11.1 Introduction

This chapter is concerned with the examination of the existing geological and hydrogeological environment in the vicinity of the proposed composting facility at Pass of Kilbride. The groundwater impacts of the proposed development are also considered. The proposed development has the potential to contribute to underlying groundwater pollution mainly due to leachate generation. Leachate is typically contaminated water that has the potential to impact on any adjacent water body and subsequently other elements of the local environment where a pathway exists.

Baseline conditions will be established and site specific monitoring will aid in assessing the potential impact of the proposed development on the surrounding groundwater environment.

11.2 Study Methodology

The development of waste management infrastructure in Ireland has been subject to an evolving range of legislative controls, a number of which relate to the protection of groundwater resources. Directives from the European Union, such as the Groundwater Directive (80/68/EEC), the Landfill Directive (1999/31/EC), Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment and the Directive on the assessment of the effects of certain plans and programmes on the environment (2001/42/EC) are playing an increasing role in the formulation of national legislation and guidance.

The national regulations that transpose the Directives place an onus on developers to implement the Best Available Techniques (BAT) to reduce risks associated with developments. The methods employed to assess the risks and determine the appropriate mitigation measures are described in the following sections.

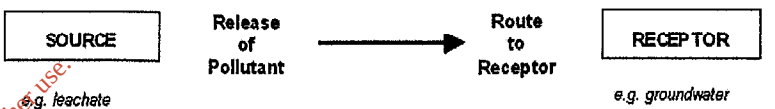
The Environmental Protection Agency (EPA) and Westmeath County Council are the main regulatory bodies charged with implementing and enforcing water resources protection legislation, and are statutory consultees in the process of determination of an application for waste treatment facilities.

The Geological Survey of Ireland (GSI) in conjunction with the Department of Environment, Heritage and Local Government (DoEHLG) and the EPA have developed a methodology for the preparation of groundwater protection schemes to assist statutory authorities to meet their responsibility to protect groundwater[1]. The methodology adopts a risk based approach to identifying areas in which certain types of developments are restricted.

The impacts on groundwater associated with the proposed development were assessed using a similar risk based approach, which is described below.

11.2.1 Risk Assessment Approach

The impacts on groundwater from a new development are minimised through the systematic assessment of risks posed by the development. Environmental risk assessment is the process of collating known information on a hazard or set of hazards in order to assess actual or potential risks to receptors. The receptor may be human, a water resource or a sensitive local ecosystem. Receptors may be connected to a hazard via one or several exposure pathways. Risks are generally managed by isolating or removing the hazard, isolating the receptor or by intercepting the exposure pathway. The absence of a source, pathway or target term in this model indicates that a significant risk is not present. This suggests that the presence of a hazard at a site does not necessarily constitute a risk.



The Risk Assessment comprises three stages, viz.:

- Hazard Assessment - Qualitative determination of potential source, pathway and receptor scenarios, along with a summary of any relevant characteristics of the proposed development and of a "do nothing scenario".
- Risk Estimation - Semi-quantitative modelling of identified contamination scenarios.
- Risk Evaluation - An assessment of the significance of identified contamination scenarios.

11.2.2 Evaluation Criteria

The geology and hydrogeology of the area are key factors in establishing the level of natural protection for groundwater and assessing the likely impacts of the proposed development on groundwater. Existing conditions are examined by means of a desktop study (non-intrusive investigation) followed by a site specific investigation (site walkover, intrusive investigation).

The local geological and hydrogeological conditions are characterised in terms of the permeability of underlying soil and bedrock, aquifer potential and background groundwater quality. These conditions provide the baseline against which impacts are measured and compared with applicable standards, and risks are assessed. This information is then used in order to determine the acceptability of the development in relation to groundwater issues and to establish the requirements for, and extent of, mitigation measures in respect of design, operations and monitoring to protect the local groundwater resources.

The geology and hydrogeology at the site were determined by collation and study of existing published information, by intrusive site investigation work and monitoring carried out by Enviros Consulting between January and April 2004.

The site investigation and monitoring data provide information in relation to:

- Groundwater levels and quality;
- The local groundwater flow regime;
- The nature of the geological strata underlying the proposed composting facility.

[1] Groundwater Protection Schemes, DoEHLG, EPA and GSI, 1999

11.2.3 Environmental Consequences

As part of the assessment, mitigation measures are identified that are necessary to ensure that groundwater quality is protected. Where necessary monitoring schemes are specified in order to measure the effectiveness of the mitigation measures incorporated into the development and to demonstrate that actual impacts do not exceed predicted values.

11.3 Receiving Environment

The environmental setting of the site is described in the following subsections by collating published and publicly available data with information obtained from a site investigation.

A desk study was undertaken which comprised a review of information from the sources detailed in the reference list.

11.3.1 Existing Site

The existing site is described in Chapter 4. The site is approximately 17.5ha in area and is generally flat with some localised hillocks and a gentle slope towards the stream in the north and northeast.

Towards the north of the site a remnant of raised bog exists. Much of the peat has been extracted and drained. This area is adjacent to the west of the proposed facility. The remainder of the site is located on undulating arable farmland.

Of particular relevance to this evaluation is the proximity of a Natural Heritage Area (NHA) to the south of the site and a stream which forms the northern boundary to the site. The NHA relates to a raised bog, known as the Milltownpass Bog NHA, which is classified as an Annex 1 habitat within Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. This designated area is adjacent to an access road which forms the southern boundary to the site. The stream is a tributary of the Kinnegad River, an important salmonid river of local and regional importance. Reference to EPA River Quality data indicates that at the monitoring location nearest to the site the river water has a biological water quality rating of Q3 - Q4 (slightly polluted) (cf. Chapter 10).

11.3.2 Site Investigation

Initial Investigation

An intrusive investigation was conducted at the site in February 2004. Three boreholes were installed in an area approximately 600m west/northwest of the proposed site. The initial findings of the site investigation revealed very poor ground conditions for the purposes of the development. It was decided at this time to change the location of the development and drilling was moved to the proposed site.

Main Investigation

The main site investigation was conducted in February 2004 and comprised nine boreholes and eleven trial pits. The boreholes were installed at the proposed site to depths ranging from 5.5m below ground level (bgl) to 13.4mbgl. The location of the boreholes and trial pits from the main site investigations are shown on Figure 11.1.

Trial pits extended to depths of between 2.3mbgl and 3.5mbgl, generally encountering shallow tills over dense gravels in the vicinity of the proposed site of the facility. The till was generally between 0.5m and 3.5m thick. The base of the gravel stratum was not proven during the trial pit investigation.

In the east of the site and at points outside the site to the northwest, peat was encountered over clay, tills and gravels. Up to 0.9m of peat was encountered in the east of the site. In the area immediately to the west and northwest of the site, the trial pits revealed up to 2.3m of peat. The trial pit logs are contained in Appendix 11.1.

Reference to the borehole logs in Appendix 11.2 indicates that the site is generally underlain by dense gravels of at least 7.5m in thickness. The base of the gravels was proven in boreholes BH3, BH6, BH7, BH8 and BH9A. Auger refusal occurred in BH 1A at a depth of 2.9mbgl. The gravels were generally overlain with up to 2.8m of clayey or silty till. Where the base of the gravels was proven, the underlying strata generally comprised sand and sandy clay.

Water ingress was generally recorded at 3mbgl, often corresponding to the top of the gravel layer. Pumping tests were attempted on some boreholes at the site, as described in Section 11.3.4.

Samples were taken from the boreholes and trial pits for testing for environmental and engineering parameters. A schedule of the testing carried out on samples and the test results are contained in Appendix 11.3.

A peat probe survey was also carried out off-site, in the peat bank near to the western boundary of the site to ascertain the volume of peat present in this area.

11.3.3 Geology

County Westmeath generally consists of gently undulating to rolling glacial topography almost absent of mountains and predominantly underlain by limestone. The ground levels on site range from a low of about 85.1mOD (Ordnance Datum) in the east to about 90.2mOD, at the west of the facility.

Solid Geology

The solid geology indicates that the site lies in a limestone region, as shown in Figure 11.2. The western and eastern portions of the site are underlain by the Lucan Formation, which comprises dark limestone and shale, and may be referred to as Calp. The northern part of the site is underlain by the Waulsortian Formation, which consists of massive unbedded lime mudstone. These rocks are Carboniferous of Dinantian age. A fault running through the site extends for several kilometres in a northwest to southeast direction.

The thickness of the strata is not known, and borehole information indicates that bedrock was not encountered during the site investigation. Boreholes were installed at depths up to 13.4m below ground level (mbgl). Unpublished data provided to the writer by the Geological Survey of Ireland (GSI) indicates that other investigative boreholes installed between 800m and 3,000m from the site reached depths up to 8.0m without encountering bedrock. This information is summarised in Appendix 11.4.

Quaternary Geology

The Quaternary period covers the past 1.6 million years. Quaternary geology relates to deposits laid down during and just after the glacial periods (glacial transportation and deposition), specifically the deposits which lie under the top soil and over the bedrock. These deposits are also referred to as "drift" or "subsoil".

Glacial deposition includes such features as boulder clay, deposits of eroded rock deposits, esker gravels deposited by glacial melt-waters, moraines and kettle holes. Changing climate following the glacial periods resulted in the growth of peat areas, with raised peat bogs developing in many small lake basins.

This area of Co. Westmeath is covered by limestone derived till, which was deposited by the most recent of several ice sheets that covered the region. The site is located in a lowland area that can have thick glacial deposits and rock exposures are reportedly rare. An area of outwash materials is recorded two miles northeast of Milltownpass, which would correspond to the an area to the northeast of the site and possibly to the sands and gravels under the site.

No exposed rock outcrops are present in the vicinity of the site. Reference to GSI geology field sheets indicates a quarry approximately 2km northeast of the site with between 1.5m and 4.6m of gravelly clay over evenly bedded grey limestone bedrock.

The National Soil Survey of Ireland (NSSI) classify the soils on the northern and western portions of the site as Glacial Till of predominantly limestone composition, the southern portion as Raised Bog and the eastern portion as Raised Bog - Cutover Reclaimed.

The Quaternary Section of the GSI confirmed that a Quaternary map of Co. Westmeath is currently being prepared, but is still in the early stages of production. The GSI provided a Draft Quaternary Geology Map of

Co. Westmeath (See Appendix 11.4). This draft map suggests that peat is predominant to the northwest, west and south of the site. The eastern portion of the site is not covered by this map, but the delineation of the subsoil types indicates that peat is the dominant subsoil in this area. Limestone Till with Gravels covers the remainder of the site. This information reflects the findings of site inspections and of the site investigation and is deemed to be more accurate than the NSSI data.

Geology field sheets at the GSI indicate that subsoil thickness ranges from 1.5m to 6m thick approximately 2.5km northeast of the site. Data from areas between 1.5km North and 3km west indicate subsoil thickness of between 5.2m and 10.4m.

More recent trial pit data received from the GSI suggests that up to 5m of clays and silts were recorded within approximately 3km east and north of the site. Gravels were recorded at depths of between 0.15mbgl and 3.0mbgl.

The information retrieved from the site investigation supports the published data for the area and indicates that in the east of the site, about 1.0m of well decomposed peat overlies about 0.5m of clayey, silty till overlying dense medium to coarse gravels.

The centre of the site comprises thin topsoil over between 1.0m and 3.0m of gravelly clay over at least 7.5m of dense fine to coarse gravel over sandy clay.

To the west of the site, beyond the site boundary, the area is covered with up to 4m of peat over gravelly till. This till covers an extended area to the west and was found in boreholes drilled 600m northwest of the site. A band of marly clay up to 0.9m thick was found beneath the peat in several areas in the west and east of the site, but was not encountered in the centre of the site.

11.3.4 Hydrogeology

Aquifer Classification

Site specific information regarding the aquifer classification for the site was obtained from the GSI. The aquifer classification presently assigned to both the LU - Lucan Formation and WA - Waulsortian Limestone rock units is Ll, denoting a locally important aquifer which is moderately productive only in local zones (see attached GSI aquifer classification letter- GSI, 2003 contained in Appendix 11.5).

The stratum of gravel beneath the till on site was encountered over much of the site. A permeability test was attempted in BH7 using a petrol-driven pump rated at 5l/s. Twenty minutes of pumping failed to create a sufficient head drop to provide acceptable pump test data, indicating a permeability greater than 0.009m/s (>777m/d). Subsequent pump tests were attempted in all eight boreholes in the vicinity of the proposed facility but no decrease in the groundwater level was detected after 30 minutes of pumping at 40 l/min.

The GSI provide guidance on the classification of gravel aquifers. For an unconfined gravel formation to be considered an aquifer, the formation must be greater than 10m thick or have a saturated thickness of greater than 5m. In addition, a gravel aquifer is classified to be Locally Important Sand/Gravel Aquifer (Lg) where its lateral extent is greater than 1km x 1km. A gravel aquifer is classified to be Regionally Important Sand/Gravel Aquifer (Rg) where its lateral extent is greater than 10km x 10km.

The gravel beneath the site should be classified as an aquifer, as its saturated thickness is greater than 5m in thickness. The thickness of the gravels was shown to be 7.5m to 8.6m thick, although is lower boundary was not reached in some cases. The lateral extent of the aquifer was not proven. However, quaternary information indicates that till was encountered to the east, north and west of the site, suggesting that the aquifer may not be of sufficient lateral extent to be classified as a Regionally Important Sand/Gravel Aquifer. However, the site investigation showed that peat to the west of the site was generally underlain by till, while quaternary information indicates that till was encountered within 1km of the site to the northeast, north and northwest, suggesting that the aquifer may not be of sufficient lateral extent to be classified as a Regionally Important Sand/Gravel Aquifer. The gravel aquifer will be treated as a Locally Important Sand/Gravel Aquifer for the purposes of assessing the vulnerability of the groundwater resource beneath the site.

Vulnerability Rating

Groundwater in the region had not been assessed for vulnerability. Vulnerability mapping of groundwater, as defined and used by the GSI, is a natural intrinsic characteristic that is used to identify the likelihood of contamination reaching an aquifer if a hazard or contaminant source exists at or near the ground surface. Vulnerability depends upon the type and thickness of soils and subsoils and upon the presence of karst or other highly permeable features. GSI have interim vulnerability mapping for the area, based on outcrops recorded on field sheets, which adopts a classification of extreme vulnerability where there are outcrops and high to low vulnerability elsewhere.

In conjunction with the GSI groundwater vulnerability classification, the GSI Well Database (GSI, 2003a) and the Quaternary geology of the area were examined and assessed.

A search of the GSI Well database within 3 km of the site produced 2 wells (see Appendix 11.6), all of which are over 2 km from the site. Both of these were bored wells; neither are natural (springs).

Table 11.1 GSI Well Database search within 3 km of Kilbride, County Westmeath (Adapted from GSI, 2003a)

Well location	Use	Yield (m³/d)	Depth to bedrock (m)	Aquifer lithography
E 249993 : N 24325	Industrial use		3	
E 24810 : N 24790	Agricultural & domestic	Poor - < 40	-	Limestone

GSI geology field sheets were also referenced for water level data. Water levels were recorded between 4.6mbgl and 7.9mbgl approximately 3km west of the site.

Measured water level data from the site indicates that in March and April 2004, the water table generally lies between 1.7mbgl and 3.8mbgl, with the shallower depths corresponding to lower lying points. The range in groundwater elevations is approximately 0.25m across the site of the proposed facility. The water table is on average approximately 0.25m higher in the peat to the west of the facility. In July 2004, the water levels were on average 0.2m lower and lay between 1.9mbgl and 4.0mbgl. The range was recorded at 0.16m across the site. The water level in the peat was 1.2m above the water table in the gravel, indicating the poorly drained conditions at this location.

As the top of the gravel aquifer is generally at between 1.2mbgl to 3.0mbgl, the vulnerability is rated as Extreme. The vulnerability code for the aquifer is therefore Lg/E, a locally important sand/gravel aquifer where the groundwater is extremely vulnerable to contamination.

Groundwater Protection Response

In conversations held with the EPA Groundwater Section, the EPA stated that for the development of a composting facility, the groundwater protection response should have regard to the Response Matrix for On-site Treatment Systems, published by the EPA. Reference to this matrix indicates that for aquifer vulnerability code Lg/E, the response is given as R2[1], indicating that percolation of treated effluent is

- *"acceptable subject to normal good practice. Where domestic water supplies are located nearby, particular attention should be given to the depth of subsoil over the bedrock such that the minimum depths required (EPA 2000) are met and that the likelihood of microbial pollution is minimised".*

A groundwater abstraction borehole will be located to the northeast of the percolation area. The borehole is situated at a point where the distance to the well from the percolation area is greater than 100 days travel time, assuming a conservative pumping rate of 5l/s.

The classification of the gravel aquifer suggests that the groundwater will need to be protected from all contamination arising at the facility by the design of the facility. Chapter 4 addresses the design issues in relation to the protection of groundwater.

In summary, Chapter 4 states that groundwater will be protected by containing site operations using a reinforced concrete base which will be formed to collect all contaminated surface water runoff (leachate) from the process areas to discrete sumps where the leachate can be re-circulated in the process or pumped to the leachate treatment plant prior to discharge to the stream along the northern boundary.

Domestic effluent will be treated using a proprietary treatment system and percolation area in accordance with the above groundwater protection response.

Clean surface water runoff from the roofs and non-process hardstanding areas will be discharged to the stream after passing through a silt trap and oil/water separator.

A strict Construction Quality Assurance (CQA) programme will be implemented from the design stage through to completion of the construction of the facility. A programme of integrity testing for the different water and wastewater streams will be implemented in agreement with the EPA and under the conditions of the Waste Licence.

Groundwater Quality

Groundwater samples were collected and submitted for analysis in March and April 2004. Analytical results are presented in Appendix 11.7 and represent baseline groundwater quality at the Kilbride. Certificates of analyses are also contained in Appendix 11.7. All results were compared against drinking water standards set out in the National Regulations SI No. 439 of 2000 and European Directive 98/83/EC and against the Surface Water Regulations, SI No. 294 of 1989.

In general the water quality of the groundwater beneath the site is good, but initial testing revealed high levels of ammoniacal nitrogen in BH4A, BH5, BH8 and BH9A and elevated iron and manganese concentrations were detected throughout the site. The principle objection to elevated iron and manganese values is for aesthetic and taste reasons and in no circumstances causes any health problems. Since both iron and manganese are present in significant amounts in soils, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron and manganese. Analysis of a second set of groundwater samples confirmed elevated levels of ammoniacal nitrogen, iron and manganese. A high nickel level at 27µg/l was recorded at BH2 during both sampling periods.

Total coliforms were detected in all of the groundwater wells during both rounds of sampling; however some coliforms grow naturally in the soil and are not of faecal origin. An examination for the presence of faecal coliforms in groundwater wells revealed only one (BH8) out of eight wells to be slightly contaminated with a count of 1 cfu/100ml during both monitoring rounds. The remaining seven groundwater wells which showed positive total coliform counts exhibited no faecal coliform counts.

The low levels of potassium, chloride, sodium, phosphorous and faecal coliforms suggest that there is no significant agricultural or septic tank pollution. The elevated ammoniacal nitrogen concentrations may be a result of microbial decomposition associated with the peat in the vicinity of these points.

Groundwater Flow Regime

While groundwater monitoring data is currently limited, the groundwater levels recorded at the site indicate that the water table is very flat, with a slight gradient to the east. The water table lies between 2.25mbgl and 4.5mbgl, representing a reduced level of between 84.5m and 85.0m AOD.

Groundwater is expected to discharge to the stream flowing along the northern boundary, and is expected to contribute significant baseflow to the stream. Groundwater levels indicate that the hydraulic gradient across the site is between 0.0006 and 0.0014, suggesting that groundwater velocities under the site are very low despite very high hydraulic conductivities. Groundwater levels are higher in the peat to the west of the site, but the peat is considered to be a separate hydrogeological unit to the gravel aquifer.

Reference to unpublished data from within 3,000m of the site indicates that groundwater levels are between 0.9mbgl and 2.6mbgl.

11.4 Potential impacts of the Proposed Development

11.4.1 Risk Assessment

Methodology

The process of risk assessment involves the following stages:

- Hazard Assessment - the source of the risk is described in the conceptual model. Pathways and receptors are identified to determine potential migration scenarios.
- Risk Estimation - An analysis of identified contamination scenarios.
- Risk Evaluation - An assessment of the significance of identified contamination scenarios.

Hazard Assessment - Conceptual Model

Source

Leachate from the composting process is considered to represent a significant hazard to the groundwater (and surface water) environment due to the high concentrations of contaminants typically found and their potential mobility through the geosphere, if composting was to proceed in an uncontrolled manner. The quantity and quality of leachate generated will depend on:

- waste quantity;
- rainfall;
- absorptive capacity of the wastes;
- surface water control.

The leachate derived from the composting process is high in COD, BOD, Suspended Solids and Ammoniacal Nitrogen, which if uncontrolled would have an adverse effect on groundwater quality in the area.

Pathways

Pathways are modes and routes of transportation for contaminants from the source to the receptor. At Kilbride, the gravel aquifer acts as a pathway for risks to the stream and the Kinnegad River into which the stream discharges and also to users of the groundwater such as the employees of the proposed facility and other nearby users.

In this context, the function of the watertight concrete base at the facility is to remove the risk by blocking the pathway.

Among the measures that will be used to ensure the integrity of the containment system at the facility are a strict Construction Quality Assurance (CQA) programme, which will be implemented from the design stage through to completion of the construction of the facility and a programme of integrity testing for the different water and wastewater streams.

Receptors

The gravel aquifer beneath the site can be regarded as a receptor as well as a pathway, as described above. Groundwater within the aquifer represents a receptor from contaminants from the facility, particularly as the groundwater is used as a source of water for the facility.

There may also be local domestic abstraction wells at the dwellings to the northeast of the site, the nearest of which is approximately 510m from the site. Groundwater under the houses to the northeast is expected to flow towards the drainage features in the area, which comprise the stream at the proposal site and a stream flowing in the same direction a further 850m northeast of the site. The stream at the site lies between the site and the nearest off-site wells.

11.5 Do-Nothing Scenario

Under this scenario there would be no impact on groundwater. Rainfall would continue to soak through the ground and recharge the gravel aquifer below.

11.6 Mitigation Measures

Surface water from the roofs and uncontaminated paved areas, e.g. carparks, facility access road, will be intercepted and kept separate from the contaminated water arising in the process areas. It is proposed to pass clean surface water through a silt trap and oil/water separator prior to discharging to the stream along the northern boundary under licensed conditions. A reserve tank will be installed to provide additional water for use in the process, as required.

The facility will be prepared and operated on the "containment" principle whereby any leachate generated by surplus moisture from the Aerated Static Piles (ASPs) is contained by the concrete base of the facility. The base will be designed to collect and convey leachate from the process areas to a dedicated drainage system through the use of slopes and bunds. The collected leachate will be recirculated through the process to maintain optimum moisture conditions while extracting and utilising all the nutrients and micro organisms present in the leachate. Surplus leachate will be conveyed to the treatment plant, prior to discharge to the stream.

The integrity of the construction of the concrete base will be delivered through a comprehensive scheme of Construction Quality Assurance (CQA) which will be applied throughout the installation. This will be completed by a competent, independent and suitably experienced company.

A programme of integrity testing and inspecting the seals and joints of the construction will help to identify areas where a deterioration of the condition of the construction would lead to an increased risk to the groundwater. This programme will be carried out as part of the Environmental Management System for the site under the conditions of the Waste Licence.

11.7 Predicted Impacts

The impacts associated with the proposed facility will be low, as the concrete base of the facility forms an effective barrier for the migration of leachate to groundwater. The CQA scheme and the integrity testing and inspection programme will ensure that the risk to groundwater beneath the site does not become significant.

11.8 Monitoring

Ongoing routine environmental monitoring will be undertaken during the construction and operation of the proposed development to ensure that there are no adverse effects on groundwater in the vicinity of the site.

Sampling of the groundwater at borehole locations on-site were undertaken to establish baseline conditions. Future monitoring will be compared to the baseline conditions to identify any deterioration in the quality of the groundwater in the vicinity of the site due to the operation of the proposed development.

11.9 Restoration and Residual Impacts

The proposed development is expected to be in operation for the foreseeable future. The implementation of good environmental management practices during operations will ensure that all mitigation measures are in place to prevent impacts on groundwater under the site. However, in the event that the facility closes, a decommissioning and restoration plan for the site will be in place in accordance with the conditions of the Waste Licence.

The plan is described in Section 4.11. Following the completion of the decommissioning plan and audit, groundwater will be monitored until such time that the Agency are satisfied that no further risks are posed by the site.

Reference list

DoEHLG/EPA.GSI. (1999). Groundwater Protection Schemes.

Finch, T. F. and Gardiner, M. J. (1977). *Soils of Co. Westmeath. Soil Survey Bulletin No. 33.* National Soil Survey of Ireland, An Foras Talúntais (The Agricultural Institute). Published by An Foras Talúntais, 19 Sandymount Avenue, Dublin 4.

Gatley, S., Sleeman, A. amd Emo, G. (2003). *Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 15, Galway - Offaly.* Geological Survey of Ireland.

Geraghty, M. and McConnell, B. (1999). *Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 13, Meath.* Geological Survey of Ireland.

Geraghty, M., MacDermot, C. and Smith, D. (1999). *Bedrock Geology 1 ; 100,00 Scale Map Series, Sheet 12, Longford - Roscommon.* Geological Survey of Ireland.

GSI. (1962). *Geological Map of Ireland (3rd Edition) (1:750,000).* Geological Survey of Ireland.

GSI. (1982). Major Aquifers of Ireland (1:1,500,000). Geological Survey of Ireland.

GSI. (2003). *Groundwater Section. Aquifer Classification letter.*

GSI. (2003a). Well Database.

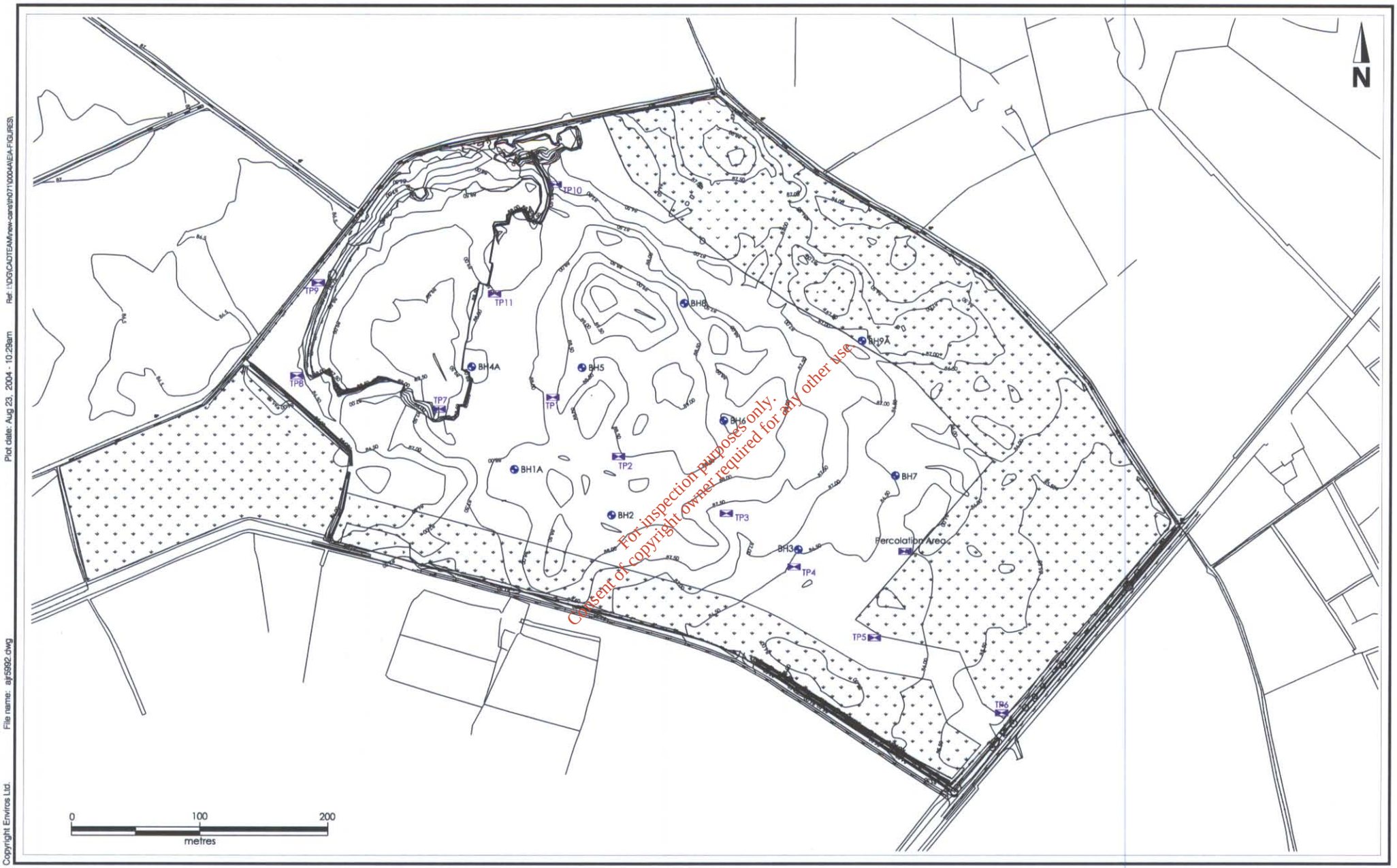
GSI. (2004). Unpublished Soil Data for Co. Westmeath, Quaternary Section, Geological Survey of Ireland.

Mc Connell, B. Philcox, M and Geraghty, M. (2001). *Geology of Meath: A geological description to accompany the Bedrock Geology 1:100,000 Scale Sheet 13, Meath.* With contributions from J. Morris, W. Cox. G. Wright and R. Meehan. Geological Survey of Ireland.

McConnell, B. and Philcox, M. (1994). *Geology of Kildare - Wicklow; A geological description to accompany the Bedrock Geology 1 ; 100,00 Map Series, Sheet 16, Kildare - Wicklow.* Geological Survey of Ireland.

McConnell, B. and Philcox, M., MacDermot, C. and Sleeman, A. (1995). *Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 16, Kildare - Wicklow.* Geological Survey of Ireland.

Morris, J., Somerville, I. and MacDermot, C. (2003). *Geology of Longford and Roscommon: A geological description of Roscommon, Longford, Westmeath, and adjoining parts of Cavan, Leitrim and Galway, to accompany the Bedrock Geology 1 ; 100,00 Scale Map Series, Sheet 12, Longford - Roscommon,* with contributions by D. G. Smith, M. Geraghty, B. McConnell, K. Claringbold, W. Cox and M. Lee. Geological Survey of Ireland.



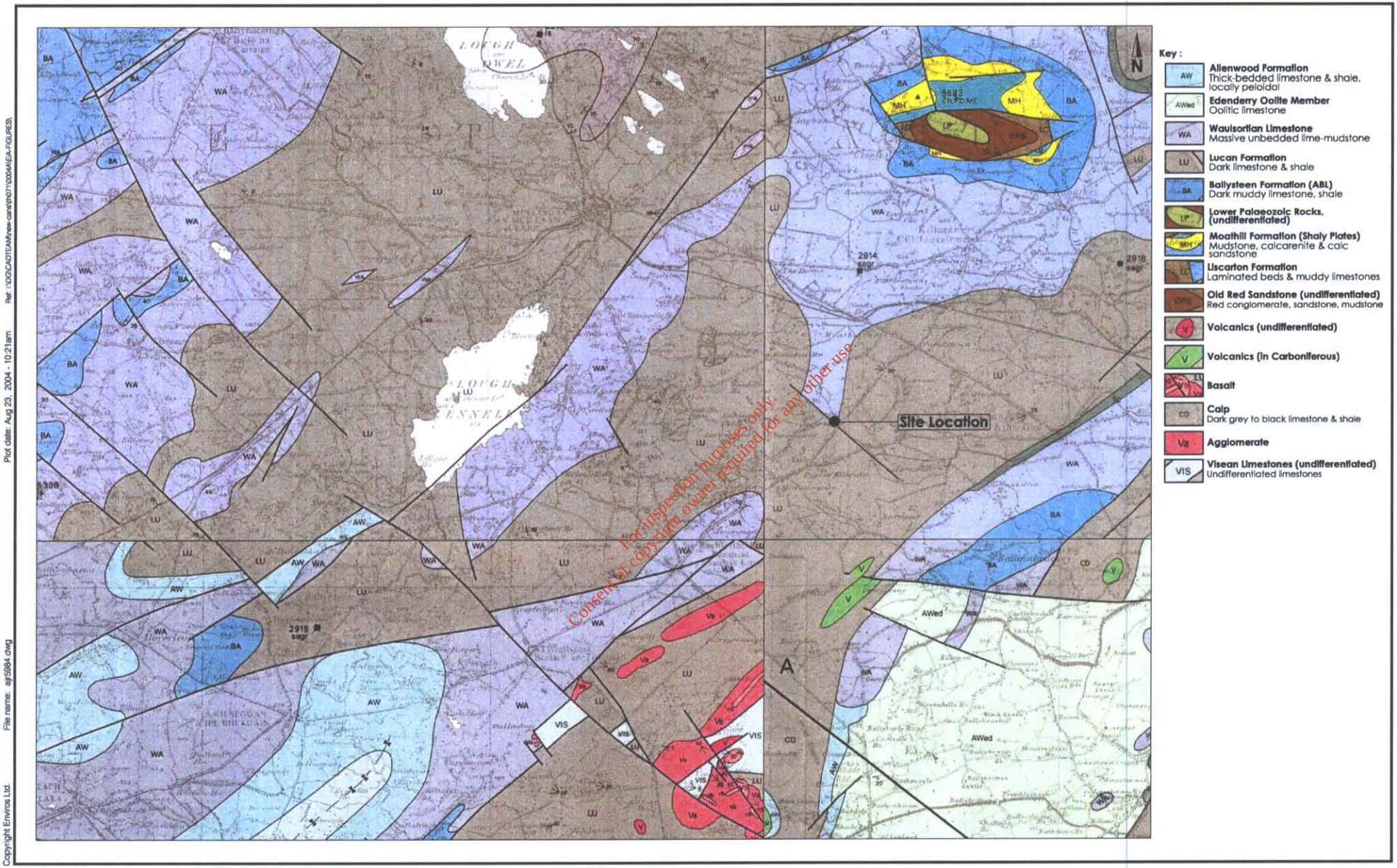
Thorntons recycling

FIGURE 11.1
SITE INVESTIGATION DETAILS

NOTES:

KEY:

- Borehole location
- Trial pit location



Thorntons recycling

FIGURE 11.2
BEDROCK GEOLOGY

NOTES: **Compiled from GSI material:-**

Gatley, S., Sleeman, A. and Emo, G. (2003). Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 15, Galway - Offaly. Geological Survey of Ireland.

Geraghty, M. and McConnell, B. (1999). Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 13, Meath. Geological Survey of Ireland.

Geraghty, M., MacDermot, C. and Smith, D. (1999). Bedrock Geology 1 : 100,00 Scale Map Series, Sheet 12, Longford - Roscommon. Geological Survey of Ireland.

McConnell, B. and Philcox, M., MacDermot, C. and Sleeman, A. (1995). Bedrock Geology 1 : 100,000 Scale Map Service, Sheet 16, Kildare - Wicklow. Geological Survey of Ireland.