Tobernaloo Water Supply Scheme

Groundwater Source Protection Zones

Prepared by:

Kevin Motherway, Natalya Hunter Williams and Geoff Wright
Geological Survey of Ireland

In collaboration with:

North Tipperary County Council

April 2002

1. Introduction

The objectives of this report are:

- To delineate source protection zones for the Tobernaloo Water Supply source.
- To outline the principal hydrogeological characteristics of the area.
- To assist North Tipperary County Council in protecting the water supplies from contamination.

2. Location and Site Description

Tobernaloo is one of three sources utilised by Thurles UDC and is situated approximately 2 km west of Thurles, in the townland of Sheskin. The wellhead consists of a 2 m diameter concrete chamber set on a foundation of crushed rock, so that only a proportion of the spring flow is captured. The overflow issues into a small stream.

The source is equipped with 3 overhead pumps and one submersible. There is a pumphouse. The water is chlorinated and fluoridated.

3. Summary of Spring Details

GSI no.	2015SWW195
Grid ref. (1:25,000)	21006 15832
Townland	Sheskin
Owner	North Tipperary County Council
Well type	Spring
Elevation (top of casing)	~ 89 m OD
Depth-to-rock	> 5m (from auger hole drilled nearby)
Static water level	87.48 m OD
Hours pumped per day	pumped on demand
Daily Abstraction	900 m^3/d (summer yield is usually 20% less)

4. Methodology

Desk study

Bedrock geology information was compiled from the GSI Geology 1:100,000 Sheet 18 (Archer *et al.*, 1996) and soils were compiled from Teagasc (1993). Basic public supply details were obtained from GSI records and County Council personnel; such details include spring chamber depth, elevation, abstraction rate, and pumping test details.

Site visits and fieldwork

The second stage of investigation comprised site visits and fieldwork in the area. This included a walkover survey in order to further investigate the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and the potential hazards. Water samples taken were analysed in the State Laboratory. Five continuous-flight auger holes were bored to ascertain the depth to bedrock in the area.

Data analysis

The assessment stage utilised analytical equations and hydrogeological mapping to delineate protection zones around the public supply spring.

5. Topography and Surface Water Hydrology

Tobernaloo WSS is located in poorly drained pastureland. The spring overflow spills over a length of bank into the Tobernaloo Stream, which runs northwestward to join the Soolvane River, which then becomes the Ballynahow River and runs generally south to join the Suir.

The Tobernaloo Stream reach adjacent to the source dries up in summer as a result of pumping the spring. The stream uphill and downhill of the well is very overgrown and appears as a marshy area in low flow.

The source is located at the mapped boundary between soils derived from till and soils derived from alluvium (Finch & Gardiner, 1993). GSI augering revealed clay subsoils with various proportions of silt, sand and gravel, which are interpreted as glacial till deposits.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the area comprises limestone sediments of Carboniferous age (Tournasian–Visean; about 330 million years old) which were subsequently folded and faulted. The rock units of the area, which are shown in Figure 1, are summarised in Table 1.

Table 1: The bedrock geology around the Tobernaloo WSS

Rock Formation	Rock Material	Thickness	Occurrence
Dolomitised Waulsortian Limestone (WAdo)	Dolmitised clean limestone: massive, unbedded micrite.	variable	Underlies the source; occurs as a NE-SW 500–700 m wide band from north of Thurles centre.
Waulsortian Limestone (WA)	Clean limestone: massive, unbedded micrite.	200 – 300 m	An 800–1000 m wide NE-SW band from Thurles centre to the south and west of the source.

6.1.1 Geological Structure

The spring issues from the dolomitised Waulsortian Limestone (WAdo) on the north limb of a major NE-SW trending syncline (V-shaped fold). Bedding dips in the immediate vicinity are gentle (5-10^{o}) and generally to the southeast. The Waulsortian Limestones in this region of County Tipperary are extensively dolomitised.

Approximately 500 m to the northwest of the source, a major NE-SW trending fault juxtaposes the underlying Ballysteen Limestone against the Waulsortian. The major faulting parallel to the fold axis is cross cut by numerous north-south faults that offset the bands of different lithologies.

6.2 Subsoils (Quaternary) Geology

No general subsoil mapping has been carried out in the area. The available information is limited to the soil map (Finch & Gardiner, 1993) and the augering carried out by GSI.

The subsoils in the area comprise glacial till and alluvium. The spring itself issues from beneath sandy stony clay till, very close to the boundary between the till and the alluvium. The limestone tills cover the bedrock to the south and east (uphill) of the spring, while the saturated alluvium (giving rise to a gley soil) occurs to the north and west of the spring, in the Tobernaloo Stream valley.

6.2.1 Limestone Till

Auger-hole drilling by the GSI determined the subsoils in the immediate vicinity of Tobernaloo spring to be sandy and stony clay. Teagasc (1993) assign the overlying soil in this area to the 'Patrickswell Series', a gravelly loam, ranging in colour from dark to pale brown. This soil type is described as well drained. The wetness of the subsoil as revealed in the auger holes apparently reflects the upward pressure of the groundwater in the underlying aquifer.

6.2.2 River Alluvium (derived from Limestone/Sandstone/Shale)

Silt and clay (accounting for up to 45% of the deposit in the top 0.4m) dominate the upper parts of the overlying gley soils, but the alluvium grades down into coarser sands and limestone gravels with <25% silt and clay.

6.3 Depth-to-rock

The depth to rock is known at selected localities from a drilling program undertaken for this study by the GSI to ascertain the thickness and type of the subsoils. The locations of the five auger holes are shown on Figure 2, and the logs are summarised in Figure 3. Depths to bedrock range from 0.75 m to more than 9.3 m. Locations with greater depth to bedrock appear to align in a north-northwest – south-southeast direction. This could possibly relate to subsoil in-filling of a faulted gully that would have high bedrock permeability.

7. Hydrogeology

7.1 Data availability

Hydrogeological and hydrochemical information for this study was obtained from the following sources:

- Hydrogeology

  Data such as flows, pumping schedules, and water levels in the spring were gained from Co. Co. personnel and collected by the GSI as part of this study.

- Hydrochemistry/water quality

  GSI targeted sampling (August 2000)
  EPA (March 1997 and in prep.)
  County Council analyses of public supplies (1992 – 1994)
  EC STRIDE Sub-programme Measure 1 (September 1993)

The hydrochemical data are summarised fully in the accompanying report "An assessment of the quality of public, group scheme and private groundwater supplies in North County Tipperary".

7.2 Rainfall and Recharge

Rainfall data for the area were obtained from Met Éireann. The mean annual rainfall (R) for the area (1961-90) was 975 mm. Potential Evaporation (PE) is estimated from a national contoured map by Met Éireann as 537 mm/yr. Actual evapotranspiration (AE) is estimated by taking 90% of the potential figure, to allow for soil moisture deficits, as 483 mm/yr. Using these figures, the potential recharge (R–AE) is taken as approximately 490 mm. Runoff is assumed to be 50% of available recharge, i.e. about 246 mm. This assumption is an empirical standard used in GSI for moderately permeable sandy till subsoils of the type which dominate the area around the Tobernaloo site. These calculations are summarised below:

Average annual rainfall	975 mm
Estimated P.E.	537 mm

Estimated A.E. (90% P.E.)	483 mm
Potential recharge	492 mm
Surface Runoff	246 mm
Recharge	246 mm

7.3 Groundwater levels

Borehole water level data are sparse in this area. The level of the water in the cased chamber was 87.48 m OD in June 2001, measured during a survey carried out by the GSI in the area. Water was encountered at a maximum of 1.8 mbgl in gravel subsoil in the trial borehole approximately 15 m from the spring (TNTB1) and two other auger holes revealed saturated clayey subsoil (TNTB2 and TNTB5).

There is only one surface drainage feature uphill (south and east) from the source, a stream that begins just south of the Thurles-Cashel road and runs northward past Poulnagappul to become Tobernaloo Stream. The proximity of the water table to ground surface both uphill (south) and downhill (northwest) of the source is indicated by boggy and marshy ground. However, uphill of the source, the sandy clay subsoil is on the order of 10 m thick in some places, so marsh could also indicate poor drainage.

7.4 Groundwater Flow Directions and Gradients

The water table in the area is assumed to broadly reflect topography with groundwater flowing toward and discharging into the spring and Tobernaloo Stream. The natural hydraulic gradient is estimated to be about 1%.

7.5 Hydrochemistry and Water Quality

Field measurements indicated an electrical conductivity of 716 μS/cm and a temperature of 11.2°C. Results of laboratory analysis of water samples are presented in Appendix 1. Data that reflect water quality are shown graphically in Figure 4. The following key points have been identified from the data:

- The groundwater samples have a calcium-bicarbonate (Ca – HCO_3) hydrochemical signature.
- Groundwater hardness is classed as 'excessively hard' (total hardness 373–453 mg/l as $CaCO_3$).
- Nitrate concentrations are relatively steady, ranging between 19.5 and 26.6 mg/l, with an average concentration of 23.2 mg/l (6 samples) over the period April 1992 to August 2000. The GSI threshold of 25 mg/l was exceeded once in the sampling period. The results are representative of general nitrate contamination by both diffuse (spreading of inorganic fertiliser and slurry) and point sources (septic tank systems and farmyards) in this area of relatively intensive farming. There is no trend apparent from the data.
- Two chloride sample concentrations are 27 and 22.9 mg/l. Chloride is a constituent of organic wastes and levels higher than 30 mg/l (away from coastal areas) usually indicate significant contamination. There are insufficient data to determine any trend.
- Bacteriological sampling measured no faecal contamination of the source in the period November 1993 to August 2000, although only two samples were taken in this time.
- Two potassium:sodium (K:Na) ratios of 0.18 and 0.21 can be calculated from the available data. The K:Na ratio is used to help indicate (along with other parameters) if water has been contaminated and may indicate contamination if the ratio is >0.4. To provide sufficient data to assess the source, it should be measured routinely in the future.
- Both iron and manganese levels are well below the EU Drinking Water Directive maximum admissible concentration (MAC; 2 samples), and in August 2000, concentrations were below the method detection limit (MDL).

7.6 Aquifer Parameters

Since the source at Tobernaloo is a spring, it was not possible to undertake a pumping test to determine aquifer parameters. Therefore, permeability and porosity measurements are established by parameter fitting to the Thiem steady state equation for steady state unconfined flow (Thiem, 1906 *in* Driscoll, 1986), combined with values used for the Waulsortian Limestone Formation in other areas. These values are summarised in Table 2.

Table 2: Estimated aquifer parameters for the rock units at Tobernaloo WSS

Parameter	**Data source**	**Waulsortian Limestone Formation (WA) parameter values**
Permeability (in upper 10 m)	• estimated from parameter fitting to analytical equation, and informed by regional experience	10 m/d
Porosity		0.03
Hydraulic gradient	• estimated from topography and surface hydraulic features	0.01 (1%)

7.7 Aquifer Category

Dolomitised Waulsortian Limestone (WAdo), in which the spring occurs, is classified as a Regionally Important fractured aquifer (**Rf**). Undolomitised Waulsortian Limestone (WA), which underlies some of the area to uphill (south) of the spring is classified as a ‘a ‘bedrock aquifer which is moderately productive only in local zones’ (**Ll**).

7.8 Conceptual Model

- The Tobernaloo spring is located at the head of the Tobernaloo Stream Valley. Overflow from the spring feeds the stream. The south-flowing stream uphill of the spring probably contributes some flow to the spring.

- Spring flow varies seasonally, between >900 m^3/d during summer and 1650 m^3/d in summer and winter respectively. Mean flow may be around 1300 m^3/d.

- The permeability of the Waulsortian Limestone Formation aquifers depends on the development of faults, fissures and fractures. In the dolomitised Waulsortian Limestone, permeablity and porosity are additionally enhanced by the dolomitisation.

- These dolomite and limestone rock units are largely overlain by moderately permeable limestone sandy clay till with some gravel. The till is saturated in areas uphill of the spring. The groundwater can, therefore, be considered as unconfined or semi-confined.

- The water table is assumed to reflect the topography of the area, with hills to the southeast, south/southwest and northeast acting as recharge mounds and groundwater flowing from these high points to the discharge points (spring and stream).

- The groundwater gradient is approximately 0.01 (1%).

8. Delineation of Source Protection Areas

8.1 Introduction

Two source protection areas are delineated:

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

8.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. the zone of contribution (ZOC), which is delineated as the area required to support average spring flow from long-term recharge. The ZOC is controlled primarily by (a) the spring flow, and (b) the recharge in the area. The ZOC is delineated as follows:

i) Topographic boundaries.

ii) An estimate of the area size obtained by using the average recharge and the spring flow rate.

Average daily abstraction at site is 900 m^3/d, although this decreases by about 20% during summer months. Mean flow must be somewhat higher than this, perhaps 1300 m^3/d. Taking the recharge to be 246 mm as indicated in Section 7.2, the area required to supply a mean flow of 1300 m^3/d is calculated to be 1.93 km^2 (193 ha). This compares with a topographically determined area of 2.24 km^2 (224 ha).

The boundaries of the 'topographic' ZOC are illustrated in Figure 1 and are delineated as follows:

Northwest Boundary: runs north-northeast to the spring from the topographic high (115.8 m OD) just south of the Hill Houses, then east-northeast from the spring to a hilltop at 113.4 m OD.

Northeast Boundary: runs southeast from the hilltop at 113.4 m OD, through Ardeen, to the hilltop at Ard na Croise (113 m OD).

Southeastern/Southern Boundaries: run southwestwards from Ard na Croise along a watershed divide parallel to the Cashel-Thurles road, before turning west to the hilltop near the Hill Houses.

These boundaries are based largely on topography, our current understanding of groundwater conditions in the area and on the available data.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) from a point below the water table to the source, and is delineated to protect from potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination. The 100-day ToT is estimated as follows and is shown in Figure 1:

Taking the permeability as 5 m/d, Effective Porosity as 0.03, and natural hydraulic gradient as 0.01, and using the Thiem steady state equation (Thiem, 1906 in Driscoll, 1986), the 100 day ToT is estimated as about 350 m. Appendix 2 gives details of the methodology.

The Inner Protection Area covers about 0.16 km^2 (16 ha), about 7 % of the ZOC.

9. Groundwater Vulnerability

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. It depends on the thickness, type and permeability of the subsoils. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DoELG/EPA/GSI, 1999).

Areas of rock outcrop and where rock is less than 3 m from the surface are rated 'Extreme' vulnerability. Where subsoils are greater than 3m thick, aquifer vulnerability ranges between 'Low' and 'High', depending upon the subsoil permeability. As this is an interim study, a distinction is made only between 'Extreme' and other vulnerability categories.

The groundwater vulnerability in the area is considered to be ‘High to Low’ for much of the area, and ‘Extreme’ in restricted parts. Vulnerability of groundwater in the Tobernaloo area is shown in Figure 5.

10. Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories), i.e. by superimposing the vulnerability map on the source protection area map. Since this is an Interim Groundwater Protection Scheme, in which only the extremely vulnerable areas are delineated, there are a total of only 4 possible source protection zones (see the matrix in the table below). Each zone is represented by a code e.g. **SO/E**, which represents an Outer Source Protection area where the groundwater is extremely vulnerable to contamination. Not all of the hydrogeological settings represented by the zones may be present around each local authority source. There are four groundwater protection zones present around the Tobernaloo source, as shown in Figure 6 and in the matrix below.

Table 3: Matrix of Source Protection Zones

VULNERABILITY RATING	**SOURCE PROTECTION**	
	Inner	***Outer***
Extreme (E)	SI/E	SO/E
High to Low (H-L)	SI/H-L	SO/H-L

11. Land use and Potential Pollution Sources

Agriculture is the principal activity in the area. Other hazards include farmyards, septic tank systems, application of fertilisers (organic and inorganic) and pesticides, and possible spillages along the roads. No detailed assessment of hazards was carried out as part of this study.

12. Conclusions and Recommendations

- The spring at Tobernaloo is fed from dolomitised Waulsortian Limestone, a regionally important fissured limestone aquifer (**Rf**). Part of the spring flow is sourced from a “bedrock aquifer that is moderately productive only in local zones” (**Ll**).
- Most of the area around the supply has ‘Low-High’ vulnerability to contamination; restricted parts are ‘extremely’ vulnerable to contamination.
- The inner and outer 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.
- Chemical and bacteriological analyses of raw water (rather than treated water) should be carried out on a regular basis (every 3 – 6 months).
- Guidelines should be drawn up for dealing with spillages along the roads and in streams in the area.

13. References

Archer, J.B, Sleeman, A.G., & Smith, D.C. 1996. *A Geological Description of Tipperary and Adjoining Parts of Laois Kilkenny, Offaly, Clare, and Limerick, to Accompany the Bedrock Geology 1:100,000 scale Map Series, Sheet 18, Tipperary.* Geological Survey of Ireland.

DoELG/EPA/GSI, 1999. *Groundwater Protection Schemes*. Department of Environment & Local Government, Environmental Protection Agency & Geological Survey of Ireland, joint publication.

Driscoll, F. (1986) *Groundwater and Wells* (2nd Ed). Johnson Filtration Systems, Minn., USA. 1089pp.

EPA (March 1997 and in preparation) *Nitrates in Groundwater County Tipperary (NR)*. EPA, Regional Inspectorate, Dublin

Finch, T.F. & Gardiner, M.J. (1993). *Soils of Tipperary North Riding*. Soil Survey Bulletin No. 42, National Soil Survey of Ireland, Teagasc, Dublin.

Hunter Williams, N. & Wright, G.R. (2001) *An assessment of the quality of public, group scheme and private groundwater supplies in North County Tipperary*. Geological Survey of Ireland.

Wright, G.R. *et al.* (1983) *Groundwater resources of the Republic of Ireland.*

Figure 1: Bedrock geology in the Tobernaloo area (based on Archer *et al.,* 1996).

Fig 2 – location map

Fig 3 - driller logs

Fig 4 - chemistry

Fig 5 -ZOC and TOT map

Fig 6 – vulnerability map

Fig 7 – Source PZs

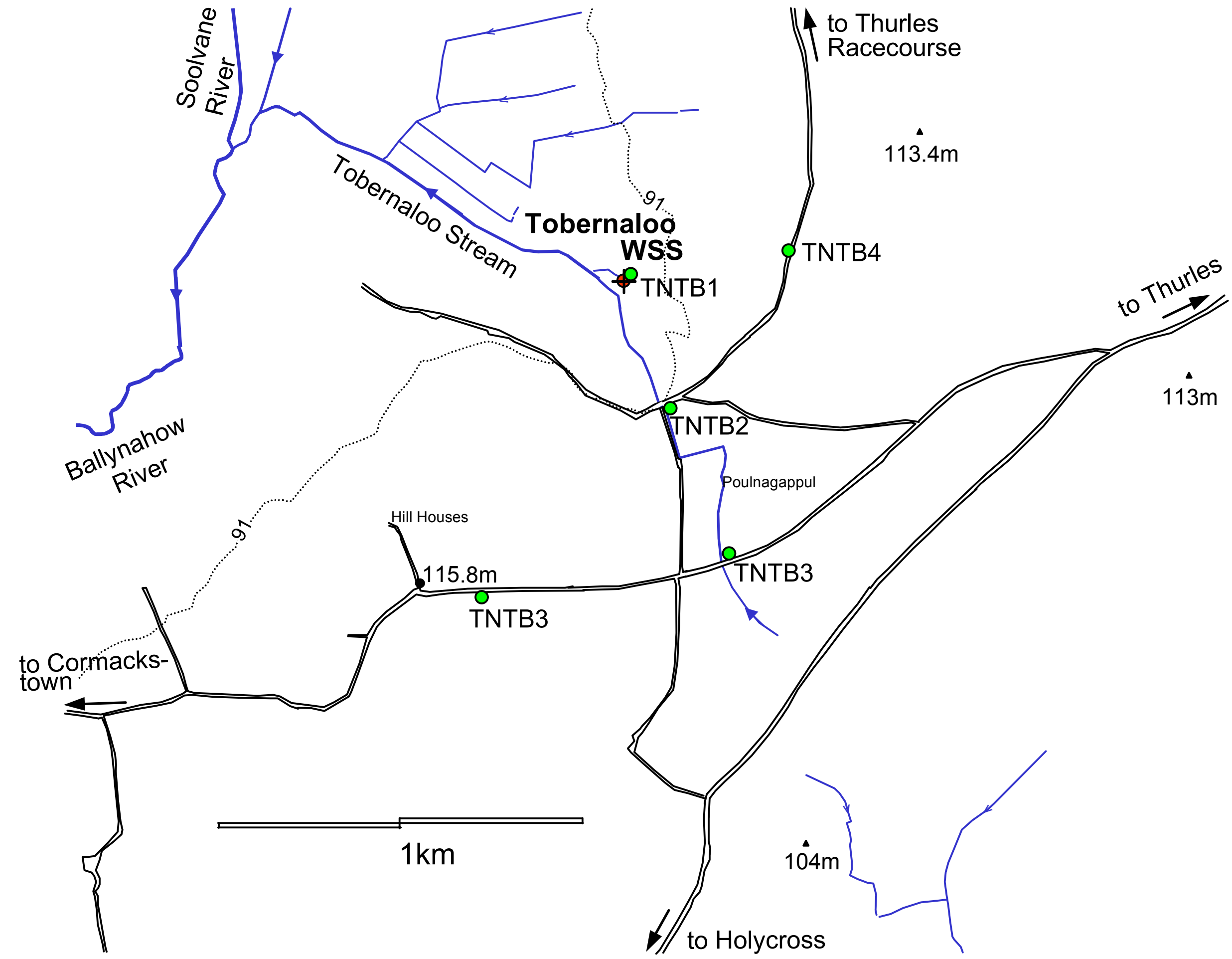
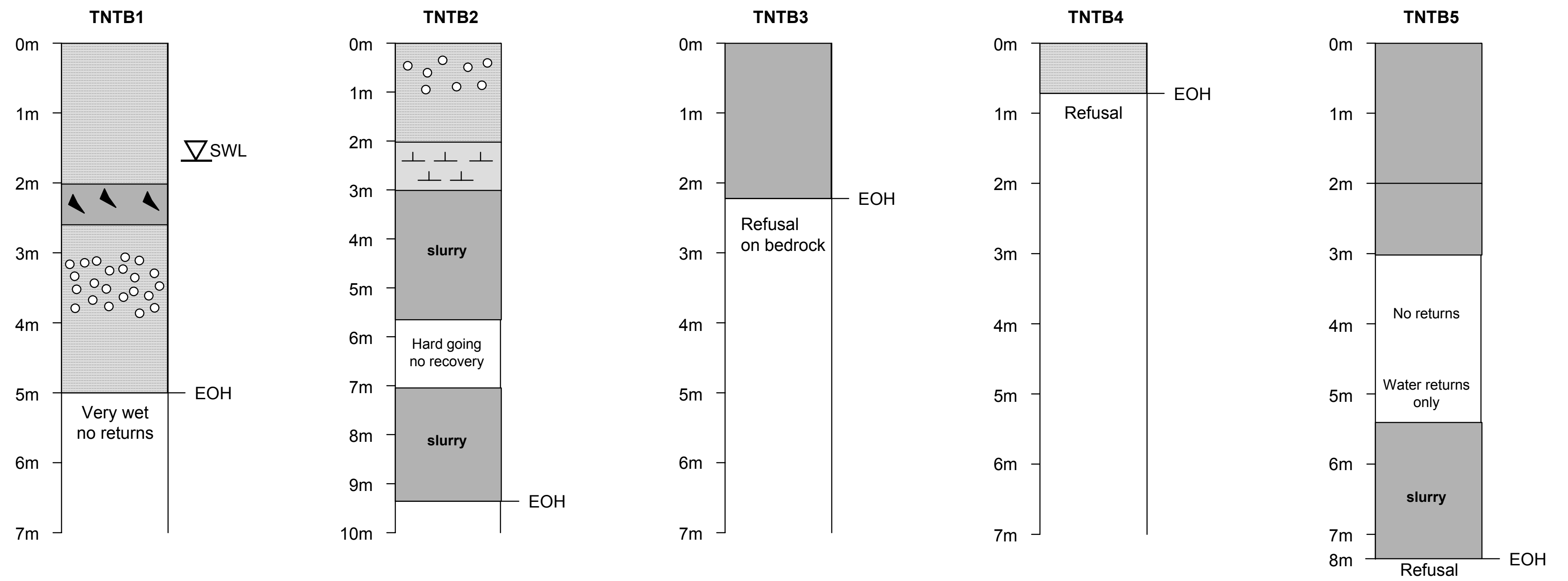


Figure 2: Location map of Tobernaloo WSS spring showing auger holes drilled by GSI to determine depth to bedrock in the vicinity (TNTB1 to TNTB5) and other hydrogeological features discussed in the text.



TNTB1 -

1.0m	Sandy CLAY
2.0m	Damp Sandy CLAY
2.6m	Stoney CLAY
3.0m	Reddish sandy CLAY
4.0m	GRAVEL with Sandy Clay
4.5m	Sandy CLAY
5.0m	V. wet NO RETURNS

SWL - 1.8m

TNTB2 -

1.0m	Sandy CLAY
2.0m	wet Sandy CLAY
3.0m	CLAY/SILT
3.5m	Clay Slurry to 5.7m
5.7m	Hard going NO RECOVERY
7.0m	CLAY slurry
9.3m	EOH

TNTB3 -

1.0m	Silty CLAY
2.0m	Silty CLAY
2.1m	Refusal on Limestone

TNTB4 -

0.75m	REFUSAL

TNTB5 -

1.0m	Soft CLAY
1.5m	Stoney CLAY
2.0m	Stoney CLAY
3.0m	Wet Silty CLAY
3.8m	NO RETURNS
4.7m	WATER RETURNS ONLY
5.5m	CLAY Slurry
8.0m	REFUSAL

Figure 3: Summary logs and lithological descriptions of auger holes drilled to assess depth to bedrock near Tobernaloo (Thurles) WSS. (See Figure 3 for locations of the auger holes.)

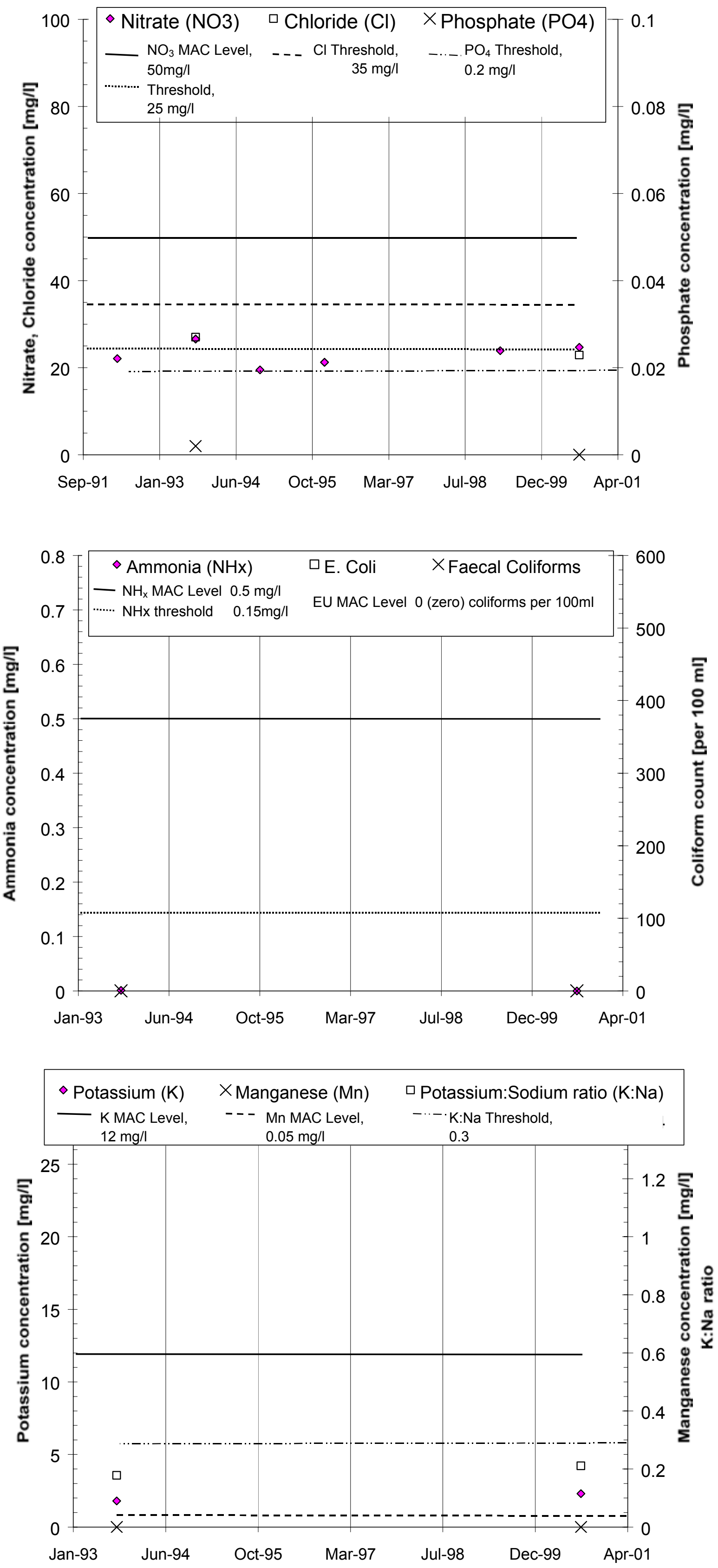


Figure 4: Key indicators of agricultural and domestic groundwater contamination at Tobernaloo (Thurles) WSS

Appendix 1: Laboratory Analyses of Groundwater at Tobernaloo WSS

Parameter	Results of Laboratory Analyses					
Sample source	dwr	Regional Water Lab	dwr	nmp	nmp	State Lab
Sample treatment		S				S
Sample date	28/04/92	23/09/93	19/11/94	15/01/96	10/03/99	09/08/00
Conductivity (µS/cm)		792				700
pH (lab)		7.5				
Total Hardness (mg/l $CaCO_3$)		452.5				373.3
Total Alkalinity (mg/l $CaCO_3$)		377				358
Calcium (mg/l)		131				112.3
Magnesium (mg/l)		30				22.2
Chloride (mg/l)		27				22.9
Sulphate (mg/l)		8				15.7
Sodium (mg/l)		10.1				10.9
Potassium (mg/l)		1.8				2.3
K:Na ratio		0.18				0.21
Nitrate (as mg/l NO_3)	22.1	*26.6*	19.5	21.25	23.91	24.7
Iron (mg/l)		0.027				<MDL
Manganese (mg/l)		0.003				<MDL
E. coli count per 100 ml		0				0
Total coliforms per 100ml		0				0
Ammonia (mg/l NHx)		0.001				<MDL

Note: **Bold type denotes E.U. MAC exceedances.**

Italic type denotes GSI threshold exceedances

'NS'/ 'S' denotes Non-source (treated) or Source (raw) water samples

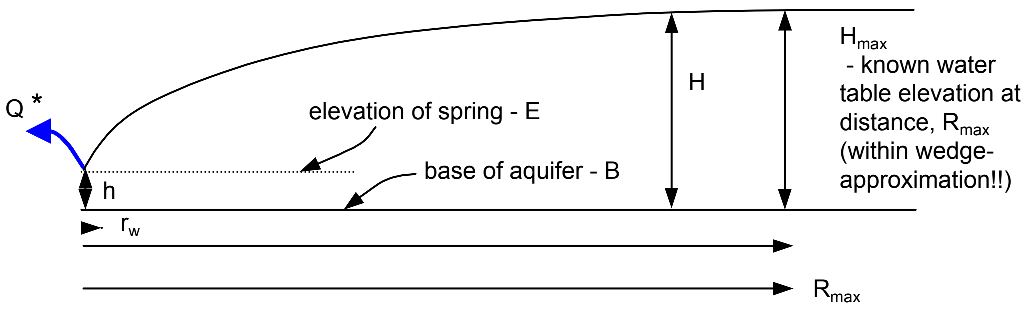
Appendix 2: Calculation of 100 day Time-of-Travel (TOT) to a spring by using the Thiem equation and approximating the zone of contribution (ZOC) to the spring by a wedge

The Thiem equation for unconfined flow is:

$$Q = \frac{1.366\,K\,(H^2 - h^2)}{\log_{10}(R/r_w)} \qquad \text{solving for H:} \qquad H = \sqrt{\frac{Q\,.\,\log_{10}(R/r_w)}{1.366\,.\,K} - h^2}$$

This equation is for radial flow to a well (i.e. flow from all sides around a cylinder), so the flow Q has to be multiplied by a factor to account for the wedge-like shape of a ZOC to a spring. This gives Q*.

In cross section, the water table has the following shape and the system is defined by these parameters:



Model parameters and predicted water table elevation at Tobernaloo WSS

Q* = 1906 m^3/d (900 m^3/d x 170°/360°)

K = 5 m/d, effective porosity = 0.03

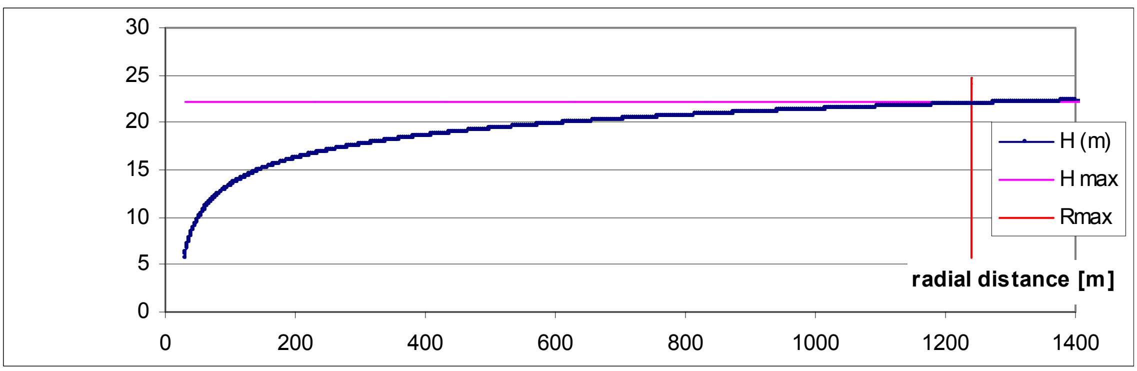
r_w = 10 m

R_{max} = 1240 m; H_{max} = 100 m (surface water elevation next to Cashel-Thurles road)

E = 87.48 m (the elevation of the spring);

B = 77.48 m (the base of the effectively flowing aquifer at the spring)

s



The 100 day ToT is estimated by computing travel times at incremental distances away from the spring by using the local groundwater gradient (i*) in the equation:

Pore or fracture velocity (m/d) = K i*/ effective porosity

100 day ToT = Pore or fracture velocity (m/d) x 100 days