Fanad North (Tri_a_Lough) Source

Extracted from:
County Donegal Groundwater Protection Scheme,
Volume II: Source Protection Zones December 2005

County Donegal
Groundwater Protection Scheme

Volume II: Source Protection Zones
December 2005

Holy Well, Fanad Head, County Doneg

James Holohan
Director of Services
Donegal County Council
County House
Lifford, County Donegal

Monica Lee and Donal Daly
Groundwater Section
Geological Survey of Ireland
Beggars Bush
Haddington Road, Dublin 4

Authors

Monica Lee, Donal Daly and Siobhan McLaughlin, Groundwater Section, Geological Survey of Ireland

Contributions from Vincent Fitzsimons, Groundwater Section, Geological Survey of Ireland

in collaboration with:

Donegal County Council

TABLE OF CONTENTS – VOLUME II

Volume I comprise an overall introduction, classifications of aquifers and vulnerability, and overall conclusions.

1 BALLYSHANNON PUBLIC WATER SUPPLY SCHEME....... 1
1.1 INTRODUCTION....... 1
1.2 SUMMARY OF SUPPLY DETAILS....... 1
1.3 METHODOLOGY....... 2
1.3.1 Desk Study....... 2
1.3.2 Site visits and Fieldwork....... 2
1.3.3 Assessment....... 2
1.4 LOCATION AND SITE DESCRIPTION....... 2
1.4.1 Topography, Surface Hydrology and Land Use....... 4
1.5 GEOLOGY....... 4
1.5.1 Introduction....... 4
1.5.2 Bedrock Geology....... 5
1.5.3 Karst Features....... 6
1.5.4 Re-Evaluation of Bedrock Geology in the Ballyshannon Area....... 6
1.5.5 Subsoil Geology....... 7
1.5.6 Depth to Bedrock....... 8
1.5.7 Groundwater Vulnerability....... 8
1.6 HYDROGEOLOGY....... 9
1.6.1 Introduction....... 9
1.6.2 Rainfall, Evaporation and Recharge....... 10
1.6.3 Discharge Estimates....... 10
1.6.4 Groundwater Levels, Flow Directions and Gradients....... 11
1.6.5 Hydrochemistry and Water Quality....... 1 4
1.6.6 Aquifer Characteristics....... 15
1.6.7 Conceptual Model....... 16
1.7 DELINEATION OF SOURCE PROTECTION AREAS....... 17
1.7.1 Introduction....... 17
1.7.2 Outer Protection Area....... 17
1.7.3 Inner Protection Area....... 19
1.8 GROUNDWATER PROTECTION ZONES....... 19
1.9 POTENTIAL POLLUTION SOURCES....... 20
1.10 CONCLUSIONS AND RECOMMENDATIONS....... 21

2 CARNDONAGH PUBLIC WATER SUPPLY SCHEME....... 23
2.1 INTRODUCTION....... 23
2.2 SUMMARY OF SUPPLY DETAILS....... 23
2.3 METHODOLOGY....... 24
2.3.1 Desk Study....... 24
2.3.2 Site Visits and Fieldwork....... 24
2.3.3 Assessment....... 24
2.4 LOCATION AND SITE DESCRIPTION....... 24
2.4.1 Topography, Surface Hydrology and Land Use....... 26
2.5 GEOLOGY....... 26
2.5.1 Introduction....... 26
2.5.2 Bedrock Geology....... 27
2.5.3 Subsoil Geology....... 27
2.5.4 Depth to Bedrock....... 28
2.5.5 Groundwater Vulnerability....... 28
2.6 HYDROGEOLOGY....... 29
2.6.1 Introduction....... 29
2.6.2 Rainfall, Evaporation and Recharge....... 30

2.6.3 Groundwater Levels, Flow Direction and Gradient 30
2.6.4 Hydrochemistry and Water Quality 3 3
2.6.5 Aquifer Characteristics 35
2.6.6 Conceptual Model 36
2.7 DELINEATION OF SOURCE PROTECTION AREAS 37
2.7.1 Introduction 37
2.7.2 Outer Protection Area 37
2.7.3 Inner Protection Area 38
2.8 GROUNDWATER PROTECTION ZONES 39
2.9 POTENTIAL POLLUTION SOURCES 40
2.10 CONCLUSIONS AND RECOMMENDATIONS 40

3 CULDAFF PUBLIC WATER SUPPLY SCHEME 42
3.1 INTRODUCTION 42
3.2 SUMMARY OF SUPPLY DETAILS 42
3.3 METHODOLOGY 43
3.3.1 Desk Study 43
3.3.2 Site Visits and Fieldwork 43
3.3.3 Assessment 43
3.4 LOCATION AND SITE DESCRIPTION 43
3.4.1 Topography, Surface Hydrology and Land Use 44
3.5 GEOLOGY 45
3.5.1 Introduction 45
3.5.2 Bedrock Geology 45
3.5.3 Subsoil Geology 46
3.5.4 Depth to Bedrock 47
3.5.5 Groundwater Vulnerability 47
3.6 HYDROGEOLOGY 48
3.6.1 Introduction 48
3.6.2 Rainfall, Evaporation and Recharge 48
3.6.3 Groundwater Levels, Flow Direction and Gradients 49
3.6.4 Hydrochemistry and Water Quality 5 0
3.6.5 Aquifer Characteristics 51
3.6.6 Conceptual Model 52
3.7 DELINEATION OF SOURCE PROTECTION AREAS 52
3.7.1 Introduction 52
3.7.2 Outer Protection Area 53
3.7.3 Inner Protection Area 53
3.8 GROUNDWATER PROTECTION ZONES 54
3.9 POTENTIAL POLLUTION SOURCES 55
3.10 CONCLUSIONS AND RECOMMENDATIONS 56

4 FANAD NORTH (TRI-A-LOUGH) PUBLIC WATER SUPPLY SCHEME 57
4.1 INTRODUCTION 57
4.2 SUMMARY OF SUPPLY DETAILS 57
4.3 METHODOLOGY 58
4.3.1 Desk Study 58
4.3.2 Site Visits and Fieldwork 58
4.3.3 Assessment 58
4.4 LOCATION AND SITE DESCRIPTION 58
4.4.1 Topography, Surface Hydrology and Land Use 59
4.5 GEOLOGY 61
4.5.1 Introduction 61
4.5.2 Bedrock Geology 61
4.5.3 Subsoil Geology 62
4.5.4 Depth to Bedrock 63

4.5.5 *Groundwater Vulnerability* 63
4.6 HYDROGEOLOGY 64
4.6.1 *Introduction* 64
4.6.2 *Rainfall, Evaporation and Recharge* 65
4.6.3 *Groundwater Levels, Flow Direction and Gradients* 65
4.6.4 *Hydrochemistry and Water Quality* 6 6
4.6.5 *Aquifer Characteristics* 68
4.6.6 *Conceptual Model* 69
4.7 DELINEATION OF SOURCE PROTECTION AREAS 69
4.7.1 *Introduction* 69
4.7.2 *Outer Protection Area* 70
4.7.3 *Inner Protection Area* 71
4.8 GROUNDWATER PROTECTION ZONES 71
4.9 POTENTIAL POLLUTION SOURCES 72
4.10 CONCLUSIONS AND RECOMMENDATIONS 73

5 **MAGHERABEG/VEAGH PUBLIC WATER SUPPLY SCHEME** 74
5.1 INTRODUCTION 74
5.2 SUMMARY OF SUPPLY DETAILS 74
5.3 METHODOLOGY 75
5.3.1 *Desk Study* 75
5.3.2 *Site Visits and Fieldwork* 75
5.3.3 *Assessment* 75
5.4 LOCATION AND SITE DESCRIPTION 75
5.4.1 *Topography, Surface Hydrology and Land Use* 77
5.5 GEOLOGY 77
5.5.1 *Introduction* 77
5.5.2 *Bedrock Geology* 77
5.5.3 *Subsoil Geology* 78
5.5.4 *Depth to Bedrock* 79
5.5.5 *Groundwater Vulnerability* 79
5.6 HYDROGEOLOGY 80
5.6.1 *Introduction* 80
5.6.2 *Rainfall, Evaporation and Recharge* 80
5.6.3 *Groundwater Levels, Flow Direction and Gradients* 81
5.6.4 *Hydrochemistry and Water Quality* 8 2
5.6.5 *Aquifer Characteristics* 83
5.6.6 *Conceptual Model* 84
5.7 DELINEATION OF SOURCE PROTECTION AREAS 85
5.7.1 *Introduction* 85
5.7.2 *Outer Protection Area* 85
5.7.3 *Inner Protection Area* 86
5.8 GROUNDWATER PROTECTION ZONES 87
5.9 POTENTIAL POLLUTION SOURCES 88
5.10 CONCLUSIONS AND RECOMMENDATIONS 88

6 **PETTIGO PUBLIC WATER SUPPLY SCHEME** 89
6.1 INTRODUCTION 89
6.2 SUMMARY OF SUPPLY DETAILS 89
6.3 METHODOLOGY 90
6.3.1 *Desk Study* 90
6.3.2 *Site visits and fieldwork* 90
6.3.3 *Assessment* 90
6.4 LOCATION AND SITE DESCRIPTION 90
6.4.1 *Topography, Surface Hydrology and Land Use* 92
6.5 GEOLOGY 92

6.5.1 Introduction *92*
6.5.2 Bedrock Geology *93*
6.5.3 Subsoil Geology *95*
6.5.4 Depth to Bedrock *96*
6.5.5 Groundwater Vulnerability *96*
6.6 HYDROGEOLOGY 97
6.6.1 Introduction *97*
6.6.2 Rainfall, Evaporation and Recharge *97*
6.6.3 Groundwater Levels, Flow Directions and Gradients *98*
6.6.4 Hydrochemistry and Water Quality *9 8*
6.6.5 Aquifer Characteristics *100*
6.6.6 Conceptual Model *101*
6.7 DELINEATION OF SOURCE PROTECTION AREAS 102
6.7.1 Introduction *102*
6.7.2 Outer Protection Area *102*
6.7.3 Inner Protection Area *103*
6.8 GROUNDWATER PROTECTION ZONES 104
6.9 POTENTIAL POLLUTION SOURCES 105
6.10 CONCLUSIONS AND RECOMMENDATIONS 105

7 REFERENCES 107

8 APPENDICES 109

LIST OF FIGURES

FIGURE 1.1. LOCATION OF BALLYSHANNON WATER SUPPLY SCHEME 3
FIGURE 1.2. BALLYSHANNON WATER SUPPLY SCHEME WELL FIELD AND FEATURES 3
FIGURE 1.3. MAPPED BEDROCK GEOLOGY OF THE BALLYSHANNON AREA 5
FIGURE 1.4. CONDUIT WITHIN THE BALLYSHANNON LIMESTONE, PARKHILL SPRING AREA. 6
FIGURE 1.5. RE-EVALUATED BEDROCK GEOLOGY OF THE BALLYSHANNON AREA (2005). 7
FIGURE 1.6. MAPPED SUBSOIL GEOLOGY OF THE BALLYSHANNON AREA 8
FIGURE 1.7. MAPPED VULNERABILITY IN THE BALLYSHANNON AREA 9
FIGURE 1.8. PARKHILL SPRING OVERFLOW (MAY 2003-SEPTEMBER 2004) 11
FIGURE 1.9. ESTABLISHED GROUNDWATER CONNECTIONS IN THE BALLYSHANNON AREA. 13
FIGURE 1.10. INDICATORS OF DOMESTIC AND AGRICULTURAL GROUNDWATER CONTAMINATION 15
FIGURE 1.11. SO AND SI AREAS AROUND THE BALLYSHANNON PUBLIC SUPPLY SCHEME BOREHOLES. 19
FIGURE 1.12. SOURCE PROTECTION ZONES FOR THE BALLYSHANNON WATER SUPPLY SCHEME 20
FIGURE 2.1. LOCATION OF CARNDONAGH WATER SUPPLY SCHEME. 24
FIGURE 2.2. CARNDONAGH WATER SUPPLY SCHEME WELL FIELD. 25
FIGURE 2.3. BEDROCK AND SUBSOIL GEOLOGY OF THE CARNDONAGH AREA. 27
FIGURE 2.4. MAPPED VULNERABILITY IN THE CARNDONAGH AREA. 29
FIGURE 2.5. MONITORING WELL LOCATIONS 32
FIGURE 2.6. SITE INVESTIGATION BOREHOLE LOCATIONS. 33
FIGURE 2.7. KEY INDICATORS OF AGRICULTURAL AND DOMESTIC CONTAMINATION 34
FIGURE 2.8. SO AND SI AROUND THE CARNDONAGH (TIRNALEAGUE) PUBLIC SUPPLY SCHEME. 39
FIGURE 2.9. SOURCE PROTECTION ZONES FOR THE CARNDONAGH PUBLIC SUPPLY SCHEME 40
FIGURE 3.1. LOCATION OF, AND FEATURES AROUND, THE CULDAFF WATER SUPPLY SCHEME. 44
FIGURE 3.2. LOCATION, TOPOGRAPHY AND SURFACE HYDROLOGY IN THE CULDAFF AREA 45
FIGURE 3.3. BEDROCK AND SUBSOIL GEOLOGY OF THE CULDAFF AREA 46
FIGURE 3.4. MAPPED VULNERABILITY IN THE CULDAFF AREA. 48
FIGURE 3.5. KEY INDICATORS OF AGRICULTURAL AND DOMESTIC CONTAMINATION 50
FIGURE 3.6. SO AND SI AREAS AROUND THE CULDAFF WATER SUPPLY SCHEME BOREHOLES 54
FIGURE 3.7. SOURCE PROTECTION ZONES AROUND THE CULDAFF PUBLIC WATER SUPPLY BOREHOLES 55
FIGURE 4.1. VIEW OF THE TRI-A-LOUGH BOREHOLE – LOOKING NORTHWEST. 58
FIGURE 4.2. TRI-A-LOUGH BOREHOLE – AVERAGE DAILY ABSTRACTION; JANUARY 2002-OCTOBER 2003 59
FIGURE 4.3. FEATURES AROUND THE TRI-A-LOUGH BOREHOLE 59

FIGURE 4.4. TOPOGRAPHY, SURFACE HYDROLOGY AND SPECIAL AREA OF CONSERVATION. 60
FIGURE 4.5. BEDROCK AND SUBSOIL GEOLOGY. 62
FIGURE 4.6. MAPPED VULNERABILITY IN THE VICINITY OF THE TRI-A-LOUGH BOREHOLE.................................. 64
FIGURE 4.7. KEY INDICATORS OF AGRICULTURAL AND DOMESTIC CONTAMINATION (CONTINUED OVERLEAF).... 66
FIGURE 4.8. DELINEATED SO AND SI AREAS FOR THE FANAD NORTH (TRI-A-LOUGH) SCHEME.......................... 71
FIGURE 4.9. SPZ AROUND THE FANAD TRI-A-LOUGH WATER SUPPLY BOREHOLE.. 72
FIGURE 5.1. LOCATION AND FEATURES OF THE MAGHERABEG/VEAGH WATER SUPPLY SCHEME......................... 76
FIGURE 5.2. EAST TO WEST VIEW (TOP). WEST TO EAST VIEW (BOTTOM).. 76
FIGURE 5.3. GEOLOGY IN THE MAGHERABEG/VEAGH AREA. 78
FIGURE 5.4. MAPPED VULNERABILITY IN THE MAGHERABEG/VEAGH AREA. 80
FIGURE 5.5. KEY INDICATORS OF AGRICULTURAL AND DOMESTIC CONTAMINATION (CONTINUED OVERLEAF).... 82
FIGURE 5.6. DELINEATED SO AND SI FOR THE MAGHERABEG/VEAGH WATER SUPPLY SCHEME. 86
FIGURE 5.7. SOURCE PROTECTION ZONES AROUND THE MAGHERABEG/VEAGH WATER SUPPLY SCHEME. 87
FIGURE 6.1. PETTIGO PUBLIC SUPPLY SCHEME WELL FIELD AND FEATURES... 91
FIGURE 6.2 PETTIGO PUBLIC SUPPLY SCHEME LOCATION MAP.. 91
FIGURE 6.3. ORIGINAL MAPPED BEDROCK GEOLOGY OF THE PETTIGO AREA... 94
FIGURE 6.4. RE-EVALUATED BEDROCK GEOLOGY OF THE PETTIGO AREA (2005). 94
FIGURE 6.5. MAPPED SUBSOIL GEOLOGY OF THE PETTIGO AREA.. 95
FIGURE 6.6. VULNERABILITY CATEGORIES IN THE PETTIGO AREA.. 96
FIGURE 6.7. KEY INDICATORS OF AGRICULTURAL AND DOMESTIC CONTAMINATION... 99
FIGURE 6.8. SO AND SI AREAS AROUND THE PETTIGO PUBLIC SUPPLY SCHEME BOREHOLES. 104
FIGURE 6.9. SOURCE PROTECTION ZONES FOR THE PETTIGO WATER SUPPLY SCHEME...................................... 105

LIST OF TABLES

TABLE 1.1 MATRIX OF SOURCE PROTECTION ZONES AT BALLYSHANNON 20
TABLE 2.1. ESTIMATED PARAMETERS FOR CARNDONAGH GRAVEL AQUIFER.. 36
TABLE 2.2 MATRIX OF SOURCE PROTECTION ZONES FOR CARNDONAGH PUBLIC WATER SUPPLY SCHEME. 39
TABLE 3.1 ESTIMATED PARAMETERS FOR CULDAFF LIMESTONE AQUIFER. 52
TABLE 3.2 MATRIX OF SOURCE PROTECTION ZONES FOR THE CULDAFF PUBLIC WATER SUPPLY SCHEME. 55
TABLE 4.1. INDICATIVE PARAMETERS FOR FANAD NORTH SAND AND GRAVEL AQUIFER.................................... 69
TABLE 4.2 MATRIX OF SOURCE PROTECTION ZONES FOR TRI-A-LOUGH BOREHOLE. 72
TABLE 5.1. SAMPLE DESCRIPTIONS AND PSD IN THE GALDONAGH AREA.. 79
TABLE 5.2. ESTIMATED PARAMETERS FOR MARBLE UNIT AQUIFER. 84
TABLE 5.3 MATRIX OF SOURCE PROTECTION ZONES FOR MAGHERBEG/VEAGH PUBLIC WATER SUPPLY SCHEME. 87
TABLE 6.1. ESTIMATED PARAMETERS FOR THE LOWER IMPURE LIMESTONE AQUIFER. 101
TABLE 6.2 MATRIX OF SOURCE PROTECTION ZONES FOR THE PETTIGO PUBLIC WATER SUPPLY SCHEME.......... 104

4 FANAD NORTH (TRI-A-LOUGH) PUBLIC WATER SUPPLY SCHEME

4.1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the Fanad North (Tri-a-Lough) Water Supply Scheme borehole.
- To outline the principal hydrogeological characteristics of the surrounding area.
- To assist Donegal County Council in protecting the water supply from contamination, based on the available data.

The protection zones are delineated to help prioritise certain areas around the source in terms of pollution risk to the abstraction point. This prioritisation is intended to provide a guide in the planning and regulation of development and human activities. The protection of public water supplies is also mentioned in Circular letter SP 5-03, which was issued from the DEHLG to all County/City Managers in July 2003. The circular states that source protection zones around public water supplies should be included in all county development plans. The implications of these protection zones are further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The report forms part of the groundwater protection scheme for the county. The maps produced for the scheme are based largely on mapping techniques that use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole county covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

4.2 Summary of Supply Details

GSI Number	2043NEW002
Grid Reference (GPS)	21977 44430
Townland	Rinmore
Source Type	Borehole
Date Drilled	June 1996
Owner	Donegal Co Co
Elevation (m O.D.)	c.10
Depth of Borehole	c.13 m
Depth of Screen	c.13 m
Diameter of Screen	200 mm
Depth to Rock	> 13 m
Static Water Level	Within 1.3 m of ground level.
Pumping Water Level	c. 1.3 m b.g.l.
Consumption	c. 400 m^3/d
Pumping Test Summary: **(i) abstraction rate m^3/d**	720 m^3/d
(ii) specific capacity	–
(iii) transmissivity	–

4.3 Methodology

4.3.1 Desk Study

Details about the borehole such as abstraction figures, depth and date commissioned and were obtained from County Council personnel and from the drilling contractor, Pat Dullea, who installed the well. Additional geological and hydrogeological information was provided by GSI and Teagasc mapping programmes (Long and McConnell, 1997; Meehan, 2004 respectively), County Council reports, reports submitted to the County Council by Halcrow Group Ltd (2001 and 2002) and Aqua-Fact International Services (no date), and information from Kevin Cullen & Co. Ltd. (KTC) in 1998.

4.3.2 Site Visits and Fieldwork

This part of the work included the following:

- meetings with Donegal County Council personnel in October 2002 and March 2003;
- water sampling in November 2002 and March 2003;
- site walkover in July 2003 to further investigate the hydrogeology, subsoil geology and vulnerability to contamination.

4.3.3 Assessment

Analysis of the data utilised field studies and previously collected data to delineate protection zones around the source.

4.4 Location and Site Description

The Tri-a-Lough borehole (also know as the Kindrum Borehole) was developed in June 1996 to augment a supply problem with the pre-existing surface water scheme. A trial well is located approximately 50 m east of the production borehole. There are no data for this well.

The Tri-a-Lough Water Supply Scheme is located at the top of the Fanad Peninsula, approximately 700 m south of Ballyhiernan Bay, in the townland of Rinmore. Kinny Lough is some 175 m to the south of the borehole (Figure 4.1). The borehole is located within a pump-house, which is locked. This building also houses treatment facility, which has been installed to improve the quality of the abstracted water. Inside the pump-house the borehole is covered by a metal grill floor panel and it can be accessed by lifting the panel.

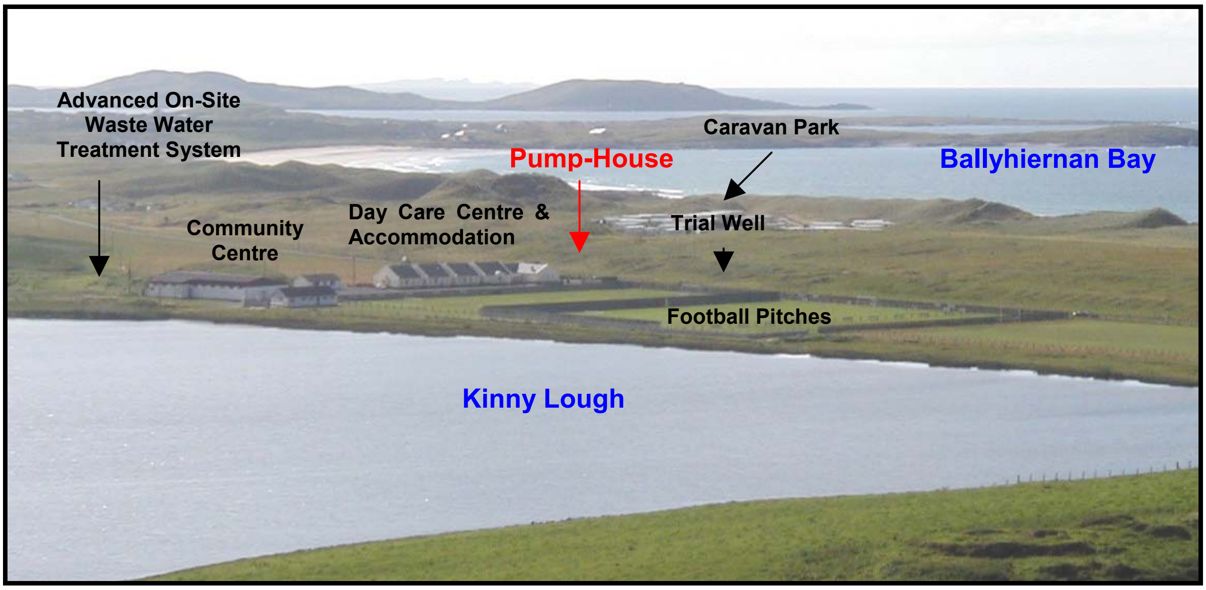


Figure 4.1. View of the Tri-a-Lough Borehole – Looking Northwest.

Groundwater from this borehole is combined with the surface water from Shannagh Lough and the limited abstraction from Naglea Lough (430 m^3/d) to supply the western Fanad Region; north and Rosnakill and west of Portsalon. According to County Council data, the abstraction rate is variable from day to day, but there has been an increase in the average abstraction of roughly 30% between 2002 and 2003. The abstraction data are shown in Figure 4.2.

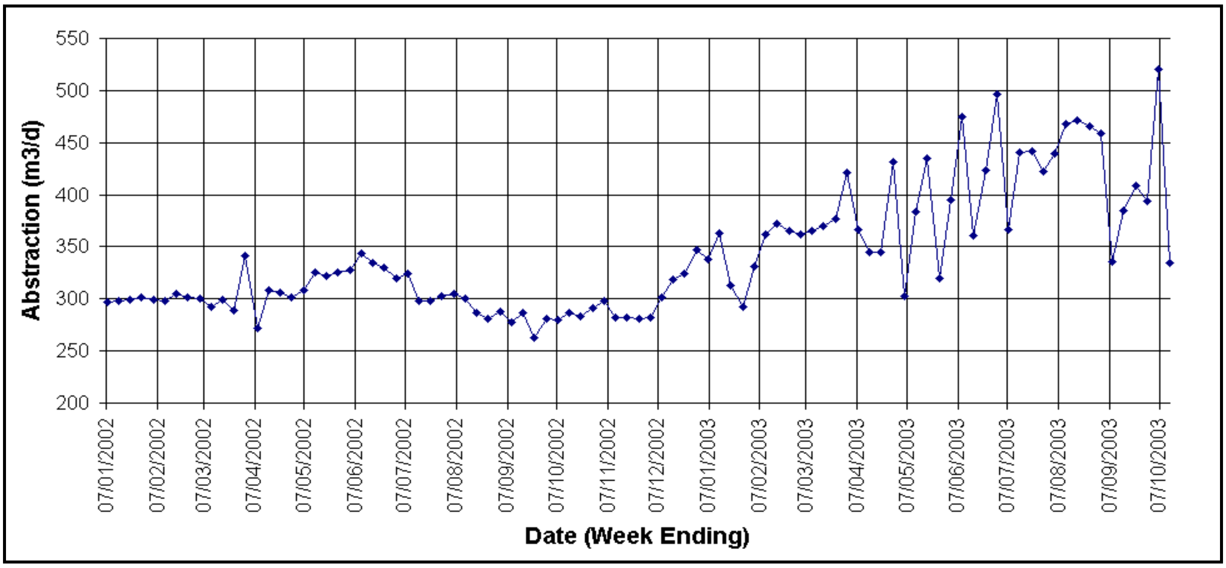


Figure 4.2. Tri-a-Lough Borehole – Average Daily Abstraction; January 2002-October 2003.

4.4.1 Topography, Surface Hydrology and Land Use

As shown in Figure 4.1, the Tri-a-Lough borehole is located in a flat, relatively low-lying area, at an elevation of 11 m O.D. Figure 4.1 also highlights the line of undulating, grassed sand dunes (up to 27 m O.D.) to the north of the borehole. The dunes are adjacent to a sand beach (Figure 4.3).

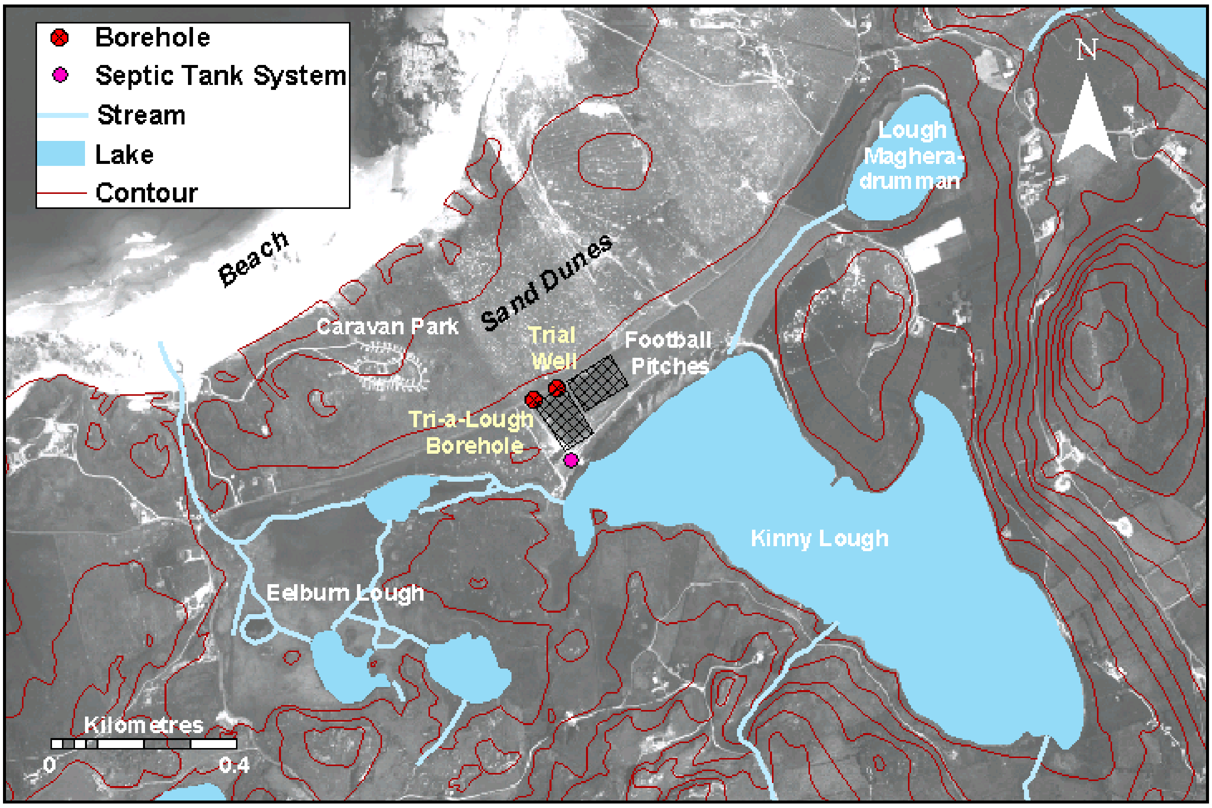


Figure 4.3. Features around the Tri-a-Lough Borehole.

Immediately to the south of the borehole, the continuing flat area is characterised by lakes (Loughs Shannagh, Magheradrumman, Kinny, Eelburn and Kindrum) which are situated in a northeast-southwest trending band, parallel to the coastline. Moving inland from the lakes, the landscape becomes rocky as it rises up sharply to form Murren Hill, at a maximum of 227 m O.D, approximately 4 km south of the borehole (Figure 4.4).

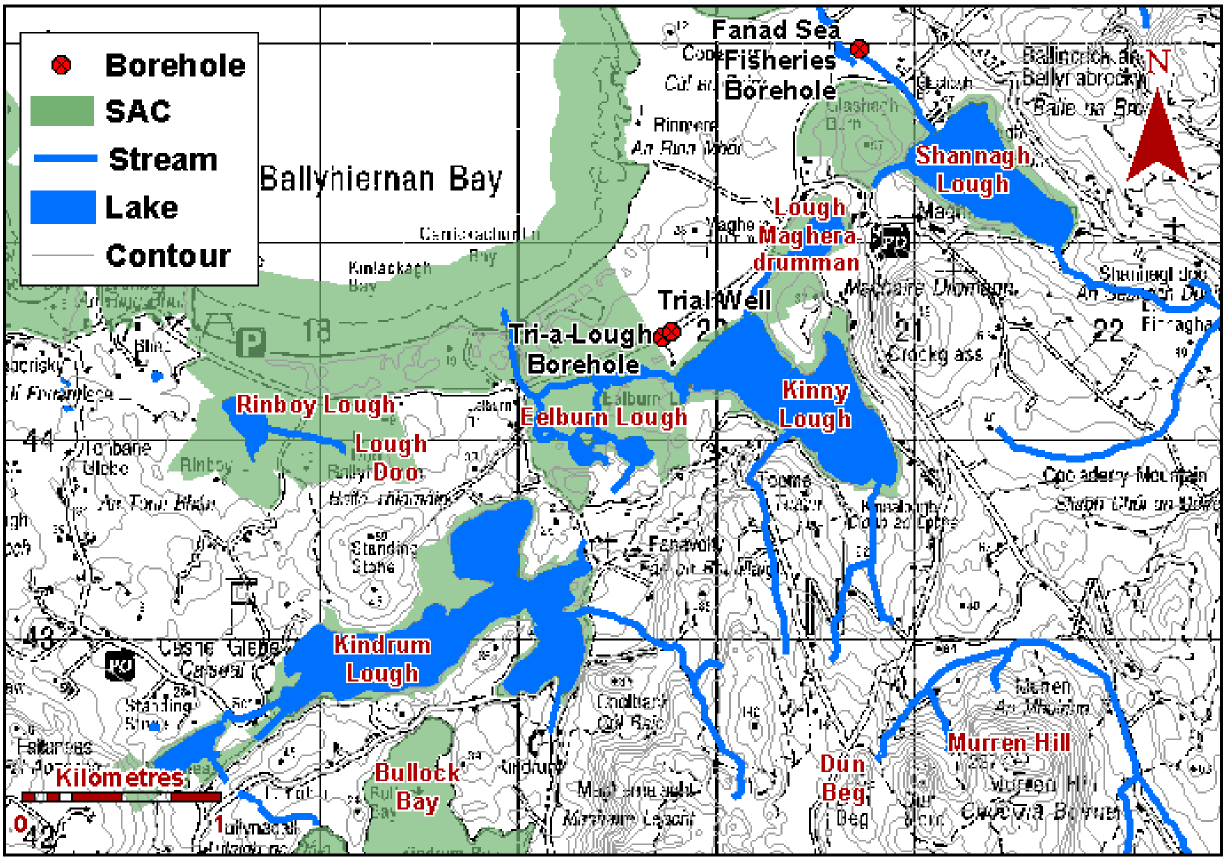


Figure 4.4. Topography, Surface Hydrology and Special Area of Conservation.

The distinctive band of lakes are the dominant surface hydrology feature in this region. They are fed by a number of un-named streams that are sourced in the higher Murren Hill area. Interestingly, Loughs Magheradrumman, Kinny and Kindrum do not discharge directly northwards into Ballyhiernan Bay, as might be expected. Kindrum Lough outflows southwards into Bullock Bay, which is the northern point of Mulroy Bay. Magherdrumman Lough outflows to the southwest and discharges into Kinny Lough. Similarly, Kinny Lough discharges into Eelburn Lough, which is further to the west. Lough Eelburn provides the main surface water discharge channel to the sea for all three lakes.

The general land use throughout this region is dominated by grazing. At a more local scale, features to note, which are highlighted in Figure 4.1, Figure 4.2 and Figure 4.4, are as follows:

- A day care centre and residential accommodation for the elderly is located immediately to the west of the pump-house. An advanced on-site wastewater treatment system and percolation area has been installed to the rear of these buildings and lies 150 m up-gradient of the Tri-a-Lough borehole.
- The Fanad United football pitches, lie immediately east of the pump-house.
- A caravan park is located 250 m to the northwest of the pump-house.
- There are a small number of minor roads across the area, the main road being directly to the north of the pump-house.
- Individual houses and farms are located along all of the roads, the closest lying some 500 m to the south of the Tri-a-Lough borehole.

The coastline between Ballyhoorisky Point and Fanad Head has been designated as a Special Area of Conservation (SAC) under the EU Habitat Directive (92/43/EEC). A large number of habitats have been identified along this portion of coastline (Appendix C) which fall into the EU Habitat Categories of 'Perennial Vegetation of Stony Banks', 'Sea Cliffs', 'Lowland Oligotrophic Lakes' and 'Hard Water Lakes'. It is noted that "this site is of ecological and conservation importance for the occurrence of examples of a number of habitats that are listed on Annex I of the EU Habitats Directive, the presence of Red Data Book plants species, including one listed on Annex II of this Directive, and for the large populations of several bird species that use it." This SAC includes the area to the south and west of the borehole, as shown in Figure 4.4. The SAC literature notes that the grazing (by both sheep and cattle), coupled with fencing off of certain areas and heavy use of fertilizers, has caused damage to some parts of the site.

4.5 Geology

4.5.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections.

Geological information was taken from a desk-based survey of available data, which comprised the following:

- Geology of North Donegal. Bedrock Geology 1:100,000 Map Series, Geological Survey of Ireland (Long and McConnell, 1997). Geological mapping in the nineteenth century (on record at the GSI).
- Forest Inventory and Planning System – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Meehan, 2004).
- Groundwater Resources of the Fanad Peninsula (KTC, May 1998).
- Borehole log for the Fanad Sea Fisheries Ltd water supply (KTC, June 1983).

4.5.2 Bedrock Geology

Structural features such as large folds and faults in the Fanad Peninsula generally trend from northeast to southwest.

The most northerly part of the peninsula is underlain by granites – undifferentiated Fanad Granite to the north of the borehole and the xenolithic facies of this same granite beneath the borehole itself. Both of these rock-types are described as coarse-grained igneous rock, with the xenolithic facies also containing locally derived material.

The area to the south and east of the borehole is underlain by quartzite rocks; Ards Quartzite (AP) and Slieve Tooey Quartzite (ST) rocks. These are both coarse-grained and contain pebbly beds and mineral bands. The southwest area is underlain by metamorphic rocks – Creeslough rock unit (CS), which comprises thin layers of metamorphosed limestone, mudstone and sandstone material, and Ards Pelite (AP) rock which is metamorphosed mudstone and shale.

These rocks are described in more detail in Section 2 (Volume 1) and their distribution around the source area is shown in Figure 4.5.

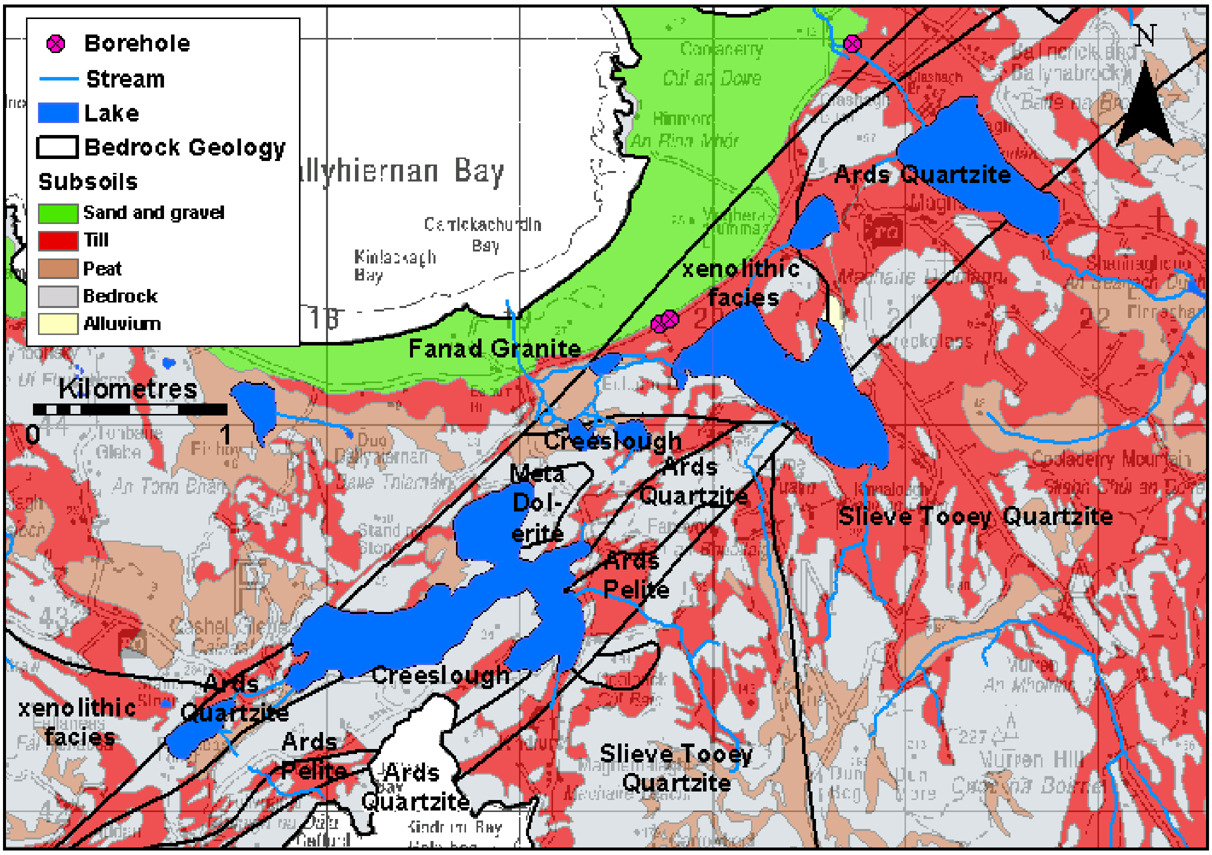


Figure 4.5. Bedrock and Subsoil Geology.

4.5.3 Subsoil Geology

The main subsoil categories in the vicinity of the source are sand and gravel, till (or 'boulder clay') and peat. The distribution of these subsoil types is shown in Figure 4.5. The subsoil characteristics are briefly described below.

Sand and Gravel

A large area of sand and gravel is mapped around, and to the north, of the borehole. It extends along the coastline from Rinboy to Currin Point, and up to 1 km inland (from Rinmore Point). These subsoils are described as 'beach sand and gravel' (KTC, 1998).

No drilling records are available for the Fanad Water Supply Scheme borehole or trial well at the time of writing. Personal communication with the drilling contractor revealed that the production borehole encountered 4-5 m of sand overlying roughly 8-9 m of coarse gravel, which is underlain by some 3 m of 'boulder clay' (till). Bedrock was not encountered during the drilling of this borehole. A borehole log does exist for the Fanad Sea Fisheries Limited well (KTC, 1983), which broadly speaking, reflects the material encountered and the Tri-a-Lough borehole (sand over gravel). From the ground surface, this log records 1.8 m of dune sand, roughly 2 m of peat, 4 m of gravel, 1.6 m of shale/gravel, 1.2 m of gravel and bedrock encountered at around 11 m below ground level. This latter borehole is located some 1.75 km to the northeast of the Tri-a-Lough borehole which suggests that the flat area of sand underlain by gravel is fairly extensive.

Till

'Till' is an unsorted mixture of coarse and fine materials laid down by ice and is the main subsoil type on the Fanad Peninsula. In the vicinity of the Tri-a-Lough borehole, the till is generally thin (< 3 m in thickness). Where the till is thicker, it is characterised by coarser-grained material that is derived from the coarse-grained igneous and metamorphic rocks in this part of Donegal. The till material does not constitute an aquifer in this region and thus its main significance is in relation to its protective capacity of the underlying sand/gravel and rock aquifers from infiltrating contaminants.

Peat

Two areas of peat are mapped to the west of the public supply borehole, the nearest being some 300 m away. Both of these area of peat are in lower-lying areas around lakes – Eelburn Lough and Loughs Rinboy and Doo. These deposits are not considered to be extensive areas of thick peat but are thought to be relatively thin (<2 m in thickness) and underlain by lake clays (Dr. R. Meehan, *pers. comm.,* 2003). Both of these areas of peat are designated as Special Areas of Conservation.

4.5.4 Depth to Bedrock

All available drilling information was previously compiled and a drilling programme undertaken by the GSI to ascertain the general changes in subsoil thickness and permeability throughout County Donegal. There are only two borehole data points in the Fanad Head area; the Tri-a-Lough public supply and the Fanad Sea Fisheries borehole. There is however, a large proportion of mapped outcrop and subcrop over the peninsula and from these data it appears that the depth to rock characteristics in the vicinity of the borehole are split into two zones:

- *Sand and gravel aquifer at the coast*: the two borehole data points both lie in this area. It appears that the aquifer occupies a bedrock trough where the rock at the borehole locations is at least ten metres deeper than the outcrop mapped around the lakes and a minimum of three metres deeper than the outcrop along the coast. It is assumed that the trough is aligned parallel to the coastline.
- *Higher ground away from the coast*: topography and rock outcrop information suggest that there is generally only a thin layer of subsoil material, if any at all. Areas of mapped till are likely to be pockets of slightly deeper material although given the high proportion of rock outcrop, it is anticipated that these pockets are less than 3 m deep.

4.5.5 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. The nature of the target changes across two zones in the vicinity of the borehole:

1) The 'target' associated with the Tri-a-Lough abstraction is the water-table in the sand and gravel aquifer. Here, the vulnerability is based on the permeability and thickness of the unsaturated material overlying the water-table. The measured water levels in the boreholes (Tri-a-Lough production and trial wells, Fanad Sea Fisheries borehole) indicate that the thickness of unsaturated sand and gravel is less than 1.5 m. Consequently, the vulnerability of the groundwater in flat area just north of the lakes is categorised as 'extreme'. Sand dunes are located to the north of the boreholes, which provide a greater thickness of unsaturated overlying materials. This increase in the protective capacity of the unsaturated material reduces the vulnerability category to 'high'.
2) In the higher ground away from the sea, the target is groundwater in the bedrock aquifers. The vulnerability of this type of target depends on the thickness (depth to rock) and permeability of the overlying subsoil. Depth to rock in this area is less than 3m and the vulnerability of the groundwater in the bedrock aquifers is therefore classified as 'extreme'. The mapped vulnerability[15] for the area of interest is shown in Figure 4.6, below.

[15] The permeability estimations and depth to water table interpretations are based on regional-scale evaluations. The mapping is intended only as a guide to land use planning and hazard surveys, and is not a substitute for site investigation for specific developments. Classifications may change as a result of investigations such as trial hole assessments for on-site domestic wastewater treatment systems. The potential for discrepancies between large-scale vulnerability mapping and site-specific data has been anticipated and addressed in the development of groundwater protection responses (site suitability guidelines) for specific hazards.

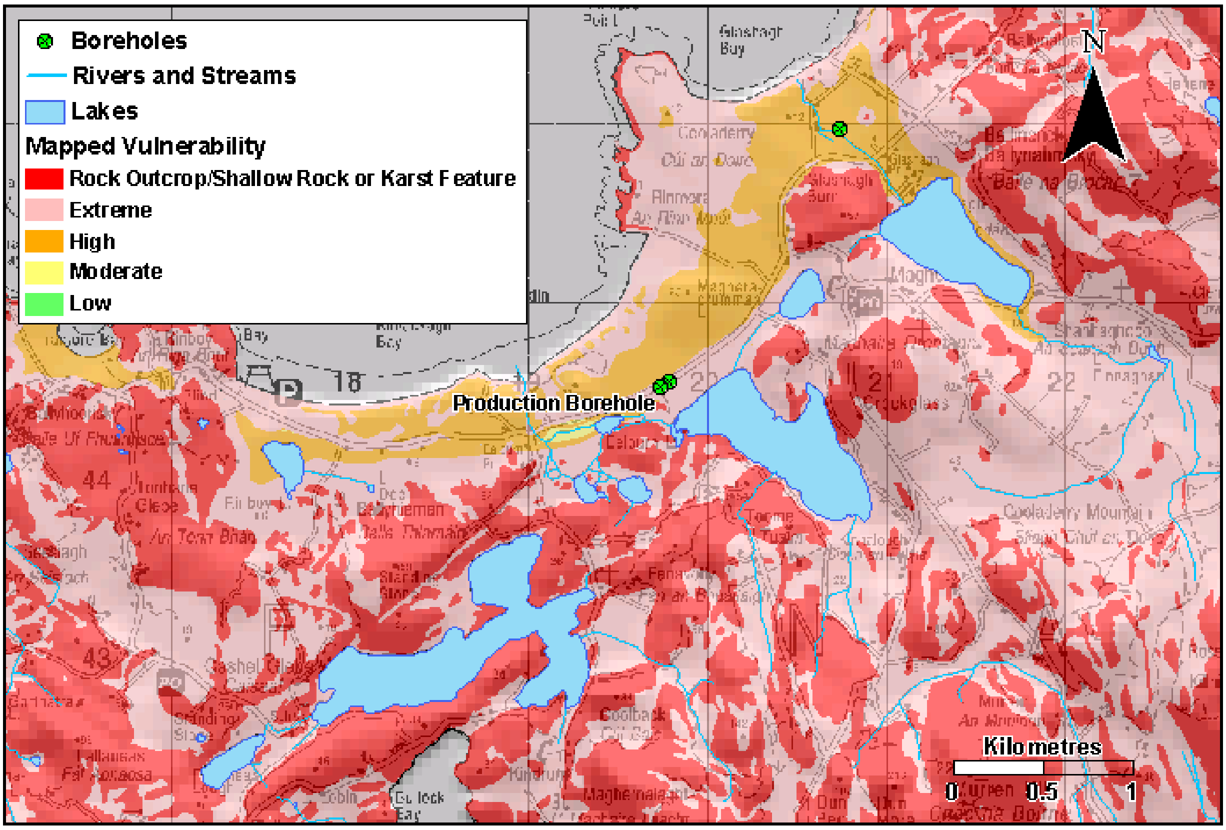


Figure 4.6. Mapped Vulnerability in the Vicinity of the Tri-a-Lough Borehole.

4.6 Hydrogeology

4.6.1 Introduction

This section presents our current understanding of groundwater flow in this area. Hydrogeological and hydrochemical data for this study were obtained from the following sources:

- Review of the Groundwater Resources, Fanad Peninsula (Halcrow Group Ltd, December 2001).
- Fanad Regional Water Supply Scheme (Mulholland & Doherty, Halcrow Water Services Ltd, October 2002) –
    - Summary Report
    - Supplementary Report No.2 Catchment Hydrology (Surface Water Sources).
    - Supplementary Report No.2 Catchment Hydrology (Groundwater Sources).
- Groundwater Resources of the Fanad Peninsula (KTC, May 1998).
- Fanad Peninsula Water Supply – Emergency Relief Progress Report (Sanitary Services, Donegal County Council, July 1996)
- Summary of environmental assessment of the impact of freshwater abstraction for the use at a proposed fish processing plant at Rinmore Point, Fanad Head, Donegal (Aqua-Fact International Services, no date).
- Site walkovers in July 2003 and levelling survey in November 2003.
- GSI depth to bedrock and subsoil permeability drilling programme (July 2002).
- GSI/County Council water quality sampling in November 2002 and March 2003.
- Water Quality analyses from the EPA (2000-2003).
- Donegal County Council drinking water returns for 1996-2000.
- GSI files and archival Donegal County Council data.

4.6.2 Rainfall, Evaporation and Recharge

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and assumed to consist of input (i.e. annual rainfall) less water losses (i.e. annual evapotranspiration and runoff), prior to entry into the groundwater system. The estimation of a realistic recharge rate is important in source protection delineation as it is used to estimate the size of the zone of contribution (i.e. the outer source protection area). The calculations are summarised below.

- *Annual rainfall:* **1210 mm**.

  The nearest rainfall gauging station is situated c.12 km to the south of the scheme (Kerrykeel G.S.; Fitzgerald and Forrestal, 1996). Although the two sites are at similar elevations, the Kerrykeel gauge is further inland. However, these values correspond to the interpreted contour maps of precipitation presented in the "Agroclimatic Atlas of Ireland" (Collins and Cummins, 1996). Hence it is assumed that these data are representative of conditions at the Tri-a-Lough borehole.

- *Annual evapotranspiration losses:* **520 mm**.

  Potential evapotranspiration (P.E.) is estimated to be 550 mm/yr (Collins and Cummins, 1996). Actual evapotranspiration (A.E.) is estimated as 95% of P.E., to allow for seasonal soil moisture deficits. More local measurements of evapotranspiration are not available.

- *Annual effective rainfall:* ~ **700 mm**.

  This figure is based on subtracting estimated evapotranspiration losses from average annual rainfall. It represents an estimation of the excess soil moisture available for either vertical downward flow to groundwater or runoff.

- *Annual recharge:* **630 mm**.

  The amount of water that will infiltrate to groundwater (recharge) is influenced by the subsoil permeability and thickness, as well as the aquifer characteristics. Recharge coefficients (rc) have been derived for various combinations of these factors (GWWG, November 2004). Given the permeable nature of the sand and gravel aquifer in the area of interest, recharge estimates are in the order of 90%. A high recharge is also indicated by the lack for surface drainage over the area of sand and gravel.

  Further inland away from the sand and gravel aquifer, runoff losses are expected to be much higher, and actual recharge correspondingly much lower. This is highlighted by the higher surface drainage densities in this area.

The calculations for the sand and gravel aquifer (mm/yr) are summarised as follows:

Average annual rainfall (R)	1210
Estimated P.E.	550
Estimated A.E. (95% of P.E.)	520
Effective Rainfall (R – A.E.)	~700
Estimated Recharge (90% of effective rainfall)	**630**

4.6.3 Groundwater Levels, Flow Direction and Gradients

Water levels. On 26th March 2003, pumping water levels were measured at 1.30 m below the ground in the production borehole at Tri-a-Lough and 1.35 m below ground in the trial well, which is 60 m east of the production well. There are no static water level data available for these boreholes. It is noted however, that the main water strike was in the gravel and similarly, the water main strike in the Fanad Sea Fisheries borehole was recorded at just over 5 m below the ground surface, which is over 1 m below the top of the gravel layer.

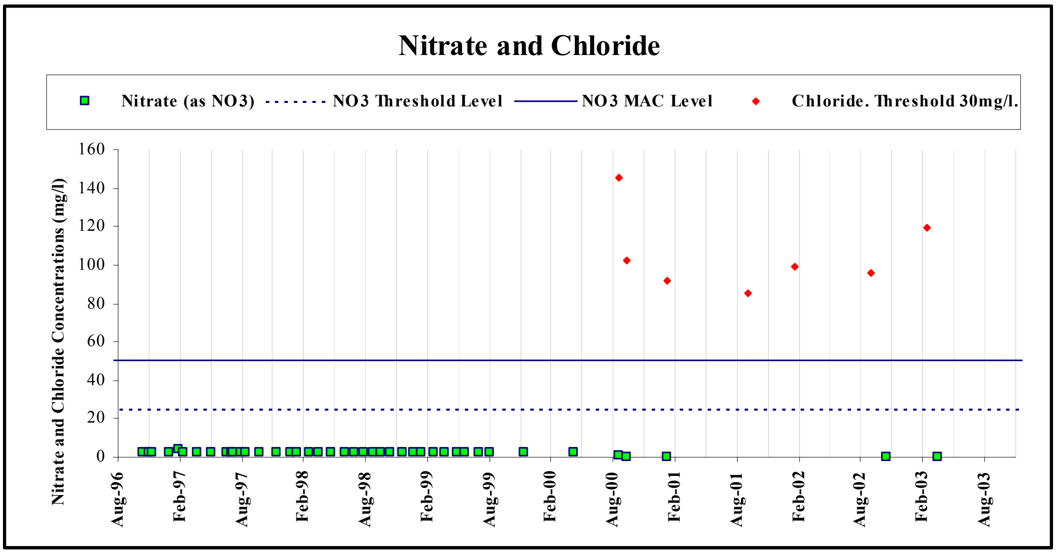
Flow Direction. In the absence of additional water level data in this region, groundwater flow direction is inferred from topography and surface drainage patterns. At a regional scale in the area to the north of Murren Hill, surface water flow is generally northwards to Ballyhiernan Bay. It is assumed that generally, the surface and groundwater flow directions coincide.

At a local scale, surface water flow direction is northeast to southwest from Lough Magherdrumman to Lough Eelburn. This flow direction is also indicated by local topography and the elevations of the lake water (Six Inches to One Mile Scale Maps Series Sheet 8, 1905). It is anticipated that the groundwater within this area will mirror the surface water flow direction. Flow in the vicinity of the borehole will also be influenced by pumping. In a high permeability sand and gravel aquifer in a flat topographic setting, groundwater will be drawn from all directions.

Gradients. Gradients between the pumping and trial wells are estimated to be 0.006, based on levelling undertaken by the County Council and the GSI.

4.6.4 Hydrochemistry and Water Quality

Hydrochemical data for the Tri-a-Lough borehole have been obtained from the County Council (1996-2000), the Environmental Protection Agency (2000-2003) and the GSI in conjunction with the County Council (2002-2003). The data are summarised graphically in Figure 4.7 below.



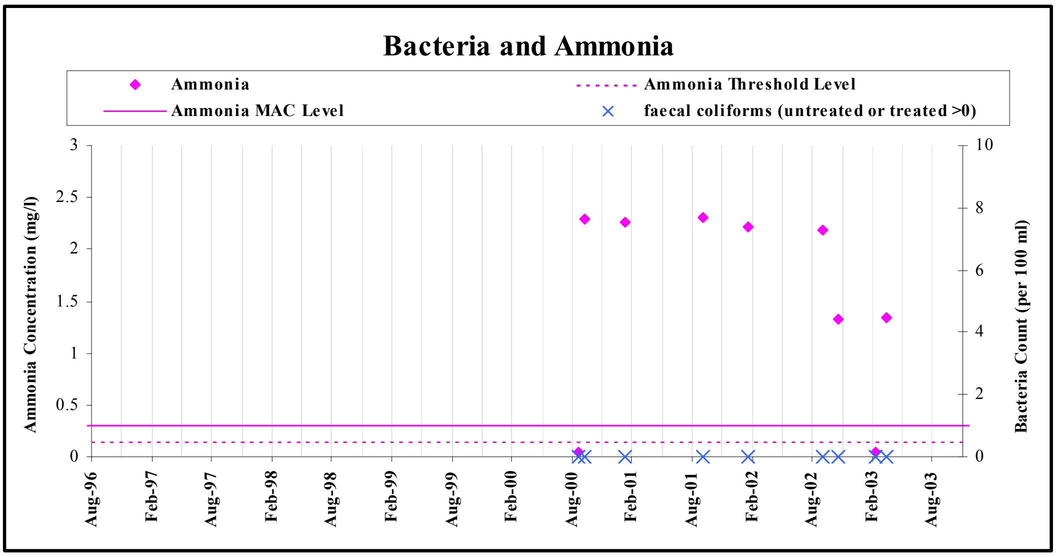


Figure 4.7. Key Indicators of Agricultural and Domestic Contamination (continued overleaf).

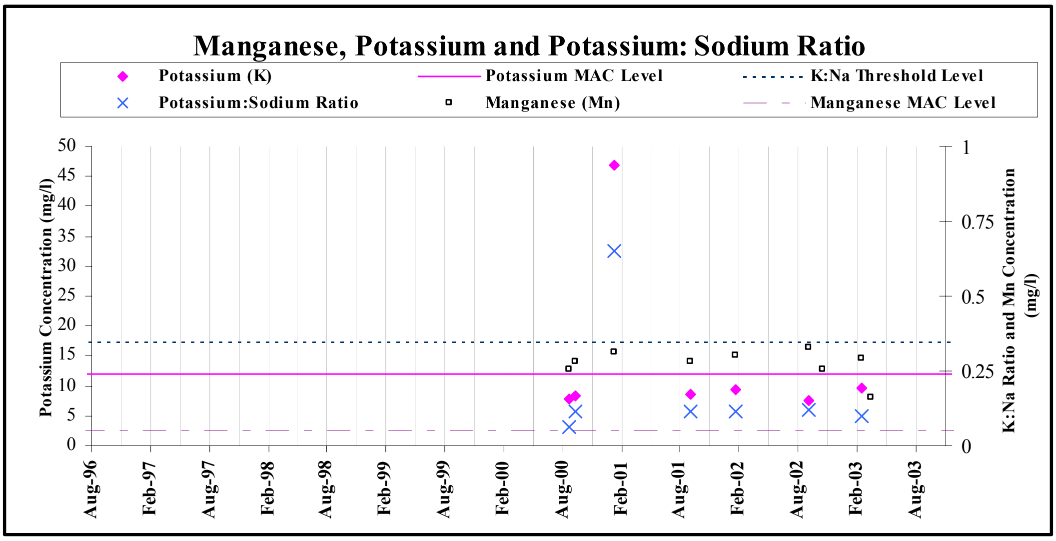


Figure 4.7. Key Indicators of Agricultural and Domestic Contamination (continued).

From these data, the following key points have been identified.

- Total hardness ranges from 180-300 mg/l. These data indicate a generally moderately hard to [illegible] (250-350 mg/l $CaCO_3$) calcium bicarbonate hydrochemical signature.
- The nitrate parameter comprises the longest record of concentrations, extending back to 1996. These concentrations are all less than 5 mg/l which does not suggest any significant anthropogenic influence. There are no evident trends in these data.
- There are no elevated levels of faecal coliforms in the nine Tri-a-Lough borehole samples taken, although the sample taken by the GSI in November 2002 did exhibit 6 counts/100 ml of total coliforms. For comparative purposes, the GSI data included surface water samples taken from Kinny Lough, which is c.175 m south of the borehole. In November 2002, 2 counts/100 ml of total coliforms were detected in the lake and in March 2003 there were 310 counts/100 ml of total coliforms and 265 counts/100 ml of faecal coliforms.
- Both iron and manganese concentrations are significantly elevated above their respective MAC levels of 0.2 mg/l and 0.05 mg/l in all of the nine available samples. Elevated levels of these parameters can indicate contamination by organic wastes. They are also associated with naturally occurring conditions, such as sand and gravel aquifers underlain by/derived from iron-rich bedrock, or the presence of reducing conditions i.e. an anaerobic environment. Peat layers are recorded in this aquifer, at the Fanad Sea Fisheries borehole. The presence of peat can result in reducing conditions. It is also likely that peat and/or alluvium around the lakes are resulting in anaerobic conditions.
- Seven of the nine available ammonia concentrations range from 1.32-2.30 mg/l, which is significantly elevated above the MAC levels (0.3 mg/l),. As with iron and manganese, elevated ammonia can result from reducing conditions due to natural or anthropogenic causes, such as organic wastes. However, the exceptionally high ammonia levels recorded in the Tri-a-Lough borehole indicate that the latter is a possible cause of concern. Furthermore, as the ammonia is known to have a low mobility in soil and subsoil, any possible sources of organic waste would be nearby.
- All of the chloride levels (seven samples) have been elevated above the guideline threshold of 30 mg/l; ranging from 85-145 mg/l. Elevated chloride levels may be due to the influence of sea spray and salty rainwater, especially as the sea is located less than 700 m away. However, not only are these levels higher than might be expected, but an anomalously high concentration of 145 mg/l was detected in September 2000, which may reflect a particular incident. Thus these data may be indicating the presence of organic waste, as suggested by the elevated ammonia concentrations.
- All of the seven available potassium concentrations exceed the GSI threshold of 4 mg/l. In one instance, it has significantly exceeded the MAC of 12 mg/l (47 mg/l in January 2001). The high

level of potassium on this occasion also caused the potassium:sodium ratio (K:Na) to exceed the 0.35 threshold. Although potassium is naturally associated with igneous rocks, it can also indicate contamination from organic wastes and the significantly elevated level detected in January 2001 is more likely to indicate a specific incident, rather than reflect natural background levels.

The chemistry data from the Tri-a-Lough borehole are not straightforward. Elevated iron, manganese, ammonia, chloride and potassium can result from natural conditions, which all exist at this location (reducing conditions under peat, proximity of the sea, igneous rocks). However, these parameters are also indicators of organic waste and the exceptionally high ammonia levels and anomalous incidents of elevated chloride and potassium may be associated with anthropogenic causes.

Locally, it is also noted that the advanced on-site wastewater treatment system for the day-care centre and accommodation for the elderly is located 150 m up-gradient of the borehole. There are 6 full-time residents and 20-28 centre attendees on two days a week (D. Gibbons, *pers.comm.*, 2004). This roughly equates to 10 full-time residents. Given the location and pressure magnitude associated with the treatment system, it cannot be ruled out as a potential source of contamination at the borehole.

4.6.5 Aquifer Characteristics

The Tri-a-Lough borehole abstracts an average of 400 m^3/d from a sand and gravel body which has been classified as a **locally important sand and gravel aquifer (Lg)**. Refer to Section 4, Volume I. This abstraction rate is limited by the capabilities of the water treatment facility rather than the productivity of the aquifer. It is understood that this borehole[16] can sustain an abstraction of 720 m^3/d (P. Dullea, *pers.comm*. 2003), and that the Fanad Sea Fisheries borehole pumps 900 m^3/d. At the production borehole, the aquifer comprises approximately 4-5 m of sand overlying 8-9 m of gravel.

There are no static water level data however, it is likely that this is close to ground level as it will be higher than the 1.3 m drawdown recorded during pumping. Similarly, the pumping water level in the trial well was 0.3 m higher than in the production borehole, and is located some 50 m east of the latter. The static water level would be expected to be slightly higher than this level.

From the available data and experience gained in similar situations, indicative aquifer parameter values can be estimated. It is recognised that much of the data required to accurately derived the parameters is not available for this particular sand and gravel deposit.

The specific capacity (Sc) is based on the present average abstraction of 400 m^3/d and a maximum drawdown of 1.3 m. This gives a value of at least 310 m^3/d/m. The transmissivity (T), which has been calculated from the Logan Method, is in the region of at least 400 m^2/d.

The permeability can be calculated by dividing the transmissivity by the saturated thickness of the aquifer. Taking an averaged thickness of the gravel (8.5 m) plus the saturated sand layer (3.5 m), the permeability (K) is approximately 35 m/d. The velocity of water moving through this aquifer to the borehole can then be calculated from Darcy's Law:

$$\text{Velocity (V)} = \frac{\text{(K x groundwater gradient (i))}}{\text{porosity (n)}}$$

The pumping gradient between the production borehole and the trial well is estimated as 0.006. A typical effective porosity for permeable sand and gravel aquifers is 0.20 (20%). Thus the velocity is in the order of 1.0 m/d. The aquifer parameters are summarised in the table below.

[16] At the time of writing, no pumping test data were available for either the Tri-a-Lough or Fanad Sea Fisheries boreholes.

Table 4.1. Indicative Parameters for Fanad North Sand and Gravel Aquifer.

Parameter	***Value***
Specific Capacities (m^3/d/m)	310
Transmissivity (m^2/d)	400
Permeability (m/d)	35
Porosity	20%
Velocity (m/d)	1.0

4.6.6 Conceptual Model

- The Fanad North (Tri-a-Lough) Public Water Supply borehole abstracts an average of 400 m^3/d. It is likely that the aquifer is capable of sustaining a higher abstraction rates.
- The water is abstracted from a **locally important sand and gravel aquifer** (**Lg**) which extends around Ballyhiernan Bay and inland as far as the band of lakes. At the borehole location, the aquifer comprise 4-5 m of sand over 8-9 m of gravel. The main groundwater flow is through the coarse gravel layer although the permeable sand is also considered to be part of the aquifer.
- The outcrop and borehole data indicate that the sand and gravel aquifer is within a bedrock trough, which is parallel to the coastline. The permeable nature of the aquifer together with the water level data from the production and trial wells suggest that the northern lip of the trough is at a higher elevation than then outcrop recorded at the coastline i.e. possibly somewhere within the higher sand dune area. This lip provides an impediment to groundwater flowing directly to sea, thus creating a significant height difference between the groundwater in the boreholes and at sea level.
- The anticipated groundwater flow direction is approximately east to west, along the long axis of the assumed bedrock trough, which is also indicated by the surface water flow direction through the lakes.
- Recharge to the well is expected to occur primarily via rainfall over the sand and gravel aquifer. There is an assumed connection between the aquifer and Loughs Kinny and Magheradrumman, which are thought to provide a small proportion of the recharge to the aquifer. It is also noted that some recharge may come from beneath the lakes and from the bedrock aquifer below.
- Over the area of aquifer, the vegetation and lack of artificial drainage infer that the soil and subsoil is free draining and thus diffuse recharge is occurring. The amount of effective rainfall recharging the sand and gravel aquifer is likely to be in the order of 630 mm/yr.
- Given the thin layer of unsaturated sand overlying the water-table in the vicinity of the borehole, the aquifer is considered to be unconfined. Furthermore, this shallow water-table results in a groundwater vulnerability classification of 'extreme'. Where the overlying unsaturated sand is thicker, the vulnerability is reduced to a 'high' category.

4.7 Delineation of Source Protection Areas

4.7.1 Introduction

This section delineates the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, and are presented in Figure 4.8.

Two source protection areas are delineated:

- ♦ Inner Protection Area (SI), designed to give protection from microbial pollution;
- ♦ Outer Protection Area (SO), encompassing the zone of contribution (ZOC) to the borehole.

4.7.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the borehole, i.e. the zone of contribution (ZOC), which is defined as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by (a) the abstraction rate, (b) the groundwater flow direction and gradient, (c) the aquifer permeability and (d) the recharge in the area. The delineation of the ZOC uses:

i. hydrogeological mapping techniques and analytical modelling to determine the boundaries,
ii. a comparison of average discharge and recharge data to estimate the area required,
iii. a safety margin to allow for any variability in the groundwater flow direction, and
iv. a safety margin to account for the larger ZOC required during the drier summer months.

Overview. As it is assumed that the majority of the recharge to the well is occurring over the sand and gravel aquifer, this will comprise the main part of the ZOC. However, the assumed connection between aquifer and Loughs Kinny and Magheradrumman implies that the lakes may contribute a (small) proportion of the recharge. It is noted, however, that the majority of the effective rainfall over the catchment area to the lakes will contribute to stream flow, due to the low permeability of the rocks in this area. These are the main considerations when delineating the ZOC boundaries, which are described below.

The **northwest and western boundaries** are on the down-gradient side of the borehole and denote the maximum down-gradient extent of supply to the borehole. From the indicative aquifer parameters, the extent of the down-gradient influence is estimated using:

$$\text{Approximate down-gradient extent} = \frac{\text{(discharge rate)}}{\text{2 x pi x (transmissivity) x (hydraulic gradient)}}$$

where the pumping rate[17] is 600 m^3/d, the transmissivity is 400 m^2/d and the hydraulic gradient is 0.006. Thus the down-gradient boundary is in the region of 40 m.

The **northern boundary** is essentially based on topography; the high points along the sand dune ridge. The uniform flow equation is used to give an indication of the up-gradient lateral extent of the borehole's influence when pumping. From the above parameters, this influence is estimated using:

$$\text{Approximate up-gradient lateral extent} = \frac{\text{(discharge rate)}}{\text{2 x (transmissivity) x (hydraulic gradient)}}$$

The up-gradient lateral extent of the area influence is estimated to be in the region of 130 m to each side of the borehole, which is within the northern boundary as based on topography. It is inferred from this estimate that the northern boundary is realistic.

The **northeast boundary** is also constrained by topography. This boundary divides the groundwater in the sand and gravel aquifer that is flowing in a south-easterly direction toward the boreholes and Lough Magheradrumman, from that which is flowing in a westerly direction towards Lough Shannagh and the Glashugh Burn.

The **southern boundary** takes into account the possible recharge from the lakes. It comprises a 30 m buffer around the lakes, main feeder streams and interconnecting streams. The buffer width is that which is used around locations of point recharge such as karst swallow holes.

The ZOC boundaries described above are based on the main sources of recharge. Given the high attenuation capacity of sand and gravel aquifers, these boundaries are considered to be sufficient to protect against most chemical and microbial contaminants.

However, even though the majority of rainfall over the catchment area to the lakes will discharge to the sea via surface flow (streams and lakes), due to the assumed connection between the lakes and the aquifer it is possible that the application of particularly persistent chemicals within the lakes'

[17] The total average abstraction rate at present is 400 m^3/d. An additional 50% is added in order to account for lower groundwater levels in summer and possible increases in abstraction.

catchment area may eventually end up in the borehole supply. The main chemicals that pose such a threat are considered to be insecticides, or sheep dip. Therefore these potential contaminants should be more rigorously regulated within the catchment area to the lakes in addition to the ZOC. The catchment to the lakes is highlighted on Figure 4.8. These boundaries are based on topography and the surface drainage patterns.

ZOC Area. The available recharge and discharge data are not comprehensive enough to undertake a water balance and thus accurately estimate the catchment area for the total discharge. However, the area of sand and gravel aquifer within the ZOC is approximately 0.4 km^2 which provides 690 m^3/d recharge. This estimate suggests that size of the ZOC across the aquifer is realistic although it cannot be assumed that there is no recharge from the lakes. Without additional data, it is difficult to justify alternative boundaries.

4.7.3 Inner Protection Area

According to "Groundwater Protection Schemes" (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area (SI) is required to protect the source from microbial contamination and it is based on the 100-day time of travel (ToT) to the supply.

Based on the indicative aquifer parameters outlined in Section 4.6.5, the groundwater velocity is calculated as being in the region of 1.0 m/d. Thus over 100 days, the groundwater will travel a distance of 100 m.

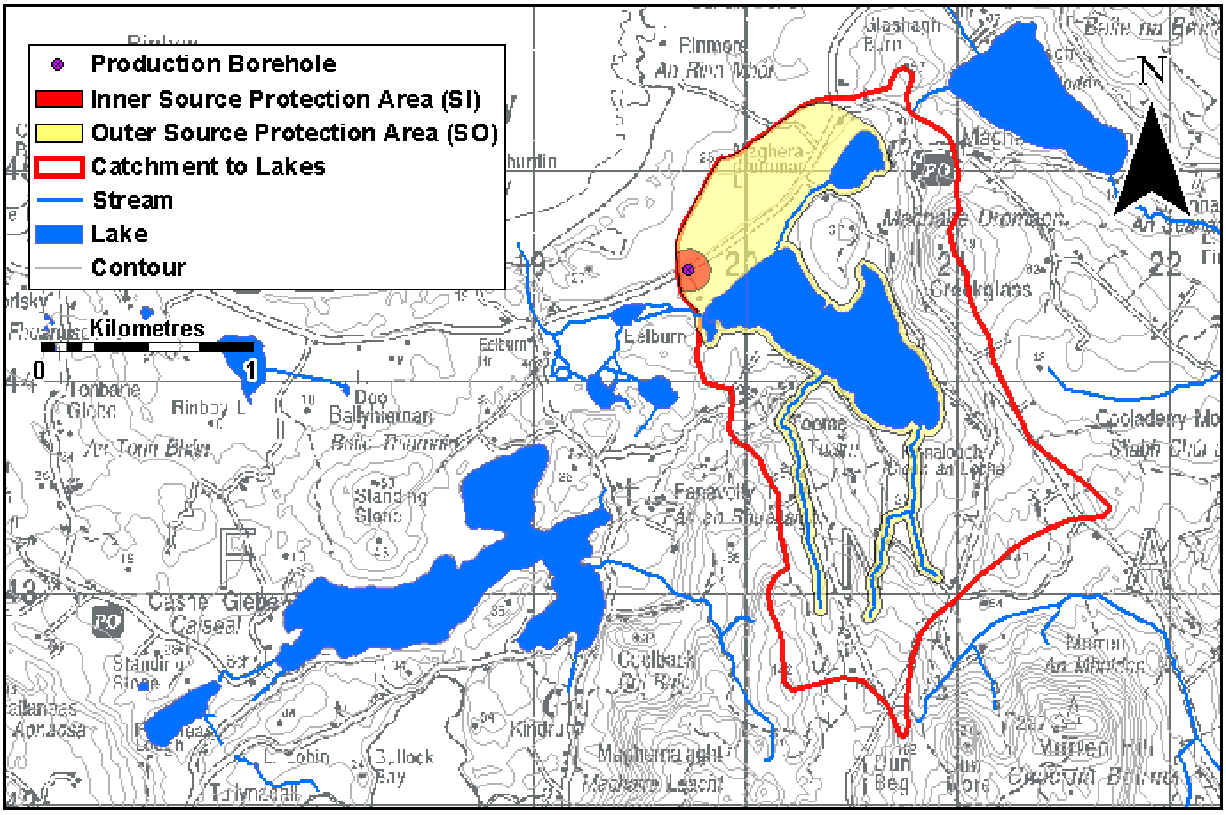


Figure 4.8. Delineated SO and SI Areas for the Fanad North (Tri-a-Lough) Scheme.

4.8 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones. In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an <u>Inner Protection area</u> where the groundwater is <u>highly</u> vulnerable to contamination.

Four source protection zones are present around the Tri-a-Lough borehole (Figure 4.9), as shown in Table 4.2 below. Over the sand and gravel aquifer, the groundwater is protected by the overlying unsaturated sand. Where the overlying unsaturated sand is thinner (<3 m in thickness), the groundwater is categorised as 'extremely' vulnerable to contamination. Underneath thicker deposits, the groundwater vulnerability is reduced to 'highly' vulnerable.

Table 4.2 Matrix of Source Protection Zones for Tri-A-Lough Borehole.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	**SI/E**	**SO/E**
High (H)	**SI/H**	**SO/H**
Moderate (M)	Not present	Not present
Low (L)	Not present	Not present

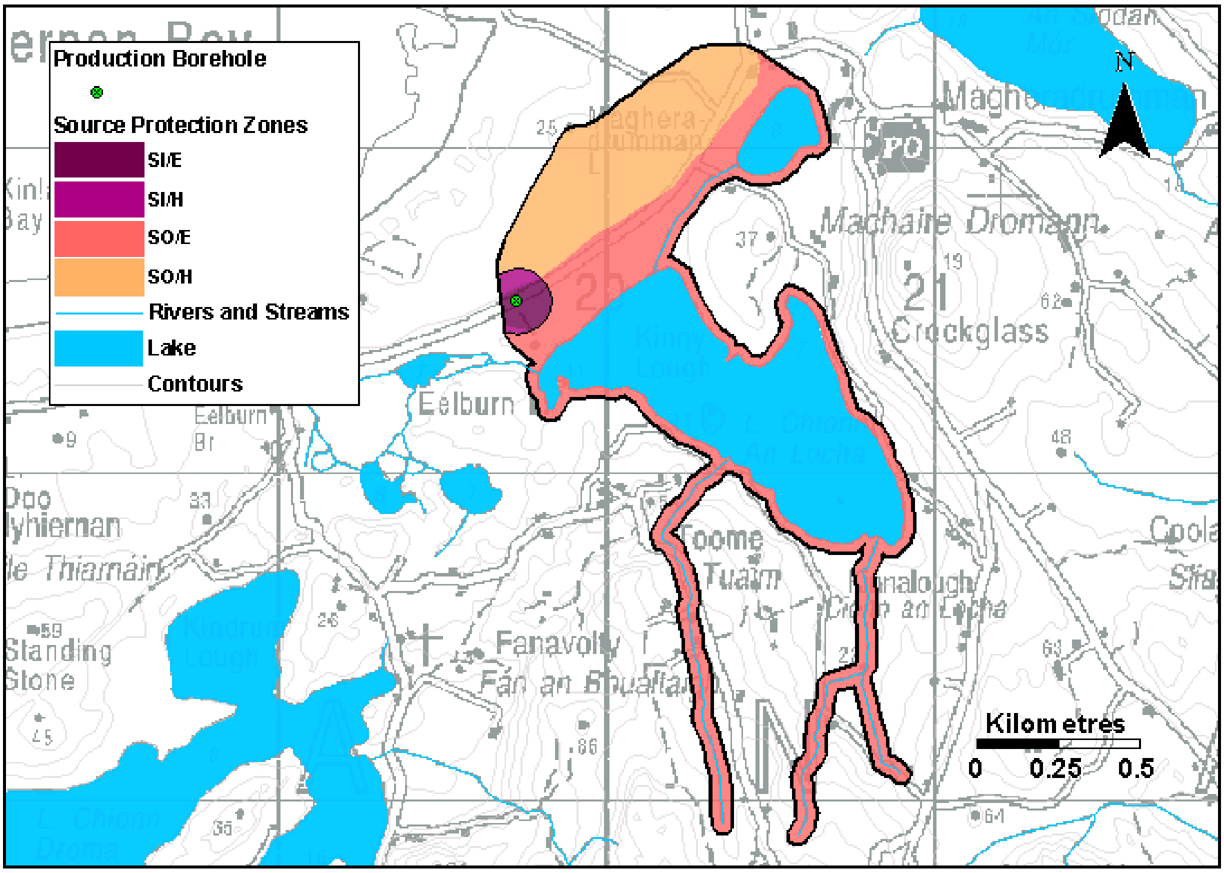


Figure 4.9. SPZ Around the Fanad Tri-a-Lough Water Supply Borehole.

4.9 Potential Pollution Sources

Within the ZOC, there are a number of potential hazards to the borehole abstraction. The advanced on-site wastewater treatment system behind the day care centre is approximately 150 m to the south-southeast of the borehole. This places it upslope of the borehole, just beyond the boundary of the inner protection zone. The Fanad United Football pitches are immediately up-gradient of the borehole and hence any treatment of the grass may prove to be a hazard for the borehole abstraction. Oil/diesel spillage within the adjacent parking or along the roads are also a possible hazard. The caravan park (Section 4.4.1), is outside both the SI and ZOC.

Assessments of the available water quality data are not straightforward as the indicator parameters may be influenced by the local natural conditions. Overall, the data do suggest that a nearby source of organic waste may be an issue, although microbial contamination does not seem to be a on-going problem. One potential source of nearly organic waste might be the advanced on-site wastewater treatment system, which is close enough to influence the chemical parameters and far enough to allow for microbial die-off. It should be noted, however, that detailed assessments of hazards were not carried out as part of this study.

4.10 Conclusions and Recommendations

- The Fanad North Water Supply Scheme abstraction from a combination of surface and groundwater sources. The Tri-a-Lough borehole abstracts groundwater at an average rate of 400 m^3/d over a 24 hour period.
- The borehole abstracts water from a **locally important sand and gravel aquifer (Lg)**.
- The ZOC mainly comprises the sand and gravel aquifer although also assumes that a small proportion of recharge comes from Loughs Kinny and Magheradrumman.
- The potential pollution sources in the ZOC include the advanced on-site wastewater treatment system, any herbicides used on the football pitches and road spillage.
- The protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.
- It is recommended that:

1. if a more accurate ZOC and SI are required, additional information is needed. This would include a) pumping tests on the Tri-a-Lough borehole in order to estimate more accurate aquifer parameters, b) further site investigation (drilling and possibly geophysics programmes) to determine the extent and depth of the aquifer, and c) comprehensive surface and groundwater monitoring to ascertain the proportion of recharge contributed from the lakes.
2. the potential hazards in the ZOC should be located and assessed, especially with regard to the up-gradient proximity of farmyards and houses.
3. particular care should be taken when assessing the location of any activities or developments that might cause contamination at the borehole.
4. full chemical and bacteriological analysis of the **raw** water at the abstraction point is carried out on a regular basis. The chemical analyses should include all major ions – ammonium, bicarbonate, calcium, chloride, magnesium, nitrate, potassium, sodium and sulphate.

7 References

Aqua-Fact International Services (no date). Summary of environmental assessment of the impact of freshwater abstraction for the use at a proposed fish processing plant at Rinmore Point, Fanad Head, Donegal. Extract from the document.

Collins J.F. and Cummins T. (1996). *Agroclimatic Atlas of Ireland.* AGMET – Joint working group on Applied Agricultural Meteorology, Dublin.

DELG/EPA/GSI (1999). *Groundwater Protection Schemes.* Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland.

Donegal County Council, Sanitary Services Section (July 1996). *Fanad Peninsula Water Supply – Emergency Relief Progress Report.*

Farrell E. (1989). Site investigation information including borehole and PSA information.

Fitzgerald, D. and Forrestal, F. (1996*). Monthly and Annual Averages of Rainfall for Ireland 1961-1990.* Meterological Service, Climatological Note No. 10, UDC 551.577.2(415).

Halcrow Group Ltd. (December 2001). *Review of the Groundwater Resources, Fanad Peninsula.*

Keegan M., Cantrell B., MacCartaigh M., and Toner P. (2002). *The Water Quality of Groundwater – Chapter 5* Water Quality in Ireland 1998 – 2000, EPA. Proceedings of the International Association of Hydrogeologists (Irish Group) Tullamore Seminar, 2002.

K.T. Cullen & Co. Ltd. (1992). *Proposed Groundwater Protection Policy for the Carndonagh Gravel Aquifer.* Report for Donegal County Council.

K.T. Cullen & Co. Ltd. (1998). *Report on a Hydrogeological Investigation of the Gleneely – Culdaff Area, Co. Donegal.* Report for Donegal County Council.

K.T. Cullen & Co. Ltd. (May 1998). *Groundwater Resources of the Fanad Peninsula.* Correspondence to Geological Survey of Ireland.

K.T. Cullen & Co. Ltd. (1997). *Report on the Drilling and Testing of a Water Well at Galdonagh.* Report for Donegal County Council.

Lee, M. and Daly, D. (1998). *County Donegal Groundwater Protection Scheme; Main Report*. Geological Survey of Ireland. Report for Donegal County Council.

Lee M. and Kelly C. (2003). *Boyle-Ardcarn Water Supply Scheme (Rockingham Spring). Source Protection Zones.* Geological Survey of Ireland. Report for Roscommon County Council.

Lee M. and Kelly C. (2003). *Killeglan Water Supply Scheme (Tobermore Spring). Groundwater Source Protection Zones.* Geological Survey of Ireland. Report for Roscommon County Council.

Long, C.B. & McConnell B.J. (1997) Geology of North Donegal: *A geological description to accompany bedrock geology 1:100,000 scale map, Sheet 1 and part of Sheet2, North Donegal.* With contributions from P. O'Connor, K. Claringbold, C. Cronin and R. Meehan. Geological Survey of Ireland.

Long, C. B., Mc Connell, B.J. (1999). *A Geological description of South Donegal, to accompany the bedrock geology 1:100,000 scale map series, Sheet 3/4, South Donegal.* With contributions from G.I. Alsop, P. O'Connor, K. Claringbold and C. Cronin. Geological Survey of Ireland.

McCarron Dr. S. (2002). *Aggregate Potential Mapping of County Donegal*. Geological Survey of Ireland. Report for Donegal County Council.

Meehan Dr. R. (2004). *Soils Parent Material Map.* Forest Inventory and Planning System – Integrated Forestry Information System (FIPS-IFS), Teagasc.

Met Eireann (2004). Digital rainfall and evapotranspiration grids 1971-2000.

Minerex Environmental Limited, (April 2003). *Ballyshannon and Rossnowlagh Water Supply Scheme; Groundwater Supply. Well design, drilling supervision, preliminary yield determinations, vulnerability assessment and reporting.* Report Reference 1492-067.

Minerex Environmental Limited, (July 2003). *Ballyshannon and Rossnowlagh Water Supply Scheme; Groundwater Supply. BH1, BH2, BH3, BH4 and Spring 2 pumping test supervision, monitoring, interpretation and reporting.* Report Reference 1492-103.

Mulholland & Doherty, Halcrow Water Services Ltd, (October 2002). *Fanad Regional Water Supply Scheme* – Summary Report; Supplementary Report No.2 Catchment Hydrology (Surface Water Sources); Supplementary Report No.2 Catchment Hydrology (Groundwater Sources).

Solmec, (1974). *Lough Inn Regional Water Supply Scheme Carndonagh Section – Trial Boreholes Logs and PSA*.

T.J. O'Connor & Assoc. (1989). *Lough Inn Regional Water Supply Scheme Carndonagh Section – Ground Investigation Report.*

GWWG, (November 2004). *Meeting Notes November 2004.* Water Framework Directive Groundwater Working Group; Sub-Committee on Recharge.

8 Appendices

Appendix C. Fanad North (Tri-a-Lough) PWS: Habitats

Site Code: 1975	**Name: BALLYHOORISKY POINT TO FANAD HEAD**	
E.U. Habitats	**E.U. Species**	**NPWS Habitats**
PERENNIAL VEGETATION OF STONY BANKS 17.3	Najas flexilis	Open marine waters
SEA CLIFFS 18.21		Sand dunes
LOWLAND OLIGOTROPHIC LAKES 22.11 & 22.31		Machair
HARD WATER LAKES 22.12 x 22.44		Sandy coastal beaches
		Shingle beaches
		Bedrock shores
		Rocky sea cliffs
		Lakes & ponds (incl. reservoirs)
		Rivers & streams
		Drainage ditches
		Lowland dry grassland (not improved)
		Lowland wet grassland (incl. rushy fields)
		Improved grassland
		Heath
		Blanket bog (upland & lowland)
		Cutaway bog
		Reedbeds & other swamps
		Freshwater marshes
		Dense bracken
		Scrub
		Dry, broadleaved semi-natural woodland
		Old walls
		Buildings & Roads

SITE SYNOPSIS

SITE NAME: BALLYHOORISKY POINT TO FANAD HEAD

SITE CODE: 001975

This large coastal site lies approximately 20 km north of Millford in north Donegal. The coastline is a series of bays with rocky headlands and steep cliffs at the east end. The underlying geology is predominantly granodiorite, a basic igneous rock. The east-facing coast is of quartzite and is exposed as a rocky shore and low cliffs. Large quantities of windblown sand dominate the northern section of the site.

Vegetated sea-cliffs, a habitat listed on Annex I of the EU Habitats Directive, are well represented at the site and are best developed to the south of Fanad Head where they reach a maximum height of 120m. The vegetation of the habitat has been little studied, however species such as Thrift (*Armeria maritima*), Sea Campion (*Silene vulgaris* subsp. *maritima*), Common Scurvygrass (*Cochlearia officinalis*) and the scarce Roseroot (*Rhodiola rosea*) occur. The Red Data Book species Scot's Lovage (*Ligusticum scoticum*), has been recently reported from sea cliffs at the site.

Shingle beaches, another habitat listed on Annex I of the EU Habitats Directive, are a feature of this site. These are best developed in the various small sheltered bays, especially between Ballyhoorisky Point and Rinboy Point and also along the stretch of coastline between Rinmore and Currin Point. The vegetation of the habitat within the site is typically sparse due to the exposed and highly mobile nature of much of the substrate. Information on the vegetation of the habitat is rather limited, but species such Sandwort (*Honkenya peploides*), Scentless Mayweed (*Matricaria maritima*) and Red Fescue (*Festuca rubra*) occur.

Machair grassland found within the site is characterised by its sandy substrate and gently undulating topography. The predominant grasses are Red Fescue, Crested Dog's-tail (*Cynosurus cristatus*), Yorkshire Fog (*Holcus lanatus*) and Creeping Bent (*Agrostis stolonifera*). A wide variety of flowering herbs are also present, including Wild Carrot (*Daucus carota*), Wild Thyme (*Thymus praecox*), Daisy (*Bellis perennis*), White Clover (*Trifolium repens*) and Wild Pansy (*Viola tricolor*). Low-lying wet areas occur where the sandy soils have eroded down to below the water table. These marshy areas are characterised by Bog Pimpernel (*Anagallis tenella*), Water Mint (*Mentha aquatica*) and Ragged-Robin (*Lychnis flos-cuculi*). Much of the machair is in a degraded state due to overgrazing and amenity pressure.

Lakes are also well represented and include some of the best examples of base-rich, nutrient-poor lakes in the county. These contain a range of rare or scarce plant species, including Slender Naiad (*Najas flexilis*), a species listed on Annex II of the EU Habitats Directive, Slender-leaved Pondweed (*Potamogeton filiformis*), Shoreweed (*Littorella uniflora*) and an excellent diversity of stoneworts, including *Chara rudis, Tolypella glomerata* and *Nitella spanioclema* (the latter probably endemic, though may be extinct).

This site contains many other coastal habitats including sandy beaches with drift line vegetation, sand dunes, wetlands, coastal heath and open marine water, the latter included in the site for its ornithological interest.

A number of rare and threatened Red Data Book plant species have been recorded from the site: Corncockle (*Agrostemma githago*), Scots Lovage and from lakes in the site, Pillwort (*Pilularia globulifera*) and Slender Naiad. The latter two species are legally protected under the Flora (Protection) Order, 1999.

The site is of ornithological importance for waterfowl, with nationally important numbers of Sanderling, Eider and Long-tailed Duck, as well as good numbers of Oystercatcer, Ringed Plover and Turnstone. Peregrine Falcon and Chough both breed within the site - these are listed on Annex I of the EU Birds Directive. The site is also used by Otter, Frog and Irish Hare, each of which is listed in the Red Data Book.

The site is grazed by both sheep and cattle and this, coupled with fencing off of certain areas and heavy use of fertilizers, has caused damage to some parts of the site.

This site is of ecological and conservation importance for the occurrence of examples of a number of habitats that are listed on Annex I of the EU Habitats Directive, the presence of Red Data Book plants species, including one listed on Annex II of this Directive, and for the large populations of several bird species that use it.

Duchas, 19.8.1999