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UK Geoenergy Observatories: Glasgow groundwater and surface water chemistry dataset release May 2024 - November 2025

UK Geoenergy Observatories programme

Open Report OR/26/046



BRITISH GEOLOGICAL SURVEY

UK GEOENERGY OBSERVATORIES PROGRAMME

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Front cover

Glasgow Observatory site
technician sampling surface
water from the River Clyde.
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UK Geoenery Observatories: Glasgow groundwater and surface water chemistry dataset release May 2024 - November 2025

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Summary

This report presents a hydrochemical summary of the monitoring of groundwater and surface water at the UK Geoenergy Observatory in Glasgow (UKGEOS Glasgow) from May 2024 to November 2025. This period represents the latest part of the operational phase for the Observatory, which is designed for research and innovation in mine water geothermal energy and thermal energy storage. Five sampling rounds were completed, with samples collected from 10 boreholes and six surface water monitoring points. It is preceded by the previous Glasgow Observatory monitoring report: *Glasgow baseline groundwater and surface water dataset release September 2022 - January 2024* (Palumbo-Roe et al., 2025), which presents a hydrochemical summary and description of the initial period of the operational phase.

The groundwater sampling, methods are discussed and quality of the water analyses are summarised. The results from the groundwater monitoring include field measurements of redox potential (ORP), pH, dissolved oxygen, electrical conductivity, alkalinity and water temperature, as well as chemical analyses of major, minor, and trace elements, reduced iron, dissolved sulphide, non-purgeable organic carbon (NPOC), polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH), volatile organic compounds (VOC), oxygen and deuterium isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), carbon isotopes in dissolved inorganic carbon (DIC) ($\delta^{13}\text{C}_{\text{DIC}}$), ammonium (NH_4), dissolved gases: radon, methane, ethane and carbon dioxide (Rn , CH_4 , C_2H_6 , CO_2). The results from the surface water monitoring include the same parameters except for exclusion of NH_4 , VOC, reduced iron, sulphide and dissolved gases.

Summary tables only are presented; except for assessment of surface water environmental quality standards (EQS) in Section 4.3, this report does not include discussion or interpretation of the results.

1 Introduction

In 2015, the British Geological Survey (BGS) and the Natural Environment Research Council (NERC) began developing new centres for research into the subsurface environment, to aid the responsible development of new low-carbon energy technologies in the United Kingdom (UK) and internationally. The UK Geoenergy Observatory in Glasgow was the first of these new centres to be built and is designed with the objective of de-risking key technical barriers to low-temperature shallow mine water heat/storage in an urbanised former mine setting (Monaghan et al., 2017; Monaghan et al., 2021).

The Observatory is located in the east of the Glasgow city region (Figure 1.1a) and comprises a network of 12 boreholes located across five sites and six surface water sampling locations (Figure 1.1b). The sampling locations extend from Dalbeth to Dalmarnock, with the main borehole cluster (11 boreholes) at the Cuningar Loop on the River Clyde. The boreholes, which extend through made ground into the superficial deposits, mined and unmined bedrock, were designed to characterise the geological and hydrogeological setting of the research infrastructure. Two of the boreholes are not available for hydrogeological testing. The groundwater and surface water monitoring is intended also to assess the environmental status before and during the lifetime of the project. Figure 1.1c shows the details of the 11 boreholes located at the Cuningar Loop.

As part of the baseline sampling programme, surface water sampling was carried out monthly at five sites along the River Clyde and one site at the Tollcross Burn from February 2019 to March 2020. The results from these 14 sampling rounds were released by Fordyce et al. (2021). Surface water data were released on their own until the new boreholes were drilled. Groundwater sampling was conducted during pumping tests on 10 boreholes at the Glasgow Observatory in January and February 2020. A test pumping data release summarising the results of these samples was produced by Palumbo-Roe et al. (2021). Once the monitoring boreholes were ready to be sampled, simultaneous baseline monitoring of groundwaters and surface waters was planned. The start of sampling was, however, halted during the early part of the COVID-19 pandemic in April 2020 and restarted in September 2020. Six sampling rounds were carried out between September 2020 and May 2021, the data collected from these six rounds were released with an accompanying report by Bearcock et al. (2022). A further six sampling rounds were undertaken between June 2021 and January 2022 and the associated chemical data released with an accompanying report by Bearcock et al. (2022).

Hereafter, the Glasgow Observatory entered the operational stage and quarterly monitoring of surface water and groundwater has been undertaken. Six sampling rounds were carried out between September 2022 and January 2024 and the associated chemical data released with an accompanying report by Palumbo-Roe et al. (2025). Five further rounds were undertaken between May 2024 and November 2025. As many of the VOCs, PAHs, and TPHs had been below, or very close to the detection limit, these analyses were not undertaken on every round during this period. From this point the baseline monitoring will be reduced to an annual frequency.

This report accompanies the water chemical data release from the five rounds of groundwater and surface water monitoring, with start date 27/05/2024 and end date 28/11/2025. It provides an introduction to the site and sampling set up. Summary statistics of the data are tabulated, and the appendices provide details of the analytical methods and the quality control process of the dataset.

1.1 CITATION GUIDANCE

This report accompanies the release of the water chemistry 27/05/2024 – 28/11/2025

<i>Any use of the data should be cited to:</i>
Walker-Verkuil, K., Bearcock, J., Brickell, J., Holliday, L. (2026). UKGEOS Glasgow groundwater and surface water chemistry dataset release (2024 - 2025). NERC EDS National Geoscience Data Centre. (Dataset). https://doi.org/10.5285/66c3799f-fb64-4e6a-96cb-d37280ef6ae8
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1.2 OVERVIEW OF THE GLASGOW OBSERVATORY

The Glasgow Observatory includes 12 boreholes (Figure 1.1, Table 1.1). Five are mine water boreholes that are drilled into, and screened through, individual former mine workings; five are environmental baseline monitoring boreholes that are drilled into, and screened through, targeted zones in bedrock above the Glasgow Upper mine working, or in superficial deposits overlying bedrock. Two boreholes were not available for hydrogeological testing: borehole GGA02 is a fully cased sensor testing borehole and GGC01 is a seismic monitoring borehole in Dalmarnock c. 2 km WNW of the main borehole cluster at the Cuningar Loop.

The main surface water body adjacent to the Glasgow Observatory at the Cuningar Loop is the River Clyde. The only other open surface water body in the vicinity is the Tollcross Burn. Six surface water sampling locations were selected, comprising five on the River Clyde and one on the Tollcross Burn (SWTC in Figure 1.1b). The locations on the River Clyde were chosen to be proximal to the borehole cluster at the centre of the Observatory in the Cuningar Loop. In addition, far-field control sample locations on the River Clyde were selected approximately 1.5 km upstream of the Cuningar Loop boreholes at location SW06 and approximately 2 km downstream at SW10 adjacent to the Site 10 seismic monitoring borehole (Figure 1.1) (Fordyce et al., 2021).

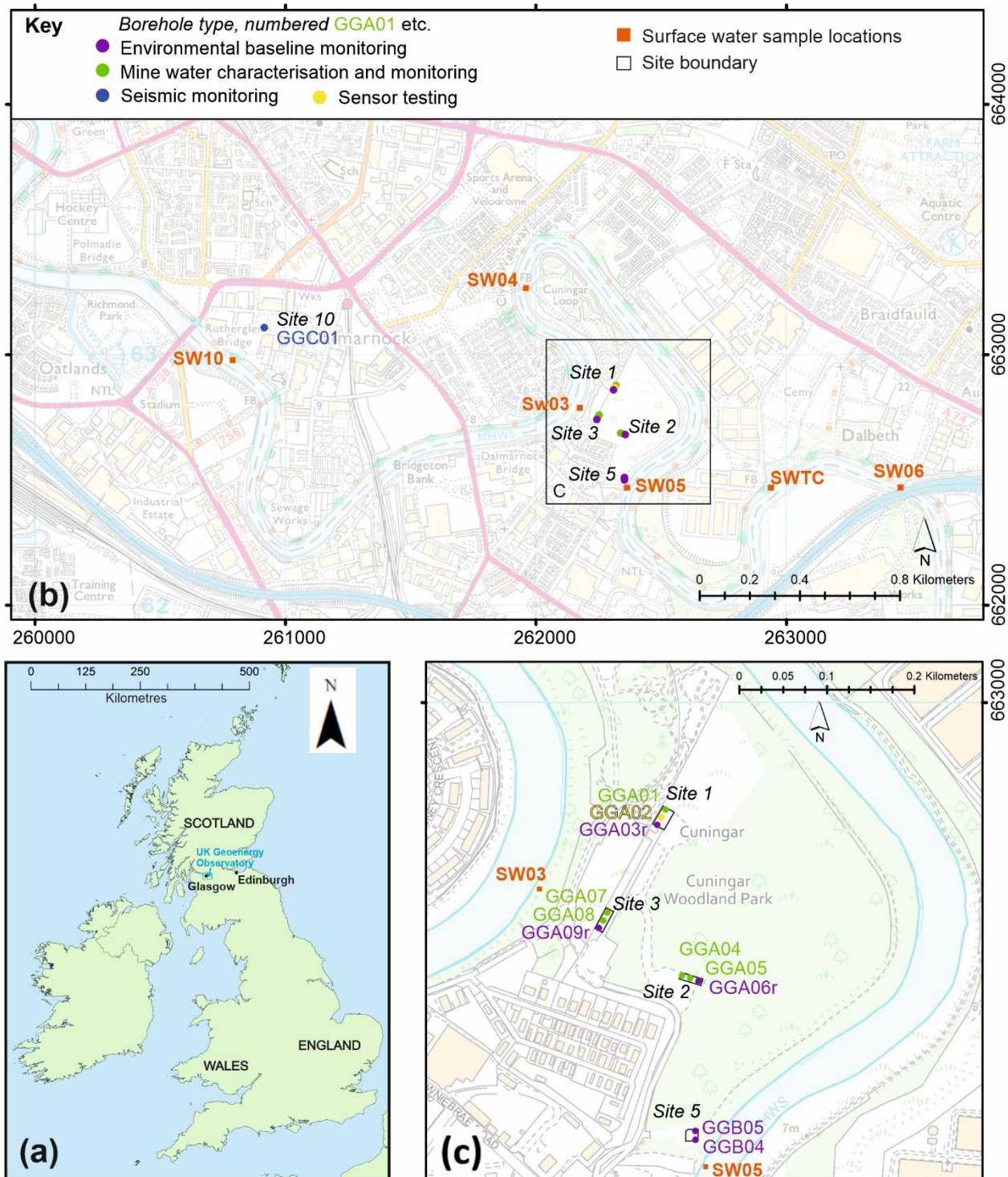


Figure 1.1(a) Location of the Glasgow Observatory in the UK (b) position of Observatory sites (c) detail of Cuningar Loop mine water and environmental baseline characterisation and monitoring boreholes. Contains OS data © Crown copyright and database rights (2026) OS AC0000824781. Contains BGS data © UKRI 2026.

Table 1.1 Glasgow Observatory borehole infrastructure, adapted from Monaghan et al. (2021)

Site name	Borehole ID	Borehole type	Target horizon	Screen depth from as-built datum (m)	Screened formation	Screened lithology
Site 1	GGA01	Mine water	Glasgow Upper mine working	44.81-48.41	Scottish Middle Coal Measures	Sandstone roof and Glasgow Upper mine working waste
Site 1	GGA02	Sensor testing	N/A (No borehole screen)	N/A	N/A	N/A
Site 1	GGA03r	Environmental baseline	Bedrock	37.00-39.81	Scottish Middle Coal Measures	Sandstone bedrock
Site 2	GGA04	Mine water	Glasgow Upper mine working	47.40-51.00	Scottish Middle Coal Measures	Sandstone roof and Glasgow Upper mine working position, coal and mudstone
Site 2	GGA05	Mine water	Glasgow Main mine working	83.60-86.30	Scottish Middle Coal Measures	Sandstone roof and Glasgow Main mine working, void to mudstone floor
Site 2	GGA06r	Environmental baseline	Superficial deposits	11.79-13.76	Gourock Sand Member	Sand and gravel
Site 3	GGA07	Mine water	Glasgow Upper mine working	50.91-53.61	Scottish Middle Coal Measures	Mudstone roof and Glasgow Upper mine working, coal pillar and void
Site 3	GGA08	Mine water	Glasgow Main mine working	85.08-87.70	Scottish Middle Coal Measures	Overlying sandstone-siltstone and Glasgow Main mine roadway void
Site 3	GGA09r	Environmental baseline	Superficial deposits	11.43-13.33	Gourock Sand Member	Sand
Site 5	GGB04	Environmental baseline	Superficial deposits	10.09-11.99	Gourock Sand Member	Sand and gravel
Site 5	GGB05	Environmental baseline	Bedrock	42.39-44.19	Scottish Middle Coal Measures	Sandstone bedrock
Site 10	GGC01	Seismic monitoring	N/A (No borehole screen)	N/A	N/A	N/A

2 Methodology

2.1 SUMMARY OF MONITORING

Samples were taken during five monitoring rounds (from round 33 to round 37), during the operational phase of the UKGEOS Glasgow Observatory, between 27/05/2024 and 28/11/2025, as detailed in Table 2.1, and in-between onsite-testing, as summarised in Figure 2.1.

Table 2.1 Sampling round dates and boreholes and surface water sites sampled during each round

Borehole / Surface Water ID	Round 33	Round 34	Round 35	Round 36	Round 37
	May-24	Sep/Oct-24	Jan-25	Feb/Mar-25	Nov-25
Start Date:	27/05/24	30/09/24	20/01/25	28/02/25	24/11/25
End Date:	31/05/24	04/10/24	23/01/25	06/03/25	28/11/25
Boreholes:					
GGA01	✓	✓	✓	✓	✓
GGA03r	✓+Duplicate	✓	✓	✓	✓
GGA04	✓	✓	✓	✓+Duplicate	✓
GGA05	✓	✓	✓	✓	✓
GGA06r	✓	✓	✓	✓	✓
GGA07	✓	✓+Duplicate	✓	✓	✓
GGA08	✓	✓	✓+Duplicate	✓	✓
GGA09r	✓	✓	✓	✓	✓
GGB04	✓	✓	✓	✓	✓
GGB05	✓	✓	✓	✓	✓+Duplicate
Surface Water sites:					
SW03	✓	✓	✓	✓	✓
SW04	No sample	✓	✓	✓	✓
SW05	No sample	No sample	✓	✓	✓
SW06	✓	✓	✓	✓	✓
SW10	✓	✓	✓	✓	✓
SWTC	✓	✓	✓	✓	✓

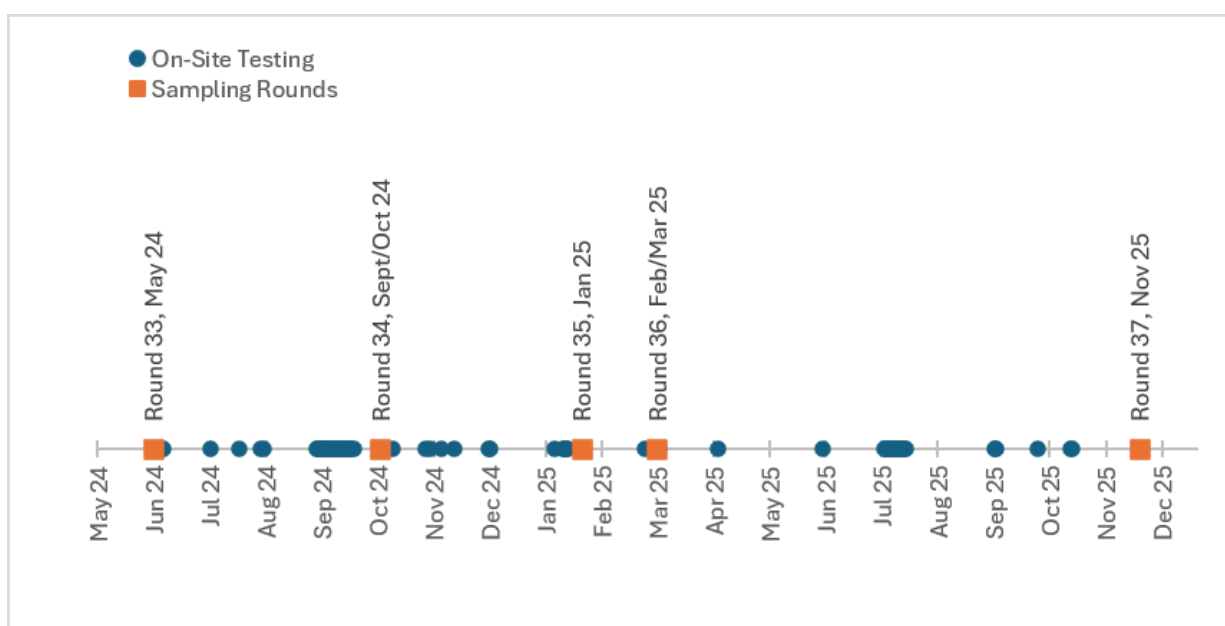


Figure 2.1 Timeline of sampling rounds and on-site testing at the UKGEOS Glasgow Observatory during the period May 2024 – December 2025. BGS © UKRI.

2.2 SAMPLE COLLECTION AND ANALYSES

2.2.1 Sampling setup

The sampling setup for each borehole varies depending on installed infrastructure. Table 2.2 shows the pump type used at each site; where relevant any pumps used prior to the installation of the geothermal infrastructure are also shown. Further details of the pumps currently used, as well as previous pumping setups can be found in Palumbo-Roe et al. (2025).

Table 2.2. Sample setup for each borehole in the Glasgow Observatory monitoring array

Site name	Borehole ID	Borehole type	Pump type	Pump depth (m below well head)	Previous pump type*
Site 1	GGA01	Mine water	Manual inertial lift pumping	23	42 mm SS High Performance Bladder Pump
Site 1	GGA03r	Environmental baseline	42 mm SS High Performance Bladder Pump	5	N/A
Site 2	GGA04	Mine water	42 mm SS High Performance Bladder Pump	20	N/A
Site 2	GGA05	Mine water	SP 46-6 Grundfos submersible groundwater pump	25	42 mm SS High Performance Bladder Pump
Site 2	GGA06r	Environmental baseline	WaSP P5 submersible pump	12	N/A
Site 3	GGA07	Mine water	SP 46-6 Grundfos submersible groundwater pump	25	42 mm SS High Performance Bladder Pump
Site 3	GGA08	Mine water	Manual inertial lift pumping	23	42 mm SS High Performance Bladder Pump
Site 3	GGA09r	Environmental baseline	WaSP P5 submersible pump	12	N/A
Site 5	GGB04	Environmental baseline	WaSP P5 submersible pump	12	N/A
Site 5	GGB05	Environmental baseline	42 mm SS High Performance Bladder Pump	15-20	N/A

Groundwater pumped using the Grundfos submersible pumps or bladder pumps was passed through a flow cell for field parameter measurements (pH, specific electrical conductance (SEC), redox potential (ORP) and dissolved oxygen (DO)). The flow cell discharged into a plastic beaker which had a thermometer probe placed in. Field parameters were taken over 20 minutes, with a minimum three readings taken five minutes apart. GGB05 could not always be pumped for 20 minutes due to its low recharge rate and variable rest water level. Following field parameter measurements, the flow cell was disconnected, and samples were collected directly from the pump discharge tube.

Manual inertial lift pumping was carried out using a foot pump. The tubing was installed through the dip tube at the well head to a depth of ~23 m below the well head. Ten litres of water were pumped prior to filling a plastic beaker for the field parameter measurements. The probes from the portable meters were placed carefully in the beaker in a customised holder to ensure that they

did not touch the sides or bottom of the beaker, or each other. The meters were left to stabilise before the readings were recorded. More water was then pumped to fill the sampling containers.

All wastewater was collected in a jerry can and discharged offsite at a suitable drain.

Surface water sampling was carried out using an extendable telescope from the banks of the River Clyde and Tollcross Burn. At each sampling location the plastic telescope and a plastic beaker were rinsed with sample water. Sample waters were then collected in the plastic telescope and transferred to the plastic beaker for the field parameter measurements. The probes from the portable meters were placed carefully in the beaker in a customised holder to ensure that they did not touch the sides or bottom of the beaker, or each other. The meters were left to stabilise before the readings were recorded for each location on a standardised field sheet.

2.2.2 Sample collection overview

At each sampling location, numerous splits of each water sample were collected for various chemical analyses (Table 2.3, Table 2.4). A detailed description of the analytical methods can be found in Bearcock et al. (2023); Bearcock et al. (2022); Fordyce et al. (2021); Palumbo-Roe et al. (2025); and Palumbo-Roe et al. (2021). A sample for dissolved gases was taken from each groundwater site on every round. Data are only reported for rounds 33 and 34 since the analytical capabilities were moved from BGS Wallingford to BGS Keyworth in November 2024. At the time of writing the samples from rounds 35 – 37 are awaiting analysis, and an updated version of the data will be released once data are available. Results for PAH, TPH and VOCs have historically been at or close to the detection limits (see Bearcock et al. (2023); Bearcock et al. (2022); Palumbo-Roe et al. (2025)), so the decision was made to reduce the sampling frequency. TPH C8-C10 and C8-C40 are no longer reported by Scottish Water, so TPH C8-C4 is the only TPH analysis going forwards.

Table 2.3 List of determinand types analysed in UKGEOS Glasgow groundwater and surface water samples from May 2024 to November 2025

Determinand Type	Groundwater	Surface water
Inorganic Chemistry Data	✓	✓
NPOC and TIC	✓	✓
PAH	Rounds 34, 35 and 37	Rounds 34, 35 and 37
TPH	Rounds 34, 35 and 37	Rounds 34, 35 and 37
VOC	Rounds 34, 35 and 37	n/a
$\delta^2\text{H}$ and $\delta^{18}\text{O}$	✓	✓
$\delta^{13}\text{C}_{\text{DIC}}$	✓	✓
NH_4	✓	n/a
Rn	Round 34	n/a
Dissolved gases CH_4 , C_2H_6 , CO_2	Rounds 33* and 34*	n/a
S^{2-}	✓	n/a
Fe^{2+}	✓	n/a

n/a indicates these parameters have not been analysed

*Rounds for which the samples have been analysed

Table 2.4 Summary of the water sample splits including a list of the parameters determined for each split.

Water Quality Parameters	Sample Splits	Analytical Method	Lab
Field Measurements:			
Temperature (°C)	No sample - measured in field	Portable meter	-
pH	No sample - measured in field	Portable meter	-
Redox potential (ORP)	No sample - measured in field	Portable meter	-
Specific electrical conductance (SEC)	No sample - measured in field	Portable meter	-
Dissolved oxygen (DO)	No sample - measured in field	Portable meter	-
Alkalinity (as HCO ₃)	No sample - measured in field	Titration	-
Laboratory Measurements:			
Non Purgeable Organic Carbon	Ag-filtered unacidified foil capped 14 mL glass vial (NPOC)	Carbon analyser	BGS
Oxygen and deuterium isotopes $\delta^{18}\text{O}/\delta^2\text{H}$	30 mL unfiltered unacidified HDPE Nalgene® bottle ($\delta\text{O-H}$)	Isotope ratio mass spectrometry (IRMS)	BGS
Carbon isotopes $\delta^{13}\text{C}$	125 mL unfiltered unacidified HDPE Nalgene® (δC)	IRMS	BGS
Major, minor and trace element cations: Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe total*, Ga, Gd, Hf, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P-Total, Pb, Pr, Rb, S-Total, Sb, Se, Si, Sm, Sn, Sr, Ta, Tb, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	0.45µm Filtered acidified 30 mL HDPE Nalgene® bottle (FA)	Inductively-coupled plasma-mass spectrometry (ICP-MS)	BGS
Major and minor anions: Br, Cl, F, HPO ₄ , NO ₂ , NO ₃ , SO ₄ , HCO ₃ (lab)	0.45µm Filtered unacidified 60 mL HDPE Nalgene® bottle (FUA)	Ion chromatography (IC) and ICP-MS	BGS
Total Petroleum Hydrocarbons TPH (C8-C40)	Unfiltered unacidified 1 L clear glass bottle dosed with sodium thiosulphate.	Gas chromatography flame ionisation detector (GC-FID)	Scottish Water
Polycyclic Aromatic Hydrocarbons Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(ghi)perylene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PAH - Total	Unfiltered unacidified 250 mL brown glass bottle dosed with sodium thiosulphate.	HPLC fluorescence detection (HPLC-FD)	Scottish Water
Ammonium (NH ₄)	0.45µm Filtered unacidified 30 mL HDPE Nalgene® bottle (NH ₄)	Colorimetric analysis	UKCEH
Radon (Rn)	Amber glass vials pre-dosed with sodium thiosulphate	liquid scintillation	Scottish Water
Methane, ethane and carbon dioxide (CH ₄ , C ₂ H ₆ , CO ₂)	Unfiltered unacidified sample in metal container	Gas chromatography	BGS
Sulphide (S ²⁻)	Unfiltered 120 mL HDPE bottle, prefilled with SAOB (sulphide antioxidant buffer).	Segmented Flow Analysis	SOCOTEC
Reduced Iron (Fe ²⁺)	Unfiltered water in 125 mL bottles pre-dosed with concentrated HCl	Colorimetric analysis	SOCOTEC
Volatile Organic Compounds: Chloromethane, Vinyl chloride, Chloroethane, Trichlorofluoromethane, 1,1-Dichloroethene, Diethyl ether, Acrylonitrile, Dichloromethane, trans 1,2-Dichloroethene, Methyl tert-butyl ether, Hexane, Iso propyl ether, cis 1,2-dichloroethene, Bromochloromethane, Trichloromethane, 2,2-Dichloropropane, 1,2-Dichloroethane µg/L, Methyl-1,3-dioxolane mg/L, 1,1,1-Trichloroethane µg/L, 1,1-Dichloropropene, Cyclohexane, Tetrachloromethane, Benzene, Dibromomethane, 1,2-Dichloropropane, Trichloroethene, Bromodichloromethane, trans 1,3-Dichloropropene, cis 1,3-Dichloropropene, 1,1,2-Trichloroethane, Toluene, 1,3-Dichloropropane, Octane, Dibromochloromethane, 1,2-Dibromoethane, Tetrachloroethene, 1,1,1,2-Tetrachloroethane, Chlorobenzene, Ethylbenzene, m,p-Xylene, Tribromomethane, Styrene, 1,1,2,2-Tetrachloroethane, o-Xylene, Total xylene, 1,2,3-Trichloropropane, Isopropylbenzene, Bromobenzene, n-Propylbenzene, 2-Chlorotoluene, 4-Chlorotoluene, 1,3,5-Trimethylbenzene, tert-Butylbenzene, 1,2,4-Trimethylbenzene, sec-Butylbenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, 4-Isopropyltoluene, 1,2-Dichlorobenzene, n-Butylbenzene, 1,2-Dibromo-3-chloropropane, N,N-Dimethylaniline, 1,3,5-Trichlorobenzene, 1,2,4-Trichlorobenzene, Naphthalene, Hexachlorobutadiene, 1,2,3-Trichlorobenzene, Methyl ethyl ketone (2-butanone)	Unfiltered 40ml Amber Glass Vial dosed with Sodium Thiosulphate	Gas chromatography mass spectrometry (GS-MS)	Scottish Water
*Fe total in this report and data release means total dissolved, not total including particulate and dissolved Fe			

3 Data Presentation

3.1 DATASET

The dataset that accompanies this report is presented in Excel® table format:

Dataset name: UKGEOS Glasgow groundwater and surface water chemistry dataset release (2024-2025)

Filenames: UKGEOSGlasgow_GroundWaterChemData4_Release_V1.xlsx, UKGEOSGlasgow_SurfaceWaterChemData5_Release_V1.xlsx

It contains the following analysis data, for the period May 2024 to November 2025:

- field parameters: pH, temperature, Eh (referenced to the standard hydrogen electrode (SHE) calculated from measured oxidation-reduction potential (ORP) values using temperature-dependent conversion tables appropriate to the VWR® probe), dissolved oxygen (DO), specific electrical conductivity (SEC) and alkalinity (field HCO_3^-)
- inorganic and organic chemical analyses.

The first sheet in the workbook holds the dataset. The second sheet contains a guide to abbreviations used in the dataset. The dataset includes descriptive information about the samples noted during fieldwork, such as location and any contamination present at site.

For the chemical data, the parameter name, element chemical symbols, analytical method, units of measurement and long-term lower limit of detection (LLD) and limit of quantification (LOQ) are reported in header rows at the top of the table.

Whilst the long-term LLD/LOQ are documented at the top of the Excel® sheet, run-specific LLD/LOQ are given in the body of the table at the head of each analytical batch. Data below the limit of detection are recorded as < the run-specific LLD. These varied slightly between analytical runs, and cases where samples with high mineral content had to be diluted prior to analysis. Therefore, the < LLD values reported in the dataset reflect the conditions in each analytical run, as opposed to the long-term LLD/LOQ recorded at the top of the dataset.

In the Excel® sheet, inorganic chemical data groups (i.e. major cations, major anions, etc.) are reported in alphabetical order by chemical symbol. The reporting units are mg/L for major and minor ions, and $\mu\text{g/L}$ for trace elements. Stable isotope data are then reported in ‰ relative to Vienna Pee Dee Belemnite (VPDB) for $\delta^{13}\text{C-DIC}$ and ‰ relative to Vienna Standard Mean Ocean Water (VSMOW2) for $\delta^{18}\text{O}$ and $\delta^2\text{H}$. Total inorganic carbon data are reported in mg/L; CH_4 and C_2H_6 in $\mu\text{g/L}$ and CO_2 in mg/L. Finally, data for organic parameters are reported in mg/L for NPOC and TPH, and in $\mu\text{g/L}$ for PAHs and VOCs.

3.2 DATA ANALYSIS IN THIS REPORT

This report is designed to present a summary only of the results of the collated data from the monitoring period May 2024 – November 2025. It presents summary results of the groundwater and surface water within the Glasgow Observatory.

The boreholes are grouped according to their target horizon (superficial deposits boreholes, bedrock boreholes, Glasgow Upper mine workings and Glasgow Main mine workings boreholes). Minimum, maximum, and median concentrations, total number of samples (n), and number of samples censored n(c) (i.e. non-detect, as measurement below detection limit) are reported for each parameter in tables. Where the dataset has greater than 80% of non-detect (n(c)), only the data range (minimum and maximum values) is quoted. Where the dataset is 100% non-detect, only the detection limit is quoted. Some parameters have multiple detection limits where, for example, the sample has been diluted.

4 Results

4.1 GROUNDWATER HYDROCHEMICAL SUMMARY DATA

This section presents the summary tables of the hydrochemical results of the groundwaters at the Glasgow Observatory sampled between May 2024 – November 2025. In the tables below, the boreholes are grouped according to their target horizons. In depth order, from shallow to deep, these are: superficial deposits, bedrock, Glasgow Upper mine workings, and Glasgow Main mine workings.

Table 4.1 shows summary statistics for physico-chemical parameters for groundwaters from all the target horizons.

Table 4.2 and Table 4.3 show summary statistics for major ions, minor elements and dissolved organic carbon for groundwaters. The Superficial Deposits and Bedrock are presented in Table 4.2, while Glasgow Upper mine workings and Glasgow Main mine workings are presented in Table 4.3.

Table 4.4 and Table 4.5 show summary statistics for trace elements in groundwaters. The Superficial Deposits and Bedrock are presented in Table 4.4, while Glasgow Upper mine workings and Glasgow Main mine workings are presented in Table 4.5.

Table 4.6 and Table 4.7 show summary statistics for PAH and TPH concentrations in groundwaters. The Superficial Deposits and Bedrock are presented in Table 4.6, while Glasgow Upper mine workings and Glasgow Main mine workings are presented in Table 4.7. These represent summaries of samples taken during rounds 34, 35 and 37 only (see Section 2.2.2 for details).

Table 4.8 shows summary statistics for $\delta^{13}\text{C}_{\text{DIC}}$, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in groundwaters from all the target horizons.

Table 4.9 shows summary statistics for dissolved CH_4 , C_2H_6 and CO_2 concentrations in groundwaters from all the target horizons. These represent the data available at the time of writing this report (rounds 33 and 34 only). The remaining data will be added to the data release once available (see Section 2.2.2 for details).

Table 4.1 Physico-chemical parameters summary data from Glasgow Observatory groundwater sites measured during sampling rounds between May 2024 and November 2025.

	Superficial Deposits					Bedrock				
Parameter	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
pH	6.63	7.09	6.92	15	0	6.91	7.15	7.05	10	0
Temperature (°C)	9.9	13.4	11.5	15	0	10.4	12.7	11.05	10	0
Eh (mV)	-14.3	399	155	15	0	44	320	142	10	0
Dissolved oxygen (mg/L)	0.05	6.87	0.49	15	0	0.21	0.65	0.335	10	0
Specific electrical conductance (µS/cm)	1280	1678	1596	15	0	1542	1678	1600	10	0
	Glasgow Upper mine workings					Glasgow Main mine workings				
Parameter	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
pH	6.83	7.18	7.09	15	0	6.97	7.21	7.07	10	0
Temperature (°C)	9	13	11.5	15	0	9.2	13.4	12.35	10	0
Eh (mV)	48	357	117	15	0	112	350	141	10	0
Dissolved oxygen (mg/L)	0.16	2.17	0.52	15	0	0.01	2.07	0.535	10	0
Specific electrical conductance (µS/cm)	1602	1703	1646	15	0	1584	1661	1634	10	0

n = number of samples, n(c) = number of samples censored

Table 4.2 Summary of the major ions, minor elements and dissolved organic carbon from Glasgow Observatory groundwater samples taken from the boreholes targeting the superficial deposits and bedrock between May 2024 and November 2025.

Superficial Deposits							Bedrock				
		Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Major ions (mg/L)											
Ca	Calcium	106	160	135	15	0	103	142	122.5	10	0
Mg	Magnesium	43.5	50	46.4	15	0	50.6	83.1	63.85	10	0
Na	Sodium	72.3	162	125	15	0	101	184	140	10	0
K	Potassium	11.7	18	15.3	15	0	8.51	19.7	13.785	10	0
HCO ₃	Total Alkalinity	569	828	756	15	0	740	854	787.5	10	0
Cl	Chloride	39	112	61.7	15	0	53.2	76.6	64.15	10	0
SO ₄	Sulphate	149	204	182	15	0	158	238	194.5	10	0
HCO ₃	Bicarbonate (from field alkalinity)	565	877	786	15	0	722	831	807	10	0
Minor ions (mg/L)											
P	Phosphorus - total	0.012	0.702	0.029	15	0	<0.005	0.007	<0.005	10	9
S	Sulphur – total	52	72.5	65.8	15	0	55.2	84.2	70.05	10	0
Si	Silicon	4.7	7.41	5.79	15	0	4.49	6.15	5.51	10	0
Br	Bromide	<0.65	0.654	0.489	15	3	<0.65	0.738	0.639	10	1
F	Fluoride	0.119	0.307	0.196	15	0	0.095	0.205	0.359	10	0
NO ₃	Nitrate	<0.3	1.74	<0.15	15	9	<0.3	3.4	<0.3	10	5
NO ₂	Nitrite	<0.5	0.053		15	13	<0.025	0.034	<0.05	10	9
NH ₄	Ammonium	3.65	21.16	17	15	0	1	17.43	6.67	10	1
NPOC	Non-purgeable organic carbon	3.2	60	4.2	15	0	0.8	66.6	2.1	10	0

n = number of samples, n(c) = number of samples censored

Table 4.3 Summary of the major, minor elements and dissolved organic carbon from Glasgow Observatory groundwater samples taken from the boreholes targeting the mine workings between May 2024 and November 2025.

Glasgow Upper mine workings							Glasgow Main mine workings				
		Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Major ions (mg/L)											
Ca	Calcium	103	109	105	15	0	103	108	106	10	0
Mg	Magnesium	39.6	55.2	50.3	15	0	49.6	56	54	10	0
Na	Sodium	166	199	181	15	0	163	184	173.5	10	0
K	Potassium	17.2	18.8	17.9	15	0	17.4	19	18.05	10	0
HCO ₃	Total Alkalinity	802	845	828	15	0	808	842	818.5	10	0
Cl	Chloride	70.8	72.8	79.4	15	0	71.1	80	73	10	0
SO ₄	Sulphate	142	175	166	15	0	142	163	148	10	0
HCO ₃	Bicarbonate (from field alkalinity)	758	886	846	15	0	797	859	797	10	0
Minor ions (mg/L)											
P	Phosphorus - total	<0.005	0.011	0.005	15	6	<0.005	0.011	0.007	10	4
S	Sulphur – total	51.6	66.6	58.9	15	0	49.9	57.1	52.45	10	0
Si	Silicon	3.47	5.87	5.1	15	0	3.89	5.28	4.815	10	0
Br	Bromide	<0.65	0.742	0.622	15	1	<0.65	0.623	0.5335	10	2
F	Fluoride	0.178	0.354	0.284	15	0	0.228	0.388	0.2815	10	0
NO ₃	Nitrate	<0.15	8.37	<0.3	15	9	<0.15	1.14	<0.3	10	7
NO ₂	Nitrite	<0.025	1.25	<0.037	15	11	<0.025	0.041	<0.05	10	8
NH ₄	Ammonium	10.85	19.26	15.42	15	0	3.38	17.1	14.725	10	0
NPOC	Non-purgeable organic carbon	1.6	2	69.7	15	0	1.80	69.1	2.1	10	0

n = number of samples, n(c) = number of samples censored

Table 4.4 Summary of trace elements from Glasgow Observatory groundwater samples taken from the boreholes targeting the superficial deposits and bedrock during sampling between May 2024 and November 2025.

Trace elements (µg/L)	Superficial deposits					Bedrock				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Ag Silver	<0.04			15	15	<0.04			10	10
Al Aluminium	0.9	6.7	3.2	15	0	0.9	3.9	1.7	10	0
As Arsenic	0.32	0.92	0.41	15	0	0.17	2.4	1.89	10	0
B Boron	329	656	458	15	0	157	377	252	10	0
Ba Barium	41.7	155	90.2	15	0	44.2	56.6	47.1	10	0
Be Beryllium	<0.08			15	15	<0.08			10	10
Bi Bismuth	<0.08			15	15	<0.08			10	10
Cd Cadmium	<0.005	0.013	0.007	15	4	<0.005	0.023	<0.005	10	5
Ce Cerium	0.029	0.128	0.076	15	0	0.009	0.06	0.0185	10	0
Co Cobalt	0.541	7.78	2.34	15	0	0.969	6.09	2.825	10	0
Cr Chromium	0.11	0.71	0.17	15	0	<0.04	0.19	0.09	10	1
Cs Caesium	<0.04	0.09	0.04	15	7	0.11	0.24	0.185	10	0
Cu Copper	<0.05	0.23	0.1	15	1	<0.05	0.075	0.56	10	4
Dy Dysprosium	0.011	0.035	0.016	15	0	<0.003	0.005	0.0035	10	4
Er Erbium	0.009	0.079	0.012	15	0	<0.003	0.005	<0.003	10	5
Eu Europium	<0.003	0.005	<0.003	15	8	<0.003			10	10
Fe Total iron	549	5795	1792	15	0	8.3	4130	1903.5	10	0
Ga Gallium	<0.04	0.1	<0.04	15	10	<0.04			10	10
Gd Gadolinium	0.008	0.022	0.013	15	0	<0.005	0.007		10	8
Hf Hafnium	<0.006			15	15	<0.006			10	10
Ho Holmium	<0.003	0.016	0.004	15	2	<0.003			10	10
La Lanthanum	0.016	0.065	0.043	15	0	0.004	0.024	0.0075	10	0
Li Lithium	<7			15	15	17	33	23.5	10	0
Lu Lutetium	<0.003	0.05	0.004	15	4	<0.003			10	10
Mn Manganese	1605	8099	2786	15	0	75.8	474	394.5	10	0
Mo Molybdenum	<0.2	2.5	0.5	15	1	0.4	0.9	0.5	10	0
Nb Niobium	<0.01	0.02		15	12	<0.01			10	10
Nd Neodymium	0.021	0.074	0.049	15	0	0.006	0.03	0.0125	10	0
Ni Nickel	2.79	22.6	3.8	15	0	3.52	5.36	3.835	10	0
Pb Lead	<0.02	0.12	<0.02	15	8	<0.02	0.09	<0.02	10	6
Pr Praseodymium	0.003	0.016	0.009	15	0	<0.003	0.006	<0.003	10	6
Rb Rubidium	5.83	12	8.08	15	0	16.5	48.8	30.05	10	0
Sb Antimony	<0.04	0.1	<0.04	15	9	<0.04			10	10
Se Selenium	<0.07	1.01	0.07	15	7	<0.07			10	10
Sm Samarium	<0.005	0.015	0.009	15	1	<0.005	0.006		10	9
Sn Tin	<0.08	3.41		15	14	<0.08	0.13	<0.08	10	7
Sr Strontium	570	1002	932	15	0	1935	3907	2843	10	0
Ta Tantalum	<0.006			15	15	<0.006			10	10
Tb Terbium	<0.004			15	15	<0.004			10	10
Th Thorium	<0.03			15	15	<0.03			10	10
Ti Titanium	0.07	0.34	0.14	15	0	<0.06			10	10
Tl Thallium	<0.02	0.04	0.02	15	5	<0.02	0.02	<0.02	10	8
Tm Thulium	<0.003	0.018	<0.003	15	10	<0.003			10	10
U Uranium	0.348	2.17	1.35	15	0	0.422	0.521	0.4595	10	0
V Vanadium	0.14	0.62	0.21	15	0	0.02	0.08	0.045	10	0
W Tungsten	<0.06	0.14		15	13	<0.06	0.1		10	9
Y Yttrium	0.109	0.313	0.147	15	0	0.023	0.061	0.0385	10	0
Yb Ytterbium	0.012	0.196	0.015	15	0	<0.004	0.005	<0.004	10	5
Zn Zinc	1.4	8.4	4.4	15	0	1.5	5.8	2.4	10	0
Zr Zircon	0.053	0.218	0.137	15	0	0.027	0.083	0.038	10	0

n = number of samples, n(c) = number of samples censored

Table 4.5 Summary of trace elements from Glasgow Observatory groundwater samples taken from the boreholes targeting the mine workings during sampling between May 2024 and November 2025.

		Glasgow Upper mine workings					Glasgow Main mine workings				
Trace elements (µg/L)		Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Ag	Silver	<0.04			15	15	<0.04			10	10
Al	Aluminium	<0.6	5.2	1.7	15	1	<0.6	3.1	2.1	10	1
As	Arsenic	0.05	1.52	0.56	15	0	0.08	0.2	0.16	10	0
B	Boron	282	395	369	15	0	315	393	361.5	10	0
Ba	Barium	36.2	54.5	40.2	15	0	36.6	54.5	48.35	10	0
Be	Beryllium	<0.08			15	15	<0.08			10	10
Bi	Bismuth	<0.08			15	15	<0.08			10	10
Cd	Cadmium	<0.005	0.017		15	12	<0.005	0.013		10	8
Ce	Cerium	<0.004	0.035	0.014	15	5	<0.004	0.011	0.001	10	5
Co	Cobalt	0.202	1.51	1.25	15	0	0.246	1.012	0.308	10	0
Cr	Chromium	0.06	0.15	0.08	15	0	0.09	0.13	0.115	10	0
Cs	Caesium	0.14	0.27	0.23	15	0	0.14	0.24	0.165	10	0
Cu	Copper	<0.05	13.3	0.21	15	4	<0.05	2.54	0.18	10	3
Dy	Dysprosium	<0.003	0.011	0.007	15	5	<0.003	0.009	0.0045	10	4
Er	Erbium	<0.003	0.009	0.006	15	5	<0.003	0.007	0.0045	10	4
Eu	Europium	<0.003			15	15	<0.003			10	10
Fe	Total iron	7.3	4067	2784	15	0	24	2689	1853.5	10	0
Ga	Gallium	<0.04	0.05		15	14	<0.04			10	10
Gd	Gadolinium	<0.005	0.007	0.006	15	7	<0.005			10	10
Hf	Hafnium	<0.006			15	15	<0.006			10	10
Ho	Holmium	<0.003			15	15	<0.003			10	10
La	Lanthanum	<0.003	0.017	0.008	15	5	<0.003	0.005	<0.003	10	6
Li	Lithium	28	34	31	15	0	28	34	30	10	0
Lu	Lutetium	<0.003		<0.003	15	15	<0.003			10	10
Mn	Manganese	132	445	348	15	0	323	411	339	10	0
Mo	Molybdenum	<0.2	2.1	<0.2	15	8	<0.2			10	10
Nb	Niobium	<0.01			15	15	<0.01			10	10
Nd	Neodymium	<0.005	0.027	0.012	15	5	<0.005	0.011	0	10	5
Ni	Nickel	2.84	5.63	3.37	15	0	1.76	3.02	2.02	10	0
Pb	Lead	<0.02	0.11	<0.02	15	10	<0.02	0.23	0.02	10	5
Pr	Praseodymium	<0.003	0.004	<0.003	15	10	<0.003			10	10
Rb	Rubidium	36.8	44.2	40	15	0	37.4	44.5	40.15	10	0
Sb	Antimony	<0.04	0.07		15	14	<0.04			10	10
Se	Selenium	<0.07			15	15	<0.07			10	10
Sm	Samarium	<0.005	0.007	<0.005	15	11	<0.005			10	10
Sn	Tin	<0.08	0.34		15	14	<0.08			10	10
Sr	Strontium	1820	2371	2229	15	0	1807	2282	1945	10	0
Ta	Tantalum	<0.006			15	15	<0.006			10	10
Tb	Terbium	<0.004			15	15	<0.004			10	10
Th	Thorium	<0.03			15	15	<0.03			10	10
Ti	Titanium	<0.06	0.31	<0.06	15	10	<0.06	0.08		10	8
Tl	Thallium	<0.02	0.05		15	14	<0.02			10	10
Tm	Thulium	<0.003			15	15	<0.003			10	10
U	Uranium	0.303	0.614	0.374	15	0	0.396	0.605	0.565	10	0
V	Vanadium	0.02	0.23	0.08	15	0	0.03	0.14	0.075	10	0
W	Tungsten	<0.06	0.09	<0.06	15	10	<0.06			10	10
Y	Yttrium	0.016	0.103	0.072	15	0	0.017	0.063	0.0435	10	0
Yb	Ytterbium	<0.004	0.012	0.008	15	3	<0.004	0.011	0.007	10	2
Zn	Zinc	1.7	92.5	13.1	15	0	2	28.1	6	10	0
Zr	Zircon	0.01	0.203	0.066	15	0	0.016	0.084	0.0575	10	0

n = number of samples, n(c) = number of samples censored

Table 4.6 PAH and TPH summary data from Glasgow Observatory groundwater samples taken from the boreholes targeting the superficial deposits and bedrock between May 2024 and November 2025.

Variable	Superficial					Bedrock				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
PAH (ug/L)										
Benzo(a)pyrene	<0.0016			9	9	<0.0016	0.0024		6	5
Benzo(b)fluoranthene	<0.0036			9	9	<0.0036			6	6
Benzo(ghi)perylene	<0.0036			9	9	<0.0036			6	6
Benzo(k)fluoranthene	<0.003			9	9	<0.003			6	6
Indeno(1,2,3-cd)pyrene	<0.0049			9	9	<0.0049			6	6
PAH-Total	<0.0151			9	9	<0.0151			6	6
TPH (mg/L)										
TPH (C8-C40)	<0.04	0.095	<0.04	9	7	<0.04			6	6

n = number of samples, n(c) = number of samples censored

Table 4.7 PAH and TPH summary data from Glasgow Observatory groundwater samples taken from the boreholes targeting the mine workings between May 2024 and November 2025.

Variable	Glasgow Upper mine workings					Glasgow Main mine workings				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
PAH (ug/L)										
Benzo(a)pyrene	<0.0016			9	9	<0.0016			6	6
Benzo(b)fluoranthene	<0.0036			9	9	<0.0036			6	6
Benzo(ghi)perylene	<0.0036			9	9	<0.0036			6	6
Benzo(k)fluoranthene	<0.003			9	9	<0.003			6	6
Indeno(1,2,3-cd)pyrene	<0.0049			9	9	<0.0049			6	6
PAH-Total	<0.0151			9	9	<0.0151			6	6
TPH (mg/L)										
TPH (C8-C40)	<0.04			9	9	<0.04	0.065		6	5

n = number of samples, n(c) = number of samples censored

Table 4.8 $\delta^{13}\text{C}_{\text{DIC}}$, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ summary data from Glasgow Observatory groundwater samples taken between May 2024 and November 2025.

Variable	Target horizon	Min	Max	Median	SD	n
$\delta^{13}\text{C}_{\text{DIC}}$ PDB ‰	Superficial deposits	-17.4	-11.2	-12.6	2.4	15
	Bedrock	-11.5	-7.4	-9.45	2	10
	Glasgow Upper	-11.8	-11.2	-11.4	0.2	15
	Glasgow Main	-11.8	-11.1	-11.3	0.2	10
$\delta^{18}\text{O}$ VSMOW2 ‰	Superficial deposits	-7.54	-7.36	-7.43	0.04	15
	Bedrock	-7.57	-7.43	-7.48	0.04	10
	Glasgow Upper	-7.52	-7.41	-7.46	0.03	15
	Glasgow Main	-7.54	-7.41	-7.46	0.04	10
$\delta^2\text{H}$ VSMOW2 ‰	Superficial deposits	-52.1	-49.8	-51.1	0.6	15
	Bedrock	-52.1	-50.3	-51.2	0.6	10
	Glasgow Upper	-52.6	-49.7	-50.9	0.8	15
	Glasgow Main	-52.1	-50.2	-51.1	0.7	10

n = number of samples

Table 4.9 Dissolved CH_4 , C_2H_6 and CO_2 summary data from Glasgow Observatory groundwater samples taken between May 2024 and October 2024.

Variable	Target horizon	Min	Max	Median	SD	n	n(c)
Methane (CH_4) ($\mu\text{g/L}$)	Superficial deposits	1.1	33.4	17.35		6	0
	Bedrock	3.4	92.1	44		4	0
	Glasgow Upper	0.4	397	161.5		6	0
	Glasgow Main	0.4	211	148.5		4	0
Ethane (C_2H_6) ($\mu\text{g/L}$)	Superficial deposits	<1				6	6
	Bedrock	<1				4	4
	Glasgow Upper	<1				6	6
	Glasgow Main	<1				4	4
Carbon Dioxide (CO_2) (mg/L)	Superficial deposits	104	256	204		6	0
	Bedrock	126	172	142		4	0
	Glasgow Upper	135	160	151.5		6	0
	Glasgow Main	135	142	138		4	0

n = number of samples, n(c) = number of samples censored

4.2 SURFACE WATER HYDROCHEMICAL SUMMARY DATA

This section presents the summary tables of the hydrochemical results of the surface waters at the 5 sampling locations on the River Clyde and at the additional monitoring site on the Tollcross Burn, sampled between May 2024 – November 2025. Samples from the River Clyde sites are reported as a separate group to those from the Tollcross Burn, given the different hydrochemistry observed in pre- September 2022 monitoring rounds.

Table 4.10 shows summary statistics for physico-chemical parameters from the surface water sites.

Table 4.11 shows summary statistics for major ions, minor ions and dissolved organic carbon in the surface water samples.

Table 4.12 shows summary statistics for trace elements in the surface water samples.

Table 4.13 shows summary statistics for PAH and TPH concentrations in the surface water samples. These represent summaries of samples taken during rounds 34, 35 and 37 only (see Section 2.2.2 for details).

Table 4.14 shows summary statistics for $\delta^{13}\text{C}_{\text{DIC}}$, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in the surface water samples.

Table 4.10 Physico-chemical parameters summary data from Glasgow Observatory surface water sites measured during sampling rounds between May 2024 and November 2025.

Field parameters	River Clyde					Tollcross Burn				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
pH	7.35	8.2	7.95	22	0	7.59	8.28	8.2	5	0
Temperature (°C)	3.8	24.9	7.6	22	0	6.7	17.7	8.4	5	0
Eh (mV)	210	463	403	22	0	359	448.5	435.1	5	0
Dissolved oxygen (mg/L)	8.25	12.2	10.8	22	0	8.94	11.06	10.6	5	0
Specific electrical conductance (µS/cm)	211	2025	310	22	0	637	1044	1031	5	0

n = number of samples, n(c) = number of samples censored

Table 4.11 Summary of the major ions, minor elements and dissolved organic carbon in Glasgow Observatory surface water samples taken between May 2024 and November 2025

		River Clyde					Tollcross Burn				
		Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Major ions (mg/L)											
Ca	Calcium	17.5	37.8	24.75	22	0	54.3	85.8	77	5	0
Mg	Magnesium	4.56	11.2	7.375	22	0	14.3	37.3	30.7	5	0
Na	Sodium	13	21	19.25	22	0	39.6	80.9	78.6	5	0
K	Potassium	2.09	4.49	2.925	22	0	6	14.7	11.4	5	0
HCO ₃	Bicarbonate (field measured)	58	139	91	22	0	222	490	375	5	0
Cl	Chloride	15.7	32	25.55	22	0	39.2	84	65.9	5	0
SO ₄	Sulphate	13.5	33.1	20.7	22	0	37.9	75.7	66.6	5	0
HCO ₃	Total Alkalinity	57.4	142	87.5	22	0	232	456	402	5	0
Minor ions (mg/L)											
P	Phosphorus - total	0.032	0.172	0.077	22	0	0.014	0.031	0.021	5	0
S	Sulphur – total	4.7	12.5	7.375	22	0	13.6	28	24.5	5	0
Si	Silicon	2.78	4.29	3.385	22	0	4.26	5.99	5.32	5	0
Br	Bromide	<0.13	0.074	0.0475	22	5	<0.13	0.252	0.227	5	1
F	Fluoride	0.047	0.1	0.075	22	0	0.172	0.243	0.211	5	0
NO ₂	Nitrite	<0.1	0.248	0.125	22	5	<0.025	0.131	0.099	5	2
NO ₃	Nitrate	0.519	13.5	8.035	22	0	4.16	9.77	7.31	5	0
NPOC	Non-purgeable organic carbon	3.6	9.5	4.7	22	0	2.1	4.4	2.6	5	0

n = number of samples, n(c) = number of samples censored

Table 4.12 Summary of trace element concentrations in Glasgow Observatory surface water samples taken between May 2024 and November 2025

		River Clyde					Tollcross Burn				
Trace elements (µg/L)		Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
Ag	Silver	<0.04	0.05		22	21	<0.04			5	5
Al	Aluminium	22.8	106	32.2	22	0	4.4	23.6	6.6	5	0
As	Arsenic	0.22	0.5	0.33	22	0	0.24	0.41	0.26	5	0
B	Boron	<53			22	22	70	168	125	5	0
Ba	Barium	58.2	135	74	22	0	47.6	61.2	59	5	0
Be	Beryllium	<0.08			22	22	<0.08			5	5
Bi	Bismuth	<0.08			22	22	<0.08			5	5
Cd	Cadmium	0.005	0.023	0.01	22	0	0.011	0.038	0.028	5	0
Ce	Cerium	0.049	0.403	0.0915	22	0	0.004	0.056	0.01	5	0
Co	Cobalt	0.124	0.222	0.1685	22	0	0.22	1.66	0.928	5	0
Cr	Chromium	0.26	15.6	0.38	22	0	0.07	0.54	0.09	5	0
Cs	Caesium	<0.04	0.04		22	19	<0.04	0.07	0.06	5	2
Cu	Copper	0.72	3.14	0.905	22	0	1.79	3.21	2.81	5	0
Dy	Dysprosium	0.009	0.053	0.0155	22	0	<0.003	0.008	0.004	5	2
Er	Erbium	0.005	0.029	0.0095	22	0	<0.003	0.006	0.003	5	1
Eu	Europium	<0.003	0.016	0.005	22	3	<0.003			5	5
Fe	Total iron	191	420	322	22	0	22.3	160	31.8	5	0
Ga	Gallium	<0.04	0.04		22	21	<0.04	0.04		5	4
Gd	Gadolinium	0.014	0.067	0.0255	22	0	0.006	0.028	0.007	5	0
Hf	Hafnium	<0.006	0.008	<0.006	22	17	<0.006			5	5
Ho	Holmium	<0.003	0.01	0.004	22	8	<0.003			5	5
La	Lanthanum	0.034	0.217	0.059	22	0	<0.003	0.031	0.006	5	1
Li	Lithium	<7			22	22	7	19	14	5	0
Lu	Lutetium	<0.003	0.004	<0.003	22	16	<0.003			5	5
Mn	Manganese	21.7	72.5	33.55	22	0	25.4	41.6	34.9	5	0
Mo	Molybdenum	<0.2	0.5	0.3	22	3	0.6	0.9	0.6	5	0
Nb	Niobium	<0.01	0.02	<0.01	22	16	<0.01			5	5
Nd	Neodymium	0.038	0.283	0.078	22	0	<0.005	0.038	0.012	5	1
Ni	Nickel	0.97	2.61	1.39	22	0	1.45	3.31	2.23	5	0
Pb	Lead	0.29	1.52	0.49	22	0	0.03	0.19	0.04	5	0
Pr	Praseodymium	0.009	0.064	0.017	22	0	<0.003	0.008	<0.003	5	3
Rb	Rubidium	2.18	4.55	2.795	22	0	8.25	23.4	16.2	5	0
Sb	Antimony	0.1	0.26	0.135	22	0	0.17	0.65	0.26	5	0
Se	Selenium	0.1	0.27	0.115	22	0	0.14	0.52	0.34	5	0
Sm	Samarium	0.006	0.063	0.019	22	0	<0.005	0.01	0.006	5	2
Sn	Tin	<0.08	0.19		22	20	<0.08			5	5
Sr	Strontium	85.9	229	129.5	22	0	578	1439	1189	5	0
Ta	Tantalum	<0.006			22	22	<0.006			5	5
Tb	Terbium	<0.004	0.009	<0.004	22	14	<0.004			5	5
Th	Thorium	<0.03	0.04		22	19	<0.03			5	5
Ti	Titanium	0.29	5.87	0.54	22	0	<0.06	1.09	<0.06	5	3
Tl	Thallium	<0.02			22	22	<0.02			5	5
Tm	Thulium	<0.003	0.004	<0.003	22	17	<0.003			5	5
U	Uranium	0.075	0.184	0.125	22	0	0.319	0.393	0.377	5	0
V	Vanadium	0.36	1.2	0.54	22	0	0.31	0.79	0.34	5	0
W	Tungsten	<0.06			22	22	<0.06			5	5
Y	Yttrium	0.052	0.286	0.1	22	0	0.022	0.051	0.027	5	0
Yb	Ytterbium	0.005	0.023	0.008	22	0	<0.004	0.008	0.005	5	2
Zn	Zinc	3	33.9	4.5	22	0	6.7	17.4	9.6	5	0
Zr	Zircon	0.043	0.333	0.066	22	0	0.021	0.084	0.031	5	0

n = number of samples, n(c) = number of samples censored

Table 4.13 PAH and TPH summary data from Glasgow Observatory surface water samples taken between May 2024 and November 2025.

Variable	River Clyde					Tollcross Burn				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
PAH (ug/L)										
Benzo(a)pyrene	<0.0016	0.0116	0.0019	14	6	<0.0016	0.0057		3	2
Benzo(b)fluoranthene	<0.0036	0.0147	<0.0036	14	11	<0.0036	0.0075		3	2
Benzo(ghi)perylene	<0.0036	0.0049		14	12	<0.0036	0.0042		3	2
Benzo(k)fluoranthene	<0.003	0.0043		14	13	<0.003			3	3
Indeno(1,2,3-cd)pyrene	<0.0049	0.006	<0.0049	14	9	<0.0049	0.0055		3	2
PAH-Total	<0.0151	0.0297		14	13	<0.0151	0.0183		3	2
TPH (mg/L)										
TPH (C8-C40)	<0.04			10	10	<0.004			2	2

n = number of samples, n(c) = number of samples censored

Table 4.14 $\delta^{13}\text{C}_{\text{DIC}}$, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ summary data from Glasgow Observatory surface water samples taken between May 2024 and November 2025.

	River Clyde					Tollcross Burn				
	Min	Max	Median	n	n(c)	Min	Max	Median	n	n(c)
$\delta^{13}\text{C}_{\text{DIC}}$ PDB ‰	-17.4*	-10.1	-11.95	22	1	-13.8	-10.4	-11.7	5	0
$\delta^{18}\text{O}$ VSMOW2 ‰	-7.82	-7.02	-7.2	22	0	-7.69	-7.24	-7.34	5	0
$\delta^2\text{H}$ VSMOW2 ‰	-54.2	-46	-48.25	22	0	-55	-48.9	-51	5	0

*1 sample could not be quantified with confidence

4.3 SURFACE WATER QUALITY

To assess the water quality at the Glasgow Observatory the water chemistry results were compared to water environmental quality standards (EQS). For surface waters, EQS for “good” river status were used (SEPA, 2014, 2020a; UKTAG, 2013) consistent with previous UKGEOS reports (Bearcock et al., 2023; Bearcock et al., 2022; Fordyce et al., 2021). There is no UK river water NO_3 standard, so commonly referenced European Standards were used instead (Polikane et al., 2019). It should be noted that the SEPA classify the River Clyde from North Calder to the tidal weir as a heavily modified water body with moderate, rather than good ecological status (SEPA, 2020b). However, the approach established by Fordyce et al. (2021) has been continued here: that is to compare data with the “good” EQS annual average (AA) and maximum allowable concentrations (MAC) to provide an indication of the impacts of urbanisation on the surface water chemistry.

From May 2024 to November 2025 monitored parameters for the River Clyde and Tollcross Burn samples were generally within the AA limits for good river status. Similarly, individual values were compared to the MAC, which also were generally below limits required for good river status. Data not within AA or MAC are detailed below. The data in this report span over a year, where AA allowances are exceeded, continuous periods of a year are also assessed.

- The mean NO_3 concentration in both the River Clyde (8.1 mg/L) and Tollcross Burn (7.1 mg/L) exceed the AA of 5.7 mg/L. There is no continuous yearly period within the monitoring where the average would be less than the AA value.
- The mean HPO_4 concentration in the River Clyde (0.113 mg/L – using half the detection limit to allow calculation) exceeded the AA of 0.069 mg/L. While there is no continuous yearly period within the monitoring where the average is less than the AA value, it should be noted that the mean was calculated using half detection limit values, so the true annual average may be different. As a guide the median value was 0.016 mg/L.

- The mean Al concentration in the River Clyde (52.1 µg/L) exceeds the AA of 15 µg/L. the MAC of 25 µg/L is exceeded in 19 of the 22 samples. There is no continuous yearly period within the monitoring where the average would be less than the AA value.
- The mean total Cu concentration in the River Clyde is 1.4 µg/L and Tollcross Burn 2.6 µg/L. When compared to the bioavailable Cu AA of 1 µg/L, given that only a fraction of the total concentration is deemed to be bioavailable, Cu is not considered to be exceeding the quality threshold.
- The AA limit for the combined total of benzo(ghi)perylene and indeno(1,2,3-cd)pyrene is 0.002 µg/L. The detection limit for each of these compounds is greater than the AA (0.0036 µg/L and 0.0049 µg/L, respectively). These parameters were not analysed on every sample round, but where they were, around a third of all surface water samples had detectable benzo(ghi)perylene and/or indeno(1,2,3-cd)pyrene. However, it is difficult to calculate a meaningful mean, given half the detection limit of indeno(1,2,3-cd)pyrene is greater than the AA limit.

The AA exceedances are similar to those reported in previous data release reports (Bearcock et al., 2023; Bearcock et al., 2022; Fordyce et al., 2021; Palumbo-Roe et al., 2025).

5 Conclusion

This report presents a summary of the data from sampling rounds 33 to 37 of the UKGEOS Glasgow Observatory groundwater and surface water monitoring. Section 1 introduces the Observatory, for background information. Section two summarises the field methodology. Section 3 describes the data presentation. Section 4 presents a series of tables presenting summary statistics and a comparison of the water data to WQS. Quality control and a summary of laboratory methodologies are discussed in the Appendix.

More detailed information summaries of previous data releases can be found in the previous data release reports (Bearcock et al., 2023; Bearcock et al., 2022; Fordyce et al., 2021; Palumbo-Roe et al., 2025; Palumbo-Roe et al., 2021). The current report represents a format change to a summary of the data, without additional description, which will be the default format for these reports for future monitoring rounds.

Appendix 1 Data Quality Control

Quality control for each analytical method is discussed below; where QC data do not meet the required quality for a given element this is noted and the analysis data for this element should be treated with caution. To ensure data quality, the groundwater samples were analysed where possible using methods accredited to ISO17025:2017 by the United Kingdom Accreditation Service (UKAS).

Where analyses are provided by external laboratories, the descriptions of the method are limited by the information provided by the laboratory.

As part of data quality control (QC), time versus concentration plots showed no systematic analytical drift either within or between batches for any of the following analytical methods. HCO_3 concentrations were compared between the field and the lab, identifying errors associated with the field HCO_3 concentrations for GF36-01 and GF36-06. Field sheets were consulted and corrections were made. Comparison between total sulphur concentrations and sulphate ion concentrations showed acceptable results with all samples. SEC values were compared to TDS concentrations, with most samples within the acceptable range, apart from GF36-01 which likely contains erroneous SEC or TDS data. A piper plot of the data was produced and compared to piper diagrams from previous reports to check the results are consistent.

Long-term lower limits of detection (LLD) and/or limits of quantification (LOQ) for the analytical methods used can be found in Bearcock et al. (2022), and Fordyce et al. (2021).

Where there are sample-specific QC concerns, for example the UKAS accreditation was lost or there is another reason to treat the sample with caution, it is noted in a field in the data release spreadsheet. Affected parameters are typically radon in round 35, and VOS, PAH and TPH in round 37.

FIELD DATA QUALITY CONTROL

As a quality control (QC) measure of the field method, one field duplicate sample set was collected in every sampling round, from a location chosen at random. The field duplicate sample set was collected in exactly the same way as the primary sample set from that location. As a further QC check, two field blank water samples were included in each monthly batch of samples. These samples were made back in the office using Type 1 ultrapure (UP) water and were a check on any contamination from the sampling method or equipment (Johnson, 2005). A detailed description of the field data quality control method is provided in Fordyce et al. (2021). The results for field duplicate analyses are reported in Table A 1 and described in the following sections with the other QC associated to the relevant analysis.

The field measured parameters generally had an acceptable variability ($\text{RSD} < 20\%$). The exceptions to this were:

- Eh: Samples from one round had an RSD of 30%
- DO: Samples from two rounds had RSDs of 24 and 107%

Table A 1 Results for field duplicate analyses

Round Number		33	33			34	34		
Sample ID		GF33-08	GF33-10	Mean	RSD (%)	GF34-10	GF34-18	Mean	RSD (%)
Field duplicate		Dup B	Dup A			Dup A	Dup B		
Borehole		GGA03r	GGA03r			GGA07	GGA07		
Date		28/05/24	28/05/24			04/10/2024	04/10/2024		
Analyte	Units								
Field parameters									
pH		7.05	7.03	7.04	0.2	6.9	7.0	6.94	0.6
Temperature	°C	12.2	12.0	12.1	1.2	11.8	12.0	11.9	1.1
Eh	mV	132	157	144	12.1	116	120	118	2.5
DO	mg/L	0.17	0.24	0.205	24.1	0.67	0.09	0.38	107.9
SEC	µS/cm	1585	1568	1576	0.8	1678	1660	1669	0.8
Field-HCO ₃	mg/L	788	788	788	0	877	898	887	1.7
Major & Minor Anions									
Lab-HCO ₃	mg/L								
Cl	mg/L	51.1	54.7	52.9	4.8	71.3	70.9	71.1	0.4
SO ₄	mg/L	223	238	230	4.6	174.0	173	173	0.4
NO ₃	mg/L	<0.3	<0.3			<0.15	<0.15		
Br	mg/L	0.760	0.710	0.735	4.8	0.660	0.640	0.647	2.5
NO ₂	mg/L	<0.05	<0.05			<0.025	<0.025		
HPO ₄	mg/L	<0.1	<0.1			<0.05	<0.05		
F	mg/L	0.195	0.095	0.145	48.8	0.287	0.288	0.2875	0.2
Major & Minor Cations									
Ca	mg/L	139	140	140	0.51	107	95	101	8
Mg	mg/L	81.9	81.8	81.9	0.09	52.4	53.6	53.0	1.6
Na	mg/L	107	108	108	0.7	191	175	183	6.2
K	mg/L	8.84	8.77	8.81	0.6	17.7	16.0	16.9	7.1
P-Total	mg/L	<0.005	<0.005			0.005	<0.005		
S-Total	mg/L	79.4	82.1	80.8	2.4	66.6	49.5	58.1	20.8
Sulphide as S	mg/L	<0.02	<0.02			0.02	<0.02		
Si	mg/L	5.60	5.63	5.62	0.4	4.33	4.78	4.56	7
SiO ₂	mg/L	12.0	12.0	12.0	0	9.26	10.2	9.73	6.8
NH ₄	mg/L	4.24	3.94	4.09	5.2	19.3	18.1	18.7	4.3
Trace Elements									
Ba	µg/L	36.8	44.3	40.6	13.1	39.8	33.8	36.8	11.5
Sr	µg/L	3640	3620	3630	0.4	2360	2070	2220	9.2
Mn	µg/L	287	354	320	14.8	415	428	421	2.2
Fe-Total	µg/L	584	264	424	53.4	2888	2507	2697	10
Reduced Fe	µg/L	630	450	540	23.6	3080	3000	3040	1.9
Li	µg/L	18	18	18	0	34	30	32	8.8
Be	µg/L	<0.08	<0.08			<0.08	<0.08		
B	µg/L	169	178	173	3.7	395	436	415	7
Al	µg/L	0.9	0.9	0.9	0	1.4	1.2	1.3	10.9
Ti	µg/L	<0.06	<0.06			<0.06	<0.06		
V	µg/L	0.04	0.02	0.03	47.1	0.07	0.04	0.055	38.6
Cr-Total	µg/L	<0.04	0.04			0.07	0.07	0.07	0
Co	µg/L	5.75	6.09	5.92	4.1	1.51	1.18	1.345	17.3
Ni	µg/L	5.02	5.36	5.19	4.6	4.00	3.18	3.59	16.2
Cu	µg/L	<0.05	0.56			1.71	0.44	1.08	83.5
Zn	µg/L	5.40	5.80	5.6	5.1	13.5	8.8	11.2	29.8
Ga	µg/L	<0.04	<0.04			<0.04	0.04		
As	µg/L	2.47	2.15	2.31	9.8	0.52	0.43	0.48	13.4
Se	µg/L	<0.07	<0.07			<0.07	<0.07		
Rb	µg/L	17.2	17.7	17.4	2	40.3	36	38.1	8
Y	µg/L	0.03	0.04	0.037	9.7	0.091	0.082	0.087	7.4
Zr	µg/L	0.075	0.067	0.071	8	0.074	0.057	0.066	18.4
Nb	µg/L	<0.01	<0.01			<0.01	<0.01		
Mo	µg/L	0.40	0.40	0.4	0	<0.2	<0.2		
Ag	µg/L	<0.04	<0.04			<0.04	<0.04		
Cd	µg/L	<0.005	0.01			0.009	0.015	0.012	35.4
Sn	µg/L	<0.08	0.13			<0.08	<0.08		
Sb	µg/L	<0.04	<0.04			<0.04	<0.04		

Round Number		33	33			34	34		
Sample ID		GF33-08	GF33-10	Mean	RSD (%)	GF34-10	GF34-18	Mean	RSD (%)
Field duplicate		Dup B	Dup A			Dup A	Dup B		
Borehole		GGA03r	GGA03r			GGA07	GGA07		
Date		28/05/24	28/05/24			04/10/2024	04/10/2024		
Analyte	Units								
Cs	µg/L	0.11	0.12	0.115	6.1	0.26	0.23	0.245	8.7
La	µg/L	0.01	0.01	0.008	17.7	0.009	0.007	0.008	17.7
Ce	µg/L	0.024	0.017	0.0205	24.1	0.014	0.014	0.014	0
Pr	µg/L	<0.003	<0.003			<0.003	<0.003		
Nd	µg/L	0.011	0.010	0.0105	6.7	0.012	0.012	0.012	0
Sm	µg/L	<0.005	<0.005			<0.005	0.005		
Eu	µg/L	<0.003	<0.003			<0.003	<0.003		
Gd	µg/L	<0.005	<0.005			0.007	<0.005		
Tb	µg/L	<0.004	<0.004			<0.004	<0.004		
Dy	µg/L	<0.003	0.003			0.01	0.01	0.01	0
Ho	µg/L	<0.003	<0.003			<0.003	<0.003		
Er	µg/L	<0.003	<0.003			0.007	0.008	0.0075	9.4
Tm	µg/L	<0.003	<0.003			<0.003	<0.003		
Yb	µg/L	<0.004	<0.004			0.009	0.009	0.009	0
Lu	µg/L	<0.003	<0.003			<0.003	<0.003		
Hf	µg/L	<0.006	<0.006			<0.006	<0.006		
Ta	µg/L	<0.006	<0.006			<0.006	<0.006		
W	µg/L	<0.06	<0.06			<0.06	<0.06		
Tl	µg/L	0.03	0.02	0.025	28.3	<0.02	<0.02		
Pb	µg/L	0.03	0.09	0.06	70.7	0.06	0.04	0.05	28.3
Bi	µg/L	<0.08	<0.08			<0.08	<0.08		
Th	µg/L	<0.03	<0.03			<0.03	<0.03		
U	µg/L	0.46	0.49	0.476	3.9	0.353	0.335	0.344	3.7
Stable Isotopes									
δ ¹³ C (PDB)	‰	-7.60	-7.50	-7.55	-0.93	-11.30	-11.60	-11.45	-1.8
δ ¹⁸ O (VSMOW2)	‰	-7.52	-7.49	-7.505	-0.28	-7.44	-7.46	-7.45	-0.2
δD (VSMOW2)	‰	-52.20	-51.40	-51.8	-1.09	-51.60	-51.80	-51.7	-0.3
Dissolved gases									
CH ₄	µg/L	14	11	12.5	17	397	223	310	39.7
C ₂ H ₆	µg/L	<1.0	<1.0			<1.0	<1.0		
CO ₂	mg/L	126	131	128.5	2.8	159	159	159	0
Organic parameters									
NPOC	mg/L	1.10	1.10	1.1	0	1.6	1.6	1.6	0
Benzo(b)fluoranthene	µg/L					<0.0036	<0.0036		
Benzo(k)fluoranthene	µg/L					0.0030	0.0030		
Benzo(a)pyrene	µg/L					<0.0016	<0.0016		
Benzo(ghi)perylene	µg/L					<0.0036	<0.0036		
Indeno(1,2,3-cd)pyrene	µg/L					<0.0049	<0.0049		
PAH-Total	µg/L					<0.0151	<0.0151		
TPH (C8-C40)	mg/L					<0.0040	<0.0040		

Round Number		35	35	Mean	RSD (%)	36	36	Mean	RSD (%)
Sample ID		GF35-14	GF35-17			GF36-09	GF36-15		
Field duplicate		Dup B	Dup A			Dup B	Dup A		
Borehole		GGA08	GGA08			GGA04	GGA04		
Date		22/01/25	22/01/25			05/03/25	05/03/25		
Analyte	Units								
Field parameters									
pH		7.07	7.08	7.075	0.1	7.12	7.09	7.105	0.3
Temperature	°C	9.2	9.2	9.2	0	11.1	11.0	11.1	0.6
Eh	mV	351	350	351	0.1	120	114	117	3.6
DO	mg/L	1.43	1.23	1.33	10.6	0.40	0.39	0.395	1.8
SEC	µS/cm	1669	1655	1662	0.6	1669	1663	1666	0.3
Field-HCO ₃	mg/L	832	839	836	0.6	810	814	812	0.4
Major & Minor Anions									
Lab-HCO ₃	mg/L								
Cl	mg/L	71.3	71.1	71.2	0.2	79.0	79.4	79.2	0.4
SO ₄	mg/L	164	163	163	0.4	160	161	160	0.4
NO ₃	mg/L	0.791	0.813	0.802	1.9	<0.15	<0.15		
Br	mg/L	0.629	0.623	0.626	0.7	0.604	0.594	0.599	1.2
NO ₂	mg/L	<0.025	<0.025			0.04	0.04	0.036	1.9
HPO ₄	mg/L	<0.05	<0.05			<0.05	<0.05		
F	mg/L	0.306	0.304	0.305	0.5	0.229	0.228	0.228	0.3
Major & Minor Cations									
Ca	mg/L	108	108	108	0	105	106	105	0.7
Mg	mg/L	49.2	50.2	49.7	1.4	52.2	55.0	53.6	3.7
Na	mg/L	178	184	181	2.3	183	178	180	2
K	mg/L	17.3	17.6	17.5	1.2	18.3	17.7	18	2.4
P-Total	mg/L	<0.005	<0.005			0.006	0.010	0.008	35.4
S-Total	mg/L	61.0	57.1	59.1	4.7	53.7	51.6	52.7	2.8
Sulphide as S	mg/L	<0.02	<0.02			0.04	0.02	0.03	47.1
Si	mg/L	5.15	5.28	5.22	1.8	6.00	5.52	5.76	5.9
SiO ₂	mg/L	11.0	11.3	11.2	1.9	12.8	11.8	12.3	5.7
NH ₄	mg/L	16.9	17.1	17	0.8	13.15	13.3	13.2	0.5
Trace Elements									
Ba	µg/L	36.7	36.6	36.7	0.2	53.1	52.7	52.9	0.5
Sr	µg/L	2210	2280	2250	2.3	1960	1940	1950	0.8
Mn	µg/L	410	411	411	0.2	358	352	355	1.2
Fe-Total	µg/L	21.3	24.0	22.7	8.4	4010	3930	3970	1.
Reduced Fe	µg/L	190	180	185	3.8	4560	4560	4560	0
Li	µg/L	32.0	34.0	33.0	4.3	30.0	28.0	29.0	4.9
Be	µg/L	<0.08	<0.08			<0.08	<0.08		
B	µg/L	318	333	325	3.3	369	369	369	0
Al	µg/L	2.1	2.2	2.15	3.3	3.3	3.2	3.25	2.2
Ti	µg/L	<0.06	<0.06			0.29	0.29	0.29	0
V	µg/L	0.05	0.04	0.045	15.7	0.18	0.17	0.175	4
Cr-Total	µg/L	0.08	0.09	0.085	8.3	0.11	0.13	0.12	11.8
Co	µg/L	0.982	1.01	0.997	2.1	1.21	1.19	1.2	1.2
Ni	µg/L	2.97	3.02	3.00	1.2	2.90	3.09	3.00	4.5
Cu	µg/L	0.47	0.54	0.505	9.8	<0.05	0.48		
Zn	µg/L	2.6	2.2	2.4	11.8	1.1	5.7	3.4	95.7
Ga	µg/L	<0.04	<0.04			<0.04	<0.04		
As	µg/L	0.09	0.09	0.09	0	1.22	1.16	1.19	3.6
Se	µg/L	<0.07	<0.07			<0.07	<0.07		
Rb	µg/L	40.7	41.7	41.2	1.7	37.1	37.6	37.4	0.9
Y	µg/L	0.021	0.025	0.023	12.3	0.075	0.073	0.074	1.9
Zr	µg/L	0.037	0.035	0.036	3.9	0.172	0.173	0.173	0.4
Nb	µg/L	<0.01	<0.01			<0.01	<0.01		
Mo	µg/L	<0.2	<0.2			0.9	1.0	0.95	7.4
Ag	µg/L	<0.04	<0.04			<0.04	<0.04		
Cd	µg/L	<0.005	<0.005			<0.005	0.017		
Sn	µg/L	<0.08	<0.08			<0.08	0.34		
Sb	µg/L	<0.04	<0.04			<0.04	<0.04		
Cs	µg/L	0.25	0.24	0.245	2.9	0.22	0.24	0.23	6.1
La	µg/L	<0.003	<0.003			0.013	0.014	0.0135	5.2

Round Number		35	35	Mean	RSD (%)	36	36	Mean	RSD (%)
Sample ID		GF35-14	GF35-17			GF36-09	GF36-15		
Field duplicate		Dup B	Dup A			Dup B	Dup A		
Borehole		GGA08	GGA08			GGA04	GGA04		
Date		22/01/25	22/01/25			05/03/25	05/03/25		
Analyte	Units								
Ce	µg/L	<0.004	<0.004			0.028	0.028	0.028	0
Pr	µg/L	<0.003	<0.003			0.004	0.003	0.0035	20.2
Nd	µg/L	<0.005	<0.005			0.018	0.016	0.017	8.3
Sm	µg/L	<0.005	<0.005			<0.005	0.007		
Eu	µg/L	<0.003	<0.003			<0.003	<0.003		
Gd	µg/L	<0.005	<0.005			<0.005	0.006		
Tb	µg/L	<0.004	<0.004			<0.004	<0.004		
Dy	µg/L	<0.003	<0.003			0.006	0.007	0.0065	10.9
Ho	µg/L	<0.003	<0.003			<0.003	<0.003		
Er	µg/L	<0.003	<0.003			0.006	0.005	0.0055	12.9
Tm	µg/L	<0.003	<0.003			<0.003	<0.003		
Yb	µg/L	0.005	0.006	0.0055	12.9	0.008	0.008	0.008	0
Lu	µg/L	<0.003	<0.003			<0.003	<0.003		
Hf	µg/L	<0.006	<0.006			<0.006	<0.006		
Ta	µg/L	<0.006	<0.006			<0.006	<0.006		
W	µg/L	<0.06	<0.06			0.06	0.06	0.06	0
Tl	µg/L	<0.02	<0.02			<0.02	<0.02		
Pb	µg/L	<0.02	<0.02			<0.02	0.05		
Bi	µg/L	<0.08	<0.08			<0.08	<0.08		
Th	µg/L	<0.03	<0.03			<0.03	<0.03		
U	µg/L	0.395	0.396	0.3955	0.2	0.572	0.570	0.571	0.2
Stable Isotopes									
δ ¹³ C (PDB)	‰	-11.60	-11.80	-11.7	-1.2	-11.50	-11.50	-11.5	0
δ ¹⁸ O (VSMOW2)	‰	-7.49	-7.47	-7.48	-0.2	-7.44	-7.47	-7.455	-0.3
δD (VSMOW2)	‰	-51.80	-50.20	-51	-2.2	-50.7	-49.7	-50.2	-1.4
Dissolved gases									
CH ₄	µg/L								
C ₂ H ₆	µg/L								
CO ₂	mg/L								
Organic parameters									
NPOC	mg/L	1.60	1.80	1.7	8.3	2.20	2.00	2.1	6.7
Benzo(b)fluoranthene	µg/L	<0.0036	<0.0036						
Benzo(k)fluoranthene	µg/L	<0.0030	<0.0030						
Benzo(a)pyrene	µg/L	<0.0016	<0.0016						
Benzo(ghi)perylene	µg/L	<0.0036	<0.0036						
Indeno(1,2,3-cd)pyrene	µg/L	<0.0049	<0.0049						
PAH-Total	µg/L	<0.0151	<0.0151						
TPH (C8-C40)	mg/L	<0.040	<0.040						

Round Number Sample ID Field duplicate Borehole Date		37 GF37-17 Dup A GGB05 26/11/25	37 GF37-18 Dup B GGB05 26/11/25	Mean	RSD (%)
Analyte	Units				
Field parameters					
pH		6.9	6.9	6.9	0.3
Temperature	°C	10.4	11.0	10.7	4
Eh	mV	44.2	68.0	56.1	30
DO	mg/L	0.28	0.22	0.25	17
SEC	µS/cm	1660	1660	1660	0
Field-HCO ₃	mg/L	815	811	813	0.3
Major & Minor Anions					
Lab-HCO ₃	mg/L				
Cl	mg/L	75.6	76.5	76.1	0.8
SO ₄	mg/L	158	160	159	0.9
NO ₃	mg/L	1.09	1.14	1.12	3.2
Br	mg/L	<0.65	<0.65		
NO ₂	mg/L	<0.5	<0.5		
HPO ₄	mg/L	<0.08	<0.08		
F	mg/L	0.294	0.306	0.300	2.8
Major & Minor Cations					
Ca	mg/L	103	103	103	0
Mg	mg/L	53.4	52.8	53.1	0.8
Na	mg/L	172.0	172.0	172	0
K	mg/L	19.7	19.6	19.7	0.4
P-Total	mg/L	<0.005	<0.005		
S-Total	mg/L	55.2	55.2	55.2	0
Sulphide as S	mg/L	<0.02	<0.02		
Si	mg/L	5.44	5.35	5.40	1.2
SiO ₂	mg/L	11.6	11.4	11.5	1.2
NH ₄	mg/L	16.4	16.2	16.3	0.9
Trace Elements					
Ba	µg/L	56.4	49.7	53.1	8.9
Sr	µg/L	2070	2060	2070	0.1
Mn	µg/L	456	416	436	6.5
Fe-Total	µg/L	3540	3610	3580	1.3
Reduced Fe	µg/L	4000	4110	4060	1.9
Li	µg/L	30	30	30	0
Be	µg/L	<0.08	<0.08		
B	µg/L	355	346	350	1.8
Al	µg/L	3.9	4.2	4.05	5.2
Ti	µg/L	<0.06	0.06		
V	µg/L	0.07	0.07	0.07	0
Cr-Total	µg/L	0.09	0.08	0.085	8.3
Co	µg/L	2.8	2.8	2.8	0
Ni	µg/L	3.81	3.74	3.78	1.3
Cu	µg/L	<0.05	0.06		
Zn	µg/L	1.6	3.2	2.4	47.1
Ga	µg/L	<0.04	<0.04		
As	µg/L	1.98	1.90	1.94	2.9
Se	µg/L	<0.07	<0.07		
Rb	µg/L	48.8	48.5	48.7	0.4
Y	µg/L	0.049	0.043	0.046	9.2
Zr	µg/L	0.038	0.041	0.0395	5.4
Nb	µg/L	<0.01	<0.01		
Mo	µg/L	0.5	0.5	0.5	0
Ag	µg/L	<0.04	<0.04		
Cd	µg/L	<0.005	<0.005		
Sn	µg/L	<0.08	<0.08		
Sb	µg/L	<0.04	<0.04		
Cs	µg/L	0.22	0.22	0.22	0

Round Number		37	37		
Sample ID		GF37-17	GF37-18	Mean	RSD (%)
Field duplicate		Dup A	Dup B		
Borehole		GGB05	GGB05		
Date		26/11/25	26/11/25		
Analyte	Units				
La	µg/L	0.024	0.02	0.022	12.9
Ce	µg/L	0.06	0.05	0.055	12.9
Pr	µg/L	0.006	0.005	0.0055	12.9
Nd	µg/L	0.03	0.021	0.0255	25
Sm	µg/L	0.006	<0.005		
Eu	µg/L	<0.003	<0.003		
Gd	µg/L	0.007	<0.005		
Tb	µg/L	<0.004	<0.004		
Dy	µg/L	0.004	0.005	0.0045	15.7
Ho	µg/L	<0.003	<0.003		
Er	µg/L	0.003	0.004	0.0035	20.2
Tm	µg/L	<0.003	<0.003		
Yb	µg/L	0.005	0.006	0.0055	12.9
Lu	µg/L	<0.003	<0.003		
Hf	µg/L	<0.006	<0.006		
Ta	µg/L	<0.006	<0.006		
W	µg/L	<0.06	<0.06		
Tl	µg/L	<0.02	0.02		
Pb	µg/L	<0.02	<0.02		
Bi	µg/L	<0.08	<0.08		
Th	µg/L	<0.03	<0.03		
U	µg/L	0.452	0.453	0.4525	0.2
Stable Isotopes					
δ ¹³ C (PDB)	‰	-11.50	-11.40	-11.45	-0.6
δ ¹⁸ O (VSMOW2)	‰	-7.44	-7.45	-7.445	-0.1
δD (VSMOW2)	‰	-50.30	-50.80	-50.55	-0.7
Dissolved gases					
CH ₄	µg/L				
C ₂ H ₆	µg/L				
CO ₂	mg/L				
Organic parameters					
NPOC	mg/L	66.6	61.2	63.9	6
Benzo(b)fluoranthene	µg/L	<0.0036	<0.0036		
Benzo(k)fluoranthene	µg/L	<0.0030	<0.0030		
Benzo(a)pyrene	µg/L	<0.0016	<0.0016		
Benzo(ghi)perylene	µg/L	<0.0036	<0.0036		
Indeno(1,2,3-cd)pyrene	µg/L	<0.0049	<0.0049		
PAH-Total	µg/L	<0.0151	<0.0151		
TPH (C8-C40)	mg/L	<0.040	<0.040		

INORGANIC PARAMETER ANALYSIS

In this section the analytical methods are briefly discussed. For a more detailed explanation see previous reports (Bearcock et al., 2023; Bearcock et al., 2022; Fordyce et al., 2021; Palumbo-Roe et al., 2025). The quality control of each analytical method is discussed below; where QC data do not meet the required standard for a given element this is noted and the analysis data for this element should be treated with caution.

Major, minor and trace element analysis by ICP-MS

Major, minor and trace element analysis was carried out at the BGS Inorganic Chemistry Laboratories by inductively coupled mass spectrometry (ICP-MS). The method is fully accredited for groundwater and surface water by UKAS to the requirements of BS EN ISO/IEC 17025:2017.

Repeat measurements of two certified reference materials (QC1 and QC2), and one secondary reference material (QC3) were included within the analytical runs. The stocks of the secondary reference material were consumed after two sample rounds, meaning there were not sufficient data to comment on the accuracy or precision of the data. The results of these analytical replicates showed mostly good precision of the data, as the RSD was $\leq 5\%$. The exceptions to this were:

- Lithium (RSD of 7.9% in QC1)
- Boron (RSD of 7.0% in QC2)
- Aluminium (RSD of 6.3% in QC1)
- Silicon (RSD of 5.4% in QC2)
- Titanium (RSD of 5.9% in QC1)

A good accuracy of these reference materials was demonstrated with most recoveries $100 \pm 5\%$. The exceptions to this were:

- Sulphur (Accuracy of 107% in QC2)
- Thorium (Accuracy of 94% in QC1)

Laboratory blanks were inserted throughout each analytical run. Most were below the detection limits for each element. The exceptions to this were:

- Magnesium: 6 of the 59 blanks analysed had detectable Mg
- Aluminium: 1 of the 59 blanks analysed had detectable Al
- Silicon: 23 of the 59 blanks analysed had detectable Si
- Phosphorus: 1 of the 54 blanks analysed had detectable P
- Sulphur: 4 of the 59 blanks analysed had detectable S
- Potassium: 1 of the 59 blanks analysed had detectable K
- Manganese: 1 of the 59 blanks analysed had detectable Mn
- Iron: 1 of the 54 blanks analysed had detectable Fe
- Nickel: 1 of the 59 blanks analysed had detectable Ni
- Copper: 1 of the 59 blanks analysed had detectable Cu
- Zinc: 4 of the 59 blanks analysed had detectable Zn
- Rubidium: 1 of the 59 blanks analysed had detectable Rb
- Strontium: 3 of the 59 blanks analysed had detectable Sr
- Barium: 1 of the 59 blanks analysed had detectable Ba

Field blank water samples were included in the analytical runs; most were below the detection limits for each element, with the following exceptions:

- Magnesium: 5 of the 10 field blanks had detectable Mg (DL = 0.003 mg/L, max = 0.013 mg/L)
- Potassium: 1 of the 10 field blanks had detectable K (DL = 0.04 mg/L, max = 0.06 mg/L)
- Barium: 4 of the 10 field blanks had detectable Ba (DL = 0.05 $\mu\text{g/L}$, max = 0.4 $\mu\text{g/L}$)
- Strontium: 5 of the 10 field blanks had detectable Sr (DL = 0.2 $\mu\text{g/L}$, max = 0.9 $\mu\text{g/L}$)

- Manganese: 2 of the 10 field blanks had detectable Mn (DL = 0.2 µg/L, max = 0.3 µg/L)
- Iron: 4 of the 10 field blanks had detectable Fe (DL = 0.4 µg/L, max = 2.4 µg/L)
- Aluminium: 9 of the 10 field blanks had detectable Al (DL = 0.6 µg/L, max = 3.9 µg/L)
- Vanadium: 4 of the 10 field blanks had detectable V (DL = 0.02 µg/L, max = 0.04 µg/L)
- Nickel: 3 of the 10 field blanks had detectable Ni (DL = 0.01 µg/L, max = 0.06 µg/L)
- Copper: 3 of the 10 field blanks had detectable Cu (DL = 0.05 µg/L, max = 0.22 µg/L)
- Zinc: 5 of the 10 field blanks had detectable Zn (DL = 0.2 µg/L, max = 0.3.2 µg/L)

Results for most field duplicate samples (Table A 1) showed good precision of the measurement process, including both field sampling and laboratory analysis.

High variation in field parameters could be caused by taking readings for the first duplicate before the probes have stabilised.

There was small variability between sample pairs (RSD ≤ 10%) of the major and minor elements (Ca, Mg, Na, K, Si). Exceptions to this were:

- P: Samples from one round had an RSD of 35%
- S total: Samples from one round had an RSD of 21%

Variability between sample pairs was generally small (RSD ≤ 10%) between sample pairs for the trace elements. Some were within the acceptable range (RSD ≤ 20%). Exceptions to this were:

- Fe total had an RSD of 53% on one sample round.
- V: Samples from two rounds had RSDs of 47% and 38%
- Zn: Samples from three rounds had RSDs of 30% 90% and 47%
- Cd: Samples from one round had an RSD of 36%
- Ce: Samples from one round had an RSD of 24%
- Nd: Samples from one round had an RSD of 25%
- Tl: Samples from one round had an RSD of 28%
- Pb: Samples from two rounds had RSDs of 71% and 28%.

Higher variability often corresponded to concentrations close to the detection limits. The variability could not be calculated when one or both values were below the detection limit. This particularly affected the Rare Earth Elements (REEs).

Major and minor anion analysis by ion chromatography (IC)

Major and minor anion analysis was carried out at the BGS Inorganic Chemistry Laboratories by ion chromatography. Samples from rounds 33 to 36 (May 2024, October 2024, January 2025, and March 2025) were analysed using the same instrument as all the previous sampling rounds (ICS-5000). The method is fully accredited by UKAS to the requirements of BS EN ISO/IEC 17025:2017. The samples from round 37 (November 2025) were analysed using a new instrument (Integrion), which has not yet attained UKAS accreditation. The Integrion method is functionally the same as the ICS-5000, however the detection limits are slightly different, and two QC solutions are used as opposed to the previous three.

Accuracy and precision were calculated from the repeated analysis of QC standards. For samples analysed by the ICS-500 three standards were used for Cl, SO₄, NO₃, and F, while one was used for Br, NO₂, and HPO₄ because these elements are above the top calibration range of the instrument in two of the standards. For samples analysed by the Integrion two standards were all used for all parameters.

Repeat analyses of these standards showed good precision for most of the data with RSD ≤ 5%, with the following exceptions for samples analysed on the ICS-5000:

- Chloride (RSD of 5.9% in QC/25)
- Chloride (RSD of 10.9% in QC/100)
- Sulphate (RSD of 9.1% in QC/100)
- Nitrate (RSD of 12.5% in QC/100)
- Nitrite (RSD of 8.1% in QC/100)
- Fluoride (RSD of 6.3% in QC/100)

The measured results demonstrated good accuracy (recovery of $100 \pm 5\%$ relative to the target values) with the following exceptions for samples analysed on the ICS-5000:

- Chloride (Accuracy of 106% in QC10)
- Chloride (Accuracy of 109% in QC100)
- Sulphate (Accuracy of 107% in QC25)
- Sulphate (Accuracy of 111% in QC100)
- Nitrate (Accuracy of 106% in QC25)

and the following exceptions for the samples analysed on the Integrion

- Chloride (Accuracy of 106% in QCLo)
- Sulphate (Accuracy of 107% in QCLo)
- Nitrate (Accuracy of 106% in QCLo)
- Nitrite (Accuracy of 106% in QCLo)

Laboratory blanks were inserted throughout each analytical run ($n=42$). Most were below the detection limits for each element, with the following exceptions:

- Sulphate: 4 of the 42 blanks analysed had detectable SO_4
- Nitrite: 3 of the 42 blanks analysed had detectable NO_3
- Phosphate: 4 of the 42 blanks analysed had detectable HPO_4

The values above detection limits were all analysed using the new Integrion instrument.

Field blank water samples were included in the analytical runs; most were below the detection limits for each element, with the following exceptions:

- Chloride: 4 of the 10 field blanks had detectable Cl (DL = 0.05 mg/L, max = 0.092 mg/L)
- Sulphate: 2 of the 10 field blanks had detectable SO_4 (DL = 0.05 mg/L, max = 0.267 mg/L)
- Nitrate: 3 of the 10 field blanks had detectable NO_3 (DL = 0.03 mg/L, max = 0.113 mg/L)
- Bromide: 3 of the 10 field blanks had detectable Br (DL = 0.01 mg/L, max = 0.03 mg/L)

Results for most field duplicate samples (Table A 1) showed good precision of the measurement process, including both field sampling and laboratory analysis; there is generally small variability between sample-pairs ($\text{RSD} \leq 10\%$) of Cl, SO_4 , Br, F (NO_3 is mostly below LOQ), with the exception of F, for which samples from one round had an RSD of 48%.

Laboratory total alkalinity analysis

Total alkalinity in mg/L (expressed in terms of bicarbonate (lab- HCO_3)) was determined using a UKAS-accredited titrimetric method at the BGS Inorganic Chemistry Laboratories.

A laboratory QC standard was analysed a number of times throughout each analytical run. This demonstrated a good accuracy (recovery 100%) and precision ($\text{RSD} 1.9\%$).

Results for field duplicate samples showed very low variability between sample-pairs ($\text{RSD} \leq 5\%$) (Table A 1).

As a further check on data quality, the field and laboratory alkalinity measurements were compared. These showed good agreement with most samples ($n=93$) having comparable analyses ($\text{RSD} \leq 10\%$). For all samples the variability was small ($\text{RSD} \leq 10\%$).

Total inorganic carbon (TIC) in mg/L was calculated by dividing the lab- HCO_3 (mg/L) by 5.0801.

Charge balance data

Ionic mass balance calculations for each of the samples resulted in a percentage balance of within $\pm 5\%$ when calculated with lab bicarbonate concentrations. The majority of the ionic mass balances calculated with the field bicarbonate are also within the acceptable range of $\pm 5\%$. While we would usually expect the field bicarbonate data to give better ionic balances than the lab data, in this instance six of the field bicarbonate ionic balances showed percentages outside the

acceptable range of $\pm 5\%$. This is probably indicative of errors in the subjective assessment of the colour change whilst doing the alkalinity titration in the field. Where the ionic mass balance was improved by using the laboratory measured bicarbonate calculation, the laboratory measured datum was reported.

Ammonium analysis

Ammonium was determined on a Seal Analytical AA3 automated colorimeter using the salicylate method at 630 nm at Wallingford on UKCEH equipment. Accuracy and precision were monitored by participation in the Laboratory of the Government Chemist (LGC) Aquacheck inter-laboratory proficiency testing scheme for waters and using an in-house reference material. For the Aquacheck scheme a certified reference material (CRM) of unknown value is sent out to laboratories in the scheme, who quantify it and report back to LGC for validation. Once LGC release their data, the CRM is used on every analytical run. The spacing of the sampling rounds meant that the Aquacheck CRM was different for every analytical run.

One AQC CRM and one in-house reference material were analysed with each batch of samples. Precision cannot be calculated for the AQC CRM, as it is different within each sample batch. The accuracy of each analysis was generally good (recoveries $100 \pm 2\%$), with the exception of round 37 (recovery 110%). Results for the in-house standard show good accuracy of the data (recovery 99%) and precision (RSD 3%).

Results for field duplicate samples (Table A 1) also showed good precision of the measurement process, including both field sampling and laboratory analysis, with low variability between sample-pairs (RSD < 6%).

Sulphide analysis

An unfiltered water sample was fixed on site using SAOB (sulphide antioxidant buffer). The buffer is a mixture of sodium hydroxide (NaOH), ethylenediaminetetraacetic acid (EDTA) and ascorbic acid ($C_6H_8O_6$). Sulphide analysis by Segmented Flow Analysis was carried out by SOCOTEC at their laboratories in Burton upon Trent. The method is UKAS-accredited, and SOCOTEC report the limit of detection is 0.02 mg/L and the uncertainty for the method is 8.8%.

Recovery for the samples in this report is within $100 \pm 5\%$. Field blanks were all below the detection limit.

Field duplicates generally had sulphide concentrations below the detection limit. One sample pair, however had an RSD of 47%, the concentrations of these samples were close to the detection limit.

Reduced iron analysis

The analysis of reduced iron (Fe^{2+}) by discrete colorimetric analysis was carried out by SOCOTEC at their laboratories in Burton upon Trent. The method is UKAS-accredited, the limit of detection for the method is 10 $\mu\text{g/L}$. Recovery for the samples in this report is within $100 \pm 5\%$. Field blanks were all below the detection limit.

It should be noted that Fe^{2+} and total Fe are analysed in two separate laboratories, with different sampling methodologies. The concentrations of Fe^{2+} commonly exceeded those of Fe Total, which were likely caused by the Fe^{2+} sample being unfiltered and the bottle being pre-dosed with HCl, while the Fe Total sample was filtered and acidified later. The oxidised iron should therefore not be calculated using the analyses of Fe Total and Fe^{2+} .

Results for field duplicate samples generally showed very low variability between sample-pairs (RSD $\leq 5\%$) with the exception of one sampling round, for which the RSD between samples was 23%. This occurred in the same sample which had a high RSD for Fe Total (Table A 1).

ORGANIC PARAMETER ANALYSIS

Non-purgeable organic carbon analysis by carbon analyser

The analysis of non-purgeable organic carbon (NPOC) was carried out on a carbon analyser at the BGS Inorganic Geochemistry Laboratories. The method is fully accredited by UKAS to the requirements of BS EN ISO/IEC 17025:2017. Three QC standards were analysed throughout each analytical run and these all showed good accuracy (recoveries $100 \pm 5\%$) and precision ($RSD < 5\%$) of the data. Of the 19 laboratory blanks, five were above the detection limit of 0.5 mg/L, the maximum of which was 0.875 mg/L. Results for field duplicate samples (Table A 1) showed good precision of the measurement process, including both field sampling and laboratory analysis ($RSD \leq 10\%$).

Total petroleum hydrocarbon analysis by GC-FID

Total petroleum hydrocarbon (TPH) concentrations were determined by gas chromatography flame ionisation detector (GC-FID) at the Scottish Water testing laboratory. The LOQ (based on 10 times the standard deviation of laboratory blanks) were reported with the data. Analysis was carried out following UKAS-accredited method ISO 17025. Three field blanks were taken throughout the period discussed in this report. Results for all three parameters were below the detection limit. All duplicate analyses were also below detection limits, so variability could not be calculated. The method performance, as of March 2026, as quoted by the Scottish Water testing laboratory shows a good accuracy (recovery 99.3%), and an acceptable precision ($RSD 7.7\%$).

Polycyclic aromatic hydrocarbon analysis by HPLC-FD

Polycyclic aromatic hydrocarbon (PAH) contents were analysed using high performance liquid chromatography fluorescence detection (HPLC-FD) at the Scottish Water testing laboratory. The LOQ (based on 10 times the standard deviation of laboratory blanks) were reported with the data. Analysis was carried out according to UKAS-accredited method ISO 17025. Three field blanks were taken throughout the period discussed in this report. Results for all six parameters were below the detection limit. Variability could not be calculated for PAH as all values were below detection limits. The method performance, as of March 2026, as quoted by the Scottish Water testing laboratory shows an acceptable accuracy (recoveries 93.8-101.7%), and acceptable precision ($RSD 9-11\%$).

Volatile organic compound analysis

Volatile organic compounds were analysed by the Scottish Water laboratory in Edinburgh. This analysis is not UKAS accredited. All the parameters in the method are analysed in the same way, but only a select few are controlled via control charts (See Palumbo-Roe et al. (2025)). Three field blanks were taken throughout the period discussed in this report. Results for all 38 parameters were below the detection limit. Variability could not be calculated for VOCs as all values were below detection limits. The method performance, as of March 2026, as quoted by the Scottish Water testing laboratory shows a good accuracy (recoveries 98.1 – 103.4%), and acceptable precision ($RSD 3.9-6.7\%$) for the selected parameters.

STABLE ISOTOPE ANALYSIS

Samples were sent to the National Environmental Isotope Facility (NEIF), formerly known as the NERC Isotope Geoscience Laboratories (NIGL) for analyses of stable isotopes of carbon ($\delta^{13}C$), oxygen $\delta^{18}O$ and deuterium δ^2H . The $\delta^{18}O$ analytical method is not UKAS accredited, but is a well-established protocol (e.g. Ryves et al., 2020) (The $\delta^{13}C$ and δ^2H analytical methods are UKAS accredited).

Carbon stable isotope analysis

Stable carbon isotopes ($\delta^{13}C$ -DIC) were determined using an isotope ratio mass spectrometer (IRMS). Since the last data release the instrument for carbonate analysis has been changed to a Elementar PreciLION with iso FLOW headspace analyser. The standards used were changed at the same time to align with the wider scientific community, which commonly employ a Carrara

marble standard to provide reliable consensus values. The reference materials used in the QC of the $\delta^{13}\text{C}$ for this period of reporting, and for the foreseeable, were:

- KCM (Keyworth Carrera marble), an in-house reference material,
- IAEA-C2, a certified reference material (CRM) supplied by the International Atomic Energy Agency (IAEA), and,
- USGS44, a certified reference material (CRM) supplied by the U.S. Geological Survey (USGS).

Repeat measurements of these materials carried out during the sample runs show that there was good reproducibility and recovery for all reference materials (Table A 2). Field duplicate $\delta^{13}\text{C}$ measurements show $\text{RSD} \leq 2\%$ for all sample pairs.

Table A 2 Results for quality control standards included in the $\delta^{13}\text{C}$ stable isotope IRMS analysis

$\delta^{13}\text{C} \text{ ‰ VPDB}$	KCM	IAEA-C-2	USGS44
Number of measurements	32	11	17
NEIF mean	2.0	-8.26	-42.2
% RSD	7.73	1.33	0.37
In-house preferred value	2.0	-8.25	-42.2
% recovery	100	100	100

Deuterium stable isotope analysis

Deuterium stable isotopes were determined using a continuous flow IRMS with liquid autosampler. Repeat measurements show good precision of the data ($\text{RSD} \leq 2\%$) (Table A 3). Field duplicate $\delta^2\text{H}$ measurements show $\text{RSD} < 3\%$ for all sample pairs.

Table A 3 Results for repeat measurements on quality control standards included in the IRMS $\delta^2\text{H}$ stable isotope analysis

$\delta^2\text{H VSMOW2 (‰)}$	CA-LO calibration		CA-HI calibration	
	IAEA CRM SMOW2/SLAP		IAEA CRM SMOW2/SLAP	
Number of measurements	12		12	
NEIF mean	-310		-49	
% RSD	0.29		1.63	

Oxygen stable isotope analysis

Oxygen isotope ($\delta^{18}\text{O}$) measurements were made using the CO_2 equilibration method with an IRMS plus Aquaprep device. Repeat measurements show good precision of the data ($\text{RSD} \leq 1\%$) (Table A 4). Field duplicate $\delta^{18}\text{O}$ measurements show $\text{RSD} \leq 1\%$ for all sample pairs.

Table A 4 Results for repeat measurements on quality control standards included in the IRMS $\delta^{18}\text{O}$ stable isotope analysis

$\delta^{18}\text{O} \text{ ‰ VSMOW2}$	CA-LO calibration		CA-HI calibration	
	IAEA CRM SMOW2/SLAP		IAEA CRM SMOW2/SLAP	
Number of measurements	15		15	
NEIF mean	-39.3		-7.3	
% RSD	0.12		0.31	

DISSOLVED GASES

Radon analysis

Radon was analysed by a UKAS accredited liquid scintillation method at the Scottish Water laboratory in Edinburgh. Scottish Water are UKAS accredited for Rn analysis on two identical liquid scintillator counters, which are regularly quality checked. The LOD is 10 Bq/L. Radon concentrations of the field duplicate samples were lower than the LOD.

The method performance, as of March 2026, as quoted by the Scottish Water testing laboratory shows a good accuracy (recoveries 99.7%) and acceptable precision (RSD 7.4%).

Methane, ethane, and carbon dioxide analysis

The analysis of CH₄, C₂H₆, and CO₂ was undertaken at the BGS Wallingford laboratories, using the headspace gas chromatography (GC) technique. Eluting methane and ethane (if present) were detected by a flame ionisation detector (FID), while CO₂ was measured by a thermal conductivity detector (TCD).

The CH₄ concentrations of field duplicate samples showed acceptable precision in round 33 (RSD <20%), while it was high in round 34 (RSD ~40%). The CO₂ concentrations of field duplicate samples showed excellent precision of the measurement process, including both field sampling and laboratory (RSD <3%). C₂H₆ was always below detection.

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