Code of Practice Environmental Risk Assessment for Unregulated Waste Disposal Sites

CLONAKILTY
TIER II SITE INVESTIGATION REPORT

Landfill Site:	**Clonakilty**
Site Reference:	**02/W**
Division:	**West Cork**
Area Office:	**Clonakilty**

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Cork County Council
January 2011

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Consultants
April 2010

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1.0 SITE SUMMARY

Cork County Councils Environment Directorate completed a Tier I report and risk assessment on Clonakilty Landfill in September 2007. The Tier I assessment was completed in accordance with the EPA CODE OF PRACTICE Environmental Risk Assessment for Unregulated Waste Disposal Sites. The Tier I Report showed Clountreem Landfill to be a **"High Risk"** site (see Appendix 1).

A Tier II Exploratory Investigation was organised for this site in October 2009. The purpose of the Exploratory Investigation was to confirm the initial conceptual site model (CSM) prior to the designing of the Main Investigation programme (in accordance with 5.3.2 of the Code of Practice). Following the Exploratory investigation a main investigation was designed and completed in accordance with the EPA Matrix (see Appendix 2) in November 2009.

2.0 SITE INTRODUCTION

Clonakilty Landfill is located approximately 500m South East of the centre of Clonakilty town (300m off the N71 on the coast road to Inchadonny Island). This landfill covers an area of approximately 4 Ha.

Location of Clonakilty Landfill

2.1 Surrounding Land Use

The landfill is on the immediate outskirts of Clonakilty Town and adjacent to Clonakilty Bay. The land to the west of the site is a GAA grounds but has been sold and is currently being developed (into shops and apartments). Clonakilty Sewage Treatment Plant is located over Area B and there is a tourist attraction called the "Model Railway Village" located over area C (see above photo for locations). There is Agricultural Land to the south west of the landfill.

2.2 Site History

This site has been used for waste disposal unofficially since the 50's. The site had been operated officially by the council since the early 70's after a 99 year leasehold on the foreshore was granted by the Department of Transport and Power[1]. Waste was placed on the foreshore and was gradually extended out over the years. The landfill site closed on the 26th February 1999.

2.3 Tier I SPR Linkage Score

The table below shows the Tier I linkage scores for Clonakilty.

Calculator	SPR Values	Maximum Score	Linkages	Normalised Score
SPR 1 =	105	300	Leachate => surface water	35%
SPR 2 =	105	300	Leachate => SWDTE	35%
SPR 3 =	63	240	Leachate => human presence	26%
SPR 4 =	63	240	Leachate => GWDTE	26%
SPR 5 =	63	400	Leachate => Aquifer	16%
SPR 6 =	0	560	Leachate => Surface Water	0%
SPR 7 =	63	240	Leachate => SWDTE	26%
SPR 8 =	42	60	Leachate => Surface Water	70%
SPR 9 =	42	60	Leachate => SWDTE	70%
SPR 10 =	105	150	Landfill Gas => Human Presence	70%
SPR 11 =	175	250	Landfill Gas => Human Presence	70%

Table 2.1: Tier I Source Pathway Receptor Linkage Scores

The Tier I linkages of concern are SPR 8 Leachate to Surface water, SPR 9 Leachate to the adjacent Surface Water Dependent Terrestrial Ecosystem and SPR 10 & 11 Landfill Gas risk to the buildings on the site.

2.4 Tier I Conceptual Site Model

The diagram below shows the Tier I Conceptual Site Model for Clountreem.

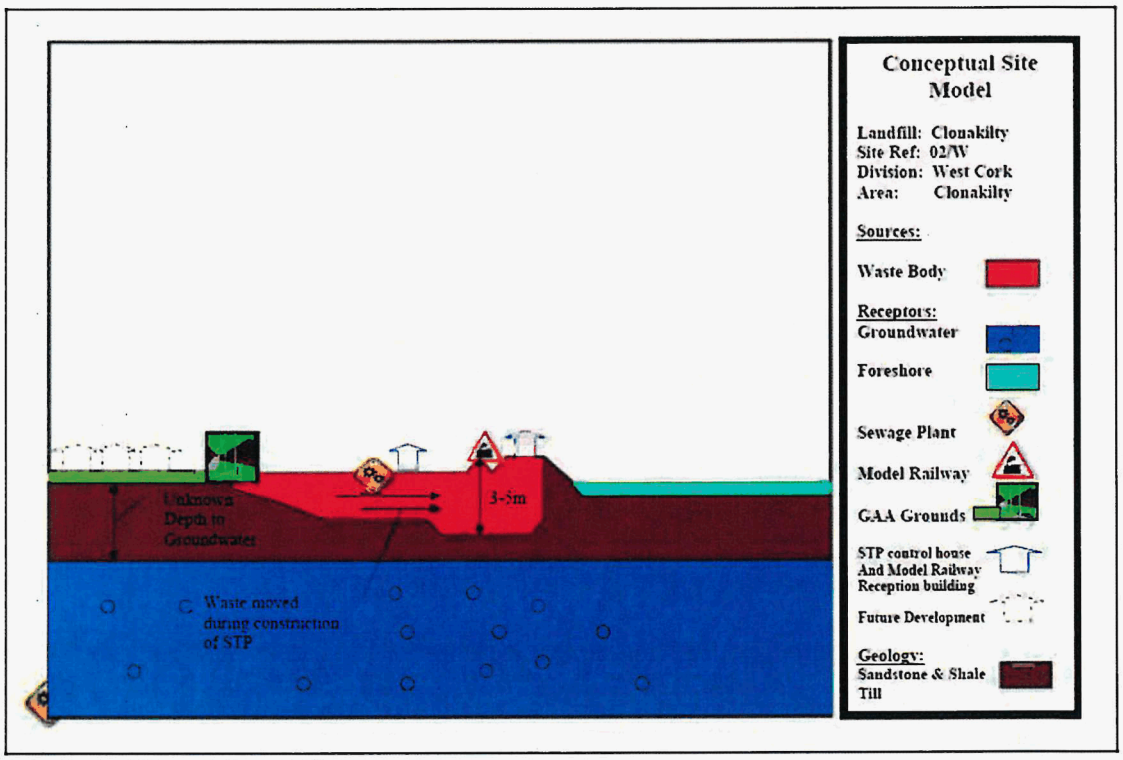


Fig 2.1: Clonakilty CSM

3.0 TIER II SITE INVESTIGATION

3.1 OBJECTIVES

The main objective of the investigation was to collect sufficient information to confirm the Tier I conceptual site model.

The objectives are summarised as follows:

- Characterise the waste on site
- Delineate the lateral and vertical extent of the waste
- Determine the depth and composition of any capping layer
- Determine the subsoil type, thickness and permeability
- Confirm if the Tier I Conceptual Site Model is valid (and adjust if required)
- Show if there is evidence of the landfill causing any environmental impacts

3.2 SITE INVESTIGATION METHODOLOGY

The site investigation included the following elements:

- Excavation of Trial Pits throughout the site
- Collection and Analysis of Surface Water Samples
- Collection and Analysis of Leachate Samples
- Collection and Analysis of the Waste
- Window Sampling of the waste

- Installation of Gas Wells
- Installation of Leachate Wells
- Completion of a Site Survey
- Ecology Survey
- Gas Monitoring

3.3 ON SITE INVESTIGATIONS

The site investigation comprised the use of a JCB to dig 6No. Trial Pits over the site. As the site is currently being used as both a Sewage Treatment Plant and a Model Railway Village much of the old landfill is covered in hard standing so the locations available for trial pitting were limited. The excavations were supervised and logged by a Cork County Council Environmental Engineer, Dr Cormac O'Suilleabhan. Each Trial Pit was logged in accordance with BS5930. Trial Pit locations can be seen below.

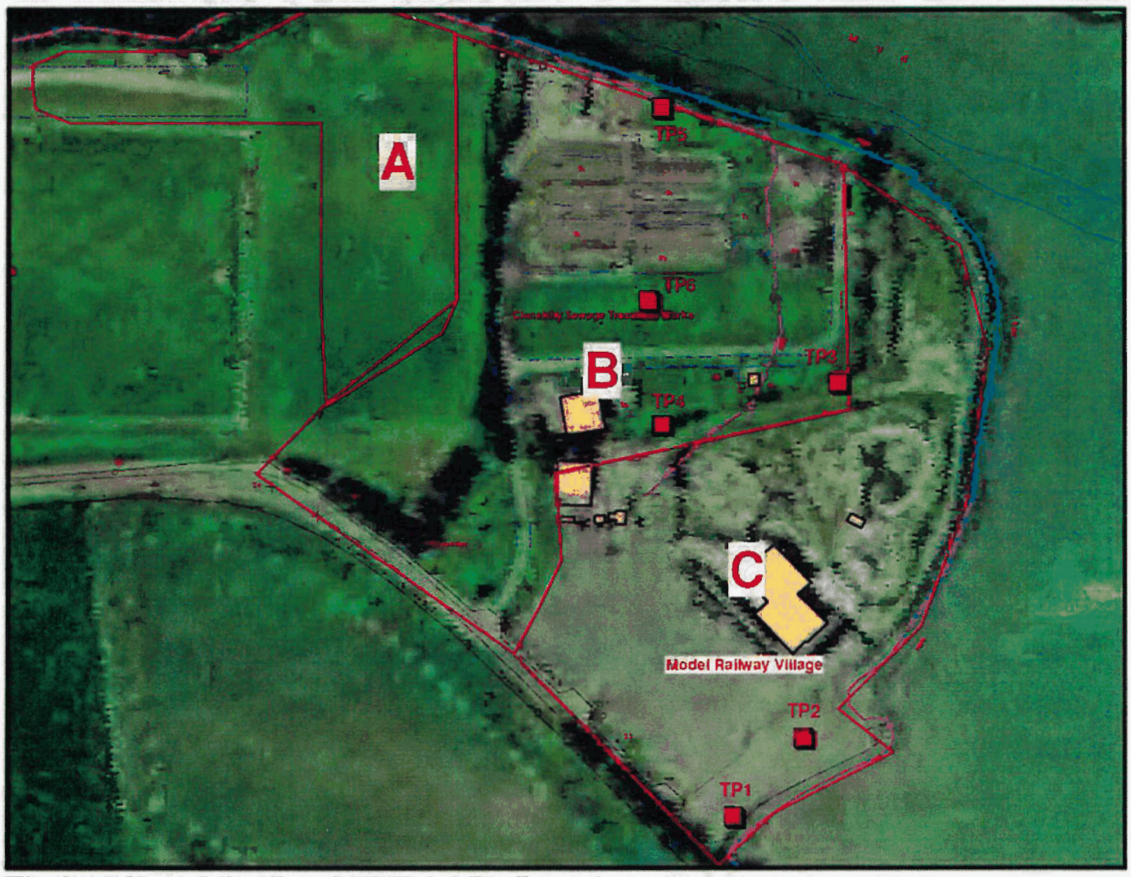


Fig 3.1: Clonakilty Landfill Trial Pit Locations

No Trial Pits were excavated in Area A because this area is not under Cork County Council ownership and the Developer was out of the country (and permission could not be secured to enter). Borehole logs from the planning application on this site were used as part of the information gathering on this site however (and have been included as a source of information in Appendix 3)

3.4 ON-SITE OBSERVATIONS

3.4.1 Waste Characterisation

Waste was found in 5 of the 6 trial pits that were excavated although only minor amounts of waste was found in the Sewage Treatment Plant Area (Area B). The majority (>95%) of the material excavated in **A**rea **B** was composed of clay, stones and boulders. The types of waste encountered included tarmac, clay piping, boulders, blocks, metal, plastics, glass, papers, tyres. (**S**ee **T**rial Pit Logs in **A**ppendix **3**). **T**rial Pit photos can be seen below:

Trial Pit No.1

Trial Pit No.2

Trial Pit No.2

Grey/Black Silt Layer found at base of Trial Pit No.2

Trial Pit No.3

Trial Pit No.3

Trial Pit No.5

Trail Pit No.6

3.4.2 Lateral and Vertical Extent of the Waste

Lateral: The trial pitting showed that the majority of the waste found was in Area C of the site (i.e. Model Railway Village). Only minor amounts of waste were found in Area B (i.e. Sewage Treatment Plant Area) which agrees with the information gathered during Tier I indicating that all or most of the waste was moved from Area B to Area C during the construction of the Sewage Treatment Plant.

Vertical: The maximum waste depth encountered during the Trial Pitting was 2.3m below ground level (bgl).

3.5 ASSUMPTIONS

3.5.1 Assumption No. 1: The Majority of the Waste in Area B was moved to Area C during the construction of the Sewage Treatment Plant:
Photos and interviews held during the Tier I Risk Assessment indicate that the waste was removed from Area B and moved to Area C during the construction of the Sewage Treatment Plant in 1986. Imported fill was then used to fill in the areas around the sewage treatment plant. The findings of the Trial Pit Survey show that Trial Pits that were excavated in Area B were largely composed of soil and stone with very minor amounts of waste (see photos from the construction of the sewage treatment plant below).

Photo No. 1 from 1986 showing construction of Sewage Treatment Plant

Photo No. 2 from 1986 showing construction of Sewage Treatment Plant

3.5.2 Assumption No. 2: Waste in Area A is estimated to be over 40 Years old (i.e. Pre-1970's) and is composed mainly of inorganic waste.

Interviews held during the Tier I risk assessment indicated that Area A was used as an unofficial landfill site from the 1950's to pre 1970. A geotechnical investigation of the GAA Pitch (which includes part of Area A) was conducted by the developer as part of the planning process for the new development on these lands. The borehole logs show waste at locations BH2 & BH3A and that the waste that was found was largely composed of inert waste such as fragments of bricks, glass, wood and some plastic. No waste was found at other locations (apart from some brick at BH1). See locations of boreholes below (copies of borehole logs are included in Appendix 3):

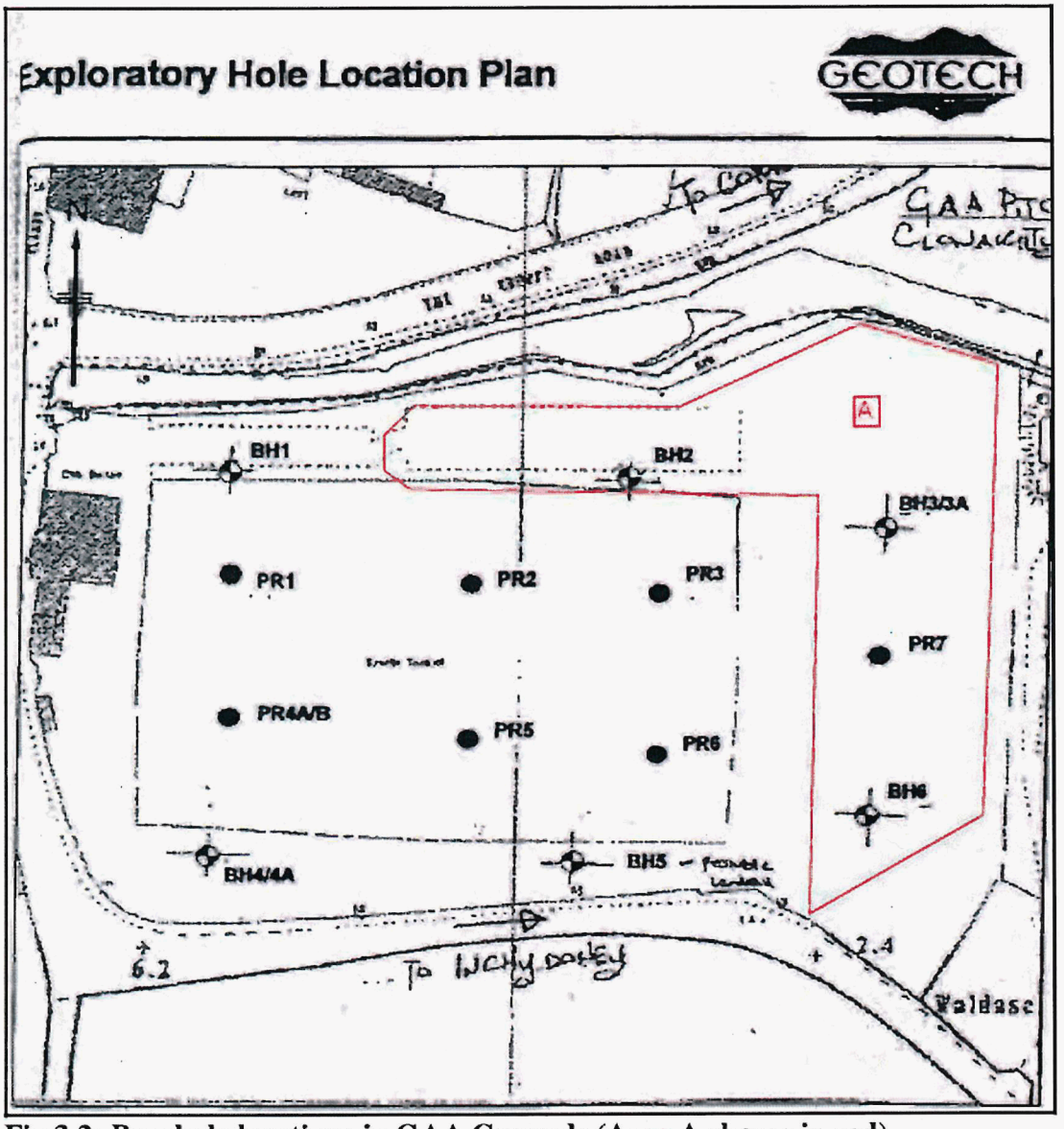


Fig 3.2: Borehole locations in GAA Grounds (Area A shown in red) Investigation part of planning application

3.5.3 Assumption No. 3: Lateral Migration of Leachate is minimal due to the installation of an Impermeable Geo-membrane surrounding all areas of the Landfill

Photographic evidence shows that an impermeable layer was installed during the construction of the sewage treatment plant.

Photo No. 3 from 1986 showing construction of Sewage Treatment Plant

3.6 SAMPLING AND ANALYSIS

3.6.1 Surface Water

Clonakilty Landfill is adjacent to the mouth of the Feagle River and Clonalkilty Bay (see CSM **Plan** below).

Fig 3.3: Conceptual Site Model Plan

Fig 3.3: Clonakilty Protected Areas Map

The landfill is also adjacent to an SAC, NHA and an SPA.

3.6.2 Surface Water Samples

3No. Surface Water samples were taken from the estuary/ river on Monday 2nd November 2009. Samples were collected and stored in accordance with BS 6068 – 6.6 Guidance on sampling of rivers and streams. Full laboratory chain of custody documentation was completed and samples dispatched to the chosen laboratory (Certificates of Analysis can be seen in Appendix 4). Samples were tested for major and minor suites in accordance with the EPA Guidance Matrix (See Appendix 2).

See sample locations below:

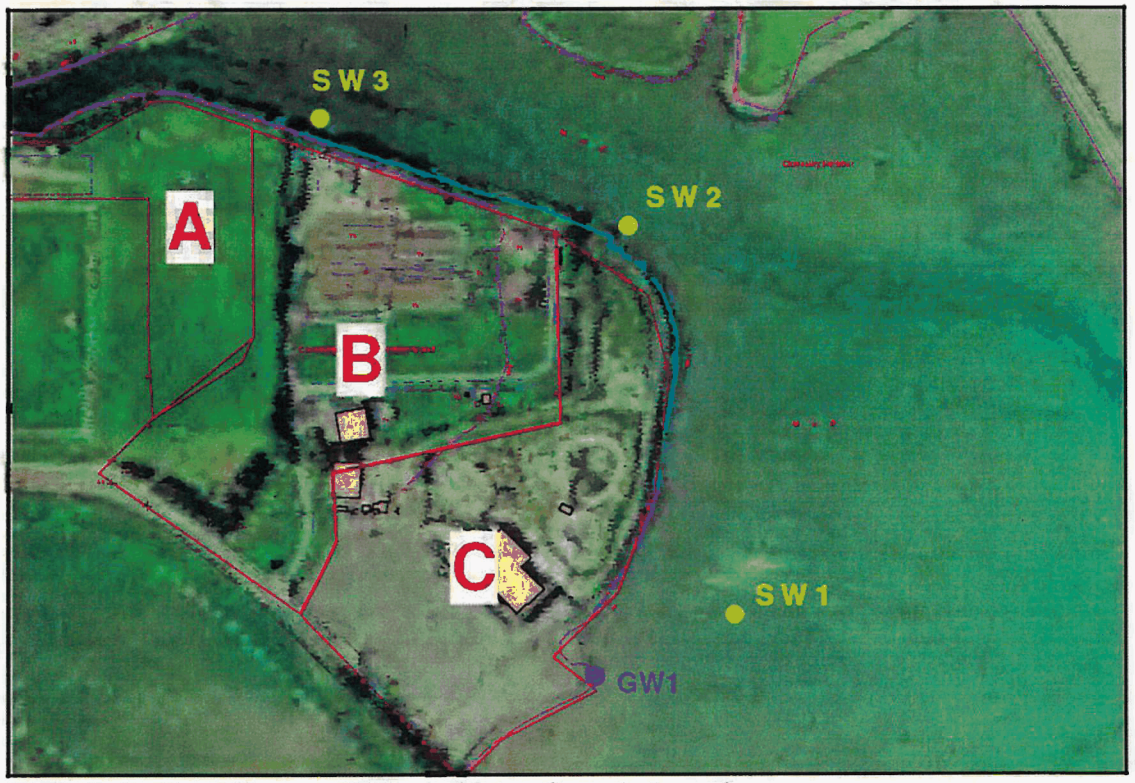


Fig 3.3: Surface Water and Groundwater Sample Locations

A small seep/spring that flows from the side of the landfill (area C) was also tested. This sample was labelled Groundwater Sample No.1 (GW1) and is shown on the location map above.

Surface Water Sample No.1 and Groundwater Sample No.1 were taken when the tide was low (11am). Surface Water Sample No.2 (3pm) and No.3 (4.30pm) were taken at high (or close to) high tide. Tide tables are shown below:

		HIGH WATER				LOW WATER			
		Morning		Afternoon		Morning		Afternoon	
Location	**Date**	**Time**	**Ht/m**	**Time**	**Ht/mtrs**	**Time**	**Ht/mtrs**	**Time**	**Ht/mtrs**
Cobh	2nd Nov	04.36	4.0	16.54	4.1	10.59	0.6	23.16	0.6
Clonakilty	2nd Nov	04.03	3.7	**16.21**	3.8	**10.26**	0.3	20.43	0.3

Table 3.1: Tide tables for 2nd November 2009

Surface water samples for Clonakilty Landfill						
Parameter	Units	SW3	SW2	SW1	GW1	EQS Values
pH (Surface Water)	pH Units	7.5	7.5	7.1	7.2	6.5 - 9.5
Conductivity (Surface Water)	uscm -1@25C	18400	388	10240	4190	1000
Solids (Total Suspended)	mg/L			404		~
Solids (Total Dissolved)	mg/L			5989		~
Ammonia (Surface Water)	mg/L as N	0.492	0.048	0.056	0.392	0.02 mg/L
Nitrogen (Total Oxidised) (Surface Water)	mg/L as N			3.36		~
Total Organic Carbon	mg/L			2.5		~
BOD (Surface Water)	mg/L	<2	<2	<2	<2	~
COD (Surface Water)	mg/L			15		~
Calcium	mg/L	93.8	21.55	75.4	85.44	~
Magnesium	mg/L	418.2	4.01	210.4	68.55	0.3 mg/L
Sodium	mg/L	2579	25.29	1420	831.1	~
Potassium	mg/L	93.8	3.71	52.2	28.42	~
Iron (Surfacewater)	ug/L	173.7	1564	704.4	7940	1000 ug/L
Manganese (Surface Water)	ug/L	39.7	113.6	31.9	311.8	~
Cadmium (Surface Water)	ug/L	<0.01	0.1	0.06	0.2	5 ug/L
Chromium (Surface Water)	ug/L	1.1	1.3	3	9.6	30 ug/L
Copper (Surface Water)	ug/L	<0.21	<0.21	2.1	15.8	30 ug/L
Nickel (Surface Water)	ug/L	1.1	2.2	2.9	9.5	50 ug/L
Lead (Surface Water)	ug/L	1.1	1.7	1.7	12.5	10 ug/L #
Zinc (Surface Water)	ug/L	<0.63	4	7.7	60.5	100 ug/L #
Arsenic (Surface Water)	ug/L	1.4	1.7	1.8	5.8	25 ug/L #
Boron (Surface Water)	ug/L	814	35.2	571.5	392.9	2000 ug/L #
Mercury	ug/L	<0.03	<0.03	<0.03	0.1	1 ug/L #
Alkalinity (Surface Water)	mg/L CaCO3			198		~
Sulphate	mg/L as SO4	801.94	15.02	417.02	177.94	200 mg/L
Chloride (Surface Water)	mg/L	5100	56.6	2978.65	201.33	250 mg/L
Phosphate (Ortho) Surface Water	mg/L as P			0.098		~
Cyanide	ug/L			<0.05		10 ug/L #
Fluoride (Surface Water)	mg/L			0.38		5 mg/L #
Atrazine	ug/L			<0.01		1 ug/L
Dichloromethane	ug/L			<1		10 ug/L
Simazine	ug/L			<0.01		1.0 ug/L
Toluene	ug/L			<0.28		10 ug/L
Tributyltin*	ug/L as Sn			<1		~
Xylene (Total)	ug/L			<1		10 ug/L
Coliforms (Faecal)	no/ 100ml			101		~
Coliforms (Total)	no/ 100ml			142		~

Note:
Standard where hardness of water is > 100mg/L $CaCO_3$

Table 3.1: Surface Water Results

3.6.3 Interpretation of Surface Water Results

The High conductivity, magnesium, sulphate and chloride readings are assumed to be due to the saline conditions in the bay (normal constituents of sea water). Noticeable increases in Ammonia and Iron above the Environmental Quality Standards are indicated in the above table. Lead levels of 12.5ug were also observed in the groundwater sample although the volume of this source was very small (<1L/minute).

It is possible that the landfill is having some minor impact on the surface water quality. A Quantitative Risk Assessment will give a clearer picture of the impact the landfill is likely to be having on the adjacent surface water quality.

3.6.4 Leachate Sample Results

1No. Leachate samples was taken during the trial pits on the 2nd November 2009. Two further samples were taken following the installation of leachate and gas wells during the main investigation (see section 4.2 below for well locations).

The leachate samples were taken was taken from the following locations:

Leachate 1 - Trial Pit No. 2
Leachate 4 - Leachate Well No.4
Leachate 7 - Leachate Well No.7

Leachate was tested as per table C2 of the EPA Landfill Monitoring Manual 2003 for Leachate (as per EPA Matrix, Appendix 2). See results below:

Parameter	Leachate 1	Leachate 4	Leachate 7	Units
pH			7.2	pH Units
Conductivity	219	752	1594	uscm -1@25C
Ammonia	138.67	1.01	16.47	mg/L as N
Nitrogen (Total Oxidised)	<0.03	<0.03		mg/L as N
BOD	10	<2	<2	mg/L
COD	2010	27		mg/L
Sulphate	3.621	17.35	63.41	mg/L as SO4
Chloride	110.69	30.36	51.4	mg/L
Phosphate (Ortho)	<0.005	0.101		mg/L as P
Cyanide	50.31	7		ug/L
Fluoride	0.24	0.28		mg/L
Atrazine	<0.01	<0.01		ug/L
Dichloromethane	<1	<1		ug/L
Simazine	<0.01	<0.01		ug/L
Toluene	<0.28	<0.28		ug/L
Tributyltin*	<4	<0.02		ug/L as Sn
Xylene (Total)	<1	<1		ug/L
Calcium	155.7	151.2		mg/L
Magnesium	35.27	8.42		mg/L
Sodium	69.95	17.39	44.89	mg/L
Potassium	50.31	7.38	25.52	mg/L
Iron (Total)	15.22	67.3		mg/L
Manganese	0.936	2.26		mg/L
Cadmium	0.2	0.1		ug/L
Chromium	2.9	<0.93		ug/L
Copper	5.4			ug/L
Nickel	8.7	5		ug/L
Lead	25.4	1.6		ug/L
Zinc	50.8	20.3		ug/L
Arsenic	11.8	1		ug/L
Boron	430.4	275.4		ug/L
Mercury	0.06	0.06		ug/L

Table 3.2: Leachate Results

3.4.6 Interpretation of Leachate Results

Ammonia concentrations averaged 52mg/L over the 3No. locations tested. Leachate 1 showed up much higher values compared to the other locations.

When comparing the above Leachate results to leachates sampled from other landfills (i.e. Table 7.1 & 7.2 EPA Landfill Site Design, 2000) 90% of the values are below Median values for the landfills that are in Stage III and Stage IV of the degradation process. It is also noted that 70% of the values that are under the Median values are an order of 10 below those median values (e.g. Median Value for Zinc from a landfill in Stage IV = 780ug, Maximum Zinc value for Clonakilty 50.8ug). It is concluded that Clonakilty landfill is likely to be in late Stage IV or Stage V (Aerobic Stage) of the

biodegradation process. The low recorded ratio between BOD and COD (>0.1) supports this view.

3.5 Conclusions and Recommendations following Exploratory Investigation

Conclusions: Only minor amounts of waste remain in the area around the sewage treatment plant. During the construction of the landfill waste was moved from Area B to Area C (i.e. Model Railway village). Waste found on site is mainly composed of mixed domestic and commercial waste. A thick mud layer was found under Trial Pits No. 1 and No.2. This layer was logged as a SILT/CLAY and is envisaged that it will act as a low to medium permeability (K value of $10^{-4} - 10^{-9}$) barrier between the waste and the groundwater.

Groundwater was encountered at varying depths from 0.25m below ground level (bgl) in Trial Pit No. 4 to up to 2.1m bgl in Trial Pit No.2. The ability of water to drain as well as the infiltration levels into the landfill are varied throughout the site (low surface water infiltration in many areas due to hard stand covering most of the site).

Based on the observations and knowledge obtained in the exploratory investigation it was concluded that the higher Risk SPR linkages in the Tier I were valid and the focus of the main investigations was to be on these SPR linkages. i.e. SPR No.8 (i.e. Leachate to Surface Water via surface water drainage), SPR No.9 (Leachate to the Surface Water Body Protected Area via surface water drainage) and SPR No.10 & 11 Gas migration to the local Human Presence (Lateral and Vertical Migration).

Recommendations: A Geophysical Survey of the site would not be suitable on this site due to the underground services throughout the site. Window sampling could be utilised during the main investigation to gain a further understanding of the nature of the waste throughout the site. The Main Investigation focuses on Area C (i.e where the majority of the waste was moved to during the construction of the sewage treatment plant).

4.0 TIER II MAIN INVESTIGATION

4.1 Tier II Main Investigation Scope

8No. Leachate Wells and 3No. Gas/Leachate Wells were installed on the site during the main investigation. The installation of the wells was combined with the collection of window samples of the waste. An Ecology Study was completed on the landfill and the Clonakilty Bay Area. Gas Wells were monitored over a period of a month.

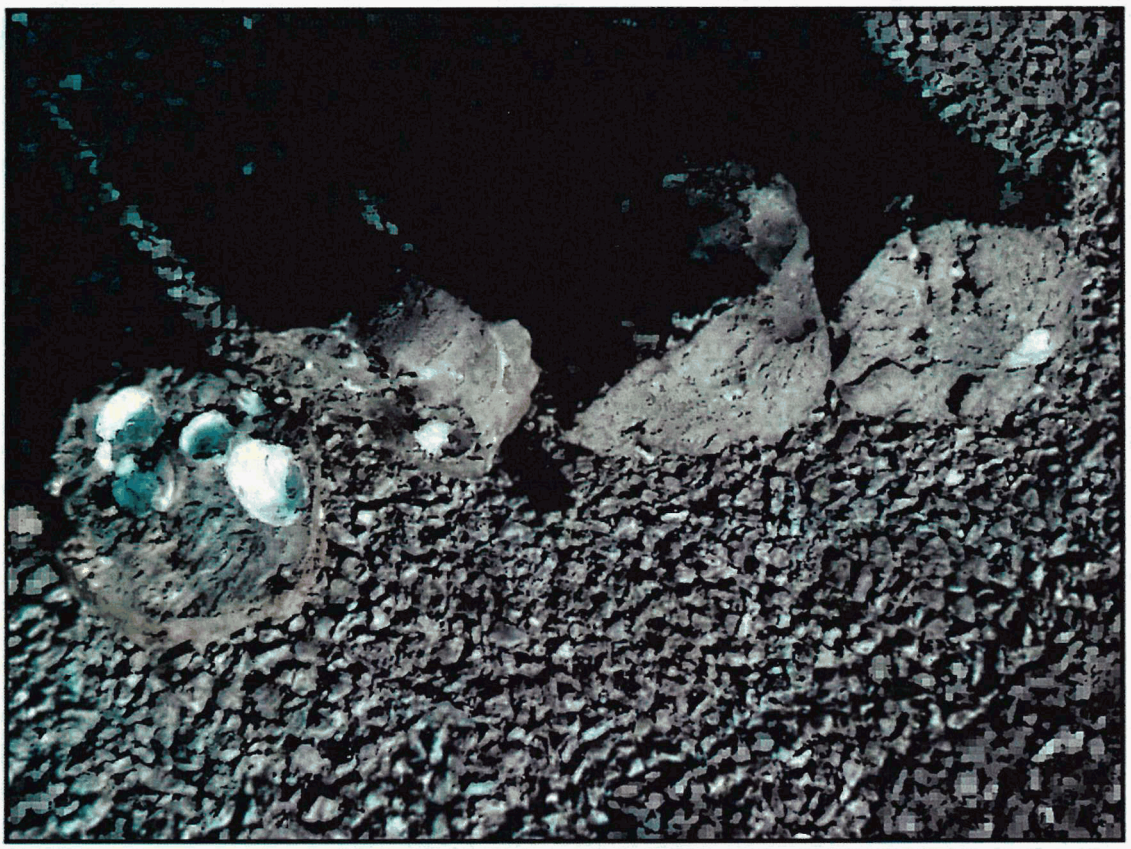
4.2 Leachate/Gas Well Installation

The installation of the leachate/Gas Wells were supervised and logged by a Cork County Council Environmental Engineer, Dr Cormac O'Suilleabhan. A *"Dando Terrier Window Sampler"* was used for obtaining window samples as well as for the installation of the wells. Each well was logged in accordance with BS5930. Well locations can be seen below.

Fig 4.1: Gas & Leachate Well Locations

Installation of Leachate Well No.5

Installation of Leachate Well No.4



Silt/Clay Layer with shells from Window Sample (Leachate Well No.4)

4.2.1 Interpretation of Window Samples

80mm diameter window samples of the waste and soil were removed during the construction of the leachate and gas wells. These were logged in accordance with BS5930. Copies of logs can be seen in Appendix 3. Waste was found to varying depths in all wells. The maximum depth was found to be 4.2m below ground level. Waste included a mix of C&D, plastic, timber, glass, metal and textiles. In many cases the waste was found to be black moist and odorous. No VOC's were detected when screening the waste with a hand held Photo Ionisation Detector.

4.2.2 Waste Sample Results

Two waste samples were analysed during the Tier II Investigation. One waste sample was taken from the window sample from Gas Well No.2 and the second was taken from Trial Pit No.2.

ParameterName	Units	Clonakilty Gas 2 26/11/09	Inert Waste	Stable Non-Reactive	Hazardous Waste
% Dry Matter	%	69.05			
Alkalinity (Leachate)	mg/Kg	438			
Arsenic (Leachate)	mg/Kg	0.0983	0.5	2	25
Aluminium (Leachate)	mg/Kg	3.269			
BTEX in Solid	mg/Kg	<0.5	6		
Toluene (Soil)	mg/Kg	<0.5			
Benzene (Soil)	mg/Kg	<0.5			
Ethylbenzene (Soil)	mg/Kg	<0.5			
m-& p-Xylene (Soil)	mg/Kg	<0.5			
Cadmium (Leachate)	mg/Kg	<0.00009	0.04	1	5
Chloride (Leachate)	mg/Kg	92.2	800	15000	25000
Chromium (Leachate)	mg/Kg	0.0063	0.5	10	70
Copper (Leachate)	mg/Kg	0.0482	2	50	100
Ammonia (Leachate)	mg/Kg	22.18			
Boron (Leachate)	mg/Kg	1.603			
Carbonate (Leachate)	mg/Kg	438			
Mercury (Leachate)	mg/Kg	<0.0002	0.01	0.2	2
Conductivity		174			
Nickel (Leachate)	mg/Kg	0.0142	0.4	10	40
Faecal Coliforms (Solid)	no/100ml	0			
Hardness (Leachate)	mg/Kg	585			
Hardness Bicarbonate (Leachate)	mg/Kg	585			
Sulphate (Leachate)	mg/Kg	165.42	1000	20000	50000
Iron (Leachate)	mg/Kg	0.5498			
Zinc (Leachate)	mg/Kg	<0.0046	4	50	200
Magnesium (Leachate)	mg/Kg	27.5			
Mineral oil by Calculation (Solid)	mg/Kg	<2.5	500		
TOC (Solid)	%	3.109	3	5	6
Manganese (Leachate)	mg/Kg	0.5442			
pH (Leachate)	pH Units	7.5			
DRO soil (>C10-28)	mg/Kg	1.21			
PRO soil (>C6-12)	mg/Kg	<5			
TPH solid (>C10-40)	mg/Kg	2.56			
Nitrate (Leachate)	mg/Kg	<0.09			
Nitrite (Leachate)	mg/Kg	<0.003			
Nitrogen (Total Oxidised) (Leachate)	mg/Kg	<0.003			
Phosphate Ortho (Leachate)	mg/Kg	<0.005			
Potassium (Leachate)	mg/Kg	47.1			
Sodium (Leachate)	mg/Kg	29.9			
Total Coliform (Solid)	no/100ml	65			

Table 4.1: Results of waste sample taken from Gas Well No.2

EURO environmental services

Client	Kieran Coffey	Batch Receipt Date	03/11/2009
Company	Cork County Council	Received/Collected	Received
	Inniscarra Waterworks	Condition	Acceptable
	Inniscarra	Report Date	17/11/2009
	Co. Cork	Job reference:	Clonakilty

ParameterName	Units	Clonakilty WAC 1 - 02/11/09	Inert Waste	Stable Non-Reactive	Hazardous Waste
% Dry Matter	%	75.0			
Antimony (Leachate)	mg/Kg		0.06	0.7	5
Arsenic (Leachate)	mg/Kg	0.1324	0.5	2	25
Barium (Leachate)	mg/Kg		20	100	300
BTEX in Solid	mg/Kg	<0.5	6		
Toluene (Soil)	mg/Kg	<0.5			
Benzene (Soil)	mg/Kg	<0.5			
Ethylbenzene (Soil)	mg/Kg	<0.5			
m-& p-Xylene (Soil)	mg/Kg	<0.5			
Cadmium (Leachate)	mg/Kg	0.0005	0.04	1	5
Chloride (Leachate)	mg/Kg	89.49	800	15000	25000
Chromium (Leachate)	mg/Kg	0.0055	0.5	10	70
Copper (Leachate)	mg/Kg	0.0615	2	50	100
Dissolved Organic Carbon (Leachate)	mg/Kg		500	800	1000
Fluoride (Leachate)	mg/Kg		10	150	500
Lead (Leachate)	mg/Kg		0.5	10	50
Mercury (Leachate)	mg/Kg	0.0049	0.01	0.2	2
Molybdenum (Leachate)	mg/Kg		0.5	10	30
Nickel (Leachate)	mg/Kg	0.057	0.4	10	40
PAH (Soil)	mg/Kg		100		
PCBs in Solid	mg/Kg		1		
Selenium (Leachate)	mg/Kg		0.1	0.5	7
Sulphate (Leachate)	mg/Kg	1068.83	1000	20000	50000
Total Dissolved Solids (Leachate)	mg/Kg		4000	60000	100000
Zinc (Leachate)	mg/Kg	0.0349	4	50	200
Phenol Index (Leachate)	mg/Kg		1		
Mineral oil by Calculation (Solid)	mg/Kg	218.12	500		
TOC (Solid)	%	3.127	3	5	6
Loss on Ignition	%				10
pH (Leachate)	pH Units	8			
DRO soil (>C10-28)	mg/Kg	228.72			
PRO soil (>C6-12)	mg/Kg	<1			
TPH solid (>C10-40)	mg/Kg	302.94			

Table 4.2: Results of waste sample taken from Trial Pit No.2

4.2.3 Interpretation of Waste Results

When the above results are compared to the acceptable leaching limit values from waste as outlined in "Council Decision of 19th December 2002, establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of the Annex II to Directive 1999/31/EC" all results fall within criteria for landfills for inert waste except for TOC (at 3.109% & 3.127% v's an acceptable limit of 3%) and Sulphate (values were high for the waste sample from Trial Pit No.2). High sulphate readings are likely due to salt water infiltration from sea.

The waste on this site can generally be regarded as being inert (as per the above Council Decision).

4.3 Gas Monitoring

4.3.1 Gas Monitoring Methodology

A GFM 430 Gas Monitoring Unit was used for taking gas samples. This unit is calibrated on a regular basis. The gas intake tube to the unit was placed on the well head gas tap and the gas tap opened. The gas readings were allowed to stabilise for 1 minute before readings were taken. Gas was monitored over a period of 1 Month. The results can be seen below:

4.3.2 Gas Monitoring Results

Location	Methane %			Carbon Dioxide %			Barometric Pressure (mb)		
TEST DATE	22/12/09	30/12/09	14/01/10	22/12/09	30/12/09	14/01/10	22/12/09	30/12/09	14/01/10
GAS 1	26.7	0.4	33.5	2.1	0	2.2	986	982	1003
GAS 2	0	0	0.1	9.2	0.5	0.7	986	982	1002
GAS 3	0	15.3	0	1.8	3	0.9	986	982	1001

Table 4.3: Gas Monitoring results

4.2.1 Interpretation of Gas Results

High Methane Gas levels were found in Gas Well No.1 on two occasions and in Gas Well No. 3 on one occasion. The high readings from Gas Well No.1 area a cause for concern as this well is close to the Model Railway Village building. Further gas monitoring will be conducted on this site.

4.3 Ecology Study

An Ecology Survey was conducted by Mr Patrick Doherty MSc, MIEEM of Doherty Environmental. A copy of the completed report can be found in Appendix 6.

2No. Mud samples were taken from the bay and analysed as part of this study. Sample points can be seen below:

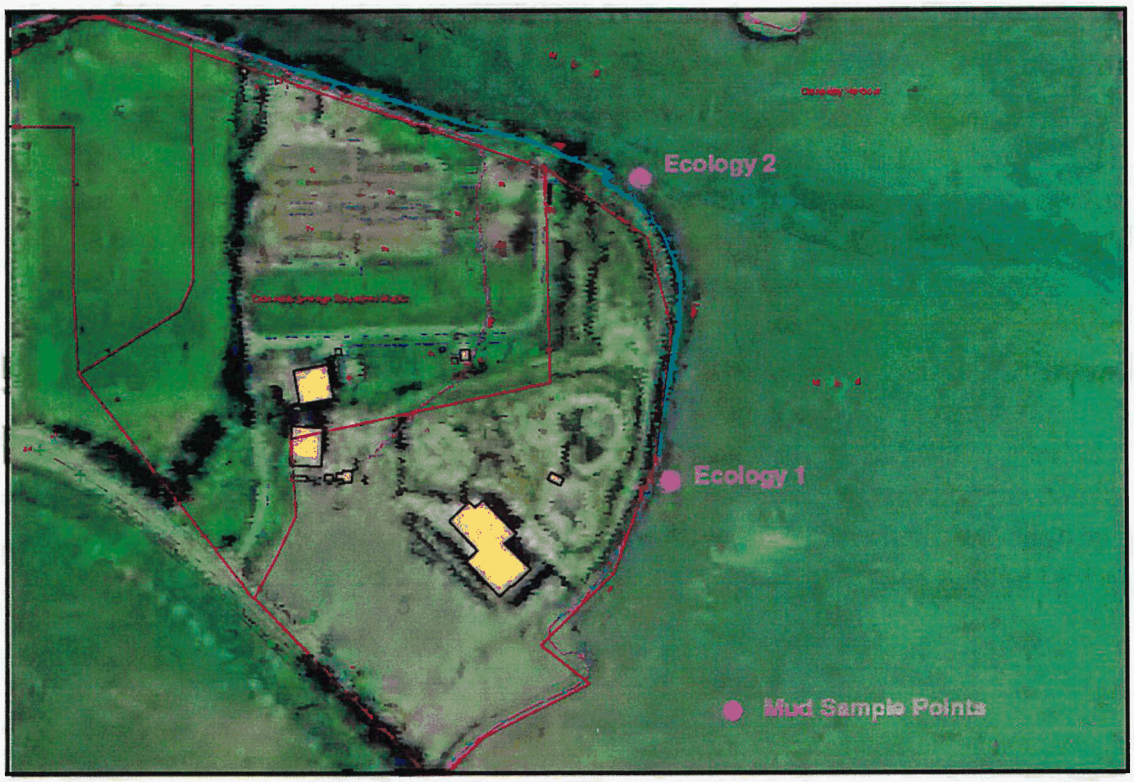


Fig 4.1: Mud Sample Points

The results of the mud samples were used as part of the ecology study (certificates of analysis are included in Appendix 4).

The Ecology Study summary findings are as follows:

Landfill Site Evaluation: The terrestrial habitats identified within and adjacent to the site as listed above are predominantly artificial in nature and do not support a high diversity of flora and fauna species. These habitats are considered to be of low conservation importance and low ecological value.

The coastal sea wall bordering the perimeter of the site is characterised by boulder rock armour that does not support fauna species. This artificial habitat is considered to be of low conservation and ecological value.

The marine habitats identified adjacent to the site include habitats listed on Annex I of the EU Habitats Directive. These habitats include: littoral mud shores which correspond to the Annex I habitat mudflats and sandflats not covered by seawater at low tide (Code 1140); estuaries (Code 1130).

In addition to the Annex I habitats that occur adjacent to the site, Clonakilty Bay also supports an internationally important populations of over-wintering Black-tailed Godwits and is ranked as the sixth most important site for over-wintering black-tailed godwit in Ireland. The Bay also supports a range of bird species listed on Annex I of the EU Birds Directive, including Little Egret and Bar-tailed Godwit.

While the results of detailed habitat assessments undertaken in 2005 concluded that it is highly likely that Clonakilty Estuary is eutrophic, the presence of a number of Annex I habitats and the estuary's role in supporting internationally important populations of birds ensure that the estuary and associated habitats are classified as international conservation importance and ecological value.

Conclusions of Ecology Report: Based on the primary information provided for this assessment it was not possible to conclude whether or not the disused landfill site is acting as a point source of pollution to the adjacent Clonakilty Estuary. The results of the water quality analysis does not indicate that landfill leachate is having an adverse affect on the chemical status of the seawater adjacent to the site. However it is noted that many contaminants are poorly soluble in water and accumulate in sediments at greater concentration than in the adjacent water column. However the results of the leaching test indicate that the leachable content of metals from sediments adjacent to the disused landfill site is low. It is noted that the effects of potential pollution on biological parameters adjacent to the site were not undertaken and that when assessing the effects of contaminants on the environment it is important to integrate chemical assessments with biological effects data.

5.0 RE-ASSESSMENT OF TIER I CONCEPTUAL SITE MODEL

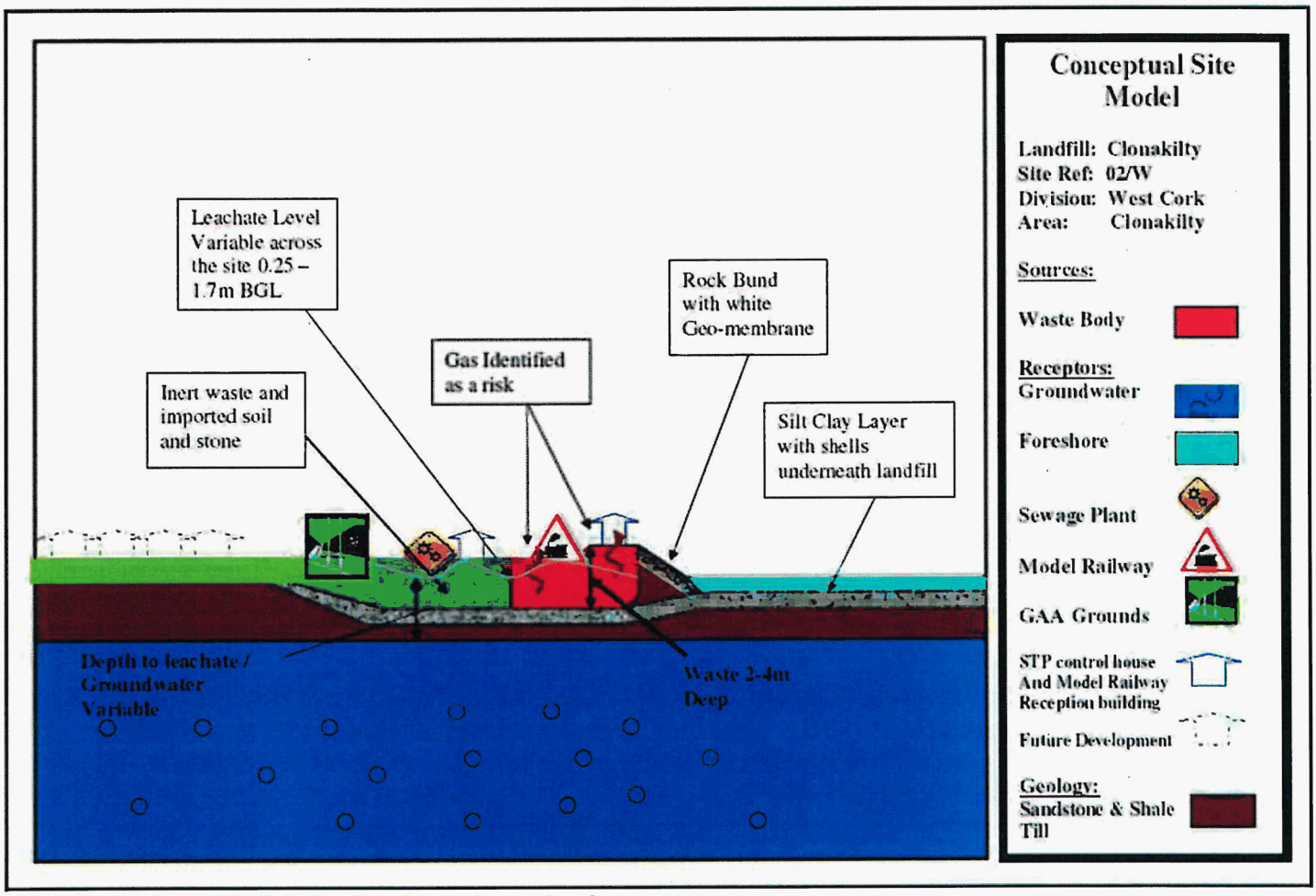


Fig 5.1: Revised CSM following Main Investigation

The CSM was revised following the Tier II Exploratory and Main Investigations. The trial pits and window samples showed a moderate to low permeability Silt Clay layer with shells under most areas of the landfill. Only minor amounts of waste were encountered in the western parts of the landfill (Areas A & B). High levels of Gas were detected at two locations on the site (Gas Well No.1 and No.3).

The depth at which leachate was found below ground level varied considerably throughout the site. The Rock Berm with a white geo-membrane is shown on the revised CSM.

6.0 QUANTITATIVE RISK ASSESSMENT

The CSM completed in the Tier 1 Assessment identified leachate and landfill gas as the sources; surface waters and humans as the potential receptors. The highest potential linkage scores were for SPR 8 (70%), SPR 9 (70%), SPR10 (70%) and SPR11 (70%) and the overall site classification was 'High Risk'.

The objective of the Tier 2 assessment was to establish if the SPR linkages identified in the Tier 1 actually existed. The Assessment identified that only SPR 10 and 11 remained as High Risk and that a Quantitative Risk Assessment was required to assess the Landfill Gas Risk at the site.

6.1 Potential Sources

6.1.1 Waste Body

The Tier 1 assessment indicated that waste had originally been deposited in three areas at the site (A, B and C). The Tier II Site Investigations identified that the waste in Area A is over 40 years old and presents minimal risk. Only minor amounts of waste remain in the area around the sewage treatment plant (Area B) as during the construction of the treatment plant, the waste from this area was moved to Area C (i.e. Model Railway village). The waste in Area C comprises typical mixed domestic and commercial waste.

Waste was encountered to a depth of 4.2m below ground level. No VOCs were detected during the field investigations. A thick alluvial mud layer was found beneath the waste. This layer is described as SILT/CLAY, which typically has a low to medium permeability (K value of $10^{-4} - 10^{-9}$) and acts a barrier between the waste and the underlying aquifer.

6.1.2 Leachate

The quality of the leachate samples collected from the boreholes and trial pits indicate that the waste is likely to be in late Stage IV or Stage V (Aerobic Stage) of the biodegradation process.

6.1.3 Landfill Gas

During the Tier 2 Site Investigation, landfill gas levels exceeding the Department of the Environment Guidelines of 1% for Methane and 0.5 % for Carbon Dioxide were detected. High methane levels were found in Gas Well No.1 on two occasions (26.7 – 33.5%) and in Gas Well No. 3 on one occasion (15.3%).

The high readings at Gas Well No.1 was a cause of concern, as this well is close to the Model Railway Village building.

Subsequent monitoring was undertaken in all the leachate and landfill gas wells in March 2010. While the levels detected in Gas Well No 1 had reduced (9.6%), they were still a cause of concern. Carbon dioxide was also detected in Gas Well 1 (2.5%) and 2 (1.3%). Elevated methane (5.7% and 3.8%) and carbon dioxide (4.6% and 3.7%) were also detected in Leachate Wells No. 5 and 6 respectively.

6.2 Potential Pathways

To establish the pollutant linkage, a pathway or pathways to a receptor must be identified. This is the route by which a hazard can move toward the receptor. The pathways may allow the passage of a hazard in any of its three basic phases or in a combination, i.e. as a liquid as a solid or as a gas. Potential pathways for the site are shown in Table 7.1.

Potential Pathway	Route
Surface Water	Leachate migration from the landfill discharging into the Feagle River estuary and Clonakilty Bay
Groundwater	Contaminant migration to the water table through the base of the landfill into the subsoil and underlying sandstone bedrock.
Air/Soil	Landfill gas migration to buildings along subsurface or surface pathway.

Table 6.1 Potential Pathways

6.3 Potential Receptors

Potential receptors are identified in Table 7.2 below:

Potential Receptor	Type
Surface Water	The Feagle River Estuary
Groundwater	Bedrock Aquifer beneath the site
Human Beings/Animals	Occupants in the Railway Village Offices and Visitor Centre

Table 6.2 Potential Receptors

6.4 Pollution Linkage

Potential hazards, pathways, and receptors have been identified at the site. For a risk to pose a significant threat to a receptor, a linkage via a pathway must be established.

6.4.1 Surface Water

Leachate generated in the waste mass has the potential to migrate laterally from the landfill into the Estuary. Three surface water samples were collected during the Tier II site investigations (SW-1,2 and 3). SW-1 is located downstream of the landfill in the Estuary, with SW-2 adjacent to the landfill close to the mouth of the Feagle River, while SW-3 is just upstream of the landfill in the River Feagle.

The monitoring results indicated that while the water quality in the river is impacted, the source of the impact appears to originate upstream of the landfill site.

During the Tier II Site Investigations no direct drainage was observed between the landfill and the Estuary. A substantial portion of the land area where waste is present i.e. Areas B and C is covered by hardstanding therefore rainfall infiltration is limited and the pathway from the landfill to the estuary is greatly inhibited.

The ecological assessment of the Estuary concluded leachate is not having an adverse affect on the chemical status of the seawater adjacent to the site. It also noted that many contaminants are poorly soluble in water and accumulate in sediments at greater concentration than in the overlying water column. The ecology report also concludes that the results of the leaching test indicate that the leachable content of metals from sediments adjacent to the site is low. Terrestrial habitats on or adjacent to the site were considered to be of low conservation importance and low ecological value. The surface water monitoring data indicates that the landfill is not having a significant impact on the Estuary, however impacts from other point sources upstream of the landfill may be impacting on the ecological status of the Estuary.

6.4.2 Groundwater

The bedrock aquifer is characterised by the GSI is classified as a locally important (**Ll**) being productive in local zones. This means groundwater flow paths are generally short 10s to 100s of metres at most and that there is shallow groundwater discharges to the Estuary.

There are no groundwater abstraction wells within 500m of the landfill site. The Tier II Site Investigation identified the presence of silt/clay layer beneath the waste (This clay layer greatly inhibits the vertical migration of leachate to the bedrock aquifer). It is also likely that groundwater in this area is at best brackish given its proximity to the sea. The groundwater pathway is not considered to be significant.

6.4.3 Landfill Gas

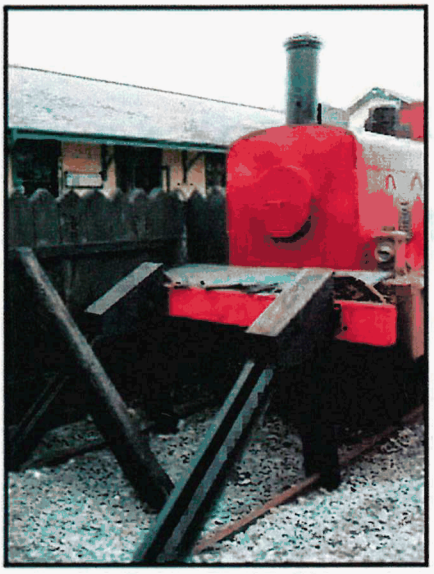
Elevated methane and carbon dioxide levels persist in Gas Well 1 and 3, Leachate Wells 5 and 6, with lower levels in Gas Well 2. Gas Well 3 and Leachate Wells 5 and 6 are at a distance from the buildings in areas that are landscaped. Landfill gas can vent to the atmosphere in these areas, thereby reducing the potential for the build up of gas pressures within the waste, which is the driver for gas migration.

Gas Wells 1 and 2 are located close to the Model Railway Buildings (Figure 4.1) in an area that is primarily covered by buildings and paving. Therefore the potential exists for landfill gas build up and migration into services adjacent to or within the buildings. To assess the risk of landfill gas build up, monitoring was undertaken within the Model Railway Building and along electrical service ducts. A copy of the report that was completed can be found in Appendix 8. No methane or carbon dioxide was detected at any of the monitoring locations within the building (apart from 0.2% CO_2 in one of the urinal drains). .

To further evaluate the risk posed by landfill gas, an assessment of the building construction was undertaken by Cork County Council. There appears to be a layer of granular material extending beneath the entire building footprint, the external seating areas and the model railway line, as indicated in the photos below.

While the thickness of the granular layer is not known, it should provide a pathway for gases to vent to atmosphere, and it is probable that this has reduced the risk of landfill gas build up in the underlying waste. The monitoring carried out to date inside the buildings has not identified the presence of landfill gas, however the monitoring should be conducted on a quarterly basis to confirm the absence of gas within the structure.

It is recommended that no future works are carried out that might seal off the granular layer and reduce its potential to act as a ventilation pathway for the gases.



Photos showing Hard Core Gravel Fill in front of Model Railway Building

External Public Seating Areas also lined with Gravel Fill to rear of Model Railway Building

7.0 CONCLUSIONS AND RECOMMENDATIONS FOR TIER II MAIN INVESTIGATION

7.1 Conclusions

Risk Category –The Tier II Exploratory Investigation showed that there is no major contamination within Clonakilty Landfill (i.e. the waste is largely inert). There was no direct drainage connection found between the landfill and the adjacent surface water body. This has reduced SPR No.8 and No.9 to a Low Risk (from a previous high risk) following a Re-run of the SPR Linkage scores. The Landfill Gas Risk (i..e SPR No.10 & 11) remains high following the measurement of high methane levels from two of the gas wells during the gas monitoring period.

Landfill Gas – High Gas levels were found in Gas Well No. 1 and Gas Well No.3. The risk from landfill Gas remains high following the Tier II Investigation.

Groundwater – The risk to the groundwater is considered to be low. The Tier II Exploratory Investigation showed that there is a low to medium permeability SILT/CLAY layer under the landfill.

SPA, SAC, NHA - The risk to the adjacent protected areas from the landfill has been reduced following the on site investigations. This is primarily due to no direct drainage connection being found between the landfill and Clonakilty Bay. Although high levels of Ammonia were found in surface water samples it is concluded that these levels are likely to be from other sources (to be confirmed by a QRA).

Surface Water - The risk to the adjacent surface water from the landfill has been reduced following the on site investigations. This is primarily due to no direct drainage connection being found between the landfill and Clonakilty Bay. Although high levels of Ammonia were found in surface water samples it is concluded that these levels are likely to be from other sources (to be confirmed by a QRA).

Quantitative Risk Assessment Findings - The QRA indicates that the only significant Source-Pathway-Receptor linkage existing at the site is for landfill gas.

While levels of carbon dioxide and methane exceeding the DOEH&LG guideline limits were detected in monitoring wells close to the Model Village Buildings, monitoring of the electrical ducts in the buildings and in the indoor areas has not detected either methane or carbon dioxide.

The buildings appear to have been founded on a granular foundation that extends outside the building footprint. This granular foundation appears to act as a pathway for the ventilation of landfill gas thereby minimising the risk of landfill gas build up within the building services or within the building.

Given that the building design appears to provide the necessary mitigation measures to minimise the landfill gas risk no further remedial measures are considered necessary.

7.2 *Recommendations*

It is recommended that monitoring be conducted on a quarterly basis in service ducts and within the buildings to confirm the absence of landfill gas.

It is recommended that no future works are carried out that might seal off the granular layer and reduce its potential to act as a ventilation pathway for the gases.