County Tipperary (South Riding)

Groundwater Protection Scheme

Main Report

2nd Revised Version, August 2001

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GROUNDWATER PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING)

1 Introduction

1.1. Location

South Tipperary (Fig.1.1) encompasses an area of 2258 sq. km and is bisected by the River Suir. The central part of the county, comprising the valleys of the Suir and its tributaries, the Multeen, Ara, Aherlow, Anner and Tar, has a general elevation between 60 m and 122 m above sea level. This central area is fringed by upland areas: the Comeraghs and Knockmealdowns in the south, the Galtees in the west, Slieve Phelim and Slievenamon in the east, and the Slieveardagh Hills in the northeast.

South Tipperary has five administrative authorities: Tipperary (South Riding) County Council, Clonmel Corporation, Tipperary, Carrick-on-Suir and Cashel Urban District Councils. Over half the population of approximately 77,000 lives in the urban areas.

Agriculture is the most important industry, with more than 80% of the area comprising farming land, the vast majority with a wide use range. The two most important types of enterprise are cattle production and dairying. Pig production has increased slightly and has become specialised in recent years, developing large integrated pig units. Less than one tenth of the area is devoted to tillage; barley and wheat are the most important crops. The other 20% of the land is mountainous and predominantly under forestry.

1.2. Reasons for Adopting a Groundwater Protection Scheme

Groundwater is widely used in South Tipperary. Demand for groundwater is continuing and is likely to increase. The numerous large springs and large baseflow in the rivers indicate a major groundwater resource which requires appropriate protection. Further development of agriculture and industry over recent years has increased the risk of groundwater pollution. Tipperary (South Riding) County Council commissioned this study to develop a Groundwater Protection Scheme to ensure that due account is taken of the ‘groundwater interest’ in the development process.

1.3. Scope and Objectives of this Report

1.3.1 Scope

This report outlines the geology, hydrogeology and groundwater quality of South Tipperary. This basic information has been used to prepare interpretive maps which will facilitate planning and resource development in the form of a Groundwater Protection Scheme and associated Groundwater Protection Response Matrices. The purpose of the scheme is to enable initial screening of potentially polluting activities. The effectiveness of the scheme depends to a large degree on its integration into the County Development Plan. The quality of the data is such that the scheme can be neither pollutant- nor site-specific. However, it does reduce the number of areas to be studied in detail by identifying those with the greatest or least limitations. The scheme should be periodically modified as further relevant information becomes available.

1.3.2 Objectives

a) An evaluation of the extent, value and general vulnerability of the groundwater resources of the county.

b) Protection of groundwater in Tipperary (South Riding) by the formulation of a Groundwater Protection Scheme and associated Groundwater Protection Response Matrices.

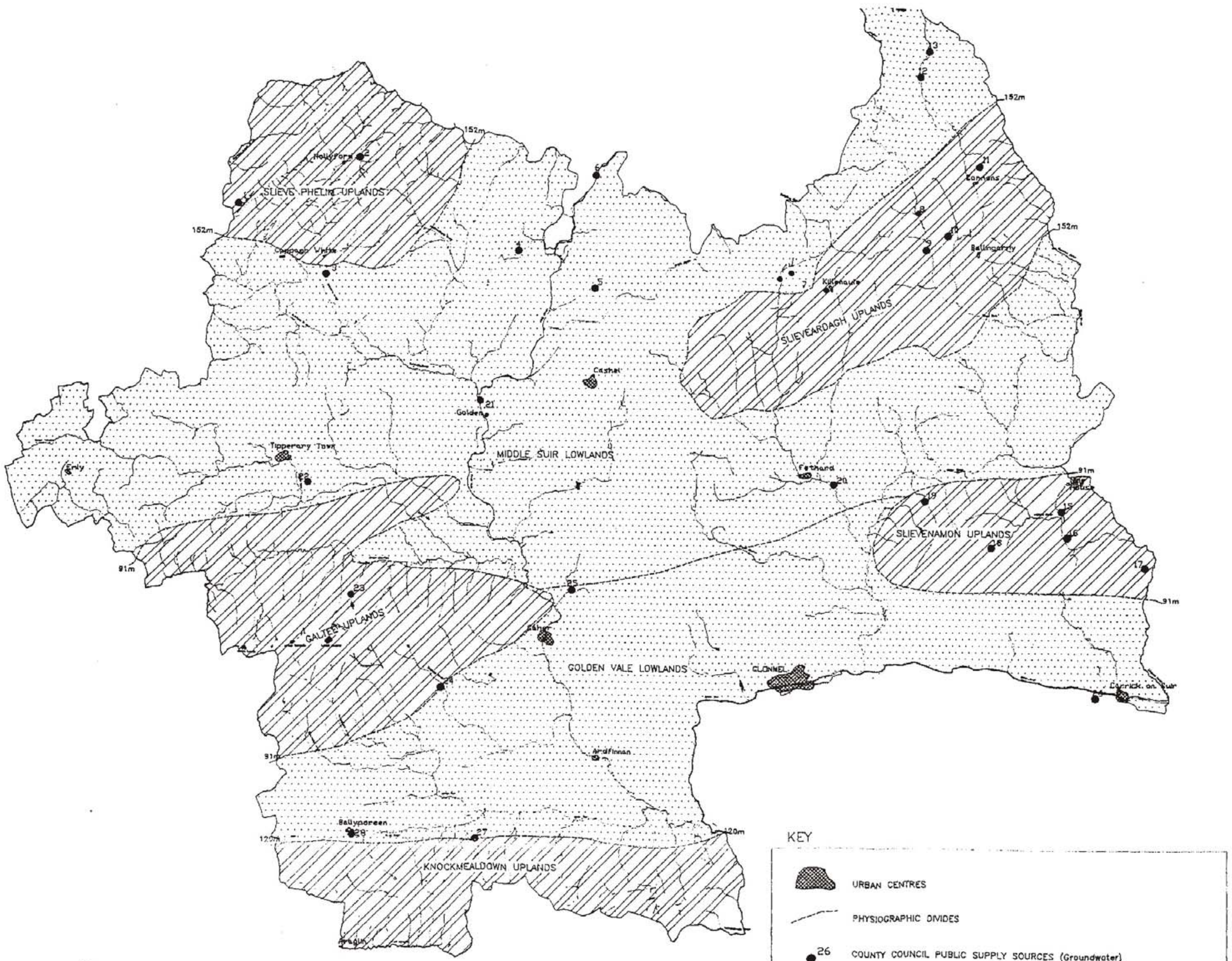

Figure 1.1 Location Map of South Tipperary, showing Physiographic Regions

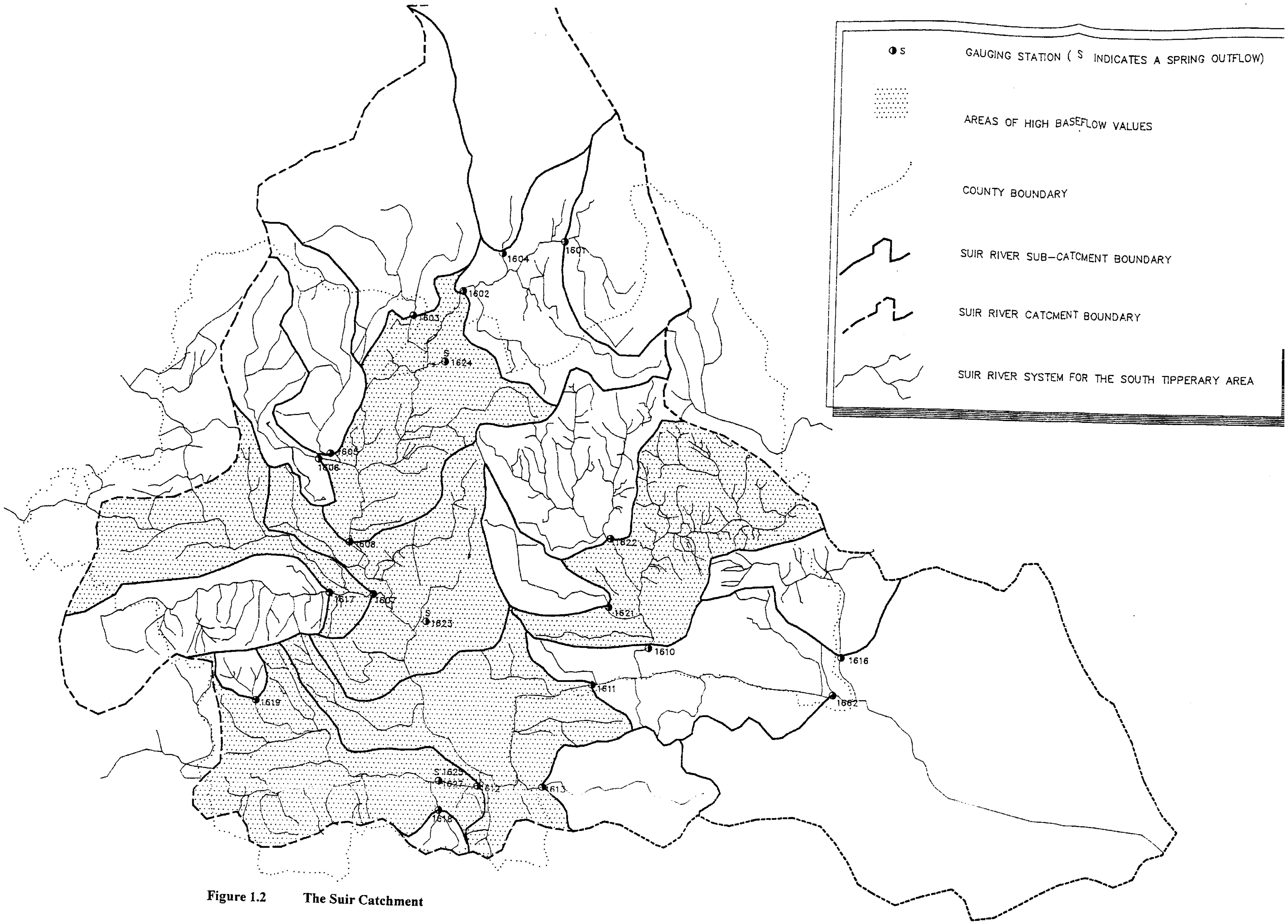

Figure 1.2 The Suir Catchment

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c) A review of legislation relating to groundwater protection in Ireland and proposals for fitting the protection scheme into the County Development Plan.
d) Detailed study of the vulnerability of a limited number of groundwater sources.

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 general groundwater protection scheme guidelines used by the GSI are given in Chapter 2. These are the basis for the county protection scheme and provide the structure for this report.

A suite of environmental geology maps accompany the report, as follows:

(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

- Bedrock aquifer map
- Potential gravel aquifer map
- Groundwater vulnerability map

(iii) Land Use Planning Map

- Groundwater Protection Zones 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.

1.4 Physical Characteristics

The county of Tipperary (South Riding) has maximum dimensions east to west of 64 km and north to south of about 53 km. It is bisected by the River Suir. There are seven physiographic regions - five uplands and two lowlands (Fig 1.1 and Table 1.1).

The five uplands are characterised by impermeable rolling ground dissected by numerous small streams. Gradients are steep, runoff is very rapid, and river flows tend to be very ‘flashy’.

The lowlands are part of the limestone plain of the ‘Golden Vale’, drained by the lower Suir river and its tributaries. The water table is usually less than ten metres below ground. The surface drainage of the lower Suir basin (within South Tipperary) is shown in Fig. 1.2 and is divided into sub-catchment basins.

Table 1.1 Summary of Physiographic Regions in South Tipperary

Physiographic Region	*Geological Succession*	*Main Rivers*	*General Ground Elevation, m*	*Peaks/Highest Ground (m. O.D.)*	*Land Use*
Slieve Phelim Uplands	Quaternary Devonian Silurian	Multeen	120 - 275	Knockastanna, 447 Knockalough, 428 Ring Hill, 426	Mountain sheep grazing, Amenity, Forestry
Middle Suir Lowlands	Quaternary Carboniferous	Suir Multeen	60 – 120	Killough Hill, 236 Mount O'Meara, 207	Tillage, Grassland
Sleieveardagh Uplands	Quaternary Carboniferous	Kings Munster Clashawley	120 – 275	Renaghmore, 344 Boggan, 335	Unsuitable for tillage, limited potential for grassland, forestry
Slievenamon Uplands	Quaternary Devonian	Lingaun Anner	120 – 450	Slievenamon, 722 Carrickabrock, 567 Knockahunna, 504	Forestry, Sheep grazing
Golden Vale Lowlands	Quaternary Carboniferous Devonian	Suir Aherlow Tar Anner Moyle	30 – 90	Bennets, 183	Tillage, Grassland
Kockmealdown Uplands	Quaternary Devonian	Duag Tar	120 – 400	Knockshanahulion, 565 Farbreaga, 520	Forestry, Sheep grazing
Galtee Uplands	Quaternary Carboniferous Devonian Silurian	Aherlow Behanagh Attychraan	120 - 640	Dawson's Table, 920 Greenane, 803 Sturraken, 520	Thin soils, Forestry

1.5 Soils and Land Use

The nature of the parent material is a principal factor in determining differences in soil properties and hence soil types. There is a wide range of bedrock and subsoils and hence soil types in the county.

The lowlands have well drained soils which are deep, medium textured, well drained, have good moisture holding capacities and are good for tillage. The parent materials are limestone tills, sands and gravels. The upland areas are characterised by poorly drained soils and therefore their uses are limited (Table 1.2).

The vulnerability of aquifers to diffuse pollution is determined largely by the attenuating capacity of the soils. In South Tipperary the soils have not been mapped in detail, so the available soil maps are of limited use in assessing vulnerability. However, they give a general indication of the land use and farming intensity and thus the likely pollution load.

Table 1.2 Summary of Soil Types and their uses in South Tipperary

Physiographic Region	*Principal Soils*	*Associated Soils*	*Primary Soil Description*	*Suitability*
Slieve Phelim Uplands	Podzolised Gleys 75% Gleys 60%	Peaty Gleys 25% Brown Earths 20%, Peaty Gleys 20%	Formed from glacial till of mixed sandstone, shale & limestone composition. Poorly drained, of sandy loam texture.	Limited use range – poorly drained, mainly due to seepage associated with stratification of underlying bedrock. Best suited to grassland.
Middle Suir Lowlands	Minimal Grey Brown Podzolics 70% Minimal Grey Brown Podzolics 80%	Gleys 20% & Brown Earths 10% Gleys 10%, Brown Earths 5% & Basin Peat 5%	Carboniferous Lime-stone till derived soils, deep, free draining, medium textured with a good moisture holding capacity. The Brown Earths are found throughout the area on kames and knolls.	Wide use range – first class grassland soils, also good tillage soils and are suitable for cereals and root crops.
Slieveveardagh Uplands	Acid Brown Earth 70% Gleys 60%	Gleys 15% & Peaty Gleys 15% Brown Earths 20% & Peaty Gleys 20%	Connected with the Upper Carboniferous sandstones and shales. Well drained but the associated soils are poorly drained and heavy textured.	Limited use range – due to their heavy texture, tillage or extensive grazing are difficult. The climate is responsible for a restricted growing season.
Slievenamon Uplands	Peaty Podzolics 75% Brown Podzolics 80% Podzols 70%	Lithosols 15%, Blanket Peats 10% Gleys 15%, Podzols 5% Gleys 15%, Peaty Gleys 15%	Outcropping rock common, peaty layer overlying coarse textured, moderately to poorly drained soil	Limited soil use – due to the high elevation, inaccessibility, peaty surface & low nutrient status/ Confined to sheep grazing, amenity and forestry.
Golden Vale Lowlands	Minimal Grey Brown Podzolics 70% Minimal Grey Brown Podzolics 80%	Gleys 20% & Brown Earths 10% Gleys 10%, Brown Earths 5% & Basin Peat 5%	Carboniferous Lime-stone till derived soils, deep, free draining, medium textured with a good moisture holding capacity. The Brown Earths are found throughout the area on kames and knolls.	Wide use range – first class grassland soils, also good tillage soils and are suitable for cereals and root crops.
Kockmealdown Uplands	Gleys 75% Peaty Podzols 75% Lithosols/rock outcrop 70%	Peaty Gleys 25% Lithosols 15%, Blanket Peat 10% Blanket Peat 25%, Peaty Podzols 5%	Formed from glacial till and sandstone outcrop. The predominant soil is poorly drained.	Limited use range – because of the poor drainage. Best used for grassland.
Galtee Uplands	Peaty Podzols 75% High level Blanket Peats	Lithosols 15%, Blanket Peats 10%	Coarse textured, outcropping rock, moderately to imperfectly drained.	Limited use range – unsuitable for tillage or intensive grassland, confined mainly to mountain sheep grazing, some amenity, some forestry.

1.6 Rainfall and Evapotranspiration

A mean annual rainfall map (Fig. 1.3) has been prepared, based on the 1951-1980 data provided by Met Eireann. The upland areas which form the western, southern and eastern perimeters have a

County Tipperary (South Riding) Groundwater Protection Scheme

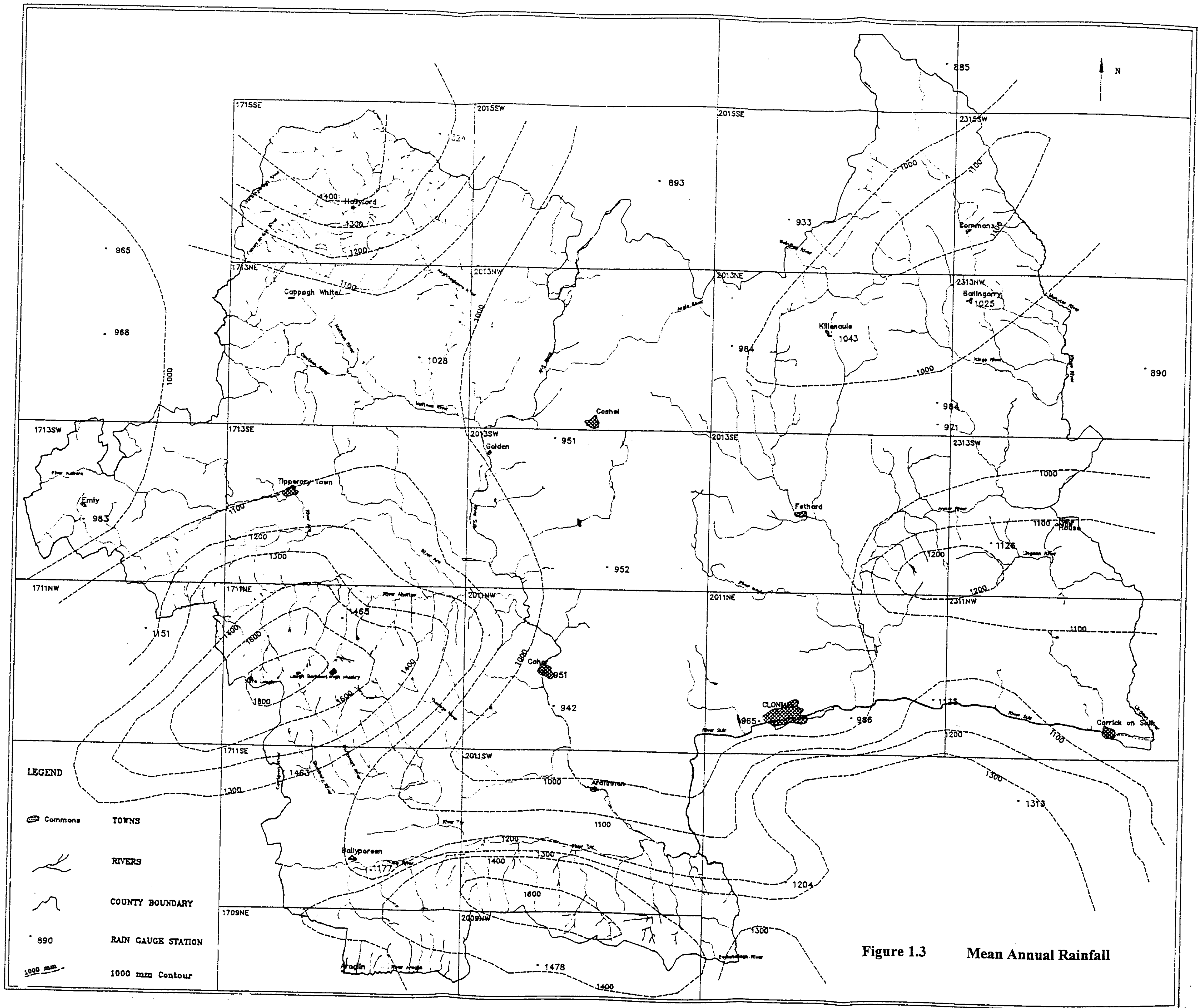

Figure 1.3 Mean Annual Rainfall

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rainfalls which vary from 1000 mm in the east to 1800 mm in the west and south. The lowlands receive less than 1000 mm per year.

Actual evapotranspiration at the nearest synoptic weather station (Kilkenny) has a range of 400-460 mm/year. The range for South Tipperary is taken to be slightly higher, as less influenced by the sea: 425-480 mm/year. Thus the effective rainfall (rainfall minus evapotranspiration) in the lowlands is less than 535-575 mm/year, and in the uplands 525-1325 mm/year.

1.7 Acknowledgements

This Groundwater Protection Scheme is the result of co-operation between Tipperary (South Riding) County Council, the Geological Survey of Ireland (GSI) and Sligo Regional Technical College. Effective communication with and constructive assistance by a variety of other groups and individuals, including Teagasc, is acknowledged.

2 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 pose increasing risks to groundwater quality: there is widespread disposal of domestic, agricultural and industrial effluents to the ground, and 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

2.1 Groundwater – A Resource at Risk

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

- lack of awareness of the risks of groundwater contamination, because groundwater flow and contaminant transport are generally slow and neither readily observed nor easily measured
- contamination of wells and springs
- widespread application of domestic, agricultural and industrial effluents to the ground
- generation of increasing quantities of domestic, agricultural and industrial wastes
- increased application of inorganic fertilisers to agricultural land, and usage of pesticides
- greater volumes of road traffic and more storage of fuels/chemicals
- manufacture & distribution of chemicals of increasing diversity and often high toxicity, used for a wide range of purposes

The main threats to groundwater are posed by:

(a) point contamination sources: farmyard wastes (silage effluent, soiled water), septic tank effluent, leakages, spillages, non-agricultural pesticides, landfill leachate, contaminated sinking streams;

(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.

2.2 Groundwater Protection through Land-use Planning: A Means of Preventing Contamination

There are a number of ways of preventing groundwater 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.

2.3 'Groundwater Protection Schemes' – A National Methodology for Preventing Groundwater Pollution

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. Three supplementary publications have also been produced, namely, **Groundwater Protection Responses for Landfills, Groundwater Protection Responses for Landspreading of Organic Wastes,** and **Groundwater Protection Responses for On-site Wastewater Treatment Systems for Single House**. Similar 'responses' publications will be prepared in the future for other potentially polluting activities and developments.

There are two main components of a groundwater protection scheme:

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

These are shown schematically in Fig. 2.1.

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 and group 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.

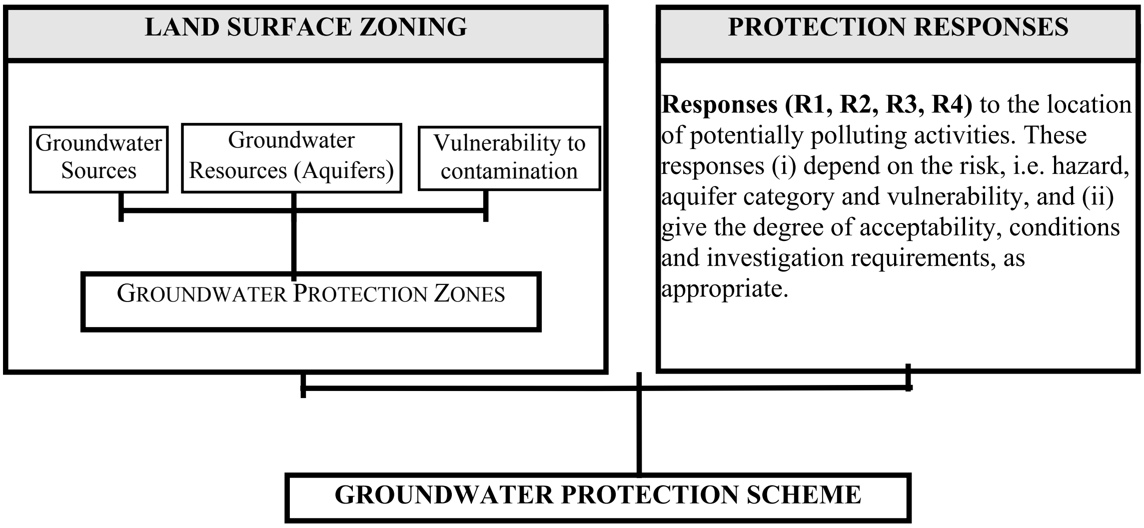

Fig. 2.1 Summary of Components of Groundwater Protection Scheme

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.

Two of the main chapters in **Groundwater Protection Schemes** are reproduced in Appendix A. While these describe the two main components of the national groundwater protection scheme, it is recommended that, for a full overview of the groundwater protection methodology, the **Groundwater Protection Schemes** publication (DELG/EPA/GSI, 1999) should be consulted.

2.4 Objectives of the South Tipperary Groundwater Protection Scheme

The overall aim of the groundwater protection scheme is to preserve the quality of groundwater in County Tipperary (S.R.) for drinking purposes and other beneficial uses, for the benefit of present and future generations.

The objectives, which are interrelated, are as follows:

- to assist the statutory authorities in meeting their responsibilities for the protection and conservation of groundwater resources;
- to provide geological and hydrogeological information for the planning process, so that potentially polluting developments can be located and controlled in an environmentally acceptable way;
- to integrate the factors associated with groundwater contamination risk, to focus attention on the higher risk areas and activities, and to provide a logical structure within which contamination control measures can be selected.

The scheme is not intended to have any statutory authority now or in the future, but to provide a framework for decision-making and guidelines for the statutory authorities in carrying out their functions. As groundwater protection decisions are often complex, sometimes requiring detailed geological and hydrogeological information, the scheme is not prescriptive and should be qualified by site-specific considerations.

2.5 Scope of South Tipperary Groundwater Protection Scheme

The geological and hydrogeological data for South Tipperary are interpreted to enable:

(i) delineation of aquifers
(ii) assessment of the groundwater vulnerability to contamination
(iii) production of a groundwater protection scheme which relates the data to possible land uses in the county and to groundwater protection responses for potentially polluting developments

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

This study compiles, for the first time, all readily available geological and groundwater data for the county and sets in place a database within the Geological Survey of Ireland (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. These are as follows:

(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

(iii) Land-use Planning Map
- groundwater protection scheme 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. However, they are not a substitute for site investigation.

2.6 Tipperary (S.R.) County Development Plan

It is envisaged that this Groundwater Protection Scheme should be incorporated into the County Development Plan, by whatever means the Council deems suitable.

2.7 Structure of Report

The structure of this report is based on the information and mapping requirements for land surface zoning. The final map, the Groundwater Protection Zone Map (Map 7) is obtained by combining the Aquifer (Map 5) and Groundwater Vulnerability maps (Map 6). The Aquifer Map, in turn, is based on the Bedrock Map (Map 1) boundaries and the aquifer categories as derived from an assessment of the available hydrogeological data (Map 4). The Groundwater Vulnerability Map is based on the Subsoils Map (Map 2), the Depth To Bedrock Map (Map 3), and an assessment of specifically relevant permeability and karstification information. This is illustrated in Fig. 2.2.

Similarly, the source protection zone maps result from combining vulnerability and source protection area maps. The source protection areas are based largely on assessments of hydrogeological data. This is illustrated in Fig. 2.3.

Chapters 3 and 4 provide brief summaries of the bedrock and subsoils geology, respectively. Chapter 5 summarises and assesses the hydrogeological data for the different rock units, explains the basis for each of the aquifer categories, and describes the potential for future groundwater development.

Chapter 6 summarises the hydrochemistry and groundwater quality in South Tipperary. Chapter 7 describes the subsoil permeability distribution and the derivation of the groundwater vulnerability categories. Chapter 8 draws the whole together and summarises the final groundwater protection zones delineated for South Tipperary.

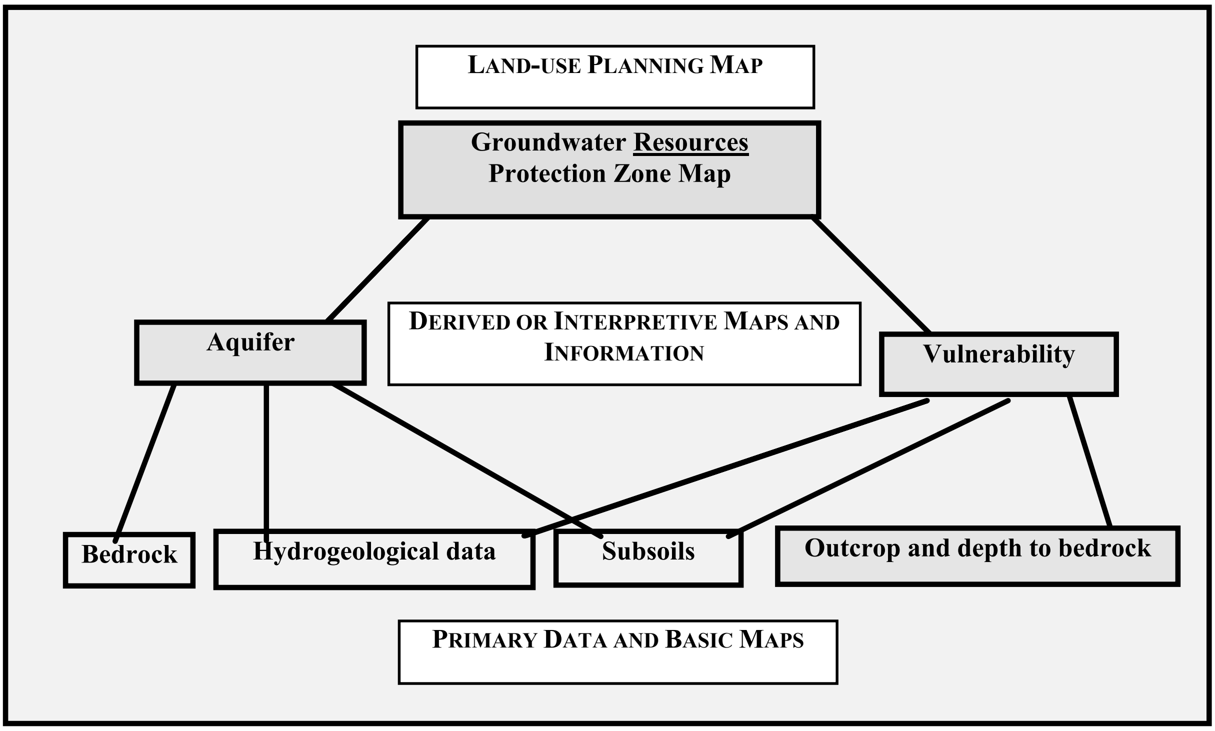

Fig. 2.2 Conceptual Framework for Production of Groundwater <u>Resource</u> Protection Zones, Indicating Information Needs and Links

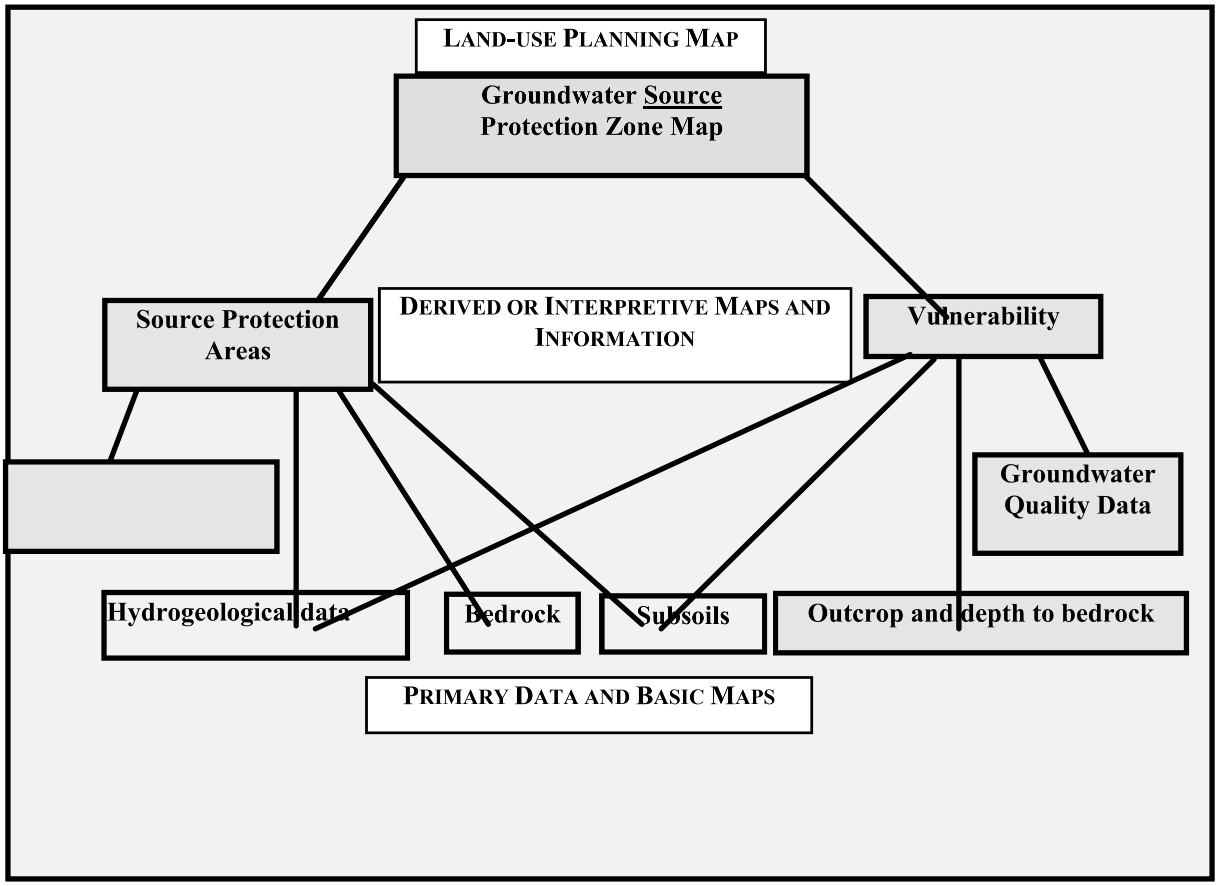

Fig. 2.3 Conceptual Framework for Production of Groundwater <u>Source</u> Protection Zones, Indicating Information Needs and Links

3 Bedrock Geology

3.1 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, which depends largely on the rock composition (lithology) and on the rock deformation that occurred during the long geological history of the county.

The geological sequence in South Tipperary extends in age from the Silurian Period (438 million years old) to the Carboniferous (300 million years old) with later deposits from the Tertiary (a very few small occurrences) and the Quaternary (very widespread), which is dealt with in Chapter 4.

The bedrock geology of South Tipperary is varied and complex. The uplands are underlain by Silurian, Devonian and Upper Carboniferous strata while the lowlands are mainly underlain by Lower Carboniferous limestone. The rocks in the southern part have been strongly affected by intense folding (the Variscan or Hercynian Orogeny) on an east-west trend, and by north-south faulting. The intensity of the folding decreased gradually northwards. In the north the structural trend changes from east-west (Variscan) to northeast-southwest (Caledonian) and the degree of folding in the Carboniferous rocks is much less intense.

Only a brief description of the different rock units and their inter-relationships is given in this report. More detailed descriptions are given in GSI booklets accompanying the 1:100,000 bedrock sheets 18 and 22. The rocks are described in groups, according to their age and starting with the oldest:

(i) Silurian rocks
(ii) Devonian rocks
(iii) Lower Carboniferous rocks
(iv) Upper Carboniferous rocks
(v) Tertiary deposits

The bedrock geology of the area is shown in Maps 1E and 1W, which were compiled from GSI bedrock sheets 18 and 22.

3.2 Silurian

The oldest rocks in South Tipperary are Silurian rocks which outcrop in the cores of Slievenamon, Slieve Phelim and the Galtee mountains (Fig. 1.1), and possibly constitute the geological basement throughout the whole area. A summary of the succession in the three areas is given in Table 3.1.

Table 3.1 Silurian Rock Nomenclature and Approximate Correlations

Slieve Phelim Uplands (from Doran, 1971)	**Galtee Uplands** (from Jackson, 1978)	**Slievenamon Uplands** (from Colthurst, 1974)
Hollyford Formation (HF) (>1000 metres thick) Greywackes and greenish-grey mudstones inter-bedded with thin siltstones and/or blackish-grey laminated siltstones, occasional grits, a few ash beds.	**Ballygeana Formation (BN)** (1275 metres thick) Black and grey siltstones and greywackes, with graptolitic shales. **Inchacoomb Formation (IB)** (1600 metres thick) Greywackes and dark greenish grey shales, purple siltstones and mudstones.	**South Lodge Formation (SL)** (>3000 metres thick) Greenish greywacke sandstones and slates, most of the greywackes have a calcareous matrix. **Rathclarish Formation (RA)** (340 metres thick) Grey graded turbiditic greywackes. **Ahenny Formation (AY)** (almost 3000 metres thick) Grey banded and blue-black slates, with some grey tuffs.

3.3 Devonian (Old Red Sandstone)

In South Tipperary the Old Red Sandstone outcrops around the Silurian inliers of Slieve Phelim, Slievenamon, the Galtees and the Knockmealdowns. The geological succession in the Devonian of South Tipperary is summarised in Table 3.2. The Devonian succession thins rapidly to the north (Capewell, 1957). As Table 3.2 shows, the Devonian rocks in the Galtees (Carruthers, 1985) and the Knockmealdowns are much thicker than the successions in Slievenamon and Slieve Phelim.

The Old Red Sandstones were folded by the Variscan (Hercynian) Orogeny. They are exposed at the surface where they cover entire anticlines (Galtees) and the flanks of these structures (Slievenamon) where the core of Silurian rocks is exposed. In the southern synclines, the Devonian sediments are overlain by thick (1,000-2,000m) Carboniferous sediments.

Table 3.2 Devonian Rock Units in South Tipperary

Galtee Uplands	Slievenamon Uplands	Knockmealdown Uplands	Slieve Phelim Uplands
Kiltorcan Fm (KT) 300m Coarse grained white-yellow sandstones, mud-flake conglomerate, red-yellow flaggy sandstone, green silty mudstone and green mudstone	**Kiltorcan Fm (KT)** 270m Coarse grained white-yellow sandstones, mud-flake conglomerate, red-yellow flaggy sandstone, green silty mudstone and green mudstone	**Kiltorcan Fm (KT)** Coarse grained white-yellow sandstones, mud-flake conglomerate, red-yellow flaggy sandstone, green silty mudstone and green mudstone	**Kiltorcan Fm (KT)** Coarse grained white-yellow sandstones, mud-flake conglomerate, red-yellow flaggy sandstone, green silty mudstone and green mudstone
Ardane Fm (AE) 70m Purple and white conglomerate, sandstone and scarce siltstone	**Carrigmaclea Fm (CI)** Red, brown and pink, quartz-cobble conglomerates, pebbly and cross-bedded sandstones and subordinate purple mudstones	**Knockmealdown Fm (KM)** Pink to purply-red medium grained sandstones with conglomerates and conglomeratic sandsones near the base	**Cappagh White Fm (CW)** Red and White sandstone and conglomerate
Poulgrania Fm (PL) 470m Fine to medium grained red sandstones with minor mudrocks		**Ballytrasna Fm (BS)** Dusky-red to purple mudstones with subordinate pale red sandstones	
Slievenamuck Fm (SL) 600m Conglomerates and pebbly sandstones with some purple mudrocks			
Lough Muskry Fm (LM) 328m Purplish conglomerate with sandstone channels and mudrocks			
Galtymore Fm (GS) 200m Massive cross-bedded and parallel-laminated medium to fine grained pale to greyish red sandstone			
Pigeon Rock Fm (PR) 160m Cobble to boulder-sized conglomerates composed mainly of Lower Palaeozoic clasts			

3.4 Carboniferous

2.4.1 Introduction

The Carboniferous was a period of marine deposition of a wide range of sediments, including sandstones, shales, muddy limestones and pure limestones. The Carboniferous in South Tipperary comprises two units: a lower (Dinantian), and an upper (Namurian and Westphalian). The Dinantian underlies the lowlands whereas the upper unit outcrops in the Slieveardagh Hills and in localised upland areas. Carboniferous rocks are the most widespread in South Tipperary.

At times during the Carboniferous, the depositional environment varied across the county and therefore rocks of a similar age have different compositions. So, for instance, the Waulsortian rocks (section 3.4.4) are overlain by a variety of rock units. The lateral variations are indicated on the legends of Maps 1E and 1W and are not described further in this report.

2.4.2 Dinantian

The Dinantian comprises various types of limestones, dolomites and shales found in a number of different structural and topographic settings. Three systems of nomenclature have been adopted for the northern, southwestern and southeastern areas as summarised in Table 3.3.

The southern region (southern synclines) is more intensively folded and faulted, and the succession is thicker there, getting progressively thinner northward.

Table 3.2 Dinantian Successions in South Tipperary

Northern Area	Southwestern Area	Southeastern Area
Clogrenan Fm (CL) Blue-grey crinoidal cherty limestone		
Ballyadams Fm (BM) Pale grey thick-bedded coarse grained crinoidal limestone with clay wayboards	**Hore Abbey Limestone Fm (HA)** Pale-grey to dark-grey limestone with variable texture	**Rathronan Fm (RR)** Massive unbedded pale-gray clean limestone with thin bedded cherts
Durrow Fm (DW) Fossiliferous limestones, some oolitic, and shales	**Lagganstown Fm (LG)** Dark-grey shaly, cherty, fine-grained limestone **Suir Limestone Fm (SU)** Pale-grey coarse limestones with shelly bands	***Fortwilliam Oolite member (CRfo)*** Fine-grained and oolitic limestone **Croane Fm (CR)** Dark-grey clean to muddy fine-grained limestone, calcareous mudstone and chert
Aghmacart Fm (AG) Very dark grey fine-grained muddy limestones, with thin dark-grey shales	**Athassel Limestone Fm (AT)** Dark-grey shale-parted fine-grained limestone with frequent chert bands and nodules, regular parallel beds	**Ballyglasheen Oolite Fm (BG)** Cross-bedded pale grey oolitic limestone **Kilsheelan Limestone Fm (KS)** Clean or slightly muddy limestones, occasionally cherty
Crosspatrick Fm (CS) Pale grey crinoidal limestone with much chert and some grey shale	**Knockordan Limestone Fm (KD)** Pale grey cherty coarse-grained linestone	**Silverspring Fm (SS)** Pale grey bedded cherts and dark limestones
Waulsortian Limestone (WA) Pale grey fossiliferous fine-grained limestones, often as massive knolls, with crinoidal or pale cherty shaly interbeds, often dolomitised	**Waulsortian Limestone (WA)** Pale grey fossiliferous fine-grained limestones, often as massive knolls, with crinoidal or pale cherty shaly interbeds, often dolomitised	**Waulsortian Limestone (WA)** Pale grey fossiliferous fine-grained limestones, often as massive knolls, with crinoidal or pale cherty shaly interbeds, often dolomitised
Ballysteen Limestone (BA) Dark grey shale-parted limestones, becoming increasingly muddy upwards ***Lisduff Oolite Member (BAld)*** Pale Grey cross-bedded oolitic limestone, variably dolomitised	**Ballysteen Limestone (BA)** Dark grey shale-parted limestones, becoming increasingly muddy upwards	**Ballysteen Limestone (BA)** Dark grey shale-parted limestones, becoming increasingly muddy upwards ***Bullock Park Bay Member (Babb)*** Cross-bedded oolitic limestone
	Ballymartin Fm (BT) Dark grey muddy limestone and inter-bedded dark-grey calcareous shales	**Ballymartin Fm (BT)** Dark grey muddy limestone and inter-bedded dark-grey calcareous shales
Lower Limestone Shale (LLS) Thin-bedded mudstones, sandstones and thin limestones	**Lower Limestone Shale (LLS)** Thin-bedded mudstones, sandstones and thin limestones	**Porter's Gate Fm (PG)** Grey sandstones, calcareous sand-stones, shales and thin limestones

3.4.3 Upper Carboniferous (Namurian & Westphalian)

The Upper Carboniferous rocks are sub-divided into the older Namurian and younger Westphalian rocks. These strata unconformably overlie the Dinantian limestones. The Slieveardagh Hills, once an important coal mining area in the northern area, has a complete Namurian succession whereas in the southern area only the lower section is found, and Westphalian rocks are absent.

3.4.3.1 Namurian

Two formations (Killeshin Silstone Formation and Bregaun Flagstone Formation) consist mainly of shales, mudstones and siltstones with occasional sandstone units. The sandstones are more common towards the middle and top of the Namurian, and a few are thick enough to be mapped.

For this study the Namurian formations of the northern area have not been subdivided. In the south (Carrick-on-Suir Syncline) the Namurian is represented by the **Giant's Grave Formation,** about 300 metres of dark mudstones with siltstones and sandstones (Keeley, 1980).

2.4.3.2 Westphalian

The Lickfinn Coal Formation occurs in the Slieveardagh Hills, conformably overlying Namurian rocks. The lowest sandstone layer is the **Glengoole Sandstone**, a coarse grey feldspathic sandstone, which comes to the surface at the perimeter and is thickest (30m) in the centre of the Slieveardagh Coalfield and thins towards the edges. It is discontinuous in the southeast, and in the southwest is replaced by another sandstone. The uppermost sandstone, the **Main Rock Sandstone**, is a grey-green, friable, micaceous sandstone, normally 8-10m thick although there is considerable variation.

3.5 Tertiary Deposits

The Tertiary Period (approximately 2 – 65 million years ago) is believed to have been a time of erosion, including the solution of the limestones and formation of extensive karst surfaces. Tertiary deposits are not extensive and are rarely exposed at the surface but have been met in boreholes at a few locations in the county. One deposit is at Ballymacadam (S 206 123) where a roughly circular hollow in Carboniferous limestone is infilled with white or bluish-white pipeclay, a very fine clay with some small silica crystals. 'Lignite' occurs above the pipeclay, apparently as local lenticular masses rather than a continuous layer. Thin drift overlies the hollow and the surrounding limestone (Watts, 1957).

Two similar deposits occur at Loughlohery (S 207 125) and one at Knockgraffon (S 204 130). Pipeclay predominates and lignite is not as well represented as at Ballymacadam, although the Loughlohery deposits are larger and deeper. The four deposits are similar in general character, and all occur at about 76 m elevation, so are probably contemporaneous (Watts, 1957). The deposits are too small to feature on the Bedrock Geology Map, and are not considered as aquifers.

3.6 Structural History

South Tipperary was affected by folding during the Caledonian (late Silurian to early Devonian) and Variscan or Hercynian (end-Carboniferous) mountain-building episodes. The effects of Caledonian deformation is seen in the Silurian rocks of the uplands, which are tightly folded and cleaved in a northeast-southwest direction. The major Variscan folds in the Devonian and Carboniferous strata have large amplitudes and wavelengths, and many of them can be traced for tens of kilometres along strike. The regional structural trend is west-southwest. Tension joints run along the crests of anticlines and the troughs of synclines, and north-south shear joints have opened. Faults tend to be planar and are often vertical or sub-vertical. The intensity of deformation decreases gradually northwards.

4 Subsoils (Quaternary) Geology

4.1 Introduction

This chapter deals with the geological materials which lie above the bedrock and beneath the topsoil. The subsoils were deposited during the Quaternary Period of geological history, which encompasses the last 1.6 million years and is sub-divided into: the Pleistocene (1.6 million to 10,000 years before present (B.P.)); and the more recent Holocene (10,000 years B.P. – present). The Pleistocene, commonly known as the 'Ice Age', comprised several periods of intense glaciation 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 (till), while others were deposited by water in and around the ice sheets and are relatively well sorted glacio-fluvial deposits (outwash).

The Holocene (Post-Glacial) epoch produced bog and alluvial deposits.

Subsoils are especially important in Irish hydrogeology because they affect groundwater movement and chemistry in the rock aquifers beneath. Subsoils are of very variable thickness and are found in many different topographic settings. Subsoils provide natural protection to groundwater, and in general offer most opportunity for attenuation of contaminants. Subsoils exhibit a wide range of permeabilities. Thick (>10m) and extensive permeable subsoils (i.e. sands and gravels) may be aquifers, often yielding large quantities of groundwater.

4.2 Availability of Information

The subsoil information for South Tipperary is sparse, but all available relevant data have been taken into account.

The 19th Century GSI 1:10,560 maps provided most of the information, but geologists at that time were mainly interested in bedrock outcrop, and little subsoil information was recorded. Simple descriptive terms such as drift (limestone or sandstone), limestone gravel, peat (bog), marl, and alluvium were used. The "drift-free" areas (with less than one metre of subsoil) are taken from the 1:63,360 GSI geology sheets. These are shown in white on Map 2.

Good information was obtained from the gas pipeline excavation which ran through the southern half of the county in the mid-1980s. Data were included from a few water wells and mineral exploration boreholes where subsoil information was recorded.

Some field mapping at 1:10,560 scale was undertaken at five sites which were taken as representative of the different environmental settings in South Tipperary. Present day field cuttings, river sections and gravel pits were mapped.

Map 2 was derived from all the information described above, taking into account the quality of the data and its intended use in evaluating groundwater vulnerability. **The map is not intended to be site-specific.**

4.3 Subsoil Types

Six subsoil types were identified in South Tipperary and are shown on Map 2:

- Till
- Sand and gravel
- Till-with-gravel

- Marl
- Alluvium
- Peat

Areas where bedrock comes within one metre of the surface are also shown on the map.

4.4 Till

Till (often referred to as boulder clay) is the most widespread and diverse deposit laid down by ice, and is more variable than any other sediment known by a single name. It may be classified in several ways, according to the type of parent material, method and environment of deposition, etc. In South Tipperary, the till can be divided into predominantly limestone or sandstone till, based on the dominant parent material. Further subdivision was not possible in the study area.

4.4.1 Limestone Till

Limestone till is the dominant type in South Tipperary, and is found throughout the lowlands. The limestone clasts have been weathered out in places, particularly in the older deposits of the Munsterian glaciation.

4.4.2 Sandstone Till

Sandstone till is found in the upland areas, associated with the underlying Old Red Sandstone, and is typically red in colour. The matrix may be more sandy than in the limestone till.

4.4.3 Namurian Till

This is not indicated on the subsoils map, as it was not delineated on the 19th Century maps. However, the Slieveardagh Hills are predominantly Namurian shales and sandstones and, based on information from a similar type area in Limerick, it is assumed that the Namurian till is a mainly clayey, shale-rich deposit with more fine material than the other tills.

4.4.4 Sands and Gravels

The central region of South Tipperary contains discontinuous pockets of sand and gravel. Deposition of sand and gravel takes place mainly during recessional phases, while glaciers melt: *kames* are formed from 'dead ice'; *eskers* are deposited from sub-glacial meltwater streams; and sandy/gravelly tills, deposited directly by the ice, have been reworked or 'cleaned out'. The subsoils deposited in these environments are primarily well rounded gravels with sand, with finer material (clay and silt) washed out.

The depth to bedrock map (Map 3) indicates sand/gravel areas with depths greater than ten metres and these may be considered as potential aquifers, depending on their grain size and sorting. Outwash deposits are cleaner and therefore more permeable than kame deposits.

4.6 Till-with-gravel

This term is used to describe the deposits in the centre of the county, which account for about 40% of the total cover. These deposits are a combination of till (which may be clayey, sandy, gravelly, stony, or a mixture of all these) with some limestone gravel. They are chaotic mixtures of permeable material, with pockets or lenses of sandy or gravelly material as well as some till, whose exact boundaries have not been mapped out. Detailed mapping probably would not radically alter the overall distribution pattern as described. The deposits are thought to be 'kame and kettle' as described by Synge (1970).

Weathering may be important in determining the permeability of limestone-dominated glacial deposits. The limestone in the till weathers out to depths greater than seven metres, leaving behind 'ghost' limestones (Warren, 1991). This probably increases its porosity, although the impact on permeability is more complex. The overall permeability of till is varied and extremely difficult to predict as tills are complex and diverse, and both lateral and vertical variations can be quite dramatic.

4.7 Marl

Marl is a whitish calcareous silt, often containing freshwater shells, and consisting of at least 90% $CaCO_3$. Originally deposited in lakes, its presence beneath bogs, marshes, and other low-lying areas indicates that lakes were once much more extensive. Marl is fine grained and compressible, with a low permeability.

4.8 Alluvium

Alluvium is a sediment deposited along the river bed and floodplain. It may include material from the coarsest sand and gravel to the finest clay and silt particles. Its permeability also varies considerably according to the grain size and sorting. Most coarse alluvial deposits are not sufficiently extensive horizontally and vertically to be considered as aquifers in their own right, but since such deposits generally comprise material reworked from older fluvio-glacial deposits, they are included with them.

4.9 Peat (Bog)

Peat is an unconsolidated brown to black organic material, a mixture of decomposed and undecomposed plant matter which accumulated in a waterlogged environment. Blanket bog is found on the higher upland areas where rainfall is very high. Basin peats are found in the low-lying areas of the central plain and are often associated with alluvium, lake clays and marls. These two peat types are nor differentiated on Map 2.

Deposition of peat occurred in post-glacial times with the onset of warmer and wetter climatic conditions. Permeability in peat is generally low and varies with the degree of humification - the more humified the peat, the less permeable. When sufficiently thick, this low permeability and the high attenuation capacity of peat ensure a high degree of protection for underlying aquifers. Peat has an extremely high water content, averaging over 90% by volume.

4.10 Subsoil Thicknesses

The thickness of the subsoil (the depth to bedrock) is a critical factor in determining groundwater vulnerability. Subsoil thicknesses vary considerably over the county and were spatially influenced by the direction of ice movement.

A depth-to-bedrock map (Map 3) has been prepared from the GSI databases, showing areas where rock outcrops at surface a,d depth-to-rock data from borehole records. There are three groups of borehole records, which are colour-coded according to the degree of locational accuracy. Data coloured red are plotted to within an accuracy of 50 m, the green data points are lessa accurately located (to within 100-500 m), while the blue data points are only referenced to the townland in which they were drilled and accuracies to within 1 km are to be expected.

Gravel deposits are usually less than 10 m thick, although there are a few deposits throughout the county which may reach greater thicknesses (see Chapter 5).

4.11 Distribution of Deposits

South Tipperary is largely covered by till, generally less than five metres thick. Pockets of thicker till and sand/gravel of variable thickness are scattered throughout the area. The predominantly limestone gravel areas in the centre of the county are surrounded by till. The deposition in this area was chaotic, and mixtures of sand, gravel and limestone till were deposited as the ice melted. The deposits surrounding the sand and gravel areas are referred to as 'till-with-gravel' deposits. Post-glacial alluvium is predominantly found along river channels and floodplains. These deposits vary from very coarse to fine along the Suir. The marl deposits at Ballagh (S 201 149) and Masterstown (S 204 133) are remnants of glacial lakes. Peat is found as raised and blanket bogs in the northeastern area, from Killough Hill (S 211 151) to Urlingford (S 228 163).

The distribution of deposits in the seven physiographic regions is outlined below:

4.11.1 Slieve Phelim Uplands

The dominant deposit in these uplands is thin Old Red Sandstone till. Smaller amounts of fluvio-glacial sand and gravel are found in the area of Ironmills. Slieve Phelim has a thin covering which is assumed to be blanket bog.

4.11.2 Middle Suir Lowlands

The central lowlands are dominated by discontinuous sand and gravel, till-with-gravel and limestone till deposits. This area is located behind the South Ireland End Moraine (SIEM). The low hummocky topography suggests ‘kame and kettle’ deposits. At Ballagh, there is a marl deposit plus a little peat and alluvium. An extensive peat deposit, assumed to be generally less than 10m deep, is found along the county boundary at Holycross (S 208 155).

4.11.3 Slieveardagh Uplands

The predominant deposit in this area is Namurian till, clayey and shale dominated. The subsoil is usually thin, with a lot of bedrock at or near the surface.

4.11.4 Slievenamon Uplands

Less than 30% of this region is covered by thin Old Red Sandstone till, with almost two thirds of the cover being limestone-dominated till. Some gravel deposits are found on the eastern side. Fresh limestone fragments(Munsterian) are found only at depth.

4.11.5 Golden Vale Lowlands

This region includes the lowland area from Mitchelstown to Carrick-on-Suir. The SIEM ice limit runs south of the Suir across to Piltown, Co. Kilkenny and then back around the outline of Slievenamon. Limestone till predominates, with a small area of till-with-gravel and scattered thin gravel deposits.

Most of the area has bedrock at less than five metres. The rivers Suir, Tar, Shanbally and Burncourt have alluvial deposits along their banks and the Suir river valley is marked out by alluvium. Around the Carrick and Kilsheelan areas, the alluvial deposits are gravelly.

4.11.6 Knockmealdown Uplands

These uplands have shallow subsoil deposits less than one metre thick. There is no information on the type of deposit but it is assumed to be Old Red Sandstone till.

4.11.7 Galtee Uplands

This area is bounded to the north by the Slievenamuck range and includes the Galtees. The predominant subsoil is till, consisting mainly of Old Red Sandstone fragments.

The Glen of Aherlow is covered by till-with-gravel, sand and gravel deposits and some Old Red Sandstone till. Some of the gravel deposits are thick; these deposits are assumed to be fairly well rounded and clean and therefore highly permeable.

Over most of the Galtees rock is close to the surface; the overlying deposits are not described, but are assumed to be Old Red Sandstone derived tills.

4.12 Hydrogeological Significance

The effect of the subsoils on groundwater movement depends on their permeability and, to a lesser extent, their thickness and area. Low permeability subsoils such as clays, silts, till and peat restrict the amount of infiltration reaching underlying aquifers. Where sufficiently thick and fine-grained, they may prevent infiltration almost completely, confining any underlying aquifer; in certain circumstances, artesian conditions may result. A positive effect of low permeability is that the movement of contaminants into an aquifer may be prevented, or their concentration sharply reduced.

Where permeable deposits are sufficiently thick, extensive, saturated and clean, they are considered to be aquifers in their own right and have potential for development. Where they are less extensive or unsaturated they are still important as allowing a high proportion of infiltration into an underlying aquifer with which they are in hydraulic continuity.

5 Hydrogeology and Aquifer Classification

5.1 Introduction

This chapter summarises the relevant available hydrogeological information for South Tipperary. The hydrogeological data points (springs, wells, and karst features) for the county are shown on Map 4 and the aquifers are shown on Maps 5E and 5W.

The geology is a controlling factor of the hydrogeologic regime. The long and complex geological history of the rocks in South Tipperary has considerably altered their hydrogeological properties. Their permeability is predominantly secondary and of the fissure type. Several geological factors influence the hydrogeological characteristics of particular strata:

- Lithology - grain size, sorting, proportion of shaly material and frequency of impermeable layers.
- Geological history of the particular strata - the degree of consolidation, metamorphic history, weathering/erosion since deposition, the amount of structural deformation and structural setting.
- The present location of the particular strata both topographically and relative to other strata and also their position relative to groundwater circulation.
- The degree of active groundwater circulation both now and in the past.

Faulting has a number of effects on groundwater flow:

- It breaks up the strata, making them more jointed.
- The faults themselves can act as conduits for flow.
- They can partially or completely cut off the flow from one part of an aquifer to another.
- They may also connect different aquifers or they may cut off the recharge area.
- Faulting may lower a formation to a depth at which development is not practical.

Folding and faulting create a secondary permeability which allows circulation along fault and joint zones. The intensity of the structural deformation is very much less in the northern region, where dolomitisation is the dominant factor influencing permeability of the limestones. Dolomitisation is associated with jointing, shrinkage cracks, sand filled cavities, vugs and extensive weathering. Although apparently scattered randomly throughout the formation, these features appear to be more concentrated at the top and along fault zones (Daly, E.P., 1993a). Undolomitised limestone in the north is very tight and has a low permeability. In the southern synclines the intensity of structural deformation, as well as dolomitisation, is responsible for secondary porosity and permeability, and even where dolomitisation is absent there is a good secondary permeability.

5.2 Data Availability

All groundwater data in the GSI and County Council files were compiled and all existing well records entered into the GSI computer database. Borehole data for exact locations are scarce.

The assessment of the hydrogeology of South Tipperary is based on the following data and reports:

- Groundwater abstraction rates for local authority (Table 5.1) and group scheme sources, and for a limited number of other high yielding private wells
- Information from approximately 400 well records in GSI files
- Information on large springs
- Reports by engineering and hydrogeological consultants
- General hydrogeological experience of the GSI, including work carried out in adjacent counties and a review of groundwater in the south Munster region (Wright, 1997)

5.3 Groundwater Usage

There are 28 public and private group water schemes in South Tipperary which use groundwater. The County Council public supplies using groundwater are summarised in Table 5.1. Areas not served by the Council or group water schemes generally rely on individual private wells as the main source of water supply.

Table 5.1 Summary of County Council Public Supplies

(compiled from County Council data)

Scheme	Abstraction (approx), m^3/d	Source type
Glengar (1)	409	Spring
Hollyford (2)	50	Spring
Ironmills (3)	1363	Borehole
Goold's Cross	237	Borehole
Synone	280	Borehole
Holycross		Borehole
Laffansbridge	980	Borehole
Coalbrook (8)	636	Borehole
Ballincurry (9)	272	Borehole
Gorteen (10)		Borehole
Commons (11)	100	Borehole
Rathbeg		Borehole
Triandra		Borehole
Inchirourke	320	Borehole
Grangemockler (15)		Borehole
Ballinvir (16)	70	Borehole
Ahenny (17)	27	Borehole
Tullohea (18)	204	Spring
Cloran (19)	2509	Spring
Mullenbawn (20)	2290	Spring
Springmount (21)	1820	Spring
Fawnagowan	3023	Borehole
Rossadrehid	2350	Borehole + Spring
Kilcoran		Borehole
Kedrah (25)		Spring
Coolnamuck		Borehole
Clogheen (27)	136	Spring
Ballyporeen		Spring

5.4 General Aquifer Classification

Bedrock aquifers (i.e. fissure flow aquifers) are divided into three main categories: **Regionally Important**, **Locally Important**, and **Poor** aquifers. Each category is sub-divided into two or three classes:

Regionally Important (R) (or Major) **Aquifers**

(i) Karstic bedrock aquifers (Rk)

(ii) Fissured bedrock aquifers (Rf)
(iii) Extensive sand/gravel aquifers (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 in local zones (Pl)
(ii) Bedrock which is generally unproductive

These aquifer categories take account of the following factors:

- The overall potential groundwater resources in each rock unit
- The area of 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
- The fact that all bedrock types can 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 tend to have 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 (usually a low permeability – 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 (pumping rate per unit drawdown), and well yields.

Although the main type of information available for aquifer classification in South Tipperary is well yields, many other sources of information have been used, including bedrock lithology, structural deformation, surface drainage characteristics and pumping tests. It should be noted that the aquifer delineation is a generalisation which reflects the overall resource potential, and that because of the complex and variable nature of Irish hydrogeology, there will often be exceptionally low or high yields which do not change the overall category given to any particular rock unit. It is also important to remember that the top few metres of any bedrock type is likely to be relatively permeable.

The principal hydrogeological features (springs, wells and karst features) are shown on Map 4. There is a great scarcity of borehole data which can be assigned to exact locations. Well yields given in GSI well records normally represent minimum yields. No detailed pumping tests were carried out for this project, so there are very few drawdown values or specific capacities. Aquifer characteristics for selected regionally and locally important aquifers, largely derived from work by E.P. Daly in the neighbouring Nore Basin, are shown in Table 5.2.

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

Table 5.2 Aquifer Characteristics in South Tipperary compared with the Nore River Basin

Strata	Aquifer Category	Well/Spring Yield (m^3/d)		Specific Capacity ($m^3/d/m$)		Transmissivity (m^2/d)	
		South Tipperary	Nore Basin	South Tipperary	Nore Basin	South Tipperary	Nore Basin
Kiltorcan Formation	Regionally Important	2509-2350	50-1300	4.12	2-270	-	40-100
Waulsortian Formation	Regionally Important	196-21600	300-3000	-	10-350	-	50-800
Ballyadams Formation	Regionally Important	164-2273	10-2000	-	100-300	-	1-500
Rathronan/ Ballyglasheen unit	Regionally Important	600	-	150	-	100-2000	-
Crosspatrick/ Silverspring unit	Locally Important	436-654	250-2400	8.6	10-250	-	20-200
Westphalian Sandstones	Locally Important	1055	100-500	-	10	-	5-15
Sands & Gravels	Locally Important	1308-1820	200-1000	48-76	50-2000	-	100-2000

5.5 Silurian Rocks

These strata outcrop in the core of the Slieve Phelim, Galtee, Slievenamon and Knockmealdown mountains. The rocks are generally similar throughout the upland areas and are predominantly greywackes, siltstones, mudstones and shales. These rocks are mainly fine-grained, and have been subjected to deep burial and intensive folding. They therefore have low permeability, and groundwater circulation will normally be restricted to the near-surface zone, although the Silurian/Old Red Sandstone unconformity is a likely zone of higher permeability They generally occur on high ground where groundwater flow does not concentrate.

Well records for Silurian rocks are scanty. In general, permeability is low, but in the upper few metres, permeabilities are often high although they decrease rapidly with depth. Local zones of higher permeability will be present, usually due to faulting. Evidence of the relatively low permeabilities is provided by the drainage density and flashy runoff response to rainfall in areas underlain by Silurian rocks. Some strata are generally unproductive, and are classified as **'Poor aquifers'**. Within the Silurian rocks, some units of limited extent are probably more permeable than the rest of the Silurian because they include some hard and brittle igneous rocks which fracture more readily than the surrounding strata: these comprise the Brownstown Member of the Ahenny Formation. This is classified as **'Poor Aquifer - generally unproductive except for local zones'** (**Pl** on the Aquifer Map). The remaining strata, principally the Hollyford Formation, are classified as '**generally unproductive'** (**Pu** on the Aquifer Map). Specific capacities in the Hollyford Formation seem to be typically less than 5 $m^3/d/m$, even at low pumping rates.

Water levels in Silurian rocks are shallow, usually less than 15m below surface. While groundwater in these rocks is usually unconfined, clayey till and peat sometimes confine the groundwater and flowing artesian boreholes can be encountered in low lying areas.

5.4 Old Red Sandstone (ORS)

(Carrigmaclea/Cappagh White, etc., formations)

This hydrogeological unit includes all Old Red Sandstone formations with the exception of the topmost unit, the Kiltorcan Sandstone Formation. These formations generally occur as relatively high ground, indicating a resistance to weathering. They also contain a lot of fine grained material (mudstone/siltstone), hence they have a low permeability except in areas of localised intense faulting. This unit is considered a moderately productive local aquifer. The sandstones have no primary permeability, but faulting provides some very local zones of secondary permeability. It usually outcrops at high elevations and so the cover is very thin and the strata unconfined. Water levels within the unit are generally less than 15 m below ground surface with an average of approximately 12 m although this varies depending on topography. There are no records of any artesian water but aquifers may be confined in places beneath less permeable mudstones and siltstones. Generally these rocks outcrop at high elevations on the flanks of hills and are unconfined. In the northern area the intensity of the faulting is reduced, therefore the localised permeability will also be reduced.

For this study this unit is classified as a **Locally Important Aquifer - moderately productive only in local zones (Ll** on the Aquifer Map**)**. This is largely based on the number of small but significant public groundwater supply sources found in this unit in the neighbouring counties of Waterford and Limerick. In South Tipperary the only important public source is the large spring at Cloran (2500 m^3/day).

Larger supplies may be developed where storage is increased by overlying gravels or where the borehole is sited close to a major fault zone.

5.7 Kiltorcan Sandstone (KT) & Porter's Gate (PG) formations

The Kiltorcan Formation (of Devonian age) has a low proportion of fine grained material and is laterally consistent. The Kiltorcan is dominated by coarse grained or flaggy sandstones, particularly at the top of the formation, as shown by numerous borehole logs in the adjoining Nore River Basin. The Porter's Gate Formation (of Carboniferous age) contains thinly interbedded units of coarse and fine material, limiting the development of transmissivity. The lower part of the formation normally contains more permeable material than the upper. The fine grained material at the top of the formation confines this aquifer and protects it from contamination.

The Kiltorcan Formation and the overlying Porter's Gate Formation are together considered to be a **Regionally Important Aquifer** - fissure flow (**Rf**) in this area. The Kiltorcan is the formation in which deepest ground-water flow is likely to occur and is important for this aspect alone.

The permeability of the different parts of the Kiltorcan Formation depends primarily on the proportion of sandstone present, the thickness of the individual sandstone units and their degree of interconnection. The well yield and permeability are greatest in the south where the deformational intensity is greatest. The thickness and transmissivity of the Kiltorcan, both in outcrop and at depth, decrease to the east.

The Kiltorcan sandstones are relatively susceptible to weathering and tend to break up and decompose relatively easily because:

- They are dolomitised in places.
- They frequently have a dolomitic or calcareous cement, which is slightly soluble.
- They contain easily weathered feldspars.

Where these features are common, the rocks will be more porous near the surface, and this will give them some intergranular permeability.
In the outcrop area the formation may be either unconfined in continuity with sands and gravels, or confined by till. At depth it is confined by the overlying shaly strata.

The permeability of this aquifer mainly results from faults, joints and microfractures. The intensity of fracturing may vary over relatively short distances. It has been established that the positive fractures extend to depths of over 100m. Its permeability is greatest towards the base of the Porter's Gate and in the upper half of the Kiltorcan, and close to major structural features. Transmissivity will be reduced at depth, where the Kiltorcan Formation is thinner in the centre of the synclines and permeability is reduced by the deep burial. Downdip towards the middle of the synclines, the aquifer becomes progressively more confined by an increase in thickness of the overlying beds. Substantial artesian flows have been recorded in this aquifer due to the pressure of the water table in the elevated outcrop area. Evidence from drilling in the Kiltorcan Formation shows that the largest well yields are obtained at relatively low elevations, close to major structural features and where at least 40 m of the upper part of the Kiltorcan is penetrated.

There is no obvious discharge zone for groundwater moving at depth in this aquifer, but it probably flows via large faults and complex pathways into shallower groundwaters. Large faults may also retard deep groundwater circulation, either by isolating all or part of one block of an aquifer from another or by isolating the recharge area from deeper parts of the aquifer.

In the northern area the dip of the strata and the intensity of structural deformation decrease.

Extensive work carried out on this aquifer in the Nore Basin indicates that transmissivities of up to 500 m^2/d are common. Specific yield is normally about 2% although near the surface it can be as high as 5% (Daly, E.P., 1988). Tests on wells in the Clonaslee Sandstone (a similar sandstone) in Co. Laois show the aquifer potential there to be somewhat less (Daly *et al*, 1997).

5.8 Dinantian Limestones

The Dinantian comprises various types of limestones, dolomites and shales found in a number of different structural and topographic settings. The aquifers in these strata are, in some cases, the most extensive and productive in the region and so are described in some detail.

Two conceptual models have been developed to describe the hydrogeology of the two areas into which the county has been divided, northern and southern. The boundary between the two areas runs from near Mullinahone, north of Slievenamon, in the east, across to the Aherlow valley, north of the Galtees in the west, and is shown in Map 1 (Bedrock Geology). The divide into north and south takes account of the hydrogeological differences in the Dinantian limestones. The conceptual models are based on work undertaken in the South Munster Synclines (Wright, 1979) and in the Nore River basin (Daly, E.P., 1992). It is assumed that the geology in the South Munster Synclines (mainly County Cork) is similar to that in the southern area and that the Nore River Basin is comparable to the northern part of South Tipperary. Baseflow analysis, hydrogeological features, well yields and specific capacities have been used in determining the aquifer properties.

The limestones in the southern area are extensively faulted and folded. The Dinantian succession according to Wright (1979) may be treated for the most part as being one aquifer as the lithology appears to be of a lesser importance than the faulting.

Some hydrogeological features are common to most limestones in South Tipperary. These are: secondary porosity and permeability due to faulting, dolomitisation and karstification. These characteristics are normally most developed in the upper 10-20m of rock, owing to the effects of weathering, geologic conditions and water movement.

conditions in the main limestone aquifers are predominantly unconfined as the water table is generally less than 10m from the surface. The annual water table fluctuation is probably less than 5m in the better aquifers. Most of the groundwater moves relatively rapidly along short flow paths and discharges into the streams which cross the aquifers. Recharge to the rock aquifers often takes place through the Quaternary deposits. Optimum well yields from the Dinantian limestones will be obtained from boreholes drilled into one of the major fault zones and penetrating at least 50-100 m of the aquifer. The extensive weathering in the dolomitised Waulsortian and Crosspatrick formations creates problems for drilling. The karstic nature of the Ballyadams Formation also creates problems for the location of high yielding sources. These zones of karstification indicate productive zones and need to be identified.

5.8.1 Lower Limestone Shale (LLS)
(including the Mellon House (MH), Ringmoylan (RM) & Ballyvergin (BV) formations)

There is little available hydrogeological information for this rock unit. However, the shaly nature suggests that permeabilities will be low. It is classed as a **Poor Aquifer which is generally unproductive (Pu)**.

5.8.2. Ballysteen (BA) & Ballymartin (BT) formations

The Ballymartin and Ballysteen formations are grouped together and predominantly consist of shales and argillaceous limestones, bounded at the base by the Kiltorcan Formation and at the top by the Waulsortian unit. The Ballymartin and the upper part of the Ballysteen are generally thin bedded and contain substantial clayey material. There are some cleaner, coarser units more susceptible to solution and karstification but this is unlikely to be significant at depth. In contrast, the lower Ballysteen Formation is cleaner, with thicker units.

This unit is generally unproductive. The lithology of the strata suggests they have no primary permeability and they tend to deform plastically when subjected to stress. They are generally unconfined where they outcrop, as the subsoil cover is usually thin. Well yields are generally low, but there are a number of medium-sized springs issuing from the Ballysteen and a few swallow holes and caves, indicating some suceptibility to karstification. It is believed that this karstification is limited to the cleaner limestones in the lower part of the Ballysteen. As a whole, the unit is classified as a **Poor Aquifer - generally unproductive except in local zones** (**Pl**).

5.8.3 WaulsortianLimestone (WA) & Silverspring (SS) formations

The Waulsortian Limestone is one of the most extensive rock units in South Tipperary and is the most important aquifer in the county. There is evidence of karstification, dolomitisation and permeability variations with depth in this aquifer. Water levels in this formation are generally quite shallow at less than 10 m although there are records of unsaturated zones of up to 30 m. Groundwater level fluctuations of 6 m between summer and winter are typical. Hydraulic gradients in the Waulsortian Limestone are typically low (0.003 – 0.007).

This unit is a highly productive aquifer in which very large springs are found, such as Poulalee and Poulatar near Ardfinnan. The adjacent Silverspring Formation comprises pale grey bedded cherts and dark grey siliceous biomicritic limestones and is included in this aquifer unit as it is also clean and affected by the intense faulting. The limestone outcrops at the surface at the edges of the synclinal basin. The overlying subsoil is usually limestone till and generally less than five metres thick.

Detailed work at Kedrah by Jones and Fitzsimmons (1992) discovered extensive dolomitisation within the Waulsortian Formation. The dolomitisation, although part of a broad regional event, appears to be fault and/or joint controlled, with a northeast trend. A varying degree of dolomitisation is exhibited in outcrop and, though not mapped in detail, is more significant in the northern area and occurs only in small localised patches in the southern synclines.

The Waulsortian Limestone and Silverspring Formation in South Tipperary are classed as **Regionally Important karstic aquifers (Rk).**

5.8.5 Crosspatrick Formation (CS)

This formation outcrops in thin narrow bands in the northern area. The Crosspatrick mainly consists of clean, generally thick bedded limestones which are dolomitised in places, especially in the east where the contact with the Waulsortian Formation is obscured. The Crosspatrick Formation is more permeable where it is dolomitised. The presence of some clayey and shale units may restrict groundwater circulation. The strata boundaries are not well defined due to the extensive dolomitisation. It overlies the dolomitised Waulsortian limestones to the northeast and the Ballysteen Formation in the west, where it only developed as mounds.

Down-dip the formation becomes confined and is probably much less permeable. Over the outcrop area the hydraulic conditions vary from unconfined, where it is in continuity with overlying sands and gravel, to being confined by thick till or till-with-gravel. The aquifer is recharged in the higher areas where the subsoils are thin and permeable. It discharges into the small streams that cross it.

Recorded well yields in the are in the range of 250-654 m^3/day, with estimated specific capacities of 8-20 m^3/day/m. Transmissivities in the Nore River Basin are 20-200 m^2/day. The Crosspatrick Formation is classified as a **Locally Important Aquifer - generally moderately productive (Lm)**.

5.8.6 Aghmacart Formation (AG), Athassel Limestone (AT), Durrow Limestone (DW) & Lagganstown (LG) formations.

The Aghmacart, Athassel, Durrow and Lagganstown formations have a generally low permeability since they are fine grained, thin bedded and compact. The clay content and the interbedding of clean and muddy limestones have restricted groundwater flow and prevented karstification. Hence these formations are classed as **Poor Aquifers - generally unproductive except in local zones (Pl)**.

5.8.7 Clean bedded limestones: Ballyglasheen Oolite (BG), Clogrenan Limestone (CL), Kilsheelan Limestone (KS), Croane Limestone (CR), Knockordan Limestone (), Rathronan Limestone (RR), Suir Limestone (SU) & Hore Abbey Limestone (HA).

Kilsheelan: The upper part of the Kilsheelan is predominantly coarse-grained thick bedded clean limestones. Permeability in is secondary; the structural deformation in this region enhanced the development of karst in the upper unit of this formation. The extent of the karstification has not been mapped but there is evidence of karst at Garyclogher (S 202 123), with abundant depressions and swallow holes, and a local stream sinks during the summer. It was reported locally that these depressions are still active: ground had once collapsed beneath a horse and plough, and more recently had engulfed a lawnmower. Mitchelstown Caves, the best-known caves in South Tipperary, in the upper part of the formation, reveal north-south fracturing at depth (Gunn, 1984). Work carried out in Mullinahone by Gunn also confirms the influence of north-south jointing.

The upper part of the Kilsheelan Formation seems more permeable than the rest of the unit. Where karstification has not developed, the lithology of the rest of the formation suggests that it is less permeable but some secondary permeability is developed in fault zones. Some dolomitisation occurs in isolated areas, especially west of Clonmel.

Croane: The Croane Formation consists of thin bedded dark micritic limestones with shales and cherts. It is generally unconfined except where overlain by about ten metres of impermeable subsoil

Reliable well data for this unit are sparse and the largest yield noted was 221 m^3/day (2.5 lps). The unit has been tentatively classified as a Regionally Important Aquifer on the basis of its known susceptibility to karstification.

Ballyglasheen: The Ballyglasheen Formation consists of clean, cross bedded, pale grey, oolitic limestones which are likely to be susceptible to solution.

Rathronan: The lithology of the Rathronan does not suggest a regionally important aquifer, but the extensive faulting and resultant karstification have created a good secondary permeability. There is very good evidence for karstification: the Thonogue river sinks southeast of Ardfinnan, and about one kilometre east of the sink, on the banks of the Suir, is a very large spring, Roaring Well. There is a postulated connection between the two (pers. com. G.Ll. Jones). The flow is more conduit-type than diffuse, but the faulting may tend to retard it as the groundwater has a tortuous pathway between blocks.

The aquifer is generally unconfined in the outcrop area. Transmissivity and storativity values are unknown for this unit. Shallow flow is towards the streams, but at depth the flow is southeasterly.

While the information in South Tipperary is poor, these limestones are tentatively classed as **Regionally Important karstic aquifers (Rk)**. Evidence suggests that the Rathronan and Kilsheelan Limestones are cleaner, more karstified and therefore more permeable than the Croane Limestone.

5.8.8 Ballyadams Limestone (BM)

The Ballyadams Formation is a very clean, massive bedded limestone with a middle unit containing some clay wayboards. The secondary permeability of these strata results from fissures and joints which have been enlarged by solution, as confirmed by the presence of swallow holes, springs and a turlough. The Ballyadams Formation is very susceptible to karstification which is accentuated along structural features such as fold axes and faults and can result in very high permeability and throughput in relatively narrow zones. This aquifer receives recharge from runoff from the Namurian hills through the swallow holes at its margins, as well as direct recharge through the subsoil.

However, only that part of the formation which crops out at the surface and lies above the lowest drainage level is considered to be a major aquifer. In the lower unit and the lower part of the upper unit of this formation there is preferential karstification, but the clay layers in the middle unit restrict groundwater circulation and therefore the vertical development of secondary permeability. In certain situations, there may be horizontal development along the clay layers. This unit is also characterised by its steeply rising water table. Faulting may allow interconnection between formational units.

Flow in the karstified systems tends to be conduit flow along the fault zones. There are considerable variations in the hydrogeological conditions in this aquifer unit, owing to the wide range in elevation of the outcrop areas and its karstic nature.

It is only possible to selectively exploit this aquifer but it has a high baseflow discharge to the rivers. This is clearly seen in the area of Loughcapple Bridge (southeast of Fethard), where there is at least a fourfold increase in baseflow over a 3km reach. The area around Fethard is a very important example of this aquifer.

The middle part of the Ballyadams Formation contains clay wayboards, and outcrops on sloping ground which limits the area exposed at surface. This will restrict groundwater circulation, and therefore the vertical development of permeability, to fairly small areas. Secondary permeability within the limestones has developed horizontally due to the presence of the clay wayboards. The extent of this horizontal development varies from 10-30m. The lower part of the formation is quite thick and a wide section of the aquifer is open to the surface and available for recharge. Solution processes are unhindered, and large groundwater circulation systems can develop, resulting in high permeability zones being formed (Daly, E.P., 1992).

The Ballyadams Limestone is classified as a **Regionally Important karst aquifer (Rk)**, largely on the basis of its many karst features - springs, swallow holes and caves, and obvious high groundwater throughput.

5.9 Volcanics

In the northwestern part of the riding there are a few small outcrops of Carboniferous volcanic rocks. Nothing is known about their hydrogeology but they are tentatively classified as a **Locally Important Aquifer - generally moderately productive** (**Lm**) on the basis of information on similar rocks in neighbouring areas of County Limerick.

The volcanic rock in Co. Limerick are of two types: 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. While it is usually thought that the more acidic volcanic rocks have the greater permeability, well records in Limerick suggest that the larger supplies come from the basaltic lavas. However, this is inconclusive as the lavas and tuffs are often interbedded and groundwater may originate in an underlying confined tuff band.

Water levels are variable, reaching up to 20 m below ground, and the groundwater is usually unconfined.

5.10 Namurian (NAM): Killeshin Siltstone (KN), Bregaun Flagstone (BE) & Giant's Grave (GG) formations

These rocks contain a lot of shale, especially in the lower part of the Namurian, confining the underlying formations and restricting groundwater movement throughout the whole succession by their impermeability. Faulting in these strata has cut off flow from one block to another; so there is no continuous flow system. Outcrops accept little recharge and there is a high percentage of run-off, which then sinks underground through swallow holes in the adjoining limestone formations.

The sandstone beds within the rock groups have a slightly higher permeability than the shales due to their greater ability to fracture. Some sandstones in the middle and upper part of the succession are extensive enough to have minor water resource potential.

The whole Namurian succession is classified as a **Poor Aquifer - generally unproductive except in local zones** (**Pl**).

5.11 Westphalian (Coal Measures) rocks

These occur only in the Slieveardagh Hills and include two important sandstone units (the Glengoole and Main Rock sandstones) and some minor ones. These two main sandstones, although very hard, and having no primary permeability, have developed significant secondary permeability as a result of the widespread folding and faulting and associated jointing. The Glengoole is the more productive. The transmissivity of these sandstones is relatively low but has been found to be an order of magnitude higher near faults. The sandstones are confined at depth by overlying shales, coal seams, and fireclays, and frequently give artesian flows. The mainly impermeable subsoils, the shaly strata and the geological structure limit the amount of recharge available and therefore the throughput of these aquifers. The hydrogeology of this area has been described in detail by E.P. Daly (1980b).

They are classified as a **Locally Important Aquifer - generally moderately productive** (**Lm**).

5.12 Sands and Gravel aquifers

Sand/gravel deposits have a dual role in groundwater development and supply: firstly, they can supply significant quantities of water, and secondly they provide storage for underlying bedrock aquifers. Even where the sands/gravels are thin they can have a major effect on the recharge and discharge of underlying rock aquifers.

A sand/gravel deposit is classed as an aquifer if it is more than 10m thick and more than one square kilometre in extent. The thickness of the deposit is taken, rather than the more relevant saturated zone thickness as the latter information is rarely available. It is generally assumed that a 10m thick deposit will have a saturated zone of at least 5m, except where deposits have a high relief, for example eskers or deposits in uplands, as these gravels often have a thin unsaturated zone.

Sand/gravel aquifers are classed as regionally important or locally important; a regionally important gravel aquifer should have an areal extent greater than about 10 km^2. This is to ensure that, in taking an average annual rainfall of 400mm, there will be enough recharge to provide a supply of one million cubic metres per year from the whole aquifer. A locally important gravel aquifer will have an area between 1 and 10 km^2, with enough storage to supply a small group scheme or village.

The sands and gravels in South Tipperary are generally thin (< 10m) except in a few areas in the central region around Tipperary town. Numerous springs discharge from limestone aquifers via through these deposits, for example at Rathcoole (S 219 137).

The hydraulic conditions of the sand/gravel aquifers depend on the type of deposit, whether outwash or valley train deposit. The outwash sand and gravel aquifers are cleaner and therefore more permeable. The water table in the sand/gravel aquifers is usually within 5m of ground level and its annual fluctuation less than 1m.

Well yields in these deposits vary significantly. The public spring source at Springmount, from a clean sand and gravel deposit, yields 1820 m^3/day, and that at Ironmills, from a fluvio-glacial deposit, 1325 m^3/day.

The sand/gravel aquifers are generally unconfined (no buried subsoil aquifers are known) and are usually in continuity with the underlying strata. The thickness of the saturated zone determines the well yield. As the subsoils have not been mapped in detail, it is difficult to define the true extent and thickness of potential aquifers.

On the basis of the subsoils map (Map 2) and the depth-to-bedrock map (Map 3) no sand/gravel deposit in South Tipperary is large enough to be considered a regionally important aquifer. There are two potential sand/gravel aquifers in the northern area, at Mocklershill (S 213 140) and Donaskeagh (R 194 141). These deposits are extensive and over ten metres thick and are classified as **Locally Important Aquifers (Lg).**

Site investigation may also prove other gravel deposits to be aquifers. 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.

5.13 Summary of Aquifer Categories

The rock units in South Tipperary are classified into the different aquifer categories in Table 5.3.

Table 5.3 Aquifer Classifications

Aquifer Category	Subdivision	Rock Unit
Regionally Important (R)	Sand/Gravel (Rg)	(none)
	Karstified (Rk)	Ballyadams Limestone Waulsortian Limestone Kilsheelan, Croane, Rathronan, Hore Abbey, Suir, Ballyglasheen Oolite, Clogrenan, Knockordan Limestones
	Fissure Flow (Rf)	Kiltorcan Sandstone/Porter's Gate formations
Locally Important (L)	Sand/Gravel (Lg)	Local deposits
	Bedrock – generally moderately productive (Lm)	Westphalian sandstones Crosspatrick Limestone Volcanics
	Bedrock – moderately productive only in local zones (Ll)	Old Red Sandstone
Poor (P)	Bedrock – generally unproductive except in local zones (Pl)	Namurian rocks Ballysteen & Ballymartin Limestones Aghmacart, Athassel, Durrow, and Lagganstown Limestones Silurian (in part)
	Bedrock – generally unproductive (Pu)	Lower Limestone Shale Silurian (in part)

5.14 Potential for Future Groundwater Development in South Tipperary

5.14.1 Waulsortian Limestone

This is the rock unit with the best proven aquifer potential in the soouthern part of South Tipperary, though less reliable in the northern part. It is capable of supplying regional schemes and large industries. However, random drilling is not recommended as it will not give optimum results. A careful hydrogeological investigation, involving the use of geophysics, will increase the probability of success. Also, as improved geological information becomes available on dolomitised areas and zones, the ability to choose high permeability areas will improve. However, developing the karstified areas may be problematical due to the uneven distribution of permeability and, in places, to the vulnerable nature of the aquifer.

5.14.2 Clean Limestones (Ballyadams, Kilsheelan, Croane, Hore Abbey, Ballyglasheen, Clogrenan, Suir and Rathronan formations)

The relatively pure nature of these limestones, and information from other counties, suggest that these have the potential to supply significant quantities of water. Careful hydrogeological investigation, involving the use of geophysics, will increase the probability of success.

5.14.3 Kiltorcan Sandstone

This rock unit has proven potential, as shown by boreholes in north Cork, Waterford, Laois and Kilkenny. However, it is important to locate wells, as far as possible, in optimum areas – close to faults and along the contact with the overlying less permeable rocks. Compared to limestone aquifers it has several advantages: it yields a softer water, it is often artesian or sub-artesian, and it generally has a lower vulnerability (Wright, 1997).

5.14.4 Sand/Gravel

Carefully sited wells would be 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.

5.14.5 Westphalian Sandstones

This rock unit has proven potential to supply small public and group water schemes. Boreholes should be located, as far as possible, in optimum areas – close to faults and at sufficient depth to develop some artesian pressure.

5.14.6 Muddy Limestones (Aghmacart, Athassel, Durrow, Lagganstown, Ballysteen, Ballymartin formations and Lower Limestone Shale)

While there are local zones of higher permeability and a number of public supplies are located in these rocks, they are unlikely to have the potential to supply regional schemes. 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.

5.14.7 Volcanics

The areas of volcanics are too small to supply regional schemes. Also, too little information is available to allow a proper assessment of the potential of these rocks.

5.14.8 Silurian rocks and Old Red Sandstone

Although well yields are highly variable, wells in high permeability fault or fracture zones are capable of supplying small public and group water schemes.

5.14.9 Namurian rocks

These rocks do not have the potential to provide sufficient yield to satisfy the likely needs of the 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 the Namurian rocks frequently have a high iron concentration.

6 - Hydrochemistry and Water Quality

6.1 Sources of information

Groundwater analyses were compiled to investigate the hydrochemistry and water quality of the main strata of South Tipperary. A total of 164 analyses, dating from 1984 to May 1993, were collected from all available sources: the County Council, Regional Water Laboratory, private springs and industrial supplies. 93 full analyses were obtained, the remainder were partial analyses. No regular sampling regime was operating during this time.

The EU Standard (Quality of Water Intended for Human Consumption, 80/778/EC) is implemented in Irish law by Water intended for Human Consumption Standards (SI 81 of 1988) (Drinking Water Standards). There are some differences between the EU and Irish standards, which have both been used for comparison of the analyses (Table 6.1). The EU standard refers to all drinking waters irrespective of their source. A statistical analysis of exceedances and compliances enables a water quality assessment.

The frequency of sampling does not allow annual variations in chemistry and water quality to be assessed. Additional sampling will be needed to verify the conclusions of this report.

Table 6.1 Parameters exceeding the Drinking Water Standards (80/778/EEC and SI 81 of 1988)

Parameter (units)	EU Drinking Water Standard (80/778/EEC)		Water Intended for Human Consumption (S.I. 81 of 1988)	
	MAC value	No. of exceedances	MAC value	No. of exceedances
Calcium (mg/l)	-	-	200	5
Chloride (mg/l)	-	-	250	1
Ammonia (mg/l)	0.38	2	0.23	3
Colour (Hazen units)	20	6	20	6
Copper (mg/l)	-	-	0.5	1
Manganese(mg/l)	0.05	17	0.05	17
Magnesium(mg/l)	50	4	50	4
Nitrate as N (mg/l)	11.3	1	11.3	1
Total Iron (mg/l)	0.2	5	0.2	5
E. *coli* (/100ml)	0	22	0	22
Total coliforms (/100ml)	0	37	0	37
Zinc (mg/l)	-	-	1	1

6.2 Hydrochemical Characteristics

6.2.1 Water Type

In general the groundwater in South Tipperary is a calcium bicarbonate rich water, due to the predominance of limestone or limestone-derived subsoils. Limestone dissolution is the principal hydrochemical process in the strata of this area.

In some analyses, from areas underlain by Silurian rocks, the water type is sodium chloride rich, due to the absence of limestones.

6.2.2 Variation within Water Types

Within the major water types there are variations in groundwater chemistry. These variations have been highlighted by investigation of total hardness and total alkalinity values and Mg/Ca ratios. One sampling event (3/10/93) of fifteen groundwater sources by J. Keohane (Regional Water Laboratory, Kilkenny) was used to examine the chemical variation.

The connection between the bedrock and groundwater types is often indirect because the groundwater reflects the mineralogy of the overlying subsoils, e.g. a sandstone bedrock aquifer overlain by limestone till might fall into a mixed calcium bicarbonate/sodium chloride water type.

The limestone bedrock aquifers and the limestone-derived sand/gravel aquifers have similar values.

The groundwater in the Galtee and Slievenamon areas displays low total hardness values which indicate little limestone-derived subsoil overlying the Old Red Sandstone. The waters in the Slieveardagh Uplands are also relatively soft.

Mg/Ca ratios can be used to describe the groundwaters and confirm conclusions derived from the hardness values. In general, limestone aquifers have a Mg/Ca ratio less than 0.3 (Table 6.2). In these studies seven sites have values exceeding this, suggesting that lithology is a dominant factor controlling the Mg/Ca ratio as all but one of the seven is located in a non-limestone aquifer. The Mg content in the sampled sources is usually less than 20mg/l except in four cases (Kiltinan, Ballincurry, Laffansbridge and Ironmills). In all but the last source this is explained by the presence of dolomite.

Natural ion exchange is a process that can reduce the hardness level in groundwater. It is indicated by a Total Hardness value significantly below the Total Alkalinity value and is usually found in confined aquifers. Natural ion exchange is suggested in three of the fifteen sources sampled (Table 6.2), these sources being in the Coal Measures (Tullohea) and the Devonian (Rossadrehid and Kilcoran).

Table 6.2 Mg/Ca Ratios, Hardness and Alkalinity (sampling event of 3 October 1993)

Source (ref)	Aquifer	Mg/Ca Ratio	Total Alkalinity (mg/l $CaCO_3$)	Total Hardness (mg/l $CaCO_3$)	Total Alk/ Total Hardness
Hollyford (2)	Silurian sandstone/shale	0.22	232	217	1.069
Ironmills (3)	Sands & Gravels	3.14	116	110	1.055
Laffansbridge (7)	Ballyadams Limestone	0.26	274	315	0.87
Coalbrook (8)	Coal Measures	0.27	181	189	0.96
Ballincurry (9)	Coal Measures	2.11	208	204	1.02
Tullohea (18)	Coal Measures	1.13	64	56	1.143
Cloran (19)	Kiltorcan Sandstone	0.6	8	10	0.8
Mullenbawn (20)	Ballyadams Limestone	0.1	340	326	1.043
Springmount (21)	Sands & Gravels	0.11	365	361	1.011
Rossadrehid (23)	Devonian sandstones/shales	2.00	31	19	1.632
Kilcoran (24)	Kiltorcan Sandstone	4.5	60	40	1.5
Coolnamuck (26)	Sands & Gravels	0.49	152	159	0.956
Poulatar (30)	Waulsortian/Silverspring Limestones	0.14	199	199	1
Poulalee (31)	Waulsortian/Silverspring Limestones	-	219	207	1.058
Kiltinan (32)	Ballyadams Limestone	0.22	334	318	1.05

6.3 Water Quality

6.3.1 Introduction

Statistical analysis of available water quality data enables background groundwater quality to be assessed. In South Tipperary there was no regular sampling programme when this project began, therefore the sampling frequency for the analyses used is variable. The assessment of the quality is related to the number of samples taken for each site. This is not ideal, but some generalisations can be made with regard to water type, quality and possible contaminants.

Parameters such as potassium (K), chloride (Cl), ammonia (NH_3), nitrate (NO_3) and E. *coli* are usually independent of rock type, and are used as pollution indicators. The potassium/sodium (K/Na) ratio is a useful indicator of local contamination by vegetative organic matter.

There are some parameters such as magnesium (Mg) and calcium (Ca) whose presence in excess in groundwater is a nuisance rather than harmful. Sudden rises in these parameters, together with the presence of other pollution indicators (e.g. potassium, chloride etc), could imply contamination. Some pollutants mobilise other relatively harmless substances which may show up as elevated values during routine analysis.

6.3.2 Pollution

Pollution is not a widespread problem in southeast Ireland, though there are local problems which are often attributable to the siting of wells and boreholes in urban areas or close to waste sources such as manure and silage pits or septic tanks (An Foras Forbartha, 1986). In South Tipperary the compliances and exceedances of the EC standards for water samples taken from the Council's sources were dealt with on a parameter-by-parameter basis. Table 6.3 shows the exceedances of EC Drinking Water Standards which highlight the polluted sources, with a summary of the sample range, number of contaminated samples for each parameter and a brief note on the overall quality. Pollution status is divided into two categories:

- insufficient data
- sufficient data - contaminated (frequently/infrequently).

Elevated bacterial counts usually indicate nearby pollution. The main concern stems from the presence of E. *coli* and Total Coliforms. E. *coli* are used to indicate contamination because they are easy to measure relative to other bacteria and viruses. Elevated levels are attributed to human/animal waste. Five sources were found to be frequently contaminated by bacteria: Ballinvir, Tullohea, Mullenbawn, Poulatar and Poulalee. These sources should be investigated further to define the source of pollution.

K/Na ratios can be used tentatively to distinguish between pollution from septic tank systems and farmyards. The ratio for cattle slurry is typically 10, whereas for septic tank effluent it is 0.1-0.3 (Henry, 1988). Entry of effluent from plant organic waste will result in an increase in the K concentration and more importantly in the K/Na ratio. The K/Na ratios in some analyses from South Tipperary are shown in Table 6.4.

6.4 Implications for Vulnerability Assessment

Aquifer characteristics such as confinement, karstification (implying a short residence time), and thickness of unsaturated zone, affect the pollution potential. Groundwater circulation tends to be rather local and the effects of pollution tend to be localised both in space and time. The pollution loading is directly linked to the groundwater vulnerability. Bacterial contamination of sources may indicate relatively high vulnerability.

Table 6.3 Indicators of Groundwater Quality for Selected Sources in South Tipperary

(each value below represents a single sampling event; - indicates no sample taken)

Source (ref)	**E. coli (/100ml)**	**Total coliforms (/100ml)**	**Total Hardness (mg/l $CaCO_3$)**	**Electrical Conductivity (μS/cm)**	**Nitrate (mg/l as N)**	**Status**
Glengar (1)	3,2	5	-	359	-	Insufficient data
Hollyford (2)	16	16	-	280	-	Insufficient data
Ironmills (3)	-	-	212	460	-	Insufficient data
Coalbrook (8)	0,0,0,2	0	115,218,166,224	465,519,453	0.2,0.25,0.4,0.3	infrequently contaminated
Ballincurry (9)	0,0,0	0,0,0	238,224,-	291,473,466	0.2,0.4	infrequently contaminated
Gorteen (10)	0	0	130	195	0.2	Insufficient data
Commons (11)	-,0,-,0	-,-,-,0,0,0	76,107,84,96,43,86	261,250,223,227	0.6,0.6,5,6.6	infrequently contaminated
Grangemockler (15)	0,0,0	0,0,0	74,76,85	208,175,189	1.5,1.4,1.3	infrequently contaminated
Ballinvir (16)	10,20,0,32,8,64,6,-,4		-	-	-	Frequently contaminated
Ahenny (17)	0,0,-,-	-,0,0,0	85,88,78,72,71	234,228,223,231,205,235	4.7,-,4.5,5,6.6	infrequently contaminated
Tullohea (18)	0,0,-,0,54,6	0,2,12,4,480,12	-	165,176,177,130,175,-,-	1,1.2,-,-,-,-,-	Frequently contaminated
Cloran (19)	0,0,-,-	-,2,0,6	-,-,8,-	45,56,53	1,-,-,-,-	infrequently contaminated
Mullenbawn (20)	0,4,4,2	20,302	307,248	615,630,655	2.7,3.1,2.2	Frequently contaminated
Springmount (21)	0,-	2,2	-	696,737	4.9,5.4	Insufficient data
Kedrah (25)	-	-	383		-	Insufficient data
Clogheen (27)	-,0	2,-	-	-*	-	Insufficient data
Muskery Springs (29)	2	2	-	113	-	Insufficient data
Poulatar (30)	-,0,-,-	32,4,52,0	190,230,224,240	359,404,394,436	9.3,14.6,11.1	Frequently contaminated
Poulalee (31)	-	18,16,24,20	198,230,220	376,412,403,423	11.1,16.4,11.1	Frequently contaminated

The overall quality of water from large springs and high-yielding wells in Ireland is good but work in the Nore River Basin has shown widespread contamination of shallow dug wells. Effluent discharged by local point sources has a far greater impact on the capture zones of low-yielding wells than it has on high-yielding boreholes and springs (Woods, 1990). Most low-yielding wells for farm and domestic water supplies are within 50m of at least one potential point source of pollution and within 100m of another. These pollution sources will be centrally located within the zone of contribution of most wells. A well supplying 2-20m^3/day will be recharged from an area of 0.2-0.5 hectares, whereas springs and boreholes producing 1,000-4,000 m^3/day under normal hydrogeological conditions will have a recharge area in the order of 100-1000 hectares. Hence large boreholes and springs give a much better reflection of the overall groundwater quality.

Table 6.4 K/Na Ratios and Nitrate Values for Sampling Event of 3 October 1993

Source (ref)	**K/Na Ratio**	**Nitrate as N (mg/l)**
Hollyford (2)	0.1772	2.3
Ironmills (3)	0.101	1.8
Laffansbridge (7)	0.3925	4.4
Coalbrook (8)	0.3404	0.7
Ballincurry (9)	0.108	1.0
Tullohea (18)	0.0784	1.2
*Cloran (19)	0.056	0.1
Mullenbawn (20)	0.457	3.6
Springmount (21)	0.13	5.6
*Rossidrehid (23)	0.0978	0.2
*Kilcoran (24)	0.1194	0.3
Coolnamuck (26)	0.17	3.1
Poulatar (30)	0.1304	3.3
*Poulalee (31)	-	3.6
Kiltinan (32)	0.202	2.8

* Analysis showed ion balance error greater than 6%

6.5 Quality of the Sources

6.5.1 Ironmills

The general water quality at this site is good, with no apparent bacterial problems. It is an unconfined sand/gravel aquifer in which the flow is intergranular, so there is some potential for attenuation of contaminants, depending on the unsaturated zone thickness.

6.5.2 Springmount

There are only a few analyses for the Springmount source. The maximum admissible concentration (MAC) for bacteria and nitrate was exceeded in two out of the nine samples. There is one lead (Pb) value which exceeds the MAC; further sampling is necessary to determine whether this indicates a problem. The flow in the gravels is intergranular and some attenuation can occur.

6.5.3 Mullenbawn

Mullenbawn is a large karst spring in the Ballyadams Formation. The aquifer is unconfined in the immediate area of the spring, with a lot of exposed rock. Bacteria/Total Coliforms are a problem at this source as ten out of the thirteen samples showed exceedances of the MAC. The aquifer is unconfined and has conduit flow.

6.5.4 Poulatar and Poulalee

These are large karst springs which discharge from unconfined Waulsortian Formation at the edge of the Tar river. As at Mullenbawn, the flow is thought to be conduit-type, with thin subsoil cover. They are very open and unprotected so it is not surprising that five out of the seven samples from Poulatar and all the samples from Poulalee were contaminated by bacteria. One sample from Poulatar had a nitrate level over the MAC and more sampling and analysis for this parameter should be carried out.

7 Groundwater Vulnerability

7.1 Introduction

Groundwater vulnerability is a measure of the ease with which unacceptable impacts upon groundwater quality can take place, and depends on the physical circumstances at any given location. It is the intrinsic characteristic which determines the sensitivity of various areas of an aquifer to contamination by an imposed pollution load. Risk arises from an activity at a given location which produces a harmful substance, but can be mitigated by preventive measures. Different levels of pollution loading may be acceptable in different vulnerability situations. The concept of groundwater vulnerability recognises that the risks of pollution from a given activity are greater in certain hydrogeological situations than others.

This study is concerned with the intrinsic vulnerability of the groundwater to pollution. The Vulnerability Map (Maps 6E and 6W) shows vulnerability irrespective of the type or concentration of the pollutant, which is dealt with in the groundwater protection responses which categorise the pollution potential of various groups of activities. The Vulnerability Map depicts areas of roughly equal vulnerability and ***must not be used for site-specific work***. At the site-specific stage the vulnerability rating must be confirmed by on-site investigation.

In the natural ('green field') situation the pollutant is discharged at zero datum level. Where the natural situation is altered, either by removal of subsoil (e.g. for a septic tank, where one to two metres of material is removed) or by changing the subsoil permeability by importing low permeability material, e.g. as a landfill liner, then the vulnerability and the pollution risk change, as the pollution discharge point has been altered. Since the main concerns of Irish local authorities relate to point pollution loading beneath the ground surface (e.g. septic tanks, other soakaways, landfills), the Vulnerability Map ignores any variations in topsoil which might affect vulnerability.

This report deals with the vulnerability of groundwater to diffuse and point sources of pollution. The vulnerability of both the subsoil and the bedrock aquifer materials are dealt with separately and then merged to form an integrated vulnerability map. The vulnerability of the groundwater in the bedrock and subsoil aquifers depends on the overlying soil, subsoil and the thickness of the unsaturated zone.

The production of the groundwater vulnerability map for South Tipperary required the following:

- Differentiating between the subsoils in order to obtain three categories of permeability: high, moderate and low
- In the case of sand/gravel aquifers, the thickness of the unsaturated zone
- The location of karst features
- Contouring depth to bedrock data

Summary information on vulnerability categories is given in Section 2.3.1; more details are given in DELG/EPA/GSI (1999).

7.2 Sources of Data

- The following sources of data were used to produce the Vulnerability Map:
- The subsoils map (Map 2)
- The depth to bedrock data from all the GSI databases (Maps 3E and 3W)
- The GSI karst database
- Six inch to one mile scale geological and topographic maps
- Site visits undertaken in South Tipperary

7.3 Method of Evaluation

Five factors have been taken to define the vulnerability of groundwater resources to pollution. These are, from the surface down:

- Soil Characteristics
- Subsoil Characteristics
- Thickness of Unsaturated Zone
- Hydrogeology
- Attenuation Processes

7.3.1. Soil characteristics

Soil characteristics (topography, depth, texture, and permeability) are significant in determining the infiltration of recharge and the natural attenuation of infiltrating pollutants. Sorption, ion exchange and precipitation are vital chemical and biological processes in attenuating pollutants and occur to varying degrees in different soil types. The effectiveness of these processes depends on the clay and organic matter content, and the thickness - the higher they are, the greater the attenuation.

7.3.2 Subsoil Characteristics

The nature of the subsoil is important because of its attenuating properties. The permeability and thickness of the deposit directly affect the attenuation capacity. Areas covered by a low permeability subsoil such as till, peat or marl with thicknesses of at least 10 metres have a low vulnerability.

Very permeable or very impermeable subsoil can cause problems, in the former case that contaminants will flow directly into the groundwater and the latter case that ponding of contaminants occurs, with the possibility of surface water being affected.

7.3.3 Thickness of Unsaturated Zone

The unsaturated zone has a crucial position between the land surface and the water table, and is a favourable environment for pollutant attenuation. The thickness of this zone is important in attenuation processes. The unsaturated zone contains air spaces within the pores, which allow more attenuating processes to operate (oxidation, aerobic biodegradation).

7.3.4 Hydrogeology

The character of aquifers, especially the size and interconnection of the openings through which the water passes, is important in the attenuation process. Aquifers with intergranular flow, (eg sand and gravel) retard pollutants only slightly, with some filtration of coarse matter and a little dilution. Karst aquifers with open solution channels are ineffective in removing pollutants, as the flow is rapid and the attenuating capacity is negligible. The dilution capacity of the aquifer is related to its storativity and throughput.

7.3.5 Attenuation Processes

The potential for groundwater pollution depends upon the level of attenuation that takes place between a pollution source and the underlying aquifer. The attenuation of most pollutants as they travel through the unsaturated zone and groundwater system depends on various chemical reactions and biological and physical processes that may cause the pollutant to change its physical state or chemical form. These changes may reduce the severity of pollution or the amounts of pollutants. There are fewer attenuating mechanisms in the saturated zone than in the unsaturated zone, but dilution is important in the saturated zone. Although the importance of these reactions in attenuating pollutants is widely recognised, it is difficult to predict how much attenuation will take place.

The degree of attenuation that occurs in the unsaturated zone depends upon (1) the grain size and sorting, and the physical, chemical and biological characteristics of the material through which the pollutant passes, (2) the duration of the contact between the pollutant and the material through which it passes, and (3) the distance that a pollutant travels through the unsaturated zone. In general, the longer the time and the greater the distance of travel, the greater the potential for attenuation. Attenuation processes may be bypassed completely if a pollutant is introduced directly into the aquifer.

The vulnerability of groundwater at a specific site can only be established with confidence by direct investigation.

7.4 Vulnerability Classification

The vulnerability classification scheme outlined in Table 7.1 takes account of the main bedrock and subsoil aquifers in South Tipperary.

The vulnerability classification does not itself depend on the quality of the data, but the reliability of the vulnerability map depends on the density of data points. It would be impractical to develop a system that includes this reliability component as there are varying levels of information throughout the area. As the vulnerability is an integral part of the Groundwater Protection Scheme and therefore the groundwater protection responses, a conservative stance has been taken where there is a doubt about the reliability of the data.

7.5 Application of Vulnerability Classification in South Tipperary

7.5.1 Vulnerability Assessment for South Tipperary

The factors involved in evaluating the vulnerability of the aquifers are discussed below:

- **Soil Characteristics**

The information on soils in South Tipperary from the Soils Association Map of Ireland is not detailed enough to determine the attenuation capacity of the soils and hence their signifance *vis-a-vis* vulnerability. Further work on the attenuating capacity of soils could assist in vulnerability assessment for diffuse pollution sources.

- **Subsoil Characteristics**

The subsoils in Tipperary vary vertically and laterally in both thickness and lithology within short distances. Depth to bedrock ranges from 0 to >30m. The detailed composition of the subsoil is unknown because no detailed mapping, drilling or geophysical investigation has been undertaken. Therefore the subsoils are divided into two broad groups: (a) a more permeable group including (predominantly) limestone sand and gravel and till-with-gravel; (b) a less permeable group including predominantly limestone and sandstone till, peat, marl and alluvium.

- **Thickness of Unsaturated Zone**

There is insufficient water level information to enable a water table map to be drawn. The water level is very important in the sands and gravels, where it is generally less than five metres from surface in low lying areas. The vulnerability classification takes this into account.

- **Hydrogeology**

The bedrock aquifers exhibit fissure flow, or conduit flow in the karst areas. Since the flow is rapid the attenuation capacity is low.

- **Attenuation Processes**

The vulnerability assessment is independent of pollutant type, and the attenuation capacity of the soils and subsoils have therefore not been explored as outside the scope of the report. Attenuation processes should be assessed for any given site and pollutant as necessary.

7.6 The Vulnerability Map

The vulnerability map (Maps 6E and 6W) is derived from combining the contoured depth to bedrock data, the subsoil types (permeabilities) and the identified karst features (see Section 2.3.1). Accurately located data points are given the vulnerability of low, moderate, high or extreme, whereas areas of interpreted vulnerability are classified as ‘probably’ low up to ‘probably’ extreme. This general classification scheme is outlined in Table 7.1.

Table 7.1 Vulnerability ratings for different hydrogeological settings

Vulnerability Rating	***Hydrogeological Setting*** (all thicknesses are approximate)
Extreme	Locations where rock is at the surface Locations where the subsoil is known to be <3m thick In the vicinity of karst features
Probably Extreme	Areas interpreted to have <3m of subsoil overlying bedrock
High	Locations where high permeability subsoil is known to be >3m thick Locations where moderate permeability subsoil is known to be 3-10m thick Locations where low permeability subsoil is known to be 3-5m thick
Probably High	Areas of high permeability subsoil interpreted to be >3m thick Areas of moderate permeability subsoil interpreted to be 3-10m thick Areas of low permeability subsoil interpreted to be 3-5m thick
Moderate	Locations where moderate permeability subsoil is known to be <10m thick Locations where low permeability subsoil is known to be 5-10m thick
Probably Moderate	Areas of moderate permeability subsoil interpreted to be <10m thick Areas of low permeability subsoil interpreted to be 5-10m thick
Low	Locations where low permeability subsoil is known to be >10m thick
Probably Low	Areas of low permeability subsoil interpreted to be >10m thick

It is emphasised that the boundaries on the Vulnerability Map 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, and will frequently require site investigations in order to assess the risk to groundwater. A combination of detailed mapping of the subsoils, assessment of surface drainage and permeability measurements would reduce the area of high vulnerability and would probably reduce the area of extreme vulnerability. However, the Vulnerability Map is a good basis for decision-making in the short and medium term.

A large proportion of the county is classified as having either extreme or high vulnerability while areas of moderate and low vulnerability are much less common. This is a consequence of the often relatively shallow thickness of subsoils in South Tipperary but it may also be a reflection of the distribution of borehole data. The 3m contour, which influences the extreme and high vulnerability categories, is based on outcrop information, Quaternary mapping and borehole data. The presence or absence of 5m and 10m contours, which influence the moderate and low categories, relies solely on borehole data and uses the shallower contours as a guide for their interpretation. Where relevant borehole data to suggest greater depths are not available, these contours cannot be ddrawn and it is probably that there are more areas of moderate and low vulnerability than are currently depicted on the map. As more information becomes available, the maps can be up-dated.

7.6.1.1 Vulnerability of the Bedrock Aquifers

The vulnerability depends primarily on the type and thickness of the overlying subsoils, which have been broadly divided into:

- Predominantly gravel areas
- Predominantly till areas, subdivided into limestone and Old Red Sandstone areas.
- Till-with-gravel areas ('kame and kettle' deposits)
- Marl, Peat, Alluvium, (including permeable river gravels which may more vulnerable)

The vulnerability of the bedrock aquifer is directly related to the ability of the subsoil to attenuate or impede pollutants, which is a function of the subsoil permeability, clay content and thickness. The subsoil deposits have been broadly divided into permeable and less permeable categories. Sands and gravels and till-with-gravel are permeable, whereas till, alluvium, marl and peat are less permeable.

Contours depicting thin (probably less than 5 metres) and thick (probably over 10 metres) subsoil have been drawn to indicate areas of different vulnerability. The presence of exposed rock helps to delineate the areas with thin subsoil. For areas with thicker subsoil, borehole depth to bedrock records and topography are required. Depth to bedrock relates two variable surfaces, i.e. the bedrock surface and topography, so dramatic changes over very short distances are common. Areas with thick subsoil are used to indicate less vulnerable areas and bedrock aquifers begin to be confined where they are saturated and have around 10m of overlying impermeable material.

An overriding factor for bedrock vulnerability is the presence of karst, which indicates extreme vulnerability due to rapid throughput. In karst areas, polluted surface water in sinking streams can recharge aquifers with no attenuation. Karst features are indicated in red on the Vulnerability Map.

7.6.1.2 Vulnerability of the Subsoil Aquifers

The subsoil aquifer vulnerability refers only to sand and gravel deposits more than 10m thick and locally extensive. No buried/confined sand and gravel aquifers have been identified. The vulnerability of unconfined sand and gravel aquifers is considered to be high because they have no protection except from soil cover, of which too little is known for its attenuating ability to be determined. The unsaturated zone is very important in these aquifers, as once a pollutant gets into the groundwater it quickly spreads. Where the water table is less than three metres below ground level these areas are classed as extremely vulnerable.

7.6.2 Conclusion

The Vulnerability Map gives a county-wide view of groundwater vulnerability, and highlights pollution-sensitive areas. Owing to the map scale and the variable data availability, it cannot be used for site specific purposes. However, it does reduce the number of areas to be studied in detail by identifying those areas with the greatest or least limitations (Zaporozec, 1985).

Approximately 60% of South Tipperary is classed as extremely or highly vulnerable. The northern area is overlain by a thin cover of permeable sand and gravel and till-with-gravel. In the southern area there is a cover of less permeable limestone and sandstone till which provides some protection for the regionally and locally important aquifers beneath it.

The zones of contribution of the five sources examined in detail exhibit extreme to high vulnerability. The data quality for these five sources is good, as the areas were examined at 1:10,560 scale. 1:10,560 scale. Source protection zones (at 1:10,560) are contained in a separate source reports.

8 GROUNDWATER PROTECTION

8.1 Introduction

In Chapetr 2, the general groundwater protection scheme guidelines were outlined and in particular, the sub-division of the scheme into two components – land surface zoning and groundwater protection response matrices for potentially polluting activities – were described. Subsequent chapters described the different geological and hydrogeological land surface zoning elements as applied to South Tipperary. This chapter draws together the elements of land surface zoning to give the ultimate and final products – the Groundwater Protection Map. It is emphasised that the map is not intended as a 'stand alone' product, but that it must be considered and used in conjunction with the relevant response matrices.

The response matrices are based on the aquifer category and the natural vulnerability and become less restrictive as one moves from source protection areas to regionally important aquifers to poor aquifers and from more vulnerable to less vulnerable areas.

8.2 Source Protection Areas

Source protection areas are intended to protect selected groundwater sources (wells or springs), by placing tighter controls on activities within all or part of their recharge area (Adams, 1991).

Zone Definitions

These zone definitions are a first approximation; note that the zone of capture for most springs is not circular.

- Source Site (SS): The immediate area around the source – some tens of square metres – must be securely protected by fencing and all potentially polluting activities prohibited.
- Inner Source Protection Area (SI): The area within a 100-day travel time or 300m radius of the source (excluding the fenced in area of the wellhead/spring outflow).
- Outer Source Protection Area (SO): The area between 300m-1000m, or the catchment area where known.

Many sources in South Tipperary are springs, for which it is more difficult to define the catchment area or zone of contribution (the area which contributes flow to the spring under natural conditions). Detailed water level mapping and flow measurement are required before this area can be accurately defined. In the absence of such information, variable shapes (SWA, 1985) can be applied. In the cases of karst springs where the catchment vulnerability is high to extreme, it will usually be advisable to designate the entire inferred catchment area (Zone of Contribution) as 'SI', since the whole of this area may be within the 100-day zone.

Karst features such as sinkholes need stringent protection as they may allow direct access to the groundwater. Other forms of conduit including mine shafts or adits and abandoned wells and boreholes should also be mapped as they constitute potential entry points into aquifers for any pollutants on the land surface (Adams, 1991). Influent (sinking) streams also should be considered as part of the Inner Zone (SI), since any polluting activity in their catchment areas could lead to the transport of the contamination to the spring.

The vulnerability of areas within these zones may not always be the same. The risk of groundwater pollution therefore may also be different depending on the vulnerability classification. The groundwater protection matrices take this into account, firstly by being pollutant group specific.

8.3 Resource Protection Zones

This deals with the aquifer type and therefore the resource as a whole. This is less restrictive than source protection as it is only a broad guideline for the protection of the groundwater.

Zone Definitions		Map Code
• Regionally Important Aquifers		
i)	Aquifers with conduit flow (Karst areas)	Rk
ii)	Aquifers with fissure flow	Rf
• Locally Important Aquifers		
i)	Generally moderately productive (bedrock)	Lm
ii)	Moderately to highly productive (sand/gravel)	Lg
iii)	Moderately productive only in local zones (bedrock)	Ll
• Poor Aquifers		
i)	Generally unproductive except in localised zones	Pl
ii)	Generally unproductive	Pu

8.4 Groundwater Protection Response Matrices

The Groundwater Protection Scheme is a planning tool which takes into account the aquifer type, groundwater vulnerability, and proximity to particular sources. EU and Irish legislation require that all groundwater be afforded protection, so the scheme protects both the sources and the resources. The objective of the schme is to control development so as to prevent contamination/pollution of water resources. The development control measures in each Groundwater Protection Response Matrix are divided into four levels of response based on the likely acceptability of a given type of development.

Responses

R4 Unacceptable in principle.

R3 Not generally acceptable, unless the developer can demonstrate that the risk is minimal and there is no practical alternative site in a lower risk area.

R2 Probably acceptable subject to investigation and assessment to confirm that the site characteristics are favourable to the development, and subject to detailed conditions.

R1 Acceptable in principle, subject to normal good practice.

These restrictions impose certain investigative requirements on the various types of potentially polluting activities. The scope of a hydrogeological investigation depends on the nature of the pollutant, the vulnerability and the type of aquifer: the most intensive investigations will be directed where the threat is greatest or where conflicts of interest are most likely to occur (Hore, 1991).

Where there are Standard Conditions, Regulations, Guidelines or Codes of Practice already in place, these should always be adhered to when granting/refusing planning permission.

The Response Matrices relate to the groundwater aspect of a development or activity and therefore the recommendations only refer to groundwater. These matrices include groundwater source and resource protection zones and include the aquifer type, the vulnerability and the activity. These matrices must be used **only** in conjunction with the groundwater protection map which illustrates the vulnerability and aquifer zone but is not pollutant specific. Some of the gradings in the matrices may need alteration in the light of further detailed information on the particular activity from relevant experts.

8.5 Groundwater Protection Map

The Groundwater Protection Map (Maps 7E and 7W) was produced by combining the vulnerability map (Maps 6E and 6W) with the Aquifer Map (Maps 5E and 5W). Each protection zone on the map is given a code which represents both the vulnerability of the aquifer to contamination and the groundwater resource (aquifer category). The codes are shown in Table 2.3, the general groundwater protection scheme matrix. Not all of the possible hydrogeological settings are present in South Tipperary.

The Groundwater Protection Map illustrates the aquifer category/vulnerability codes. It is a complex map and should not be solely used to decide on site specific situations. It gives only an indication of the sensitivity of the groundwater.

6.3 Groundwater Source Protection Reports and Maps

The techniques used to delineate source protection zones (see Section 2.3.2) have been applied to specific groundwater sources in South Tipperary. These have been produced as separate source reports.

6.4 Conclusion

The Groundwater Protection Scheme presented in this report will be a valuable tool for Tipperary (South Riding) County Council in helping to achieve sustainable water quality management and in the location of potentially polluting actoivities.

9 ADDITIONAL RECOMMENDATIONS

1. In developing the scheme, data compilation comprised a substantial proportion of the work. Primary data in the form of bedrock geology maps, subsoil maps, borehole records, geotechnical information; hydrogeological information, well records, consultants' reports, and hydrochemical analyses, provided the basis for the development of hydrogeological and vulnerability concepts. Geological and hydrogeological factors are critical to the determination of the groundwater vulnerability, the assessment of potentially polluting developments and the alleviation of groundwater pollution problems. Good primary data for the county are very sparse. The Council should make every effort to ensure that, in all Council activities, good water resource-related data are collected, recorded and collated in a central department. This will greatly improve future revisions of the Groundwater Protection Scheme.

2. Well records, hydrochemistry analyses, geotechnical reports and consultants' reports should be forwarded to the Groundwater Section of GSI for centralised data storage. This would prevent the duplication of work and thus provide economic resources for additional site investigations. All private well records should be sent to the GSI with special emphasis on the drilling companies to record exact locations, borehole logs and pumping test data.

3. Regular chemical and bacterial monitoring of groundwater in representative sources of major aquifers is neded for an overview of the present situation and to check on future changes. This programme's sampling frequency should take account of temporal variations in water quality. The programme should allow for the pre-chlorination sampling of waters (as well as post-chlorination) so that the bacterial quality of the raw water can be assessed.

4. Resources should be made available to investigate the hydrogeological situation in the vicinity of productive and potential sources. Further research is required for the delineation of spring capture zones and zones of influence of boreholes.

5. Wellheads and spring outflows should be adequately protected by covering and fencing to reduce access by animals and vandals. Pump houses should be fitted with sampling taps to facilitate pre-treatment sampling and monitoring.

6. The attenuation capacity of the soil and subsoil for specific pollutants and associated travel times requires detailed research. Following on from these studies, pollutant-specific groundwater protection plans could be developed.

10 References

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