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Administration,
Office of Climate, Licensing & Resource Use,
Environmental Protection Agency,
P.O. 3000,
Johnstown Castle Estate,
County Wexford.

8th January 2009.

Re: Review Application in respect of Kinsale Road Landfill at Ballyphehane, Curraghconway, Inchisarsfield, South City Link Road, Cork **Ref: W0012-03**

Dear Sir/Madam,

I refer to the above application and enclose herewith an original and two copies of Hydrogeological Assessment Report in respect of same.

I would be obliged if you could acknowledge receipt at your convenience.

Yours sincerely,

J.T. MOYNIHAN
ADMINISTRATIVE OFFICER
ENVIRONMENT

HYDROGEOLOGICAL ASSESSMENT REPORT

KINSALE ROAD LANDFILL

CORK

EPA WASTE LICENCE REF. W0012-02

ORIGINAL

Prepared for:

Cork City Council
City Hall
Cork

Prepared by:

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January 2009

HYDROGEOLOGICAL ASSESSMENT

KINSALE ROAD LANDFILL

CORK

EPA WASTE LICENCE REF. W0012-02

User is Responsible for Checking The Revision Status Of This Document

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Client: Cork City Council

Abstract: Fehily Timoney and Company (FTC) was retained by Cork City Council to prepare a detailed hydrogeological assessment for the Kinsale Road Landfill Site. The report presents an outline of the site history, infrastructure, geology, hydrology and hydrogeology. The report includes a water balance assessment from 2007 and presents a risk screening of Groundwater Directive List I and List II chemicals which are routinely tested under the licence conditions.

Keywords: Kinsale Road Sanitary Landfill, Waste Licence W0012-02, Hydrogeological Assessment, Geology, Hydrogeology, Hydrology, Groundwater Directive, Interim Guidance Values.

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1. INTRODUCTION

The Kinsale Road Landfill is licensed by the Environmental Protection Agency (hereafter referred to as 'the Agency') for the disposal and recovery of waste (Waste Licence Ref. W0012-02). As part of the Waste Licence Review for the establishment of a waste transfer station, , Cork City Council is required to submit a hydrogeological assessment of the site in order to assess risks associated with leachate on the site and the potential for leachate to enter the groundwater and surface water systems on or close to the site.

This report presents an overview of the site geology, hydrology and hydrogeology, and presents a basic model of the site characteristics. This study includes a substance specific risk screening in terms of the chemicals tested from List I and II of the 1979 Groundwater Directive (80/68/EEC). No trigger values presently exist for these parameters on this site.

The first water balance assessment was submitted to the Agency in 1997 as part of the Waste Licence Application. Fehily Timoney and Company (FTC) prepared subsequent water balance calculations annually thereafter for inclusion in the facility's Annual Environmental Report submitted to the Agency. The most recent water balance calculation was conducted 2007 data and this data is referenced in this report.

2. SITE SETTING

The Kinsale Road Landfill is located in the Tramore River Valley and covers an area of approximately 61.5 hectares, including the Blackash Road Park and Ride Facility site. It is bounded to the south and west by the South City Ring and Link Roads respectively, to the north by residential development and to the east by playing pitches.

2.1. Site History

The site commenced operation as a landfill in approximately 1963, with waste filling at the north-western corner of the site, now an ESB-owned pitch & putt course. Waste deposition subsequently developed to the eastwards of this location. Geographical constraints at the time limited further landfilling of this area, and in approximately 1975, landfilling operations commenced at the area presently referred to as the Blackash Road site, west of both the existing landfill and the South City Link Road. Waste filling to these locations was completed by the early 1980s, at which time the Blackash Road site was capped with approximately 1 m of clay and was subsequently developed as a Park and Ride Facility.

After the Blackash Road waste filling phase, landfilling was recommenced in the main site, to an area south of the pitch & putt course, and was also carried out in areas south of the original course of the Tramore River until the river was diverted southwards to its current route (in the 1990s) which resulted in the merging of the landfills.

The landfill was developed as a dilute and disperse-model facility, with waste placed directly onto unlined ground surfaces. Site ground conditions are discussed in Chapter 3 of this report.

2.2. Site Infrastructure

Existing infrastructure at the site comprises:

- Administrative offices,
- Civic amenity facility
- Timber recycling facility
- C & D reprocessing facility
- Stormwater pond and reed beds
- Covered leachate lagoon and contaminated stormwater lagoons
- Leachate conditioning plant and temporary stormwater conditioning plant
- Landfill gas abstraction and flaring/electricity generation infrastructure
- Park and ride car parking area
- Green waste composting facility.

To date, approximately 140,200 m^2 of the main landfill has been capped using an engineered cap including a geomembrane. The capped areas are shown in Drawing No. 2007-011-003-03 (Appendix A). An engineered cap has also been constructed over the Blackash Park and Ride Facility site, an area of approximately 3 ha. The next area scheduled to be capped is marked as Contract 09 on the drawing.

2.3. Summary of Waste Quantities

Table 2.1 summarises the annual waste quantities accepted at the site. It is noted that from 1997 to 2001, amounts exceeding 140,000 tonnes per annum (TPA) were landfilled. It is estimated that these materials were approximately 50% Construction and Demolition waste (C&D) with the remaining 50% consisting of Municipal Solid Waste (MSW).

From 2001 onwards, commercial waste was subject to quota and finally banned entirely as were other non Cork Corporation (City Council) materials. All C&D wastes were stockpiled, crushed and if suitable, used in the Agency-approved engineered landfill cap. Waste landfilling to unlined areas at the site will not be permitted after July 2009 in accordance with the Landfill Directive.

Table 2.1: Waste Quantities Placed at the Site

Year	Waste Acceptance (tonnes/annum)	Waste-In-Place (tonnes)	Year	Waste Acceptance (tonnes/ annum)	Waste-In-Place (tonnes)
1964	18,500	18,500	1988	67,000	943,000
1965	18,900	37,400	1989	67,000	1,010,000
1966	19,200	56,600	1990	70,000	1,080,000
1967	19,600	76,200	1991	70,000	1,150,000
1968	20,300	96,500	1992	80,000	1,230,000
1969	20,500	117,000	1993	100,000	1,330,000
1970	23,000	140,000	1994	120,000	1,450,000
1971	21,000	161,000	1995	130,000	1,580,000
1972	25,900	186,900	1996	130,000	1,710,000
1973	25,100	212,000	1997	140,000	1,850,000
1974	29,000	241,000	1998	159,000	2,009,000
1975	32,000	273,000	1999	172,000	2,181,000
1976	35,000	308,000	2000	186,000	2,367,000
1977	38,000	346,000	2001	201,000	2,568,000
1978	41,000	387,000	2002	125,000	2,693,000
1979	44,000	431,000	2003	125,000	2,818,000
1980	47,000	478,000	2004	72,000	2,890,000
1981	50,000	528,000	2005	61,000	2,951,000
1982	53,000	581,000	2006	41,480	2,992,480
1983	54,000	635,000	2007	38,000	3,030,480
1984	57,000	692,000	2008	67,200	3,097,680
1985	59,000	751,000	2009	70,000	3,167,680
1986	61,000	812,000			
1987	64,000	876,000			

Notes on Table 2.1:

1. Waste totals in the above table are inclusive of waste placed at the Park & Ride and Blue Demons Sites.

3. GEOLOGY AND HYDROGEOLOGY

The literature reviewed included:

1. Groundwater Protection Scheme for County Cork, 1999 (on GSI website)
2. Geology of South Cork - Sheet 25 (GSI, 1995)
3. Geology of The Cork District - 1:40,000 scale map (UCC, 1988)
4. General Soil Map of Ireland - Second Edition. (National Soil Survey 1980)

3.1. Existing Soils and Geology

The existing geology is described in terms of the bedrock geology, overburden geology and hydrogeology.

3.1.1. Surface Soils

The General Soil Map of Ireland, 1:575,000 scale shows that the soils of this area of Cork belong to the "Rolling Lowland" broad physiographic division.

The site area includes principal Acid brown Earth soils with associated Grey Brown, and Gleys derived from mixed sandstone and limestone glacial tills.

3.1.2. Quaternary Geology

Figure 3.1 shows a summary of the Quaternary Geology for the site and surrounds. The majority of the site is shown to be underlain by made ground (landfill), surrounded by glacial till derived predominantly from Devonian sandstones.

The site area is also known to have been located within an area of bogland which lay on the floodplain of the Tramore River. As discussed previously, the course of the Tramore River was diverted to the south of the site in 2001.

3.1.3. Bedrock Geology

Figure 3.2 shows a summary of the bedrock geology of the site and surrounding area. The survey "*Geology of South Cork*"' (Geological Survey of Ireland (GSI), 1995) is the reference source for the description of the bedrock geology of the region. The GSI 1:100,000 scale bedrock geology map (Sheet 25) shows that the site covers two distinct east-west trending stratigraphies.

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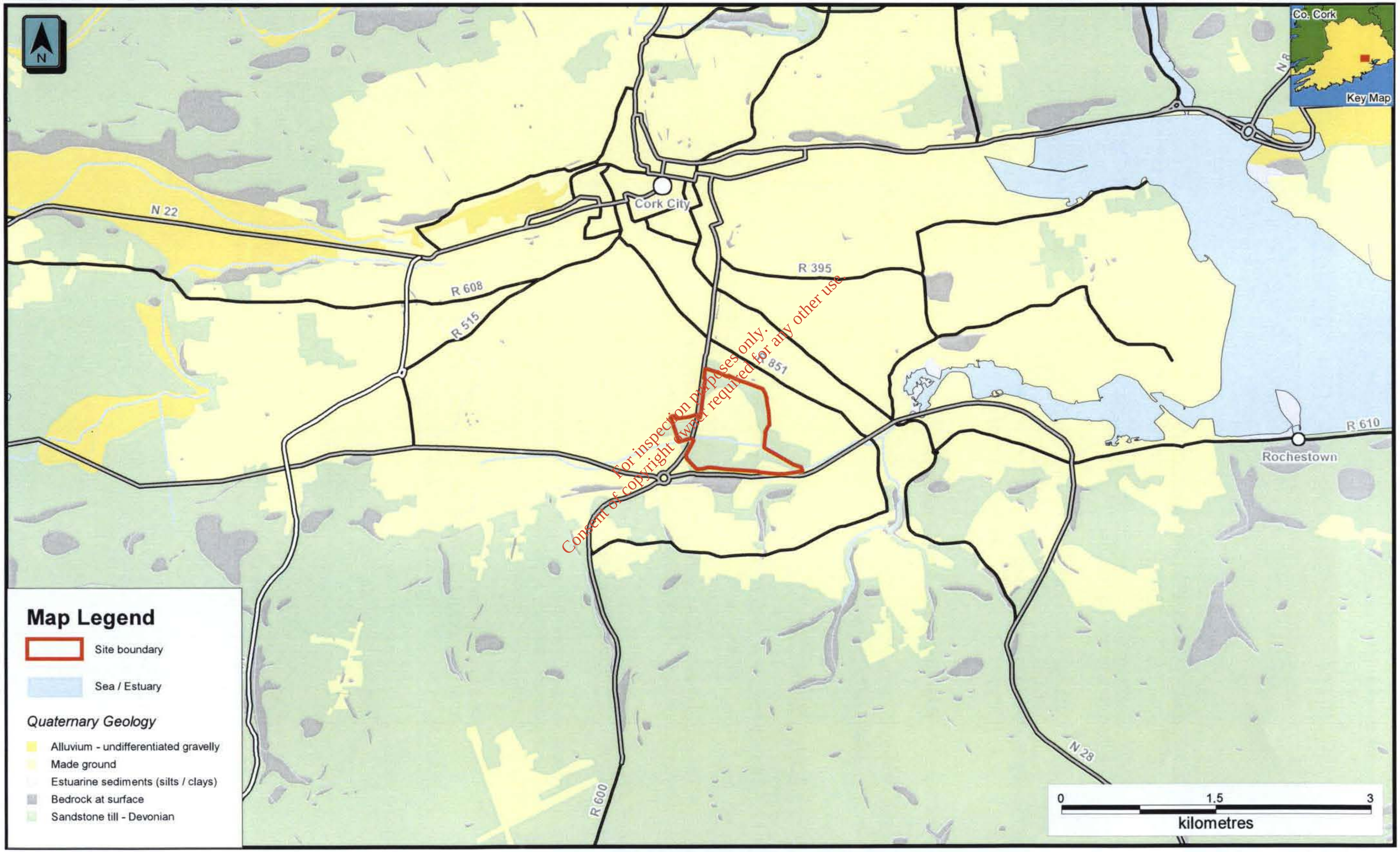
CE08-011-05_Figure 3.1_Quaternary Geology_Rev A



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Quaternary Geology

Figure 3.1

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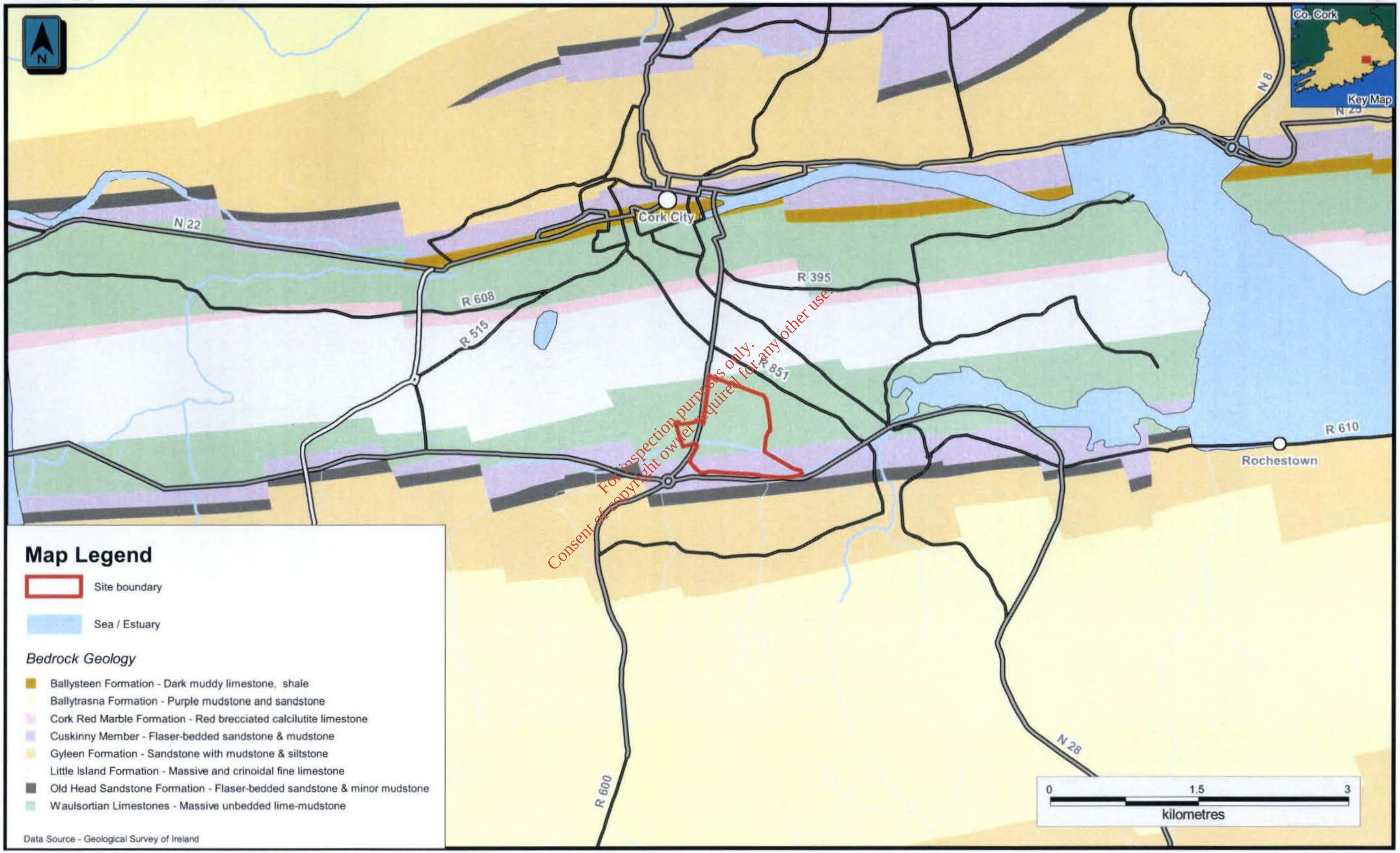

Map Legend

Site boundary

Sea / Estuary

Bedrock Geology

- Ballysteen Formation - Dark muddy limestone, shale
- Ballytrasna Formation - Purple mudstone and sandstone
- Cork Red Marble Formation - Red brecciated calcilutite limestone
- Cuskinny Member - Flaser-bedded sandstone & mudstone
- Gyleen Formation - Sandstone with mudstone & siltstone
- Little Island Formation - Massive and crinoidal fine limestone
- Old Head Sandstone Formation - Flaser-bedded sandstone & minor mudstone
- Waulsortian Limestones - Massive unbedded lime-mudstone

Data Source - Geological Survey of Ireland

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Bedrock Geology

Figure 3.2

The majority of the site, excluding the extreme south of the site, is underlain by Carboniferous age (Dinantian) Waulsortian Limestone Formation which comprises massive, unbedded fine-grained limestone, part of a thick sequence of limestones which were deposited in the South Munster Basin during the Carboniferous period. The beds reach a thickness of about 750 m in the Fermoy area and somewhat less in the Mitchelstown area.

The southernmost part of the site is underlain by Carboniferous (Dinantian) Kinsale Formation. The strata comprises flaser bedded sandstone and mudstone. The Kinsale Formation within this area is represented by the Cuskinny Member which consists of relatively thick, sometimes conglomeratic sandstone units alternating with thin mudstones with sandstone laminae, massive claystone and heterolithic sediments.

3.1.4. Structural Geology and Topography

The topography of the Cork area is one of undulating hills and valleys which have been formed as a result of the east-west trending anticlines and synclines formed during the Variscan Orogeny. The folding events followed the deposition of vast thicknesses of limestones during the Carboniferous age. The ridges consist of sandstones and mudstones of the older Devonian 'Old Red Sandstone' while the valleys are floored by poorly exposed Carboniferous limestones, often covered by recent Quaternary sediments.

Structurally, apart from the regular folding of the strata, the area is cut by several faults which predominantly trend in a north-northwest to south-southwest direction. The faults occur within all formations although they are common within the Carboniferous Limestone and are largely absent from the Devonian Old Red Sandstones.

The dip of the bedrock is again dictated by the east-west trend of the folding. Due to the nature of the limestones, forming the core of the synclines, it is likely that the bedding will be near-horizontal. However due to the massive nature of the limestone deposition, no dip direction is given on the geological maps of the area. As the Kinsale Formation is located on the southern limb of the syncline, these beds dip steeply, approximately 85° to the north.

3.2. Regional Hydrogeology

3.2.1. Aquifer Classification

The GSI categorises the Carboniferous limestone in Cork as a Regionally Important Aquifer - Karstified, diffuse (Rk). The aquifer provides typical well yields of between 200 to 1,500 m^3/d and specific capacities of between 150 to 750 m^3/d/m. The capacity of the aquifer depends on the degree of fracturing and faulting within the rock.

The Kinsale Formation is classified as a Locally Important Aquifer (LI). Well yields within this stratum typically range from 20-50 m^3/d, except in low-lying faulted areas or the more permeable units where they may be in excess of 200 m^3/d. The aquifer classifications are shown in Figure 3.3.

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CE08-011-05_Figure 3.3_Aquifer Classification_Rev A

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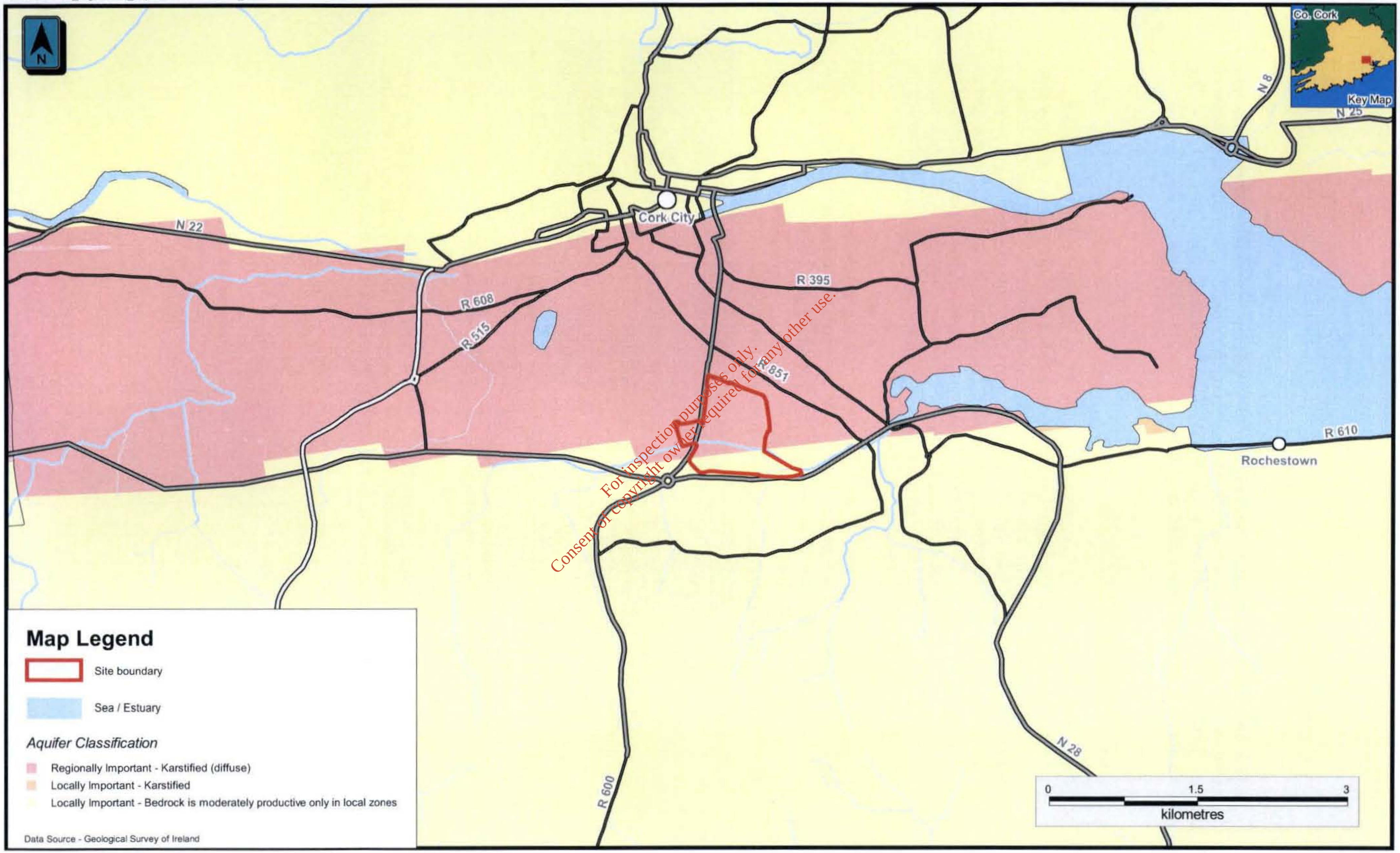

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Aquifer Classification

Figure 3.3

The waters in these aquifers are predominantly calcium magnesium bicarbonate type waters with total dissolved solids of less than 500 mg/l. The total hardness of groundwaters in the sandstones is usually less than 200 mg/l (as $CaCO_3$). The hardness of the limestone waters usually range from 200-400 mg/l (as $CaCO_3$).

3.2.2. Groundwater Vulnerability

Groundwater vulnerability, as defined by the GSI, is the term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. The factors used in assessing groundwater vulnerability include subsoil type and thickness, and recharge type. The GSI procedure whereby groundwater protection is assessed is outlined in the EPA-GSI publication 'Groundwater Protection Schemes'. The procedure proposes a matrix, which relates vulnerability, source and resource such that a particular site is given a Response ("R") to specific activities. The GSI vulnerability assessment is shown classification is shown on Figure 3.4.

Previous site investigations on the site show that the overburden cover over the bedrock varies across the site, being thickest in the south of the site and thinnest in the north. Table 3.1 details the assessed aquifer vulnerability of the site.

Table 3.1: GSI Guidelines – Aquifer Vulnerability Mapping

Vulnerability rating	**Hydrogeological Conditions**		
	Subsoil Permeability (Type) and Thickness		
	High Permeability (Sand/gravel)	**Moderate Permeability (e.g. Sandy soil)**	**Low Permeability (e.g. Clayey subsoil, clay, peat)**
Extreme (E)	0 - 3.0 m	0 - 3.0 m	0 - 3.0 m
High (H)	>3.0 m	3.0 -10.0 m	3.0 - 5.0 m
Moderate (M)	N/A	>10.0 m	5.0 - 10.0 m
Low (L)	N/A	N/A	>10 m

Notes:
N/A = Not Applicable
Precise permeability values cannot be given at present.
Release point of contaminants is assumed to be 1-2m below ground surface.

The GSI's Response Matrix for Landfills combines the aquifer vulnerability (M-H), and the classification of the aquifer (Rk/LI), to give a response for site suitability for landfills. Table 3.2 details the response matrix for landfills under the GSI guidelines.

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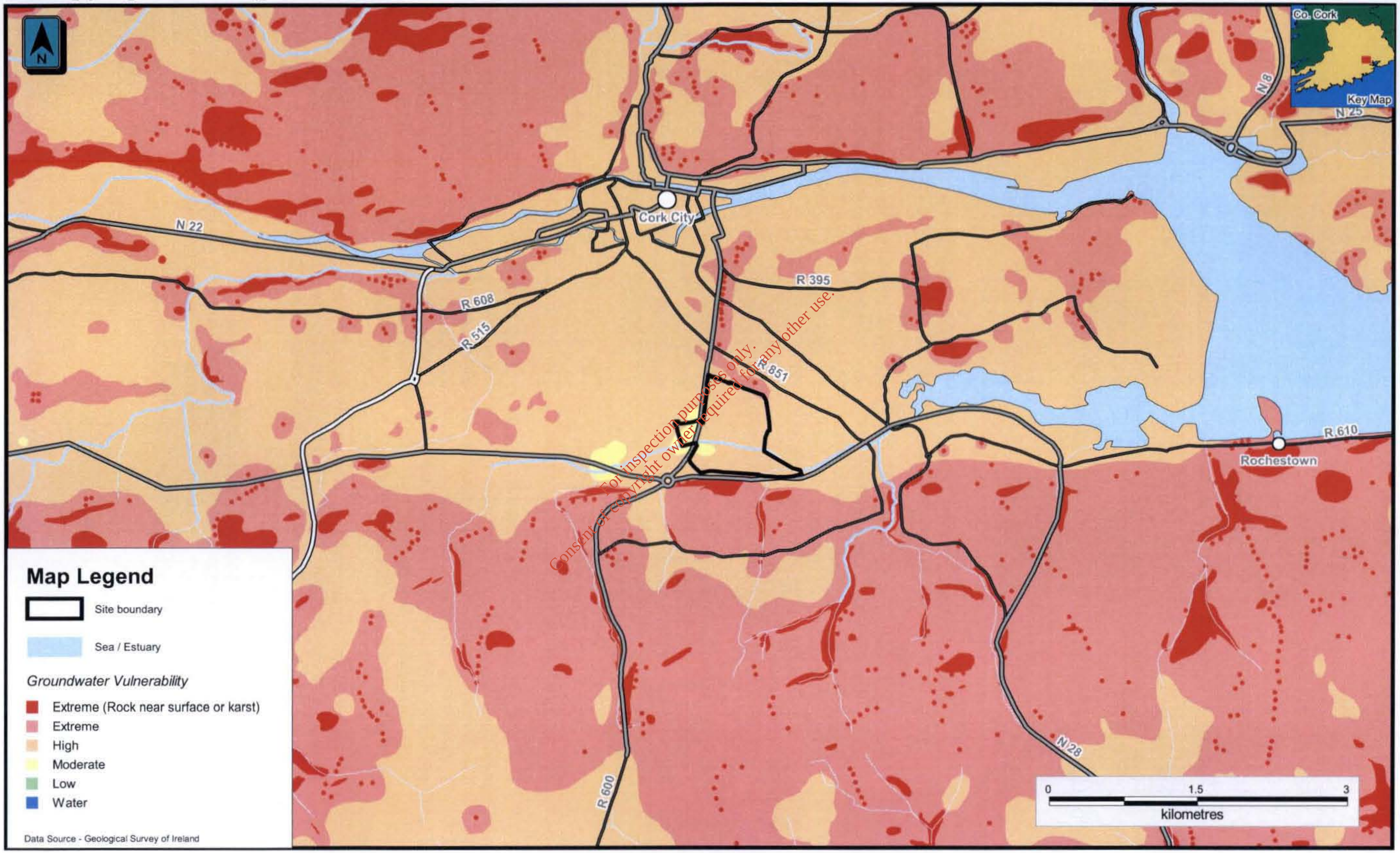

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Groundwater Vulnerability

Figure 3.4

Table 3.2: GSI Guidelines – Response Matrix for Landfills (limestone aquifer)

Vulnerability Rating	RESOURCE PROTECTION Aquifer Category					
	Regionally Important (R)		Locally Important (L)		Poor Aquifers (P)	
	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	R4	R4	R3[2]	R2[2]	R2[2]	R2[1]
High (H)	R4	R4	R3[1]	R2[1]	R21	R1
Moderate (M)	R4	R3[1]	R2[2]	R2[1]	R2[1]	R1
Low (L)	R3[1]	R3[1]	R1	R1	R1	R1

- This guidance is for the siting of landfills for non-hazardous wastes.
- New landfills should not generally be developed on regionally important aquifers.
- The siting, design, operation and monitoring of landfills must comply with the guidelines outlined in the EPA's Landfill manuals except where facilities hold a waste licence issued by the EPA.
- It is recommended that all landfills be located in, or as near as possible to, the zone in the bottom right hand corner of the matrix.
- Special attention should be given to checking for the presence of more permeable zones, such as faults, particularly in fractured bedrock."

Thus, a resource protection response for the limestone aquifer of R4 is adopted. According to the EPA Landfill Design Manual (1999), "R4" is "Not acceptable". Although the landfill was opened and licensed well before the Landfill Design Manual was produced, it is worth noting that this hydrogeological setting would not now be acceptable for the siting of a landfill.

3.3. Site Geology

The geology of the Kinsale Road Landfill is interpreted from a number of site investigations carried out since 1987. The first site investigation was carried out by K.T. Cullen Ltd. and involved the installation of wells prefixed by the letters 'KC', many of which have since been decommissioned during site activities. The main source of geological information is the site investigation activities carried out as part of waste licence application, prepared in 1997. This involved the installation of wells prefixed with the letters 'OB' (for overburden wells), or 'BR' (for bedrock wells).

To monitor the effectiveness of the leachate collection drain at the site, nine overburden wells were also installed (prefixed with the letters NW), from which data is collected on a monthly basis. These have been used to establish overburden groundwater quality.

For the previous water balance assessments, three bedrock monitoring wells (BH1, BH2, BH3) and two leachate wells (L1, L2) were installed within the body of the landfill. The purpose of these wells is primarily to establish vertical gradients between the aquifer and the leachate and confirm groundwater flow directions.

A geophysical survey was also carried out at the eastern boundary of the site during October – November 2003. This was carried out to augment the geophysical information collected in 1997 and to locate a suspected North - South fault.

From the site investigations, the geology of the site can be summarised as follows:

- Average of approximately 20 m of municipal solid waste.
- Up to 6 m of peat
- Up to 11 m of silty clay
- Up to 3 m of gravel
- Limestone or sandstone/slate bedrock

3.3.1. Waste

Historical data indicates that disposal of waste commenced in about 1963 at the area now occupied by the ESB Pitch and Putt course. Drilling carried out on that site indicates up to 10 m of waste, capped with approximately 1 m of low permeability clay. The waste rests directly on natural material. Levels of waste deposited in the main landfill vary and indications are that waste can be 5 m below original ground levels in limited places.

It is probable that the weight of the waste above the peat and silty clays has resulted in their settlement (and surging). The highest finished formation level of the landfill (post-settlement) is about 25 mOD.

3.3.2. Peat

Peat deposits are present across the entire site, being thickest along the river channels on the southern side of the site, and thinning towards the northern part of the site, where it is largely absent. The presence of peat is confirmed by trial pits and trenches excavated outside the extent of the waste. Recent drilling at the site, through the waste body, indicated the presence of peat at only one location. Its absence (or it not being detected) may be attributed to:

- The compaction of the peat
- The displacement of the peat by the loading of waste
- The drilling technique

Samples of peat were collected previously by others and analysed for hydraulic conductivity, both laboratory and field measurements. Available information is summarised in Table 3.3.

Table 3.3: Hydraulic Conductivities of Peat

Material	Hydraulic Conductivity Laboratory (m/sec)	Location	Hydraulic Conductivity Field (m/sec)
Peat	4.9×10^{-8}	BH 1 ASP (1989)	3.5×10^{-7} N
Peat	7.3×10^{-8}	BH 3 ASP (1989)	9.2×10^{-7} N

N = Denotes Northern Section of Site.

Laboratory values are lower by more than an order of magnitude and may be considered more representative of vertical hydraulic conductivity. Field measurements are affected by lateral water movements.

3.3.3. Silty Clay

Underlying the peat is pink silty clay. In the northern parts of the site, sand and gravel lenses are present in this material. The peat and the clays confine the underlying bedrock aquifer.

Samples of the clay were collected previously by others and during the site investigation carried out in 2003 at the Blackash Road site. The samples collected during the site investigation at the Blackash Road were analysed for a wide range of geotechnical parameters, including hydraulic conductivity. The historic data and recent data is summarised in Table 3.4.

Table 3.4: Hydraulic Conductivities of Silty Clay

Material	Hydraulic Conductivity Laboratory (m/s)	Location	Hydraulic Conductivity Field (m/sec)
Silty Clay	1.8×10^{-9}	LG 12 FTW (1997)	7.5×10^{-8} S
Silty Clay	1.4×10^{-9}	LG 13 FTW (1997)	3.66×10^{-7} S
Silty Clay	1.8×10^{-9}	OB 4 FTW (1997)	4.4×10^{-7} S
Sandy Clay	4.5×10^{-10}	BH6 Glover (2003)	---

S = Denotes Southern Section of Site.

Again, the values obtained in the laboratory are much lower than those obtained from field tests.

3.3.4. Gravel

The sands and gravels are not continuous beneath the site. They appear to grade into gravelly clay beneath the centre and southern part of the site but thicken as sands and gravels in the northern areas. These are water-bearing strata.

3.3.5. Limestone Bedrock

Much of the site is underlain by Waulsortian limestone bedrock. The limestone is highly fractured and is infilled with alluvial silts in the mid to southern section of the site. The south-eastern section of the site is underlain by siltstone/mudstone, which is weathered. This unit is considered to be part of the Kinsale Formation Sandstone, which forms the high ground to the south of the site.

A geophysical survey, undertaken as part of the preparation of the Waste Licence Application in 1997, indicated the presence of a fault zone trending east-west in the southern section of the site. Within the fault zone the rock is highly fractured. To the south of the fault zone the rock is comprised of sandstone and grey slates of the Kinsale Formation Sandstone (Cuskinny Member).

To the north of the fault the bedrock comprises blue grey Waulsortian Limestone of varying degrees of competence.

In November 2003, an additional geophysical survey was carried out in the north-west area of the site, to the north of the current administration buildings. This survey indicated the presence of another possible fault zone or buried channel, trending north-south near the north-west boundary of the site. The survey also shows a marked increase in overburden thickness within this part of the site.

3.4. Site Hydrogeology

As discussed, several site investigations have taken place at the Kinsale Road landfill, involving the installation of a number of environmental monitoring boreholes. The Waste Licence (Ref W0012-02, from www.epa.ie) requires environmental monitoring of the following boreholes:

- Boreholes prefixed with the letters BR or KC, installed into the bedrock aquifer. Those prefixed with the letters OB are installed into the overburden. The purpose of these wells is to monitor the groundwater quality of the relevant aquifer on a quarterly basis.
- Boreholes prefixed with the letters NW are boreholes installed adjacent to the leachate collection drain, into the overburden. The purpose of these wells is to assess overburden water quality, and monitor the efficiency of the leachate collection drain. They are monitored on a monthly basis.

The monitoring locations are shown on Drawing No. CE080011-01-001 (Appendix B). Details of the required testing regime are shown on the extract of the waste licence, reproduced as Appendix D. These wells, and additional wells installed, were used to establish groundwater flows, throughput and vertical groundwater movement.

3.4.1. Groundwater Flow

The Kinsale Road area was largely bog before its development as a landfill; hence a perched groundwater table was present in the peat, essentially at its original ground level. The peat is underlain by a variable thickness (generally at least 2 metres) of low-permeability pink/grey silty/sandy clay, which acts as an aquiclude, restricting the vertical groundwater movement.

The low-permeability silty clay and peat act as a confining layer over the limestone bedrock aquifer, at least in the central and southern areas of the site.

Previous groundwater readings within the bedrock monitoring wells on the site indicate that groundwater flow is generally to the east.

3.4.2. Gradients

Horizontal Gradients

Because the limestone bedrock aquifer is a major aquifer, the groundwater gradient is correspondingly low. The gradient measured from previous groundwater data indicates that the bedrock horizontal gradient is approximately 0.003.

Gradients within the waste body are much higher, typically around 0.05, both because of the surface expression of the landfill, and the low permeability of the waste body.

Vertical Gradients

The vertical groundwater flow at the site is important, since it will determine whether leachate will leak to the underlying bedrock aquifer or not. For the three new well pairs installed, the difference in head between the leachate borehole and the bedrock borehole was determined, and the vertical distance between each well pair was measured. A range of vertical hydraulic gradients were obtained (see Table 4.4).

The formula used to calculate the vertical gradient was as follows:

$$Gradient_{vertical} = \frac{dl}{dx}$$

Where:

dl = Head difference between the leachate well and the bedrock well

dx = Vertical difference between wells

Table 3.5 shows the depths to water as measured from the Top of the Chamber (TOC) for each respective well in January 2008. The leachate head has been obtained from leachate wells at the site and the piezometric head of the confined bedrock groundwater aquifer from the monitoring wells. This data is presented in Table 3.6.

Table 3.5: Depths to Groundwater

Monitoring Location	Easting	Northing	Depth to Water from TOC Measured (m)	TOC (m)OD
BH1	168336	69570	9.1	25.4
L1	168334	69571	7.58	25.32
BH2	168222	69584	7.53	20.3
L2	168219	69582	5.44	20.41

Table 3.6: Vertical Gradients

	Well Pairs	Water Level (mOD)	dl	dx	$^{dl}/_{dx}$
Leachate/Bedrock Monitoring Boreholes	BH1	16.3	1.44	-22.09	-0.0652
	L1	17.74			
	BH2	12.77	2.2	-27.76	-0.0793
	L2	14.97			

Note: Water / leachate levels measured January 2008

Positive values indicate an upwards-vertical gradient, whereas negative values indicate that the vertical hydraulic gradient is downwards. From Table 3.6, it is apparent that the leachate has the potential to migrate downwards to the bedrock aquifer.

To change the vertical gradient between the bedrock and leachate from downwards to upwards, the leachate level in the active area would need to be lowered to approximately 3.0 mOD. As capping works progress, the amount of rainfall infiltrating into the active area will decrease and this will cause the leachate head to lower to this level.

3.4.3. Throughput

Horizontal Throughput (Overburden)

Overburden groundwater contours to the west of the Kinsale Road Landfill are not well defined. Therefore the quantity of water reaching the landfill from this area is unknown, though with the current high leachate head, it is unlikely to be significant. Lowering of the leachate head at the landfill will allow groundwater ingress from the west, the quantity of which will be strongly limited by the low permeability of the peats and clays.

Horizontal Throughput (Bedrock)

Horizontal throughput is calculated through a measurement of horizontal gradients, and previously collected pump test data. The following equation is used:

$$Throughput = T.w.\frac{dh}{dl}$$

Where:

T (Transmissivity, from old pump test data) = 285 m^2/day

w (western perimeter length of Landfill) = 650 m (Tramore River to ESB Pitch & Putt)

$\frac{dh}{dl}$ *(Horizontal Hydraulic Gradient)* = 0.003 for bedrock aquifer

Therefore, throughput is 556 m^3/day (or 202,940 m^3/year) for the bedrock aquifer.

This calculation, and all other calculations in this report, assumes homogeneity of each individual geological unit (i.e. clay, bedrock, waste, etc.). Over a really extensive site, such as the Kinsale Road landfill, experience has shown that local factors (such as buried channels, springs, faults, disused drainage networks etc.) may strongly influence the quantity and direction of groundwater throughput.

Vertical Throughput (migration)

The vertical throughput, i.e. a quantification of the migration of leachate to the underlying aquifer through the clay, is presented below. Using the parameters for the peat and silty clays given in the original waste licence application, the vertical leachate migration is estimated.

The equation for migration to groundwater is given as follows:

$$Migration = \frac{k(h_1 - h_2)}{b}$$

Where:

k = hydraulic conductivity, this value varies in the site from a maximum of 1.8 x 10^{-9} m/sec (1.56 x 10^{-4} m/day) to a minimum of 4.5 x 10^{-10} m/sec (3.89 x 10^{-5} m/day).

b = clay thickness = 8 m (south of site) and 2 m (north of site)

h_1 = head of leachate = 16.4 m OD (south, average of leachate level in borehole L1 and L2) and 4.5 m OD (north, assumed)

h_2 (groundwater level in bedrock) = 4.2 m OD (average for site, obtained from Cork City Council 2007 monitoring data)

Because the peats and clays reduce in depth to the north and because leachate head increases greatly to the south, calculations have been made for the northern and southern portions of the site separately.

3.4.4. Northern Portion of the Site

$$Migration = \frac{3.9\times10^{-5}\times(4.5-4.2)}{2} \quad \text{or} \quad = \frac{1.6\times10^{-4}\times(4.5-4.2)}{2}$$

for the range of permeability values.

Therefore:

Migration = 5.85 x 10^{-6} to 2.4 x 10^{-5} m^3/day per m^2 landfilled area in northern portion of site (This is equivalent to 0.06 to 0.24 litres per day per m^2 of the landfill)

The area of waste in northern portion of site = 232,500 m^2. Hence in the Northern Portion of the Site, potential migration to bedrock ranges from: 1.36 m^3/d to 5.58 m^3/d.

3.4.5. Southern Portion of the Site

$$Migration = \frac{3.9 \times 10^{-5} \times (16.4 - 4.2)}{8} \quad \text{or} \quad = \frac{1.6 \times 10^{-4} \times (16.4 - 4.2)}{8}$$

for the range of permeability values.

Therefore:

Migration = 5.95×10^{-5} to 2.44×10^{-4} m^3/day per m^2 landfilled area in southern portion of site (This is equivalent to 0.006 to 0.02 litres per day per m^2 of the landfill)

The area of waste in southern portion of site = 274,630 m^2. Hence in the southern portion of the site - potential migration to the bedrock ranges from: 16.3 m^3/d to 67.0 m^3/d.

Table 3.7: Total Leachate Migration to Groundwater

Leachate Migration	Minimum (m^3/yr)	Maximum (m^3/yr)
Migration in the North Portion (m^3/yr)	496.4	2,036.7
Migration in the South Portion (m^3/yr)	5,949.5	24,455
Total Migration to the bedrock aquifer (m^3/yr)	**6,445.9**	**26,491.7**

This compares to a figure of 5,195 m^3/year calculated for the Waste Licence Application. The difference in figures is accounted for largely by the increase in the leachate migration calculated for the southern area of the site. This is a result of increased data on the leachate head in the area, obtained from a 2003 site investigation. The maximum figure calculated for the 2006 AER was 30,266 m^3, and the decrease over the 2007 period is due mainly due to the increased groundwater level in bedrock for the site i.e. from 3.5 m in 2006 to 4.2 m in 2007. Furthermore, the decrease in leachate migration may be associated with the decrease in leachate production during 2007. Calculations based on 2008 data were not yet complete at the time of writing.

3.5. Leachate Generation Volumes

The volumes of leachate produced, conditioned and discharged to sewer at the Kinsale Road Sanitary Landfill are provided in Table 3.8.

Table 3.8: Leachate Conditioning and Production Volumes (2007)

Month	Estimated Leachate Produced (m^3)	Volume of Treated Leachate (m^3)	Monthly surplus/deficit (m^3)
January	9,401	8,922	479
February	15,687	8,941	6,746
March	6,843	10,386	-3,543
April	0	9,099	-9,099

Month	Estimated Leachate Produced (m^3)	Volume of Treated Leachate (m^3)	Monthly surplus/deficit (m^3)
May	0	8,960	-8,960
June	9,882	8,568	1,314
July	3,886	9,446	-5,560
August	970	8,965	-7,995
September	0	8,025	-8,025
October	5,103	8,407	-3,304
November	5,429	8,236	-2,807
December	15,190	6,288	8,902
Annual Total	**72,390**	**104,243**	**-31,853**

Note on Table 4.10: Leachate is treated on site at the leachate conditioning plant.

The monthly surpluses/deficits given in the above table are not unexpected as there is a time lag between incident rainfall and leachate recovery. The use of monthly meteorological data in calculations may also lead to minor underestimation of leachate production values.

The figure of 72,390 m^3 of leachate produced in 2007 is 36.8% less than the 2006 figure (114,532 m^3). This decrease in leachate production is due to the decreased effective rainfall and modifications to the active landfill area size. There has also been an increase in the capped area (Phase 3 Capping Works - 3.4. hectares) of the landfill since 2007 which would further reduce leachate production. Table 4.10 has demonstrated that the leachate management infrastructure onsite is performing with sufficient reliability and at sufficient capacity to treat collected leachate.

Dilution of leachate by the bedrock aquifer can be estimated by dividing throughput by migration. The range of migration rates obtained means that leachate may be diluted by a factor of between 9 and 35.

3.5.1. Future Leachate Generation

With the completion of capping and closure of the landfill, infiltration of water into the waste body will be greatly reduced. Currently, the head of leachate reaches approximately 17.7 mOD at the highest area of the site. The invert level of the leachate drain surrounding the site is approximately 1 mOD. This head differential drives leachate towards the collection trench. With the reduction in infiltration, this head differential will gradually reduce, with two effects:

1. The drainage rate to the collection trench will reduce
2. The migration to the bedrock aquifer will reduce

4. HYDROLOGY

This chapter summarises the main drainage features in the area of the landfill, including the rivers and the main drainage infrastructure. Data on rainfall and evapotranspiration are presented for the most recent periods and for long-term averages. The landfill is divided into hydrological areas based on the surface finish/capping, slope and activity in order to estimate the volume of run-off and infiltration.

4.1. Surface Water

The landfill lies in the Tramore River Valley. The Tramore River flows along the southern site boundary for a length of approximately 1,250 m. It is the main river draining the site. It originally flowed through the centre of the site but was diverted along the southern boundary to permit enlargement of the landfill in the early 1990s. Remedial works on the river, to improve the fisheries, were carried out in 1999 and 2000. The original river channel was also considered to be an environmental risk, since it could be a preferential pathway for the eastward migration of leachate and landfill gas. Sheet piling was therefore carried out in 2001 across the channel to cut-off such a pathway. The sheet pile is adjacent to the eastern intersection of the leachate collection drain and the old Tramore River channel.

The new Tramore River channel is up to 8 m wide and less than 1 m deep. There are no hydrometric stations on the river. The river is tidal up to the south-eastern corner of the landfill. FTC recorded approximate flow measurements at the upstream and downstream locations during low tide conditions.

The Trabeg River flows along the eastern site boundary and part of the northern boundary for a length of approximately 1,200 m and meets the Tramore River at the southeast corner of the site. The lower section of this river was also diverted during diversion works on the Tramore River. The river channel is typically 4 m wide and less than 0.5 m deep. As with the Tramore River, there are no hydrometric stations on the Trabeg. Flow measurements recorded by FTC are summarised in Table 4.1.

Table 4.1: Summary of Flow Measurements – Tramore & Trabeg Rivers

Date	Rainfall in Previous 48 hrs* (mm)	Flow (m^3/s)		
		Trabeg	Tramore (in)	Tramore (out)
04 Jul 03	0.1	0.082	-	0.427
16 Jul 03	25.7	0.181	-	0.984
24 Jul 03	11.5	0.081	-	0.682
02 Sep 03	0.0	0.130	0.265	0.320
12 Sep 03	1.2	0.111	0.265	0.411

* For Cork Airport. Data obtained from www.met.ie/climate/

Data could only be measured accurately at one location on the Trabeg River because the river channel is very muddy and has low flow rates.

The Tramore (in) flow monitoring location is at the western side of the site. It is part of the original river channel and thus has a relatively well-defined wide (~8 m), gravelly bed.

The Tramore (out) flow monitoring location is upstream of the confluence with the Trabeg River at the south-eastern corner of the landfill. The Tramore River has been diverted to this part of the site, so the channel has been cut from the peat bog and is approximately 5 m wide.

All surface water drainage from the engineered cap is collected by drainage swales, which discharge into the stormwater pond.

4.1.1. Other Site Drainage

The paved site access roads are drained via the swale to the stormwater pond in the south-eastern corner of the site. Reed beds are used for primary treatment of this stormwater.

A leachate collection drain has been constructed at the site, generally with a formation level of –1 mOD. The leachate collection drain consists of a HDPE slotted drainage pipe surrounded with granular fill at a depth approximately equal to 3 m below existing ground level and a network of eight sumps along its length. These sumps direct collected leachate to the leachate conditioning system. To the southwest corner of the site, a sheet pile wall has been established 40 m south of the drain. This provides hydrological separation from the Tramore River.

4.1.2. Baseflow

Baseflow is the water contribution that a surface water channel receives from the hydrogeological (groundwater) environment. Analysis of flow measurements in Table 4.1 for periods of low rainfall (when virtually all flow is baseflow), shows the Tramore River receives a baseflow of at least 0.028 m^3/s from the landfill (i.e. half the difference between the flow in and flow out rates). This is evident from the flow measurements recorded in September 2003. This figure assumes that there is an equal contribution to baseflow from each bank.

5. WATER BALANCE CALCULATIONS

5.1. Climatic Data

Rainfall data and evapotranspiration figures for 2007 was obtained from Met Éireann for Cork Airport, located approximately 3 km south of the site. The monthly rainfall data is provided in Table 5.1 which also shows the potential evapotranspiration (PE) for the same period and the effective rainfall.

Table 5.1: Rainfall Data (in mm): Cork Airport 2007

Month	Incident Rainfall (mm)	Evapotranspiration (mm)	Effective Rainfall (mm)
January	89.4	12.9	76.5
February	141.9	14.3	127.6
March	89.3	33.6	55.7
April	27	64.6	0.0
May	64.6	89.8	0.0
June	155.7	75.3	80.4
July	117.5	85.9	31.6
August	80.2	72.3	7.9
September	36.3	51.5	0.0
October	64	22.5	41.5
November	56.8	12.6	44.2
December	134.7	11.1	123.6
Totals	**1057.4**	**540.4**	**588.9**

Note on Table 5.1: For months where evapotranspiration was greater that incident rainfall, the effective rainfall was taken as 0 mm.

5.2. Hydrometric Areas

To estimate the surface water infiltration and runoff from the landfill, it is necessary to sub-divide the site into different hydrometric areas.

Previous water balance calculations for the site have divided it into fourteen hydrological areas (Water Balance Assessment, December 2003). However, due to the completion of Phase 3 capping, the site is now divided into 15 areas. The format has been retained and updated for the 2007 water balance calculations, to reflect the ground conditions (i.e. areas capped, areas being filled etc), as shown in Drawing CE08-011-01-003 Rev 0 (Appendix C).

Table 5.2: Summary of Subdivisions for Water Balance Calculations

Description	Area (ha)	Infiltration Coefficient	Surface Water Runoff (m^3)	Infiltration as Leachate (m^3)
Area 1	8.32	0.49	24,990	24,010
Area 1a	0.97	1	0	5,713
Area 2	5.31	0.13	27,211	4,066
Area 3	4.74	0.20	22,319	5,580
Area 4	2.37	0.77	3,213	10,756
Area 5	0.99	0.76	1,396	4,421
Area 6	4.39	0.13	22,485	3,360
Area 7	2.36	0.00	13,917	0
Area 8	5.49	0.005	32,182	162
Area 9	7.2	0.86	5,933	0
Area 10	1.43	0.0	8,397	0
Area 11	2.35	0.86	1,936	11,894
Area 12	8.36	0.00	49,233	0
Area 13	3.96	0.1	20,995	2,333
Area 14*	3.31	0.005	19,396	97
Total	**61.55**		**253,603**	**72,390**

* Infiltration coefficient for Area 14 (Phase 3 Capping Area) was taken as the same as that for Area 8 (Phase 2 Capping Area).

The fraction of effective rainfall estimated to infiltrate into the ground is represented by the infiltration coefficient. For the purposes of this water balance, several infiltration values were estimated, depending on the cover nature of that area. It should be noted that these coefficients are conservative estimates only, and actual values will vary locally.

5.3. Annual Water Balance (2007)

Table 5.3 represents a summary of the monthly water balance for the site in 2007. The areas and infiltration coefficients used are provided in Table 5.2.

Table 5.3: Summary of Monthly Water Balance

Month	Leachate (m^3)	Surface Water Runoff (m^3)
January	9,401	32,935
February	15,687	54,955
March	6,843	23,973
April	0	0
May	0	0
June	9,882	34,621
July	3,886	13,613
August	970	3,397
September	0	0
October	5,103	17,878
November	5,429	19,018
December	15,190	53,214
Totals	**72,390 m^3**	**253,603 m^3**
Average Flow	**2.30 l/s**	**8.00 l/s**