Environmental Impact Statement for Ballymurtagh Landfill

Volume 2
Main EIS Document

November 2009

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Section 1
Introduction

1.1 Introduction

This Environmental Impact Statement (EIS) relates to a Waste Licence Review Application being made to the Environmental Protection Agency (EPA) under Section 46 of the Waste Management Acts 1996 to 2008.

The **Applicant** for this Waste Licence Review Application is:

Wicklow County Council
County Buildings
Wicklow.

1.2 Background to the EIS

Wicklow County Council operated a landfill at Ballymurtagh in a part of the abandoned West Avoca Mines site in Avoca, Co. Wicklow between the years of 1989 and 2002. A Civic Waste Facility operated by the County Council is now located at the site. A description of the site and its current and historical operations is included in **Section 2**.

An application was made to the EPA on the 1 October 1997 for a waste licence to operate the landfill under Section 39 of the Waste Management Act 1996. This application was made in response to the Waste Management (Licensing) Regulations, 1997. These Regulations provide for a system of licensing of waste disposal facilities by the EPA and give details of the application procedure.

A Waste Licence was granted by the EPA to Wicklow County Council in April 2001 (EPA Licence Register W0011-01). The landfill was closed in 2002. Restoration commenced in 2004, capping was carried out in 2005 and landscape works was completed in 2006. Under the terms of the Waste Licence, the landfill is subject to on-going environmental monitoring and aftercare.

A European Court of Justice (ECJ) Case was brought against Ireland relating to breaches of the EU Groundwater Directive (80/68/EC) with regard, inter alia, to Ballymurtagh Landfill. The outcome of the case (ECJ Case 248/05) was that, in the Courts view, Ireland had failed to correctly account for provisions of the EU Groundwater Directive in the planning for, operation and subsequent licensing of Ballymurtagh Landfill.

At a meeting with the European Commission on 12 December 2007, it was determined that the existing Waste Licence W0011-01 should be reviewed. In subsequent correspondence, the EPA instructed Wicklow County Council to apply for a review of the current Ballymurtagh Landfill Waste Licence. Noting the findings of the ECJ, the EPA advised that the application should "*concentrate on the aspects of risk to surface and groundwaters, currently and into the future, for the facility as constructed*".

The EPA further directed that "the application will have to examine the effectiveness of the existing monitoring, emissions management and abatement (i.e. pollution control) measures, as well as engineering design features (including natural characteristics) and aftercare management provision for the facility, and evaluate these against BAT as may be appropriate to such a facility (then and now)".

Following the advice of the European Commission, the EPA also instructed that an EIS would be required for the review application. Unlike a normal supporting EIS, however, the EPA directed that the "*scope and detail of this EIS will on account of the unique circumstances, be narrow in focus and should concentrate on risks to surface and groundwater, and any other emissions management as may be relevant*".

Furthermore, as it now forms part of the facility, the EPA directed that "the operation of the associated Civic Waste Facility be included in the review application and EIS".

1.3 EIS Scoping

A meeting was held with the EPA on 21 November 2008 and this constituted a formal EIS scoping meeting. A follow-on scoping exercise was carried out by contacting other Statutory Bodies, as well as non-Governmental Organisations, interested parties and the local community to ascertain any other significant environmental impacts that may need to be addressed in the EIS.

Wicklow County Council issued scoping letters to seventeen statutory bodies, all twenty four elected members of the Council and one hundred and sixty one members of the public. A list of the organisations and individuals contacted as well as a copy of the scoping letters issued are included as **Appendix A**.

Four submissions have been received to date. The issues of concern in the submissions are presented below in **Table 1.2**. A copy of the original responses are included in **Appendix B**.

Table 1-1: Scoping Submissions

Contributor	Issues Outlined	Addressed in EIS
An Taisce	Background to the EIS	Section 1
	Historical Setting	Section 1
	Addressing the ECJ judgement	Section 1 Section 6 Section 7
Eastern Regional Fisheries Board	Leachate containment	Section 7
	Quantification of landfill leachate contamination	Section 7
	Impact of leachate discharge and length of time for leachate production at the site	Section 7
	Treatment of AMD from the mines.	Not applicable to this EIS
	Abstraction from the upper reaches of the Avoca River system for public water supply	Not applicable to this EIS
	Alternative abstraction for public water supply from lower reaches of the Avoca River	Not applicable to this EIS
Minister Dick Roche T.D	Gas Flaring and Utilisation	Section 9
Department of Agriculture, Fisheries & Food	Impact on Local Water Supplies	Section 7
	Impact of Traffic	Section 4
	Impact of Nuisances including Birds, Vermin, Dust, Litter, Noise and Odour	Section 4
	Methane Emissions	Section 9

1.4 EIS Structure and Content

The EPA has directed that the "scope and detail of this EIS will on account of the unique circumstances, be narrow in focus and should concentrate on risks to surface and groundwater, and any other emissions management as may be relevant".

This is because the ECJ decision specifically referred to groundwater and surface water only and the EIS has concentrated on the risks to these water bodies in detail. However, because an EIS and Waste Licence Review are governed by Irish and EU legislative procedures, all other environmental impacts in relation to the landfill have also been assessed.

The EIS has been prepared in accordance within the following legislation framework:

- Guidelines on the information to be contained in an EIS issued by the Environmental Protection Agency (March 2002);
- Advice notes on the current practice in the preparation of an EIS issued by the Environmental Protection Agency (1995);
- European Communities Environmental Impact Assessment (Amendment) Regulations 1999 (SI No. 93 of 1999);
- The Planning & Development Regulations (2001);
- EU Landfill Directive (99/31/EC);
- Groundwater Directive (80/68/EEC);

- (New) Groundwater Directive (2006/118/EC);
- Water Framework Directive (2000/60/EC);
- Dangerous Substances Directive (76/464/EEC); and
- Habitats Directive (92/43/EEC).

1.5 Methodology of Environmental Impact Assessment

The ‘Grouped Format Structure’ for the EIS has been adopted as outlined in the EPA guidelines for the preparation of an EIS and the information to be contained in an EIS. This format examines each aspect of the environment as a separate section referring to the existing environment, the potential impact of the development, and the mitigating measures to ameliorate these impacts.

- Volume 1 provides the Non-Technical Summary of the EIS. This is a self-contained document and presents a condensed non-technical version of the Main EIS Document.
- Volume 2 contains the Main EIS Document and details the major environmental aspects of the closed landfill and the principal measures used to mitigate against any potential impacts.
- Volume 3 contains Appendices to the Main EIS Document including supporting information such as contacts with and replies from statutory bodies and interested parties, environmental monitoring data, reports, maps and drawings.

The following potential impacts are fully discussed within the EIS:

- Human Beings (**Section 4** of this document);
- Soils and Geology (**Section 5**);
- Surface Water (**Section 6**);
- Groundwater (**Section 7**);
- Ecology (**Section 8**);
- Air Emissions and Climate (**Section 9**);
- Land Use and Landscape (**Section 10**);
- Material Assets (**Section 11**);
- Interaction of the Foregoing (**Section 12**);
- Alternatives (**Section 13**); and
- Further Considerations (**Section 14**).

1.6 Technical Difficulties

Access to sampling and monitoring locations on occasion proved difficult because Wicklow County Council only have ownership of the Landfill and Civic Waste Facility. A number of monitoring locations are on private lands outside the landfill boundary.

1.7 EIS Study Team

Wicklow County Council has prepared this Environmental Impact Statement with the help of consultants CDM.

Specialist consultants and public bodies contributing reports that have been used in the preparation of this document are:

- Geological Survey of Ireland;
- CDM;
- RPS Consulting Engineers;
- Margaret Gowan and Co. Ltd, Archaeological Consultants;
- Conservation Services, Ecological Consultants;
- Euro Environmental, Noise Monitoring Consultants;

- Bioverde Power Systems Ltd;
- SLR Consulting Ltd, Geotechnical Consultants; and
- Roger Goodwillie & Associates, Flora and Fauna Consultants.

Section 2
Waste Management Policies

2.1 EU Waste Policy

In the last decade, Ireland has been increasingly affected by initiatives contained in the EU Environment Programme. The Council Directive on Waste (75/442/EEC) was made in 1975 and completely revised in 1991 (91/692/EEC, amended in 1996(96/350/EC) and amended again in 2006 as 2006/12/EC. The Directive requires member states to establish an integrated network of disposal facilities, based on the principle of best available technology not exceeding excessive cost. The aim of this network is for the EU to become self-sufficient in disposal capacity and for individual member states to work toward such a goal.

2.2 Landfill Directive

The overall objective of the Council Directive on the Landfill of Waste (99/31/EC) is to tightly define and unify the nature of acceptable landfill usage, as well as promoting EU-wide standards for landfill site design, operation and post-closure. Overall, the purpose is to reduce and minimise the potential environmental impacts which may otherwise occur at any point in the life-cycle of a landfill.

The Directive has had a significant influence on the design of new landfill sites. The requirements for such matters as lining, leachate control and site closure have already become standard practice in Ireland. Ballymurtagh Landfill was designed in 1987 and waste acceptance commenced at the facility in 1989 tens years prior to the Landfill Directive of 1999. The Ballymurtagh facility closed in 2002 and restoration and landscaping at the site was completed in 2006. The facility is subject to ongoing monitoring by Wicklow County Council and inspection by the EPA.

2.3 National Waste Management Policy

In Ireland, national waste management policy is captured in a number of pieces of legislation (giving effect to the Waste Directive and the Landfill Directive) in the Waste Management Acts 1996 to 2008. The following government policy documents also impact upon waste management in Ireland.

2.3.1 1998 Policy Statement - Changing Our Ways

In September 1998, the Minister for the Environment & Local Government issued a policy statement on waste, entitled “Waste Management - Changing Our Ways”. A key objective of the policy statement was to stabilise, and in the longer term reverse, the growth in waste generation. This statement set out national objectives for the future management of waste in Ireland with particular reference to the Landfill Directive and the diversion of biodegradable waste.

In implementing the Replacement Waste Plan for County Wicklow 2006 – 2011, Wicklow County Council is actively pursuing measures to ensure that the requirement for the diversion of biodegradable waste will be met beginning in 2010.

2.3.2 2002 Policy Statement – Delivering Change

A second waste-specific policy statement was published by the Department of the Environment & Local Government in 2002, entitled “Preventing and Recycling Waste: Delivering Change”. This complemented and developed some of the themes of the earlier policy document “Changing Our Ways”, particularly in relation to waste prevention, re-use, recovery and recycling. The Civic Amenity Facility at Ballymurtagh provides a recycling and recovery facility for the local community.

“Delivering Change” has brought about the introduction of the landfill levy to incentivise the diversion of waste away from landfill sites, as well as the introduction of a ban on the landfilling of particular types of waste that can be recycled like farm plastics and rubber tyres. The current landfill levy rate of €20 per tonne is collected by Wicklow County Council at its Rampere Landfill and is then paid into the Government Environment Fund.

2.3.3 2004 Policy Statement – Taking Stock and Moving Forward

On 5 April 2004, a further national waste management policy document – "Waste Management: Taking Stock and Moving Forward" – was launched. Taking Stock assesses progress on the implementation of a variety of aspects of the Waste Management Act 1996.

At that time a review of all of the existing waste management plans was required under the "National Overview of Waste Management Plans". The Replacement Waste Management Plan for County Wicklow 2006 – 2011 was adopted by the Wicklow County Manager in July 2006 to deal with the recovery, recycling and disposal of waste arisings in County Wicklow.

The closure of Ballymurtagh Landfill facility in 2002 was referred to in the Replacement Waste Management Plan for County Wicklow in Section 4.2.3, Operational EPA Licenced Waste Management Facilities. The Waste Licence Review Application sought by Wicklow County Council for Ballymurtagh Landfill from the EPA is in accordance with the County Wicklow Replacement Waste Plan 2006 – 2011.

2.3.4 2005 Policy Direction – Movement of Waste

The policy direction of May 2005 on the movement of waste has no implication for the closed Ballymurtagh Landfill facility.

2.4 County Wicklow Development Plan

The Wicklow County Development Plan 2004–2010 was adopted on the 2nd of November 2004. The policies and objectives of the Development Plan with regard to waste management are as follows:

- To provide and operate, or arrange for the provision and operation of, such facilities as may arise for the recovery and disposal of household waste arising within its functional area according to Section 38 (1) of the 1996 Waste Management Act.
- To facilitate the provision of waste disposal sites as necessary in accordance with the needs arising within the County, the Wicklow Waste Management Plan 2000-2004 and the proper planning and development of the county.
- To have regard to the County Wicklow Sludge Management Plan (2003), facilitating the implementation of its aims and objectives where appropriate.
- To encourage waste minimisation strategies for domestic, industrial and commercial wastes.
- To promote the re-use and recycling schemes in accordance with the principles of sustainable development.
- To identify proposed locations for recycling centres and bring sites to be developed within the lifetime of this Plan and to continue to provide for the same at the identified locations.
- To monitor the production, storage and movement of hazardous and dangerous waste within the County and enforce the provisions of the 1979 Toxic and Dangerous Waste Regulations.
- To have regard to the SEVESO (Major Accidents) Directive" (96/82/EC) which relates to the control of major accidents involving dangerous substances with an objective to prevent major accidents and limit the consequence of such accidents.

The Waste Licence Review Application sought by Wicklow County Council for Ballymurtagh Landfill from the EPA is in accordance with the County Wicklow Development Plan 2004 – 2010.

Section 3
Description of Site

3.1 Location

Ballymurtagh Landfill is located in the townlands of Ballymurtagh, Ballygahan Upper, Ballygahan Lower, and Tinnahinch in the Vale of Avoca approximately 1.5 km north-west of the village of Avoca in Co. Wicklow. The site is accessed from the R752 road between Rathdrum and Arklow. It is situated in the catchment of the Avoca River, which rises in the Wicklow Mountains and enters the Irish Sea at Arklow. The site location is shown on **Figure 3-1** (at the end of the Section).

3.2 Management And Staffing Structure

Ballymurtagh Landfill is under the overall operational control of the Director of Services and Senior Engineer of the Water and Environmental Services Section of Wicklow County Council. The facility manager carries out the day-to-day management at the site.

The current contact details are as follows:

Wicklow County Council Tel: 0404 20100

The current management structure at the facility is presented on the **Table 3-1**.

Table 3-1: Management Structure & Organisational Chart

Name	Grade	Position	Qualifications/ Experience
Bryan Doyle	Director of Services	Water and Environmental Services	28 yrs. Local Authority Administration and Environmental Services Manager.
Philip Duffy	Senior Executive Officer	Water and Environmental Services	33 yrs. Local Authority Administration Planning and Environment.
Michael Geaney	Senior Engineer	Water and Environmental Services	28 yrs. Local Authority 6 yrs. Waste Collection Services for Bray Town Council.
Andrew Lawless	Senior Executive Engineer	Waste Management	Degree in Civil Engineering (B.A., B.A.I). 31 years Local Authority. FÁS Waste Management Course.
Seamus Breslin	Chief Technician	Facility Manager	30 yrs experience in water and waste management services. FÁS Waste Management Course.
Myles Doyle	Supervisor	Supervisor of the Civic Waste Facility	20 yrs experience in waste management services FÁS Waste Management Course.
Seamus Curran	Site Operative	Site Operative at the Civic Waste Facility	FÁS Supervisor for 10 years

3.3 Present Operations

Recycling at the Civic Waste Facility is the only current activity at the Ballymurtagh Landfill site. Site Operations are stipulated in the current Waste Licence for the facility and are carried out with procedures for waste acceptance, waste handling, and transfer of materials.

The Civic Waste Facility was opened in February 2003 after the closure of the landfill in December of 2002. The layout of the Civic Waste Facility is shown on **Figure 3-2** (at the end of the Section).

Table 3-2 provides summary information on wastes received at the Civic Waste Facility and which was subsequently sent off-site for recovery during 2008.

Table 3-2: Total Quantities of Waste Accepted at the Ballymurtagh Civic Waste Facility (RPS, 2008)

Waste Type	EWC Code	Approx. Monthly Quantities	Materials transported Off-site
Aluminium cans	19 12 03	472 Kg	5663 Kg
Steel Cans	20 01 40	1345 Kg	16140 Kg
Paper / Cardboard packaging / tetrapak	20 01 01	21816 Kg	261792 Kg
Fluorescent tubes / Bulbs	20 01 21	45 Kg	543 Kg
Fridges / Freezers	20 01 23	1183 Kg	14195 Kg
WEE small: Photocopiers, Keyboards, TVs, Videos, Monitors, Printers, PCs, Scanners, Smoke alarms	20 01 36	3171 Kg	38050 Kg
Plastics	20 01 39	5755 Kg	69063 Kg
Batteries	20 01 33/34	537 Kg	6441 Kg
Mixed Municipal Waste	20 03 01	853 Kg	10240 Kg
Waste Oils	20 01 25/26	275 Kg	3300 Kg
Ink jet cartridges,	08 03 13	26 Units	308 Units
Glass	20 01 02	7043 Kg	84519 Kg
WEE large: Cookers, Washing machines, Dryers	19 12 02	2618 Kg	31421 Kg
Textiles, Clothes	20 01 10/11	2110 Kg	25320 Kg
Scrap Metal	20 01 40	1682 Kg	20180 Kg
Mobile Phones		17 Units	204 Units

All recyclable materials brought to the Civic Waste Facility are subject to the following procedure:

- Only private and small commercial vehicles use the facility. The Civic Waste Facility is not used as a transfer station for disposal of waste by commercial waste disposal contractors or local authority waste collection vehicles.
- Unless the prior agreement of the Agency is given only household waste for recovery is accepted at the Civic Waste Facility.
- There is no cap on the quantity of waste to be accepted at the Civic Waste Facility. No hazardous waste, with the exception of household hazardous waste including waste oil, batteries and fluorescent tubes is accepted at the facility. Wicklow County Council organises an annual collection of Household Hazardous Waste to which the public can bring this waste type on a pre-arranged date. This waste is removed from the site on the day of collection and brought to an approved off–site facility.
- Waste sent off-site for recovery or disposal is only conveyed by an authorised waste contractor as agreed by the Agency.
- All wastes removed off site for recovery or disposal is transported from the facility to the consignee in a manner that does not adversely affect the environment.

Materials accepted at the Civic Waste Facility are separated out and stored in labelled receptacles. These materials are subsequently transported off-site for treatment to suitable Licenced or permitted facilities for recovery.

3.4 Historical Operations

3.4.1 Operation of Ballymurtagh Landfill

Wicklow County Council operated a landfill at Ballymurtagh in an area of the abandoned West Avoca Mines site in Avoca, Co. Wicklow between the years of 1989 and 2002. The landfill was designed in 1987, twelve years prior to the EU Landfill Directive (99/31/EC) entering into force in 1999.

The landfill occupies a disused Open Lode pit of the closed Avoca mines known as the Ballymurtagh Open Pit or Pond Lode. The Ballymurtagh Open Pit was excavated by Avoca Mines

Ltd between 1973 and 1979 on the surface extension of the Pond Lode, which had been previously mined by underground methods. Extensive caving of these workings occurred in the early 1960s due to "pillar robbing" by Saint Patrick's Copper Mining Company Ltd.

Prior to its use as a landfill, the open pit was used for the settlement of mine tailings. Tailings are fine, silty waste products from the primary and secondary crushing of ore after the base materials have been abstracted. During mining operations, the liquid tailings at West Avoca were pumped from the former mine mill to the Ballymurtagh Open pit. In 1987 prior to the infill of the landfill, the tailings were found to be quite dense and consolidated as drainage had taken place through the base of the open pit (Kevin T. Cullen, 1987).

Detailed engineering and hydrogeological studies preceded the construction of the landfill, while an EIS was prepared in 1998 to accompany the retrospective application for a Waste Licence from the EPA. This licence (W0011-01) was granted on 3 April 2001. The landfill was designed to operate under a ‘disperse and dilute’ method. The landfill included a bottom liner in the form of low-permeability mine tailings whose function would reduce or limit the risk of pollution to groundwater.

The principal activity between 1989 and 2002, was to *‘deposit [waste] in, on or under land’*. It is estimated that approximately 480,000 tonnes of waste were deposited at the site from the date it became operational in 1989 until waste acceptance ceased on the 31 December 2002. The landfill accepted only non-hazardous waste emanating mainly from the domestic sector, although smaller amounts of industrial non-hazardous sludge were also accepted. The landfill can be broadly separated into three filling areas, the ‘upper’, ‘middle’ and ‘lower’ slopes. Historically the upper and middle slopes contain the main body of waste. The total fill area is approximately 6.3 hectares in size.

The annual and total volumes of compacted waste are shown as **Table 3-3**.

Table 3-3: Total Quantities of Waste Accepted at the Ballymurtagh Landfill (RPS, 2006)

Year	Total Waste Quantities (Tonnes)
1989	10,189
1990	14,611
1991	18,523
1992	16,061
1993	17,025
1994	20,000
1995	23,000
1996	44,992
1997	63,582
1998	61,431
1999	44,982
2000	49,107
2001	50,919
2002	45,919
Total	**480,341**

From 2001, the landfill was operated in accordance with Waste Licence (W0011-01) issued by the EPA, which allowed for the annual disposal of 42,000 tonnes of non-hazardous waste. Table 3-3 shows extra tonnage over and above what was allowed in the Waste Licence in 2001 and 2002. These tonnage quantities are based on weighbridge records from the site. In 2001 and 2002 inert material for cover and interim capping was imported and stored at the site for future usage. As every vehicle entering the landfill was weighed at the weighbridge, including vehicles transporting this additional material, the overall tonnage entering Ballymurtagh Landfill was exceeded. However, the maximum allowable tonnage for non-hazardous waste disposal for this period was not exceeded.

3.4.2 Closure & Restoration

Upon closure, a Restoration and Aftercare Plan (RPS, 2003) was prepared in accordance with the EPA Landfill Manual ‘Landfill Restoration and Aftercare’ (1999), the Council Directive (99/31/EC) on the Landfill of Waste and the EPA Waste Licence W0011-01. The objective of the plan was to create a woodland type of habitat, which would blend in with the surrounding landscape.

Capping and restoration works in accordance with the terms of the Waste Licence and the Restoration and Aftercare Plan (RPS-MCOS, 2003) commenced in October 2004 and were completed in November 2005. The site has been landscaped and vegetation was successfully established during 2006. The final Landscaping Plan for the site is shown as **Figure 3.3**.

An Environmental Management Plan (EMP) is drawn up for the site on an annual basis and submitted to the EPA. This plan outlines the on-going monitoring and procedures carried out at the site to ensure the protection of the surrounding environment. At the end of each year an Annual Environmental Report (AER) is prepared describing the performance of the landfill from an environmental point of view. The most recent AER for Ballymurtagh Landfill (2008) can be viewed on the EPA website.

3.4.3 Ongoing Monitoring

Routine environmental monitoring is carried out at Ballymurtagh Landfill in accordance with the Waste Licence W0011-01.The aim of the monitoring programme is to carry out an accurate assessment of the impact of the landfill on the surrounding environment. The scope of the monitoring programme includes surface water, groundwater, leachate, landfill gas, odours, noise and dust.

Schedule E of the waste licence sets out the type of monitoring, the sampling locations, the sampling frequency and the types of analysis carried out. A brief outline of the monitoring that has occurred is given below, with the full descriptions contained in the relevant sections of the EIS. The monitoring infrastructure is shown as **Figure 3-4**.

- Landfill gas monitoring of boreholes is carried out monthly and monitoring of the site office is carried out weekly
- Landfill gas flare emissions are monitored also. Some parameters are monitored biannually and some annually.
- Surface water from the Avoca River is monitored at four locations. Two monitoring points are located upstream of the landfill and two are downstream. The monitoring is carried out quarterly, with a broad suite of parameters analysed on an annual basis.
- Groundwater has been monitored at several locations both onsite and offsite over the years. The monitoring is carried out quarterly, with a broad suite of parameters analysed on an annual basis. Groundwater level monitoring is also carried out on a routine basis.
- Leachate monitoring is carried out quarterly, with a broad suite of parameters analysed on an annual basis. Leachate level monitoring is conducted weekly.
- Noise monitoring was conducted at four noise sensitive locations since the Licence was granted in 2001 until 2006. From 2007 monitoring has been carried out at two locations as agreed with the EPA as there have been no noise issues at the site.
- Dust monitoring was carried out at two locations until the restoration of the landfill was completed.

The monitoring programme will continue during the aftercare phase of the landfill.

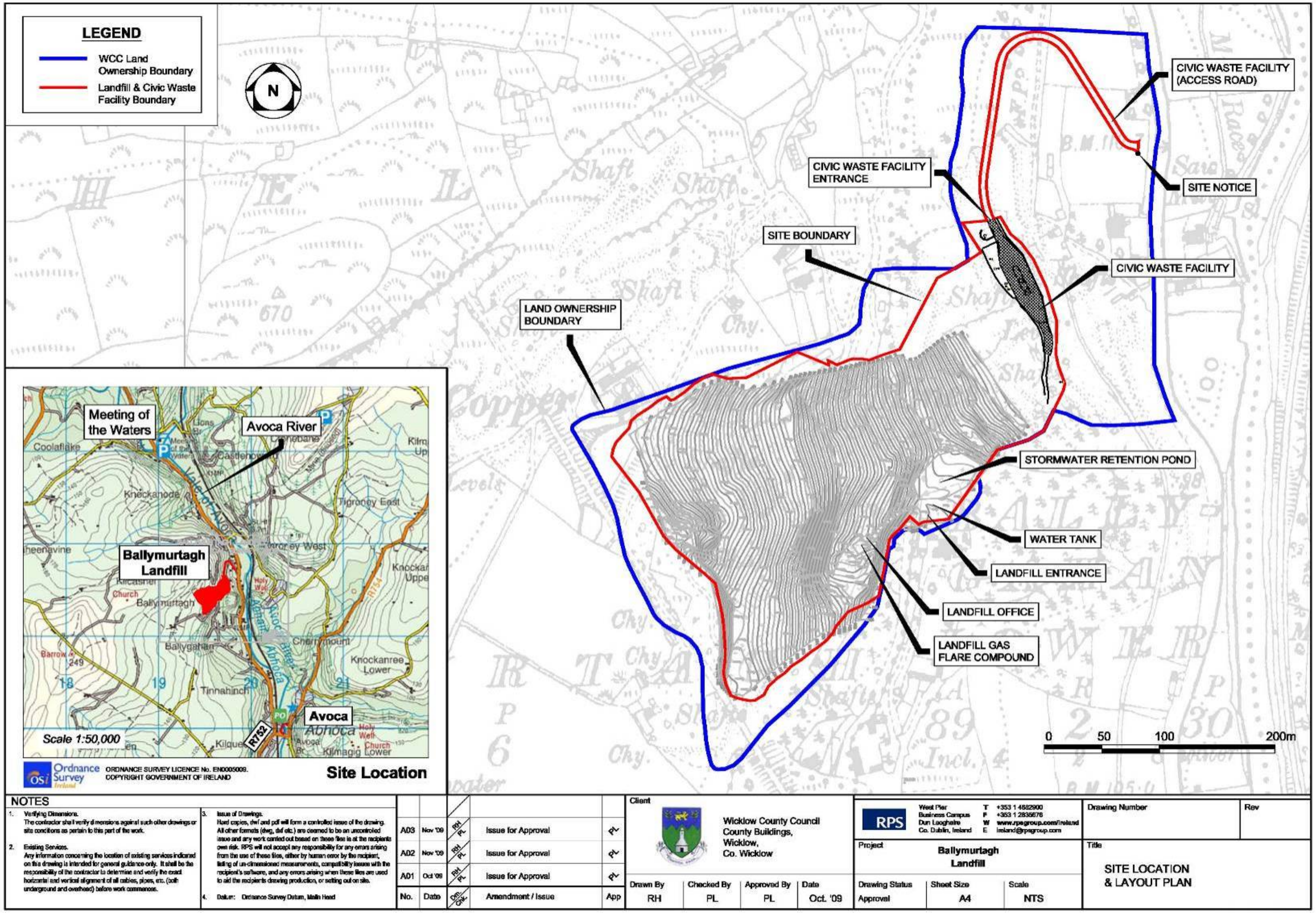

Figure 3-1: Site Location (RPS, 2008)

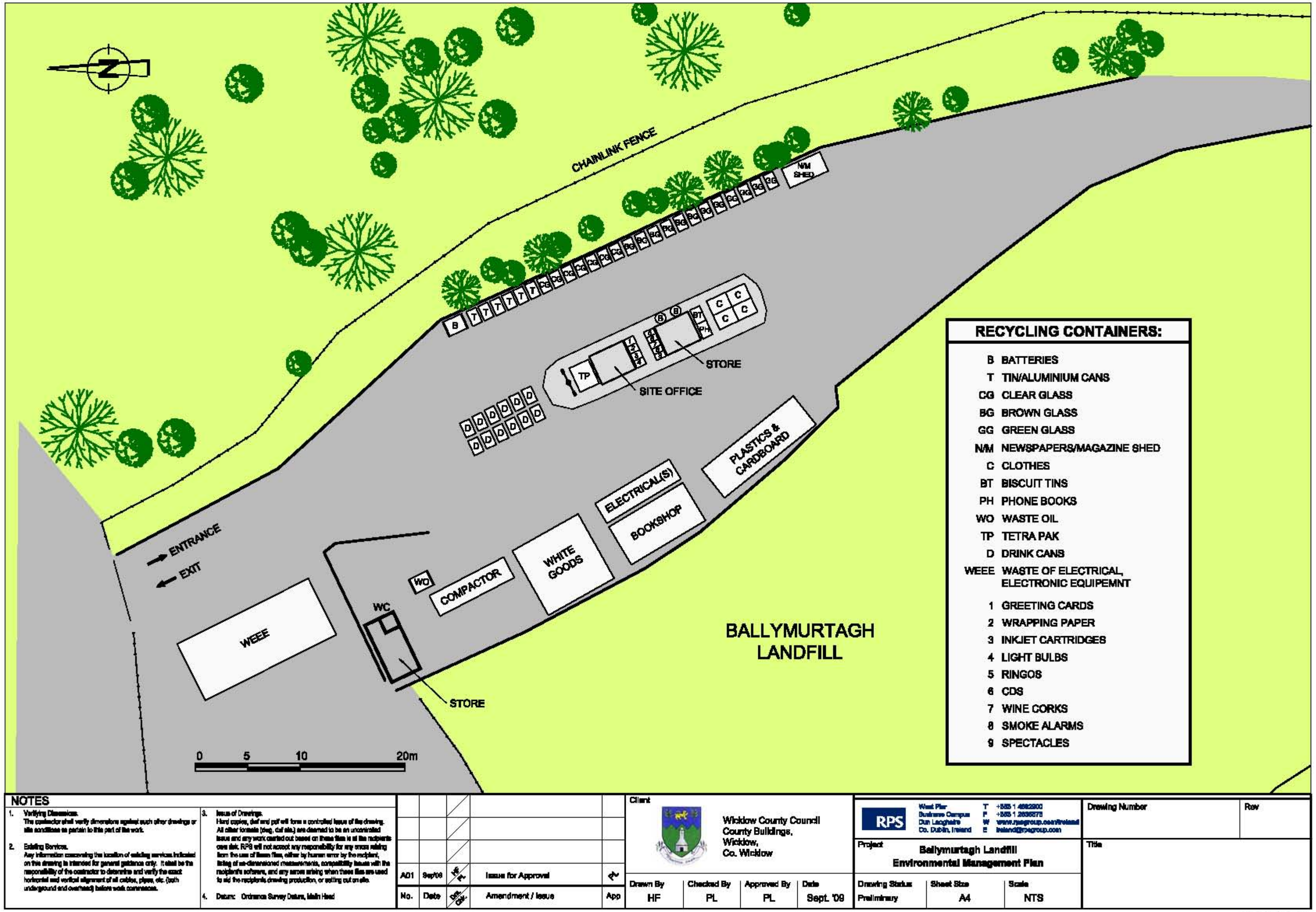

Figure 3-2: Layout of Civic Waste Facility (RPS, 2008)

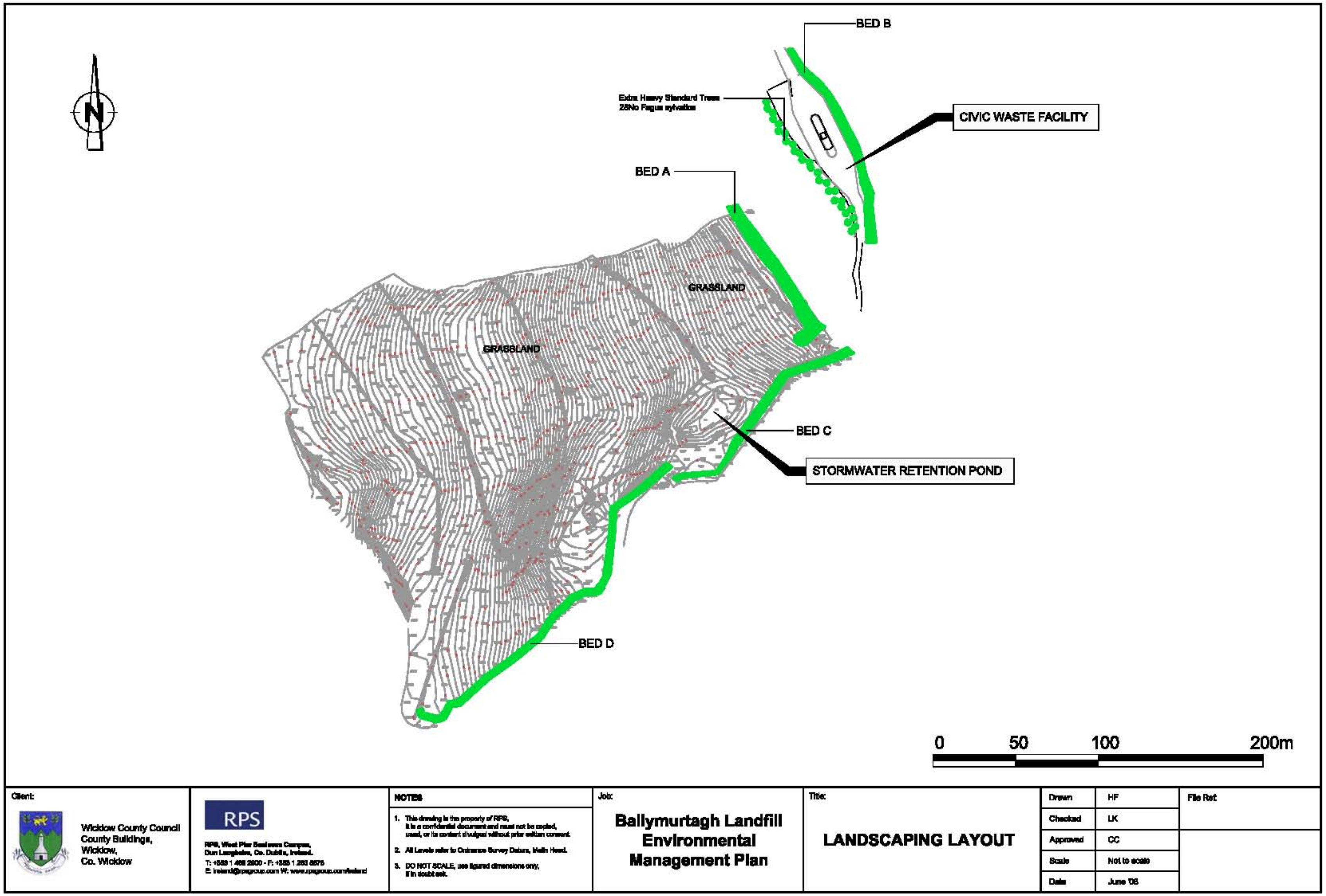

Figure 3-3: Final Landscaping Plan (RPS, 2008)

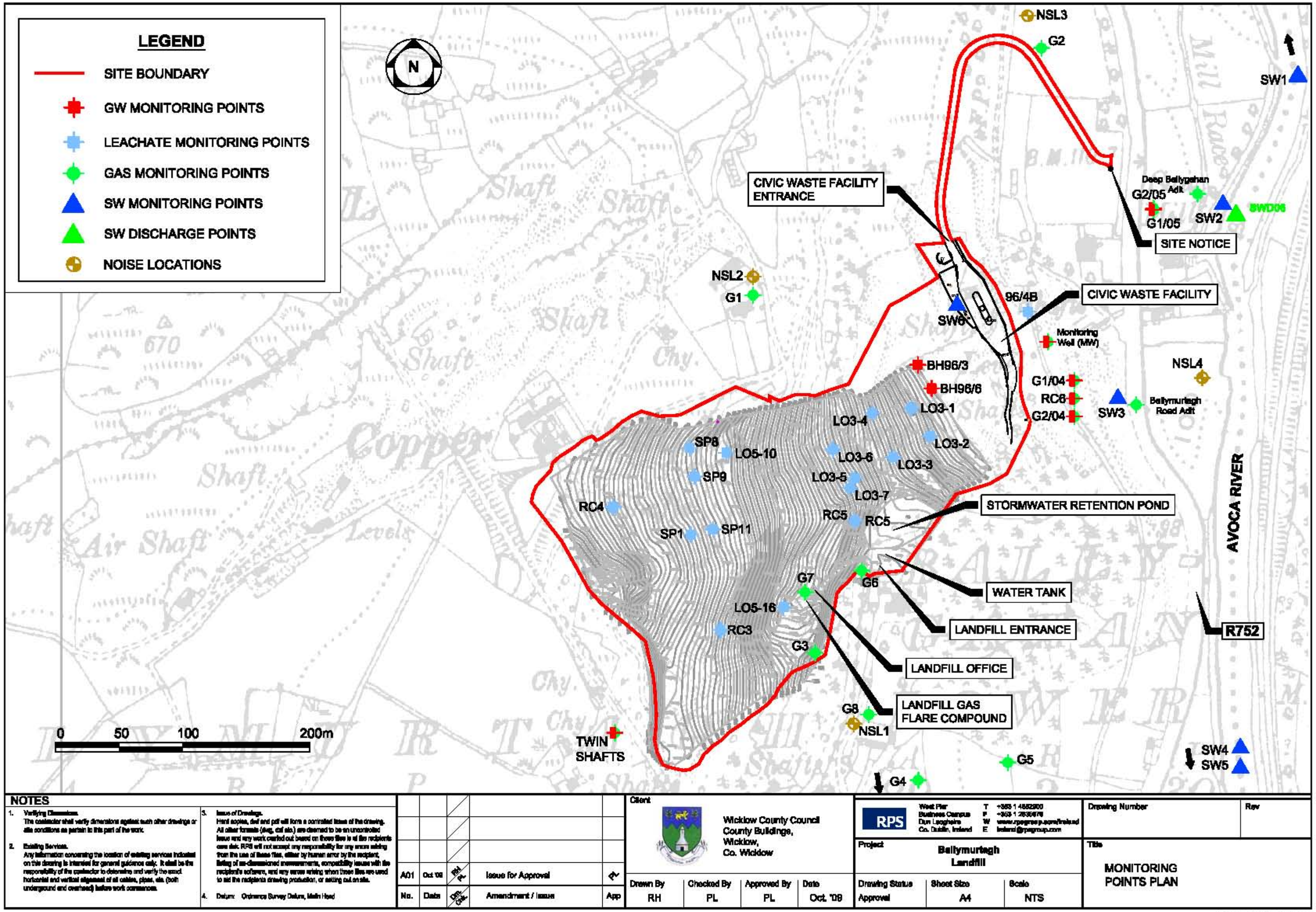

Figure 3-4: Site Monitoring Infrastructure (RPS, 2008)

Section 4
Human Beings

4.1 Introduction

Landfill facilities have the potential to create a local nuisance to the surrounding community. Such nuisances include vermin, pests, litter, traffic, noise, odour and dust. Closure of the Ballymurtagh Landfill was planned and managed with a comprehensive restoration and aftercare plan, which specifically set out to minimise the impact of the facility on human beings.

This section of the EIS considers the effects of the closed landfill on human beings in relation to the following:

- Noise;
- Traffic;
- Fire; and
- Other nuisances, such as pests and litter.

Other impacts the landfill may have an impact on human beings are discussed in detail in the relevant sections of the EIS, these include:

- Air emissions (**Section 9.2**);
- Dust (**Section 9.3**);
- Odours (**Section 9.5**);
- Visual impacts (**Section 10**); and
- Material assets (**Section 11**).

4.2 Noise

Noise is generally defined as unwanted sound and the generation of noise at an active landfill is an inevitable consequence of the activities being carried out. Excessive noise can become a problem if sources are not monitored and controlled.

Under the terms of Waste Licence W0011-01, four noise sensitive locations (NSL1-4) were chosen outside the perimeter of the site to coincide with the nearest residential housing and monitored annually as part of compliance. Schedule F.1 of the licence sets down noise emission limits, shown in **Table 4-1**.

Table 4-1: Noise Emission Limits

Day dB(A) L_{Aeq}(30 minutes)	Night dB(A) L_{Aeq}(30 minutes)
55	45

Noise monitoring was conducted at four noise sensitive locations since the Waste Licence was granted in 2001 until 2006. From 2007 monitoring has been carried out at two locations as agreed with the EPA as there have been no noise issues at the site.

The most recent noise survey was carried out in March 2009 at the two most noise sensitive monitoring locations NSL1 and NSL4. The 55dB(A) day limit was not exceeded at monitoring point NSL4. NSL1 exceeded the recommended daytime limits of 55dB(A) at 57dB(A), although this was attributed to traffic on the main R752 road which runs adjacent to the site. No noise could be detected from operations at the landfill at NSL1 at the time of monitoring. While gas flaring still occurs, the generator has been replaced by mains power and is no longer a source of noise. No noise emanating from the gas flare was audible at NSL1, the nearest noise sensitive location to the flare. The Civic Waste Facility continues at the site and occasional noise can be generated at low levels, which are not detectable at the noise sensitive locations NSL1 and 4.

Noise levels continue to be monitored but do not create an environmental problem at Ballymurtagh Landfill and Civic Waste Facility.

4.3 Traffic

Ballymurtagh Landfill is situated to the north of the R752 Regional Route, which connects the villages of Woodenbridge, Avoca, Rathdrum and Rathnew with the N11 National Primary Route and Arklow. The location of Ballymurtagh Landfill in relation to the surrounding road network is presented on the Site Location Plan, Figure 3-1 in Section 3.

When it was an operational landfill, significant traffic used this road to bring refuse to the landfill. Upon closure, capping and restoration of the landfill involved significant construction activity, including traffic. This ceased upon completion of the restoration activities in 2006.

The Civic Waste Facility is located on the site of the closed landfill and is accessed via an access road which links with the R752. The facility is open to the public five days a week from Tuesday to Saturday. It is estimated that approximately 150 cars per day use the Civic Waste Facility.

The impact of this regular traffic is offset by the local and regional benefit of the Civic Waste Facility, which permits and encourages recycling in line with Wicklow County Council and national policy to achieve materials recycling of 35% of municipal waste.

Traffic does not create an environmental problem at Ballymurtagh Landfill and Civic Waste Facility.

4.4 Fire

Fires at landfill sites may arise from burning waste arriving at the site or self ignition of waste due to increased temperatures from decomposition. When operational, there were no instances of fire recorded at the landfill facility.

There is also a risk of fire at closed landfill sites due to the emission of flammable gaseous by-products of the waste degradation process. This is reduced by the active venting system installed in the landfill mass. A flaring system is continually in operation on the site at present. Since closure, there has been no fire related incidents on site.

Any fires on the site would be regarded as emergencies and dealt with immediately, either by extinguishing them or by calling the emergency services. This is dealt with under the Emergency Response Procedure in the Environmental Management Plan (2008).

4.5 Other Nuisances

4.5.1 Vermin and Pests

Vermin and pests are attracted to waste disposal areas due to the high organic component of the waste and the fact that waste disposal can create shelter and habitats for a number of species for example flies and rats. The number of gulls and corvids are increased at landfill sites by the quantity of waste food present. However, birds did not pose a major problem at the landfill while it was operational. Since closure, bird activity in the vicinity of the landfill is normal for the area.

Vermin and pests can be controlled by making food sources inaccessible and living conditions as unattractive as possible. The closure and capping of the landfill addressed the issue of vermin and pests by covering the waste that attracted them. Vermin control is still carried out at the Civic Waste Facility.

4.5.2 Litter

Windblown litter can cause a problem at active landfills if it is not controlled. When operational, specific protocols ensured that the facility was kept free from litter. In the event of fly tipping, the Facility Manager was notified to organise for the proper disposal of the waste.

Litter continues to be managed in this way at the Civic Waste Facility, but is not considered to be a nuisance.

4.6 Mitigating Measures

Significant effort has been made to minimise or remove the impact on human beings from the Ballymurtagh Landfill, which is no longer operational, and the Civic Waste Facility, which continues to operate.

Closure of the Ballymurtagh Landfill was planned and managed with a comprehensives restoration and aftercare plan, which specifically set out to minimise the impact of the facility on human beings. Mitigating measures are in place for all of the nuisances which impact upon human beings, including vermin, pests, litter, traffic, noise, odour and dust.

Monitoring of noise emissions over recent years under Waste Licence W0011-01 has found that Ballymurtagh Landfill has no impact at the noise sensitive locations. This monitoring continues at the most noise sensitive locations.

To date there has been no fire related incidents at the site. Any fires on the site would be regarded as emergencies and dealt with immediately, either by extinguishing them or by calling the emergency services. This is dealt with under the Emergency Response Procedure in the Environmental Management Plan (2008).

Access traffic to the Civic Waste Facility is not perceived to have a negative impact on human beings. The facility has a positive impact as it serves the community with an essential recycling service.

Any nuisances relating to vermin, pests or litter are prevented and dealt with according to the Environmental Management Procedures for the site (RPS, 2008). Weekly inspections are carried out for the entire landfill site, including the Civic Waste Facility and its access road, as well as the Red Road, which was the access road to the landfill prior to its closure in 2002.

Details of nuisances, if any, relating to vermin, birds, flies, mud, dust, litter, fly-tipping, odours, fencing and the gas flare are documented on Inspection Report Forms. Corrective action is carried out when required.

Section 5
Soils & Geology

5.1 Introduction

This section outlines the geology of the present landfill site, which is situated in the Pond Lode Pit. The pit was excavated between 1973 and 1979 on the surface extension of the Pond Lode, which had been previously mined by underground methods. Mining activities ceased at the site in 1982.

5.2 Bedrock Geology

A geological map of the Ballymurtagh Landfill and Avoca Mining Area is included in **Figure 5-1**.

The Ballymurtagh Landfill is surrounded and underlain by Ordovician volcanics and metasediments of the Duncannon Group. The rocks of the Duncannon Group form the 'host rock' to the ore bodies that were mined at Avoca. They comprise a variety of lithologies, including felsitic and sericitic tuffs, rhyolite volcanics and breccias, as well as mudstones, schists, and shales.

The Avoca ore bodies that were mined consisted of massive and stringer deposits of banded chalcopyrite-pyrite ore and a pyritic copper-zinc-lead ore. The uppermost 30 to 60 m of the ore deposits have been oxidised. The most important minerals include iron oxides, chalcocite (Cu2S) and covellite (CuS) together with various copper and iron oxides (CDM, 2008).

The host rock and ore bodies surrounding the Ballymurtagh Landfill have been subjected to intense structural deformation and show different degrees of metamorphism (Gallagher & O'Connor, 1997). Isoclinal fold structures are visible and superimposed on generally SE-dipping geological strata.

A fault line, mapped, by the GSI, runs NW-SE through the Avoca mine area, and offsets the main NE-SW trending ore bodies to the east and west of the Avoca River.

5.3 Soils and Subsoils

The upland areas immediately surrounding the Ballymurtagh Landfill are overlain by subsoils derived from glacial till and weathering of bedrock. Subsoils are mostly thin (<2 metres) and even absent on some hilltops.

Immediately to the southeast of the landfill, glacial tills are exposed along the river valley, comprising large sub-angular cobbles lodged in fine-grained, clayey and silty till matrices. Downgradient (east/northeast) of the landfill, in the Avoca River valley, subsoils are represented by river alluvial deposits which attain reported thicknesses of more than 20 metres (CDM, 2008). The transition from the glacial till to the river alluvium is rapid as a function of the glacial U-shape of the valley and erosive capacity of the river.

Northeast of the landfill, mine tailings occupy an area called the "Emergency Tailings" adjacent to the river. These tailings directly overlie river alluvial deposits.

5.3.1 Spoils and Tailings in West Avoca

Mine spoils and tailings are a prominent feature of the Avoca Mining Area. In West Avoca, spoils and tailings cover a total area of about 10 hectares. Spoils are present immediately downgradient of the landfill, as fill material, between the Civic Waste Facility and the Avoca-Rathdrum road. The present locations of spoil heaps (and other mining-related features) in West Avoca are shown in **Figure 5-2**, while the volumes and areas of different spoils heaps are presented in **Table 5-3** (CDM, 2008).

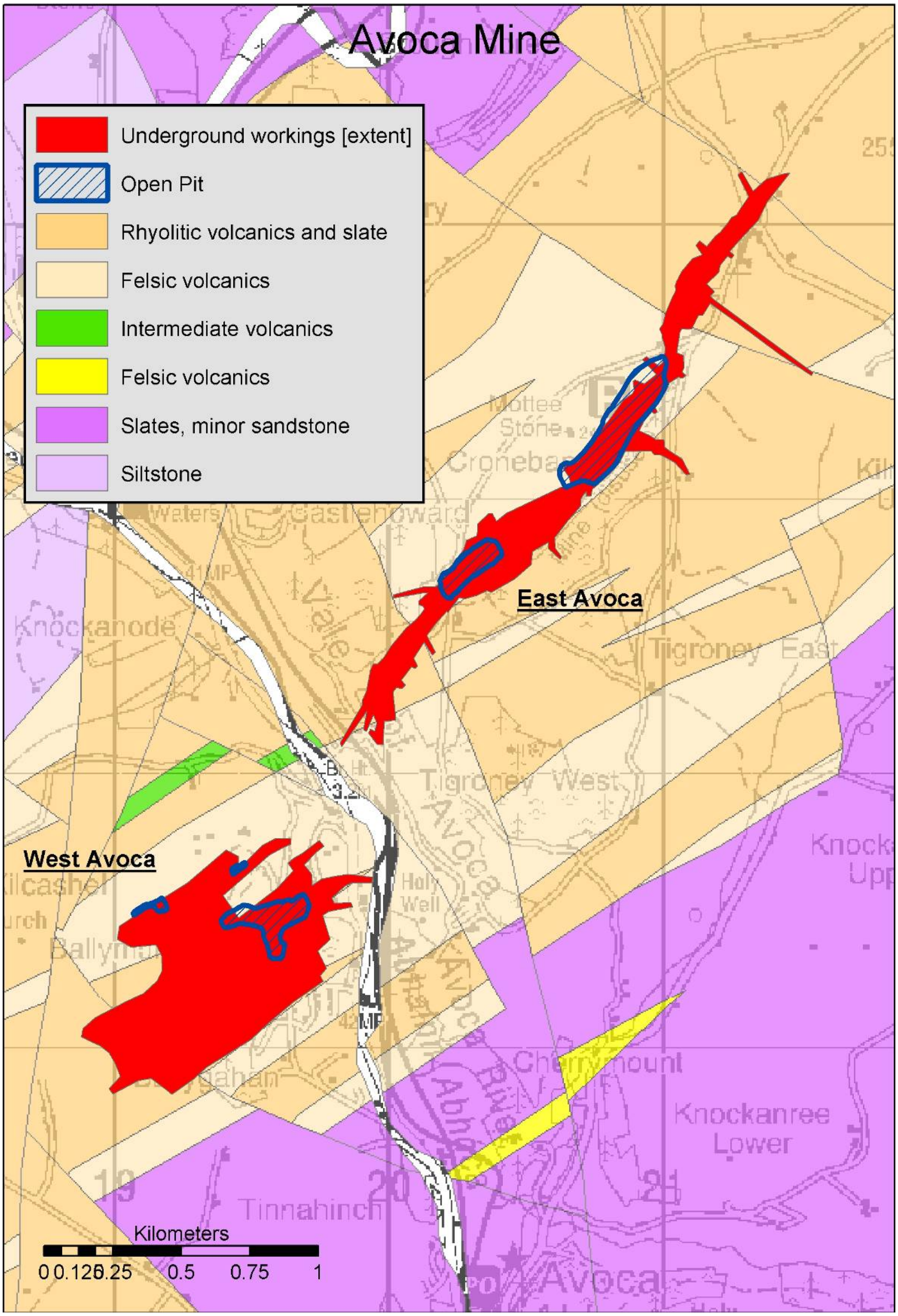

Figure 5-1: Avoca Geology (From GSI)

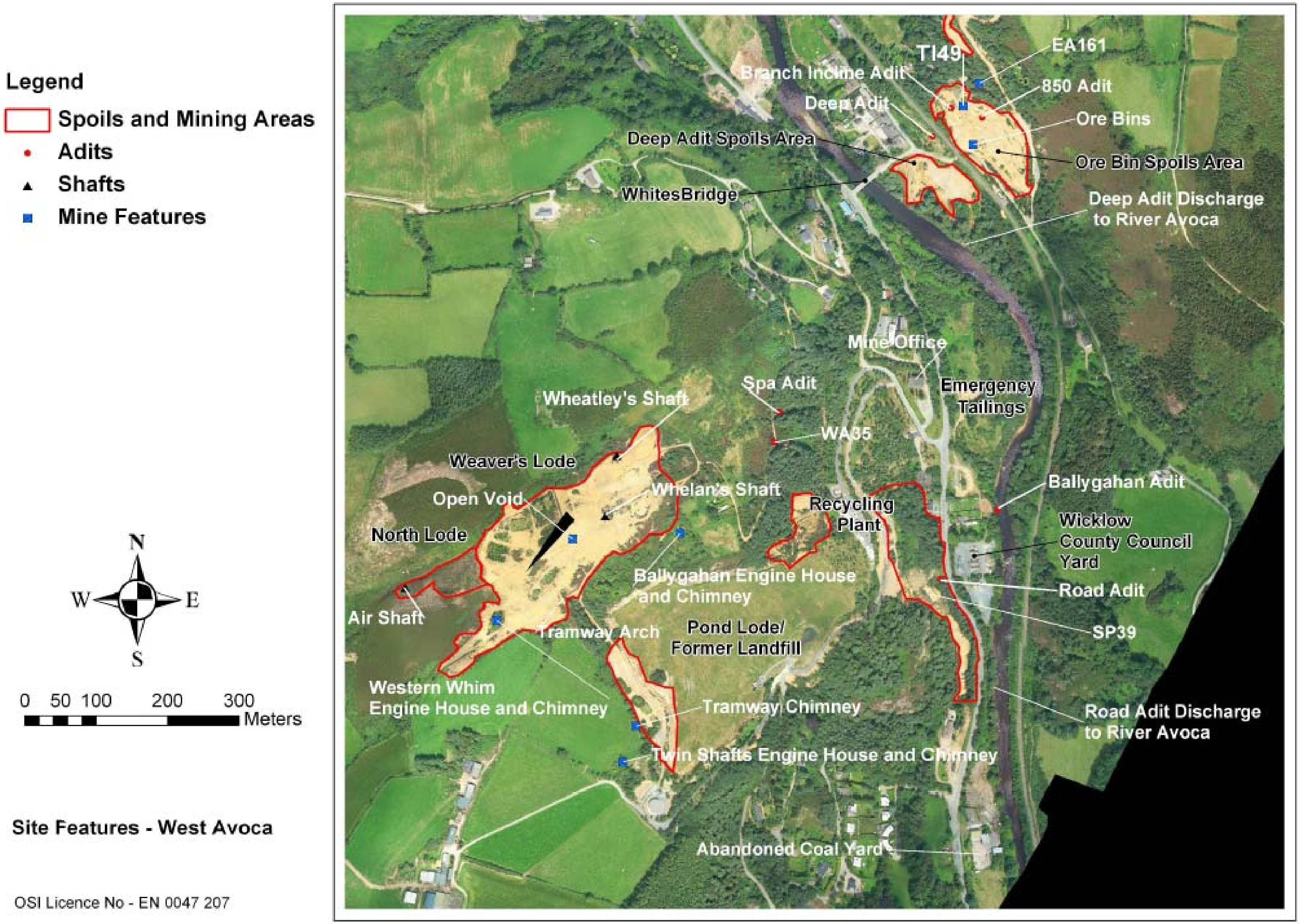

Figure 5-2: Location of spoil heaps in West Avoca (From CDM, 2008)

Table 5-2: Summary of West Avoca Spoil Heaps

GSI Reference	Location	Notes	Area (m^2)	Volume (m^3)
SP33	N of Ballymurtagh Landfill (Pond Lode Pit). The Knight Tunnel is on the NE side.	19th Century. Red-brown, extensive oxidation, 20-50mm clasts in fine matrix	7,253	7,253
SP34	Fills upper part of and extends NE from North Lode Pit	The lower portion of the North Pit (excavated in the 19th century) is filled with 20th century tailings and capped with 20th century spoils. Red-brown, extensive oxidation, 1-100mm clasts in fine matrix	14,304	233,220
SP34A	NE of Wheatley's Shaft and N of Weaver's Pit	19th Century. Red-brown, extensive oxidation, 10-100mm clasts in fine matrix	1,034	20,680
SP34B	Northwest of the Ballymurtagh Landfill (Pond Lode Pit). The Tramway Arch is located on the SE side.	19th Century. Sapsford and Williams (2005) conducted humidity cell testing on this material. Red-brown, extensive oxidation, 1-100mm clasts in fine matrix	25,028	25,028
SP35	SW of Western Whim Chimney and Engine House	19th Century. Red-brown, extensive oxidation, 10-200mm clasts in fine matrix	242	4,840
SP36	Between Tramway Arch & Tramway Engine House Stack	19th Century. Light coloured on surface, red-brown, extensive oxidation underneath, 10-30mm clasts in fine matrix	808	3,232
SP37	SW of Ballymurtagh Landfill (Pond Lode Pit)	19th Century. Red-brown, extensive oxidation, 30-40% of clasts >20mm in fine matrix	17,902	17,902
SP38	Within S lobe of Pond Lode Pit		526	1052
SP39	S of Ballymurtagh Landfill (Pond Lode Pit)	19th Century. Red-brown, extensive oxidation, 10-50mm clasts in fine matrix	14,593	109,071
		Total	**81,690**	**422,278**

5.3.2 Spoils and Tailings Beneath the Ballymurtagh Landfill

Although the landfill itself covers a total area of 6.3 hectares, the open pit floor covers a smaller footprint of about 1.2 hectares (approx. 200 m long x 60 m wide, bounded by steep-sided rock faces). Prior to the landfill becoming operational, wet mine tailings (effectively a liquid sludge) were deposited into the open pit. The tailings consist of silt-grade waste materials from the primary and secondary crushing of ore after the base materials had been extracted. The placement of tailings into the open pit ceased in 1982.

In 1986, several boreholes were drilled through the open pit tailings and into the underlying bedrock, partly to investigate the nature and thickness of the tailings, and partly to characterize groundwater levels in the tailings and bedrock (KT Cullen, 1987). Based on drilling results from 9 boreholes, the reported thickness of the tailings range from <2 m to 16.5 m.

Although deposited as a liquid, the tailings were at the time of drilling partly dried out and semi-consolidated, with only the ‘deeper levels below 6 m’ showing signs of ‘softening’ (KT Cullen, 1987). Standpipes installed within the tailings were all reported as dry, indicating that drainage had taken place through the base of the open pit. Three boreholes installed into the underlying bedrock further demonstrated groundwater levels below the tailings were below the base level of the pit, controlled by the underground mine workings within bedrock.

At the time of drilling, the reported top elevation of the relatively flat open pit was +70 m OD. Each of the three bedrock boreholes recorded competent (‘sound’) bedrock to their total depths (i.e., did not intersect any underground workings) at the locations of drilling.

5.4 River Deposits (Alluvium)

Along the Avoca River, borehole records indicate that river alluvial deposits are up to 20 metres thick in East Avoca (near the Deep Adit spoils area) and greater than 20 metres thick in West Avoca near the Emergency Tailings area (CDM, 2008). Similar indications of thick river alluvial deposits are reported from Ballymurtagh Landfill investigations (RPS, 2006) and trial well drilling further downstream near Woodenbridge (White Young Green, 2006).

The alluvial sediments are primarily of fluvial origin, i.e., they were deposited by the Avoca River. As evidenced from drilling, the alluvial sediments are coarse grained, comprising sub-angular sands and gravels with occasional bands or thin layers of fine silts and clays.

The alluvium partly represents reworked boulder clay (glacial till). Exposed cobbles comprise shale, slate, rhyolite, and granitic rocks (the latter transported from the Leinster granite in the core of the Wicklow Mountains at higher elevation).

5.5 Potential Impacts on Soils and Geology

During the period of active landfill operations, onsite activities consisted almost entirely of waste deposition into the open pit. As such, there would have been no impacts in terms of physical disturbances to soils and geology at the landfill site.

Following closure, the landfill has been subject to a restoration and aftercare plan. This has entailed engineering a low-permeability cap over the landfill area, constructing surface water drains and a stormwater retention pond, and diversion ditches along the perimeter of the landfill.

As such, and with adequate maintenance, there will be no post-closure impacts on the soils and geology of the landfill.

In West Avoca, all mining pits have already been partially backfilled, through its use as a landfill. As such, the risks of failure, through collapse or slippage of exposed rock faces of former pits are greatly reduced (CDM, 2008). In this respect, the use of the Pond Lode pit as a backfilled landfill has had positive health and safety impact for the mines area in West Avoca.

5.6 Mitigating Measures

Periodic inspection and maintenance of the landfill cap is carried out. In addition, slope stability inspection is carried out on an annual basis. The most recent slope stability inspection was undertaken by SLR Consulting Ireland in December 2008 at the request of Wicklow County Council. It reported that

"*existing slopes at Ballymurtagh are stable and are expected to remain so, provided existing collector drains and vegetation cover are maintained. As degradation of the landfilled waste continues, particularly across the mid-slope section, the annual topographic survey data should continue to be reviewed to ensure that differential settlement of the waste does not give rise to a reduction or reversal in gradients of existing drains, thereby hindering their effectiveness.*"

However, any earth movement associated with cap maintenance will not require any specific mitigating measures related to existing soils and geological conditions.

Section 6
Surface Water

6.1 Introduction

The EPA classes the Avoca River as among the most polluted in Ireland in successive national water quality reports (EPA, 2005). This is a legacy of over 200 years of industrial scale mining at Avoca, in particular from impacts of acid rock drainage to the river. The acid rock drainage enters the river primarily from adits draining both the East and West Avoca mining areas but also from more diffuse discharges associated with spoil heaps and tailings (CDM, 2008).

The acid rock drainage is characterized by low pH values and high levels of iron, copper, zinc, and aluminium. The impact to river water quality is greatest during low flow conditions in the river. This has been documented in numerous previous studies such as the EU-funded LIFE project (Gallagher & O'Connor, 1987), a study undertaken by the University of Newcastle for the Eastern Regional Fisheries Board (Doyle *et al.* 2003), as well as extensive published research over many years by researchers from universities.

A major Feasibility Study for the Management and Remediation of the Avoca Mining Area was completed on behalf of the Minister of Communications, Energy and Natural Resources in 2008 (CDM, 2008).This report contributed new information about the complex pollutant loading patterns to the river. Two site-wide combined remedial alternatives were developed during the 2008 Feasibility Study to address physical hazards and both solid and water contamination for all locations at the Avoca Site. Each combined alternative comprises process options evaluated for each individual site location. Both combined alternatives are designed to protect human health and the environment while addressing the physical hazard health and safety concerns outlined in the Site remedial action objectives. Heritage and long-term site management are also considered. Implementation of the recommendations of this Feasibility Study is subject to a decision by the Minister for Communications, Energy and Natural Resources.

The Avoca catchment was also examined as part of the Eastern River Basin District (ERBD) project, one of several related projects undertaken to implement the Water Framework Directive across Ireland. The ERBD River Basin Management Plan 2009-2015 has been adopted by the members of Wicklow County Council at their meeting in October 2009. This Plan will now be forwarded to the EU Commission for assessment and approval in 2010. In the Plan, the Avoca River has been classified as "poor status" as a result of acid mine drainage.

6.2 Hydrological Context of the Ballymurtagh Landfill

A proportion of the rainfall that falls over the capped landfill generates surface runoff and flows towards the Avoca river valley as "overland flow". Several drains have been constructed within the landfill perimeter to intercept the runoff. These drain approximately 80% of the landfill area and direct the runoff water to a stormwater settlement pond near the south-eastern corner of the landfill. From this pond the surface water is directed downslope through a four-inch pipe connecting to the surface water drainage system from the Civic Waste Facility. From this connection, the surface water drains through a nine-inch pipe directly to the Avoca River as presented on **Figure 6-1**, Surface Water Drainage Layout Plan. Runoff over the lowest section of the landfill escapes the settlement pond, and naturally runs off towards the front embankment of the landfill. Runoff from the landfill does not flow or discharge to any lateral areas or side-gradient streams.

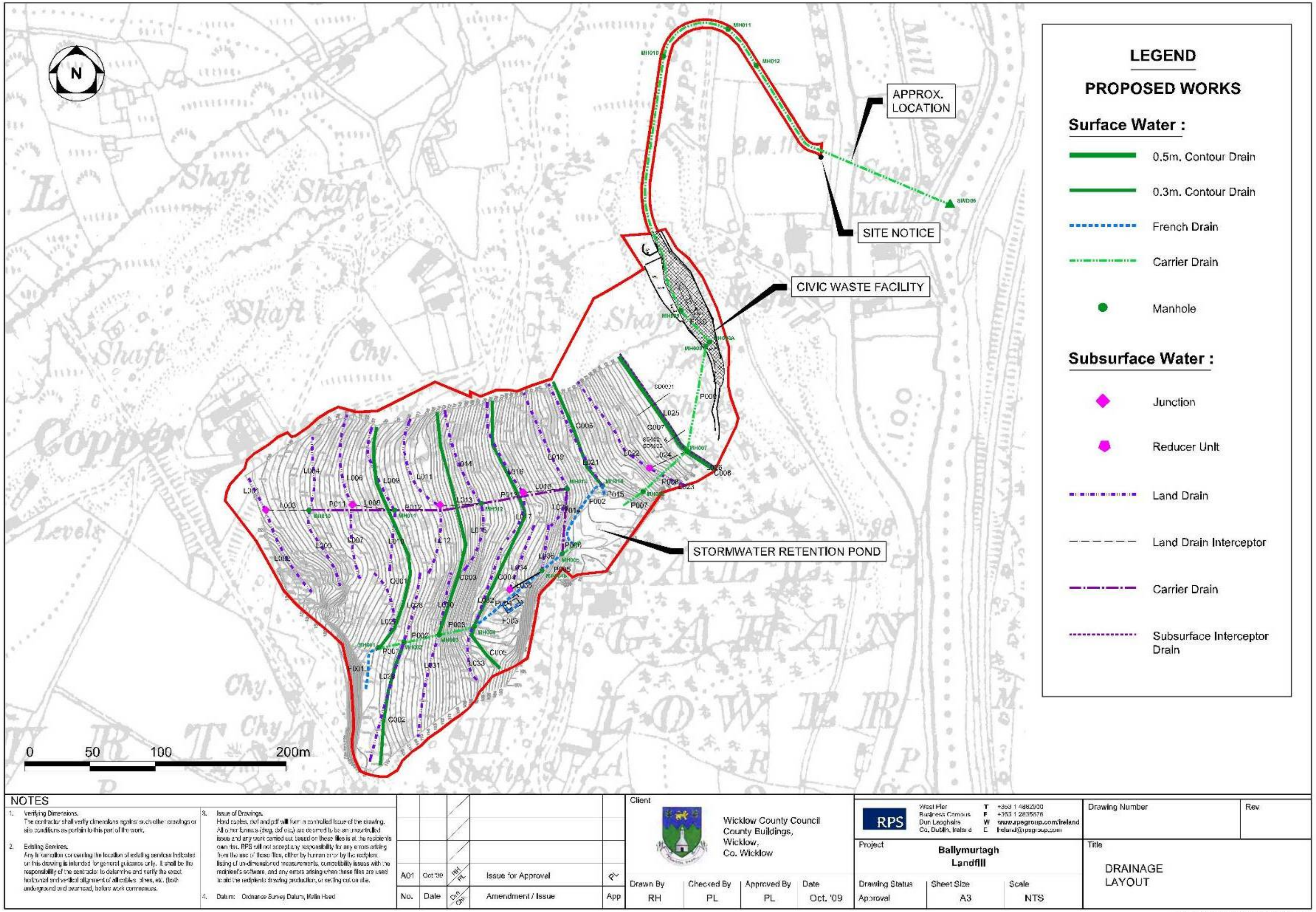

Figure 6-1: Surface water drainage at Ballymurtagh Landfill (RPS, 2008)

An estimated range of the quantity of surface runoff generated across the landfill area, under long-term average climatological conditions, is provided below:

- Precipitation (P): 1082 mm/yr (Met Éireann 30 year average 1961-1990);
- Potential Evapotranspiration (PE): 540 mm/yr (Met Éireann 30 year average 1961-1990);
- Actual Evapotranspiration (AE): 486 mm/yr (90% of PE);
- Potential Recharge (PR): P-AE = 596 mm/yr;
- Runoff Percentage (RP): 60-90% of PR = 358 – 536 mm/yr;
- Landfill Area (LA): 6.3 hectares or 63,000 m^2;
- Quantity of Surface Runoff over LA (SR): 22,554 – 33,768 m^3/yr, depending on RP.

The actual RP is not known but is assumed to be in the range of 60 to 90% of P based on slope information and the fact that the engineered cap is composed of a low-permeability clay material.

Actual quantities of runoff that are generated over the landfill are not measured but are expected to vary significantly in any given year according to both rainfall amounts and rainfall intensities.

Following the same procedures as above, the remainder of the water balance on the landfill is represented by Available Recharge (AR – i.e., water available as potential infiltration through the landfill cap). Even though the cap consists of a low-permeability clay matrix, some water can be expected to infiltrate into the landfill. On the assumption that AR is 10 to 40% of PR, the potential quantity of AR is:

- Potential Recharge (PR): P-AE = 596 mm/yr;
- Recharge Coefficient (Rc): 10-40% of PR = 60 – 238 mm/yr;
- Landfill Area (LA): 6.3 hectares or 63,000 m^2;
- Available Recharge (infiltration) over LA (AR): 3,800 – 15,000 m^3/yr, depending on Rc.

Given the low-permeability nature of the cap, the extensive vegetation covering the cap (see **Section 8**), as well as the surface drainage of the cap, expected values for Rc and AR are at the low end of the range indicated above.

Rainwater that infiltrates (i.e., AR) through the engineered landfill cap will come into contact with landfill waste materials and may contribute to the generation of leachates within the landfill. Leachates will subsequently flow, following paths of least resistance and accumulate in topographically lower areas within the landfill cell. Alternatively, the leachate may escape the landfill cell, either diffusively through the landfill slope at the downgradient edge of the landfill, or through preferential pathways.

As rainwater infiltrates, leachate levels can be expected to increase episodically with rainfall/recharge events. Similarly, leachate water levels may increase steadily over longer time periods if leachates accumulate in ‘storage’ areas within the landfill cell. Conversely, in periods of dry weather, leachate levels can be expected to drop, and wells may ‘dry up’. This latter scenario was experienced at the end of October 2009 after a dry period of almost five weeks.

Compared to flow volumes of the Avoca River, the quantities of runoff and leachates generated by the landfill are volumetrically negligible. Although the Avoca River is not yet gauged, the Q_{50}, mean flow of the Avoca River has been estimated through computer simulation to be on the order of about 15 m^3/s (CDM, 2007). In comparison, using the water balance figures presented above, the maximum estimated long-term average discharge of surface runoff water from the landfill into the Avoca River is 0.0011 m^3/s.

Using a high-end runoff percentage at the landfill of 90%, the runoff generated by the landfill represents only 0.003% of the mean flow of the Avoca River. In comparison, the minimum estimated long-term average discharge of surface runoff water from the landfill is 22,554 m^3/yr or 0.0007 m^3/s, whereas the estimated Q_{95} flow of the Avoca River near Avoca is approximately 1.2 m^3/s (CDM, 2007; Kevin T Cullen, 1987). Therefore the runoff generated by the landfill even under low flow conditions is only 0.05% of the estimated low flow of the Avoca River.

The computer-simulated river flow of the Avoca River between 1993 and 2005 is shown in **Figure 6-2**. The flows were simulated from rainfall-runoff modelling as part of the Eastern River Basin

District project (ERBD, 2007). The estimated flow for the period between 1993 and 2005 ranged from 1.12 to 144.5 m^3/s. The wide range of simulated flow conditions implies a rapid response to rainfall which in turn is a function of the physical characteristics of the Avoca River catchment of high rainfall, steep topography, thin soil cover and low permeability bedrock.

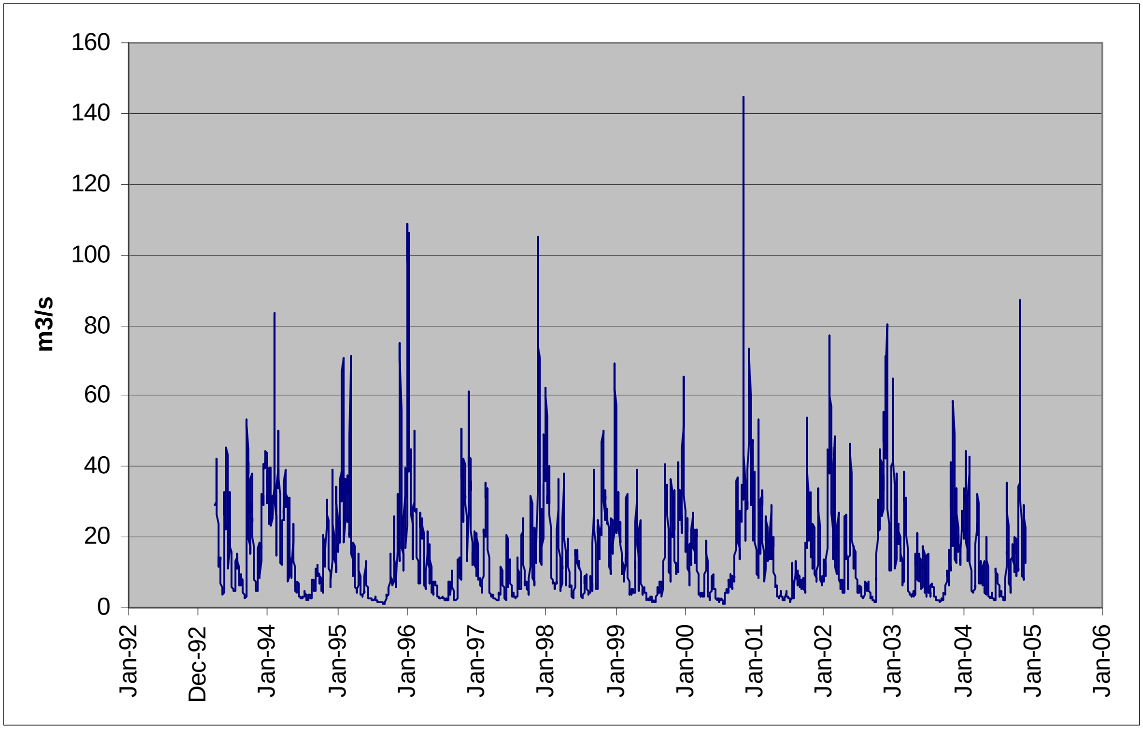

Figure 6-2: Net Simulated Flow of the Avoca River Near the Avoca Mines

There are no stream flow gauges on the Avoca River near the landfill or the Avoca Mining Area. The nearest stream gauge with good rating curves is Station 10002 (Rathdrum) on the Avonmore River, approximately 7 km to the north of the landfill. The flow record of Station 10002, reproduced in **Figure 6-3**, shows measured flows ranging from >40 m^3/s (following major rainfall events) to less than 1-2 m^3/s during low-flow conditions (mostly in late summer). Records from this station (as well as Station 10028 on the Aughrim River were used to calibrate the hydrological input parameters for the Avoca catchment simulations.

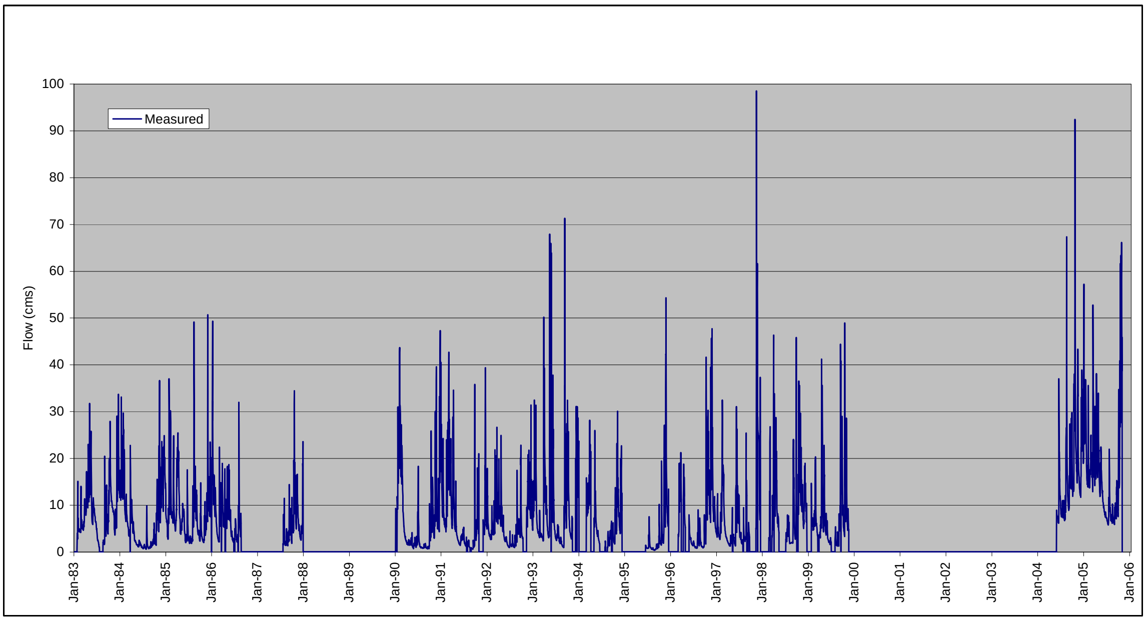

Figure 6-3 Measured Flow at Station 10002 on the Avonmore River

Although there are no flow recorders on the Avoca River near the landfill or the Avoca Mining Area, there is a staff gauge at the southern end of the Wicklow County Council maintenance yard. Using this gauge the river height is recorded manually by the County Council mainly on a daily basis. **Figure 6-4** shows the recorded river stage height between June 2007 and January 2008.

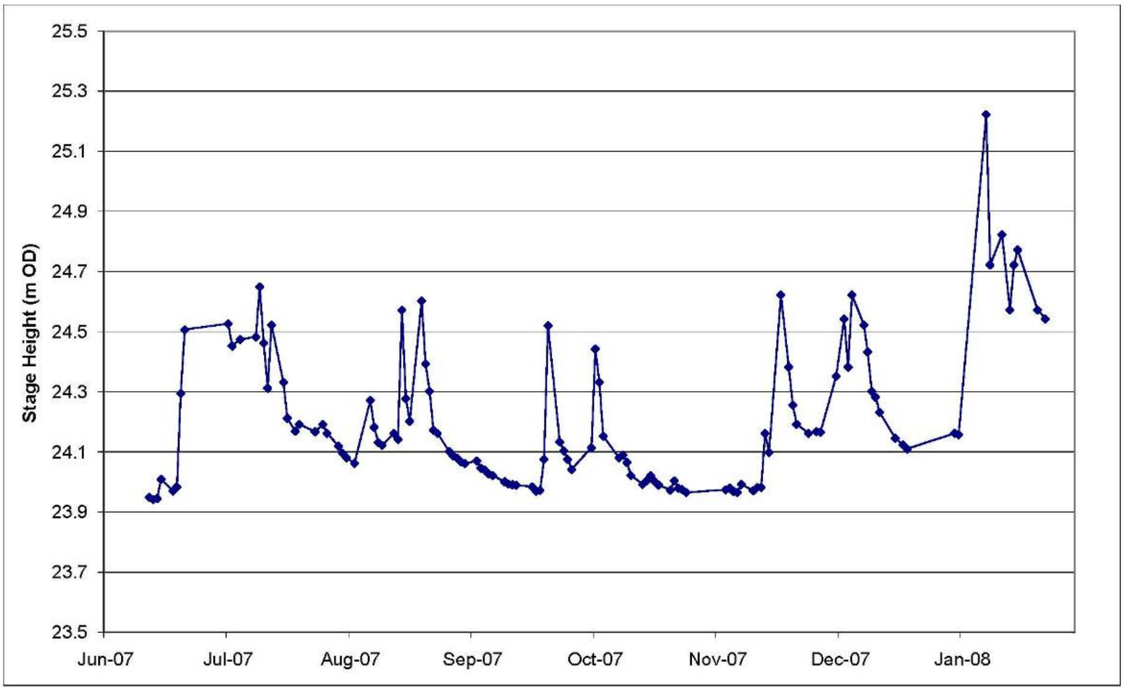

Figure 6-4: Stage Height of the Avoca River at the Wicklow County Council Maintenance Yard

There is no rating curve for the staff gauge, so the recorded stage heights cannot be converted to river flows, but the graph nonetheless demonstrates the flashy nature and recession characteristics of the Avoca River.

The majority of the runoff from the landfill is collected and piped directly to the Avoca River from the settlement pond within the landfill perimeter. In 2006 and 2007 the EPA requested quality analysis of the surface water run-off discharging to the Avoca River. The test results, presented in **Appendix C**, indicate that the quality of the surface water discharge is within the EPA surface water quality standards and no further characteristic data was requested from the EPA. The Avoca River is subject to routine water quality testing and monitoring by Wicklow County Council and the EPA. Other institutions such as the Eastern Regional Fisheries Board also conduct periodic sampling and testing of the Avoca River. Avoca River water quality results for 2008 are also presented in **Appendix C**.

6.3 Potential Impacts of Landfill Runoff on the Avoca River

The Avoca River is known from numerous past studies to be impacted by acid rock drainage from the Avoca Mining Area, both in West Avoca and East Avoca. There are two main acid rock discharge points – the East Avoca Deep Adit and the West Avoca Ballymurtagh (Road) Adit. In addition, polluted groundwater discharges diffusively along the river, mainly related to the mine spoil and tailing heaps that cover or are stockpiled the Avoca Mining Area (CDM, 2008).

The surface water generated from the Ballymurtagh Landfill is discharged directly to the Avoca River, is unpolluted, and is therefore independent of the adit discharge points or any diffuse groundwater sources. As such, the present runoff from the landfill is not a source of pollution to the Avoca River.

6.4 Mitigating Measures

No mitigating measures are required in connection with runoff from the capped Ballymurtagh Landfill. However, it is recommended that estimates of discharge quantities from the settlement pond be measured regularly, to improve the certainty of the water balance associated with the landfill.

Section 7
Groundwater

7.1 Introduction

This section of the EIS discusses the impact on groundwater of the capped and closed landfill.

The following primary sources of information were used in this assessment:

- Ballymurtagh Open Pit: Report on the Hydrogeological Survey of a Proposed Waste Disposal Site. Report to Wicklow County Council (Kevin T. Cullen, 1987);
- Feasibility Study for Management and Remediation of the Avoca Mining Area, Report for Department of Communications, Energy & Natural Resources (CDM, 2008);
- Characterization of the Avoca Mine Site: Geology, Mining Features, History and Soil Contamination Study (EU Life project) (Gallagher & O'Connor, 1997);
- County Wicklow Groundwater Protection Scheme (GSI, 2003);
- Wicklow County Council Environmental Monitoring Data, 1998-2009; and
- Relevant Irish groundwater-related legislation.

7.2 Hydrogeological Context of the Ballymurtagh Landfill

Ballymurtagh Landfill is underlain by Ordovician age metasediments comprising metamorphosed volcanic tuff. The GSI has categorised the rocks in the West Avoca area as being of type "Pu", defined as a "poor aquifer, generally unproductive". Rocks of this type are generally characterised as "poorly productive aquifers" (PPAs), in other words, they tend to transmit limited quantities of water and are not generally suitable for water production beyond supply for private homes.

Groundwater flow in bedrock at Avoca occurs naturally through fractures, fissures and cleavage planes. PPAs are characterized by low transmissivity and storage properties, and as such, groundwater occurrences are unpredictable and flow patterns are determined by heterogeneities associated with the geometries of related fractures and fissures.

Because of their low transmissive and storage properties, PPAs may not be able to "accept" all of the recharge that is available from rainfall, resulting in rejected recharge (Aldwell et al, 1983). Rejected recharge typically results in increased surface runoff and/or shallow groundwater flow near the top of bedrock in a zone commonly referred to as the "transition zone" (fractured, broken, weathered bedrock).

Groundwater pathways in the landfill area are complex. Under natural conditions, groundwater flow would be from topographically higher areas towards the Avoca River valley. However, the underground mine workings beneath the landfill site have significantly altered the hydrogeological conditions in the West Avoca mining area.

The mine workings consist of a complex system of interconnected shafts, stopes, tunnels and haulage ways at different elevations and stages. These passages serve as hydraulic sinks, whereby groundwater in bedrock is hydraulically 'captured' by the mine workings. As such, the mine workings act as preferential conduits for the captured groundwater which subsequently emerges in mine adits in the Avoca River valley.

In the West Avoca Mining Area, groundwater levels and discharges are primarily controlled by the Ballymurtagh (Road) Adit, and occasionally the Ballygahan Adit, depending on water levels within the mining system. The Ballymurtagh (Road) Adit discharges groundwater at an elevation of +31 m OD. In comparison, the base level of the landfill is at approximately +70 m OD.

Any groundwater that escapes the mine workings discharges "diffusively" to the alluvial deposits along the Avoca River valley. This flux component has been estimated to be between 1 to 3 L/s per Km of river length. In comparison, the mean annual flow of the Ballymurtagh (Road) Adit (which drains the underground mine workings) is approximately 17.7 L/s (Gallagher & O'Connor, 1997; CDM, 2008).

In context of groundwater quality protection, the GSI has published a Groundwater Protection Scheme (GWPS) for Co. Wicklow (GSI, 2003). This protection scheme defines groundwater vulnerability to pollution across Wicklow and presents risk management options ("permissible land use activities") related to potential pollution sources such as landfills, onsite wastewater treatment systems, and integrated pollution control (IPC) facilities.

For landfills, the GWPS includes a 'response matrix' of actions that may be recommended based on the mapped groundwater vulnerability and aquifer type at a given location. For the combination of hydrogeological conditions found in West Avoca (and which includes the landfill), GSI's response matrix for landfills carries a code "R2[1]". This code denotes that landfilling is "*acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence*" (DELG/GSI/EPA, 1999).

The rocks beneath the Ballymurtagh landfill have natural, low permeability characteristics, however, the underground mine workings are a man-made form of higher permeability zones. This does not directly imply that the risk of groundwater pollution from the landfill is increased. As described in subsequent sections, the base of the landfill is lined with silt-grade mine tailings which partly act as a buffer to the interaction between the landfill and underlying groundwater.

Finally, there are no water supply wells downgradient of the landfill, and there are no projected future developments of groundwater in the West Avoca Mining Area.

7.3 Potential Groundwater (Leachate) Pathways from the Landfill

Measured leachate levels within the landfill are significantly higher in elevation than measured groundwater levels in the surrounding host rock. Any leachates that escape the engineered landfill cell will move downward and downslope following paths of least resistance.

There are three potential pathways out of the landfill cell:

- Scenario 1 - vertical migration through the base of the landfill into underlying bedrock;
- Scenario 2 - diffuse lateral migration through the embankment at the front of the landfill;
- Scenario 3 - preferential migration through natural or man-made features for example former monitoring wells or old mine shafts that may intersect the base level of the landfill, which was a former open mine pit.

Each scenario is depicted in **Figure 7-1** which also represents a conceptual hydrogeological model of West Avoca.

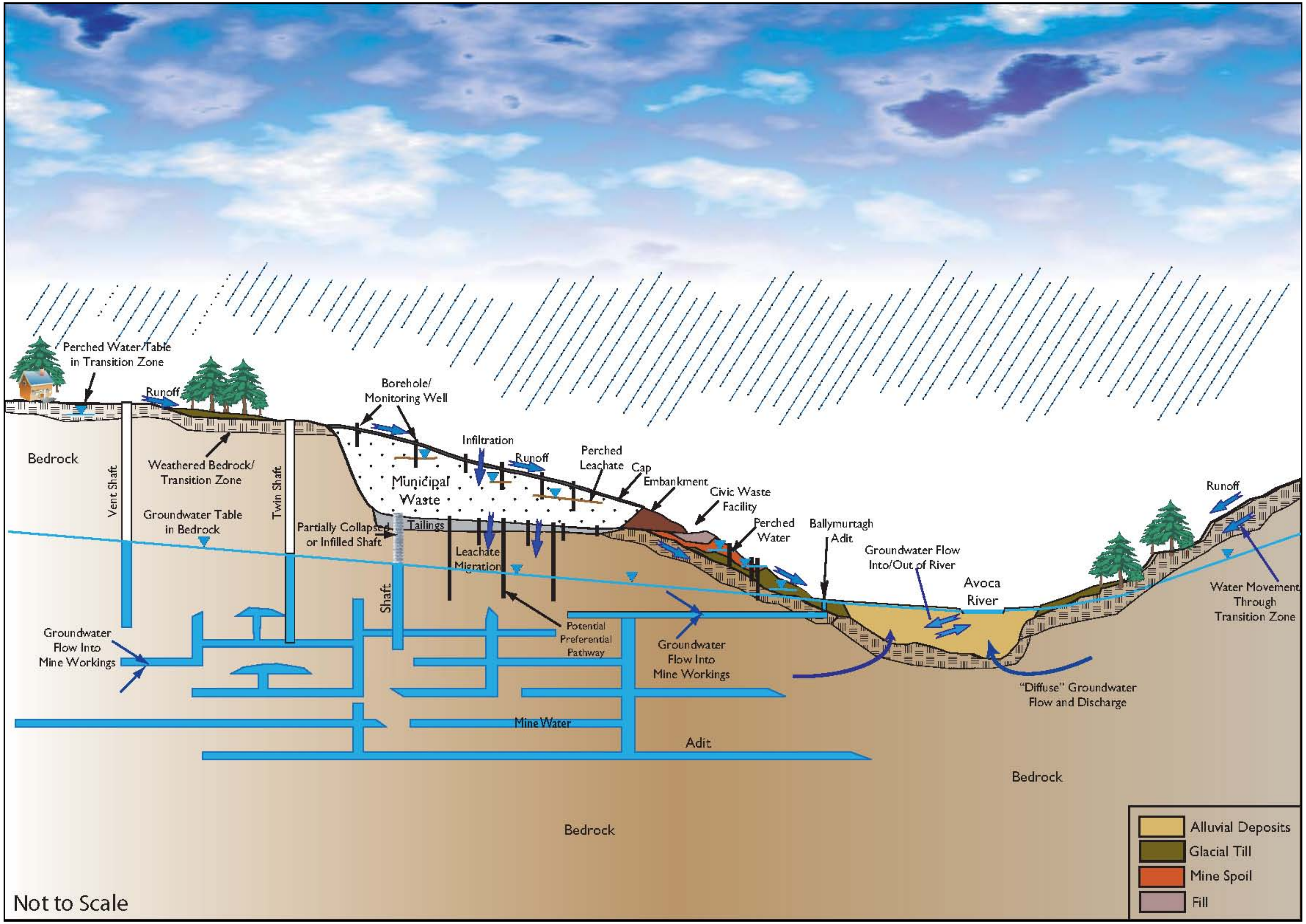

Figure 7-1: Schematic Cross-Section of West Avoca Including the Conceptual Hydrogeology of Ballymurtagh Landfill

7.3.1 Scenario 1:

Scenario 1 involves diffuse vertical migration of leachates through the base of the landfill, through the mine tailings that line the base of the former open Pond Lode pit as shown in **Figure 7-2**. As described in **Section 3**, prior to landfill operations, the footprint of the Pond Lode pit was 'lined' with mine tailings. Reports from drilling of 9 boreholes in 1986 indicates that the tailings materials range in thickness from <2 m to 16.5 m (Kevin T Cullen 1987). The significance of this lining is that it separates the landfill waste and leachate from the underlying bedrock. Conceptually, it therefore provides a buffer between the landfill, a potential pollution source and groundwater in bedrock, a potential receptor of pollution.

Any vertical leachate migration through the lining would be controlled by the vertical hydraulic conductivity (Kv) of the tailings as well as the head of leachate in the landfill. There are no accurate details on the Kv of the tailings, but on the basis of being described as a silt-grade material (KT Cullen, 1987), a value of 1.0E-08 m/s is considered reasonable.

Over the 1.2 hectare footprint of the base of the landfill, this would equate to a potential leachate quantity of approximately 3,700 m^3/yr migrating vertically through the liner. In comparison, the total estimated average infiltration through the landfill cap ranges from 3,800 – 15,000 m^3/yr, depending on which recharge coefficient that is used (10-40% of potential recharge).

Based on available information (RPS, 1998; Kevin T Cullen, 1987), the entire base of the landfill is covered with mining tailings. As well, there is evidence that at least the lower part of the landfill was lined with a butyl rubber 'mat'. The low-permeability, silt-grade mine tailings were deposited and spread over the rubber as suggested by the photograph included in **Figure 7-2.** Whether or not the rubber liner covers the entire floor of the open pit has not yet been possibly to verify.

Figure 7-2: Rubber liner and mine tailings in Pond Lode Pit

7.3.2 Scenario 2:

The downgradient edge of the engineered landfill, near the present recycling facility, consists of an approximately 10 m high embankment between elevations +70 and +80 m OD. The base level of the landfill, represented by the mining tailings “liner”, is at an elevation +70 m OD.

There are several leachate monitoring wells within the landfill. In the lower, downgradient part of the landfill, measured leachate levels range from approximately +75 to +78 m OD (RPS, 2008). These measured levels indicate that leachates are partly stored behind the engineered landfill embankment. The first 5 m of the original embankment were lined with a butyl rubber material, and the embankment was subsequently constructed with low-permeability materials. With an apparent head of leachate behind it, it is expected that small quantities of leachate may be seeping through the upper slope of this embankment (as controlled by the permeability of the embankment material and the leachate head within the landfill).

The embankment is heavily vegetated, and there are presently no obvious signs of seepage on its exterior. However, the presence of small seepages can not be ruled out as they may be hidden by the dense undergrowth. Seepages that are not evapotranspirated would seep to the base of the embankment at the front of the recycling facility and infiltrate into the ground. Water levels in monitoring wells along the access road to the recycling facility are 25-30 m lower than leachate levels within the landfill. The unsaturated zone at this location is therefore nearly 25-30 metres thick. It is expected that there may be multiple small, perched water tables in the subsoils immediately downgradient of the landfill.

Although unlikely, it is not known whether there is a continuous leachate ‘water table’ within the landfill or if leachates are perched in small pockets within the waste materials. Given the heterogeneous nature of filling landfills, the latter condition is probably more realistic. Available monitoring data suggests that some wells periodically dry up. For example, well L05-10 was dry at the beginning of October 2009 following a one-month period of no rainfall. In contrast, wells L03-1 and L03-2 remained ‘wet’ (i.e., had measurable water levels). This may support a theory that the upper parts of the landfill (e.g., near L05-10 and L05-16) slowly drain towards the lower parts (e.g., L03-1 and L03-2), and that leachate accumulates behind the lower embankment.

Post-landfill capping (2005), there appears to be a steady increase in leachate levels in landfill wells L03-1 and L03-2 between 2006 and 2008, as shown in **Figure 7-3.** This trend appears to flatten out or reverse itself in 2009. Wicklow County Council will continue active monitoring of these leachate levels.

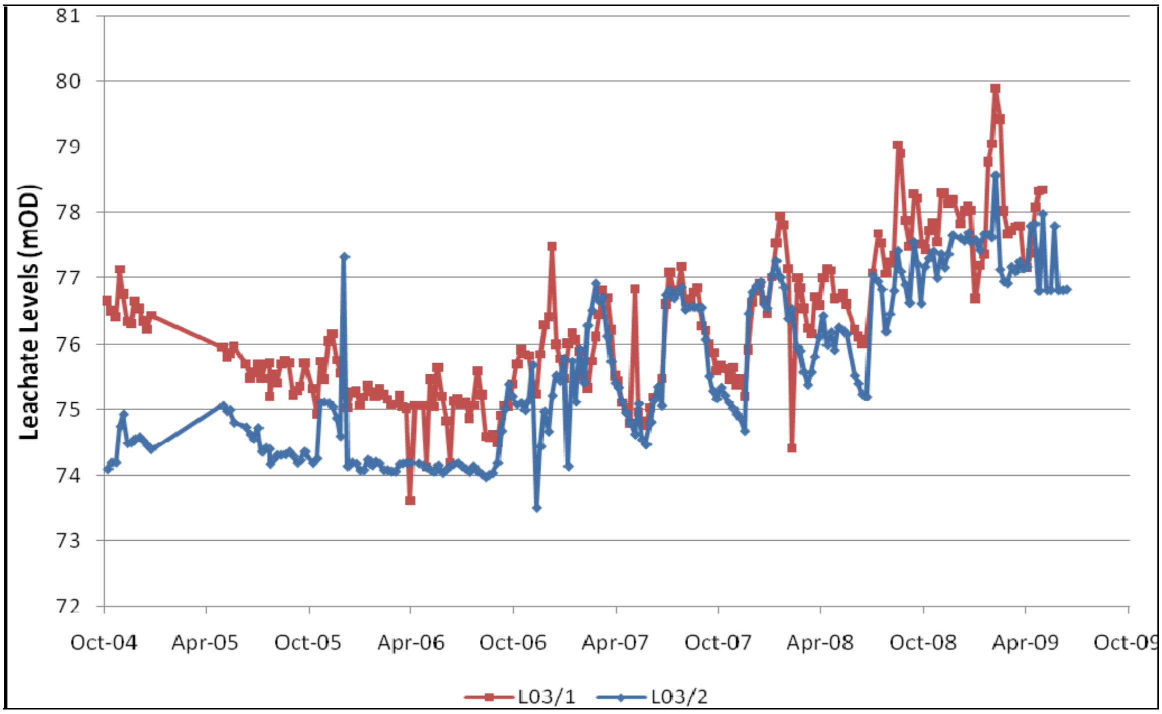

Figure 7-3: Leachate Levels in Wells L03-1 and L03-2, 2004-2009

7.3.3 Scenario 3:

A third potential pathway of leachate from the landfill relates to artificial, man-made, features which may enhance leachate migration out of the landfill. These relate to old mine workings from collapsed vertical shafts and the existence of at least three wells within the landfill perimeter that were drilled in 1986 and penetrated the tailings liner into bedrock (Kevin T Cullen, 1987). If the latter wells were not backfilled with grout before landfill operations began, they may act as conduits of leachate directly into bedrock.

Similarly, any shafts or tunnels that may have been exposed at the base of the open pit prior to landfilling may act as vertical preferential pathways for leachate migration to bedrock. Finally, past blasting operations within the mine system may have artificially opened up fractures and fissures to create pathways that did not otherwise occur.

7.4 Leachate and Groundwater Quality

Leachate, groundwater and surface water have been routinely tested for more than 10 years as part of Wicklow County Council's environmental monitoring programme, and in accordance with the current Waste Licence for the landfill. **Figure 7-4** shows the locations of leachate, ground and surface water monitoring points. Monitoring wells outside the landfill are shallow and monitor water quality in subsoil deposits (either glacial till, spoil materials or river alluvium). Two wells also monitor groundwater quality in bedrock.

Importantly, the monitoring network includes monitoring point SW3, which represents the Ballymurtagh (Road) Adit and which drains most of the underground mine workings in West Avoca.

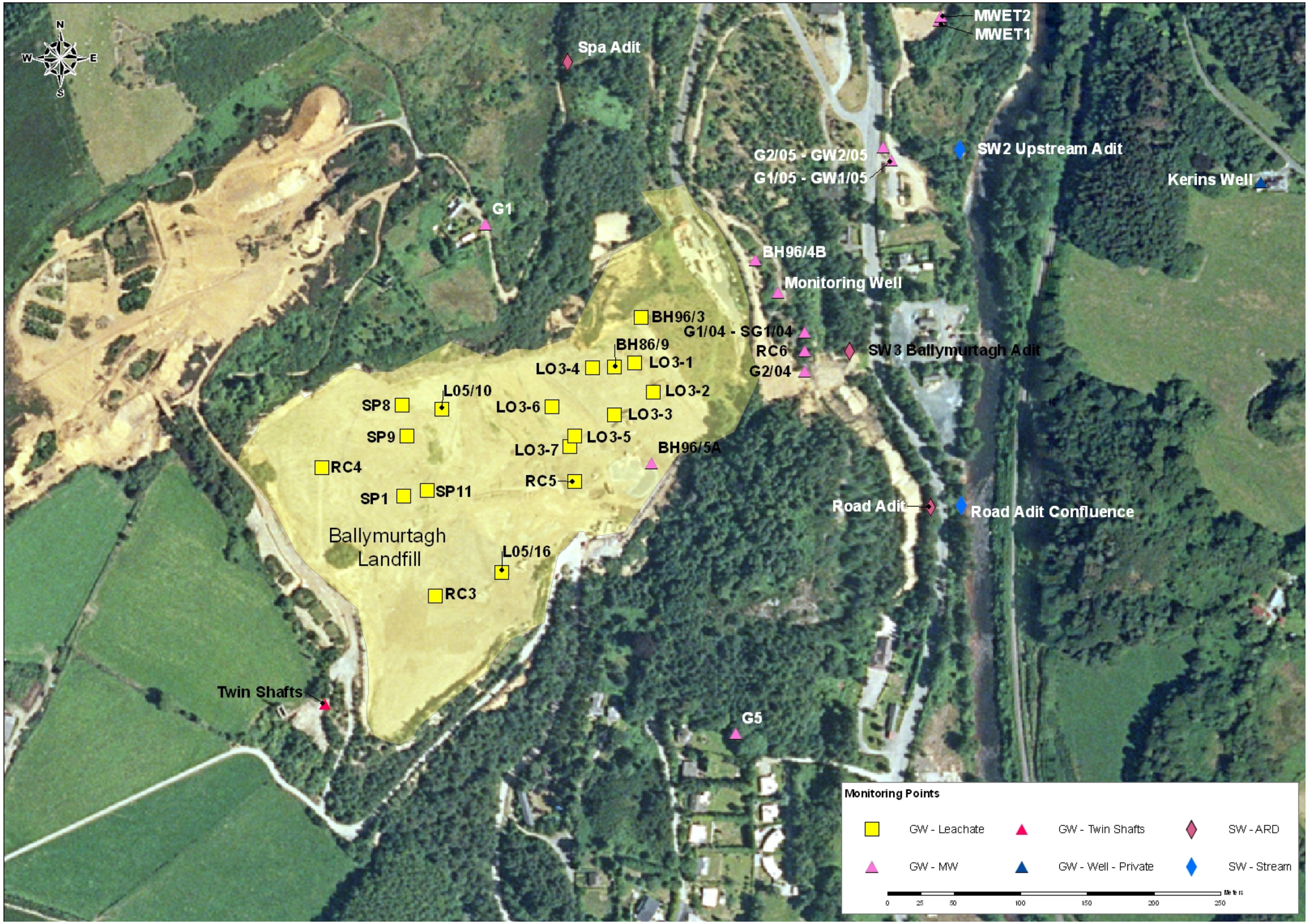

Figure 7-4: Monitoring Points in vicinity of the Landfill

Table 7-1 presents the quality of leachate well L05-10 between 2005 and 2009. Sample point L05-10 is representative of the leachate quality in the landfill, and the observed chemical signature is typical of a municipal waste landfill - with elevated electrical conductivity, chloride, ammonium, sulphate, BOD and COD concentrations. Some leachate samples from the landfill also indicate the presence of phenols, albeit at very low concentrations near or at its detection limit as discussed in **Section 7.3.1**.

Heavy metals such as copper, lead and zinc are largely absent from leachate samples. These metals effectively provide the chemical signature of acid rock drainage (ARD) associated with the Avoca mines as discussed in **Section 7.5**.

Table 7-2 presents the water quality of groundwater which discharged from the Ballymurtagh (Road) Adit in 2007 and 2008. Results indicate a primary chemical signature of ARD, however, it also includes elevated concentrations of ammonium at 7-9 mg/L.

Although the water quality of the Ballymurtagh (Road) Adit is described primarily by ARD, the presence of ammonium suggests a connection between the adit and the landfill. This differentiates the Ballymurtagh (Road) Adit from the Deep Adit in East Avoca. The East Avoca Mining Area does not include any landfills, shows low ammonium concentrations, and the water quality of the Deep Adit is entirely representative of ARD (CDM, 2008).

Although not shown in **Table 7-2**, the pH of both adits is indicative of ARD impacts, with reported pH values between 3 and 4 (CDM, 2008).

A common feature between the Deep and Ballymurtagh (Road) Adits is that heavy metal concentrations may vary seasonally by several orders of magnitude (CDM, 2008). These variations relate to the oxidation of sulphides and bacteriological activity that takes place within the mine workings (CDM, 2008).

The only pre-landfill groundwater samples available from West Avoca are those contained in the hydrogeological study of the proposed landfill site in 1986 (KT Cullen, 1987). **Table 7-3** is a scanned reproduction of analytical results from 1986, and shows results from samples that were collected from the Ballymurtagh (Road) Adit (surface water sample No. 4) and three wells (BH7, BH8, and BH9) completed in bedrock below the present landfill. These samples were therefore taken before landfill operations began and are free from landfill influence.

Although the range of analyses is restricted to a single sample, and therefore does not show temporal variability, the data nonetheless indicate that the three bedrock wells beneath the Pond Lode pit have similar physical-chemical characteristics to Ballymurtagh (Road) Adit. The low pH, high sulphate and metals such as copper, iron, and zinc are consistent with ARD. The elevated sulphate is explained by the mineralogy of the ore bodies containing different types of metal sulphides.

Importantly, the pre-landfill results beneath the Pond Lode pit and at the Ballymurtagh (Road) Adit provide evidence that List I and II substances specified in the current Waste Licence were present in groundwater in West Avoca prior to the landfill.

Table 7-1: Leachate Quality in Well L05/10 for years 2005 to 2009

			2005		2006				2007				2008				2009	
Parameter	**Units**	**LI / LII**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
pH			7.6	7.8	7.7	7.8	7.7	7.7	8	8.2	7.8	7.9	7.7	7.5	7.7	7.5	7.8	--
Conductivity	uS/cm at 20°C		10,390	10,700	12,000	12,050	12,870	10,190	10,670	11,430	10,600	11,220	9,580	10,580	9,330	8,240	9,230	--
Alkalinity	mg/l HCO_3		--	5,250	--	--	--	5,300	--	--	--	5,900	--	--	--	4,500	--	--
COD	mg/l O_2		1,476	--	1,850	1,496	1,640	1,430	1,054	1,182	1,068	1,110	1,018	1,122	1,117	939	947	--
BOD	mg/l O_2		58	--	105	101	60	90	49	50	51	56	52	84	67	41	47	--
TON	mg/l N		<0.89	9	1.2	<1.5	0.6	<0.41	<0.2	0.62	<0.86	<1.27	<0.71	<0.9	<2.46	<0.41	<0.71	--
Ammonium	mg/l NH_4	II	1,197	1,230	1,257	1,057	1,177	16	1,025	1,309	1,186	962	1,012	1,271	717	13	522	--
Boron	mg/l B	II	--	3.43	--	--	--	2.89	--	--	--	2.43	--	--	--	0.069	--	--
Cadmium	mg/l Cd	I	--	<0.03	--	--	--	<0.03	--	--	--	<0.03	--	--	--	0.0018	--	--
Calcium	mg/l Ca		--	37	--	--	--	53	--	--	--	47	--	--	--	77	--	--
Chloride	mg/l Cl		976	44	1,121	1,099	1,080	946	896	977	850	969	759	868	760	682	718	--
Chromium	mg/l Cr	II	--	0.05	--	--	--	<0.05	--	--	--	0.05	--	--	--	41	--	--
Copper	mg/l Cu	II	--	<0.05	--	--	--	<0.05	--	--	--	0.006	--	--	--	0.021	--	--
Cyanide (total)	mg/l CN	I	--	0.02	--	--	--	0.01	--	--	--	0.01	--	--	--	<0.01	--	--
Iron	mg/l Fe		--	5	--	--	--	4.96	--	--	--	5.18	--	--	--	6.4	--	--
Lead	mg/l Pb	II	--	<0.2	--	--	--	<0.2	--	--	--	0.015	--	--	--	7.2	--	--
Magnesium	mg/l Mg		--	60	--	--	--	60	--	--	--	65	--	--	--	53	--	--
Manganese	mg/l Mn		--	0.27	--	--	--	0.19	--	--	--	0.093	--	--	--	0.17	--	--
Mercury	mg/l Hg	I	--	<0.0001	--	--	--	0.0002	--	--	--	0.0003	--	--	--	<0.0001	--	--
Ortho-Phos	mg/l PO_4		--	<1	--	--	--	23	--	--	--	27	--	--	--	9	--	--
Phos (total)	mg/l P		--	4.3	--	--	--	10.2	--	--	--	11	--	--	--	7.8	--	--
Potassium	mg/l K		--	609	--	--	--	573	--	--	--	527	--	--	--	427	--	--
Phenols	mg/l C_6H_5OH	II	--	0.23	0.26	0.19	0.19	0.29	<0.05	0.08	0.27	0.39	0.25	<0.05	0.14	<0.05	0.09	--
Sodium	mg/l Na		--	763	--	--	--	735	--	--	--	726	--	--	--	545	--	--
Sulphate	mg/l SO_4		--	78	--	--	--	3	--	--	--	18	--	--	--	41	--	--
Zinc	mg/l Zn	II	--	0.03	--	--	--	0.04	--	--	--	0.015	--	--	--	0.02	--	--

Table 7-2: Water Quality of the Ballymurtagh Road Adit and the East Avoca Deep Adit

Parameter	Location	Deep Adit Conf.	Road Adit Conf.	Road Adit	Deep Adit	Deep Adit	Road Adit
	Sample Date	31/07/2007	31/07/2007	31/07/2007	14/11/2007	19/02/2008	21/02/2008
Acidity	mg$CaCO_3$/l	820	630	-	715	930	535
Ammonia	mg/l as N	0.33	6.59	-	0.27	0.28	7.09
Chloride	mg/l	13	40	-	12	13	2171
Nitrate	mg/l as N	<0.37	<0.37	-	<0.37	<0.37	<0.37
Nitrite	mg/l as N	0.033	0.024	-	0.006	<0.005	<0.005
Phosphorus (React)	mg/l as P	0.02	0.02	-	<0.01	0.01	<0.01
Sulphate	mg/l	1362	1539	-	963	1047	2171
Suspended Solids	mg/l	10	<10	-	<10	<10	<10
T.O.C.	mg/l	0.4	1.2	-	1.2	0.9	1.6
TON	mg/l as N	<0.37	<0.37	-	<0.37	<0.37	<0.37
Total Alkalinity	mg$CaCO_3$/l	<10	<10	-	<10	<10	<10
Total Dissolved Solids (180°C)	mg/l	1770	2434	-	1600	2140	2140
Total Kjeldahl Nitrogen	mg/l as N	<0.5	10.2	-	<0.5	<0.5	12.3
Total Phosphorus	mg P/l	<0.01	<0.01	-	<0.01	<0.01	<0.01
Dissolved Mercury	ug/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sodium	mg/l	8	27.5	-	8.5	8.3	28.7
Sodium Unfiltered	mg/l	8	26	-	-	-	-
Potassium	mg/l	2.1	11.9	-	2.2	1.1	12.1
Potassium Unfiltered	mg/l	2.2	12	-	-	-	-
Total Mercury	mg/l	<0.05	<0.05	-	-	<0.05	<0.05
Dissolved Aluminium	ug/l	9	984	20930	84020	131800	28520
Total Aluminium	ug/l	76570	15820	-	-	80.86	18.75
Dissolved Antimony	ug/l	<1	<1	<1	<1	<1	<1
Total Antimony	ug/l	<1	<1	-	-	<0.05	<0.05
Dissolved Arsenic	ug/l	1	3	6	<1	<1	<1
Total Arsenic	ug/l	1	2	-	-	<0.05	<0.05
Dissolved Barium	ug/l	63	25	17	7	7	18
Total Barium	ug/l	29	39	-	-	<0.05	<0.05
Dissolved Cadmium	ug/l	<0.4	<0.4	12.3	91.4	142.7	10.9
Total Cadmium	ug/l	99	10	-	-	0.12	<0.05
Dissolved Calcium	ug/l	8188	219100	227600	8913	10270	176500
Total Calcium	ug/l	29230	224300	-	-	11.05	142.4
Dissolved Chromium	ug/l	<1	9	<1	<1	<1	<1
Total Chromium	ug/l	9	3	-	-	<0.05	<0.05
Dissolved Cobalt	ug/l	9	<1	134	105	117	137
Total Cobalt	ug/l	108	129	-	-	0.1	0.13
Dissolved Copper	ug/l	<1	2	268	1133	1380	309
Total Copper	ug/l	830	311	-	-	1.32	<0.05
Dissolved Iron	ug/l	293	30	150700	49220	21080	85390
Total Iron	ug/l	17300	111500	-	-	17.49	77.11
Dissolved Lead	ug/l	<1	1	308	1339	2247	366
Total Lead	ug/l	1534	270	-	-	1.54	0.24
Dissolved Magnesium	ug/l	81610	133400	143300	77460	93680	131300
Total Magnesium	ug/l	84190	126600	-	-	74.72	108.4
Dissolved Manganese	ug/l	961	42	13240	4280	4358	11730
Total Manganese	ug/l	3573	11040	-	-	3.35	9.74
Dissolved Nickel	ug/l	42	7	61	39	39	58
Total Nickel	ug/l	88	62	-	-	<0.05	<0.05
Total Phosphorous	ug/l	394	348	-	-	-	-
Dissolved Selenium	ug/l	<1	<1	3	<1	<1	1
Total Selenium	ug/l	2	3	-	-	0.11	0.18
Dissolved Silver	ug/l	<2	<2	<2	<2	<2	<2
Total Silver	ug/l	<2	<2	-	-	<2	<2
Dissolved Thallium	ug/l	<1	<1	2	2	2	2
Total Thallium	ug/l	2	2	-	-	<1	<1
Dissolved Tin	ug/l	<1	<1	<1	<1	<1	<1
Total Tin	ug/l	1	<1	-	-	<1	<1
Dissolved Titanium	ug/l	10	4	3	4	7	4
Total Titanium	ug/l	7	6	-	-	6	4
Dissolved Uranium	ug/l	<1	3	3	9	12	4
Total Uranium	ug/l	12	7	-	-	11	4
Dissolved Vanadium	ug/l	2	<1	<1	<1	<1	<1
Total Vanadium	ug/l	1	<1	-	-	0.18	0.25
Dissolved Zinc	ug/l	43090	10600	10950	48630	48860	11060
Total Zinc	ug/l	39290	9480	-	-	-	-

Table 7-3: Results of Water Quality, 1986, Pre-Landfill

Parameter	Unit	Surface Water Samples				E.E.C. Guidelines	
		Sample No. 1 Upstream of Mines	Sample No. 2 Fox Avoca	Sample No. 3	Sample No. 4 West Avoca Dischg	Guide Level	Admis Max.
Calcium	Ca mg/1	6.0	3.0	4.8	Int	100	-
Magnesium	Mg mg/1	1.0	4.0	6.3	Int	30	50
Sodium	Na mg/1	5.0	5.0	5.0	10	20	175
Potassium	K mg/1	0.8	1.2	0.9	2.6	10	12
Bicarbonate	HCO3 mg/1	N.E.	N.E.	N.E.	N.E.	-	-
Sulphate	SO4 mg/1	13	19	32	5200	25	250
Chloride	Cl mg/1	12	12	12	50	25	-
Ammonium	NH4 mg/1	<0.1	<0.1	<0.1	1.03	0.05	0.5
Nitrite	NO2 mg/1	<0.01	<0.01	<0.01	<0.01	-	0.1
Nitrate	NO3 mg/1	2.2	1.8	1.6	<0.1	25	50
Copper	CU mg/1	<0.1	0.1	0.1	4.0	0.1	-
Iron	Fe mg/1	0.2	0.6	2.0	160	0.05	0.2
Manganese	MN mg/1	0.1	0.3	0.4	105	0.02	0.05
P.V. @ 4 hours	O2 mg/1	3.9	4.2	4.2	Int	2	5
T.O.C.	C mg/1	4.7	5.7	8.1	2.9	-	-
pH	units	6.3	4.6	4.5	3.7	6.5-8.5	-
Hardness	CaCO3 mg/1	20	24	38	Int	-	-
Colour	Hazen	20	30	15	150	1	20
Turbidity	N.T.U.	1.4	4.9	4.3	7.5	1	10
Conductivity	Us/cm	56	72	100	5,200	400	-
Alkalinity	CaCO3 mg/1	3	<1	<1	<1	-	-
B.O.D.	O2 mg/1	0.9	1	1.3	23		
Temperature	C	7.75	7.75	8.0	15.75	12	25

NOTE: N.E. = Not Examined; N.D. = None Determined < = less than Int = Interference

Parameter	Unit	West Avoca			East Avoca	E.E.C. Guidelines	
		B.H. No. 7 1	B.H. No. 8 2	B.H. No. 9 3	Deep Adit	Guide Level	Admis Max.
Calcium	Ca mg/1	Int	Int	Int	118	100	-
Magnesium	Mg mg/1	Int	Int	Int	N.E.	30	50
Sodium	Na mg/1	6.0	11	6	1.0	20	175
Potassium	K mg/1	24	22	4.6	0.5	10	12
Bicarbonate	HCO3 mg/1	N.E.	N.E.	N.E.	N.E.	-	-
Sulphate	SO4 mg/1	3250	2500	2450	1020	25	250
Chloride	Cl mg/1	40	60	40	1200	25	-
Ammonium List II	NH4 mg/1	1.3	1.4	1.5	N.E.	0.05	0.5
Nitrite List II	NO2 mg/1	<0.1	<0.1	<0.003	N.E.	-	0.1
Nitrate	NO3 mg/1	<0.01	<0.01	<0.1	N.E.	25	50
Copper List II	CU mg/1	0.3	6.0	50	21.6	0.1	-
Iron	Fe mg/1	200	120	25	50	0.05	0.2
Manganese	MN mg/1	57	7	10	N.E.	0.02	0.05
P.V. @ 4 hours	O2 mg/1	<0.1	Int	<0.1	N.E.	2	5
T.O.C.	C mg/1	2.2	3.7	3.2	N.E.	-	-
pH	units	3.2	2.8	3.1	3.3	6.5-8.5	-
Hardness	CaCO3 mg/1	Int	Int	Int	N.E.	-	-
Colour	Hazen	10	50	<5	N.E.	1	20
Turbidity	N.T.U.	1.6	4.1	1.7	N.E.	1	10
Conductivity	Us/cm	3,400	2,700	2,200	2050	400	-
Alkalinity	CaCO3 mg/1	<1.0	<1.0	<1.0	0	-	-

NOTE: N.E. = Not Examined; N.D. = None Determined < = less than Int = Interference

Surprising elements of the pre-landfill results are the presence of ammonium in the bedrock and adit samples at 1.0-1.5 mg/L, and the reported BOD of 23 mg/L in Ballymurtagh (Road) Adit. Combined, these detections point to a source organic loading of groundwater in West Avoca, and is presumed to be associated with agricultural activities in the upland areas to the west of the landfill.

Since the landfill became operational, ammonium concentrations increased in the Ballymurtagh (Road) Adit to a maximum reported concentration of 30 mg/L in 2001 and 2003. Post-2001 and post-landfill capping (in 2005), there has been a steady downward trend in ammonium concentrations at the Ballymurtagh (Road) Adit, as shown in **Figure 7-5**.

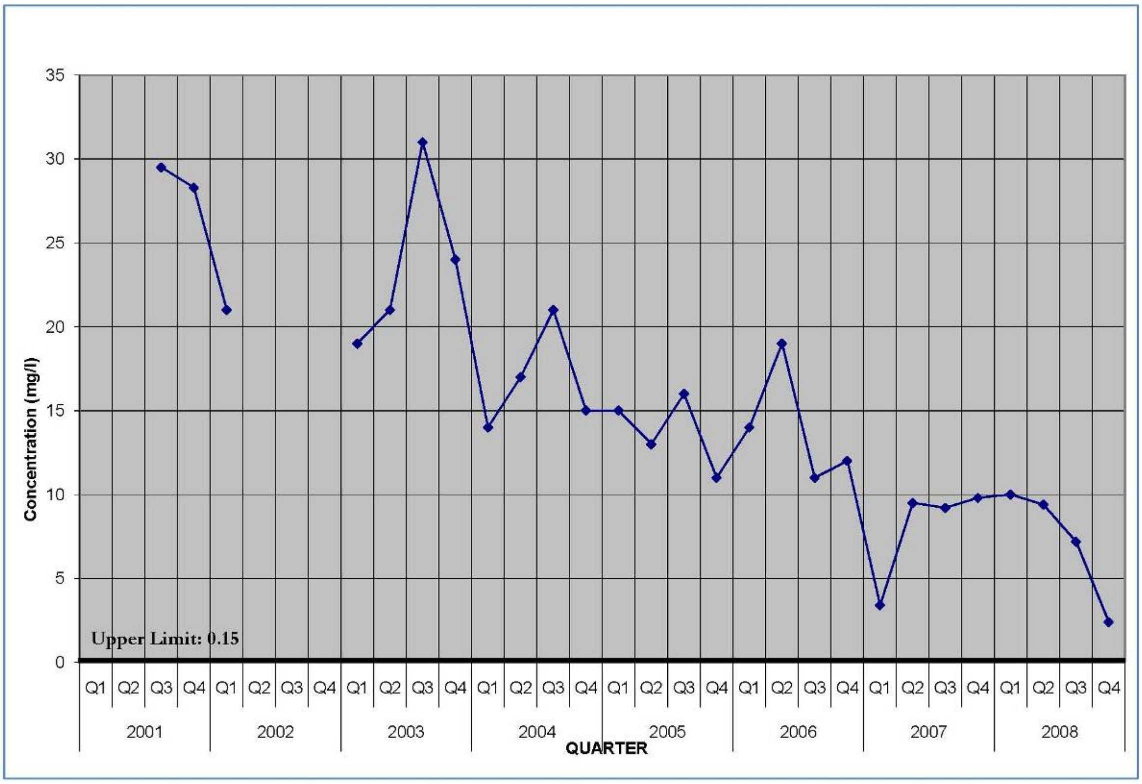

Figure 7-5: Ammonium Concentrations in the Ballymurtagh (Road) Adit, 2004-2008

In the first quarter of 2009, the reported ammonium concentration in Ballymurtagh (Road) Adit was 8 mg/L.

All groundwater monitoring wells downgradient of the landfill show the chemical signature that is linked to ARD as discussed in **Section 7.5**. However, a few wells, located close to the landfill also show an impact from leachates, primarily those located along the access road to the present recycling facility. The locations of these wells, G1/04, G2/04, RC6, and "monitoring well" are shown on **Figure 7-4**. Logs or notes of samples included with Wicklow County Council environmental reporting also suggest the periodic presence of organic materials in the water based on sample odour descriptions such as "shoe polish", "chemical" and "hydrocarbon".

Further downgradient and along a flow line from the northern limit of the landfill, the chemical signature of ARD is evident in two wells (G1/05 and G2/05) near the main Avoca-Rathdrum road. In these wells, the maximum reported ammonium concentration is 2.2 mg/L in G2/05 in 2007), however, most sample results for ammonium are non-detect (<0.08 mg/L). Similarly, at wells MWET-1 and MWET-2 located further north in the floodplain and constructed in 2007, water quality results are indicative of ARD only.

7.4.1 Summary of List I and II Substances

Table 7-4 summarises List I and II results through the second quarter of 2008 from leachate, groundwater and Ballymurtagh (Road) Adit samples.

Results of monitoring demonstrate that many List I and II substances (e.g., copper, cadmium, zinc) are detected at higher concentrations in groundwater outside the landfill compared to the leachate inside the landfill. As presented in **Section 7.6**, these substances can be attributed to acid rock drainage associated with past mining operations in West Avoca.

An extended suite of water quality parameters were tested in early 2009 at key locations to detect if contaminants other than those routinely monitored by Wicklow County Council are present in leachate and groundwater surrounding the landfill. The extended suite of parameters included volatile organic compounds (VOCs), semi-VOCs (SVOCs), and organochlorine pesticides (OPs). Analytical data are tabulated in full in **Appendix E**.

Key sample locations that were included in 2009 were leachate well L05-10, the Ballymurtagh (Road) Adit (sample location SW3), and bedrock well G5 ('Hall's Well") to the south of the landfill as shown in **Figure 7-4**. Results show:

- L05-10: Several organic pollutants were detected at relatively low concentrations (<28 ug/L), including BTEX compounds and a small number of diesel or waste oil related compounds. The exception and highest detection was bis(2-ethylhexyl)phthalate which was detected at 180 ug/L. Only two OPs were detected above their reported detection limit – dichlobenil at a concentration of 0.135 ug/L and 1, 2, 4-trichlorobenzene at 0.095 ug/L.
- Ballymurtagh Road Adit (SW3): Organic chemicals were virtually absent from the sample - VOCs and OPs were not reported above their detection limit (of 1 ug/L) and there were only three detections of SVOCs at or near their detection limit of 1 ug/L; naphthalene, benzo(b/k)fluoranthene, and bis(2-ethylhexyl)phthalate.
- G5 (Hall's Well): This bedrock well, located due south of the landfill, was tested to check on groundwater quality south of the landfill. It has not been included in routine monitoring in the past. Analytical results show a distinct chemical signature of ARD. Like SW3, organic chemicals were virtually absent from the sample. The only detections were naphthalene at 7 ug/L and bis(2-ethylhexyl)phthalate at 3 ug/L.
- The bis(2-ethylhexyl)phthalate detections may be a laboratory error as the blank sample gave a detection of 3ug/l. The reported detections should therefore be verified through a second round of sampling. There are no Irish or EU water quality standards for either of these compounds.

The presence of the hydrocarbons in leachate well L05-10 is notable but is not unexpected for a well screened in municipal landfill waste. The near absence of organic pollutants in the adit sample SW3 and the G5 well is indicative of the expected attenuation and dilution that takes place between the landfill and the underlying groundwater system. This is discussed further in **Section 7.7**.

Table 7-4: Summary of Monitored List I and II Substances through Q2 2008

			Leachate Samples (Landfill)															
			L05-10			L05/16			L03-2			LO3-1			BH 96/3			
Parameter	Units	List I/II	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples
pH			7.5	8.2	12	6.7	7.6	12	7	7.9	16	7	7.8	6	5.5	7.5	18
Conductivity	uS/cm at 20°C		9580	12870	12	1378	4190	12	1121	8940	16	3090	9850	6	3530	4560	18
Residue	mg/l @ 180°C														3084	4337	4
C.O.D.	mg/l O_2		1018	1850	11	67	420	12	183	12230	16	558	4345	6			
B.O.D.	mg/l O_2		49	105	11	16	119	12	15	2010	16	44	1595	6			
Dissolved O_2	mg/l O_2														0.3	7.4	17
T.O.C.	mg/l											60	60	1	4.3	38	18
T.O.N.	mg/l N		<0.41	9	12	<0.17	0.7	12	<0.17	<3.5	16	<0.16	0.6	6	<0.17	27	18
Total Alkalinity	mg/l HCO_3		5250	5900	3	650	1500	3	1250	2500	4	1300	3250	2	220	850	4
Ammonium	mg/l NH_4	II	16	1309	12	22	296	12	79	746	16	161	1094	6	6.8	235	18
Boron	mg/l B	II	2.43	3.43	3	0.15	0.61	3	0.72	2.08	4	3.178	3.178	1	0.15	0.74	4
Cadmium	mg/l Cd	I	<0.03	<0.03	3	<0.03	<0.03	3	<0.03	<0.03	4	<0.03	<0.03	2	<0.03	<0.03	4
Calcium	mg/l Ca		37	53	3	164	289	3	101	262	4	143	205	2	364	468	4
Chloride	mg/l Cl		44	1121	12	24	235	12	168	1084	16	204	1017	6	19	75	18
Chromium	mg/l Cr	II	<0.05	0.05	3	<0.05	<0.05	3	<0.05	<0.05	4	<0.05	<0.05	2	<0.05	<0.05	4
Copper	mg/l Cu	II	<0.05	0.0059	3	<0.05	0.0014	3	<0.05	<0.05	4	<0.05	<0.05	2	<0.0078	<0.05	4
Cyanide	mg/l CN	I	0.01	0.02	3	<0.01	<0.01	3	<0.005	0.01	4	<0.005	<0.005	1	<0.01	<0.01	4
Fluoride	mg/l F	II	0.3	1.4	3	0.2	0.4	3	0.14	1.4	4	0.4	0.4	1	0.22	0.7	4
Iron	mg/l Fe		4.96	5.18	3	0.057	22	3	1.39	58	4	1.06	4.87	2	0.24	474	18
Lead	mg/l Pb	II	0.015	0.015	3	<0.0002	<0.2	3	<0.02	<0.02	4	<0.2	<0.2	2	<0.0002	<0.2	4
Magnesium	mg/l Mg		60	65	3	50	56	3	44	174	4	40	84	2	263	408	4
Manganese	mg/l Mn		0.093	0.27	3	5.637	8	3	0.72	2.7	4	0.53	1.46	2	12.96	17	4
Mercury	mg/l Hg	I	<0.0001	0.0003	3	<0.0001	7E-05	3	<0.0001	0.0004	4	0.0003	0.0003	2	<0.00002	<0.0001	4
Nickel	mg/l Ni	II										<0.1	<0.1	1			
Nitrate	mg/l NO_3																
Nitrite	mg/l NO_2	II															
Ortho-Phos	mg/l PO_4		<1	27	3	<1	<1	3	<1	<1	4	<1	<1	1	<1	<1	4
Total Phos as P	mg/l P		4.3	11	3	0.55	0.81	3	0.85	1.9	4	16	16	1	<0.05	0.86	4
Potassium	mg/l K		527	609	3	28	80	3	157	352	4	129	400	2	24	76	18
Phenols	mg/l C_6H_5OH	II	<0.05	0.39	11	<0.05	0.16	11	<0.05	0.27	7				<0.05	0.14	18
Sodium	mg/l Na		726	763	3	81	135	3	264	407	4	179	487	2	21	63	18
Sulphate	mg/l SO_4		3	78	3	66	491	3	270	1890	4	253	296	2	1055	3043	15
Zinc	mg/l Zn	II	0.015	0.04	3	0.005	0.03	3	0.01	0.03	4	0.02	0.04	2	0.0071	0.08	4
Total Coliforms	CFU / 100ml		0	>500	12	0	>500	12	0	1640	15	15	2000	4	0	>1000	18
Faecal Coliforms	CFU / 100ml		0	55	12	0	90	12	0	60	15	0	100	4	0	>1000	18

	Groundwater Samples (Wells/Shafts)																		Groundwater Samples (Adits)		
	Twin Shafts			G1/04			G2/04			R6			G1/05			G2/05			SW3		
Parameter	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples	Min.	Max.	No. Samples
pH	6	7.3	36	2.8	3.5	16	3.5	4.2	4	2.5	3	4	3.7	4.3	12	3.7	4.4	12	3.8	4.9	25
Conductivity	328	565	36	9250	11830	16	3090	3360	4	5490	6710	4	1240	2000	12	1064	1468	12	1767	2880	25
Residue	242	433	17	19178	25856	4	4637	5142	2	9286	10146	2	1420	2292	3	1069	1347	3	5	8	3
C.O.D.																			14	56	25
B.O.D.																			<2	19	25
Dissolved O_2	1.4	11	34	2	7.9	15	2.7	6	3	6.5	7.7	4	1.9	9.3	11	4.1	9.9	11	3.4	9.6	24
T.O.C.	0.3	3.4	35	0.3	14	16	2.6	5.3	4	4.4	5.8	4	1	2	12	1.4	9.2	12	1	34	21
T.O.N.	<0.41	7	36	0.6	11	16	<2.9	3.2	4	1.1	4	4	1	4	12	1.3	1.9	12	<0.34	1	6
Total Alkalinity	30	65	17	<0.5	<5	4	<5	<5	2	<0.5	<5	2	<0.5	<5	3	<0.5	75	3	<0.5	<5	6
Ammonium	<0.08	0.8	36	<0.08	2	15	<0.08	1	4	<0.08	0.19	4	<0.08	0.08	12	<0.08	2.2	12	3.4	31	25
Boron	<0.01	0.05	17	<0.01	0.41	4	0.03	0.03	2	0.11	0.52	2	<0.01	0.05	3	<0.01	0.02	3			
Cadmium	0.01	0.04	18	0.77	1.41	4	0.09	0.12	2	0.14	0.2	2	122	190	3	116	130	3	<0.03	0.04	6
Calcium	30	74	33	274	310	4	121	151	2	140	201	2	0.03	0.07	3	<0.03	0.03	3	167	211	6
Chloride	22	518	36	8	40	16	6	15	4	4	21	4	<0.05	<0.05	3	<0.05	<0.05	3	34	89	25
Chromium	<0.05	<0.05	19	0.22	0.86	4	0	0.06	2	0.07	0.11	2	13	23	12	14	26	12	<0.05	<0.05	6
Copper	<0.05	0.01	18	62.23	201	4	51	57	2	76	77	2	9.2	14.1	3	5.8	7.5	3	0.38	0.9	5
Cyanide	<0.005	<0.05	18	<0.01	<0.01	4	<0.01	<0.01	2	<0.01	<0.01	2	<0.01	<0.01	3	<0.01	<0.01	3			
Fluoride	0.2	0.3	17	3.2	20	4	<0.01	9.2	2	2.5	7	2	1.5	2.1	3	1.1	1.3	3			
Iron	<0.01	0.32	36	25.8	485	16	2.8	12.5	4	82	279	4	0.22	31.325	12	0.0836	82	12	140.34	330	6
Lead	<0.004	0.1	18	0.42	1.097	4	0	0.27	2	0.23	0.25	2	<0.3	0.366	3	<0.01	<0.02	3	<0.02	0.57	6
Magnesium	13	20	18	1487	1927	4	305	345	2	542	614	2	76	152	3	59	78	3	136	286	6
Manganese	0.17	0.35	18	50	82	4	12	15	2	19	24	2	5.3	9.436	3	3.9	4.781	3	11.119	25	6
Mercury	<0.00002	<0.0001	7	<0.0001	0.0004	4	<0.0001	<0.0001	2	<0.00002	<0.0001	2	<0.00002	<0.0001	3	<0.00002	<0.0001	3	<0.0002	<0.0001	6
Nickel																					
Nitrate	3	24	11																		
Nitrite	<0.05	<1	11																		
Ortho-Phos	<0.1	<1	17	<5	<5	4	<1	<5	0	<5	<5	2	0.06	0.22	3	0.18	3.6	3	0	0	0
Total Phos as P	<0.1	5.4	17	0.1	0.73	4	0.1	19	2	0.05	1.9	2	<1	<1	3	<1	<1	3	<0.05	0.12	6
Potassium	3.2	13	36	2	<5	15	<1	6	4	<1	<5	4	2	3	12	2	3	12	11	17	6
Phenols	0.017	0.35	36	<0.05	0.11	16	<0.05	0.07	1	<0.05	0.25	4	<0.05	<0.1	12	<0.05	0.31	12			
Sodium	6.6	93	36	<5	12	16	4	6	4	1.8	6	4	10	21	12	11	20	12	22	52	6
Sulphate	91	240	28	122	19940	15	3364	3846	3	7227	8506	3	799	4522	12	700	1103	12	1179	2517	15
Zinc	0.09	14	17	200	398	4	29	40	2	47	55	2	10	23.4	3	6.3	8.8	3	13	31	6
Total Coliforms	0	>100	30	0	28.57	14	0	10	2	0	120	2	0	27	12	0	30	12			
Faecal Coliforms	0	77	30	0	20	14	0	0	2	0	2	2	0	22	12	0	20	12			

7.5 Potential Landfill Impact on Groundwater and Surface Water Quality

The key challenge in assessing the nature and extent of potential landfill impacts on groundwater and surface water quality in West Avoca is being able to distinguish between the impacts of the landfill from those of the mine workings. This is especially important because the landfill overlies the mine workings and therefore a co-mingling of contaminants can be expected in downgradient areas. Thus, to be able to demonstrate impacts of the landfill, it is critical that the leachate be "fingerprinted" to the extent possible, and that this fingerprinting can subsequently be used to recognise the landfill signature in co-mingled samples.

Chemical fingerprinting techniques are commonly used in environmental investigations to differentiate between different source areas, and there is a considerable volume of literature that demonstrate their practical uses and limitations (Olmez et al, 1994; Guler et al, 2002; Lee et al, 2007; Helena et al, 2000).

To be able to assess potential impacts of the Ballymurtagh Landfill against other potential sources of groundwater contamination in West Avoca, a multivariate (multiple variables/constituents) statistical method known as a Principal Component Analysis (PCA) has been carried out on water quality data collected since the mid-1990s, when long-term monitoring began.

The advantages of the PCA are many, but key amongst the outputs of a PCA is an attribution of probability of assignment of a sample to a particular source, which is described by relative variances of individual chemical constituents against a particular chemical fingerprint.

7.6 Principal Component Analysis

7.6.1 Introduction

PCA has been used widely in cases and situations where scientists seek to be able to assign a chemical fingerprint to a specific source area of contamination. Practical applications include contaminated land scenarios as well as remediation of disused mines.

Briefly, PCA is a data analysis method conducted in order to assist the environmental scientist with the identification and/or recognition of correlation patterns or structure among multiple samples and multiple variables (analytical constituents). The basic idea is that such correlation patterns, if present, define a distinctive dataset geometry shaped by the underlying environmental factors affecting the particular environment under study. When the shaping factors are due to sources of contamination, for example, the patterns produced by PCA should reflect these sources of contamination.

Davis (2002), Manly (2000), and Shaw (2003) present very understandable and practical introductions to PCA with minimal mathematical details, while Jackson (2003), Jolliffe (2002), Johnson & Wichern (1998), and Legendre and Legendre (1998) present the mathematical details.

The methodology for the PCA carried out for this EIS is discussed in **Appendix D**. In short, PCA transforms a dataset containing p variables, interrelated or correlated to various degrees, to a new dataset containing p orthogonal, uncorrelated variables called principal components (PCs). For our evaluations, 17 variables (chemical constituents) were used, as extracted from all analytical data for available water samples collected by Wicklow County Council (e.g., environmental monitoring from 1998 to present), the Geological Survey of Ireland (GSI, 2006 and 2007), and CDM for the GSI (2007 and 2008). The sampling results are contained in a master database included as **Appendix E** which includes more than 300 sample records for Alkalinity, Cadmium, Calcium, Chloride, Chromium, Conductivity, Copper, Iron, Lead, Magnesium, Manganese, Ammonia, pH, Potassium, Sulphate, Sodium and Zinc.

The output from the PCA describes variance and correlation factors in the dataset used. Results are typically displayed as bar graphs illustrating correlations between variables and the PCs. **Figures 7-6** and **7-7** provide bar graphs for PC1 and PC2, respectively, for the Avoca dataset that was used.

A variable is considered to be an important contributor to a PC if its component loading (score) exceeds about 0.75 (solid bars), moderately important if between about 0.50 and 0.75 (hachured bars), and unimportant if less than about 0.5 (open bars). Note that for PC1, pH is < -0.75; i.e., highly correlated negatively with metals such as Zn and Cu (> 0.75); that is, at low pH values, the metals have high concentrations.

For PC1 (**Figure 7-6**), the important variables are cadmium (CD), copper (CU), iron (FE), magnesium (MG), manganese (MN), pH (PH), sulphate (SO4), and zinc (ZN); and the moderately important variables are conductivity (COND) and lead (PB). As discussed further below, this association of variables in PC1 is considered primarily related to degree of impact from acid rock waters, or acid rock drainage (ARD).

For PC2 (**Figure 7-7**), the important variables are chloride (CL), ammonia (NH3), potassium (K), and sodium (NA); and the moderately important variables are alkalinity (ALK), calcium (CA), conductivity (COND), and magnesium (MG). As also discussed further below, this association of variables in PC2 is considered to be primarily related to a degree of impact from landfill leachate

7.6.2 Component Loadings

The component loadings that are derived from the PCA may be used to calculate a sample multiplied by the PC matrix of component scores to produce a value of each PC for each sample.

Figure 7-8 provides the resulting PC1 versus PC2 scores plot, where the samples have been coded according to sample type or category. As shown, the following ten sample types are coded by symbol and colour to facilitate evaluation:

Groundwaters (GW): Leachate wells (on the landfill), boreholes (near the landfill), monitoring wells (MW), private (homeowner) wells, springs and Twin Shafts samples.

Surface Waters (SW): Streams (Avoca River, Vale View, Sulphur Brook, etc), reference streams (Avonmore and Avonbeg), acid rock drainage (ARD – mine adit discharges, mine pit lakes, etc), runoff/drainage (storm water runoff and ditches).

The sample type for each of the sample locations is provided in the table of location descriptions in **Appendix E.** The closer the sample symbols (each representing a single sample) are together on **Figure 7-8**, the more similar are the PC scores and concentrations of the chemical constituents.

As shown in **Figure 7-8** (PC scores plot), the samples tend to cluster into three primary areas or groups:

Group 1 – Low PC1 and low PC2 scores (lower left cluster) consisting primarily of streams (including reference streams), private groundwater wells, and Twin Shafts samples.

Group 2 – High PC1 and low PC2 scores (lower right cluster) consisting primarily of mine water discharge (ARD), adit discharge impacted streams, and some groundwater and landfill monitoring well samples.

Group 3 – Low PC1 and high PC2 scores (upper left cluster) consisting primarily of landfill leachate wells and some landfill borehole samples.

In conjunction with the scores plot, **Figure 7-9** provides a corresponding loadings vector plot for PC1 versus PC2. The loadings vector plot contains the same information provided in **Figures 7-6 and 7-7** but shows the two PCs plotted against each other.

As indicated in **Figure 7-9** (PC loadings plot), the separation of Group 1 and Group 2 samples is based primarily on high loading vectors for copper (CU), iron (FE), manganese (MN), pH (PH), sulphate (SO4), and zinc (ZN); and moderately high loading vectors for cadmium (CD) and lead (PB). All of these variables are elevated in acid rock/rock waters at the site (pH is lower, i.e., high H+ concentration; and metal concentrations are high). This indicates that the PCA is contrasting these two groups based on degree of impact of acid rock drainage (ARD): Group 1 samples are less impacted (or not impacted at all) and Group 2 samples are more impacted (containing most of the actual ARD samples themselves).

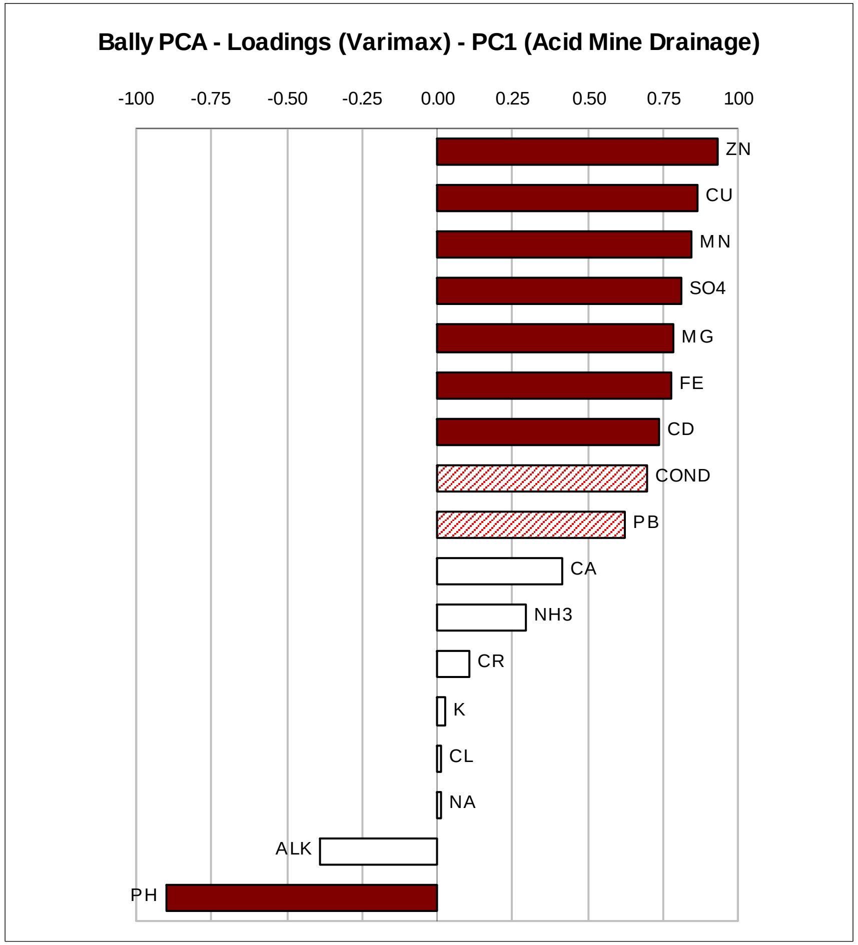

Figure 7-6: PCA – Loadings (Varimax) – PC1 (Acid Rock Drainage). Solid bars > 0.75, hachured bars > 0.50 to 0.75, and open bars < 0.50

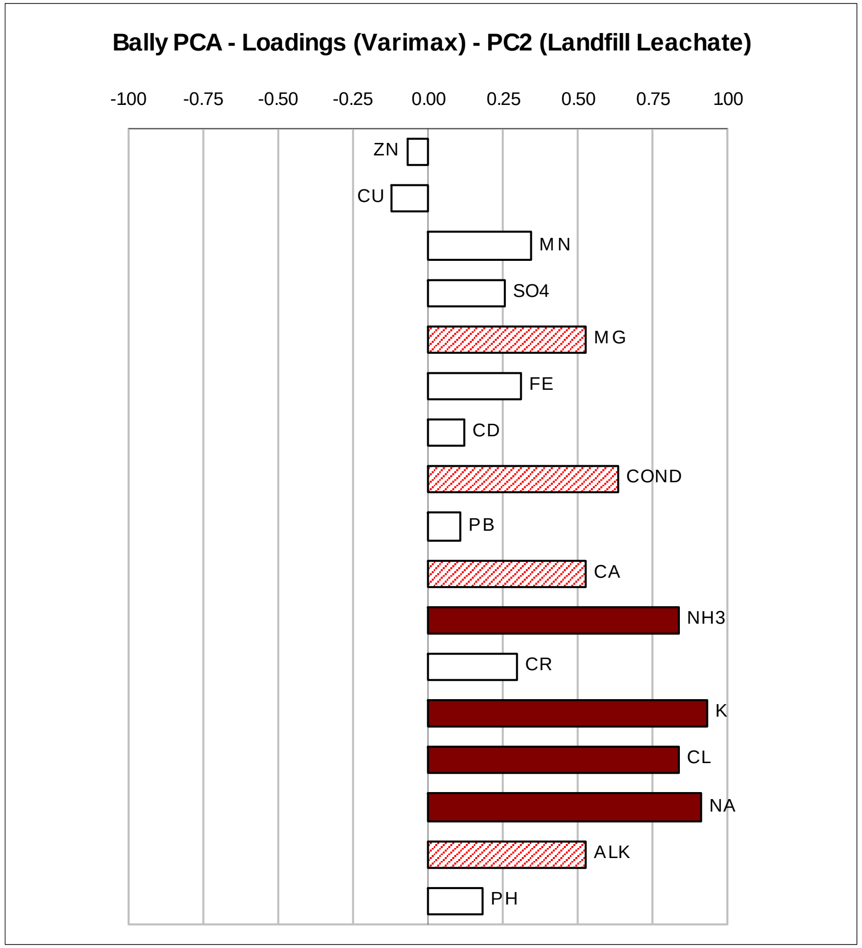

Figure 7-7: PCA – Loadings (Varimax) – PC2 (Landfill Leachate). Solid bars > 0.75, hachured bars > 0.50 to 0.75, and open bars < 0.50

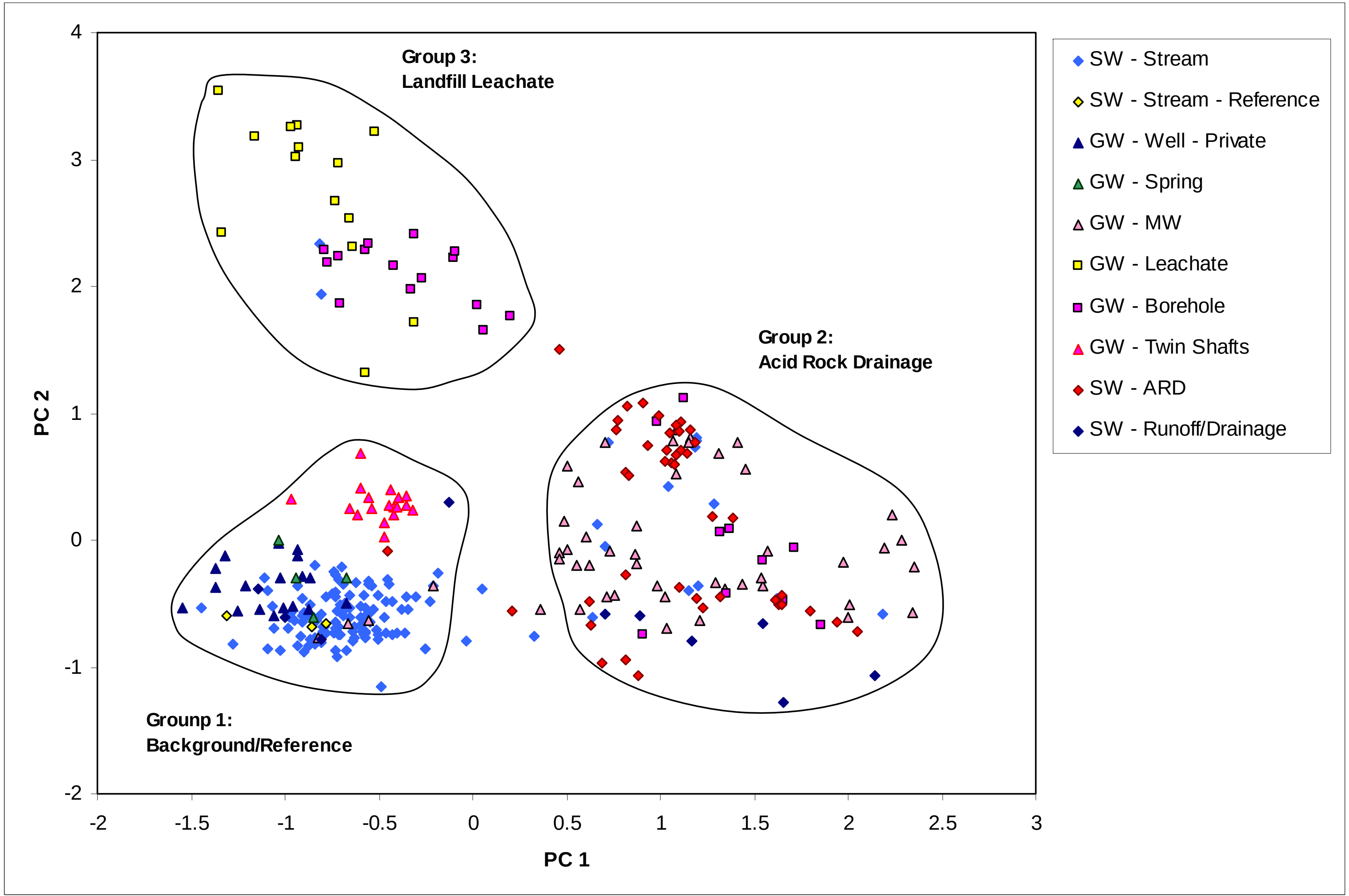

Figure 7-8: PC1 vs. PC2 scores plot coded by sample type for Ballymurtagh PCA (varimax rotation)

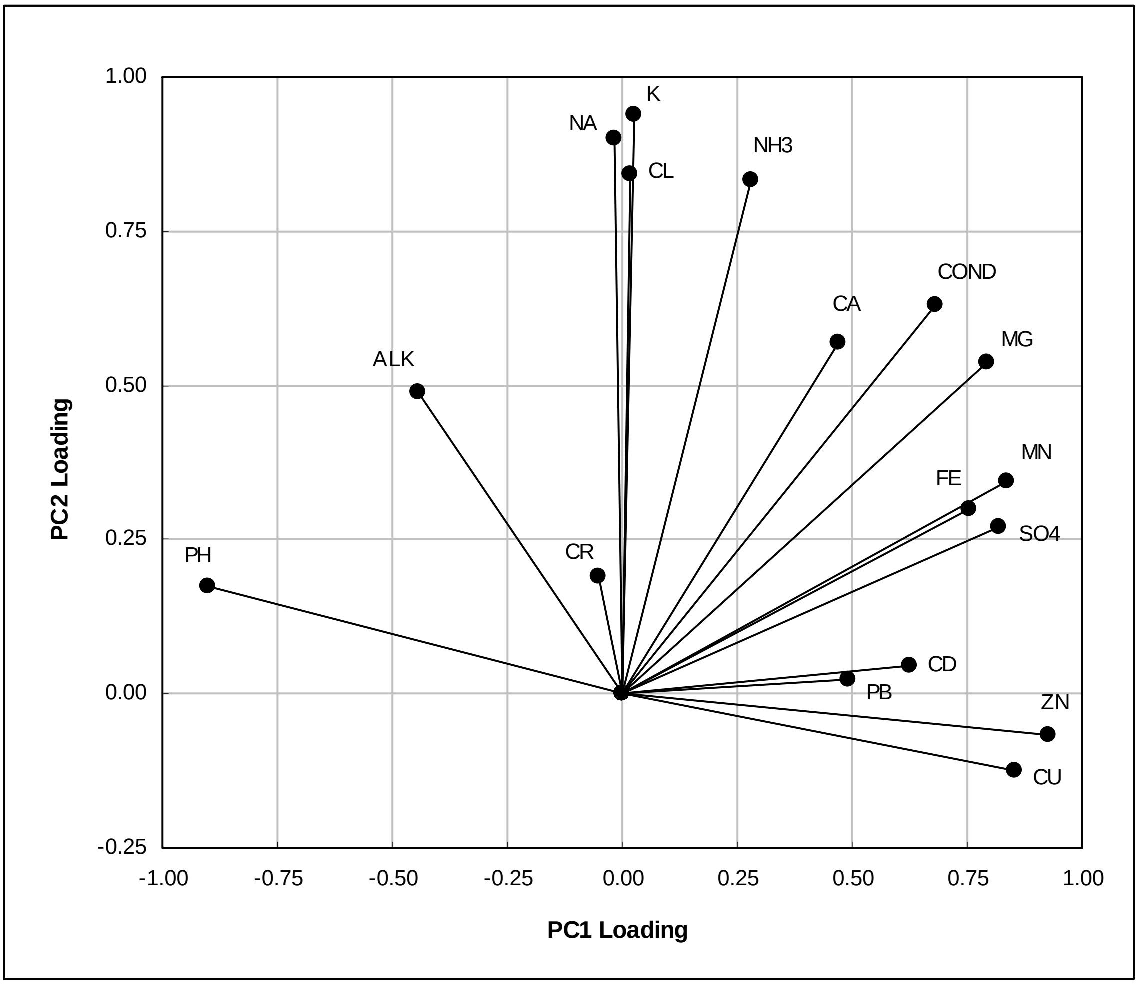

Figure 7-9: PC1 vs. PC2 loadings vectors for Ballymurtagh PCA (varimax rotation)

The separation of Group 3 samples (from both Group 1 and Group 2) is based primarily on high loading vectors for ammonia (NH3), chloride (CL), potassium (K), and sodium (NA); and moderately high loading vectors for alkalinity (ALK), calcium (CA), conductivity (COND), and magnesium (MG). All of these variables are elevated in the landfill leachate waters at the site, indicating that the PCA is contrasting Group 3 based on degree of impact of landfill leachate: Group 1 and Group 2 samples are less impacted (or not impacted at all) and Group 3 samples are more impacted (containing all of the actual leachate samples themselves).

7.6.3 Spatial Analysis

Group 1, Background: Group 1 contains the three yellow diamonds which are upgradient, reference stream samples collected on the Avonbeg and Avonmore Rivers. This group also contains most of the stream samples (blue diamonds) including most Avoca River samples. These stream samples contain little contamination (similar to the up stream, reference samples). The group also contains all the private homeowner wells, all the springs and all the Twin Shaft samples (upgradient of the landfill). The group also contains some of the runoff/drainage samples. Group 2 also contains some of these runoff/drainage samples. The runoff/drainage samples will either be in Group 1 or Group 2 depending upon the runoff area (e.g., samples of storm runoff from Mount Platt plot in Group 2, ARD).

Apparently anomalous samples are the four groundwater monitoring well samples (four pink triangles). Two of these samples were collected from a shallow monitoring well installed on a property belonging to Mr Paddy Fuller on the east side of Avoca River, upgradient of the mine sites. This well was installed by CDM in 2007 to provide a background (reference) shallow alluvial monitoring well in the area and has only two records in the database. The other two monitoring well samples were collected from MWET2 (deep monitoring well at the emergency tailings, 15 November 2007 sample) and G1NSL2 (well north of the West Avoca mine area).

G1NSL has only one record in the database. There are two records in the database for MWET2, the other sample (February 2008) plots in Group 2. The MWET2 sample in Group 1 is the pink diamond that is the closest to Group 2.

Group 2, ARD: Group 2 contains all the mine adit discharge samples (SW-ARD, red diamonds) including Deep Adit (Tigroney), Ballymurtagh (Road) Adit, Spa Adit, Connary Adit, Cronebane Shallow Adit and Cronebane Intermediate Adit samples. Two exceptions are the Kilmacoo Adit and one sample from the Road Adit – see separate discussion below concerning samples between groups. The monitoring wells (pink triangles) plot in this group (except the four samples previously discussed and one discussed below. The monitoring wells in Group 2 include monitoring wells at the base and east of the landfill (G1/04, RC6, G2/04, “monitoring well”) and other monitoring well locations in or near spoils (G2/05, G1/05, MWET1, MWET2, MWDA1, MWDA2). All of these wells have acid rock drainage characteristics.

The runoff/drainage samples (navy diamonds) that plot in this group are runoff samples from spoil piles that reflect acid rock drainage characteristics (low pH and high metal concentrations). This group also contains mine pit lakes (Cronbane and East Avoca) and spoil seep samples and are coded as SW-ARD. Some surface water steam samples are also in this group (blue diamonds). These are typically samples collected in the Avoca River immediately downgradient of the discharges from the Deep and Road Adits (called mixing zone or confluence samples) and reflect the higher concentrations of metals from the adit discharges.

There are also four samples from location SW2, collected in February 1998, May 1998, June 1998 and February 1999 in this group. This location is called the “upstream Adit” location and is collected from the Avoca River near the Ballygahan Adit location. This adit is located just upstream of the Wicklow County Council maintenance yard and is collapsed. In all, 17 samples from 1998 to 2007 are contained in the database from this location and 13 of the samples plot in Group 1. The four samples that plot in Group 2 were collected from the actual discharge early in the sampling programme.

Samples from boreholes (red squares) also are in this group (BH96/4B and BH96/5A). These sample locations are not on the landfill but are east and south of the landfill as shown on **Figure 7-4** and reflect acid rock contamination. BH96/5A is south of the actual landfilled area, but inside the landfill boundary as presented in the yellow area in figure.

Group 3, Landfill Leachate: This group contains all the samples collected from the leachate monitoring wells on the landfill (yellow squares) including L03/1, L03/02, L05/10 and L05/16 sample locations as shown on **Figure 7-4**. Also included in this group are samples collected from boreholes (red squares). In particular the boreholes located on the landfill (BH86/9 and BH96/3) plot in this group indicating landfill contamination. Two apparently anomalous stream samples (blue diamonds) also plot in this group. To test the PCA, two samples from Arklow Town taken downgradient of the untreated effluent discharge point were purposefully included in the analysis. These samples reflect municipal waste contamination and as expected, plot near the landfill (municipal waste) sector of the PCA scores plot.

Samples between the three groups as shown on **Figure 7-10**: Samples that plot between groups are typically mixtures of the various groups. These samples are identified as samples 1 to 6 on **Figure 7-10** and are discussed separately in this section.

Samples 1 to 5 plot between groups 1 and 2 reflecting a mixture of these two groups (background quality and acid rock drainage contamination). Sample 1 was collected in the Avoca River in the mixing zone downgradient from the Road Adit and contains some acid rock drainage. Sample 2 was collected from location SW2 (Q4 2001) and also contains some acid rock drainage. Sample 3 is the Kilmacoo adit discharge which is not very contaminated with acid rock drainage (compared to other mine adits). Sample 4 is from the Red Road “stream” collected on 14 November 2007. Apparently this sample was more contaminated with metals than other samples collected from this location.

Two other samples from the Red Road Stream in the database plot within Group 1. Sample 5 is from G2/05 collected on 16 November 2007 and is not as contaminated with acid rock drainage as other samples collected from this location which plot in Group 2. Sample 6 plots between Groups 2 and 3 and reflects a mixture of these two groups (acid rock drainage and landfill leachate). This one sample is from the Road Adit collected on 21 February 2008. All other samples, consisting of a total of 23 collected from the Road Adit plot in Group 2. No samples plot between groups 1 and 3 reflecting that there is no mixing of landfill leachate and background water quality.

7.7 Summary of PCA

The basic conclusions from the PCA of water quality data from the Avoca Mining Area are as follows:

- Two Principal Components explain most of the variation (almost 69 %) observed in the available water quality data. PC2 identifies Landfill Leachate and PC1 identifies Acid Rock Drainage as discussed in **Section 7.6.**
- Three overall, unique and distinct groups of samples are observed: background samples, acid mine impacted samples and landfill leachate impacted samples as presented on **Figure 7-8**.
- The landfill leachate is associated with high levels of sodium, potassium, ammonium, chloride, magnesium, calcium, alkalinity and conductivity. Landfill leachate is not associated with metals such as cadmium, zinc, and copper as shown in **Figure 7-6** and **Figure 7-7**.
- Acid Rock Drainage is associated with high levels of metals including zinc, copper, manganese, cadmium, iron and lead. ARD is also associated with high sulphate concentrations, high conductivity and low pH values as shown on **Figures 7-6.** .
- Monitoring wells and boreholes outside the landfill are dominated by contamination from acid rock drainage. Boreholes and leachate wells on the landfill are dominated by landfill leachate contamination.
- Some stream samples at and downgradient of the Avoca Mining Area show contamination by acid rock drainage. No stream samples show dominant contamination by landfill leachate. Two samples from Arklow Town were purposely included to demonstrate municipal waste contamination downstream of the town's effluent discharge location.

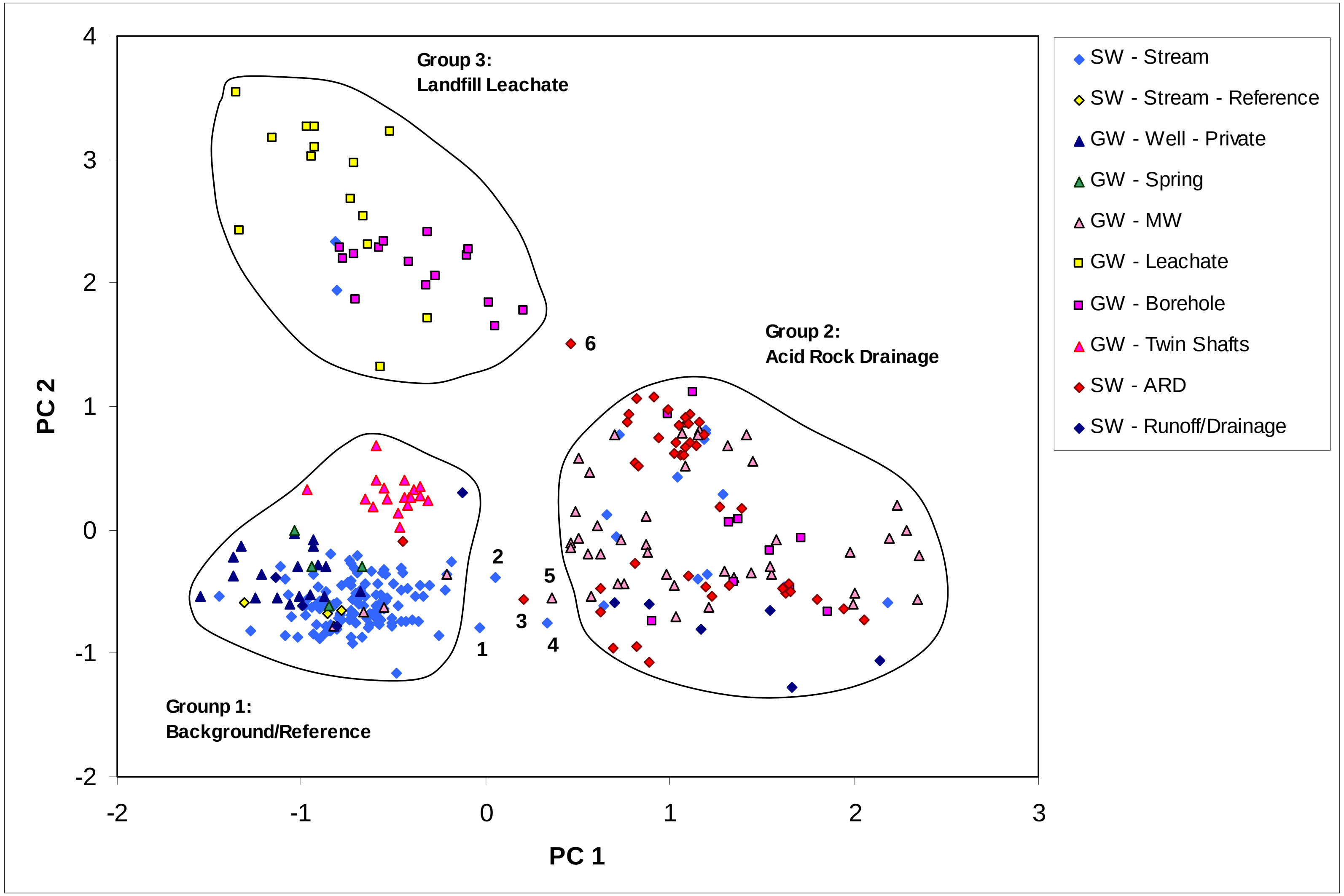

Figure 7-10: PC1 vs. PC2 scores plot coded by sample type for PCA (varimax rotation). Numbered points are discussed in the report.

7.8 Groundwater /Surface Water Interaction

Groundwater in the Avoca Mining Area flows towards the Avoca River valley whether through the adit systems or diffusively in bedrock and subsoils.

Diffuse groundwater, that is the flow component not intercepted or discharged by the underground mine workings, flows in an east and north-easterly direction from the landfill, through both bedrock and subsoils. The subsoils are represented by boulder clays or 'tills and "made ground" comprising fill and/or mine spoil materials. Based on available well construction information, wells that are screened in the subsoils are RC6, G2/05, and a well simply referred to as "Monitoring Well" at the locations indicated on **Figure 7-4.** Wells that are screened in bedrock are G1/04 and G1/05. Available information suggests that well G2/04 appears to be screened across both boulder clay and bedrock.

Towards the Avoca River, the boulder clays become partly or wholly truncated by the erosive action of the river. In the northern part of the West Avoca mining area, river alluvium has been deposited along the river to form a narrow "floodplain" which in the mining area extends from just north of Whitesbridge to a point near the Wicklow County Council maintenance yard where the Avoca River valley narrows and where boulder clays are exposed along the river banks.

Along the stretch of river opposite the West Avoca mining area, the river alluvium extends westward to approximately the main Rathdrum-Avoca road. There is a topographic break just west of the main road where land to the west rises sharply up to the landfill. This area comprises fill materials, including mine spoil and to a lesser extent, boulder clays, depending on location.

There are several wells that monitor groundwater conditions in the river alluvium – notably MWET-1 and MWET-2 in West Avoca, and MWDA-1, MWDA-2 and MWPF-1 in East Avoca located further north and near the East Avoca Deep Adit. All of these wells were constructed for the purpose of monitoring groundwater chemistry in and downgradient of waste spoil heaps associated with the West and East Avoca mining areas (CDM, 2008). Although only two of these wells relate to West Avoca (MWET-1 and MWET2), all are representative of the geology and groundwater conditions of the alluvial deposits associated with the river. Hydraulically, these river deposits are significant. Based on drilling results, they are thick (up to 20-30 m deep), coarse grained and very permeable (CDM, 2008).

Water levels in the different wells in West Avoca have been monitored routinely for several years, and hydrographs show a variety of hydraulic responses.

Groundwater in the river deposits ("river gravels") are in direct hydraulic communication with the Avoca River, and groundwater levels fluctuate up and down in tune with the river during and following storm events. It is an extremely dynamic system with water level fluctuations of nearly 1 m, as exemplified in **Figure 7-11** (CDM, 2008).

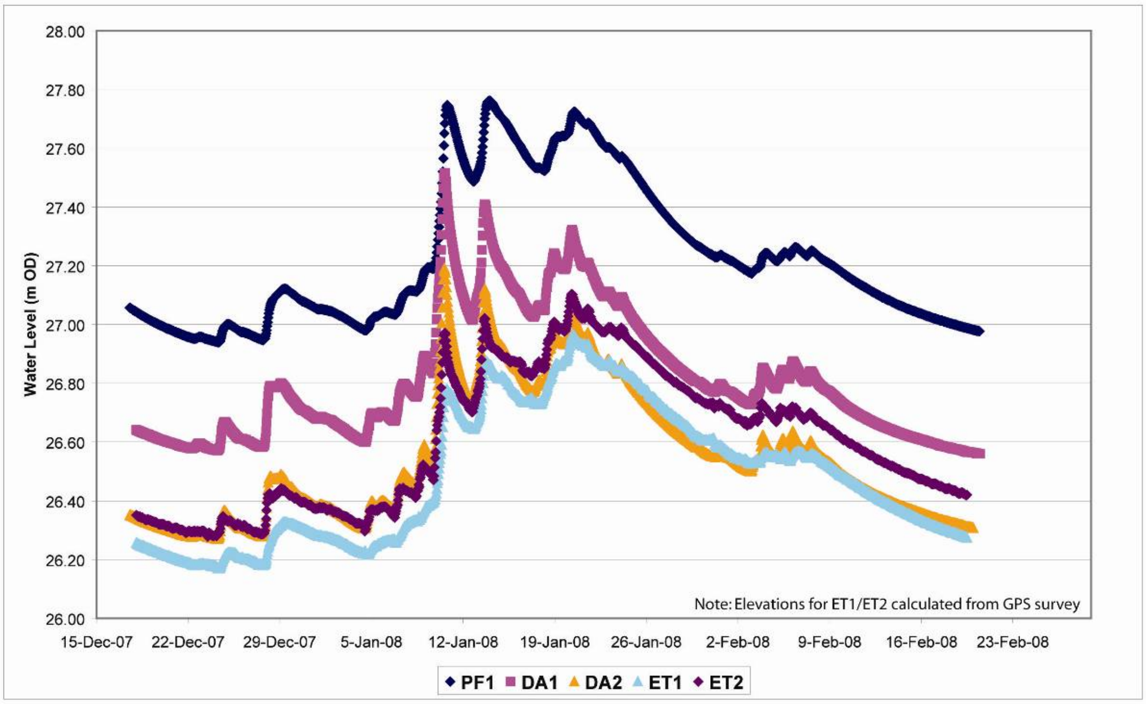

Figure 7-11: Groundwater hydrographs (river gravels) in West and East Avoca

In **Figure 7-11**, wells ET1 and ET2 represent West Avoca river gravels, whereas wells PF1, DA1 and DA2 are located in East Avoca river gravels near Whitesbridge and the Deep Adit.

Wells GW1/05 and GW2/05 are located at the very margin of the "floodplain", but are screened in bedrock and boulder clay. They are nonetheless influenced by the response of the river/alluvium, as shown in **Figure 7-12.** This suggests that the bedrock, boulder clay, and the river gravels are hydraulically connected at this lower location.

The hydrographs in **Figures 7-11** and **7-12** overlap in time between December 2007 and end-February 2008. The peak event in January 2008 is of a similar magnitude in respective hydrographs, although the timing of the equivalent peak in wells GW1/05 and GW/05 appears to be delayed compared to the observed peak in the river gravel wells from **Figure 7-11**. This time-lag would be expected because they are farther away from the river.

For any given snapshot of time, the recorded water levels in wells MWET1 and MWET2 may be higher or lower than the equivalent water levels in wells GW1/05 and GW2/05, suggesting a 'pulsed' movement of water through the river gravels. Gradients change towards and away from respective pairs of wells with time, as the alluvial aquifer responds to the hydraulic conditions of the Avoca River. Consequently, groundwater can flow both towards and away from the river and valley margins depending on the hydraulic "state" of the river.

The monitoring wells closer to the landfill (e.g., RC6, G1/04, and G2/04) and away from the floodplain depict a relatively muted hydraulic response represented by the relatively flat hydrographs shown in **Figure 7-13**. These wells are located at higher elevation and appear to be hydraulically isolated from the influence of the river, the exception being that of G1/04, which is a bedrock well).

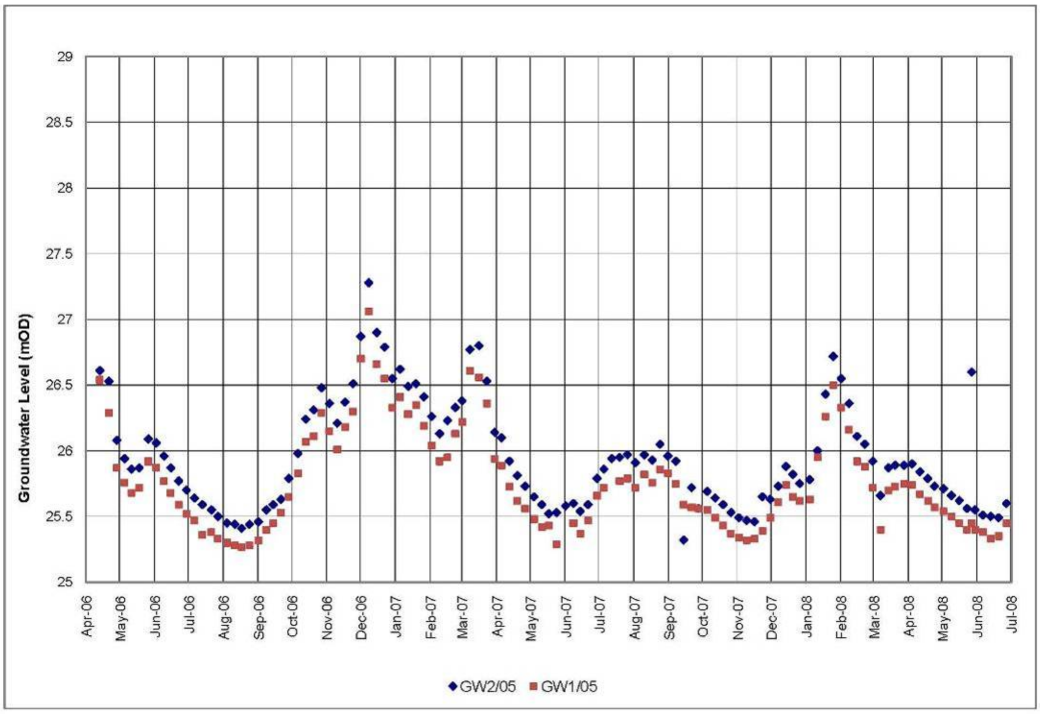

Figure 7-12: Groundwater hydrographs (bedrock/till) at the margin of the floodplain

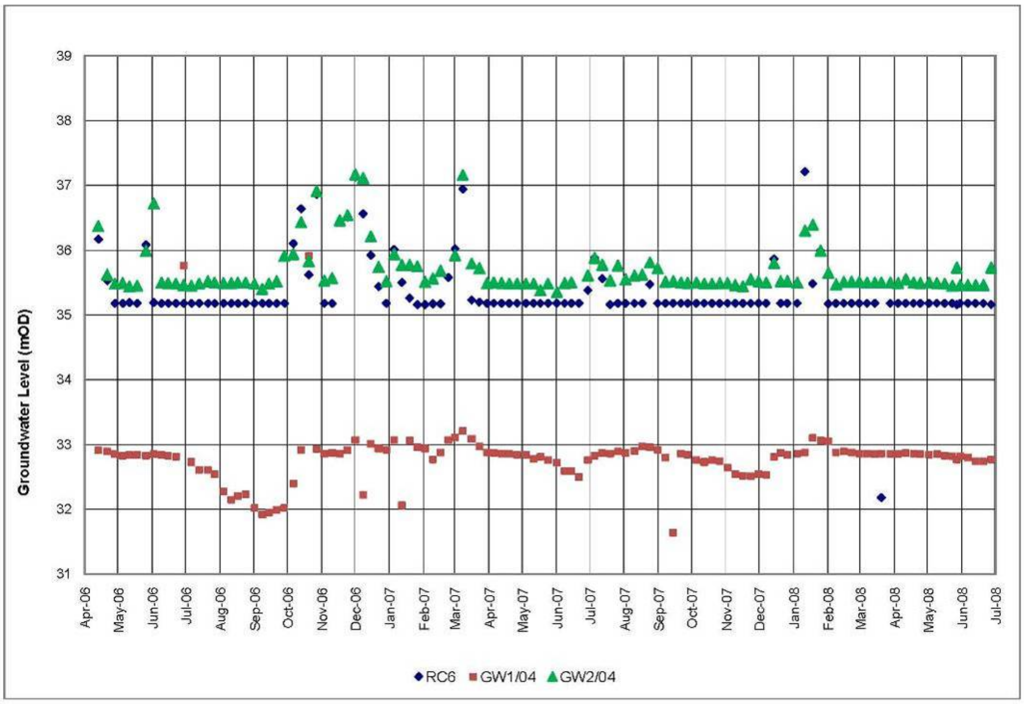

Figure 7-13: Groundwater hydrographs (till/fill) immediately downgradient of the landfill

7.8.1 Groundwater/Surface Water Mixing and Dilution

The alluvial deposits along the river are of hydraulic significance and, where present, will exert a considerable influence on the fate of any pollutants that flow from the landfill towards the Avoca River valley. The dynamic interaction between the alluvial deposits and the river, as well as the very permeable nature of the alluvium, implies that the groundwater flux in the alluvium will be considerably greater than the more apparent static flux from the landfill area (in bedrock and/or subsoils). As a result, diffuse pollutants from the landfill are expected to be significantly mixed and diluted once they reach the alluvial system. The general absence of ammonium in wells GW1/05 and GW2/05 provides supporting evidence of this.

In the alluvial deposits, groundwater levels are greatly influenced by the changes in flow conditions of the Avoca River. Associated water levels in the Avoca River respond very quickly to rainfall. During high river levels, water propagates outward into the alluvial aquifer, and groundwater levels rise. During low river levels, groundwater levels also fall and groundwater may start to flow back towards the river (depending on the timing and changes in gradients). With this dynamic, the Avoca River both loses and gains flow to and from the alluvial aquifer. This continuous action/reaction to rising and falling water levels results in a very dynamic and direct hydraulic interaction between groundwater and the river.

The alluvial deposits are very permeable. Falling and rising head tests were attempted in new monitoring wells in 2007, but the high permeability of these sediments rendered the results meaningless (CDM, 2008). Pump testing of trial wells in similar deposits near Woodenbridge (for the Arklow Water Supply Scheme) indicate "sustainable" well yields ranging from approximately 600 m^3/day to 2,000 m^3/day (White Young Green, 2004). The reported transmissivities range from 500-1,000 m^2/d, corresponding to a mean hydraulic conductivity of approximately 40-50 m/d (White Young Green, pers. comm.).

In contrast, pumping tests carried out in water supply wells at Redcross and Roundwood, in bedrock types similar to those found in Avoca, indicate transmissivity values of approximately 30 m^2/day (Woods, 2003).

Site investigations by the GSI in the Avoca area indicate that groundwater flow is most likely to take place in the upper 20-30 m of bedrock (Gallagher & O'Connor, 1997; GSI, 2005). Using a transmissivity value of 30 m^2/day over an effective saturated thickness of 30 m (i.e., the assumed depth over which groundwater flow in bedrock takes place), this equates to an equivalent hydraulic conductivity value of 1 m/d (for a porous media equivalent).

Using this data, a hydraulic gradient of 0.01, and an effective aquifer thickness of 30 m, the estimated diffuse groundwater flux (Darcy flow) from West Avoca in bedrock towards the river valley would, in theory, be about 55,000 m^3/yr over the maximum 500 m length of river that overlaps with the physical area covered by the landfill as shown in **Figure 7-4**.

In reality, this flux value may be even smaller, as the bulk of groundwater in bedrock in West Avoca is hydraulically captured by the underground mine workings and discharges through the Ballymurtagh (Road) Adit. The actual hydraulic capture zone of the Ballymurtagh (Road) Adit probably extends beyond the boundaries of the landfill on account of its discharge head and flow, (CDM, 2008).

In the context of the West Avoca water balance, the equivalent groundwater flux from the subsoils at the front of the landfill towards the river valley is negligible. The direct infiltration area is small, the subsoils consists of lower permeability materials (e.g., mine spoils), and given the heterogeneous nature of the subsoils, groundwater is expected to be discontinuous laterally and may even be perched across individual lower-permeability horizons.

In the alluvium, the groundwater flux would be significantly greater than those estimated for bedrock. Although hydraulic conductivity values are not a measure of dilution, they nonetheless highlight the contrast in the resulting volumetric fluxes that would be expected, all other Darcy variables (hydraulic gradient, cross-sectional area of aquifer) being constant.

In terms of the Ballymurtagh (Road) Adit, its mean annual discharge rate is reported as 17.7 L/s and the recently reported variations in reported flows range from 13.4 L/s to 26.3 L/s (CDM, 2008). The mean annual flow of 17.7 L/s corresponds to 0.017 m^3/s. The mean annual flow of the Avoca River has been estimated to be about 15 m^3/s (CDM, 2007). Any landfill leachates that discharge to groundwater in bedrock and subsequently discharges via the Ballymurtagh (Road) Adit to the Avoca River are therefore significantly mixed and diluted by a dilution factor of at least 1,000 (i.e., three orders of magnitude).

Directly beneath the landfill, the leachates are also initially diluted when they come into contact with groundwater in bedrock. From **Section 7.3**, the estimated volume of leakage beneath the landfill was estimated to be approximately 3,700 m^3/yr. In comparison, the total mean annual discharge from the Ballymurtagh (Road) Adit is 0.017 m^3/s, or 558,000 m^3/yr.

Although the above numbers remain somewhat theoretical, and do not take into account attenuation or other chemical reactions that may take place within the mine workings, they nonetheless demonstrate the mixing and dilution capacity of the groundwater and surface water systems associated with the landfill, mine workings, and the Avoca River.

The restricted diffuse groundwater flux towards the river valley, as well as the significant mixing and dilution that takes place in the river gravels downgradient of the landfill probably explain why leachate components such as ammonium and phenols are mostly absent in the G1/05 and G2/05 well cluster at the margin of the floodplain.

7.9 Summary of Potential Impacts to Receptors

There are three basic groundwater receptors associated with the Ballymurtagh Landfill:

- Groundwater in bedrock directly beneath the landfill which is captured by the underground mine workings and which discharges to the Ballymurtagh (Road) Adit;
- Groundwater in bedrock beneath the landfill that may escape capture by the underground mine workings, and which subsequently flows and discharges into the river valley; and
- Groundwater in fill and boulder clay at the downgradient edge of the landfill, near the present recycling facility.

As detailed in **Sections 7.3** through **7.6**, List I and II substances detected in groundwater beneath and downgradient of the Ballymurtagh Landfill can primarily be attributed to the West Avoca mine workings. The mines and mine waste areas pre-date the landfill, and samples collected from groundwater and the Ballymurtagh (Road) Adit in 1986, prior to landfilling, proves that groundwater contained elevated concentrations of List I and II substances prior to landfill operations.

There are several documented sources of river pollution from the Avoca mining works: the East Avoca Deep and Ballymurtagh (Road) Adits, runoff from spoil heaps on both sides of the river, emergency tailings in West Avoca, and diffuse groundwater seeps and discharges associated with spoil heaps and underground mine works (CDM, 2008).

7.10 Regulatory Compliance in Context of Groundwater and Surface Water Contamination

7.10.1 Existing Legislation

During the planning and operations of the Ballymurtagh Landfill, the primary legislation that determined environmental compliance is:

- The Groundwater Directive (80/68/EEC), on the protection of groundwater against pollution caused by a) certain dangerous substances, also commonly referred to as the Groundwater Directive;
- The Waste Management Act, 1996 (Statutory Instrument No. 10 of 1996), notably Section 40(4) which addresses management activities, permissible emissions, environmental monitoring, and reporting.

Per Article 3 of EC Directive 80/68/EEC, Member States shall:

a) prevent the introduction into groundwater of substances in list I; and

b) limit the introduction into groundwater of substances in list II so as to avoid pollution of this water by these substances.

As detailed in **Sections 7.3** through **7.6**, List I and II substances detected in groundwater beneath and downgradient of the Ballymurtagh Landfill can be attributed to the West Avoca mine workings, and not the landfill. The mines and mine waste areas pre-date the landfill, and samples collected from groundwater and the Ballymurtagh (Road) Adit in 1986, prior to landfilling, proves that groundwater contained elevated concentrations of List I and II substances prior to landfill operations.

Leachate samples from the landfill do include a small number of detections of List I and II substances common to municipal waste. However, the frequency of detection and the concentrations are lower than those detected in the Ballymurtagh (Road) Adit. The Ballymurtagh (Road) Adit is the main groundwater discharge point from the mining area which also encompasses the boundaries of the landfill.

Given the strong hydrochemical influence of the mine workings, and as discussed in **Section 7.5**, the substances that can be attributed with certainty to the landfill are sodium, potassium, ammonium, chloride, magnesium, calcium, alkalinity and conductivity. None of these substances are within List I of the Annex of the EC Directive 80/68/EEC. Only one substance, ammonium is directly named within List II. Substances such as sodium and chloride are linked to List II through potential impacts on taste of water.

The List I substance cadmium is attributed to the mine workings. Importantly, cadmium is detected at elevated concentrations in the East Avoca mine area (CDM, 2008), as evidenced by discharges from the East Avoca Deep Adit (which is free from any hydrochemical influences of a landfill)

Article 4(2) of EC Directive 80/68/EEC states that "should prior investigation reveal that the groundwater into which the discharge of substances in list I is envisaged is permanently unsuitable for other uses, especially domestic or agricultural, the Member States may authorize the discharge of these substances provided that their presence does not impede exploitation of ground resources".

The groundwater quality in the entire West Avoca mining area is impaired and impacted by acid rock drainage. As such, the groundwater quality in the immediate mines area, which includes the landfill, is unsuitable for domestic or agricultural uses. Impacts from acid rock drainage are documented on both sides of the river, and an impact to groundwater was documented prior to the landfill being constructed (KT Cullen, 1987).

As well, the groundwater resources of the Avoca Mining Area are naturally limited by the hydrogeology of the bedrock. Bedrock in the area is characterised and mapped by the Geological Survey of Ireland as "poorly productive" on the basis of evidence from geological mapping, drilling and private wells in the area (Gallagher & O'Connor, 1997; GSI, 2005). As such, the bedrock aquifer does not have the yield potential for development beyond small-scale usages (e.g., private homes, animal watering).

The subsoils in the area between the landfill and the alluvial floodplain are not considered a suitable resource for groundwater exploitation. They consist of glacial till materials overlain by man-made fill including mine spoil. The area has been extensively reworked over the years in connection with the operations of the mines.

The alluvial gravels associated with the Avoca River do represent a potential groundwater resource for exploitation. However, the groundwater quality of this resource is impaired by acid rock drainage (CDM, 2008). As well, in the West Avoca area, the deposits are overlain (covered) by mine tailings ("emergency tailings"). It is therefore unlikely, indeed probable, that the alluvial gravels downgradient of the landfill will not be exploited for water supply purposes in the future unless complex and costly treatment options of the water are considered. If the Avoca River valley groundwater system is to be considered for exploitation in the future, there are far better, unpolluted, alternatives both upstream and downstream of the Avoca Mining Area.

Following on from the above discussion, Article 4(2) of EC Directive 80/68/EEC also states that "These authorizations may be granted only if all technical precautions have been taken to ensure that these substances cannot reach other aquatic systems or harm other ecosystems".

The ultimate receptor of contamination and the most important aquatic ecosystem in the Avoca Mining Area is the Avoca River. The Avoca River is long known to be impacted by acid rock drainage, and has been the subject of numerous studies in the past as well as routine monitoring by Wicklow County Council and the EPA. Based on work carried out under the EU Water Framework Directive (see below), the EPA has assigned a "poor" qualitative and ecological status to the river on the basis of impacts from the Avoca mines.

Although leachate constituents have been detected in the groundwater of Ballymurtagh (Road) Adit, the flow contribution of the adit to the river is negligible (orders of magnitude lower) compared to the flow of the river, and leachate constituents are not identified as the cause of the river's water quality problems (which are described by low pH conditions and elevated heavy metal concentrations).

In terms of any leachates that escape the underground mine workings and migrate towards the river valley, these become instantly mixed and diluted with the groundwater in the alluvial deposits, and/or with the river once groundwater reaches the river bank. As such, diffuse groundwater containing leachate constituents such as ammonium are not expected to contribute to the documented water quality problems of the Avoca River.

As described below, the landfill was designed to operate under a 'disperse and dilute' method, under determined advice that this method would not result in harm to the Avoca River. The engineered landfill included a bottom liner in the form of low-permeability mine tailings whose function would reduce or limit the risk of pollution to groundwater.

Moreover, there is evidence that closure and capping of the landfill in 2005 has resulted in a lowering of ammonium concentrations at the Ballymurtagh (Road) Adit from 30mg/l (in 2001) to approximately 9 mg/l at present. As demonstrated by **Figure 7-5**, there is a clear and distinct downward trend in the ammonium concentrations which could in part imply that less concentrated solutes are migrating from the landfill. This is important because it reduces any perceived risks of polluting the river further.

Article 5 of EC Directive 80/68/EEC is similar in nature to Article 4, but addresses List II substances. The same conclusions apply.

Per Article 7 of EC Directive 80/68/EEC, "prior investigations referred to in Articles 4 and 5 shall include examination of the hydrogeological conditions of the area concerned, the possible purifying powers of the soil and subsoil and the risk of pollution and alteration of the quality of the groundwater from the discharge and shall establish whether the discharge of substances into groundwater is a satisfactory solution from the point of view of the environment".

The hydrogeological conditions of the planned landfill were examined in 1986 and subsequently reported to Wicklow County Council (Kevin T Cullen, 1987). The report concluded that the Pond Lode pit location was "suitable as a modern landfill with its location, structure and associated spoil heaps providing many operation advantages". The report discussed two different landfill design and operations alternatives and further concluded that the "unique hydrochemical conditions existing beneath West Avoca and in the Avoca River downstream of the mining district would allow the open pit to be operated as a fully contained landfill or as a dilute and disperse site without affecting the overall quality of either the local groundwater or the Avoca River".

The two design alternatives considered were: a) a contained landfill system with an impermeable geotextile covering the base and sides of the landfill, with an associated leachate collection and treatment system; and b) a dilute and disperse system, whereby leachates are allowed to drain (migrate) through the base of the landfill and pass into groundwater in bedrock and the underground mine workings beneath the landfill.

The report concluded that the dilute and disperse method would result in leachates which are attenuated during its passage through the tailings at the base of landfill, diluted in groundwater in the underground mine workings, and further diluted in the Avoca River following discharge via the "mine overflow pipe" (Ballymurtagh (Road) Adit).

The report also concluded that the dilute and disperse method "would not add to the pollution levels already affecting the Avoca River and would therefore not effect any plans to remediate this major river in the years to come".

The work carried out as part of this EIS would support these broad conclusions. As such, the discharge of reported substances from the landfill into groundwater is not believed to be the cause of the documented water quality problems or aquatic ecosystem of the Avoca River.

Per Article 8 of EC Directive 80/68/EEC, "The authorizations referred to in Articles 4, 5 and 6 may not be issued by the competent authorities of the Member States until it has been checked that the groundwater, and in particular its quality, will undergo the requisite surveillance."

The Waste Licence under which the landfill has operated includes stipulations of requisite surveillance. Wicklow County Council has carried out monitoring in response to the requirements of the Waste Licence. This monitoring has included leachate, groundwater (including the Ballymurtagh (Road) Adit), and surface water (Avoca River), as well as monitoring of private wells in vicinity of the landfill. The monitoring results have been summarised annually in environmental monitoring reports, and have been submitted to the EPA in compliance with Waste Licence conditions. These activities will continue.

In relation to Article 10 of EC Directive 80/68/EEC, the main item to be considered is the measures for monitoring groundwater quality in context of the leachates that are migrating out of the landfill cell and into groundwater locally beneath and downgradient of the landfill. The present work carried out as part of this EIS has identified opportunities to improve the present monitoring network. This pertains to: a) improving the quantification of water balance components of the landfill; and b) optimising resources in context of future EPA monitoring of the Avoca Mining Area. This is described in **Section 7.11**.

In terms of the Waste Management Act, an EIS was prepared in 1998 to support Wicklow County Council's application for a landfill Waste Licence from the EPA. The EIS was carried out per EIS regulations and best available information at the time. Importantly, the EIS defined proposed landfill capping and closure measures, and the baseline field study that was carried out has formed the basis for the subsequent long-term environmental monitoring programme that has been implemented by Wicklow County Council since 1998.

7.10.2 Recent (New) Legislation

National regulations implementing the EU Water Framework Directive (2000/60/EC) were enacted in Ireland in 2003 (S.I. No. 733 of 2003). The primary goals of the WFD are to ensure the environmental protection of water resources and the health and status of aquatic ecosystems (see www.wfdireland.ie for further details). In Ireland, the WFD has been implemented across six river basin districts, with participation of all major regulatory and scientific bodies, as well as local authorities, since 2004.

Under the WFD, the Avoca River is subject to water quality and ecological monitoring by the EPA. This monitoring is ongoing and is carried out per WFD requirements as identified and published by the EPA in 2006 (EPA, 2006). The monitoring programme will be reviewed and may be modified in 6-year river basin management cycles based on assessment of results and any associated mitigating measures that may be undertaken to address site-specific water quality or ecological problems (ERBD, 2008).

EPA's WFD-related national monitoring programme does not yet include groundwater at Avoca. This is because EPA's operational monitoring programme under the WFD has not yet been finalised. Operational monitoring is required where groundwater bodies are at poor qualitative status or where groundwater bodies are at risk from not meeting the WFD's stipulated environmental status objectives by year 2015. The groundwater body associated with Avoca, and which includes the mine and landfill, has been classified as being at poor status by the EPA (EPA, 2006; EPA, 2008). This classification is based on the groundwater contamination associated with acid rock drainage. The landfill has not been named or identified as a significant source of contamination in the context of the Avoca River.

As the operational monitoring programme becomes defined by the EPA, an opportunity exists to integrate the landfill into the WFD monitoring. A suggestion to this effect is included in **Section 7.11**.

In context of the WFD, water bodies that are of poor status should be subjected to mitigating measures that address the environmental problems at hand and that ensure that the WFD status objectives are met by year 2015. Basically, all water bodies, including groundwater bodies, should be to at least "good status" by year 2015 (as determined by the EPA). The success of future mitigating measures is subsequently judged from monitoring data.

There are cases where WFD status objectives simply cannot be met by year 2015, either because the needed or required measures are judged to be technically infeasible or disproportionally expensive. In such cases, Less Stringent Environmental Objectives (LSO) may apply, as studied, agreed to and defined by the various implementing and regulatory bodies. All LSO cases are subject to an extensive cost-benefit analysis before a final decision can be taken.

The Avoca mine legacy has been identified as a candidate LSO derogation case under the draft river basin management plan of the Eastern River Basin District (ERBD, 2008). Whatever the outcome of the candidacy, the Avoca Mining Area is certain to be subject to rigorous monitoring in the future.

Besides the WFD, the other piece of recent legislation which may influence what happens at Avoca is the Protection of the Environment Act (S.I. No. 27 of 2003). Partly representing an amendment to the Waste Management Acts of 1996 and 2001, as well as the Environmental Protection Agency Acts of 1992 and 2003, the Protection of the Environment Act addresses general waste emissions (polluting matters) to the environment. It also updates requirements for waste licensing associated with potentially polluting activities.

As determined from existing monitoring data, known leachate emissions from the landfill do not *impact* the Avoca River, which is the aquatic ecosystem under indirect environmental threat from the landfill. Monitoring data collected by Wicklow County Council and others are consistent in demonstrating that the Avoca River is impaired by mine waste, notably acid rock drainage.

There is an indirect linkage between the landfill and the river, via the Ballymurtagh (Road) Adit, but there is a considerable mixing and dilution that takes place at the adit discharge point into the river. The water quality problems of the river are described by low pH and elevated concentrations of certain heavy metals attributable to acid rock drainage from a multitude of sources.

A pollutant loading analysis of the Avoca River conducted as part of the Feasibility Study for Management and Remediation of the Avoca Mining Area (CDM, 2008) concluded that besides the main adits, there are several pollution sources to the Avoca River, as follows:

- Overland flow in contact with mine spoils (only during rain events);
- Seepage from spoils and tailings adjacent to the river (which can occur for long periods following a rain event);
- Seepage from "losing" adit ditches near the river (which may partly soak into ground before reaching the river);
- Diffuse flow (groundwater inflow) from spoil areas and polluted bedrock; and
- Desorption from or dissolution of metal-bearing coatings on river sediment.

Although loadings from these sources are difficult to quantify compared to the main discharge adits, the study nonetheless demonstrated that the Avoca River is subject to a very complex loading pattern. Importantly, the loading analysis suggests that water quality standards in the Avoca River would be exceeded for copper and zinc even if the loading from the Ballymurtagh (Road) Adit was eliminated (e.g., through active treatment of the adit water).

The existing Groundwater Directive (80/68/EEC) will be replaced by the new Groundwater Directive (2006/118/EC) in 2013. The amended and updated directive has close linkages to the WFD and addresses the protection of groundwater against pollution and deterioration. The updated directive is important because it sets criteria for setting WFD status objectives for groundwater, both in term of quality and quantity. Article 6 specifically addresses measures to prevent or limit the input of pollutants into groundwater. For the Avoca area, relevant measures have been presented in the River Basin Management Plan for the Eastern River Basin District (ERBD, 2009). This Plan has been adopted by the members of Wicklow County Council at their meeting in October 2009.

Although the new Groundwater Directive will not be enacted into Irish law until 2013, it nonetheless sets the standard for all of the WFD-related work that has been carried out in Ireland to date and into the future (see www.wfdireland.ie).

In terms of leachate migration from the landfill, the new directive does not materially change the basic conclusions drawn in this report. Although the landfill is not defined as a specific cause of the water quality problems of the Avoca River, it would be prudent and advisable to continue the ongoing monitoring activities of Wicklow County Council, and to integrate results with ongoing and future monitoring activities of the EPA as part of WFD implementation. Future restoration activities of the Avoca River should and will likely focus on mine remediation unless decisions are taken with regards to LSOs.

7.11 Mitigating Measures

7.11.1 Maintenance of Landfill Cap

The landfill cap which was constructed in 2005 is, by its nature, protective of the environment. Its purpose is to reduce infiltration and therefore the quantities of leachates that may be produced inside the landfill cell. Evidence that the cap is functioning as intended is suggested by the fact that ammonium concentrations at the Ballymurtagh (Road) Adit show a decreasing trend over recent years.

As such, it is important that the landfill cap be maintained properly in the future as outlined and described in the existing aftercare plan associated with landfill closure (RPS, 2003).

7.11.2 Runoff Measurements

The runoff coefficient over the landfill is estimated to be between 60-90% of potential recharge (see **Section 6**). To improve the water balance of the immediate landfill area, and therefore reduce uncertainties associated with estimates of infiltration through the cap, it is proposed that runoff volumes over the landfill be measured over a 6-12 month period. Runoff presently collects in a stormwater holding pond from where it is discharged directly via a 4-inch diameter pipe to the Avoca River. Measurement of runoff quantities into the holding pond would be accompanied by rainfall measurements as well.

7.11.3 Proposed Modifications to Ongoing Monitoring

The present monitoring programme implemented by Wicklow County Council will continue, but on the basis of the data analysis conducted as part of this EIS, certain targeted modifications to the monitoring programme are proposed.

Ongoing landfill monitoring should be continued both in terms of leachate levels and quality. Leachate levels should be recorded in all available wells. It is noted that wells that are accessible for monitoring may change with time, as they become structurally damaged from settlement of waste materials.

Leachate quality should be carried out in wells for which time-series data have been established, notably L05-10, L05-16, L03-1, L03-2, and BH96/3. On account of the findings in 2009 and discussed in **Section 7.3.1**, analysis of leachate samples from well L05-10 should be expanded to include VOCs, SVOCs, and OPs. It is also proposed that the expanded analysis be carried out in well BH96/3 as it is located in the lower part of the landfill and has a suitable time-history of analytical results. L05-10 and BH96/3 are regarded as being representative sample locations for leachate.

Ongoing groundwater monitoring efforts outside the landfill should be slightly modified to target future monitoring where the PCA, as discussed in **Section 7.5,** demonstrates impact to groundwater, notably the wells at the front of the landfill and Ballymurtagh (Road) Adit.

These sample locations would undergo analysis for the suite of parameters that are presently undertaken on a routine basis by Wicklow County Council.

It is also proposed that the monitoring of the Ballymurtagh (Road) Adit be expanded to include analysis for other List I and II parameters that have not been routinely monitored in the past, notably VOCs, SVOCs, and OPs. For the expanded analysis, it is proposed that the expanded analysis be carried out on an annual basis.

Two further modifications to the existing landfill/groundwater monitoring programme of Wicklow County Council are proposed:

- Reduction in the scope of monitoring of private wells – existing private wells in the mines area have been extensively tested to date and available test results do not indicate any contamination. For this reason, it is proposed that the scale of private well testing be scaled back to include only private wells to the south of the landfill – i.e., Merrigan and O'Laoire. This deemed prudent as some of the mine workings extend to the southern landfill boundary.
- Addition of sample location G5 (Hall's well) to the programme – this well is located south of the landfill in an area that was only monitored in 2009 as discussed in **Section 7.3.1**. Results indicate an impact from acid rock drainage. The low-level detection of naphthalene may suggest an influence from the landfill, but could also be from other sources external to the landfill. The fact that naphthalene was detected in isolation without any other VOCs or SVOCs merits re-testing. It is therefore proposed that G5 be included in the monitoring programme for a period of 2 years so that verification samples can be collected. It would be subject to annual monitoring of VOCs, SVOCs, and OPs.

No further wells are planned within the pathways from the landfill on the basis that groundwater beneath and downstream of the landfill is not usable due to overriding impacts from acid mine drainage.

All other sampling locations that are impacted by acid rock drainage in the West Avoca Mining Area are candidate locations to be included in EPA's future operational monitoring programme as they relate directly to impacts from the Avoca mines and are subject to monitoring under WFD requirements. This includes surface water sampling locations upstream and downstream of the mines, seeps and springs, and mine-related monitoring wells in East and West Avoca. In West Avoca, duplication of effort would be avoided whereby EPA and Wicklow County Council's respective sampling programmes would be discussed, agreed and coordinated.

Section 8
Ecology

8.1 Introduction

Prior to the change of use from an open pit to a landfill, the site was already compromised environmentally. As part of the EIS (1998), terrestrial ecology specialists Roger Goodwillie & Co. Ltd prepared a report which concluded that the landfill site had no factors of ecological importance due mainly to the fact that flora and fauna were reduced by the adverse conditions created by the metallic residues in the tailings.

Similar open pits remaining from the era of mining at Avoca presently exist in East Avoca at Cronebane and Tigroney. These open pits continue to be compromised ecologically, and the nature of the spoils and low pH of the leachate do not support much fauna and flora.

Following closure of the Ballymurtagh landfill in 2002, a restoration and aftercare plan was prepared to address closure, aftercare and long term management of the facility (RPS, 2002). In 2006 the restoration of the landfill was carried out, planting the final configuration with ecologically appropriate species, tolerant to the site conditions as woodland, heathland and wild grasses. The restored landfill is mainly a grassland habitat, as shown in **Figure 8-1**.

Figure 8-1: Photograph of Restored Landfill Showing Established Grassland Habitat (Oct, 2009)

This section outlines the existing ecological conditions at the closed landfill site for both aquatic and terrestrial ecology along with the potential impacts and mitigating measures.

8.2 Aquatic Ecology

Ballymurtagh Landfill is located close to the Avoca River and there is a small tributary of the Avoca to the south of the landfill called Red Road Stream.

Most of the Avoca River is characterised as a medium sized stream with cobble and gravel substrates, little silt or fine grained sediment, iron staining of the substrates in areas most affected by low pH and elevated metals concentrations.

In 1998 as part of the original EIS a biological water quality assessment was carried out on the Avoca River by Conservation Services, Ecological and Environmental Consultants. Based on the relative abundance of indicator species, a biotic index (Q-rating) was determined for the Avoca River upstream and downstream of the landfill. The biological water quality assessment indicated slightly polluted conditions at the two sites upstream of the landfill. The river was moderately polluted at Avoca Bridge, which is almost 2 km downstream of the landfill and the composition of the fauna also indicated a toxic effect.

As part of the Avoca Mines Feasibility Study a screening level benthic macroinvertebrate survey was carried out in April 2007, results are presented in **Table 8-1**. The survey indicated that the communities in the Avoca River below the mining impacted areas (from Whitesbridge to SW4) were impaired relative to the reference stations, which was probably due to mining related contaminants (CDM, 2008). It is not until the Shelton Abbey location, which is approximately 7 km downstream of the landfill and mining areas, there is a substantial recovery in the macroinvertebrate community, as the number of organisms greatly increases, this is mainly due to the dilution of Avoca River by the Aughrim River.

Table 8-1: Results of Benthic Macroinvertebrate Survey (CDM, 2008)

Sampling Location	Approx Distance DS from Landfill	Number of Macroinvertebrates
Meeting of the Waters	Upstream	140
Whitesbridge	Upstream	29
DS of Deep Adit (East Avoca)	Upstream	35
DS of Road Adit (SW4)	0.5 km	15
Avoca Bridge	2 km	27
US of Aughrim Confluence	6 km	4
US of Shelton Abbey	7 km	113

8.2.1 Fish

The fish community in the Avoca River is currently neither abundant nor diverse, primarily as a result of mine-related contamination. The types of fish that currently occur in nearby waters or those that have potential to occur most abundantly in the Avoca River are salmonid fish (CDM, 2008).

Species of fish in the Avoca River include salmon (*Salmo salar*), sea trout (*Salmo trutta*), eel (*Anguilla anguilla*) and three species of lamprey: brook (*Lampetra planeri*), river (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*). Both salmon and all three species of lamprey are listed Annex II species under the EU Habitats Directive. Fish kills occur regularly during low flow periods and thirteen fish kills have been recorded on the Avoca River between approximately 2000 and 2003. Species killed included adult salmon, sea trout, and juvenile lamprey (Doyle *et al.* 2003). Most salmon (*Salmon salar*) and sea trout (*Salmon trutta*) were attempting to swim upstream to spawning grounds, while all lampreys found were metamorphosed juveniles. Even though migratory salmonids successfully spawn in the headwaters of the Avoca catchment there is a potentially significant mortality risk to salmon and sea trout smolts as they migrate downstream to the sea. Although the polluted section supports little by way of resident salmonids, other species including lamprey and eel were present. This suggests that these species may have some tolerance to this form of toxic pollution (Doyle *et al.* 2003).

8.3 Terrestrial Ecology

8.3.1 Introduction

An overview of the landfill and surrounding areas habitat classification is presented in **Figure 8-2**, which is an extract from the Feasibility Study for Management and Remediation of the Avoca Mining Area (CDM, 2008). Habitats were classified according to The Heritage Council's *A Guide to Habitats in Ireland* (Fossitt 2000). Agricultural land is generally pasture land located to the west of the site. There are plantations of coniferous woodland adjacent to the site with stands of broad leaved species lower down the slopes along the valley of the Avoca River. There are areas of open grassland adjacent to the site and along the banks of the Avoca River.

Field surveys of vegetation and fauna were carried out to assess the importance of the landfill site in terms of terrestrial ecology. As part of the original EIS (1998), terrestrial ecology specialists Roger Goodwillie & Co. Ltd prepared a report which concluded that the landfill site had no factors of ecological importance due mainly to the fact that flora and fauna were reduced by the adverse conditions created by the metallic residues in the tailings.

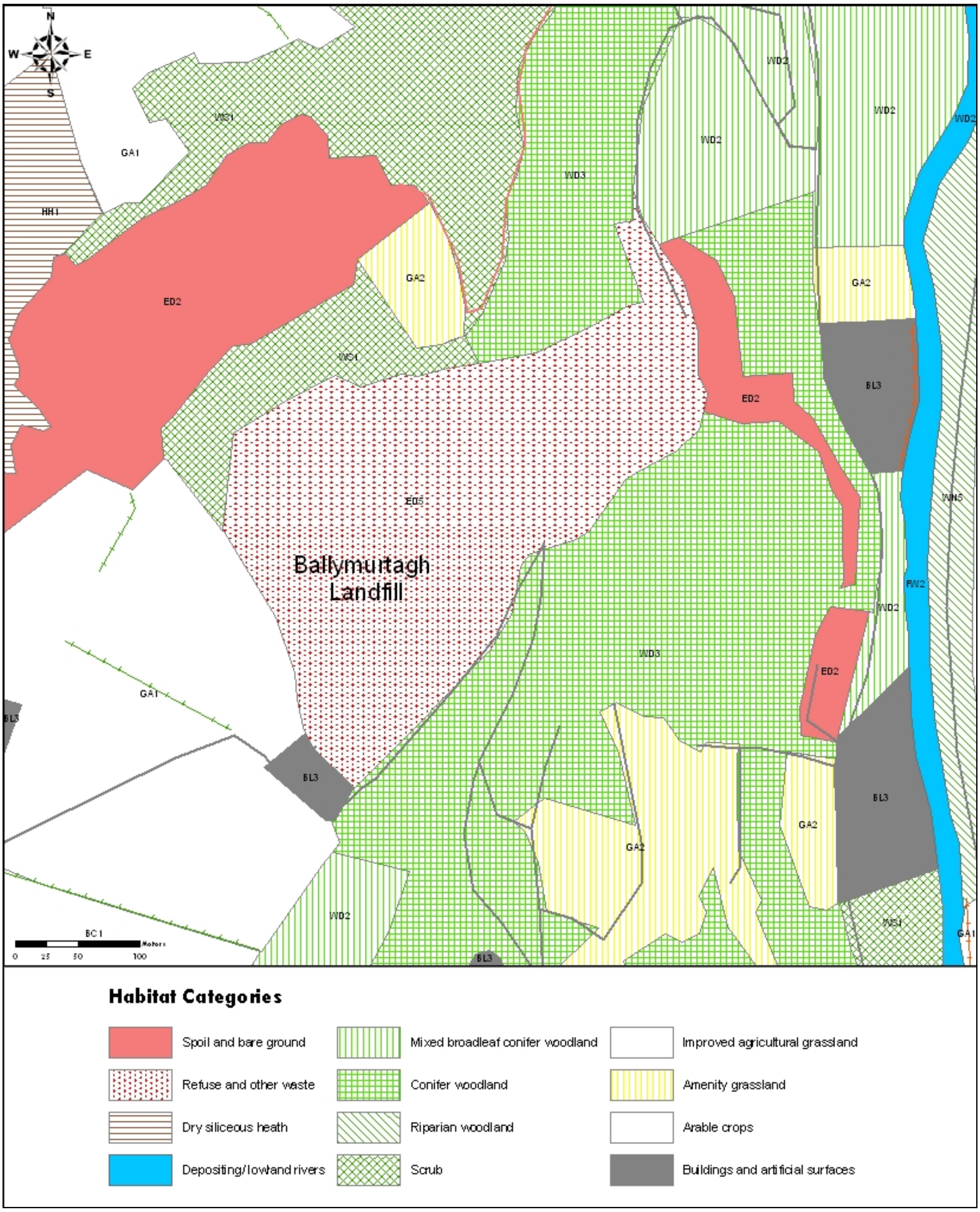

Figure 8-2: Habitat survey in the West Avoca Mining Area (CDM, 2008)

Dr Goodwillie has regularly updated his assessment of terrestrial flora and fauna. The latest update, "Monitoring report on Ballymurtagh Landfill, Avoca, Co Wicklow - Terrestrial Flora and Fauna" was completed in April 2009. A summary of the findings of these reports can be found below.

There are no specially protected species of plant or animal dependent on the site and no habitats which require special conservation under the EU Habitats Directive (92/43/EEC). Annex I species under the Birds Directive (79/409/EEC) that may occur close to the site are peregrine, merlin and nightjar. There are no Natural Heritage Areas proposed adjacent to the site, the nearest being the oakwoods of the Avoca River valley (#1748) which run from 1 km south of the village to Woodenbridge and beyond.

8.3.2 Vegetation

Prior to the construction of Ballymurtagh Landfill little natural vegetation was present in the upland areas. The upland terrestrial environment was highly disturbed by past mining activities. These areas included open pits, waste/spoils piles and tailings.

Following the capping of the landfill the site has been regenerated as a grassland habitat. The surface of the landfill has been sown with grasses into which other species are now spreading, including trees and bushes at the eastern more sloping end. The soil has been compacted by machinery but is well covered by vegetation. The main part of the site has a mixed cover of grasses with some broad-leaved species. **Table 8-2** displays the species list in approximate order of abundance that based on a walkover transect by Dr. Goodwillie in 2009.

Table 8-2: Ballymurtagh Landfill Vegetation Species List

Common Names	*Latin Names*
Red fescue	*Festuca rubra*
Yorkshire fog	*Holcus lanatus*
Vanilla grass	*Anthoxanthum odoratum*
Common meadow grass	*Poa pratensis*
Couch grass	*Elytrigia repens*
Common bent	*Agrostis capillaris*
Ryegrass	*Lolium perenne*
Common vetch	*Vicia sativa*
Red clover	*Trifolium pratense*
Curled dock	*Rumex crispus*
Dock leaf	*R.obtusifolius*
Birds-foot trefoil	*Lotus corniculatus*
Black medic	*Medicago lupulina*
Creeping thistle	*Cirsium arvense*
Grass like starwort	*Stellaria graminea*
Pointed spearwort	*Calliergon cuspidatum*
Marsh birds-foot trefoil	*Lotus pedunculatus*
Willow herb	*Epilobium parviflorum*
Cuckoo flower	*Cardamine pratensis*
Common gorse	*Ulex europaeus*
Meadow buttercup	*Ranunculus acris*
Common daisy	*Bellis perennis*
Soft rush	*Juncus effusus*
Tufted hair grass	*Deschampsia cespitosa*
Creeping buttercup	*Ranunculus repens*
Creeping cinquefoil	*Potentilla reptans*
Compact rush	*Juncus conglomeratus*

The established trees on the slope are now three to four metres in height and include birches (*Betula pubescens* and *B.pendula)*, pines (*Pinus contorta*, *P.sylvestris)*, and willows (*Salix cinerea* and a little *S.aurita)* and the gorse is now two metres high. Willows and gorse also occur as a narrow strip under the cliff at the northern edge of the landfill.

The front slope of the landfill has nutritionally richer soil and recent tree planting has occurred as shown in **Figure 8-3**. The upper trees are planted along a new bank and the water drains and accumulates towards the south. This allows floating sweet grass (*Glyceria fluitans)*, jointed rush (*Juncus articulatus)* and a single plant of pendulous sedge (*Carex pendula)* into the vegetation.

Figure 8-3: Photograph Showing Established Vegetation on the Lower Slope and Recent tree Planting (Oct, 2009)

8.3.3 Fauna

Prior to the construction of the landfill the vertebrate fauna of the site consisted of few species because it was a disused open pit. The grassland fauna now consists primarily of insects and the ringlet and meadow brown have which been noted in the past. Mammals are present, in the form of hare and rabbit though their grazing influence is small. Visiting species include fox and sika deer though the absence of browsing damage on the broad-leaved trees suggests their numbers are very low.

The birds seen on or over the landfill have been raven, jackdaw, wood pigeon, pheasant, goldfinch, linnet and meadow pipit. A pair of meadow pipits was nesting on site in 2009. The habitat may favour nesting linnets in future in gorse but the upland site probably would reduce potential numbers.

Bats in Ireland are protected under Irish and EU legislation. Under the Wildlife Act (1976) and Wildlife (Amendment) Act 2000, it is an offence to intentionally harm a bat or disturb its resting place. Bats constitute a large proportion of the mammalian biodiversity in Ireland. A bat survey was carried out from September to November of 1995 (Fay, 1996). Six evenings were spent monitoring bat activity at the Avoca mines (Fay, 1996). They monitored three sites: one at East Avoca open pit and two by the landfill at West Avoca shaft and West Avoca closed adit. The West Avoca mine area was determined not to support large populations of bats. Bats feed largely on moths and night-flying insects so would make use of few of the species found at landfills.

Frogs breed in the lagoon on the southern margin where there are also two dragonfly species the common darter *Sympetrum striolatum* and ruddy darter *S. sanguineum* (Goodwillie, 2009).

8.4 Potential Impacts on Ecology

In terms of the restoration of the landfill site the situation now is considerably better than when first visited by Dr Goodwillie in 1998. The ecological objectives of the Restoration and Aftercare Plan have been largely achieved. The surface now is stabilised and its vegetation coming to resemble that on the rest of the valley side, run-off from the area has been managed and a smaller area of the old mining site is exposed to weathering.

In general, the reintegration of the closed landfill into the landscape has been a success. Dr Goodwillie concludes that the vegetation and habitat on site suggest that the landfill is still effectively isolated below the capping material and causes little if any impact on the surface or the surroundings.

The potential impacts on surface water quality and subsequently the aquatic ecology are discussed in detail in **Section 7**.

8.5 Mitigating Measures

It is envisaged that there will be a gradual extension of the tree growth but also the further colonisation by plant and animal species from the surroundings. Vegetation management will be necessary at the site in the medium term. This should include weeding, cutting and fertilising. Fencing will be necessary for the capped landfill site in the medium term which is generally out of bounds to the public and native fauna.

Overall, the site and area in general has benefitted ecologically from the infilling of the open pit, a legacy of decades of open cast mining at Avoca and a difficult environment for fauna and flora of many types. The planned revegetation of the landfill capping has improved the habitat, both for fauna and flora. This will continue to improve with time, to a point where the landfill site is completely integrated with its surrounding environment.

Section 9
Air & Climate

9.1 Introduction

The air quality of the surrounding area is good with a low density of housing within 1 km of the site and no significant industrial emission sources nearby. The landfill is surrounded by relatively steep cliff walls along the western and southern boundaries. The nearest houses are situated about 200 m downslope below the grade of the landfill, along the Red Road, and are well protected by the boundary embankment and a dense stand of mature trees.

The types of air pollutants resulting from landfill operations are as follows:

- Dust;
- Aerosols and airborne particulates;
- Odours; and
- Landfill Gas.

9.2 Ambient Air Quality

The air quality in County Wicklow is classified as very good by the EPA. Ambient concentrations of sulphur dioxide and nitrogen dioxide in the vicinity of Avoca will be comparable to levels measured in rural parts of Ireland removed from significant industrial emission sources. Rural parts of Ireland are defined under the Air Quality Standards Regulations 2002 (S.I. No 271 of 2002) as a “Zone D” region. Zone D regions are considered areas of good air quality, which is reflected in the absence of a requirement for continuous air monitoring. There are no significant industrial emission sources within 2 km of the site boundary and it is bordered by pasture land and mature stands of both broadleaf and coniferous trees.

Air quality in the area was monitored during a series of monitoring events in 2003, which was prior to capping of the landfill (TMS Environmental Ltd, 2003). Measurements were focussed on parameters that give an indication of general air quality such as SO_2, NO_X and BTEX. Sulphur dioxide was higher than the average expected rural range of 3 to 6 $\mu g/m^3$ but generally lower than the expected range for urban areas (25 to 100 $\mu g/m^3$). The results were significantly lower than the limit for sulphur dioxide average over 24 hours (125 $\mu g/m^3$). It was concluded that the possible explanation for slightly elevated sulphur dioxide readings was from acid rock drainage or from sulphur compounds released from the landfill which are oxidised in the air.

9.2.1 Aerosols and PM_{10}

Aerosols are fine particulate material, water droplets and microbial emissions from activities carried out at landfills. Small particles that can penetrate the lungs and cause damage are known as PM_{10} (diameter less than 10µm). In terms of ambient PM_{10} levels it is predicted that given the largely rural location existing ambient concentrations are low.

9.3 Dust

The generation of airborne dust at landfill sites is primarily related to construction activities at the site and to the transportation and deposition of waste. The movement of dust is determined by a number of parameters including prevailing wind direction, wind speed, vehicle movement and type of waste deposited.

Under the current Waste Licence W0011-01 dust monitoring was required to be carried out three times per annum at two locations. The emission limit value set down is the licence was 350 $mg/m^2/day$. The results during the operational and restoration phase of the landfill showed compliance with the emission limit value. Dust monitoring ceased after the restoration of the landfill in 2005 as dust was no longer a potential issue as the landfill was capped and there were no more trucks along the access road.

9.4 Landfill Gas

9.4.1 Introduction

The biodegradation process in a landfill produces both leachate and landfill gas. The primary constituents of landfill gas are methane (CH_4), carbon dioxide (CO_2) and water vapour which are produced by the micro-organisms within the landfill under anaerobic conditions. Over 99% of the volume is comprised of methane, carbon dioxide and nitrogen with the remainder consisting of a large number of trace gases.

Landfill gas comprises about up to 65% methane and up to 35% carbon dioxide but this can vary during the life of the landfill especially during the early and later phases of operation. Initially, carbon dioxide is the dominant gas during the early stages of the decomposition of material while aerobic conditions prevail. As the oxygen is depleted due to the compaction of the waste material anaerobic conditions develop as organic waste matter decays and methane becomes the dominant gas. Eventually the levels of methane and carbon dioxide decrease and air is drawn into the pore spaces within the landfill and the fill then becomes biologically inert.

Capping the surface and covering with top-soil and reseeding can substantially reduce vertical diffusion of landfill gas from a site. A gas collection system connecting the vents within the completed cells to a flare-stack can also significantly reduce the volume of emissions of methane, carbon dioxide and trace compounds from the site. Ballymurtagh Landfill has been capped and has a gas extraction network system that operates effectively on a 24-Hour basis.

9.4.2 Landfill Gas Generation and Collection

The rate of landfill gas production is a function of a number of factors including waste types, depth, moisture content, degree of compaction, landfill pH, temperature and the length of time since the waste was deposited. This makes it difficult to predict the onset of landfill gas production and also its cessation. Gas production will likely continue for a number of years, eventually declining due to the decrease in microbiological activity in the site.

GasSim, a landfill gas modelling software package was used to simulate the expected production of landfill gas at Ballymurtagh Landfill based on the amount of waste accepted (RPS, 2009). **Figure 9-1** shows the average hourly rate of landfill gas generation for each year for Ballymurtagh Landfill.

The EU Landfill Directive (99/31/EC) requires that:

- Appropriate measures are taken in order to control the accumulation and migration of landfill gas;
- Landfill gas should be collected from all landfills receiving biodegradable waste and the landfill gas should be collected and treated and used or as a minimum the gas should be flared; and
- The collection, treatment and use of landfill gas should be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health.

At Ballymurtagh Landfill a network of 12 landfill gas wells were installed in 1998 in the upper section of the landfill. These wells were connected to a flaring station to reduce emissions of methane, carbon dioxide and trace constituents. Flaring of gas at Ballymurtagh initially began in 1998 with an open flare system. This was replaced by an enclosed Hasse flare that commenced full flaring on 18 January 2002. The Hasse Flare has a max flow capacity of $500m^3$/Hr.

The landfill gas system was extended in order to reduce the risk of gas migration into the surrounding environment. A further nine gas abstraction wells were installed in the middle section of the landfill in December 2002 which also feeds into the gas flare. In 2005 the landfill gas extraction system was extended further to incorporate the areas of the landfill where there were no existing wells.

The waste heat from landfill gas flares can be used to heat facilities on site and/or buildings located nearby. The utilisation of landfill gas as an energy resource depends on the quality of the gas, the gas yield and the availability and economics of a suitable market. It was considered that the relatively limited volume of waste deposited at the site and the relative low content of methane in the landfill gas mean that commercial utilisation of the landfill gas produced at the site was not feasible. The gas management infrastructure at the site is presented on **Figure 9-2**.

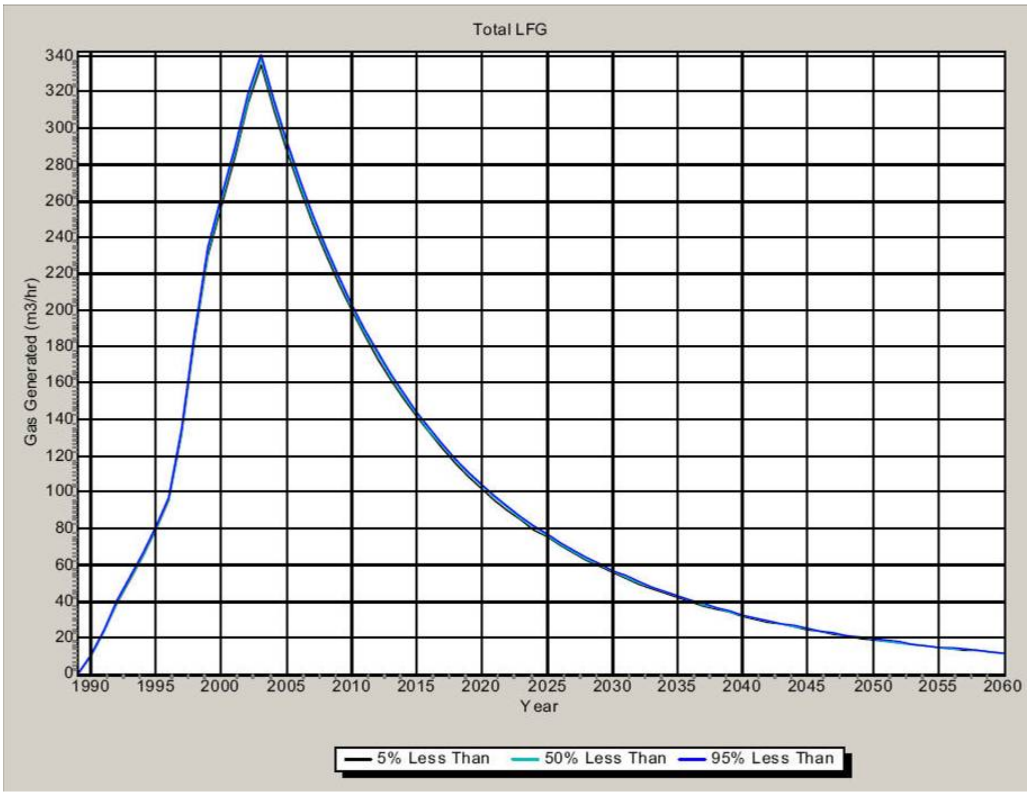

Figure 9-1: Average Hourly Rate of Landfill Gas Generated for Each Year 1990 to 2060 (RPS, 2009)

9.4.3 Landfill Gas Monitoring

Under the current Waste Licence monthly monitoring of landfill gas is carried out at Ballymurtagh Landfill at 15 perimeter locations. Landfill gas monitoring is carried out weekly at the site office and daily at the inlet to the Flare. The landfill gas trigger levels for any other point located outside the body of the waste are set down in Condition F.2 of the waste licence and are shown in **Table 9-1**.

Table 9-1: Landfill Gas Concentration Limits

Methane	Carbon Dioxide
20 % LEL (1% v/v)	1.5 % v/v

Monitoring of landfill gas over the years has shown exceedances of the 1.5% v/v limit for carbon dioxide. The most recent report on landfill gas monitoring at the site is presented in the Annual Environmental Report (AER) for Ballymurtagh Landfill for 2008 in **Appendix F**. Carbon dioxide levels exceeded the limit of 1.5 %v/v at G6 (2.0% - 4.6%) and at G7 (3.0% - 5.3%) throughout 2008. Exceedances of carbon dioxide were recorded at other wells on occasion during 2008 as shown in the 2008 AER. Methane levels did not exceed the emission limit value at any of the points monitored during 2008.

An investigation into the elevated levels of carbon dioxide was carried out in July 2007 by RPS. The resulting report was submitted to the EPA in December 2007 and recommended further assessment into the natural occurrences of CO_2 due to the geological conditions in the area and an assessment of dissolved CO_2 in water samples.

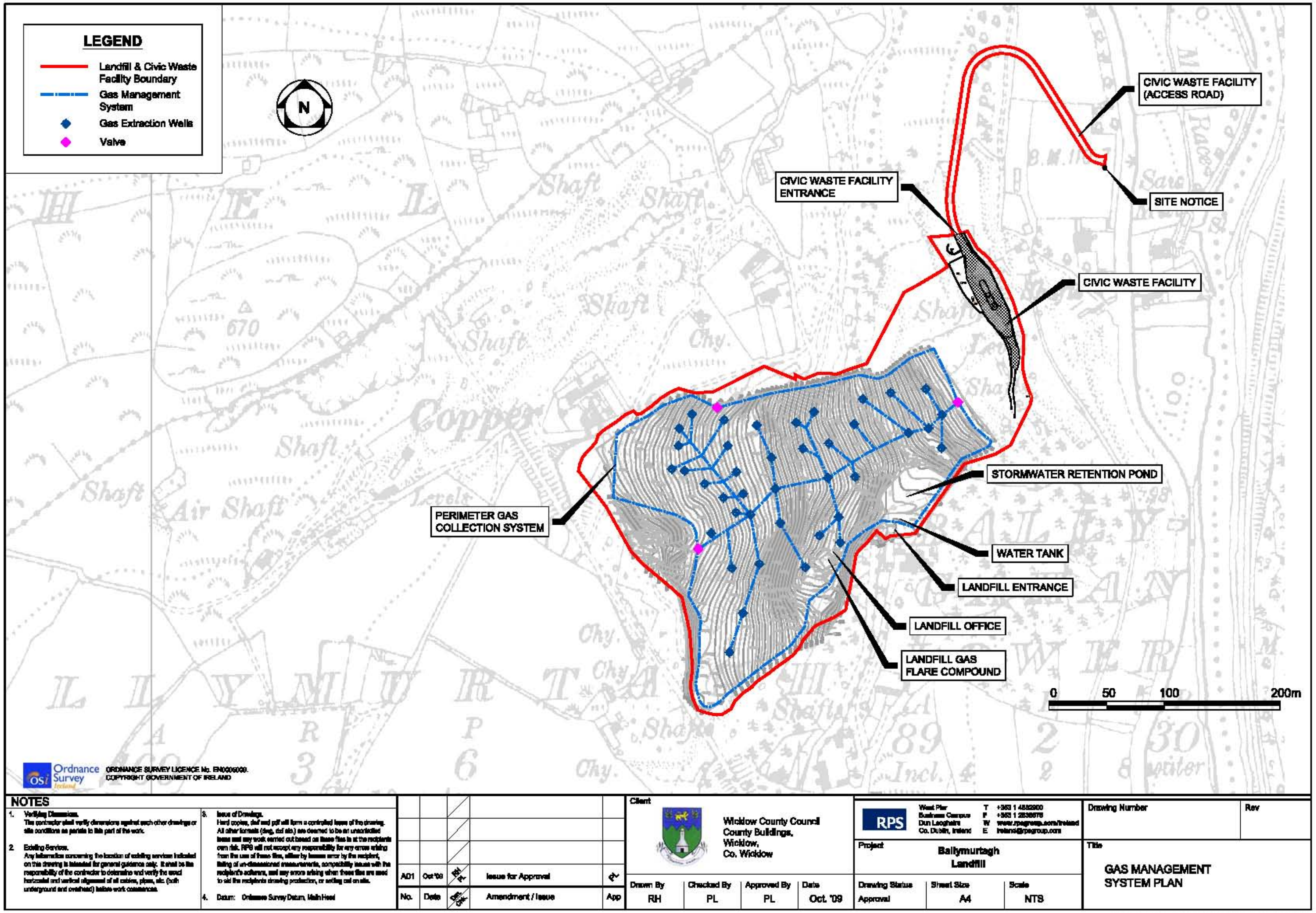

Figure 9-2: Landfill Gas Management Infrastructure (RPS, 2009)

9.4.4 Flare Emissions

High-temperature combustion with a Haase flare stack is used to treat the contaminated landfill gas at Ballymurtagh Landfill. Combustion of landfill gas reduces the risk of uncontrolled landfill gas emissions and explosion, and subsequently the risk to human health and environmental impacts.

Dispersion modelling was used to predict the incremental additions to ground level concentrations of relevant criteria pollutants as a result of emissions from the flare stack (TMS Environmental Ltd., 2003). The model used was the Industrial Source Complex Short Term Dispersion Model (ISCST3) which was developed for use in situations with complex terrain. The modelling demonstrated that under normal operating conditions the landfill flare does not have an averse effect impact on the local ambient air quality or at local residences in close proximity to the landfill.

As part of the continued long term management of the facility, RPS Group undertook monitoring of the landfill gas flare and the gas abstraction sampling points throughout 2008. Methane levels averaged at 24%, carbon dioxide at 28% and oxygen at 1.3%. Although the methane content is low and decreasing, this is indicative of the stage of the microbial degradation. The remaining percentage is most likely made up of hydrogen, nitrogen, carbon monoxide and water vapour derived from the atmosphere. The methane, carbon dioxide and oxygen levels recorded at the flare have decreased proportionately. Oxygen levels have increased slightly in comparison to 2007.

Under the current Waste Licence, the landfill gas flare emissions have to be monitored, some parameters are biannually and some are annually. Flare outlet monitoring was undertaken in June 2008 and November 2008 to comply with the bi-annual requirements. **Table 9-2** gives a summary of the 2008 results and shows that the landfill flare gas emissions are in compliance with the emission limit values set in Schedule F.5 of the current waste licence. The full report is contained in the 2008 AER.

Table 9-2: Flare Emissions Monitoring 2008

Parameter	Units	Emission Limit Value	June Results	November Results
Nitrogen oxides as (NO_2)	mg/m^3	500	0	0.5
Carbon Monoxide (CO)	mg/m^3	650	39	119
Sulphur Dioxide (SO_2)	mg/m^3	None	14	48
TA Luft Organics Class I	mg/m^3 (at mass flows > 0.1 kg/hr)	20	13.34	-
Hydrogen Chloride	mg/m^3 (at mass flows > 0.3 kg/h)	50	0.91	-
Hydrogen Fluoride	mg/m^3 (at mass flows > 0.05 kg/h)	5	0.18	-

9.5 Odours

Odour may be defined as that characteristic property of a substance which makes it perceptible to the sense of smell.

Over one hundred trace constituents have been identified in landfill gas and similarly for leachate. Unpleasant odours are usually associated with the sulphur-containing compounds, primarily mercaptans and sulphides. These compounds also have the lowest odour threshold concentrations making them easier to detect than other compounds.

Closed landfills such as Ballymurtagh have the potential for causing odours from sources such as:

- Landfill gas emissions from cracks and vents in capped cells;
- Leaking gas wells and collection piping; and
- Malfunctioning flares and utilisation plants.

Odours may become a nuisance to the general public if they are detectable past the site boundary. The perception of odour as a nuisance will depend on a number of factors, such as the concentration of that substance in the atmosphere, the frequency of releases, intermittency of releases and the sensitivity of the individuals impacted.

The impact of odours on the ambient air quality depends on the emission rate, the distance downwind to the sensitive receptor location and the wind speed/direction. The distance downwind at which the odour detection concentration is reached may be within a few metres of the odour source if the rate of emissions is low or a considerable distance if the emission rate is very strong. The wind speed and direction are also major factors in determining whether emissions from the landfill will cause a community nuisance beyond the site boundary.

Under Condition 6.1 of the Waste Licence W0011-01 weekly odour inspections have to be carried out at Ballymurtagh Landfill. Prior to capping the landfill in 2005 there were a few complaints made to Ballymurtagh Landfill in relation to short term odours detected beyond the site boundary. The source of odour was investigated and corrective action was taken at the time of the incidents. Odour has not been an issue since the capping of the landfill. Indeed the last complaint with respect to any issue in relation to Ballymurtagh Landfill was made in 2005. There have been no complaints in the last 4 years.

9.6 Climate

The climate of Co. Wicklow is characterised by the passage of Atlantic low pressure weather systems and associated frontal rain belts from the west during much of the winter period. In the summer the influence of anticyclonic weather systems will occasionally result in prolonged dry periods over this part of Ireland interspersed by the passage of Atlantic frontal systems.

The nearest meteorological station is located at Dublin Airport (approx 65 km to the N). The prevailing winds in the Wicklow region are from a SW direction with about 45-50% of the hourly observations from this direction. The wind field is generally dominated by winds of less than 5 m/s with about 60% of hourly observations less than this wind speed and slack winds (< 2 m/s, including calm conditions) occurring for about 15% of the year. Winds in excess of 9 m/s occur for about 15% of the time and are associated with SW-W winds. The Avoca area is sheltered to a certain extent from westerly winds by the local topography. The incidence of high wind speeds are lower with a subsequent increase in the number of days when low wind speeds are recorded. During relatively calm weather over the Wicklow region in the Avoca area the microclimate will become dominant.

The thirty year average rainfall in the area is approximately 1082mm per annum, with the winter months (Oct-Jan) normally receiving the greatest monthly rates. The maximum daily rainfall rate varies little throughout the year although the duration and intensity may differ significantly between summer and winter due to the prevailing conditions. During the winter the rainfall will be commonly associated with Atlantic frontal depressions whereas during the summer months high rainfall amounts will tend to be associated with intense thundery showers.

The microclimate is defined as the climate within the immediate locality of the landfill site over an area, typically within 1-2km of the site. The microclimate can be characterised by a north east facing slope leading down to the Avoca River which is approximately 30m O.D. The landfill site is at the top of this slope and it rises from approximately 80 to 130m O.D. Above the landfill the ground continues to rise to about 140 to 150m O.D. The type of microclimate in the locality will therefore be characteristic of local valley wind patterns with up-slope winds during the day and down-slope winds in the evening. If the prevailing wind conditions are sufficiently strong then this circulation feature will be destroyed.

9.7 Mitigating Measures

As landfill gas generation continues long after the closure of the site so too will the flaring of gas and the monitoring of landfill gas generated and the flare emissions.

Weekly maintenance checks of the gas extraction system and the landfill gas flare will also continue. It is the aim to minimise flare failure and keep the flare operating 100% of the time. Flare failures can lead to landfill gas migration and subsequent contributing greenhouse gas emissions. Minimising flare shutdowns will also reduce the potential for odour emissions.

Although the potential for odour and dust generation at the site is minimal as the landfill is capped, any nuisances relating to this will be prevented and dealt with according to the Environmental Management Procedures for the site (RPS, 2008). Weekly inspections are carried out for the entire landfill site, including the Civic Waste Facility and its access road, as well as the Red Road. Details of any nuisances relating to odour and dust are documented on an Inspection Report Form. Corrective action is carried out for any nuisances determined during the weekly inspections or otherwise.

Section 10
Land Use & Landscape

10.1 Introduction

In this section of the EIS the potential effects of Ballymurtagh Landfill on the landscape and land use are addressed.

10.2 Land Use

The land use in the area is dominated by agricultural production and commercial forestry. Agricultural land is generally pasture land located to the west of the site. There are plantations of coniferous woodland adjacent to the site with stands of broad leaved species lower down the slopes along the valley of the Avoca River. There are areas of open grassland adjacent to the site and along the banks of the Avoca River. This is shown in **Section 8**, **Figure 8-2** which shows the results of a habitat survey in the West Avoca Mining Area (CDM, 2008).

The restoration and aftercare plan (RPS, 2003) prepared to address the closure, aftercare and long term management of the facility proposed to create a woodland type habitat to blend in with the surrounding landscape. Capping and restoration took place in 2006 and the landfill is now a well established grassland habitat.

10.3 Landscape/ Visual Impact

The former landfill is located on the west bank of the Avoca River adjacent to the Avoca to Rathdrum road and is cut into the steeply rising ground that forms part of the western escarpment of the Avoca valley.

There are short distance views into the site from the Avoca to Rathdrum road. The site however is well screened by trees and blends quite naturally into the surrounding landscape. There are long distance views into the site from the west-facing slopes of the hills located further to the east, as shown in **Figure 10-1**.

Figure 10-1: Views into the Ballymurtagh Landfill Site, from the West Facing Slopes of Avoca Valley

The views out of the site are directed by the enclosing slopes and plantations towards the south-east, over the valley of the Avoca River and the landscape beyond. The heavily planted corridor of the river, together with its flanking slopes, provides a strong visual compartmentation at the eastern end of the site.

In terms of the impact in the surrounding countryside the short-term impact of the landfill is moderate due to its small scale relative to the scale of the hinterland.

The landfill is now closed, and as discussed previously capping and restoration took place in 2005 and 2006. The profile of the restored facility has allowed the integration of the height and form of the surrounding topography. The final configuration was planted with ecologically appropriate species, tolerant to the site conditions as woodland and wild grasses.

The combination of the profiling and revegetation has resulted in a significantly improved environment through the progressive reintegration of the site into its natural surrounding environment. The landscape is a significant improvement on the pre-landfill ‘scarred’ landscape which was in place prior to the commencement of landfilling.

10.4 Mitigating Measures

No mitigating measures are needed as the landscape plan has been implemented. The gradual extension of the tree growth but also the further colonisation by plant species from the surroundings in the future will further integrate the landfill into the surrounding landscape.

Overall, the site and area has benefitted from the infilling of the open pit, a legacy of decades of open cast mining at Avoca and a difficult environment for fauna and flora of many types. The planned revegetation of the landfill capping has improved the overall landscape. This will continue to improve with time, to a point where the landfill site is completely integrated with its surrounding environment.

Section 11
Material Assets

11.1 Introduction

Resources that are valued and that are intrinsic to specific places are called material assets. They may be of either human or natural origin and the value may arise for either economic or cultural reasons. The objective is to ensure that these resources are used in a sustainable manor so that they will be available for future generations.

11.2 Wicklow County Development Plan

Tables 11-1, 11-2, 11-3 and **11-4** list the Protected Structures, National Inventory of Architectural Heritage and National Monuments and Prospects respectively in the vicinity of Ballymurtagh Landfill and Prospects as contained in the Wicklow County Development Plan 2010 – 2016. These are shown in relation to the landfill on **Figure 11-1**.

Table 11-1: Protected Structures

Ref Number	Number	Address	Structure	Townland	Description
35-03	35	Ballymurtagh Avoca	Mines	Ballymurtagh	Old mining office, tramway arch, Western Whim engine house, twin shafts, engine house and chimney stack north, twin shafts chimney stack base south. Tramway engine house stack, drawing shaft engine house, chimney at incline, engine house and Ballygahan engine house, spoil heaps and associated disturbed ground.
35-13	35	Tigroney West East Avoca Mines	Mines	Tigroney West	Williams engine house and chimney, Baronet engine house and chimney, flat rod tunnels, spoil heaps and associated disturbed ground.
PA 88	Proposed Addition	Tinnahinch, Arklow	Farm House	Ballygahan Upper	Detached two storey vernacular farmhouse

Table 11-2: National Inventory of Architectural Heritage

ID	Description	Appraisal	Date From	Date To	Category of Special Interest
16403506	Detached three-bay single-storey over basement Methodist church, built c.1870. The building is finished in render with stone dressings. The timber sheeted door is flanked by plain pilasters and has a semi-circular arched radial fanlight. Windows are semi-circular arched and have metal multiple pane frames with margins. There is a small roundel window above the entrance. The pitched roof is finished with natural slate and has cast-iron rainwater goods. The building is at the side of the road and is slightly set back behind wrought-iron railings with square gate pillars.	Located on the road side with the far side of the valley as a backdrop, this small but well preserved church compliments its setting.	1860	1880	Architectural Social
16403508	Ruins of various copper and sulphur mainly open cast mines, established c.1850. The grouping comprises now	Though mainly ruinous, these structures	1840	1860	Architectural Social Technical

ID	Description	Appraisal	Date From	Date To	Category of Special Interest
	mainly ruinous buildings tall industrial chimneys and various tramways. The buildings are all roofless and are constructed in granite while the chimneys are constructed either in brick or a mixture of brick and stone. Large scars are still visible across the landscape.	(belonging to a once vital mining complex) are an important part of County Wicklow's industrial heritage.			
16403509	Freestanding tram bridge, built c.1860 formerly associated with an open cast copper and sulphur mine. The bridge is constructed of rubble granite with roughly hewn voussoirs. It is single arched and carries a tramway over a dirt road.	Now derelict collection of mine related structures. These caused great environmental damage to a dramatic landscape yet as nature reclaims the area it has assumed a somewhat romantic air.	1850	1870	Architectural Technical

Table 11-3: National Monuments

SMR No.	Os Name	Classcode	Misc Item1	Misc Item2	Townland	Smr	Inventory
WI035-028	'Kilcashel Church (in ruins) Grave Yd'	ECCL	OO	OO	Kilcashel	T	T
WI035-02801		CHUR	OO	OO	Kilcashel	T	T
WI035-02802		GRAV	SI	OO	Kilcashel	T	T
WI035-02803		ECCE	OO	OO	Kilcashel	T	T
WI035-029	Not indicated	ENCL	PO	OO	Kilcashel	T	T
WI035-03001	'Tobernacla'	CHUR	SI	OO	Tigroney West	T	T
WI035-03002	'Tobernacla'	HOWE	OO	OO	Tigroney West	T	T
WI035-031	Not indicated	ENCL	OO	OO	Cherrymount	T	T
WI035-032	Not indicated	ENCL	OO	OO	Cherrymount	T	T

Table 11-4: Prospects

Prospect ID	Origin of View	Description	Area
37	R752 from the White Bridge to The Meetings	Prospect eastwards and westwards towards Avoca valley and deciduous forests	2
64	Holy Year Cross, Tigroney	Prospect of Avoca at River Valley from the viewing point at the Holy Year	2

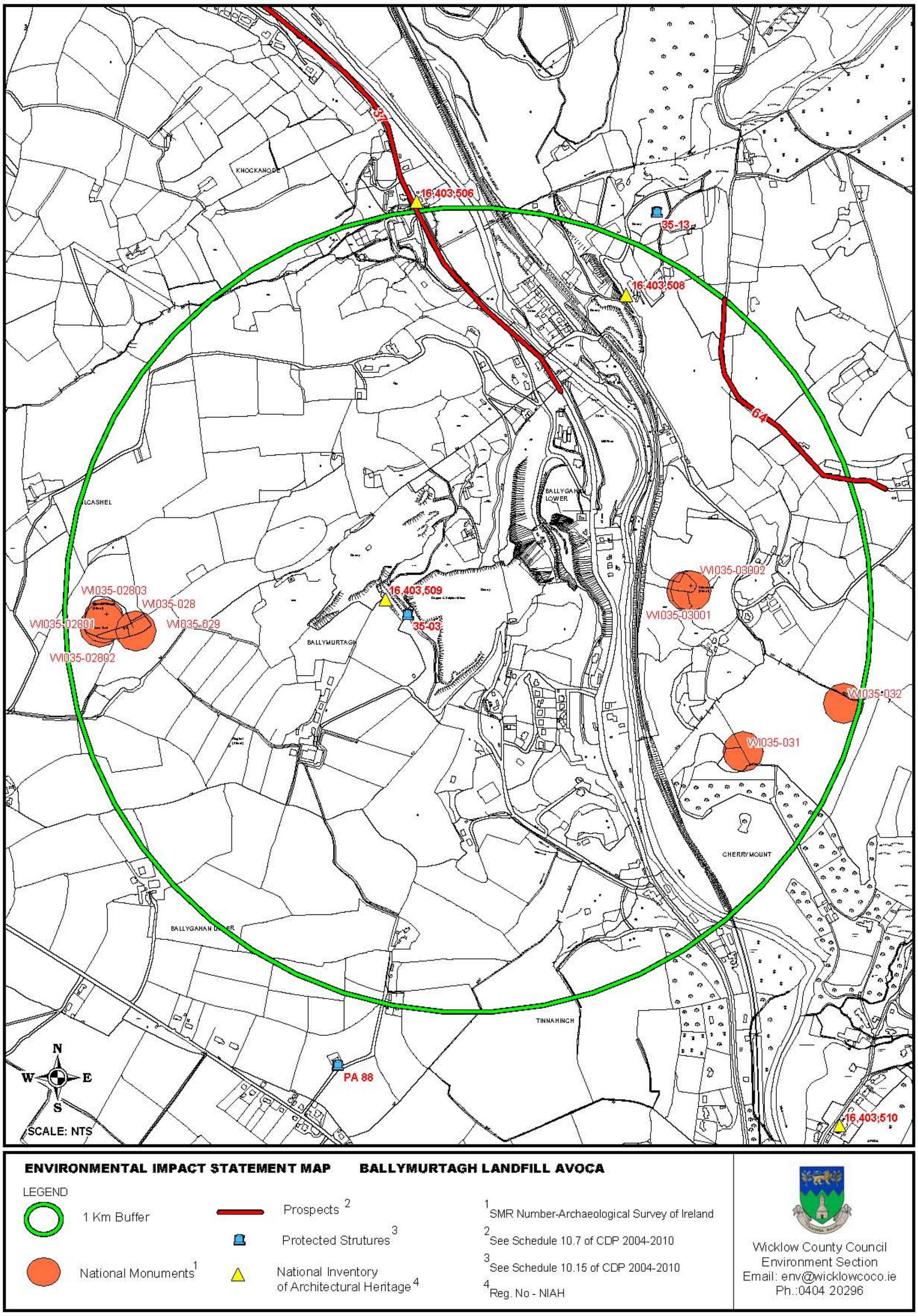

Figure 11-1: From Wicklow County Development Plan

11.3 Industrial Archaeology

Industrial-scale mining began at Avoca around 1720 and continued until the mines were closed in 1982, by which time some 12 Mt of ore had been extracted, much of it through open cast mining. A considerable legacy of this long period of mining activity remains around Avoca in the form of heritage features and industrial archaeology sites.

The heritage aspects of the mining area have been subject to significant investigations in recent years, in addition to conservation works for some structures. As part of their feasibility study of the Avoca Mining Area CDM (2008) with Seán Harrington Architects (SHA) performed a comprehensive review of industrial archaeology, building on work that SHA had previously undertaken work for the Avoca Mining Heritage Trust.

This study included the townland of Ballymurtagh the area surrounding the landfill. The condition of many of these features was addressed in detail in the Health & Safety Audit of the Avoca Mining Area prepared by GWP Consultants (GWP, 2008). SHA provided descriptions and photography of the features and artefacts and evaluated the significance of the various features.

In summary, the visible industrial archaeology artefacts within Ballymurtagh consist of the:

- Old mining office;
- Tramway Arch;
- Western Whim Engine House;
- Twin Shafts Engine House and Chimney;
- Tramway Engine House Chimney;
- Ballygahan Engine House; and
- Spoil heaps and associated disturbed ground.

These are included in the Record of Protected Structures which forms part of the Wicklow County Development Plan 2004-2010. Their designation within the Development Plan ensures that remediation works and plans for the overall Avoca Mining Area will need to preserve the heritage integrity of these structures. Wicklow County Policy HL47 states that *"The Council will have regard to structures, sites, and objects which are part of the county's industrial heritage, in particular features which relate to former mining and/or transport activities."*

11.4 Archaeology

In 1998, prior to the closure of Ballymurtagh Landfill an archaeological study was carried out by Margaret Gowen & Associates, Archaeological Consultants. This study included an assessment of the impact of landfill operations on the receiving archaeological environment. The report was based on a field inspection and a study of records and files at The National Museum of Ireland, Sites and Monuments Records of Duchas, and several documentary and literary sources.

The study concluded that there are no listed archaeological sites within the boundary of or in close proximity to the landfill. The study showed that the nearest archaeological site of antiquity is a holy well and possible church site (009:030) located 150m east of the landfill across the Avoca River. This is the only site within a 500m radius of the landfill as shown on **Figure 11-1**.

Closure and capping of the landfill and the continued operation of the Civic Waste Facility do not impact upon any archaeological sites or any sites of industrial archaeology importance.

11.5 Tourism

Wicklow is known as the Garden of Ireland and is renowned for its scenery. The landfill is located in the Vale of Avoca a popular tourist destination with forest and hill walking being popular activities for visitors to the area.

Tourism figures are compiled by Failte Ireland in accordance with a number of regional groupings. County Wicklow is in the Midlands East Region which has seen an increase of 6% in the number of visitors to its most popular paying tourist attraction from 2003 to 2008 (Fáilte Ireland, 2009). **Table 11-5** shows the numbers of visitors to these attractions from 2003 to 2008.

The Meeting of the Waters which is located at the confluence of the Avonmore and Avonbeg rivers is the closest tourist attraction to Ballymurtagh Landfill. It was immortalised almost 200 years ago by the poet, Thomas Moore who wrote the words of the Irish Melody *"The Meeting of the Waters"*.

The site is also close to the village of Avoca which is on the Avoca River and famous for the hand weaving looms and the craft shop of the Avoca Handweavers. Avoca has also in recent years been recognised as the location for the well known television series *"Ballykissangel".*

Table 11-5: Numbers of Visitors to the Most Popular Paying Attractions in Co. Wicklow (Fáilte Ireland, 2009)

Name of Attraction	2003	2004	2005	2006	2007	2008
Powerscourt House & Gardens	209,904	213,871	219,267	223,027	245,532	232,257
Glendalough Visitor Centre	99,015	100,285	101,022	106,159	102,953	96,585
Avondale House & Forest Park	45,200	48,600	52,500	60,000	75,000	62,000
Russborough House	40,000	30,000	30,000	25,000	40,000	40,000
Wicklow Gaol	48,000	-	-	-	-	37,000
Killruddery House & Gardens	-	-	-	-	2,257	2,581
Knockmore Gardens	40	-	200	100	120	120
Altidore Castle	83	85	25	112	70	66

11.6 Potential Impacts on Material Assets

No impacts on archaeology are envisaged during the remainder of the operation of the closed landfill site as there are no known registered archaeological sites within the boundary of the site. The landfill does not restrict access to the archaeological sites nearby and the restored landfill is sympathetic to the surrounding landscape.

The landfill site although situated close to the village of Avoca and the popular tourist attraction of the Meeting of the Waters, is visually well removed from both locations. The site is well screened by trees and blends quite naturally into the surrounding landscape.

The overall impact of the closure and capping of the landfill has been to improve the visual landscape in the vicinity of Ballymurtagh. Closure has also reduced traffic from heavy vehicles and other nuisances that are associated with operational landfill sites.

11.7 Mitigating Measures

No mitigating measures are required for the protection of material assets, which are not impacted by the closed landfill or the operational Civic Waste Facility.

Section 12
The Interaction of the Foregoing

Each of the specific natural and environmental parameters has been discussed in detail in their particular sections of this EIS. It is also important to consider and identify the interaction of these environmental parameters, as a change to one parameter may affect another parameter. The criteria for this assessment follows that presented in the *'Guidelines on the information to be contained in Environmental Impact Statements'* (EPA, 2002).

Table 12-1: EPA Classification Criteria (Source: EPA, 2002)

Impact Quality	**Description**
Negative	A change which reduces the quality of the environment
Positive	A change which improves the quality of the environment
Neutral	A change which does not affect the quality of the environment
Duration of Impacts	**Description**
Temporary	Impact lasting for one year or less
Short-term	Impact lasting one to seven years
Medium-term	Impact lasting seven to twenty years
Long-term	Impact lasting twenty to fifty years
Permanent	Impact lasting over fifty years
Significance of Impacts	**Description**
Slight	An impact which causes changes in the character of the environment which are not significant or profound
Moderate	An impact that alters the character of the environment in a manner that is consistent with existing and emerging trends
Significant	An impact which by its magnitude, duration or intensity alters an important aspect of the environment

Generally the interactions between the environmental parameters at Ballymurtagh Landfill are considered minimal as the facility is no longer active. The landfill has been restored as a grassland habitat that integrates well with the surrounding landscape. The facility is now in its aftercare phase and the only environmental parameters associated with the landfill are those of landfill gas, emissions to groundwater and landscape. The interaction of the various parameters are described below.

- Terrestrial ecology and human beings are the two potential receptors of the impact from landfill gas. Landfill gas emissions at Ballymurtagh landfill are subject to on-going monitoring and are controlled by a gas extraction and flaring system. Daily and weekly maintenance and functioning checks will continue to ensure gas flare optimisation and efficiency. Until the production of landfill gas ceases the impact from landfill gas will be slightly negative in the medium-term and neutral in the long-term.
- The Avoca River is the receptor of surface water run-off from the site. Surface water run-off is collected and controlled and discharges directly to the river. The quality of this surface water run-off is unpolluted and therefore has a neutral impact on the aquatic ecology. The overall impact of surface water collection at the landfill and diversion from the underground mine workings is a slightly positive long-term impact as it results in slightly less water being available for the production of AMD.
- The underlying groundwater is the receptor of percolating water that escapes overland flow to the Avoca Valley and the surface water capture system of the capping but follows a pathway through the landfill waste and base lining of the landfill. Because this groundwater is

historically contaminated as a result of AMD from the mines, the impact of the landfill on the underlying groundwater is neutral.

- The planned revegetation of the landfill capping has improved the overall landscape. This will continue to improve with time, to a point where the landfill site is completely integrated with its surrounding environment. The overall impact of the landfill on the landscape is a long-term, moderate and positive visual impact for human beings and material assets.
- The landscaping also has a positive effect on the terrestrial ecology as the landfill is located in an open pit where the flora and fauna were impoverished prior to the infill and restoration of the landfill. A new grassland habitat has been created and there will be a gradual extension of the tree growth but also the further colonisation by plant and animal species from the surroundings. The overall impact of the landfill on the ecology of the area is a long-term, moderate and positive impact.
- The existence of the landfill, infilling a disused and unsafe open mining pit has a long-term, significant, positive impact for human beings and material assets. Similar open pits remaining from the era of mining at Avoca presently exist in East Avoca at Cronebane and Tigroney. These open pits continue to be compromised ecologically and could potentially represent a health and safety risk in their present condition.

Section 13
Alternatives

13.1 Introduction

Two alternatives were considered for the purposes of this EIS.

- **Alternative A**: Continue to monitor the closed landfill in line with the Closure and Aftercare Plan (2003) and the annual Environmental Management Plans. In addition the proposed modifications to ongoing monitoring and mitigating measures presented in this EIS require implementation.
- **Alternative B**: Removal of waste from Ballymurtagh Landfill.

13.2 Alternative A

As detailed in this EIS, the impacts of the closed Ballymurtagh Landfill can generally be summarised as follows:

- **Human Beings:** Now that the landfill has been closed and capped, the overall impact to human beings is slightly **positive**. This is because the documented nuisance aspect of having a disused open pit has been removed. Furthermore, the Civic Waste Facility has a **positive** benefit to human beings, providing an important local service and allowing Wicklow County Council to contribute towards national waste management targets for recycling.
- **Soils and Geology:** The overall impact with respect to soils and geology is slightly **positive**. This is because the landfilling of the Pond Lode has removed the steep sidewall stability issues of an open pit. The continued operation of the Civic Waste Facility has no impact upon soils and geology.
- **Surface Water and Groundwater:** the overall impact with respect to water is discussed at length in Sections 6 and 7. The impacts can be described as **neutral** or slightly **positive** as the diversion of surface water through the capping drainage makes less water available for AMD. The continued operation of the Civic Waste Facility has no impact upon surface water and groundwater.
- **Ecology:** Now that the landfill has been closed and capped, the overall impact with respect to ecology is slightly **positive**. The floor of the open pits did not sustain any ecology whatsoever (due to the heavy metals content and acidity in the tailings at the base of the pit). The capping of the landfill has allowed a range of fauna and flora to develop around the closed landfill site. The continued operation of the Civic Waste Facility has no impact upon ecology.
- **Air and Climate:** Now that the landfill has been closed and capped, the overall impact with respect to air quality is slightly **negative** due to the ten percent of methane emissions that are not burned through the on-site gas flare. However these emissions will ultimately cease. The continued operation of the Civic Waste Facility has no impact upon air and climate.
- **Land Use and Landscape:** Now that the landfill has been closed and capped, the overall impact with respect to the landscape is moderately **positive**. The open pits were generally a manmade negative impact on the landscape, as can be seen in East Avoca. The capping of the landfill has allowed the natural, pre-mining, gradients and landscape to be restored. The continued operation of the Civic Waste Facility has no impact upon land use and landscape.
- **Material Assets:** The overall impact with respect to material assets can be described as **neutral**. The closed landfill or the Civic Waste Facility has no impact upon the important industrial archaeology in the area, or important tourism sites such as Avoca village.

Overall, the cost of Alternative A consists of the continued operation and monitoring costs as well as the proposed additional monitoring outlined in this EIS amounting to a total cost of approximately €300,000 per annum. The overall impact on the environment of Alternative A is **neutral or slightly positive**.

The Civic Waste Facility has a **positive** impact, providing an important local service and allowing Wicklow County Council to contribute towards national waste management targets for recycling.

13.3 Alternative B

The EPA met with the EU Commission on 12 December 2007 regarding ECJ Case 248/05. One of the possible outcomes of the ECJ case discussed at that meeting was the removal of the waste from the closed facility. Implementation of such a decision would be a major engineering and environmental challenge, creating a considerably more complicated set of environmental consequences than are set out in this EIS. However it would ensure that no leachate would reach the groundwater.

In considering the removal of the waste from the site, it is likely that the removal could not be confined simply to the non-hazardous waste material disposed of by Wicklow County Council. The toxic nature of the mine waste in the Avoca Mining Area make it likely that the mine waste underlying the landfill may also need to be removed and disposed of safely. The implications of removing this waste are estimated to be as follows:

- The non-hazardous waste material could be disposed of at a non-hazardous waste facility. The gate charges, required by the Landfill Directive, for this disposal would be in the order of €45 million, plus an additional €10 million for landfill tax, totalling €55 million. This does not include costs that may be involved for the diversion of the biodegradable fraction of this waste from 2010.
- The remaining waste material consisting of contaminated mine spoil and tailings would require initial on-site treatment to segregate and reduce the volumes of material involved. Disposal or further treatment at a hazardous waste facility would be required at a cost in excess of a hundred million euro.
- Approximately 25,000 specialist, leak-proof, 20 tonne trucks would be required to remove the non-hazardous waste material from the site. This would involve 50,000 truck movements through the Vale of Avoca to and from the landfill. The nearest non-hazardous disposal facility that could accept the non-hazardous portion of waste is the privately operated Greenstar Landfill facility at Ballynagran, approximately 22 km from Ballymurtagh. The environmental impact of the transportation of the non-haxardous waste to the Greenstar facility would be significant involving 25,000 x 44km round trips.
- The current Waste Licence for the Greenstar facility at Ballynagran limits the acceptance of waste at the facility to a maximum annual tonnage of 175,000 tonnes. A review of the Waste Licence would be required so that the removal of the waste from Ballymurtagh could be completed in a timely manner and further risk to the environment could be minimised.
- There would still be a need to find or construct a hazardous waste facility for the relatively large volume of contaminated mine waste materials.
- The waste is producing explosive and flammable methane gas and the asphyxiant CO_2; therefore workers hired to excavate the facility would have to use full breathing apparatus and would be working in an extremely dangerous environment.
- The odour impact at the excavation site and the deposit site would have a significant impact on the local communities.

Importantly, the removal of the waste from Ballymurtagh Landfill will not result in any discernible improvement to groundwater or surface water quality in terms of the List I and List II substances from the acid mine drainage. For Alternative B the impacts of the removal of the waste from Ballymurtagh Landfill are outlined as follows:

- **Human Beings:** the impact to human beings in the short term of removing the waste would be potentially **very negative** because of the severe nuisance impact of odour, dust, noise, vermin, and scavenging birds from the exposed decaying waste. In addition there is likely to be a significant impact on the local community from the traffic of heavy goods vehicles (HGVs) required to remove the material from the site. In the long term the resulting large open pit would potentially provide a heath and safety risk for local land users. The Civic Waste Facility would be required to close with the loss of an important local recycling service. The overall impact on human beings is **negative.**
- **Soils and Geology:** The overall impact with respect to soils and geology for removal of the waste would be potentially **negative**. This is because the landfilling of the Pond Lode has removed the steep sidewall stability issues of an open pit.

- **Surface Water and Groundwater:** in removing the waste, the overall impact with respect to groundwater and surface water would be slightly **negative** as the diversion of surface water that currently occurs through the drainage system in the landfill capping would not exist. As a result rainwater falling into the open pit would add to the AMD. In addition the removal of the waste would not result in any discernible improvement in the quality of either the groundwater or the water in the Avoca River because of the AMD.
- **Ecology:** The overall impact with respect to ecology in removing the waste would be **negative.** The floor of the previous open pit did not sustain any ecology whatsoever (due to the heavy metals content and acidity in the tailings at the base of the pit). A reinstated open pit would also not be capable of sustaining significant plant or animal life.
- **Air and Climate:** In the short term the impact on air quality from removing the waste would be **negative** as a result of emissions from the decaying waste. In the long term the impact would be slightly **positive** due to the elimination of methane and other landfill gas emissions.
- **Land Use and Landscape:** The overall impact with respect to the landscape in removing the waste would be **negative**. The reinstated open pit would return a manmade negative impact on the landscape.
- **Material Assets:** The overall impact with respect to material assets in removing the waste would be **very negative** in the short term as the volume of HGVs passing through the Avoca District would have a negative impact on tourism. In addition the severe nuisance of odour, dust, noise, vermin, and scavenging birds from the exposed decaying waste would also have a potential negative impact on tourism that could last more then of three years.

The overall costs of Alternative B would require detailed engineering studies, but could cost in excess of a hundred million euro. The overall impact on the environment of Alternative B would be **negative** both during the removal work and in the long term. As pointed out previously removal of the waste from Ballymurtagh Landfill will not result in any discernible improvement in groundwater quality or in the quality of the water in the Avoca River.

13.4 Other Alternatives

In considering other options, for example, retrospectively fitting a complete containment system to the base and sides of the landfill to contain, collect and treat the leachate, there can be no absolute guarantees that the system would capture all the waste and not prevent leachate migration. In addition the engineering works that may be required at the east side of the landfill to provide such a system, could have the potential to undermine the stability of the front holding embankment that could result in a major environmental emergency with serious health and safety considerations. Importantly, even if such a containment system was successful, it would not result in any discernible improvement to groundwater or surface water quality in terms of the List I and List II substances from the acid mine drainage.

Treatment of the groundwater for substances that may to attributable to the landfill, such as ammonia was also examined. To be effective such treatment could not be confined to the ammonia in the groundwater of the Ballymurtagh (Road) Adit, but would also have to address the diffuse groundwater flow. For treatment of the ammonia in the Ballymurtagh (Road) Adit, the relatively low concentration of ammonia as well as the low pH and the heavy metal loading from the AMD in this flow stream make this treatment unviable. In addition the detection of ammonia in the Ballymurtagh (Road) Adit has shown a marked decreasing trend since the landfill was capped. Importantly, similar to any leachate containment measures there would be no discernible improvement to the quality of groundwater or the Avoca River as a result.

Section 14
Further Considerations

The comprehensive Feasibility Study for Management and Remediation of the Avoca Mining Area referred to in several sections of this EIS was completed in December 2008 (CDM, 2008) on behalf of the Minister for Communications, Energy and Natural Resources. The work was conducted under the direction of the Geological Survey of Ireland and is awaiting publication.

This study focussed on the entire Avoca Mining Area, and as such included the impact of the former Pond Lode pit at West Avoca, the site of Ballymurtagh Landfill. The study looked at the overall legacy of over 250 years of mining, how surface waters and waterways have been impacted by acid rock drainages and discharges and the unsafe conditions that exist as a result of open pits, abandoned shafts and adits, unstable piles and pit walls, and potential subsidence.

The overall objective of the Feasibility Study was to prepare a realistic, cost-effective, and achievable integrated management plan for the entire Avoca Mining Area, that addresses the many issues at the site including human and ecological concerns, safety and physical hazards, heritage, future uses, and long-term site management.

The Pond Lode Pit in West Avoca, which covered an area of 64,000 m^2 and was up to 50 m deep had in the order of 1 Mt of ore bearing material extracted from this site before closure in 1982. The impact of spoils and tailings on surface and groundwater as a result of mining activity are considered significant. About 200,000 m^3 of tailings were disposed in the 19th Century, North Lode, open-pit in West Avoca. In addition an area on the west bank of the Avoca River, downgradient of Ballymurtagh Landfill was used as an emergency tailings disposal area and it is estimated to contain 129,300 m^3 of tailings. Some tailings estimated to be in the order of 100,000 m3 were also disposed of in the Pond Lode Pit where Ballymurtagh Landfill is sited.

The quality of the water in the Avoca River is not documented prior to the commencement of mining in the 18th Century, but acid waters from the mines reduced its quality. The river continues to be significantly contaminated by acid waters with elevated concentrations of heavy metals, which enter the water from adits draining both East and West Avoca. Acid rock drainage (ARD) generated in waste piles and underground workings contribute to these flows.

The acid mine discharges have low pH values and high levels of iron, copper, zinc, and aluminium. This has been documented in numerous previous studies such as the EU-funded LIFE project (GSI, 1987), a study undertaken by for the Eastern Regional Fisheries Board (Doyle *et al.* 2003) and extensive published research over many years by academics.

Both direct and diffuse discharges of metals impact the water quality in the Avoca River. The impact is the greatest during low flow conditions in the river. A conclusion drawn in the Feasibility Study (2008) is that treatment of the adits alone, including the Ballymurtagh Road Adit, will not sufficiently improve the quality of the water in the Avoca River. The diffuse groundwater flows from both sides of the Avoca valley contribute a significant contamination load from the AMD and this diffuse element of pollution will also require to be addressed if the quality of the River Avoca is to meet relevant water quality standards.

The report makes a number of recommendations with respect to improving the quality of the water in the Avoca. The overall impact on the environment of the Avoca River particularly the aquatic environment would be **very positive** if the recommendations of this Feasibility Report were implemented.

Section 15
EIS Summary

This EIS relates to a Waste Licence Review Application for Ballymurtagh Landfill being made by Wicklow County Council to the EPA under Section 46 of the Waste Management Acts 1996 to 2003.

The application is in response to the outcome of the European Court of Justice decision (ECJ Case 248/05) that Ireland had failed to fulfil its obligations under the provisions of the Groundwater Directive (80/68/EC) with respect, inter alia, to Ballymurtagh Landfill.

All of the environmental impacts in relation to the landfill have been assessed in this EIS in accordance with Irish and EU legislative procedures. As directed by the EPA, the EIS has concentrated on the risks to surface and groundwater and a comprehensive assessment of the groundwater and surface water regime at Ballymurtagh Landfill has been presented.

All available qualitative monitoring data from the Avoca Mining Area, both East and West, over a 30-year period has been reviewed and assessed.

The landfill is underlain by Ordovician Age, metasediments comprising metamorphosed volcanic tuff, categorised by the GSI as a *'poor aquifer, generally unproductive'*. Rocks of this type tend to transmit limited quantities of water and are not generally suitable for water production.

Groundwater pathways in the Ballymurtagh Landfill area are complex. The underground mine workings beneath the landfill site have significantly altered the hydrogeological conditions in the West Avoca mining area. The complex system of interconnected shafts, stopes, tunnels and haulage ways at different elevations and stages serve as hydraulic sinks, whereby groundwater in bedrock is hydraulically 'captured' by the mine workings. As such, the mine workings act as preferential conduits for the captured groundwater which subsequently emerges in mine adits in the Avoca valley.

In the West Avoca Mining Area, groundwater levels and discharges are primarily controlled by the Ballymurtagh Road Adit. Any groundwater that escapes the mine workings in West Avoca discharges "diffusively" to the alluvial deposits that exist along the Avoca River valley.

The groundwater underlying the landfill is historically contaminated by Acid Mine Drainage (AMD) as a result of centuries of mining in the area. As documented in numerous past reports, the water quality and aquatic ecology of the Avoca River is impaired. The type and nature of the reported impacts are attributed to acid rock drainage from both East and West Avoca.

The presence of heavy metals and low pH of the groundwater underlying the landfill makes this groundwater body '*permanently unsuitable for other uses, especially domestic and agriculture'* in accordance with Article 4(2) of the Groundwater Directive (80/68/EEC).

Ballymurtagh Landfill commenced acceptance of waste in 1989, ten years prior to the EU Landfill Directive (99/31/EC) entering into force in July 1999. The landfill was designed to operate under a 'disperse and dilute' method, under determined advice that this method would not result in harm to the Avoca River. The engineered landfill included a bottom liner in the form of low-permeability mine tailings whose function would reduce or limit the risk of pollution to groundwater. The embankment constructed to the front of the landfill was also partially lined to a height of 5 m with butyl rubber.

The key challenge in assessing the nature and extent of potential landfill impacts on groundwater and surface water quality in West Avoca is to be able to distinguish between the impacts of the landfill from those of the mine workings. A Principal Component Analysis (PCA) was used in this EIS to assist with this assessment.

The PCA was carried out for seventeen chemical constituents, extracted from the analytical water test data from the area over an eleven year period. The analysis shows that the chemical signature of leachate from the landfill is very different to the chemical signature of the AMD. When water samples from the Avoca River at and downstream of the Avoca Mining Area were assessed using PCA, the samples showed contamination from AMD and not from landfill leachate.

Leachate attenuation takes place through the tailings at the base of the landfill. Dilution occurs in the underlying groundwater of the mines. Any leachate that escapes the underground mine workings and migrates towards the river valley becomes mixed and diluted with the groundwater in the alluvial deposits.

Although ammonium is detected in the groundwater of Ballymurtagh Road Adit, there is evidence that closure and capping of the landfill has resulted in a lowering of ammonium concentrations. A graph of ammonium concentrations from groundwater samples from the Road Adit presents a clear and distinct downward trend from a maximum of 30mg/l in 2001 to a concentration of 9mg/l at present.

Existing private wells in the mines area have been extensively tested to date and available test results do not indicate any contamination. No further wells are planned within the groundwater pathways from the landfill on the basis that groundwater beneath and downstream of the landfill is primarily impacted by acid rock drainage, and as such is not usable for drinking water purposes.

The overall impact of the landfill with respect to groundwater is neutral and the overall impact with respect to surface water is slightly positive as the surface water capture system of the capping diverts surface water away from the underground mines, making less water available for the production of AMD.

Mitigating Measures identified for groundwater in this EIS include maintenance of the capping system of the landfill, more detailed monitoring of surface water emissions and modifications in the nature of quality analyses for leachate and groundwater samples from the site to demonstrate compliance with the existing Groundwater Directive (80/68/EEC) and the new Groundwater Directive (2006/118/EC).

With the exception of air quality, which is slightly negative in the medium-term, the overall impact of the existing landfill on the other environmental parameters assessed as part of this EIS is neutral or slightly positive.

Two alternatives have been considered in some detail in this EIS. The first, Alternative A, is to continue to follow the closure and aftercare plan for the facility and to implement additional monitoring and mitigating measures presented in the EIS. The other alternative would be to remove the waste from the site. This Alternative B would ensure no leachate reaches the underlying groundwater.

Alternative A has an overall permanent and slightly positive impact on the environment with positive impacts for human beings, soils and geology, surface water, ecology, landscape and material assets. Alternative A has a medium-term slightly negative impact on air quality until landfill gas production ceases.

Alternative B has a short-term significant negative impact on the environment and a permanent moderate negative impact on the environment. By removing the waste there will be negative impacts for human beings, soils and geology, surface water, ecology, landscape and material assets.

Other alternatives such as retrospectively fitting a complete containment system or treatment of the ammonium in the groundwater were considered but discounted as it was apparent from the outset that such measures would not result in any discernible improvement to the groundwater or the surface water in terms of the List I and List II substances in both these water bodies from acid mine drainage.

A comprehensive Feasibility Study for the Management and Remediation of the Avoca Mining Area, (CDM, 2008) is awaiting publication. The overall impact on the environment of the Avoca River particularly the aquatic environment would be very positive if the recommendations of this Feasibility Report are implemented.

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