

Lake and River Monitoring Stations operated by the Marine Institute, Newport

Technical Description, Maintenance
and Operating Guide.

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Contents

1	History.....	1
2.	Lake Monitoring Stations.....	1
2.1.	Development of the lake monitoring station prototype.....	1
2.2.	Lake Monitoring stations as currently installed	2
2.3.	Profiling System (Winch).....	7
3.	River Monitoring Stations.....	10
3.1.	Development of the river monitoring station prototype.....	10
3.2.	River Monitoring stations as currently installed.....	14
3.2.1.	Black River	15
3.2.2.	Glenamong.....	16
3.2.3.	Rough River	17
3.2.4.	Mill Race	18
4.	Data Sheets.....	20
4.1.	Introduction	20
4.2.	CR1000.....	21
4.3.	CR1000X	21
4.4.	CR200	21
4.5.	CR6	21
4.6.	AM416.....	21
4.7.	SDM-SIO1	21
4.8.	CELL215.....	22
4.9.	RF422 (RF407 series).....	22
4.10.	LoggerNet Software.....	22
4.11.	RTMC Pro software.....	22
5.	Contacts.....	23
5.1.	Campbell Scientific Ltd	23
5.2.	Chelsea Technologies Ltd.....	23
5.3.	Lakeland Instrumentation Ltd	23
5.4.	LI-COR.....	23
5.5.	Kipp & Zonen.....	24
5.6.	Seapoint.....	24
5.7.	SUNA (Nitrate sensor).....	24
5.8.	Williamson Pumps.....	24
5.9.	Windspeed (Vector Instruments).....	24
5.10.	KVH Industries (Compass engine).....	25

1 HISTORY

In 1993, the then Salmon Research Agency (which merged with the Marine Institute on 1st July 1999), National Parks and Wildlife Service (Killarney), Trinity College Dublin, Empresa Provincial de Aguas de Córdoba (Provincial Water Company of Córdoba, Spain), the University of Granada (Spain), the Environment Agency of England and Wales (now the Environment Agency and Natural Resources Wales) and Scottish Natural Heritage (now NatureScot) joined a consortium led by the Institute of Freshwater Ecology (now the UK Centre for Ecology & Hydrology) to apply for funding from the European Union for a 'Technology demonstrator' project under the LIFE programme called '*The Development of an Automated Network of Water Quality Monitoring Stations in a series of European lakes. (LIFE 93/UK/3167)*'. This started more than 10 years of collaboration between the Salmon Research Agency/Marine Institute and the Institute of Freshwater Ecology/Centre for Ecology & Hydrology.

The original Lake Monitoring station on Lough Feeagh, supplied under this initial project, was designed by Martin Rouen and others at the Institute of Freshwater Ecology and although the station has been upgraded several times since the original deployment in the 1990s, the original buoy platform and some of the original sensors have remained in service for more than 25 years.

The Institute of Freshwater Ecology led three more European-funded projects, involving different consortia, but all included the Marine Institute:

1. Response of European Freshwater Lakes to Environmental and Climatic Change (REFLECT) under the Framework IV programme (Project Number: PL970936)
2. Using Automatic Monitoring and Dynamic Modelling for the Active Management of Lakes and Reservoirs LIFE98 ENV/UK/000607 (1999 to 2002)
3. Climate and Lake Impacts in Europe (CLIME) under the Framework V programme 1 January 2003 to 31 December 2005 (Contract Number: EVK1-CT-2002-00121)

Under these projects the three River Monitoring Stations were installed, and significant upgrades were made to the Lake Monitoring Station on Lough Feeagh.

Martin Rouen left the Centre for Ecology & Hydrology in 2004 and became self-employed in 2005, setting up Lakeland Instrumentation Ltd (registered in England and Wales) in October 2007. Lakeland Instrumentation Ltd has provided technical support for all the stations from 2008 to date.

In 2008, funded under the European Regional Development Fund, a second Lake Monitoring Station originally deployed on Lough Leane under the original LIFE project was refurbished by the Marine Institute and Lakeland Instrumentation Ltd for redeployment on Furnace Lough. An automatic profiling system was added to the station.

The Rough River Station was destroyed by a catastrophic flooding event in the Rough River and was replaced in 2010, again supplied by Lakeland Instrumentation Ltd. The station on the Black River was upgraded after a flood event there in 2016 and a simple system was installed at the Mill Race to record water temperature in the same year.

A significant upgrade of the Lough Feeagh station was carried out in late 2020/early 2021.

2. LAKE MONITORING STATIONS

2.1. DEVELOPMENT OF THE LAKE MONITORING STATION PROTOTYPE

Two Lake Monitoring Stations are operated by the Marine Institute in the Burrishoole catchment, one on Lough Feeagh and the second on Furnace Lough. The station on Lough Feeagh has operated for about 30 years and has had two major upgrades and numerous minor upgrades. The station on Furnace Lough has operated on Furnace Lough for nearly 20 years (having been originally installed on Lough Leane, Co Kerry in 1997).

The Lough Feeagh station is mounted on a buoy and records readings at high frequency (every two minutes) from an array of meteorological and water quality sensors. It is a flexible design that can accommodate additional sensors/instruments using either analogue or digital interfaces. The station does not require frequent routine servicing and the power consumption is minimised and controlled in such a way that selected sensors can be powered down between measurements and switched off under fault conditions. The station monitors its own performance, records this diagnostic information and can relay this information to an engineer based at a remote site.

The lake stations were originally based on Datalogger DT500 data loggers and used UHF telemetry to link back to shore stations comprising a second UHF telemetry transceiver, microcontroller and telephone modem. A major refit replaced this system with Campbell Scientific CR10X data loggers with GSM modems (rendering the shore station redundant) and further, more incremental upgrades have seen the CR10X replaced by the Campbell Scientific CR1000 and more recently the CR1000X. The telemetry moved to GPRS and latterly 4G (LTE), using Campbell Scientific CELL215 modules.

The Furnace Lough station is closely related to the Lough Feeagh station, but a fully automatic winch to raise and lower a multi-parameter sonde (taking measurements at multiple depths) replaces the chain of underwater temperature sensors.

The buoy

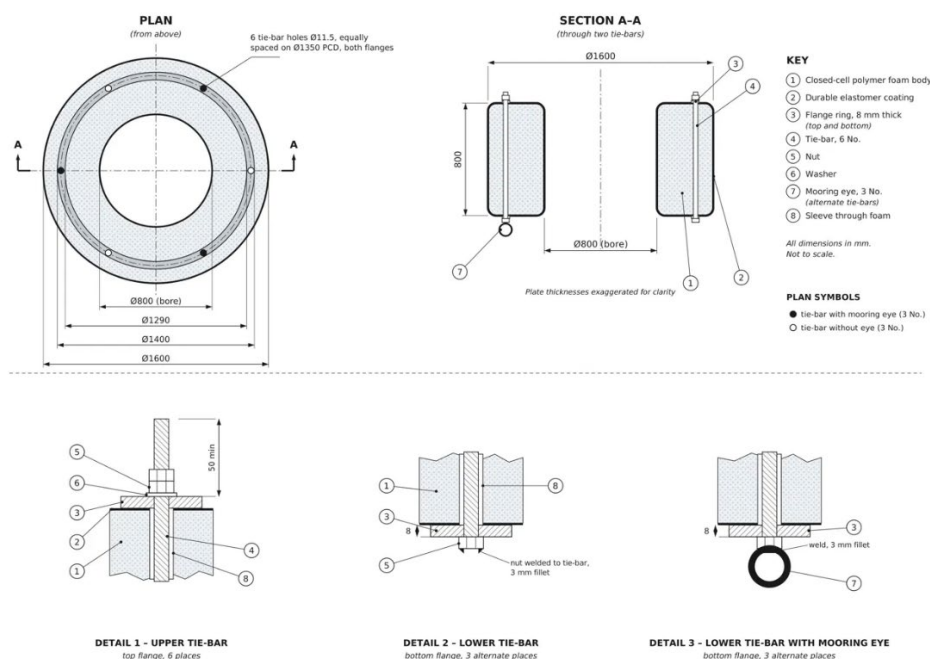


Figure 2.1 Simplified general arrangement of the buoy (dimensions in mm, not to scale).

The buoy was custom manufactured by Trelleborg CRP Ltd. The mechanical design of the station is based on the proven configuration. The buoy is made using closed-cell polymer foam and is coated in a durable elastomer. This coating is very unlikely to be punctured, but even if it were damaged, the closed-cell internal construction would prevent the buoy from losing significant buoyancy.

The buoy is moored using a three-point mooring where the chains/cables are attached to eyelets fixed to the underside of the buoy. This configuration minimises the rotation of the buoy and prevents the mooring chains from becoming entangled with the sensor cables.

2.2. LAKE MONITORING STATIONS AS CURRENTLY INSTALLED

The overall design

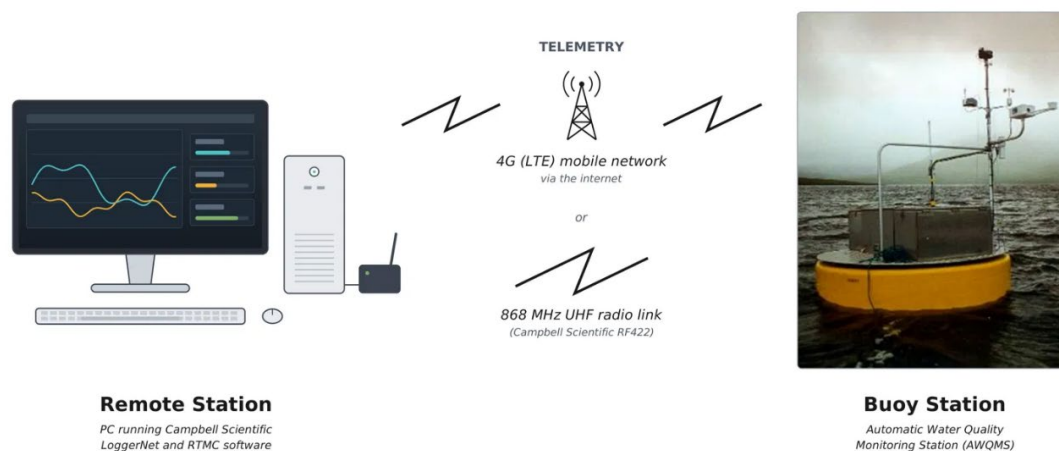


Figure 2.2 The components of an Automatic Water Quality Monitoring Station.

The schematic diagram in Figure 2.2 shows the basic features of the Automatic Water Quality Monitoring Station (AWQMS). In functional terms, the system is based on two components: the Buoy Station deployed on the lake and the Remote Station used to download the acquired data to a remote site. An operator can use the Remote Station (e.g. located in the laboratory) to contact the buoy station to retrieve recorded data or to examine measurements in real-time.

Figure 2.3 shows the typical configuration of the buoy station. The buoy station comprises:

- A toroidal buoy secured to the lake bed using a three-point mooring.
- Stainless steel housings mounted on the buoy containing rechargeable sealed lead-acid batteries to power the station and the station's electronic systems to record data and telemeter stored and real-time data via the GPRS/4G (LTE) (cell phone) network
- A mast supporting meteorological sensors and antenna for telemetry.
- A selection of water quality sensors suspended in the water column.

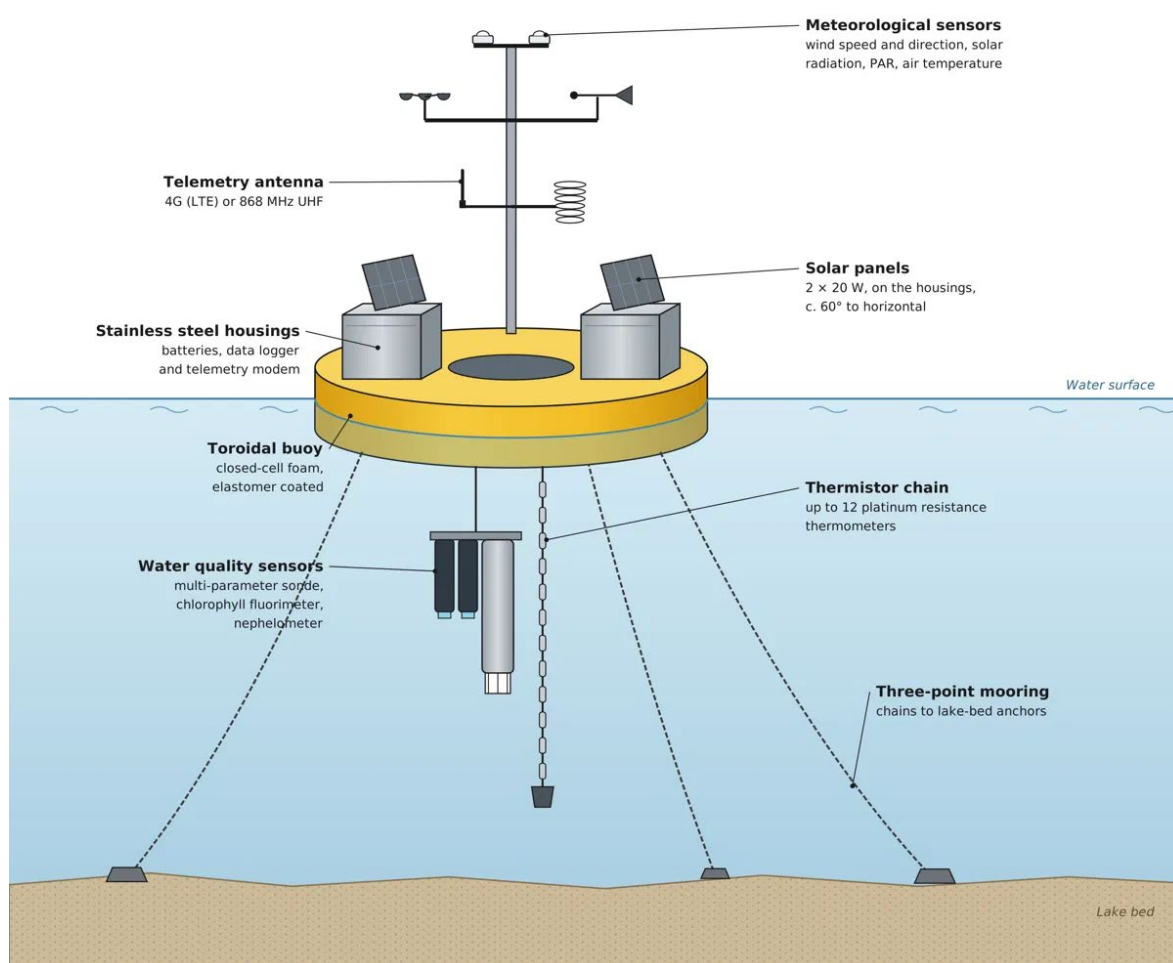


Figure 2.3 Schematic Diagram of Automatic Water Quality Monitoring Station Lough Feeagh.

The selected sensors

Table 2.1 lists the range of sensors fitted to the Lake Monitoring Station on Lough Feeagh. The sensors were selected from a range of commercial options, after careful evaluation supplemented in many cases by comparative tests. The current selection can be replaced with improved or additional sensors as and when these become available.

Table 2.1 Sensors fitted to the Lough Feeagh station

Parameter	Sensor type	Model	Manufacturer	Range	Notes
Meteorological					
Wind speed	Cup anemometer	A100L2	Vector Instruments	0 to 50 m s ⁻¹	Measured c. 2.5 m above the water surface
Wind direction	Wind vane (potentiometer)	W200P	Vector Instruments	0 to 360°	Corrected for rotation of the buoy using the compass
Buoy bearing	Compass	–	KVH Industries	0 to 360°	
Barometric pressure	Semiconductor strain gauge	PDCR1830	Druck	0 to 2000 mbar	
Air temperature	Thermistor probe in louvred screen	–	–	–	PRT at Furnace Lough

Parameter	Sensor type	Model	Manufacturer	Range	Notes
Photon flux density (PAR)	Photodiode quantum sensor	LI-192SZ	LI-COR	0 to 3000 $\mu\text{mol m}^{-2} \text{s}^{-1}$	
Solar radiation	Pyranometer	CMP6	Kipp & Zonen	0 to 2000 W m^{-2}	
Water quality					
Water temperature profile	Chain of 12 platinum resistance thermometers	–	Labfacility Ltd	–5 to +40 °C	Sensors at 1, 3, 6, 9, 12, 14, 16, 18, 20, 25, 30 and 40 m
Underwater PAR	Underwater quantum sensor	–	–	–	Calibration to be verified
Water temperature	Platinum resistance sensor	DataSonde DS5x	Hydrolab	–5 to +40 °C	Multi-parameter sonde (SDI-12)
Conductivity / salinity	Conductivity cell	DataSonde DS5x	Hydrolab	–	Sonde
pH	pH electrode	DataSonde DS5x	Hydrolab	pH 1 to 14	Sonde
Dissolved oxygen	Clark cell	DataSonde DS5x	Hydrolab	0 to 500 %	Sonde
Chlorophyll a	Fluorimeter	Minitracka (C)	Chelsea Technologies	0 to 100 $\mu\text{g L}^{-1}$ (in acetone)	Power switching disabled in the current program
Suspended solids	Nephelometer	Minitracka (N)	Chelsea Technologies	0 to 100 FTU	
CDOM	UV fluorometer	–	–	–	
Dissolved CO ₂	CO ₂ sensor with CR200 interface	–	–	–	Read every 10 min; CO ₂ concentration calculated by the logger

The Furnace Lough station carries the same meteorological sensors (with a platinum resistance thermometer for air temperature), a nephelometer and chlorophyll fluorimeter, and a multi-parameter sonde on the profiling winch. It has no temperature chain, underwater PAR sensor, CDOM fluorometer or CO₂ sensor.

The meteorological sensors

For certain parameters (e.g. wind measurements) some compromise in performance is unavoidable due to the nature of the buoy platform. The wind instruments manufactured by Vector Instruments are developments of the 'Porton' design. In this design, the rotation of the cups is measured using a slotted optical disc arrangement. This type of sensor is very reliable and consumes very little electrical current. The height at which wind speed is measured is of necessity different to that used in a land-based installation. The standard height of measurement at a terrestrial meteorological station is 10m. The anemometer on the buoy is mounted at a height of 2.5 m. This was considered to be high enough for uninterrupted measurement but low enough for servicing without compromising the physical stability of the buoy. Wind direction is recorded as the direction of the wind vane relative to the alignment of the sensor casing. A compass recording the bearing of the buoy is mounted with a fixed alignment relative to the wind direction sensor and is used to compensate the Wind direction measurement for rotational movement of the buoy. Although the three-point mooring constrains any rotation of the buoy

around a vertical axis, it cannot eliminate this movement and hence the use of the compass to compensate.

There are two light measurements recorded by the station: the solar radiation measured using a pyranometer recording shortwave radiation (i.e. incident visible and infra-red radiation) as energy per unit area per unit time, and photon flux density, the number of incident photons in the visible spectrum per unit area per unit time. Although the solar radiation and photon flux density measurements are related, they are not identical. Solar radiation is of particular interest for physical studies of heat transfer, while photon flux density is used by biologists when considering the light available for photosynthesis. Both incident light sensors are mounted at the top of the mast to ensure that they cannot be shaded by any part of the station. Lough Feeagh also has an underwater quantum sensor that measures the photon flux density below the surface.

Air temperature is measured using a thermistor probe (Lough Feeagh) or a platinum resistance thermometer (Furnace Lough) housed in a louvred solar screen. In common with all non-aspirated sensors, errors of several degrees Celsius can occur on very still days with bright sunlight due to solar heating of the louvred screen. Such conditions are quite rare in Ireland and the UK but aspirated sensors could be fitted to stations deployed in very sunny locations.

Barometric pressure is recorded using a pressure transducer based on a semiconductor strain gauge, chosen for its reliability, accuracy and low hysteresis. No special concerns arise from this being buoy mounted rather than fixed at a terrestrial site.

The water quality sensors

The temperature structure of the water column is recorded using a chain of up to 12 temperature sensors. These are assembled specially for each site with the number of sensors and spacing between them chosen according to the depth of the water column and the mixing characteristics of the lake. On Lough Feeagh the 12 sensors are at 1, 3, 6, 9, 12, 14, 16, 18, 20, 25, 30 and 40 m. The sensors are high-precision platinum resistance thermometers (PRTs), encapsulated in a stainless steel sheath. A PTFE cable connects each sensor to a termination box on the buoy station. This enables individual sensors to be replaced as necessary. A four-wire measurement of each sensor is made, which enables any measurement errors that could result from cable or contact resistance to be completely compensated.

The station can accommodate one or two sondes (multi-parameter water quality instruments) where high-resolution conductivity (salinity), pH and dissolved oxygen measurements are required at a particular site. These sensors, however, require regular cleaning and recalibration so are only fitted at sites where the stations can be serviced at fortnightly or monthly intervals. The Hydrolab DataSonde DS5x sonde was chosen as the preferred sonde for the lake monitoring stations, but the station can also accommodate a range of other sondes which use the SDI-12 data interface (e.g. most models manufactured by YSI Incorporated including the EXO2 or earlier models or other manufacturers unit such as the Manta II).

The station also supports sensors that provide two types of optical measurements:

- A nephelometer that measures the optical scatter of light at a wavelength of 470nm - used as a general measure of the concentration of all suspended particles.
- A chlorophyll fluorimeter that measures the fluorescence of the water at a wavelength of 685nm when excited with light at 470nm - used as a measure of the biomass of phytoplankton.

- A CDOM fluorometer (Lough Feeagh and the river stations) that measures the fluorescence of coloured dissolved organic matter under ultraviolet excitation.

All these sensors require regular calibration. At most sites, the relationship between the optical measurement and the variable of interest will change from month to month and from year to year. A full discussion of these calibration procedures is beyond the scope of this report. They include the regular collection of water samples for phytoplankton counts and pigment analysis and the gravimetric determination of suspended solids.

Lough Feeagh also has a dissolved CO₂ sensor, read every 10 minutes over SDI-12 through a separate CR200 interface. The data logger calculates the dissolved CO₂ concentration (mmol L⁻¹ and mg L⁻¹) from the sensor output and temperature, using the barometric pressure measured on the buoy.

Storing the data

Data are recorded using a Campbell Scientific data logger (currently CR1000X at Lough Feeagh, Furnace Lough and the Rough River, CR6 at the Black River and CR1000 at the Glenamong and Mill Race; see Table 3.3) loaded with a custom written control program. In this data logger, the memory used to store data is divided into several areas each configured as 'circular buffers'. The size of each buffer is set automatically to maximise the storage time until the buffers are full. Once the allocated storage area is full, the oldest data are overwritten. In practice, about four weeks of high resolution data can be stored before any such data is overwritten. Each program stores high-resolution values every scan (every 1 to 4 minutes, depending on the station), hourly averages, and daily averages, minima and maxima for the day ending at 09:00.

Retrieving the stored data

Stored data can be retrieved on-site by plugging a portable PC directly into a connector on the station. The portable PC runs a program supplied by Campbell Scientific that retrieves the data and stores it as a comma separated value (csv) file that can be imported into almost any spreadsheet or database software. 4G (LTE) telemetry (or, at the Rough River, the 868 MHz radio link) is used to provide the same functionality to PCs based remotely from the station (e.g. at the Marine Institute and/or Lakeland Instrumentation Ltd).

As well as retrieving data, a directly connected PC, or a remote PC connected through the mobile network, can be used to examine measurements in real-time and (if necessary) to update the control software running on the buoy. A major advantage of this facility to connect to the station remotely is that engineers can also check the performance of the station and diagnose most problems without having to arrange a site visit.

Powering the station

The station is powered by 6 sealed, lead-acid batteries each housed in a carry case and equipped with a simple connector to enable them to be exchanged easily, if necessary, on a service visit. The retrieved batteries are then recharged for a subsequent visit. A pair of 20W solar panels are attached that will maintain the charge in the batteries, for all or most of the year (depending on weather conditions).

Diagnostic features

In addition to recording measurements of scientific interest, the station also records a range of technical parameters (e.g. battery voltage, current consumption, operating temperature, etc). These measurements can be invaluable for establishing the cause of any fault and for tracking any changes in the configuration of a particular installation.

Servicing the station

Most of the sensors fitted to the AWQMS require relatively little servicing. For stations not equipped with any sondes or optical sensors the service interval can be three months or more. Stations fitted with a sonde, a fluorimeter or a nephelometer require more frequent maintenance. If a sonde is fitted, the pH sensor will require regular cleaning and recalibration. The service interval for the optical instruments depends on the productivity of the lake, the depth of the sensor and the underwater light climate.

The Remote Station

The remote station consists of a PC connected to the internet. The PC is used to run a software package produced by Campbell Scientific Ltd called LoggerNet, which allows the operator to establish a connection to the buoy station, to retrieve stored data and view measurements in real-time. LoggerNet also has facilities for managing and checking the output from a network of recording stations. Additional software (RTMC Pro) can be used to generate real-time graphs, and LoggerNet Database (LNDB) software to automatically upload data into a relational database.

2.3. PROFILING SYSTEM (WINCH)

The Winch (Furnace Lough station)

The winch unit is designed to enable a sonde to be lowered to set depths in sequence under the control of the data logger thereby enabling vertical profiles to be measured.

The data logger controls the winch through a serial link to the winch controller, using simple feed, retract and query commands. Two rotary encoders, on the cable and on the drum, report the position after every movement, and the logger checks that the cable and drum have moved by the expected amount, that they agree with each other and that the depth reported by the sonde matches the length of cable paid out. A profile starts by parking the sonde at the upper limit switch and zeroing the encoders; the sonde is then lowered in steps to a maximum depth of 12.5 m (or 2 m when restricted), with readings taken on the way down and/or up. Profiles can be started manually or automatically every hour or every six hours. Any fault stops profiling and is logged with a fault code.

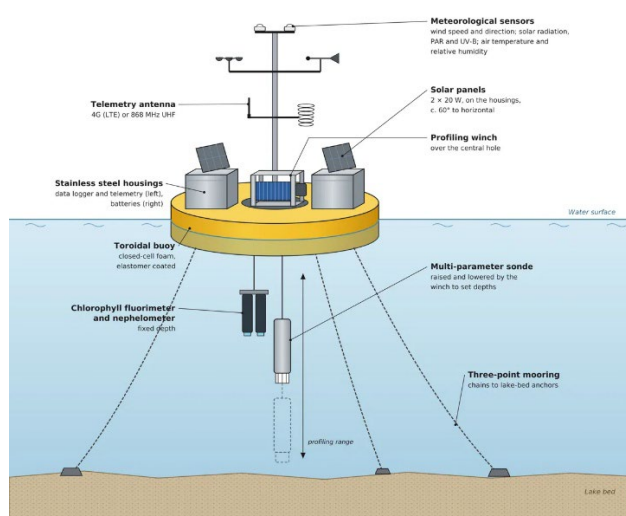


Figure 2.4 Schematic diagram showing the station as deployed on Furnace Lough

The specification for the winch defined the cable diameter, cable length, load weight, required speed, operating voltage, control communications, and overall dimensions of the unit. There is also a requirement for high reliability and low power consumption. Regular service and maintenance requirements for the sonde dictate that the winch must be easily removable to enable the sonde to be withdrawn through the centre hole of the buoy. At the time that this system was designed (1999), no commercially available winch systems met the requirements, or came close enough to be modified to meet the requirements, hence an 'in house' design was undertaken. This is still believed to be the case.

Drum

The diameter of the umbilical cable and the required operating depth resulted in a drum with a core of 250 mm diameter by 126 mm wide. The core of the drum is machined from aluminium and has separate side plates of 340mm diameter. The drive system uses a system of toothed belts to synchronise the rotation of the drum and the lay gear mechanism from a single lay shaft which is driven by the motor unit. The motor unit comprises a reversible 12 V D.C. motor and an integral worm type reduction gearbox. It is non-back drivable thereby eliminating the need for a braking mechanism. A commercial 24-way slip-ring assembly provides cable continuity through the bearing system. All connections to the umbilical cable are made via at least two contacts on the slip ring. This should reduce any risk of 'noisy' contacts interfering with the normal operation of the submerged sub-systems.

Cable Laying Mechanism

The winch cable, when it is wound or unwound from the winch drum, traverses across the face of the drum. At the same time the cable runs through a set of fixed cable guides that maintain its position downstream from the winch. The lay gear is the mechanism that causes the cable to be traversed across the face of the drum in an orderly manner and inhibits the build-up of cable upon itself. The lay gear is driven from the lay shaft by means of a toothed belt drive and the traverse is controlled by means of a dual helix "Yankee" screw. The relationship between the traverse and the drum is such that 1 revolution of the drum causes a linear displacement by the traverse equivalent to one cable diameter.

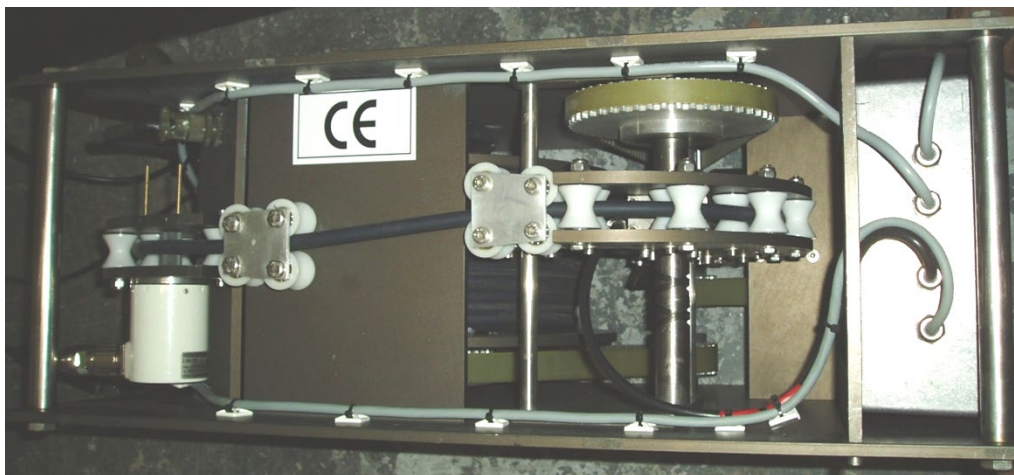


Figure 2.5 Winch Mechanism

Figure 2.5 shows the mechanism, while Figure 2.6 shows the drive belts and drive motor.

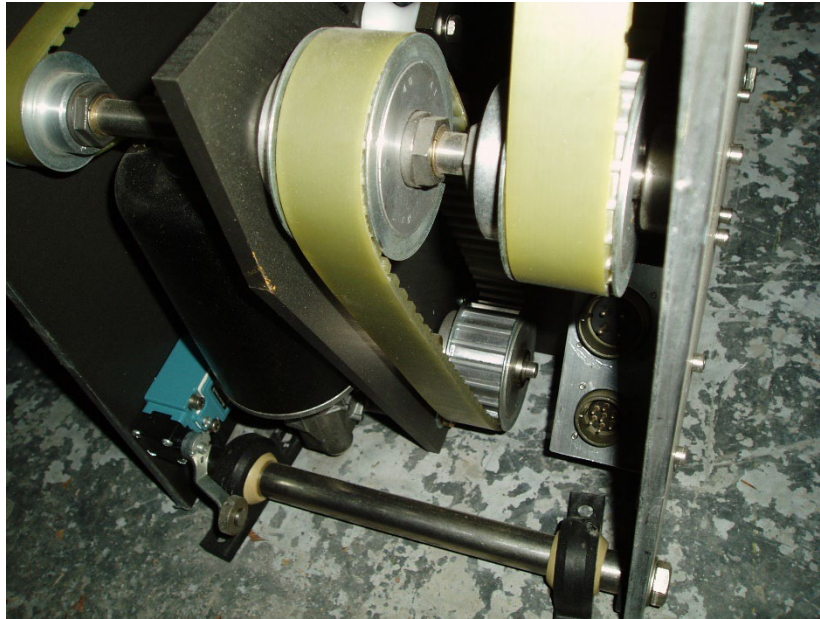


Figure 2.6 Winch Mechanism - main drive system.

Figure 2.7 shows the cable guide mechanism.

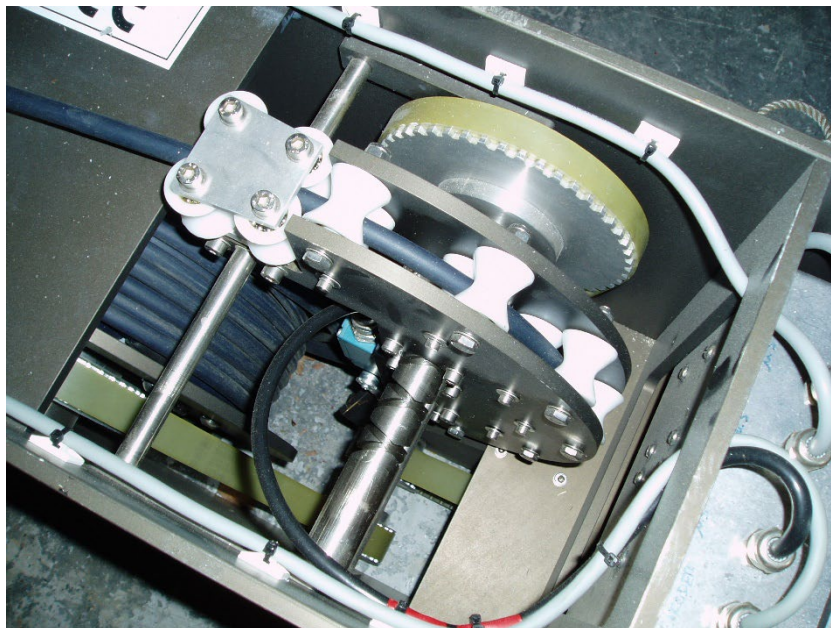


Figure 2.7 Winch Mechanism - cable feed guide.

3. RIVER MONITORING STATIONS

The River Monitoring Stations are effectively much simplified versions of the Lake Monitoring Stations (described in section 2.2), but housed adjacent to the stream/river being monitored and in the cases of the Black and Rough Rivers, using a pumped system to carry water from the river through a flow cell on the bank side. At the Glenamong, the sensors are directly in the river housed in a protective cage.



Figure 3.1 The variant of the Automatic River Monitoring Station deployed in the Glenamong. This uses an in situ system of sensors mounted in a strong protective cage.



Figure 3.2 The variant of the Automatic River Monitoring Station deployed in the Rough and Black Rivers. This uses a mains-powered peristaltic pump (inset) to deliver water to a system of sensors mounted in a flow cell.

3.1. DEVELOPMENT OF THE RIVER MONITORING STATION PROTOTYPE

The river stations were developed later than the original Lake monitoring stations and are of a simpler design and support a more limited range of sensors. Figure 3.3 shows a prototype station.



Figure 3.3 The prototype Automatic River Monitoring Station (ARMS).

In the prototype station, river water was pumped through an array of sensors using a hydraulic ram powered by the head of water. Sensors for measuring water temperature, pH, conductivity and turbidity were located in a small tank and an additional sensor (a pressure transducer mounted in a stilling well) for measuring the depth of water was deployed at a convenient point on the bed

of the river. The advantage of this configuration is particularly apparent in streams prone to spate, where sensors installed in the stream are easily damaged.



Figure 3.4 The hydraulic ram pump used on the original prototype

Table 3.1 lists the standard suite of sensors connected to the prototype river monitoring system.

Table 3.1 Sensors connected to the Automatic River Monitoring Station

Parameter	Supplier	Range	Resolution	Accuracy
Temperature	RS Components	-10 to 50°C	0.01°C	± 0.02°C
pH	AmpHel/Whatman	1 to 11 pH units	0.01	± 0.02
Conductivity	LTH Electronics	0 to 2000µS.cm ⁻¹	0.1µS.cm ⁻¹	± 1µS.cm ⁻¹
Nephelometer	Chelsea Instruments	0.04-100 FTU	0.01 FTU	-
Depth Sensor	Druck	0 to 3.5m	1mm	± 5mm

When this water delivery system was tested in the UK it proved very reliable but a similar system deployed in Ireland failed to deliver a regular flow of water and was eventually replaced by two other designs:

1. A system where the water was abstracted from the river by a mains-powered peristaltic pump (Figure 3.5). As with the original design, this reduced the risk of damage during spate conditions but could only be used in the lower reaches where there was a convenient mains power supply.
2. An *in situ* system of sensors mounted in a strong protective cage (Figure 3.6). This system is mechanically quite robust but can only be used on rivers where there are no forestry operations and no risk of damage from floating logs.

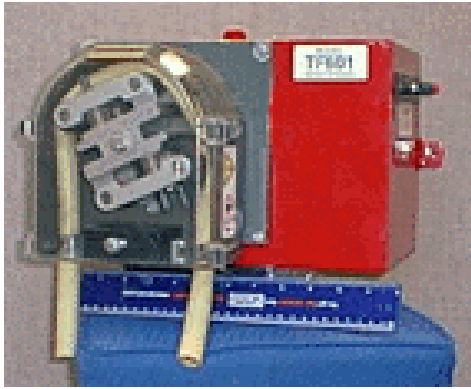


Figure 3.5 The mains-powered peristaltic pump used in one variant of the Automatic River Monitoring Station (ARMS)



Figure 3.6 The variant of the Automatic River Monitoring Station using an in situ system of sensors mounted in a strong protective cage

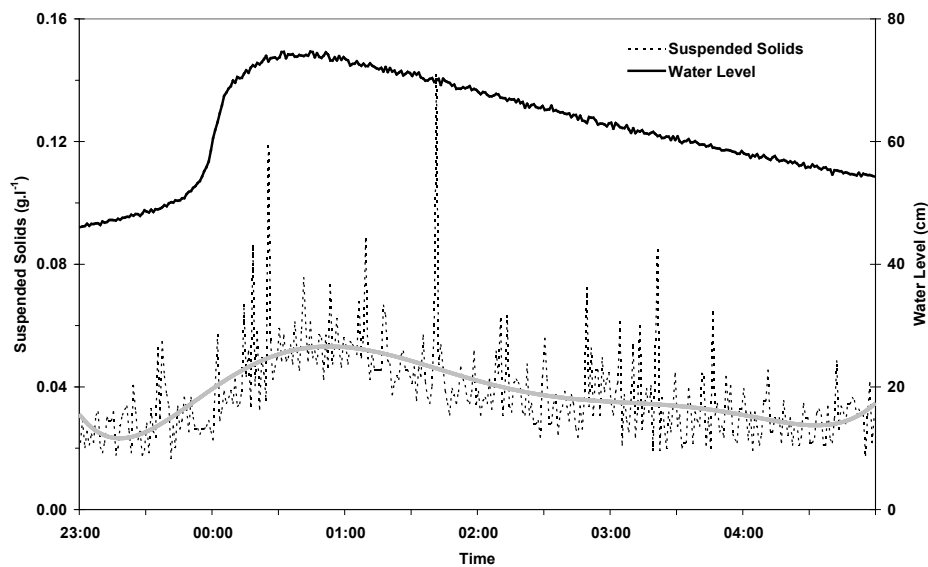


Figure 3.7 The high-resolution measurements recorded by the ARMS station deployed on the Rough River on the night of 31 March / 1 April 2002

The example outputs in Figures 3.7 and 3.8 show some of the high-resolution records acquired by these systems. The example in Figure 3.7 is taken from the shore-based system deployed on the Rough River and shows the minute-by-minute measurements taken during a spring flood event. The example in Figure 3.8 is taken from the *in situ* system deployed on the Glenamong over a seven-day period. During this period, the level of the stream (Figure 3.8d) rises on several occasions in response to rainfall events. The specific conductivity of the water falls as the level rises due to dilution (Figure 3.8c). The Suspended Solids concentration (Figure 3.8b), however, rises with rising level as more peat is washed from the catchment during these rainfall events. A clear diel pattern is evident in the Water Temperature (Figure 3.8a).

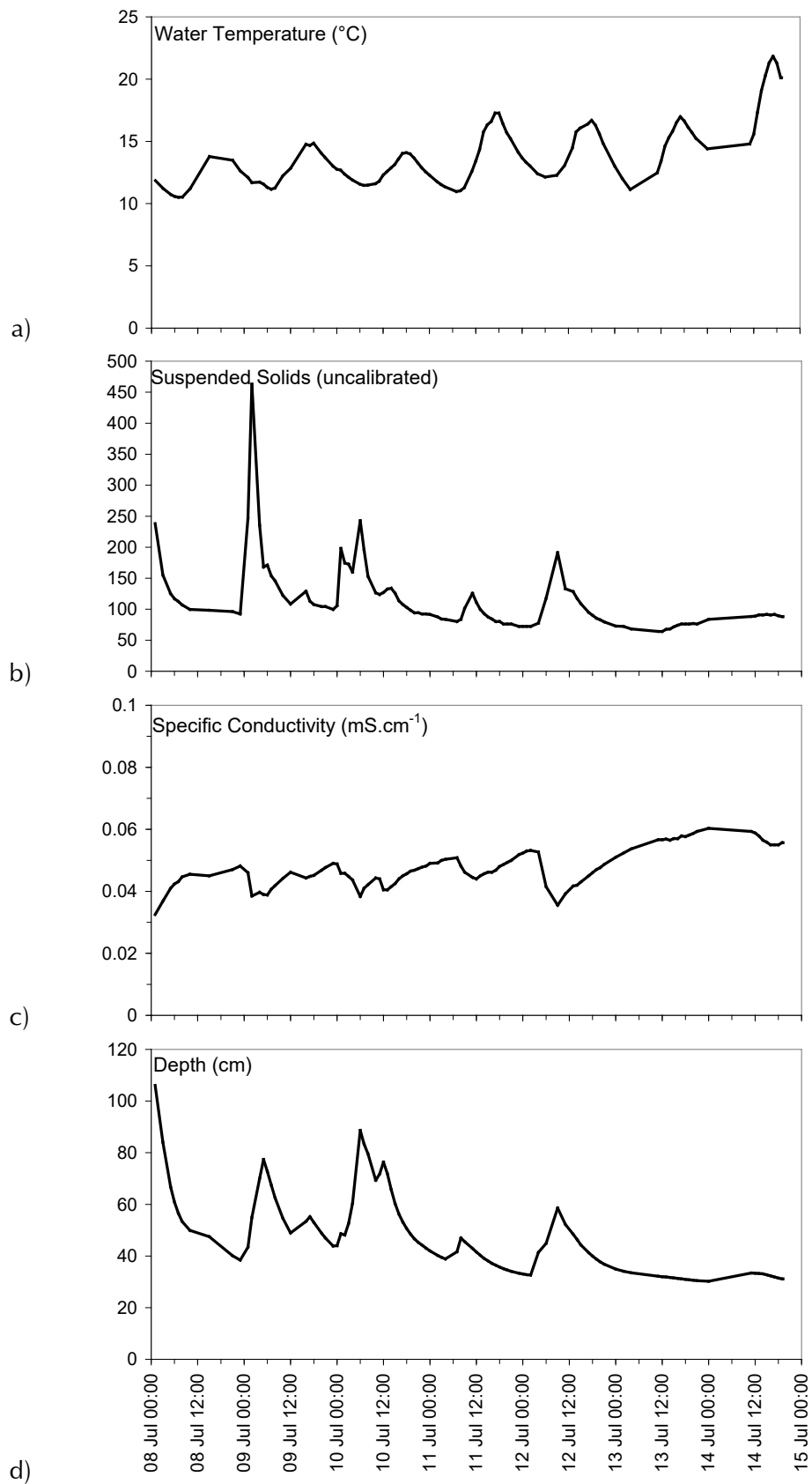


Figure 3.8 Sample a) Water Temperature, b) Suspended Solids, c) Specific Conductivity and d) Depth data recorded by the Automatic River Monitoring Station (ARMS) deployed on the Glenamiong during a week-long period in summer 2002.

3.2. RIVER MONITORING STATIONS AS CURRENTLY INSTALLED

There are three River Monitoring Stations currently installed: Black River, Glenamong and Rough River. A simpler station is installed at the Mill Race.

Table 3.2 summarises the sensors and data loggers at each river station, and Table 3.3 summarises the data logger programs at all six stations.

Table 3.2 Sensors and data loggers at the river monitoring stations

Parameter	Sensor	Black	Glenamong	Rough	Mill Race
Water temperature	Thermistor (measured by the logger)	✓	✓	✓	✓ (3)
Conductivity	LTH Electronics cell	✓	✓	✓	
Water level	Druck pressure transducer	✓	✓	✓	
Suspended solids	Chelsea Minitracka nephelometer	✓	✓	✓	✓
CDOM	Seapoint UV fluorometer	✓	✓	✓	✓
pH	Campbell Scientific pH sensor (CS525)		✓	✓	
Dissolved oxygen	D-Opto optical sensor	✓		✓	
Dissolved oxygen	In-Situ RDO optical sensor		(✓)		
Nitrate	Sea-Bird SUNA	✓			
Multi-parameter sonde	Hydrolab DS5x	✓	✓		
Multi-parameter sonde	Eureka Manta			✓	
Sonde parameters		Temp, pH, SpC, DO	Temp, pH, SpC, DO, Chl a	Temp, pH, SpC, DO, Chl a, turbidity	
Data logger	Campbell Scientific	CR6	CR1000	CR1000X	CR1000
Recording interval		4 min	2 min	2 min	2 min

Table 3.3 summarises the data logger and program at each of the six stations, as read from the programs loaded in October 2026.

Table 3.3 Data logger configuration of the monitoring stations

Station	Data logger	Program version	Recording	Telemetry
Lough Feeagh	CR1000X	2.23 (April 2021)	2 min; hourly; daily to 09:00; CO ₂ every 10 min	CELL215 4G; modem power-cycled every 6 h
Furnace Lough	CR1000X	2.03	1 min; hourly; daily to 09:00; winch profiles	CELL215 4G
Black River	CR6	1.33 (December 2025)	4 min; hourly; daily to 09:00	Huawei 4G router; gateway for the RF422 radio network
Glenamong	CR1000	1.23 (file 1.24)	2 min; hourly; daily to 09:00	CELL215 4G; modem reset every 2 h

Station	Data logger	Program version	Recording	Telemetry
Rough River	CR1000X	2.00	2 min; hourly; daily to 09:00	868 MHz RF422 link via two repeaters to the Black River
Mill Race	CR1000	2.03 (August 2024)	2 min; hourly	None at present

3.2.1. Black River

Physical Arrangements

The station is located about 10m from the river in a timber shed with mains power. Water is pumped using a 110V peristaltic pump (located in the shed) from the river to a flow cell (tank) in which the sensors are suspended. The outflow is returned to the river. The Water level is measured using a pressure transducer in a stilling well in the river – this is the only sensor in the river itself. The Black River is prone to spate, so this configuration minimises the risk of damage to sensors etc. The electronics, based on a CR6 data logger, are housed in a wall-mounted IP65-rated enclosure. At this station sensors are wired directly to the data logger panel rather than via connectors. The system is powered from a sealed lead acid battery continuously float-charged from the mains via a 12V charger.



Figure 3.9 The Black River station: the timber shed housing the pump, flow cell and electronics.

Sensors/Key components

The station records data from the following sensors every four minutes (along with hourly and daily means):

- Water Temperature
- Conductivity
- Water Level
- Dissolved Oxygen (D-Opto LDO)
- Nephelometer (suspended solids)
- CDOM (Coloured Dissolved Organic Matter)
- Multi-parameter sonde (Water Temperature, pH, Specific Conductance, Dissolved Oxygen)

- Nitrate (SUNA sensor)
- The station also records diagnostic information (Data logger Temperature, Data Logger supply voltage, Nitrate sensor diagnostics and the radio signal levels of the RF network).

Telemetry

Unlike the other stations, telemetry to the Black River is provided using a 4G Huawei modem. The 3G/4G signal is relatively strong at this site and provides a very reliable service. Although there are occasional short breaks in service, the Huawei modem reconnects to the mobile network fully automatically. The Black River data logger is also the gateway of the 868 MHz RF422 radio network that links the Rough River station (section 3.2.3); every 10 minutes it reads the radio signal level of each node on the network and stores the values hourly.

3.2.2. Glenamong

Physical Arrangements

The station is located close to the river housed in an IP65 rated suitcase style housing (Peli case) within a weather resistant stainless steel housing. All sensors connect via military-grade connectors. The system is based on a CR1000 data logger. The river at the Glenamong site is slower moving and less prone to dramatic level changes. All sensors at the Glenamong site are directly in the river, but protected by a strong metal cage. The system is powered from a sealed lead acid battery charged from a 20W solar panel.

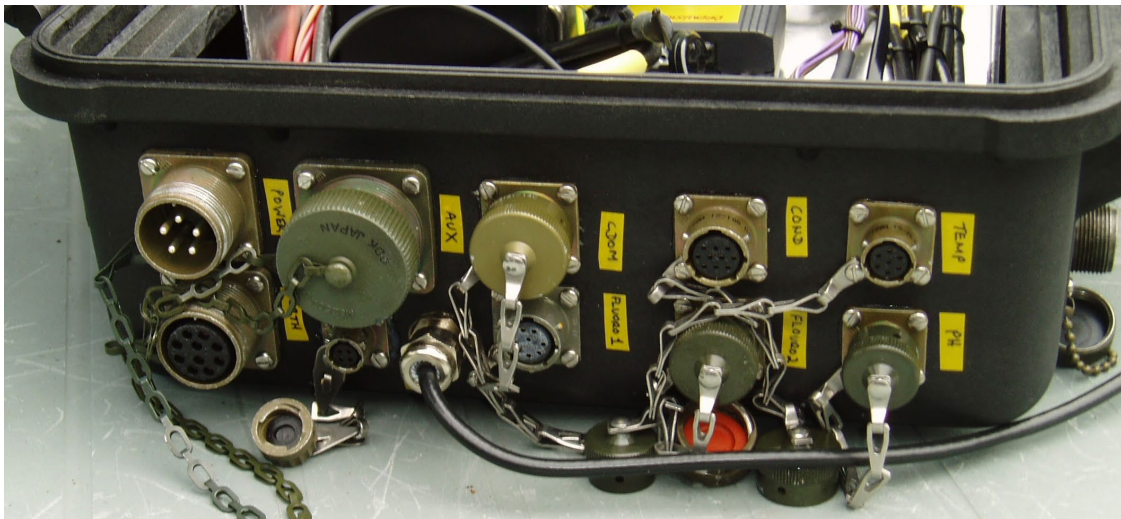


Figure 3.10 The Glenamong electronics in the IP65 case, showing the military-grade sensor connectors.

Sensors/Key components

The station records data from the following sensors every two minutes (along with hourly and daily means):

- Water Temperature
- Conductivity
- Water Level
- pH (Campbell Scientific pH sensor – the raw voltage is recorded and converted to pH during data processing)
- Provision for Dissolved Oxygen (In-situ RDO) – not currently in use
- Nephelometer (suspended solids)
- CDOM (Coloured Dissolved Organic Matter)

- Multi-parameter sonde (Water Temperature, pH, Specific Conductance, Dissolved Oxygen, Chlorophyll a)
- The station also records diagnostic information (Data logger Temperature, Data Logger supply voltage, Sonde supply voltage).

Telemetry

Telemetry to the Glenamong is provided using a 4G Campbell Scientific CELL215 modem. The 3G/4G signal is weak at this site and a high gain directional antenna is used. This provides a reasonably reliable service. Although there are occasional breaks in service, the CELL215 modem generally reconnects to the mobile network automatically. In addition, the data logger program closes the connection and power-cycles the modem every two hours to restore the link if it has dropped.

3.2.3. Rough River

Physical Arrangements

The station is located close to the river, but on raised ground in a timber shed with mains power. Water is pumped using a 110V peristaltic pump (located in the shed) from the river to a flow cell (tank) in which the sensors are suspended. The outflow is returned to the river. The Water level is measured using a pressure transducer in a stilling well in the river – this is the only sensor in the river itself. Like the Black River, the Rough River is prone to spate, so this configuration minimises the risk of damage to sensors etc. The electronics are housed in an IP65 rated suitcase style housing (Peli case) within a weather resistant stainless steel housing. All sensors connect via military-grade connectors. The system is based on a CR1000X data logger. The system is powered from a sealed lead acid battery continuously float-charged from the mains via a 12V charger.

Sensors/Key components

The station records data from the following sensors every two minutes (along with hourly and daily means):

- Water Temperature
- Conductivity
- Water Level
- Dissolved Oxygen (D-Opto LDO)
- pH
- Nephelometer (suspended solids)
- CDOM (Coloured Dissolved Organic Matter)
- Multi-parameter sonde (Eureka Manta: Water Temperature, Specific Conductance, pH, Dissolved Oxygen, Chlorophyll, Turbidity)
- The station also records diagnostic information (Data logger Temperature, Data Logger supply voltage, Sonde battery voltages and the radio signal level).

Telemetry

There is no mobile coverage at the Rough River, and the analogue phone line used previously is no longer reliable. The station is now linked to the Black River station through the 868 MHz RF422 radio network, using two RF422 modules as repeaters, and its data are collected through the Black River 4G connection. The data logger records the radio signal level every scan.

3.2.4. **Mill Race**

Physical Arrangements

The station is located about 5m from the river in a block/brick built hut with mains power. Sensors are directly in the stream. The electronics are housed in a wall mounted IP65 rated enclosure based on a CR1000 data logger, which has replaced the original CR10X (the current program, version 2.03, dates from August 2024). At this station sensors are wired directly to the data logger panel rather than via connectors. The system is powered from a sealed lead acid battery continuously float-charged from the mains via a 12V charger.

Sensors/Key components

The station records data from the following sensors every two minutes (along with hourly means):

- Water Temperature (3 sensors)
- Nephelometer (suspended solids)
- CDOM (Coloured Dissolved Organic Matter)
- The station also records diagnostic information (Data Logger supply voltage).

Telemetry

Telemetry to the Mill Race is not currently operational. An old point-to-point UHF modem has been used previously. It is hoped that it may be possible to provide a link using the mesh radio network (not yet deployed).

4. DATA SHEETS

4.1. INTRODUCTION

In this chapter, we list, with links to the manufacturer's data sheets, the key electronics subassemblies currently used in the lake and river monitoring stations. The following table summarises the deployments:

Table 4.1 List of key modules used in the lake and river monitoring stations.

Module	Furnace Lough	Lough Feeagh	Black River	Glenamang	Rough River	Mill Race	Notes
CR1000				✓		✓	Retired (replaced by CR1000X)
CR1000X	✓	✓			✓		Retired (replaced by CR1000Xe)
CR200		✓					CO ₂ sensor interface. Retired (replaced by CR300 series)
CR6			✓				Current
AM416	✓	✓					Retired (replaced by AM16/32B)
SDM-SIO1		✓					Provision for a TriLux fluorometer (not in use). Retired (replaced by SDM-SIO1A)
CELL215	✓	✓		✓			Current
RF422			✓		✓		Plus two RF422 repeaters. Current

RF422 modules (see RF407 series data sheet) are used to link the Rough River Station (which is located in an area with no mobile coverage) to the Black River Station (via two RF422 modules used as repeaters).

LoggerNet and RTMC software (running on a PC at the Marine Institute, Newport) collect, display and store data and serve near-real-time web pages.

Manufacturers' data sheets. Sections 4.2 to 4.12 give links to the relevant product pages and documents on the Campbell Scientific UK website, where the current versions can be downloaded free of charge. The links were checked in October 2026; if a link has moved, search for the model number at www.campbellsci.co.uk. Several of these products are now retired. Campbell Scientific continues to host documentation for most retired products, but users are advised to keep their own copies of the documents for the equipment they maintain.

4.2. CR1000

Status (October 2026): Retired product (no longer available for new orders); replaced by the CR1000X series.

Product page: <https://www.campbellsci.co.uk/cr1000>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_cr1000.pdf

Specifications: https://s.campbellsci.com/documents/eu/product-brochures/s_cr1000.pdf

Operator's manual: <https://s.campbellsci.com/documents/eu/manuals/cr1000.pdf>

4.3. CR1000X

Status (October 2026): Retired product (no longer available for new orders); replaced by the CR1000Xe.

Product page: <https://www.campbellsci.co.uk/cr1000x>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_cr1000x.pdf

Specifications: https://s.campbellsci.com/documents/us/product-brochures/s_cr1000x.pdf

Product manual (online, covers CR1000X and CR1000Xe):
<https://help.campbellsci.com/CR1000X/Default.htm>

4.4. CR200

Status (October 2026): Retired product. The CR200 series was superseded by the CR200X series, which has itself been replaced by the CR300 series. Used at Lough Feeagh as the CO2 sensor interface.

Product page (CR200X series): <https://www.campbellsci.co.uk/cr200x>

Specifications (CR200X series): https://s.campbellsci.com/documents/eu/product-brochures/s_cr200x.pdf

Operator's manual (CR200/CR200X series):
https://s.campbellsci.com/documents/eu/manuals/cr200_200x.pdf

4.5. CR6

Status (October 2026): Current product.

Product page: <https://www.campbellsci.co.uk/cr6>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_cr6.pdf

Specifications: https://s.campbellsci.com/documents/us/product-brochures/s_cr6.pdf

Product manual (online): <https://help.campbellsci.com/CR6/Default.htm>

4.6. AM416

Status (October 2026): Retired product (replaced by the AM16/32 in 2001, now the AM16/32B). Replacement parts are still available. (No UK product page was available; the international page is given.)

Product page: <https://www.campbellsci.com/am416>

Data sheet (AM416 Relay Multiplexer): https://s.campbellsci.com/documents/eu/product-brochures/b_am416.pdf

4.7. SDM-SIO1

Status (October 2026): Retired product (no longer available for new orders); replaced by the SDM-SIO1A.

Product page: <https://www.campbellsci.co.uk/sdm-sio1>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_sdm-sio1.pdf

User guide: <https://s.campbellsci.com/documents/eu/manuals/sdm-sio1.pdf>

4.8. **CELL215**

Status (October 2026): Current product (4G LTE Cat-1 cellular module for EMEA countries).

Product page: <https://www.campbellsci.co.uk/cell215>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_cell215.pdf

Product manual (CELL200 series):

<https://s.campbellsci.com/documents/eu/manuals/cell200-series-eu.pdf>

4.9. **RF422 (RF407 SERIES)**

Status (October 2026): Listed as a current product (868 MHz radio, the European member of the RF407 series).

Product page: <https://www.campbellsci.co.uk/rf422>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_rf422.pdf

Product manual (RF407 series): <https://s.campbellsci.com/documents/eu/manuals/rf407-series%20-%201143.pdf>

4.10. **LOGGERNET SOFTWARE**

Status (October 2026): Current product (LoggerNet 4.x).

Product page: <https://www.campbellsci.co.uk/loggernet>

Brochure: https://s.campbellsci.com/documents/eu/product-brochures/b_loggernet.pdf

Product manual: <https://s.campbellsci.com/documents/us/manuals/loggernet.pdf>

4.11. **RTMC PRO SOFTWARE**

Status (October 2026): Current product.

Product page: <https://www.campbellsci.co.uk/rtmcpro>

Brochure (RTMC, RTMC Pro, RTMC Run-Time and CSI Web Server):

https://s.campbellsci.com/documents/eu/product-brochures/b_rtmc.pdf

Product manual: <https://s.campbellsci.com/documents/eu/manuals/rtmc-pro%20-%200673.pdf>

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5.4. **LI-COR**

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5.5. **KIPP & ZONEN**

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5.7. **SUNA (NITRATE SENSOR)**

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www.techworks.ie

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5.8. **WILLIAMSON PUMPS**

www.wmcpumps.com

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Unit 5 Lady Bee Industrial Estate, Southwick West Sussex BN42 4EP UK

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5.9. **WINDSPEED (VECTOR INSTRUMENTS)**

www.windspeed.co.uk

Windspeed Limited (Vector Instruments)

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5.10. KVH INDUSTRIES (COMPASS ENGINE)

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