8 Cavan Aquifer Hydrochemistry

8.1 Introduction

This chapter aims to provide an overview of the chemical characteristics of groundwater in County Cavan, based on available hydrochemical data. This includes the background chemistry of the various aquifer types present in Cavan, and of the water quality and chemical indicators of typical pollutants in the county. Relationships are examined between water quality problems and human pressures, and vulnerability. An understanding of these relationships will help decision-makers prioritise:

- hazard surveys,
- remedial measures,
- more detailed water quality monitoring.

This chapter is intended for use by engineers, planners, regulators and hydrogeologists who are considering the causes of groundwater quality problems across the county.

8.2 Scope

8.2.1 Key Concepts

Assessments are built upon laboratory analyses of raw water samples taken prior to treatment from public water supplies, private industrial supplies, and some domestic supplies, in order to gather and present as much information as possible. The chemical signature of groundwater bodies is discussed (where data are available). Contamination indicators have been selected for discussion as follows; nitrates, chloride, ammonia, E. coli or faecal coliforms, potassium, sodium, iron and manganese. Concentrations of these indicators in each supply are compared with GSI recommended guide levels to help identify where groundwater is likely to be susceptible to pollution. Many of the results are one-off samples collated from individual reports, therefore bacteriological results in particular cannot always be taken as completely representative of the ongoing groundwater quality status, as their occurrence in groundwater is typically intermittent.

Groundwater chemistry results from different boreholes are discussed within the framework of the Groundwater Bodies (GWBs)[1] delineated for the Water Framework Directive (Groundwater Working Group, 2005). The understanding is that the aquifer system within a groundwater body is essentially a contained body of water which should be influenced only by the bedrock type, subsoil type and activities within the surface extent of the groundwater body.

Appendix I describes how the contaminant indicators are helpful in diagnosing the following contamination hazards: landspreading, on-site waste-disposal systems (e.g. septic tank systems), and farmyard point hazards. Clearly, there are many other potential hazards, such as manufacturing industry and small commercial enterprises. Though individual pollution incidents related to these activities can be serious in terms of public health, they are likely to be localised, and rarely influence the regional groundwater quality situation. Consequently, such activities are not considered in this report.

8.2.2 Limitations

Discussion on groundwater chemistry from different results often involves comparison between samples from which different suites of analyses have been undertaken. Therefore, the absence of an account of certain parameters is not necessarily an indication that there is not a related groundwater quality issue.

[1] Groundwater bodies define the management unit under the WFD that is necessary for the subdivision of large geographical areas of aquifer in order for them to be effectively managed.

The distribution and causes of quality problems in raw groundwater are discussed in the context of the contaminant indicators and contaminant hazards described above. Public health considerations are a matter for the relevant Health Authorities. Issues relating to other parameters, such as pesticides and hydrocarbons, and other activities, such as petroleum storage and sheep dipping, are not considered in this report.

No detailed, specific field hazard surveys have been undertaken by GSI. The assessments have been made on the basis of water quality data and cannot be used to link quality problems with specific enterprises unless they are accompanied by field hazard surveys.

8.3 Methodology

8.3.1 Selection of Groundwater Supplies

Table 8.1 outlines the list of supplies under consideration. Forty-one sample results were used for categorising the water chemistry in the different aquifers (full suite of cation and anion analyses required), whilst 56 sample analyses were assessed for contaminant indicator parameters. The 56 wells assessed in the study include four public supply sources, 13 group water scheme (GWS) sources (of which ten are currently in use), ten industrial supplies, 21 domestic wells and eight GWS trial wells. Pumping rate data are not available for many of the sample results discussed in this report. Although many industrial well results are included, these data are only taken into account as being representative of the general aquifer chemistry when there is more than one well characterising the chemistry and quality of the groundwater in an aquifer.

Results from wells which are located in close proximity (within 500 m of each other and within the same groundwater body) – such as industrial wells, and supply wells which abstract from adjacent wells – have been averaged in many cases. There are 26 areas from which water results are available as presented in Figure 8-1, which plots the location of the sampling points within County Cavan.

All available bacteriological results have been considered for this report, as their presence in a borehole supply is typically representative of groundwater local to the well anyway. There are substantially more bacteriological analyses than the number of analyses which include a full suite of the major elements

8.3.2 Data Sources

The data used were derived from available analyses on bacteriological and inorganic chemical analyses from 1990 to 2007. Data were compiled from the following sources:

- EPA groundwater quality monitoring carried out between September 1999 and August 2005 by the EPA Regional Inspectorate, (The Glen, Monaghan). Data were supplied by the Environmental Protection Agency (EPA). All analyses were from raw water samples.
- One-off sampling of selected public groundwater supply schemes carried out by Cavan County Council during 2007. Analyses were carried out by the EPA Regional Inspectorate (The Glen, Monaghan).
- Consultants reports for projects undertaken in County Cavan.

Table 8.1 Inventory of Groundwater Wells used in the Water Quality Assessment

Well Name	Well No.	Well Type[i]	Rock Unit	GWB	RPZ[ii]	Well Use	Typical discharge m^3/d	Population Served	Treatment Process	Depth of Borehole (m)	Depth to Rock (m)
Blacklion, Ture	1	W	Knockmore Limestone Member	Marble Arch	Rk/E	PWS	45			128	1
Swanlinbar GWS	2	Sp	Benbulben Shale Formation	Ballinamore-Swanlinbar	Ll/L	GWS	390			90	21
Abs.BH Kearns	3	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/L	domestic					
Abs.BH McGuire	4	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/L	domestic					
Abs.BH N.Cem.Wk	5	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/E	industry					
Quinns Quarry (N)	6	MW	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/E	industry					
Quinns Quarry (S)	7	MW	Meenymore Formation	Newtown-Ballyconnell	Rk/L	industry					
Ballyconnell PWS TW1	8	TW	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/H	n/a				70	6
Ballyconnell PWS TW2	9	TW	Crinoidal limestone	Newtown-Ballyconnell	Rk/E	n/a				90	0
Ballyconnell PWS	10	Sp	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/H	PWS				n/a	n/a
Ballyconnell PWS Doon Well	11	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/L	PWS	578	2000	Disinfection	~20.7	~8.5
Skellin Farm	12	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/E	industry					
Frehill	13	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/E	domestic					
Quinn Group Swanlinbar	14	MW	Meenymore Formation	Newtown-Ballyconnell	Rk/E	industry				34 to 96	1 to 7.5
Ballymagauran well	15	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/E	GWS	475	400	Disinfection		
Bawnboy PWS (Kilsob)	16	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/L	GWS				42.7	10
Bawnboy PWS (old)	17	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/H	n/a	170	600	Disinfection	22	
Killdallan Cairn	18	W	Crinoidal limestone	Newtown-Ballyconnell	Rk/H	GWS				77.7	

i Well Types: W =well, Sp = spring, MW = monitoring well, TW = trial well, nk = not known
ii Resource Protection Zone (RPZ) is a combination of Aquifer type / Groundwater vulnerability. Codes are described in *Table 8.2*

Note that this table comprises abstractions selected for the purposes of an overall assessment of water quality in County Cavan. It does not constitute a complete list of groundwater wells in County Cavan, but is a reflection of the data available at the time of writing the report.

Table 8.1 Contd/. Inventory of Groundwater Wells used in the Water Quality Assessment

Well Name	Well No.	Well Type[i]	Rock Unit	GWB	RPZ[ii]	Well Use	Typical discharge m^3/d	Population Served	Treatment Process	Depth of Borehole (m)	Depth to Rock (m)
Kildallan Burren	19	W	Crinoidal limestone	Newtown-Ballyconnell	Rk/L	GWS	480			80.8	
Corlough GWS	20	Sp	Dergvone Shale Formation	Aneirin-Cuilcagh East	Pu/H	GWS	518	250	Disinfection		
Milltown, Derrybrick	21	W	Ballysteen Formation	Killashandra	Ll/H	GWS				67	
Milltown Creamery	22	W	Ballysteen Formation	Killashandra	Ll/H	GWS	550			51.8	
Milltown	23	W	Ballysteen Formation	Killashandra	Rf/M	GWS	560	400	Activated Carbon + Disinfection		
Lakeland dairies	24	W	Cooldaragh Formation	Killashandra	Ll/L	industry					
Crow	25	W	Castlerahan Formation	Louth	Pl/L	industry					
Burgos Ltd	26	W	Lough Avaghon Formation	Cavan	Pl/E	industry					
Foxfield Mushrooms	27	W	Lough Avaghon Formation	Cavan	Pl/E	industry					
Bruse Hill	28	W	Coronea Formation	Cavan	Pl/E						
Ballymachugh GWS (PW1&PW2)	29	W	Ballysteen Formation	Inny	Ll/H	GWS				131 / 132.6	7.6 / 8.5
Ballymachugh (TW3)	30	TW	Lucan Formation	Inny	Ll/E	n/a				91.44	7.6
Ballymachugh (TW1)	31	TW	Lucan Formation	Inny	Ll/M	n/a				91.44	6.7
Mr Tom Lee	32	nk	Lucan Formation	Inny	Ll/H	domestic					
Liffey Meats Ltd	33	MW	Oghill Formation	Inny	Pl/H	industry	n/a			27 to 58	5 to 6
Mr Austin Cullen	34	nk	Lucan Formation	Inny	Ll/H	domestic					
Mr Austin Cullen	35	nk	Visean Limestones (undifferentiated)	Ballymanus	Rk/H	domestic					
Kingscourt PWS TW10	36	TW	Carrickleck Sandstone Member	Kingscourt	Outside Cavan Lm/L	n/a				91	18
Kingscourt PWS TW14	37	TW	Kingscourt Gypsum Formation	Kingscourt Gypsum	Pl/L	n/a				91.4	21.3

i Well Types: W =well, Sp = spring, MW = monitoring well, TW = trial well, nk = not known
ii Resource Protection Zone (RPZ) is a combination of Aquifer type / Groundwater vulnerability. Codes are described in *Table 8.2*

Note that this table comprises abstractions selected for the purposes of an overall assessment of water quality in County Cavan. It does not constitute a complete list of groundwater wells in County Cavan, but is a reflection of the data available at the time of writing the report.

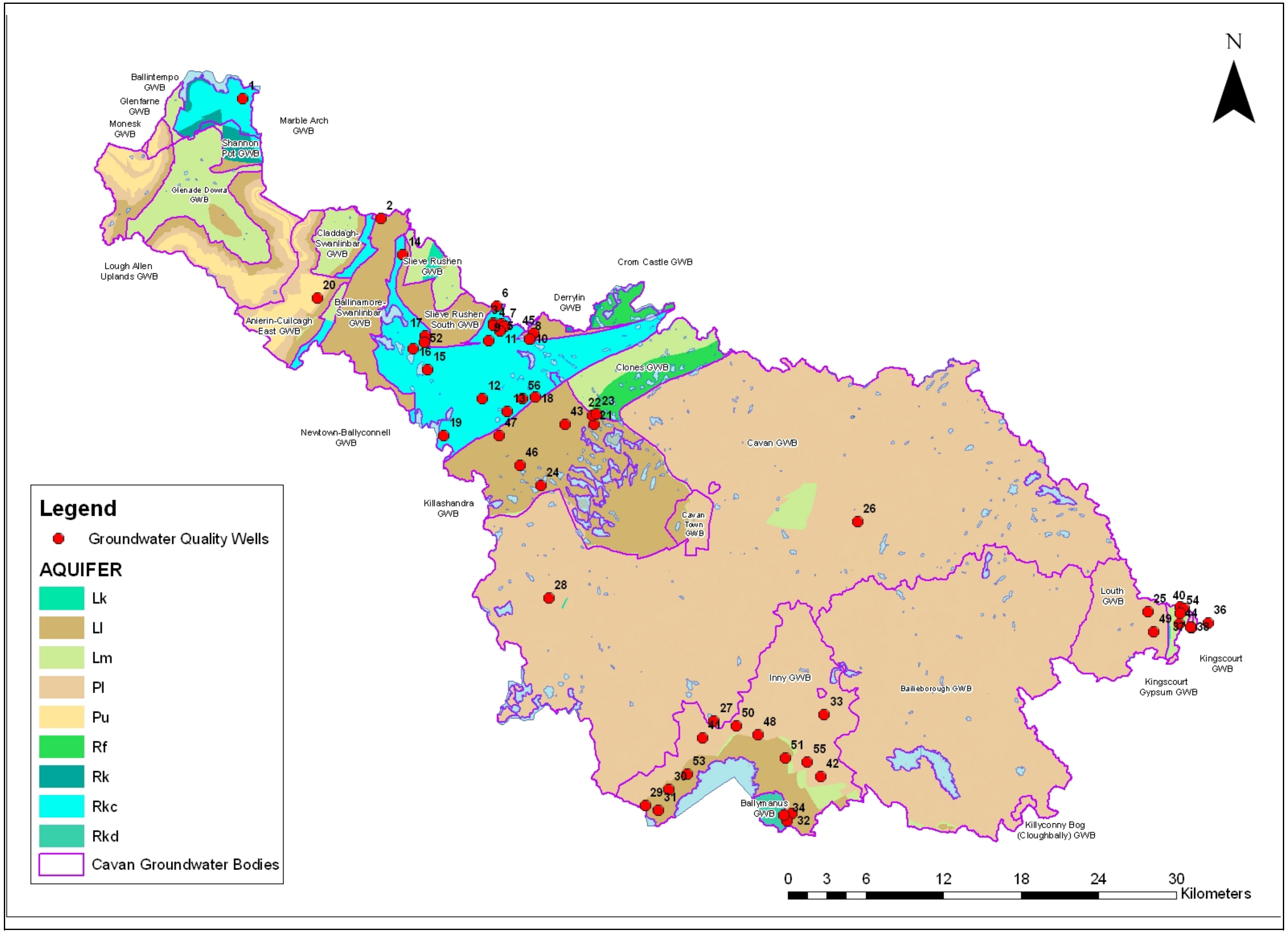
Table 8.1 Contd/. Inventory of Groundwater Wells used in the Water Quality Assessment

Well Name	Well No.	Well Type[i]	Rock Unit	GWB	RPZ[ii]	Well Use	Typical discharge m^3/d	Population Served	Treatment Process	Depth of Borehole (m)	Depth to Rock (m)
Kingscourt PWS TW14a	38	TW	Kingscourt Gypsum Formation	Kingscourt Gypsum	Pl/L	n/a				92	22
Kingscourt PWS TW5	39	TW	Kingscourt Sandstone Formation	Kingscourt	Lm/H	n/a				120	38
Gilmore, Mrs (Cormey)	40	nk	Kingscourt Sandstone Formation	Kingscourt	Lm/E	domestic					
Cavan Ballyheelin NS	41	nk	Lough Avaghon Formation	Inny	Pl/H	n/a	0				
Cavan Boylan	42	nk	Castlerahan Formation	Inny	Pl/E	domestic					
Cavan Brady	43	nk	Drumgesh Shale Formation	Killashandra	Ll/L	domestic					
Cavan Burns	44	nk	Kingscourt Sandstone Formation	Kingscourt	Lm/M	domestic					
Cavan Cassidy	45	nk	Bundoran Shale Formation	Derrylin	Ll/L	domestic					
Cavan Finlay	46	W	Drumgesh Shale Formation	Killashandra	Ll/M	domestic					
Cavan Fitzpatrick	47	W	Drumgesh Shale Formation	Killashandra	Ll/L	domestic	61				
Cavan Gordon	48	nk	Oghill Formation	Inny	Pl/M	domestic					
Cavan Kingscourt Parochial House	49	W	Castlerahan Formation	Louth	Pl/M	domestic					
Cavan Lynch	50	nk	Lough Avaghon Formation	Inny	Pl/H	domestic					
Cavan McCabe	51	W	Ballysteen Formation	Inny	Ll/E	domestic	65				
Cavan McKieran	52	W	Dartry Limestone Formation	Newtown-Ballyconnell	Rk/H	domestic	109				
Cavan Moydristan (Co. Co. well)	53	W	Lucan Formation	Inny	Ll/H						
Cavan Nelson	54	W	Kingscourt Sandstone Formation	Kingscourt	Lm/M	domestic					
Cavan Walsh	55	W	Castlerahan Formation	Inny	Pl/E	domestic	0				
Cavan White	56	W	Crinoidal limestone	Newtown-Ballyconnell	Rk/M	domestic					

i Well Types: W =well, Sp = spring, MW = monitoring well, TW = trial well, nk = not known
ii Resource Protection Zone (RPZ) is a combination of Aquifer type / Groundwater vulnerability. Codes are described in *Table 8.2*

Note that this table comprises abstractions selected for the purposes of an overall assessment of water quality in County Cavan. It does not constitute a complete list of groundwater wells in County Cavan, but is a reflection of the data available at the time of writing the report.

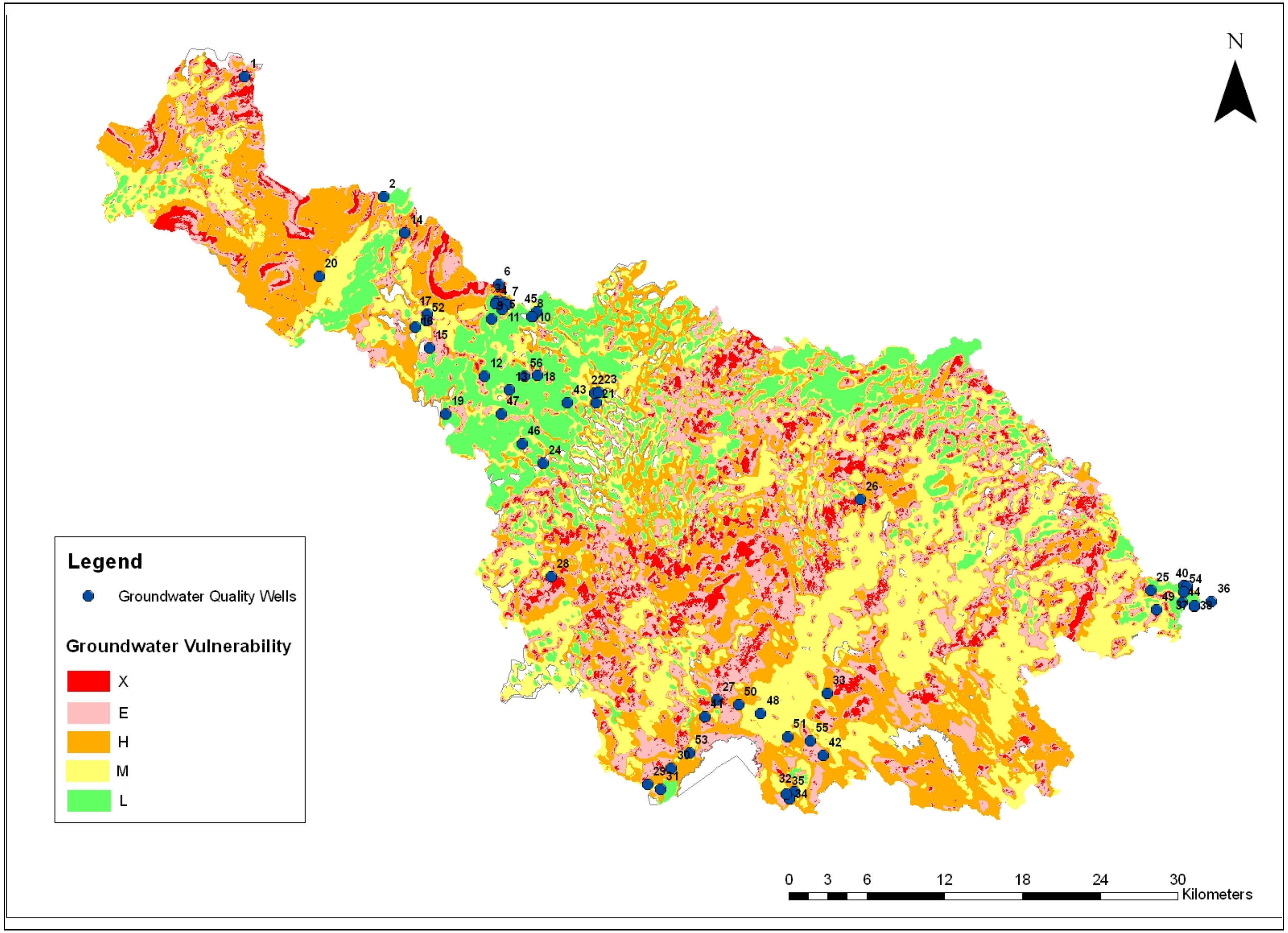
Figure 8-1: Boreholes/springs within County Cavan from which groundwater chemistry results were assessed. Bedrock aquifer and Groundwater Bodies are also shown.



Notes:

- See Table 8.1 for Well Numbers.
- Groundwater bodies (GWBs) are named on the map.
- Results from wells which are located in close proximity (within 500 m of each other and within the same groundwater body), such as industrial wells, and supply wells which abstract from adjacent wells have been averaged in many cases for the purpose of analysis.

Figure 8-2: Boreholes/springs within County Cavan from which groundwater chemistry results were assessed. Groundwater Vulnerability is also shown.



Notes:

- See Table 8.1 for Well Numbers.
- Results from wells which are located in close proximity (within 500 m of each other and within the same groundwater body), such as industrial wells, and supply wells which abstract from adjacent wells have been averaged in many cases for the purpose of analysis.

Table 8.2 Matrix of Groundwater Resource Protection Zones

VULNERABILITY RATING	RESOURCE PROTECTION ZONES					
	Regionally Important Aquifers (R)		Locally Important Aquifers (L)		Poor Aquifers (P)	
	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	Rk/E	Rf/E	Lm/E	Ll/E	Pl/E	Pu/E
High (H)	Rk/H	Rf/H	Lm/H	Ll/H	Pl/H	Pu/H
Moderate (M)	Rk/M	Rf/M	Lm/M	Ll/M	Pl/M	Pu/M
Low (L)	Rk/L	Rf/L	Lm/L	Ll/L	Pl/L	Pu/L

8.3.3 Data Accuracy and Screening

- For samples taken after treatment, data on total coliforms, faecal coliforms/*E. coli*, were ignored unless counts were above 0/100 ml.
- Data which had anomalous values untypical of groundwater were, where possible, verified in terms of the well location relative to industry and with the lab that carried out the analysis. Where verifications were not possible, strongly anomalous data were omitted.
- Samples in which the ionic balance error exceeded 15% were excluded as being potentially erroneous[2].

8.3.4 Data Analysis

Data has been assessed for elevation in any of the major cations or anions, which may relate to the natural hydrochemical processes in the aquifer as a result of interaction with the water bearing formations. Such issues include:

- Iron/manganese in sandstone and shaly limestone aquifers.
- Hydrogen sulphide in shaly limestone aquifers.
- Hardness in limestone aquifers.
- Corrosion in sandstone, mudstone, granite and volcanic aquifers where they are overlain by thin subsoil.

Assessment of samples for indications of contamination used the European Union Maximum Admissible Concentration (MAC) (S.I. No. 439 of 2000) and to the GSI guide levels as a basis for comparison of concentration levels.

The distribution of each of the key contaminant indicators was assessed in the context of groundwater vulnerability, aquifers and point hazards. The vulnerability of the groundwater and the flow regimes within an aquifer both have a strong bearing on the ease with which contaminants can reach a supply source abstracting from it. Chapters 2 and 4 in Volume I discuss the geology and consequent aquifer characteristics in the county, while Chapter 5 of Volume I outlines the basis for vulnerability classifications.

[2] Normally the acceptable limit for the ionic balance of groundwater samples is typically to within 5%, however, the scarcity of sample results precluded this lower limit.

8.4 Natural Groundwater Quality and Characteristics

8.4.1 Introduction

Pure water, in a chemical sense, is not found in nature, even in areas remote from development. Natural water contains both dissolved and suspended solids (which may be of organic or inorganic origin) gathered by the water on its way through the atmosphere and soil, on its way to streams, rivers, lakes or water tables (EPA, 1999).

This chapter describes the natural characteristics of the groundwater in County Cavan. The rock types through which groundwater flows impart a distinct chemical signature to the groundwater. For example, limestone bedrock and limestone-dominated subsoils are common in Ireland. Consequently, groundwater is often hard and contains high concentrations of calcium, magnesium and bicarbonate. However, in areas where volcanic rocks or granites are present, and also in many sandstone areas, soft water is normal (Daly, 1994). The hydrochemistry can be further modified naturally by the residence time of the groundwater in the subsurface, which influences the amount of rock that dissolves in the groundwater.

8.4.2 Groundwater Occurrence and Exploitation in County Cavan

There are three public supply schemes abstracting from groundwater in Cavan, and approximately 38 group water schemes (GWSs) supplied by groundwater. Several industries (twelve are listed in Table 8.1) also use groundwater supplies for processing, and it is expected that many agricultural holdings would also use groundwater from private wells as their principal water supply. The output of groundwater from GWSs is more than 3,200m^3/day (based on 2006 County Council data, abstraction data for two springs unknown). As the total water abstraction for the county amounts to approximately 25,000 m^3/day, groundwater represents some 14% of this. This estimate excludes households which are not served by the County Council or group water schemes. These households generally rely on individual private wells as their source of water.

Although a significant volume of the county's water supply comes from lake abstraction, it should be recognised that much of the lake water is either located in:

- areas of karst bedrock, where groundwater and surface water are often directly hydraulically connected,

or in:

- areas of poorly productive aquifers where the groundwater flow paths are short and inflow to the lake and rivers includes groundwater from the area surrounding the lake/rivers.

Therefore, the quality of the groundwater in County Cavan has a direct impact on the quality of the surface water.

8.5 Chemical Signatures of Groundwater in County Cavan

Fifty two samples results with complete suite analyses from bedrock boreholes were available for assessment of the chemical signature of groundwater in County Cavan. Eleven of these have not been included in this discussion as the ionic balances were excessively high (refer to section 8.3.3). Figure 8.3 plots the available samples based on their respective chemical signatures, and also groups them into the groundwater bodies in which they are located.

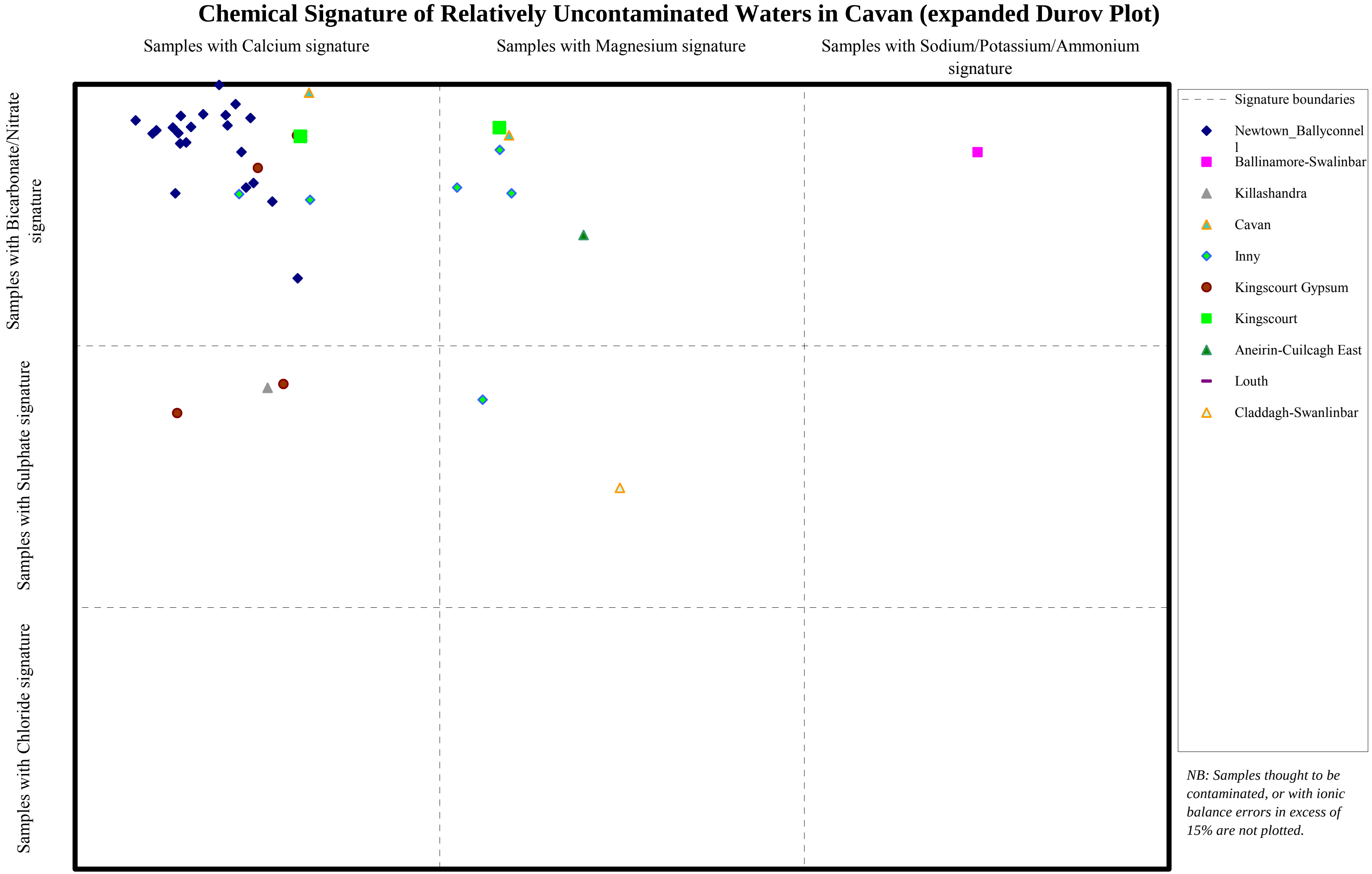
The plot shows that most of the groundwater sampled is either calcium-bicarbonate type or magnesium-bicarbonate type, reflecting the high usage of groundwater in the pure bedded limestones in north-west Cavan and around Lough Sheelin. The magnesium contribution to the groundwater signature of the Inny groundwater body (magnesium bicarbonate type) is expected to result from the muddier (shale content) of the carboniferous bedrock around Lough Sheelin, and the influence of igneous and metamorphic bedrock in the northern part of the Inny catchment. Likewise, the Cavan catchment encompasses the igneous and metamorphic bedrock of the Ordovician and Silurian, so one of the two samples from this groundwater body also has a magnesium bicarbonate signature. The

Corlough GWS sample in the Aneirin-Cuilcagh groundwater body is located in Namurian shales which are also expected to contribute to the magnesium content in the groundwater due to their muddy nature.

The Kingscourt Gypsum formation contains high concentration of sulphate minerals in the bedrock as the formation indicates (gypsum is a calcium-sulphate mineral), so the samples from this groundwater body have a calcium sulphate signature. Elevated concentrations of sulphate have historically been found in wells in the Killashandra to Monaghan aquifer also (An Foras Forbartha, 1981), hence the calcium sulphate signature for the sample from this groundwater body.

The magnesium-sulphate signature of the Sralaghan spring in the Claddagh-Swanlinbar groundwater body may be due to the recharge for the spring occurring in the layers of Namurian shales and sandstones of the Cuilcagh Mountains, which are mud-rich and reported to include coal bearing horizons, which are typically rich in sulphide minerals. The groundwater at this point is not highly mineralised, but the relative concentrations of magnesium and sulphate are greater than that of calcium and bicarbonate which are unusually low (there are also historic reports of sulphur spa wells in the Swanlinbar area).

Figure 8-3: Durov plot of groundwater samples with full analysis suite. Samples grouped by Groundwater Body.



8.6 Indicators of Groundwater Contamination

8.6.1 Introduction

GSI has developed guide levels for certain key chemical and microbiological parameters. These guide levels can be used to help indicate situations where the water quality of a groundwater supply source has been affected to a significant degree by certain human activities but not necessarily to the extent that concentrations exceed the EU MAC for drinking water. In essence, the indicators help identify groundwater supply sources which are contaminated but not necessarily polluted. The benefits of examining contamination in addition to pollution are:

- An 'early warning' can be provided for supplies which may become polluted in the future.
- Evidence of contamination may provide an indication that the supply is polluted at certain times of the year but that these incidences of pollution are not being identified by the existing monitoring regime.

Consequently, supplies with concentrations of indicator parameters above GSI guide levels may benefit from measures including additional monitoring, improved well head engineering, and hazard surveys, to help prevent more significant water quality problems. The use of contaminant indicators is described in more detail in Appendix I.

Comparison between nitrate levels in Cavan groundwater and other commonly associated contamination indicators (faecal coliforms and ammonia) are generally not possible as many of the available analyses do not include a full suite of all major parameters.

The key indicators are given below (Table 8.3), along with the GSI's guide levels and the EU MAC level:

Table 8.3: Key indicators of diffuse groundwater contamination

Parameter	**GSI Guide Level** (mg/l)	**EU MAC** (mg/l)
Faecal bacteria	0	0
Nitrate	25	50
Potassium	4	12
Chloride	30	250
Ammonia	0.15	0.4
K/Na ratio	0.4	-
Phosphate (as P)*	0.02	2.2
Iron**	-	0.2
Manganese**	-	0.05

Levels higher than the guide are likely to influence river phosphate problems where groundwaters contribute more than 50% of the annual flow to rivers.
*****Elevated levels of iron and manganese, though often influenced by the natural geology, can also provide an indirect indication of contamination.***

Sections 8.6.2 to 8.6.5 provide a discussion of each contaminant indicator, where EU MAC or GSI guide levels are exceeded, and the general status of the groundwater bodies from which well samples have been assessed.

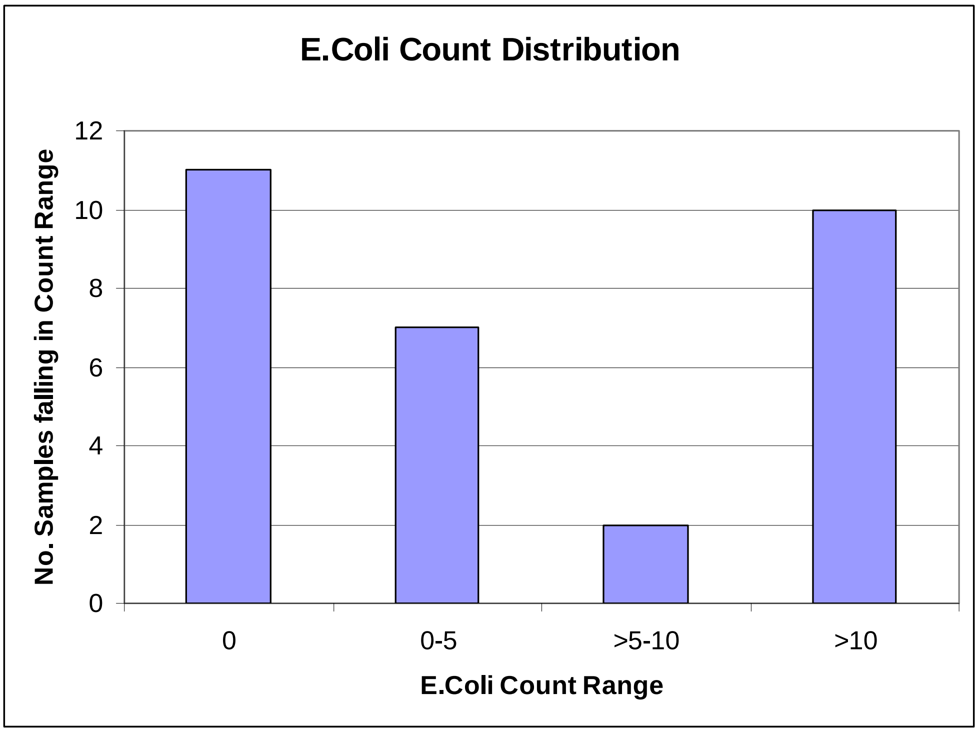
8.6.2 E. coli

E. coli is commonly analysed because it is easily detected and identified, and because it originates in the intestine, along with many pathogenic organisms. (Faecal Coliforms are frequently analysed, a coliform group which principally consists of E. Coli in most analyses). More information is provided in Appendix I.

Samples with E. Coli which were examined included only those from which there was more than one sample take from the same well. This was in order to avoid misrepresentation, as this contamination index ideally requires regular monitoring.

There are 30 wells considered altogether. The worst case scenario (i.e. the highest count) is represented from each well. Samples which are represented in the assessment of bacteriological contamination are included in Table 8.1, and the plot of the counts breakdown is included as Figure 8-4.

Figure 8-4: Division of E. Coli Counts in County Cavan Groundwater Samples



The distributions of coliform sample results were compared to the aquifer units in which the borehole was located, and the vulnerability of the aquifer in the immediate vicinity of the sampling point. The key points from the assessment are as follows:

- E. coli or faecal coliforms are in excess of 0 counts/100 ml in one or more raw water samples from nineteen (63%) of the thirty supply sources examined.
- Nine of the eleven samples which were clear of coliforms are situated in locally important or poor aquifers, and two in regionally important Dinantian limestone aquifers.
- Four of the samples from the highest contamination bracket (>10 counts/100ml) are in regionally important aquifers, and four are in locally important aquifers.
- Seven of ten samples in the highest contamination bracket (>10 counts/100ml) are located in areas of extreme or high vulnerability.

The conclusion drawn is that the aquifers least prone to bacteriological contamination are the less productive, lower conductivity aquifers, in which bacteriological contaminants cannot migrate far and hence, are not intercepted in wells in these formations. This may imply that the regionally important, higher conductivity aquifers are most prone to bacteriological contamination. However, there are insufficient data to verify this assumption. Areas with higher groundwater vulnerability are more likely to experience higher levels of contamination.

It is stressed that these values do not necessarily represent human health concerns. Samples are mainly of ‘raw waters’, having been taken from points prior to water treatment at the supplies.

8.6.3 Nitrate, Ammonium & Potassium

Forty sample results were assessed for elevated nitrate, ammonium and potassium as indicators of contamination. Samples in close proximity to each other (e.g. a quarry site, or a group of supply abstraction points) were grouped together, and the geometric average of the concentrations taken. The majority of samples are individual samples rather than repeat samples over time. The geometric average was also taken of any repeat samples.

The normal concentrations of Nitrate and Ammonia are low in uncontaminated groundwater (less than 5 mg/l and less than 0.15 mg/l respectively). Nitrate is quite mobile in the subsoil and groundwater environment, so it is a good indicator of background contamination by fertilisers and waste organic matter. Ammonia has a low mobility, and therefore typically reflects nearby contamination sources.

Examination of both nitrate and ammonia together can help to determine (when both parameters are elevated) that organic contamination is an issue, as opposed to the contamination coming from an inorganic source. Elevated potassium concentrations are similarly a further indication of organic contamination nearby, and particularly a K:Na ratio above the background level of 0.4 is a positive indication of proximal organic contamination. More information is provided in Appendix I.

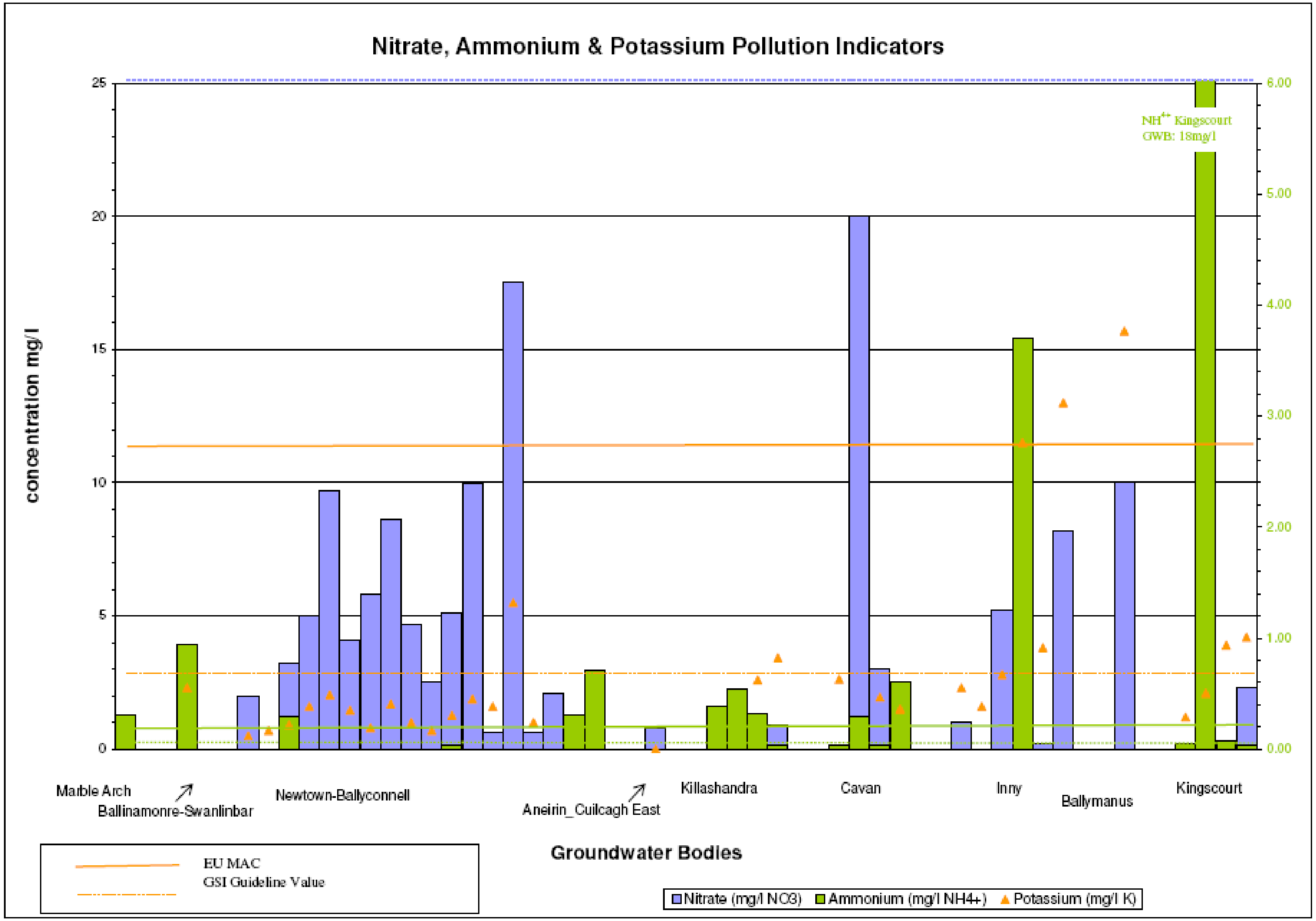
A graph of nitrate, ammonium and potassium concentrations is shown in Figure 8-5. The results have been grouped into the groundwater bodies which they fall into (in order to identify whether there is a problem in a particular area). Key points to note are as follows:

- All available nitrate concentrations were low (less than the GSI guide value of 25 mg/l). The faecal coliform counts were also low in the majority of samples (95%) where faecal coliforms were detected in sample with a corresponding nitrate analyses.
- Ammonium values exceed the EU MAC of 0.3 mg/l in ten of the 33 available samples, and exceed the GSI guideline in a further 12 sample results.
- The Killashandra Groundwater Body has the highest proportion of ammonia-related contamination, and a very high value of 18 mg/l was detected at the Kingscourt supply trial well TW14.
- Two samples have levels of potassium which exceed the EU MAC of 12 mg/l, and a further four out of 34 sample results exceed the GSI guideline value of 4 mg/l.
- A K:Na ratio >4 was found at two locations: Ballymagauran GWS well and Liffey meats. Ballymagauran well had correspondingly elevated Nitrogen (relative to levels elsewhere in Cavan, although still below the GSI guideline level and EU MAC), a high count of E. Coli, and an orthophosphate level elevated above the GSI guide level, suggesting there is a contamination issue local to this supply.

The generally low nitrate concentrations imply that there is no residual background organic contamination, much of which may be due to the high rainfall and aquifer throughput in the regionally important aquifers, and the short flow paths in the poor aquifers from which analyses were assessed (such that elevated nitrate is not detected in many wells). In low groundwater vulnerability areas, the main contaminant pathway will be overland; waters recharging the aquifer will carry only a small percentage of total loading applied to the ground surface.

The necessity of regular sampling in order to fully assess the occurrence, or verify the absence, of contamination in aquifers in such a setting cannot be overemphasised. Localised contamination is evident from elevated ammonium concentrations in several wells, such as in the Inny and Kingscourt groundwater bodies (Figure 8-5). This is likely to be due to a combination of landspreading of organic wastes and septic tank systems. There is a degree of correlation between vulnerability and elevated ammonium: nine of the twelve elevated ammonium samples are located in areas of high to extreme vulnerability. Localised contamination in high and extreme vulnerability areas may therefore be the chief contributory factor for the elevated concentrations measured.

Figure 8-5: Nitrate, Ammonium and Potassium concentrations in different Groundwater Bodies



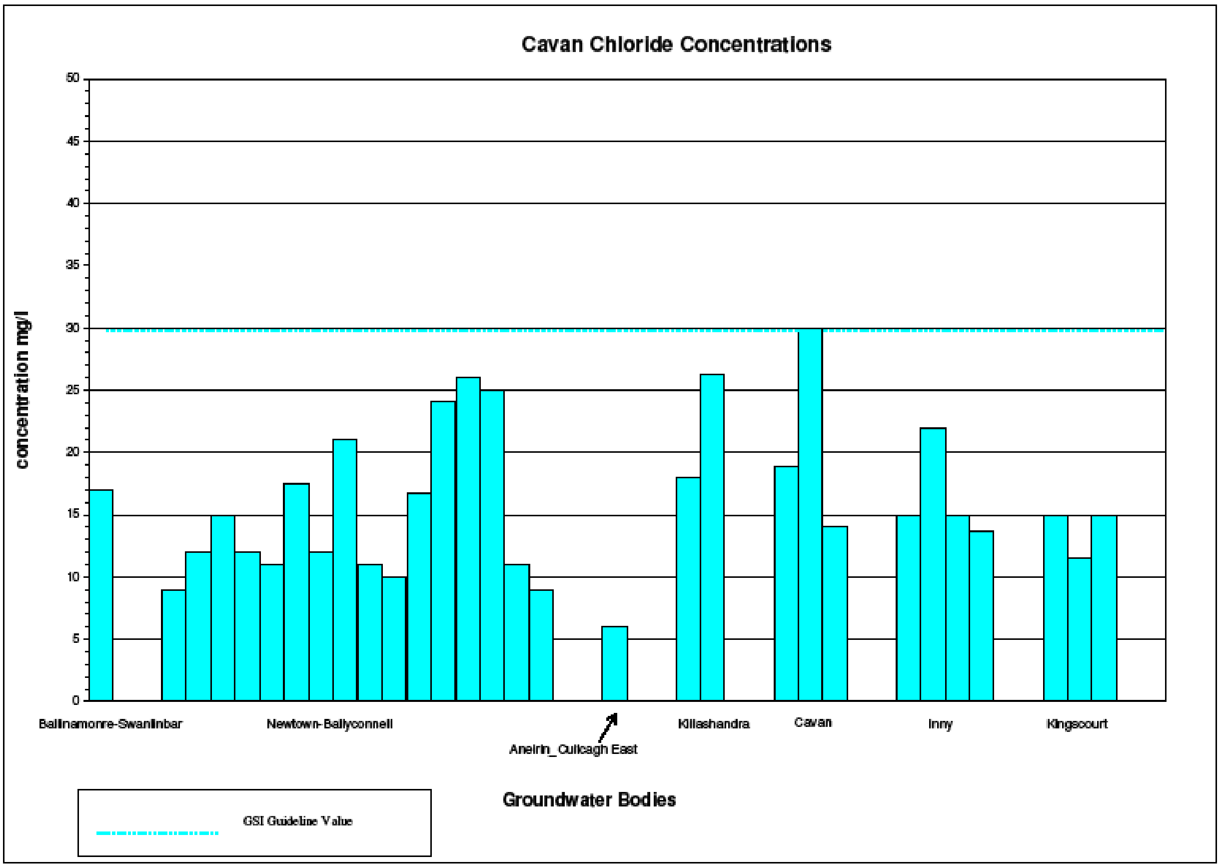
Note the different scale on the right hand side of the graph for the ammonium concentrations.

Regular monitoring of inorganic water chemistry is available for only seven EPA boreholes since 1999. A trend was seen in one borehole (Skellin Farm) of increasing contamination over time.

8.6.4 Chloride

Chloride concentrations above 30 mg/l can often be related to sources of contamination (except in coastal areas). Thirty sample results were available for assessment of chloride concentrations as a possible indication of contamination. One sample result was just above the GSI guideline value. The geometric mean of all available chloride results is 15 mg/l, concentrations above this could be considered to be as a result of organic contamination when considered alongside parameters discussed in sections 8.6.2 and 8.6.3. Chloride concentrations in Cavan are presented as Figure 8-6.

Figure 8-6: Chloride concentrations measured in groundwater samples in County Cavan

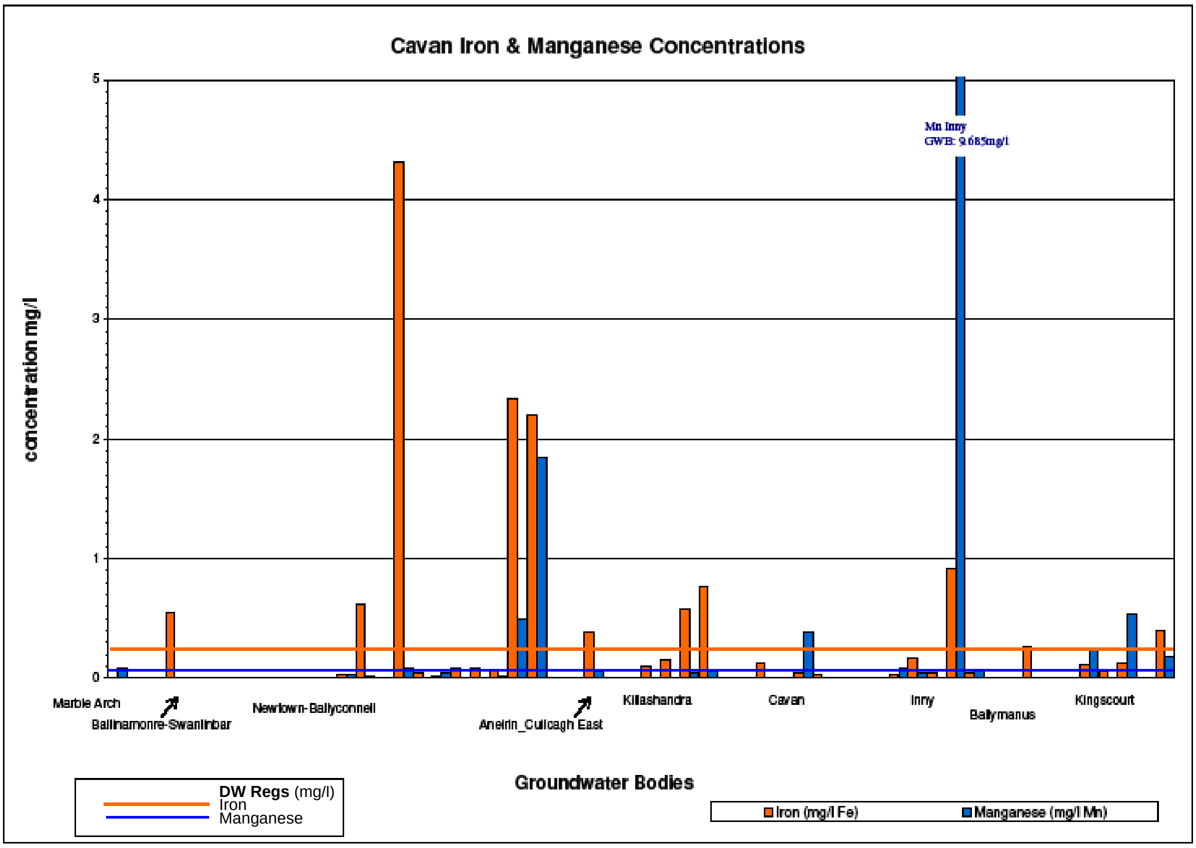


8.6.5 Iron & Manganese

Iron and Manganese are present in groundwater under a variety of natural conditions (impure limestones, shales and boggy areas may contain high iron and manganese). However, they can also be good indicators of contamination by organic wastes as they get leached from the soil when oxygen levels are reduced by organic contaminants. More information is provided in Appendix I.

A plot of Iron and Manganese grouped into their respective groundwater bodies is presented as Figure 8-7. Iron exceeds the EU Mac in 11 of the 39 (28%) sample results examined, and manganese exceeds the EU MAC in 13 of the 30 (43%) available results. The particularly high iron concentrations at three of the locations in the Newtown-Ballyconnell groundwater body (Skellin Farm, Killdallan Cairn and Killdallan Burren) are likely to be due to contamination, as elevated ammonia was also seen in the same samples. TW14 (Kingscourt GWB) and the Liffey meats wells (Killashandra GWB) have elevated concentrations which can similarly be attributed to organic contaminant origins. It would not be untypical for groundwater bodies in central and south-east Cavan to have elevated iron and manganese levels due to the igneous and metamorphic minerals in the bedrock, therefore elevated concentrations at other sites are inconclusive in relation to contamination, as other contaminant indicators are not available.

Figure 8-7: Iron and Manganese concentrations measured in groundwater samples in County Cavan



8.7 Conclusions

- The available groundwater analyses in Cavan indicate that the majority have a calcium-bicarbonate signature, with a minor number of samples showing a dominance of magnesium and/or sulphate ions.
- E. coli or faecal coliforms are in excess of 0 counts per 100 ml in at least one raw water sample (on more than one occasion) from 80% of the wells examined. Bacteriological pollution is encountered least in poor aquifers, and is expected to be encountered most in regionally important aquifers, and in areas with a high to extreme vulnerability rating.
- Nitrate levels are low in the available well sample data, although ammonium levels suggest that organic contamination is an issue at almost one third of wells samples examined. A combination of dilution in highly transmissive aquifers, and absence of regular sample results is thought to be the explanation for low nitrate levels relative to other contamination indicators.
- In combination with inferences from vulnerability mapping, the contaminant indicators suggest overall that localised contamination of domestic or agricultural organic wastes, such as poorly-managed farmyard ‘dirty water’, landspreading on poor aquifers, and poorly-located or poorly-constructed on-site wastewater treatment systems (e.g. ‘septic tanks’), are a significant influence on groundwater quality across the county.
- High iron and manganese concentrations in combination with elevated ammonia suggests aquifer contamination is occurring at wells in the Newtown-Ballyconnell, Killashandra and Kingscourt groundwater bodies.

- Evidence of organic contamination at the Ballymagauran (Ballymagovern) GWS well has been detected from a high faecal coliform count, elevated levels of nitrates, and a high K:Na ratio.

8.8 Recommendations

- Sampling of raw water as well as treated water is recommended for all supplies on a regular basis, including full analyses of major ions. In addition to the usual analyses, indicators of petroleum, pesticides and herbicides should also be examined, perhaps on a less frequent basis (e.g. twice yearly).
- A hazard survey is recommended for the Ballymagauran source to identify and minimise contaminant hazards. As there is no source protection area delineated for this supply, a survey might begin within an area between 300 m down slope and 500 m upslope.
- In order to try to minimise the potential for contamination, new supplies would ideally comprise boreholes drawing water from confined aquifers or from moderate to low vulnerability groundwater in areas away from point hazards such as poorly maintained farmyards. These boreholes would preferably be constructed so as to seal off shallow groundwater strikes and to eliminate the potential for surface water ingress to the well. The bottled water standards produced by the Irish Standards Authority give guidance as to the correct procedure for well production and maintenance (NSAI, 1992).

8.9 Acknowledgements

The following people provided water chemistry information:

- EPA Clonskeagh staff and Regional Inspectorate Monaghan staff, particularly Matthew Craig, Maeve Quinn and Brendan Magennis

The following collected water samples specifically for this report:

- Colm O'Callaghan, Cavan County Council.

8.10 References

An Foras Forbartha, 1981. Groundwater Resources in The N.E.(R.D.O.) Region; V1 Summary report, V2 Main Report, V3 Technical Appendices.

Daly, 1994. Chemical Pollutants in Groundwater: a Review of the Situation in Ireland. Paper presented at *Conference "Chemicals – a Cause for Concern?"* in Cork, 3-4 November 1994.

Environmental Protection Agency, 1999. The Quality of Drinking Water In Ireland.

National Standards Authority of Ireland, 1992. Bottled water. NSAI IS 432:1992.

Working Group on Groundwater, 2005. Approach to Delineation of Groundwater Bodies, Guidance Document No. GW2.

S.I. No. 439 of 2000. European Communities (Drinking Water) Regulations, 2000. Office of the Attorney General, Dublin, Ireland.