Catchment CARE
Community Actions for Resilient Ecosystems

Sampling and Analysis of Groundwater at selected locations on the island of Ireland

Finn Catchment Hydrochemistry Report

UK Research and Innovation/British Geological Survey
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MARCH 2023

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British Geological Survey

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European Regional Development Fund

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta
Department of Housing, Local Government and Heritage

A project supported by the European Union's INTERREG VA Programme, managed by the Special EU Programmes Body (SEUPB).

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Section 1 Introduction

1.1 Background

The British Geological Survey (BGS) appointed CDM Smith Ireland Ltd (CDM Smith) to undertake a programme of groundwater monitoring at locations across the Finn catchment. This work was completed as part of the CatchmentCARE project.

Six monitoring events were carried out between November 2020 and August 2022:

- November 2020
- May 2021
- October 2021
- March /April 2022
- June 2022
- August 2022

Between seven and thirteen monitoring wells were sampled during each monitoring event as newly drilled wells were added to the monitoring programme during successive monitoring events. In total, 59 samples were collected over the two-year monitoring period.

This report presents the fundamental hydrochemical characteristics of the Finn catchment based on the six monitoring events. The hydrochemistry across the catchment is summarised, an initial assessment of the water types is provided and potential anthropogenic pressures in the catchment are discussed.

1.2 Site Background

The Finn catchment straddles the border between the Republic of Ireland and Northern Ireland (Figure 1). Samples were collected in five locations across the catchment. All samples from any one location are grouped together for analysis and interpretation purposes in this report. The locations/groups and total number of samples per group are given below and presented in Figure 1:

- Group 1: Angler's Car Park (n= 12)
- Group 2: Lough Muc (n = 17)
- Group 3: Fish Pass (n = 9)
- Group 4: St. Columba's School (n= 12)
- Group 5: Reelin Water (n= 9)

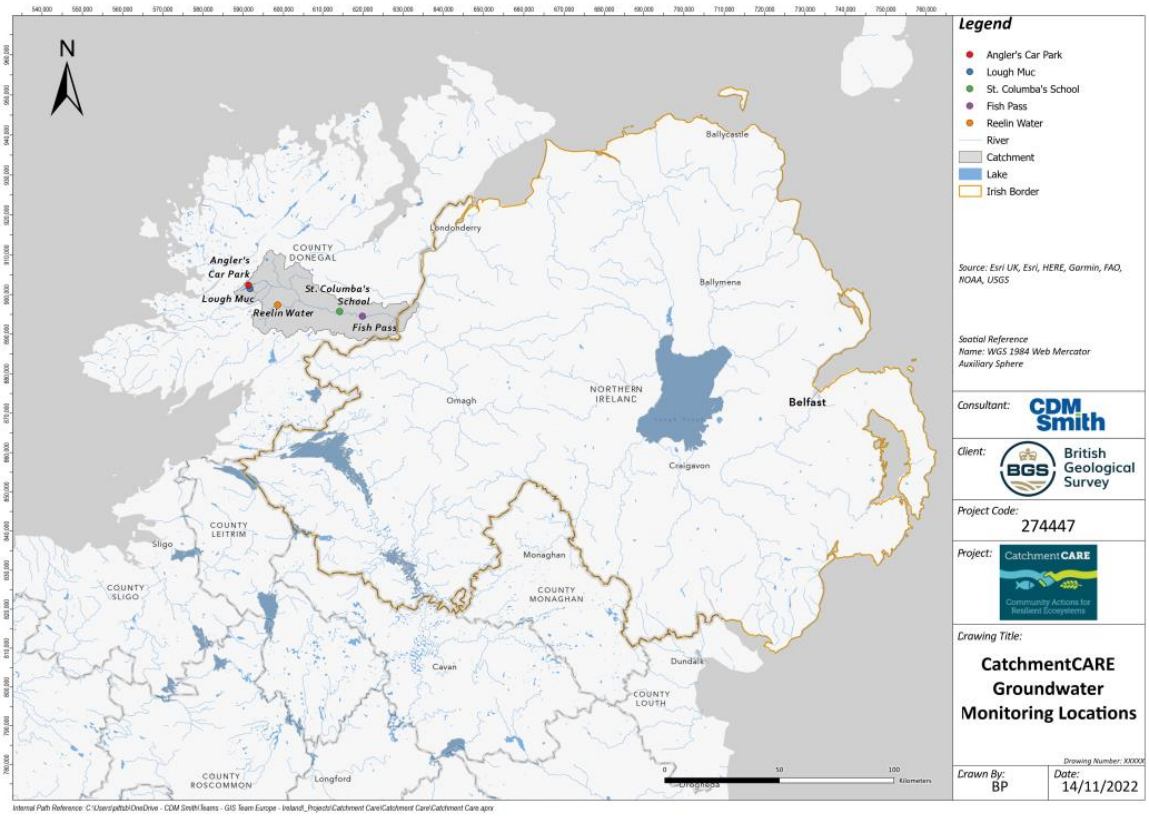

Figure 1: Finn Catchment Location

The Corine 2018 Landcover dataset indicates that the landuse across the Finn catchment is predominantly agricultural pastures, which comprise ~75% of the area of the catchment to the east (Corine Landcover 2018). Moving westward there are small patches of coniferous forests which give way to forest and semi-natural areas; scrub and/or herbaceous vegetation associations; transitional woodland scrub which in turn give way to peat bogs to the west and north-west of the catchment.

Subsoils across the catchment are largely variable metamorphic till (diamictons) ((GSI Map Viewer; UK Soil Observatory) with bedrock at or close to surface (GSI Map Viewer; GSNI GeoIndex). There is some blanket peat to the west and particularly northwest, and alluvium along the banks of the Finn river. Soils are largely poorly drained peat (mainly acidic) gleys derived from mainly non-calcareous parent materials to the west of the catchment (EPAMaps), with some deep well-drained loamy mineral soils (acidic broth earths/brown podzolics) to the east of the catchment (EPAMaps; UK Soil Observatory).

The aquifer across the catchment is largely Pl (Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones), with two areas of Ll (Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones); one in the northeast section and one south running north-south through the centre of the catchment. The Finn Catchment aquifer vulnerability is generally “high” to “extreme”, with smaller areas of “moderate” to the west of the catchment (GSI Map Viewer & GSNI GeoIndex).

Bedrock geology and associated general mineralogy at each of the five groups are presented in Table 1.

Table 1 Bedrock Geology and Associated General Mineralogy

Location	Bedrock geology	General Mineral composition
Group 1: Angler's Carpark	Loughros Formation (Quartzite with semi-pelitic schist)	Quartzite: predominantly quartz (quartz 88-98%), with iron hydroxides (2-3%), silicon and chalcedony (4-5%). Quartz: Silica Semi-pelitic schist: quartz + sillimanite/kyanite + K-feldspar + Fe-Ti oxides + garnet and biotite.
Group 2: Lough Muc	The Glencolumbkille Pelite Formation (Black graphitic pelitic schist)	Graphite (carbaon), mica (silica, aluminum, potassium, iron), talc (magnesium), chlorite (magnesium, iron, aluminium, silicon).
Group 3: Fish pass	Aghyaran and Killygordon Limestone formation (Marble, quartzite, psammite, graphitic).	Marble: silica, aluminium, Magnesium. Quartzite: predominantly quartz (quartz 88-98%), with iron hydroxides (2-3%), silicon and chalcedony (4-5%). Psammite: quartz (silicon), feldspar (potassium, sodium, silicon, aluminium, barium) and mica (silica, aluminium, potassium, iron).
Group 4: St. Columba's school	Lough Eske Psammite Formation (Feldspathic psammite, quartzite and marble)	Feldspathic psammite: largely feldspar (potassium, sodium, silicon, aluminium). Quartzite: predominantly quartz (quartz 88-98%), with iron hydroxides (2-3%), silicon and chalcedony (4-5%). Marble: silica, aluminium, Magnesium.
Group 5: Reelin water	Croaghubbrid Pelite Formation (Graphitic pelite, thin psammite and marble)	Psammite: quartz (silicon), feldspar (potassium, sodium, silicon, aluminium) and mica (silica, aluminium, potassium, iron). Marble: silica, aluminium, Magnesium.

Section 2 Methodology

2.1 Field Sampling Method

Groundwater samples were collected using either the low-flow technique or fixed volume technique. Ground water purging and sampling was carried out using pumps as follows:

- Bladder pump (low flow);
- Peristaltic pump (low flow); or
- Suction pump (fixed volume).

Groundwater levels were measured at all wells prior to pumping using a portable electronic water level meter and the initial static water level was recorded.

Field water quality parameters (temperature, pH, oxidation-reduction potential (ORP), conductivity and dissolved oxygen (DO)) were measured at all wells.

For low flow monitoring, the field water quality parameters were monitored in the field during low-flow purging using a flow-through cell to minimise oxidation by the atmosphere. Purging continued until the water quality indicator parameters stabilised (pH < ± 0.1; specific electrical conductivity < 3%; temperature < ± 0.1 ° C). The water level was measured throughout the purging process to monitor drawdown. The field data were recorded in a Survey123 Groundwater Purging and Sampling Survey digital form using a handheld portable electronic device every approximately three-five minutes during the purging process. After the well was purged and stable parameters measured, the flow was reduced for low-flow sample collection (500 ml / minute).

Fixed volume purging was carried out by purging three times volume of the complete water column in the well. The well was then allowed to recharge before sampling using either the peristaltic pump or suction pump.

All samples for trace metal analyses were filtered in the field using a 0.45-micron membrane filter before filling bottles containing nitric acid preservative. New bottles supplied by the laboratories were used for sample collection.

2.2 Laboratory Analysis

Analysis of water samples was undertaken by McQuillan Environmental, Antrim, Northern Ireland, United Kingdom and Element Materials Technology (Element), Deeside, United Kingdom. Both laboratories are accredited by the United Kingdom Accreditation Service (UKAS) in accordance with ISO/IEC 17025:2005.

Water samples were either collected by a courier on the day of sampling (McQuillan Environmental) or dispatch by DHL to Element in UK.

The laboratory monitored parameters fall into three groups:

1. Inorganic parameters: 52 parameters, including metals, major anions and cations, macronutrients (nitrogen and phosphorus species), physico-chemical parameters (analysed by McQuillan Environmental);

2. Organic parameters: up to 81 parameters, including pesticides, and insecticides (analysed by Element); and

3. Microbial parameters: *E. coli*, total coliforms and *Clostridium Perfringens* (analysed by McQuillan Environmental).

Section 3 Data Quality and Usability Evaluation

3.1 Introduction

Laboratory data quality and usability were assessed using data quality indicators (DQIs). Data "usability" means that the data are acceptable to use for their intended purpose and associated evaluations. The DQIs for assessing data are expressed in terms of precision and accuracy. These DQIs provide a mechanism to evaluate and measure laboratory data quality throughout the project. The definitions and methods of measurement of precision and accuracy are discussed below.

3.2 Precision

Precision is the measurement of the ability to obtain the same value on re-analysis of a sample (i.e., the reproducibility of the data). The closer the results of the measurements are together, the greater is the precision. Precision is not related to accuracy or the true values in the sample; instead, precision is focused upon the random errors inherent in the analysis that result from the measurement process and are compounded by the sample vagaries. Precision is measured by analysing two portions of the sample (sample and duplicate) and then comparing the results. This comparison can be expressed in terms of relative percent difference (RPD). RPD is calculated as the difference between the two measurements divided by the average of the two measurements, as follows:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2) \times 0.5} \times 100$$

where:

RPD	=	Relative percent difference
D_1	=	First sample value
D_2	=	Second sample value (duplicate)

Acceptable RPD values for field duplicates are usually 50 % to 150 %. Field duplicates were generated for this project. One field duplicate was collected each round, totalling six for the project.

3.2.1 Field QA/QC Samples

The results are used to evaluate the combined reproducibility of both the laboratory analyses, transport and field sampling.

One duplicate sample per round was generated in the field and sent blind to McQuillan Environmental for analysis. Table 2 (monitoring events 1, 2 & 3) and Table 3 (monitoring events 4, 5 & 6) provide the results of 52 parameters and the calculated RPD between each pair of samples. Note, where both the original and duplicate result are less than the limit of detection (LOD), the RPD is zero. Where only one value is less than the LOD, half of the LOD value is used to permit calculation of the RPD; in such cases the "0.5 X <LOD" value is indicated by grey fill. Table cells with a blue fill indicates an RPD greater than 50% but less than 150%. Yellow filled cells indicate an RPD greater than 150%.

Table 2 Duplicate data and associated RPD (%), monitoring events 1,2 & 3

		Round 1			Round 2			Round 3		
Sample Description		Kilomulty Spring		% RPD	CCF06 (FSTC Intermediate)		% RPD	CCF07 (F-STC-DEEP)		% RPD
Lab ref		077002	077003		082086	082085		086071	086073	
Date Sampled	Units	19/11/2020			25/05/2021			13/10/2021		
Alkalinity, Bicarbonate as CaCO3	mg/l	399	407	2.0	170	195	13.7	140	135	-3.6
Alkalinity, Total	mg/l	404	410	1.5	199	198	-0.5	148	138	-7.0
Aluminium (diss.filt)	ug/l	11.3	5	-77.3	<10	<10	0	19.1	18	-5.9
Ammonia as N	mg/l	0.37	0.39	5.3	< 0.11	<0.11	0	0.34	0.055	-144
Anions	ueq/l	9440	9530	0.9	5,900	5,900	0	4,600	4,340	-5.8
Arsenic (diss.filt)	ug/l	12.8	12	-6.5	<0.5	<0.5	0	<0.5	<0.5	0
Barium (diss.filt)	ug/l	267	252	-5.8	87.3	86.3	-1.2	27.2	27.1	-0.4
Boron (diss.filt)	ug/l	18.8	23.8	23.5	13	5	-88.9	<10	<10	0.0
Bromide	mg/l	0.207	0.207	0	0.202	0.207	2.4	0.0873	0.0994	13.0
Cadmium (diss.filt)	ug/l	<0.08	<0.08	0	<0.08	<0.08	0	<0.08	<0.08	0
Caesium, Dissolved	ug/l	<1.0	<1.0	0	< 1.0	<1	0	< 1.0	< 1.0	0
Calcium (diss.filt)	mg/l	120	121	0.4	49.6	50	0.8	13.058	13.788	5.4
Cations	ueq/l	9570	9580	0.1	5,600	5,700	1.8	4,190	4,300	2.6
Cerium, Dissolved*	ug/l	<1.0	<1.0	0	< 1.0	< 1.0	0.0	-	-	-
Chloride as Cl	mg/l	37	39.1	5.5	33.1	33.5	1.2	27.7	25.0	-10.2
Chromium (diss.filt)	ug/l	<1	<1	0	<1	<1	0	<1	<1	0
Cobalt (diss.filt)	ug/l	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5	0
Copper (diss.filt)	ug/l	0.338	0.15	-77.0	<0.3	<0.3	0	<0.3	<0.3	0
Dissolved Organic Carbon	mg/l	5.07	5.28	4.1	3.08	3.53	13.6	< 2.0	< 2.0	0
Electrical Conductivity	uS/cm	885	894	1.0	557	559	0.4	442	439	-0.7
Fluoride as F	mg/l	0.45	0.455	1.1	0.59	0.58	-1.7	1.67	1.65	-1.2
Iodide*	mg/l	<0.1	<0.1	0	<0.1	<0.1	0.0	-	-	-
Ionic Balance	%	0.6	0.3	-66.7	-2.6	-1.7	-41.9	-4.7	-0.5	-162
Iron (diss.filt)	mg/l	9.39	9.47	0.8	0.167	0.15	-10.7	<0.019	<0.019	0
Lead (diss.filt)	ug/l	<0.2	<0.2	0	<0.2	<0.2	0	<0.2	<0.2	0
Lithium (diss.filt)	ug/l	7.69	8.04	4.5	19.8	19.8	0	12.4	12.7	2.4
Magnesium (diss.filt)	mg/l	22.7	22.6	-0.4	13	13.4	3.0	4.17	4.31	3.3
Manganese (diss.filt)	ug/l	93.3	90.7	-2.8	34.7	34.2	-1.5	8.73	8.05	-8.1
Mercury (diss.filt)	ug/l	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0
Nickel (diss.filt)	ug/l	1.21	1.15	-5.1	<0.4	<0.4	0	<0.4	<0.4	0
Nitrate as N	mg/l	0.58	0.04	-174	<0.08	<0.08	0	0.13	0.09	-36.4
Nitrite as N	mg/l	<0.05	<0.05	0	< 0.05	< 0.05	0	< 0.05	< 0.05	0
Nitrogen, Total	mg/l	<1	<1	0	<1	<1	0	<1	<1	0
pH	Units	6.8	6.92	1.7	7.82	7.84	0.3	8.47	8.53	0.7
Phosphate, Ortho as P	mg/l	<0.07	<0.07	0.0	< 0.07	< 0.07	0.0	<0.02	<0.02	0

		Round 1			Round 2			Round 3		
Sample Description		Kilomulty Spring		% RPD	CCF06 (FSTC Intermediate)		% RPD	CCF07 (F-STC-DEEP)		% RPD
Lab ref		077002	077003		082086	082085		086071	086073	
Date Sampled	Units	19/11/2020			25/05/2021			13/10/2021		
Phosphorus (diss.filt)	ug/l	68.4	34.1	-66.9	<10	<10	0.0	10	20	66.7
Potassium (diss.filt)	mg/l	8.23	8.21	-0.2	11.9	12	0.8	7.05	7.47	5.8
Selenium (diss.filt)	ug/l	<1	<1	0	<1	<1	0	<1	<1	0
Sodium (diss.filt)	mg/l	21.3	21.2	-0.5	39.8	40.8	2.5	68.80	70.50	2.4
Strontium (diss. filt)	ug/l	1750	1700	-2.9	424	420	-0.9	236	234	-0.9
Sulphate as SO4	mg/l	11.5	11.2	-2.6	47.00	47.20	0.4	41.00	41.80	1.9
Total Dissolved Solids	mg/l	528	526	-0.4	343	345	0.6	245	229	-6.8
Total Organic Carbon	mg/l	4.14	4.14	0	2.43	2.46	1.2	1	0.09	-167
Total Oxidised Nitrogen as N	mg/l	0.58	0.04	-174	< 0.08	< 0.08	0	0.13	1	154
True Colour	mg/l Pt/Co	14.4	6.78	-72.0	<1	<1	0	<1	<1	0
Turbidity	ntu	92.1	88.8	-3.6	3.21	3.64	12.6	0.93	1.03	10.2
Uranium (diss.filt)	ug/l	<0.5	<0.5	0	17.9	18	0.6	10.9	10.7	-1.9
Zinc (diss.filt)	ug/l	1.6	2.77	53.5	1.67	0.5	-108	6.53	3.14	-70.1

* Removed following absence of detections in any well

Table 3 Duplicate data and associated RPD (%), monitoring events 4, 5 & 6

		Round 4			Round 5			Round 6		
Sample Description		CCD08 (D-DIW-TRANS)		% RPD	FPBH02		% RPD	RW-BH-03		% RPD
Lab ref (MCQ)		101359	101365		105794	105796		108346	108349	
Date Sampled	Units	10/03/2021			16/06/2022			25/08/2022		
Alkalinity, Bicarbonate as CaCO3	mg/l	70.6	90	24.2	250	295	16.5	133	84.7	-44
Alkalinity, Total	mg/l	70.3	89.6	24.1	280	274	-2.2	119	105	-13
Aluminium (diss.filt)	ug/l	<10	<10	0	11.3	5	-77.3	17.1	21.9	25
Ammonia as N	mg/l	0.055	0.14	87.2	<0.11	<0.11	0	<0.11	<0.11	0
Anions	ueq/l	2820	3890	31.9	6720	6580	-2.1	3050	2850	-7
Arsenic (diss.filt)	ug/l	<0.5	<0.5	0	0.674	0.882	26.7	1.77	1.8	2
Barium (diss.filt)	ug/l	79.9	77.8	-2.7	163	163	0	25	24.3	-3
Boron (diss.filt)	ug/l	18.9	11.5	-48.7	11.6	10.5	-10.0	<10	<10	0
Bromide	mg/l	0.0866	0.102	16.3	0.114	0.116	1.7	0.071	0.104	38
Cadmium (diss.filt)	ug/l	0.125	0.04	-103	<0.08	<0.08	0	<0.08	<0.08	0
Caesium, Dissolved	ug/l	<1.0	<1.0	0	<1.0	<1.0	0	1	1	0
Calcium (diss.filt)	mg/l	31.7	41	25.6	54	55	1.8	27.3	26.4	-3
Cations	ueq/l	2480	3240	26.6	6350	6500	2.3	2540	2490	-2
Cerium, Dissolved*	ug/l	-	-	-	-	-	-	-	-	-

		Round 4			Round 5			Round 6		
Sample Description		CCD08 (D-DIW-TRANS)		% RPD	FPBH02		% RPD	RW-BH-03		% RPD
Lab ref (MCQ)		101359	101365		105794	105796		108346	108349	
Date Sampled	Units	10/03/2021			16/06/2022			25/08/2022		
Chloride as Cl	mg/l	15.2	33.3	74.6	25.8	25.3	-2.0	19.1	20.4	7
Chromium (diss.filt)	ug/l	<1	<1	0	1.05	1.13	7.3	<1	<1	0
Cobalt (diss.filt)	ug/l	<0.5	<0.5	0	<0.5	<0.5	0	3.81	3.83	1
Copper (diss.filt)	ug/l	0.388	1.93	133	1.93	2.04	5.5	<0.3	<0.3	0
DOC	mg/l	10	3.1	-105	3.4	3.4	0	4.7	3.5	-29
Electrical Conductivity	uS/cm	298	410	31.6	643	642	-0.2	285	260	-9
Fluoride as F	mg/l	0.0614	0.022	-94.5	0.304	0.286	-6.1	0.0698	0.764	167
Iodide*	mg/l	-	-	-	-	-	-	-	-	-
Ionic Balance	%	-6.5	-9.1	33.3	-2.8	-0.6	-129	-9.3	-6.6	-34
Iron (diss.filt)	mg/l	<0.019	<0.019	0	<0.019	<0.019	0	10.9	11.2	3
Lead (diss.filt)	ug/l	0.1	0.208	70.1	0.343	0.325	-5.4	<0.2	<0.2	0
Lithium (diss.filt)	ug/l	<1	<1	0	26.1	26.1	0	1.65	1.78	8
Magnesium (diss.filt)	mg/l	5.45	5.91	8.1	20	20.5	2.5	1.82	1.74	-4
Manganese (diss.filt)	ug/l	3.23	241	195	23.8	23.1	-3.0	1320	1290	-2
Mercury (diss.filt)	ug/l	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0
Nickel (diss.filt)	ug/l	0.585	0.481	-19.5	1.03	1.29	22.4	3.15	3.16	0
Nitrate as N	mg/l	9.46	13	31.5	0.1	0.1	0	<0.08	<0.08	0
Nitrite as N	mg/l	<0.05	<0.05	0	<0.05	<0.05	0	<0.05	<0.05	0
Nitrogen, Total	mg/l	9.22	12.5	30.2	<1	<1	0	<1	<1	0
pH	Units	6.22	6.18	-0.6	7.87	7.87	0	6.56	6.47	-1
Phosphate, Ortho as P	mg/l	<0.02	<0.02	0	<0.02	<0.02	0	<0.02	<0.02	0
Phosphorus (diss.filt)	ug/l	10	23.6	81.0	<20	<20	0	77.9	75.7	-3
Potassium (diss.filt)	mg/l	0.833	4.8	141	23.3	23.8	2.1	<0.87	<0.87	0
Selenium (diss.filt)	ug/l	<1	<1	0	<1	<1	0	<1	<1	0
Sodium (diss.filt)	mg/l	9.65	12.9	28.8	32.5	33.4	2.7	8.82	8.74	-1
Strontium (diss. filt)	ug/l	140	166	17.0	1240	1250	0.8	68.4	67.7	-1
Sulphate as SO4	mg/l	14.8	11.1	-28.6	18.3	18.1	-1.1	6.46	8.3	25
Total Dissolved Solids	mg/l	152	263	53.5	367	374	1.9	167	163	-2
Total Organic Carbon	mg/l	2.8	15	137	3.3	3.2	-3.1	5	3.7	-30
Total Oxidised Nitrogen as N	mg/l	9.46	13	31.5	0.1	0.1	0	<0.08	<0.08	0
True Colour	mg/l Pt/Co	0.5	2.1	123	4.48	4.47	-0.2	12.2	45	115
Turbidity	ntu	0.616	0.427	-36.2	0.452	0.359	-22.9	64.4	81.8	24

		Round 4			Round 5			Round 6		
Sample Description		CCD08 (D-DIW-TRANS)		% RPD	FPBH02		% RPD	RW-BH-03		% RPD
Lab ref (MCQ)		101359	101365		105794	105796		108346	108349	
Date Sampled	Units	10/03/2021			16/06/2022			25/08/2022		
Uranium (diss.filt)	ug/l	<0.5	<0.5	0	46.8	46.7	-0.2	1.03	1.06	3
Zinc (diss.filt)	ug/l	9.91	8.4	-16.5	3.44	3.49	1.4	16.5	10.3	-46

* Removed following absence of detections in any well

The majority of RPD values were below 50%. In total, 26 of the 312 (i.e., 8%) of RPD > 50% but less than 150%. There were seven instances of RPD > 150%. With one exception, these exceedances/high RPDs were generally associated with low concentrations and often with one value being at the LOD (and thus 0.5 x LOD used for the calculation).

For manganese in the round four duplicate, the recorded concentrations were 3.23 ug/L and 241 ug/L. All other parameters for these two duplicates are in line with expected values for a duplicate pair. The manganese concentrations were checked with the laboratory who confirmed their accuracy and suggested the deviation may be due to a contamination issue at some point.

Overall, the duplicate %RPD data are considered satisfactory.

3.3 Ionic Balance/Charge Balance

Within a water sample, the number of positive charges and negative charges should be equal, resulting in a charge balance or ionic balance of close to zero. Determining the ionic balance of a sample is a useful means of checking the laboratory analysis of ions have been carried out correctly. Values of ± 10% are satisfactory for this QA/QC test.

A description of the ionic balance data for the 59 samples is presented below. Of the 59 values, 54 were within ± 10%, with median value of -2.3 %. Two of the fives balances which exceeded ± 10% were within ± 15%, at:

- 10.5% (Lough Muc well Lab ref: MCQ105715, sampled on 15/06/2022), and
- 14.5 % (Finn well Lab ref: MCQ076926, sampled on 09/12/2020).

One ionic balance was slightly higher at 15.1 % (Fish pass well Lab ref: MCQ105795, sampled on 16/06/2022).

The remaining two balances were:

- -18% (Reelin Water well Lab re: MCQ102137 sampled on 05/04/2022), and
- -23.6% (Fish Pass well Lab ref: MCQ102134 sampled on 04/04/2022).

The laboratory checked the results for samples with elevated ionic balances and confirmed analysis were correct and data accurate.

Overall, the ionic balances were acceptable indicating good and complete analysis, with all major anions and cations analysed.

Section 4 Data Summary & Interpretation

4.1 Summary Statistics

This section provides a statistical summary of the analytical results and a comparison of the analytical results against selected assessment criteria. Where the reported values were below the detection limit (<LOD), the values were substituted with a value of half the limit of detection (0.5 x <LOD). The summary statistics apply to all 59 samples collected during the six monitoring events across all wells.

The summary statistics presented are briefly described below:

- IGV: EPA Interim Guide Value (Towards Setting Guideline Values for The Protection Of Groundwater In Ireland – Interim Report http://www.epa.ie/pubs/advice/water/ground/towardssettingguidelinevaluesfortheprotectionofgroundwaterinireland.html)
- GTV: Groundwater Regulations Threshold Value (S.I. No. 9 of 2010)
- LOD: laboratory analytical limit of detection
- WQS: water quality standard value/threshold to which the results are compared
- Source: WQS source
- Min: minimum detected value above the LOD
- Mean: mean of dataset
- Maximum: maximum value detected
- Median: median value of dataset
- 97.7th percentile: 97.7th percentile of dataset
- No. of Samples: number of samples analysed for this parameter
- No. of WQS Exceedances: number of exceedances of the WQS threshold
- % of WQS Exceedances: percentage of values above the WQS threshold
- No. of Detections: number of values above the detection limit
- % of WQS Detections: percentage of values above the limit of detection

Summary statistics of the field physico-chemical water quality parameters along with major and minor elements are contained in Table 4.

Table 5 contains the summary statistics of the trace metals (trace elements). Exceedances of the respective WQS are indicated by orange highlight of the number and percentage WQS exceedance.

There were exceedances of the respective threshold/WQS for the following field parameters, and major and minor elements (Table 4):

- pH (exceedance no. 7, or 12 %);
- Specific Electrical Conductivity (exceedance no. 2, or 3 %);
- Potassium (exceedance no. 37, or 63 %);
- Fluoride (exceedance no. 6, or 10 %); and
- Magnesium (exceedance no. 4, or 7 %).

There were exceedances of the respective threshold/WQS for the metals (trace elements) (

Table 5):

- Uranium (U) (exceedance no. 15 or 29 %);
- Iron (Fe) (exceedance no. 15, or 25 %);
- Barium (Ba) (exceedance no. 13, or 22 %);
- Manganese (exceedance no. 10, or 17 %);
- Zinc (exceedance no. 2, or 3 %); and
- Aluminium (exceedance no. 1, or 2 %)

Table 4: Summary statistics of field parameters, and major and minor elements

Test	Units	LOD	WQS	Source	Min*	Mean	Max	Median	97.7th percentile	No. Samples	No. Detections	% Detections	No. WQS Exceedances	% WQS Exceedances
pH		-	<6.5, >9.5	IGV 2003	6.2	8.1	11.7	7.8	11.4	59	59	100	7	12
Specific Electrical Conductivity	µS/cm	1	800	GTV 2016	110	504	1050	542	941	59	59	100	2	3
Temperature	°C	-	-	-	5.8	10.3	14.9	10.5	13.5	59	-	-	-	-
Redox	mV	-	-	-	-499	145.4	194	-96.1	173	59	59	-	-	-
Dissolved oxygen	mg/l	-	-	-	0.19	2.69	19.6	0.835	10.5	59	-	-	-	-
Potassium	mg/l	0.174	5	IGV 2003	0.1	15.9	83.5	8.8	79	59	58	98	37	63
Fluoride	mg/l	0.024	1	IGV 2003	0.0	0.4	1.7	0.2	1.6	59	58	98	6	10
Magnesium	mg/l	0.101	50	IGV 2003	0.11	16.7	54.1	11.5	53.8	59	59	100	4	7
Sodium	mg/l	0.145	150	GTV 2010	7.1	28.9	71.3	25.7	67.6	59	59	100	0	0
Calcium	mg/l	0.101	200	IGV 2003	2.8	33.2	94.2	28	83	59	59	100	0	0
Chloride	mg/l	0.35	187.5	GTV 2016	10.9	22.3	33.1	21.8	32.4	59	59	100	0	0
Sulphate	mg/l	5	187.5	GTV 2016	5.6	21.7	60.5	14.1	51.3	59	48	81	0	0
Alkalinity, as $CaCO_3$	mg/l	5	NO WQS	No WQS	17.8	198	420	198	407	59	59	0	0	0
Nitrate (as N)	mg/l	0.08	37.5	GTV 2016	0.08	0.2	1.9	0.0	1.7	59	26	44	0	0
Nitrite (as N)	mg/l	0.05	No WQS	-	0.14	0.0	0.2	0.0	0.1	59	3	5	0	0

Test	Units	LOD	WQS	Source	Min*	Mean	Max	Median	97.7th percentile	No. Samples	No. Detections	% Detections	No. WQS Exceedances	% WQS Exceedances
Ammonia (as N)	mg/l	1	No WQS	-	0.11	0.7	3.2	0.5	2.1	59	8	14	0	0
Ortho-phosphate as P	mg/l	<0.02 or <0.07	No WQS	-	-	-	-	-	-	59	0	0	0	0
Total phosphorus	ug/l	<20	No WQS	-	20.2	28	107	15	92	46	22	48	0	0
Total organic carbon	mg/l	1.5	No WQS	-	1.5	13.2	93	2.9	84.3	59	43	73	0	0
Dissolved organic carbon	mg/l	1.5	No WQS	-	1.3	13.5	98	2.9	84.7	59	44	75	0	0

*Minimum result above detection limit

Table 5: Summary statistics of metals (trace elements)

Test	Units	LOD	WQS	Source	Min*	Mean	Max	Median	97.7th percentile	No. Samples	No. Detections	% WQS Detections	No. WQS Exceedances	% WQS Exceedances
U	Ug/l	0.5	9	IGV 2003	0.6	7.6	45.7	1.4	41	52	34	65	15	29
Fe	mg/l	0.019	0.2	IGV 2003	0.020	1.4	47.2	0.028	11	59	32	54	15	25
Ba	ug/l	0.2	100	IGV 2003	2.6	134	732	33.4	719	59	59	100	13	22
Mn	ug/l	3	50	IGV 2003	3.5	251	4,780	5.4	2156	59	39	66	10	17
Zn	ug/l	1	75	GTV 2016	1.1	7	123	2.1	73.2	59	49	83	2	3
Al	ug/l	10	150	GTV 2016	10.2	20	282	5	122	59	24	41	1	2
As	ug/l	0.5	7.5	GTV 2016	0.6	0.5	1.8	0.3	1.6	59	16	27	0	0
B	ug/l	10	750	GTV 2010	10.1	10.6	114	5	22.4	59	26	44	0	0

Test	Units	LOD	WQS	Source	Min*	Mean	Max	Median	97.7th percentile	No. Samples	No. Detections	% WQS Detections	No. WQS Exceedances	% WQS Exceedances
Br	ug/l	0.06	No WQS	No WQS	0.06	0.1	0.3	0.1	0.2	59	46	78	0	0
Cd	ug/l	0.08	3.75	GTV 2010	0.1	0.0	0.2	0.20	0.1	59	2	3	0	0
Cr	ug/l	1	37.5	GTV 2016	-	-	-	-	-	59	0	0	0	0
Cs	ug/l	1	No WQS	No WQS	1	0.7	3.5	0.5	2.6	59	7	12	0	0
Cu	ug/l	0.3	1500	GTV 2010	0.3	0.3	3.0	0.2	2.3	59	12	20	0	0
Li	ug/l	1	No WQS	No WQS	1.0	26.4	118	20.6	103	59	55	93	0	0
Ni	ug/l	0.4	15	GTV 2010	0.4	1.0	5.6	0.2	5.2	59	27	46	0	0
Pb	ug/l	0.1	7.5	GTV 2016	0.2	0.2	1.2	0.1	0.5	59	10	17	0	0
Se	ug/l	1	No WQS	-	1.4	1.9	83.5	0.5	1.4	59	3	5	0	0
Sr	ug/l	1	No WQS	-	19.6	5301	1740	287	1737	59	59	0	0	0

*Minimum result above detection limit

Section 5 Water Physiochemical Characteristics and Water Type

This section provides analysis and interpretation of water physicochemical characteristics and the water types. As previously mentioned, for the purposes of assessing the water physicochemical characteristics and assessing the water types, the wells are divided into five groups. Each group represents a cluster of wells which are in close geographical proximity within the catchment. The five groups are:

- Group 1: Angler's Car Park;
- Group 2: Lough Muc;
- Group 3: Fish Pass;
- Group 4: St Columba's School; and
- Group 5: Reelin Water.

The following are assessed in this section:

- Water chemistry:
  - Major cations and anions, with box plots and interpretation in Section 5.1, and
  - Major and minor (/trace) constituents, with box plots and interpretation in Section 5.2.
- Water physiochemistry, via assessment of alkalinity, pH and redox with box plots and interpretation in Section 5.3.1; and
- Water type, by piper diagram assessment of major ions in Section 5.3.2;

5.1 Major Cations and Anions

A summary of the concentration pattern of each of the major cations and anions is provided below.

5.1.1 Calcium

- Calcium (Ca) concentrations within the Finn Catchment range from 2.78 mg/L at Group 2: Lough Muc to 94.2 mg/L at Group 5: Reelin Water (Figure 2).
- The widest range of values occurs at Group 3: Fish Pass cluster while Group 1: Angler's Car Park shows the narrowest range of values.
- Group 3: Fish Pass and Group 4: St. Columba's school show similar pattern of Ca concentrations, as do Group 1: Angler's Car Park and Group 5: Reelin Water.
- Generally, the lowest concentrations were recorded at Group 2: Lough Muc, all other four locations have similarly higher concentrations.

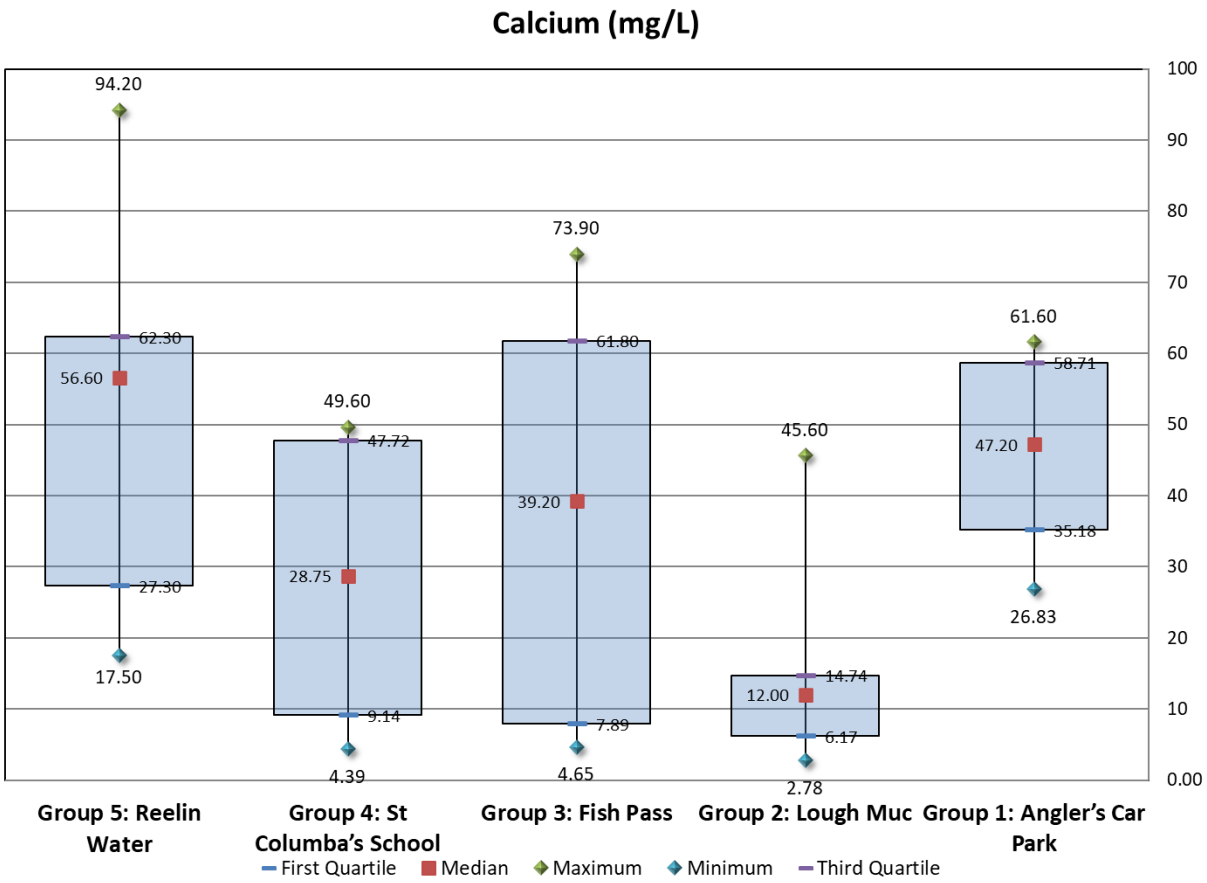

Figure 2: Calcium (Ca) boxplot

5.1.2 Magnesium

- Magnesium (Mg) concentrations within the Finn Catchment ranged from 0.12 mg/L at Group 5: Reelin Water to 54.10 mg/L at Group 1: Angler's Car Park (Figure 3).
- Group 2: Lough Muc and Group 5: Reelin Water show similar pattern of Mg concentrations, with the other three groups showing relatively distinct patterns.
- Group 1: Angler's Car Park was very distinct from all other sites with no overlap in concentrations between this group and the concentrations in any other group.
- The lowest concentrations were generally recorded at Group 2: Lough Muc and Group 5: Reelin water.
- The highest concentrations were consistently recorded at Group 1: Angler's Carpark.

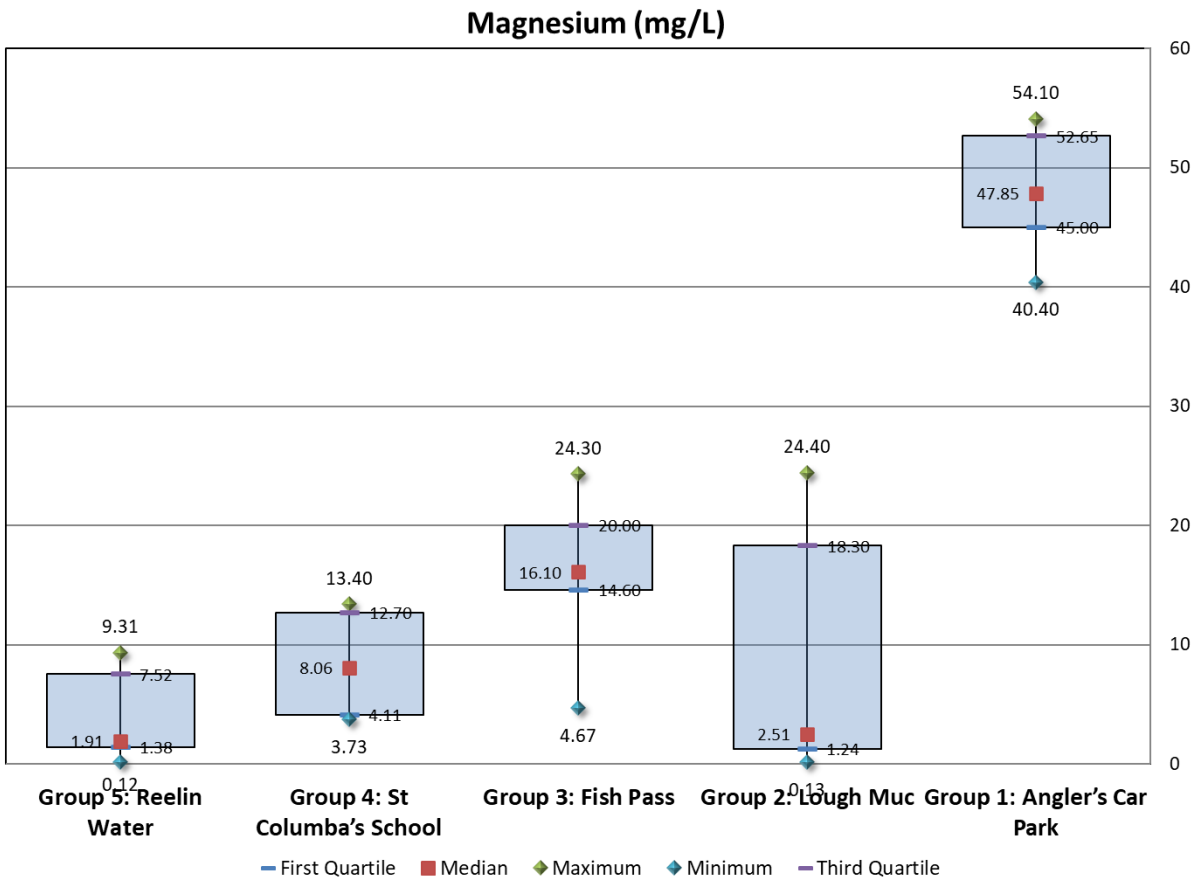

Figure 3: Magnesium (Mg) boxplot

5.1.3 Sodium

- Sodium (Na) concentrations within the Finn Catchment ranged from 7.10 mg/L at Group 2: Lough Muc, to 73.10 mg/L at Group 4: St. Columba's School (Figure 4).
- Both Group 4: St. Columba's School and also Group 3 Fish pass had the widest range of concentrations, while the narrowest range of concentrations were observed in samples from both Group 1: Angler's Car Park and Group 5: Reelin Water.
- Group 1: Angler's Car Park and Group 2: Lough Muc showed similar pattern of Na concentrations, with the other three groups showing relatively distinct patterns.
- Generally, the highest Na concentrations were observed at Group 4: St. Columba's School, and the lowest at Group 5: Reelin water.

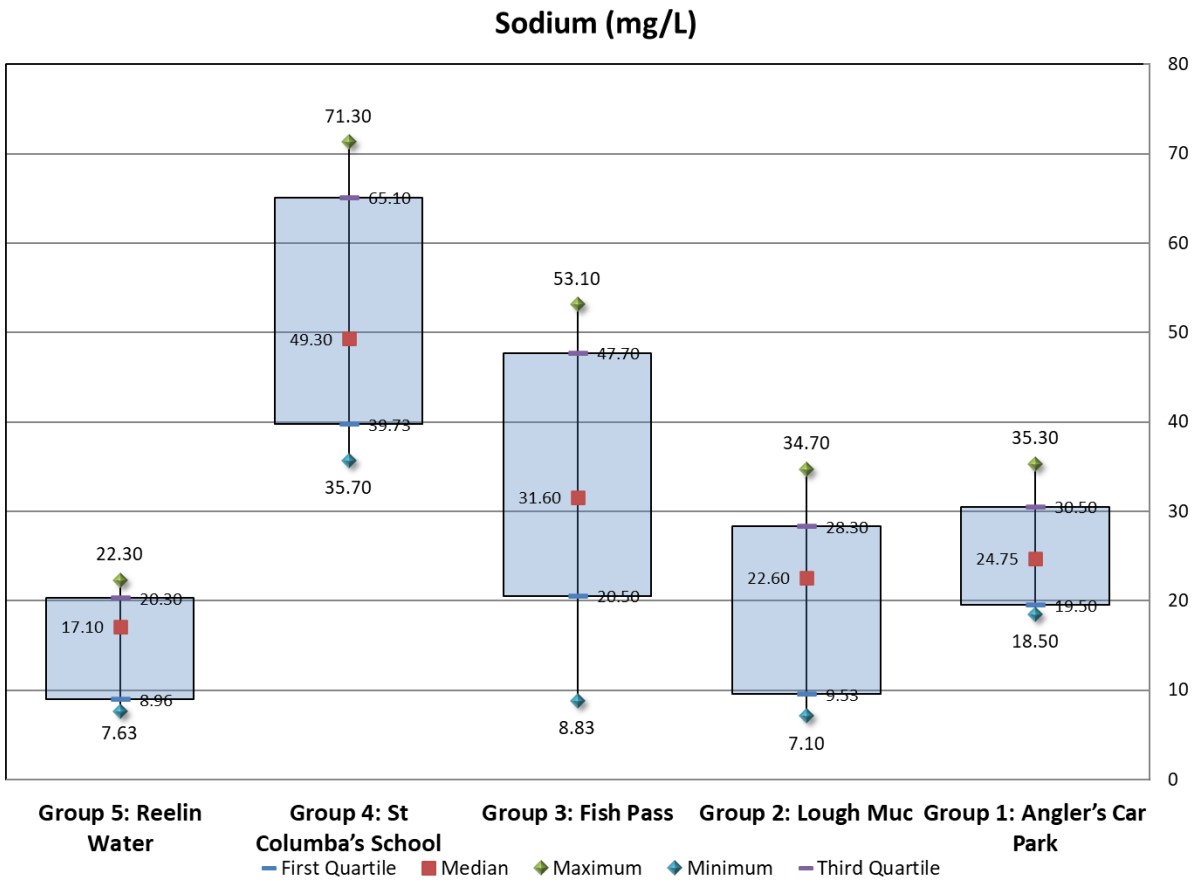

Figure 4: Sodium (Na) boxplot

5.1.4 Chloride

- Chloride (Cl) concentrations within the Finn Catchment ranged from 10.9 mg/L at Group 2: Lough Muc, to 33.10 mg/L at Group 4: St. Columba's School (Figure 5).
- The range of concentrations of Cl was relatively narrow compared to other parameters.
- Generally, higher concentrations of Cl were recorded at Group 4: St. Columba's School followed by Group 3: Fish Pass, and lower concentrations were recorded at Group 5: Reelin Water.

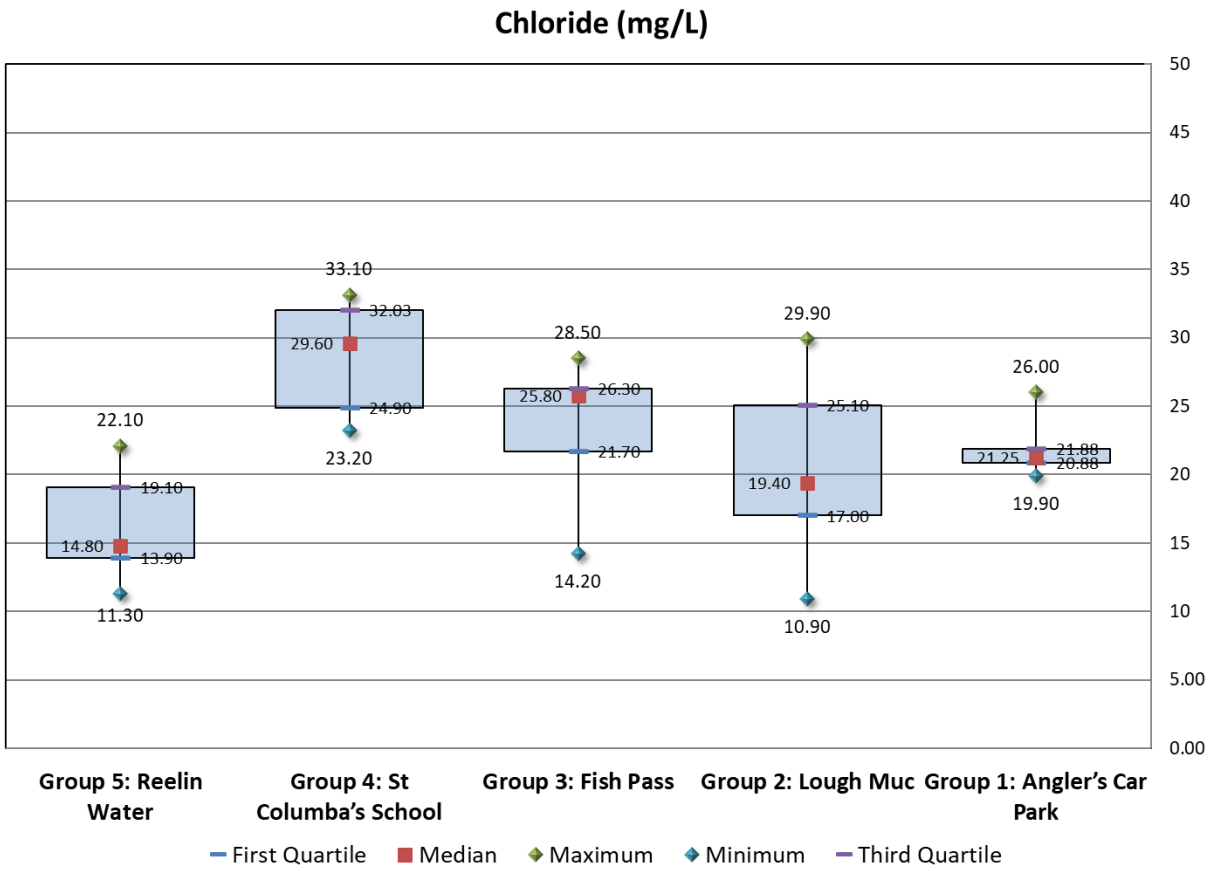

Figure 5: Chloride (Cl) boxplot

5.1.5 Potassium

- Potassium (K) concentrations within the Finn Catchment ranged from 0.07 mg/L at Group 2: Lough Muc, to 83.50 mg/L at Group 3: Fish pass (Figure 6).
- Group 2: Lough Muc, Group 3: Fish pass and Group 5: Reelin Water had relatively wide ranges of concentrations, with the other two groups showing relatively narrower ranges.
- Generally, higher concentrations of K were recorded at Group 3: Fish pass, and lower concentrations at Group 1: Anglers Carpark.

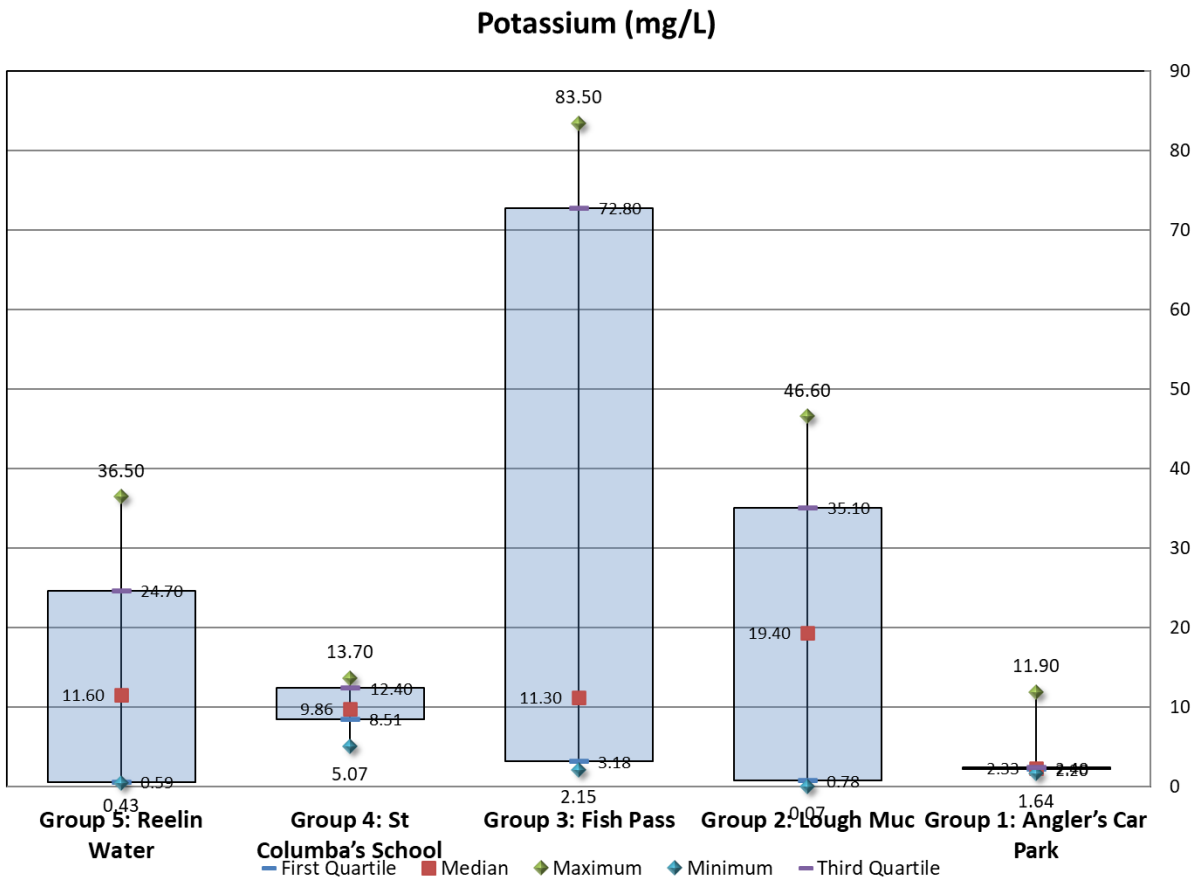

Figure 6: Potassium (K) boxplot

5.1.6 Sulphate

- Sulphate (SO_4) concentrations within the Finn Catchment ranged from 2.5 mg/L at Group 5: Reelin Water, to 60.50 mg/L at Group 2: Lough Muc (Figure 7).
- Generally, higher concentrations of SO_4 were recorded in Group 4: St Columba's School and Group 2: Lough Muc, while the lowest concentrations were obtained from Group 1: Angler's Car Park and Group 5: Reelin Water.
- Group 2: Lough Muc had the widest range of concentrations, while the narrowest range of concentrations was observed in samples obtained from Group 1: Angler's Car Park.
- Group 3: Fish Pass and Group 2: Lough Muc had overlapping ranges (at lower end of concentrations), as did Group 2: Lough Muc and Group 4: St Columba's School (at the upper end of concentrations).
- Group 1: Angler's Carpark and Group 5: Reelin water had overlapping ranges, but the concentrations of the former were at the lower end of the range and of the latter at the upper end of this range.

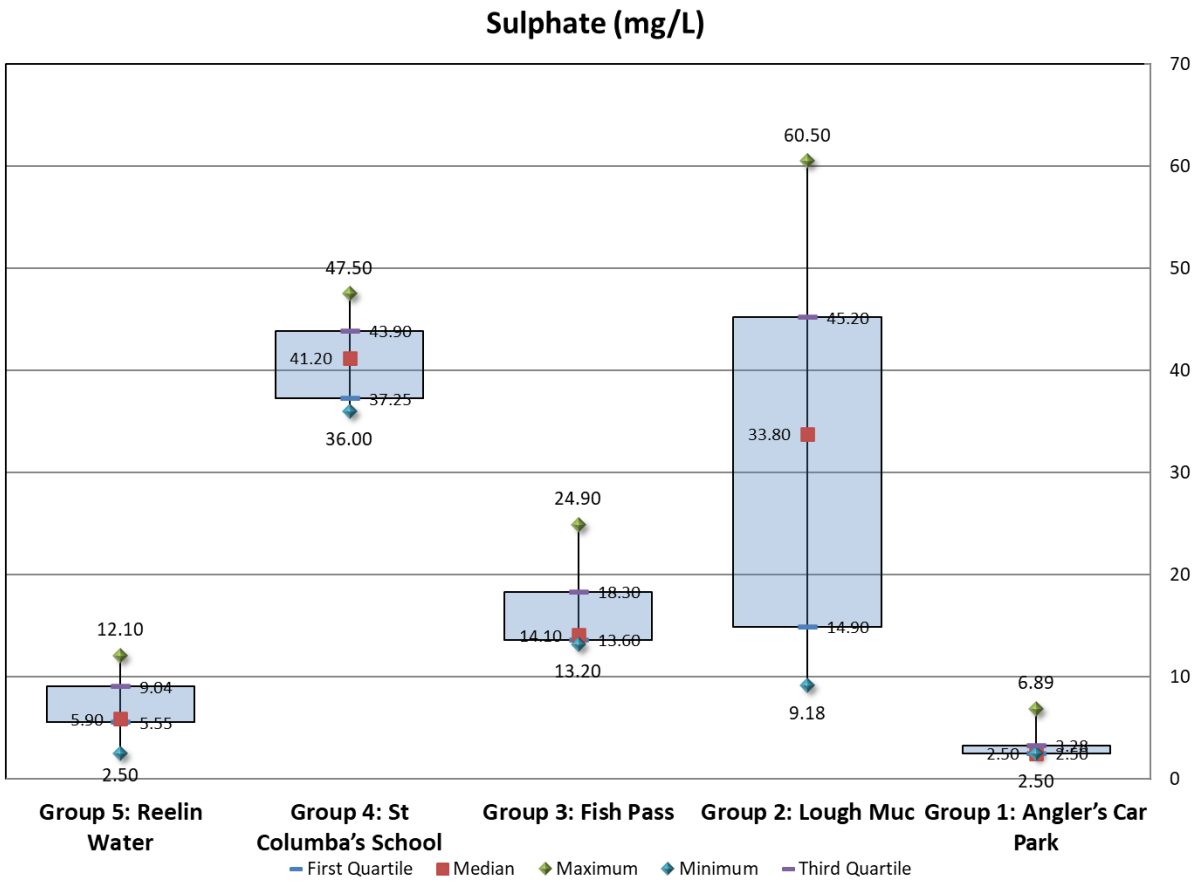

Figure 7: Sulphate (SO_4) boxplot

5.1.7 Fluoride

- Fluoride (F) concentrations within the Finn Catchment ranged from 0.01 mg/L at Group 5: Reelin Water, to 1.67 mg/L at Group 4: St Columba's School (Figure 8).
- Higher concentrations of dissolved F were recorded in samples from Group 4: St Columba's School and lower F concentrations were recorded in samples from Group 5: Reelin Water. The range of F concentrations in the other three group overlap and fall between the high concentrations of Group 4: St Columba's School and low concentrations of Group 5: Reelin Water.
- Group 4: St Columba's School had the widest range of F concentrations, while the narrowest range of F concentrations was observed in samples obtained from Group 5: Reelin Water.

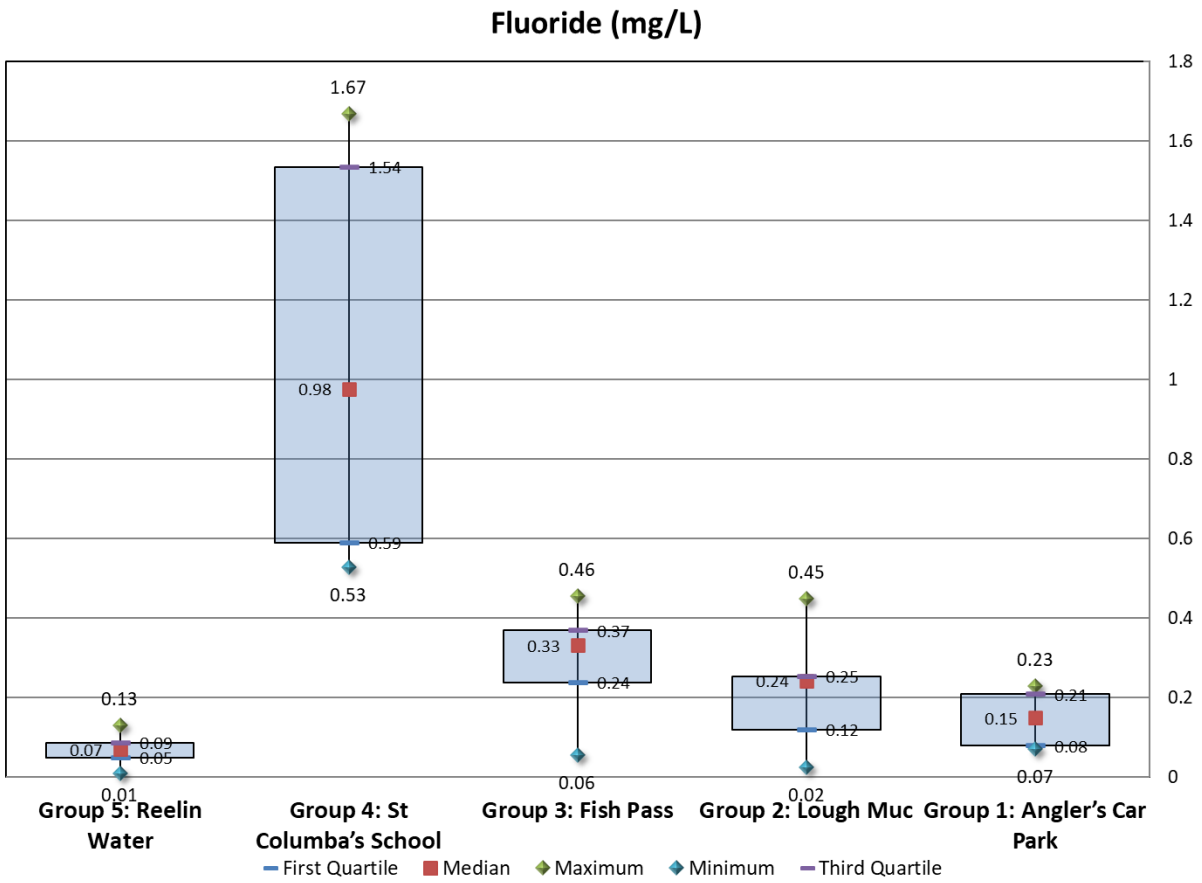

Figure 8: Fluoride (F) boxplot

5.1.8 Nitrate (NO_3 as N)

- Nitrate (NO_3) concentrations within the Finn Catchment ranged from <LOD (0.08 mg/L, included in the graph as 0.04 mg/L) at all groups, to 1.85 mg/L at Group 2: Lough Muc (Figure 9).
- Generally, higher concentrations of NO_3 were recorded in Group 2: Lough Muc and Group 3: Fish Pass.
- Group 2: Lough Muc had the widest range of concentrations, while the narrowest range of concentrations was observed in samples obtained from Group 5: Reelin water (where all results were <LOD).

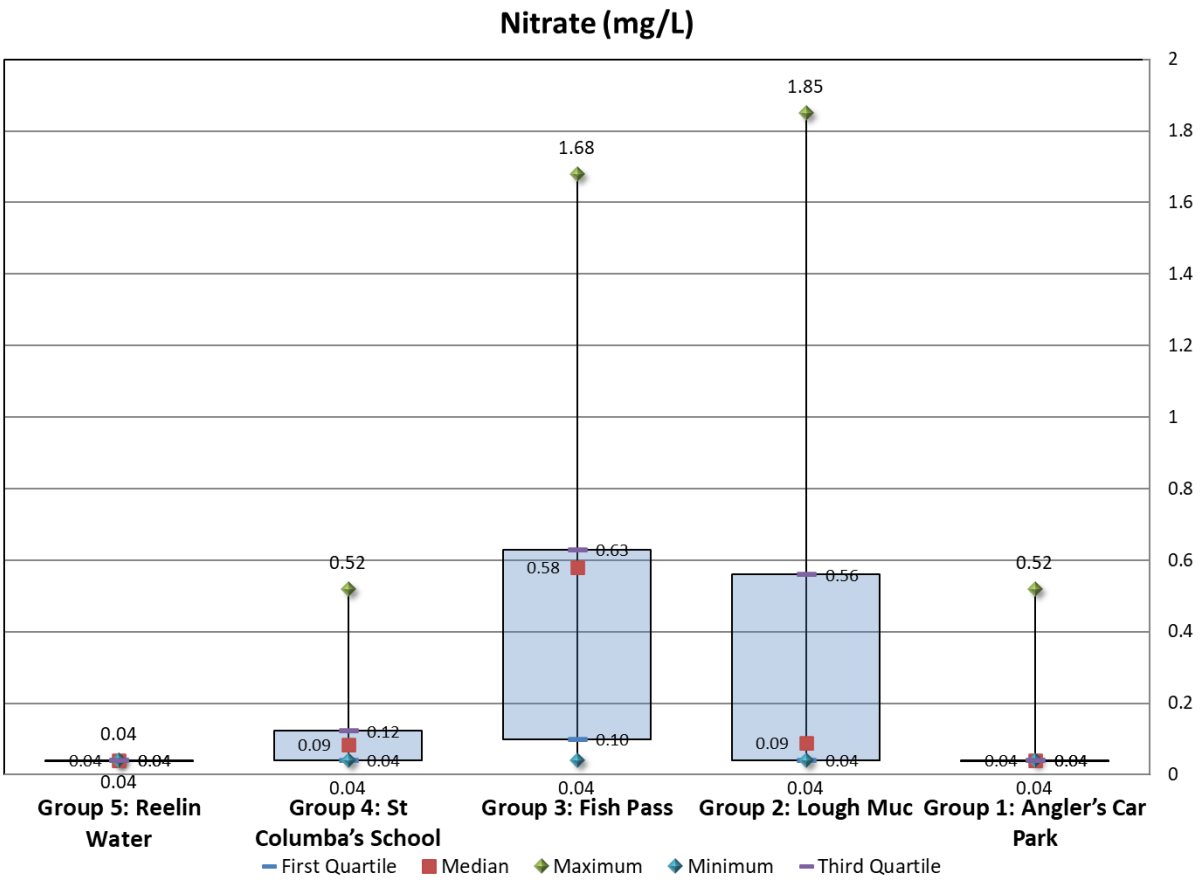

Figure 9: Nitrate (NO_3 as N) boxplot

5.2 Major and Minor (Trace) Elements

A summary of the concentration patterns of major and minor (trace) elements, for which there were detections at one site at a minimum, is provided below. The data are grouped based on clusters of wells as previously discussed.

5.2.1 Dissolved Iron

- Dissolved iron (Fe) concentrations within the Finn Catchment ranged from <LOD (0.02 mg/L, included in the graph as 0.01 mg/L) at all groups, to 47.2 mg/L at Group 3: Fish Pass (Figure 10).
- Group 3: Fish Pass had the widest range of concentrations, while the narrowest range of concentrations was observed in samples obtained from Group 2: Lough Muc.
- Generally, higher concentrations of dissolved Fe were recorded at Group 5: Reelin water and Group 3: Fish Pass, with lower concentrations at Group 2: Lough Muc and Group 4: St Columba's School.

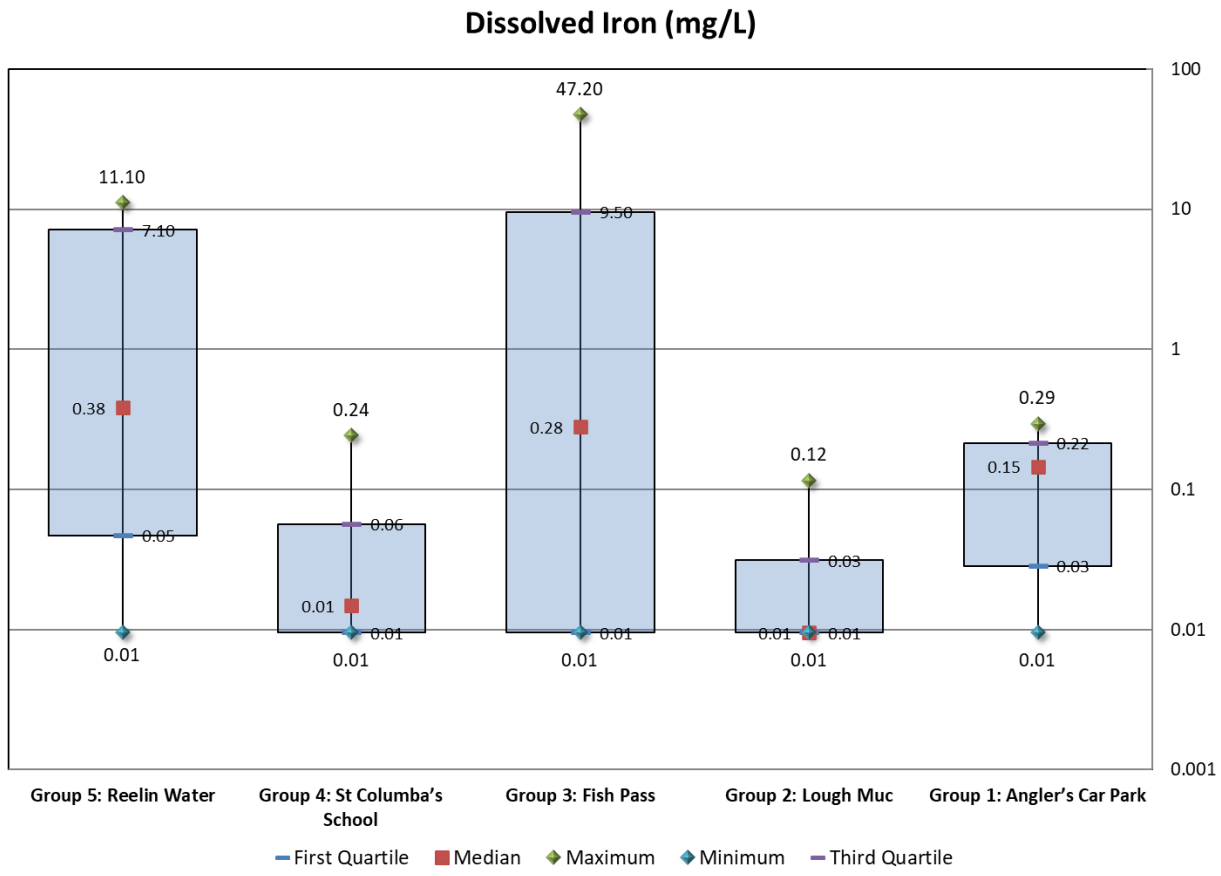

Figure 10: Dissolved Iron (Fe) boxplot, where y-axis is log scale

5.2.2 Dissolved Aluminium

- Dissolved aluminium (Al) concentrations within the Finn Catchment ranged from <LOD (10 mg/L, included in the graph as 5 mg/L) at all groups, to 282 mg/L at Group 2: Lough Muc (Figure 11).
- Group 2: Lough Muc had the widest range of concentrations, while the narrowest range of concentrations was observed in samples obtained from Group 1: Angler's Car Park where all records were <LOD.
- Generally, higher concentrations of dissolved Al were recorded at Group 2: Lough Muc.
- The concentration ranges of all four groups for which there were detections overlap.

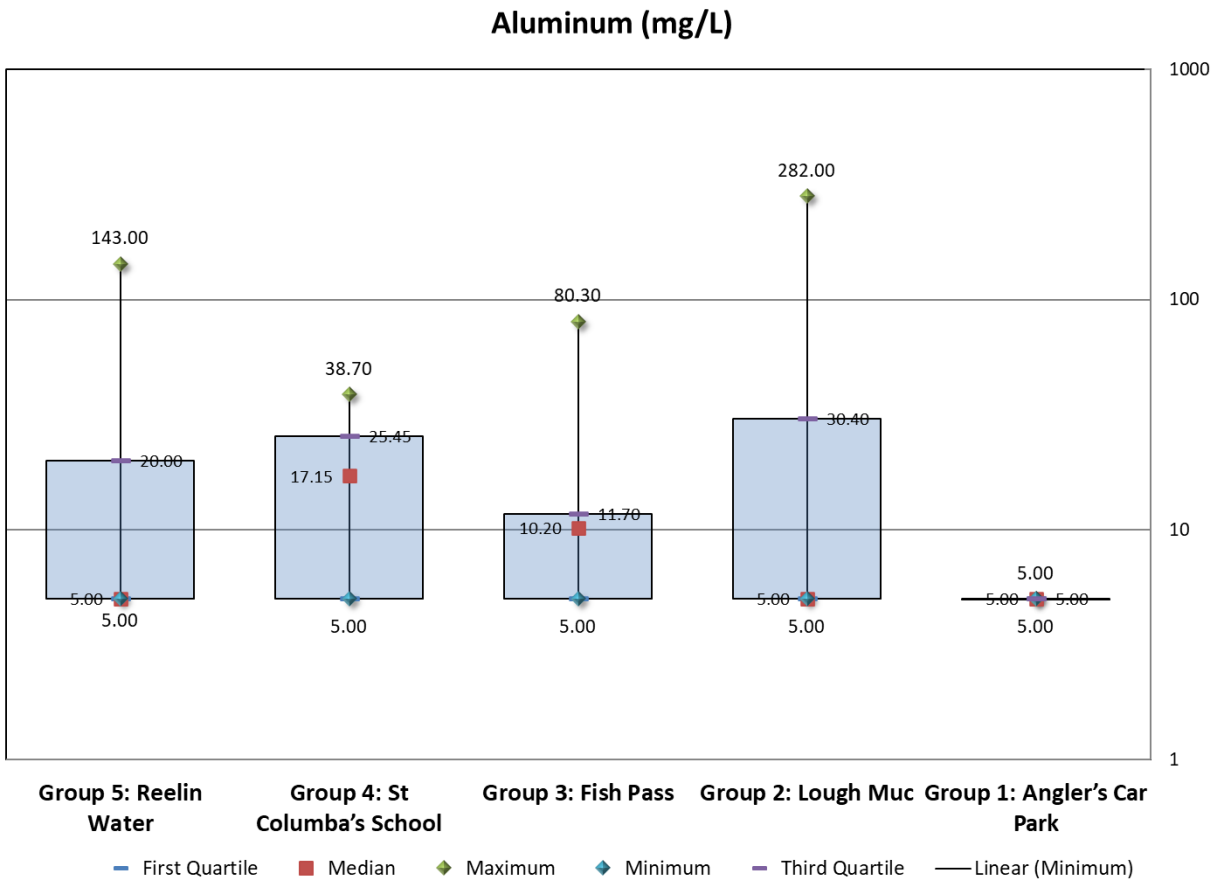

Figure 11: Aluminium (Al) boxplot, where y-axis is log scale

5.2.3 Dissolved Barium

- Dissolved barium (Ba) concentrations within the Finn Catchment ranged from 2.59 mg/L at Group 2: Lough Muc, to 732 mg/L at Group 1: Angler's Car Park (Figure 12).
- Group 1: Angler's Car Park had the widest range of concentrations, and Group 2: Lough Muc displayed the narrowest range.
- Higher concentrations of dissolved Ba were recorded at Group 1: Angler's Car Park and lower Ba concentrations were recorded in samples from Group 2: Lough Muc. The concentrations in the other three group overlap each other and fall between the high concentrations of Group 1: Angler's Carpark and low concentrations of Group 2: Lough Muc.

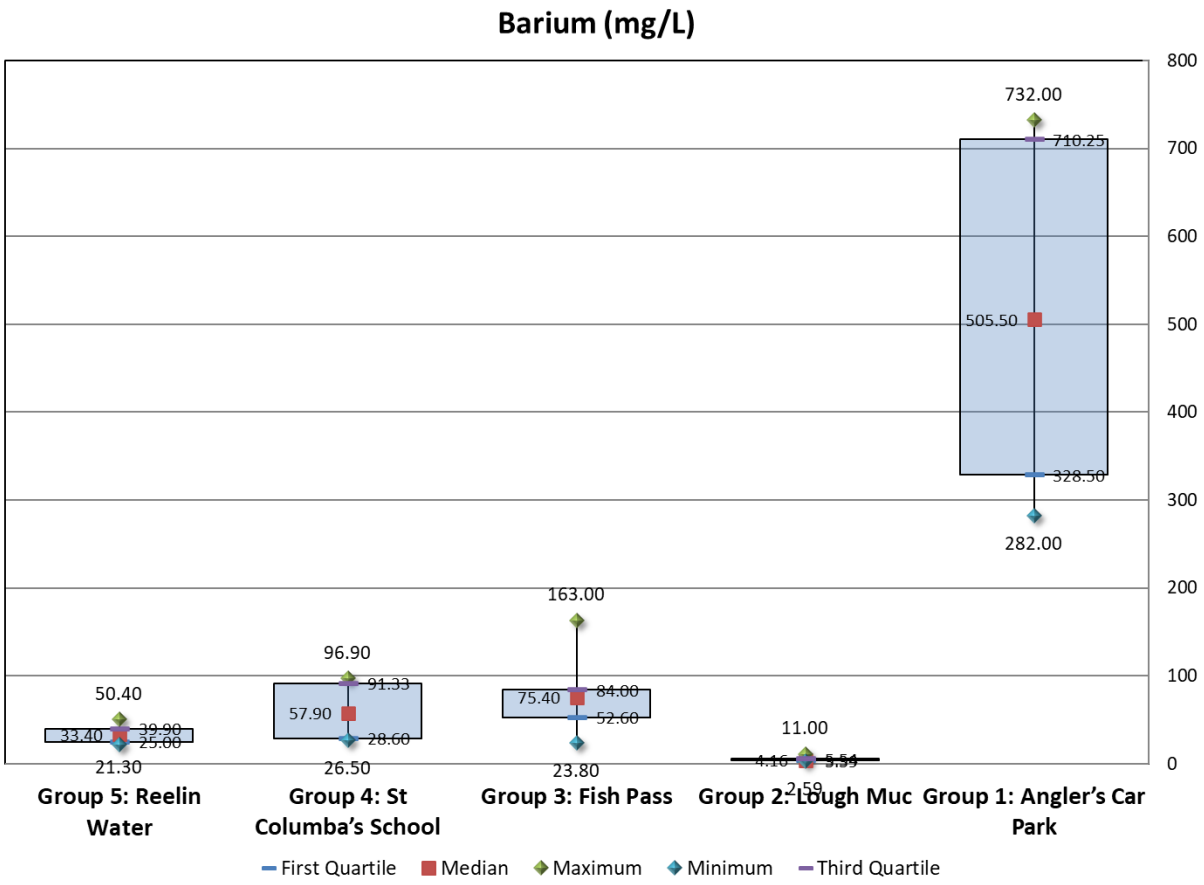

Figure 12: Barium (Ba) boxplot

5.2.4 Dissolved Nickel

- Dissolved nickel (Ni) concentrations within the Finn Catchment ranged from <LOD (0.04 mg/L, included in the graph as 0.02 ug/L) at all groups, to 5.58 mg/L at Group 5: Reelin Water (Figure 13).
- Group 5: Reelin Water had the widest range of concentrations, while the narrowest range of concentrations was observed in samples obtained from Group 4: St. Columba's school.
- Generally, higher concentrations of dissolved Ni were recorded at Group 5: Reelin Water, and the lowest concentrations were recorded at Group 1: Angler's Car Park where most concentrations were below the LOD.
- The concentration range of nickel at Group 5: Reelin water is generally unique from that of the other four groups which are comparable to each other.

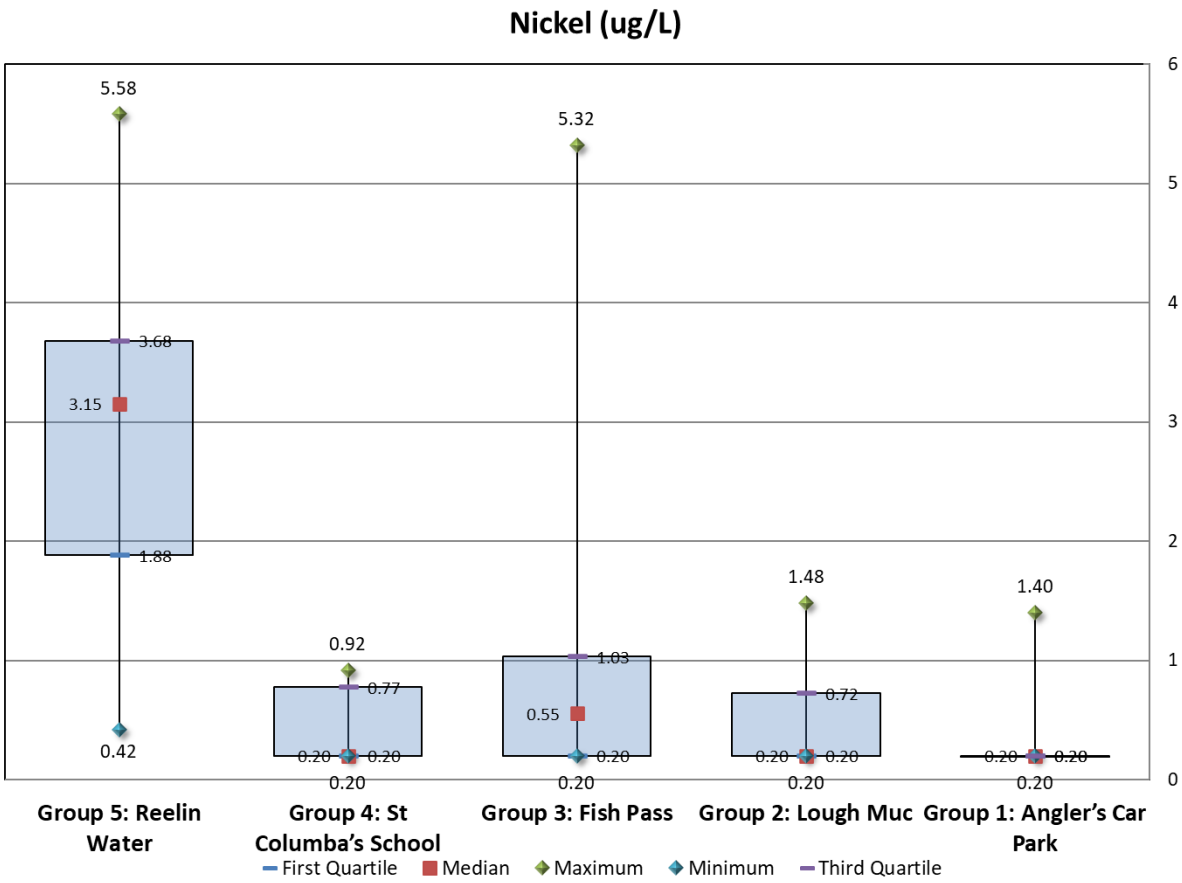

Figure 13: Nickel (Ni) boxplot

5.2.5 Dissolved Zinc

- Dissolved zinc (Zn) concentrations within the Finn Catchment ranged from <LOD (1 ug/L, included in the graph as 0.5 ug/L) at all groups, to 123 mg/L at Group 4: St Columba's School (Figure 14).
- Group 4: St Columba's School had the widest range of concentrations.
- The concentration ranges of all five groups overlap (due to <LOD values at all locations).
- The ranges across all sites are similar and overlapping with median values across all sites ranging from 1.25 to 5.16 ug/L.

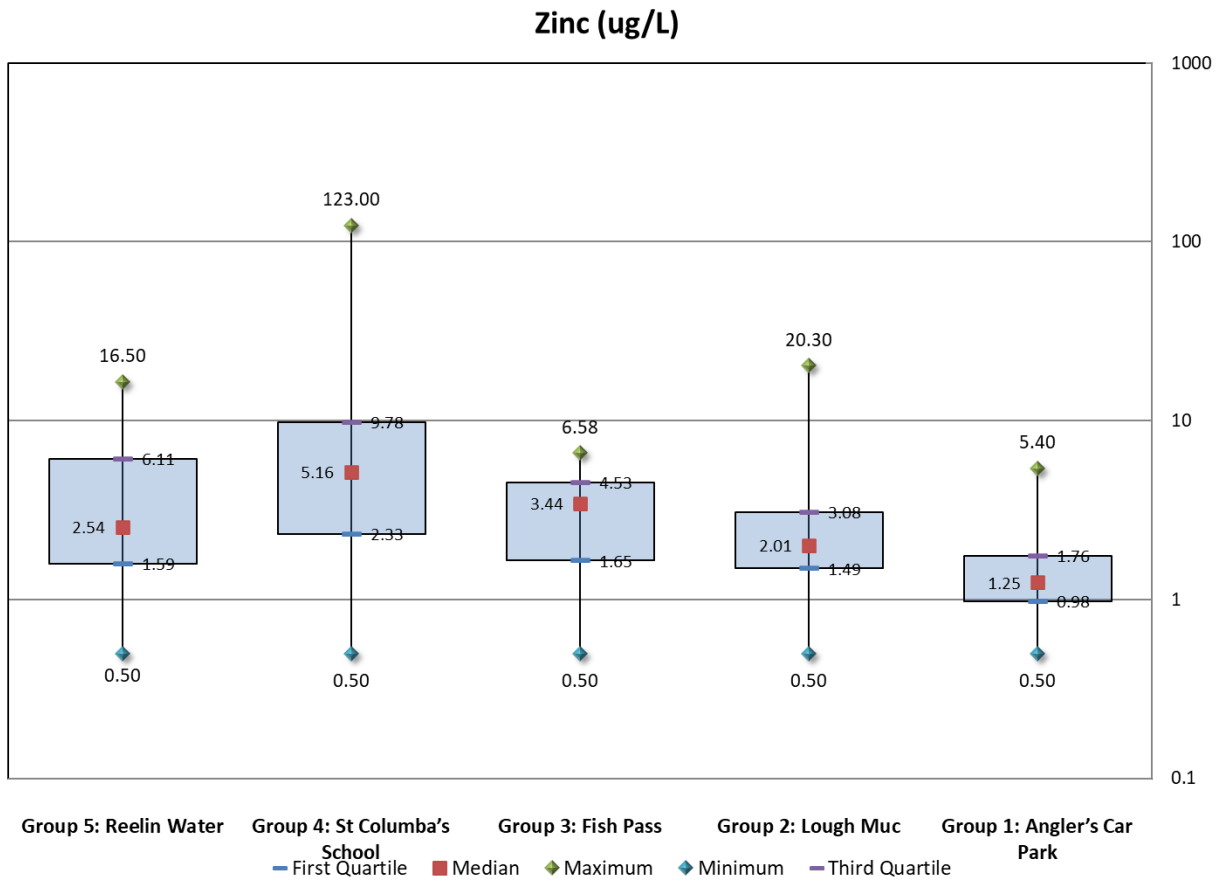

Figure 14: Zinc (Zn) boxplot, where y-axis is log scale

5.2.6 Dissolved Strontium

- Strontium (Sr) concentrations within the Finn Catchment ranged from 19.6 mg/L at Group 1: Angler's Car Park, to 1,740 mg/L at Group 3: Fish Pass (Figure 15).
- Generally, higher concentrations of dissolved Sr were recorded in samples from wells in Group 3: Fish Pass and Group 1: Angler's Car park, and lower Sr concentrations were recorded in samples across the other three well groups/locations.
- Group 3: Fish Pass had the widest range of Sr concentrations, while the narrowest range of Sr concentrations was observed in samples obtained from Group 5: Reelin Water and Group 4: St. Columba's School.

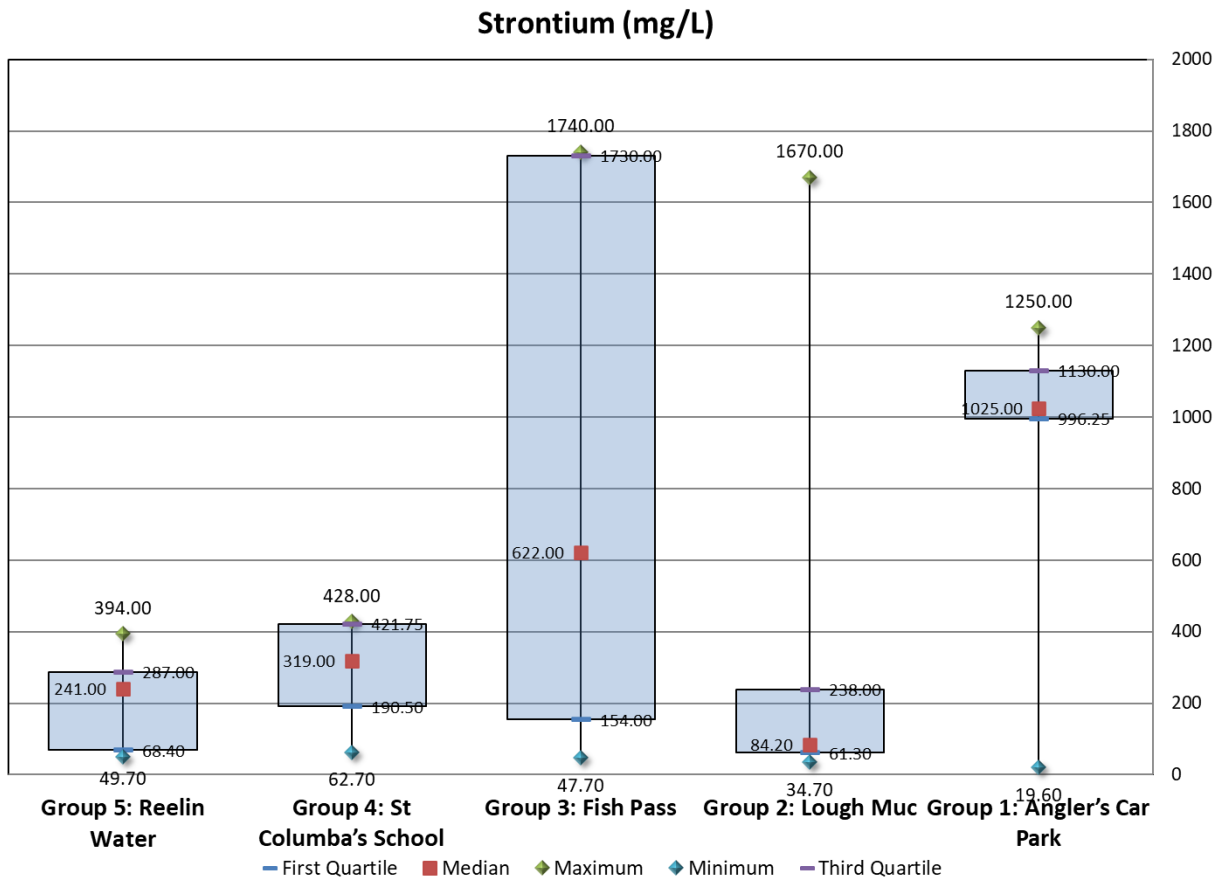

Figure 15: Strontium (Sr) boxplot

5.2.7 Dissolved Manganese

- Manganese (Mn) concentrations within the Finn Catchment ranged from <LOD (3 ug/L, included in the graph as 1.5 ug/L) at all groups, to 4,780 mg/L at Group 3: Fish Pass (Figure 16).
- Generally, higher concentrations of dissolved Mn were recorded in samples from wells in Group 5: Reelin water and Group 3: Fish Pass, and lower concentrations were recorded in samples from wells in Group 1: Angler's Car park.
- Samples from wells in Group 3: Fish Pass had the widest range of Mn concentrations, while the narrowest range of Mn concentrations was observed in samples obtained from wells in Group 1: Angler's Car Park.

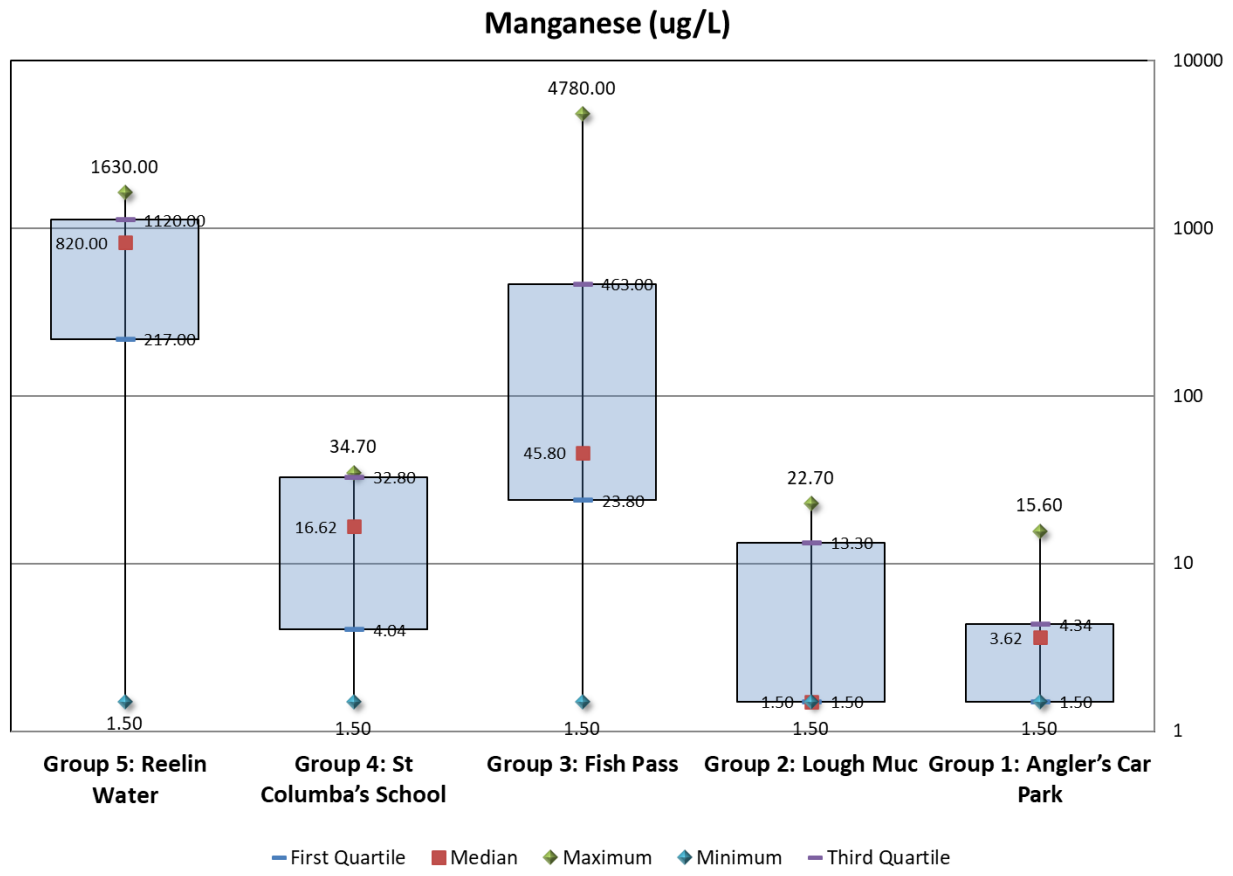

Figure 16: Manganese (Mn) boxplot, where y-axis is log scale

5.2.8 Dissolved Lithium

- Dissolved lithium (Li) concentrations within the Finn Catchment ranged from <LOD (1 ug/L, included in the graph as 0.5 ug/L) at Group 2: Lough Muc and Group 3: Fish Pass, to 118 mg/L at Group 3: Fish Pass (Figure 17).
- Group 3: Fish Pass had the widest range of concentrations, while the narrowest range of concentrations was observed for Group 4: St Columba's School.
- Generally, higher concentrations of dissolved Li were recorded at Group 2: Lough Muc, with a greater frequency of lower concentrations at Group 3: Fish Pass.
- The concentration ranges of all five groups overlap.

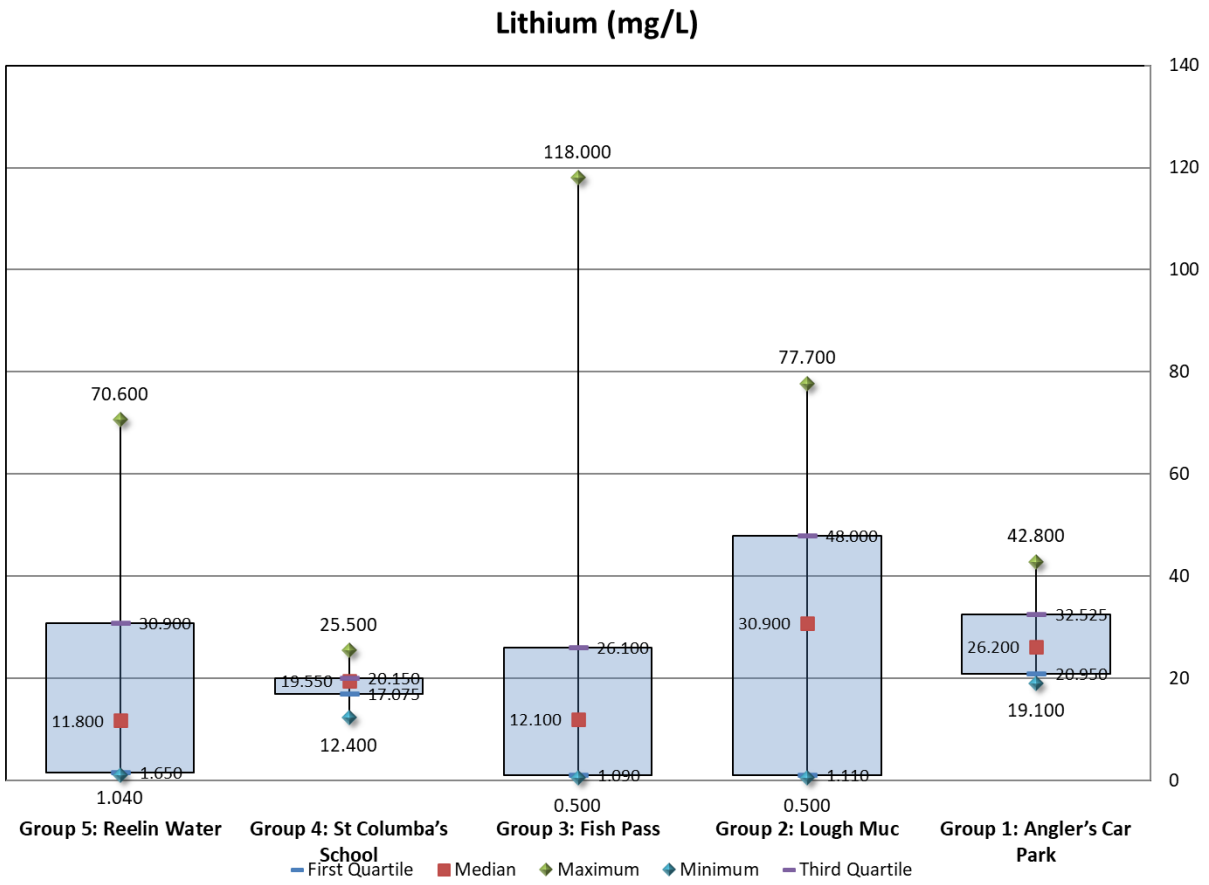

Figure 17: Lithium (Li) boxplot

5.2.9 Dissolved Uranium

- Dissolved uranium (U) concentrations within the Finn Catchment ranged from <LOD (0.5 ug/L, included in the graph as 0.25 ug/L) at Group 1: Angler's Car Park, Group 2: Lough Muc and Group 5: Reelin Water, to 45.7 ug/L at Group 3: Fish Pass (Figure 18).
- Group 3: Fish Pass had the widest range of concentrations, while the narrowest range of concentrations was observed for Group 1: Angler's Car Park, and Group 5: Reelin Water.
- Generally, higher concentrations of dissolved U were recorded at Group 3: Fish Pass and Group 4: St. Columba's school, with a greater frequency of lower concentrations detected in samples from Group 1: Angler's Car Park, Group 2: Lough Muc and Group 5: Reelin Water.
- The concentration ranges of all five groups overlap.

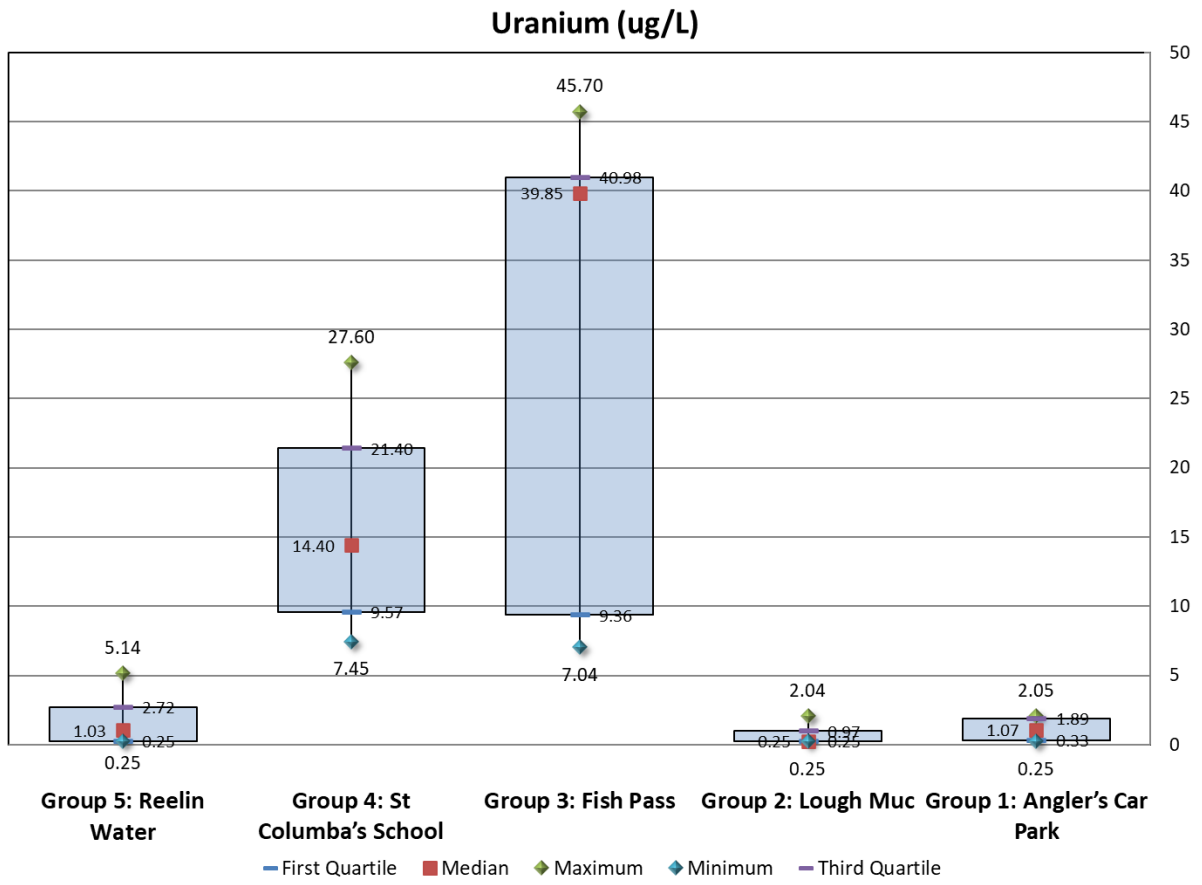

Figure 18: Uranium (U) boxplot

5.3 Physicochemical Characteristics and Water Types

5.3.1 Water physiochemistry: Alkalinity, Oxidation-Reduction Potential (ORP) & pH

A summary of water chemistry parameters alkalinity, pH and redox are presented below.

Alkalinity (Bicarbonate a $CaCO_3$)

The alkalinity within the Finn Catchment ranged from 1 mg/L in Group 5: Reelin Water to 420 mg/L in Group 1: Angler's Carpark (Figure 19).

Group 5: Reelin Water had the widest range of alkalinities, while similarly narrower ranges were recorded at the remaining four locations.

Generally, higher alkalinities were recorded in wells in Group 1: Angler's Car Park, Group 3: Fish Pass and Group 4: St. Columba's School, and somewhat lower alkalinities were observed in wells in Group 2: Lough Muc.

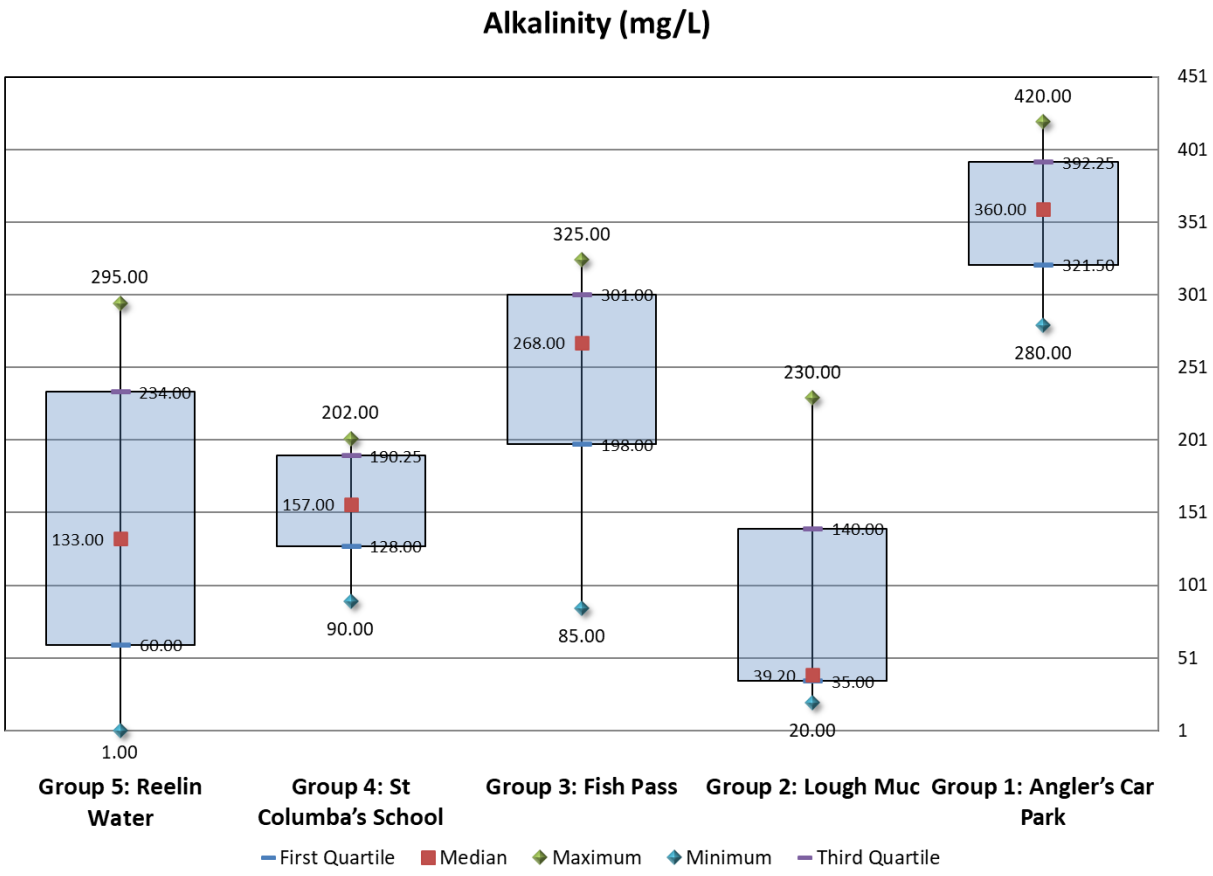

Figure 19: Alkalinity (Bicarbonate as $CaCO_3$) boxplot

Redox

The redox potential within the Finn Catchment ranged from -499 mV in Group 1: Anglers carpark, to 194 mV in Group 3: Fish Pass (Figure 20). All groups showed relatively wide distributions of redox values. Predominantly negative redox values and thus reducing conditions were observed at all locations except for Group 3: Fish Pass where redox values were more frequently positive and conditions oxidising.

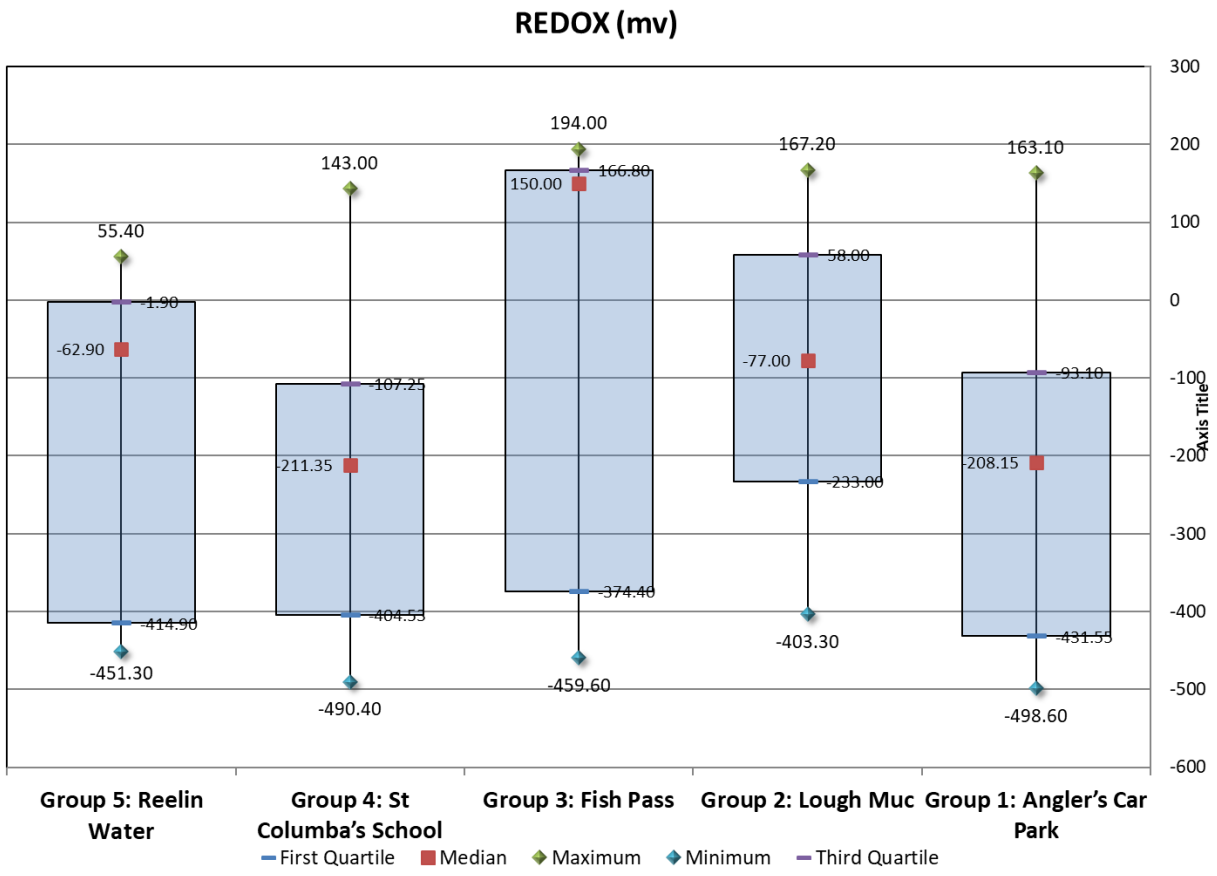

Figure 20 Redox boxplot

pH

The pH values within the Finn Catchment had similar ranges of values across all five groups (Figure 21). The median pH values ranged from 7.43 to 8.54. The highest pH value was recorded in a sample obtained from Group 5: Reelin Water (11.70) and Group 2: Lough Muc (11.10) and the lowest pH was recorded in a sample from Group 3: Fish Pass (6.24). The small number of unusually high pH values recorded at Group 5: Reelin Water and Group 2: Lough Muc may be an artifact of recent well completion i.e., cement contamination.

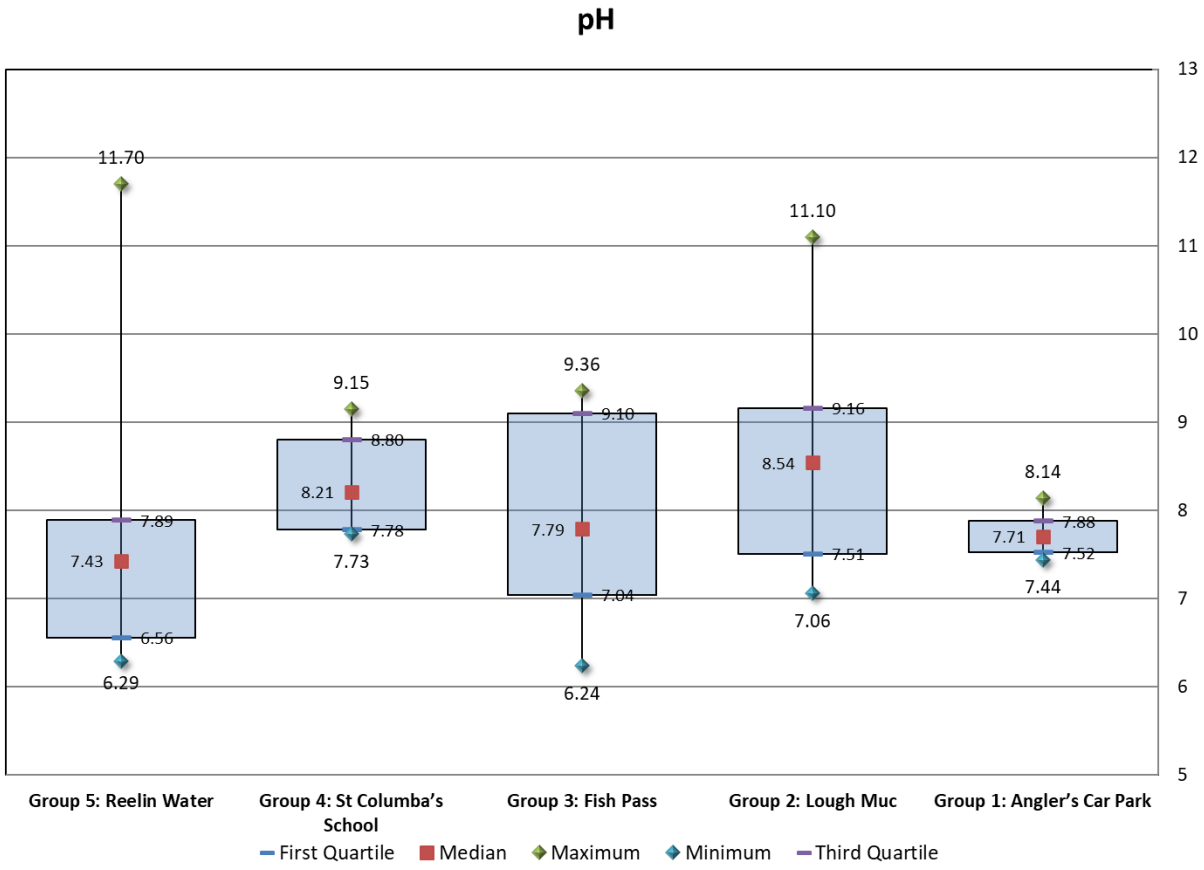

Figure 21: pH boxplot

5.3.2 Water Type

Piper diagrams are used to determine the water type in the Finn catchment (Figure 22) and in each location/group of wells within the catchment (Figure 23).

Overall, the groundwater in the Finn catchment appears to be of the Ca-Mg-HCO_3 type, however some samples appear to be of a mixed type of groundwater with a few plotting on the Na-K-HCO_3 type (Figure 22).

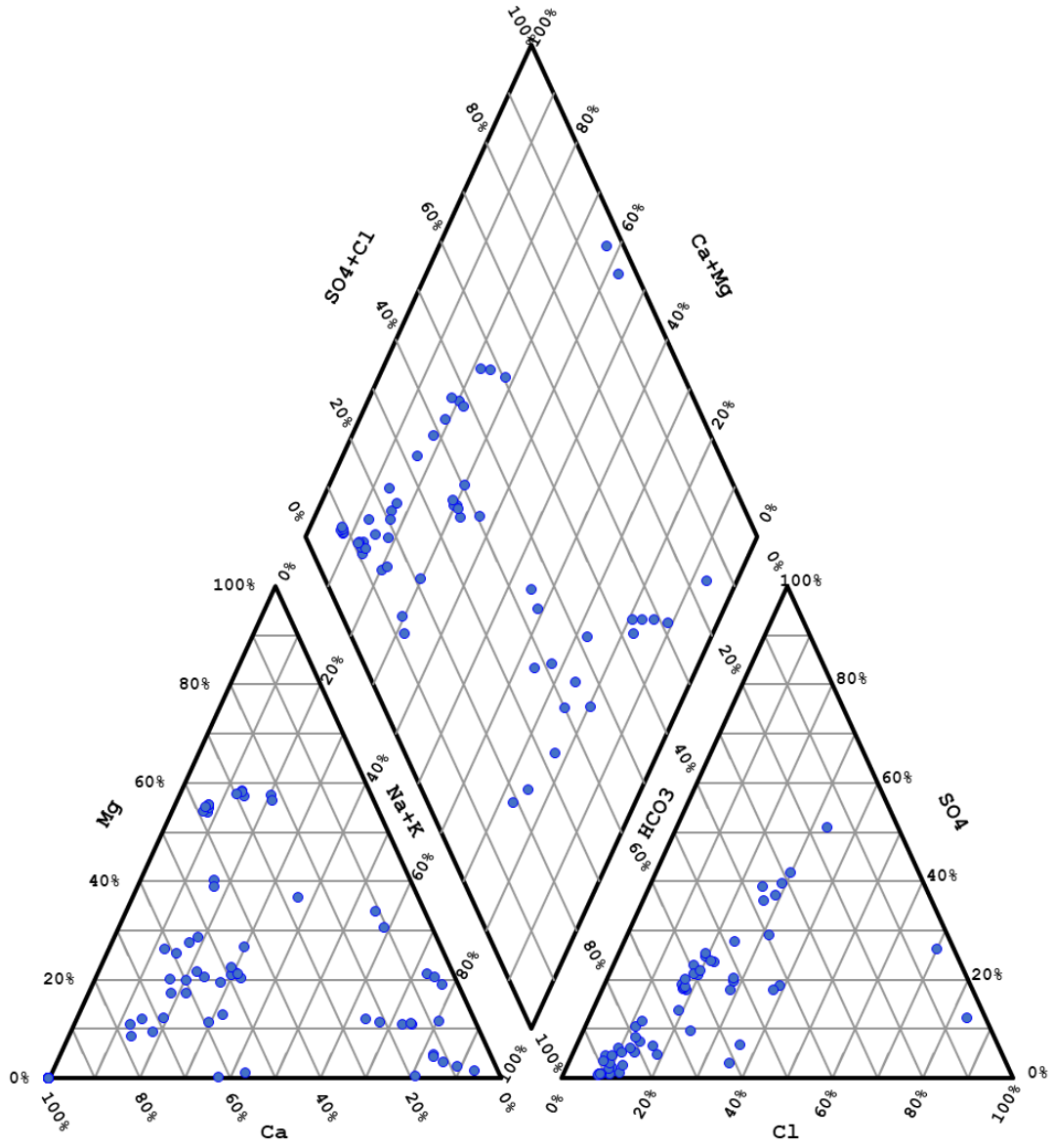

Figure 22: Piper diagram of all samples across the Finn catchment

A Piper diagram of the grouped data (groups 1 through 5 as previously described) was prepared to assess the water type in the five different areas of the catchment (Figure 23).

There are variations in the water types of the different area within the Finn catchment (Group 1-5). Groundwaters from Group 1 (Angler's Car Park) appears to be predominantly Mg-HCO_3 water type, while Group 2 (Lough Muc) is predominantly Ca-HCO_3 water type. Groundwater from Group 4 (St. Columba's School) is predominantly Na-K-HCO_3 and Group 3 (Fish Counter/Pass) groundwater is predominantly Ca-Na-K- HCO_3 water type. Group 5 (Reelin Water) is predominantly Ca-HCO_3 water type.

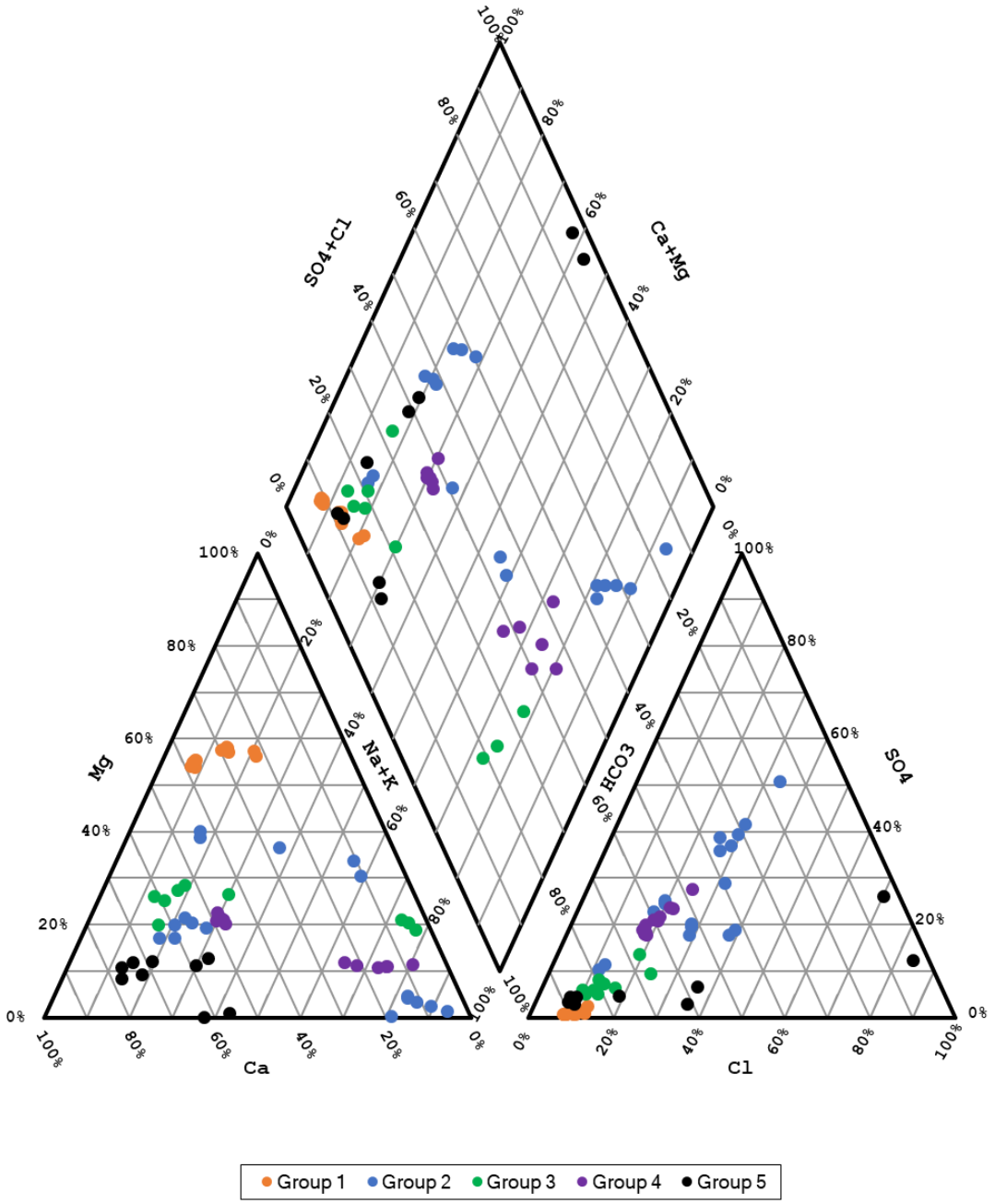

Figure 23: Piper diagram for the grouped wells within the Finn Catchment

5.4 Organic and Microbial Parameters

A number of organic parameters and microbial parameters were monitored as pollution indicator parameters.

5.4.1 Organic parameters

Organic parameters which may be associated with anthropogenic pressures were monitored. These included pesticides and insecticides.

Five wells were monitored in Round 1 (November 2020) (Lough Muc-DEEP, Lough Muc - SHALLOW, Lough Muc -INTER, Anger's Car Park-Deep, Anger's Car Park -Shallow) for up to 81 organic parameters including the herbicide 2-methyl-4-chlorophenoxyacetic acid (MCPA) and

the insecticide cypermethrin. There were no detections of any organic parameter at any location.

Three wells were monitored for up to 218 organic parameters including MCPA (< 0.01 µg/l), cypermethrin (<100 µg/l) and glyphosate (<0.2 µg/l) in Round 6 (August 2022). These wells were monitored at they are the shallowest in the catchment and thus expected to be mostly likely to be impacted by an anthropogenic pressure. The wells monitored were Fish Pass-BH03 (FPBH03), Lough Muc-Shallow (BH03) and Reelin Water BH03 (RWBH03).

Low concentrations of the poly aromatic hydrocarbons (PAHs) acenaphthylene (0.006 µg/l), acenaphthene (0.034 µg/l), fluorene (0.012 µg/l) and phenanthrene (0.012 µg/l) were detected at FPBH03. Very low concentrations of acenaphthene (0.005 µg/l), benzo(a)anthracene (0.006 µg/l) and chrysene (0.006 µg/l) were detected at BH03. PAHs are ubiquitous and persistent in the environment. They are typically formed by the incomplete burning of organic material (wood and domestic refuse) and fossil fuels (coal, possibly peat), ash, tar, asphalt (road runoff) etc. Historically, PAHs have been associated with human activities such as cooking, heating homes and industries and fuel for operating automobiles, although low levels of PAHs may also be present in the environment from natural sources, such as gorse fires. Their presence in the environment at higher concentrations is an artifact of habitation and is due to the widespread practice of emptying fireplaces, stoves, boilers, domestic refuse, etc. in rural and urban areas over the past several hundred years. As a result, it is very common to detect "background" levels of PAHs in soils. Fluorene is a major component of fossil fuels and may be residual from well construction. Acenaphthylene, phenanthrene and acenaphthene may also be found in pesticides.

At Reelin Water BH03 (RWBH03), there were no detections of any of the 218 parameters analysed.

5.4.2 Microbial parameters

Three wells were monitored for three microbial parameters (*E. coli*, total coliforms and *Clostridium Perfringens*) in Round 6 (August 2022). The wells were monitored at they are the shallowest in the catchment and thus expected to be mostly likely to be impacted by an anthropogenic pressure. These wells were Fish Pass-BH03 (FPBH03), Lough Muc-Shallow (BH03) and Reelin Water BH03 (RWBH03).

There were no detections of any microbial parameter in either FPBH03 or RW-BH-03.

Total coliforms and *E. coli* were detected in at low levels, both 4 cfu/100 ml, in Lough Muc-Shallow (BH03). This indicates that Lough Muc-Shallow (BH03) may be subject to contamination from human or animal waste.

Section 6 Discussion and Recommendations

6.1 Water Type

When considering all samples across the catchment, the groundwater in the Finn catchment appears to be of the Ca-Mg-HCO_3 type, however some samples appear to be of a mixed type of groundwater with a few plotting on the Na-K-HCO_3 type. Groundwaters from Group 1 (Angler's Car Park) appears to be predominantly Mg-HCO_3 water type, while Group 2 (Lough Muc) is predominantly Ca- HCO_3 water type. Groundwaters from Group 4 (St. Columba's School) is predominantly Na-K- HCO_3 and Group 3 (Fish Counter/Pass) groundwater is predominantly Ca-Na-K- HCO_3 water type. Group 5 (Reelin Water) is predominantly Ca- HCO_3 water type.

6.2 Exceedances, Pressures & Pollution Indicators

Notably, landuse in the catchment is agriculture with some forestry and bog to the west and aquifer vulnerability is high to extreme.

There were exceedances of the respective thresholds for the physicochemical parameters and major and minor elements:

- Potassium (exceedance no. 37, or 63 %);
- pH (exceedance no. 7, or 12 %);
- Fluoride (exceedance no. 6, or 10 %); and
- Magnesium (exceedance no. 4, or 7 %)
- Specific Electrical Conductivity (exceedance no. 2, or 3 %);

There were exceedances of the respective thresholds for the metals (trace elements):

- Uranium (U) (exceedance no. 15 or 29 %);
- Iron (Fe) (exceedance no. 15, or 25 %);
- Barium (Ba) (exceedance no. 13, or 22 %);
- Manganese (exceedance no. 10, or 17 %);
- Zinc (exceedance no. 2, or 3 %); and
- Aluminium (exceedance no. 1, or 2 %).

The locations of the exceedances of WQS thresholds are outlined in Table 6, with yellow fill indicating relatively few exceedances of the relative threshold (<5%) and orange fill indicating higher numbers of exceedances.

Table 6 Exceedances of WQS parameters relative to well group/well location

Parameter	Potassium	Uranium	Iron	pH	Manganese	Fluoride	Barium	Magnesium	Specific EC	Zinc	Aluminium
Group 1: Angler's carpark											
Group 2: Lough Muc											
Group 3: Fish Pass											
Group 4: St. Columba's school											
Group 5 Reelin Water											

Generally, the exceedances of the respective thresholds are expected to be associated with natural geology rather than anthropogenic inputs. Potassium, magnesium, aluminium and barium are common minerals in the bedrock geology across the catchment (Table 1).

Manganese is mobilized from minerals under reducing conditions. The oxidation-reduction potential indicates generally reducing conditions at all locations.

The elevated uranium is expected to be due to the presence of graphitic minerals with variations in uranium concentrations and exceedances among areas/well groups reflecting varying geology and prevalence of graphitic minerals across the catchment.

Elevated fluoride was detected at St. Columba's well and may be due to geology though minerals with fluoride are generally rare. Minerals with manganese are also generally rare.

The elevated pH values recorded at Group 2: Lough Muc, Group 5: Reelin Water may be an artifact of relatively recent well completion i.e., cement contamination.

The concentrations of nutrient pollution parameters (nitrogen and phosphorous species) were low, with large numbers of non-detections. There were no recorded exceedances of any of the WQS for any of ortho-phosphate, total phosphorous, nitrate, nitrite or ammonia. In addition, there were no detections of any pesticides or herbicides analysed as part of the organic suits of parameters, which MCPA (<0.01 µg/l), cypermethrin (<100 µg/l) and glyphosate (<0.2 µg/l). There were a small number of detections of organic parameters (PAHs) which are ubiquitous at low levels.

Microbial parameters were detected in only one of the three wells monitored (Lough Muc-Shallow (BH03)). The detection of microbial parameters associated with animal waste at Lough

Muc-Shallow (BH03) may indicate that agriculture or domestic waste water may be a pressure in this section of the catchment.

While agriculture is the main landuse in the catchment, the data do not indicate that agriculture is a pressure on the groundwater across the Finn catchment. With the exception of minor microbial detections at Lough Muc, the data does not indicate that the groundwater across the Finn catchment is impacted by anthropogenic inputs/pressures. It is noted that the dataset is limited and patterns and trends indicating impacts of anthropogenic pressures may become apparent with larger a larger dataset with greater temporal range.

6.3 Recommendations

It is recommended that monitoring is continued to prepare develop a robust baseline dataset, and to identify changes and elucidate any trends that might become apparent in a longer term dataset.

While the aquifer across the catchment is largely poorly productive and of limited significance as a potable water source, given the agricultural landuse in the area and high vulnerability aquifer, a programme of monitoring of organic parameters across the catchment, including pesticides and herbicides, would be prudent.

It is recommended that analysis of microbial parameters be continued at Lough Muc-Shallow (BH03) and extended in this location to determine the extent, source and pattern of microbial inputs.

Further work might include better definitions of individual wells (including assessment of fluoride at Group 4: St. Columba's well, and manganese at Group 3: Fish Pass and Group 5: Reelin water). Further work might include probability plots or other statistical methods to develop background values when a larger dataset is available.

Section 7 References

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