DOWER SPRING
(WHITEGATE REGIONAL WATER SUPPLY SCHEME)

GROUNDWATER SOURCE PROTECTION ZONES

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DOWER SPRING (WHITEGATE REGIONAL WSS)

1. INTRODUCTION

This Source Protection Report has been compiled from:

a) Data available from various sources over a period of nearly 40 years.

b) Data collected by Cork County Council (Michael Cogan, Southern Division) and GSI since 1976.

c) Data collected by Cecilia Gately in the course of her M.Sc. dissertation project (Environmental Science, TCD) during summer 1996.

d) Vulnerability mapping by Una Leader, 2000-2001.

2. SOURCE LOCATION AND SITE DESCRIPTION

The Dower Spring is located about one mile east-southeast of Castlemartyr, national grid reference 1979 0728 (Map 1). The spring emerges from a cave in a low limestone cliff on the south side of a minor road. Static water level in the spring is approximately 7 m O.D. (Poolbeg datum). The pump inlet pipes are in the mouth of the spring and the pump house is just south of the spring. Normal abstraction averages 4545 m^3/d (1 Mgd) to supply the Whitegate Refinery (1,364 m^3/d) and domestic consumers in the Ballinacurra, Ballycotton, Churchtown, Garryvoe/Shanagarry, Gyleen/Trabolgan, Saleen, Upper Aghada and Whitegate areas.

3. TOPOGRAPHY, DRAINAGE AND LAND USE

The land immediately to the east, west and north of Dower Spring is somewhat undulating, ranging in elevation from 12 to 30 metres. Further north, beyond the Killeagh-Mogeely road, the land rises quite steeply up to the major ridge which divides the Cork-Midleton-Youghal valley from the Bride valley to the north. To the south, between the Dower and the Womanagh River, the land is low-lying and is boggy in places.

Downstream of the spring, the Dower River flows in a southeasterly direction for about 800 metres before joining the Womanagh River and then flowing eastwards to Youghal Bay.

Agriculture is the principal activity in the area.

4. GEOLOGY

4.1 Bedrock geology

The geology of Southeast Cork is characterised by a series of major folds - anticlines and synclines - along east-west axes. The anticlines form ridges reaching an altitude of over 200 metres, and are composed of Devonian sandstones and mudstones, while the synclines form valleys underlain by Carboniferous limestones, at an elevation generally below 30 metres. The 30 metre (100 foot) contour usually marks the break in slope between valley and hillside.

Map 1 shows the bedrock geology of the Dower catchment and surrounding area, based on the GSI 1/100,000 geological map (Sheets 22 and 25). Eight geological formations are shown, and the brief descriptions in Table 1 are based on the GSI booklets accompanying the above sheets. The Dower Spring is located in the Waulsortian Limestone.

Table 1. Geological Succession

Geological Age	Map Code	Formation Name	Description
Carboniferous	LI	Little Island Formation	Massive crinoidal fine grained limestone
	CK	Cork Red Marble Formation	Red brecciated calcilutite limestone
	WA	Waulsortian Limestone	Massive unbedded lime-mudstone
	BA	Ballysteen Limestone	Fossiliferous dark-grey muddy limestone
	RM	Ringmoylan Formation	Calcareous shale and crinoidal limestone
	KNcs	Kinsale Formation, Cuskinny Member	Flaser-bedded sandstone and mudstone
	KNcu	Kinsale Formation, Castle Slate Member	Grey mudstone
Devonian	GY	Gyleen Formation	Sandstone with mudstone and siltstone
	BS	Ballytrasna Formation	Purple mudstone with some sandstone

4.2 Quaternary (subsoils) geology

The 19th Century Geological Survey field sheets record only 'Drift' in a few places, and this can refer to any type of Quaternary glacial sediment. Recently these deposits have been mapped by Teagasc. Additional information was available from the Dairygold Co-operative's environmental impact statement for the Annistown Piggery Extension, from local well drillers, from a geotechnical report, from examination of aerial photographs, and field mapping by Cecilia Gately and Una Leader (GSI).

The following types of Quaternary deposits in the Dower catchment are found:

Glacial Till ('boulder clay') - Gravelly, Clayey, or 'Undifferentiated'
Sand & Gravel
Peat

There are also rock outcrops and areas where rock appears to be within one metre of the ground surface. These rocky areas are widespread within the limestone valley.

In general, Sand & Gravel deposits predominate in the southern part of the catchment, underlain by Limestone bedrock, whereas Till predominates in the northern (upland) part of the catchment, which is underlain by Devonian mudstones & sandstones. From the limited amount of fieldwork undertaken, the Till appears to be mainly Sandy Till, generally free-draining and of moderate permeability.

A few small areas of peat occur: one in an upland area in the far north of the catchment, and two smaller bogs on low ground between Mogeely and Killeagh.

4.3 Soils

The predominant soils in the catchment area are of two types: Acid Brown Earths are found on the valley bottom and Brown Podzolics on the hills. In addition, there are the peat bogs mentioned above.

Apart from the peat areas, the soils are generally well drained.

4.4 Depth to bedrock

Depth to bedrock contours were drawn, based on GSI well records, exploration company and well drilling company data, geological field sheets and a limited amount of field survey. The density of available data is rather low.

In the upland part of the catchment, bedrock generally appears to be between 3 and 10 metres deep, with areas of shallower depth limited to the small incised valleys of the streams.

In the valley, the depth to bedrock is more variable, due to the uneven bedrock topography characteristic of karst land surfaces. Thus there are extensive areas of outcropping or subcropping (<1m) rock and of very shallow bedrock (<3m), but also several areas where bedrock is over 10 metres below surface, especially at the foot of the hillside.

5. HYDROGEOLOGY

5.1 Pumping Test

A 72 hour pumping test with a recovery test was carried out on the Dower spring in September 1976, at the end of the severe drought of that year (details in Appendix A). The test showed that, when pumped in a dry period, the spring behaves like a very large well, ceating a wide (at least 1500 metres), shallow cone of depression.

5.2 Groundwater levels

The static water level in the spring is about 7 m O.D. Comparisons with water levels in wells are difficult because of the absence of accurate levels at well-heads, but groundwater gradients within the limestone are low, probably around 0.001-0.002. Some of the dug wells in the area appear to be tapping perched water tables, probably within patches of less permeable Quaternary deposits.

The annual fluctuation of water levels in the limestone is about 3-5 metres, as illustrated by the hydrographs for Attiquin (4 km west of the Dower, outside the catchment) and Ballyquirk (3 km northeast of the Dower, inside the catchment), in Figures 1 and 2. The natural water level in the Dower spring itself normally varies by less than half a metre from winter to summer, although extreme flood events can add a further 0.3 m or so to this figure.

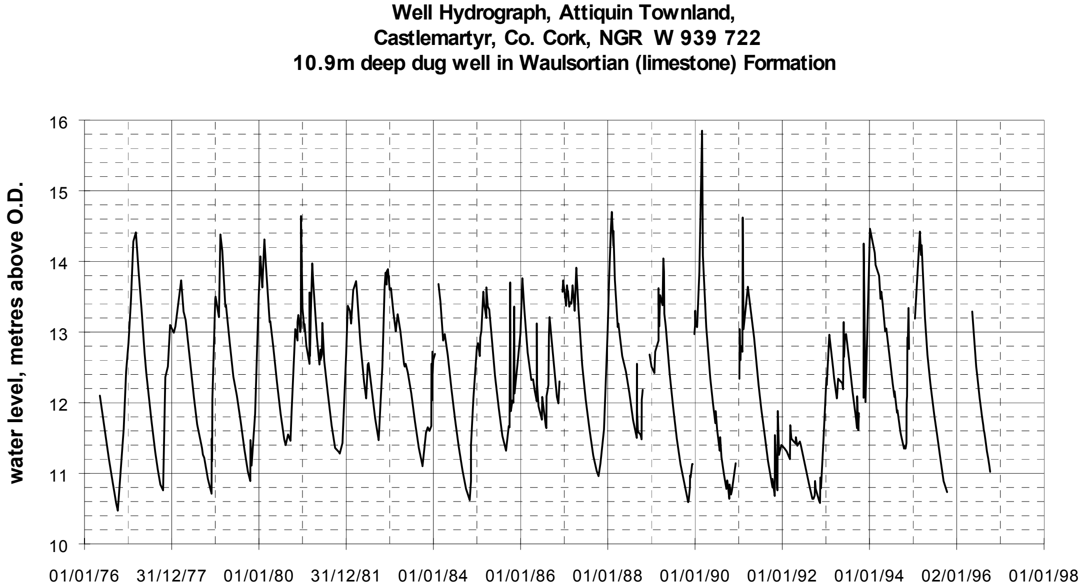

Figure 1: Well hydrograph, Attiquin

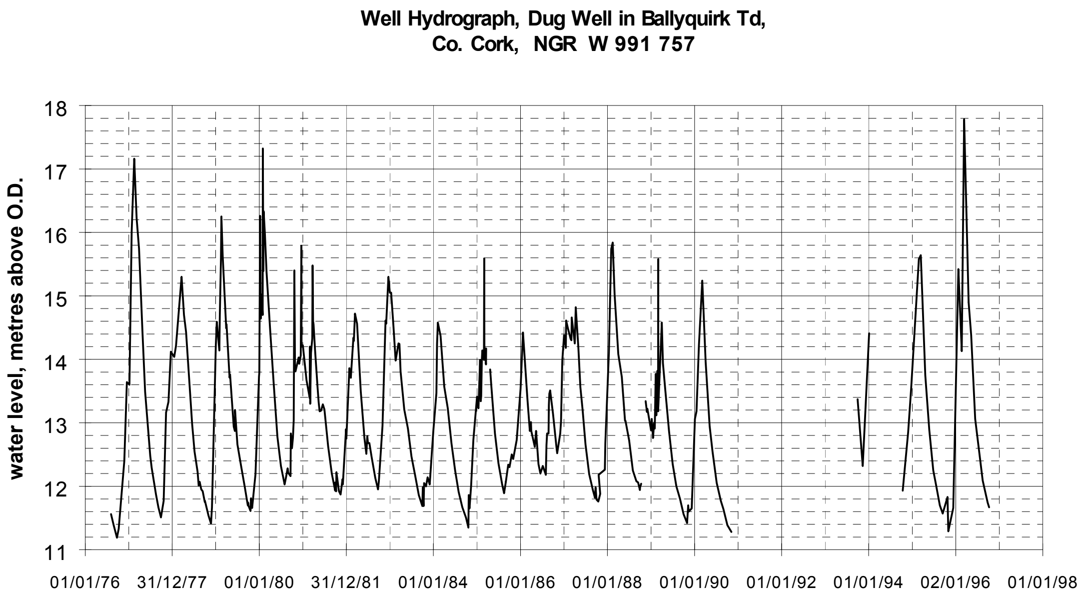

Figure 2: Well hydrograph, Ballyquirk

5.3 Rainfall, evaporation and recharge

Rainfall data for the lowland area is taken from the rainfall station (altitude 7m. O.D.) at Ballinacurra, 9km to the west. Mean annual rainfall as recorded by the Meteorological Service for the years 1941-1970 was 990mm. Rainfall data for the upland area is taken from the rainfall station (altitude 92m. O.D.) at Ballincurrig, 16km to the northwest. Mean annual rainfall as recorded by the Meteorological Service for the years 1941-1970 was 1226mm. Since the catchment is roughly 54% upland and 46% lowland, the annual average rainfall for the whole catchment is approximately 1117mm. If this is increased by 5% to allow for the known (but variable) under-recording of standard rain gauges, the total is 1173mm/year.

The nearest synoptic weather station at which evaporation data are collected is at Cork Airport. Potential evapotranspiration (P.E.) for 1980 was estimated as 466.6 mm (Met Eireann, personal communication), so average PE is estimated as 450-470mm. Actual evapotranspiration (A.E.) is then calculated by taking 90% of the potential figure, to allow for soil moisture deficits for part of the year, so A.E. is estimated as 405-420mm/year.

In the lower catchment, the presence of free-draining topsoils, sandy Till and Sands & Gravels shows that a high proportion of effective rainfall (E.R.) infiltrates to the water table. Where local runoff occurs, such as after heavy rain, the resulting surface drainage will generally infiltrate further downstream, so that infiltration is effectively 100%. In the upper catchment, the subsoil is less permeable, slopes are steeper, and rainfall is higher, so that surface runoff is appreciable. For the water balance, runoff is taken as 75%, to include interflow (shallow groundwater flow which re-emerges as surface drainage). The runoff from the upper catchment is assumed to recharge the limestone aquifer via swallowholes.

5.4 Spring Discharge Data

A 3m wide rectangular thin plate weir is located about 60m downstream of the cave. There is probably a significant amount of flow through the stream bed beneath the weir. There are staff gauges both in the cave mouth and below the weir. An automatic water level recorder is located just downstream of the weir and data from this recorder are processed by the Environmental Protection Agency (EPA, formerly by An Foras Forbatha (AFF)). Another automatic water level recorder in the cave mouth was installed by GSI in 1978. All water levels in the cave mouth and the stream are affected to some extent by weed growth, which is removed once a year. It appears that weed growth may be more abundant in recent years, which could be due, for instance, to higher nitrate levels in the water.

Discharge records (estimates) kept by CCC (Michael Cogan) are available for intervals varying between one week and one month. Weekly readings were not complete for any year except 1980, but are almost complete for 1979 (47 readings). Therefore the data for 1979 and 1980 were used to estimate annual discharge for 1979 (12,001,440 m^3) and 1980 (15,138,180 m^3). These are equivalent to average discharges of about 32,880 m^3/day (1979) and 41,500 m^3/day (1980), or 380 lps and 480 lps respectively.

Daily abstraction for the Womanagh Regional Scheme is 6,222 m^3, equivalent to 72 lps. In very dry periods, the abstraction exceeds the natural flow, but the spring behaves like a very large well, creating a wide, shallow cone of depression, as was proved by the 1976 pumping test. Spring discharges for the years 1978-1983 are presented in Figure 3.

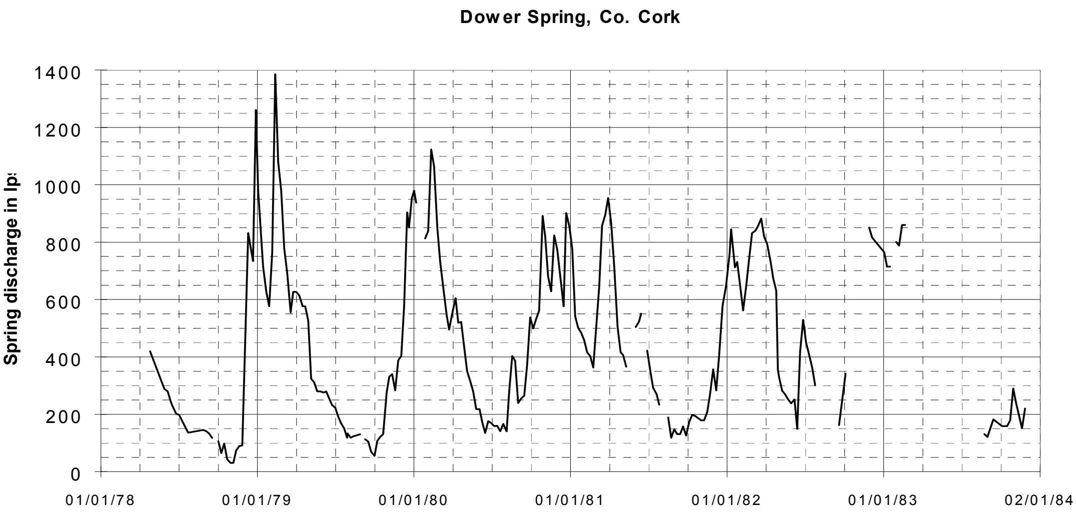

Figure 3: Dower Spring discharges, 1978-83

5.5 Karst hydrogeology

The Dower cave was surveyed in August 1968 by members of the Craven Potholing Club (Yorkshire, England, 1968). In 1984 cave divers re-visited the cave (Cave Diving Group, 1988) in an attempt to explore further upstream, but made little progress.

The area around, and particularly to the north of, the Dower Spring is characterised by an abundance of karst features (landforms produced by the solution of the limestone bedrock). The main karst features are:

Poulnahorka Cave:	A deep depression due to collapse of the overlying rock into a cave system, about 700 metres west of Dower Spring
'Dower Ford':	A wider, shallower depression (c. 120m x 70m) probably caused by collapse, about 300 metres west of the Dower. The depression contains a spring from which water flows into a pool, and then into a swallowhole in the southeast corner. This water was proved by dye tracing in July 1979 to re-emerge at the Dower Spring within 18 hours.
Knockane Cross Caves:	About 1400 metres north-northeast of Dower Spring, these caves have been explored and are known to contain flowing water. A connection with Dower Spring has not been established, but is probable.
Carrignashinny Swallowhole:	About 2200 metres northwest of Dower Spring, this swallowhole is fed by a small stream draining the hillside to the north. A tracing experiment by C. Gately in July 1996 indicated a travel time to Dower Spring of about 3 days.
Ballyvorisheen Swallowhole:	About 1700 metres north of Dower Spring, this swallowhole is also fed by a small stream draining the hillside to the north. A tracing experiment in August 1979 indicated a travel time to Dower Spring of 82 hours (3□ days).

5.6 Areal extent of the Dower catchment

In order to prepare a Source Protection Scheme, the catchment area of the Dower spring must be defined. The potential catchment area can be divided into two parts: an upland area to the north which is underlain by Devonian sandstones and mudstones, and a lowland area (the valley floor) which is underlain by Carboniferous limestones.

The catchment area was first estimated by examining the surface drainage and the underground karstic connections. The eastern limit is defined by the Dissour river and its tributaries, and also by Ballyhonock Lake which is fed by springs and drains to the east (Map 1). The northern limit is defined by the topography of the hill (187m) near Knockanenakirka. The western limit is the catchment of the Kiltha River which runs through Castlemartyr; it appears that this catchment boundary lies within 200 metres of the river itself. Within the boundaries indicated by the topography, the catchment area of the Dower is approximately 19.5 km^2, comprising 10.5 km^2 in the upland (north of the 100 foot contour) and 9 km^2 in the lowland.

The combined flow into the two swallowholes at Ballyvorisheen and Carrignashinny was estimated as 34.7 lps in May 1976 and 10.8 lps in mid-July 1976 (Wright, 1978), compared with Dower flows of perhaps 200 lps and 100 lps respectively. Thus, during dry periods the input from sinking streams is relatively small, but in wet periods it is probably much larger.

Since the groundwater divides do not always correspond with surface water divides, especially in karst areas, it is necessary to try to check the surface catchment by another method - by comparing the apparent input to the catchment (from rainfall) with the discharge of the spring, i.e. by calculating a water balance:

		Upper catchment (10.5 km^2)			Lower catchment (9km^2)
Rainfall	=	1226mm		=	990mm
Rainfall (+5%)	=	1287mm		=	1040mm
PE	=	450mm		=	470mm
AE	=	405mm		=	423mm
ER	=	882mm		=	616mm
Runoff (75%)	=	661mm	Infiltration	=	616mm

(recharge to the spring comprises Runoff from the upland and Infiltration in the lowland)

Discharge	=	6,948,000 m^3	Discharge	=	5,548,000 m^3

Then, Total discharge = 12,496,000 m^3/year = 396 lps

This compares with estimated average discharges of 380 lps (1979) and 480 lps (1980).

These calculations can be repeated using different values for rainfall, evaporation, and infiltration, with slightly different results each time. However, the above calculation is sufficient to indicate that the surface catchment of 19.5 km^2 is close to the actual area.

5.7 Hydrochemistry and water quality

Data on the hydrochemistry and quality of the Dower water have been supplied by the Council's laboratory at Inniscarra. The data comprised C1 (1993-6) and C2 (1992-6) analyses for treated water (chlorination and fluoridation), and P1 and P2 analyses (1990-5) for the raw water. Sampling intervals varied between one week and over one month. The C1 analyses were most frequent and the raw water analyses least frequent. Additional data are available from analyses carried out for GSI by the State Laboratory.

The analyses show that the Dower water is slightly alkaline, the pH ranging between 7.18 and 7.8. Table 2 summarises the more important parameters. The degree of variation in temperature and conductivity indicates that a high proportion of the flow is derived from conduit flow rather than diffuse flow, indicating a rather high vulnerability for the catchment.

In the raw water, the general levels of nitrate (especially since 1992) indicate significant contamination of the spring, although the M.A.C. has not been exceeded. Periodically, levels of Ammonia, *E. coli* and total coliforms have been unsatisfactory, probably following heavy rain when the sinking streams could be expected to carry contaminated surface runoff.

Table 2: Summary of Dower Spring hydrochemical and water quality data

Parameter	Units	Range	No. of samples	M.A.C. (EU)
Temperature	□C.	4.5 - 20	30	25
pH		7.18 - 8.25	30	>6.0<9.0
Colour	Hazen	5 - 40	10	20
Suspended solids	mg/l	0 - 22	7	(none)
Electrical conductivity	□S/cm @ 20□C	219 - 740	90	1500
Nitrate	mg/l NO_3	12.0 - 37.55	30	50 (G.L. = 25)
Nitrite	mg/l NO_2	0.00 - 0.03	21	0.1
Phosphate	mg/l P_2O_5	0.09 - 0.23	8	5
Faecal coliforms	/100ml	Treated: 0 - 1 Untreated: 20 - 620	82 3	0
Total coliforms	/100ml	Treated: 0 - 6 Untreated: 120 - 12,500	82 3	0
Ammonia	mg/l NH_4	0.001 - 0.27	29	0.3
Chloride	mg/l	34.2 - 46.69	6	250
Aluminium	mg/l Al	0.00 - 0.04	66	0.2

5.8 Aquifer coefficients

The analysis of the 1976 pumping test suggested apparent transmissivities of several thousand m²/d. A specific yield of approximately 0.03 was inferred from the recession constant of the spring (Wright, 1978). Away from the immediate vicinity of the spring, these coefficients are probably reduced. The pumping tests in the boreholes of the Cloyne-Aghada water scheme suggested transmissivities of a few hundred m²/d and specific yield of about 0.01-0.02.

5.9 Aquifer categories

The Limestone (Waulsortian Limestone, Cork Red Marble and Little Island formations) is classed as a **regionally important aquifer** which is **characterised by karst flow (Rk).**

The remaining formations are classified as **locally important aquifer, moderately productive in local zones**.

6 VULNERABILITY

The vulnerability of groundwater is defined by the GSI as "a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities". The GSI uses four vulnerability categories: Extreme, High, Moderate and Low.

The vulnerability zones in and around the Dower catchment are shown on Map 2. The predominant vulnerability rating is 'High', but there are substantial areas of 'Extreme' vulnerability on the valley floor and along the streams, while small areas of 'Moderate' vulnerability occur along the edge of the valley, at the foot of the slope, and in peaty areas in the valley.

7 DELINEATION OF SOURCE PROTECTION AREAS

7.1 Source Site

The enclosure around the source at the Dower, owned by the Council, lies entirely downstream of the spring, and therefore provides little sanitary protection for the spring except to keep the cave mouth free from large animals.

7.2 Inner Protection Area

In the GSI Groundwater Protection Scheme, the Inner Protection Area (SI) is normally the area defined by a 100 day time of travel (ToT) from a point below the water table to the source. It is intended 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. However, in karst areas, the speed of groundwater movement is commonly several metres to several hundreds of metres per day, and a 100-day ToT could extend for several kilometres, so the Inner Protection Area must be defined differently.

In the case of the Dower Spring, the 100-day ToT would be expected to reach the westerly and easterly catchment boundaries, and in the north would extend to the northernmost limit of the karst limestone. For example, the tracing of water from the swallowholes indicated travel times of 3-4 days, and the 1976 pumping test showed that, after three days, the effects of pumping extended to at least 1500 metres north of the spring. Therefore, the Inner Protection Area, as shown in Map 3, must include the total extent of the karst limestone up-gradient of the spring. In addition, water in any part of the streams which sink at the swallowholes and feed the spring must also reach the spring in much less than 100 days. Therefore, the margins of these streams must also be included in the Inner Protection Zone. On Map 3, these margins have been arbitrarily set at 30 metres from the stream, but final boundaries should be determined by field surveys which take account of the soil types and topographic slopes.

7.3 Outer Protection Area

The Outer Protection Area (SO) includes the remainder of the Dower Spring's catchment area, and is bounded by the zone of contribution (ZOC), as outlined above. Most of the Outer Protection Area is an upland underlain by Devonian sandstones and mudstones and by sandy glacial till.

8 GROUNDWATER SOURCE PROTECTION ZONES

Combining the Source Protection Areas, as described above, with the vulnerability ratings produces the groundwater protection zones for the source at the Dower (Map 3). These are listed here in order of decreasing degree of protection required:

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

9 POTENTIAL POLLUTION SOURCES

The predominant land use in the area is agricultural, with some agro-industrial developments. The small town of Castlemartyr lies just west of the catchment, but the village of Mogeely is within the catchment.

9.1 Agriculture

Approximately 54% of the land in the catchment is used for grassland and 38% for tillage, the remainder being used for housing and industrial purposes. Crops such as barley, spring and winter wheat, sugar beet and peas are grown, mainly in the valley where the soils are better. The soil has adequate lime, 6-10ppm phosphorus and 80-120ppm potash. Fertiliser with N:P:K of 18:6:12 in generally used. Dairy and beef farming are important, mainly in the northern upland part of the catchment, with a stocking density of 1.2 acres/livestock unit. Almost all farmers make silage for winter feed. (Personal communication, J.J. Hartley (Teagasc, Midleton) to C. Gately).

It has been observed (C. Gately) that large numbers of silage bales are stored together in one location, whereas the original objective of silage baling was to allow silage to be stored in the fields in small quantities, thus minimising the impact of leakage from any one bale.

9.2 Agro-industry

There is a large creamery (Imokilly), spread over 7 acres in the village of Mogeely, about 2.5km northwest of the spring. The creamery mainly produces cheese and butter for export to Europe and employs 100 people full-time. The creamery has an effluent plant to treat its waste, and the liquid effluent is discharged under licence to the Kiltha river. The area of the creamery is underlain by Sand & Gravel and by Waulsortian Limestone. Its groundwater resource protection zoning is Rk/H and it lies within the Inner Source Protection Area as proposed in this report.

A large pig-rearing unit (Dairygold) is located off the Mogeely-Killeagh road. The piggery itself is situated on the transition zone between Sand & Gravel and the Till, and along the geological boundary between the Gyleen Formation and the Ballysteen Formation. It falls within the Outer Source Protection Area and the local vulnerability to pollution is rated as ‘Moderate’. However, surface runoff from the area of the piggery drains directly to the stream which sinks at the Ballyvorisheen swallowhole and feeds the Dower spring. The information in the E.I.S. indicates significant contamination of the piggery’s own well, as shown by levels of nitrate, phosphorus and COD.

9.3 Domestic

The urban areas of Castlemartyr and Mogeely are served by public water supply and sewerage schemes. In the remainder of the catchment area, houses depend upon wells and septic tanks. In the valley, the subsurface topography of the limestone bedrock is very variable, and the thickness of the subsoil cover can vary from over 10m to a few centimetres over a distance of 300m or less. Many houses have been built where the subsoil is very thin, and in such areas septic tank effluent is unlikely to be completely attenuated and contaminants can move easily into the underlying karst limestone. The P2 analyses of the Dower water show that bacterial contamination is occurring, and the effluent from poorly located, constructed or operated septic tanks may be the source of some of it.

9.4 Road drainage

The catchment area is crossed by a number of roads, including the trunk road between Midleton and Youghal, which is also the major route between Cork and Wexford/Rosslare and carries very heavy traffic. Drainage from all the roads will probably enter the underlying aquifers, and this is especially true in the area underlain by the karst limestone. Data from a GSI automatic water level recorder beside the dual carriageway near Carrigtwohill provide clear evidence of the speed with which road drainage can enter the karst limestone.

Under ordinary conditions, road drainage will carry some fine sediment and contaminating matter, especially hydrocarbons. However, the most serious risk occurs in the event of a collision, spillage, etc. when large volumes of very polluting material may be spread over the road and may drain naturally or be hosed away by the Fire Service into the aquifer.

10 CONCLUSIONS

The source at The Dower is a very large spring, one of the largest in Ireland, which has been an important public water source for several decades and should continue to be available for public supply for the indefinite future. The spring also represents the regional limestone aquifer, which contains an even larger and more important public resource which requires protection, conservation and management.

- It is recommended that a Source Protection Scheme for the Dower should be adopted by the County Council, including:
  - ⇒ The demarcation of Inner and Outer Source Protection Areas
  - ⇒ The demarcation of Source Protection Zones (SI/E, SI/H, SI/M, SO/E, SO/H, and SO/M)
  - ⇒ An inventory of potential sources of pollution
- The margins of the streams feeding the swallowholes should be examined in the field with a view to defining more precisely the Inner Source Protection, i.e. where surface runoff or spillages would be expected to drain directly to the streams and hence to the Dower Spring.
- Following the adoption of the scheme and the inventory, consideration should be given to a programme of measures to reduce the risk of pollution by appropriate measures, for example by cleaning up farmyards, concentrating on those locations which present the greatest risk to the spring.
- The Council and the emergency services should revise their contingency plans for road accidents to take account of the Source Protection Scheme, to ensure that, as far as possible, contaminating or hazardous substances are not washed into the aquifer and that, if any such contamination does occur, the water services are alerted as soon as possible.
- Since the three streams which sink at Ballyvorisheen, Carrignashinny and 'Dower Ford' represent an important part of the input to the spring, the Council should consider installing permanent monitoring stations on these streams to measure the flow and water quality.
- Continuous monitoring of the temperature and conductivity of the water in the cave mouth would provide valuable information about flood flows and their relationship with the inputs at Ballyvorisheen and Carrignashinny.
- A detailed study of the actual flow regime within the Dower cave might enable the Council to devise engineering measures to reduce the likelihood of contamination of the intake water.

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APPENDIX A: REPORT ON THE DOWER PUMPING TEST, 21-24 SEPTEMBER 1976

G.R. Wright, Senior Geologist, Geological Survey of Ireland

(This report is reproduced as written in 1976, except for a few minor amendments/insertions)

1. Objective

The objective of the test was to determine whether the Dower Spring could sustain a yield of about three million gallons per day, rather more than double the current maximum pumping rate.

Previous tests of the spring have been carried out and reported sketchily in reports by consultants. These tests, carried out at yields of over 6 Mgd, appear to have been undocumented and therefore are of little use now. This test was designed to take systematic readings of water levels in the spring, discharge rates, and water levels in nearby wells which might be affected.

2. Set-up

The test was designed to use the pump supplying the Whitegate Scheme, augmented by two mobile six-inch pumps hired from SLD Pumps Ltd. These were a Sykes Univac and a Godwin. The two mobile pumps were rated individually over the 10 foot rectangular notch before the test, and the Godwin was later checked by the horizontal pipe free-fall formula. The assumed capacities of the three pumps were:

Whitegate pump	55,000 gph	(250 m^3/hr)
Godwin pump	60,000 gph	(273 m^3/hr)
Sykes pump	50,000 gph	(227 m^3/hr)

The suction inlets of the mobile pumps were placed in the pool in the mouth of the cave, as deep as possible. The discharge was emptied into a large pool created upstream of the weir by means of a sandbagged and polythene-lined dam. The pool was also lined with polythene.

Discharge over the weir was measured on a temporary staff gauge and the stream stage downstream was also measured on a staff gauge.

During the test, after ten hours pumping, the sandbagged dam broke and the mobile pump was stopped. Pumping recommenced at 17½ hours and from then on, the water was discharged directly downstream of the weir.

Pumping rate was not constant throughout the test, for various reasons. The pumps used and discharge rates achieved were as follows:

Time (hours)	Pumps	Discharge rate assumed, gph
0 - ¾	Sykes	50,000
¾ - 1¼	Sykes + Godwin	110,000
1¼ - 2	Godwin	60,000
2 - 10	Godwin + Whitegate	115,000
10 - 17½	Whitegate	55,000
17½ - 18½	Godwin + Whitegate	115,000
18½ - 20	Godwin	60,000
20 - 23½	Godwin + Whitegate	115,000
23½ - 23¾	Whitegate	55,000
23¾ - 24	Godwin + Whitegate	115,000
24 - 25	Sykes + Godwin + Whitegate	165,000
25 - 72	Godwin + Whitegate	115,000

Thus the discharge rate was constant for the last two days of the test at 115,000 gph, or 2.76 Mgd. The total quantity of water pumped during the test was about 7.69 million gallons (all the above figures are probably slightly conservative), giving an average pumping rate over the 72 hours of 106,800 gph, or 2.56 Mgd.

The Whitegate pump was shut down for one hour only before the test and for 25 hours after it, to allow recovery.

3. Observation Wells

On 21 September, before the test commenced, eleven wells were selected as observation wells, based on the well survey carried out by Maire Mellerick in August-September. The wells were all within about a mile of the spring and located within the limestone outcrop to the north and east of it. Details of the wells are listed in Table 1. Three were boreholes, six were dug wells and two were natural fissures in the limestone which were being pumped as wells. Later, another dug well was added to the list when the owner complained of his well being pumped 'dry'.

All eleven of the initial observation wells were 'dipped' to measure the static water level on 21 September before pumping started. All but one (#335) were measured the following day, and all twelve on the 23rd. On the 24th, all but three were dipped - one (#36) because the well was blocked and two (#339 and #335) because by that time it was clear that they were unaffected.

In interpreting the water level changes, it has to be borne in mind that all the wells are in daily use and this induces short-term fluctuations. There were also difficulties in taking accurate measurements in the 'fissure well' #44 due to the shape of the fissure, the position of the pipes and the undergrowth around the well.

4. Results

4.1 Water levels in Dower Cave

Figure A1 is a semi-log plot of the drawdown of the cave water level.

The test can be regarded as falling into three phases:

Phase 1, 0 to 10 hours, during which the pumping rate was constant at 115,000 gph after the first two hours. The time-drawdown curve plots as a remarkably straight line on semi-log paper. Drawdown after 10 hours was 159mm (6¼ inches).

Phase 2, 10 to 17½ hours, the period after the dam burst, when only the Whitegate pump was operating and no drawdown readings were taken. The water level recovered partially, to 102mm (4 inches) of drawdown.

Phase 3, 17½ to 72 hours, during which the pumping rate was generally 115,000 gph, and constantly so after 25 hours. The changes in discharge rate before 25 hours caused some short-term fluctuations in the water level. The gradient of the curve is very difficult to assess before 25 hours because of the short-term fluctuations, but after 25 hours two distinct straight-line gradients can be made out.

4.2 Water Level Changes in Observation Wells

OW#56 was easy to read and gave consistent readings.

OW#44 was difficult to read and some of the readings were doubtful because of instrument troubles. Though further from the spring than OW#56, this well showed greater drawdowns and must, therefore, be more directly connected to the spring's fissure system.

OW#43 was clearly affected by its own pump, especially on 22 September, and the readings are therefore unreliable.

OW#36 became inaccessible after 23 September, due to some blockage in the borehole.

OW#38 was not measured until 23 September but thereafter was not pumped so the readings are unaffected by self-pumping but the original water level (pre-test) is not known exactly.

OW#33 was a very shallow well in gravel, with a perched water table unrelated to the spring.

OW#35 showed consistent, though small, drawdowns, and was the furthest such well to do so.

Observation Wells #339, #338, #335, #25 and #26 showed no significant drawdown and were clearly unaffected by the test.

Figure 2 *(not in this Appendix)* shows three distance-drawdown plots on semi-log graph paper, showing how drawdowns varied with distance from the spring on the three successive days of the test.

The graphs show that a very rough relationship can be established, but OW#44 is clearly anomalous. The five observation wells which showed no significant drawdown are not plotted but these also would appear anomalous compared with OW#35. Figure 3a,b,c *(not in this Appendix)* show water level variations through the test, for all wells and in the cave.

4.3 Recovery

The recovery of the water level in the cave is plotted on semi-log paper in Figure 4 *(not in this Appendix)*. The graph can be broken down into two parts, early and late (roughly 0 - 3 hours and over 3 hours). The cave water level did, in fact, recover to a level over 50mm above its pre-test level. This was probably due both to the heavy rainfall of September 24/25 and to the fact that the Whitegate pump was shut down for much longer after the test than before it. For these reasons the recovery results cannot be relied upon.

The recovery was also measured in four of the observation wells. OW#44 recovered in much the same way as the spring, and after a day was above its pre-test level. The other three recovered much more slowly and in the cases of OW#56 and OW#43, apparently incompletely.

[Footnote: A Mr Michael Cosgrave of Ballyoughtera, Attiquin, about 2 miles (3,200m) WSW of the spring, complained about his well having been dried up by the test. However, his well did not dry up until 8 days after pumping ceased! (He said the well also dried up during the 1969 test) The most that can be said is that the test helped to reduce water levels in the general area, but even this appears doubtful, considering the recovery of some of the wells subsequently.]

4.4 Water Quality

The electrical conductivity of the water in the cave fell slightly from 549 to 520 μS/cm between the start and end of the test. This may indicate some rapid through-flow from sinking streams fed by the rainfall of the 23/24 September, or more likely it indicates that a recharge source (see below) was feeding lower-salinity water into the system.

5 Interpretation

Interpretation of the time-drawdown curve and distance-drawdown curves for the cave and the observation wells is difficult because in four fundamental respects the situation at The Dower departs from the assumptions involved in the standard 'borehole' analysis methods:

a) The aquifer is strongly anisotropic and inhomogeneous.

b) The shutdown of the Whitegate pump before the test was not long enough to allow 'natural' water table conditions to prevail.

c) The discharge rate throughout the test was not constant.

d) The 'effective radius' of the 'well' (i.e. the cave pool) is very large.

Nevertheless, the 'well' does have some helpful features - it is obviously very efficient, with water entrance velocities very low, and since the discharge rate was very high, the large storage in the cave pool is offset to a large extent. The drawdown curves certainly show some recognisable features which are capable of at least semi-quantitative analysis.

The time-drawdown curve for the cave, Figure A1, gives three straight-line segments for which gradients (mm per log cycle) can be calculated. The gradients are:

2 - 10 hours	188mm per log cycle
25 - 45 hours	256mm per log cycle
45 - 72 hours	116mm per log cycle

Using the gradient of the first segment in the Jacob equation gives an apparent aquifer transmissivity of 12,200 m^2/day.

Using the gradient in the second segment would give a lower figure, but this segment has been distorted by the changes in discharge rate. The significance of the clear 50% reduction at 45 hours is that this indicates the onset of boundary condition - the cone of depression has expanded to intercept a recharge source, such as a stream or lake, subaerial or underground. The distance of this source cannot be accurately calculated because the cone of depression will obviously be asymmetrical, but may be around 1500-2000 metres, judging by the distance-drawdown graphs in Figure 2.

Calculation of the aquifer transmissivity from the distance-drawdown plots gives a value of 20,800 m^2/day. The recovery graph gives a value of 8,500 m^2/day.

Calculation of a storage coefficient is more difficult, but a very crude value can be estimated by calculating the volume of aquifer dewatered during the test and comparing it with the volume of water pumped out. This results in a figure of about 3.6%, but this may be considerably in error.

One other point to note is that, from the distance-drawdown plots, it appears that the 'effective radius' of the 'well' was over 100 metres by the end of the test. In fact the 'effective radius' (i.e. the radius over which the water level is identical to that in the cave itself) evidently extends along fissures almost as far as OW#44. It is very clear from the test that the fissure system is very well developed and that water levels in open fissures will fall faster than elsewhere under these conditions (cf. OW#35 and #335).

Extrapolation of the cave time-drawdown curve suggests that, in the absence of further recharge by rainfall, the total drawdown after one month's continuous pumping would be about 380mm, i.e. 80mm below the level at the end of the test. After three months the total drawdown would be 420mm, and after 12 months 470mm. This indicates that the tested pumping rate is sustainable, though, of course, it would adversely affect water levels in wells over an increasingly wide area.

6. Main Conclusions

6.1 Extrapolation of the water level drawdown in the cave during the test indicates that continuous pumping at the test rate of about 2¾ Mgd for several months without recharge would produce acceptable drawdowns.

6.2 Several wells in the area around the spring are affected by heavy pumping and since many wells are very shallow, a permanent increase in pumping rates from the spring would put several wells out of action.

6.3 The radius affected during the test appeared to be around 1,500 metres; prolonged pumping would affect a wider area and monitoring would be advisable up to about 3,000 metres from the spring, within the limestone syncline.

6.4 Very approximate calculations of the aquifer properties suggest a transmissivity of several thousand m^2/day and a storage coefficient of around 3-4%.

7. Recommendations

A further test next year *(1977)* would be advisable; this should be planned well in advance and should include the following features:

- More precise measurements of discharge rate from pumps, e.g. by orifice pipe, and maintenance of constant discharge rate.
- More frequent measurements of observation well levels, perhaps including some automatic recorders, and if possible, using some unpumped wells.
- Longer shutdown of Whitegate pump prior to test, e.g. for one day.
- Accurate levelling of observation well sites.
- Liaison with well-owners before test, and provision of compensation water where necessary.
- Water quality monitoring of water discharge.

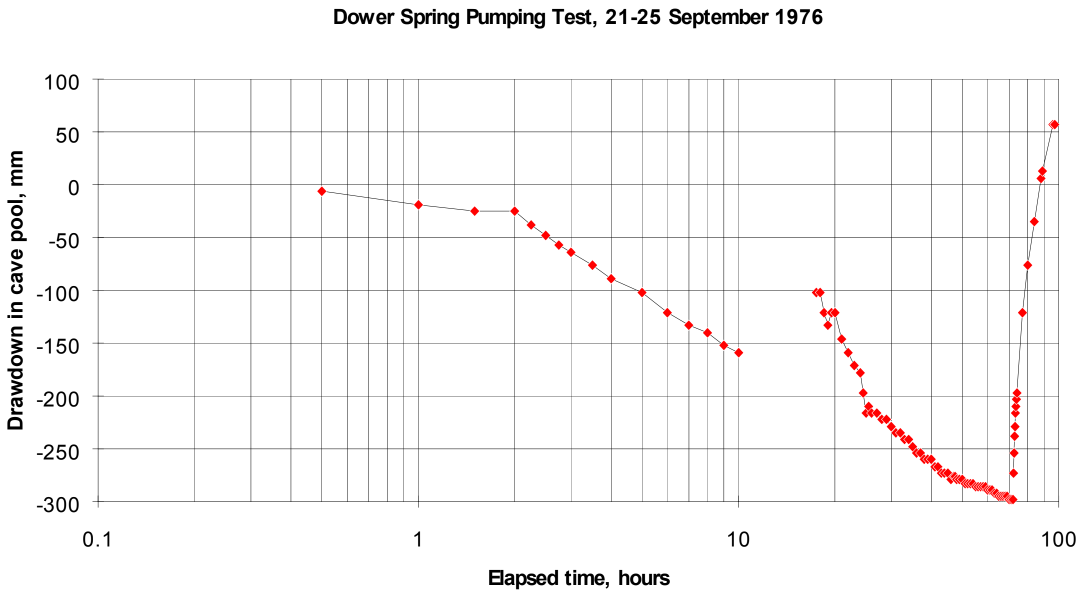
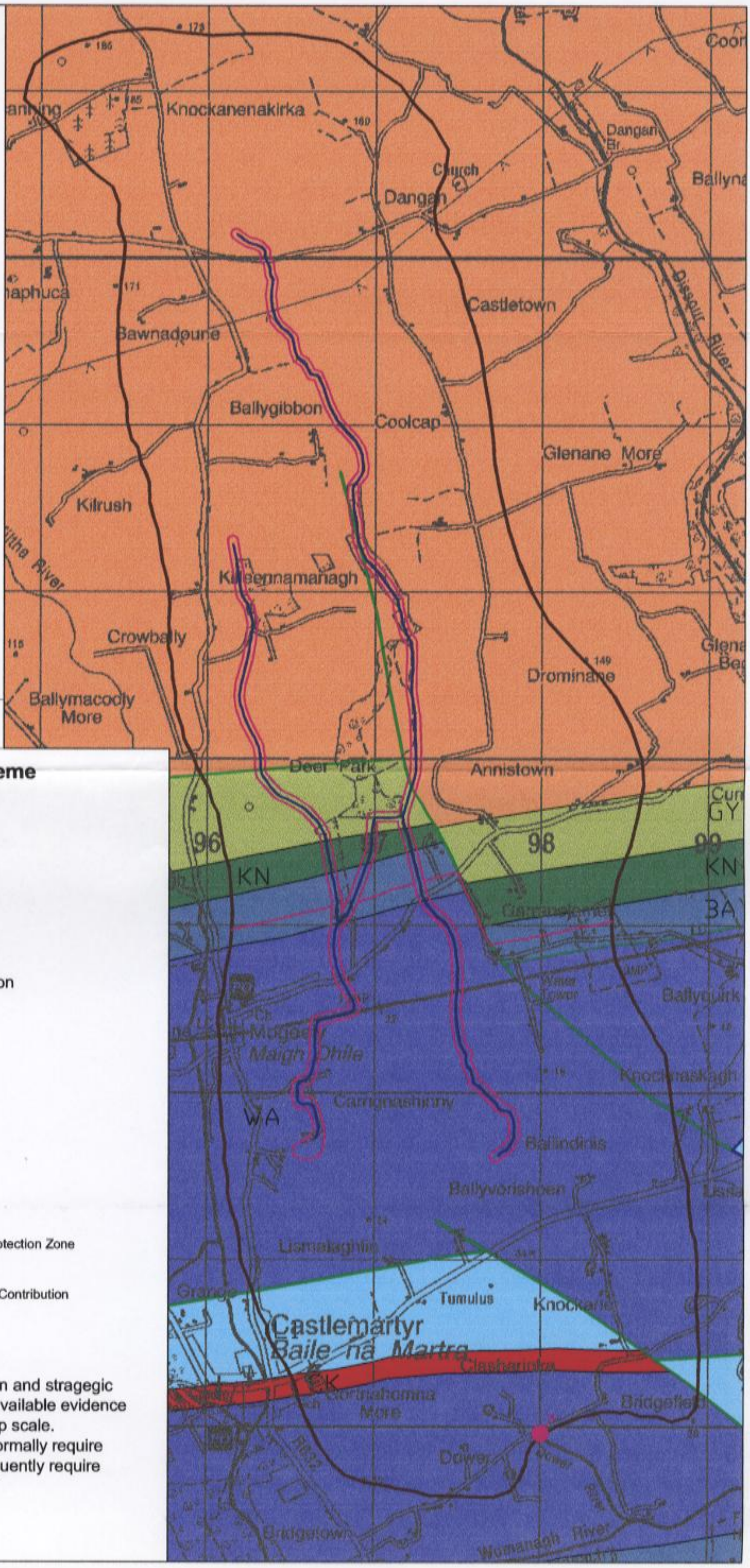


Figure A1: Time-drawdown graph of Dower cave water level, 21-25 September 1976

Dower Water Supply Scheme

Map 1. Geology

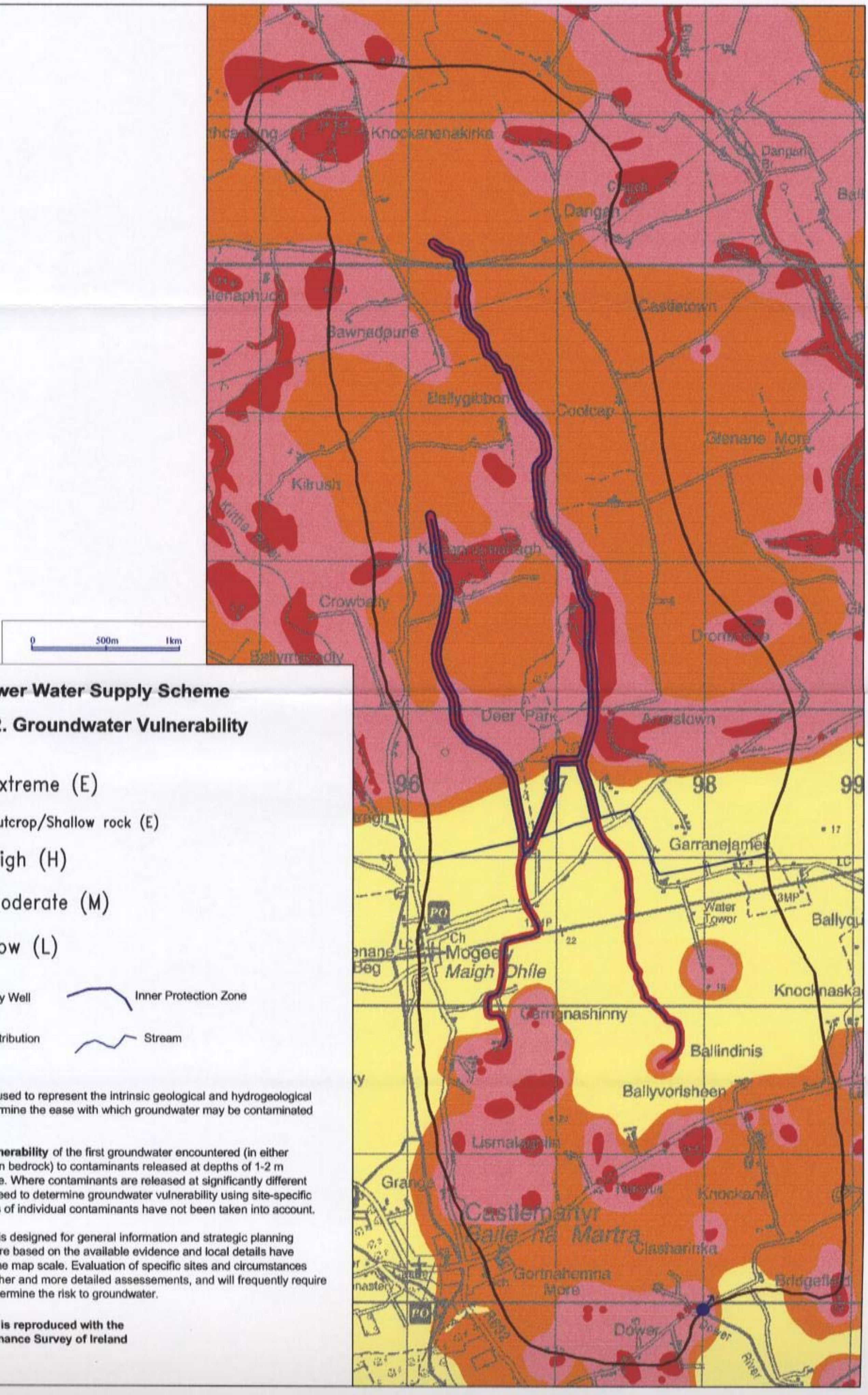


- KN Kinsale Formation
- LI Little Island Formation
- CK Cork Red Marble Formation
- WA Waulsortian Limestones
- BA Ballysteen Formation
- GY Gyleen Formation
- BS Ballytrasna Formation

Fault
Inner Protection Zone
Public Supply Spring
Zone of Contribution
Stream

This Bedrock Map is designed for general information and stragegic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments, and will frequently require site investigations.

The topographic base is reproduced with the permission of the Ordnance Survey of Ireland



Dower Water Supply Scheme

Map 2. Groundwater Vulnerability

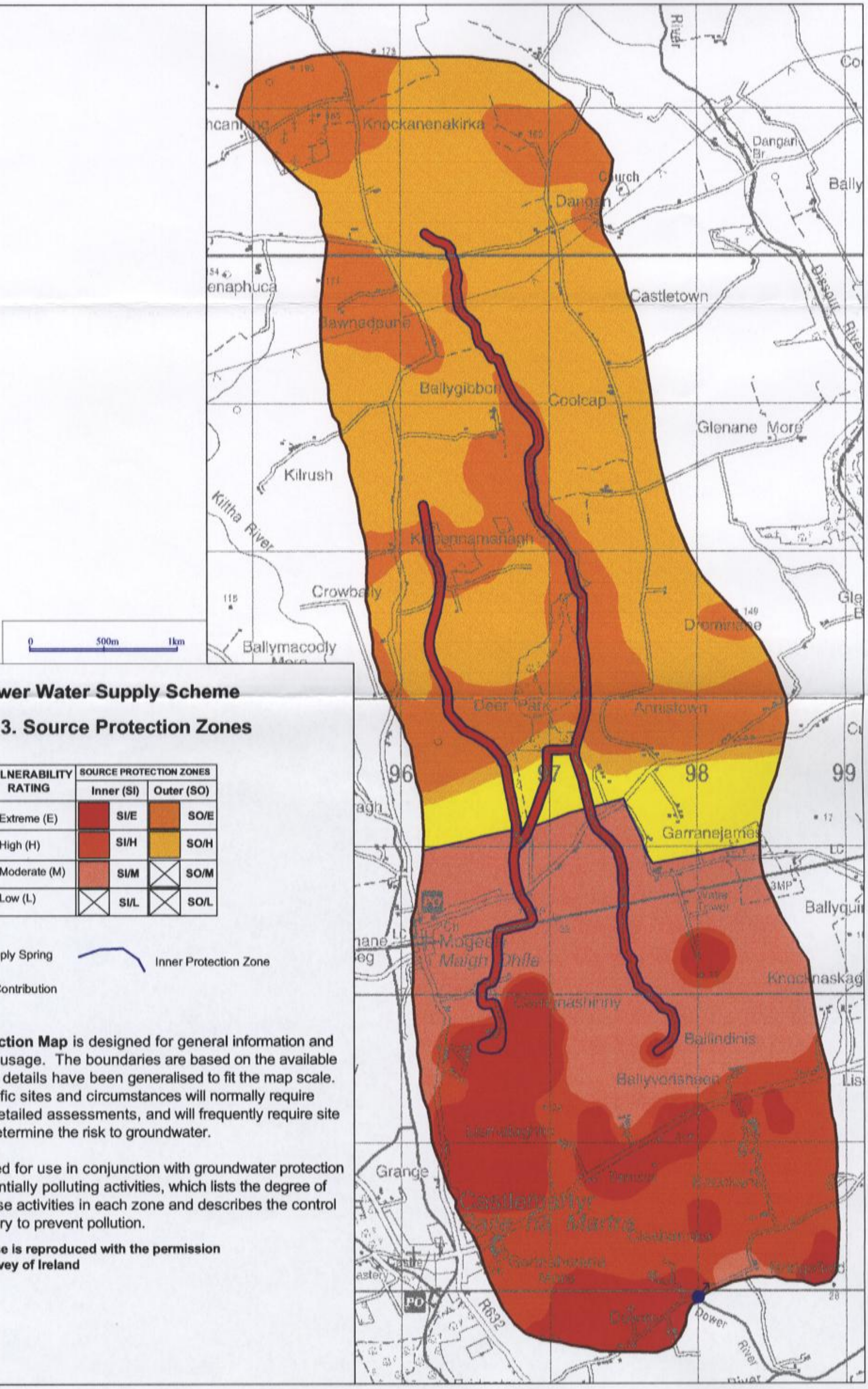
- Extreme (E)
- Outcrop/Shallow rock (E)
- High (H)
- Moderate (M)
- Low (L)

- Public Supply Well
- Inner Protection Zone
- Zone of Contribution
- Stream

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.

The map shows the **vulnerability** of the first groundwater encountered (in either sand/gravel aquifers or in bedrock) to contaminants released at depths of 1-2 m below the ground surface. Where contaminants are released at significantly different depths, there will be a need to determine groundwater vulnerability using site-specific data. The characteristics of individual contaminants have not been taken into account.

This **vulnerability** map is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessements, and will frequently require site investigations to determine the risk to groundwater.



Dower Water Supply Scheme

Map 3. Source Protection Zones

VULNERABILITY RATING	SOURCE PROTECTION ZONES Inner (SI)		Outer (SO)	
Extreme (E)		SI/E		SO/E
High (H)		SI/H		SO/H
Moderate (M)		SI/M		SO/M
Low (L)		SI/L		SO/L

Public Supply Spring

Inner Protection Zone

Zone of Contribution

This **Source Protection Map** is designed for general information and stragegic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments, and will frequently require site investigations to determine the risk to groundwater.

The map is intended for use in conjunction with groundwater protection responses for potentially polluting activities, which lists the degree of acceptability of these activities in each zone and describes the control measures necessary to prevent pollution.