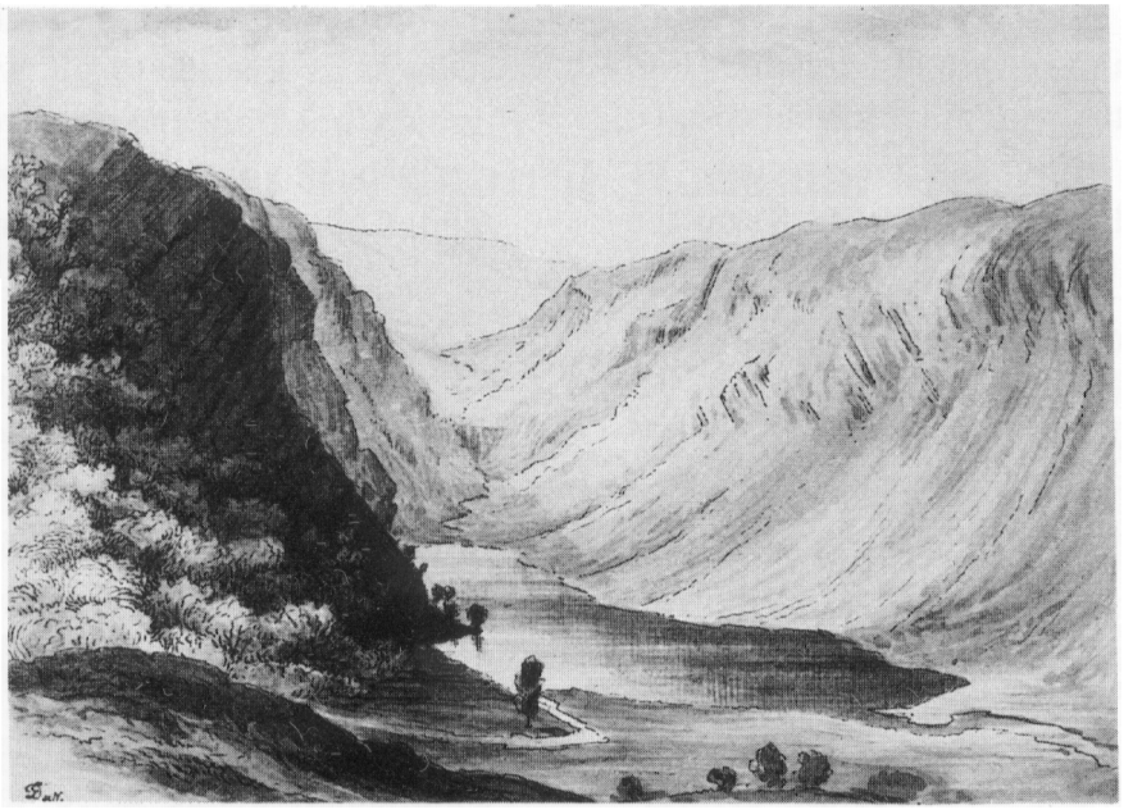
WICKLOW COUNTY COUNCIL
GROUNDWATER PROTECTION SCHEME



Glendalough, viewed from the north slope of Derry Bawn Mountain, looking west (G.V. Du Noyer, GSI)

Main Report

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Wicklow County Council
County Buildings
Wicklow

Louise Woods & Geoff Wright
Groundwater Section
Geological Survey of Ireland
Beggars Bush, Haddington Road, Dublin 4

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1. Introduction

1.1 Groundwater Protection – A Priority Issue for Local Authorities

The protection of groundwater quality from the impact of human activities is a high priority for land-use planners and water resources managers. This situation has arisen because:

- ❖ groundwater is an important source of water supply;
- ❖ human activities are posing increasing risks to groundwater quality as there is widespread disposal of domestic, agricultural and industrial effluents to the ground and the volumes of waste are increasing;
- ❖ groundwater provides the baseflow to surface water systems, many of which are used for water supply and recreational purposes. In many rivers, more than 50% of the annual flow is derived from groundwater and more significantly, in low flow periods in summer, more than 90% is groundwater. If groundwater becomes contaminated the rivers can also be affected and so the protection of groundwater resources is an important aspect of sustaining surface water quality;
- ❖ groundwater generally moves slowly through the ground and so the impact of human activities can last for a relatively long time;
- ❖ polluted drinking water is a health hazard and once contamination has occurred, drilling of new wells is expensive and in some cases not practical. Consequently ‘prevention is better than cure’;
- ❖ groundwater may be difficult to clean up, even when the source of pollution is removed;
- ❖ unlike surface water where flow is in defined channels, groundwater is present everywhere;
- ❖ EU policies and national regulations are requiring that polluting discharges to groundwater must be prevented as part of sustainable groundwater quality management.

1.2 Groundwater – A Resource at Risk

Groundwater is a resource which is under increasing risk from human activities, for the following reasons:

- ❖ since groundwater flow and contaminant transport are neither readily observed nor easily measured, and both processes are generally slow, there can be a lack of awareness about the risks of groundwater contamination;
- ❖ contamination of wells and springs is occurring;
- ❖ there is widespread application of domestic, agricultural and industrial effluents to the ground;
- ❖ the quantities of domestic, agricultural and industrial wastes are increasing;
- ❖ there has been a significant increase in the application of inorganic fertilisers to agricultural land and in the usage of pesticides in recent years;
- ❖ there are greater volumes of road traffic and more storage of fuels/chemicals; and
- ❖ chemicals of increasing diversity and often high toxicity are being manufactured, distributed and used for a wide range of purposes.

The main threats to groundwater are posed by (a) point contamination sources – farmyard wastes (mainly silage effluent and soiled water), septic tank effluent, sinking streams where contamination of surface water has occurred, leakages, spillages, pesticides used for non-agricultural purposes and leachate from waste disposal sites, and (b) diffuse sources – spreading of fertilisers (organic and inorganic) and pesticides. While point sources have caused most of the contamination problems identified to date, there is evidence that diffuse sources are increasingly impacting on groundwater.

1.3 Groundwater Protection through Land Use Planning: A Means of Preventing Contamination

There are a number of ways of preventing contamination, such as improved well siting, design and construction and better design and management of potential contamination sources. However, one of the most effective ways is integrating hydrogeological factors into land-use policy and planning by means of groundwater protection schemes.

Land-use planning (including environmental impact assessment), integrated pollution control licensing, waste licensing, water quality management planning, water pollution legislation, etc., are the main methods used in Ireland for balancing the need to protect the environment with the need for development. However, land-use planning is a dynamic process with social, economic and environmental interests and impacts influencing to varying degrees the use of land and water. In a rural area, farming, housing, industry, tourism, conservation, waste disposal, water supply, etc., are potentially interactive and conflicting and may compete for priority. How does groundwater and groundwater pollution prevention fit into this complex and difficult situation, particularly as it is a resource that is underground and for many people is 'out of sight, out of mind'? Groundwater protection schemes enable planning and other regulatory authorities to take account of both geological and hydrogeological factors in locating developments; consequently they are an essential means of preventing groundwater pollution.

1.4 'Groundwater Protection Schemes' – A National Methodology for Groundwater Pollution Prevention

The Geological Survey of Ireland (GSI), the Department of Environment and Local Government (DELG) and the Environmental Protection Agency (EPA) have jointly developed a methodology for the preparation of groundwater protection schemes (DELG/EPA/GSI, 1999). The publication ***Groundwater Protection Schemes*** was launched in May 1999, by Mr. Joe Jacob TD, Minister of State at the Department of Public Enterprise. Three supplementary publications have also been published: ***Groundwater Protection Responses for Landfills***; ***Groundwater Protection Responses for Landspreading of Organic Wastes;*** and ***Groundwater Protection Responses for on-site wastewater treatment systems***. Further 'responses' publications are planned for other potentially polluting activities and developments.

A groundwater protection scheme has two main components:

- ❖ Land surface zoning
- ❖ Groundwater protection responses for potentially polluting activities

These are shown schematically in Fig. 1.1.

Land surface zoning provides the general framework for a groundwater protection scheme. The outcome is a map which divides any chosen area into a number of groundwater protection zones according to the degree of protection required.

There are three main hydrogeological elements to land surface zoning:

- ❖ Division of the entire land surface according to the **vulnerability** of the underlying groundwater to contamination. This requires production of a vulnerability map showing four vulnerability categories – extreme, high, moderate and low.
- ❖ Delineation of **areas contributing to groundwater sources** (usually public supply sources); these are termed source protection areas.
- ❖ Delineation of areas according to the value of the groundwater resources or **aquifer category**: these are termed resource protection areas.

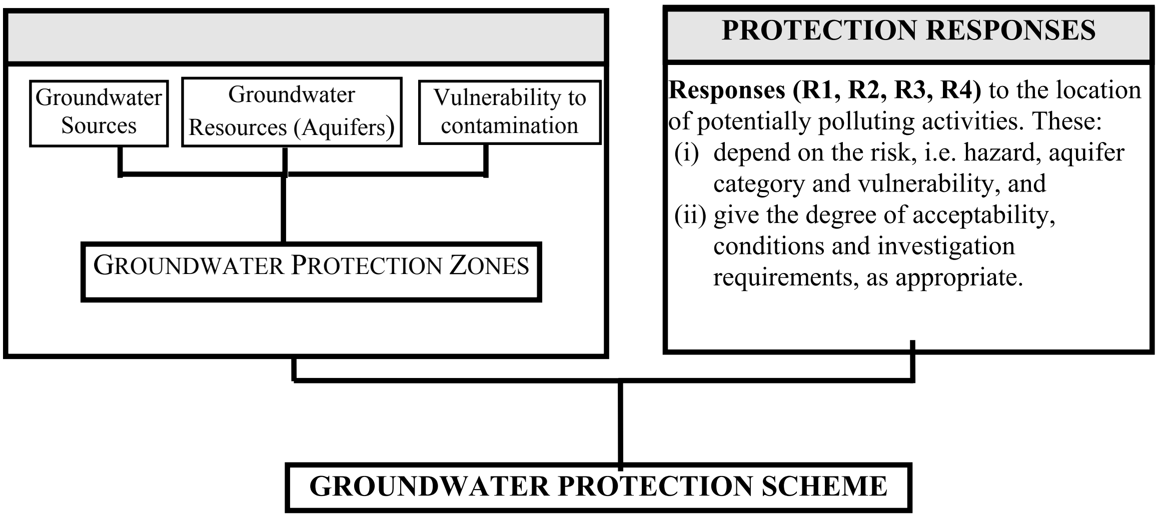

Fig. 1.1 Summary of Components of a Groundwater Protection Scheme

The vulnerability maps are integrated with each of the other two to give maps showing **groundwater protection zones**. These include source protection zones and resource protection zones.

The location and management of potentially polluting activities in each groundwater protection zone is by means of a **groundwater protection response matrix** for each activity or group of activities, which describes: (i) the degree of acceptability of each activity; (ii) the conditions to be applied; and, in some instances (iii) the investigations that may be necessary prior to decision-making.

While the two components (the protection zone maps and the groundwater protection responses) are separate, they are incorporated together and closely interlinked in a protection scheme.

For a full overview of the groundwater protection methodology, the **Groundwater Protection Schemes** publication (DELG/EPA/GSI, 1999) should be consulted.

1.5 Objective and Scope of Groundwater Protection Scheme

This report was initiated to provide Wicklow County Council with a comprehensive groundwater protection scheme. Although the main focus is on groundwater protection, the overall objective was to collect, compile and assess all readily available data on the geology, hydrogeology and groundwater quality to facilitate both groundwater resource management and public planning.

The groundwater protection scheme involved co-operation between the County Council, the Geological Survey of Ireland (GSI) and Trinity College Dublin (TCD). The Brittas Bay study was carried out by Sarah Casey as part fulfillment of her M.Sc. at the Environmental Sciences Unit, TCD.

The geological and hydrogeological data for County Wicklow have been interpreted to enable:

(i) delineation of aquifers;

(ii) assessment of the groundwater vulnerability to contamination;

(iii) delineation of protection areas around public supply wells and springs; and

(iv) production of a groundwater protection scheme which relates the data to possible land uses in the county and to codes of practice for potentially polluting developments.

By providing information on the geology and groundwater, this report will enable the balancing of interests between development and environmental protection.

This study has compiled, for the first time, all readily available geological and groundwater data for the county and sets in place a computerised database within the GSI, which can be accessed by the local authority and others, and which can be up-dated as new information becomes available.

A suite of environmental geology maps accompany the report:

(i) Primary Data or Basic Maps:

- ❖ bedrock geology map
- ❖ subsoils (Quaternary geology) map
- ❖ outcrop and depth to bedrock map
- ❖ hydrogeological data map

(ii) Derived or Interpretive Maps:

- ❖ aquifer map
- ❖ groundwater vulnerability map
- ❖ groundwater protection map

These maps can be used not only to assist in groundwater development and protection, but also in decision-making on major construction projects such as pipelines and roadways.

Detailed regional hydrogeological investigations in County Wicklow were limited to areas around four public supply sources – Blessington, Baltinglass Roundwood and Redcross – and a study of Brittas Bay. Consequently, the available data are somewhat limited and do not allow a fully comprehensive assessment of the hydrogeology of County Wicklow. However, this report provides a good basis for strategic decision-making and for site-specific investigations.

1.6 Wicklow County Development Plan

It is envisaged that the County Wicklow Groundwater Protection Scheme will be adopted by the County Council and referred to in the County Development Plan.

1.7 Structure of Report

The structure of this report is based on the information and mapping requirements for land surface zoning. The groundwater resources protection zone map (Map 7) is a land-use planning map and is the ultimate or final map as it is obtained by combining the aquifer (Map 5) and groundwater vulnerability maps (Map 6). The aquifer map boundaries, in turn, are based on the bedrock map (Map 1) boundaries and the aquifer categories are obtained from an assessment of the available hydrogeological data. The groundwater vulnerability map is based on the subsoils map (Map 2) and the depth to rock map (Map 3) and an assessment of relevant permeability information. This is illustrated in Fig. 1.2.

Similarly, the source protection zone maps result from combining groundwater vulnerability and source protection area maps. The source protection areas are based largely on assessments of hydrogeological data. This is illustrated in Fig. 1.3.

Chapter 2 summarises the bedrock geology and Chapter 3 the subsoils (Quaternary) geology. Chapter 4 summarises and assesses the hydrogeological data for the different rock units, gives the basis for each of the aquifer categories, and describes the potential for future groundwater development. Chapter 5 gives a summary of a separate report on the hydrochemistry and groundwater quality in Co. Wicklow. Chapter 6 gives the basis for the groundwater vulnerability categories. Chapter 7 draws the whole lot together and summarises the final groundwater protection zones present in County Wicklow. The conclusions and recommendations are presented in Chapter 8, and references are listed in Chapter 9.

1.8 Acknowledgements

The preparation of this groundwater protection scheme involved contributions and assistance from many people:

- Wicklow County Council staff, particularly Breege Kilkenny, all the area engineers and caretakers and many others.
- GSI Groundwater Section staff: Ruth Buckley, Donal Crean, Donal Daly, Cecilia Gately, Paul Ginnetty, Marie Hogan, Grainne O'Shea and Deirdre O'Sullivan.
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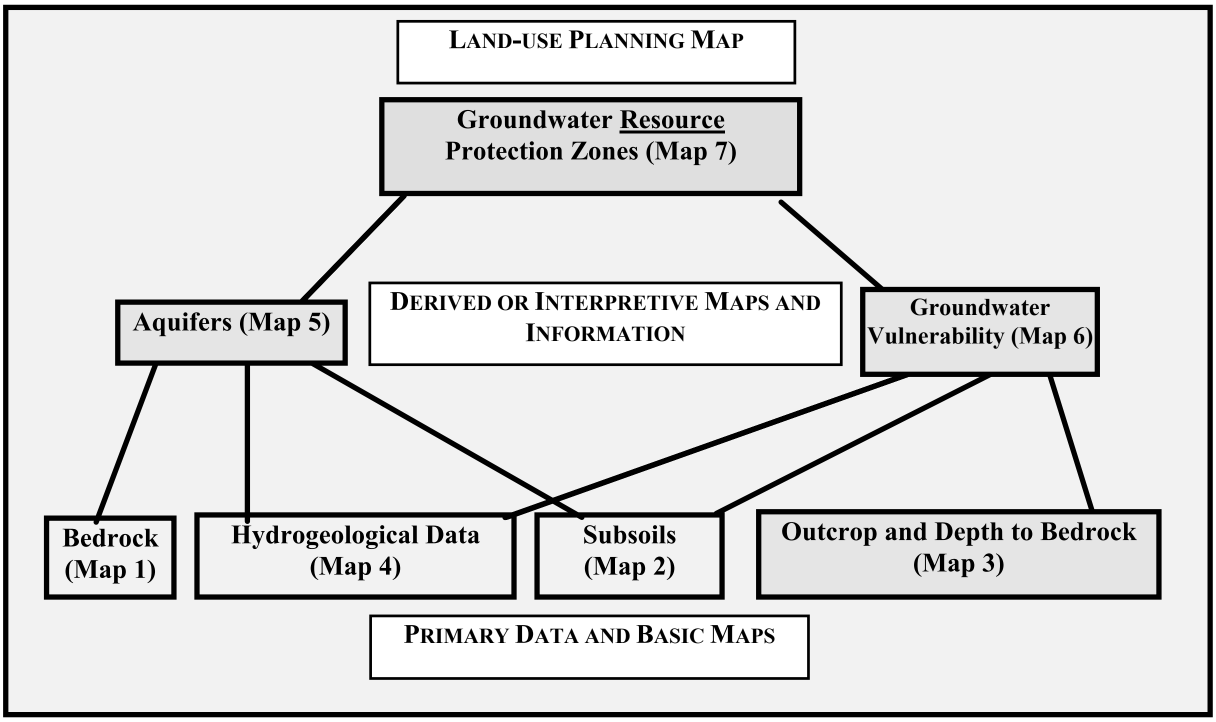


Fig. 1.2 Conceptual Framework for Production of Groundwater Resource Protection Zones, Indicating Information Needs and Links

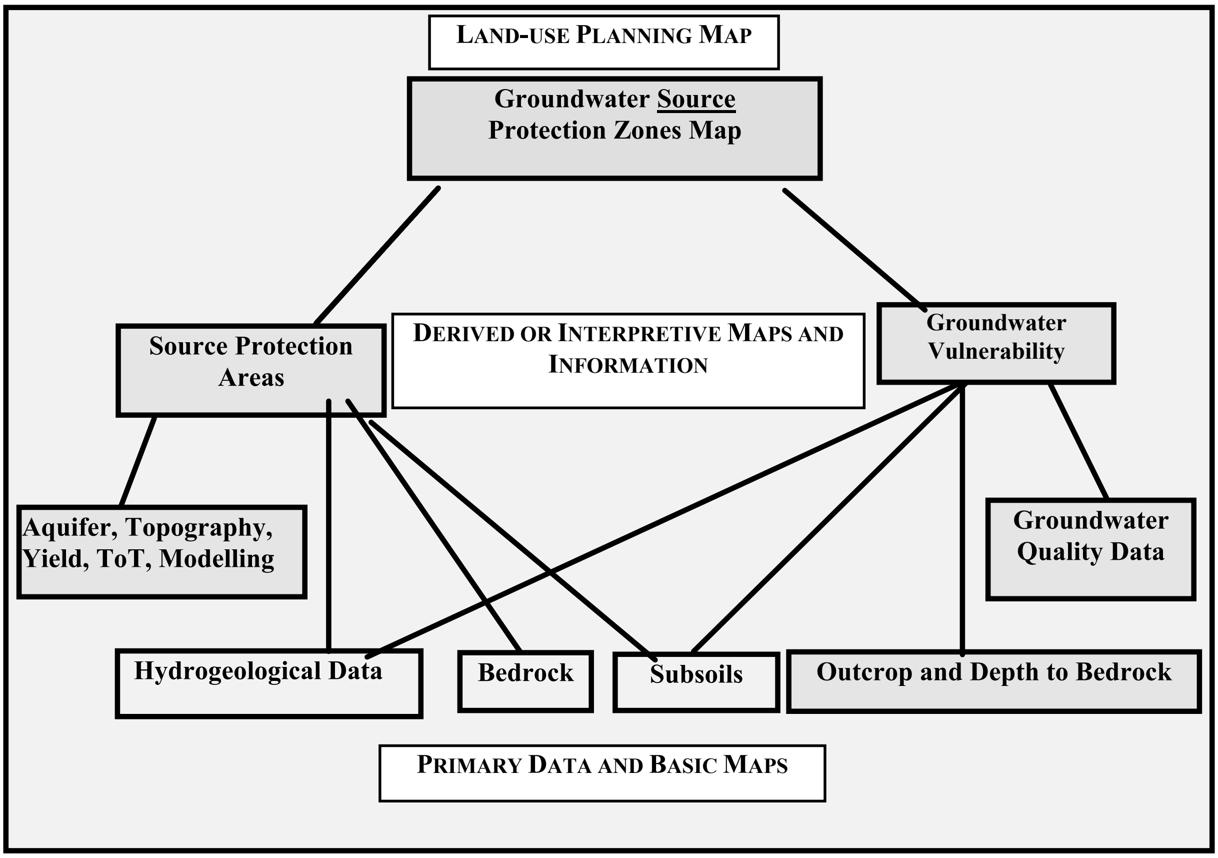


Fig. 1.3 Conceptual Framework for Production of Groundwater Source Protection Zones, Indicating Information Needs and Links

2. Bedrock Geology

2.1 Introduction

The objective of this chapter is to present a brief description of the elements of the bedrock geology that are relevant to the hydrogeology. The hydrogeology of the bedrock of County Wicklow depends largely on the rock composition (lithology) and on the rock deformation that occurred during the long geological history of the county.

The bedrock geology of Co. Wicklow comprises a series of rocks ranging in age from Cambrian (540 million years old) to Silurian (410 million years) to Granites which are Devonian in age (400 million years). The rocks deposited in this period consist of both sedimentary – sandstones and shales – and igneous rocks. Many of these rocks have been highly altered or metamorphosed.

The landscape of Co. Wicklow reflects the varied underlying geology. The mountains in the centre of the county are composed of Granite, with the older Ordovician and Silurian rocks to the east and west. The quartzites of the Bray Group are more resistant to weathering and erosion and form many hills: the Great Sugarloaf, the Little Sugarloaf, Bray Head, and Carrick Mountain.

The geology of the county is complex with both temporal and lateral changes in rock composition. Only a brief description of the different rock units and their inter-relationships is given in this report; more detailed descriptions may be obtained from the GSI reports (McConnell et al, 1994, and Tietzsch-Tyler et al, 1994). The rocks are described in groups, according to their age and starting with the oldest:

(i) the Bray Group
(ii) the Ribband Group
(iii) the Duncannon Group
(iv) the Granites

The oldest rocks are greywackes, slates and quartzites of the Bray Group and occur around Bray Head and southwards to Ashford. These rocks were deposited in a marine basin during the Cambrian.

The Ribband Group consists of fine-grained sedimentary rocks, generally siltstones and mudstones with volcanics rocks. This group was deposited over the Bray Group in a deeper marine basin more distant from the sediment source. The deepening of the basin may have resulted from the closure of the Iapetus Ocean, which produced a lot of volcanic activity. The volcanic rocks are generally comprised of basalts (pillow lavas) and andesites (tuffs) and are interbedded in the Ribband Group.

After the deposition of these sediments, there was a period of mountain building, when these rocks were uplifted and eroded, this produced an unconformity between the Ribband Group and the succeeding Duncannon Group.

The Duncannon Group consists of marine sediments interbedded with volcanics which occurred as a result of the continued closure of the Iapetus.

The youngest rocks in the area, the Kilcullen Group, represent continual submarine deposition by turbidity currents, and the sediments become finer upwards.

Finally, during the Caledonian mountain building period at the end of the Silurian to early Devonian, much faulting and shearing occurred allowing the intrusion of the Leinster Granite. In addition to the granite intrusions in the area, a swarm of dolerite sheets, both sills and dykes, were intruded particularly at the northern end of the Leinster Granite.

As a result of limited bedrock outcrop in some areas, the geological boundaries may be inaccurate. The orientations of many of the faults are also speculative or conceptual and this must be remembered when interpreting the geology and aquifer maps.

The bedrock geology of the area is shown on Maps 1N and 1S. (Formal rock unit names are used in this chapter, together with their letter code which is shown on the maps.) This map was compiled and produced by the Bedrock Section of the GSI and is now reproduced for the protection scheme. Some simplification has been used, particularly in the Granites, which have all been grouped together. A brief summary of the bedrock geology is given below and the descriptions of these rocks have been taken from the GSI reports on Sheet 16 and 19.

2.2 Bray Group

These are the oldest rocks found in Co. Wicklow and are Cambrian in age (540-510 million years). These rocks occur around Bray Head and southwards and consist of greywacke sandstones, shales and quartzites. These rocks are in faulted contact with younger rocks of the Ribband Group (Cambrian to Ordovician in age).

The Bray Group is sub-divided into two formations, an older Devil's Glen Formation and a younger Bray Head Formation. These rocks have been highly folded and faulted by several phases of deformation.

2.2.1 Devil's Glen Formation (DG)

This formation consists of thick bedded greywacke sandstones interbedded with green and red shales and a massive quartzite. Around the Newcastle area there are generally more sandstone units and near Roundwood the rocks are dominated by red and green shales and medium to thick bedded sandstones. Only one quartzite unit is found in this formation, which is 20 to 30m thick and is characterised by a fine sugary texture which distinguishes it from the quartzites of the Bray Head Formation.

2.2.2 Bray Head Formation (BH)

The Bray Head Formation is dominated by greywacke sandstones interbedded with slates, shales and distinctive massive quartzite units which range in thickness from 10 m to over 100 m. The quartzite units are very distinctive in grain size and texture and form the Great and Little Sugar Loaf mountains.

2.3 Ribband Group

The Ribband Group was deposited after the Bray Group or partly contemporaneously and consists of mudstones, siltstones, quartzites and volcanic rocks. These rocks outcrop on either side of the Leinster Granite and are divided into seven formations: the Maulin Formation to the east; the Wicklow Head, Ballylane and Oaklands formations to the southeast; the Glencullen River Formation to the northeast; the Aghfarrell Formation to the northwest; and the Butter Mountain Formation to the west.

2.3.1 Maulin Formation (MN)

The Maulin Formation consists predominantly of fine grained sedimentary rocks which have been metamorphosed by the intrusion of the granite. The sedimentary rocks are dark to grey laminated siltstones and shales. The closer to the granite, the greater the metamorphism and the occurrence of quartzite units. South of Roundwood there are also highly deformed and altered basalts.

2.3.2 Wicklow Head Formation (WH)

This formation is equivalent to the Maulin Formation, but has undergone much greater metamorphism and deformation. The rocks are described as mica schists and occur around Wicklow town and Wicklow Head.

2.3.3 Glencullen River Formation (GL)

The Glencullen River Formation is exposed only near Enniskerry and consists of massive buff coloured sand to silt grade tuff interbedded with greywacke siltstones. This formation is considered to be the youngest part of the Ribband Group in this region.

2.3.4 Aghfarrell Formation (AG)

This formation consists of thinly bedded greywacke siltstones and slates with occasional andesite lavas and sills. These rocks outcrop in the centre of an anticline to the north of Kilbride and underlie the Butter Mountain Formation.

2.3.5 Butter Mountain Formation (BZ)

The Butter Mountain Formation consists mainly of dark grey slates that become schistose towards the granite and interbedded with grey quartzites. Interbedded volcanic rocks are abundant, particularly andesitic tuffs.

2.3.6 Ballylane Formation (BY)

The Ballylane Formation is found to the southwest of Wicklow town and consists of green and grey shales and siltstones, occasional greywacke sandstone and andesitic volcanics and is overlain by the Oaklands Formation.

2.3.7 Oaklands Formation (OA)

This formation has interbedded red-purple, buff and green-grey mudstones and siltstones and occurs in faulted blocks to the southwest of Wicklow town.

2.4 Duncannon Group

In County Wicklow the Duncannon Group is composed of four formations: the Kilmacrea, the Avoca, the Arklow Head and the Ballymoyle formations. These rocks outcrop from the south of Wicklow town to Rathdrum, Avoca and Arklow. This region is highly faulted.

2.4.1 Kilmacrea Formation (KA)

This formation consists of dark grey and black mudstones, slates and shales with occasional pale grey sandstones and tuffs.

2.4.2 Avoca Formation (AV)

The Avoca Formation has undergone copper mineralisation and is thus highly altered. The unmineralised rocks are pale coloured rhyolites, rhyolitic tuffs and breccias interbedded with black slaty mudstones and shales.

2.4.3 Arklow Head Formation (AH)

The Arklow Head Formation is found at Arklow Head and consists of black slaty mudstones overlain by pale rhyolitic tuffs.

2.4.4 Ballymoyle Formation (BL)

This is similar to the Avoca Formation but has not undergone the hydrothermal alteration which is characteristic of the Avoca Formation.

2.5 Kilcullen Group

The Kilcullen Group rocks are located in west Wicklow from Brittas and Blessington to Grangecon. These rocks are Silurian in age and are divided into five formations: the Pollaphuca, the Slate Quarries, the Glen Ding, the Tipperkevin and the Carrighill. The Kilcullen Group consists of greywackes and shales deposited as turbidites and the successions fine upwards.

2.5.1 Pollaphuca Formation (PO)

This consists of coarse grey greywacke sandstones and grits and dark grey shales.

2.5.2 Slate Quarries Formation (SQ)

This consists of dark grey slates with occasional minor interbedded grey greywackes.

2.5.3 Glen Ding Formation (GD)

The Glen Ding Formation comprises dark green to grey greywacke sandstones and shales.

2.5.4 Tipperkevin Formation (TK)

This formation consists of generally medium to fine grained greywacke sandstones and shales. The contact with the Glen Ding Formation is everywhere faulted.

2.5.5 Carrighill Formation (CZ)

This is the youngest formation in the group and consists of greywacke siltstone and shales. The greywackes have a distinctive calcareous matrix which is largely iron rich dolomite, dolomite and calcite.

2.6 The Leinster Granite (Gr)

The Leinster Granite extends from Dun Laoghaire to New Ross in Co. Wexford. This granite was intruded during the Caledonian deformation and has been dated at around 405 Million years ago. The granite consists of five northeast trending plutons. The plutons are generally rounded magma intrusions with a broadly concentric internal zonation.

The granites in north Wicklow form uplands and are generally poorly exposed due to the coverage of blanket bog. Exposures are found in deeply incised valleys such as Glencullen, Glencree, Glendasan and Glenmalure. These valleys occur along a set of northwest trending fractures (Brück & O'Connor 1980).

The granites were intruded into the surrounding Lower Palaeozoic rocks as a series of plutons. The granite altered (through extreme heat or thermal metamorphism) the surrounding local country rocks to form an envelope of metamorphic rocks or mica-schists which ranges in width from one to three kilometres around each pluton. Within each pluton there are variations both compositional and textural within the granite which can be distinguished. The granites are most commonly composed of pale coloured crystals of quartz and feldspar with some mica.

There are also several minor intrusions ranging from dolerites to dolerite dykes, diorites and granodiorites which occur throughout the region.

2.7 Dolerite (D), Diorite (Di), Volcanics (V)

Throughout Wicklow igneous intrusions cut through the Lower Palaeozoic rocks, forming dykes. Some of these are basaltic or doleritic in composition, while others are rhyolitic or microgranite. Many of these dykes are too small to show on the map.

Large sheets of dolerite and diorite were intruded into the Duncannon Group as sills around Wicklow Head and Arklow Head. Three diorite intrusions are found within the Dunncannon succession in southeast Wicklow, the Carrigmore, Westaston Hill and Rockstown Diorites. The intrusions have been deformed by the regional deformation and the diorites have fractured and are strongly cleaved. Breccia zones are locally developed. A suite of dolerite intrusions are found at Castletimon Hill, Brittas and Balleese Wood. All the dolerites are strongly fractured and in places brecciated and cleaved.

A suite of five minor granodiorites and associated dykes have intruded the Ribband group in the Aughrim-Ballinaclash area. These are generally massive and are not affected by the regional deformation, but are faulted.

As the Iapetus Ocean closed, a number of volcanic arcs formed, which produced rhyolites and rhyolitic tuffs. Occasionally, andesitic lavas and tuffs were extruded at the surface. These rocks were then interbedded with the sedimentary rocks.

2.8 Structural Deformation

The Lower Palaeozoic rocks represent a complex geological history and comprise a large range of rock types including greywackes (turbidites), volcaniclastic sediments, lavas, shales, mudstones and cherts. During the Ordovician the Iapetus Ocean began to close and volcanoes formed adjacent to the continental margins, giving rise to a complex suite of volcanic and deep water sediments. As two continents collided, the accumulated sediments were squeezed up to form a chain of mountains (Caledonian Orogeny).

These rocks are thus highly folded and faulted representing polyphase deformation. Large plutons of granite were intruded and the surrounding rocks have been metamorphosed on a regional scale transforming the original shales and sandstones and giving the rocks their pervasive fabric or cleavage which allows these rocks to be instantly recognisable.

The structural geology of the county has caused varying degrees of rock deformation. Bedrock permeability is influenced by this deformation. Rocks deform mainly by folding and faulting; both of which are associated with fracturing and permeability development.

3. Subsoils (Quaternary) Geology

3.1 Introduction

This chapter deals primarily with the geological materials which lie above the bedrock and beneath the topsoil. The subsoils were deposited during the Quaternary period of glacial history, which encompasses the last 1,600,000 years and is sub-divided into: the Pleistocene (1.6M – 10,000 years ago), and the more recent Holocene (the last 10,000 years). The Pleistocene, more commonly known as the 'Ice Age', was a period of intense glaciations separated by warmer interglacial periods. The Holocene, or post-glacial, saw the onset of a warmer and wetter climate approaching that which we have today.

During the Pleistocene the glaciers and ice sheets laid down a wide range of deposits, which differ in thickness, extent and lithology. Material for the deposits originated from bedrock and was subjected to different processes within, beneath and around the ice. Some were deposited randomly and so are unsorted and have varying grain sizes, while others were deposited by water in and around the ice sheets and are relatively well sorted and coarse grained.

3.2 Subsoil Types

There are seven subsoil types identified in Co. Wicklow and shown on Maps 2E and 2W:

- till
- sands and gravels
- slope deposits (also known as 'head')
- lake deposits
- alluvium
- peat
- aeolian and marine deposits

Areas where bedrock comes within 1 m of the surface are also shown on the maps.

3.3 Till

Till ('boulder clay') is the most widespread subsoil in Co. Wicklow. On Maps 2E and 2W, it is classified according to the dominant clast lithology and the matrix composition (texture).

The dominant clast type (lithology) is the principle basis for classifying the tills in Wicklow. Till deposits in County Wicklow have a widespread distribution and are classified according to their lithological composition. Seven main lithological types are present:

(a) limestone till (Lower Carboniferous)

(b) limestone till (Lower Carboniferous) - Irish Sea Basin derived

(c) poorly sorted sandstone (greywackes) and slate till (Cambrian) - Irish Sea Basin derived

(d) poorly sorted sandstone (greywackes) siltstone, shale, schist till (Lower Palaeozoic) Irish Sea Basin derived

(e) poorly sorted sandstone (greywackes) siltstone, shale, schist till (Lower Palaeozoic)

(f) granite till

(g) chert till (Lower Carboniferous)

The subdivision of tills based on matrix composition depends on the proportions of different sized particles present in the matrix. There are five broad categories: clayey tills, silty tills, sandy tills, gravelly tills and stony tills. The categories are determined by visual assessment and particle size analysis. For example, a clayey till has a high percentage of clay particles, a silty till has a high percentage of silt in its matrix, and so on. The main confusion which may arise lies in distinguishing between a gravelly and a stony till. A gravelly till has a sandy gravelly make-up and the clasts within it will be subrounded to rounded. (Distinguishing between this and a dirty gravel comes solely from a genetic interpretation.) A stony till, on the other hand, can have any sort of matrix composition and is often clay rich, while the stones and boulders within it are also more angular in nature (Warren, W. P., pers. comm.).

Boundaries based on till texture are not shown on the subsoils maps; however, symbols indicate the texture at specific locations. Also, a limited number of particle size analyses were carried out to help assess the till texture.

3.4 Sands and Gravels

Deposition of sands and gravels takes place mainly when glaciers are melting, giving rise to large volumes of meltwaters with great erosive and transporting power. The subsoils deposited in this environment are primarily well rounded gravels with sand, with the finer fractions (clay and silt) washed out. Outwash deposits take the form of fans of stream debris dropped at the glacier front via drainage channels. Deltaic deposits are similar but form deltas where the drainage channels discharge into a standing body of water. Deposits remaining in the drainage channels form eskers, similar to a river drainage system in arrangement with tributaries converging downstream.

The presence of sand and gravel is often reflected in the topography as ridges (eskers), hummocks and hollows (kames and kettle holes) or in large fan shaped deposits (outwash, deltas).

Where the dominant clast lithology is known, the gravels are differentiated into two main types – limestone and sandstone – with the former being the most common.

3.5 Slope Deposits (‘Head’)

Slope deposits are accumulations of rock waste derived from underlying bedrock. They are primarily found on hill and mountain slopes where they are often associated with outcropping rock, thin tills and peat. The deposits are extremely variable and are very much dependent on the parent rock type. Clasts are angular and interstices may be filled with a variable matrix. These deposits are also known as hillwash and rubble.

3.6 Lake Deposits

Small areas of post-glacial lake clays and silts occur in small, often isolated, hollows.

3.7 Alluvial Deposits

Alluvial sediments are deposited by rivers and include unconsolidated materials of all grain sizes, from coarse gravels down to finer silts and clays, and they may also contain organic detritus.

Alluvial deposits may be subdivided into gravels, sands and silts, but insufficient information exists for Wicklow to enable such subdivision to be shown on the subsoils map. Alluvial sediments are expected to be primarily silty deposits. They are likely to be more sandy where flow velocities are faster – on and close to the hills and mountains. Alluvial gravels are also present in places.

3.8 Peat

Deposition of peat occurred in post-glacial times with the onset of warmer and wetter climatic conditions. Peat is an unconsolidated brown to black organic material comprising a mixture of decomposed and undecomposed plant matter which has accumulated in a waterlogged environment. Peat has an extremely high water content averaging over 90% by volume.

The largest areas of peat in Co. Wicklow are the blanket peats on the higher ground in the centre of the county.

3.9 Marine Deposits

Marine deposits in Wicklow are also post glacial in age. They occur on the eastern coast of the county and do not encroach inland to any large degree. They may be subdivided in the same manner as alluvial deposits into beach gravels, blown sands and estuarine silts and muds.

3.10 Subsoil Thickness

The subsoil thickness (i.e. depth to bedrock) is a critical factor in determining groundwater vulnerability. Subsoil thicknesses vary considerably over the county, from very thin to depths of more than 70-100 metres. The direction of ice movement has spatially influenced the subsoil thickness.

Depth-to-rock maps (Maps 3N and 3S) have been prepared from the GSI databases. These maps show areas where rock crops out at surface and depth-to-rock data from borehole records. The borehole records are colour-coded according to the degree of locational accuracy: data points coloured red are plotted to within an accuracy of 50 m, the green data points are less accurately located, to +/- 100-500 m.

Generally speaking, the thickest deposits are tills or gravels, and they are found scattered throughout the county. Some gravel deposits reach up to 100 m thick in the northwest of the county, particularly around Blessington.

Gravel deposits are usually less than 10 m thick but there are 8 deposits throughout the county which reach greater thicknesses (Chapter 4). Head deposits are usually thin as they occur on mountain slopes and would normally vary from less than 1 m up to 3-5 m thick. Thicknesses of lake and alluvial deposits are unknown but are unlikely to be more than 5 m. The peat deposits are very thin on the Wicklow Mountains where deposits range up to 3 metres in depth.

4. Hydrogeology and Aquifer Classification

4.1 Introduction

This chapter summarises the relevant and available hydrogeological and groundwater information for County Wicklow. A brief description of the hydrogeology of each rock unit is given, followed by its aquifer category based on the GSI aquifer classification scheme. The hydrogeological data for the county are summarised on Maps 3N and 3S and the aquifers are shown on Maps 4N and 4S.

4.2 Data Availability

All the groundwater data in the GSI and from County Council files, consultants and drillers were compiled and all existing well records were entered into the GSI groundwater database.

The assessment of the hydrogeology of County Wicklow is based on the following data and reports:

- Groundwater abstraction rates for local authority sources (Table 4.1), group scheme sources, and for a limited number of other high yielding private wells.
- Information from over 1,900 well records in the GSI.
- Records from 110 grant-aided boreholes drilled in 1998-2001.
- Specific capacity data and Productivity data for some wells. (Specific capacity is the rate of abstraction per unit drawdown; the unit used is $m^3/d/m$. Productivity is a ranking in five classes which is based on the specific capacity and the pumping rate.)
- Pumping tests carried out on 4 public supply wells as part of this project (see summary of results in Table 4.2), and other available pumping test data.
- Information on large springs.
- Reports by engineering and hydrogeological consultants.
- General hydrogeological experience of the GSI, including work carried out in adjacent counties.

4.3 Rainfall and Evapotranspiration

Mean annual rainfall in Wicklow for 1951–1980 varied from 833 mm (Bray) in the lower topographic areas along the coast to over 2120 mm (Glendalough) in the mountainous areas of mid-Wicklow (Met Eireann data).

There are no Met Eireann evapotranspiration stations in Co. Wicklow and the closest one is that at Dublin Airport where the long term mean annual potential evapotranspiration (PE) is calculated as 549 mm (Met Eireann data). The mean annual PE for Co. Wicklow is estimated to vary from approximately 500 to 600 mm. Actual evapotranspiration is estimated to be about 90 to 95% of the PE. The mean annual potential recharge (rainfall minus actual evapotranspiration) values are therefore estimated to be in the range 300 to 1580 mm, with the lowest levels in the low-lying areas and the highest in the mountains. The actual annual recharge to the groundwater in many areas is estimated to be less than 50% of the potential recharge. This is partly due to the low permeability of the subsoils but mainly to the steep topographic gradients, particularly in the mountainous areas, producing high runoff to streams.

4.4 Groundwater Usage

There are approximately 50 public and numerous private group water schemes in Co. Wicklow, of which 18 are partially or wholly supplied from groundwater (EPA, 2000 & Wicklow Co. Co. 2003), from about 22 separate sources. In total these schemes abstract some 3401 m^3/d, which comprises approximately 15% of total public water consumption in the County Council area. The Council's public groundwater sources are summarised in Table 4.1. Areas not served by the County Council or Group Water Schemes generally rely on individual private wells as the main source of water supply.

Table 4.1. Summary of Co. Council Public Groundwater Supplies

WATER SUPPLY	ABSTRACTION (approx.)	SOURCE
Wicklow Area		
Barndarrig WS	18 m^3/d	Borehole
Redcross/Conary/Kilmacoo WS	155 m^3/d	Borehole
Roundwood WS	135 m^3/d	Borehole
Blessington Area		
Blessington WS	860 m^3/d	Boreholes (4)
Dunlavin WS	363 m^3/d	Springs
Grangecon WS	23 m^3/d	Borehole
Stratford WS,) Ballyhook/Eadestown)	184 m^3/d	Springs
Valleymount WS	35 m^3/d	Spring
Hollywood WSS	250 m^3/d	Borehole
Tinahely Area		
Lathaleere, Baltinglass*	)	Boreholes (2)
Tinoran, Baltinglass	) *(combined)* 997 m^3/d	Boreholes (2)
Parkmore, Baltinglass	)	Springs
Coolboy/Coolafancy WS	98 m^3/d	Spring
Kiltegan WS	57 m^3/d	Borehole
Knockananna WS	39 m^3/d	Borehole
Arklow Area		
Ballycoogue WS	28 m^3/d	Borehole
Kirikee WS (old)	14 m^3/d	Borehole
Kirikee WS (new)	12 m^3/d	
Rathdrum WS (supplementary)	100 m^3/d	Borehole
Thomastown WS	35 m^3/d	Borehole
Kilballyowen	8 m^3/d	Borehole
TOTAL	3401 m^3/d	

(data from Wicklow County Council 2003)

Many of the groundwater abstractions are unmetered and thus many of these values are estimated

** Lathaleere boreholes, Baltinglass, were closed in November 2002 due to the unacceptable concentration of Uranium^{238} discovered in the water. A new well at Carsrock has been drilled, with an estimated yield of 150 m^3/day.*

Table 4.2. Summary of the Project Pumping Tests

Water Supply Scheme	**Roundwood**	**Redcross**	**Baltinglass** Lathaleere	**Baltinglass** Tinoran
GSI Well No.	2919NE 025	3217NW 217	2617NE 042	2617NE 032
Grid ref.	31866 20335	32472 18368	28777 18780	28536 18883
Depth (m)	61	60	61	61
Aquifer (Formation)	Maulin	Kilmacrea	Granite	Butter Mountain
DTB[a] (m)	~1.5	~12-15	~4-12	~8
SWL[b] (m)	3.9	5.6	8.0	5.2
s[c] (m)	6.64	7.82	29.9	4.17
Q[d] test (m^3/d)	325	350	260	340
Q normal (m^3/d)	–	–	260	340
Hrs/day pumped	12	12	12	12
Q/s[e] 12 hrs (m^3/d/m)	49	45	9	82
Q/s 1 week (m^3/d/m)	40	35	7	72
KD[f] (m^2/d)	65	45	25	130
[Range]	[55–80]	[32–50]	[20–30]	[125–155]

Notes:

a) Depth-to-bedrock below ground level
b) Static water level below ground level
c) Drawdown during 12 hour test
d) Discharge (*Q test* is the pumping rate during the pumping test. *Q normal* indicates the quantity of water abstracted daily.)
e) Specific capacity (*Q/s 12 hrs* is the specific capacity during the pumping test. *Q/s 1 week* is extrapolated from the pumping test data.)
f) Transmissivity (= Permeability x saturated aquifer thickness)

4.5 General Aquifer Classification

The aquifer classification used by GSI (DELG/EPA/GSI, 1999) has three main aquifer categories, with each category sub-divided into two or three classes:

Regionally Important (**R**) (or Major) **Aquifers**
- (i) Karstified aquifers (**Rk**)
- (ii) Fissured bedrock aquifers (**Rf**)
- (iii) Extensive sand/gravel (**Rg**)

Locally Important (**L**) (or Minor) **Aquifers**
- (i) Sand/gravel (**Lg**)
- (ii) Bedrock which is generally moderately productive **(Lm)**
- (iii) Bedrock which is moderately productive only in local zones **(Ll)**

Poor (**P**) **Aquifers**
- (i) Bedrock which is generally unproductive except for local zones **(Pl)**
- (ii) Bedrock which is generally unproductive **(Pu)**

These aquifer categories take account of the following factors:
- the overall potential groundwater resources in each rock unit
- the localised nature of the higher permeability zones (e.g. fractures) in many of our bedrock units;
- the highly karstic nature of some of the limestones
- all bedrock types give enough water for domestic supplies (therefore all are called ‘aquifers’).

Aquifers are defined on the basis of:

- ❖ Lithological and/or structural characteristics of geological formations which indicate an ability to store and transmit water. Pure limestones and clean sandstones are more permeable than muddy limestones and clayey sandstone, respectively. Areas where strong folding and faulting has produced strong joint systems has led to increased permeability.
- ❖ Hydrological indications of groundwater storage and movement e.g. the presence of large springs (indicating a good aquifer); absence of surface drainage (suggesting high permeability) or high density of surface drainage (low permeability situation usually – the main exception is in low lying areas where there is no outlet for the water); high groundwater base flows in rivers, etc.
- ❖ Information from boreholes, such as high permeabilities from pumping tests, specific capacities (rate per unit drawdown), and well yields.

The main type of information available for aquifer classification in County Wicklow is from well yields and productivities, but other sources of information have been used (e.g. bedrock lithology, structural deformation, and surface drainage). It is emphasised that aquifer delineation is a generalisation which reflects the overall resource potential, and because of the complex and variable nature of Irish geology, there will often be exceptionally low or high yields which do not detract from the overall category given to any particular rock unit. It is also important to remember that the top few metres of all the bedrock types are likely to be relatively permeable.

The rock units in County Wicklow are listed in Table 4.3, together with a summary of the useful well data for each formation, and the aquifer category.

Information from wells throughout Wicklow and neighbouring counties shows a wide variation in well yields, with ‘excellent’, ‘good’, ‘moderate’ and ‘poor’ wells all in close proximity. The details from most of these wells are limited and thus interpretation is difficult from the available records. As a result of this, aquifer classification is difficult to achieve.

The sections that follow examine the hydrogeological information available for each rock unit and concludes by giving the aquifer category.

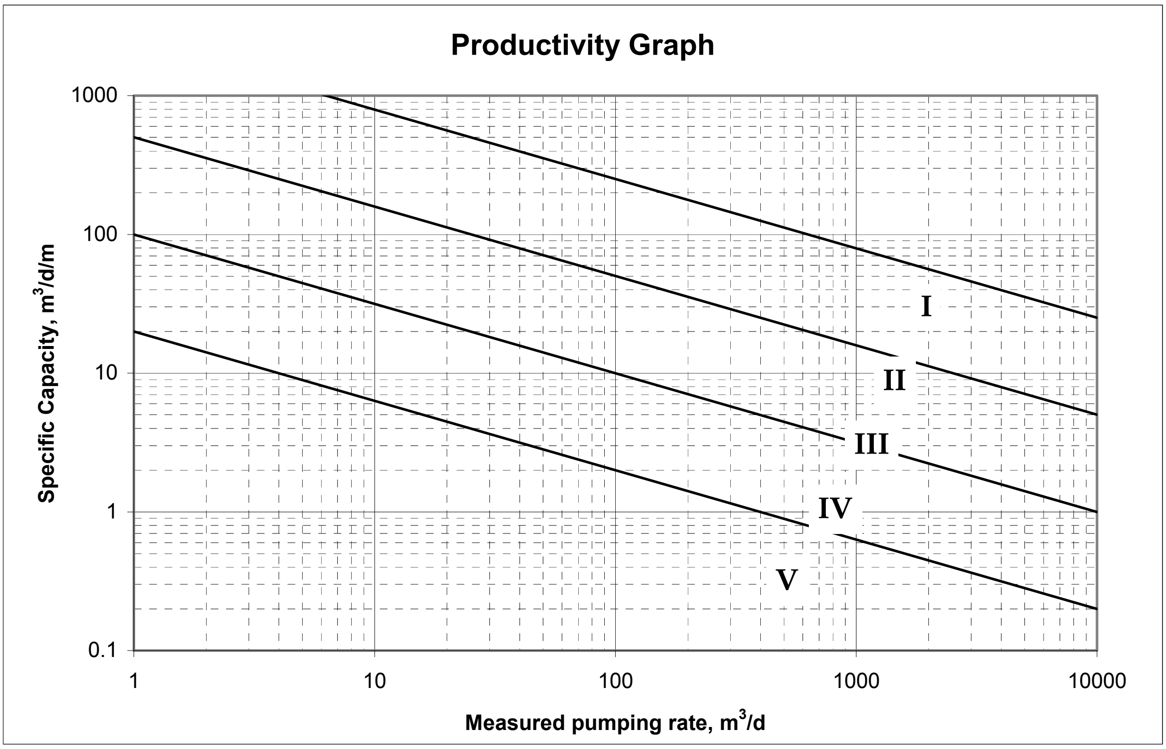
4.5.1 Aquifer Classification Criteria

As well yield is one of the main concerns in groundwater development projects, yields from existing wells are conceptually linked with the main aquifer categories:

- Regionally important (**R**) aquifers should have (or be capable of having) a large number of ‘excellent’ yields: in excess of approximately 400 m^3/d.
- Locally important (**L**) aquifers are capable of ‘good’ well yields 100-400 m^3/d.
- Poor (**P**) aquifers would generally have ‘moderate’ or ‘low’ well yields - less than 100 m^3/d.

In practice, well yield information is often difficult to use because reliable, long term yield test data are uncommon (particularly for less productive aquifers). In practice, the following criteria are used in aquifer classification as presented in Table 4.3:

- Permeability and transmissivity data from formal pumping tests, where discharge and water levels readings have been taken over a period of many hours or days.
- Productivity data from wells where either good pumping tests have been undertaken or at least discharge and drawdown data are available. The GSI has developed the concept of ‘productivity’ as a semi-quantitative method of utilising limited well test data (Wright, 2000). A well ‘productivity index’ is assigned from one of five classes: I (highest), II, III, IV, and V, using a graphical comparison (see chart below) of well discharge with specific capacity (discharge per unit drawdown).



- Occurrence of springs with ‘high’ flows (greater than 2160 m^3/day total flow).
- Occurrence of wells with ‘excellent’ yields (greater than 400 m^3/day discharge).
- Hydrological information such as drainage density (where overlying strata are thin), and baseflows in rivers (better aquifers will support higher baseflows).
- Lithological and/or structural characteristics of geological formations which indicate an ability to store and transmit water. For example, clean and sorted sands and gravels are more permeable than poorly sorted glacial tills. Clean limestones are generally more permeable than muddy limestones. Areas where folding and faulting has produced extensive joint systems tend to have higher bulk permeabilities than areas where this has not occurred.

All factors are considered together; productivity and permeability data are only given ‘precedence’ over lithological and structural inferences where sufficient data are available. Data from neighbouring counties in similar geological environments are included.

Table 4.3. Well Yields, Productivities and Aquifer Categories

Group	Rock Unit (formation)	Well Yield Categories (Co. Wicklow)		Productivity Classes (Wicklow & adjacent counties)					Transmissivities (Ranges, m^2/d)	Aquifer Category
		Excellent (>400m^3/d)	Good (100-400m^3/d)	I	II	III	IV	V		
Quaternary	Sands/gravels	8	14	(n/a – too dependent on well construction)						Lg
Igneous Rocks	Dolerite (D), Diorite (Di), Volcanics (V)									Pl
	Granite (Gr)	1	9	1	0	22*	13	14	(4 – 15, exceptionally 110)	Pl
Kilcullen Group	Carrighill (CZ)			0	0	0	2	2		Pu
	Tipperkevin (TK)		2	0	0	3	2	3	(10 - 40)	Pl
	Glen Ding (GD)			0	0	1*	0	0		Pu
	Slate Quarries (SQ)									Pu
	Pollaphuca (PO)		2	0	0	0	1	0		Pl
Duncannon Group	Ballymoyle (BL)		3	0	1	0	1	0		Pl
	Arklow Head (AH)		1							Pu
	Avoca (AV)			0	0	0	1	1		Pu
	Kilmacrea (KA)	5	16	0	2	10	5	2	(30-50), (10-20), (60-130), (20-30), (5-20), (20-40), (30-100), (80), (10-20)	Ll
Ribband Group	Oaklands (OA)		1	1	3	2	1	0		Ll
	Ballylane (BY)	1	3	0	0	2	2	0	(10 - 20)	Pl
	Glencullen (GL)		1							Pl
	Maulin (MN) & Butter Mountain (BZ)	3	12	0	3	20*	7	13	(40 - 80), (55 - 80), <15	Ll
	Wicklow Head (WH)		4	0	1	1	3	0	(50 - 60 ?)	Pl
	Aghfarrell (AG)									Pl
Bray Group	Bray Head (BH)	2	16	0	1	1	2	7	20	Pl
	Devil's Glen (DG)	2	2	0	0	4*	1	1		Pl

(1) * denotes most class III data are very approximate productivity values at low pumping rates, from well grant data.

(2) While there are >1900 well records for Co. Wicklow, most have neither drawdown data to enable the specific capacities to be calculated nor maximum yield information.

(3) Details of all 'excellent' and 'good' wells have been checked as far as possible.

(4) Shaded aquifers represent those with the best potential for future development in Co. Wicklow.

4.6 Bray Group

4.6.1 Devil's Glen Formation (DG)

Recent information from the drilling of private wells indicates two 'good' wells at Ballardbeg (approximately 400 metres apart). Both of these wells were fully lined due to the highly broken nature of the bedrock. The GSI well database shows two 'excellent' wells, at Ballycullen and at Parkmore near Ashford. No tests have been conducted on these wells. The two 'excellent' wells seem to be located close to faults, which could explain their high yields.

Owing to the limited information on the aquifer characteristics of this formation, the aquifer classification is based on the rock lithology. The Devil's Glen Formation is dominated by shales, and the greywackes have less quartz and more matrix material. There is only one 20 - 30m thick quartzite unit which is characterised by a fine sugary texture. These rocks are finer grained, less resistant or competent and thus overall probably less fractured, than the Bray Head Formation.

The rocks of the Devil's Glen Formation in the northeast of the county are classed as a **poor aquifer - generally unproductive except for local zones (Pl).**

4.6.2 Bray Head Formation (BH)

Well records for the Bray Head Formation in the northeast of the county indicate two 'excellent' wells and sixteen 'good' wells. The 'excellent' wells were in the Greystones and Courtfoyle (north of Ashford) areas, and indicate very broken bedrock. A specific capacity of 8.8 $m^3/d/m$ was calculated for a private supply in Coolnaskeagh and a transmissivity of 10.6 m^2/d from a 72 hour test. Eleven productivity values are recorded, 9 of which fall into the lowest two categories, V and IV. The remaining two are in categories III and II, and the highest value (Land Commission Well 1780, pumped at 62.7 m^3/d for a drawdown of only 0.6 m) may be unduly affected by overlying sand deposits. Overall, these data are taken to be most characteristic of a poor aquifer.

The lithology of this formation suggests that the permeability of these rocks will be relatively low and they will not produce large quantities of groundwater. However, no detailed investigations are known. Results from the drilling of private domestic wells or for small commercial concerns, have shown that occasional local zones of higher permeability occur, either associated with fractures and faults or with the numerous quartzite units which are found within the Bray Head Formation. The data collected from this study are insufficient to establish if the higher yields are being obtained from the quartzite units or the surrounding greywackes. It is suspected that where sands and gravels are also encountered, greater storage for groundwater is provided, but as these subsoils are generally cased off, they do not directly provide water to the well. There are areas overlying the Bray Head Formation where the sands and gravels are classified as aquifers.

Fractures and faults result from the stress variations that have occurred during geological history and are most frequent where the stress variations were the greatest. Finer grained rock such as shales and mudstones are incompetent and deform rather than fracture under stress, while coarser grained or competent rocks such as siltstones and sandstones fracture. The quartzite units are very competent and should fracture cleanly, producing a higher permeability than the surrounding finer grained rocks. The resulting fractures, fissures and faults are then subjected to weathering which may enlarge these pathways for the movement of water. The finer grained sediments may weather to clay, which could later infill the fractures, reducing the permeability.

The greywackes and siltstones are less competent than the quartzites and thus less fractured, although fractures intensify adjacent to faults. The Bray Head Formation are among the oldest rocks and have thus undergone a lot of deformation, producing some local zones of higher permeability. Given the present data it is not possible to delineate the areas of higher permeability. The surface weathered zone will also show higher permeabilities which decrease rapidly with depth.

Examination of the data in the GSI well database shows that water levels in these Cambrian rocks are shallow, usually less than 10 m below surface, although deeper levels are encountered which may just be a reflection of the higher topography. There is one record of an artesian well at Kiltimon and aquifers may be confined in places beneath less permeable rocks or thick clays. Generally speaking however, these rocks crop out at high elevations on the flanks of hills and are unconfined.

The Bray Head Formation in northeast Wicklow is classed as a **poor aquifer which is generally unproductive except in local zones (Pl)**.

4.7 Ribband Group

4.7.1 Maulin Formation (MN)

There are 15 records of wells providing supplies in excess of 100 m^3/d, three of which give more than 400 m^3/d. Roundwood Public Supply (abstraction rate 325 m^3/d) draws its water from this aquifer. A twelve hour pumping test at this site gave a transmissivity of 65 m^2/d [range 55–80 m^2/d], with a relatively high specific capacity (extrapolated to 1 week) of 40 m^3/d/m. The three larger supplies are found at Raheen, southwest of Roundwood at the Council's depot, Roundwood village and Parkmore, to the south of Roundwood.

At Raheen some basaltic pillow lavas are found and the area is structurally very complex with many faults, providing higher permeabilities than normal. The basalts are thought to be similar hydrogeologically to the Ordovician volcanic aquifers which extend from Wicklow Head through Wexford to the Waterford Coast (Daly, E.P 1991).

Analysis of the seven day continuous pumping test at Raheen (abstraction rate varied from 2,160 to 870 m^3/d) indicated an apparent transmissivity ranging from 40-80 m^2/d and a relatively high specific capacity (1 week) of 33 m^3/d/m.

A private supply well near Rathdrum which was tested for 48 hours at a rate of 200 m^3/d, showed a relatively low specific capacity of 13 m^3/d/m, from a shale bedrock. At an OPW site north of Roundwood, tests only indicated yields up to 45 m^3/d, an apparent transmissivity of less than 15 m^2/d and very low specific capacity of 1-2 m^3/d/m. This location is within the Metamorphic aureole of the granite, indicating that this zone may have a lower groundwater potential.

The Maulin Formation is in places also overlain by large gravel deposits, which may be contributing to the well yields, although many of the well logs indicate that the subsoils are cased off. Occasionally the gravels are screened as at Ballyraine Lower (120 m^3/d), thus contributing to the yield of the well. Many of the well logs from the higher yielding wells indicate that fractured rocks at depth are responsible for the large yields. At Ballyknockan Lower a major fracture was encountered at 30 m, at Park House major water entries were noted at 22.9, 36.6 and 51.8 metres.

The chain of volcanic rocks within the Ribband and Duncannon groups, extending from Wicklow through Wexford to Waterford, contains aquifers of regional importance, especially in Wexford, chiefly the Campile Formation, but this formation is not found in Wicklow, nor any equivalent.

It was anticipated that the permeability of the rock formations in Wicklow would be relatively low and thus not produce large quantities of groundwater. As a result, these rocks were never subjected to detailed groundwater investigations. Results mainly from the drilling of private domestic wells or for small industrial companies have shown that local zones of higher permeability are present, indicated by the 'high' yields encountered. These yields are often associated with fractures and faults. It is not possible, given the present data, to delineate the areas of higher permeability within the formation. The surface weathered zone will also show higher permeabilities which decrease rapidly with depth.

There is very little information on water levels, but available data indicate they are generally less than 10 m below ground surface although this varies depending on topography. These rocks are generally unconfined, but may be locally confined beneath less permeable mudstones and siltstones.

The Maulin Formation is classed as a **locally important aquifer** which is **moderately productive only in local zones (Ll)**. Larger supplies may be developed where storage is increased by overlying gravels or where the borehole is located close to a major fault zone.

4.7.2 Wicklow Head Formation (WH)

Although this formation is equivalent to the Maulin Formation, it has undergone much greater metamorphism and deformation (due to the greater depth of burial) and the rocks are generally described as silvery grey mica schists which do not provide very high yields.

The well records show four 'good' supplies, just in excess of 100 m^3/d. There are only 5 productivity values, from just two sites, showing 3 in class IV, one in class III and one in class II. There are insufficient data to warrant classification as a locally important aquifer.

This formation has been classified as a **Poor aquifer - generally unproductive except for local zones (Pl).**

4.7.3 Glencullen River Formation (GL)

There is only one record of a well yield around 100 m^3/d. In the absence of other data, the aquifer classification is based on the rock lithology (massive buff coloured sand to silt grade tuff interbedded with greywacke siltstones), and it is classed as a **Poor aquifer - generally unproductive except for local zones (Pl).**

4.7.4 Aghfarrell Formation (AG)

This formation is associated with the Maulin and is probably equivalent to the Bray Group. There are no hydrogeological data for this rock unit. Therefore, the aquifer classification is based on the rock lithology consisting of greywacke siltstones and slates, thermally metamorphosed. The Dowery Hill Member is a distinct andesite breccia, dolerite and metasedimentary rock. This formation has been classified as a **Poor aquifer - generally unproductive except for local zones (Pl).**

4.7.5 Butter Mountain Formation (BZ)

This rock unit consists of grey quartzites and abundant volcanic rocks with substantial thickness of andesites and andesitic tuffs and breccia (Donard Member), and is a lateral equivalent of the better known Maulin Formation. GSI well records show five 'moderate' wells in this formation. Only three productivity values are recorded, one class II (Tinoran public supply well), one class IV and one class V.

The Tinoran Public Supply (abstraction rate 340 m^3/d) occurs on a fault zone between this formation and the Pollaphuca Formation. This well has a high specific capacity of 72 $m^3/d/m$ (extrapolated to 1 week) and a 12 hour pumping test gave a transmissivity of about 130 m^2/d [125–155 m^2/d].

This formation is classed as a **locally important aquifer** which is **moderately productive only in local zones (Ll)**, largely on the basis of comparison with the Maulin Formation.

4.7.6 Ballylane Formation (BY)

Available well data show one 'excellent' well at Tomanierin Upper (545 m^3/d – driller's estimate) and three 'good' wells: at Hawkestown Upper (200 m^3/d), at Ballynagran and at Johnstown Hill (112 m^3/d). The last well also encountered 9.5 m of gravel (cased off) and is close to a faulted contact with the Kilmacrea Formation. Four productivity records exist: two in class IV, and two in class III.

At Ballynagran, analysis of a 48 hour pumping test (abstraction rate 205 m^3/d) indicated an apparent transmissivity of 12-20 m^2/d and a relatively low specific capacity of 7 $m^3/d/m$. The sustainable yield was estimated at 140 m^3/d. Storativity ranged from 4.8×10^{-5} to 6.7×10^{-5}. The well showed artesian conditions with a head of 4.4 m above ground (17/11/94) (EIS for proposed East Wicklow Landfill). The Ballynagran well is also close to a faulted contact with the Kilmacrea Formation.

The rocks of this formation are slates with thin sandstones occurring in fault bounded blocks. Based on the above information it is classed as a **Poor aquifer - generally unproductive except for local zones (Pl).**

4.7.7 Oaklands Formation (OA)

The GSI well records show one 'good' well at Newtown (196m^3/d, estimated - no pumping test was conducted). Seven productivity values, mainly from counties Wexford and Kilkenny, give: one class I, three class II, two class III, and one class IV.

Therefore, the aquifer classification is mainly based on the rock lithology (mudstones and siltstones, found in fault bounded blocks) and well productivity data from outside Wicklow. The formation is classed as a **Locally Important aquifer** which is **moderately productive only in local zones (Ll)**.

4.8 Duncannon Group

4.8.1 Kilmacrea Formation (KA)

There are 21 records of wells providing supplies in excess of 100 m^3/d, five of which give more than 400 m^3/d. Redcross Public Supply (abstraction rate 350 m^3/d) draws its water from this aquifer. A twelve hour pumping test at this site gave a transmissivity of 45 m^2/d [range 32–50 m^2/d], with a relatively high specific capacity (extrapolated to 1 week) of 35 m^3/d/m.

The five 'excellent' groundwater sources in this rock unit are located at Coolmore, Ballynacarrig and Ballyduff. Eleven trial wells were drilled in this unit as part of the Arklow Water Supply project in 1993. The wells encountered clay overlying very weathered shale and occasionally sandstone bedrock. Pumping tests were conducted on these wells indicating safe yields between 100 and 550 m^3/d. The borehole logs indicated that the bedrock was often highly weathered and very broken. The weathered shale, between 3.1 and 15.2 m thick, was often the source of the main inflow of water into the well. Deeper inflows were also recorded from fissured zones. Two of these wells encountered a greywacke sandstone bedrock overlying shale at Ballyduff Water Works and Ecawn, and showed artesian conditions. Transmissivity values ranging from 5 to 130 m^2/d were interpreted from the pumping test data and the specific capacity values ranged from 4 to 36 m^3/d/m from the Arklow area.

Nineteen productivity values are available (including one from Co. Wexford), as follows: two class II, 10 class III, 5 class IV, and two class V.

These rocks were not subjected to detailed investigations until the drilling programme commenced for the Arklow Water Supply project. The results from this drilling and from the drilling of private domestic wells have shown that local zones of higher permeability are present, indicated by the 'high' yields encountered. These yields seem to be associated with a very fractured, broken, weathered surface zone. It is not possible given the present data to delineate the zones of higher permeability. The surface weathered zone will also show permeabilities which decrease rapidly with depth.

The rocks of this formation are extensively jointed, fractured and weathered. This results in higher permeabilities closer to the surface, and along fault zones. Trial wells are generally less than 100 metres deep, thus there are few reports of inflow of water below this level. The permeability decreases rapidly with depth from the ground surface. The bedrock is often relatively well fractured to a depth of 30 metres.

Water levels vary depending on topography, ranging from near surface to depths of over 20 m. Artesian supplies may be obtained where boreholes penetrate the aquifer through confining clay layers or impermeable bedrock. Larger supplies may be developed where storage is increased by overlying gravels or where the borehole is located close to a major fault zone.

The Kilmacrea Formation is classed as a **Locally Important Aquifer** which is **moderately productive only in local zones (Ll)**.

4.8.2 Avoca Formation (AV)

The hydrogeological data available for the Avoca Formation show that low yields are generally encountered. Drilling data from Avoca (O Suilleabhain et al. 1996) show highly fractured rock, particularly in the top 20 to 30 m. The majority of the groundwater flow was encountered in this fractured zone. Below this zone fractures were less frequent and permeabilities considerably reduced.

Pumping tests conducted by O Suilleabhain in 1995 at Avoca indicated transmissivity values ranging 0.04 to 11.5 m^2/d. The wells were pumped at very low rates (4 to 8 m^3/d), producing drawdowns of 0.5 to 20 m, with some evidence of dewatering of fractures during the tests. Aquifer storage was also very low. Groundwater levels in the Avoca mine area were generally between 5 and 15 m below ground level except along the steep valley sides, where levels were much deeper.

Just two productivity values are recorded, one each in classes IV and V.

These rocks are classed as a **Poor Aquifer** which is **generally unproductive (Pu)**.

4.8.3 Arklow Head Formation (AH)

The information for this formation is very poor, with no productivity values recorded. The areal coverage is small. Based on its lithology, it is classed as a **Poor Aquifer** which is **generally unproductive (Pu)**.

4.8.4 Ballymoyle Formation (BL)

The GSI well records show three 'good' wells at Threemilewater with yields over 200m^3/d. Sands and gravels in the vicinity provide supplementary storage for one of the wells. Just two productivity values are known, in classes II and IV.

Based mainly on its lithology (rhyolitic volcanics) it is classed as a **Poor Aquifer - generally unproductive except for local zones (Pl).**

4.9 Kilcullen Group

The lithologies of the Killcullen Group are generally greywacke sandstones and shale, and the entire succession fines upwards, giving rise to variable transmissivities. The coarser, thicker sandstone units are likely to have a greater degree of fracturing than the more plastic interbedded shales.

Water levels are variable but are usually less than 10 m below ground surface and the aquifers are generally unconfined.

4.9.1 Tipperkevin Formation (TK)

Well records confirm a 'good' yield in excess of 200 m^3/d, at Rathsallagh House, and another of 212 m^3/d just east of Dunlavin. Pumping tests from both wells indicated transmissivity values in the range of 10-40 m^2/d with relatively low specific capacities of 10-15 m^3/d/m. Eight productivity values are known, six from Wicklow and two from Kildare: 3 class V, 2 class IV, and 3 class III.

4.9.2 Pollaphuca Formation (PO)

The well records show two 'good' wells, at Golden Hill (100 m^3/d) and at Three Castles (200 m^3/d). One productivity value is known (class IV), from Co. Kildare.

4.9.3 Carrighill Formation (CZ)

Only four productivity values are available, all from Co. Kildare: 2 in class IV, 2 in class V.

4.9.4 Glen Ding Formation (GD)

One very approximate class III value is known, but this is uncertain.

4.9.5 Slate Quarries Formation (SQ)

No productivity values are known.

The Tipperkevin Formation and Pollaphuca Formation are classed as a **Poor Aquifer - generally unproductive except for local zones (Pl).**

Mainly on lithological grounds (but with no significant contradictory data), the Carrighill, Glen Ding and Slate Quarries formations are classed as **Poor Aquifers which are generally unproductive (Pu)**.

4.10 Leinster Granite (Gr)

The granites are found in the central upland of County Wicklow. These rocks are crystalline in nature, do not normally provide large groundwater supplies and are rarely the subject of detailed investigation. In general they provide domestic and farm supplies.

Fresh granite has no primary permeability, a porosity normally less than 1%, and any pores present are generally small and unconnected (Davis & De Wiest, 1966). Permeability in the granites has developed through fracturing and weathering, which is generally restricted to the top 100 m below ground (Daly, E.P. 1994). The weathered zone may commonly be up to 15 m thick, and is overlain by a variable thickness of Quaternary deposits. Porosity of completely weathered granite can be up to 15%, giving significant groundwater storage and a permeability comparable with that of gravel. The permeability of unweathered granite is in the order of 0.01-1 m/d (Daly, E.P. 1994).

Within the granite there are numerous horizontal joints, which are laterally extensive as well as the vertical fractures and faults, which increase the permeability of the near surface granites. This highly weathered zone can provide relatively high groundwater storage, which has provided significant groundwater supplies, for example at Lathaleere in Baltinglass.

At Turlough Hill, the construction of the artificial reservoir and underground power station by the ESB in the early 1970s showed the granite to be highly weathered and altered. In places the granite had weathered to a sandy material. Seven exploratory boreholes had not shown the poor rock conditions in the area. The alteration is concentrated along fractures and is thought to be post-glacial in age and associated with deep permafrost weathering, the maximum depth of which is uncertain. The glaciation of the Wicklow Mountains would have removed much of the broken rock, particularly on higher, exposed ground. The area is crossed by a series of fault zones; the main fault has a width of about 15 m and was encountered twice during construction of the access tunnel. Weathered fault zones with groundwater flows were encountered at various depths to 170 m below ground and there were numerous other faults in the area (Knill, 1971).

Studies by Spruijt (1978) and Van Engelen (1980) showed that in upland areas of high rainfall, shallow water tables with large and often rapid response to rainfall, due to the relatively low storage in the upper weathered zone, gave rise to a large amount of circulating water which accelerated the near surface weathering and solution along fracture zones. The maximum depth of this weathering was estimated to be 20-30 m. At greater depths the fractures and joints in the granite do not seem to be very well connected and thus provide small groundwater flows.

Permeability tests by De Buisonje (1977) and Van Engelen (1980) in weathered granite indicated values of 10-100 m/d but in the underlying fresh granite values of 1-3 m/d were obtained.

In Wicklow there are few hydrogeological data for the granite, so data from other counties (Carlow, Kilkenny and Kildare) have also been examined. One exceptionally productive well at Bawnoge, Baltinglass (K.T. Cullen & Co., 2000) was tested at 488 m^3/day for a drawdown of only 3m. This is the only recorded 'Excellent' yield in granite in Wicklow.In Carlow four wells are recorded with yields between 60 and 100 m^3/d with specific capacities from 4 to 38 m^3/d/m. In Wicklow nine wells indicate yields between 100 and 300 m^3/d. The Council well at Knockananna gave a specific capacity of 30 m^3/d/m for a discharge of 155 m^3/d, but no transmissivity could be established from the 72 hour pump test. The Baltinglass borehole at Lathaleere (abstraction rate 260 m^3/d) in a twelve hour pumping test gave a transmissivity of 25 m^2/d [range 20–30 m^2/d], with a relatively low specific capacity (extrapolated to 1 week) of 7 m^3/d/m.

Productivity values are recorded from 50 wells in the Leinster Granite, 26 of them from Wicklow. These break down as follows: 1 class I (the Bawnoge well), 22 class III (but most of these are very approximate), 13 class IV, 14 class V.

Based on the generally known aquifer properties of granites, and the productivity data above, the Granite is classed as a **Poor Aquifer - generally unproductive except for local zones (Pl).**

4.11 Dolerite (D), Diorite (Di), Volcanics (V)

There are no hydrogeological data for these rocks in Wicklow, consequently their aquifer classification is based upon their lithology and information from other counties, principally Wexford, Waterford and Limerick.

Dolerites are found as dykes and produce very resistant rocks. The Diorites are very similar to the granites. These rocks are classed as **Poor Aquifers** which are **generally unproductive except for local zones (Pl)**.

The volcanics can be grouped into two hydrogeological units based on rock type: the tuffs, and the lava flows and intrusives. Permeabilities are developed primarily by fracturing. The tuffs are more acidic (silica-rich), weather more easily and contain vesicles which increase the porosity. Permeabilities are increased in the basaltic flows by columnar jointing which has opened up the otherwise hard rocks.

The volcanic rocks are classed as a **Poor Aquifer** which is **generally unproductive except for local zones (Pl)**.

4.12 Sand/Gravel Aquifers

Sand/gravel deposits have a dual role in groundwater development and supply in Co. Wicklow. Firstly, they can supply significant quantities of water and are therefore classed as aquifers. Secondly they provide storage for underlying bedrock aquifers.

A sand/gravel deposit is classed as an aquifer if the deposit is more than 10 m thick and is greater than one square kilometre in areal extent. The thickness of the deposit is taken rather than the more relevant saturated zone thickness as the information on the latter is rarely available. In most instances it may be assumed that a deposit with a thickness of 10 m will have a saturated zone of at least 5 m. This is not the case where deposits have a high relief, for example eskers or deposits in high topographic areas, as these gravels often have a thin saturated zone.

There are two categories of sand/gravel aquifers – regionally important and locally important. The two differ in areal extent and estimated annual throughput (see Table 4.4).

Table 4.4 Sand/gravel Aquifer Classification

	Regionally important	*Locally important*
Areal extent	> 10 km^2	1-10 km^2
Saturated thickness	> 5 m	> 5 m
Throughput	> 10 Mm^3/a	1-10 Mm^3/a

A regionally important gravel aquifer should have an areal extent of at least 10 km^2. This is to ensure that, assuming an average annual rainfall of 400 mm, there will be enough recharge to provide a supply of one million cubic metres per year from the whole aquifer. A locally important aquifer on the other hand is required to have enough storage to supply a small group scheme or village.

Eight sand and gravel aquifers have been identified in Co. Wicklow (Table 4.5 below) and are illustrated on the aquifer map (Maps 5N and 5S). Although two of these sand and gravel deposits are at or marginally above the 10 km^2 threshold, in neither case is there sufficient confirmatory evidence of the extent, continuity, and thickness to warrant them being considered as regionally important aquifers. Therefore, all eight are classified as locally important gravel aquifers. Three of them are termed 'potential' local aquifers as there are no water supplies currently developed in them and their resource availability is therefore not proven. They have been identified on the basis of the subsoils maps (Maps 2N and 2S) and the depth-to-rock maps (Maps 3N and 3S).

There are several other smaller gravel deposits which have not been classed as locally important aquifers as they do not meet the areal extent criterion, as mapped on the ground surface. It is possible that there are gravel deposits buried beneath till, for example around Bray, where two boreholes encountered yields of 300 m^3/d from gravels. At Woodbrook Golf Club gravel was encountered beneath till from 21 to 30.5 m. The extent of this gravel is not known. It is assumed that the saturated thickness provides adequate storage, which, in conjunction with the high recharge, provides enough water to maintain an adequate supply for the golf club; the deposit is therefore locally important.

Table 4.5. Sand/gravel Aquifers in Co. Wicklow

Gravel deposit	Areal extent	Estimated deposit thickness
Sand and gravel aquifers		
Enniskerry	10 km^2	10 - 30 m
Kilpeddar / Kilcoole	11 km^2	10 - 30 m
Ashford	3.5 km^2	10 - 30 m
Blessington	5.5 km^2 (in Co. Wicklow; 9 km2 including area in Co. Kildare)	10 - 35 m (but much thicker in places)
Tober	1 km^2	10 - 12 m
Potential sand and gravel aquifers		
Lemonstown	4 km^2	10 - 15 m
Dunlavin	1.5 km^2	10 - 15 m
Baltinglass	4 km^2	10 - 20 m

Site investigation may also prove other gravel deposits to be aquifers but in the absence of more detailed information, the smaller deposits, and those of unknown thickness or suspected thin saturated zones, are not included here. In addition, some of the larger till-with-gravel deposits may prove, on investigation, to have lenses of clean gravel within them which meet the classification criteria.

On the Powerscourt Estate an artesian gravel well had an overflow of 230 m^3/d and a yield of 545 m^3/d. Gravel was encountered between 13 and 29.8 m. This well confirms the thickness of the Enniskerry gravel and its groundwater potential.

A well for a factory near Kilcoole encountered gravels to 14 metres, with a yield of 435 m^3/d and a specific capacity of 40 m^3/d/m. A transmissivity value could not be determined.

The Waterford Co-op well outside Ashford indicated gravels to depths greater than 12 m and an estimated yield of 500 m^3/d.

The Blessington sand & gravel aquifer supplies water to several private housing estates (Ashton, Beechdale and Glenview Court) on the outskirts of Blessington village. The boreholes indicate yields between 300 and 660 m^3/d, with specific capacities from 60 to 2200 m^3/d/m.

Blessington Sand & Gravel Aquifers

For the purposes of this study, two gravel aquifers are identified near Blessington: one to the north of Blessington Village, covering an area in of approximately 9 km^2, of which about 5.5 km^2 lies in Co. Wicklow and the rest in Co. Kildare; and a second which lies to the southwest of the village and has an area of approximately 2 km^2, entirely in Co. Kildare. The deposits vary in thickness, averaging 10 to 35 m. The northerly deposit extends further northwest into Co. Kildare, but to the north of the topographic divide and therefore is not considered as part of this aquifer.

A deep borehole drilled by GSI in 1980 recorded a depth of 74 m in Newpaddocks, half a mile north of Blessington, with water at 22 m. At Bishopslane, Co. Kildare, 3 km south-southwest of Blessington another deep GSI borehole in 1980 encountered gravels to a depth of 104 m and did not hit bedrock.

Five wells have been drilled in the aquifer at the Council Depot, Naas Road, Blessington. The first two wells were drilled in 1993, for private housing estates (Ballymore Homes No. 1, 12.2 m deep & No. 2, 11.7 m deep) with yields from 300 to 660 m^3/d.

A test on Ballymore Homes Well No. 2 (17-20 May 1995) at 660 m^3/d gave a specific capacity of 2170 m^3/d/m. Towards the end of the test, the drawdown was increasing (though slowly), and from the late data a Transmissivity of around 1500 m^2/d is suggested. This well is equipped with 1.4 m of stainless steel wirewound screen at the bottom.

The Council drilled a further three wells in 1995. The first was abandoned as no water was met by 33.5 m. The other two wells, WCC No.1 (14.6 m deep) and WCC No.2 (18.6 m deep), were tested. WCC No.2 was tested (31 Oct.-3 Nov. 1995) at 301 m^3/d for a drawdown of 3.3 m, giving a specific capacity of 91 m^3/d/m and an apparent transmissivity of 140 m^2/d. This pumping test was repeated (27-30 Nov. 1995) at 307 m^3/d to monitor the effects on the nearby wells. Starting from a lower water table, the drawdown was 9.6 m, specific capacity 32 m^3/d/m and apparent transmissivity 30 m^2/d. The adjacent Council well (No.1) showed a drawdown of 0.11 m and the private well 0.12 m from the pumping of Well No.2. No other wells were affected during this pumping test. The substantial decrease in specific capacity between these two tests, just a few weeks apart, suggests that the upper part of the aquifer is particularly important in terms of its permeability.

WCC No.1 was tested at 455-470 m^3/d for a final drawdown of 5.3 m, giving a specific capacity of 88 m^3/d/m. The effects on the adjacent wells were also monitored during the test and none of the wells showed drawdowns of more than a few centimetres.

The results of the tests are difficult to analyse as the gravel aquifer responds rapidly to any rainfall events which can mask the effects of the pumping giving the inconsistent and anomalous results above.

In the townlands of Deerpark and Dillonsdown, 1.5 km northwest of Blessington village, extensive drilling to extend the sand and gravel pit has revealed gravel thicknesses of up to 40 m. Water table depths in this area ranged from 10 to 20 m below ground.

Recent site investigations 1 km from the village along the Naas Road indicated similar geological conditions with over 14 metres of glacial sediments. A pumping test gave a yield of 340 m^3/d for a drawdown of 2.4 m, giving a specific capacity of 140 m^3/d/m.

Two water quality analyses are available for this sand and gravel aquifer, from 1994 and 1996. Both analyses indicate that the water is a calcium bicarbonate type water which is hard and typical of limestone gravel aquifers. The samples also indicate high chloride values of 75-80 mg/l and sodium of 57 mg/l. No sampling of this aquifer was conducted as part of this project and regular monitoring should be carried out to establish if this aquifer is being contaminated.

In this area of Co. Wicklow, most private groundwater supplies are obtained from the sand and gravel deposits, with many housing estates being supplied by group scheme wells, sourced in the sand and gravel.

As a result of their high permeability, all sand and gravel areas are highly vulnerable to pollution; the Blessington sand and gravel aquifer is no exception and adequate precautions to prevent pollution are necessary.

4.13 Summary of Aquifer Categories

The rock units in County Wicklow are classified into the different aquifer categories in Table 4.6. More than 90% of the area is classified as either ‘Ll’ or ‘Pl’. In the southern part of the county, ‘Ll’ predominates, and there is only one local gravel aquifer. In the northern part, ‘Pl’ predominates, but there are several local gravel aquifers.

Table 4.6. Bedrock aquifer classifications

Aquifer Category	Subdivision	Rock Unit
Regionally important (R)	Sand/gravel (**Rg**)	None
	Karst – conduit flow dominant (**Rk**)	None
	Fissure flow (**Rf**)	None
Locally important (L) **(43.1%)**		
	Sand/gravel (**Lg**) **(2.2 %)**	Eight deposits (see Table 4.5)
	Bedrock which is generally moderately productive (**Lm**)	None
	Bedrock which is moderately productive only in local zones (**Ll**) **(40.9 %)**	Maulin Formation (MN), Ribband Group Butter Mountain Formation (BZ), Ribband Group Oaklands Formation (OA), Ribband Group Kilmacrea Formation (KA), Duncannon Group
Poor (P) **(55.8%)**		
	Bedrock which is generally unproductive except for local zones (**Pl**) **(52.5 %)**	Bray Head Formation (BH), Bray Group Devil’s Glen Formation (DG), Bray Group Wicklow Head Formation (WH), Ribband Group Glencullen River Formation GL), Ribband Group Aghfarrell Formation (AG), Ribband Group Ballylane Formation (BL), Ribband Group Ballymoyle Formation (BY), Duncannon Group Pollaphuca Formation (PO), Kilcullen Group Tipperkevin Formation (TK), Kilcullen Group
		Granites (Gr) Dolerites (D) and Diorites (Di) Volcanics (V)
	Bedrock which is generally unproductive (**Pu**) **(3.3 %)**	Avoca Formation (AV), Duncannon Group Arklow Head Formation (AH), Duncannon Group Slate Quarries Formation (SQ), Kilcullen Group Glen Ding Formation (GD), Kilcullen Group Carrighill Formation (CZ), Kilcullen Group

Note: The percentages refer to the proportional areal extent of each aquifer category in Co. Wicklow. Approximately 1.2% of the county is occupied by lakes/reservoirs.

4.14 Potential for Future Groundwater Development in County Wicklow

As already noted, County Wicklow is not blessed with major groundwater resources. Drilling water wells in the bedrock aquifers will always be difficult and well yields are hard to predict. Since the success of a well depends on hitting sufficient water-bearing fissures, the use of geophysical survey methods which help to identify such fissures is advisable where it is important to get a good yield.

4.14.1 Bray Group

These rocks seem to have a slightly greater aquifer potential in County Wicklow than previously anticipated, and are occasionally capable of supplying group schemes and small commercial concerns. However, random drilling is not recommended. A careful hydrogeological investigation, involving the use of geophysics, will increase the probability of success. Also, as improved geological information becomes available on fractured zones, the ability to identify higher permeability areas will improve. Developing these aquifers will always be problematical due to the uneven distribution of permeability and, in places, to the vulnerable nature of the underlying aquifer. The water quality is generally good.

4.14.2 Ribband Group

Within this group the Maulin Formation has the greatest aquifer potential, and seems capable of supplying significant quantities of water. As with the Bray Group, a careful hydrogeological investigation, involving the use of geophysics, will increase the probability of success due to the uneven distribution of permeability. The other formations may be capable of relatively high yields, particular where faults and fracture zones or volcanic units are encountered. The water quality from these formations may vary, with locally high iron and manganese levels, but in general is very good. The Butter Mountain Formation, the lateral equivalent of the Maulin, may have equal potential for further development, but confirmatory data are lacking.

4.14.3 Duncannon Group

Within the Group, the Kilmacrea Formation has the highest proven potential. Locating the wells is important, close to faults and fracture zones, where deep weathering has occurred or where volcanic units are found, will be important. Once again the water quality is good, although local variation may occur. It is proposed to develop this aquifer for the Arklow Water Supply.

4.14.4 Sand/gravel

Although the known or inferred sand/gravel aquifers in Wicklow occupy a relatively small area (43 km^2, or 2.1% of the county), they are located in important areas of the northeast and northwest of the county, where development is particularly rapid and there may be significant pressure on available water resources. Moreover, some of the aquifers extend into Co. Kildare, which provides some additional resources.

All the sand/gravel aquifers remain poorly defined both as to their thicknesses and their lateral extent. A modest programme of exploratory drilling, perhaps coupled with geophysical surveys, would help to resolve these uncertainties and might identify some additional resources.

Carefully located, constructed and developed wells in these aquifers are capable of supplying large quantities of water. These aquifers could be particularly important in areas not supplied or unlikely to be supplied by regional schemes. Site investigations again will be required to design the wells for optimum yield and protection of the zone of contribution. The water quality of the sand and gravel deposits will depend strongly on the composition of the deposit, its depositional history and the degree of natural protection in the area.

4.14.5 Granites

While there are local zones of high permeability and relatively deep weathered zones in the granites, it is not anticipated that they are likely to have the potential to provide substantial supplies. Even where significant quantities of groundwater are found from individual wells, there may be problems with high iron concentrations and with yield reductions in dry weather.

4.14.6 Volcanics

The areas of volcanics are too small to provide substantial supplies.

4.14.7 Kilcullen Group

Although well yields are highly variable, wells in high permeability fault zones are capable of supplying small public and group scheme supplies.

4.14.8 Remaining Rock Units

None of the remaining rock units listed in Table 4.6 has the potential to provide sufficient yield to satisfy the likely needs of Wicklow County Council. While an occasional high yielding well is always possible in view of the folded and faulted nature of bedrock in Ireland, yields are generally low and may reduce further in dry weather. Also, wells in some of these rocks frequently have high iron concentrations and also associated high manganese.

5. Groundwater Quality and Hydrochemistry

5.1 Introduction

This chapter summarises a separate Groundwater Quality Report which assesses the available groundwater chemistry and quality data for public and group scheme supply sources in County Wicklow.

5.2 Sources of Information

Three full suites of analyses by the State Laboratory, including all major anions and cations and the more important heavy metals, followed sampling in February, May and August 1997. Bacteriological analyses (Total Coliforms and *E. coli.*) were carried out concurrently at the Council Laboratory in Wicklow. All were raw water samples except where pre-chlorination could not be avoided. Nine different aquifers were sampled: the Maulin, Ballylane, Wicklow Head, Kilmacrea, Butter Mountain, Pollaphuca, Tipperkevin, and Glen Ding formations and Granite. The analyses are given in the Groundwater Quality Report.

In July 1997 a detailed groundwater sampling programme was undertaken in the Brittas Bay area to assess the water quality and vulnerability of the area. Two EPA draft reports on nitrates in groundwater in County Wicklow (EPA, 1997, 2001) included data for 30 sources (Table 5.1).

Table 5.1. Nitrate data for Groundwater in Co. Wicklow

EPA Ref	Name	Source Type	Aquifer (Formation)	No.	Min.	Max.	Mean
WIC 2	Ballycoogue	Bore	Kilmacrea	13	<0.44	18.4	12.43
WIC 7	Baltyboys GWS	Spring		1			34.51
WIC 8	Barndarrig	Bore	Kilmacrea	17	2.54	54.00	25.87
WIC 10	Carrigacurra GWS	Spring	Gravels	9	10.12	3.08	13.20
WIC 11	Coolboy/Coolafancy WS	Spring + Bore	Ballylane	15	5.69	41.27	26.56
WIC 12	Donard	Gallery	Gravels	10	4.60	23.14	7.89
WIC 13	Dunlavin	Springs	Tipperkevin	9	9.68	32.44	18.34
WIC 15	Grangecon	Bore	Glen Ding	6	6.16	19.80	10.03
WIC 16	Hollywood WS	Spring/Gallery	Gravels	16	1.20	20.92	10.21
WIC 17	Humphreystown GWS	Spring		1			7.51
WIC 22	Kiltegan	Bore	Granite	13	2.15	21.70	14.20
WIC 23	Kirikee	Bore	Maulin	17	<0.44	11.00	5.14
WIC 24	Knockananna WS	Bore	Granite	5	11.44	29.62	20.22
WIC 25	Oldcourt GWS	Spring		2	<0.44	35.22	
WIC 26	Redcross	Bores	Kilmacrea	27	4.00	34.23	22.65
WIC 27	Roundwood	Spring + Bore	Maulin	27	6.16	27.78	18.14
WIC 29	Stratford Coolmoney	Spring/Gallery	Gravels	13	7.04	37.00	14.64
WIC 31	Valleymount	Spring	Granite	10	4.30	16.74	11.64
WIC 32	Windgates/Templecarrig	Springs		15	7.92	28.60	18.10
WIC 33	Ashtown GWS/Blessington	Bore	Gravels	24	1.00	31.17	11.52
WIC 43	Baltinglass WSS	Bore	Granite/fault zone	23	14.52	25.96	21.14
WIC 44	Bulford Farm	Bore		9	0.24	22.05	18.49
WIC 47	Kerry Foods (Shillelagh)	Well		9	12.58	26.13	21.99
WIC 48	Blessington	Bore		4	24.20	27.81	26.63
WIC 49	Rathdrum WS	Spring/well		3	4.28	30.48	13.21
WIC 50	Brittas Bay (South)	Bores		1			3.08
WIC 51	Thomastown	Bore	Kilmacrea	8	2.00	17.60	10.28
WIC 54	Tober	Spring	Gravels	1			13.73
WIC 55	Druids Glen	Bore		2	12.87	16.22	
WIC 61	Windgates/Templecarrig			6	5.81	36.40	25.82

(Data source: EPA, March 1997, September 2001)

5.3 Hydrochemistry

5.3.1 Groundwater characteristics

Total hardness, i.e. the sum of the concentrations of calcium and magnesium ions, varies depending upon rock type and overlying subsoils. The following classification (Table 5.2) was used for hardness levels:

Table 5.2 Groundwater Hardness Classification System

soft	<50 mg/l as $CaCO_3$	**moderately hard**	151–250 mg/l as $CaCO_3$
moderately soft	51–100 mg/l as $CaCO_3$	**hard**	251–350 mg/l as $CaCO_3$
slightly hard	101–150 mg/l as $CaCO_3$	**very hard**	>350 mg/l as $CaCO_3$

Groundwater in the County is mainly moderately soft with average total hardness of 50–100 mg/l ($CaCO_3$), as the bedrock is mainly comprised of sandstones and shales of Cambrian to Silurian age and the rocks are not overlain by limestone-dominated subsoils. Softer waters are found in the higher upland areas of central Wicklow, where hardness can be as low as 20 mg/l. Moderately hard to hard waters are found only where the overlying subsoils are derived from limestones.

The low mineralisation of the Wicklow groundwaters indicates a short residence time within the ground, resulting in many of the analysis showing similarities to rain water.

The hydrochemistry of groundwater in the different main rock types in Co. Wicklow is discussed below.

5.3.2 Maulin Formation

Six Council sources were sampled; data are also available for several other areas. Groundwaters are generally of calcium bicarbonate type, and **soft** to **moderately soft** (20–80 mg/l $CaCO_3$). Some areas in east Wicklow, around Enniskerry and Ashford, show slightly higher hardness and alkalinity, probably because the overlying tills, sands and gravels contain limestone.

5.3.3 Kilmacrea Formation

This is similar to the Maulin Formation. Four Council sources were sampled, and data are available for several other areas. Groundwaters are generally of calcium bicarbonate type, and **moderately soft** to **moderately hard** (50–250 mg/l $CaCO_3$). Around Brittas Bay some show slightly higher hardness, alkalinity and conductivity, due either to salt water intrusion or retention of salt in the porespace of Quaternary deposits in once-tidal areas.

5.3.4 Granites

Five council sources were sampled. The groundwater is a calcium bicarbonate type and is **soft** to **moderately hard** (50–250 mg/l $CaCO_3$).

5.3.5 Other Formations

Shales and Sandstone dominate the remaining formations in Co. Wicklow and produce calcium bicarbonate type waters. They are generally **moderately soft** to **moderately hard** waters, but where the overlying subsoils are more carbonate-rich, they are classed as **hard** waters (260–340 mg/l as $CaCO_3$), and conductivities are also higher, reaching over 650 µS/cm.

A major problem in shale- and sandstone-dominated rocks is the frequent presence of high concentrations of iron, up to 20 mg/l (total Fe) and manganese, up to 0.75 mg/l.

5.4 Background Factors in Assessing Groundwater Quality

As human activities affect most groundwater in Ireland, there are few areas where groundwater is in pristine condition. Most groundwater is somewhat contaminated but not necessarily polluted. In assessing groundwater quality, the EU maximum admissible concentrations (MAC) should not be the sole focus; the degree of contamination should also be assessed. Thresholds for certain parameters can help to indicate situations where significant contamination but not pollution is occurring. The thresholds used in assessing groundwater quality in County Wicklow are given in Table 5.3 below.

Table 5.3 GSI Groundwater Contamination Thresholds

Parameter	**Threshold** (mg/l)	**EU MAC** (mg/l)
Nitrate	25	50
Potassium	4	12
Chloride	30-50 *(depending on proximity to sea)*	250
Ammonia	0.15	0.3
K/Na ratio	0.3	
Faecal bacteria	0	0

Other useful indicators of contamination include conductivity, iron, manganese, sulphate and nitrite.

Groundwater quality problems can be due to the impact of human activities or to natural conditions. Nitrate (NO_3) and faecal bacteria are the main contaminants from human activities in Co. Wicklow. The main quality problem caused by the natural chemistry of groundwater is the presence of iron.

In the following section, the above thresholds are used in assessing the groundwater quality based on the data in the Groundwater Quality Report; this is followed by appraisals of specific problem constituents (nitrate, faecal bacteria and iron) and the situation at selected groundwater sources.

5.5 General Groundwater Quality Assessment of Public Supplies

The public supplies were divided into four categories, based on the degree of contamination with respect to the major contaminant indicators nitrate, chloride, potassium and *E. coli (from raw water analyses)* and exceedances of the drinking water limits. The public supply sources are listed in under each of the four categories in Table 5.4.

Note that the assessment was largely based on raw water samples. Many of the sources in Group AI have chlorination and in Group AII have iron and manganese treatment, which enable the groundwater from these sources to be supplied to the public.

5.5.1 Nitrate

Nitrate is one of the commonest contaminants identified in groundwater. The nitrate ion is not adsorbed on clay or organic matter, is highly mobile and under wet conditions is easily leached from the root zone and through soil and permeable subsoil. It poses a potential health hazard to babies.

Sources of Nitrate

Septic tank effluent contains 30-45 mg/l of nitrogen. As this is usually converted to nitrate, it poses a risk to groundwater and can significantly raise nitrate levels in the vicinity of the septic tank system.

Farmyards produce large volumes of organic wastes, but most are spread on land and cause no significant problems. However, infiltration of soiled or dirty water into the ground beneath and around farmyards can increase nitrate levels (and pollution by faecal bacteria). Many farm wells in Ireland have been contaminated by soiled water.

Landspreading of slurry from cattle does not usually pose a significant risk to groundwater as the nutrients are recycled. In contrast, organic wastes from piggeries and hatcheries do pose a significant risk unless the rates and timing of spreading match crop needs.

Inorganic fertilisers are a hazard, particularly in tillage areas (leaching of nitrates from tillage crops is generally greater than from grassland) and intensive dairying areas.

Identifying the source of elevated nitrate levels in any particular well depends on assessing not only the nitrate data, but also other parameters, particularly faecal bacteria, ammonia, potassium, chloride and the potassium/sodium ratio. It also requires some knowledge of the zone of contribution (ZOC) of the well, and the vulnerability and potential hazards in the ZOC.

Nitrate data from large abstractions give the best indication of general nitrate levels in groundwater because they represent large catchment areas where the impact of nearby point sources is minimised. Nitrate levels in small sources tend to reflect the impact of nearby farmyards and septic tank systems.

Appraisal of Nitrate Data

In County Wicklow the nitrate situation is relatively good, with no sources above the MAC (50 mg/l). Nine (Rathnew, Redcross, Tinoran, Parkmore, Knockananna, Coolboy, Barndarrig, Kilballyowen, and Freynestown) have nitrate values between 25 mg/l (guide level) and 50 mg/l. Four sources (Roundwood, Lathaleere, Thomastown, Dunlavin) have nitrate values around the guide level. The remaining nine sources are below the guide level (Kiltegan, Valleymount, Kirikee, Rathdrum, Threewells, Annacurragha, Ballycoogue, Eadestown and Grangecon). Some statistical analyses of the EPA nitrate data are given in Table 5.1 and are not further commented on here.

Table 5.4 Groundwater Quality classification of Wicklow County Council public supplies

CATEGORY AI (13% of analysed supplies) Sources in which one or more parameters exceed the EU MAC as a direct result of human influence, and which are therefore considered polluted at the time of sampling.	Parkmore Springs (*E. coli*) Rathdrum (*E. coli*, Fe, Mn)	Kilballyowen (K, *E. coli*)
CATEGORY AII (23% of analysed supplies) Sources in which one or more parameters (e.g. Iron & Manganese) exceed the EU MAC naturally, and which are therefore considered to be naturally polluted at the time of sampling.	*Roundwood (Mn) Thomastown (Fe, Mn) Kirikee (Fe, Mn)	Threewells (Fe, Mn) Annacurragh (Mn)
CATEGORY B (32% of analysed supplies) Sources which show concentrations of the contaminant indicators chloride, nitrate & potassium below the MAC, but above the GSI thresholds, indicating significant contamination and warning that pollution may be occurring at times other than when the sample was taken, or may occur in the future. *Note: background levels of chloride and potassium may vary naturally. Chloride is generally higher in coastal areas. Potassium levels are higher in some sandstones and volcanic rocks; a threshold of 4 mg/l may be used.*	Redcross (NO_3) Tinoran (NO_3) Knockananna (NO_3) Coolboy (NO_3, Coliforms)	Barndarrig (NO_3) Freynestown (NO_3) Rathnew (NO_3)
CATEGORY C (18% of analysed supplies) Sources with slight anomalies in the analyses which may be naturally induced or indicative of some slight contamination.	Lathaleere (Coliforms) Valleymount (Coliforms) Dunlavin (Coliforms)	Grangecon (Coliforms)
CATEGORY D (14% of analysed supplies) Sources which have shown no evidence of contamination	Kiltegan Ballycoogue	Eadestown

* Based on GSI analyses only.
Rathdrum is used as a backup supply only; Rathnew and Lathaleere have now been decommissioned.

5.5.2 Faecal Bacteria

In general, faecal bacteria in groundwater samples indicate contamination by organic wastes originating from septic tank effluent and farmyards. However, animals and birds in the vicinity of uncovered springs or poorly constructed wells can have some impact.

Raw waters in public groundwater supplies in Co. Wicklow (1997 analyses only) are generally of good microbial quality. Only three sources showed the presence of *E. coli* (Parkmore, Rathdrum and Kilballyowen) while six others showed total coliforms greater than 10/100 ml (Coolboy, Valleymount, Thomastown, Freynestown, Dunlavin, Grangecon). The presence of small numbers of coliforms in an open spring is not considered crucial, as slight contamination (e.g. by birds) is inevitable, and chlorination is generally adequate to eliminate it. However, the situation with bored wells is far less satisfactory, particularly as the water from these sources is often not chlorinated.

Data are also available from 22 private wells, mainly in the Brittas Bay area, with four having *E. coli* (one testing clear on re-sampling) and a further two having total coliforms greater than 10/100 ml. It appears that a significant proportion of wells intermittently contain faecal bacteria in areas where the groundwater is highly to extremely vulnerable. The primary origins of bacterial pollution in Co. Wicklow are likely to be septic tank systems and organic wastes in farmyards.

5.5.3 Iron

The source of iron can be iron minerals in rocks (shales and sandstones) or soils (boggy areas), pollution by organic wastes (from farmyards, etc.), or occasionally the corrosion of iron fittings. Manganese is frequently associated with iron although it is less prevalent.

Iron concentrations exceeded the EU MAC in five public supplies, listed in Table 5.5.

Table 5.5 Groundwater Sources with High Iron Concentrations

Geological Formation	Public Supplies	Comments
Maulin	Roundwood	Manganese only (1997)
	*Kirikee	
	Rathdrum	
	Threewells	
	Annacurragha	Manganese only
Kilmacrea	*Thomastown	

*Iron and Manganese treatment installed in pump house

There is no evidence that iron problems in Co. Wicklow are due to anything other than the rock type or natural conditions. In particular, high iron is prevalent in the shale-dominated rock formations.

5.6 Appraisal of Groundwater Quality in Selected Sources

5.6.1 Roundwood

The water is moderately soft (50-64 mg/l $CaCO_3$), and of calcium bicarbonate type with low alkalinity (32-45 mg/l $CaCO_3$). While the quality is generally good, some parameters may be increasing slightly. There is intermittent natural contamination from iron and manganese which seems to coincide with high turbidity and suspended solids. Chloride is low (c. 15 mg/l) and conductivity ranges 130-170 µS/cm. Nitrate (mean 19 mg/l) is below the EU guide level, with no apparent increasing trend.

The aquifer is unconfined and is mapped as ‘extremely’ to ‘highly’ vulnerable to contamination. Point sources, particularly farmyards and septic tank systems, probably pose the main threats to the well. A survey of point sources in the ZOC was carried out (see source report). In view of the vulnerability and the potential sources of contamination in the ZOC, the risk to this source is relatively high.

5.6.2 Redcross

The analyses indicate a moderately soft (58–62 mg/l $CaCO_3$) calcium bicarbonate type water with low alkalinity (38-56 mg/l $CaCO_3$). Conductivities range 200-220 µS/cm, with chloride 20-25 mg/l. Nitrate levels are fairly high and have exceeded the EU guide level of 25 mg/l NO_3 with an average of 27 mg/l, but have never exceeded the EU MAC of 50 mg/l NO_3

The aquifer is unconfined and of 'low' to 'moderate' vulnerability. The main potential sources of contamination appear to be Redcross village and the surrounding houses and farmyards. There is no sewerage scheme and there is a concentration of septic tanks adjacent to the source. Although the ZOC appears to exclude the main residential area, it includes the new Council estate to the west of the well.

5.6.3 Baltinglass

Tinoran

The analyses indicate a calcium bicarbonate water type, moderately soft (82-94 mg/l $CaCO_3$) with low alkalinity (70 mg/l $CaCO_3$). Water quality is very good except for nitrate, which is 25-39 mg/l. Chloride averages 17 mg/l and conductivity 210-250 µS/cm.

The water quality in the adjacent Tinoran stream is very variable with high ammonium, iron, nitrite and potassium together with high numbers of bacteria which all indicate farmyard contamination.

The main risk to the source is from surface runoff from farmyards and landspreading of organic wastes. Well construction details are unavailable; the boreholes may not be sealed against contaminated surface water. Steep local gradients allow substantial and rapid runoff to occur. Septic tanks may threaten the groundwater quality. Point sources in the ZOC have been surveyed (see source report).

The Tinoran groundwater is 'extremely' to 'highly' vulnerable.

Lathaleere

The hydrochemical analyses indicate a moderately hard (204-216 mg/l $CaCO_3$) calcium bicarbonate water with a moderate alkalinity (178-190 mg/l $CaCO_3$).

The quality of the groundwater is good. There are some background coliforms which are below levels which cause concern. Nitrate levels are just below the guide level – mean 19 mg/l, max. 23 mg/l.

The groundwater is 'moderately' to 'highly' vulnerable. The main potential sources of contamination appear to be developments at the eastern edge of Baltinglass village and the surrounding houses and farmyards. A sewerage scheme exists but not all the houses are connected and there are some septic tanks adjacent to the source. The ZOC extends under some residential estates and industrial developments. The main sewer runs along the main road within 20 m of the wells.

There is also a risk from surface runoff from farmyards and landspreading of organic wastes. A survey of point sources has been carried out in the zone of contribution of the well (details in source report).

The Lathaleere source was closed in November 2002 due to the concentrations of Uranium found in the water. A new well drilled at Carsrock will be commissioned in the summer of 2003 to augment the supplies from the Tinoran and Parkmore sources.

Parkmore Springs

The hydrochemical analyses indicates a calcium bicarbonate water type which is hard (286-324 mg/l $CaCO_3$) with a moderate alkalinity (238-280 mg/l $CaCO_3$).

The water tends to have intermittent contamination from *E. coli*. Chloride ranges 16-19 mg/l. Conductivity is high (524-605) due to dissolution of $CaCO_3$ from the limestone-dominated subsoils. Nitrate levels are generally above the EU Guide Level, ranging 23-39 mg/l with a mean of 27 mg/l.

The main risk is posed by surface runoff around the two springs following landspreading of organic wastes. The aquifer is unconfined and 'highly' to 'extremely' vulnerable, due to the gravelly subsoils.

5.6.4 Kilballyowen

Groundwater at Kilballyowen is moderately soft (216-255 mg/l $CaCO_3$), calcium bicarbonate type water with very low alkalinity (10–38 mg/l $CaCO_3$) and electrical conductivity around 240 µS/cm.

In general the quality is fair, but slight contamination occurs at times. Chloride was above background, (average 30 mg/l). Nitrate was slightly above EU guide level (average 32 mg/l) but seems not to be increasing with time. Potassium was above EU MAC on 3/2/97 at 13 mg/l, and on 12/5/87 and 12/8/97 was over the threshold level. The water shows very high levels of coliforms and occasionally *E. coli*.

The aquifer is unconfined and is assessed as 'extremely' to 'highly' vulnerable to contamination. Point sources of contamination, in particular septic tanks, pose the main threats to the well, and investigation should be undertaken to eliminate the source of high potassium and coliforms.

5.7 Relationship between Vulnerability and Groundwater Quality

A comparison between vulnerability and water quality suggests that sources showing contamination were usually in areas where the groundwater was mapped as extremely and/or highly vulnerable.

5.8 Overall Assessment and Conclusions

- The hydrochemistry of groundwater in Co. Wicklow is primarily influenced by the non-limestone dominated bedrock geology.
- The groundwater in most of the county is soft to moderately hard and is of a calcium bicarbonate water type. The softer waters are generally found in the upland areas of central Wicklow.
- The presence of limestone dominated subsoils around the margins of Co. Wicklow permits the dissolution of the calcium carbonate, producing a much harder calcium bicarbonate water.
- The main groundwater quality problems due to natural conditions in the ground and the natural chemistry of groundwater are caused by iron (Fe) and manganese (Mn).
- The main water quality problems caused by the impact of human activities are due to faecal bacteria and nitrate (NO_3). Chloride and potassium provide good indicators of contamination.
- Mean nitrate levels were greater than the EU guide level in nine out of 22 public sources (41%). None of the sources was above the EU MAC.
- There may be slight evidence of a trend of increasing nitrate concentrations in some of the sources. Further sampling is required to confirm this.
- Groundwater quality from the smaller and shallower sources tends to be poorer than from the larger and deeper sources.
- The presence of faecal bacteria in sources is a major concern. The location of these wells close to septic tank systems and/or farmyards is likely to be the main reason for the relatively poor quality.
- The smaller sources are more likely to be affected by point source contamination than by diffuse contamination.
- There is a good correlation between groundwater vulnerability and groundwater quality.

In general, groundwater quality in County Wicklow is relatively good and contamination is not extensive. However, some groundwater sources are polluted by faecal bacteria and there is some nitrate contamination. The pollution and most of the significant contamination is probably caused by point sources, particularly farmyards and septic tanks, and by poor sanitary protection of wells.

5.9 Recommendations

- To improve the groundwater quality database, it is recommended that:

⇒ analyses of raw water rather than treated water should be carried out on a regular basis (at least twice a year until the situation and trend in each source is confirmed);

⇒ full analyses (including all major ions) should be carried out on these samples;

⇒ where there is evidence of contamination, the sampling frequency should be increased.

- Particular attention should be given to the Group A and Group B sources listed in Table 5.4.
- A continued review of the most recent nitrate data for the sources listed in Group B is recommended; with increased monitoring of untreated water, monitoring and assessment of other parameters, surveys of potential contamination sources, and assessment of the likely source(s) of nitrate; using vulnerability zones and groundwater protection zones in the assessment process
- Boreholes indicating coliforms should be disinfected and a treatment system installed.
- A programme of undertaking groundwater protection zone delineation around public and group scheme supplies, using the GSI guidelines, over the next few years is recommended.
- A programme of checking the sanitary protection at each well and spring site (i.e. on Council property immediate around the source) would help to ensure that shallow groundwater and surface water is not entering the source and that accidental spillages would not contaminate the source.

6 Groundwater Vulnerability

6.1 Introduction

The production of the groundwater vulnerability map for County Wicklow required the following:

- differentiating between subsoils to obtain three classes of permeability – high, moderate and low;
- in the case of sand/gravel aquifers, the thickness of the unsaturated zone;
- contouring of depth to bedrock data.

Summary information on vulnerability categories is given in Section 2.3.1.

6.2 Sources of Data

The following sources of data were used to produce the vulnerability map:

- the subsoils maps (Maps 2N and 2S)
- depth to bedrock data from all the GSI databases (Maps 3N and 3S)
- six inch to one mile scale geological and topographic maps
- 1:50,000 scale topographical maps and digital data
- site visits undertaken in Co. Wicklow
- a depth to bedrock drilling programme undertaken by GSI for this project
- grain size analyses of samples obtained during the mapping and drilling programmes.

6.3 Permeability of the Subsoils

The permeability of a subsoil is largely a function of the percentage of clay and silt size grains present. The higher this percentage, the lower the permeability. Permeability can also be assessed by examining the drainage characteristics of the various subsoils. The qualitative permeability values of subsoils in County Wicklow, given in Table 6.1, were assigned on the basis of textural descriptions, particle size analyses and general relationships between subsoil types and matrix compositions.

The boundary between moderate and low permeability is estimated from limited piezometer data over the country to be in the region of 10^{-8} m/s to 10^{-9} m/s at the field scale (Swartz, 1999). Using limited country-wide pump test data, the boundary between the moderate to high boundary is estimated to be in the region of 10^{-4} m/s (O'Suilleabhain, 2000). However, permeability measurements are highly scale dependent: laboratory values, for example, are often up to two orders of magnitude smaller than field measurements which in turn are smaller than regional assessments measured from large scale pumping tests. Consequently, qualitative assessments, incorporating the engineering behaviour of the subsoils and recharge characteristics are considered more appropriate for regional vulnerability mapping than specific permeability measurements.

Table 6.1. Permeability and Distribution of Subsoils in County Wicklow

Subsoil	Assumed Permeability	Distribution
Limestone Till	Low	West Wicklow: Ballymore Eustace, Dunlavin, Grangecon, Baltinglass.
Limestone Till (ISB)	Low	Northeast Wicklow: Bray to Greystones.
Greywacke Till (ISB)	Low	East Wicklow: Newtownmountkennedy, Kilcoole, Newcastle, Ashford.
Lower Palaeozoic Till	Moderate	East Wicklow: Enniskerry, Roundwood, Laragh, Rathdrum, Aughrim, Tinahely, Shillelagh; West Wicklow: Baltinglass, Hollywood, Blessington, Brittas.

Lower Palaeo-zoic Till (ISB)	Low	East Wicklow: Wicklow, Redcross, Arklow.
Granite Till	Moderate	Central Wicklow: Wicklow Mountains.
Chert Till	Moderate	West Wicklow: Blessington, Donard, Stratford, Baltinglass.
Quartzite Till	Moderate	Northeast Wicklow: Western flanks of Great Sugar Loaf.
Sand & Gravel	High	Enniskerry, Greystones, Kilpedder, Ashford, Blessington, Dunlavin region, Baltinglass.
Lake Deposits	Low	Around Pollaphuca Reservoir and along the Glencree river.
Alluvium	Moderate/High	Along many of the river valleys and the coast.
Peat	Low	Upland areas of the Wicklow mountains.
Marine deposits	Moderate	Along the coast.

6.3.1 Tills

Till deposits in County Wicklow have a widespread distribution and are classified according to their lithological composition (Section 3.1).

Limestone tills occur in northeast Wicklow, extending to just south of Greystones on the east coast, and in west Wicklow around Ballymore Eustace, Dunlavin, Grangecon and Baltinglass. The limestone tills are generally clayey silt to fine sand and are often lodgement tills which are overconsolidated and therefore are taken to have a **low permeability**. In northeast Wicklow, the limestone till is Irish Sea basin derived and is a more clayey silty or silty clayey, with a sticky, firm texture, few clasts and a high calcium content (Bakker 1997) and are also considered to have a **low permeability**. Irish Sea basin derived tills are also generally over-consolidated and contain shell fragments.

Cherty tills are present in three areas of west Wicklow – several small areas around Pollaphuca Reservoir (about 6 km^2) a much larger area around Donard, Stratford and the Glen of Imaal (about 65 km^2), and a third area southeast of Baltinglass (about 25 km^2). They are similar to the limestone tills except in being partly decalcified. Along with the dissolution of the limestone clasts, they are thus relatively enriched with the more resistant chert clasts. A typical cherty till is a matrix-supported fine sandy till. Clayey silty to silty sandy cherty tills are also found. Five particle size analyses were carried out on samples of cherty tills. In five samples the percentage fines was 23, 37, 37, 43, and 62%. Around Baltinglass the cherty tills are very gravelly, probably reworked glacio-fluvial gravels, and are therefore considered to be generally of a **moderate permeability**, depending on the compaction and percentages of fines. Occasionally the tills are over-consolidated, as in the Glen of Imaal. The dissolution of the limestone clasts seems to be post-depositional and indicates water movement through the till, confirming a moderate permeability.

Both the Lower Palaeozoic and cherty tills may have varying permeabilities, ranging from low to moderate, depending on local factors. In areas where the local information is insufficient to determine the permeability, a **moderate permeability** is assigned, thus adopting a conservative approach.

Greywacke till deposits around Newtownmountkennedy, Kilcoole, Newcastle and to just north of Ashford, are Irish Sea basin derived. They are characterised by a clayey to silty matrix, few clasts and a high calcium content, overconsolidated (Bakker 1997) and therefore have a **low permeability**.

Like the limestone tills, the **Lower Palaeozoic tills** can also be subdivided into two groups: Lower Palaeozoic tills or Lower Palaeozoic, Irish Sea basin derived tills. These tills occurs in east Wicklow, along the foothills of the Leinster Granite mountains from near Enniskerry, southward to Roundwood, Laragh, Rathdrum, Aughrim and west to Tinahely and Shillelagh. Smaller areas occur around Blessington and Baltinglass in west Wicklow.

The Lower Palaeozoic tills are generally clayey silty to silty sandy and matrix supported. Grain size analyses shows around 30% fines (clay & silt) and 40% sand. In northeast Wicklow, towards the coast the Lower Palaeozoic tills are Irish Sea basin derived tills and possess a silty clayey to clayey silty matrix, with a firm, sticky appearance. The till has few clasts and is rich in calcium and shell fragments (Bakker 1997). Typically the grain size analysis of an Irish Sea till has around 60% of the bulk and 70% of the matrix composed of silts and clays, whereas the sand fraction comprises about 25%. These tills are often lodgement tills which are over-consolidated. They are taken to have a low permeability. For the Lower Palaeozoic tills further inland, a moderate permeability may be more appropriate, due to the lower percentage of fines (on average), and because, as a result of the higher topography, the tills are only slightly over-consolidated. The boundary between the Lower Palaeozoic tills seems to be gradational. In situations where bedrock is close to the surface, the tills are often stony, and close to granite bedrock or Lower Palaeozoic sandstones and siltstones, the matrix of the tills may be very sandy.

The Lower Palaeozoic Irish Sea Basin-derived tills along the coast are considered to have a **low permeability** while the Lower Palaeozoic tills inland are considered to have a **moderate permeability**.

Granite tills are found high on the Wicklow Mountains. These thin tills show only slight variation and are matrix-supported sandy till with sub-angular granite clasts. Particle size analyses (12 are available) indicate that typically around 50% of the grains are sand and 25% clay and silt. Maximum percentage of fines was 36%, in two samples. Occasionally stony granite tills with a sandy matrix are found where bedrock is close to the surface. Where the dominant grain size is greater than 2 mm the tills are classified as gravelly tills. In some places the granite tills are slightly overconsolidated and are considered as lodgement tills. The granite tills are considered to have a **moderate permeability**.

A small area of **Quartzite Till** is located on the western flanks of the Great Sugar Loaf. The till has a silty sandy matrix with many (sub)angular quartzite clasts and is considered to have a **moderate permeability**.

6.3.2 Lake Deposits

These underlie several small areas around Pollaphuca Reservoir, amounting to about 7 km^2. Lake clays and silts have a **low permeability** – usually less than 10^{-3} m/d (10^{-8} m/s) and frequently less than 10^{-4} m/d. One particle size analysis is available (sample no. MB136, from 2-4m depth in borehole 97/108) which showed a 92% fines content.

6.3.3 Alluvial Deposits

These are variable, ranging from highly permeable sandy gravelly deposits to clayey silty low permeability deposits and they also vary depending on their topographic location. For the purposes of this study, alluvial deposits in upland and lowland areas are considered separately.

Upland areas:

Deposits are classed as **high permeability** deposits as they are likely to be coarser grained and more gravel rich than in lowland areas.

Lowland areas:

1. Deposits are generally classed as **moderate permeability**, i.e. considered as a sandy silty deposit.

2. Where depth-to-rock is more than 10 m in an area mapped as alluvium, the composite vulnerability must be considered, as alluvial deposits often do not reach these depths. In these cases, the vulnerability of the likely underlying deposit is combined with the alluvium to give an overall estimate of the vulnerability of the entire deposit. Large alluvial flood plains, where deposits are likely to be thicker, however, are an exception. In these areas the alluvium is given more weighting in the composite vulnerability and is assumed to be a sandy silty deposit of **moderate permeability**. Undoubtedly there are substantial areas where the deposits are silty/clayey; however, in the absence of better quality data the more conservative assumption on the permeability is taken.

3. In areas where alluvial deposits are mapped as 5-10 m thick they are given priority in the composite vulnerability as underlying deposits are likely to be thin and they are therefore considered to be of **moderate permeability**.

4. Along coastal sections where the deposits are often very sandy they are then considered to be of a **high permeability**.

6.3.4 Peat

Peat underlies approximately 140 km^2 of Co. Wicklow, the great majority of this is upland areas. Peat permeabilities depend on the degree of peat decomposition (humification) and the effects of subsidence. Apart from the upper layer of intact bogs, peat has a relatively **low permeability** – often $<10^{-3}$ m/d (10^{-8} m/s).

Although peat has a relatively low permeability, each peat deposit is considered separately because in places it is just a thin cover over an underlying permeable deposit, where its presence may be due to a high water table. In these instances the vulnerability is based on consideration of the composite of all the subsoils overlying the bedrock. In Wicklow blanket peat deposits generally overlie bedrock and are rarely thicker than 3 m. Hence almost all the peat areas are classed as 'Extreme'. There are a few small areas of lowland peat in the west, near the Co. Kildare boundary, where the vulnerability ranges from High to Low, depending on the thickness and permeability of the underlying till or alluvium.

6.3.5 Marine Deposits

In the absence of adequate information on the type and permeability and in view of their variable nature, marine deposits are classed as having a **moderate permeability**, even though they are likely to be silty and clayey in places.

6.4 Thickness of the Unsaturated Zone

The thickness of the unsaturated zone is only relevant in vulnerability mapping over sand/gravel aquifers. The water table is generally >3 m deep, except where the sand/gravel is in a low-lying area (usually close to major rivers), therefore the vulnerability is generally high rather than extreme.

6.5 Depth to Bedrock

Along with permeability, the subsoils thickness (depth to bedrock) is a critical factor in determining groundwater vulnerability to contamination. A brief description of subsoil thicknesses is given in Section 3.10. The guidelines used in contouring the depth to bedrock data are outlined below.

6.5.1 Guidelines for contouring depth-to-bedrock in County Wicklow

- Contouring was carried out by hand at 1:50,000 scale, incorporating topographical information on the O.S. Discovery Series maps, as it was deemed the most suitable scale for the available data.
- The boundaries of areas where rock is mapped as being close to the surface on the Quaternary maps were taken to represent a 1 m depth-to-rock contour.
- All isolated rock outcrops were assumed to be surrounded by an area of extreme vulnerability.
- An average distance from rock outcrops to the 3 m contour was estimated, using the available point depth-to-rock data, (from 40 different situations in Co. Wicklow) to be about 200 m.
- An average distance from the 1 m to the 3 m contour and the 3 m to the 5 m contour was estimated, using the available point depth-to-rock data, to be in the region of 130 m. Contour shapes are often strongly influenced by the topographical contours.
- The 10 m contours are more dependent on the presence of adequate borehole information although an estimated distance between the 5 m and 10 m contours of 200 m was used as a guide. It appears that in Co. Wicklow deposits that reach thicknesses of 10 m or more do so with a steeper gradient than the more shallow deposits.

- Only data points with an accuracy of +/- 100 m were used in the actual contouring although less accurate data were used, within their respective limitations, for confirmation of the general thicknesses.
- Depending on the size of the area to be contoured, at least two or three data points were necessary to include a contour. The average interval distances were consistently used except where there were point data to the contrary. The deeper 5 m and 10 m contours were included only where the data facilitated it. Their absence from an area does not necessarily imply that deposits do not reach those thicknesses but that their existence was inconclusively proven from the available data.
- Due to the spread and variable quality of data, the irregularity of the bedrock topography, and the subjective opinions of the drillers in logging the bedrock surface, it was inevitable that some data points did not fit the interpreted depth-to-rock contours. This was particularly highlighted in areas where there were extensive investigations and may be a consequence of boreholes encountering fault zones. It must be emphasised that the contours are only interpretations highlighting *areas* of different thicknesses and are not definitive boundaries.

6.6 Groundwater Vulnerability Map

The vulnerability map (Maps 6E and 6W) is derived by combining the depth to bedrock data and the subsoil types and permeabilities. The general classification distribution is outlined in Table 6.2.

Table 6.2. Summary of Vulnerability Classification Scheme

Vulnerability Rating	Hydrogeological Setting
Extreme 61.8%	• Areas where where rock is at the ground surface • Areas where the subsoil is known or interpreted to be <3m thick • Areas of *sand/gravel aquifer* where the water table is <3m below surface
High 28.3%	• Areas of *high* permeability subsoil known or interpreted to be >3m thick • Areas of *moderate* permeability subsoil known or interpreted to be 3-10m thick • Areas of *low* permeability subsoil known or interpreted to be 3-5m thick • Areas of *sand/gravel aquifer* where the water table is >3m below surface
Moderate 5.4%	• Areas of *moderate* permeability subsoil known or interpreted to be >10m thick • Areas of *low* permeability subsoil known or interpreted to be 5-10m thick
Low 3.3%	• Areas of *low* permeability subsoil known or interpreted to be >10m thick

Note: approximately 1.2% of the county is occupied by lakes/reservoirs

Note that the vulnerability boundaries are based on the available data and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments, often requiring site investigations, in order to assess the risk to groundwater. Detailed subsoil mapping, assessment of surface drainage and permeability measurements would reduce the area of high vulnerability and would probably reduce the area of extreme vulnerability. However, in the short and medium term the vulnerability maps are a good basis for decision-making.

Over 90% of the county is classed as having either Extreme or High vulnerability while areas of Moderate (6.35%) and Low (3.12%) vulnerability are much less common. This is a consequence of the often shallow thicknesses of subsoils in Co. Wicklow but it may also reflect the distribution of borehole data. The 3 m contour, which influences the Extreme and High vulnerability categories, is based on outcrop information, Quaternary mapping and borehole data. The presence or absence of 5 m and 10 m contours, which influence the moderate and low categories, depends solely on borehole data and the shallower contours are used as a guide for their interpretation. Where relevant borehole data to suggest greater depths are not available, these contours cannot be drawn and there are probably more areas of Moderate and Low vulnerability than are currently depicted on the map. In addition, the particle size analyses indicate that, in places, some other till types, notably the Lower Palaeozoic till, can be quite impermeable and there may be more areas of Moderate and Low vulnerability than have been mapped. As more information becomes available, the maps should be up-dated.

The large areas of Extreme vulnerability where rock is generally at or close to surface include the upland areas of the Wicklow Mountains, the foothills, and particularly along the coast. When the upland areas (which have little development or potential for development) are excluded, the proportion of the county's groundwater that is Extremely vulnerable is significantly reduced. High vulnerability areas are then the most common category across the county.

There are isolated patches of Moderate vulnerability and Low vulnerability in places, particularly along the coast and around Blessington to Baltinglass. These are found where the subsoils (limestone tills and Irish Sea tills) have a low permeability and the depth to bedrock information indicates thicknesses of over 10 metres. However such thick deposits may not be a uniform till but may have interbedded sands and gravels in places; further confirmation by site investigation is essential to verify the vulnerability for specific developments.

Water quality variations in the public supply sources were found to have a good correlation with the vulnerability classifications assigned to the zones of contribution of the sources. Thus sources with relatively poor quality are often located in areas of extreme and high vulnerability.

7 Groundwater Protection

7.1 Introduction

In Chapter 1, the general groundwater protection scheme guidelines were outlined and in particular, the two main components of the scheme – land surface zoning and groundwater protection responses for potentially polluting activities – were described. Subsequent chapters describe the different geological and hydrogeological land surface zoning elements as applied to County Wicklow. The final products of land surface zoning are the groundwater protection scheme map and the source protection maps. It is emphasised that these maps are not intended to 'stand alone', but to be considered and used in conjunction with the groundwater protection responses.

7.2 Groundwater Protection Maps

The groundwater protection maps (Maps 7N and 7S) were produced by combining the vulnerability maps (Maps 6N and 6S) with the aquifer maps (Maps 5N and 5S). Each protection zone on the map is given a code which represents both the vulnerability of the groundwater to contamination and the groundwater resource (aquifer category). The codes are shown in Table 7.1, the general groundwater protection scheme matrix. Not all of the possible hydrogeological settings are present in County Wicklow; the zones not present are omitted from Table 7.1.

Table 7.1. Matrix of Groundwater Resource Protection Zones

VULNERABILITY RATING	RESOURCE PROTECTION ZONES					
	Regionally Important Aquifers (R)		Locally Important Aquifers (L)		Poor Aquifers (P)	
	Rk	Rf	Lm/Lg	Ll	Pl	Pu
Extreme (E)			Lg/E (0.01%)	Ll/E (25.4%)	Pl/E (34.4%)	Pu/E (1.9%)
High (H)			Lg/H (2.1%)	Ll/H (11.1%)	Pl/H (14.2%)	Pu/H (0.7%)
Moderate (M)				Ll/M (2.3%)	Pl/M (2.8%)	Pu/M (0.3%)
Low (L)				Ll/L (2.0%)	Pl/L (1.0%)	Pu/L (0.3%)

Note: 1. Approximately 0.2% of the county is included within Groundwater Source Protection Zones.
2. Approximately 1.2% of the county is occupied by lakes/reservoirs.

7.3 Groundwater Source Protection Reports and Maps

Source protection zones have been delineated for four public groundwater supply sources in County Wicklow: Roundwood, Redcross, Baltinglass and Blessington. These have been produced as separate source reports. A special report has also been produced on the Brittas Bay area, based on a M.Sc. study (at Trinity College Dublin) by Sarah Casey.

7.4 Up-dating

This report and the accompanying maps are based on the best information available to the compilers. The maps are intended to be up-dated periodically as additional data become available in the future. It is suggested that this be undertaken every four to five years, preferably in advance of the periodic review of the County Development Plan.

The next opportunity for significant up-dating of the maps will arise under the river basin district management projects, which commenced in early 2002 (South Eastern River Basin District). Work on the Eastern River Basin District is expected to begin early in 2003.

7.5 Groundwater Protection Responses

To date, Groundwater Protection Responses have been published for Landfills, Landspreading (IPC licensed), and for On-site Wastewater Disposal Systems.

Interrogation of the GIS (MapInfo) maps for Co. Wicklow allows the appropriate response for any site to read directly. The respective areas and percentages of the county for the various responses are:

7.5.1 Landfills

Code	**Response** (abbreviated – see DELG/EPA/GSI publication for full description)	Area, km^2	% of county
R1	Acceptable subject to EPA Landfill Design Manual or conditions of waste licence	**87**	**4.3**
R2^1	Acceptable subject to EPA Landfill Design Manual or conditions of waste licence. Check for high permeability zones: if present, landfill should only be allowed if risk of leachate movement to these zones is insignificant. Special attention to existing down-gradient wells and to future development of the aquifer.	**655**	**32.3**
R2^2	Acceptable subject to EPA Landfill Design Manual or conditions of waste licence. • Check for high permeability zones: if present, landfill should only be allowed if risk of leachate movement to these zones is insignificant. Special attention to existing down-gradient wells and to future development of the aquifer. • Groundwater control measures (e.g. cut-off walls, interceptor drains) may be necessary to control high water table, or the head of leachate may be required to be maintained at a level lower than the water table depending on site conditions.	**1213**	**59.8**
R3^1	Not generally acceptable, unless it can be shown that: • The groundwater in the aquifer is confined; or • There will be no significant impact on the groundwater; and • It is not practicable to find a site in a lower risk area.	**43**	**2.1**
R4	Not acceptable	**3.0**	**0.15**

7.5.2 Landspreading of (IPC licensable) organic wastes

Code	Response	Area, km^2	% of county
R1	Acceptable subject to normal good practice	**746**	**36.8**
R2^1	Acceptable subject to maximum organic nitrogen load (including that deposited by grazing animals) of 170 kg/hectare/yr.	**1.0**	**0.05**
R3^1	Not generally acceptable, unless at least 1m of soil and subsoil can be demonstrated.	**1252**	**61.7**
R3^2	Not generally acceptable, unless at least 2m of soil and subsoil can be demonstrated.	**0**	**0**
R3^3	Not generally acceptable, unless no alternative areas are available and detailed evidence is provided to show that contamination will not take place.	**0.3**	**0.02**
R4	Not acceptable.	**1.8**	**0.09**

7.5.3 On-site wastewater systems for single houses

Code	**Response** (abbreviated – see DELG/EPA/GSI publication for full description)	**Area, km^2**	**% of county**
R1	Acceptable subject to normal good practice (i.e. system selection, construction, operation and maintenance in accordance with EPA, 2000)	**746**	**36.8**
R2^1	Acceptable subject to normal good practice. Where domestic water supplies are nearby, pay particular attention to depth of subsoil such that the minimum depths required (EPA, 2000) are met, to minimise likelihood of microbial pollution.	**1252**	**61.7**
R2^3	Acceptable subject to normal good practice, and: (1) There is at least 2m unsaturated soil/subsoil beneath the invert of the percolation trench of a conventional septic tank system. OR (1) A proprietary treatment system is installed, with at least 0.6m unsaturated soil/subsoil (P/T values >1<50) (plus the polishing filter which should be at least 0.6m deep), beneath the invert of the polishing filter (i.e. 1.2m in total). AND (2) Based on the groundwater quality of the source and the number of existing houses, cumulative significant nitrate/microbiological contamination is unlikely.	**0.95**	**0.05**
R2^4	Acceptable subject to normal good practice, conditions (1) and (2) above AND Not within 60m of the public, group scheme or industrial water supply source.	**0.6**	**0.03**
R3^1	Not generally acceptable, unless: At least 2m unsaturated soil/subsoil beneath the invert of the percolation trench of conventional septic tank system OR A proprietary treatment system is installed, with at least 0.6m unsaturated soil/subsoil (P/T values >1<50) (plus the polishing filter which should be at least 0.6m deep), beneath the invert of the polishing filter (i.e. 1.2m in total). AND (1) Based on the groundwater quality of the source and the number of existing houses, cumulative significant nitrate/microbiological contamination is unlikely. (2) Not within 60m of the public, group scheme or industrial water supply source. Management and maintenance agreement with the systems supplier.	**1.1**	**0.05**
R3^2	Not generally acceptable, unless: A proprietary treatment system is installed, with at least 0.6m unsaturated soil/subsoil (P/T values >1<50) (plus the polishing filter which should be at least 0.6m deep), beneath the invert of the polishing filter (i.e. 1.2m in total). AND (1) Based on the groundwater quality of the source and the number of existing houses, cumulative significant nitrate/microbiological contamination is unlikely. (2) Not within 60m of the public, group scheme or industrial water supply source. Management and maintenance agreement with the systems supplier.	**0.5**	**0.0**

7.6 Summary of the Groundwater Protection Situation in County Wicklow

A review of the groundwater protection responses for the county (above) indicates:

- Landfills: From a groundwater viewpoint, the great majority of the county (over 95%) is broadly suitable for the construction of landfills. This reflects the fact that there are no regionally important aquifers, and that landfills can be engineered so as to take account of any vulnerability constraints. In other words, groundwater conditions are unlikely to be a decisive factor in the location of any new landfills.
- Landspreading of licensable organic wastes: Just over a third of the county is essentially suitable for this type of development. This reflects the fact that subsoil thicknesses are generally low. However, a further proportion, perhaps another 30%, is likely to be suitable, subject to detailed ground investigation and checking.
- On-site wastewater treatment systems (septic tanks, etc.): The great majority of the county (over 95%) is essentially suitable for these systems, subject to site permeability testing.

8 Conclusions and Recommendations

8.1 General

County Wicklow has relatively poor groundwater resources, with no regionally important (i.e. major) aquifers. However, a significant number of small to medium sized public water supply sources depend on groundwater (providing about 15% of the county's public water supply), as do thousands of residents in rural areas who have their own private water supplies. Hence many thousands of Wicklow residents have a direct interest in ensuring that the county's groundwater resources are well protected.

Despite the generally high to extreme vulnerability of the groundwater resources in Wicklow, the quality of the groundwater is generally good, and the implementation of this groundwater protection scheme should ensure that the groundwater quality remains good. The groundwater protection scheme will be a valuable tool for Wicklow County Council in helping to achieve sustainable water quality management and in the location of potentially polluting activities.

A review of the groundwater protection responses for the county indicates:

- Landfills: From a groundwater viewpoint, over 95% of the county is broadly suitable for the construction of landfills. This reflects the absence of regionally important aquifers, and the possibility of engineering landfills to take account of any vulnerability constraints.
- Landspreading of licensable organic wastes: Just over a third of the county is essentially suitable, reflecting the fact that subsoil thicknesses are generally low. An additional proportion, perhaps 30%, is also likely to be suitable, subject to detailed investigation and checking.
- On-site wastewater treatment systems (septic tanks, etc.): Over 95% of the county is essentially suitable for these systems, subject to site permeability testing.

8.2 Groundwater Development Prospects

County Wicklow is not blessed with major groundwater resources. The best aquifers, in general, are the thicker sand/gravel deposts. Although these occupy a relatively small area (abou 43 km^2, or 2.1% of the county), they are located in important areas of the northeast and northwest of the county, where development is particularly rapid. Some of the aquifers extend into Co. Kildare, which provides some additional resources. The thickness and lateral extent of the sand/gravel aquifers remain poorly defined; exploratory drilling, perhaps coupled with geophysical surveys, would help to resolve these uncertainties and might identify some additional resources.

Drilling water wells in the bedrock aquifers will always be difficult and well yields hard to predict. Where it is important to get a good yield, the use of geophysical survey methods which help to identify water-bearing fissures is recommended.

The better prospects in the bedrock aquifers appear to be in the Maulin, Butter Mountain, Oaklands and Kilmacrea formations. However, this conclusion is tentative because the database of aquifer properties is relatively poor. Expert advice on, and supervision of, groundwater development in any specific area, should always be sought.

8.3 Groundwater Vulnerability

Overall, the groundwater vulnerability in County Wicklow breaks down as follows:

- Extreme 61.8%
- High 28.3%
- Moderate 5.4%
- Low 3.3%

However, these figures may give a misleading view of the situation, because a large part of the 'Extreme' and 'High' vulnerability areas are in the mountain areas of central Wicklow where there is little or no development which could give rise to pollution.

The subsurface topography of the county, on which the groundwater vulnerability largely depends, is very variable. Given the available data, and the scale of the mapping, only a generalised picture can be given. For any specific development, the actual likely vulnerability at the site needs to be considered in the light of the available data.

8.4 Groundwater Quality

The chemistry of groundwater in Co. Wicklow is mainly influenced by the non-limestone dominated bedrock geology. In most of the county the groundwater is soft to moderately hard and of a calcium bicarbonate water type. The softer waters are generally found in the upland areas of central Wicklow. The limestone-dominated subsoils around the margins of the county produce a much harder water.

The main groundwater quality problems due to natural conditions are caused by iron (Fe) and manganese (Mn).

The main groundwater quality problems caused by human activities are due to faecal bacteria and nitrate (NO_3). Groundwater quality from the larger and deeper sources tends to be better than from the smaller and shallower sources, which are more likely to be affected by point source contamination than by diffuse contamination.

No source had a nitrate level above the EU MAC, but mean nitrate levels were above the EU guide level in nine out of 22 public sources (41%). There is evidence of increasing nitrate concentrations in some sources. Further sampling is required to confirm this.

The presence of faecal bacteria in some sources is a concern. The location of these wells close to septic tank systems and/or farmyards is likely to be the main reason for the relatively poor quality.

There is a good correlation between groundwater vulnerability and groundwater quality.

In general, groundwater quality in County Wicklow is relatively good and contamination is not extensive. However, some groundwater sources are polluted by faecal bacteria and there is some nitrate contamination. The pollution and most of the significant contamination is probably caused by point sources, particularly farmyards and septic tanks, and by poor sanitary protection of wells.

To improve the groundwater quality database, it is recommended that:

- Analyses of raw water should be carried out regularly (at least twice a year until the situation and trend in each source is confirmed); where there is evidence of contamination, the sampling frequency should be increased.
- Full analyses (including all major ions) should be carried out on these samples;
- Boreholes indicating coliforms should be disinfected and a treatment system installed.
- A programme of groundwater protection zone delineation around public and group scheme supplies, using the GSI guidelines, is recommended over the next few years.
- A programme of checking the sanitary protection at each well and spring (i.e. on Council property immediately around the source) would help to ensure that shallow groundwater and surface water is not entering and that accidental spillages would not contaminate the source.

8.5 Redcross WSS

The Redcross source is relatively high yielding; an increased yield could be obtained by increasing the storage capacity and pumping more continuously. The water analyses indicate no water quality problems except for the nitrate values. The groundwater vulnerability in the source catchment varies from **low** to **extreme,** due to the varying thickness of the low permeability till. All of the Inner

Protection area is located in a low vulnerability zone. The well is located beside the road and is very vulnerable to accidental spillages.

8.6 Roundwood WSS

The Roundwood source is moderately high yielding; an increased yield could be obtained by increasing the pump size and the rising main diameter. Alternatively an increase in storage would allow continuous pumping. The water analyses indicate no major water quality problems at this source, except for the naturally high iron and manganese. However the source catchment is **extremely** to **highly** vulnerable to pollution.

8.7 Baltinglass WSS

The Baltinglass sources have good yields.

At Tinoran an increased well yield is possible. The water analyses indicate no water quality problems at this source, except that nitrate is above guide level but below MAC. However the groundwater in the source catchment is **extremely** to **highly** vulnerable to pollution. The groundwater quality may also depend on the stream water quality as the stream could be recharging the aquifer.

The Tinoran source catchment extends into County Kildare, and co-operation from Kildare County Council will be essential in controlling potentially polluting activities in the protection zones.

The Lathaleere source was closed in November 2002 due to the concentrations of Uranium found in the water. A new well drilled at Carsrock will be commissioned in the summer of 2003 to augment the supplies from the Tinoran and Parkmore sources.

8.8 Blessington WSS

The Blessington gravel deposits constitute a locally important sand and gravel aquifer which is highly vulnerable to pollution. This important groundwater resource could be further developed.

The groundwater analyses indicate that there are no major water quality problems, except for the naturally high iron and manganese. While there has been concern regarding possible contamination from illegal landfill sites, groundwater analyses carried out in Spring 2003 have indicated that, so far, this is not the case.

To better define the source protection areas and the ultimate sustainable yield of the aquifer, a programme of test drilling is recommended, including the area in County Kildare to the west.

Further controlled pumping tests should be carried out to improve the characterisation of the aquifer and enable numerical modelling to define the source protection areas.

The recommendations of this report should be taken into account for any developments planned for water supply in this area.

8.9 Brittas Bay

In the Brittas Bay area over 50% of the houses are holiday homes with intermittent occupancy. At present there is no mains water in the area and the houses depend solely on groundwater sources.

The rocks of the area are mainly classed as locally important aquifers (moderately productive only in local zones (Ll)).

The subsoils of the area comprise marine and aeolian sands along the coast, glacial till to the west, and alluvial deposits at Buckroney Marsh in the south and along Potters River in the north. Overall the area comprises 55% low vulnerability, 10% moderate, 20% high and 15% extreme vulnerability.

As the area has no mains sewerage, there are many septic tanks, mostly using soakpits for effluent disposal. The density of the tanks is high in several places, leading to local groundwater quality problems. The agriculture of the study area is both arable and pasture. Both have the potential to contaminate local groundwater.

Of 24 samples taken, 15% showed the presence of faecal coliforms and 42% showed total coliforms. Of 22 samples for chemical testing, 33% exceeded the MAC for at least one parameter. Contamination derives from both natural and human sources. Of the samples taken 25% showed contamination, with human activities the possible source of pollution. Overall the groundwater in the area is of relatively good quality with small pockets of contamination occurring.

It is recommended that more chemical and bacteriological analyses should be carried out to monitor the groundwater quality, enabling any potential pollution sources to be identified and measures taken, and allowing seasonal trends to be identified. More investigations are recommended to establish what is happening in the study area in relation to nitrogen. The nitrate loading should also be assessed for the various surface catchments of the area.

Better protection is recommended on a number of the wells investigated, especially wells located within farms. Where bacteriologial contamination occurred, water should be chlorinated regularly. All wells should be located upgradient and as far as possible from potential sources of pollution.

8.10 Stakeholder Participation

The major stakeholders are the thousands of County Wicklow residents and visitors who use groundwater in their everyday lives. In order to ensure that groundwater is safeguarded, it is essential that the public are better informed about its existence and importance, and about how they can contribute to its protection. A number of ways can be suggested:

- Distribution to all householders of leaflets outlining the Groundwater Protection Scheme
- Making the GWPS available for public viewing in the Council's offices (and sub-offices), both as paper copies (with poster versions of maps) and in GIS format on dedicated computer terminals.
- Attaching conditions to planning permission, e.g. governing appropriate location and sanitary completion of new water wells.
- Signposts on public roads indicating the extent of public water source protection areas.

8.11 Up-dating and Revision

The Groundwater Protection Scheme is provisional, and will always be so. It is based on the best available information at the time of compilation. The availability of computerised databases and Geographic Information Systems (GISs) mean that the GWPS maps can be rapidly up-dated, provided that the necessary resources of staff and time are available.

New geological and hydrogeological information is constantly being generated, e.g. through the excavation of new exposures of rock and subsoil, the drilling of new water wells, the analysis of additional water samples, and investiagtions relating to Environmental Impact Statements and IPC licensing applications. In order to ensure that new information is available for incorporation into the scheme, it is essential that records of such data are properly filed and copied to the appropriate agencies, including GSI.

It is recommended that a formal revision process should be scheduled to coincide with the revisions of the County Development Plan.

At the present time, work is going ahead on a River Basin District Management Project for the South Eastern River Basin District, which includes a small part of southern Co. Wicklow. This project is due for completion in 2006. Most of the county falls within the Eastern River Basin District, for which a similar project is scheduled for 2003-2007. On completion of these projects, which will incorporate new soil and subsoil mapping by Teagasc, a major revision will be possible.

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