TOBERDALY PUBLIC SUPPLY

GROUNDWATER SOURCE PROTECTION ZONES

(DRAFT)

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September 1996

TOBERDALY PUBLIC SUPPLY

1. SUMMARY OF WELL DETAILS - POOL WELL

GSI no.	:	2323SEW002
Grid ref.	:	25176 23171
Owner	:	Offaly County Council
Well type	:	Spring
Elevation (ground level)	:	Approx. 80.5 m OD (Poolbeg).
Depth	:	4 m + (the spring is deeper at the centre)
Diameter	:	Approx. 10 m
Depth-to-rock	:	10.2 m b.g.l.
Static water level :	:	80.01 m O.D. on 9/9/82
Pumping water level	:	Approx.79.0 m O.D. on 31/7/96
Drawdown	:	Approx. 1.0 m
Abstraction rate	:	2500 m^3/d (23000 gal/hr)
Normal consumption	:	2500 m^3/d (approx. 550,000 gal/d on average, over 24 hours)
Pumping test summary:	:	No test pumping has been carried out on Pool Well.

SUMMARY OF WELL DETAILS - HEAVEY'S WELL (currently not in use)

GSI no.	:	2323SEW 031
Grid ref.	:	25175 23172
Owner	:	Offaly County Council
Well type	:	Spring
Elevation (ground level)	:	Approx. 81 m OD (Poolbeg).
Depth	:	2.80 m
Well Dimensions	:	Approx. 10 m x 35 m
Depth-to-rock	:	12.4 m b.g.l.
Static water level :	:	80.11 m O.D. on 31/7/96 and 80.4 m O.D. (prior to the test pumping on 4/10/1982)
Pumping water level	:	79.37 m on 27/9/88 and 79.7 m O.D. on 9/9/82
Drawdown	:	0.7 m during general pumping in 1982.
Normal consumption	:	The well is no longer pumped, however a significant overflow occurs during the winter months.
Pumping test summary:	:	Test pumping was carried out in October 1982 (see section 6.2.1.).

SUMMARY OF WELL DETAILS - MOUNT WELL (currently not in use)

GSI no.	:	2323SEW 032
Grid ref.	:	25176 23172
Owner	:	Offaly County Council
Well type	:	Spring
Elevation (ground level)	:	Approx. 81.5 m OD (Poolbeg).
Depth	:	2.66 m
Well Dimensions	:	Approx. 7.5 m x 10 m
Depth-to-rock	:	7.5 m b.g.l.
Static water level :	:	80.05 m O.D. on 31/7/96, 80.00 on 9/9/82
Pumping water level	:	79.37 m on 27/9/88
Drawdown	:	Approximately 0.6 m during general pumping.
Normal consumption	:	The well is no longer pumped, however a significant overflow occurs during the winter months.
Pumping test summary:	:	Test pumping was carried out at Mount well in October 1969 and in October 1976 (see section 6.2.1.).

2. METHODOLOGY

There were three stages involved in assessing the area, a detailed desk study, site visits and fieldwork, and analysis of the data. The desk study was conducted in the Geological Survey where the subsoil and bedrock geology's were compiled from the original 6" field sheets and more recent geological maps at 1:100,000 scale. Well details and chemical analyses were obtained from Offaly County Council (Sanitary Services Section). A consultants report on Toberdaly springs by K.T. Cullen & Company and a Geophysical survey by the Geological Survey of Ireland were also available for interpretation.

The second stage comprised site visits and fieldwork in the surrounding area. This included a walkover survey in order to further investigate the subsoils, geology, hydrogeology and vulnerability to contamination of the area around the source.

Stage three, the assessment stage, utilised analytical equations and hydrogeological mapping to delineate protection zones.

3. SPRING LOCATION AND SITE DESCRIPTION

The springs are located approximately 11 kilometres west of Edenderry, 2 km SW of Rhode (see Figure 1). Three springs are present at Toberdaly: Heavey's Well, Mount Well and Pool Well. Pool Well is the only well currently being used. This well was deepened in 1991/1992 in order to replace Heavey's well because the water levels in Heavey's Well were drawn down below the pump intake level during periods of dry weather. Mount Well was used by the E.S.B. to supply water to the nearby power station at Rhode, this supply has been replaced by a bored well at the power station. All three wells are on the site of springs which have been deepened in order to improve their natural yield.

Heavy's well and Mount Well are walled and covered by concrete while the Pool Well is covered by a corrugated steel structure; all the wells are fenced off.

The output from Pool Well is pumped to three separate group schemes at Fahy, Croghan and Rhode.

4. TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE

The wells are located 300 metres to the north of the Grand Canal at an elevation of 80-81m O.D (Poolbeg). The land slopes gently upwards to the north-east at first, and then more steeply around Toberdaly House, up to a height of approximately 100 metres. Topographic highs also occur 1.5 km to the west (over 150 m O.D.) and beyond Toberdaly House at Clonin Hill (135 m O.D.).

Large areas of peat bog occur to the west, north-west and south of Toderdaly. The area of bog to the north-west is being cut away, for use at Rhode power station.

Most of the land to the north and east of Toberdaly is free draining, no surface streams (including the canal feeder stream) were visible during the walkover survey on 14/8/96. This land is used predominantly for pasture.

5. GEOLOGY

5.1 Bedrock geology

The wells at Toberdaly are located at the contact between the Calp Limestone to the west and the Allenwood Limestone to the east. The Allenwood Limestone is a dark grey, coarse grained, crystalline limestone, which has a well developed bedding and jointing network. This limestone forms a roughly north-south trending outcrop area, about 500 metres wide, and is exposed to the east and north of Toberdaly House where the beds dip between 20°-30° NW (Figure 1).

Allenwood Limestone is also shown on recent geology maps (McConnell and Philcox, 1995 and Hitzman, 1992) 1.5 km west of Toberdaly. The limestone is shown to outcrop around the margins of the volcanic rocks (lavas and ash deposits) which form Croghan Hill. The limestone is poorly exposed in this area, however the few visible exposures suggest that the dip of the beds is generally between 5 and 15° to the east. It is possible that this outcrop of Allenwood Limestone forms the western part of a syncline and this limestone is connected to the limestone around Toberdaly Springs, however the local structural geology is uncertain due to the lack of information.

Recent discussions with Conor MacDermot at the GSI, together with an examination of outcrop descriptions and borehole data, suggest that the limestone shown on the geology map immediately to the east of Croghan Hill is in fact Calp Limestone (rather than Allenwood Limestone). Therefore there is some doubt over the geology of this area.

The Allenwood limestone is partially dolomitised and elsewhere has shown evidence of karstification (MacDermot, C., pers comm).

The Calp Limestone is a fine grained, dark grey-black limestone which is generally thinly bedded. This limestone forms much of the low lying ground around Toberdaly, a large proportion of which is overlain by peat bog.

The Edenderry Limestone outcrops to the east of the Allenwood Limestone. This limestone is a medium-dark grey, coarse grained, oolitic limestone (composed of small spherical grains) which is generally well bedded.

A NE-SW trending fault is shown on the recent geology maps to the north-west of Toberdaly House (this fault is marked on Figure 1). The exact position of the fault is uncertain; however N-S and E-W trending faults are more typical of the Carboniferous limestones in this area (MacDermot, C., pers comm).

5.2 Quaternary (subsoils) geology

The Quaternary map of the area shows the subsoils immediately to the north and east of Toberdaly as limestone till; this till coincides with an area of well drained land. The general drainage suggests a moderately permeable deposit.

Three wells drilled by K.T.Cullen & Co. in September 1990 on the site of the springs indicated that the subsoil in this area consists of a sequence of alternating clayey till (often with a silty or gravely component) and sand and gravel. The uppermost 3-5 metres were generally dominated by clay till and the lower 5-12 metres were a combination of sand and gravel and clayey till units. The till units are generally less than 2 metres thick, however the log for the borehole drilled near Heavey's Well shows clayey till and sand and gravel units up to 4.5 metres thick. Apart from these boreholes there is no additional evidence for sand and gravel within the till (no gravel pits are visible in the area).

The Quaternary map shows that areas of land to the west, north-west and south of Toberdaly are covered by peat. Information from a recent trial pit 500 m NW of the springs (from Offaly Co Co.) showed that the peat was thin (0.3 m) and there was clayey till down to a depth of 3 m. The subsoils are shown in Figure 2

5.3 Depth-to-rock

Bedrock is exposed to the east and north of Toberdaly House and a large area of rock close to surface has been delineated by Quaternary mapping (Figure 2). Borehole records at the springs show that the subsoils vary between 7.5 and 12.4 metres in thickness. These subsoils are likely to thin northwards towards the area of rock outcrop around Toberdaly House. This is supported by geophysical data which suggest that rock is close to the surface 200 metres NE of Toberdaly (and also to the southeast of the springs, towards the Grand Canal). Therefore in the area immediately north of the well the subsoils are generally considered to be between 3 and 10 m. The borehole drilled by the GSI to the west of Clonin Hill (see Figure 1) penetrated 13 m of subsoil before reaching bedrock. Elsewhere information is scarce and the thickness of the subsoil is uncertain.

Depth to bedrock contours have been drawn at 3 and 10 metres. The 10 m contour is tentative (based mainly on topography with some borehole records).

6. HYDROGEOLOGY

6.1 Data availability

There are several sources of data available for interpretation, for the springs at Toberdaly and the surrounding area. The data are summarised below:

- Discharge measurements were taken at Toberdaly Springs by the E.S.B. during 1959 and 1960.
- A pumping test was carried out on Mount Well in October 1969 by Ryan and Associates.
- A second pumping test was carried out, by the County Council between October 13th - October 17th, 1976, by blocking the canal feeder downstream of Mount Well.
- A third pumping test was carried out by K.T. Cullen & Co. between the 4th October - 11th October 1982 on Heavey's Well. In addition to water level measurements taken in the three springs at Toberdaly, water level measurements were taken in 9 additional locations in the area surrounding Toberdaly.
- A report by K T. Cullen into the yield of the springs accompanied the third pumping test and examined all the previous data.
- Water level measurements were taken in the all three springs on 4 occasions, between 12th September 1988 and the 6th October 1988, by Offaly Co. Co.
- A borehole was drilled (cored) by the GSI in the summer of 1989, approximately 2km north of Toberdaly.
- Borehole logs are available for three wells drilled at Toberdaly, by K.T. Cullen & Company in 1990.
- A geophysical survey was undertaken by the GSI of the area around the springs.
- Water levels were measured at all the springs on the 31st July 1996 as part of the current protection zone study.
- Chemical analyses are available from samples taken by the Co. Co. and by the GSI at various dates between 1964 and 1995.

6.2 Groundwater levels

In general the water table is close to the surface in the immediate vicinity of the springs, and at the ground surface during winter (there is a significant overflow from the springs in winter). Elsewhere the groundwater levels suggest that the water table is a subdued reflection of topography. Groundwater levels are low at Toberdaly springs and further to the south and east (stations 9,10 and 11). Higher groundwater levels were measured on the hills to the north and west of Toberdaly (stations 4, 5, 12 and 13). Groundwater levels were generally 1-3 metres below the surface in the area around Toberdaly.

The canal feeder was dry to the north of Toberdaly during the site visit and according to a nearby landowner it has been dry in recent years. This could be due to increased abstraction from the springs or as a result of draining of the bog to the west.

A summary of water level data for the springs at Toberdaly is shown in Table 6.1.

More detailed water level measurements in the surrounding area are given in Appendix 1 (and Figure 1).

Table 6.1 A Summary of Available Water Level Data for Toberdaly Springs

	9/9/82	12/9/88	20/9/88	27/9/88	6/10/88	31/7/96
Pool Well	80.01	*78.93	*78.93	*79.00	*79.04	*80.01
Mount Well	*80.00	*79.12	*79.12	*79.37	*79.55	80.11
Heavey's Well	*79.7	*78.74	*78.76	*79.05	*79.15	80.05
* This well was being pumped at the time of measurement All water levels in m O.D. (Poolbeg).						

6.2.1 Test Pumping Data

The test pumping carried out in October 1959 involved pumping the Mount Well at an estimated rate of 10,200 gph (1112 m³/d) continuously for 9 days, with a resulting drawdown of 13 inches (33.02 cm). The water levels in Heavey's Well and Pool Well were not affected by the pumping in Mount Well.

The test pumping carried out by the County Council in October 1976 involved blocking the canal feeder downstream of Mount Well and pumping from the temporary lagoon at an estimated pumping rate of 26,000 gph (2834 m³/d). The test was carried out for 4 days and resulted in a drawdown of 25.44 inches (64.61 cm). Water levels in Mount Well were affected by the pumping test while the water level in the Pool Well remained stationary.

The final test, carried out on Heavey's Well in October 1982, involved an average pumping rate of 24,200 gph (2637 m³/d) with a resulting drawdown of 32.67 inches (92.98 cm). Water levels in Mount Well and Pool Well were both affected by the pumping test.

The test pumping produced unit drawdowns between 2.5 and 3.5 cm per 1000 g.p.h. pumped.

6.3 Groundwater flow directions and gradients

Calculated groundwater gradients in the limestones to the north of Toberdaly ranged from 0.0075 to 0.01. The steepest gradient occurred between station 5 and Toberdaly (Figure 1), with shallower gradients to the east and west of the high ground.

The groundwater gradients measured to the west of Toberdaly, between stations 12 and 13 and the low ground to the east were relatively steep, between 0.026 and 0.09. This is likely to be a reflection of the lower permeability of the volcanic rocks and limestones in this area. The gradients calculated around station 12 also suggest the bedrock here is Calp Limestone rather than Allenwood Limestone (lower permeabilities and higher gradients are expected in the Calp).

The groundwater level data suggest that groundwater flows to the west, east and south of the high ground to the north of Toberdaly, the steeper gradients and therefore the dominant flow direction is southwards.

6.4 Meteorology and recharge

Rainfall data for the area are taken from the Meteorological Service for the nearest station at Daingean. For the years 1951 - 1980 the mean annual rainfall for the area was 847 mm. Evaporation data for the area are taken from the station at Birr as recorded by the Meteorological Service. Potential evapotranspiration (P.E.) is calculated as 467 mm/yr. Actual evapotranspiration (A.E.) is then calculated by taking 95% of the potential figure, to allow for soil moisture deficits for part of the year, so A.E. is estimated as 444 mm/yr. Using these figures the effective rainfall (E.R.) is taken to be approximately 403 mm/yr.

The presence of free draining soils, moderately permeable till and rock close to surface over the area to the north of Toberdaly suggests that a high proportion of effective rainfall is infiltrating to the water table. Although the proportion of effective rainfall infiltrating to the water table is not known with certainty, it is assumed that 90% is a realistic figure and that actual annual recharge in the area is therefore approx. 362 mm.

These calculations are summarised below:

Average annual rainfall	847 mm
Estimated P.E.	467 mm
Estimated A.E. (95% P.E.)	444 mm
Effective rainfall	403 mm
Recharge (90% E.R.)	362 mm

6.5 Hydrochemistry and water quality

Samples of groundwater from the public supply are analysed regularly by the County Council. Approximately 40 samples are available for analyses, half of these are comprehensive analyses.

The chemical analyses for Toberdaly Springs indicate a **hard** water (251 - 350 mg/l $CaCO_3$), with a relatively high alkalinity (270 - 290 mg/l). Conductivity values are typical of groundwater from limestones (500 - 600 µS/cm), as are the pH values (7.0 - 7.7). Chloride levels are normally between 10-15 mg/l with occasionally slightly elevated values (up to 22 mg/l). Levels of sulphate are also occasionally higher than normal (39 mg/l on 22/5/81). Faecal coliforms were detected on several occasions between 1973 and 1987. In addition numerous algae, diatoms and rotifers have been detected in Heavey's well and Pool well (1987-1988). Concentrations of ammonia, nitrates and potassium are all normal and there are no iron problems at this well. The origin of the recorded faecal pollution is uncertain, it may be that the well is occasionally polluted by organic waste, probably from a farmyard or a septic tank or this may be the naturally occurring pollution from wildlife, as all the wells are open to some degree.

The temperature of the groundwater from Toberdaly Springs is approximately 2° warmer than the average expected groundwater temperature, suggesting a geothermal origin for some of the groundwater. The available temperature data is shown in Appendix 2.

6.6 Aquifer coefficients

Hydrogeological data on the nature of the limestone (and the till) around the source is poor. The Allenwood Limestone is a clean, coarse grained limestone which has a well developed bedding and jointing network. The limestone is partly dolomitised and elsewhere is known to show evidence of karstification. These features suggest that the limestone is moderately - highly permeable. The permeability (k) for the upper limestone layers is estimated at 5-10 m/d. It is emphasised that these (somewhat conservative) estimates are based on permeability values from limestones for other areas, and from the GSI conceptual model of groundwater flow in limestones. Site investigations would be necessary to derive definitive permeability values. The effective porosity of the limestone is also estimated, at 0.02 (2%).

The Edenderry Limestone is presumed to have similar characteristics to Allenwood Limestone; it is relatively clean and coarse grained and has a well developed bedding and jointing network. In order to simplify the delineation of the 100 day time of travel zone to the springs (see section 8.2) and to maintain a conservative approach, this limestone is considered to have similar coefficients to the Allenwood Limestone.

6.7 Conceptual Model

The public supply at Toberdaly consists of three natural springs which have been deepened in order to improve their potential yield. The springs are at the contact of two geological units, the Calp Limestone to the west and the more permeable Allenwood Limestone to the east.

The close proximity of the springs and the available discharge and test pumping data suggest that the springs are derived from the same groundwater source.

Three wells drilled on the site of the springs show that the bedrock is overlain by between 7-12 m of clayey till with less frequent interbedded sand and gravel units. While some groundwater flow to the springs is likely to occur through the sand and gravel units, these appear relatively thin and limited in extent, in the area to the north of the springs. The available geophysical information suggests permeable bedrock down to at least 30 metres in the area around the springs.

The limestone bedrock is therefore considered to be the major source of groundwater. A larger proportion of this groundwater flow is likely to be concentrated in the more permeable Allenwood and Edenderry Limestones than in the Calp Limestone. Water level data however, shows the water table to be close to the surface in the limestones to the north of Toberdaly. This suggests a lower permeability than might be expected for these cleaner, bedded and jointed limestones. More water level data is needed before definitive conclusions can be made from this information (including the depths of the measured wells).

The geophysical (resistivity) survey carried out by the GSI between the springs and Toberdaly House indicated two areas of low resistivity which can be attributed to more permeable water bearing zones.

A broad area of low resistivity, over 30 metres in thickness, occurs to the north of the springs. This area is likely to represent permeable limestone bedrock. Part of this area (immediately to the NW of the springs) is shown on the geology map as Calp Limestone which is considered to be of a relatively low permeability. The geophysics suggests that the Calp Limestone is more permeable (possibly as a result of the fault) or that the area is in fact underlain by Allenwood Limestone (the second option is considered to be more likely). Either way the geophysics for this area suggests a bedrock aquifer to the north of the site.

A second area of even lower resistivity suggests a high permeability zone runs beneath the springs in an east-west direction, at a depth of at least 30 metres. Although the nature of this zone is unknown, a fault or fracture zone is likely.

Groundwater level data indicate that the water table is a subdued reflection of topography, with a recharge mound coinciding with the topographically high ground to the north of Toberdaly. Groundwater flow is likely to radiate out from the recharge mound, with a significant component of groundwater flowing SSW towards the springs.

Water level data from stations 4 and 5 (Figure 1) suggest the existing orientation of the NE-SW trending fault may be incorrect, or that the fault is not a zone of higher permeability. Faults in relatively clean limestones such as the Allenwood Limestone are often zones of higher permeability whereas the measured water levels along the proposed fault were close to the surface, indicating a relatively low permeability bedrock at these locations. It is likely that the fault has a more N-S orientation, as N-S or E-W orientated faults are more typical in Carboniferous limestones in this area (MacDermot, C., pers comm).

Although the exact location of this fault and the east-west orientated fault (suggested by the geophysical survey) are not known, these faults are likely to provide important groundwater flowpaths to the springs.

A significant proportion of groundwater therefore is likely to flow southwards from the proposed recharge mound within the more permeable limestones, and discharges at the surface, at the contact with the less permeable Calp Limestone. It is also likely that the proposed faults act as zones of high permeability, aiding groundwater flow to the springs.

A simple water balance for the springs at Toberdaly (see section 8.1) suggests that the recharge area required to supply the discharge from the springs is 3.3 km². Given the last paragraph the likely catchment area to the spring is 1.8 km²; this area is too small to provide the output required at the springs. There are two possible reasons for this:

(a) Some of the water is coming from depth, probably along a fault zone, from a distant recharge area.

(b) Our understanding of the hydrogeology given in the previous sections is wrong.

There is evidence to support the first explanation:

The elevated groundwater temperature (see Section 6.5 and Appendix 2) suggests that some of the water discharging at the springs is derived from relatively deep within the underlying bedrock. Average groundwater temperatures are normally between 9-11 °C depending on the time of year. The groundwater at the springs is approximately 2° C above the expected temperature. Average temperature gradients suggest an increase of 2° C per 100 metres depth however, the groundwater temperature measured at the springs is likely to be a minimum geothermal temperature (geothermal waters will cool while rising to the surface and may mix with shallow groundwater). The origin of the geothermal groundwater component is likely to be in excess of 200 metres. Geothermal groundwaters in Ireland are often associated with faults and there is evidence of faulting in the vicinity of Toberdaly Springs. Apart from the faults mentioned previously, it has also been suggested that there are larger scale regional faults at depth in this area, this is shown on cross section A-B of the 1:100,000 scale bedrock map for sheet 16, published by the GSI (McConnell and Philcox, 1995).

The location of the recharge area to this geothermal groundwater component is unknown, however it is likely that some groundwater may be derived from recharge to the hill to the west of the springs. The presence of volcanic rocks at depth in this area supports this idea. This groundwater would have to flow eastwards, through the bedrock, beneath the low permeability peat and the Calp Limestone. The groundwater would therefore be confined beneath the Calp Limestone (probably within the Allenwood Limestone) and groundwater flow would be driven by the higher groundwater head to the west. This explanation requires the Allenwood Limestone to extend beneath the Calp Limestone, between Toberdaly and Croghan Hill.

The area to the west of Toberdaly could therefore be the recharge area for the geothermal component of groundwater discharging at Toberdaly springs. Problems exist with this interpretation however, as evidence suggests that the Allenwood Limestone around Croghan Hill is more limited in extent than shown on recent geological maps (section 5.1), reducing the potential recharge area to the springs. In addition, the structural connection between the Allenwood Limestone to the west of Croghan Hill and Toberdaly is by no means certain. A future possibility is that recharge to the volcanic rocks in this area could provide the additional groundwater discharging at the springs.

While it is likely that there is a significant geothermal input to the springs, the exact location of the faults in the area around the springs is unknown and the location of the recharge area for the geothermal groundwater component is problematic. The most likely area would appear to be Croghan Hill.

The proportion of spring discharge originating from deep within the bedrock is estimated to be approximately 40%, the remaining 60% is likely to be shallow groundwater from the Allenwood and Edenderry Limestones to the north of the springs. These figures are based on the proposed catchment area to the springs.

6.8 Aquifer category

This Allenwood Limestone is classified as a **Regionally Important** aquifer where fissure flow is dominant (**Rf**). The Edenderry Limestone is classified as a **Locally Important** aquifer which is generally moderately productive (**Lm**). The Calp Limestone is classified as a **Locally Important** aquifer which is moderately productive only in local zones (**Ll**).

7. VULNERABILITY

The subsoils to the north and east of Toberdaly have been mapped as limestone till. Although there is evidence of some gravel layers at Toberdaly (which may be influencing the location of the springs), it is assumed that these are not laterally extensive.

The subsoil composition and the free draining appearance of the area suggest that these subsoils are moderately permeable. The areas where this subsoil is considered to be less than 3 m thick (around Toberdaly House for example) are given the vulnerability category of 'probably extreme'. The areas where the subsoil is between 3 and 10 m are given the vulnerability category of 'probably high'. Areas where the subsoils are greater than 10 m thick are given the vulnerability category of 'probably moderate'.

The vulnerability zones are shown on Figure 3.

8. DELINEATION OF SOURCE PROTECTION AREAS

The source protection area is delineated for a higher output than is currently abstracted, to take into account the overflow from the springs during the winter months. Total discharge measurements from the springs (taken by the E.S.B.) are only available for the period March 1959 to March 1960. The total discharge for the three springs for this period is calculated at 1,200,000 m^3 or an average of 3,288 m^3/d. Total precipitation figures at Daingean, for the period March 1959 to March 1960 are 856 mm compared with the average yearly precipitation for the period 1951-1980 of 845 mm. Potential evapotranspiration calculated for the nearest station at Birr between the period March 1959-March 1960 was 534 mm compared to an average annual figure of 466 mm (between 1951-1980).

Precipitation figures for the period March 1959 -March 1960 are close to the average value. Although the potential evaporation figures between March 1959-March 1960 and the average value differ by 68 mm the actual evapotranspiration values are also likely to be very similar. This is because the summer of 1959 was relatively dry and actual evapotranspiration during the year would be lower as a result of soil moisture deficits. Although the period March 1959-March 1960 was marked by a relatively dry summer and a relatively wet winter the total values for precipitation and actual evapotranspiration appear to be very similar to the average values, the discharge from the springs during this period is therefore considered to be a reasonable estimation of the average yearly spring discharge.

8.1 Outer Protection Area

The Outer Protection Area (SO) normally includes the complete catchment area (ZOC) to a spring. This area is calculated from the annual average recharge to the area and the average spring discharge.

Taking the average annual recharge to be 362 mm as previously indicated, the area required to supply the estimated average spring discharge of 3288 m^3/d, is calculated to be 3.31km^2 ; this is equivalent to a circular area with a radius of 1027 m.

In this case the proposed ZOC is based on the likely catchment area to the springs and is 40 % smaller than the area needed to supply the spring discharge; this is a result of the proposed geothermal origin for some of the groundwater. Due to the lack of information it is not possible to locate the recharge area for the geothermal component of groundwater discharge. Therefore, the proposed ZOC refers only to the shallow component of groundwater flow (Figure 4).

This ZOC is controlled primarily by the proposed recharge mound to the north of the supply and by the estimated groundwater gradients and groundwater flow directions derived from groundwater level measurements. The ZOC is extended northwards to Clonin Hill where a groundwater divide is assumed to mark the northernmost boundary.

Based on the conceptual model outlined above, the shallow groundwater discharging from the springs during the winter months is derived from an area to the north of the well. However, groundwater levels are drawn down slightly by the well during the summer, consequently the ZOC is enlarged slightly to take in an area immediately south of the well.

A buffer (safety margin) is normally included in the zone of contribution by incorporating an error margin in the estimated groundwater flow direction (± 20°). In this case the buffer zone is restricted by the likely groundwater flow directions in the area to the north of Toberdaly. The resulting source protection area is 2.17 km^2, this represents 70% of the area needed to supply the spring discharge. The proposed ZOC and the final source protection area are shown in Figure 4.

The boundaries of the ZOC are a best estimate based on the data available.

8.2 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel from a point below the water table to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination.

A range of values for permeability, between 5 and 10 m/d, were used to estimate the 100 day time of travel zone distance to the well. These permeability values are considered typical for limestones in general, and they are used in the absence of more accurate data for the Allenwood Limestone. Using an effective porosity = 0.02, and a calculated groundwater gradient = 0.01, the 100 day time of travel distance to the well is estimated at between 250 and 500 m. The more conservative distance is chosen (see Figure 4). It is emphasised, however, that there are no data to enable the aquifer coefficients to be calculated for this source, consequently the boundary to this zone is uncertain.

8.3 Source Site

In addition to the Inner and Outer Areas there is a third protection area, the Source Site (SS), which is delineated as the area in the immediate vicinity of the source (minimum 10 m radius) in order to maintain good wellhead sanitary protection. The fenced off enclosures around the springs at Toberdaly are designated the Source Site Area.

9. GROUNDWATER PROTECTION SCHEME

Combining the Source Protection Areas, as described above, with the vulnerability ratings produces seven groundwater protection zones for the source at Toberdaly. These zones are listed here and are shown in Figure 5 (with the exception of the Source Site):

- Source Site / High
- Inner Protection Area / Moderate
- Inner Protection Area / High
- Inner Protection Area / Extreme
- Outer Protection Area / Moderate
- Outer Protection Area / High
- Outer Protection Area / Extreme

It is not within the scope of this report to delineate the protection zones in the surrounding area and this is dealt with at the regional resource protection scale.

The accompanying code of practice imposing restrictions on developments will follow when discussions as to the degree of restriction necessary in each protection zone have been carried out between the Council, the EPA and the GSI.

10. POTENTIAL POLLUTION SOURCES

Several farms are located between 300 and 400 metres north east of Toberdaly. Potential pollution sources include cattle pens, silage stores and general farmyard waste. In addition several houses are located close to the springs, to the south and west. These houses, and houses to the north of Toberdaly Demesne, are likely to have septic tank systems.

11. CONCLUSIONS AND RECOMMENDATIONS

The springs at Toberdaly are an important groundwater resource which is used to supply much of east Offaly.

The recent development of the Pool Well and the use of this source rather than Heavey's Well appears to have improved the sustainability of the supply (Pool Well was still in use during the dry summer of 1995).

Although no test pumping has been carried out at Pool Well it is likely to be able to support an increased yield.

From the available information it was only possible to delineate a zone of contribution that will account for 65% of the groundwater discharging at the springs. The remaining water is likely to be coming from depth, probably along a fault zone, from a distant recharge area. Croghan Hill is considered to be the most likely recharge area.

Recharge to the springs from a distant source such as Croghan Hill is likely to have a long travel time, greatly reducing the risk to the quality of the groundwater discharging at the springs. However, major industrial developments in this area could still pose a threat to the springs. In the (perhaps unlikely) event of such a development being proposed, the potential impact on Toberdaly Springs would need to be considered in detail.

Much of the catchment to the springs is classed as having a 'high' or 'extreme' vulnerability.

The occasional faecal bacteria recorded at the springs may be due to sources at the spring site (birds, other animals) however, pollution by other sources cannot be ruled out.

It is recommended that the raw water from all the springs should be analysed regularly (chemically and microbiologically) in order to examine the effects of any potentially polluting activities near to the well. In addition it is recommended that potentially polluting activities in the delineated groundwater source protection zones should be controlled and monitored.

Temperature measurements of the groundwater should be taken during the winter in order to examine the potential geothermal origin for some of the water.

Water level data and discharge rates should be monitored continuously and together with rainfall data, should be correlated and analysed to aid in the further development of the springs and in the more precise delineation of the groundwater source protection zones (these recommendations were also made to Offaly County Council by K.T.Cullen in 1982).

In addition, further drilling (probably of deep wells) and more detailed geophysical investigations are almost certainly necessary if the origin of the geothermal water supplying the springs is to be found.

Furthermore, in future considerations of the Toberdaly water supply it is suggested that the potential for drainage of the raised bog to impact on the output from Toberdaly should be examined. We have no evidence to suggest that it is having any impact and the probability of any impact may be low; however, it is an issue that should be kept in mind.

12.

REFERENCES

Cullen, K.T., (1982) Report on the Investigations into the yield of the Toberdaly Springs, County Offaly. K.T.Cullen & Company.

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13.

APPENDICES

13.1 Appendix 1

Water Levels Measured in the Toberdaly Area, During the Summer of 1982 (From K.T.Cullen & Co.)

Station Number (**see Figure 1**)	Description	Well Head (m O.D.)	S.W.L. (m O.D.)	Date
1	Heavey's Well	82.17	79.70**	9/9/82
2	Mount Well	83.05	80.00	9/9/82
3	Pool Well	80.74	80.01	9/9/82
4	Well	91.79	89.41	1/9/82
5	Limestone Quarry	-	90.85	9/9/82
6*	Well	83.61	81.36	1/9/82
7*	Well	77.49	75.13	1/9/82
8	Well	89.60	-	1/9/82
9	Well	80.06	79.49	1/9/82
10	Well	-	78.61	1/9/82
11	Well	78.57	75.50	9/9/82
12	Well	106.16	104.42	9/9/82
13	Well	114.77	113.25	9/9/82
* Not shown on Figure 1 ** This figure is believed to represent a pumping water level. All elevations in m O.D. (Poolbeg)				

13.2 Appendix 2

Temperature Data For Toberdaly Springs

Date	Water Temperature °C	Air Temperature °C
29/4/83	12.6	?
2/6/83	12.65	14
17/1/84	12.5	2
28/2/84	12.2	7
16/3/84	12.4	3
4/2/86	12.5	5
31/7/96	13.2	?
Data from records kept by C. R. Aldwell at the GSI, except 31/7/96 which was taken on the site visit that accompanied this report.		

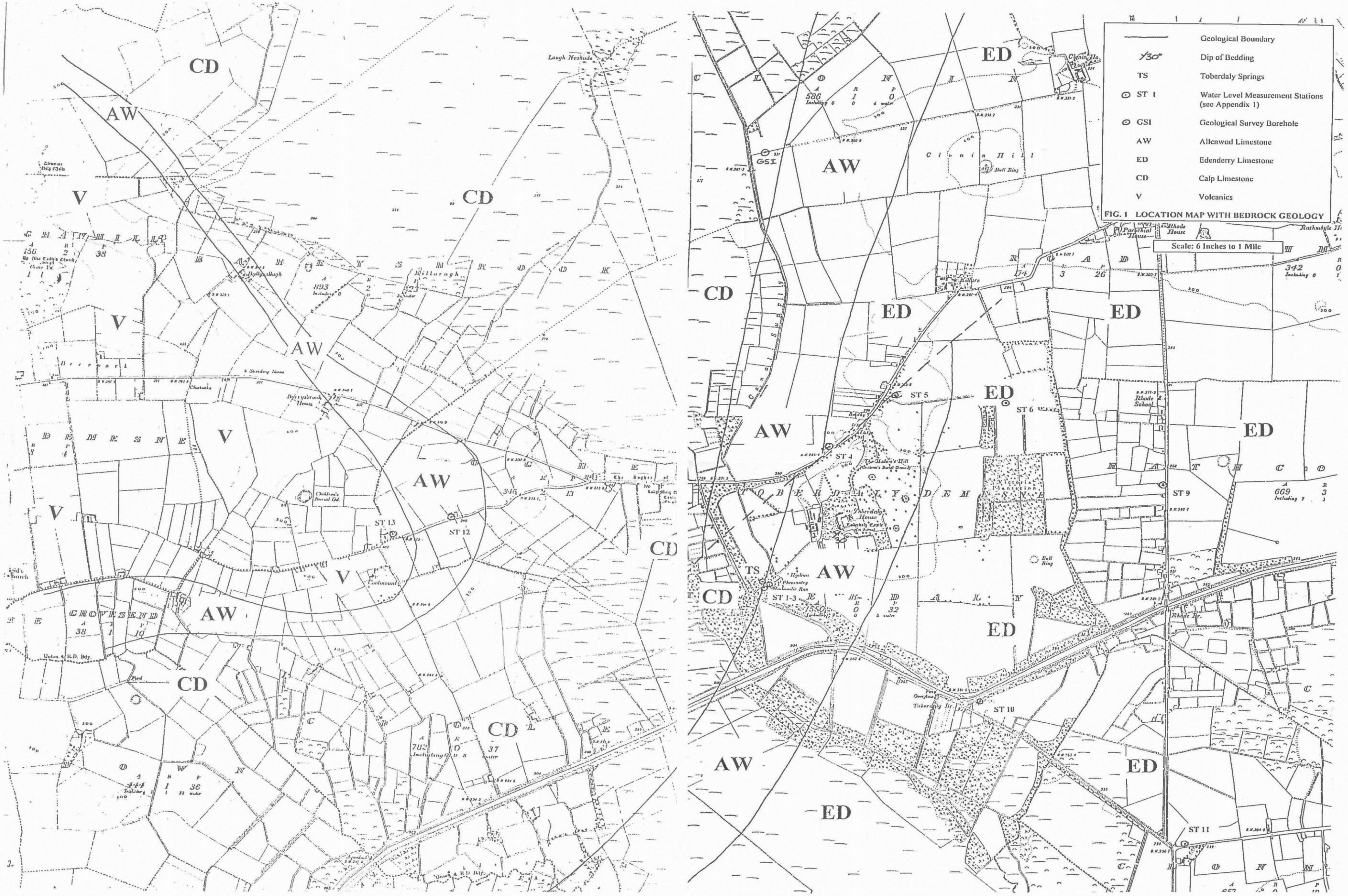

FIG. 1 LOCATION MAP WITH BEDROCK GEOLOGY

Scale: 6 Inches to 1 Mile

FIG. 2 SUBSOILS AND DEPTH TO BEDROCK

FIG. 3 VULNERABILITY

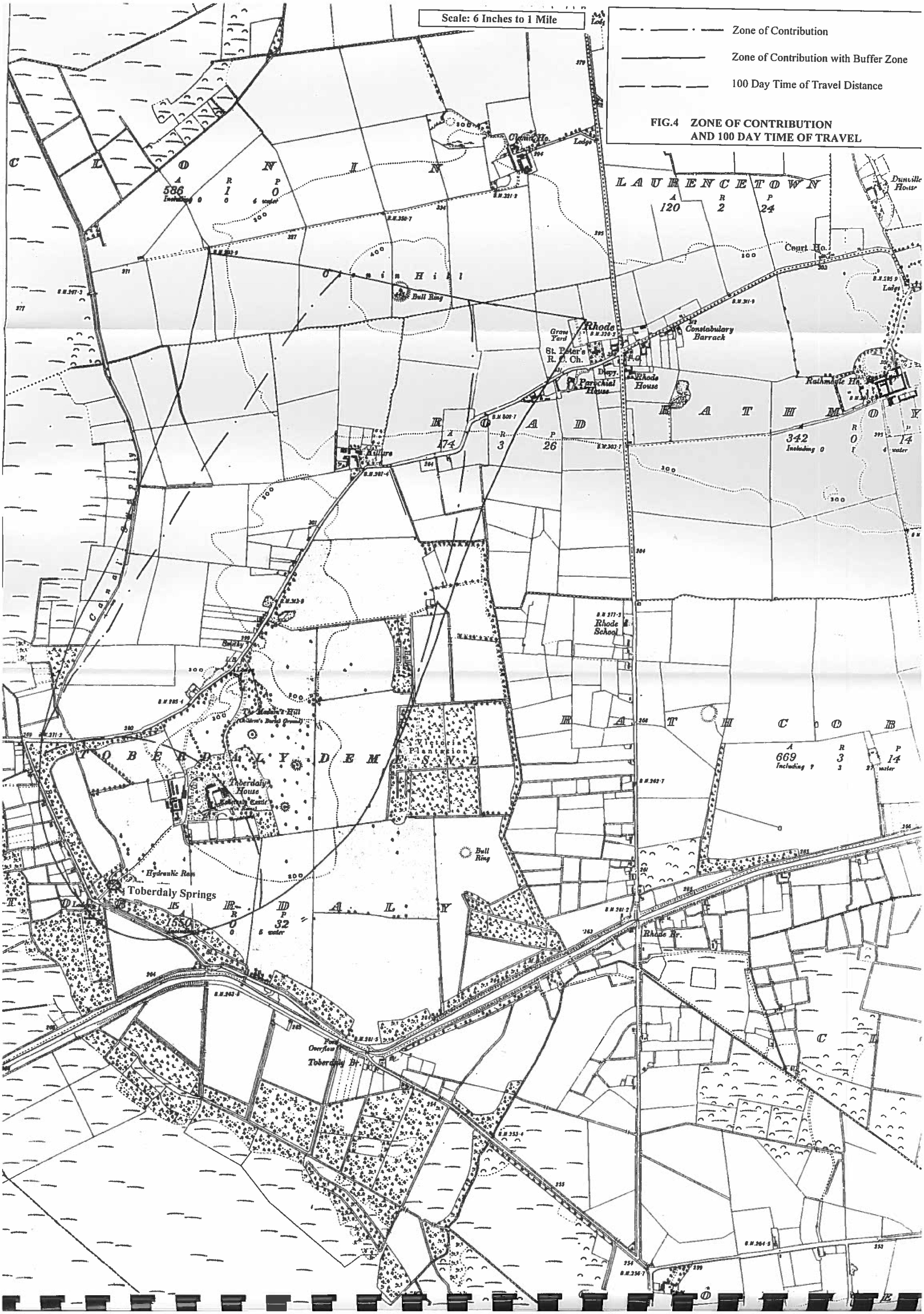

FIG.4 ZONE OF CONTRIBUTION AND 100 DAY TIME OF TRAVEL

FIG. 5 GROUNDWATER PROTECTION ZONES