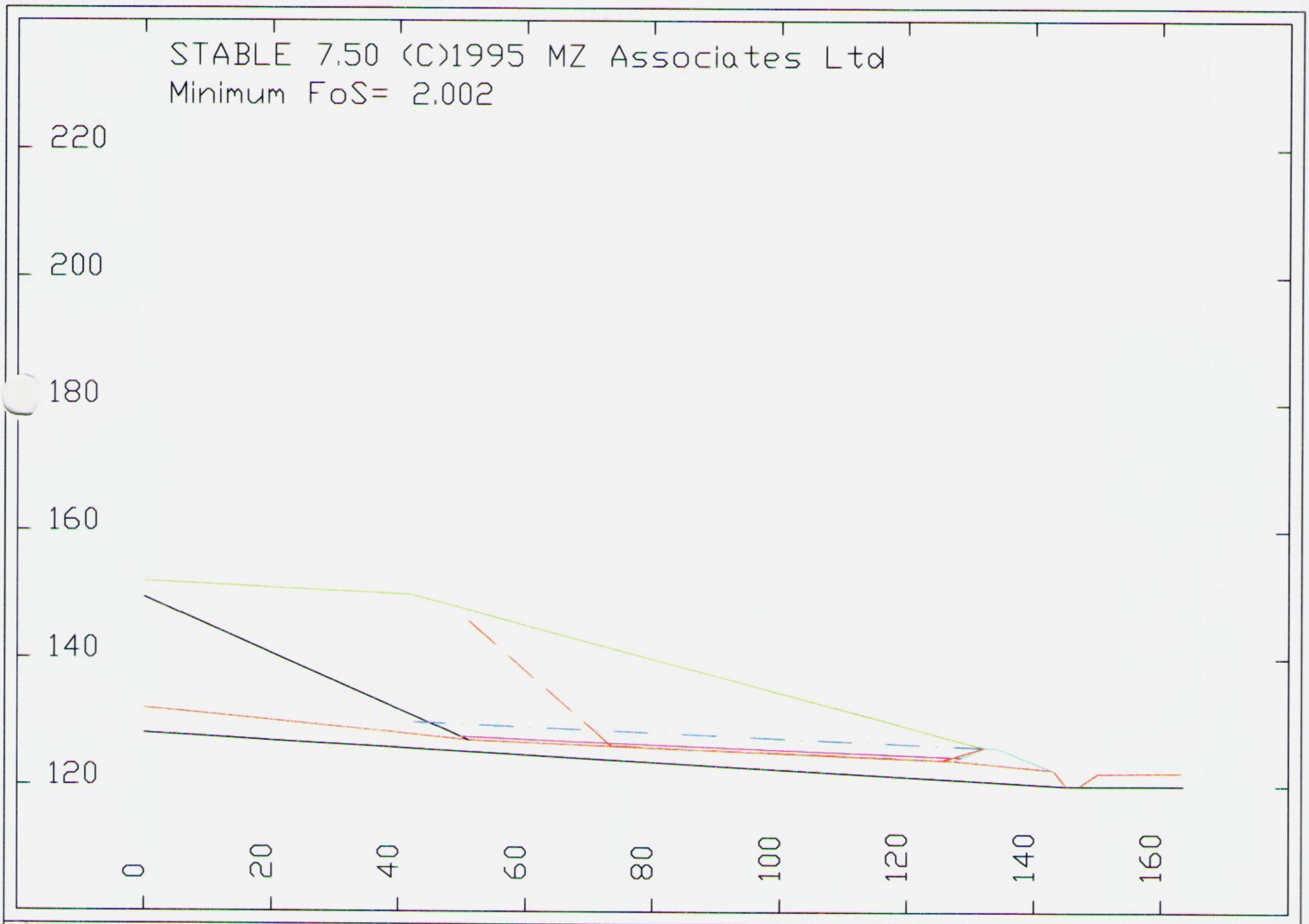
Title: Nant y Caws Mode 1 inc bund

Site	NANTYCAWS LANDFILL SITE	
Project	STABILITY ASSESSMENT-PPC APPLICATION	
Date	MAY 2004	Scale N/A
Drawing	**Figure A1-3**	Appendix No. **1**

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA



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Title: Nant y Caws Mode 2 inc bund

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A

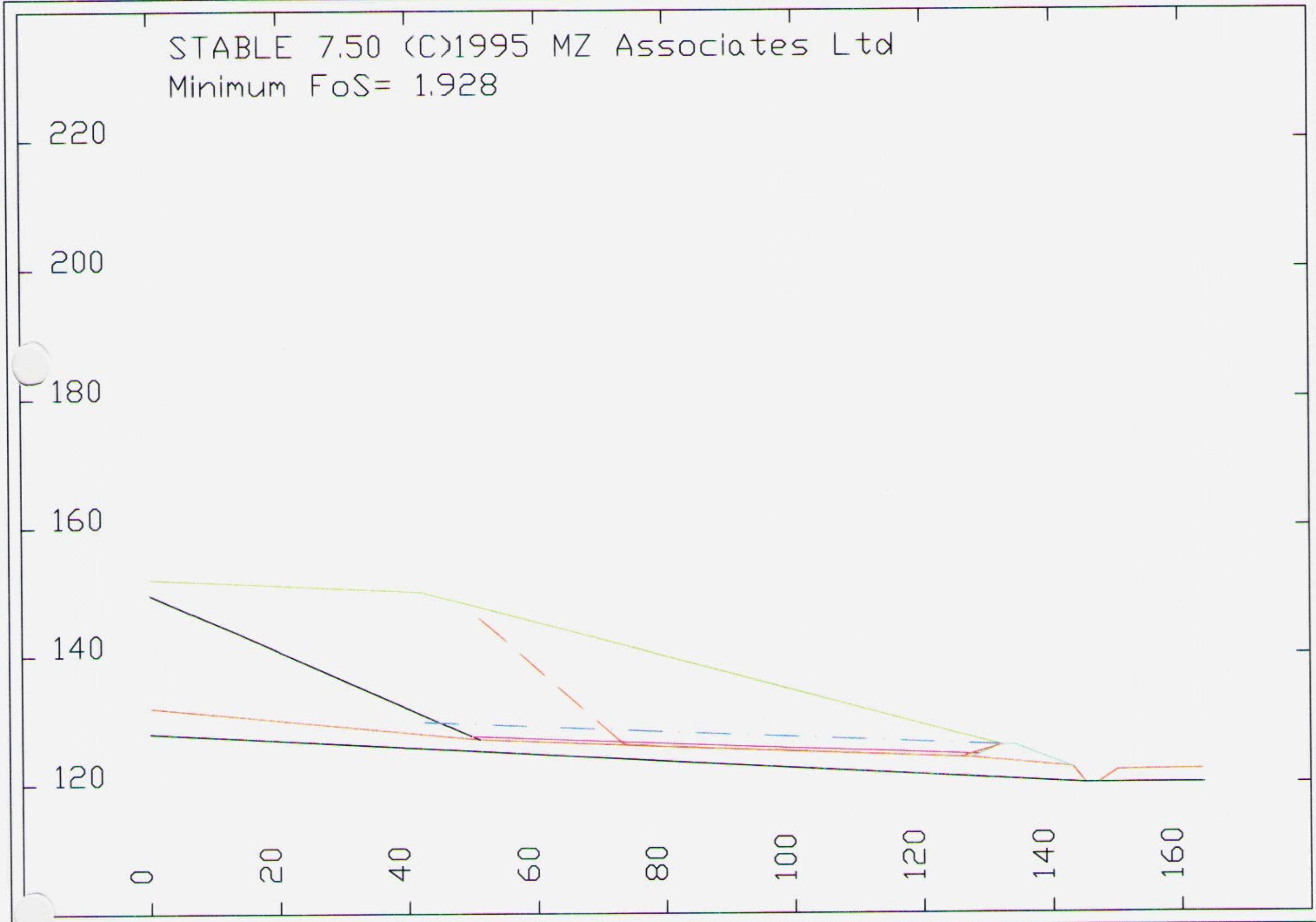
Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Drawing

Figure A1-4

Appendix No.

1



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Title: Nant y Caws Mode 2 inc bund

SECOR

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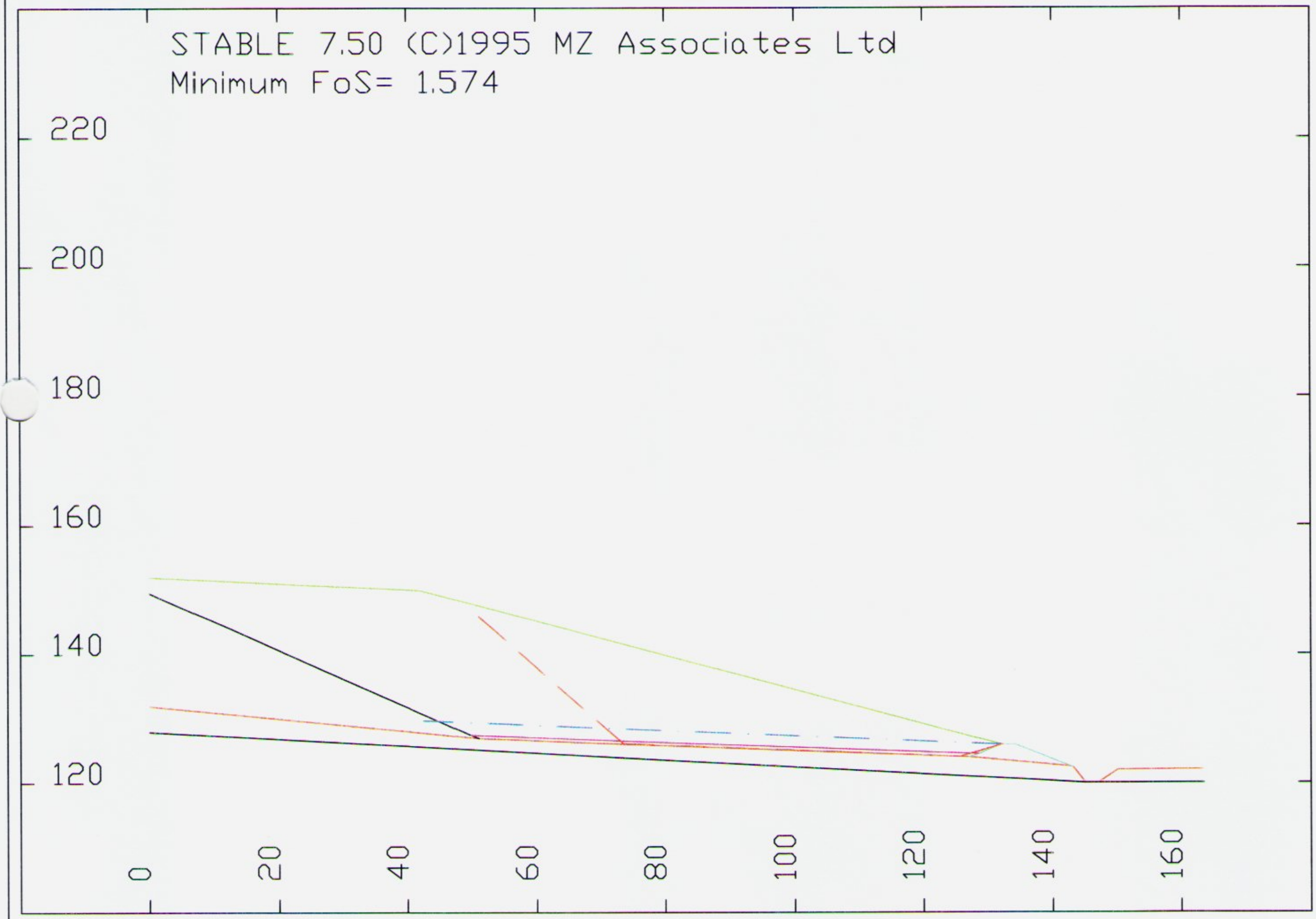
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	**Figure A1–5**
Appendix No.	1



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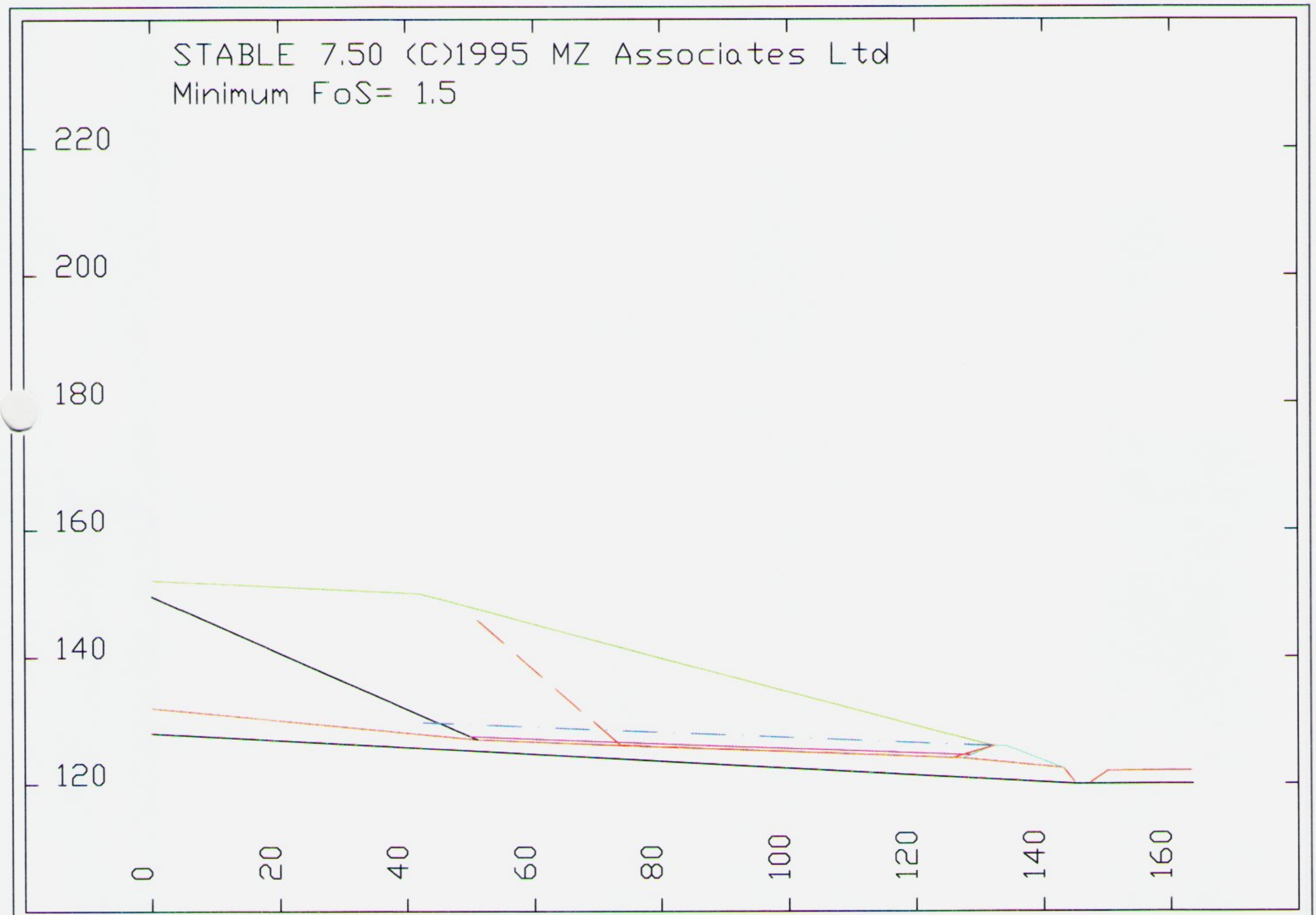
Title: Nant y Caws Mode 2 inc bund

SECOR

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-6
Appendix No.	1

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA



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Title: Nant y Caws Mode 2 inc bund

SECOR

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	**Figure A1-7**
Appendix No.	1

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE		
Project	STABILITY ASSESSMENT–PPC APPLICATION		
Date	MAY 2004	Scale	N/A

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Drawing
Figure A1-8

Appendix No.
1

JOB TITLE : Nant y Caws Landfill, Basal Lining System Geosynthetics Integrity Analysis, Deformed FLAC Grid

FLAC (Version 4.00)

LEGEND

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step 6
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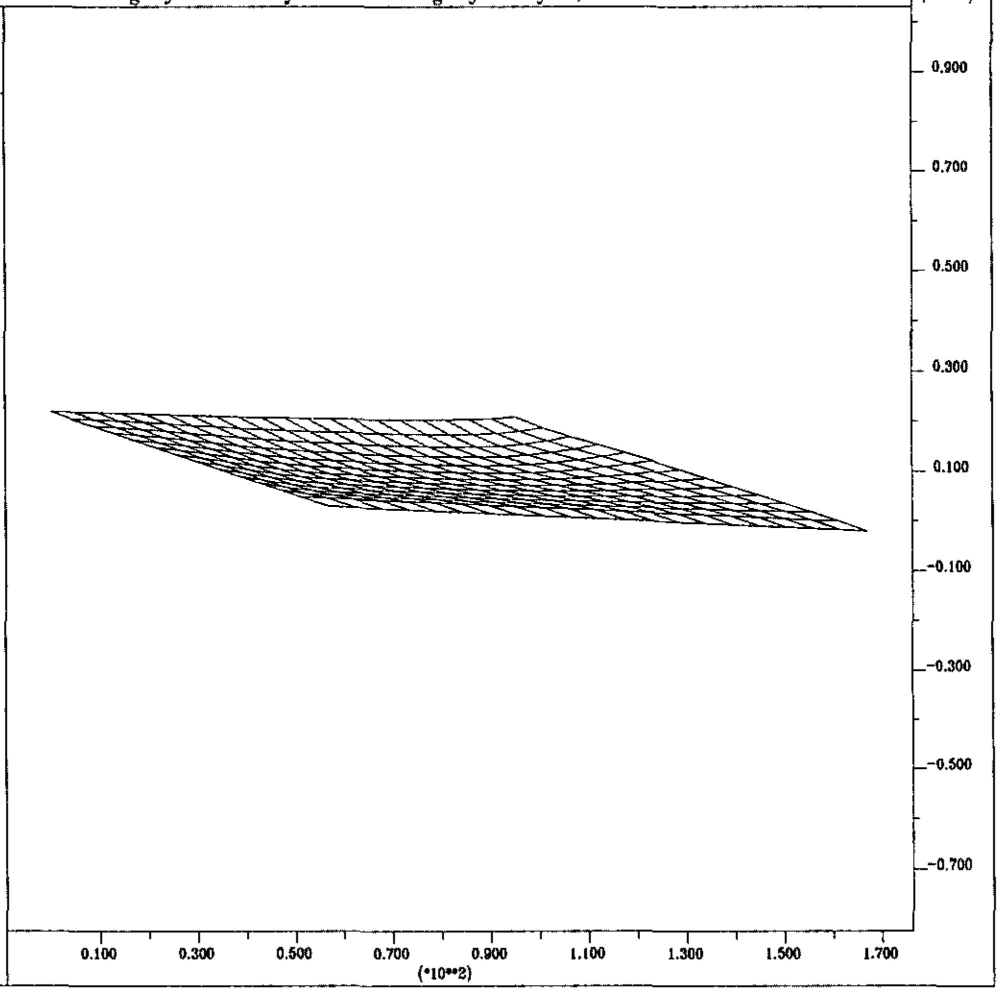
-8.256E+01 <y< 1.030E+02

Grid plot

0 5E 1



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Revision 0 April 2004 MJA
48.610.002 NTCSRAAP1_0 48/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	**Figure A1-9**
Appendix No.	1

JOB TITLE : Nant y Caws Landfill, Basal Lining System Geosynthetics Integrity Analysis, Grid Displacements

FLAC (Version 4.00)

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-8.256E+01 <y< 1.030E+02

Displacement vectors
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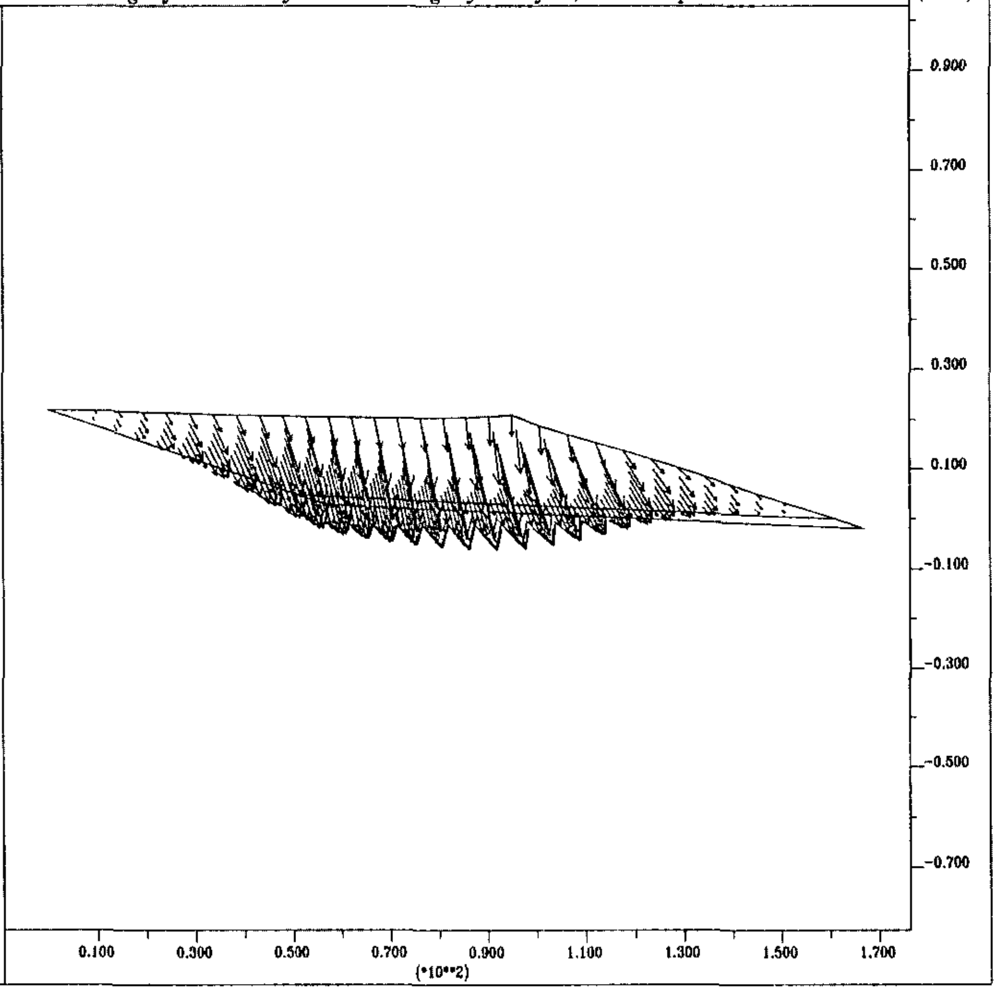

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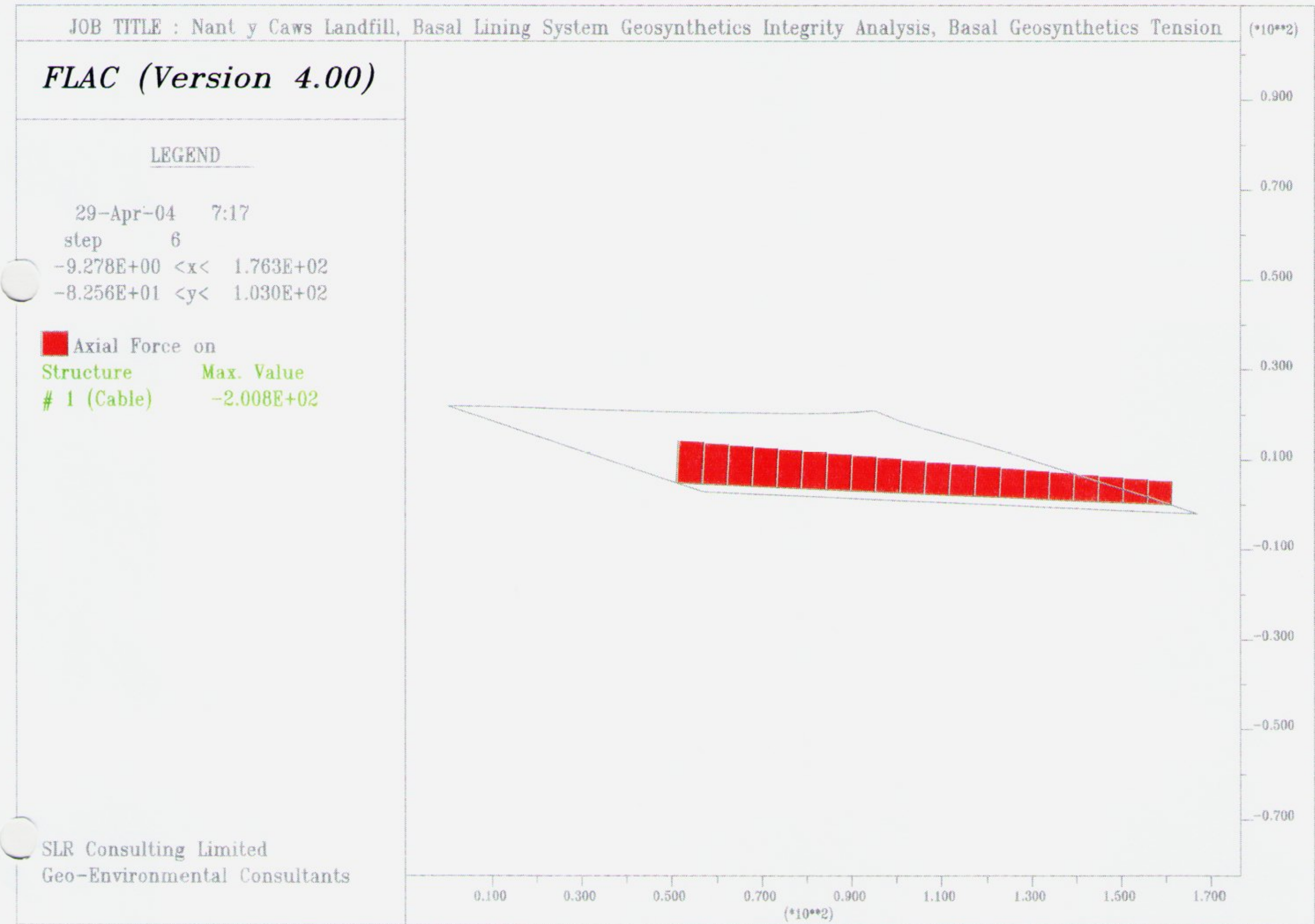
GWM ENVIRONMENTAL

SLR

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT-PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-10
Appendix No.	1



CWM ENVIRONMENTAL

SLR

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-11
Appendix No.	1

JOB TITLE : Nant y Caws Landfill, Basal Lining System Geosynthetics Integrity Analysis, Basal Shear Displacements

FLAC (Version 4.00)

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step 6
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Rel. Shear Displacement
on Interface # 1
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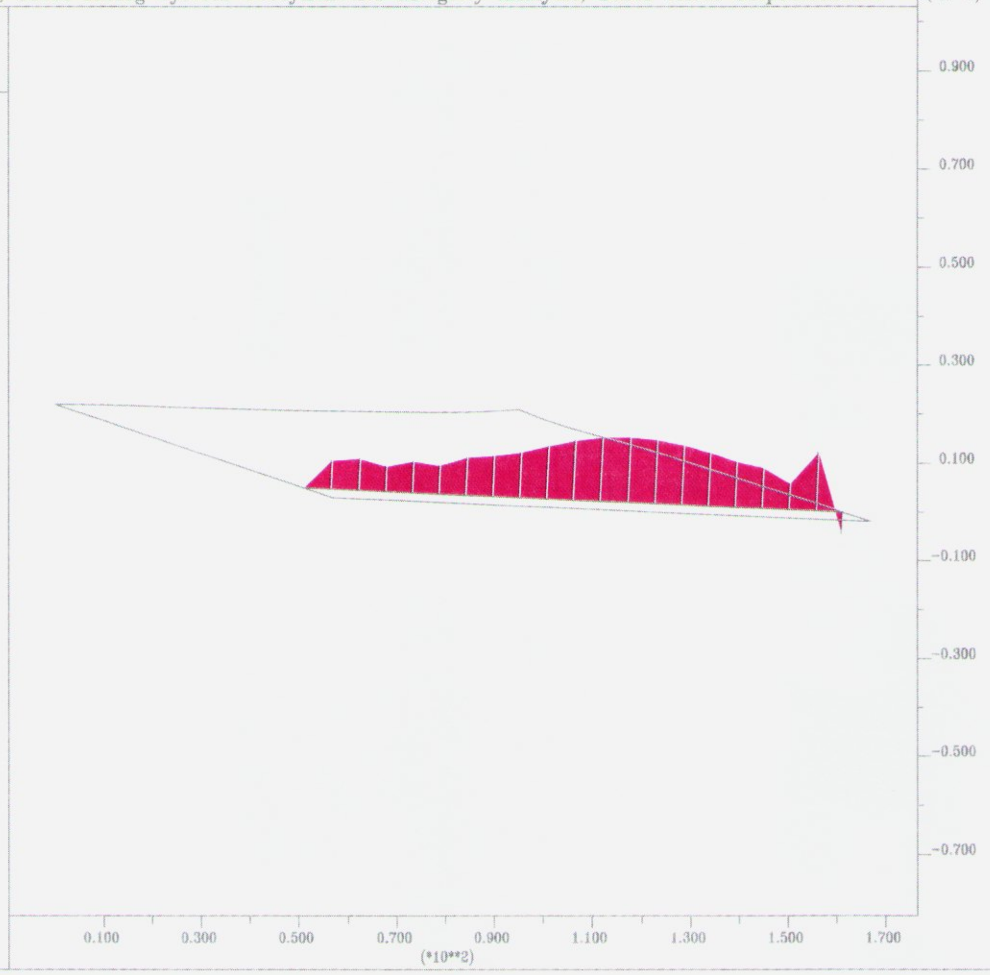

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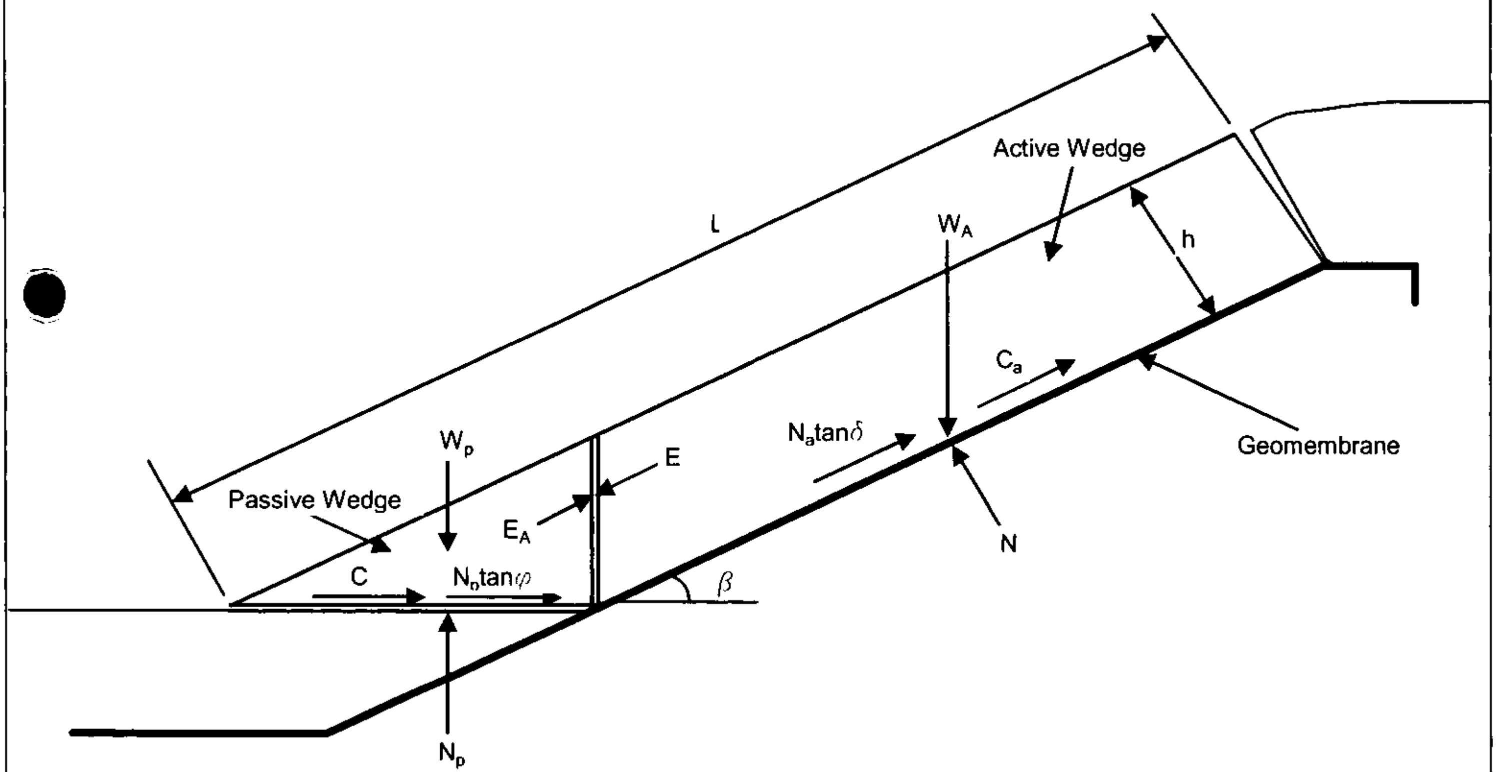
Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT–PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A1-12
Appendix No.	1

Revision 0 April 2004 MJA
4B.610.002 NTCSRAAP1_0 4B/MJA

SRA APPENDIX 2



Title: Schematic for Capping Stability Analysis

Site	NANTYCAWS LANDFILL SITE
Project	STABILITY ASSESSMENT FOR PPC APPLICATION
Date	MAY 2004
Scale	N/A
Drawing	Figure A2-1
Appendix	2

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Revision 0 April 2004 MJA/IU
4B.610.002 Appendix2.dwg 4B/MJA

Capping System Interface Stability

Input Parameters			Peak Case 1	Peak Case 2	Peak Case 3	Residual Case 1	Residual Case 2	Residual Case 3
β	Slope Angle	°	19.30	16.80	19.70	19.30	16.80	19.70
H	Slope height	m	7.00	25.00	14.00	7.00	25.00	14.00
h	Thickness of cover soils	m	1.00	1.00	1.00	1.00	1.00	1.00
ϕ	Friction angle of cover soil	°	26.00	26.00	26.00	26.00	26.00	26.00
c	Cohesion of cover soil	kPa	0.00	0.00	0.00	0.00	0.00	0.00
δ_{ct}	Interface friction angle Cover/Drainage -protection geotextile interface	°	26.00	26.00	26.00	22.00	22.00	22.00
α_{ct}	Apparent cohesion of Cover/Drainage -protection geotextile interface	kPa	0.00	0.00	0.00	0.00	0.00	0.00
δ_g	Interface friction angle VFPE Geomembrane/Drainge geotextile interface	°	26.00	26.00	26.00	22.00	22.00	22.00
α_g	Apparent cohesion of VFPE Geomembrane/Drainge geotextile interface	kPa	2.00	2.00	2.00	0.50	0.50	0.50
δ_{gs}	Interface friction angle Regulation layer/Waste interface	°	25.00	25.00	25.00	20.00	20.00	20.00
α_{gs}	Apparent cohesion of Regulation layer/Waste interface	kPa	0.00	0.00	0.00	0.00	0.00	0.00
PRS	Parallel Submerged Ratio		0.15	0.15	0.15	0.15	0.15	0.15
γ_d	Dry unit weight of cover soil	kN	16.00	16.00	16.00	16.00	16.00	16.00
γ_{sat}	Saturated weight of cover soil	kN	18.00	18.00	18.00	18.00	18.00	18.00
h_w	Thickness of saturated cover soil	m	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**
W_A	Weight of active wedge	kN	**319.50**	**1380.89**	**651.68**	**319.50**	**1380.89**	**651.68**
W_P	Weight of passive wedge	kN	**25.72**	**28.99**	**25.28**	**25.72**	**28.99**	**25.28**
U_n	Resultant pore water pressure perpendicular to slope	kN	**29.64**	**123.82**	**58.32**	**29.64**	**123.82**	**58.32**
U_h	Resultant pore water pressure on interwedge surface	kN	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**
N_{Abo}	Effective force normal to failure plane of active wedge above impermeable layer	kN	**271.94**	**1198.16**	**555.26**	**271.94**	**1198.16**	**555.26**
N_{Abb}	Effective force normal to failure plane of active wedge below impermeable layer	kN	**301.58**	**1321.98**	**613.58**	**301.58**	**1321.98**	**613.58**
U_v	Resultant vertical pore water pressure acting on passive wedge	kN	**0.32**	**0.37**	**0.31**	**0.32**	**0.37**	**0.31**
L	Slope Length	m	**21.18**	**86.50**	**41.53**	**21.18**	**86.50**	**41.53**
Cover/Drainage -protection geotextile interface								
	Quadratic Equation Parameters	a	99.68	382.09	206.83	99.68	382.09	206.83
		b	-154.57	-629.65	-303.24	-133.09	-533.64	-259.49
		c	21.38	82.38	44.53	17.71	68.24	36.88
	Factor of Safety Against Failure		1.40	1.50	1.30	1.19	1.25	1.09
	Tension in Geocomposite	kN	-87.53	-393.76	-154.91	-31.17	-153.78	-42.27
			No Tension	**No Tension**	**No Tension**	**No Tension**	**No Tension**	**No Tension**
VFPE Geomembrane/Drainge geotextile interface								
	Quadratic Equation Parameters	a	99.68	382.09	206.83	99.68	382.09	206.83
		b	-194.55	-795.26	-381.44	-143.08	-575.04	-279.04
		c	28.21	106.77	58.18	19.42	74.34	40.30
	Factor of Safety Against Failure		1.79	1.94	1.68	1.28	1.36	1.18
	Tension in Mineral Liner	kN	-39.74	-200.23	-62.22	-7.79	-59.16	2.93
			No Tension	**No Tension**	**No Tension**	**No Tension**	**No Tension**	**Tension**
Regulation layer/Waste interface								
	Quadratic Equation Parameters	a	99.68	382.09	206.83	99.68	382.09	206.83
		b	-162.12	-660.35	-317.65	-132.99	-530.83	-258.53
		c	22.67	86.90	47.04	17.69	67.83	36.72
	Factor of Safety Against Failure		1.47	1.58	1.37	1.18	1.25	1.09

N.B. This calculation assumes friction angles and cohesion as published in the Loughborough University report.

Site	NANT Y CAWS LANDFILL		
Project	STABILITY ASSESSMENT FOR PPC APLICATION		
Date	Apr-04	Appendix	
	Table 2-1	**SRA 2**	

SLIDING BLOCK ANALYSIS WITH SURFACE LOADS (P & S) AND GEOTEXTILE TENSILE FORCE (Tg)

Method of Kerkes, D.J. (1999), "Analysis of equipment loads on geocomposite liner systems", Proc Geosynthetics 99, pp.1043-1054

BULLDOZER SPREADING SOIL UPSLOPE

Spreadsheet and associated VB macros, Version 2003.02

1. STEP 1. PARAMETER SPECIFICATION

Unit weight of soil cover	16.00	kN/cu.m
Depth of soil cover (1st lift, D)	0.50	m
Dozer type	CAT D4H LGP	
Total dozer weight	123	kN
Track length (L)	2.62	metres
Track width (W)	0.76	metres
Width of dozer blade (Wb)	3.26	metres
Height of soil pile (Hb)	1.00	metres
Length in front of blade (Lb)	1.00	metres
Weight of soil being spread	52.16	kN
Slope angle, alpha	14.00	degrees
Soil cover friction angle	26	degrees
Interface friction angle	22	degrees
Interface adhesion	0	kN/sq.m
Unit tension (geosynthetic)	8	kN/m

2. STEP 2. ITERATION

Select trial values for beta and theta. Press the button to calculate the factor of safety. Then select new trial values and try again.

Beta (Passive wedge)	10	degrees (minus alpha to 90d)
Theta (Active wedge)	45	degrees (slope angle to 90d)

Iterate to find the minimum factor of safety for this calculation method.

Results		Infinite slope
Factor of safety	1.30	1.62
Mobilized soil friction angle	20.6	16.8
Mobilized interface friction angle	17.3	14.0
Moblized interface adhesion	0.0	0.0
Notes		(interface)

3. WORKING AREA

Block	Weight		Bottom surface area	
Passive (1)	5.92	kN		
Central (2)	25.59	kN	3.30	sq.m
Active (3)	3.36	kN		
P/2	61.5	kN (per track)		
S/2	18.7	kN (per track)		
Tg	10.1	kN (width at interface * unit tension)		

Forces

N(1)	8.29	kN	Fig.8 & Eqn.3 of reference
N(2)	84.10	kN	Fig.8 & Eqn.5 of reference
N(3)	2.95	kN	Fig.8 & Eqn.7 of reference
N(4)	4.51	kN	Fig.8 & Eqn.4 of reference
N(5)CB	1.30	kN	Fig.8 & Eqn.6 of reference
N(5)AB	1.30	kN	Fig.8 & Eqn.8 of reference

LANDFILL GAS RISK ASSESSMENT

SECTION D

SECTION D

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1.0 INTRODUCTION

1.1 Report Context

SLR Consulting Ltd (SLR) has been appointed by CWM Environmental Limited (CWM) to prepare a Landfill Gas Risk Assessment in support of a PPC Permit application for the Nantycaws Landfill site, approximately 8km east of Carmarthen and 1.5km to the south-east of the village of Nantycaws. This report develops the Conceptual Site Model for the landfill, and attempts to characterise the source term and the potential pathways and receptors for the subsequent landfill gas risk assessment.

The application site is being engineered in five cells, on the principle of engineered containment, and primarily as a land raise. It is understood that prior to waste deposition, up to a metre of clay was stripped from the pre-existing ground surface. To date, Cells 1, 2 and 3 have been completed, although only part of Cell 1 has been finally capped, with the remaining areas of these Cells being temporarily capped. Cell 4 has been engineered and is currently being infilled, the remaining Cell 5 is yet to be developed.

The site is bounded to the south by an older area of landfilling (known as Phase 1) which was completed in 1997 and has been fully restored. This site was developed using the principle of dilute and attenuate, and is not included in the PPC Permit application. The Phase 1 area is both physically and technically separate from the application site but does supply a small proportion of gas to the utilisation plant. This plant is however, directly associated with and principally used by Phase 2. However, as a small proportion of gas is supplied by Phase 1, it has been considered when estimating gas generation rates and the potential impact of emissions from the landfill gas utilisation plant on the environment.

The landfill gas utilisation plant is greater than 3MW thermal input and as such will be regarded as a separate technical unit (STU) and will be regarded as a Listed Activity under the PPC Regulations. This STU is operated by a third party and accordingly a separate PPC application will be made to operate this plant. As the landfill gas utilisation plant is a directly associated activity to the primary activity ie. The landfill it has been included within the installation boundary to which this PPC application relates.

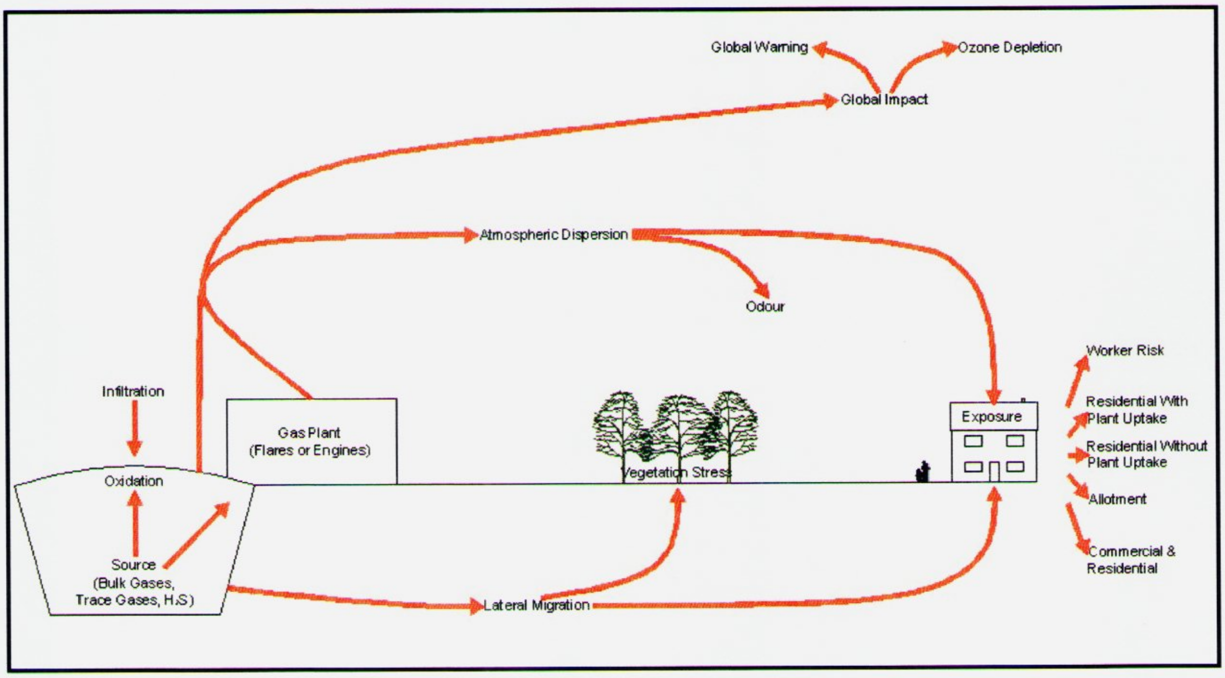
Relevant environmental information, site monitoring data and development information to characterise the source term and the potential pathways and receptors for contaminant transport are detailed within the site's Environmental Setting and Installation Design (ESID) report [1].

1 Nantycaws Landfill Site, Environmental Setting and Installation Design Report, prepared for CWM by SLR Consulting, Report Ref: 4B-610-002-ESID, May 2004.

1.2 Conceptual Landfill Gas Site Model

The landfill gas risk assessment has been undertaken using the GasSim [2] model. The conceptual model for the assessment is presented in Figure LFGRA1 and a description of the sources, exposure pathways and receptors is provided in Sections 1.2.1 to 1.2.3.

FIGURE LFGRA1: LANDFILL GAS CONCEPTUAL MODEL



1.2.1 Sources

Nantycaws Landfill Site has been in operation since March 1997 and receives predominantly domestic waste, with smaller quantities of commercial, industrial, and inert wastes, ash, asbestos and sewage sludge. Annual waste inputs to date have typically been approximately 100,000 tonnes. It is estimated that a further 280,000 tonnes will be deposited prior to the cessation of tipping in 2006. Due to the nature of the waste deposited within the landfill, landfill gas is, and will continue to be, generated from the decomposition of the waste.

The Landfill Gas Risk Assessment has assessed the risks associated with Phase 2, however, in addition, Phase 1 has also been considered as and when necessary in order to gain an full impression of the potential impacts associated with the gas generated within the PPC Application site and the treatments methods used.

The existing landfill cells incorporate the following design:

2 Environment Agency, 2004, GasSim (v1.03)

- A composite basal and sidewall liner comprising a combination of HDPE geomembrane, geosynthetic clay liner and engineered clay. The lining system extends up the full height of the sidewall of the perimeter bunds in Cells 2, 3 and 4. For the purposes of this assessment, a worst case lining system has been modelled, as described in Section 2.4.2.

- The capping of Cell 1 has been undertaken using a 1.0mm VFPE geomembrane and protection geotextile. Currently 800mm of restoration soils have been placed on top of the cap, although this will be supplemented to the full restoration profile in the future. Cells 2 and 3 have a temporary cap consisting of 250mm of mixed soils and clay. This assessment has assumed that a 1.0mm geomembrane and 1.0m of restoration soils will be used in final capping.

As set out within Section 1.1, the PPC Application area includes the landfill and the ground flare and the gas engine, which are associated with, and principally used by, Phase 2. Phase 1 is a restored site that operated under the principles of dilute and disperse. It is physically separate from the PPC Application site. However, the landfill gas that is collected from Phase 1 is processed at the gas utilisation plant that lies within this PPC application installation boundary. When estimating gas generation rates and the potential impact of emissions from the landfill gas utilisation plant (dioxins and furans, nitrogen dioxide, and carbon monoxide), it has therefore been necessary to assess both Phase 1 and the PPC application Site.

An active gas management system has been constructed at the landfill consisting of a network of gas extraction wells, connected to a system of gas mains and spurs. The gas collection system directs collected gas from the application site and the adjacent Phase 1 area to a single Jenbacher 420 gas engine and a single high temperature, enclosed gas flare.

The gas extraction system will be progressively expanded as the landfill develops and the completed cells are permanently capped. This will ensure that the quantity of landfill gas collected at any one time is optimised.

1.2.2 Pathways

There are a number of pathways whereby landfill gas has the potential to affect on-site and off-site receptors. These include:

- Fugitive emissions of landfill gas from the surface of the landfill (active landfill, partially restored and fully restored surfaces) into the atmosphere where they will be diluted and dispersed.

- Lateral migration of landfill gas through the landfill liner and subsurface.

- Emissions of landfill gas combustion products from the landfill gas utilisation plant such as the gas engine and flare. Emissions will be from the stack associated with the engine and flare and as with fugitive releases will be diluted and dispersed in the atmosphere depending on meteorological conditions.

Human exposure to landfill gas emissions in the atmosphere may arise via a number of pathways as follows:

- Direct inhalation of airborne contaminants and particles, including airborne contaminants that may arise from lateral migration of landfill gas;
- Deposition of contaminants on to soils, vegetation and surfaces and subsequent ingestion of soils, vegetation and deposited dust;
- Dermal contact with contaminated soils and dust; and
- Contamination of vegetation via deposition and uptake through leaves and roots.

Human exposure to contaminants present in landfill gas can also occur from the ingestion of other food products such as locally grown dairy products and meat (exposure occurs by the animal ingesting contaminated soils and vegetation). However, this pathway is not included within the GasSim model.

1.2.3 Receptors

The Nantycaws Landfill Site is located approximately 1.5km south-east of the village of Nantycaws and 8km east of Carmarthen at National Grid Reference SN470171. The land surrounding the site is predominantly agricultural with open fields to the north and east. A large poultry unit is located to the immediate west of the site. To the immediate south of the site is Phase 1 of the Nantycaws Landfill which has formed a low, domed feature following capping and restoration. The receptors that have been considered in the risk assessment are detailed in Table LFGRA1.

TABLE LFGRA1: SENSITIVE RECEPTORS CONSIDERED FOR THE LANDFILL GAS RISK ASSESSMENT

Receptor	Receptor Type	Distance & Direction from the Gas Utilisation Compound	Distance & Direction from the Boundary of Nearest Cell	Distance & Direction from the Centre of the Site
Awelfan ✓	Residential	470m NNW	420m N	650m NE
Filling Station ✓	Commercial	470m N	420m NNE	700m NE
Llety-dau-filwr ✓	Residential	290m E	380m E	650m ENE
Blaenisfael ✓	Residential	675m SW	190m SW	380m SW
Ty-Hen ✓	Residential	440m NW	335m NNW	440m N
Civic Amenity Site ✓	Commercial	50m E	130m E	410m NE

The exposure module within GasSim model allows for five different critical groups, although not all of them may be relevant for an individual landfill. These groups are as follows:

- Residential receptor with plant uptake;
- Residential receptor without plant uptake;
- Allotments;
- Commercial and industrial receptors; and
- On-site workers.

For the receptors selected for the landfill gas risk assessment the critical group that has been assigned to each for the exposure assessment is presented in Table LFGRA1.

Whilst the configuration of the GasSim software significantly constrains the nature of the receptors that can be considered , it has been conservatively assumed that plants, which could potentially be contaminated, are consumed at all of the considered residential receptors. GasSim assumes that residential receptors are children aged between 0 and 6 years, and commercial receptors are female workers aged between 16 and 59 years.

2.0 LANDFILL GAS RISK ASSESSMENT

2.1 The Nature of the Landfill Gas Risk Assessment

The site's conceptual landfill gas model, which includes the estimations of potential landfill gas generation, indicates that potential gas volumes cannot be considered to be negligible. Consequently, there is a requirement for a greater level of assessment complexity than just risk screening.

For the purposes of this assessment, GasSim was used to provide an indication of the potential risks posed by the Nantycaws Landfill.

This assessment has included the impact of emissions attributable to the combustion of landfill gas extracted from the Nantycaws Phase 1 landfill, which will be connected to the same utilisation plant as the application site. All results relating to CO, NO_X, and dioxins and furans are taken from a combined GasSim model which incorporates both sites. Results relating to odour and surface emissions are taken from a model based only on the application site. The input parameters for both models are presented in Appendices LFGRA1a and LFGRA1b. The total waste input to the Phase1 landfill has been estimated at 1,000,000 tonnes, with waste breakdowns assumed to be comparable to those at the application site.

2.2 The Proposed Assessment Scenarios

2.2.1 Lifecycle Phases

In order to provide an estimate of how the potential risk from landfill gas may evolve through the lifecycle of the Nantycaws Landfill Site, five different scenarios were considered within this risk assessment as discussed in Table LFGRA2.

TABLE LFGRA2: PROPOSED LANDFILL GAS RISK ASSESSMENT SCENARIOS

Scenario	Considered Year(s)	Reasons for Choice
Operational period (for dispersion and odour assessment)	2005	This year is predicted to be the year of maximum surface emissions from the application site model.
Operational period (for human exposure assessment – dioxins and furans)	2003 - 2008	The predicted six year period of maximum landfill gas production from the combined sites model.
Operational period (for human exposure assessment – benzene, vinyl chloride and H_2S)	2003-2008	The predicted six year period of maximum surface emissions of landfill gas from the application site model (i.e. maximum landfill gas generation whilst a proportion of the site is unrestored).
Maximum gas generation	2006	This year is predicted as the period of peak landfill gas production from the combined sites model.
Following closure and restoration of the site, i.e. during aftercare phase	2020	To provide an indication of potential risks associated with the site following site closure and while gas generation is still occurring.

2.3 The Generated Gases to be Modelled

The GasSim model contains default information for a wide range of gases that typically are emitted from landfill sites, either from the landfill surface or from landfill gas utilisation plant and/or flares.

With respect to emissions to air there are two main issues associated with landfill sites, as follows:

- Odorous emissions that may be the result of a single contaminant (e.g. hydrogen sulphide) but more generally for landfill sites occur as a result of a complex mixture of contaminants.

- The emission of contaminants that may be harmful to health. These contaminants may be contained within the waste itself, generated during decomposition processes within the waste and/or they may be combustion products generated during the utilisation of landfill gas in gas engines or flares.

It is not necessary to consider all of the contaminants that may be emitted from the landfill site but to consider a range of contaminants that will provide an assessment of the potential risk of the landfill with regard to landfill gas emissions. The GasSim model provides default *data on a range of contaminants emitted from landfills. A selection of these contaminants* have been used to assess the potential risk and are discussed below.

Total Odours

The impact of the landfill site on odours has been assessed by consideration of total odours and the European odour unit (OU_E). The use of the OU_E takes into account the odour potential of all substances contained within a mixture. In terms of odour units, ambient air will generally contain a number of odorous substances and may have an odour concentration of 5 OU_E m^{-3}, or higher in rural locations, (*i.e.* if a sample of ambient air was subjected to odour analysis under laboratory conditions, 50% of an odour panel would not detect an odour when the sample is diluted five times using clean air).

Hydrogen Sulphide

Hydrogen sulphide (H_2S) has been selected, as this contaminant is commonly present within landfill gas and has potential impacts on odour nuisance at low concentrations as well as potential human health impacts at higher concentrations. Hydrogen sulphide and other organic sulphides are generated during the decomposition process by sulphate reducing bacteria and may be a particular problem where waste rich in sulphate (*e.g.* calcium sulphate) has been disposed of at the landfill. The GasSim model incorporates an optional hydrogen sulphide module to simulate the generation of H_2S from landfills where sulphate rich waste has been deposited. Although it is understood that such wastes have been accepted at the application site in the past, there are currently no proposals to accept significant quantities of such wastes in the future and should wastes of this type be accepted at the site, co-disposal with putrescible waste would not occur. Therefore, the assessment of H_2S emissions has not used the hydrogen sulphide module but has been assessed based on assumptions of typical H_2S concentrations in landfill gas.

Benzene

Benzene has been included in the assessment as this is a contaminant commonly present within landfill gas and for which there is a statutory UK air quality standard. Consequently, predicted concentrations can be compared with standards that have been set for the protection of human health.

Nitrogen Dioxide

Elevated concentrations of nitrogen dioxide (NO_2) are not present within landfill gas but the oxides of nitrogen (NO_x) are generated during the combustion of landfill gas within gas engines and flares. Oxides of nitrogen emitted to atmosphere as a result of combustion will consist largely of nitric oxide (NO), a relatively innocuous substance. Once released into the atmosphere, nitric oxide is oxidised to nitrogen dioxide (NO_2), which is of concern with respect to health and other impacts. As a worst-case it is assumed that NO_x emitted from landfill gas engines and flares comprises entirely of NO_2.

Carbon Monoxide

Along with NO_x, carbon monoxide (CO) is emitted from landfill gas engines and flares and together they are considered to be the most significant pollutants with regard to their potential impact on local air quality. Carbon monoxide may also be present within landfill gas.

Vinyl Chloride

Vinyl chloride is a contaminant that is often associated with landfill sites. It is a known human carcinogen and is, therefore, of concern for human health effects.

Dioxins and Furans

Polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are commonly referred to as dioxins and furans. They may be formed during combustion processes where chlorine is present although they can be controlled by careful management of the combustion process to minimise their formation and maximise their destruction.

Dioxins and furans are a class of compounds with a particular chemical structure that contain carbon, hydrogen, oxygen and chlorine atoms. Each separate chemical is known as a *congener*. Of these PCDDs and PCDFs, 17 congeners are of concern with respect to human health, with the most toxic being (2,3,7,8-TCDD). In addition to direct human health effects (*e.g.* via inhalation exposure), dioxins and furans are of concern from indirect exposure pathways (*e.g.* via the ingestion of soils or food products that may be contaminated). Contamination of soils and food products can occur from the deposition of dioxins directly on to soils and vegetation and from the uptake of contaminants by vegetation from soils or air. Using the exposure module within GasSim, the impact of dioxins and furans (as 2,3,7,8-TCDD) has considered both direct and indirect exposure pathways (*e.g.* the ingestion of soil/dust and vegetation and dermal contact with contaminated soil).

2.4 Numerical Modelling

2.4.1 Justification for Modelling Approach and Software

Given the nature of the proposed development and the site's environmental setting, it was considered appropriate to carry out the risk assessment modelling in a "complex" [3] fashion using GasSim (Version 1.03) to provide an indication of the potential risks associated with the Nantycaws Landfill site.

For the GasSim assessment, the 95% percentile (%ile) confidence level has been used, unless otherwise stated. The 95%ile presents a low probability of occurrence and is typically chosen

[3] As defined by the Environment Agency, November 2002, Draft Guidance on the Management of Landfill Gas. Complex assessments should be carried out in a quantitative manner using stochastic techniques. They should be carried out when the site setting is sufficiently sensitive to warrant detailed assessment and a high level of confidence needs to be provided.

in these circumstances. Furthermore, the Environment Agency commonly considers a 95%ile to be a reasonable assessment level in a GasSim assessment.

2.4.2 Model Parameterisation

The input parameters used for the GasSim model for the Nantycaws Landfill site are presented in Appendix LFGRA1a (the application site model) and Appendix LFGRA1b (inclusive of the closed Phase 1 landfill, referred to as the combined sites model). Where there is no site specific information, the GasSim default values have been used or the experience and knowledge of the SLR assessor has been used to develop parameters that would be appropriate for the Nantycaws Landfill site and the activities and design details for the site. Where there is uncertainty concerning the parameter to be used, probability density functions (PDFs) have been used to provide an appropriate range for the parameter. These are detailed in the model reports in Appendices LFGRA1a and LFGRA1b.

Details relating to the parameters used for the application site model are discussed below. The parameters used in the combined model have not been discussed in detail. In summary, the same parameters have been used in both models, with the exception of landfill geometry, waste inputs and waste breakdowns. For the Phase 1 landfill, waste parameters have been established from anecdotal evidence in order to take account of the influence of this area on emissions from the gas utilisation plant.

Infiltration and Landfill Characteristics

The input value for the infiltration coefficient has been assumed as Normal (154.0, 15.4) mm a^{-1} as 10% (with a standard deviation of 1%) of the average precipitation recorded for the site location. However, it should be noted that the waste moisture content has not been calculated and therefore this parameter has not been used in the modelling.

The landfill geometry assumed for the Nantycaws Landfill is as follows:

- Landfill length (north-south) 175 m;
- Landfill length (east-west) 470 m;
- Area of landfill 82,250 m^2.

The landfill characteristics have been obtained from typical construction details for lining and capping systems. The permeability and thickness PDF's for the liner and cap are presented in Table LFGRA3.

TABLE LFGRA3: INPUT VALUES FOR THE LANDFILL CHARACTERISTICS

Characteristic	Material	Thickness (m)	Hydraulic Permeability (m s^{-1})
Landfill cap	VFPE geomembrane	Single(0.001)	LogTriangular (1.0×10^{-14}, 1.0×10^{-13}, 1.0×10^{-12})
Landfill basal and sidewall liner	HDPE geomembrane	Single(0.002)	LogTriangular (1.0×10^{-14}, 1.0×10^{-13}, 1.0×10^{-12})
	Engineered clay	Uniform(0.25,0.30)	Single (1.0×10^{-9})

These are based on the GasSim defaults and design characteristics and assume the worst case conditions due to long term potential degradation of the liner and cap. The liners and cap have been constructed under independent Construction Quality Assurance (CQA) supervision, and it is assumed that the material is generally equal or less than the maximum permeability requirements of 1.0×10^{-9} m s^{-1}.

Source

The waste breakdowns assumed for the application site are presented in LFGRA4. These figures are based on data supplied by CWM. All figures shown are percentages of the total input for each year.

TABLE LFGRA4: WASTE BREAKDOWN FOR NANTYCAWS LANDFILL

Year	Domestic	Commercial	Industrial	Inert	Ash	Sewage
1997	Single (92.5)	-	-	Single (0.3)	Single (3.6)	Single (3.6)
1998	Single (85.9)	-	-	Single (1.5)	Single (6.3)	Single (6.3)
1999	Single (81.3)	Single (0.2)	Single (0.2)	Single (13.5)	Single (2.4)	Single (2.4)
2000	Single (83.6)	Single (0.8)	Single (0.8)	Single (12.0)	Single (1.4)	Single (1.4)
2001	Single (88.3)	Single (0.4)	Single (0.4)	Single (9.7)	Single (0.6)	Single (0.6)
2002	Single (87.9)	Single (1.2)	Single (1.2)	Single (6.7)	Single (1.5)	Single (1.5)
2003	Single (90.3)	Single (1.0)	Single (1.0)	Single (5.3)	Single (1.2)	Single (1.2)
2004-2006	Single (87.2)	Single (0.5)	Single (0.5)	Single (7.0)	Single (2.4)	Single (2.4)

The waste information indicates that the past waste inputs have been around 100,000 tonnes per year. This figure is likely to be slightly higher in 2004 and 2005, with site closure predicted in 2006.

The waste compositions are presented in Appendix LFGRA2; the breakdown for domestic waste is derived from the National Household Waste Analysis Programme and is the GasSim default. For industrial waste, the waste compositions have been derived from information provided in Waste Strategy 2000.

The percentage of waste in place that is capped will be dependent on the proposed restoration of the landfill and the development of individual cells and phases. GasSim does not allow gas to be collected from cells that are not capped. However, it is possible to collect gas from un-restored cells and assumptions have been made regarding the proportion of un-restored cells that are capped to allow the gas to be collected and utilised. Details of the percentage of the waste in place that is capped for each year are presented in Table LFGRA5.

TABLE LFGRA5: PERCENTAGE OF WASTE IN PLACE THAT IS CAPPED

Year	% Capped	Year	% Capped
1997	Uniform (10.0, 20.0)	2002	Uniform (70.0, 80.0)
1998	Uniform (45.0, 55.0)	2003	Uniform (75.0, 85.0)
1999	Uniform (75.0, 85.0)	2004	Uniform (75.0, 85.0)
2000	Uniform (70.0, 80.0)	2005	Uniform (80.0, 90.0)
2001	Uniform (70.0, 80.0)	2006	Uniform (85.0, 95.0)

Methane and Carbon Dioxide Concentrations

Summary data provided by CWM concerning the concentration of methane and carbon dioxide present in the landfill gas and assumed for this assessment are as follows:

- Carbon dioxide (%) Uniform(30.0, 40.0); and
- Methane (%) Uniform(45.0, 55.0).

Cellulose Decay Rates

Cellulose decay rates which correspond to slightly wetter than average waste have been used in this assessment to calibrate the combined sites model against recorded current collection rates of approximately 700 $m^3 hr^{-1}$. The decay rates used are as follows:

- Slow cellulose decay rate of 0.061;
- Moderate cellulose decay rate of 0.096;
- Fast cellulose decay rate of 0.405.

Waste Moisture Content

Other parameters relating to the waste are as follows:

- the waste density is assumed to be the GasSim default of Uniform (0.8, 1.2) tonnes m^{-3};
- leachate head is assumed to be the GasSim default of Single (1.0) m; and

- hydraulic conductivity of the waste is assumed to be the GasSim default of LogUniform (1.0×10^{-9}, 1.0×10^{-5}) m s^{-1}.

Trace Gases

As a conservative, worst-case assumption, the GasSim default values for trace gas concentrations in landfill gas have been used except for hydrogen sulphide. The default concentrations tend to be worst-case values as they have been derived from measurements at problem sites, particularly for hydrogen sulphide where measurements were recorded at a site that experienced significant hydrogen sulphide emissions due to the disposal of calcium sulphate waste at the landfill. It is understood that the Nantycaws Landfill did accept such wastes in 1997 and 1998, which resulted in odour problems. Measures were taken at the time to deal with the odour issues and, since the introduction of active gas extraction, no further odour complaints have been recorded. SLR has been informed that these waste types are no longer accepted at the site. Consequently, based on SLR's experience a more realistic range has been used for hydrogen sulphide concentrations in landfill gas based on monitoring of this contaminant within the raw gas. Trace gas concentration data used for hydrogen sulphide is as follows:

- For hydrogen sulphide - LogTriangular(0.0029, 10, 1000) mg m^{-3},
- The GasSim (Version 1.03) default is LogTriangular(0.00057, 2.4, 5570) mg m^{-3}

Gas Plant

The application site has been in operation since 1997 and landfill gas generated at the site is collected and treated by a single Jenbacher 420 landfill gas engine and an enclosed, high temperature flare with a maximum capacity of 1,500 m3 hr^{-1}. The landfill gas plant is located to the east of Cell 1.

A summary of the landfill gas engine and flare used to treat gas at the site is presented in Table LFGRA6. The decommissioning dates have been estimated from the predicted gas generation at the site.

TABLE LFGRA6: LANDFILL GAS ENGINE AND FLARE

Flare/Engine	Operational Period	Capacity (Nm^3 h^{-1})
LSM Flare	2002 to 2015	300 to 1,500
Jenbacher 420 engine	2002 to 2009	650

A landfill gas collection efficiency of 70 to 90% has been assumed.

In addition, a smaller flare will be required (assumed to be from 2015) to treat the smaller quantities of gas that will be generated at this time.

Trace gas emissions of carbon monoxide and nitrogen oxides from the landfill combustion plant that have been assumed for the assessment are presented in Table LFGRA7.

TABLE LFGRA7: EMISSION CONCENTRATIONS OF CARBON MONOXIDE AND NITROGEN OXIDES FROM GAS ENGINE AND FLARE

Gas Plant	**Carbon Monoxide ($mg\ Nm^{-3}$)**	**Nitrogen Oxides (as NO_2) ($mg\ Nm^{-3}$)**
Agency draft guidance for engines (a)	Uniform(1500, 2250)	Uniform(650, 975)
Agency draft guidance for flares (b)	Uniform(100, 150)	Uniform(150, 225)

(a) Draft Guidance for Monitoring Landfill Gas Engine Emissions (November 2002) with higher values representing 1.5 times the standard.

(b) Draft Guidance for Monitoring of Enclosed Landfill Gas Flares (December 2002) with higher values representing 1.5 times the standard.

The Environment Agency's draft guidance on emissions limits for gas engines and flares have been used and represent the standard for proposed limits. The upper value is derived by multiplying the limit by 1.5 to provide a worst case assessment. The guidance identifies two sets of emission limits, each relating to the commissioning date of an engine or flare. For each item of plant, the higher limits have been used in order to maintain the worst case conditions.

The GasSim(Version 1.03) default emission of dioxins and furans (as 2,3,7,8-TCDD) from engines and flares are as follows:

- Engines: LogTriangular(2×10^{-10}, 8.8×10^{-9}, 2.36×10^{-6}) $mg\ m^{-3}$
- Flares: LogTriangular(9×10^{-9}, 3.1×10^{-8}, 3.6×10^{-7}) $mg\ m^{-3}$

These figures are based on an analysis of a database of reported exhaust emissions carried out by Land Quality Management Ltd. There was a significant variation between the gas engine emissions of dioxins and furans from the detection limit of 1.1×10^{-9} $mg\ m^{-3}$ to over 1.0×10^{-6} $mg\ m^{-3}$. The data confirmed the correlation between levels of chlorine in the landfill gas and emissions of dioxins and furans, although this relationship is not significant for low total chlorine levels within the supply gas. The highest recorded concentration for typical household/commercial sites was 4.6×10^{-9} $mg\ m^{-3}$ with a chlorine level of 77.9 $mg\ m^{-3}$. For a co-disposal site with chlorine levels of 584 $mg\ m^{-3}$ the highest concentration was 1.3×10^{-8} $mg\ m^{-3}$. Therefore we have assumed the following gas engine emission concentration of dioxins and furans in the model, which represents a worst case:

- LogTriangular(2.0×10^{-10}, 4.6×10^{-9}, 1.3×10^{-8}) $mg\ m^{-3}$

The emissions of dioxins and furans from landfill gas flares was found to range between 2.8×10^{-9} $mg\ m^{-3}$ to 8.0×10^{-9} $mg\ m^{-3}$ with a median of 5.3×10^{-9} $mg\ m^{-3}$, therefore the following flare emission concentration has been used in the model.

- Normal(5.3×10^{-9}, 2.6×10^{-9}) mg m^{-3}

Lateral Migration

The data input values for the Geosphere have been derived from typical values for boulder clay, as the waste does not extend significantly below ground level. The moisture content may be higher than assumed by the model, but due to the programming of the model, the moisture content value must be less than or equal to the lowest porosity. Parameters that have been assumed are as follows:

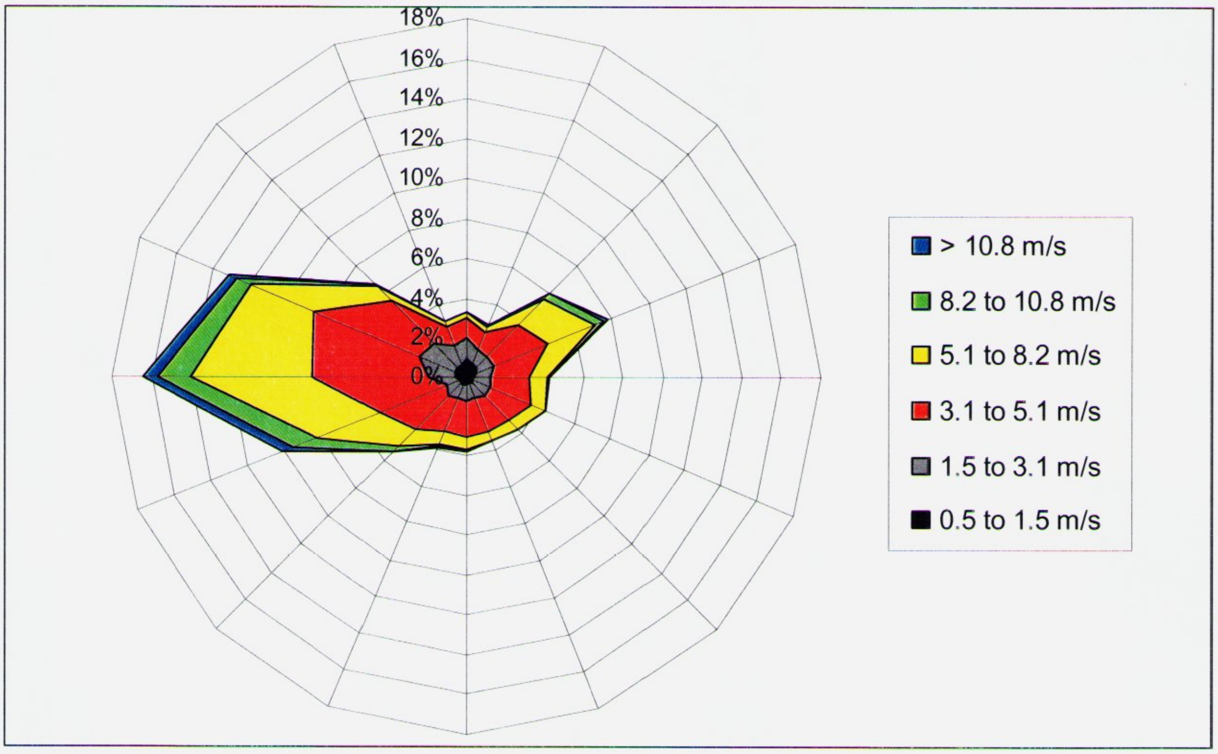
- moisture content of 10 to 15%; and
- porosity of 15 to 20%.

Sub-surface migration of landfill gas may typically occur through the ground or along service ducts and pipelines resulting in exposure to emissions at receptors located some distance from a landfill site. In the case of Nantycaws, which is predominantly a land raise development, sub-surface migration of landfill gas across significant distances is considered to be unlikely. A qualitative assessment of the risks associated with the lateral migration of landfill gas from the Nantycaws Landfill site has been undertaken in Section 2.5.2.

Atmospheric Dispersion

For atmospheric dispersion modelling, a meteorological data set for the site location has been obtained from Trinity Consultants. Data for five years has been obtained from the meteorological observing station at Rhoose, located approximately 80 km to the south east of the Nantycaws Landfill site. Information on wind direction frequency, wind speed, frequency of stability conditions and mixing height were obtained for the site. Details of the parameters used along with other assumption used for the atmospheric dispersion module are presented in Appendix LFGRA1. A windrose for the Rhoose observing station for the period 1998 to 2002, providing the frequency of wind speed and direction, is presented in Figure LFGRA2.

FIGURE LFGRA2: WINDROSE FOR RHOOSE OBSERVING STATION (1998 TO 2002)



The predominant wind direction is from the west, occurring for approximately 16.5% of the time. Winds from the west southwest and west northwest also occur relatively frequently at 10.0% and 13.0% of the time respectively. Wind directions from the northern and southern sectors occur relatively infrequently. The parameters used for the assessment are presented in Table LFGRA8.

TABLE LFGRA8: METEOROLOGICAL PARAMETERS USED WITHIN GASSIM

Wind Vector (a)		*Frequency of Wind Vector*	
0		5.1%	
30		5.8%	
60		11.0%	
90		22.2%	
120		15.1%	
150		5.1%	
180		4.2%	
210		4.6%	
240		10.3%	
270		5.8%	
300		6.0%	
330		4.9%	
	Frequency	*Wind Speed*	*Mixing Layer Depth*
Stability A	<0.1%	$0.9\ m\ s^{-1}$	1,482 m
Stability B	3.7%	$1.9\ m\ s^{-1}$	1,326 m
Stability C	9.8%	$3.2\ m\ s^{-1}$	1,196 m
Stability D	63.3%	$5.7\ m\ s^{-1}$	1,328 m
Stability E	14.1%	$2.9\ m\ s^{-1}$	296 m
Stability F	8.9%	$1.8\ m\ s^{-1}$	122 m

(a) GasSim requires wind data to be input as wind vectors (*ie* the direction to which the wind is blowing)

2.5 Risks to the Environment and Human Health

The landfill gas risk assessment has focussed on the risks associated with the following hazards:

- sub-surface migration;
- the odour nuisance potential of the landfill gas;
- the impact of the emissions to air on human health; and
- global warming and ozone depletion potential of landfill gas emissions.

2.5.1 Landfill Gas Emissions

Predicted landfill gas emissions (bulk landfill gas) are presented graphically in Appendix LFGRA3. Total gas generation (application site), surface emissions (application site) and flare and engine emissions (combined model) are presented.

Maximum predicted values can be summarised as follows (as the 50%ile):

- Landfill gas generation – 1,190 m^3 hr^{-1} in 2006 from the combined sites model;
- Engine output – 620 m^3 hr^{-1} between 2002 and 2009 from the combined sites model;
- Flare output – generally less than 500 m^3 hr^{-1} suggesting that a smaller flare could be utilised but it should be noted that these are annual average values and the flares should be sized to utilise all of the gas that may be generated from the site in the event that the gas engine cannot be used; and
- Surface emissions – from the application site reach a maximum of 380 m^3 hr^{-1} in 2006, then decrease steadily.

2.5.2 Sub-surface Migration and Vegetation Stress

GasSim Predictions

The GasSim model takes a simplified approach to predicting lateral migration. GasSim considers the movement of gas molecules due to pressure gradients (advection) and concentration gradients (diffusion). GasSim assumes that gas migration through the subsurface occurs effectively in the horizontal plane and neglects buoyancy driven gas flow and temperature driven gas flow in the vertical. Consequently, the over-simplified lateral migration module may not be appropriate for all applications.

SLR's experience of using the GasSim model is that the model is appropriate for modelling lateral migration from cells that have a synthetic component within the lining system. Although the application site has such a component, in the form of a geomembrane liner, GasSim does not allow consideration of land raise activities and assumes that waste is below ground level. Therefore GasSim is not able to accurately predict lateral migration for the site.

Qualitative Risk Assessment of Gas Migration

Because of the high degree of uncertainty regarding the behaviour of gases in the ground, a simple qualitative assessment has been carried out to determine the risks associated with lateral gas migration. The qualitative assessment has considered the nature of the source, the receptors that may be affected and the pathways that might link them. Receptors have been classified in accordance with the recommendations of the Environment Agency as set out in their draft Consultation document 'Guidance on the Management of Landfill Gas', November 2002. The assessment has focused on two scenarios, firstly the risk in the absence of gas control and then the risk as assessed with the provision of gas management measures.

The application site has been developed as a land raise, on the principle of engineered containment. The site benefits from a composite liner which incorporates elements of engineered clay, geomembrane and geosynthetic clay liner. The site will ultimately benefit from a geomembrane cap. Waste inputs at the site are predominantly domestic waste, therefore a significant volume of landfill gas is being generated.

The gas is actively controlled using a series of extraction wells, from which gas is carried via HDPE carrier lines to the gas utilisation compound which is situated to the east of the landfill. Landfill gas is utilised by a single Jenbacher 420 gas engine to produce electricity which is exported to the National Grid. An enclosed, high temperature ground flare is provided to treat any excess gas or as a back-up in the event that the engine is not operating. The Phase 1 landfill that lies adjacent to the southern boundary of the permit application area is an uncontained former landfill that is no longer licensed. It is fully restored and has an active gas management system that directs gas to the utilisation plant that is shared with the application site.

CWM has undertaken off-site monitoring of landfill gas from 18 perimeter boreholes, details of which are provided in the ESID report[1]. Their locations are shown on Drawing ESID8. Concentrations of methane, carbon dioxide and oxygen have been monitored at the perimeter borehole locations on a monthly basis.

Data accumulated during the period February 2002 to January 2004 have been reviewed as part of the risk assessment. The minimum, maximum and average concentrations of the methane and carbon dioxide concentrations recorded have been tabulated in Table LFGRA9.

TABLE LFGRA9: PERIMETER BOREHOLE GAS MONITORING DATA

Monitoring Borehole	No. of Readings	Methane Reading (%)			Carbon Dioxide Reading (%)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
201	54	0	0	0	0	8.2	0.3
202	54	0	0.4	0	0	5.3	0.4
203	54	0	5.8	0.2	0	26.7	1.1
204	37	0	0	0	0	5	0.2
205	2	0	0	0	0	0	0
212	63	0	0	0	0	1.7	0.1
213	64	0	0.1	0	0	1.7	0.2
214	46	0	0	0	0	1.2	0.1
215	79	0	0	0	0	2.6	0.3
219	72	0	0.8	0	0	2.6	0.4
220	54	0	0.7	0	0	7.0	0.5
221	56	0	1.7	0.1	0	8.6	0.7
225	55	0	0	0	0	5.1	0.9
226	54	0	0	0	0	2.1	0.2
227	55	0	0	0	0	2.0	0.1
228	54	0	0	0	0	12.9	1.0
229	54	0	0	0	0	8.6	0.4
230	54	0	0	0	0	12.5	0.3

The summarised data show that elevated methane above the normal trigger level of 1% v/v has been detected at two of the 18 perimeter boreholes during the monitoring period, up to a maximum of 5.8% in BH203. It should be noted that this borehole is located adjacent to the boundary of the dilute and attenuate site to the south, and may be influenced by this alternative source. Even under these circumstances, only two methane readings above 1% v/v have been recorded at BH203, dating back to July and August 2002. Two elevated methane readings have also been recorded at BH221, to the north of Cell 3. These occurred in November 2003, to a maximum of 1.7% v/v, but no elevated readings have been recorded since. Average methane readings are generally at or close to zero, which indicates that the gas management system is effectively preventing lateral migration of landfill gas. Likewise, all mean carbon dioxide readings are below the normal trigger level of 1.5% v/v. In the absence of site specific background monitoring data, it is not possible to draw comparisons with natural background levels of methane or carbon dioxide. In the event that elevated readings were to be detected in boreholes BH202 to BH212 in the future, it would be difficult to identify the source, as these locations are all adjacent to the restored Phase 1 landfill area.

The application site is a land raise and the waste extends approximately 1.0m below the surrounding ground surface. The near surface geology around the site consists of boulder clays with a low permeability, and therefore available pathways for lateral gas migration are considered to be minimal, particularly given the level of engineered containment being provided. In the unlikely event of containment failure, there may be limited potential pathways to the east of Cell 1, where the site offices are located, due to the presence of granular sub-base materials used in developing the site infrastructure and sub-surface ducts and pipelines associated with services supplied to the site.

The landfill is generally remote from sensitive off-site receptors, although consideration has been given in this assessment to site buildings, and the Civic Amenity site which is under construction to the east of the site offices. These are the only receptors that are considered to be at risk (other than from odour, see below) in the absence of gas control, due to their proximity to the waste. Even in the absence of gas control, the engineering of the site and the fact that it is a land raise have resulted in a classification of low to medium risk.

All other buildings and roads are considered to be low risk receptors with or without gas control due to their respective distances from the site and the limited potential for gas to migrate through the near surface geology.

The risk of odour nuisance has been assessed on the basis of receptor proximity to the landfill boundary and, under the 'with control' scenario, considers the possibility of a malfunction in the utilisation plant which could result in gas being vented to the atmosphere from a point source (i.e. the flare stack). It is considered that such a failure would be unlikely, hence a low risk classification. The odour risk is not considered to decline for residential receptors beyond 250m from the site as the Llety-dau-filwr property lies due east of the site, directly in the path of the prevailing wind.

Other receptors that are potentially at risk from lateral gas migration and which adjoin parts of the site are the adjacent farmland, including its users. An assessment of the relative risks to these receptors from landfill gas both with and without gas control is presented in Table LFGRA10 below.

TABLE LFGRA10: QUALITATIVE RISK ASSESSMENT OF LANDFILL GAS MIGRATION WITH AND WITHOUT CONTROL

Sensitive Receptor	Without Control					With Control				
	Toxicity	Eco-toxicity	Explosion	Asphyxiation	Odour	Toxicity	Eco-toxicity	Explosion	Asphyxiation	Odour
Site buildings (offices, weighbridge etc.)	L/M	L/M	L/M	L/M	M	L	L	L	L	L/M
Residential properties (up to 250m)	L	L	L	L	L/M	L	L	L	L	L
Residential properties (250 – 500m)	L	L	L	L	L/M	L	L	L	L	L
Commercial and industrial properties	L/M	L/M	L/M	L/M	M	L	L	L	L	L/M
Schools	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hospitals	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Public footpaths	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Highways	L	L	L	L	L	L	L	L	L	L
Farmland and other open spaces	L	L	L	L	M	L	L	L	L	L/M

The assessment of landfill gas risk at Nantycaws Landfill needs to be kept under review and assessed periodically with appropriate action taken in response to results and trends in monitoring data.

2.5.3 Atmospheric Dispersion and Odour

Predicted Off-site Impacts – Air Quality

The impact on local air quality of the following has been assessed:

- Oxides of nitrogen as (nitrogen dioxide, NO_2);
- Carbon monoxide (CO);
- Hydrogen sulphide (H_2S); and
- Benzene.

The oxides of nitrogen and carbon monoxide provide an indication of the impact on air quality of the landfill gas engines and flares whereas hydrogen sulphide and benzene provide an indication of the impact on air quality of surface emissions.

Predicted annual average concentrations for the three years (2005, 2006 and 2020) are presented in Tables LFGRA11 to LFGRA13. Predicted concentrations are compared to appropriate air quality standards and guidelines for the protection of human health.

For the contaminants emitted from the Landfill Gas Utilisation Plant (NO_2 and CO), concentrations have been predicted using the distance from the gas engine and flare, and the combined sites model. For the other contaminants that are more likely to be emitted from the surface of the landfill, concentrations have been predicted using the distance from the centre of the application site. A selection of pollution roses presenting the predicted distribution of contaminants around the site for the three years assessed are presented in Appendix LFGRA4.

TABLE LFGRA11: PREDICTED 95%ile OF ANNUAL AVERAGE CONTAMINANT CONCENTRATIONS FOR 2005

Sensitive Receptor	NO_x (as NO_2) ($\mu g\ m^{-3}$)	CO ($mg\ m^{-3}$)	H_2S ($\mu g\ m^{-3}$)	Benzene ($\mu g\ m^{-3}$)
Awelfan	0.97	0.0021	0.0032	0.00057
Filling Station	1.0	0.0022	0.0028	0.00050
Llety-dau-filwr	8.0	0.018	0.0032	0.00057
Blaenisfael	1.3	0.0028	0.0070	0.0013
Ty-Hen	1.1	0.0023	0.014	0.0024
Civic Amenity Site	8.1 (20.3)	0.020	0.0066	0.0012
Environmental Assessment Level (EAL)	**40 (a)**	**10 (b)** 350 *	**7 (c)** **140 (d)**	**5 (e)** 16.25 *

(a) Annual average air quality objective for NO_2 to be achieved by 31 December 2005
(b) Maximum eight hour air quality objective for CO, annual mean predictions should be substantially less than the maximum eight hour standard
(c) WHO 30 minute guideline concentration for substantial odour nuisance, predicted concentrations as the annual mean should be substantially less that this value
(d) Long-term EAL for the protection of health
(e) Annual mean air quality objective for benzene to be achieved by 31 December 2010

* Long term EAL's from H1

TABLE LFGRA12: PREDICTED 95%ile OF ANNUAL AVERAGE CONTAMINANT CONCENTRATIONS FOR 2006

Sensitive Receptor	NO_x (as NO_2) (µg m^{-3})	CO (mg m^{-3})	H_2S (µg m^{-3})	Benzene (µg m^{-3})
Awelfan	0.99	0.0022	0.0029	0.00065
Filling Station	1.0	0.0023	0.0026	0.00058
Llety-dau-filwr	8.1	0.018	0.0029	0.00065
Blaenisfael	1.3	0.0028	0.0065	0.0014
Ty-Hen	1.1	0.0024	0.013	0.0028
Civic Amenity Site	8.1	0.020	0.0062	0.0014
Environmental Assessment Level (EAL)	**40 (a)**	**10 (b)**	~~7 (c)~~ **140 (d)**	**5 (e)**

(a) Annual average air quality objective for NO_2 to be achieved by 31 December 2005
(b) Maximum eight hour air quality objective for CO, annual mean predictions should be substantially less than the maximum eight hour standard
(c) WHO 30 minute guideline concentration for substantial odour nuisance, predicted concentrations as the annual mean should be substantially less that this value
(d) Long-term EAL for the protection of health
(e) Annual mean air quality objective for benzene to be achieved by 31 December 2010

Predicted concentrations for all contaminants considered and all years considered are within the appropriate air quality standard or guideline value. Relative to their air quality standards, highest concentrations occurred at the Civic Amenity Site for NO_2 where maximum predicted concentrations were 8.1 µg m^{-3} (20.3% of the air quality standard for NO_2) for 2005 and 2006. However, NO_x emitted from the gas engine will comprise nitric oxide (NO) a relatively innocuous contaminant and nitrogen dioxide (NO_2). The assessment assumes that all of the NO_x is emitted as NO_2 and, as such, is a worst case assumption as only 20% of the NO_x is likely to comprise of NO_2 at the receptor locations considered. Assuming 20% NO_2, the maximum predicted concentration of NO_2 at the Civic Amenity Site would be 1.6 µg m^{-3} (only 4.1% of the air quality standard for NO_2).

TABLE LFGRA13: PREDICTED 95%ile OF ANNUAL AVERAGE CONTAMINANT CONCENTRATIONS FOR 2020

Sensitive Receptor	NO_x (as NO_2) ($\mu g\ m^{-3}$)	CO ($mg\ m^{-3}$)	H_2S ($\mu g\ m^{-3}$)	Benzene ($\mu g\ m^{-3}$)
Awelfan	0.060	0.000040	0.000031	0.0000094
Filling Station	0.063	0.000042	0.000028	0.0000084
Llety-dau-filwr	0.48	0.00033	0.000031	0.0000094
Blaenisfael	0.078	0.000053	0.000068	0.000021
Ty-Hen	0.065	0.000044	0.00013	0.000039
Civic Amenity Site	0.36	0.00028	0.000065	0.000020
Environmental Assessment Level (EAL)	**40 (a)**	**10 (b)**	**7 (c)** **140 (d)**	**5 (e)**

(a) Annual average air quality objective for NO_2 to be achieved by 31 December 2005
(b) Maximum eight hour air quality objective for CO, annual mean predictions should be substantially less than the maximum eight hour standard
(c) WHO 30 minute guideline concentration for substantial odour nuisance, predicted concentrations as the annual mean should be substantially less that this value
(d) Long-term EAL for the protection of health
(e) Annual mean air quality objective for benzene to be achieved by 31 December 2010

For all contaminants considered, the assessment of atmospheric dispersion of contaminants on off-site receptors indicates that Nantycaws Landfill site would have negligible impact on human health (from direct inhalation).

Comparison of Predicted Ground Level Concentrations with Background Air Quality

A comparison of the maximum predicted concentration (PC) has been added to the background concentration to estimate the Predicted Environmental Concentration (PEC). A comparison of the PC and PEC with air quality standards and guidelines is provided in Table LFGRA14. For nitrogen dioxide, the PC figure is derived from 20% of the worst case prediction for NO_x, as discussed above.

TABLE LFGRA14: COMPARISON OF PREDICTED CONCENTRATIONS WITH BACKGROUND AIR QUALITY AND AIR QUALITY STANDARDS

Substance	Environmental Assessment Level (EAL)	Background	Maximum Concentration (PC) (f)	Predicted Environmental Concentration (PEC) (g)
Nitrogen dioxide ($\mu g\ m^{-3}$)	**40 (a)**	8.17	1.60 (4.0%)	9.80 (24.5%)
Carbon monoxide ($mg\ m^{-3}$)	**10 (b)** 350	0.16	0.020 (0.2%)	0.18 (1.8%) 0.05
Hydrogen sulphide ($\mu g\ m^{-3}$)	**7 (c)**	0.15	0.014 (0.2%)	~~0.16 (2.3%)~~
	140 (d)	0.15	0.014 (0.01%)	0.16 (0.11%) ✓
Benzene ($\mu g\ m^{-3}$)	**5 (e)** 16.25	0.10	0.0028 (0.06%)	0.10 (2.0%) 0.6

(a) Annual average air quality objective for NO_2 to be achieved by 31 December 2005
(b) Maximum eight hour air quality objective for CO, annual mean predictions should be substantially less than the maximum eight hour standard
(c) WHO 30 minute guideline concentration for substantial odour nuisance, predicted concentrations as the annual mean should be substantially less that this value
(d) Long-term EAL for the protection of health
(e) Annual mean air quality objective for benzene to be achieved by 31 December 2010
(f) The value given in parentheses is the PC/EAL
(g) The value given in parentheses is the PEC/EAL

Background concentrations for NO2, CO and benzene for use by local authorities in their Review and Assessment reports, can be calculated in accordance with Local Air Quality Management (LAQM) Technical Guidance from mapped data provided by the National Environmental Technology Centre (NETCEN) on their website. Mapped data was obtained and adjusted to the year dictated by maximum predicted concentration. Background for H2S is not provided on the NETCEN website, and therefore the World Health Organisation data[4] were used.

An emission is regarded as significant if the maximum predicted concentration (PC) exceeds 1% of the relevant air quality standard.

The maximum predicted concentration of NO_2 is 4.1% of the EAL and is therefore regarded as significant. However, the relative contribution of the emissions from the landfill gas plant to the total predicted environmental concentration (PEC) is small compared with the background concentration.

The predicted concentration for H_2S is only 0.2% of the WHO guideline concentration. It is understood that investigations were undertaken in the late 1990's in connection with elevated hydrogen sulphide and subsequent odour problems. SLR have been advised that, since the implementation of improvements in site operations, there have been no further odour problems and no record of any complaints relating to odour have been received.

[4] Guidelines for Air Quality, WHO (2000).

The maximum predicted concentrations of carbon monoxide and benzene are less than 1% of their respective EAL's therefore the impact on air quality associated with these contaminants is considered to be negligible.

Predicted Off-site Impacts – Odour

Predicted off-site odour concentrations for the sensitive receptors are presented in Table LFGRA15.

Predicted odour concentrations are below the assessment criteria of 1 OU_E m^{-3}. At worst, the highest predicted 95%ile odour concentration occurs at Ty-Hen at 0.029 OU_E m^{-3}. However, this value only represents 2.9% of the assessment criteria. This suggests that an odour from the landfill is unlikely to be detected and would be of such a low intensity that it is unlikely to cause an odour nuisance.

TABLE LFGRA15: PREDICTED 95%ile OF ODOUR CONCENTRATIONS PREDICTED USING GASSIM

Sensitive Receptor	**2005 (a)**	**2006 (a)**	**2020 (a)**
Awelfan	0.0063 (0.029)	0.0069 (0.032)	0.00016 (0.00074)
Filling Station	0.0056 (0.026)	0.0061 (0.028)	0.00014 (0.00066)
Llety-dau-filwr	0.0063 (0.029)	0.0069 (0.032)	0.00016 (0.00074)
Blaenisfael	0.014 (0.062)	0.015 (0.067)	0.00036 (0.0015)
Ty-Hen	0.027 (0.12)	0.029 (0.14)	0.00067 (0.0031)
Civic Amenity Site	0.013 (0.059)	0.015 (0.064)	0.00034 (0.0015)
Odour Nuisance Criteria (b)	**1**	**1**	**1**
(a) Presented as the 95%ile annual mean and the 95%ile of Stability F conditions given in parentheses			
(b) As adopted by GasSim			

For ground level sources such as the landfill site, odour nuisance is more likely to occur during stable conditions (Stability F). Therefore, predicted 95%ile odour concentrations for Stability F conditions are also presented in Table LFGRA15. GasSim has predicted that the odour nuisance criteria will not be exceeded at any of the sensitive receptors, even under very stable conditions.

The distribution of odours is presented as a contour plot in Appendix LFGRA5. Predicted concentrations that are above the odour nuisance criteria of 1 OU_E m^{-3} are presented as a solid colour.

Predicted concentrations are below the odour nuisance criteria at less than 20m from the centre of the site therefore this suggests that the landfill site is unlikely to cause an odour nuisance off-site. According to site records held by CWM there have been no complaints regarding odour nuisance originating from the landfill since the introduction of active gas extraction.

On-site Worker Exposure

On-site workers are likely to be exposed to higher contaminant concentrations but Occupational Exposure Standards (OESs) will be less stringent than the corresponding air quality standards for the protection of the potentially sensitive population. Predicted on-site concentrations of NO_2, CO, H_2S and benzene are compared to OESs in Table LFGRA16.

For the contaminants considered, all predicted on-site concentrations are well within the relevant OESs. Therefore, the impact of the landfill on on-site worker health effects is considered to be negligible under normal operating conditions.

TABLE LFGRA16: PREDICTED ANNUAL AVERAGE CONTAMINANT CONCENTRATIONS FOR ON-SITE WORKERS

Contaminant	Year	Predicted Concentration (mg m^{-3})	Occupational Exposure Standard (mg m^{-3}) (a)
Nitrogen dioxide (b)	2005 2006 2020	0 0 0	5.7 mg m^{-3} as the long term exposure limit (LTEL) 9.6 mg m^{-3} as the short term exposure limit (STEL)
Carbon monoxide (b)	2005 2006 2020	0.0036 (0.010%) 0.0036 (0.010%) 0.0000757 (0.00022%)	35 mg m^{-3} as the LTEL 232 mg m^{-3} as the STEL
Hydrogen sulphide (b)	2005 2006 2020	0.00054 (0.0077%) 0.00050 (0.0071%) 0.0000050 (0.000071%)	7 mg m^{-3} as the LTEL 14 mg m^{-3} as the STEL
Benzene (c)	2005 2006 2020	0.000098 (0.0010%) 0.00011 (0.0012%) 0.0000016 (0.000016%)	9.7 mg m^{-3} as the long term Maximum Exposure Limit (MEL)
Vinyl chloride (c)	2005 2006 2020	0.00080 (0.0095%) 0.00068 (0.0081%) 0.000012 (0.00014%)	8.4 mg m^{-3} (3 ppm) as the long term Maximum Exposure Limit (MEL)

(a) The long term OESs are based on the 8 hour time weighted average (TWA) and the short term OESs are based on 15 minute maximum concentrations. However, the GasSim predictions are the 95%ile annual mean concentrations. Therefore, concentrations occurring over a period of 8 hours may be significantly higher than the annual average. This should be allowed for when interpreting the results.

(b) Value in parentheses is the predicted concentration as a percentage of the LTEL.

(c) Value in parentheses is the predicted concentration as a percentage of the MEL.

2.5.4 Off-site Exposure Assessment

The GasSim software allows the potential off-site exposure assessment to be considered. However, this aspect of the model is not flexible and so the assessment is significantly constrained by the "hardwiring" of the model. As set out within Section 2.3, there is no site-specific information to indicate the significant presence of benzene, dioxins and furans, and vinyl chloride at the PPC Application site. However, as a worst case conservative assessment, full human health exposure assessments have been undertaken that consider both direct (inhalation) and indirect (ingestion, dermal contact) exposure pathways. These contaminants have been selected for this assessment, as they are contaminants that have exposure criteria and they also, under certain circumstances, may be associated with landfill gas. For dioxins and furans, benzene and vinyl chloride predicted daily intakes are presented in Tables LFGRA17 to LFGRA19, respectively.

For the residential receptors, the recipient is assumed to be a child that is between 0 and 1 year old in 2003 and which is exposed for six years until they are age 6 at the end of 2008. For the remaining receptors, which have been classified as commercial/industrial, the recipient is assumed to be a female exposed to emissions from 16 years of age in 2003 to 59 years of age.

TABLE LFGRA17: PREDICTED INTAKE OF DIOXINS AND FURANS (2,3,7,8-TCDD) FOR NANTYCAWS LANDFILL (a)(b)(c)

Sensitive Receptor	Commercial (pg kg^{-1} day^{-1}) (c)	Residential (pg kg^{-1} day^{-1}) (c)
Awelfan	-	0.072 (3.6%)
Filling Station	0.0000098 (0.00049%)	-
Llety-dau-filwr	-	0.56 (28.0%)
Blaenisfael	-	0.089 (4.5%)
Ty-Hen	-	0.077 (3.8%)
Civic Amenity Site	0.0000061 (0.00031%)	-

(a) The World Health Organisation (WHO) provide a Tolerable Daily Intake for dioxins and furans of 1-4 pg I-TEQ kg^{-1} day^{-1} (picogrammes per kilogramme bodyweight per day)

(b) The UK Food Standards Agency (FSA) recommends a TDI of 2 pg I-TEQ kg^{-1} day^{-1}

(c) 1 picogramme is equivalent to 10^{-12} grammes

(d) Value in parentheses is the predicted contribution as a percentage of the FSA TDI

Predicted concentrations of Dioxins and Furans are all well within the WHO and FSA guidelines and recommendations for the Tolerable Daily Intake (TDI). The TDI is the maximum amount of a contaminant that can be consumed every day over a lifetime without causing harm. Given the conservative assumptions assumed, this demonstrates that there is a negligible risk associated with this exposure route.

TABLE LFGRA18: PREDICTED INTAKE OF BENZENE FOR NANTYCAWS LANDFILL (a)(b)

Sensitive Receptor	Commercial (mg kg^{-1} day^{-1}) (c)	Residential (mg kg^{-1} day^{-1}) (c)
Awelfan	-	1.27×10^{-6} (0.042%)
Filling Station	2.65×10^{-8} (0.00087%)	-
Llety-dau-filwr	-	1.28×10^{-6} (0.043%)
Blaenisfael	-	1.68×10^{-6} (0.056%)
Ty-Hen	-	3.60×10^{-7} (0.012%)
Civic Amenity Site	1.29×10^{-6} (0.043%)	-

(a) There is no UK criteria for the exposure of benzene via direct and indirect pathways

(b) US EPA Region 9 Preliminary Remedial Goals (PRGs) are published by the US EPA, an oral reference dose of 3.0×10^{-3} mg kg^{-1} day^{-1} and inhalation reference dose of 1.7×10^{-3} mg kg^{-1} day^{-1} have been published for 2002

(c) Value in parentheses is the predicted contribution as a percentage of the oral reference dose

For benzene, predicted doses are well within the oral and inhalation reference doses referenced by the US EPA Region 9. Given the conservative assumptions assumed, this demonstrates that there is a negligible risk associated with this exposure route.

TABLE LFGRA19: PREDICTED INTAKE OF VINYL CHLORIDE FOR NANTYCAWS LANDFILL (a)(b)

Sensitive Receptor	Commercial (mg kg^{-1} day^{-1}) (c)	Residential (mg kg^{-1} day^{-1}) (c)
Awelfan	-	5.34×10^{-6} (0.18%)
Filling Station	8.40×10^{-8} (0.0028%)	-
Llety-dau-filwr	-	5.62×10^{-6} (0.19%)
Blaenisfael	-	7.18×10^{-6} (0.24%)
Ty-Hen	-	1.49×10^{-6} (0.050%)
Civic Amenity Site	9.08×10^{-7} (0.030%)	-

(a) There are no UK criteria for the exposure of vinyl chloride via direct and indirect pathways

(b) US EPA Region 9 Preliminary Remedial Goals (PRGs) are published by the US EPA, an oral reference dose of 3.0×10^{-3} mg kg^{-1} day^{-1} and inhalation reference dose of 28.6×10^{-3} mg kg^{-1} day^{-1} have been published for 2002

(c) Value in parentheses is the predicted contribution as a percentage of the oral reference dose

For vinyl chloride, predicted doses are well within the oral and inhalation reference doses published by the US EPA Region 9. Given the conservative assumptions assumed, this demonstrates that there is a negligible risk associated with this exposure route.

Dioxins and furans, benzene and vinyl chloride have been used as indicators of potential health effects arising from contaminants emitted from landfill facilities. The assessment indicates that Nantycaws Landfill site would have negligible impact on off-site human health. Given the conservative assumptions assumed, this demonstrates that there is a negligible risk associated with this exposure route.

2.5.5 Global Atmospheric Impact

The potential global atmospheric impact of Nantycaws Landfill site has been predicted using the GasSim model. The Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) have been assessed using the default data provided by GasSim. The results of the assessment are provided in Table LFGRA20. Predictions are presented for the 50%ile.

TABLE LFGRA20: PREDICTED GLOBAL ATMOSHPERIC IMPACTS OF NANTYCAWS LANDFILL SITE

Year	Global Warming Potential (tonnes of CO_2)	Ozone Depletion Potential (tonnes of trichlorofluromethane)
2005	33,500	0.011
2006	35,800	0.0092
2020	5,750	0.000076
Sum of all years	**529,000**	**0.11**

For an estimated total waste input of 960,554 tonnes over the lifetime of the application site the Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) are 0.55 tonnes of CO_2 and 1.1×10^{-7} tonnes of trichlorofluoromethane per tonne of waste deposited, respectively. It should be noted that actual carbon dioxide emissions would be lower and that the greenhouse potential of methane emissions has been converted to GWP CO_2 equivalents.

2.6 Landfill Gas Completion Criteria

Generated bulk landfill gas rates predicted by the GasSim model are presented in Appendix LFGRA3. This indicates that peak gas production will occur in 2006 and thereafter, gas generation rates will decrease rapidly such that predicted gas generation in 2011 is approximately 600 $m^3 hr^{-1}$. If all of this generated gas is collected this would be sufficient to operate an on-site gas engine, according to the criteria provided by the Environment Agency [5].

Beyond 2036, landfill gas generation rates are predicted to be less than 100 $m^3 hr^{-1}$. However, it may not be possible to collect all of the generated gas and it may be necessary to consider a

[5] Guidance on the Management of Landfill Gas (Consultation Draft), Environment Agency (November 2002)

smaller flare, some other operational practice (i.e. the operation of the flare on a non-continuous basis) or the use of new technologies.

3.0 GAS MANAGEMENT PLAN

3.1 Control Measures

Details of the landfill gas control measures in place or proposed for the PPC Nantycaws Landfill are provided in the site's gas management plan (LFGRA6). The gas management and monitoring system is also outlined in the Drawing ESID8.

3.2 Monitoring and Sampling Plan

Details of the landfill gas monitoring and sampling plan for the PPC Nantycaws Landfill are described in the site's gas management plan (LFGRA6). The locations of wells and boreholes that are or will be monitored or sampled are shown in Drawing ESID8.

3.3 Compliance Limits and Action Plan

Details of the landfill gas Action Plan for the PPC Nantycaws Landfill are provided in the site's gas management plan (LFGRA6). Other specific details on emission levels, trigger levels and emission limits are provided in the following sections.

3.3.1 In-waste Landfill Gas Monitoring Control and Trigger Levels

In waste monitoring of the following parameters is routinely undertaken at the landfill site:

- Methane;
- Carbon Dioxide;
- Oxygen; and
- Pressure.

Temperature and carbon monoxide are measured as and when required. Trace Gas Emissions Monitoring will be carried out in accordance with the final and post-consultation Environment Agency guidance which is appropriate to the site as and when such guidance is published and in force.

3.3.2 Perimeter Landfill Gas Monitoring – Sub Surface

Perimeter Borehole Location and Spacing

The perimeter borehole locations are presented in Drawing No. ESID8 of the Environmental Setting Installation Design report [1]. Given the presence of the Phase 1 landfill area adjacent to this boundary, and the findings of this risk assessment, it is considered that the current borehole locations are adequate.

Control/Trigger Levels/Frequency of Monitoring

Details of perimeter gas monitoring that will be routinely undertaken at the monitoring boreholes identified in Drawing No. ESID8 are provided in Table LFGRA21. The detection limit and accuracy of the gas monitoring equipment is assumed to be +/- 0.1% v/v. Monitoring will be carried out in accordance with the final and post-consultation Environment Agency guidance which is appropriate to the site as and when such guidance is published and in force.

TABLE LFGRA21: PERIMETER LANDFILL GAS MONITORING – SUB-SURFACE EMISSIONS

Substance	Control Level, detection limit and accuracy	Trigger level, detection limit and accuracy	Frequency of Monitoring
Methane (a)	0.5% v/v; 0.1%; ± 0.1%	1.5% v/v; 0.1%; ± 0.1%%	Monthly
Carbon dioxide (b)	8.5% v/v; 0.1%; ± 0.1%%	10% v/v; 0.1%; ± 0.1%	Monthly

(a) The trigger level for methane is based on 20% of the lower explosive limit for gas.

The trigger level for carbon dioxide is based on 20% of the 8 hour British Occupational Exposure Standard (OES), above a local background of 2% v/v.

The trigger levels have been derived in accordance with the Environment Agency's guidance on landfill gas management[5], being set at 1.0% and 1.5% above background levels for methane and carbon dioxide respectively. Although there is no pre-tipping background monitoring data available, it is likely that background methane concentrations are close to zero, given the near surface geology of the area. Control levels for methane have been set at 0.5% v/v, to allow for very minor fluctuations in readings or instrument error.

It is considered likely that background carbon dioxide concentrations will be more variable, and therefore control levels have been set using the perimeter borehole monitoring data provided by CWM for use in preparation of this report.

3.3.3 Perimeter Landfill Gas Monitoring – Aerial Emissions

Details of the monitoring points where these are proposed are provided in Table LFGRA22. Perimeter site monitoring of landfill gas will only be undertaken in response to persistent odour or nuisance complaints or as part of the Action Plan relating to the detection of landfill gas in perimeter monitoring boreholes.

It is not appropriate to undertake perimeter monitoring of airborne contaminants as contaminant concentrations will vary considerably depending on the variation in the emission source and in particular with meteorological conditions. For the majority of the time contaminants will not be detected at the perimeter. Since monitoring of the majority of the contaminants would require spot sampling methods, it would be misleading to use these techniques for monitoring potentially highly fluctuating concentrations. The decision to undertake monitoring of air quality at the boundary would be dependent on the receipt of meaningful data on persistent complaints attributable to landfill gas.

TABLE LFGRA22: PERIMETER AERIAL EMISSIONS MONITORING

Substance	Control Level, detection limit and accuracy	Trigger level, detection limit and accuracy	Frequency of Monitoring
No monitoring proposed			
Monitoring Location	**Height Above Ground Level (m)**	**Proximity to Boundary**	**Local topography Relative to Monitoring Location**
No monitoring proposed			

3.3.4 Receptor Monitoring – Aerial Emissions

Off-site monitoring of landfill gas will only be undertaken in response to persistent odour or dust complaints attributable to landfill gas or as part of the Action Plan relating to the detection of landfill gas in perimeter monitoring boreholes.

As discussed in Section 3.3.3, it is not appropriate to undertake off-site monitoring of airborne contaminants either at the site perimeter or at sensitive receptors. Contaminant concentrations will vary considerably depending on the variation in the emission source and in particular with meteorological conditions. For the majority of the time contaminants will not be detected at the perimeter or at sensitive receptors. Since monitoring of the majority of the contaminants would require spot sampling methods, it would be misleading to use these techniques for monitoring potentially highly fluctuating concentrations. Monitoring of methane would be undertaken at the perimeter and at sensitive locations as discussed above and can be used as an indicator of the presence of landfill gas. Since the majority of contaminants are associated with landfill gas, off-site monitoring of methane is considered to be sufficient.

The decision to undertake monitoring of air quality at boundary or receptor locations would be dependent on the receipt of meaningful data on persistent complaints at these locations.

3.3.5 Landfill Gas Engine and Flare Emissions

Gas Engines Emissions to Air

As stated in Section 1.1 above the landfill gas utilisation plant is subject to a separate PPC application and as such it is not appropriate to specify emissions to air for the gas engine.

Gas Engine Noise Emissions

As stated in Section 1.1 above the landfill gas utilisation plant is subject to a separate PPC application and as such it is not appropriate to specify noise emissions for the gas engine.

Flare

Details of emissions monitoring, emission levels and trigger levels for the flares are provided in Table LFGRA23. Flare emissions monitoring will be carried out in accordance with the final and post-consultation Environment Agency guidance which is appropriate to the site as and when such guidance is published and in force.

TABLE LFGRA23: EMISSIONS MONITORING OF THE LANDFILL GAS FLARE

Flare & Substance	Frequency of Monitoring	Emission Level	Trigger Level (mg Nm^{-3})(a)
LSM flare			
NO_x	Annually	150 mg Nm^{-3}	172 mg Nm^{-3}
CO	Annually	100 mg Nm^{-3}	112 mg Nm^{-3}
Total VOC's	Annually	10 mg Nm^{-3}	12 mg Nm^{-3}
Non-Methane VOC's	Annually	5 mg Nm^{-3}	6 mg Nm^{-3}
(a) Trigger levels have been derived on the basis of the use of the M2 guidance referenced sampling method and sampling from an appropriately located sampling port.			

4.0 CONCLUSIONS

4.1 Compliance with the Landfill Regulations, 2002

The landfill gas risk assessment undertaken for the Nantycaws Landfill has demonstrated that, given the design, control and management and monitoring for the site, the landfill will be in compliance with the requirements of the Landfill Regulations, 2002. In particular:

- Appropriate measures will be taken in order to control the accumulation and migration of landfill gas.

- The landfill has received biodegradable wastes and landfill gas generated is collected, treated and, to the extent possible, used. The landfill gas will be used to generate electricity using gas engines employed at the landfill as long as sufficient gas is generated.

- The collection, treatment and use of landfill gas is carried out in a manner that minimises damage to or deterioration of the environment and risk to human health.

- Odour nuisance will be minimised by the management and monitoring of landfill gas. Odours may be detected on occasions but these will not occur sufficiently often to cause a nuisance.

LFGRA APPENDIX 1

Project Details

Project name: Nantycaws PPC site
[redacted]t: CWM Environmental Limited
Model: C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
Model Date: 22/04/2004 17:17:11
Comments:
LFGRA in support of PPC Permit application. This model uses the application site only - a second model has been set up to a ess the impact of emissions from gas utilisation plant which also uses gas from an adjacent site

Start Year : 1997
Simulation Period : 150 years
Operation Period : 10 years
Iterations: 251

Infiltration

NORMAL(154.0, 15.4)

Justification:
Based on 10% of annual rainfall, with 1% used as the standard deviation

Waste Input

Year	Amount Deposited [t]	Composition	% Waste In Place Capped
[redacted]	SINGLE(70248)	Nantycaws	UNIFORM(10.0, 20.0)
[redacted]	SINGLE(94583)	Nantycaws	UNIFORM(45.0, 55.0)
1999	SINGLE(97508)	Nantycaws	UNIFORM(75.0, 85.0)
2000	SINGLE(102840)	Nantycaws	UNIFORM(70.0, 80.0)
2001	SINGLE(99662)	Nantycaws	UNIFORM(70.0, 80.0)
2002	SINGLE(99529)	Nantycaws	UNIFORM(70.0, 80.0)
2003	SINGLE(101184)	Nantycaws	UNIFORM(75.0, 85.0)
2004	SINGLE(115000)	Nantycaws	UNIFORM(75.0, 85.0)
2005	SINGLE(115000)	Nantycaws	UNIFORM(80.0, 90.0)
2006	SINGLE(65000)	Nantycaws	UNIFORM(85.0, 95.0)

single values - ranges would be more appropriate

Justification:
Information provided by CWM

100% Cap at end of operational period

Justification:
Estimated from plans and lifespan of the site

W[redacted]e Moisture Content

Average
Justification:
Default Value

Waste Density [t/m3]: UNIFORM(0.8, 1.2) ✓
Default Value

Leachate Head [m]: SINGLE(1) ✓
Default Value

Hydraulic Conductivity [m/s]: LOGUNIFORM(1.00E-09, 1.00E-05) ✓
Default Value

Waste Breakdown

1997

Domestic	SINGLE(92.5)
Inert	SINGLE(0.3)
[redacted]wage Sludge	SINGLE(3.6)
[redacted]nerator Ash	SINGLE(3.6)

1998	
Domestic	SINGLE(85.9)
Inert	SINGLE(1.5)
Sewage Sludge	SINGLE(6.3)
Incinerator Ash	SINGLE(6.3)
1999	
Domestic	SINGLE(81.3)
Commercial	SINGLE(0.2)
Industrial	SINGLE(0.2)
Inert	SINGLE(13.5)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)
2000	
Domestic	SINGLE(83.6)
Commercial	SINGLE(0.8)
Industrial	SINGLE(0.8)
Inert	SINGLE(12)
Sewage Sludge	SINGLE(1.4)
Incinerator Ash	SINGLE(1.4)
2001	
Domestic	SINGLE(88.3)
Commercial	SINGLE(0.4)
Industrial	SINGLE(0.4)
Inert	SINGLE(9.7)
Sewage Sludge	SINGLE(0.6)
Incinerator Ash	SINGLE(0.6)
2002	
Domestic	SINGLE(87.9)
Commercial	SINGLE(1.2)
Industrial	SINGLE(1.2)
Inert	SINGLE(6.7)
Sewage Sludge	SINGLE(1.5)
Incinerator Ash	SINGLE(1.5)
2003	
Domestic	SINGLE(90.3)
Commercial	SINGLE(1)
Industrial	SINGLE(1)
Inert	SINGLE(5.3)
Sewage Sludge	SINGLE(1.2)
Incinerator Ash	SINGLE(1.2)
2004	
Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)
2005	
Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

2006

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

Justification:
Information provided by CWM

Proportion to Carbon Dioxide [%] UNIFORM(30.0, 40.0)
Justification:
Information provided by CWM

Proportion to Methane [%] UNIFORM(45.0, 55.0)
Justification:
Information provided by CWM

Cellulose Decay Rates

	Dry	Average	Wet
Slow	SINGLE(0.013)	SINGLE(0.061)	SINGLE(0.076)
Moderate	SINGLE(0.046)	SINGLE(0.096)	SINGLE(0.116)
Fast	SINGLE(0.076)	SINGLE(0.405)	SINGLE(0.694)

Justification:
Used to calibrate the model against known collection rates

Trace Gases

Source Gases	**Concentration [mg/m3]**
1,1,1,2-*Tetrafluorochloroethane*	LOGTRIANGULAR(0.002, 0.2, 2.0)
1,1,1-Trichlorotrifluoroethane	LOGTRIANGULAR(0.005, 0.4, 8.0)
1,1,2-Trichloroethane	LOGTRIANGULAR(0.004, 1.0, 10.0)
1,1-Dichloroethane	LOGTRIANGULAR(1.00E-03, 1.00E-01, 6.18E+04)
1,1-Dichloroethene	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.52E+03)
1,1-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.05, 0.25, 6.4)
1,2-Dichloropropane	SINGLE(0)
1,2-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.01, 9.8, 300.0)
1-Chloro-1,1-difluoroethane	LOGTRIANGULAR(0.04, 0.57, 31.0)
Chloro-1,1,1-trifluoroethane	LOGUNIFORM(0.05, 1.5)
Propanol	LOGTRIANGULAR(0.005, 2.0, 34.0)
Acetalehyde (ethanal)	LOGTRIANGULAR(0.1, 0.2, 52.0)
Acetone	LOGTRIANGULAR(0.005, 0.1, 50.0)
Acrylonitrile	*LOGTRIANGULAR(0.02, 0.4, 38.0)*
Benzene	LOGTRIANGULAR(1.00E-03, 1.00E-01, 1.14E+02)
Bromodichloromethane	SINGLE(0)
Butadiene (modelled as 1,3-Butadiene)	LOGTRIANGULAR(0.05, 1.45, 6.0)
Butane	LOGTRIANGULAR(0.19, 1.0, 709.0)
Butene isomers	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.80E+00)
Carbon disulphide	LOGTRIANGULAR(0.01, 0.1, 11.0)
Carbon monoxide	LOGTRIANGULAR(0.11, 1.1, 5000.0)
Carbon tetrachloride (tetrachloromethane)	LOGTRIANGULAR(2.00E-04, 2.00E-01, 1.52E+02)
Carbonyl sulphide	LOGTRIANGULAR(0.006, 0.2, 4.4)
Chlorobenzene	LOGTRIANGULAR(0.002, 0.01, 7466.0)
Chlorodifluoromethane	LOGTRIANGULAR(0.005, 0.1, 9900.0)
Chloroethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.15E+03)
Chlorofluorocarbons (CFCs) (Total)	*LOGTRIANGULAR(0.06, 102.3, 1230.0)*
Chlorofluoromethane	LOGTRIANGULAR(0.008, 0.2, 110.0)
Chloroform (trichloromethane)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 7.00E+01)
hlorotrifluoromethane	LOGTRIANGULAR(0.1, 0.2, 49.0)
chlorodifluoromethane	LOGTRIANGULAR(0.01, 9.0, 790.0)
Dichlorofluoromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.02E+02)
Dichloromethane (methylene chloride)	LOGTRIANGULAR(1.00E-03, 2.00E-02, 1.52E+03)
Diethyl disulphide	LOGTRIANGULAR(1.00E-03, 2.00E-02, 2.60E+00)

Dimethyl disulphide	LOGTRIANGULAR(1.00E-03, 2.00E-02, 4.00E+01)
Dimethyl sulphide	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.00E+01)
Ethane	LOGTRIANGULAR(0.005, 6.25, 200.0)
Ethanethiol (ethyl mercaptan)	LOGTRIANGULAR(0.01, 0.01, 41.9)
Ethanol	LOGTRIANGULAR(0.005, 0.2, 810.0)
Ethyl toluene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 8.30E+00)
Ethylbenzene	LOGTRIANGULAR(1.00E-03, 1.00E-03, 8.75E+02)
Ethylene	UNIFORM(0.2, 5.8)
Ethylene dibromide	SINGLE(0)
Ethylene dichloride	LOGTRIANGULAR(0.006, 0.01, 1820.0)
Fluorotrichloromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.00E+03)
Formaldehyde (methanal)	LOGTRIANGULAR(0.2, 0.2, 52.0)
Freon 113	LOGTRIANGULAR(0.013, 4.8, 125.0)
Halons	SINGLE(0)
Hexachlorocyclohexane (all isomers)	SINGLE(0)
Hexane	LOGTRIANGULAR(1.00E-03, 9.60E+00, 4.40E+01)
Hydrochlorofluorocarbons (HCFCs) (Total)	LOGTRIANGULAR(0.02, 128.8, 916.2)
Hydrofluorocarbons (HFCs) (Total)	SINGLE(0)
Hydrogen sulphide	LOGTRIANGULAR(0.0029, 10.0, 1000.0)
Limonene	LOGTRIANGULAR(1.00E-03, 1.00E-01, 2.40E+02)
Mercury	SINGLE(0)
Methanethiol (methyl mercaptan)	LOGTRIANGULAR(0.005, 0.01, 87.0)
Methyl chloride (chloromethane)	LOGTRIANGULAR(0.006, 0.2, 10.0)
Methyl chloroform (1,1,1-Trichloroethane)	LOGTRIANGULAR(1.00E-03, 1.80E+02, 1.60E+03)
Methyl ethyl ketone (2-butanone)	LOGTRIANGULAR(0.005, 0.005, 73.0)
Methyl isobutyl ketone	LOGTRIANGULAR(0.005, 0.2, 9.9)
Nitric acid	SINGLE(0)
Odour Units (Predicted)	TRIANGULAR(5.00E+04, 1.25E+05, 2.50E+05)
PAH (reported as Naphthalene)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.70E+01)
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	LOGTRIANGULAR(0.006, 0.05, 2.7)
Pentane	LOGTRIANGULAR(0.02, 0.3, 105.0)
Pentene (all isomers)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.10E+01)
Perfluorocarbons (PFCs) (Total)	SINGLE(0)
Phenol	SINGLE(0)
PM10s	SINGLE(0)
Propane	LOGTRIANGULAR(1.00E-03, 1.90E+00, 1.29E+01)
Propanethiol	LOGTRIANGULAR(0.2, 0.2, 2.1)
Sulphide, total simulations with H2S	LOGTRIANGULAR(1.00E-03, 2.40E+00, 5.58E+03)
Sulphide, total simulations without H2S	LOGTRIANGULAR(5.00E-04, 8.00E-03, 3.50E+00)
Sulphur reduced (reported as SO2)	LOGUNIFORM(30.8, 430.5)
t-1,2-Dichloroethene	LOGTRIANGULAR(0.006, 1.0, 41.0)
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	LOGUNIFORM(1.00E-03, 5.00E+01)
Tetrachloroethylene (Tetrachloroethene)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 7.70E+03)
Toluene	LOGTRIANGULAR(0.01, 0.1, 1250.0)
Total chloride (reported as HCl)	LOGTRIANGULAR(14.7, 79.5, 850.0)
Total fluoride (reported as HF)	LOGTRIANGULAR(5.6, 251.2, 735.0)
Total non-methane volatile organic compounds (NMVOCs)	LOGUNIFORM(0.05, 1473.0)
Trichlorobenzene (all isomers)	LOGTRIANGULAR(0.01, 0.01, 0.13)
Trichloroethylene (trichloroethene)	LOGTRIANGULAR(0.01, 2.0, 608.0)
Trichlorofluoromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.00E+03)
Trichlorotrifluoroethane	LOGTRIANGULAR(1.00E-03, 4.80E+00, 2.40E+01)
Trimethylbenzene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.87E+02)
Vinyl chloride (chloroethene, chloroethylene)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 7.66E+03)
Xylene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-03, 6.18E+04)

Justification:
SLR default used for H2S

Trace Gas Half-life (years) NORMAL(4.11, 1.56)

Justification:
Default Value

Landfill Characteristics

Landfill Geometry

Length N/S [m]	SINGLE(175)
Length E/W [m]	SINGLE(470)
Area [m2]	82250

Justification:
Taken from site plans

Engineered Controls

Cap
Single Liner

Thickness [m]	SINGLE(0.001)
Hydraulic conductivity [m/s]	LOGTRIANGULAR(1.00E-14, 1.00E-13, 1.00E-12)

Justification:
Thickness: Assumed permanent cap in line with Cell 1A
Conductivity: Based on typical specification for these materials

Liner
Composite
First Layer:

Thickness [m]	SINGLE(0.002)
Hydraulic Conductivity [m/s]	LOGTRIANGULAR(1.00E-14, 1.00E-13, 1.00E-12)

Second Layer:

Thickness [m]	UNIFORM(0.25, 0.3)
Hydraulic Conductivity [m/s]	*SINGLE(0.000000001)*

Justification:
Thickness: Based on Cell 1 engineering
Conductivity: Based on typical specification for these materials

Gas Plant

Engine	2002 to 2009	500	Downtime [%]: UNIFORM(3.0, 5.0)

Justification:
Information supplied by CWM, capacity scaled down to represent % contribution from the application site

Engine	2002 to 2015	230 to 1150	Downtime [%]: UNIFORM(3.0, 5.0)

Justification:
Information supplied by CWM, capacity scaled down to represent % contribution from the application site

Flare	2015 to 2035	75 to 375	Downtime [%]: UNIFORM(3.0, 5.0)

Justification:
Based on model predictions

Justification for Ordering:
Engine use preferred in accordance with EA guidance

	Air/Fuel ratio	*Methane Destruction Efficiency [%]*	*Hydrogen Destruction Efficiency [%]*
Flares	5	SINGLE(99)	SINGLE(99)
Engines	7	SINGLE(99)	SINGLE(99)

	Height [m]	Orifice Diameter [m]	Temperature [C]
Flares	7.9	1.9	850
Engines	5.5	0.35	420

Justification:
Default Value }
Default Value } should be site specific data.

Collection Efficiency — UNIFORM(70.0, 90.0)

Justification:
Default Value

Trace Gas Plant

Compound / Process	Products	Value
1,1,1,2-Tetrafluorochloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1,1-Trichlorotrifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1,2-Trichloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1-Dichloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1-Dichloroethene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1[illegible]ichlorotetrafluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,2-Dichloropropane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,2-Dichlorotetrafluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1-Chloro-1,1-difluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
2-Chloro-1,1,1-trifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
2-Propanol		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acetalehyde (ethanal)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acetone		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acrylonitrile		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Benzene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Benzo(a)pyrene		
Engine:	combustion products	LOGUNIFORM(1.10E-06, 9.00E-02)
Flare:	combustion products	LOGUNIFORM(1.00E-06, 6.00E-04)
Bromodichloromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Butadiene (modelled as 1,3-Butadiene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Butane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Butene isomers		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Carbon disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Carbon monoxide			
	Engine:	combustion products	UNIFORM(1.50E+03, 2.25E+03)
	Flare:	combustion products	UNIFORM(100.0, 150.0)
Carbon tetrachloride (tetrachloromethane)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Carbonyl sulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorobenzene			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorodifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chloroethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorofluorocarbons (CFCs) (Total)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorofluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chloroform (trichloromethane)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorotrifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichlorodifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichlorofluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichloromethane (methylene chloride)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Diethyl disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dimethyl disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dimethyl sulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dioxins and furans (modelled as 2,3,7,8-TCDD)			
	Engine:	combustion products	LOGTRIANGULAR(2.00E-10, 4.60E-09, 1.30E
	Flare:	combustion products	NORMAL(5.30E-09, 2.60E-09)
Ethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Ethanethiol (ethyl mercaptan)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Ethanol			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Ethyl toluene (all isomers)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)

Ethylbenzene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene dibromide		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene dichloride		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Fluorotrichloromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Formaldehyde (methanal)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Freon 113		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Halons		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hexachlorocyclohexane (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hexane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrochlorofluorocarbons (HCFCs) (Total)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrofluorocarbons (HFCs) (Total)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrogen sulphide		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Limonene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Mercury		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methanethiol (methyl mercaptan)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl chloride (chloromethane)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl chloroform (1,1,1-Trichloroethane)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl ethyl ketone (2-butanone)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl isobutyl ketone		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Nitric acid		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Nitrogen oxides		
Engine:	combustion products	UNIFORM(650.0, 975.0)
Flare:	combustion products	UNIFORM(150.0, 225.0)

Odour Units (Predicted)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
P[illegible] (reported as Naphthalene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Pentane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Pentene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Perfluorocarbons (PFCs) (Total)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Phenol		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
PM10s		
Engine:	combustion products	LOGTRIANGULAR(1.0, 9.3, 38.0)
Flare:	combustion products	UNIFORM(1.0, 10.0)
Propane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Propanethiol		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Sulphide, total simulations with H2S		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Sulphide, total simulations without H2S		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Sulphur reduced (reported as SO2)		
Engine:	combustion products	LOGTRIANGULAR(1.0, 112.0, 540.0)
Flare:	combustion products	LOGUNIFORM(18.0, 482.0)
t-1,2-Dichloroethene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Tetrachloroethylene (Tetrachloroethene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Toluene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Total chloride (reported as HCl)		
Engine:	combustion products	LOGTRIANGULAR(0.015, 10.0, 710.0)
Flare:	combustion products	LOGUNIFORM(1.0, 110.0)
Total fluoride (reported as HF)		
Engine:	combustion products	LOGTRIANGULAR(0.18, 7.0, 45.0)
Flare:	combustion products	LOGTRIANGULAR(0.4, 2.5, 33.0)
Total non-methane volatile organic compounds (NMVOCs)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trichlorobenzene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
[illegible]loroethylene (trichloroethene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Trichlorofluoromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trichlorotrifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trimethylbenzene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Vinyl chloride (chloroethene, chloroethylene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Xylene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Atmospheric Dispersion

Meteorological Data

Atmospheric Temperature [°C]: 20
Pressure [mbars]: 1013.6
Atmospheric Density [g/m3]: 1293
Potential Density Gradient [K/m]: 0.009

Not Deposited

Terrain Type: Sea ← ?
Roughness Length [m]: 1
Effective Windspeed Coefficient: 0.2

Default Value !!

Odour

No Compound Selected

Default Value

Lateral Migration

Bulk Gases
Air Diffusion Coefficients
Carbon Dioxide [cm2/s]: SINGLE(0.1613)
Methane [cm2/s]: SINGLE(0.2192)
Hydrogen [cm2/s]: #UNDEFINED?

Default Value

Geosphere
Moisture Content [%]: #UNDEFINED?
Porosity [%]: #UNDEFINED?

ok, as lat migration module not used.

Default Value

Trace Gases

Gas	Air Diffusion Coefficient
1,1,1,2-Tetrafluorochloroethane	SINGLE(0.071)
1,1,1-Trichlorotrifluoroethane	#UNDEFINED?
1,1,2-Trichloroethane	#UNDEFINED?
1,1-Dichloroethane	SINGLE(0.0742)
1,1-Dichloroethene	#UNDEFINED?
[illegible]Dichlorotetrafluoroethane	#UNDEFINED?
1,2-Dichloropropane	#UNDEFINED?
1,2-Dichlorotetrafluoroethane	#UNDEFINED?
1-Chloro-1,1-difluoroethane	#UNDEFINED?

2-Chloro-1,1,1-trifluoroethane	#UNDEFINED?
2-Propanol	#UNDEFINED?
Acetalehyde (ethanal)	SINGLE(0.1235)
Acetone	#UNDEFINED?
Acrylonitrile	#UNDEFINED?
Benzene	SINGLE(0.088)
Benzo(a)pyrene	SINGLE(0.043)
Bromodichloromethane	#UNDEFINED?
Butadiene (modelled as 1,3-Butadiene)	SINGLE(0.102)
Butane	#UNDEFINED?
Butene isomers	SINGLE(0.0977)
Carbon disulphide	SINGLE(0.108)
Carbon monoxide	SINGLE(0.2013)
Carbon tetrachloride (tetrachloromethane)	SINGLE(0.078)
Carbonyl sulphide	#UNDEFINED?
Chlorobenzene	SINGLE(0.073)
Chlorodifluoromethane	#UNDEFINED?
Chloroethane	SINGLE(0.1085)
Chlorofluorocarbons (CFCs) (Total)	SINGLE(0.0826)
Chlorofluoromethane	#UNDEFINED?
Chloroform (trichloromethane)	SINGLE(0.104)
Chlorotrifluoromethane	#UNDEFINED?
Dichlorodifluoromethane	#UNDEFINED?
Dichlorofluoromethane	#UNDEFINED?
Dichloromethane (methylene chloride)	SINGLE(0.099)
Diethyl disulphide	#UNDEFINED?
Dimethyl disulphide	SINGLE(0.0898)
Dimethyl sulphide	SINGLE(0.0898)
Dioxins and furans (modelled as 2,3,7,8-TCDD)	SINGLE(0.104)
Ethane	#UNDEFINED?
Ethanethiol (ethyl mercaptan)	#UNDEFINED?
Ethanol	#UNDEFINED?
Ethyl toluene (all isomers)	SINGLE(0.0796)
Ethylbenzene	#UNDEFINED?
Ethylene	SINGLE(0.0796)
Ethylene dibromide	#UNDEFINED?
Ethylene dichloride	SINGLE(0.104)
Fluorotrichloromethane	#UNDEFINED?
Formaldehyde (methanal)	SINGLE(0.1591)
Freon 113	#UNDEFINED?
Halons	SINGLE(0.0754)
Hexachlorocyclohexane (all isomers)	#UNDEFINED?
Hexane	#UNDEFINED?
Hydrochlorofluorocarbons (HCFCs) (Total)	SINGLE(0.0967)
Hydrofluorocarbons (HFCs) (Total)	#UNDEFINED?
Hydrogen sulphide	SINGLE(0.1623)
Limonene	#UNDEFINED?
Mercury	#UNDEFINED?
Methanethiol (methyl mercaptan)	#UNDEFINED?
Methyl chloride (chloromethane)	SINGLE(0.1724)
Methyl chloroform (1,1,1-Trichloroethane)	SINGLE(0.078)
Methyl ethyl ketone (2-butanone)	#UNDEFINED?
Methyl isobutyl ketone	#UNDEFINED?
Nitric acid	#UNDEFINED?
Nitrogen oxides	SINGLE(0.2276)
Odour Units (Predicted)	#UNDEFINED?
PAH (reported as Naphthalene)	SINGLE(0.059)
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	SINGLE(0.069)
Pentane	SINGLE(0.1999)
Pentene (all isomers)	SINGLE(0.1999)
Perfluorocarbons (PFCs) (Total)	SINGLE(0.071)
Phenol	#UNDEFINED?
PM10s	#UNDEFINED?
Propane	#UNDEFINED?
Propanethiol	#UNDEFINED?
Sulphide, total simulations with H2S	#UNDEFINED?
Sulphide, total simulations without H2S	#UNDEFINED?

Sulphur reduced (reported as SO2)	SINGLE(0.1289)
t-1,2-Dichloroethene	#UNDEFINED?
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	SINGLE(0.071)
Tetrachloroethylene (Tetrachloroethene)	SINGLE(0.072)
Toluene	SINGLE(0.087)
Total chloride (reported as HCl)	SINGLE(0.1763)
Total fluoride (reported as HF)	SINGLE(0.2081)
Total non-methane volatile organic compounds (NMVOCs)	#UNDEFINED?
Trichlorobenzene (all isomers)	SINGLE(0.03)
Trichloroethylene (trichloroethene)	SINGLE(0.079)
Trichlorofluoromethane	#UNDEFINED?
Trichlorotrifluoroethane	#UNDEFINED?
Trimethylbenzene (all isomers)	SINGLE(0.0619)
Vinyl chloride (chloroethene, chloroethylene)	SINGLE(0.1126)
Xylene (all isomers)	SINGLE(0.0684)

Default Value

Global Impact

Bulk Gases
Global Warming Potential
Carbon Dioxide [t]: 1
Methane [t carbon dioxoide]: 21
Hydrogen [t carbon dioxide]: 0

Default Value

Ozone Depletion Potential
Carbon Dioxide [t trichlorofluoromethane]: 0
Methane [t trichlorofluoromethane]: 0
Hydrogen [t trichlorofluoromethane]: 0

Default Value

Trace Gases

Gas	Global Warming Potential	Ozone Depletion Potential
1,1,1,2-Tetrafluorochloroethane	620	0.04
1,1,1-Trichlorotrifluoroethane	6000	0.8
1,1,2-Trichloroethane	0	0
1,1-Dichloroethane	0	0
1,1-Dichloroethene	0	0
1,1-Dichlorotetrafluoroethane	0	0
1,2-Dichloropropane	0	0
1,2-Dichlorotetrafluoroethane	0	0
1-Chloro-1,1-difluoroethane	2300	0.065
2-Chloro-1,1,1-trifluoroethane	0	0.06
2-Propanol	0	0
Acetalehyde (ethanal)	0	0
Acetone	0	0
Acrylonitrile	0	0
Benzene	0	0
Benzo(a)pyrene	0	0
Bromodichloromethane	0	0
Butadiene (modelled as 1,3-Butadiene)	0	0
Butane	0	0
Butene isomers	0	0
Carbon disulphide	0	0
Carbon monoxide	0	0
Carbon tetrachloride (tetrachloromethane)	0	0
Carbonyl sulphide	0	0
Chlorobenzene	0	0
Chlorodifluoromethane	1900	0.055
Chloroethane	0	0
Chlorofluorocarbons (CFCs) (Total)	0	0
Chlorofluoromethane	0	0.02

Chloroform (trichloromethane)	4	0
Chlorotrifluoromethane	14000	1
Dichlorodifluoromethane	10600	1
Dichlorofluoromethane	0	0.04
Dichloromethane (methylene chloride)	9	0
Diethyl disulphide	0	0
Dimethyl disulphide	0	0
Dimethyl sulphide	0	0
Dioxins and furans (modelled as 2,3,7,8-TCDD)	0	0
Ethane	0	0
Ethanethiol (ethyl mercaptan)	0	0
Ethanol	0	0
Ethyl toluene (all isomers)	0	0
Ethylbenzene	0	0
Ethylene	0	0
Ethylene dibromide	0	0
Ethylene dichloride	0	0
Fluorotrichloromethane	0	0
Formaldehyde (methanal)	0	0
Freon 113	0	0.05
Halons	0	0
Hexachlorocyclohexane (all isomers)	0	0
Hexane	0	0
Hydrochlorofluorocarbons (HCFCs) (Total)	0	0
Hydrofluorocarbons (HFCs) (Total)	0	0
Hydrogen sulphide	0	0
Limonene	0	0
Mercury	0	0
Methanethiol (methyl mercaptan)	0	0
Methyl chloride (chloromethane)	0	0
Methyl chloroform (1,1,1-Trichloroethane)	0	0
Methyl ethyl ketone (2-butanone)	0	0
Methyl isobutyl ketone	0	0
Nitric acid	0	0
Nitrogen oxides	0	0
Odour Units (Predicted)	0	0
PAH (reported as Naphthalene)	0	0
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	0	0
Pentane	0	0
Pentene (all isomers)	0	0
Perfluorocarbons (PFCs) (Total)	0	0
Phenol	0	0
PM10s	0	0
Propane	0	0
Propanethiol	0	0
Sulphide, total simulations with H2S	0	0
Sulphide, total simulations without H2S	0	0
Sulphur reduced (reported as SO2)	0	0
t-1,2-Dichloroethene	0	0
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	0	0
Tetrachloroethylene (Tetrachloroethene)	0	0
Toluene	0	0
Total chloride (reported as HCl)	0	0
Total fluoride (reported as HF)	0	0
Total non-methane volatile organic compounds (NMVOCs)	0	0
Trichlorobenzene (all isomers)	0	0
Trichloroethylene (trichloroethene)	0	0
Trichlorofluoromethane	4600	1
Trichlorotrifluoroethane	6000	0.8
Trimethylbenzene (all isomers)	0	0
Vinyl chloride (chloroethene, chloroethylene)	0	0
Xylene (all isomers)	0	0

Exposure

Scenario: Residential without Plant Uptake
Year: 1997
Distance from boundary [m]: 0
Direction: North East
Emissions to model: <None Selected>
Gas Viscosity [N.hr/m2]: 0.000000005
Henry's law constant:
Soil Type: Loam
Soil Organic Matter [%]: 5
Wind speed above ground surface in ambient mixing zone [cm/s]:12
Depth below ground to contaminated source zone [cm]:1

Building Characteristics

Area of walls in living space [m2]:	186
Area of windows [m2]:	20
Area of floor [m2]:	74.1
Height of Living space [m]:	5.4
Air exchange rate (total exchanges per hour)	1
Perimeter of building [m]:	34.4
Air pressure inside house [Pa]:	101321.5
Area of house walls in cellar [m2]:	6.88
Height of subfloor void [m]:	0.5
Air pressure inside subfloor void [Pa]:	101325
Temperature inside house [C]:	565
Floor resistance [NH/m3]:	27.8
Average height of all openings [m]:	2

Building Materials

Material	Total Porosity [cm3/cm3]	Air-filled porosity [cm3/cm3]	Thickness [m]
Hardcore	0.5	0.25	0.1
Blinding Sand	0.5	0.5	0.05
Concrete	0.068	0.034	0.1
Insulating layer (floors)	0.9	0.9	0.05
Brick (external walls)	0.5	0.25	0.1
Lightweight block (walls)	0.068	0.068	0.1
Insulating layer (walls)	0.9	0.9	0.055
Plasterboard (ceiling)	0.068	0.068	0.0125
Insulating layer (roof)	0.9	0.9	0.1
Screed (over beam/block floor)	0.068	0.068	0.05
Suspended timber floor	0.2	0.2	0.03

Project Details

Project name: Nantycaws PPC site
Client: CWM Environmental Limited
Model: C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
Model Date: 22/04/2004 17:01:00
Comments:
LFGRA in support of PPC Permit application. This model uses the application site and adjacent Phase 1 to calibrate the sour
term against known collection rates and assess the impact of emissions from the gas utilisation plant

Start Year : 1982
Simulation Period : 150 years
Operation Period : 25 years
Iterations: 251

Infiltration

NORMAL(154.0, 15.4)

Justification:
Based on 10% of annual rainfall, with 1% used as the standard deviation

Waste Input

Year	Amount Deposited [t]	Composition	% Waste In Place Capped
1982	SINGLE(50000)	Nantycaws	UNIFORM(10.0, 20.0)
1983	SINGLE(55000)	Nantycaws	UNIFORM(10.0, 20.0)
1984	SINGLE(60000)	Nantycaws	UNIFORM(20.0, 30.0)
1985	SINGLE(60000)	Nantycaws	UNIFORM(25.0, 35.0)
1986	SINGLE(65000)	Nantycaws	UNIFORM(35.0, 40.0)
1987	SINGLE(65000)	Nantycaws	UNIFORM(40.0, 45.0)
1988	SINGLE(65000)	Nantycaws	UNIFORM(45.0, 50.0)
1989	SINGLE(70000)	Nantycaws	UNIFORM(50.0, 55.0)
1990	SINGLE(70000)	Nantycaws	UNIFORM(55.0, 60.0)
1991	SINGLE(70000)	Nantycaws	UNIFORM(60.0, 65.0)
1992	SINGLE(70000)	Nantycaws	UNIFORM(65.0, 70.0)
1993	SINGLE(75000)	Nantycaws	UNIFORM(65.0, 70.0)
1994	SINGLE(75000)	Nantycaws	UNIFORM(70.0, 75.0)
1995	SINGLE(75000)	Nantycaws	UNIFORM(75.0, 80.0)
1996	SINGLE(75000)	Nantycaws	UNIFORM(80.0, 85.0)
1997	SINGLE(70248)	Nantycaws	UNIFORM(80.0, 85.0)
1998	SINGLE(94583)	Nantycaws	UNIFORM(80.0, 85.0)
1999	SINGLE(97508)	Nantycaws	UNIFORM(85.0, 90.0)
2000	SINGLE(102840)	Nantycaws	UNIFORM(85.0, 90.0)
2001	SINGLE(99662)	Nantycaws	UNIFORM(85.0, 90.0)
2002	SINGLE(99529)	Nantycaws	UNIFORM(90.0, 95.0)
2003	SINGLE(101184)	Nantycaws	UNIFORM(90.0, 95.0)
2004	SINGLE(115000)	Nantycaws	UNIFORM(90.0, 95.0)
2005	SINGLE(115000)	Nantycaws	UNIFORM(95.0, 100.0)
2006	SINGLE(65000)	Nantycaws	UNIFORM(95.0, 100.0)

Justification:
Estimates provided by CWM used to simulate Phase 1 site

100% Cap at end of operational period

Justification:
Estimated

Waste Moisture Content

Average
Justification:
Default Value

Waste Density [t/m3]: UNIFORM(0.8, 1.2)
Default Value

Leachate Head [m]: SINGLE(1)
Default Value

Hydraulic Conductivity [m/s]: LOGUNIFORM(1.00E-09, 1.00E-05)
Default Value

Waste Breakdown

1982

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1983

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

[illegible]

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1985

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1986

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1987

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1988

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1989

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1990

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1991

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1992

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1993

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1994

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1995

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1996

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

1997	
Domestic	SINGLE(92.5)
Inert	SINGLE(0.3)
Sewage Sludge	SINGLE(3.6)
Incinerator Ash	SINGLE(3.6)
1998	
Domestic	SINGLE(85.9)
Inert	SINGLE(1.5)
Sewage Sludge	SINGLE(6.3)
Incinerator Ash	SINGLE(6.3)
1999	
Domestic	SINGLE(81.3)
Commercial	SINGLE(0.2)
Industrial	SINGLE(0.2)
Inert	SINGLE(13.5)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)
2000	
Domestic	SINGLE(83.6)
Commercial	SINGLE(0.8)
Industrial	SINGLE(0.8)
Inert	SINGLE(12)
Sewage Sludge	SINGLE(1.4)
Incinerator Ash	SINGLE(1.4)
2001	
Domestic	SINGLE(88.3)
Commercial	SINGLE(0.4)
Industrial	SINGLE(0.4)
Inert	SINGLE(9.7)
Sewage Sludge	SINGLE(0.6)
Incinerator Ash	SINGLE(0.6)
2002	
Domestic	SINGLE(87.9)
Commercial	SINGLE(1.2)
Industrial	SINGLE(1.2)
Inert	SINGLE(6.7)
Sewage Sludge	SINGLE(1.5)
Incinerator Ash	SINGLE(1.5)
2003	
Domestic	SINGLE(90.3)
Commercial	SINGLE(1)
Industrial	SINGLE(1)
Inert	SINGLE(5.3)
Sewage Sludge	SINGLE(1.2)
Incinerator Ash	SINGLE(1.2)
2004	
Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

2005

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

2006

Domestic	SINGLE(87.2)
Commercial	SINGLE(0.5)
Industrial	SINGLE(0.5)
Inert	SINGLE(7)
Sewage Sludge	SINGLE(2.4)
Incinerator Ash	SINGLE(2.4)

Justification:
Information provided by CWM used to simulate Phase 1 site

Proportion to Carbon Dioxide [%] UNIFORM(30.0, 40.0)
Justification:
Information provided by CWM

Proportion to Methane [%] UNIFORM(45.0, 55.0)
Justification:
Information provided by CWM

Cellulose Decay Rates

	Dry	Average	Wet
Slow	SINGLE(0.013)	SINGLE(0.061)	SINGLE(0.076)
Moderate	SINGLE(0.046)	SINGLE(0.096)	SINGLE(0.116)
Fast	SINGLE(0.076)	SINGLE(0.405)	SINGLE(0.694)

Justification:
Adjusted to calibrate the model against current collection rates

Trace Gases

Source Gases	**Concentration [mg/m3]**
1,1,1,2-Tetrafluorochloroethane	LOGTRIANGULAR(0.002, 0.2, 2.0)
1,1,1-Trichlorotrifluoroethane	LOGTRIANGULAR(0.005, 0.4, 8.0)
1,1,2-Trichloroethane	LOGTRIANGULAR(0.004, 1.0, 10.0)
1,1-Dichloroethane	LOGTRIANGULAR(1.00E-03, 1.00E-01, 6.18E+04)
1,1-Dichloroethene	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.52E+03)
1,1-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.05, 0.25, 6.4)
1,2-Dichloropropane	SINGLE(0)
1,2-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.01, 9.8, 300.0)
1-Chloro-1,1-difluoroethane	LOGTRIANGULAR(0.04, 0.57, 31.0)
2-Chloro-1,1,1-trifluoroethane	LOGUNIFORM(0.05, 1.5)
2-Propanol	LOGTRIANGULAR(0.005, 2.0, 34.0)
Acetalehyde (ethanal)	LOGTRIANGULAR(0.1, 0.2, 52.0)
Acetone	LOGTRIANGULAR(0.005, 0.1, 50.0)
Acrylonitrile	LOGTRIANGULAR(0.02, 0.4, 38.0)
Benzene	LOGTRIANGULAR(1.00E-03, 1.00E-01, 1.14E+02)
Bromodichloromethane	SINGLE(0)
Butadiene (modelled as 1,3-Butadiene)	LOGTRIANGULAR(0.05, 1.45, 6.0)
Butane	LOGTRIANGULAR(0.19, 1.0, 709.0)
Butene isomers	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.80E+00)
Carbon disulphide	LOGTRIANGULAR(0.01, 0.1, 11.0)
Carbon monoxide	LOGTRIANGULAR(0.11, 1.1, 5000.0)
Carbon tetrachloride (tetrachloromethane)	LOGTRIANGULAR(2.00E-04, 2.00E-01, 1.52E+02)
Carbonyl sulphide	LOGTRIANGULAR(0.006, 0.2, 4.4)
Chlorobenzene	LOGTRIANGULAR(0.002, 0.01, 7466.0)
Chlorodifluoromethane	LOGTRIANGULAR(0.005, 0.1, 9900.0)
Chloroethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.15E+03)

Chlorofluorocarbons (CFCs) (Total)	LOGTRIANGULAR(0.06, 102.3, 1230.0)
Chlorofluoromethane	LOGTRIANGULAR(0.008, 0.2, 110.0)
Chloroform (trichloromethane)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 7.00E+01)
Chlorotrifluoromethane	LOGTRIANGULAR(0.1, 0.2, 49.0)
Dichlorodifluoromethane	LOGTRIANGULAR(0.01, 9.0, 790.0)
Dichlorofluoromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.02E+02)
Dichloromethane (methylene chloride)	LOGTRIANGULAR(1.00E-03, 2.00E-02, 1.52E+03)
Diethyl disulphide	LOGTRIANGULAR(1.00E-03, 2.00E-02, 2.60E+00)
Dimethyl disulphide	LOGTRIANGULAR(1.00E-03, 2.00E-02, 4.00E+01)
Dimethyl sulphide	LOGTRIANGULAR(1.00E-03, 1.00E-02, 6.00E+01)
Ethane	LOGTRIANGULAR(0.005, 6.25, 200.0)
Ethanethiol (ethyl mercaptan)	LOGTRIANGULAR(0.01, 0.01, 41.9)
Ethanol	LOGTRIANGULAR(0.005, 0.2, 810.0)
Ethyl toluene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 8.30E+00)
Ethylbenzene	LOGTRIANGULAR(1.00E-03, 1.00E-03, 8.75E+02)
Ethylene	UNIFORM(0.2, 5.8)
Ethylene dibromide	SINGLE(0)
Ethylene dichloride	LOGTRIANGULAR(0.006, 0.01, 1820.0)
Fluorotrichloromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.00E+03)
Formaldehyde (methanal)	LOGTRIANGULAR(0.2, 0.2, 52.0)
Freon 113	LOGTRIANGULAR(0.013, 4.8, 125.0)
Halons	SINGLE(0)
Hexachlorocyclohexane (all isomers)	SINGLE(0)
Hexane	LOGTRIANGULAR(1.00E-03, 9.60E+00, 4.40E+01)
Hydrochlorofluorocarbons (HCFCs) (Total)	LOGTRIANGULAR(0.02, 128.8, 916.2)
Hydrofluorocarbons (HFCs) (Total)	SINGLE(0)
Hydrogen sulphide	LOGTRIANGULAR(0.0029, 10.0, 1000.0)
Limonene	LOGTRIANGULAR(1.00E-03, 1.00E-01, 2.40E+02)
Mercury	SINGLE(0)
Methanethiol (methyl mercaptan)	LOGTRIANGULAR(0.005, 0.01, 87.0)
Methyl chloride (chloromethane)	LOGTRIANGULAR(0.006, 0.2, 10.0)
Methyl chloroform (1,1,1-Trichloroethane)	LOGTRIANGULAR(1.00E-03, 1.80E+02, 1.60E+03)
Methyl ethyl ketone (2-butanone)	LOGTRIANGULAR(0.005, 0.005, 73.0)
Methyl isobutyl ketone	LOGTRIANGULAR(0.005, 0.2, 9.9)
Nitric acid	SINGLE(0)
Odour Units (Predicted)	TRIANGULAR(5.00E+04, 1.25E+05, 2.50E+05)
PAH (reported as Naphthalene)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.70E+01)
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	LOGTRIANGULAR(0.006, 0.05, 2.7)
Pentane	LOGTRIANGULAR(0.02, 0.3, 105.0)
Pentene (all isomers)	LOGTRIANGULAR(1.00E-03, 2.00E-01, 1.10E+01)
Perfluorocarbons (PFCs) (Total)	SINGLE(0)
Phenol	SINGLE(0)
PM10s	SINGLE(0)
Propane	LOGTRIANGULAR(1.00E-03, 1.90E+00, 1.29E+01)
Propanethiol	LOGTRIANGULAR(0.2, 0.2, 2.1)
Sulphide, total simulations with H2S	LOGTRIANGULAR(1.00E-03, 2.40E+00, 5.58E+03)
Sulphide, total simulations without H2S	LOGTRIANGULAR(5.00E-04, 8.00E-03, 3.50E+00)
Sulphur reduced (reported as SO2)	LOGUNIFORM(30.8, 430.5)
t-1,2-Dichloroethene	LOGTRIANGULAR(0.006, 1.0, 41.0)
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	LOGUNIFORM(1.00E-03, 5.00E+01)
Tetrachloroethylene (Tetrachloroethene)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 7.70E+03)
Toluene	LOGTRIANGULAR(0.01, 0.1, 1250.0)
Total chloride (reported as HCl)	LOGTRIANGULAR(14.7, 79.5, 850.0)
Total fluoride (reported as HF)	LOGTRIANGULAR(5.6, 251.2, 735.0)
Total non-methane volatile organic compounds (NMVOCs)	LOGUNIFORM(0.05, 1473.0)
Trichlorobenzene (all isomers)	LOGTRIANGULAR(0.01, 0.01, 0.13)
Trichloroethylene (trichloroethene)	LOGTRIANGULAR(0.01, 2.0, 608.0)
Trichlorofluoromethane	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.00E+03)
Trichlorotrifluoroethane	LOGTRIANGULAR(1.00E-03, 4.80E+00, 2.40E+01)
Trimethylbenzene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 1.87E+02)
Vinyl chloride (chloroethene, chloroethylene)	LOGTRIANGULAR(1.00E-03, 1.00E-02, 7.66E+03)
Xylene (all isomers)	LOGTRIANGULAR(1.00E-03, 1.00E-03, 6.18E+04)

Justification:
[illegible]LR default used for H2S

Trace Gas Half-life (years) NORMAL(4.11, 1.56)

Justification:
Default Value

Landfill Characteristics

Landfill Geometry

Length N/S [m]	SINGLE(470)
Length E/W [m]	SINGLE(240)
Area [m2]	112800

Justification:
Taken from site plans

Engineered Controls

Cap

Single Liner

Thickness [m]	SINGLE(0.001)
Hydraulic conductivity [m/s]	LOGTRIANGULAR(1.00E-14, 1.00E-13, 1.00E-12)

Justification:
Thickness: Assumed permanent cap in line with Cell 1A
Conductivity: Based on typical specification for these materials

Liner

Composite

First Layer:

Thickness [m]	SINGLE(0.002)
Hydraulic Conductivity [m/s]	LOGTRIANGULAR(1.00E-14, 1.00E-13, 1.00E-12)

Second Layer:

Thickness [m]	UNIFORM(0.25, 0.3)
Hydraulic Conductivity [m/s]	SINGLE(0.000000001)

Justification:
Thickness: Based on Cell 1 engineering
Conductivity: Based on typical specification for these materials

Gas Plant

Engine 2002 to 2009 | 650 | Downtime [%]: UNIFORM(3.0, 5.0)
Justification:
Information supplied by CWM

Flare 2002 to 2015 | 300 to 1500 | Downtime [%]: UNIFORM(3.0, 5.0)
Justification:
Information supplied by CWM

Flare 2015 to 2035 | 100 to 500 | Downtime [%]: UNIFORM(3.0, 5.0)
Justification:
Based on model predictions

Justification for Ordering:
Engine use preferred in accordance with EA guidance

	Air/Fuel ratio	Methane Destruction Efficiency [%]	Hydrogen Destruction Efficiency [%]
Flares	5	SINGLE(99)	SINGLE(99)
Engines	7	SINGLE(99)	SINGLE(99)

	Height [m]	Orifice Diameter [m]	Temperature [C]
Flares	7.9	1.9	850
Engines	5.5	0.35	420

Justification:
Default Value
Default Value

Collection Efficiency UNIFORM(70.0, 90.0)

Justification:
Default Value

Trace Gas Plant

1,1,1,2-Tetrafluorochloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1,1-Trichlorotrifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1,2-Trichloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1-Dichloroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1-Dichloroethene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,1-Dichlorotetrafluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,2-Dichloropropane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1,2-Dichlorotetrafluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
1-Chloro-1,1-difluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
2-Chloro-1,1,1-trifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
2-Propanol		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acetalehyde (ethanal)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acetone		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Acrylonitrile		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Benzene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Benzo(a)pyrene		
Engine:	combustion products	LOGUNIFORM(1.10E-06, 9.00E-02)
Flare:	combustion products	LOGUNIFORM(1.00E-06, 6.00E-04)
Bromodichloromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Butadiene (modelled as 1,3-Butadiene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Butane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Butane isomers			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Carbon disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Carbon monoxide			
	Engine:	combustion products	UNIFORM(1.50E+03, 2.25E+03)
	Flare:	combustion products	UNIFORM(100.0, 150.0)
Carbon tetrachloride (tetrachloromethane)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Carbonyl sulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorobenzene			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorodifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chloroethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorofluorocarbons (CFCs) (Total)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorofluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chloroform (trichloromethane)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Chlorotrifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichlorodifluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichlorofluoromethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dichloromethane (methylene chloride)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Diethyl disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dimethyl disulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dimethyl sulphide			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Dioxins and furans (modelled as 2,3,7,8-TCDD)			
	Engine:	combustion products	LOGTRIANGULAR(2.00E-10, 4.60E-09, 1.30E
	Flare:	combustion products	NORMAL(5.30E-09, 2.60E-09)
Ethane			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)
Ethanethiol (ethyl mercaptan)			
	Engine:	non-combustion products	SINGLE(99)
	Flare:	non-combustion products	SINGLE(99)

Ethanol		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethyl toluene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylbenzene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene dibromide		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Ethylene dichloride		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Fluorotrichloromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Formaldehyde (methanal)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Freon 113		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Halons		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hexachlorocyclohexane (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hexane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrochlorofluorocarbons (HCFCs) (Total)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrofluorocarbons (HFCs) (Total)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Hydrogen sulphide		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Limonene		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Mercury		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methanethiol (methyl mercaptan)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl chloride (chloromethane)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl chloroform (1,1,1-Trichloroethane)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl ethyl ketone (2-butanone)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Methyl isobutyl ketone		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Nitric acid

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Nitrogen oxides

Engine:	combustion products	UNIFORM(650.0, 975.0)
Flare:	combustion products	UNIFORM(150.0, 225.0)

Odour Units (Predicted)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

PAH (reported as Naphthalene)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Pentane

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Pentene (all isomers)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Perfluorocarbons (PFCs) (Total)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Phenol

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

PM10s

Engine:	combustion products	LOGTRIANGULAR(1.0, 9.3, 38.0)
Flare:	combustion products	UNIFORM(1.0, 10.0)

Propane

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Propanethiol

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Sulphide, total simulations with H2S

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Sulphide, total simulations without H2S

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Sulphur reduced (reported as SO2)

Engine:	combustion products	LOGTRIANGULAR(1.0, 112.0, 540.0)
Flare:	combustion products	LOGUNIFORM(18.0, 482.0)

t-1,2-Dichloroethene

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Tetrachloroethylene (Tetrachloroethene)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Toluene

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Total chloride (reported as HCl)

Engine:	combustion products	LOGTRIANGULAR(0.015, 10.0, 710.0)
Flare:	combustion products	LOGUNIFORM(1.0, 110.0)

Total fluoride (reported as HF)

Engine:	combustion products	LOGTRIANGULAR(0.18, 7.0, 45.0)
Flare:	combustion products	LOGTRIANGULAR(0.4, 2.5, 33.0)

Total non-methane volatile organic compounds (NMVOCs)

Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Trichlorobenzene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trichloroethylene (trichloroethene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trichlorofluoromethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trichlorotrifluoroethane		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Trimethylbenzene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Vinyl chloride (chloroethene, chloroethylene)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)
Xylene (all isomers)		
Engine:	non-combustion products	SINGLE(99)
Flare:	non-combustion products	SINGLE(99)

Atmospheric Dispersion

Meteorological Data

Atmospheric Temperature [°C]: 20
Pressure [mbars]: 1013.6
Atmospheric Density [g/m3]: 1293
Potential Density Gradient [K/m]: 0.009

Not Deposited

Terrain Type: Sea
Roughness Length [m]: 1
Effective Windspeed Coefficient: 0.2

Default Value

Odour

No Compound Selected

Default Value

Lateral Migration

Bulk Gases
Air Diffusion Coefficients
Carbon Dioxide [cm2/s]: SINGLE(0.1613)
Methane [cm2/s]: SINGLE(0.2192)
Hydrogen [cm2/s]: #UNDEFINED?

Default Value

Geosphere
Moisture Content [%]: #UNDEFINED?
Porosity [%]: #UNDEFINED?

Default Value

Trace Gases

	Air Diffusion Coefficient
1,1,1,2-Tetrafluorochloroethane	SINGLE(0.071)
1,1,1-Trichlorotrifluoroethane	#UNDEFINED?
1,1,2-Trichloroethane	#UNDEFINED?

1,1-Dichloroethane	SINGLE(0.0742)
1,1-Dichloroethene	#UNDEFINED?
1,1-Dichlorotetrafluoroethane	#UNDEFINED?
1,2-Dichloropropane	#UNDEFINED?
1,2-Dichlorotetrafluoroethane	#UNDEFINED?
1-Chloro-1,1-difluoroethane	#UNDEFINED?
2-Chloro-1,1,1-trifluoroethane	#UNDEFINED?
2-Propanol	#UNDEFINED?
Acetalehyde (ethanal)	SINGLE(0.1235)
Acetone	#UNDEFINED?
Acrylonitrile	#UNDEFINED?
Benzene	SINGLE(0.088)
Benzo(a)pyrene	SINGLE(0.043)
Bromodichloromethane	#UNDEFINED?
Butadiene (modelled as 1,3-Butadiene)	SINGLE(0.102)
Butane	#UNDEFINED?
Butene isomers	SINGLE(0.0977)
Carbon disulphide	SINGLE(0.108)
Carbon monoxide	SINGLE(0.2013)
Carbon tetrachloride (tetrachloromethane)	SINGLE(0.078)
Carbonyl sulphide	#UNDEFINED?
Chlorobenzene	SINGLE(0.073)
Chlorodifluoromethane	#UNDEFINED?
Chloroethane	SINGLE(0.1085)
Chlorofluorocarbons (CFCs) (Total)	SINGLE(0.0826)
Chlorofluoromethane	#UNDEFINED?
Chloroform (trichloromethane)	SINGLE(0.104)
Chlorotrifluoromethane	#UNDEFINED?
Dichlorodifluoromethane	#UNDEFINED?
Dichlorofluoromethane	#UNDEFINED?
Dichloromethane (methylene chloride)	SINGLE(0.099)
Diethyl disulphide	#UNDEFINED?
Dimethyl disulphide	SINGLE(0.0898)
Dimethyl sulphide	SINGLE(0.0898)
Dioxins and furans (modelled as 2,3,7,8-TCDD)	SINGLE(0.104)
Ethane	#UNDEFINED?
Ethanethiol (ethyl mercaptan)	#UNDEFINED?
Ethanol	#UNDEFINED?
Ethyl toluene (all isomers)	SINGLE(0.0796)
Ethylbenzene	#UNDEFINED?
Ethylene	SINGLE(0.0796)
Ethylene dibromide	#UNDEFINED?
Ethylene dichloride	SINGLE(0.104)
Fluorotrichloromethane	#UNDEFINED?
Formaldehyde (methanal)	SINGLE(0.1591)
Freon 113	#UNDEFINED?
Halons	SINGLE(0.0754)
Hexachlorocyclohexane (all isomers)	#UNDEFINED?
Hexane	#UNDEFINED?
Hydrochlorofluorocarbons (HCFCs) (Total)	SINGLE(0.0967)
Hydrofluorocarbons (HFCs) (Total)	#UNDEFINED?
Hydrogen sulphide	SINGLE(0.1623)
Limonene	#UNDEFINED?
Mercury	#UNDEFINED?
Methanethiol (methyl mercaptan)	#UNDEFINED?
Methyl chloride (chloromethane)	SINGLE(0.1724)
Methyl chloroform (1,1,1-Trichloroethane)	SINGLE(0.078)
Methyl ethyl ketone (2-butanone)	#UNDEFINED?
Methyl isobutyl ketone	#UNDEFINED?
Nitric acid	#UNDEFINED?
Nitrogen oxides	SINGLE(0.2276)
Odour Units (Predicted)	#UNDEFINED?
PAH (reported as Naphthalene)	SINGLE(0.059)
p-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	SINGLE(0.069)
Pentane	SINGLE(0.1999)
Pentene (all isomers)	SINGLE(0.1999)
Perfluorocarbons (PFCs) (Total)	SINGLE(0.071)

Phenol	#UNDEFINED?
PM10s	#UNDEFINED?
Propane	#UNDEFINED?
Propanethiol	#UNDEFINED?
Sulphide, total simulations with H2S	#UNDEFINED?
Sulphide, total simulations without H2S	#UNDEFINED?
Sulphur reduced (reported as SO2)	SINGLE(0.1289)
t-1,2-Dichloroethene	#UNDEFINED?
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	SINGLE(0.071)
Tetrachloroethylene (Tetrachloroethene)	SINGLE(0.072)
Toluene	SINGLE(0.087)
Total chloride (reported as HCl)	SINGLE(0.1763)
Total fluoride (reported as HF)	SINGLE(0.2081)
Total non-methane volatile organic compounds (NMVOCs)	#UNDEFINED?
Trichlorobenzene (all isomers)	SINGLE(0.03)
Trichloroethylene (trichloroethene)	SINGLE(0.079)
Trichlorofluoromethane	#UNDEFINED?
Trichlorotrifluoroethane	#UNDEFINED?
Trimethylbenzene (all isomers)	SINGLE(0.0619)
Vinyl chloride (chloroethene, chloroethylene)	SINGLE(0.1126)
Xylene (all isomers)	SINGLE(0.0684)

Default Value

Global Impact

Bulk Gases

Global Warming Potential
- Carbon Dioxide [t]: 1
- Methane [t carbon dioxoide]: 21
- Hydrogen [t carbon dioxide]: 0

Default Value

Ozone Depletion Potential
- Carbon Dioxide [t trichlorofluoromethane]: 0
- Methane [t trichlorofluoromethane]: 0
- Hydrogen [t trichlorofluoromethane]: 0

Default Value

Trace Gases

C[illegible]	Global Warming Potential	Ozone Depletion Potential
1,1,1,2-Tetrafluorochloroethane	620	0.04
1,1,1-Trichlorotrifluoroethane	6000	0.8
1,1,2-Trichloroethane	0	0
1,1-Dichloroethane	0	0
1,1-Dichloroethene	0	0
1,1-Dichlorotetrafluoroethane	0	0
1,2-Dichloropropane	0	0
1,2-Dichlorotetrafluoroethane	0	0
1-Chloro-1,1-difluoroethane	2300	0.065
2-Chloro-1,1,1-trifluoroethane	0	0.06
2-Propanol	0	0
Acetalehyde (ethanal)	0	0
Acetone	0	0
Acrylonitrile	0	0
Benzene	0	0
Benzo(a)pyrene	0	0
Bromodichloromethane	0	0
Butadiene (modelled as 1,3-Butadiene)	0	0
Butane	0	0
Butene isomers	0	0
Carbon disulphide	0	0
Carbon monoxide	0	0
Carbon tetrachloride (tetrachloromethane)	0	0

Carbonyl sulphide	0	0
Chlorobenzene	0	0
Chlorodifluoromethane	1900	0.055
Chloroethane	0	0
Chlorofluorocarbons (CFCs) (Total)	0	0
Chlorofluoromethane	0	0.02
Chloroform (trichloromethane)	4	0
Chlorotrifluoromethane	14000	1
Dichlorodifluoromethane	10600	1
Dichlorofluoromethane	0	0.04
Dichloromethane (methylene chloride)	9	0
Diethyl disulphide	0	0
Dimethyl disulphide	0	0
Dimethyl sulphide	0	0
Dioxins and furans (modelled as 2,3,7,8-TCDD)	0	0
Ethane	0	0
Ethanethiol (ethyl mercaptan)	0	0
Ethanol	0	0
Ethyl toluene (all isomers)	0	0
Ethylbenzene	0	0
Ethylene	0	0
Ethylene dibromide	0	0
Ethylene dichloride	0	0
Fluorotrichloromethane	0	0
Formaldehyde (methanal)	0	0
Freon 113	0	0.05
Halons	0	0
Hexachlorocyclohexane (all isomers)	0	0
Hexane	0	0
Hydrochlorofluorocarbons (HCFCs) (Total)	0	0
Hydrofluorocarbons (HFCs) (Total)	0	0
Hydrogen sulphide	0	0
Limonene	0	0
Mercury	0	0
Methanethiol (methyl mercaptan)	0	0
Methyl chloride (chloromethane)	0	0
Methyl chloroform (1,1,1-Trichloroethane)	0	0
Methyl ethyl ketone (2-butanone)	0	0
Methyl isobutyl ketone	0	0
Nitric acid	0	0
Nitrogen oxides	0	0
Odour Units (Predicted)	0	0
PAH (reported as Naphthalene)	0	0
p-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	0	0
Pentane	0	0
Pentene (all isomers)	0	0
Perfluorocarbons (PFCs) (Total)	0	0
Phenol	0	0
PM10s	0	0
Propane	0	0
Propanethiol	0	0
Sulphide, total simulations with H2S	0	0
Sulphide, total simulations without H2S	0	0
Sulphur reduced (reported as SO2)	0	0
t-1,2-Dichloroethene	0	0
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	0	0
Tetrachloroethylene (Tetrachloroethene)	0	0
Toluene	0	0
Total chloride (reported as HCl)	0	0
Total fluoride (reported as HF)	0	0
Total non-methane volatile organic compounds (NMVOCs)	0	0
Trichlorobenzene (all isomers)	0	0
Trichloroethylene (trichloroethene)	0	0
Trichlorofluoromethane	4600	1
Trichlorotrifluoroethane	6000	0.8
Trimethylbenzene (all isomers)	0	0
Vinyl chloride (chloroethene, chloroethylene)	0	0

Xylene (all isomers)	0	0

Exposure

Scenario: Residential without Plant Uptake
Year: 1982
Distance from boundary [m]: 0
Direction: North East
Emissions to model: <None Selected>
Gas Viscosity [N.hr/m2]: 0.000000005
Henry's law constant:
Soil Type: Loam
Soil Organic Matter [%]: 5
Wind speed above ground surface in ambient mixing zone [cm/s]:12
Depth below ground to contaminated source zone [cm]:1

Building Characteristics

Area of walls in living space [m2]:	186
Area of windows [m2]:	20
Area of floor [m2]:	74.1
Height of Living space [m]:	5.4
Air exchange rate (total exchanges per hour)	1
Perimeter of building [m]:	34.4
Air pressure inside house [Pa]:	101321.5
Area of house walls in cellar [m2]:	6.88
Height of subfloor void [m]:	0.5
Air pressure inside subfloor void [Pa]:	101325
Temperature inside house [C]:	565
Floor resistance [NH/m3]:	27.8
Average height of all openings [m]:	2

Building Materials

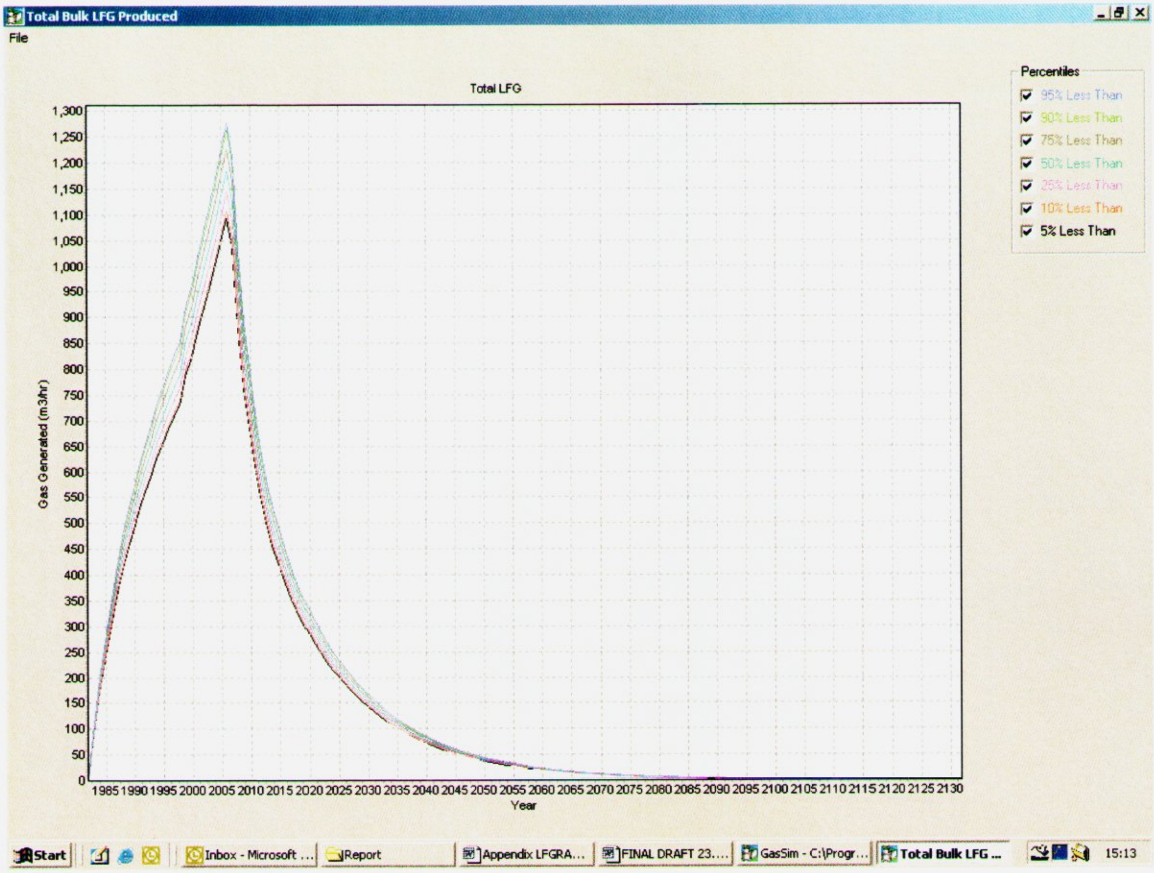
Material	Total Porosity [cm3/cm3]	Air-filled porosity [cm3/cm3]	Thickness [m]
Hardcore	0.5	0.25	0.1
Blinding Sand	0.5	0.5	0.05
Concrete	0.068	0.034	0.1
Insulating layer (floors)	0.9	0.9	0.05
Brick (external walls)	0.5	0.25	0.1
Lightweight block (walls)	0.068	0.068	0.1
Insulating layer (walls)	0.9	0.9	0.055
Plasterboard (ceiling)	0.068	0.068	0.0125
Insulating layer (roof)	0.9	0.9	0.1
Screed (over beam/block floor)	0.068	0.068	0.05
Suspended timber floor	0.2	0.2	0.03

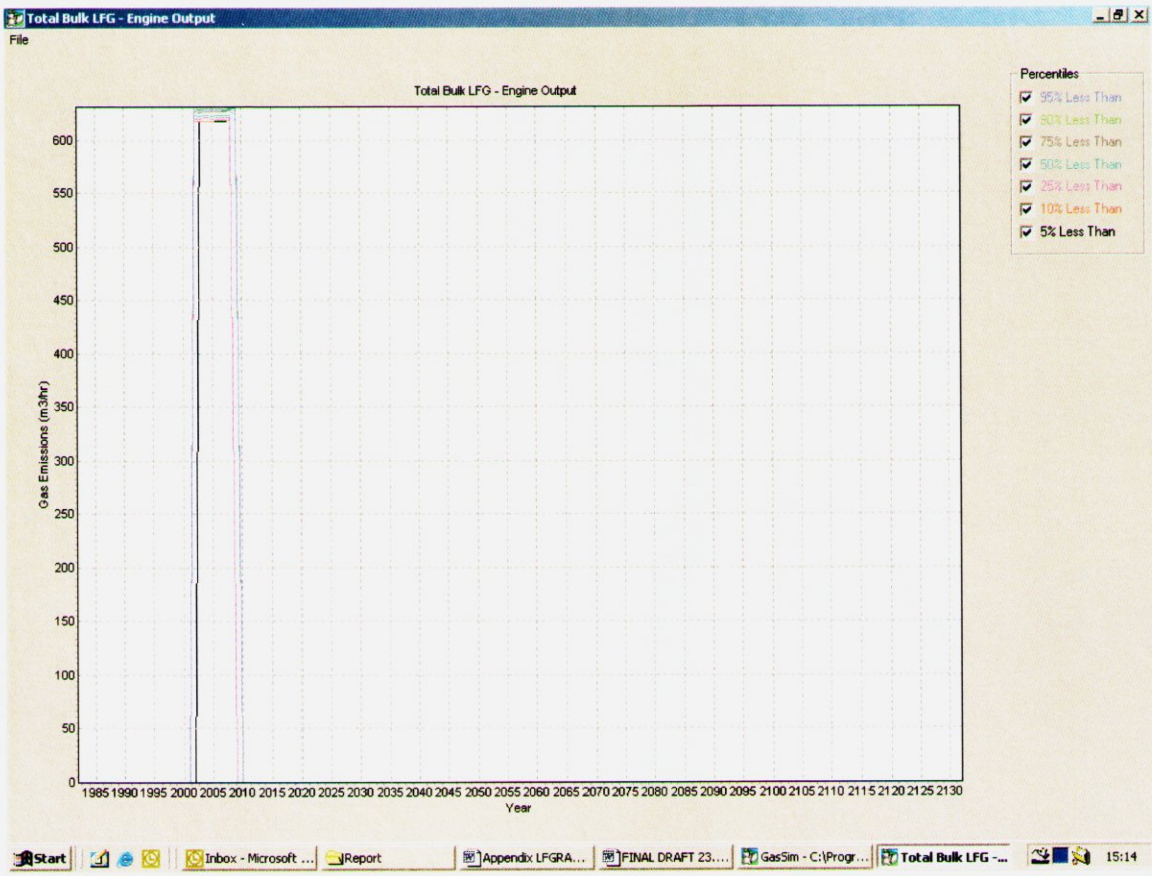
LFGRA APPENDIX 2

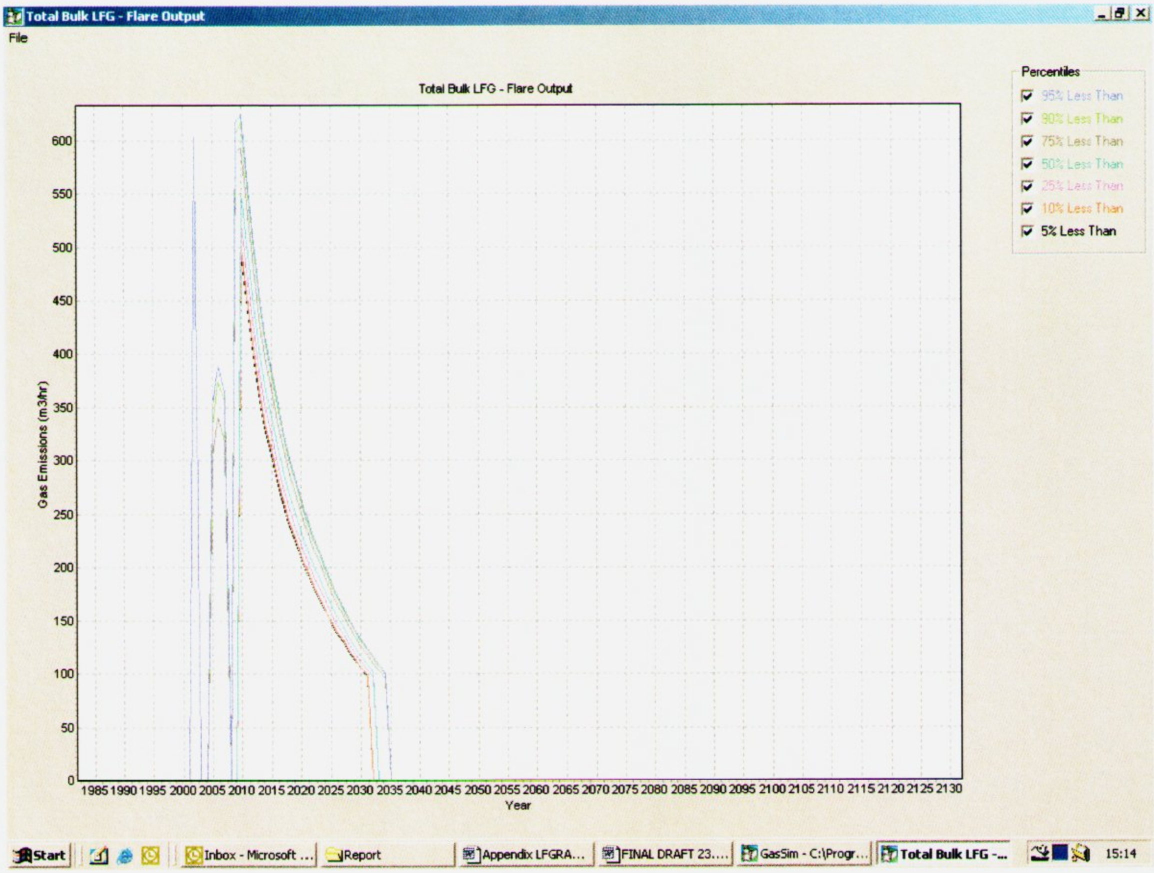
NANTYCAWS LANDFILL SITE: Waste Composition to 2010

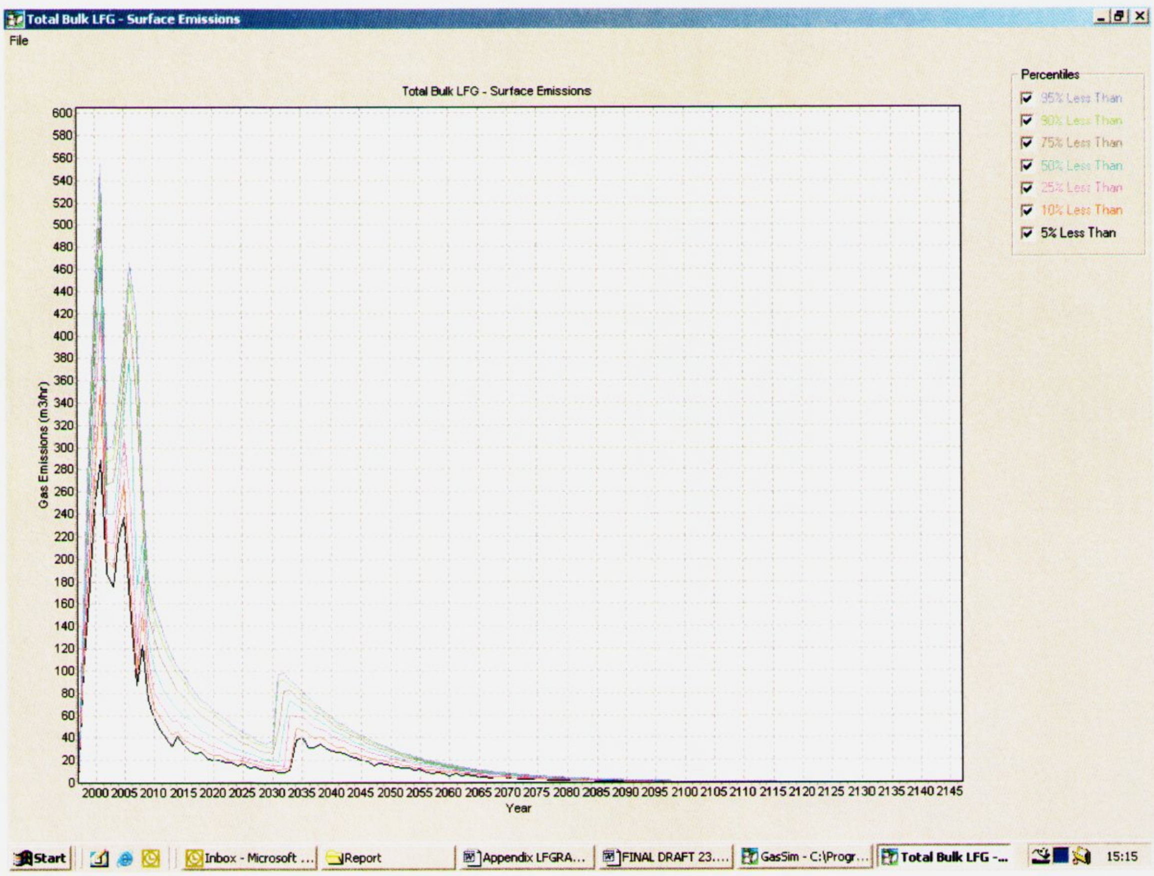
Waste Fraction		Domestic (%)	Civic Amenity (%)	Commercial (%)	Industrial (%)	Inert (%)	Liquid Inert (%)	Sewage Sludge (%)	Compost Org Material (%)	Incinerator Ash (%)	Waste sorted at MRF (%)	Recycling Schemes (%)	Chemical Sludges (%)	Industrial Liquid Waste	Water Content (%)	Cellulose (%)	Hemi-cellulose (%)	Decomposition (%)
Papers/Card	Newspaper	SINGLE(11.38)	SINGLE(10)	SINGLE(10)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(48.5)	SINGLE(9)	SINGLE(35)
	Magazines	SINGLE(4.67)	SINGLE(11)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(42.3)	SINGLE(9.4)	SINGLE(46)
	Other Paper	SINGLE(10.07)	single(0)	SINGLE(50.1)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(67.4)	SINGLE(8.4)	SINGLE(98)
	Liquid Cartons	SINGLE(0.51)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(57.3)	SINGLE(9.9)	SINGLE(64)
	Card packaging	SINGLE(3.84)	single(0)	single(0)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(57.3)	SINGLE(9.9)	SINGLE(64)
	Other Card	SINGLE(2.83)	single(0)	single(0)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	SINGLE(57.3)	SINGLE(9.9)	SINGLE(64)
Textiles	Textiles	SINGLE(2.36)	SINGLE(3)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(25)	SINGLE(20)	SINGLE(20)	SINGLE(50)
Miscellaneous combustibles	Disposable Nappies	SINGLE(4.35)	single(0)	single(0)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(20)	SINGLE(25)	SINGLE(25)	SINGLE(50)
	Other misc combustibles	SINGLE(3.6)	single(0)	single(0)	NORMAL (5.0, 1.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(20)	SINGLE(25)	SINGLE(25)	SINGLE(50)
Putrescible	Garden waste	SINGLE(2.41)	SINGLE(22)	single(0)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(65)	SINGLE(25.7)	SINGLE(13)	SINGLE(62)
	Other putrescibles	SINGLE(16.38)	single(0)	SINGLE(15)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(65)	SINGLE(55.4)	SINGLE(7.2)	SINGLE(76)
Fines	10mm fines	SINGLE(7.11)	SINGLE(15)	single(0)	NORMAL (10.0, 2.0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(40)	SINGLE(25)	SINGLE(25)	SINGLE(50)
Sewage Sludge	Sewage Sludge	*single(0)*	*single(0)*	*single(0)*	*NORMAL (5.0, 1.0)*	*single(0)*	*single(0)*	*SINGLE(100)*	*single(0)*	*single(0)*	*single(0)*	*single(0)*	*single(0)*	*single(0)*	SINGLE(70)	SINGLE(14)	SINGLE(14)	SINGLE(75)
	Composted organics	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(100)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	UNIFORM(7.47, 9.59)	UNIFORM(7.47, 9.59)	SINGLE(57)
	Incinerator ash	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	SINGLE(100)	single(0)	single(0)	single(0)	single(0)	SINGLE(30)	TRIANGULAR(0.5, 0.7, 1.5)	TRIANGULAR(0.5, 0.7, 1.5)	SINGLE(57)
Non-degradeable	Non-degradeable	SINGLE(28.86)	SINGLE(39)	SINGLE(24.6)	NORMAL (20.0, 4.0)	SINGLE(100)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)	single(0)

LFGRA APPENDIX 3

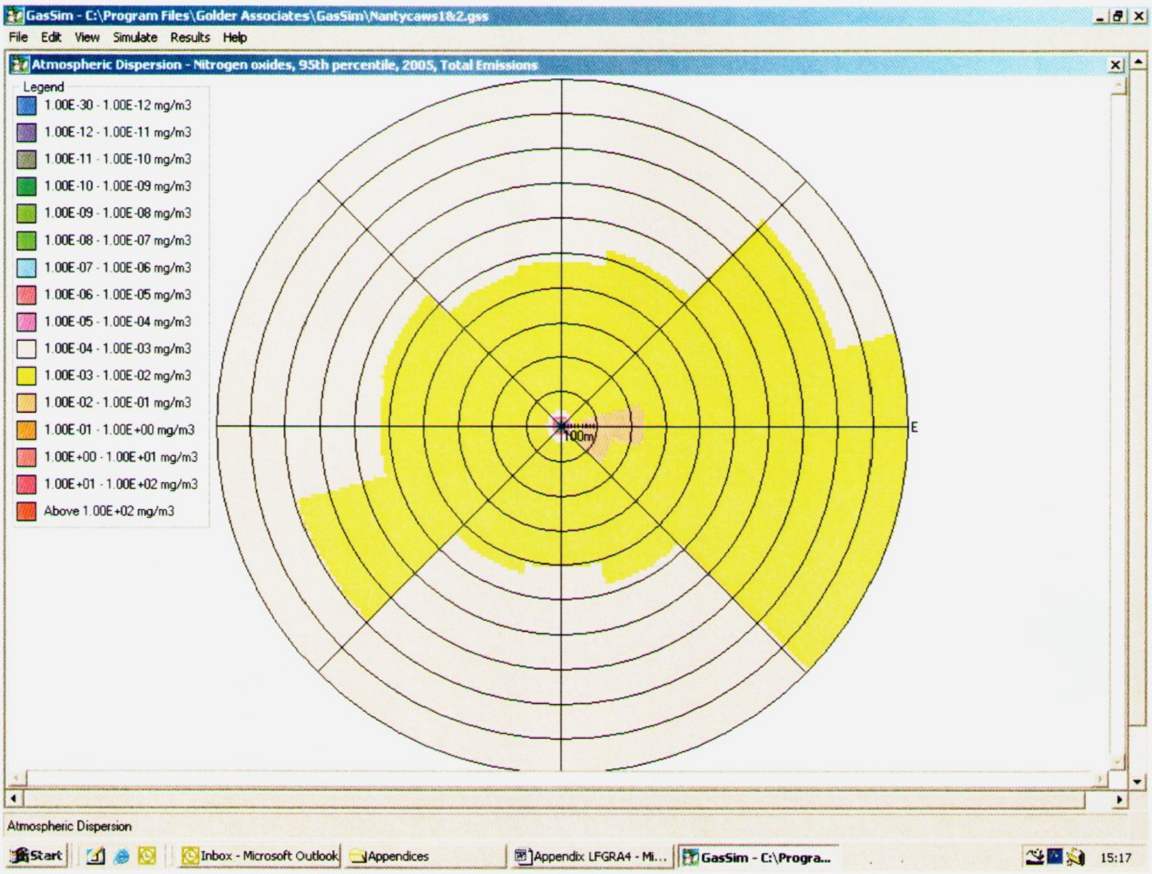

Total Bulk LFG Produced
File
Total LFG
Percentiles
95% Less Than
90% Less Than
75% Less Than
50% Less Than
25% Less Than
10% Less Than
5% Less Than
Gas Generated (m3/hr)
Year

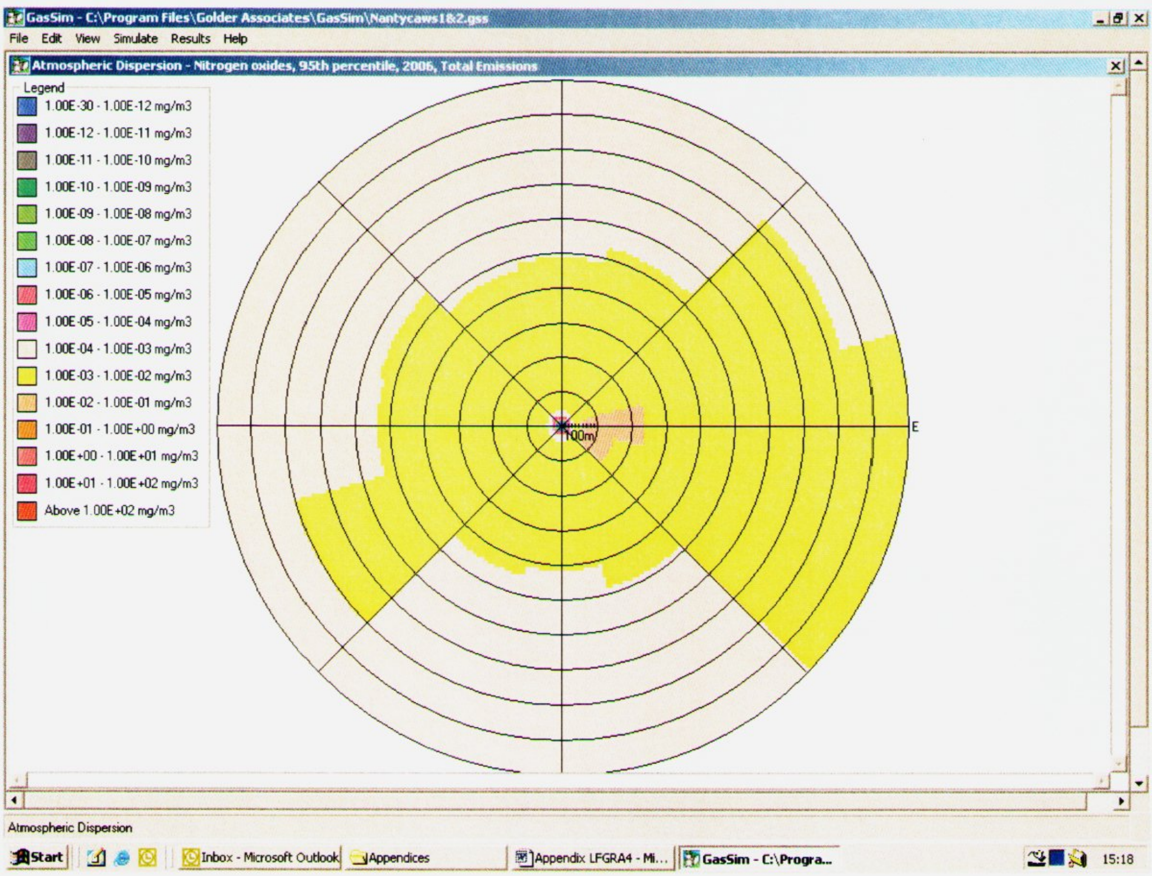

Total Bulk LFG - Engine Output
File
Total Bulk LFG - Engine Output
Percentiles
95% Less Than
90% Less Than
75% Less Than
50% Less Than
25% Less Than
10% Less Than
5% Less Than
Gas Emissions (m3/hr)
Year

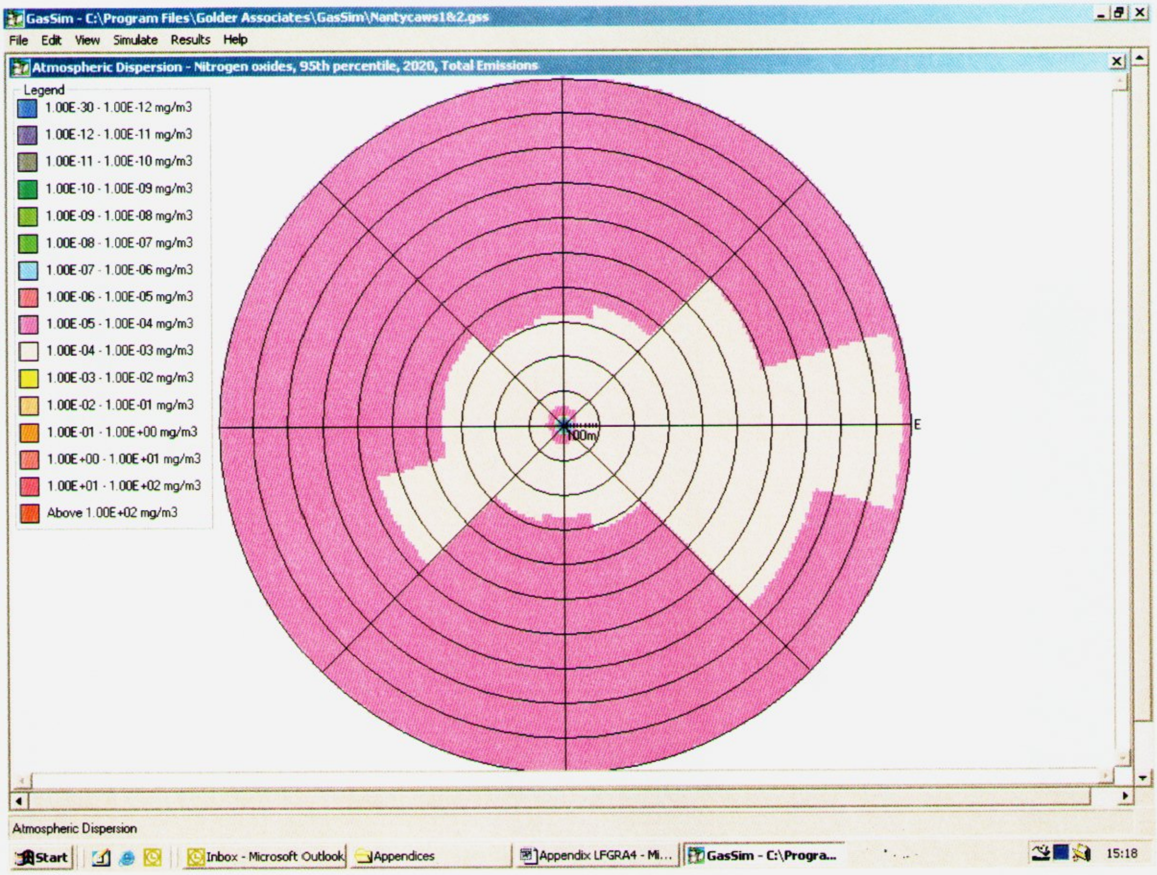

Total Bulk LFG - Flare Output
File
Total Bulk LFG - Flare Output
Percentiles
95% Less Than
90% Less Than
75% Less Than
50% Less Than
25% Less Than
10% Less Than
5% Less Than
Gas Emissions (m3/hr)
0
50
100
150
200
250
300
350
400
450
500
550
600
1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130
Year
Start
Inbox - Microsoft ...
Report
Appendix LFGRA...
FINAL DRAFT 23....
GasSim - C:\Progr...
Total Bulk LFG -...
15:14

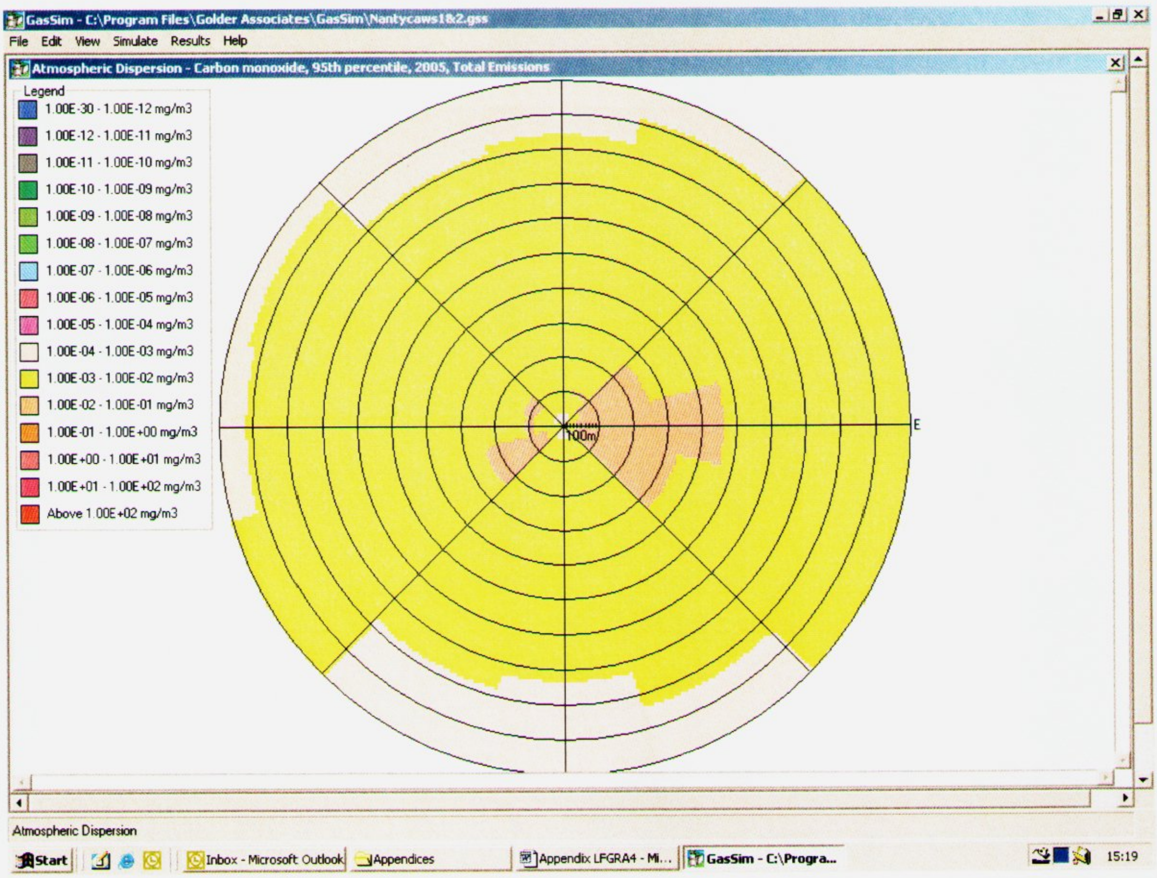

Total Bulk LFG - Surface Emissions
File
Total Bulk LFG - Surface Emissions
Percentiles
95% Less Than
90% Less Than
75% Less Than
50% Less Than
25% Less Than
10% Less Than
5% Less Than
Gas Emissions (m3/hr)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145
Year
Start
Inbox - Microsoft ...
Report
Appendix LFGRA...
FINAL DRAFT 23....
GasSim - C:\Progr...
Total Bulk LFG -...
15:15

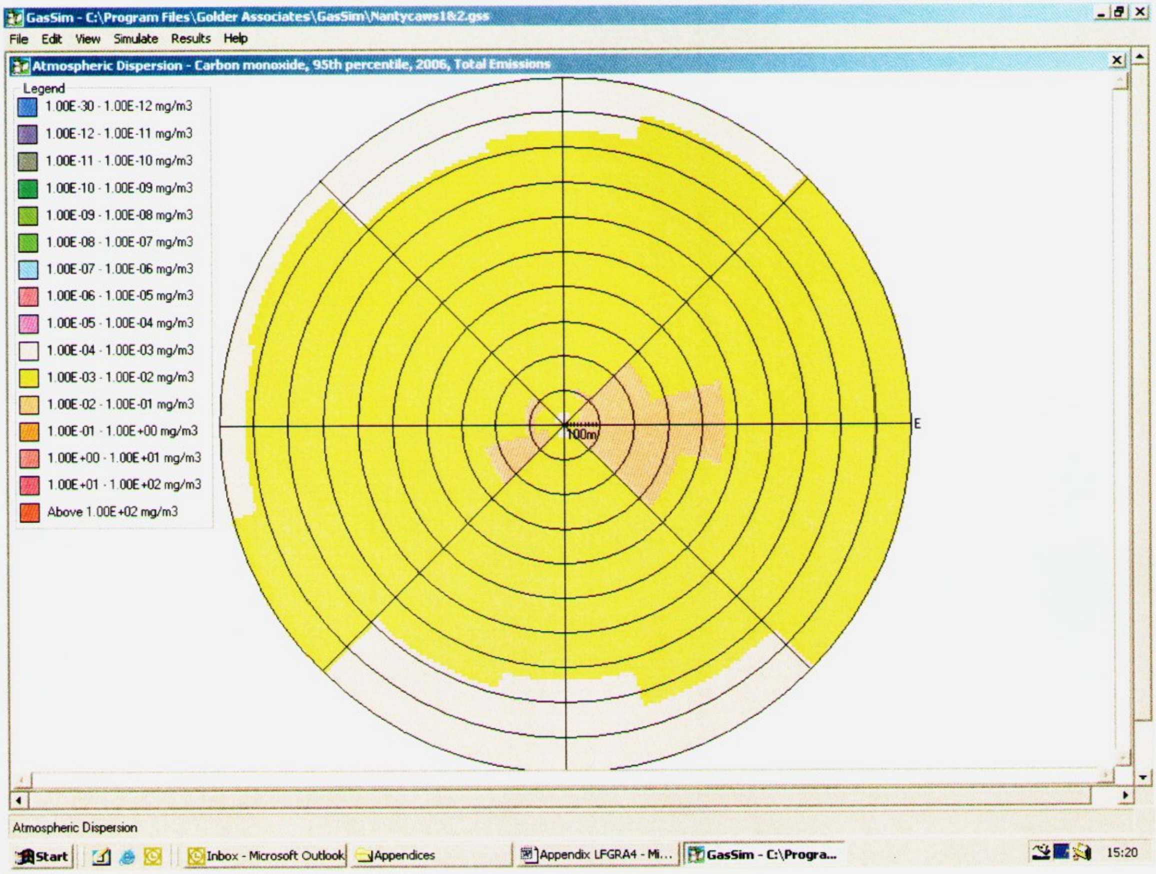
LFGRA APPENDIX 4

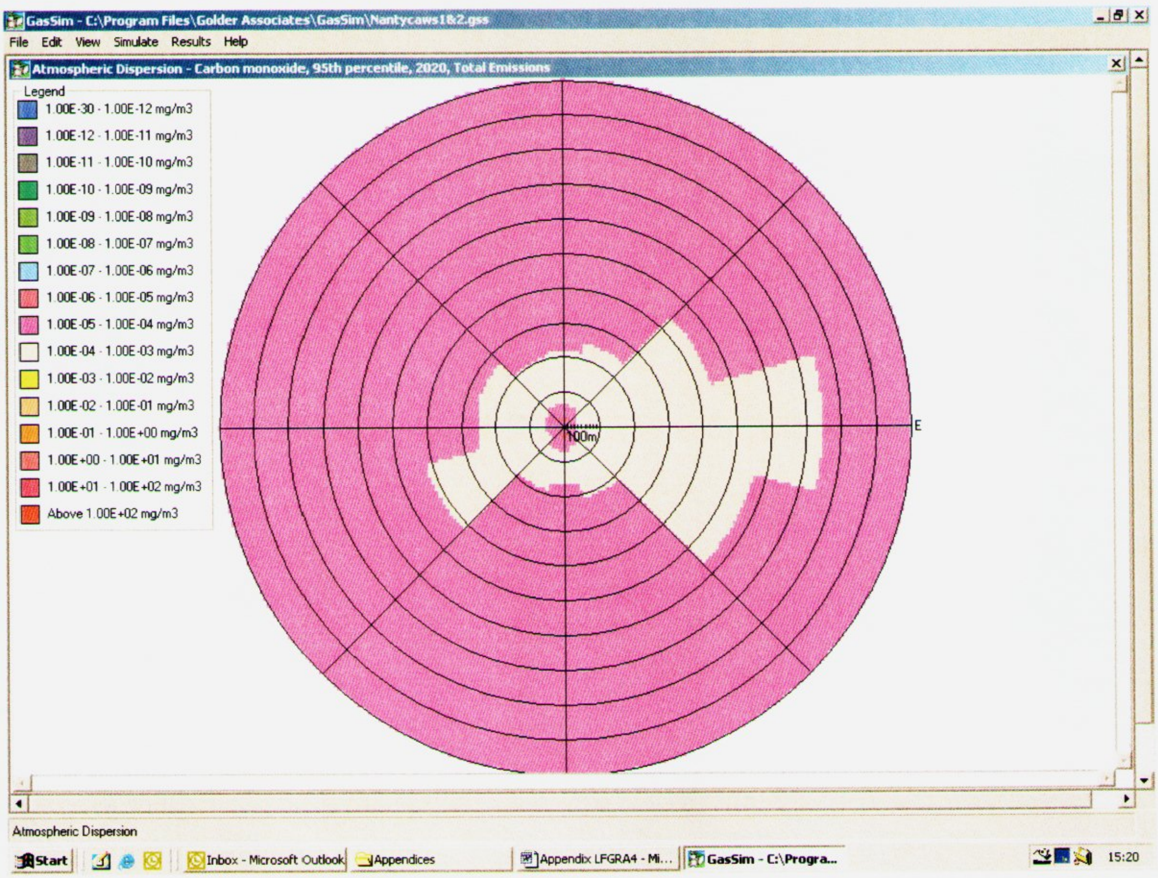

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Nitrogen oxides, 95th percentile, 2005, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:17

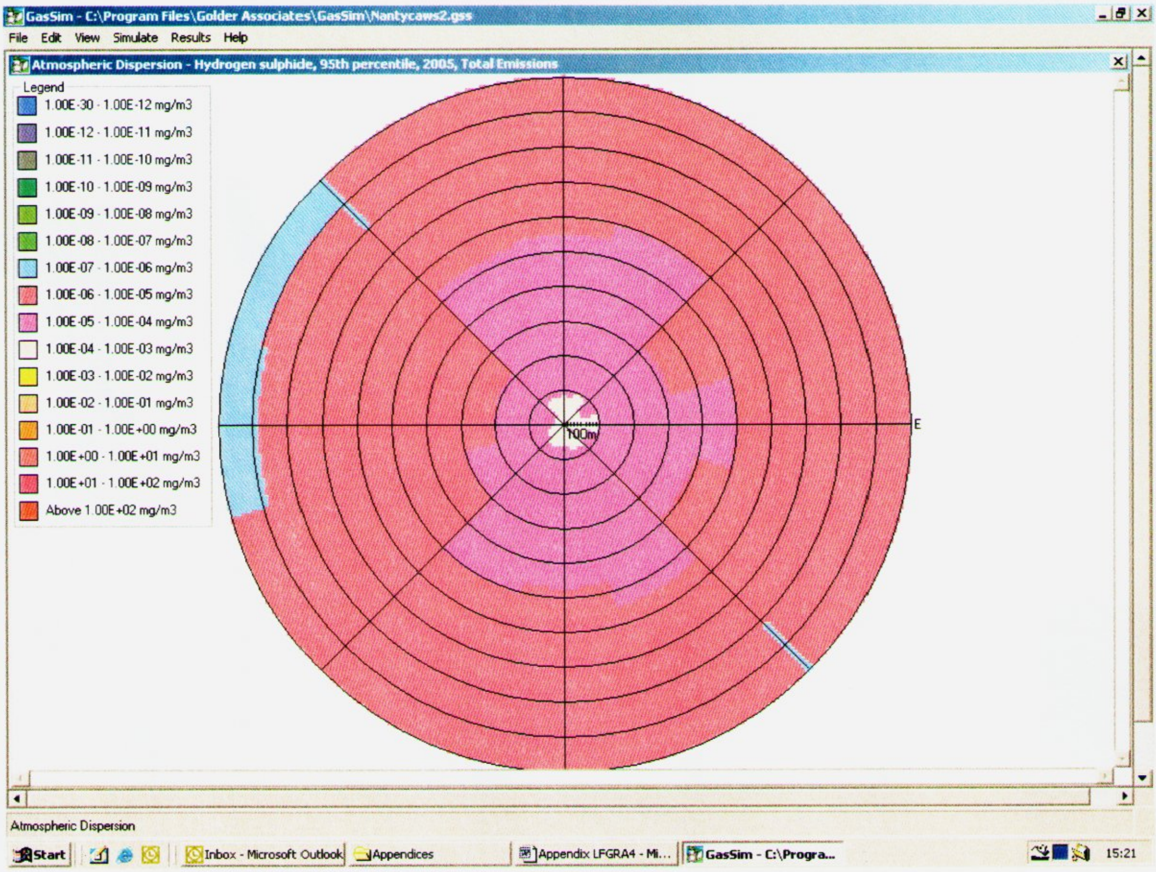

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Nitrogen oxides, 95th percentile, 2006, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:18

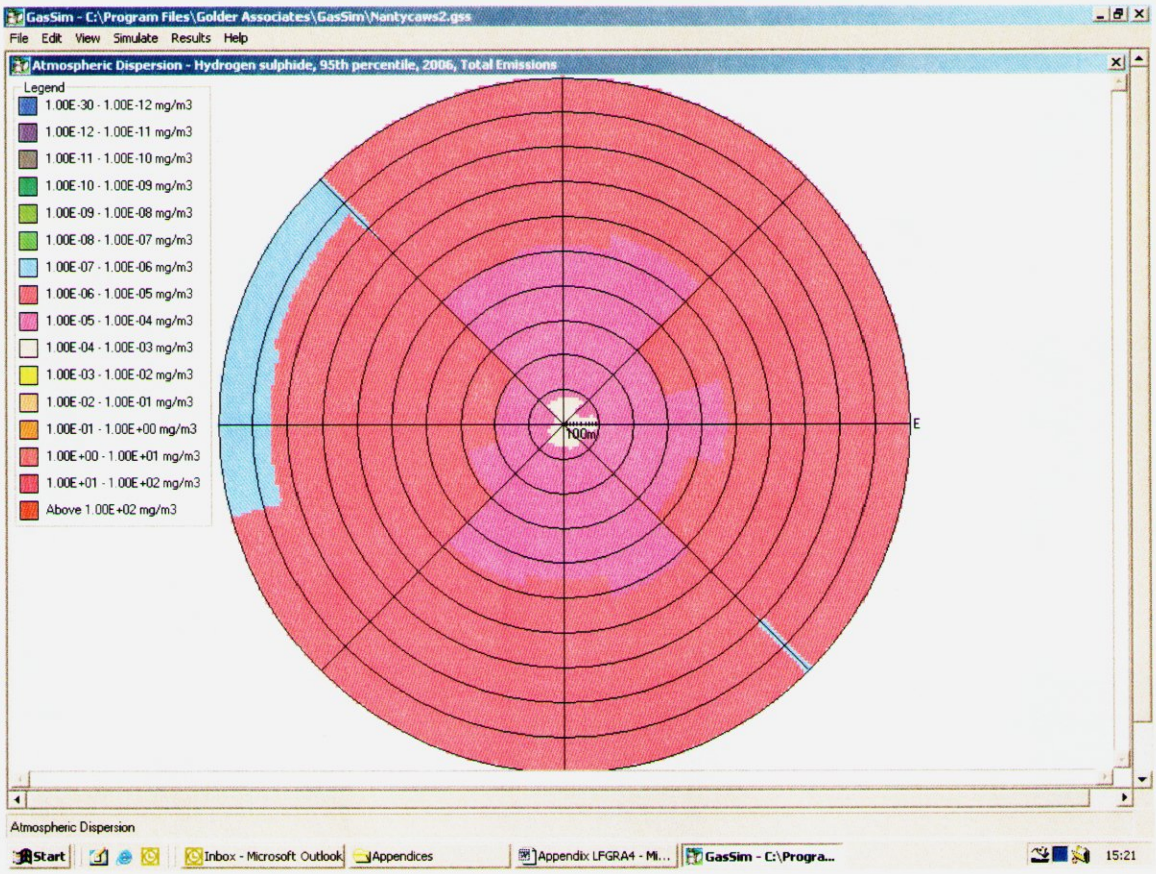

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Nitrogen oxides, 95th percentile, 2020, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:18

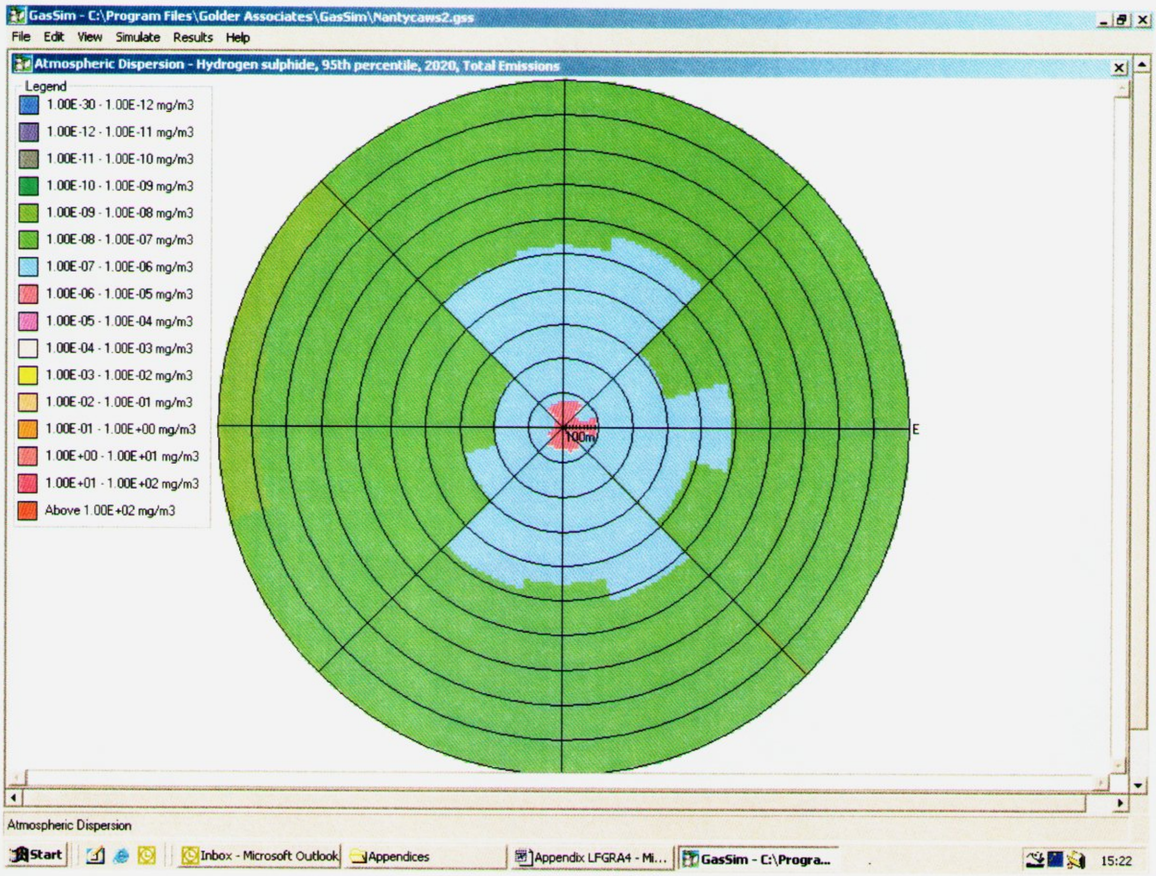

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Carbon monoxide, 95th percentile, 2005, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:19

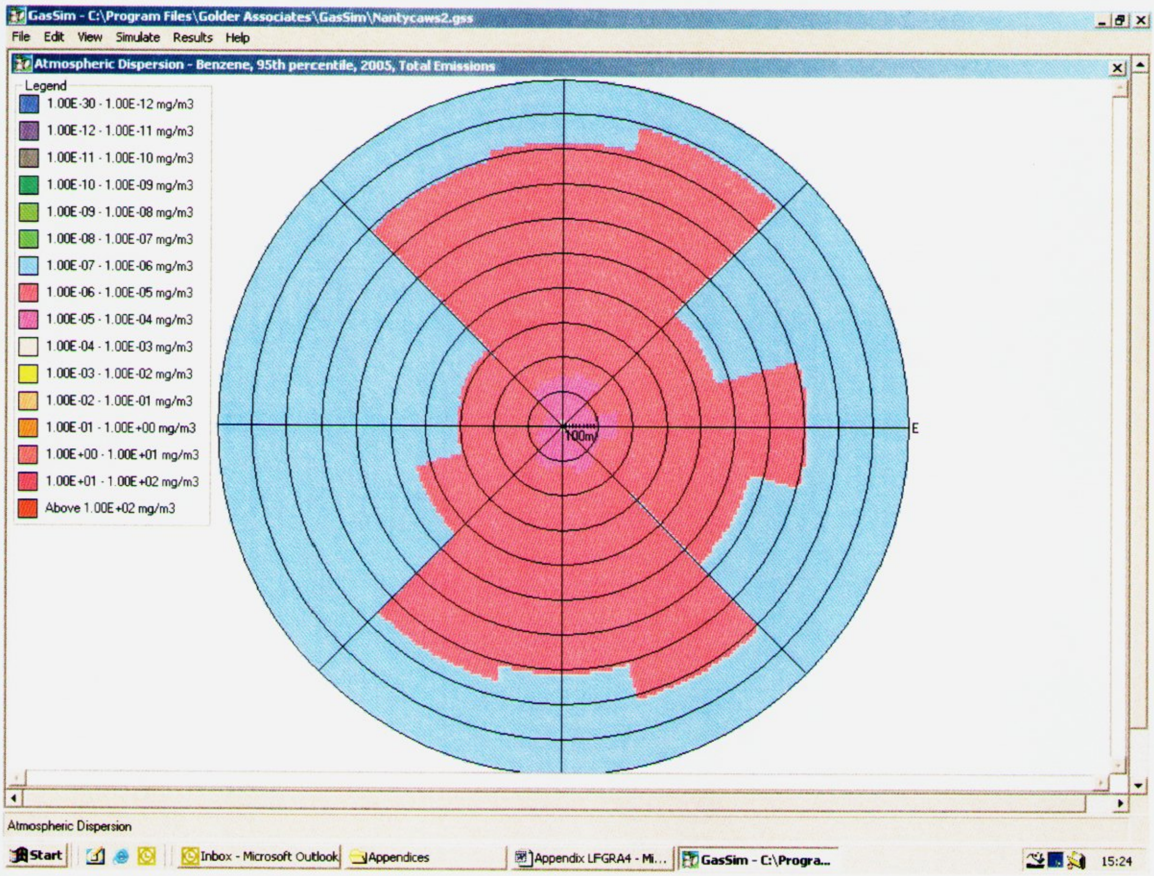

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Carbon monoxide, 95th percentile, 2006, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:20

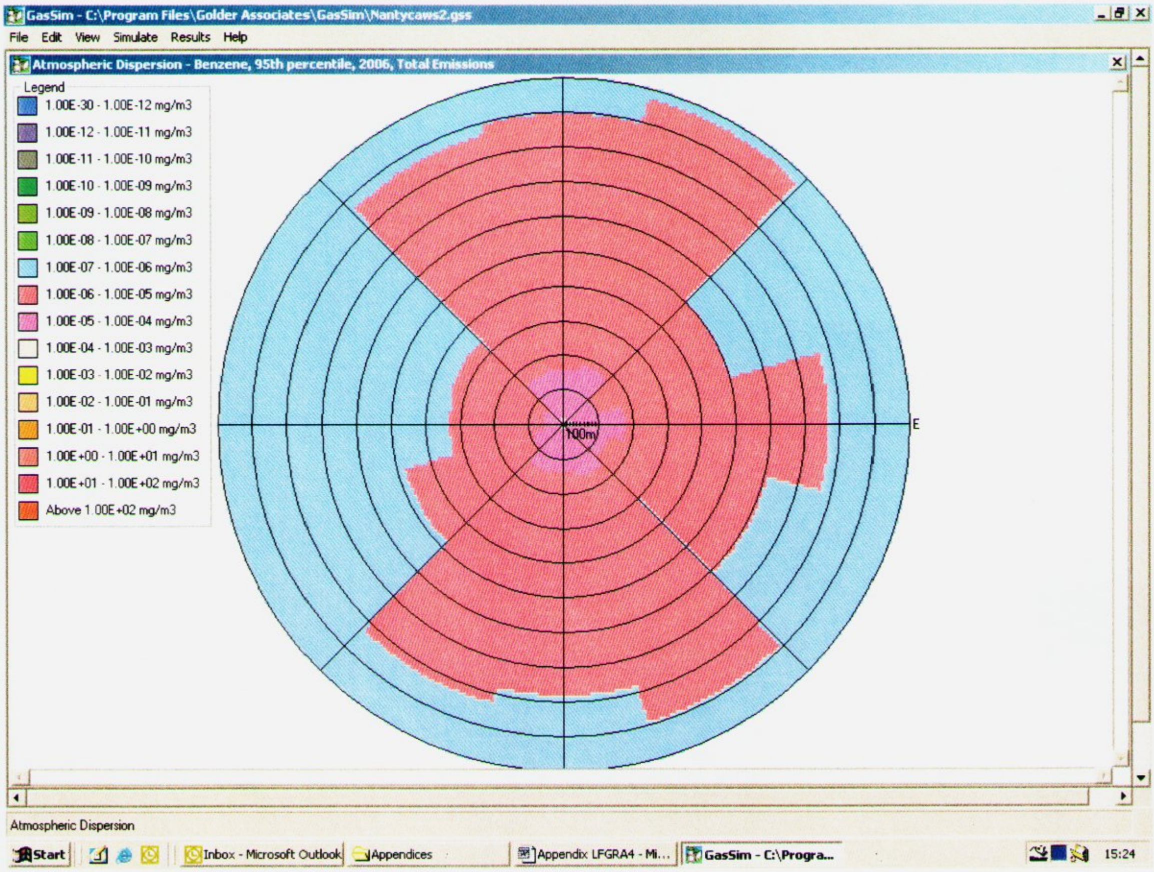

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws1&2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Carbon monoxide, 95th percentile, 2020, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:20

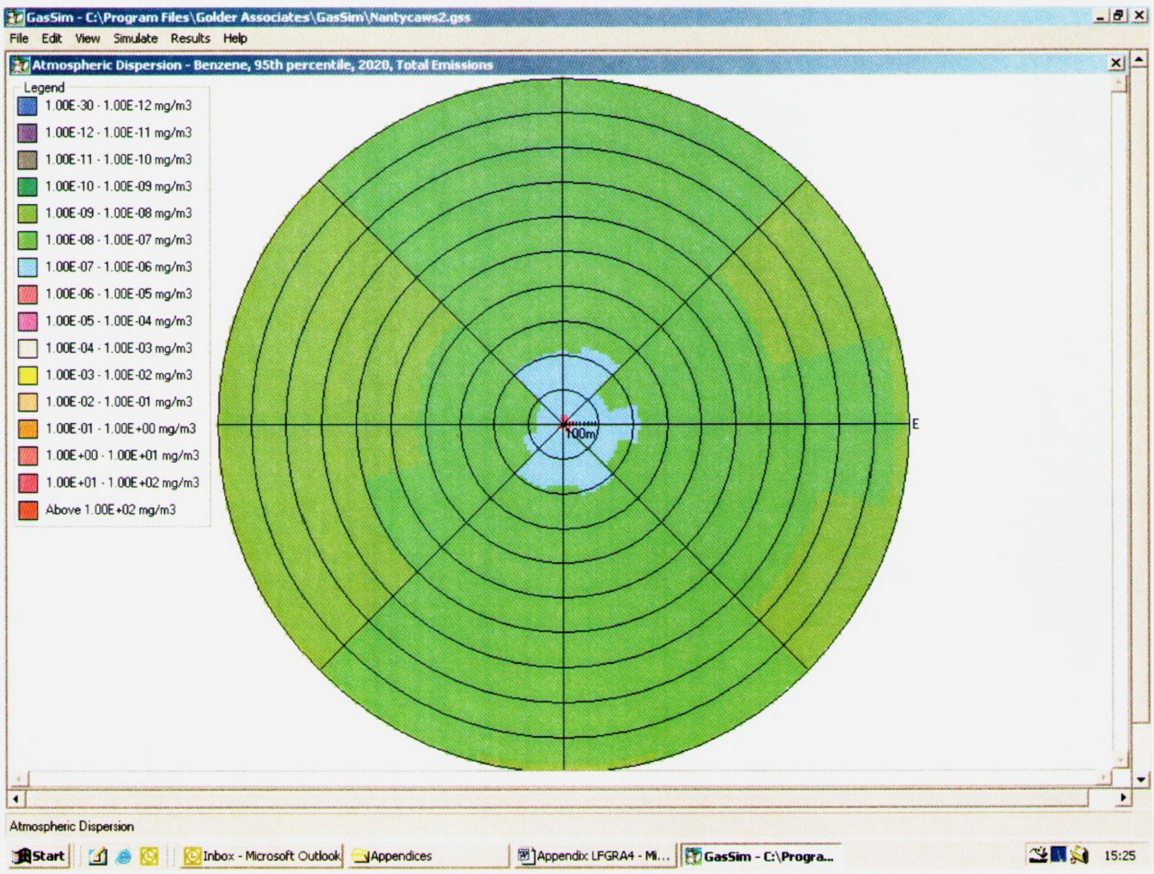

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
Atmospheric Dispersion - Hydrogen sulphide, 95th percentile, 2005, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
15:21


GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
Atmospheric Dispersion - Hydrogen sulphide, 95th percentile, 2006, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
15:21

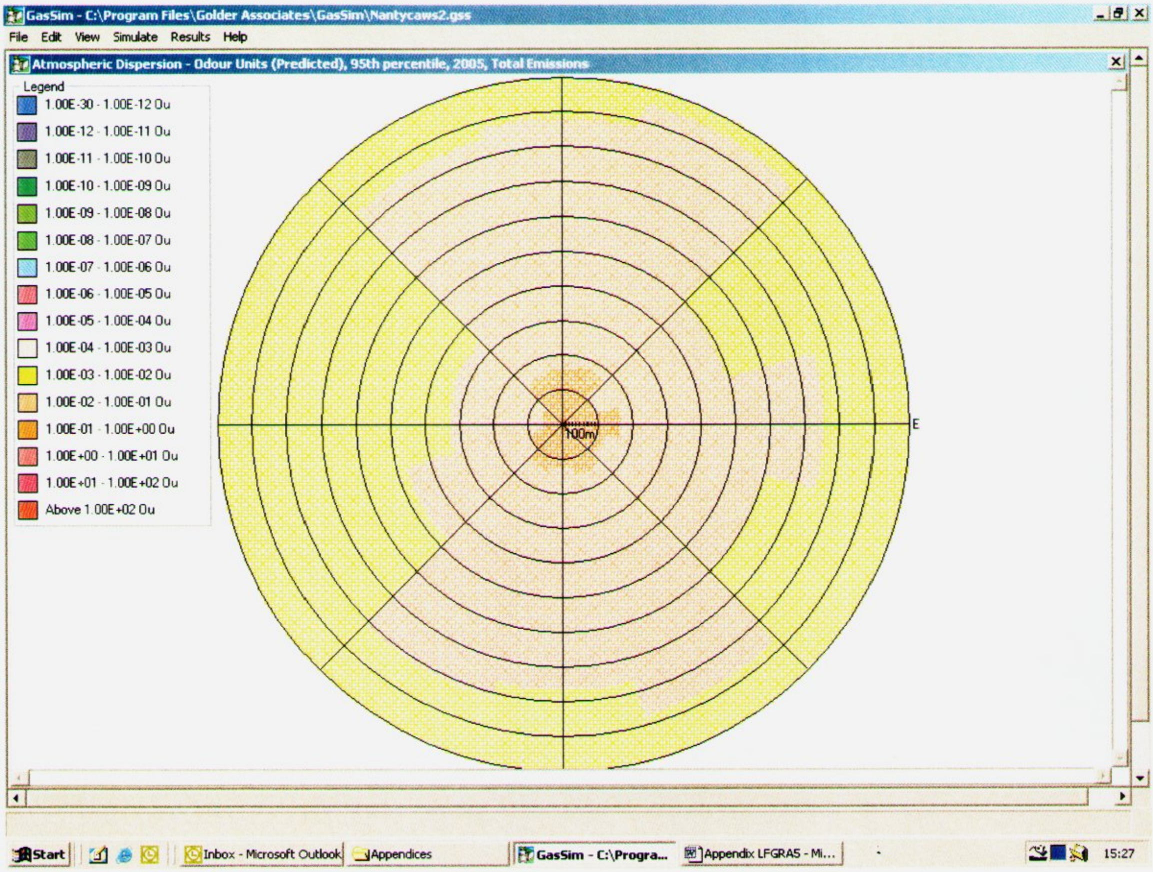

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Hydrogen sulphide, 95th percentile, 2020, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:22

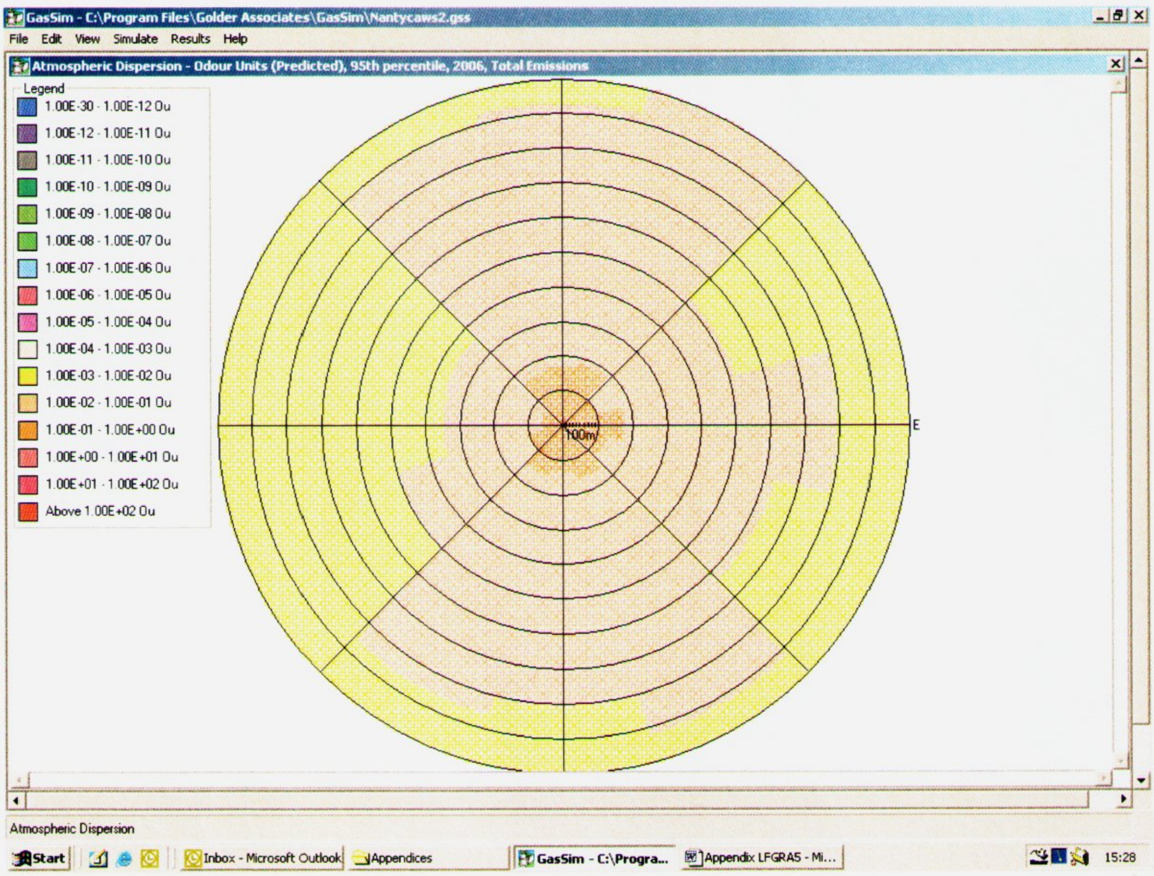

GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Benzene, 95th percentile, 2005, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:24


GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Benzene, 95th percentile, 2006, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:24


GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Benzene, 95th percentile, 2020, Total Emissions
Legend
1.00E-30 - 1.00E-12 mg/m3
1.00E-12 - 1.00E-11 mg/m3
1.00E-11 - 1.00E-10 mg/m3
1.00E-10 - 1.00E-09 mg/m3
1.00E-09 - 1.00E-08 mg/m3
1.00E-08 - 1.00E-07 mg/m3
1.00E-07 - 1.00E-06 mg/m3
1.00E-06 - 1.00E-05 mg/m3
1.00E-05 - 1.00E-04 mg/m3
1.00E-04 - 1.00E-03 mg/m3
1.00E-03 - 1.00E-02 mg/m3
1.00E-02 - 1.00E-01 mg/m3
1.00E-01 - 1.00E+00 mg/m3
1.00E+00 - 1.00E+01 mg/m3
1.00E+01 - 1.00E+02 mg/m3
Above 1.00E+02 mg/m3
100m
E
Atmospheric Dispersion
Start
Inbox - Microsoft Outlook
Appendices
Appendix LFGRA4 - Mi...
GasSim - C:\Progra...
15:25

LFGRA APPENDIX 5


GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Odour Units (Predicted), 95th percentile, 2005, Total Emissions
Legend
1.00E-30 - 1.00E-12 Ou
1.00E-12 - 1.00E-11 Ou
1.00E-11 - 1.00E-10 Ou
1.00E-10 - 1.00E-09 Ou
1.00E-09 - 1.00E-08 Ou
1.00E-08 - 1.00E-07 Ou
1.00E-07 - 1.00E-06 Ou
1.00E-06 - 1.00E-05 Ou
1.00E-05 - 1.00E-04 Ou
1.00E-04 - 1.00E-03 Ou
1.00E-03 - 1.00E-02 Ou
1.00E-02 - 1.00E-01 Ou
1.00E-01 - 1.00E+00 Ou
1.00E+00 - 1.00E+01 Ou
1.00E+01 - 1.00E+02 Ou
Above 1.00E+02 Ou
100m
E
Start
Inbox - Microsoft Outlook
Appendices
GasSim - C:\Progra...
Appendix LFGRA5 - Mi...
15:27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File Edit View Simulate Results Help
Atmospheric Dispersion - Odour Units (Predicted), 95th percentile, 2006, Total Emissions
Legend
1.00E-30 - 1.00E-12 Ou
1.00E-12 - 1.00E-11 Ou
1.00E-11 - 1.00E-10 Ou
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1.00E-08 - 1.00E-07 Ou
1.00E-07 - 1.00E-06 Ou
1.00E-06 - 1.00E-05 Ou
1.00E-05 - 1.00E-04 Ou
1.00E-04 - 1.00E-03 Ou
1.00E-03 - 1.00E-02 Ou
1.00E-02 - 1.00E-01 Ou
1.00E-01 - 1.00E+00 Ou
1.00E+00 - 1.00E+01 Ou
1.00E+01 - 1.00E+02 Ou
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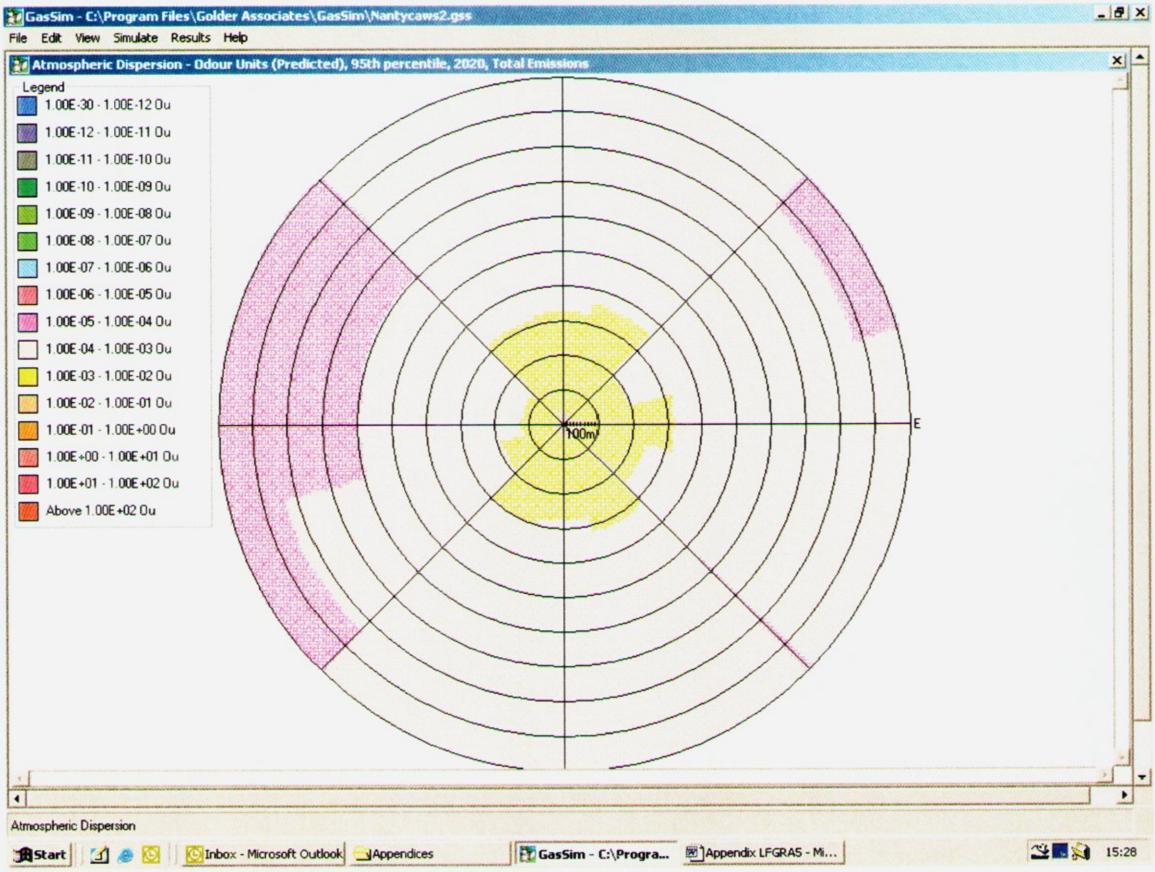
GasSim - C:\Program Files\Golder Associates\GasSim\Nantycaws2.gss
File Edit View Simulate Results Help
Atmospheric Dispersion - Odour Units (Predicted), 95th percentile, 2020, Total Emissions
Legend
1.00E-30 - 1.00E-12 Ou
1.00E-12 - 1.00E-11 Ou
1.00E-11 - 1.00E-10 Ou
1.00E-10 - 1.00E-09 Ou
1.00E-09 - 1.00E-08 Ou
1.00E-08 - 1.00E-07 Ou
1.00E-07 - 1.00E-06 Ou
1.00E-06 - 1.00E-05 Ou
1.00E-05 - 1.00E-04 Ou
1.00E-04 - 1.00E-03 Ou
1.00E-03 - 1.00E-02 Ou
1.00E-02 - 1.00E-01 Ou
1.00E-01 - 1.00E+00 Ou
1.00E+00 - 1.00E+01 Ou
1.00E+01 - 1.00E+02 Ou
Above 1.00E+02 Ou
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Appendices
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LFGRA APPENDIX 6

UNITED UTILITIES GREEN ENERGY LTD

LGRA A6

NANTYCAWS LANDFILL SITE
ELECTRICITY GENERATION PROJECT

OPERATIONAL PLAN FOR THE GAS COLLECTION, FLARING AND UTILISATION SCHEME

FEBRUARY 2002

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BEDFORD
MK42 9TW
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FAX: (01234) 271709

Operational Plan for the Gas Collection, Flaring and Utilisation Scheme

Operational Plan for the Gas Collection, Flaring and Utilisation Scheme

1.0 Brief Specification

1.1 Background

This brief specification outlines the permanent gas collection system installed at the Nantycaws Landfill Site. The system has been designed both to provide appropriate means for controlling gas migration from the site and to supply gas to a landfill gas fuelled electricity generating facility constructed at the site.

1.2 System Design

The system enables landfill gas to be abstracted from the restored/filled areas of the landfill at Nantycaws and consists of the following:

- Vertical gas wells.
- Wellhead on each well to provide monitoring facilities.
- Connecting pipe linking each gas well individually to a manifold.
- Manifolds to connect the gas wells to the gas main and provide further monitoring and control facilities.
- Gas mains to connect the manifolds to the gas compound.
- Condensate knockout pots to remove condensate from the mains.
- Gas abstraction and flaring plant

The above is installed so as to give complete control of the suction applied to each gas well by the monitoring and adjustment of valves at the manifolds. This enables the gas quantity and quality to be optimised for delivery to the generator and to give full migration control across the site. A plan of the current system layout has been attached.

1.2.1 Gas Wells

A number of new vertical gas wells have been installed across the Site at typically 40 - 70 metre intervals. These gas wells are constructed for permanent operation and are constructed using a proprietary MDPE or polypropylene-based well screen. The well casing is of varying diameters, but is to at least SDR 11 rated to minimise damage from the settlement of the landfill.

Gas wells are drilled to a depth of typically 10 – 20 metres. The depth is at least 1 metre short of the anticipated base of the site, an accurate level and location of well was surveyed prior to drilling to accurately determine the drilling depth. The wells were drilled to a diameter of 300mm or greater where a rotary barrel auger technique, or 350mm where flight auger has been used.

The annulus of the gas well was filled with a washed, non-calcareous, gravel pack of 20 to 40mm to a depth of one metre above the top of the slotted well case.

The gas well annulus is sealed with a minimum of 3 metres of bentonite or a chemical sealant such as polyurethane foam.

<u>Operational Plan for the Gas Collection, Flaring and Utilisation Scheme</u>

1.2.2 Gas Wellheads

Connection to the gas wells are made via pre-fabricated wellheads, the wellheads are based around a black MDPE 90° bends or black MDPE equal tees and include gas monitoring and leachate dipping points.

The wellhead fit inside the well casings and a flex-seal coupling and supporting ring fits externally to provide a gas tight seal and prevent the ingress of debris.

The wellhead allows for the movement of the gas well in relation to the waste in both the horizontal and vertical directions with a flexible hose connection to the outgoing connecting pipework.

Gas wellhead chambers shall be installed within the capping layers upon final restoration to provide protection for the wellheads and allow for the wellheads and pipework to be below ground level.

1.2.3 Connecting Pipework

The connecting pipework connects each well individually to a manifold and is constructed from black MDPE pipework and is joined using electrofusion couplers. This permits all routine monitoring and control to be carried out from the manifolds.

All connecting pipework is laid to maximise the fall to the manifolds. Ideally falls should be 1:25 or greater.

The connecting pipework is currently a mixture of surface laid, deep and shallow buried depending on the current state of the capping across the site. Surface or shallow buried pipes shall be systematically disconnected prior to the capping works and remain disconnected during the capping operation. Once the capping operation has been completed in an area the lines will be reconnected and buried within the restoration soils directly above the engineered cap.

1.2.4 Manifolds

A number of manifolds are fabricated from black MDPE pipe with a single valved outlet for connection to the gas main and a blank end flange. The manifold includes valved inlets for each gas well connecting pipe. Isolating and control valves and gas sampling points are provided for each incoming gas line.

The outlet of all the manifolds comprise a single MDPE pipe and be fitted with a butterfly type valve and gas sampling points for isolation and control. The manifolds are connected to the gas main black MDPE pipework.

Initially the manifolds are installed on a bed of clean stone on the surface of the landfill within the uncapped area. These shall be systematically disconnected prior to the capping works and remain disconnected during the capping operation. Once the capping operation has been completed in a specific area any manifolds occupying these areas will be reconnected. The manifolds shall then be buried within the restoration soils on a concrete raft directly above the engineered cap.

A blockwork chamber shall be constructed around the manifold within the restoration layers to provide protection from the weather and vandalism. The chamber lid design will prevent the ingress of water and enable the chamber to be locked.

1.2.5 Gas Main

Gas mains are constructed from black MDPE pipework and joined using electrofusion or fully automatic butt welding techniques. The gas mains connect the manifolds to the gas abstraction plant.

The gas mains is laid to fall to no less than 1:50 towards condensate knockout pots installed at predetermined low points.

Where possible the gas mains are installed off the landfill within virgin ground. Where this is not possible the gas mains are installed either within the restoration material in the already capped area or surface laid across the uncapped area.

1.2.6 Condensate knockout pots

Either pumped condensate knockout pots or condensate dewatering legs have been installed within the gas main to enable the removal of condensate (the water released by the saturated landfill gas as it cools) They aid the removal of liquid by altering the gas stream's velocity and/or direction.

In the case of the pumped knockout pot the liquid will gather within the unit until it reaches a predefined level where it shall be removed using either compressed air or electrical operated pumps. The condensate will be returned to the landfill via a purposely installed sump.

In the case of the condensate dewatering leg the liquid will gather within the unit and gradually decant back into the waste.

A water and vandalism proof chamber is installed around the knockout pots for protection.

1.2.7 Gas Plant

The gas plant consists of fans, valves, controls, instrumentation, a flare and pipework, capable of supplying gas at a constant pressure to the generating facility. The plant is located within the generation compound

The gas plant and flare are capable of automatic operation with gas abstracted from the site at the optimum rate, commensurate with providing full environmental control, and supply to the generator(s) with surplus spilt to the flare.

Operational Plan for the Gas Collection, Flaring and Utilisation Scheme

2.0 Quality Control

2.1 Design and Standardisation

The Works shall be designed to a high standard and to facilitate inspection, cleaning and repair to ensure continuity of satisfactory operation under all working conditions for a period of at least fifteen years and be subject to an approved CQA plan (attached).

All plant and apparatus supplied shall be of a make, type, design, material and construction approved by the Engineer and, unless specified to the contrary, shall comply with the most recent applicable British Standard or other equivalent approved National or International Standards.

2.2 Drilling Logs

The Contractor will be expected to complete a drilling log for each well detailing the nature of the waste / material drilled through, the presence of any leachate levels (perched or otherwise), the depth to base and top of the stone annulus and top of the slotted well casing.

2.3 MDPE Pipe Jointing

2.3.1 Butt Fusion

All pipes shall be joined using electrofusion or butt welding techniques and equipment except where specified otherwise. Hand welded joints will not be accepted.

Where butt-welding is used, a fully automatic machine shall be used, the machine shall be capable of recording and storing weld specific parameters such as heater temperature, bead pressure, heat soak time, fusion pressure and actual and target cooling times. It shall also record the date, time, operator and joint number. This information shall also be written on the pipe adjacent to each joint with a permanent market type pen.

If a fully automatic jointing cycle fails, the failed joint shall, where possible, be cut out, numbered and retained, and the joint repeated. The Contractor shall complete a written log of all failed or dummy joints and the action taken, e.g. removed, retrimmed etc

2.3.2 Electro-fusion

Where electrofusion couplers are used, the pipe shall be first mounted in the appropriate clamps to prevent pipe movement during the jointing cycle. Only fully automatic electrofusion machines shall be used. The fusion machines shall be capable of recording and storing weld specific parameters such as target and actual fusion times together with the date, time, operator and joint number.

The Contractor shall keep a log of all electro-fused joints. This shall provide details on the type of fitting or coupler used, whether the pipe was clamped and scraped, and the target and actual fusion and cooling times together with the operator's name. This information shall also be written on the pipe adjacent to each joint with a permanent market type pen

If for any reason an electro-fusion joint fails or does not achieve the target fusion time, the joint shall be cut out, numbered and retained and the joint repeated.

All butt fused and electrofused joints shall be permanently labelled with a unique number. Records of the locations of these joints shall be kept and submitted with an as-built drawing after project completion.

The above procedures form part of the Purchaser's Quality Assurance measures and must be adhered to. Any joints not performed in the manner described above, without first consulting the Engineer, will be rejected and shall be repeated at the Contractor's expense.

2.4 Pressure Testing

All fabricated MDPE components must be factory tested to 1 bar gauge and supplied to Site with a pressure certificate manufacture number.

2.5 Commissioning

The method and programme for commissioning of the Works shall be agreed between the Contractor and the Engineer before the Works begin. It shall include pressure testing to 1 bar on the gas main from the gas plant to the inlet valves from each well at the manifolds and shall include the pumped knockout pot. The system downstream of the wellhead valves and upstream of the fan, including the knockout pot, shall also be leak tested under vacuum at the maximum working suction under "no-flow" conditions. The Compressed air main and leachate discharge pipework shall be pressure tested to 10 bar from the gas plant to each termination point.

The Contractor shall be responsible for the removal, transport, repair or replacement of any defective items during the commissioning period.

2.6 Health and Safety

The Contractor shall ensure that proper safety controls and responsibilities are in place prior to commencing work on the Site. All workers employed by the Contractor shall be properly trained and supervised in all safety matters and suitably equipped. In particular the Contractor and all persons employed by the Contractor should be aware of the specific site safety

requirements.

The Contractor shall comply with the Construction (Design and Management) Regulations. The Contractor will be required to prepare and develop a Health and Safety Plan prior to starting work on Site. The Contractor must supply the Purchaser with a copy of their Health and Safety Policy prior to commencement of work. The Purchaser retains the right to impose their Health and Safety terms and conditions on the Contractor.

2.7 As Built Drawings

The Contractor will be required to carry out a proper survey of the completed scheme. All pipeline routes, gas wells and other fabrications should be located and levelled. All joint locations shall be marked on the plan.

The survey shall be carried out to an accuracy approved by the Engineer and, where possible, shall be referenced to the site grid and datum.

3.0 Operation and Servicing

3.1 Gas Utilisation

Whilst the site has an operational landfill gas electricity generation scheme, the gas extracted from the site will be utilised within the generator as fuel. It is intended that the generator shall use the gas for a minimum of 92% of the year the remaining time the flare will be operational. This downtime is set aside for servicing of the engine.

3.2 Gas Plant

The gas plant will remain operational for no less than 99% of the year with 1% downtime set aside for servicing. The gas plant is serviced no less than once every six months. In the case of a fault, if the gas plant is to be unoperational for more than 24hrs a temporary flare will be brought to site to restore migration control to the site.

During normal operation, gas plant manual checks shall be made on a weekly basis. These checks shall incorporate but not be limited to the following:

- Pressure drop across all filters to check for blockages
- Pressure drop across all flame arrestors to check for blockages
- Check flow rates, temperatures and suction pressures
- If running – check temperature of flame
- Aural check for booster health and operation
- Condensate drains should be emptied

3.3 Gas Collection System

During normal operation readings shall be taken and adjustments made to the gas collection system on a weekly basis. The readings taken will be as follows:

- CH_4
- CO_2
- O_2
- Suction pressure (mb)
- Valve positions
- Flow readings (gas plant only)

These readings shall be compared to the previous set of readings, gas extraction will therefore be optimised weekly. These readings will also be correlated against migration monitoring results, any migration will then be controlled by careful adjustment of the gas collection system immediately. At all times care will be taken to optimise the amount of suction on a well, at no time will suction be applied such as to reduce the gas quality below 40% methane. This operation will reduce the possibility of underground 'tip fires'. Where adjustments have been made to control gas migration from the site, further readings shall be taken from the off site migration wells the following day to assess the effectiveness of the adjustments made.

WEEKLY SITE RECORD

DETAILS

SITE	*Nantycaws Generation Project*	DATE	
ENGINEER	*George Augood*	TIME	

GAS FIELD

		CH_4	CO_2	O_2	-mb	Valve	Comments/Adjustments
Flare	Before						
	After						
M1	Before						
	After						
M2	Before						
	After						
M3	Before						
	After						
M4	Before						
	After						

FLARE

Inlet	P mBar	
Outlet	P mBar	
Temp	^oC	
Set Filter	Flow	
	^P	

WELL PUMPS

PUMPS	CNT	TIME
2/1		
2/3		
2/4		
2/9		
3/3		
3/6		

	HOURS RUN	SERVICE DUE (HRS)
Fan		
KOP Pump		
Compressor		

FIELD KOP	*CNT*	*HRS*

COMMENTS