



Protocols Manual for Real-Time Water Quality Monitoring in NL

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Contents

Contents.....	1-1
Appendices	1-2
List of Figures	1-3
List of Tables.....	1-4
Abbreviations and Acronyms	1-5
Acknowledgements.....	1-7
1 Introduction	1-7
1.1 Purpose/Scope	1-8
2 Quality Assurance, Control and Assessment.....	2-10
2.1 Quality Assurance	2-10
2.2 Quality Control.....	2-10
2.3 Quality Assessment.....	2-11
3 Equipment Selection	3-12
3.1 Instrument and Display Selection	3-12
3.1.1 Multi-Parameter Instruments	3-13
3.1.2 Single Parameter Instruments.....	3-14
3.1.3 Groundwater Monitoring Instruments	3-15
3.1.4 Spectroscopic Instruments	3-15
3.1.5 Display Units	3-16
3.2 Data Logger Selection	3-16
3.3 Communication Options	3-17
3.3.1 Telephony.....	3-17
3.3.2 Satellite.....	3-18
3.3.3 Global System for Mobile (GSM).....	3-20
3.3.4 Radio	3-20
3.4 Power Supply	3-20
4 Station Planning.....	4-22
4.1 Permanent RTWQ Stations	4-23
4.1.1 Surface Water Stations	4-24
4.1.2 Groundwater Stations	4-25
4.1.3 Seasonal Stations	4-26
4.2 Local Networked Stations.....	4-26
4.3 Temporary Stations and Integrated Stations	4-27
4.4 Deployment Techniques.....	4-27
4.4.1 Shore Deployment on Lake/River Bed	4-28
4.4.2 Shore Deployment in Piping.....	4-29
4.4.3 Bridge/Pier Deployment	4-30
4.4.4 Buoy Deployment	4-31
4.4.5 Well Deployment	4-32
4.4.6 Under Ice Deployment.....	4-33
4.5 Reconnaissance Survey.....	4-34
4.5.1 Hydrologic Conditions	4-34
4.5.2 Bed Material	4-35
4.5.3 Riparian Environment.....	4-36
4.5.4 Communication and Power Availability	4-37
4.5.5 Accessibility.....	4-37
4.5.6 Land Designations.....	4-38
4.5.7 Existing Infrastructure.....	4-38
5 Safety.....	5-39
5.1 Water and Ice	5-39
5.2 Contaminated Areas.....	5-40

5.2.1	Bacteriological Contamination	5-40
5.2.2	Mining Effluent.....	5-40
5.2.3	Other Contamination	5-40
5.3	Remote Areas and Working Alone	5-41
5.4	Personal Protective Equipment	5-42
6	Field and Laboratory Components.....	6-43
6.1	Field Logistics	6-43
6.2	Field Visits	6-44
6.2.1	Field Sheet	6-44
6.2.2	Field Instrument.....	6-44
6.2.3	QAQC Instrument.....	6-44
6.2.4	Comparison Rankings	6-45
6.2.5	QAQC Grab Samples	6-46
6.2.6	Station Safety and Security.....	6-47
6.3	Calibration and Maintenance of RTWQ Instrumentation	6-47
6.3.1	Laboratory Calibration Form.....	6-47
6.3.2	Log Files	6-48
6.3.3	Communication with Data Logger	6-48
6.3.4	Bio-Fouling Mitigation	6-48
7	Data Management and Reporting	7-50
7.1	Automatic Data Retrieval System (ADRS).....	7-51
7.2	Raw Data Display	7-51
7.3	QAQC Data Validation.....	7-53
7.4	Field Sheet	7-54
7.5	Deployment Spreadsheet.....	7-54
7.6	Deployment Report.....	7-54
7.7	RTWQ Webpage	7-55
8	Inventory Management	8-56
8.1	Inventory Tracking	8-56
8.2	Servicing and Repairs	8-56
9	References	9-58

Appendices

A	Station Shelter Design.....	ii
B	Instrument Protective Casing Design	vi
C	Field Visit Checklist	viii
D	Field Sheet	x
E	Laboratory Calibration Form.....	xiii
F	Data Variance Form	xv
G	Deployment Spreadsheet.....	xvii

List of Figures

Figure 3-1: Multi Parameter Water Quality Instruments
Figure 3-2: Single Parameter Water Quality Instruments
Figure 3-3: Groundwater Monitoring Instruments
Figure 3-4: Handheld Display Units for Water Quality Data
Figure 3-5: Veda's Data logger
Figure 3-6: CR1000 Data Logger
Figure 3-7: Installation of GOES antennae on an RTWQ monitoring station
Figure 3-8: Web Camera with Iridium Satellite on an RTWQ station
Figure 3-9: Iridium Base Station
Figure 3-10: Radio Communication Network Design
Figure 3-11: Battery, Solar Panel, and Solar Panel Regulator on an RTWQ station

Figure 4-1: RTWQ Station Shelter Designs
Figure 4-2: Animal Damage and Mitigation at an RTWQ station
Figure 4-3: Surface Water RTWQ Monitoring stations
Figure 4-4: Groundwater RTWQ Monitoring stations
Figure 4-5: RTWQ station deployed during the winter season
Figure 4-6: Mobile Environmental Monitoring Platform (MEMP)
Figure 4-7: Protective Casings for RTWQ Instruments
Figure 4-8: Shoreline Deployment Diagram
Figure 4-9: Shoreline Deployment in a Pipe Diagram
Figure 4-10: Shoreline Deployment in a Pipe Example
Figure 4-11: Bridge or Pier Deployment Diagram
Figure 4-12: Bridge or Pier Deployment Example
Figure 4-13: Buoy Deployment Technique Diagram
Figure 4-14: Buoy Deployment Example
Figure 4-15: Well for RTWQ Monitoring Diagram
Figure 4-16: Well Monitoring Station Example
Figure 4-17: Under Ice Deployment Diagram
Figure 4-18: Under Ice Deployment Example
Figure 4-19: Stream Flow Conditions for RTWQ
Figure 4-20: Bed Material for RTWQ
Figure 4-21: Custom built apparatus in sandy river reach
Figure 4-22: Macrophyte growth at an RTWQ station
Figure 4-23: Communication with an RTWQ station via satellite
Figure 4-24: Accessibility to an RTWQ station and the water body

Figure 5-1: Safety in Water and Ice
Figure 5-2: Safety in Contaminated Areas
Figure 5-3: Personal Locator Beacon and Satellite Telephone
Figure 5-4: Personal Protective Equipment

Figure 6-1: Field Visit Preparation
Figure 6-2: Grab Sample Bottles and Sampling
Figure 6-3: Cleaning, Calibrating and Maintaining RTWQ Instruments
Figure 6-4: Biofouling Growth minimized by covering the instrument with pantyhose

Figure 7-1: Flowchart for Data Management and Reporting
Figure 7-2: Flowchart for Automatic Data Retrieval System
Figure 7-3: NL Departmental webpage for RTWQ rolling graphs
Figure 7-4: NL Departmental webpage for RTWQ station names

Figure 8-1: Inventory tracking

List of Tables

Table 3-A: Commonly Measured Water Quality Parameters

Table 3-B: Parameters Available for S::can

Table 6-A: QAQC Comparison Chart

Abbreviations and Acronyms

A	Ampere
ABS	Acrylonitrile Butadiene Styrene
ADRS	Automatic Data Retrieval System
Ah	Ampere-Hour
ATV	All Terrain Vehicle
BOD	Biochemical Oxygen Demand
BGA	Blue-Green Algae
BTX	Benzene, Toluene, Xylene
°C	Degree Celsius
CCG	Canadian Coast Guard
CCME	Canadian Council of Ministers of the Environment
cm	Centimeters
COD	Chemical Oxygen Demand
CSC	Campbell Scientific Canada
DCS	Data Communication Systems
EC	Environment Canada
GOES	Geostationary Operational Environmental Satellite
GSM	Global System for Mobile
GPS	Global Positioning System
mA	Milliamperes
MEMP	Mobile Environmental Monitoring Platform
mg/L	Milligrams per Liter
NESDIS	National Environmental Satellite, Data, and Information Service
NIST	National Institute of Standards and Technology
NL	Newfoundland and Labrador
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Unit
OHS	Occupational Health and Safety
ORP	Oxidation-Reduction Potential
PAR	Photosynthetically Available Radiation
PCB	Polychlorinated Biphenyl
PEGNL	Professional Engineers and Geoscientists Newfoundland and Labrador
PFD	Personal Flotation Device
PPE	Personal Protective Equipment
PTE	Performance Evaluation Testing
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAQC	Quality Assurance and Quality Control
QC	Quality Control
RS-232	Recommended Standard 232
RTWQ	Real Time Water Quality
SD	Secure Digital
SDI	Serial Digital Interface
SPOT	Système Pour l'Observation de la Terre (System for Earth Observation)
TDS	Total Dissolved Solids

TOC	Total Organic Carbon
TSS	Total Suspended Solids
US	United States
USB	Universal Aerial Bus
µS/cm	MicroSiemens per Centimeter
UV254	Ultra Violet 254 nanometer
V	Volt
W	Watt
WRMD	Water Resources Management Division
WT	Water Tracing
YSI	Yellow Springs Instrument

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1 Introduction

Water quality monitoring is imperative in providing the Water Resources Management Division (WRMD) with the physical and chemical properties of water bodies throughout Newfoundland and Labrador (NL). This information is the basis on which the health of these waterways' is determined. Water quality monitoring has been conducted traditionally by collecting grab samples from lakes, rivers and streams across the province for many years. These samples are then sent to an accredited laboratory for analysis. Grab samples taken on a monthly, weekly or even daily schedule, only represent water quality at a particular moment in time. The natural environment is constantly changing and water quality can fluctuate quickly and dramatically with potentially adverse effects to aquatic life, their habitats and the surrounding environment. With the introduction of real time water quality (RTWQ) instrumentation, in situ sensors now can measure water quality data continuously. This information is transmitted through communication systems and made available to the end user in near real time. This allows the end user to identify, understand, follow and potentially mitigate harmful water quality events should they occur in a water body.

While RTWQ monitoring is gaining in interest and popularity, it *cannot* and *should not* be used to replace traditional grab sampling networks. Many grab sampling stations have long term historical databases which provide an essential and valuable source of information for a particular watershed over a long period of time.

RTWQ monitoring can be a useful tool in many aspects of water resource management. Even a short deployment period of RTWQ instrumentation can collect valuable information and help determine key stressors on a water body. NL has found this component of RTWQ extremely useful in urban impacted streams as well as water bodies under pressure from nearby industrial developments. As development expands in NL with respect to construction and natural resource exploration, it is important to find a balance between economic development and environmental protection. RTWQ has contributed significantly to the way in which partnering industries can identify their potential impact on streams and their influence on the health of a watershed. All water quality data gathered through the RTWQ monitoring network is available online for the general public, environmental awareness groups, other government organizations, and the private sector. It is paramount that data being viewed is of the highest quality. When working in the natural environment it is important to standardize protocols and procedures to reduce the likelihood of errors and inconsistencies, hence providing accurate, precise and reliable data.

Since the implementation of the NL RTWQ monitoring program in 2001, the program has expanded across NL. Currently, the RTWQ monitoring program consists of over 30 stations (2013). Most stations operate in partnership with Environment Canada (EC) and industry partners.

1.1 Purpose/Scope

The inception, expansion and improvements of the NL RTWQ monitoring program has been a lengthy process with many partners consistently working to improve and advance the program. Through experience learned, the WRMD has identified many of the necessary components for the development and management of a successful RTWQ network. This manual aims to document the components from the conception and production stages through to data management and reporting. Streamlined processes and procedures to be followed by all WRMD personnel are outlined. It is the responsibility of all WRMD personnel to

exercise diligence during tasks to reduce the possibility of errors or inconsistencies during these processes.

This manual will be used as a reference guide in relation to: site and instrument selection, deployment techniques, field procedures, calibration and maintenance of continuous water-quality instruments, quality assurance and quality control measures and data analysis and reporting.

2 Quality Assurance, Control and Assessment

To ensure the effectiveness and reliability of the RTWQ monitoring program, quality assurance (QA), quality control (QC) and quality assessment procedures have been implemented. Proper procedures outlined in this manual and its attachments should be adhered to consistently. Anything outside the procedure should be documented to explain reasoning. It is essential that all RTWQ personnel ensure that their responsibilities and tasks are completed in reference to this manual. All RTWQ personnel have the responsibility and authority to manage, perform and verify that their work follows QA, QC and quality assessment protocols. Specific components of QA, QC and quality assessment in RTWQ monitoring are summarized below. Specific *procedures* relating to QA, QC and quality assessment are explained within their respective sections throughout the manual.

2.1 Quality Assurance

QA includes all high-level activities, structures and mechanisms used to ensure and document the accuracy, precision, completeness, effectiveness and representativeness of the RTWQ monitoring program. QA ensures the overall integrity of the program design and consists of two separate but interrelated activities: QC and quality assessment. QA program elements include:

- Annual proficiency testing and evaluations of instrument function
- Personnel qualifications and training
- Technical procedures for sampling and conducting field and analytical work
- Troubleshooting of instruments, recording equipment, installations, transmission of data and corrective action plans
- Record keeping including field sheet and chain of custody for grab samples, deployment field sheet, logbooks and instrument calibration records
- Implementation of QAQC procedures including data verification, validation and variance forms
- Preparation of analytical reports, data packages and RTWQ web page
- Auditing adherence to program requirements and following internal procedures
- Peer review of RTWQ program design, QAQC procedures and data analysis
- Investigation of emerging RTWQ technology, QAQC procedures, and analysis techniques
- First-hand knowledge of each RTWQ station watershed through observation and field visits

2.2 Quality Control

QC refers to the use of technical activities which ensure that the data collected are adequate for quality assessment purposes. This includes feedback systems to ensure activities are occurring as planned and intended, and to verify that procedures are being carried out satisfactorily. QC program elements include:

- Monthly maintenance and calibration of the probe and its sensors
- Inspection and maintenance of RTWQ station installation
- Field readings taken at the time of removal and redeployment of the probe using a field QAQC instrument

- In situ validation of field and QAQC instrument readings according to comparison table and troubleshoot to determine cause if significant discrepancies occur
- Collection of a water quality grab sample at the time of redeployment of the probe to be sent to an accredited laboratory for analysis
- Updating spreadsheet with grab sample results once laboratory analysis is complete

2.3 Quality Assessment

Quality assessment activities are implemented to quantify the effectiveness of the quality control procedures. Quality assessment program elements include:

- Calculate long-term and monthly period summary statistics
- Produce time series graphs for each parameter and evaluate for gaps, data errors, and guideline exceedances for pH, dissolved oxygen and turbidity
- Publishing near-real time updates of RTWQ data on the WRMD web page for public review
- Produce a report for each station corresponding to deployment periods, including any problems with maintenance, calibration and QAQC procedures; any data issues; time series graphs and summary statistics for each parameter; brief explanations for observed results; and data qualification statements
- Archiving of RTWQ monitoring data records
- Identify any issues with the parameter order, sensor failure or missing data transmissions in a data variance report
- Regular updates to the calibration schedule on the web page

3 Equipment Selection

There are many options when it comes to RTWQ monitoring with respect to available instrumentation and communication. The WRMD has devoted significant time to researching, testing, and comparing results from different instruments available combined with various communication options. Available documents summarizing specific research and data comparisons are on the departmental webpage.

As the field of RTWQ monitoring progresses, it is important to stay informed about advancements in research and technology. The WRMD is committed to continuous investigation of new instrumentation and communication options worldwide.

There are a variety of communication options to facilitate water quality data transfer from a water body to an end user. Existing power and telecommunication infrastructure may be incorporated to create a station. In other cases, a station may be designed to stand alone in a remote location. It is advantageous to understand all the alternatives before a site is chosen and a station is installed. This section summarizes the instrumentation and communication options the WRMD has incorporated or tested in the NL RTWQ network.

3.1 *Instrument and Display Selection*

This section describes some of the different types of instruments available for incorporation in an RTWQ monitoring station or network. Instrument technology is constantly developing and improving. When selecting an instrument for an RTWQ station or network, it is important to first choose the parameters that are of highest priority and will provide meaningful data. The parameters usually of considerable importance to RTWQ monitoring in NL are temperature, pH, specific conductivity, dissolved oxygen and turbidity. Additional parameters such as chlorophyll, blue-green algae (BGA), and total suspended solids (TSS) are considered on a site-by-site basis.

There are a variety of continuous water quality monitoring instruments available from different manufacturers which offer different designs, options and combinations of sensors. Once the parameters of interest have been determined, it is important to verify the range, accuracy and resolution of the individual sensors. This information is important in determining the type of data the instrument will provide and if the data collected will satisfy the stations objective.

In addition to parameter and sensor selection, there can be many other options and upgrades to the instruments. It is important to weigh each of the options presented and consider their value to the station. One of these factors is the suggested deployment length. Most manufacturers of optical multi-parameter instruments suggest a 30 day deployment period. Spectroscopic instruments can sometimes be deployed for longer periods of time. Some sensors or instruments feature self-cleaning devices which in the experience of the WRMD and the NL RTWQ network have proven useful even in areas not prone to biofouling. Some sensors or instrument casings are available in titanium (vs. stainless steel) and can be used in salt water environments. Due to the errors introduced from biofouling, many manufacturers now offer an anti-bio-fouling kit. Finally, it is important to consider the functioning of the instrument. Instruments may feature battery packs and internal logging capabilities and memory. All of these options will need to be considered when selecting and purchasing an instrument. Background information about the water body will aid in determining what the necessary features are for an instrument to meet monitoring requirements.

3.1.1 Multi-Parameter Instruments

Many parameters can be assessed simultaneously using a series of electrochemical and optical sensors connected to the same instrument. Multi-parameter instruments offer multiple ports for sensors and can be designed specifically to measure parameters of interest (Figure 3-1). A multi-parameter instrument can be purchased in a variety of sizes. It is the size of the instruments that determines the number of sensors and/or parameters to be measured (Table 3-A). Depending on the instrument, data can be recorded internally or transmitted through another means of communication.

Multi parameters instruments (e.g. Hydrolab, YSI) are most commonly used throughout the NL RTWQ network. RTWQ sites in NL measure chemistry parameters including temperature, pH, specific conductivity, dissolved oxygen and turbidity. These measured parameters can be used to further calculate additional parameters such as total dissolved solids (TDS) and percent saturation. Additional sensors that have been incorporated into the NL RTWQ network include chlorophyll a, BGA, and oxidation-reduction potential (ORP).

Current research by the WRMD examines the potential to extrapolate additional parameters such as TSS, as well as various major ion concentrations such as chloride, sodium, calcium and sulfates. These parameters can be deduced by determining the relationship between measured parameters and laboratory results from grab samples. A report detailing the relationship between specific conductivity and major ions is available on the departmental webpage.

Table 3-A: Commonly measured water quality parameters (CSC, 2012; YSI, 2011)

Parameters Available for Hydrolab and YSI Products			
Dissolved Oxygen	Turbidity	BGA	Chloride
Conductivity	Depth	Ammonia	ORP
pH	Chlorophyll α	Nitrate	Total Dissolved Gas
Rhodamine WT	PAR	Temperature	



Figure 3-1: Examples of YSI and Hydrolab multi parameter instruments (CSC, 2012; YSI, 2011, 2013)

3.1.2 Single Parameter Instruments

Single parameter instruments function similarly to the multi-parameter instruments; however, each instrument is specialized for measuring one specific parameter. There are cases where a single parameter is of considerable interest or of high priority. The user may require more detailed data such as higher resolution or improved accuracy or range.

WRMD have tested single parameter instruments designed for measuring turbidity and inferring TSS concentrations (Figure 3-2). WRMD is currently evaluating the difference between the accuracy of the single parameter sondes versus the multi-parameter sondes more commonly used in the network. TSS is an important water quality parameter for many industry partners especially during construction phases as it is a regulatory parameter with defined guidelines. Turbidity is easily measured in the water column by the instrument's optics and has a significant relationship with TSS. Further research in this area will be carried out to determine if turbidity readings from the multi-parameter instruments are accurate for TSS prediction and analysis. These single parameter instruments also function as a back-up should a sensor fail mid deployment. WRMD will continue to invest time and research into understanding the differences between the accuracies of the various sondes and the relationship between turbidity and TSS.

Single parameter temperature sensors have also been incorporated into the NL RTWQ network. This economical sensor can easily be integrated at existing water quantity stations and can provide useful information about water bodies both at the surface and ground water levels.



Figure 3-2: Examples of single parameter turbidity instruments (CSC, 2012; FTS, 2012)

3.1.3 Groundwater Monitoring Instruments

RTWQ Groundwater monitoring instruments are very similar to the multi and single parameter instruments. Groundwater multi-parameter instruments tend to be smaller than surface water instruments in order to accommodate the narrow diameter of drilled wells (Figure 3-3). The water quality parameters of interest for groundwater monitoring differ from surface water monitoring. Groundwater multi-parameter instruments are usually equipped with sensors to measure depth, ORP as well as typical water quality parameters like specific conductivity, pH, temperature *etc.* The NL RTWQ network has incorporated both Hydrolab Quanta G and YSI 600XLM models into the RTWQ groundwater monitoring network.



Figure 3-3: Examples of groundwater monitoring multi parameter instruments (CSC, 2012)

3.1.4 Spectroscopic Instruments

Spectroscopic instruments use wavelength technology to measure water quality parameters. These instruments have capabilities above and beyond measuring the basic water quality parameters offered by multi parameter instruments. These instruments are available in single or multi-parameter models. Spectroscopic instruments, such as the S::can Spectro::lyser have the ability to be calibrated for specific water quality parameters that possess a unique absorbance signature. Table 3-B displays a small selection of the parameters commonly measured by the Spectro::lyser. Potentially hundreds more can be detected and specific parameter signatures can be purchased from the manufacturer.

Table 3-B: Parameters available for S::can (AL, 2005)

Parameters Available for S::can Spectro::lyser		
UV254	BOD	Turbidity
COD	TOC	Temperature
Nitrate	BTX	Phenolics
Colour		

3.1.5 Display Units

Hand held display units are usually sold in conjunction with the multi or single parameter instruments. There are different models available depending on the instrument and manufacturer chosen.

Hand held display units are useful in the field setting and connect to the instrument via a short (~5-10m) field cable. The field units allow the user to view the water quality data in situ or via connection in the station shelter. This can be done quickly and easily from the safety of the shore. (Figure 3-4).

Hand held display units allow the user to verify current water quality data from the instrument in the stream which is necessary in order to compare live field instrument readings with QAQC instrument readings, a component of the QC procedure during deployment.



Figure 3-4: Hand held display units for viewing water quality data in-situ

3.2 Data Logger Selection

Data loggers bridge the gap between instruments immersed in a water body and the telemetry system used to relay water quality data back to a database. The data logger will retrieve and store data from the water quality instrument at pre-determined intervals specified in the data logger programming and ensure the data is available to the telemetry unit.

When selecting a data logger, it is important to choose one that is compatible with the instrument and telemetry equipment in use. Water quality instruments can be connected to a data logger using an analogue connection such as a 4 – 20 mA current loop, via an RS-232 (9-pin) connection or through an SDI-12 interfaces. All NL RTWQ stations use the digital interface SDI-12. SDI-12 is considered critical to water quality instrumentation in the network since it provides a power supply and good data signal strength over moderate distances.

Features such as touch screens, USB and SD card access are often optional features that add flexibility to data access, but are not necessary in the monitoring stations established in NL.

A variety of data loggers have been used throughout the NL network over the years including but not limited to: Valcom - VEDAS II (Figure 3-5); Sutron - Satlink II and 8210; CSC - CR1000 (Figure 3-6) and FTS data loggers. Data loggers can be found mounted in the station shelters in a protective casing preventing damage from climate, moisture, animals and vandals.

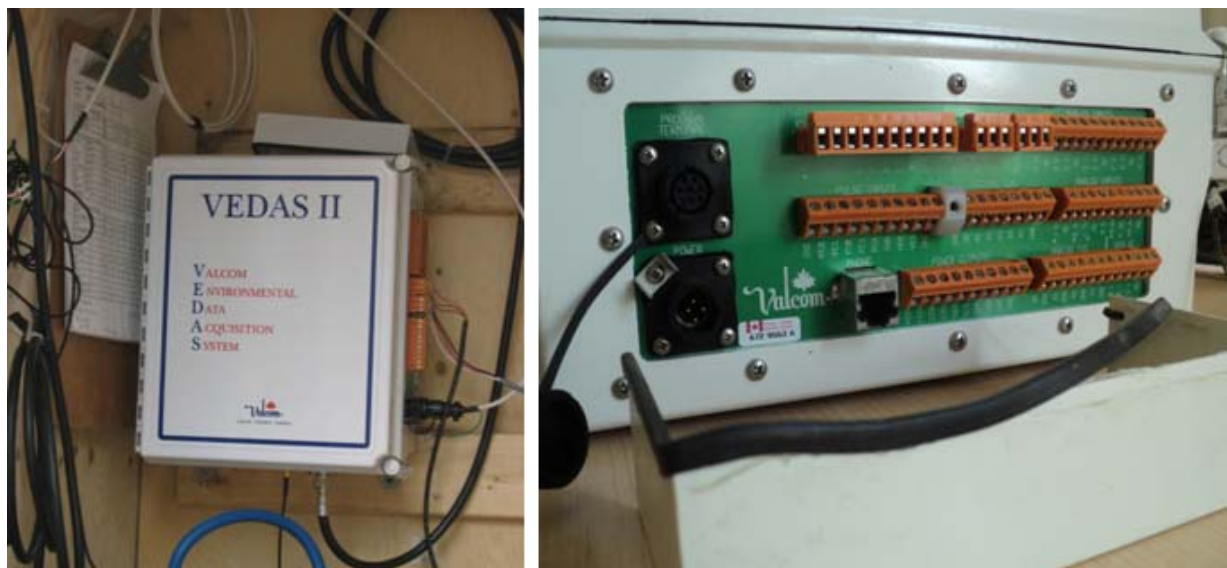


Figure 3-5: VEDAS data logger in an RTWQ monitoring station

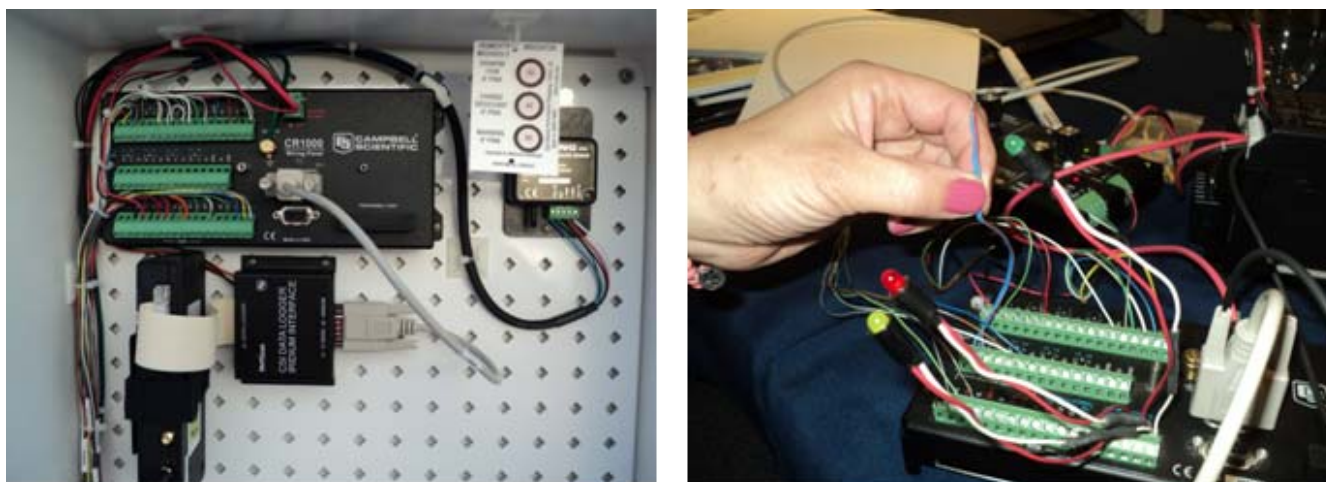


Figure 3-6: CSC CR1000 data logger in an RTWQ monitoring station

3.3 Communication Options

In RTWQ monitoring applications, a method to connect field equipment to a centralized server is required. There are several options available, each with its own advantages and disadvantages. Commonly used methods of telemetry include telephone, cellular and satellite. The following section will detail the various connectivity options available and the equipment needed namely cost, bandwidth, power requirements and reliability.

3.3.1 Telephony

At predetermined intervals a server can be programmed to establish a dial-up connection with a data/fax modem connected to the data logger. Water quality data is then uploaded to the server and the connection closes.

At various times, either due to fault of the telephone line and/or the modem malfunctioning, this method has become complicated and unreliable to the point where it has been abandoned largely in favor of GOES satellite telemetry.

Depending on the proximity of phone lines to the station, this method of telemetry may be expensive if the installation of telephone poles is required. If a phone line is nearby, a basic monthly telephone account is needed in addition to a data/fax modem. Such modems are generally simple to configure for use with a data logger and normally use an RS-232 port on the data logger.

3.3.2 Satellite

RTWQ stations can be situated in remote areas, therefore it may not be feasible to consider telephone service. The use of satellite telemetry is the only practical solution. Two broad categories of satellite communication exist: geostationary and low-earth orbit. While the scope of both platforms is the same, the equipment necessary is different. Two potential satellite telemetry options that are currently used in the NL network, GOES and Iridium, are described in the following sections. There are numerous other available satellite communication options worldwide.

Geostationary Operational Environmental Satellite (GOES)

Geostationary satellites, that are situated approximately 36000km above the equator, have an orbiting period equal to the rotation of Earth. A geostationary satellite maintains an immobile position relative to the ground and requires a directional antenna aimed according to a specific azimuth and elevation that changes depending on geographic location (Figure 3-7).

The Data Communication System (DCS) aboard the GOES satellites is operated by National Environmental Satellite, Data, and Information Service (NESDIS), a division of National Oceanic and Atmospheric Administration (NOAA) in the United States (US). The system offers an affordable and simple method for remote telemetry of RTWQ data. Accessing this system is without cost, assuming the conditions and scope of the DCS system are met. To qualify, the group requesting DCS access must be engaged in environmental monitoring and the data being recorded must be of interest to a US Federal Government department (acting as a sponsor). Equipment for DCS communication is relatively inexpensive and offers simple (one way) uplink communication.

As a result of the geostationary placement of the satellite, polar areas may be under serviced and patchy, especially in mountainous terrain.



Figure 3-7: Installation of GOES antennae on a RTWQ monitoring station

Iridium

The Iridium network consists of 66 cross-linked operational satellites, and six in-orbit spare satellites all over the planet. The network is considered a meshed constellation of interconnected satellites so that each satellite communicates with the other nearby satellites in front, behind and in adjacent orbits. The satellite network hands off voice or data communications automatically from one spot beam to another within the satellite footprint, and from one satellite to the next as they pass overhead. At least one satellite is above the horizon at a time and available for communication with a modem equipped with an omni-directional antenna (no aiming required). Iridium provides essentially 100% global, high- bandwidth, bidirectional coverage at a cost per kilobyte of data (Figure 3-8).

The high-power requirement for an Iridium modem demands that power consumption is considered when programming the data logger. Generally, the modem is turned on at predetermined intervals to answer a scheduled call from the base station (Figure 3-9). Once the file is uploaded, the modem is powered off to conserve battery power.

As an added benefit, during the window that the modem is powered up, troubleshooting data can be accessed from the remote station and programming changes may be made if the window time is long enough.



Figure 3-8: RTWQ station with web camera is equipped with iridium satellite for communication in remote areas.



Figure 3-9: Iridium base station located at WRMD headquarters in St. John's receives data from remote stations

3.3.3 Global System for Mobile (GSM)

The coverage of high-speed digital cellular networks has increased to the point where they have become a viable and affordable telemetry option. These networks offer low-powered, bi-directional communication at a fraction of the cost of Iridium.

GSM is the primary means of high-speed data communication and incorporates some of the concepts between satellite and telephony solutions. GSM, like satellite, requires no physical link to telephone wires, however, good reception from a nearby cell tower must be available. Because of this, application is limited to specific areas (mostly urban).

From a practical point-of-view, each station with cellular telemetry should be equipped with a static internet protocol (IP) address. A static IP address is a permanent IP address for the station as opposed to a dynamic IP address which would change every time the modem is power cycled. A static IP address ensures the ADRS can connect to the station with same address each time.

A sever will communicate the cellular modem over the internet and download the water quality data directly. Billing for this type of application can be a monthly fee with a bandwidth cap or a pay-as-you-go plan where a block of bandwidth is purchased and can be used up.

3.3.4 Radio

Radio transmission is useful for short-distance relay of data from a secondary station to a master station (Figure 3-10). An example of this may be a buoyed platform containing an RTWQ instrument. The buoy is tethered to the bottom of the water body but is still free to move with the water. It would be impossible to maintain the line-of-sight required to operate a GOES transmitter. Instead a radio transmitter with an omni-directional antenna passes data on to a shore-based master base station which then forwards data on to headquarters using one of the previously discussed telemetry methods.

Both the buoy and shore-based stations must be outfitted with their own data loggers and transmitters for reliable communication.

Radio communication has not yet been implemented in the NL RTWQ network. Research and testing continues to verify equipment and specifics required to incorporate this type of technology into the existing network in the future.

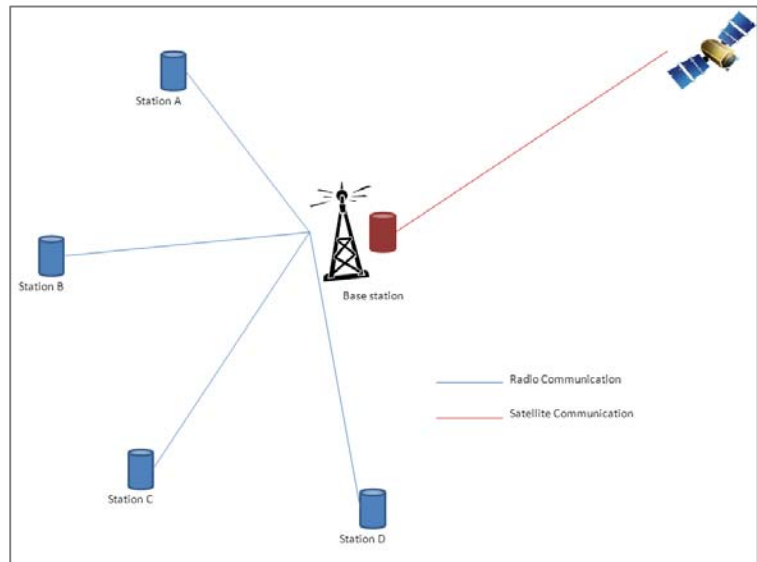


Figure 3-10: Networked or buoy stations can be set up using radio communication

3.4 Power Supply

The power requirement for a monitoring station varies depending on the equipment to be used. In most situations throughout NL, these stations are remote and solar power is the only feasible option. Other times, typically in urban areas, an electrical supply can be established from the power grid by contacting the local power provider.

If solar power is chosen, the following series of steps will assist in engineering a robust system able to withstand the cumulative power draw of all the equipment in use even on the shortest days of the year.

1. Take stock of all the equipment to be used at the monitoring station including water quality instrumentation, hydrometric instrumentation, data logger, modem (whether satellite, cellular or telephone), plus any other equipment that may be co-located during special projects.
2. The documentation included with the equipment identified in the first step should detail the electrical current (in amps) required in standby mode and active mode.
3. Determine the monitoring schedule for the station: How frequently will the instrument gather data? How frequently the station will transmit data?
4. Establish how much time a day (in hours) each instrument spends in its operating modes.
5. Multiply the time spent in each mode by the current draw required to derive the amp-hour requirement of each instrument.
6. Sum the amp-hour requirement for each device to get the total amp-hours and add 15% as a safety factor. This value will determine the minimum size of the battery bank required. Keep in mind that during long periods of low sun conditions, strain will be placed on the battery supply. It might be prudent to have a week's worth of capacity (ie, multiply the total daily amp-hours by 7).
7. To continue, multiply the total amp-hours of all the equipment by 12 V (the typical voltage rating of a solar panel). This, in conjunction with the latitude of the station, determines the required watt rating of the solar panel.

A solar equipment salesperson should be able to design a simple solar system armed with only the daily watt-hours of a station. Most new stations in NL rely on a single 50 W solar panel and a single 100 Ah deep-discharge battery with a 6 A power regulator (Figure 3-11).



Figure 3-11: (L) 12V Battery to power an RTWQ station; (M) solar panel on an RTWQ Station; (R) Solar power regulator on RTWQ Station

4 Station Planning

There are many factors that need to be considered when planning and establishing an RTWQ station. From station purpose to safe accessibility, it is important to know the different options and factors which must be considered to efficiently and effectively obtain accurate water quality data and maximize economic investment in an RTWQ station. This section discusses the types of deployment techniques and data collected.

Prior to the commissioning of an RTWQ station, a well-defined purpose for the station and the data to be collected should first be formulated. There are a few questions that need to be answered or at least acknowledged after deciding to install an RTWQ monitoring station. The following list of questions may appear overwhelming but are necessary to help justify and create a successful station or future network of stations. The data from this station should be useful and informative to all parties and target groups involved. The rationale of a station has implications on all decisions made.

- **What do you want to capture?**
Baseline or changes in water quality? And/or water quantity?
What parameters are going to help you to capture these changes?
- **Why do you want to capture these parameters?**
Is there a community or fragile ecosystems being potentially affected downstream?
Is it regulatory management?
- **Where do you want to monitor?**
Lake? Stream? Tailings pond? Well?
Upstream of development for baseline water quality or downstream from development for potentially impacted waters?
- **Who will benefit from this data?**
Are there non-governmental groups that will be interested?
Will the public be interested?
Will other government departments (forestry, mines and energy, etc.) be interested?
- **When do you want to monitor the water quality?**
Is this a temporary deployment? 1 month? 6 months?
Or a long term commitment? 5 years? 10 years?
Are you limited by the seasons? Will winter monitoring be an option?
- **How are you going to monitor?**
How will you access the site?
How will you deploy the instrument?
What type of instrument would be suitable?
- **Are there other factors that could add to the data you will collect?**
Is there a weather station nearby?
Is there an existing water quantity/quality monitoring station nearby?

The answers to these questions may change slightly throughout the planning process so it is important to keep coming back to these points regularly making sure each is satisfied to an extent. Some aspects of the project may be more of a priority than others so it may be necessary to compromise with one or more of the factors. The following sections will shed some light on many of these factors and help the user to understand the options and potential

for an RTWQ network. Further questions may arise as different options are presented. This following section aims at summarizing the experience of the WRMD with respect to planning and installing an RTWQ station or network of stations.

4.1 *Permanent RTWQ Stations*

Each RTWQ station is unique, ranging from the water quality parameters measured to the deployment technique used, no two RTWQ stations are alike. The following section highlights some of the different station types in the NL RTWQ network.

The NL RTWQ program has resources for both temporary and permanent project-based deployments. In general, most deployments in NL are of a permanent basis and the station is expected to remain in that area for the duration of the project or longer.

For a permanent station, a station shelter is constructed to protect the data logger, battery and cabling from weather, vandalism or damage by animals. Shelter designs can vary depending on the purpose and economic investment. Generally the structure is a 4'x4' footprint with an angled roof (Figure 4-1). Larger shelters have been incorporated into the NL RTWQ network to satisfy secondary purposes such as equipment testing and auto samplers. Smaller, more discreet fiberglass enclosures have been incorporated into the NL RTWQ network in order to maintain a more aesthetically pleasing environment. A locked door or enclosure provides limited protection from vandalism so increased safety measures (e.g. fencing, alarm system) may be required in some site locations. Metal siding has been added to some stations to prevent animals from damaging the shelters (Figure 4-2). Shelter designs are included in Appendix A.

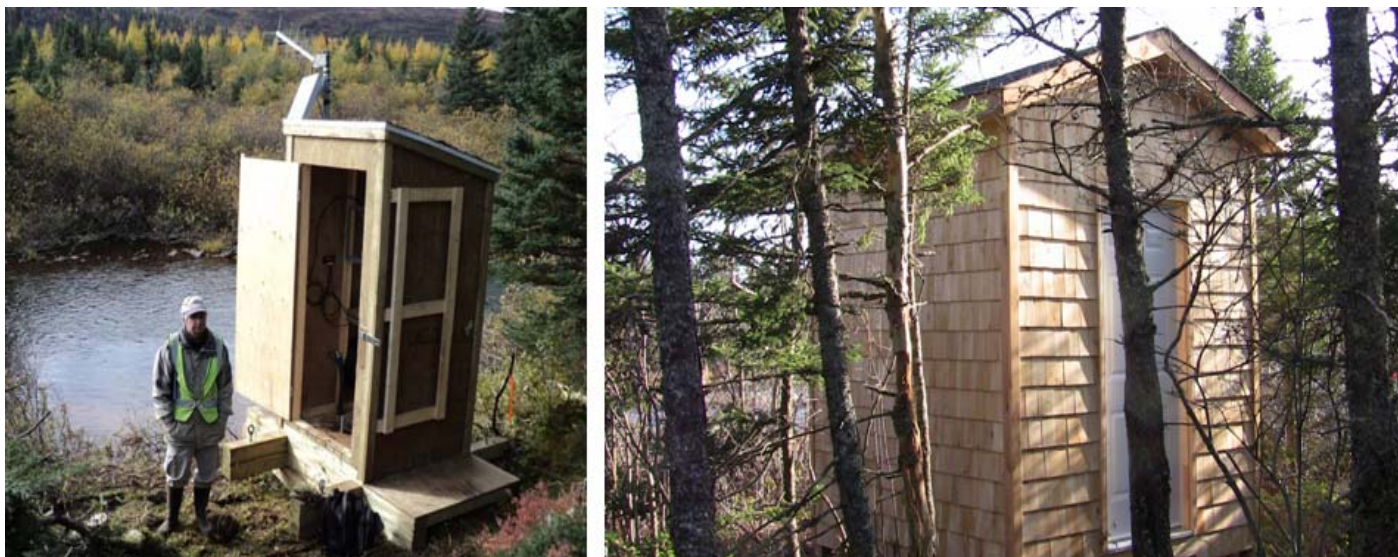


Figure 4-1: (L) Standard design for RTWQ monitoring station; (R) Modified design for RTWQ monitoring test station



Figure 4-2: (L & M) Animal damage to an RTWQ station on the Churchill River; (R) Metal siding is wrapped around the station shelters to prevent damage by animals

4.1.1 Surface Water Stations

Surface water stations are the most common type of station in the NL RTWQ network (Figure 4-3). A station shelter is situated at the edge of the water body where monitoring is to take place. The instrument is deployed adjacent to the station shelter and is connected directly to the shelter. Deployment techniques for surface water stations will be further discussed in section 4.4.



Figure 4-3: (L) Example of shoreline deployment in a lake; (M & R) Examples of shore line deployment in a river

4.1.2 Groundwater Stations

RTWQ monitoring is not limited to surface water in lakes and rivers. The NL RTWQ network now incorporates a groundwater monitoring program. Each station consists of a well, usually with a type of enclosure such as a station shelter, placed over the head of the well (Figure 4-4). This provides an enclosed space to work in and house the data logger and communication equipment.

RTWQ groundwater monitoring stations work together in a network, with at least 3 wells required to determine groundwater flow direction, hydraulic gradient and to compare field parameters between up gradient and down gradient locations. Groundwater flow direction and gradient can be used to identify the pathway of potential contamination. If contamination is an issue from a pending development, wells may be required to surround the development area. It may only be cost effective to equip one well with RTWQ while other wells can be monitored for depth. This would still provide valuable data for groundwater flow and gradient. A groundwater grab sampling program in the surrounding wells (e.g weekly/monthly/seasonal sampling) will aid in understanding the RTWQ data collected from the well and help to explain or catch any changes in water quality.



Figure 4-4: Examples of well monitoring stations

4.1.3 Seasonal Stations

Depending on geographic location and seasonal weather patterns, it may only be possible to deploy an instrument at a particular location during certain seasons. This situation is common in regions with prolonged cold winter temperatures. At some locations, a water body may freeze solid and fully encase an instrument (Figure 4-5). Freezing can cause damage to sensors, and the movement of ice throughout the winter can displace an instrument from its deployment location and sever the connection cable. It may be necessary to refine the deployment season based on the potential freezing from year to year. Safe access to the station may also be an issue during winter months due to ice or snow conditions and should be considered during the planning stages.



Figure 4-5: Example of an RTWQ station during the winter season when ice is not present

4.2 Local Networked Stations

Given the scope of some large-scale industrial developments, it is often reasonable to establish a series of interrelated monitoring stations. In the case of mining operations, the area of land in question can be so large that a single station is not sufficient to track changes in water quality in a natural watercourse that makes its way through the property.

Network stations provide a more detailed picture of the health of the stream or river. These networks require an intensive survey of the entire watershed so that the station can be placed effectively. It is important to make note of the watersheds and individual waterways that are likely to be affected by the development and plan to establish a baseline station upstream of all (or most) industry activities. This station gives the user a clear understanding of the background or 'normal' conditions before the influence of industrial development occur near the water body. It will be necessary to meet with industry officials to map out where outfalls and runoff will be occurring. The planning of an RTWQ network happens before construction/development even begins. One or more stations can be planned for downstream of the baseline station throughout the developed area to capture a multitude of impacts.

4.3 Temporary Stations and Integrated Stations

After the establishment of several permanent stations in the RTWQ network across NL, the need for a special issue-based temporary RTWQ station became apparent. The Mobile Environmental Monitoring Platform (MEMP) is an integrated real time weather station and water quality/quantity station housed in a mobile trailer (Figure 4-6). The MEMP is essential in its ability to respond to issues requiring rapid response (e.g. chemical spills, short term construction). The MEMP can accommodate a mobile weather station including wind speed and direction, temperature and humidity, as well as precipitation. Water quality and quantity are measured by instruments deployed directly from the platform. The MEMP also has the capability to incorporate auto samplers complete with a refrigeration unit for sample preservation and a variety of data loggers. Communication components can be either satellite or cellular. The MEMP is a large heavy unit and due to its weight and size, there are maneuverability restrictions imposed by off-road conditions. To be mobile, the MEMP requires towing by a 4x4 pickup.



Figure 4-6: Mobile Environmental Monitoring Platform (MEMP)

4.4 Deployment Techniques

Several techniques exist to facilitate data collection from water bodies in NL. It is essential that each site is safely accessible and is representative of the water body.

The instrument is typically enclosed in a protective casing with large one inch diameter holes at the sensor end of the casing to allow for water flow (Figure 4-7) (casing design is included in Appendix B). The casing is important to protect the instrument from rocks, gravel and/or movement that may occur during high flow or turbulent events. The casing is sometimes covered with a small mesh to help prevent larger debris, such as leaves from being caught on the actual sensors. The casing can be fabricated from a variety of materials depending on the level of protection required. Stainless steel, PVC and ABS casing have all been used in the NL network.



Figure 4-7: (L) Example of stainless steel casing used to protect RTWQ instrument during deployment; (M) Example of ABS protective casing used to protect instruments in calmer environments; (R) Example of damage caused to metal casing by ice movement during winter deployment

4.4.1 Shore Deployment on Lake/River Bed

Deployments located on the bank or shore of rivers and lakes are the most commonly used technique in the NL RTWQ network (Figure 4-8). When selecting this method of deployment, variation in water level, bank stability and slope must be considered. Locations with shallow stream profiles, minimal bank slope and low flow are often the simplest deployments.

The long field cable between the instrument and the station shelter is fed through a flexible protective conduit, and where possible the conduit is buried under ground for protection. Burying the conduit minimizes potential for damage by animals, the elements and vandals. The conduit is lined along the outside with a stainless steel aircraft cable which is looped at the end and attached to the instrument during deployment. With shore deployments, the instrument and protective casing may be under threat from high flow, wave action or ice movement. The purpose of the aircraft cable is to strengthen the connection and minimize the possibility of losing equipment due to the field cable being severed. The aircraft cable is also useful during instrument retrieval as it can be used to haul the instrument on shore rather than pulling on the conduit and field cable.

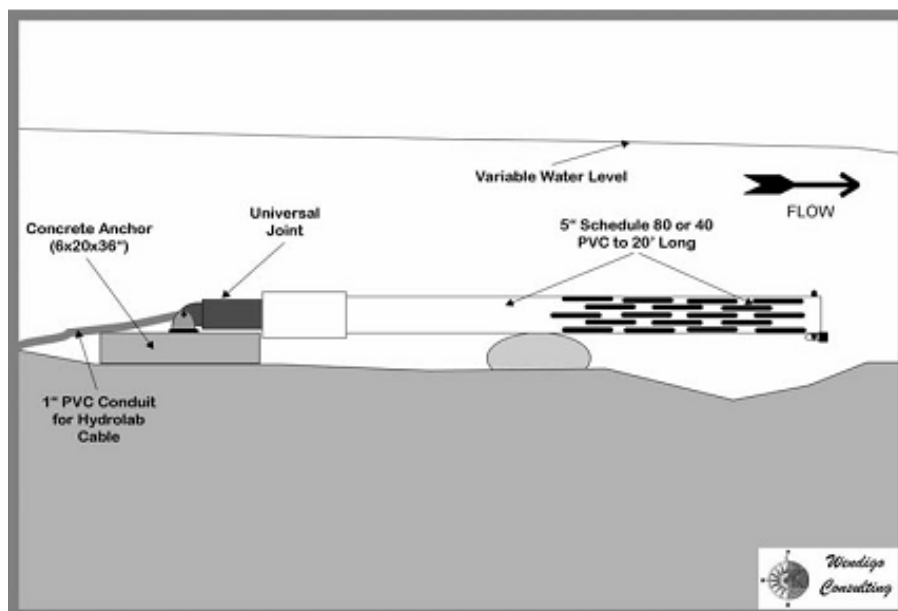


Figure 4-8: Diagram showing shoreline deployment (csc, 2007)

4.4.2 Shore Deployment in Piping

Deployment on ponds and streams with steep banks may require a more robust installation (Figure 4-9). Water depth may increase very quickly, creating an unsafe working environment. A deployment apparatus can be built to better position an instrument in an area with deep water and a steep bank. The structure is a series of angle-iron supports driven into the river bed and/or bank which supports a length of 2x12 pressure treated wood (Figure 4-10). Attached to the wood is a length of PVC pipe (or other durable plastic such as ABS) which holds the instrument at the desired depth above silt but is accessible to personnel on the bank by pulling on the aircraft cable attached to the instrument.

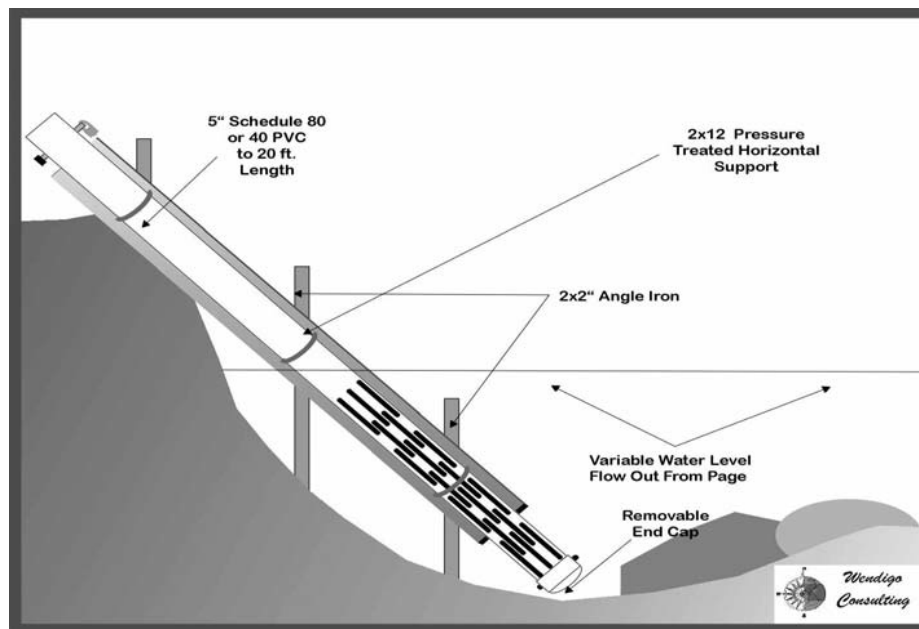


Figure 4-9: Diagram showing shoreline deployment in a pipe (CSC, 2007)



Figure 4-10: Example of shoreline deployments in a river using a pipe

4.4.3 Bridge/Pier Deployment

Deployments may be required in large lakes or rivers utilizing the preexisting structure of a bridge or pier (Figure 4-11). The general structure for such a deployment is a PVC or other durable plastic pipe affixed to the vertical column of a bridge. The instrument is fed through the piping to the desired depth within the water column (Figure 4-12). At the end of the pipe, 1 inch holes are cut in the pipe to allow for adequate water flow over the sensors. The instrument can be accessed from the pier or bridge by pulling the instrument up through the pipe by the attached aircraft cable.

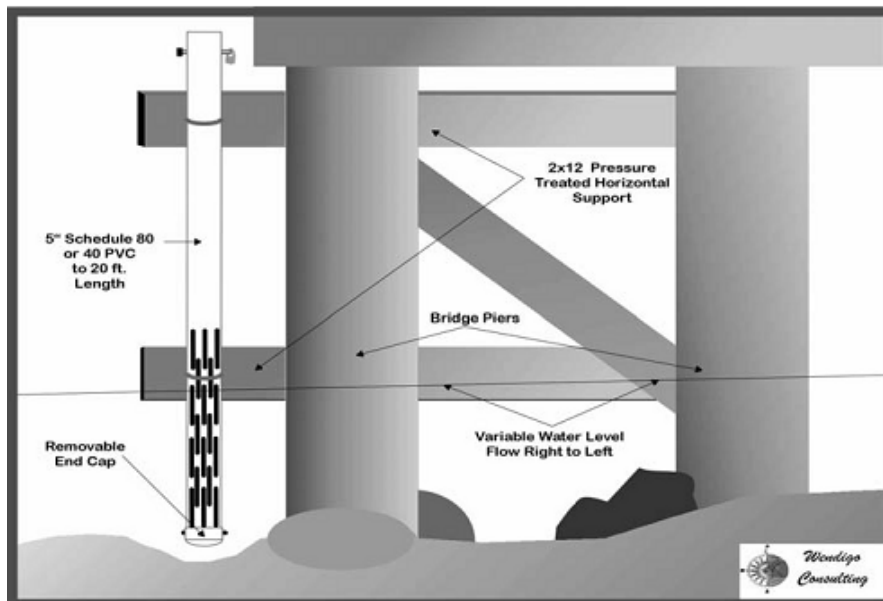


Figure 4-11: Diagram showing bridge or pier deployment pipe (CSC, 2007)



Figure 4-12: Example of a bridge deployment on the Humber River in Western Newfoundland

4.4.4 Buoy Deployment

In pond and lake monitoring applications, a shoreline deployment may not be sufficient to capture a true representation of the water quality. It may be necessary to deploy in the middle of the pond or lake. Floating buoys are available from a variety of manufacturers which can facilitate a deployment off shore. These buoys typically are complete with an instrument positioning unit and telemetry hardware.

The buoy can be moored independently from the shore or as was the case at the Paddy's Pond test station facility, connected to the shore with a rope (Figure 4-13). This enabled WRMD staff to have access to the instrument in the buoy without requiring a boat. The buoy can be attached to a loop of rope and attached to a mooring offshore. The buoy and instrument can be retrieved by pulling on the rope (Figure 4-14). Similarly, the buoy is redeployed offshore by pulling on the other side of the loop.

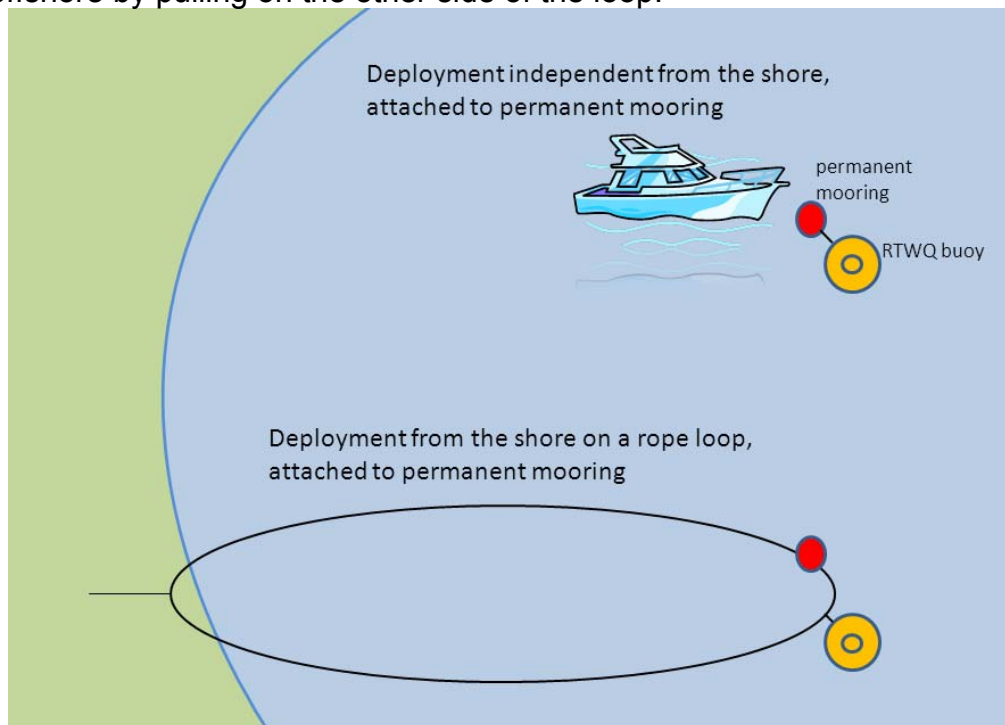


Figure 4-13: Example of buoy deployment techniques



Figure 4-14: Example of a buoy deployment at the Paddy's Pond NL RTWQ research site

4.4.5 Well Deployment

Groundwater quality monitoring stations require a well deployment. The well must be large enough in diameter for the instrument to fit into the well (between 2-4 inch diameter). A shelter can be placed over the wellhead for additional protection and to house the data logger and communication equipment from the elements.

The well should be constructed by a licensed and certified drilling company. The monitoring well construction should be overseen by a hydrogeologist or professional engineer experienced in identifying water bearing zones and certified by the Professional Engineers and Geoscientists of Newfoundland and Labrador (PEGNL). The correct placement of the screen in the well ensures proper function of the monitoring well.

The instrument should be deployed within the screened interval ensuring that aquifer water is flowing around the instrument and is collecting data representative of groundwater conditions (Figure 4-15).

Before being deployed, the instrument is attached to a long field cable and a secure aircraft cable (Figure 4-16). Generally, groundwater monitoring instruments can remain deployed for longer periods of time when compared to the multi-parameter surface water instruments. The manufacturer will be able to provide more specific guidelines on deployment length for different instruments.

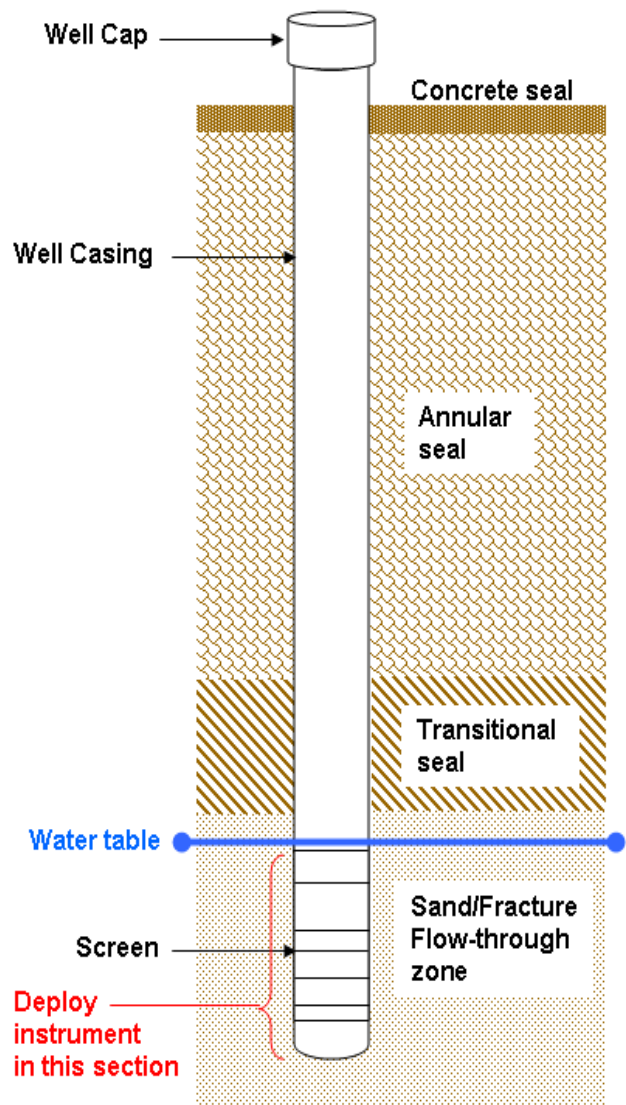


Figure 4-15: Diagram showing typical well construction required for a RTWQ station



Figure 4-16: Examples of a well deployment

4.4.6 Under Ice Deployment

In some situations, under ice deployments are necessary to capture water quality events during the winter months. Personal safety should be the number one consideration when working on frozen water bodies. For more information about working on or around a frozen water body, consult the departmental policy for working on and around ice covered areas. Under ice deployments are not typically practiced throughout the NL RTWQ network as there is a considerable risk to employee safety as well as to the instrumentation. Ice movement can cause significant instrument and station damage or loss of equipment.

Conduit that houses the long field cable can be run from the on shore station shelter out across the ice surface to the deployment location (Figure 4-17). Attach a heavy aircraft cable to the instrument's protective casing and lower the instrument into the water body. The instrument in its protective casing should be lowered so that it is near or just slightly above the river bottom. Secure the aircraft cable to an anchor point on shore (station shelter or large tree). The conduit and long field cable should pass through a separate hole into the water body and can freeze into the ice. Make sure there is enough cable at the end of the conduit to ensure the instrument can be retrieved no matter what the ice thickness. The conduit and long field cable run along the ice surface to the station shelter on shore. Cover the larger open hole (where the instrument is lowered through) with a 'door' constructed of plywood, 2 x 4 lumber and fiberglass insulation to help reduce the amount of ice formed between deployments (and to assist in relocation) (Figure 4-18).

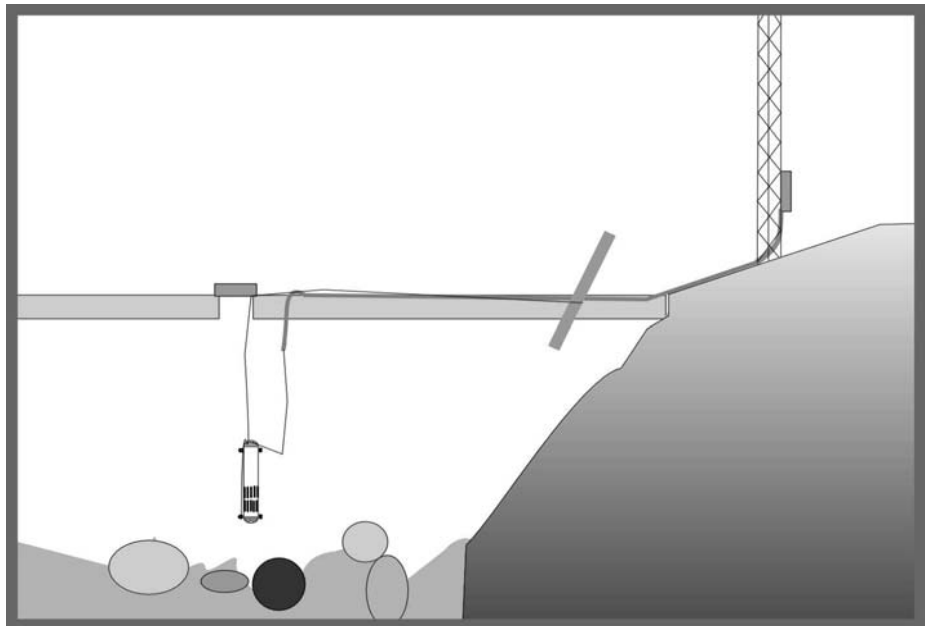


Figure 4-17: (L) Diagram showing an under ice deployment (Source: CSC, 2007);



Figure 4-18: Under ice deployment on a frozen lake

4.5 Reconnaissance Survey

Once the purpose of the station is defined, an important component to site selection is finding a suitable location for monitoring. The term “suitable” is multi-faceted, which is typically a balance of station purpose, accessibility and aquatic and riparian conditions. A suitable station must satisfy to some degree each of these components.

After having determined the specific purpose of an RTWQ station, a reconnaissance trip to the water body of interest should be made to become familiar with the terrain and features of the area including accessibility. Complete the research before heading out in the field. Collect any maps, air photos, or Google maps that will help navigate the area or identify manmade structures like weirs, sewage or storm drainage outfalls. Tidal information may be useful in marine areas and can help to understand how the station profile will change.

It can be useful to take a water sample during the reconnaissance survey. The results will aid in understanding the general water chemistry and which instrument, sensors and calibration methods to use in future deployments. If an RTWQ monitoring instrument is available, take it along to quickly deploy in the water body and record the current conditions.

Additional items to bring include a GPS and camera (with extra batteries), a compass, flagging tape to mark areas to be cleared or the station shelter location, and a measuring tape to assist in estimating the distance from the desired shelter location to the actual deployment location in the water body. This information is very important for determining cable lengths and conduit requirements. Hip waders, personal floatation devices and all related personal protective equipment for the field will be required to properly survey and assess the potential location. The information gathered in the field notes during the reconnaissance survey is invaluable in the development of a monitoring station and all records should be maintained for the life of the station.

The following section contains a series of guidelines to consider when choosing the location of a new monitoring station.

4.5.1 Hydrologic Conditions

One of most important requirements for an RTWQ station is the suitability of the water flow conditions. For optimal results, steady, laminar flow unaffected by rapids or falls is desired. Rapids and falls can create localized conditions that may not be representative of the overall conditions in the water body (ex. white water can cause false data). Stagnant water pools can cause biofouling, and without adequate flow, the instrument will not give an accurate representation of the water body chemistry (Figure 4-19).



Figure 4-19: (L) Steady, laminar flow is best for an RTWQ deployment; (M) Stagnant water can cause biological growth on RTWQ instruments and should be avoided; (R) Highly fluctuating water levels on steep shorelines can cause instruments to be exposed to air during the deployment period

Water level should be sufficient to completely submerge the instrument. In cases of highly fluctuating stage levels, keeping the instrument submerged during the deployment period, especially during low flow periods may be challenging and could be addressed by adjusting the deployment techniques. If the water body is at a low level during the visit, the high level water mark should be indicated by the riparian vegetation.

Important hydrological features should be documented during the reconnaissance trip. Naturally occurring elements that should be noted include: tributaries, potential for changes in water level that could have adverse effects, unmapped flow from small rivers and streams or heavy groundwater flow. Fragile wetlands and protected areas should be avoided to prevent unneeded destruction. Note any manmade structures such as outfalls from storm drainage, sewage, or industry, dams or spillways, weirs, docks or piers, and bridges.

4.5.2 Bed Material

Cobble or rocky bottoms are preferred for a lake or river bed deployment where the instrument simply rests on the bottom during deployment (Figure 4-20). This prevents smaller sand and silt sediment from being deposited in and around the instrument deployed. Sandy or silty streambeds can cause problems. Silty environments can overtime result in damaged sensors should silt encrust or become lodged in crevices on the instrument. While this can compromise data quality, if a sandy or silty bottom is unavoidable, adjusting the deployment technique to keep the instrument off the bottom of the water body can help avoid these issues (Figure 4-21).



Figure 4-20: (L) Small rocky bed material is best for an RTWQ deployment; (R) Sandy river reaches should be avoided if possible for RTWQ monitoring as sand and silt can cause the sensors to fail



Figure 4-21: A custom built stand was created to hold the instrument off the surface of a sandy river bottom at an RTWQ monitoring station in Labrador

4.5.3 Riparian Environment

At the riparian zone, it is important to note vegetation and earth conditions. In small shallow streams direct sunlight can influence water temperature readings and provoke excessive algal and biofilm growth (Figure 4-22). This growth may intensify maintenance regimes and can skew data. Record the presence of biological growth on the bed material. Identify if it is covered with plants or slippery to walk on. If the rocks are slippery from biological growth, there is a good chance the RTWQ instrument will be subjected to the same biological growth during a deployment period.

It is important to note if there is potential for damage to the natural environment should the area be cleared and a station shelter constructed. Removing trees from the riparian zone destabilizes the earth on the bank and could encourage erosion and deposition of silt into the river.



Figure 4-22: Macrophytes growing in the water body may impact the monitoring instrument

4.5.4 Communication and Power Availability

If the station is to be powered by a battery that is charged by a solar panel, ensure adequate sunlight is available to fully charge the solar panel.

Consider communication options for the site in question. Note the potential to obtain power from a local provider and/or if the area has cell service. Topographic features should be noted as there is a potential for large hills or mountains to block communication with satellites.



Figure 4-23: Stations located in valleys may experience satellite communication issues

4.5.5 Accessibility

Accessibility and stability of the deployment site are important in ensuring the safety and security of personnel and equipment (Figure 4-24). Stations located in urban settings are usually accessible by vehicle or on foot. Urban stations may require additional provisions to prevent and protect from vandalism. In remote sites, access may be restricted to ATV/snowmobile or helicopter. In the case of helicopter access sites, a standard sized helicopter pad should be included in site preparations with adequate room for safe landing. If an aerial survey is conducted, make note any roads or path ways to the water body. This may enable you to have multiple access options to the station.

Accessibility encompasses more than transportation concerns. Weather and season have major implications on accessibility. Can you access the station safely? Can you access the shoreline safely? Can you deploy/retrieve the instrument safely?

In heavy rain, wind or snow, some rivers experience flow increases which make it unsafe to approach a river. In freezing conditions, attention should be paid to ice conditions that could result in slip hazards. Ice conditions in winter and early spring can make maintenance visits impossible in some cases. The benefit of regular maintenance and calibration of RTWQ instruments should be weighed against personal safety and potential damage to equipment.



Figure 4-24: (L) Clear access to the water body; (M) Unsafe access because of large amounts of debris and trees; (R) Helicopter access stations with regulation sized landing pads

4.5.6 Land Designations

It may be necessary to place an RTWQ station on protected land. Protected areas including wildlife and ecological reserves, provincial and national parks or other designated land areas (aboriginal), privately owned, or crown lands may not be clearly marked in remote areas. Updated maps should be consulted if the station is in or around these areas. Approval from the governing party must be sought prior to any accessing the land, site preparation or construction.

Cottages and cabins may be small and difficult to see through thick brush so perform a thorough survey of any existing structures, roads or pathways near the potential site. If in doubt, seek guidance from the appropriate lands management officials. GPS coordinates, sketches and photos of the area are usually necessary to obtain required permits.

4.5.7 Existing Infrastructure

In some cases, partnering with other agencies and using existing water quantity stations may be beneficial. In NL, many of the RTWQ stations are co-located with EC's water quantity monitoring sites. The benefits of partnering are twofold. First, the infrastructure may already exist (station shelter with data logger and communication equipment). Second, in addition to water quality data, the station provides water quantity data which can be useful in understanding changes to water quality (stage changes, flow increase/decrease). The importance of this continued partnership is fundamental to the NL RTWQ program to ensure cost effectiveness is maximized and knowledge is shared.

Benthic invertebrate sampling has taken place at some NL RTWQ sites as well. Water quality data collected from the station is important in determining the relationship between water quality and the communities of benthic organisms that inhabit the water body. Benthic invertebrates are an important indicator in the health of a water body. RTWQ stations have also been located in conjunction with climate monitoring stations which important data for the research being done on climate change and water quality and quantity.

Choosing a location with existing water quality information also may be beneficial. With growing population, activities upstream of an existing station may change, hence increasing the need to adjust from monthly/seasonal grab samples to continuous water quality monitoring. The historical water quality data provided by grab samples will aid in understanding the water body and any changes in water quality that may occur.

5 Safety

Safety in the workplace and in the field is a priority for the Government of NL. The NL Occupational Health and Safety (OHS) Branch recognizes that all workers have a fundamental right to a workplace that neither impairs their health nor imperils their safety. This is achieved by working together with stakeholders to establish, promote and enforce safe workplace practices, standards and procedures (NL Gov, 2012).

There are a number of special factors that increase the risk of accident or illness when setting up or visiting an RTWQ station. Each employee must take every effort to ensure that potential hazards and risks have been identified before heading out in the field, upon arrival at the site, and continually throughout the day.

5.1 Water and Ice

It is essential that all employees take all necessary precautions when working in and around a water body. Even if the same site is visited regularly, conditions may have changed affecting stability of the bank (frost & thaw, erosion, etc.), or in-stream conditions (depth, current, etc.). Employees should refer to the CCME Protocols Manual for Water Sampling in Canada for specific protocols relating to sampling in different environments (CCME, 2011).

Moving water in a riverine environment can be particularly hazardous and extreme caution should be taken in these areas. In the winter, ice and snow conditions can pose additional risks to employees working in the field (Figure 5-1). Employees should have certification in swift water and/or ice safety rescue. While course certification is useful and can provide the necessary skills required to execute a rescue if needed, employers and employees still must take all necessary precautions to prevent such incidents from occurring.



Figure 5-1: (L) Large ice wall prohibits safe access to a RTWQ station on the Lower Churchill River in Labrador every spring; (M) Windy conditions can cause high surf preventing deployments at RTWQ stations; (R) Ice and snow can causes slippery and dangerous conditions especially during spring.

5.2 Contaminated Areas

In some cases, an RTWQ station may be located in an area identified as contaminated. Most commonly these situations would include areas of bacteriological contamination and mining effluents but is not limited to and could also include areas contaminated with PCBs or other hazardous materials. It is essential to determine these risks before setting up an RTWQ station.

5.2.1 Bacteriological Contamination

When conducting sampling of effluents or receiving waters, the collector should wear appropriate protective gear (gloves, goggles, waders, etc.). Elevated levels of contaminants at some locations may warrant further safety practices. Equipment used for ambient water quality sampling should not be used for effluent water sampling. Each specific type of sampling should have equipment dedicated for only that use. Check with municipal governments to correctly identify potential hazardous contamination from sewage and storm flow outfalls (Figure 5-2).

Cyanobacteria may also cause toxic contamination in areas experiencing algal blooms. The toxin is most often harmful to humans if ingested but can sometimes produce a gas that can also be toxic if inhaled. While not all algal blooms produce the toxic microcystin chemical, caution should be taken when working in these conditions.



Figure 5-2: (L) Sign indicating sewage contamination; (R) Algal blooms in the water body.

5.2.2 Mining Effluent

In Canadian mines, the discharge samples will not be hazardous to the sampling personnel. However, some of the process chemicals and effluent constituents such as arsenic and cyanide can pose a personal hazard if they are found in high concentrations (EC, 2001). When working at industrial sites and near mining operations, check with the Health and Safety department of the operation to determine if there are any potential risks and follow guidelines set by the local authority.

5.2.3 Other Contamination

RTWQ stations with the potential to contain other chemical contamination hazards such as PCBs, petroleum hydrocarbons, volatile organic compounds etc. These sites should be approached with caution. Do not proceed unless proper authority has been granted and

safety protocol measures have been clearly identified and adhered to. Check with local land authority and site managers before accessing these areas.

5.3 Remote Areas and Working Alone

It is important for employers to take into account the wide variety of situations where workers work alone. Take into consideration the hazards specific to their particular workplaces and develop and adopt effective health and safety procedures and policies that address these hazards. The NL OHS branch has suggested a number of things employers and employees can do to help ensure the safety of a lone worker in the Working Alone Safety Guidelines for Employers and Employees (NL Gov, 2012).

- Assess the hazards of the workplace.
- Talk to workers about their work. Get their input about the work they do and possible solutions.
- Investigate incidents at the workplace and those from similar workplaces.
- Avoid having a lone worker whenever possible, especially for jobs with a recognized risk.
- Take corrective action to prevent or minimize the potential risks of working alone.
- Provide or avail of appropriate training and education.
- Report all situations, incidents or "near misses" where working alone increased the severity of the situation. Analyze this information and make changes to company policy where necessary.
- Establish a check-in procedure. Make sure regular contact is kept with all workers.
- For most lone workers, the telephone will be the main source of contact. If work is at a desk or station, have a telephone close by. If work is away from a main office or work station, the use of a cellular phone is very helpful. If a cellular phone is unreliable in the area, be sure to have alternative methods of communication available (such as use of public telephones or satellite technology (Figure 5-3).
- Allow the use of a "buddy system" in high risk situations - ensure that workers are aware that this option is available to them.
- Where appropriate, provide employees with a Personal Locator Beacon with GPS Interface (Figure 5-3).



Figure 5-3: (L) GPS personal locator beacon used to track movement in the field or signal for help if necessary; (R) Iridium satellite telephone can be used to call for help in an emergency

In addition to the NL OHS Working Alone Safety Guidelines for Employers and Employees, the WRMD is currently developing its own working alone policy. This policy will be specific to situations encountered by WRMD employees. This document will be available on the departmental webpage.

5.4 Personal Protective Equipment

The proper use of Personal Protective Equipment (PPE) provides an additional degree of protection against harm or injury in the workplace and therefore its importance must not be underestimated. PPE is intended to be used in conjunction with other safe workplace practices. NL OHS has published a PPE policy. The policy is intended to further encourage a safety culture within the NL Government, by establishing clear roles, responsibilities and accountabilities regarding PPE. Please refer to this policy for further information (NL Gov, 2011).

PPE may be required to access industrial sites (mines, hydroelectric generation facilities, construction sites, etc.) The employee must follow all rules and regulations set forth by the industry responsible for that site (Figure 5-4).

PPE is not limited to specific industry requirements and may include additional items to: (1) protect oneself from injury, (2) changing weather conditions, (3) safety in and around water and/or ice, (4) contaminated areas, and (5) transport to and from the site (helicopter safety training, vehicle/ATV/snowmobile safety kits etc.).



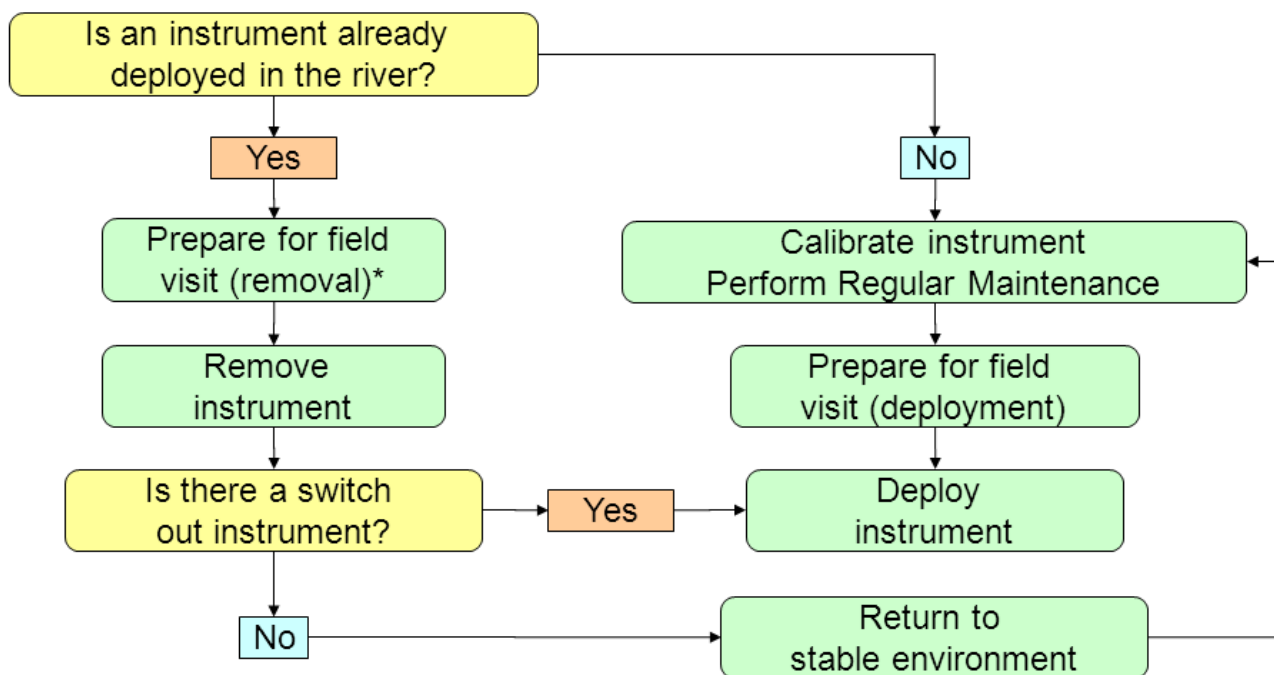
Figure 5-4: WRMD employee wears full PPE attire while working on a construction site.

6 Field and Laboratory Components

This section identifies and outlines the general components for instrument preparation, and field visits for deployment and removal. The NL RTWQ Procedures and Protocols Manual is available from the NL Departmental webpage and features a specific step by step guide on calibration, maintenance, and field visits for a Hydrolab DS5X instrument at a surface water station functioning by way of GOES transmission. This is the most common set up in the NL RTWQ for which the procedures manual was designed for.

6.1 Field Logistics

Planning and preparation is extremely important before site visits. When preparing for a site visit, there are a number of items, personal gear and equipment necessary to complete tasks at the station safely and efficiently. Items required for site visits will change depending on the type and amount of work that needs to be completed on site (Figure 6-1). Seasonal and weather conditions will also dictate the type of emergency and safety apparel taken. A checklist for a general RTWQ site visit has been included in Appendix C.



*If an instrument is removed and a new one deployed during the same visit, make sure to calibrate and perform regular maintenance on the instrument that is to be deployed.

Figure 6-1: Flowchart to help plan RTWQ station visits.

Transportation availability should be organized prior to each site visit (i.e. 4x4 vehicle, ATV, snowmobile, helicopter etc.). The mode of transportation to the site is generally decided in the initial planning stages. The RTWQ Site Visit checklist does not include specific items related to policies for transportation in vehicle, boat, ATV, snowmobile, helicopter etc. These policies may include items in addition to the basic safety apparel included in the checklist.

6.2 Field Visits

The length of a deployment period will depend on the instrument selected however generally is 30 days for the surface water multi-parameter instruments. These are the most commonly used instruments in the NL RTWQ network. The deployment period length may vary for a variety of reasons (e.g. adverse stream conditions, inclement weather, and unavailability of transportation). Depending on the specific instrument deployed, the manufacturer specifications may suggest a longer or shorter deployment period. It is important to consider the length of deployment when selecting the instrument and specific parameters that are to be measured.

Generally, multi-parameter instruments, confounding data errors from calibration drift and bio-fouling drift increase a great deal after a 30 day deployment. It is important to maintain the integrity and accuracy of the data by regularly tending to the station and the instrument. Subsequent site visits may be necessary (if possible) to tend to data transmission errors or potential instrument errors. Every employee should strive to visit the station on a monthly basis.

6.2.1 Field Sheet

The NL RTWQ field sheet has been designed to easily record all field data at both deployment and removal site visits (Appendix D). A site visit is broken up into 'removal' and 'deployment'. Removal refers to the procedures and QAQC data collected during instrument retrieval. In most cases, this instrument will be returned to the lab immediately to be cleaned and calibrated before being returned to the same site the following day for deployment. In the case where there are two instruments for one site, the second instrument is deployed immediately after the first instrument is removed during the same site visit. This is a useful planning technique especially at remote sites where the cost of one helicopter trip nearly offsets the cost of a second instrument. The field sheet summarizes all data collected during the site visit(s) and is designed to be easily entered into the deployment spreadsheet. This electronic version of the field sheet uses the data to calculate QAQC rankings, data summary statistics, and graphical data displays.

6.2.2 Field Instrument

The field instrument is the term used to describe the RTWQ instrument that is to be deployed in the water body for the deployment period (~30 days). This instrument is generally hooked up upon arrival at the station. Live readings should be accessed either by way of a direct connection to hand held computer device or through the data logger in the station shelter. It is important to ensure the instrument is functioning correctly before leaving the site especially in the case of a remote station.

6.2.3 QAQC Instrument

The QAQC instrument is an important component of the QAQC protocols established for the NL RTWQ program. The purpose of the QAQC instrument is to gather an accurate duplicate measurement at the time of deployment as well as at removal. The QAQC instrument is typically not deployed for any length of time in the water body. The QAQC instrument should be the same instrument make as the field instrument being deployed and should be calibrated carefully at the beginning of each field visit. The QAQC instrument is deployed adjacent to the field instrument at every site visit and all values should be recorded for an accurate comparison.

6.2.4 Comparison Rankings

At both deployment and removal site visits, the QAQC instrument values and the field instrument values should be recorded on the RTWQ field sheet for comparison. The comparison chart was developed statistically to provide a range that water parameters and water data can be evaluated against to indicate the accuracy of the readings (Table 6-A). The less the difference is between the corresponding values collected from the field and QAQC instruments, the more positive ranking is applied. If there is a great difference between the corresponding values, a negative ranking is applied. This gives reassurance to the quality of the data that will be recorded or that has been recorded during the 30 day period.

The comparison table is featured on the NL RTWQ field sheet and can be used as a quick reference to check to see all parameters are ideally yielding positive rankings. The data will be categorized as 'excellent', 'good', 'fair', 'marginal' or 'poor' based on the difference between the field and QAQC instrument readings. 'Excellent' and 'good' readings identify that there is confidence in the integrity of the data. Readings that are identified as 'fair', 'marginal' and 'poor' may indicate a problem with the instrument.

At the time of deployment, if rankings are found to be 'poor' or 'marginal', it is at the judgment of the WRMD staff to remove and recalibrate the field instrument or continue with deployment of instrument. Negative rankings at the beginning of the deployment period can result in the collection of inaccurate data. Comparison rankings are also calculated at instrument removal to see if there is any change in the corresponding values. The QAQC instrument should be newly calibrated, while the field instrument has been deployed for 30 days. If the rankings were positive at the beginning and remain positive at the end, there is confidence in the data collected as the field instrument has appears to maintain its calibration. If the rankings are positive at the beginning and negative at the end of the deployment period, data may have been compromised at some time throughout the deployment period. It may be necessary to increase the amount of field visits if poor rankings are consistently found at removal.

Stabilization time for some sensors (especially pH) can take a long time and it is important to let both instruments stabilize completely before calculating the comparison ranking. Knowing the average values for each of the parameters for each station is useful to determine whether or not there is an issue with a sensor or instrument accuracy.

Table 6-A: QAQC Comparison Chart

Parameter		Rank				
		Excellent	Good	Fair	Marginal	Poor
Temperature °C		± 0.2	± 0.2-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
pH (units)		± 0.2	± 0.2-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
Specific Conductivity	>35 µS/cm	± 3	± 3-10	± 10-15	± 15-20	± 20
	<35 µS/cm	± 3%	± 3%-10%	± 10%-15%	± 15%-20%	± 20%
Dissolved Oxygen (mg/L)		± 0.3	± 0.3-0.5	± 0.5-0.8	± 0.8-1.0	± 1.0
Turbidity	<40 NTU	± 2	± 2-5	± 5-8	± 8-10	± 10
	>40 NTU	± 5%	± 5-10%	± 10-15%	± 15-20%	± 20%

6.2.5 QAQC Grab Samples

QAQC procedures defined for the time of deployment dictate taking a water grab sample from each station (Figure 6-2). The sample is sent to an accredited laboratory for analysis. The values can then be compared to the field instrument and ranked with the comparison table (Table 6-A). Only pH, turbidity and conductivity grab sample values are available from the lab for comparison against the instrument parameters.

The other parameters monitored with this sample may include but are not limited to the following:

- **Physical Parameters**
 - Conductivity
 - pH
 - Color
 - Turbidity
 - Total Dissolved Solids
- **Chemical Parameters**
 - Metals and trace elements
 - Major Ions
 - Nutrients

Documentation corresponding with the grab samples must be complete. Maintain sample integrity by following protocols suggested by the laboratory performing analysis (i.e. keep below 10°C, prevent from freezing, deliver to laboratory within 5 days of collection etc.). For grab samples, NL adheres to the protocols established and outlined by the CCME Protocols Manual for Water Quality Sampling in Canada (CCME, 2011).



Figure 6-2: (L) Example of grab sample bottles from an accredited laboratory; (R) WRMD takes a RTWQ QAQC grab sample from a hole in the ice

6.2.6 Station Safety and Security

There are certain measures that should be taken to maintain station safety and secure equipment. Upon leaving the site, always make sure all non-essential electrical connections are broken. Secure all loose connections with electrical tape to prevent moisture from getting to the cables. Secure conduit opening with duct tape or plastic bag.

As it is important to break all non-essential connections, it is equally important to ensure all necessary connections are connected. This is essential for data transmission to occur in real time. Make sure all gates and locks are closed upon leaving the site.

6.3 Calibration and Maintenance of RTWQ Instrumentation

Calibration of water quality instruments is essential to ensure accurate data collection and a reliable network. These tasks can be a time consuming step that should not be overlooked and be attentively performed by each employee before deployment.

Maintenance and calibration of the instruments is essential in order to maintain data integrity. The following procedures outlining the regular maintenance and calibration steps should become very familiar to the staff responsible for performing these tasks. The instruments cannot be maintained or calibrated enough and the frequency and quality of maintenance and calibration is directly related to the quality of data collected. The more the instruments are maintained and calibrated, the higher the quality of data will be. The NL RTWQ program has incorporated multiple types of instruments into its network (Hydrolab, YSI, S::can). Each type of instrument should be calibrated as per the manufacturer's recommendations.

In addition to following the manufacturer specifications for calibration and maintenance, the NL WRMD has developed some helpful tools and tips that should be included in all types of deployments.

6.3.1 Laboratory Calibration Form

Documentation during maintenance and calibration is important for the tracking of instrument and/or identifying specific instrument issues. The laboratory calibration form was created to summarize maintenance and track calibration for each instrument (Appendix E) (Figure 6-3). In order to consistently record this information, the laboratory calibration form should be filled out during the procedure. The laboratory calibration form acts as a checklist during monthly maintenance and calibration. The information is documented to assist in recording the use of an instrument. The laboratory

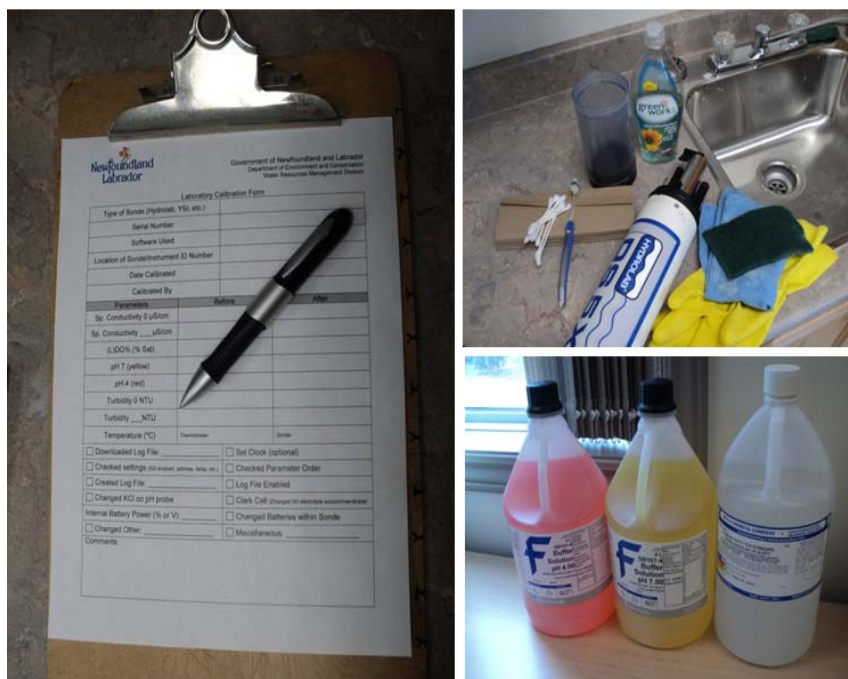


Figure 6-3: (L) Laboratory calibration form is filled out during calibration; (R) Cleaning and calibration supplies

calibration form summarizes the before and after values for each sensor reading during calibration. Field and QAQC instruments must be calibrated against factory NIST solutions in a temperature controlled setting (e.g. laboratory, office, etc.) (Figure 6-3).

6.3.2 Log Files

Some RTWQ instruments have the ability to collect and store data in the instruments internal memory. These files are sometimes referred to as log files. Log files are an important feature of RTWQ instrumentation as well as in the QAQC procedures and protocols set forth by the NL RTWQ program. Although the data is not available in real time, it can be downloaded from the instrument at the time of removal. In the event transmission fails at the station, the data from the log file is used as a back up to supplement transmitted data.

6.3.3 Communication with Data Logger

Ensuring the RTWQ instrument can communicate with the data logger is an important technological component in the preparation for a deployment. NL WRMD staff make this a regular component of their maintenance and calibration checks before each deployment. The data loggers used in the majority of the NL RTWQ network are programed by a third party and do not change therefore it is the responsibility of the WRMD staff visiting the station to ensure the instrument is set to communicate with the logger in a very specific manner. This check includes making sure that the data collected from the instrument is sent to the logger in a particular order so that the logger can name the data appropriately before it is transmitted. This ensures that when the end user receives the data, they are certain what data they are looking at.

6.3.4 Bio-Fouling Mitigation

Bio-fouling can greatly impact the integrity of the data collected at RTWQ stations. Instruments can be plagued with a build up of biological growth that can compromise the sensors ability to function correctly. Not only is the data not useable, it can sometimes cause long term problems with instruments and require replacement of parts.

In the case of stations that are prone to biological growth, there are certain measures that can be taken to slow or prevent the potential for bio-fouling to occur on your instrument. Anti-fouling materials such as copper have been proven to reduce the amount of biofouling growth on instruments and can increase the deployment period for some locations (YSI, 2010) (Figure 6-4). Custom designed sensors and guards may not be available or may add additional costs to an instrument inventory. Other useful methods that have been used by the WRMD include using a pantyhose material to cover the instrument prior to deployment (Figure 6-4). The material allows water to flow through and reach the sensors and prevents biofouling growth to accumulate on the sensors. Additionally, duct tape can be used to cover an instrument casing to aid in clean up at the end of the deployment. The biofouling growth occurs on the instrument casing and is easily removed with the tape at the end of the deployment period.



Figure 6-3: (L) Pantyhose used to cover the instrument prior to deployment can sometimes reduce biofouling growth on the instrument (R) Copper plated sensors are sometimes used to reduce the biofouling growth at RTWQ stations (YSI, 2010)

7 Data Management and Reporting

Data management and reporting is an integral part of a successful RTWQ program. An enormous amount of raw data is collected in just a short amount of time and must be properly organized and easily accessible to the end user in a useful format. QAQC data verification is essential. Finally it is important that the information collected is reported in an organized standard and timely fashion. There are several steps to the QAQC and data reporting processes which are summarized in Figure 7-1. The following sections briefly describe the steps involved beginning with the data received by the automatic data retrieval system (ADRS), through to displaying and reporting the data.

Data Management and Reporting Steps

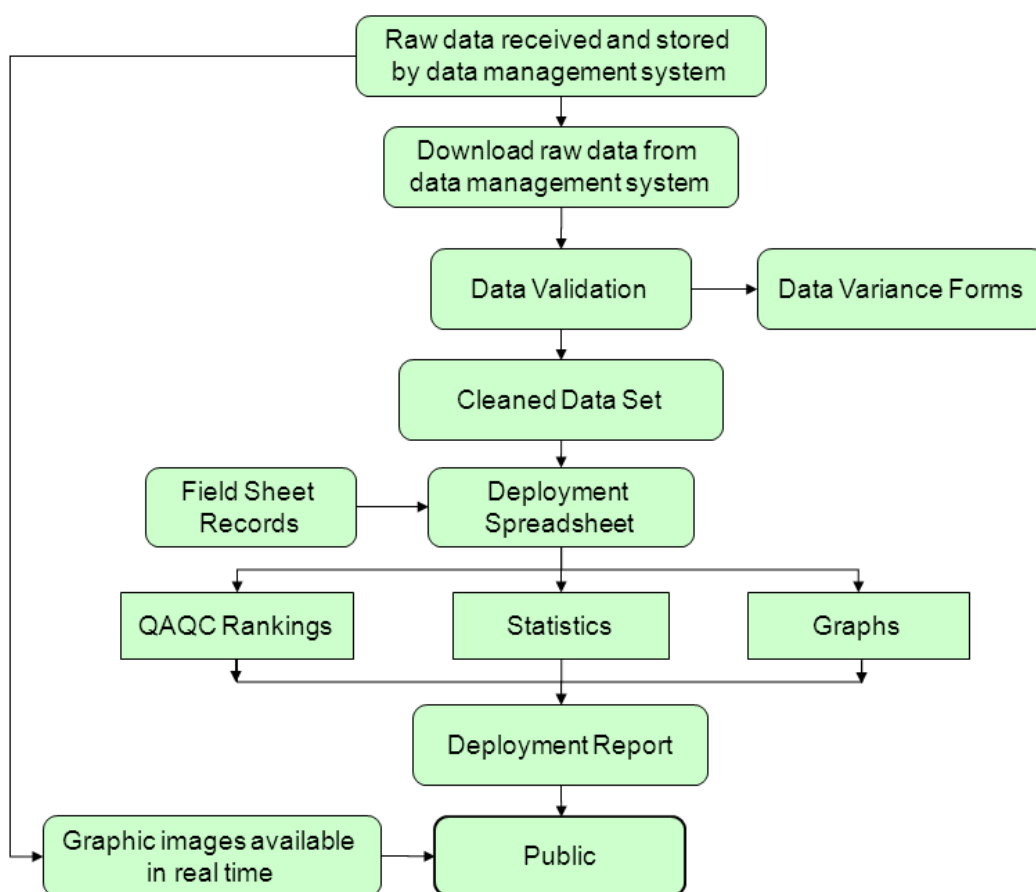


Figure 7-1: Flowchart summarizing data management and reporting steps.

7.1 Automatic Data Retrieval System (ADRS)

The ADRS was developed by the WRMD. It is a series of microcomputer based programs which automatically collects, processes and distributes the RTWQ data, hydrometric data and climate data.

The ADRS is used to store and collect all the raw data collected in the NL RTWQ network. ADRS collects data from four different pathways (Figure 7-2). In the NL RTWQ network, data is most often collected and transmitted by way of GOES satellite. However, the very first stations worked through a dial up modem. This remains a valid method of data collection still being used in NL. IP and Satellite modems are also used throughout the NL RTWQ network and are functional with the ADRS system.

ADRS is an investigative tool that provides an efficient method of access to all data for the lifespan of the RTWQ monitoring station. NL RTWQ stations are recording large amounts of data, from fifteen minute intervals to hourly intervals occurring throughout the day. The ADRS allows raw data to be exported and downloaded to be utilized at the user's discretion. The ADRS allows for individual parameter data to be graphed independently of others, identify a trend over specific time periods and provides a method for tracking any disturbances or changes in water characteristics. The system populates RTWQ graphs for every parameter at every RTWQ station on-line (30 day rolling graphs); this allows for a visual representation of the parameters. These graphs are available for the public to view online and are updated approximately every two hours.

For most of the stations in the NL RTWQ network, parameter data is logged by the data logger at the RTWQ monitoring site then transmitted via high data rate transmission (every hour) to the GOES. It is immediately transmitted to the National Environmental Satellite Data Information System (NESDIS) that is operated by NOAA in Maryland, USA. At regular intervals, the data is received from Maryland via the ADRS which processes and populates an internal Oracle database. This information is then distributed to the government's web site and internal windows and web applications where the data is then reviewed by WRMD employees.

7.2 Raw Data Display

In an effort to enhance transparency and accountability to the public, stakeholders and partners, WRMD has placed the RTWQ data online. The raw data is transmitted directly to the departmental webpage in near real-time and is available for public viewing (Figure 7.3).

In an effort to increase the confidence in the raw data that is collected, the WRMD trialed a pilot project in 2010. The pilot project involved identifying the amount of drift experienced by the various sensors during the scheduled deployment period. The drift was used to calculate and correct the raw data. The result of the study indicated that neither biofouling drift nor calibration drift changed or influenced the raw data significantly as was originally assumed. The study determined that resources are best directed at ensuring the 30 day deployment schedule is maintained. A report documenting this pilot project is available on the departmental webpage.

Biofouling is likely the largest factor causing data drift. In the summer of 2009, a short term bio-fouling study was conducted and it was found that biofouling on sensors was significant only after (approximately) 60 continuous days of deployment. Even then, biofouling was most evident in the shallow urban streams that have a tendency to warm up quickly and remain warm for longer periods. The findings from the bio-fouling study did indicate that some sensors are more sensitive to biofouling while others are more influenced by calibration drift. The cooler water temperatures in NL generally prevent

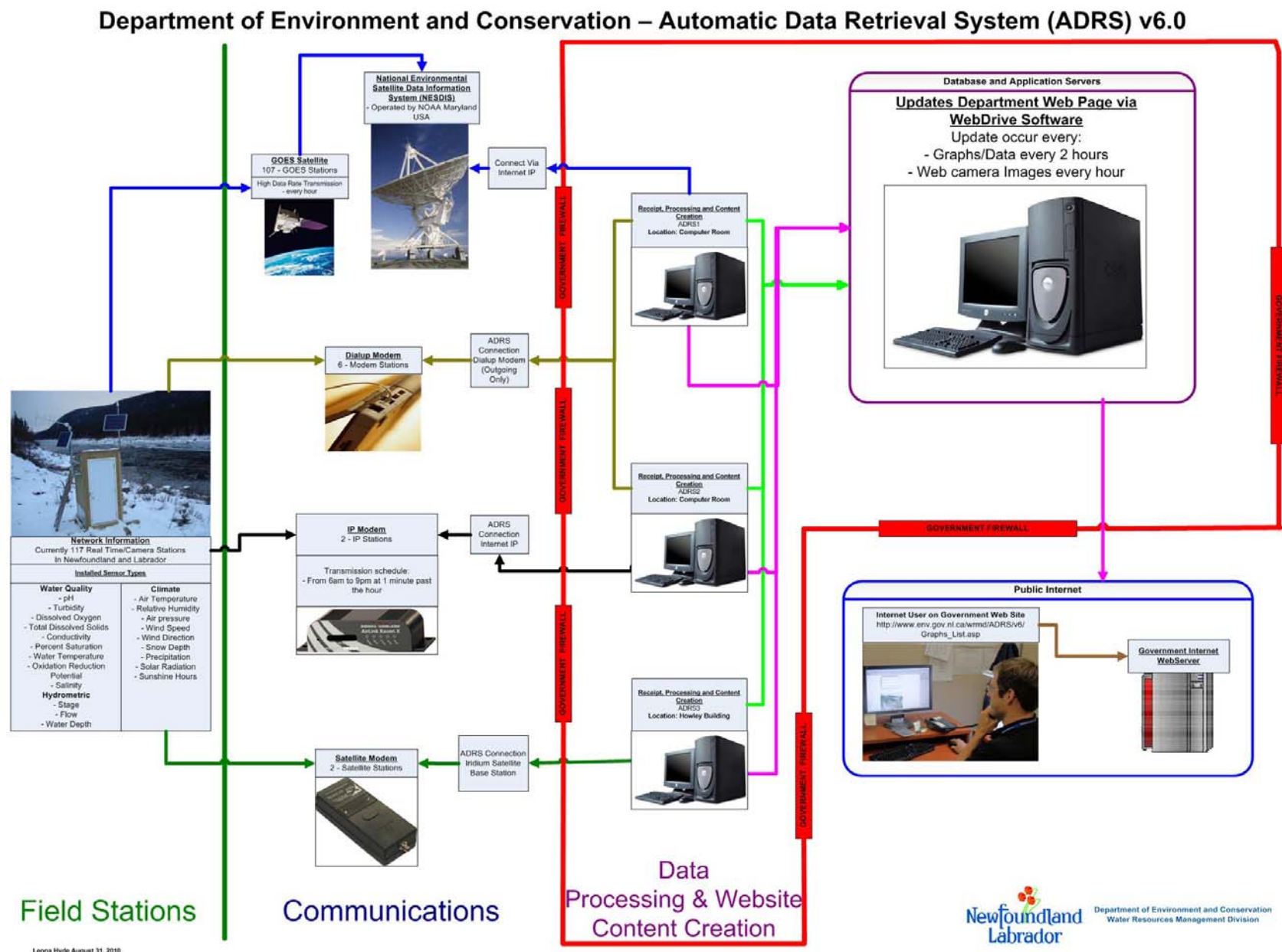


Figure 7-2: Flowchart summarizing ADRS data collection and processing

significant bio-fouling growth in the summer months. Additionally, for those sensors that are more sensitive to calibration drift, the WRMD's standard 30 day deployment period ensures that the data is being monitored before calibration drift becomes a concern. A report documenting the bio-fouling study is available on the departmental webpage.

The findings from both the pilot project and the bio-fouling study lead to the conclusion that WRMD will continue to display the raw data onto the webpage. There was not enough of a significant difference between the corrected data (after drift was removed) and the raw data to warrant following the intensive procedures to calculate drift. The pilot project and the bio-fouling study provided confidence in the near real time data and answered the questions WRMD had regarding variables and influences on raw data.

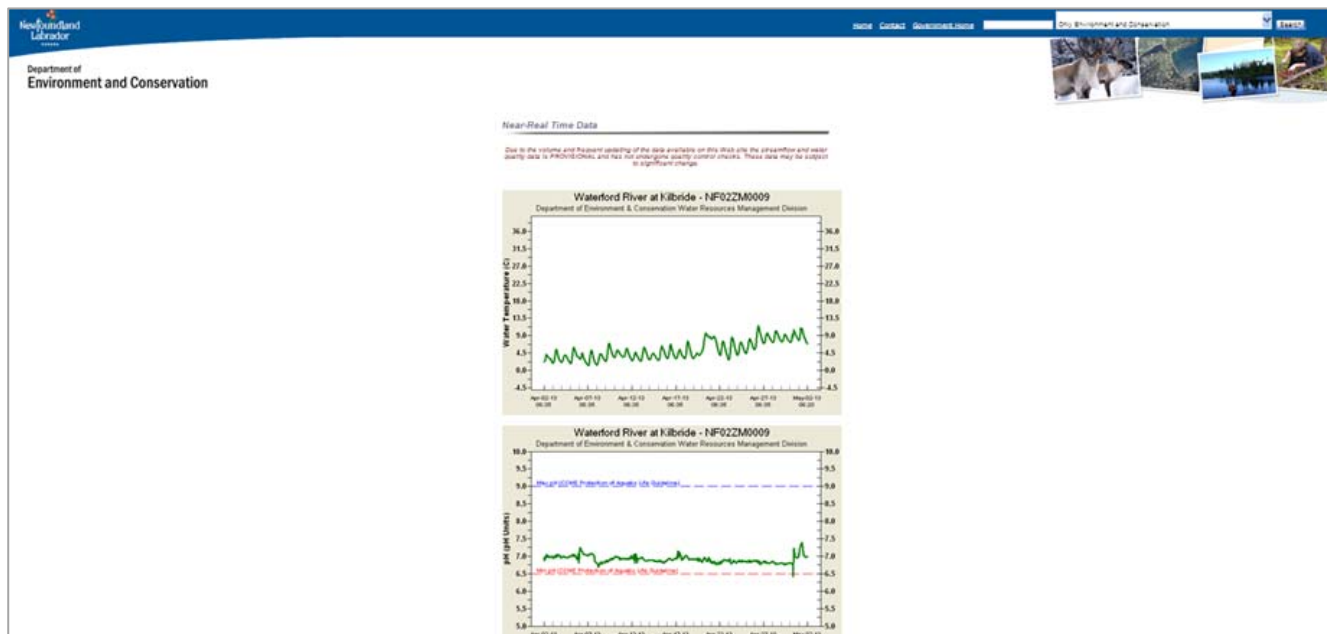


Figure 7-3: Screenshot of the NL RTWQ webpage displaying raw data graphs.

7.3 QAQC Data Validation

Although biofouling and calibration drift are not significant enough to warrant corrected data, there are still a number of instances when raw data is not reliable due to noise, erratic data, missed data transmissions or invalid data from sensor failure. These issues are addressed during preparation of the deployment report. If the issue is long term (i.e. a sensor fails mid deployment) a note is placed on the online 30 day rolling graph of raw data indicating that the values being reported are inaccurate.

At the end of the deployment period, all data values are downloaded from the ADRS windows application available internally to WRMD employees. Data is reviewed for missed transmissions, repeat transmissions, and any data that is inaccurate or questionable. The difference between noise and an actual water quality event is usually easily detectable with water quality events happening over multiple hours or days with distinct patterns (e.g. sharp increase followed by recovery period over multiple hours/days). In the event a transmission error occurred during the deployment period resulting in significant gaps in data, log file data directly downloaded from the instrument can be used to supplement the data available from ADRS.

For data that is flagged, a data variance form is completed (Appendix F). This form summarizes all data that is inaccurate and should be removed or used with caution. It is the employee's choice whether or not to include this data in the deployment report for illustrative purposes but the final data set should have any necessary values removed. The data variance forms assist future users of the QAQC'd data with understanding why values are missing or explain any questionable data. Data variance forms should be provided with the final data set.

7.4 Field Sheet

In the previous sections, there has been reference made to the field sheet used to systematically record information concerning RTWQ deployment, calibration, and removal (Appendix D). The RTWQ staff must ensure that all information collected during the monthly site visit is accurate. Field notes are the foundation to ensure the water quality data is reliable. WRMD has created the field sheet that outlines the necessary information required to ensure accurate and efficient record processing.

The field sheet summarizes the side by side readings from the deployed field instrument and the QAQC instrument at the beginning of the deployment and at the end of the deployment period during removal. These values are used to calculate comparison rankings. The field sheet also includes weather and aquatic conditions, and a place for any additional information that may be useful to explain changes in water quality. The field sheet is to be used at every deployment and removal; it should be completed clearly and thoroughly.

7.5 Deployment Spreadsheet

The deployment spreadsheet is a Microsoft Excel formulated document that allows the recorded data to be reviewed and graphed (Appendix G). There are several components to describing and reporting on data. This spreadsheet streamlines procedures and minimizes repetitive data entry to efficiently produce useful products to be used in the deployment reports.

Data collected on the field sheet during removal and deployment is entered into the spreadsheet. QAQC'd data originally downloaded from ADRS is copied into the spreadsheet. The spreadsheet has been populated with formulae to automatically rank the deployment and removal against the QAQC data, graph the monthly data and produce simple statistics about the data set.

7.6 Deployment Report

At the end of each deployment period WRMD staff are responsible for completing a deployment report on the station conditions and the data collected during deployment. For industry owned stations, an annual deployment report is written to summarize yearly data trends and events. One deployment report can include more than one RTWQ station which is often the case for local networked stations (i.e. multiple stations in one area or river).

A monthly report is a brief document describing water quality events and circumstances at each site, including any variation in the water parameters. Reports generally cover field visit summaries, QAQC rankings, and brief discussions for each parameter including summary statistics, general trends and any water quality events observed. Many times, changes in water quality can be related to weather events. Precipitation and temperature data recorded by EC, available through the National Climate Data and

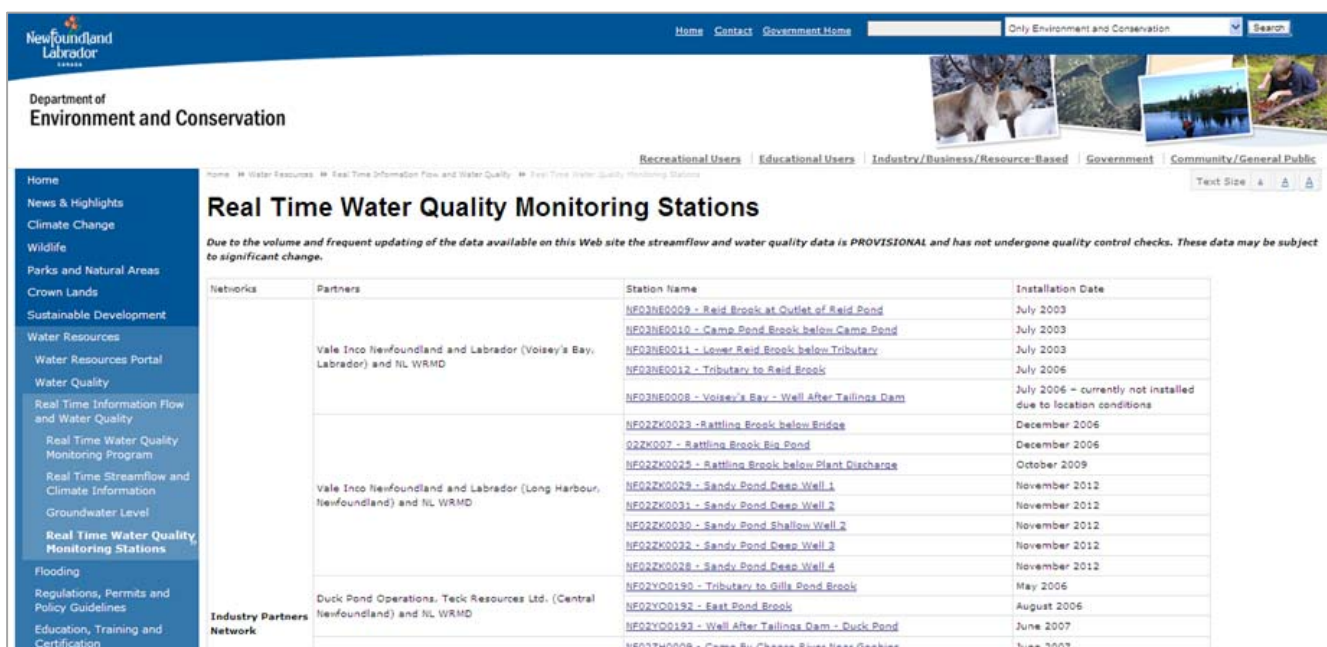
Information Archive, are also included in the deployment reports and used to describe changes in water quality when applicable.

Deployment reports are posted on the departmental webpage and are readily available to the public. Industry partners are directly provided with the completed deployment reports.

7.7 RTWQ Webpage

The webpage is continuously updated with all available raw data from deployed stations, deployment reports, station information, special projects and research findings.

The RTWQ data is categorized in a table by network, partner, station name, and installation date (Figure 7-4). All graphs are linked to the station name; therefore clicking on this link will open the graphs for that station. This tool will display the most recent data for that RTWQ monitoring station that WRMD can provide. The individual parameter graphs display 30 day continuous rolling data for the RTWQ Station, which is updated every 2 or 3 hours. The graphs also include water quantity data collected by EC, which consists of stream flow and stage level.



The screenshot shows the 'Real Time Water Quality Monitoring Stations' page on the Newfoundland and Labrador Department of Environment and Conservation website. The page features a sidebar with navigation links and a main content area with a table of monitoring stations. A disclaimer states that the data is provisional and has not undergone quality control checks.

Networks	Partners	Station Name	Installation Date
Vale Inco Newfoundland and Labrador (Vale's Bay, Labrador) and NL WRMD		NF03HE0009 - Reid Brook at Outlet of Reid Pond	July 2003
		NF03HE0010 - Camp Pond Brook below Camp Pond	July 2003
		NF03HE0011 - Lower Reid Brook below Tributary	July 2003
		NF03HE0012 - Tributary to Reid Brook	July 2006
		NF03HE0008 - Vaisey's Bay - Well After Tailings Dam	July 2006 - currently not installed due to location conditions
		NF02ZK0023 - Rattling Brook below Bridge	December 2006
		02ZK007 - Rattling Brook Big Pond	December 2006
		NF02ZK0025 - Rattling Brook below Plant Discharge	October 2009
		NF02ZK0028 - Sandy Pond Deep Well 1	November 2012
		NF02ZK0031 - Sandy Pond Deep Well 2	November 2012
Vale Inco Newfoundland and Labrador (Long Harbour, Newfoundland) and NL WRMD		NF02ZK0030 - Sandy Pond Shallow Well 2	November 2012
		NF02ZK0032 - Sandy Pond Deep Well 3	November 2012
		NF02ZK0028 - Sandy Pond Deep Well 4	November 2012
		NF02YQ0190 - Tributary to Gills Pond Brook	May 2006
		NF02YQ0192 - East Pond Brook	August 2006
		NF02YQ0193 - Well After Tailings Dam - Duck Pond	June 2007
		NF02ZH0009 - Come By Chance River near Gobies	June 2007
Industry Partners Network	Duck Pond Operations, Teck Resources Ltd. (Central Newfoundland) and NL WRMD		

Figure 7-4: Screenshot of the NL RTWQ webpage showing station names, partners, installation date etc.

A hardcopy of the data can be exported via excel spreadsheet and retrieved by any user. Hourly data is available for the most recent 7 days, daily summaries are available for the past 35 days and monthly summaries are available for the past year.

8 Inventory Management

To ensure integrity and confidence in the raw data from the RTWQ monitoring instruments, WRMD has developed a management system that incorporates the required maintenance, testing and monitoring of all water quality monitoring instruments. Every service or repair on an instrument in WRMD's inventory is recorded for traceability. Maintaining detailed records of instrument function and regular servicing increases the accountability of the WRMD to its industry partners and provides reliability in the real time data. Inventory management also provides WRMD with the ability to track and chart the costs associated with such a large number of instruments, providing assistance when budget forecasting for the new fiscal year.

8.1 Inventory Tracking

The inventory list is a tool that tracks the organization of the RT instruments and associated RT equipment (i.e. hand held display units, cables, chargers, SDI-12 adapter cables, data loggers etc.) (Figure 8-1). The inventory list contains details such as historical information, serial numbers, warranty information and location of equipment. The list allows RTWQ personnel to track any problems or issues with equipment. The inventory list is frequently updated to ensure all recent particulars are logged, and it is accessible for all WRMD staff. The WRMD inventory list automatically flags instruments due for PTE testing. Maintaining a current inventory and servicing log also assists in monitoring the economic investment associated with life-cycle management for water quality instruments.



Figure 8-1: Tracking instrument inventory is essential to understand instrument performance, maintenance schedules and economic investment.

8.2 Servicing and Repairs

All RTWQ monitoring instruments undergo a performance testing and evaluation (PTE) each year by a certified technician. Recently, the NL WRMD trained its own staff to perform PTEs on certain models of multi-parameter instruments. The result from the PTE identifies what may be required in the form of, necessary repairs, sensor replacements or firmware upgrades. All necessary materials required for repairs are purchased from the manufacturer or a certified supplier. If additional or complex repairs are required, the instrument will be returned to the manufacturer for further maintenance.

During the PTE all sensors are inspected visually for wear and tear, cracks, and moisture intrusion. The instrument casing is inspected for any external damage. Firmware is

updated, desiccant packs changed, and power draw from individual sensors is assessed. The PTE is generally completed with a check of the overall functionality of the instrument, by placing it in a controlled water bath for at least 24 hours. The findings from the PTE are presented to the required personnel in an overall service report with graphs of the data recorded during the bath test.

9 References

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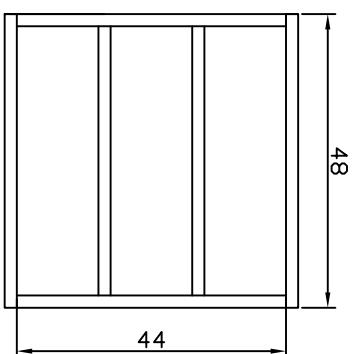
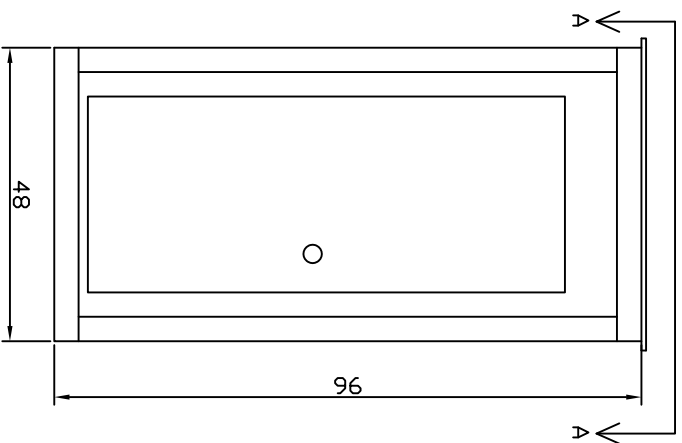
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Appendices

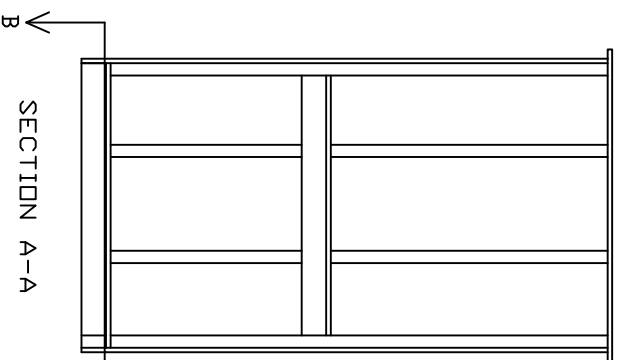
Appendix A - Station Shelter Design	ii
Appendix B - Instrument Protective Casing Design	vi
Appendix C –Checklist	viii
Appendix D - Field Sheet	x
Appendix E - Laboratory Calibration Form	xiii
Appendix F - Data Variance Form	xv
Appendix G - Deployment Spreadsheet	xvii

Appendix A

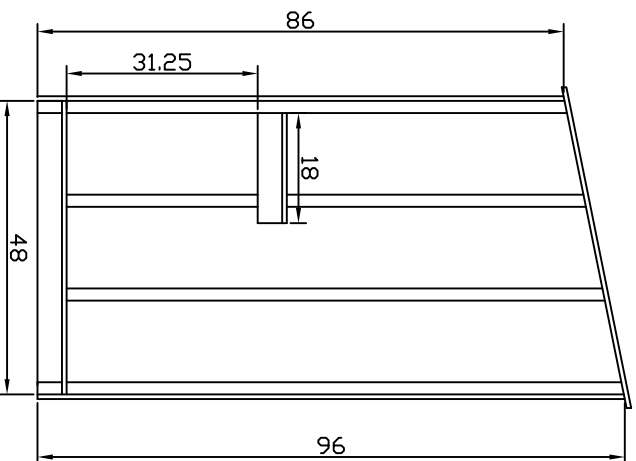
RTWQ Station Shelter Design



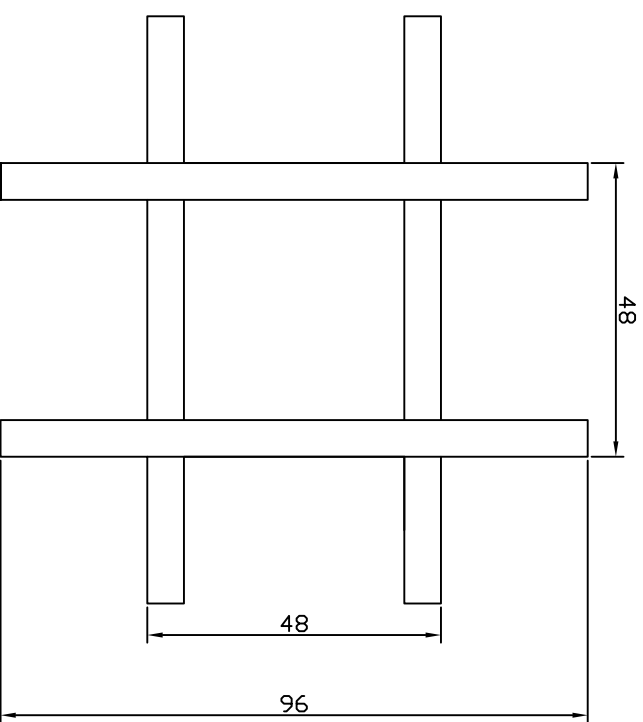
SECTION B-B



SECTION A-A

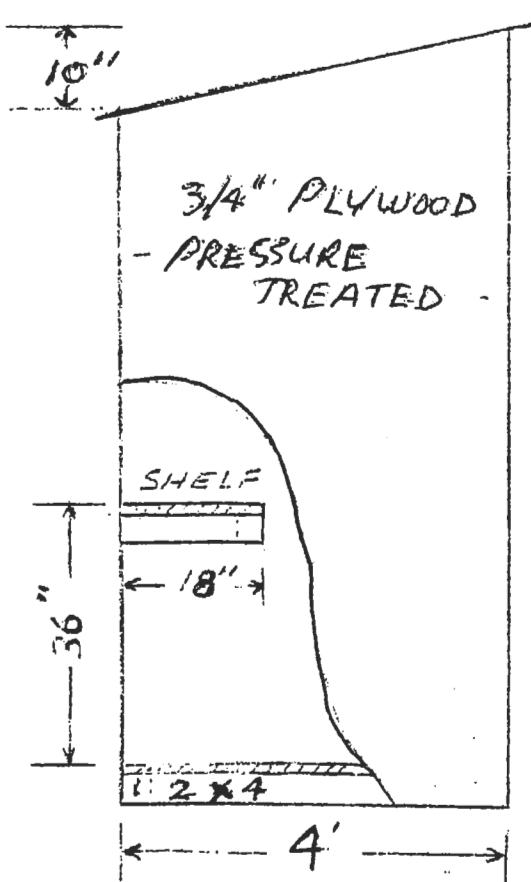


- Notes:
1. All measurements in inches.
 2. Exterior, floor, roof, shelf 3/4" pressure treated plywood, roof c/w shingles.
 3. Inside studs not pressure treated
 - Steel door, 2'8" x 6'8" wooden box, 3 hinge, non lock, passage set
 4. Shelf supported on all sides with 2x4 on edge.
 5. Corner boards 1"x4" pressure treated.
 6. Hut floor is 2"x4" on edge, covered with 3/4" plywood
 7. Hut foundation is 6"x6" pressure treated 8' lengths. All pieced are half-lap jointed. Two sections thick, 8 pieces required. Mark ends for easy field assembly.

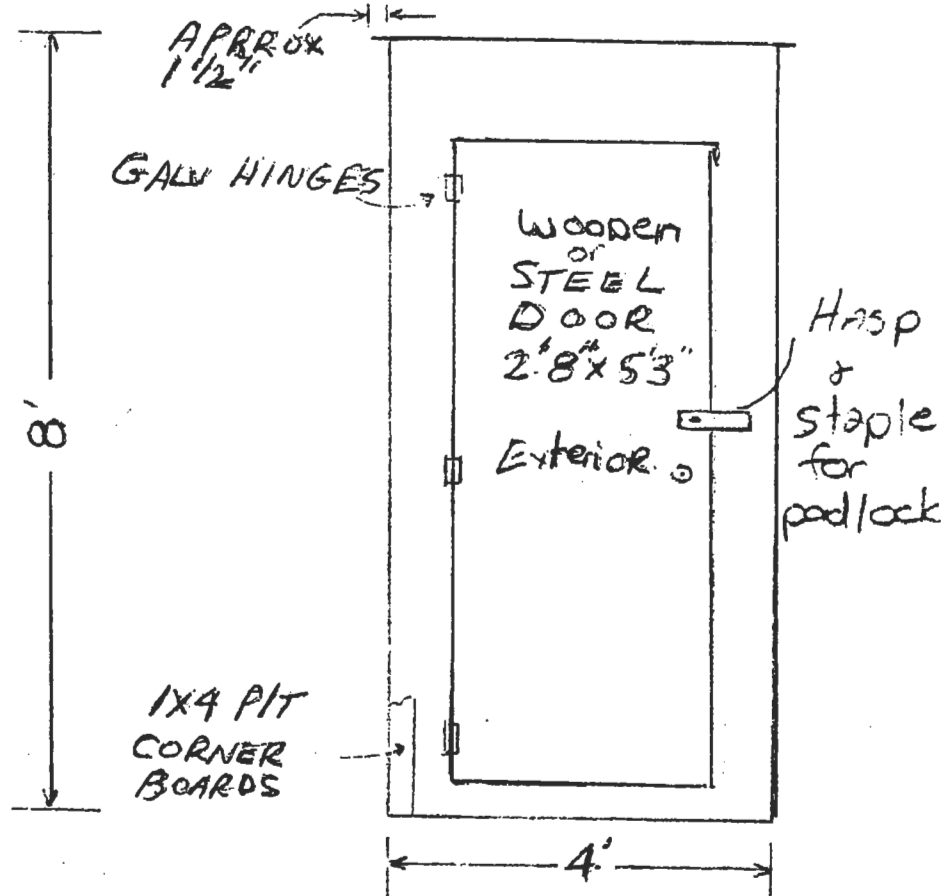


HUT FOUNDATION

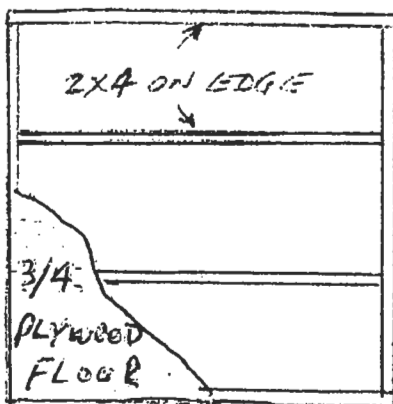
INSTRUMENT SHELTER



- SIDE VIEW -



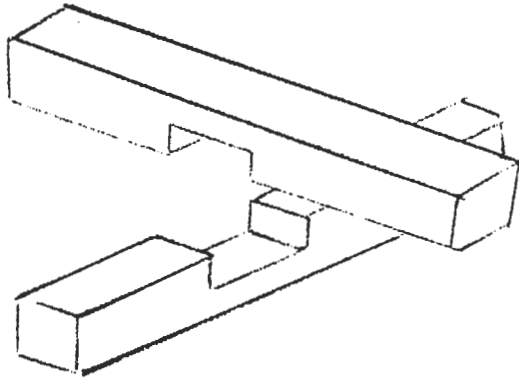
- FRONT VIEW -



- FLOOR -

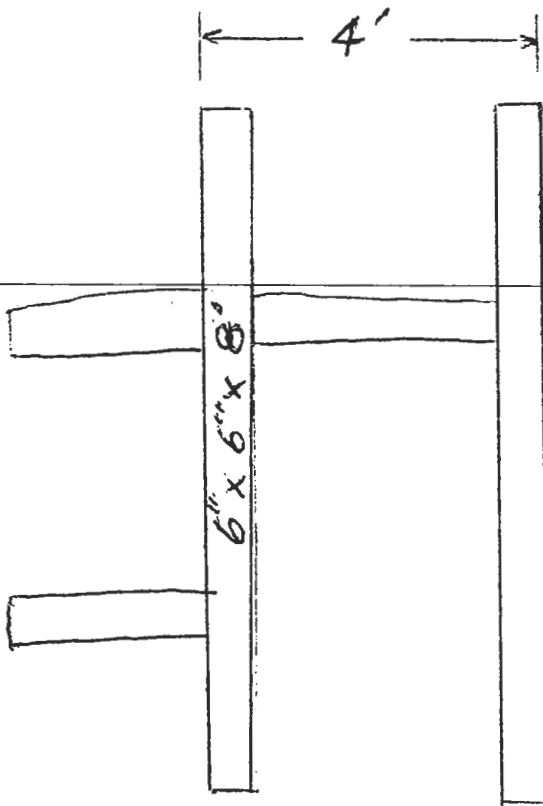
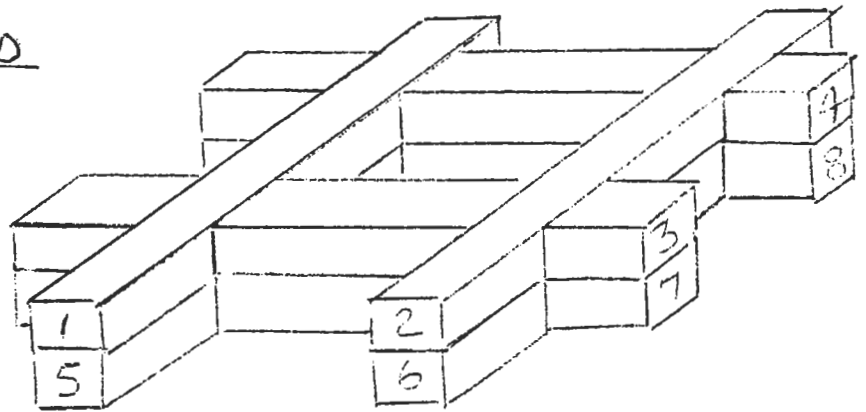
- EXTERIOR 3/4" P/T PLYWOOD
- FLOOR 3/4" P/T PLYWOOD
- FOUNDATION 2x4 P/T
- ROOF 3/4" P/T PLYWOOD c/w SHINGLES
- INSIDE STUDS 2x9 NOT P/T
- DOOR - STEEL 2'8" X 6'8" WOODEN BOX, 3 HINGE, NON LOCK PASSAGE SET
- SHELF 3/4" P/T PLYWOOD, SUPPORTED ON ALL SIDES WITH 2x4 ON EDGE
- CORNER BOARDS 1x4 P/T
- INTERIOR OPEN STUDS NOT SHEETED UP
- Instrument shelter to be attached to Foundation using appropriate size lag bolts

SHELTER FOUNDATION



ALL PIECES LAP JOINTED

MARK ENDS
FOR EASY FIELD
ASSEMBLY.



BUILDING FOUNDATION

6" x 6" 8' LONG

8 PIECES REQUIRED

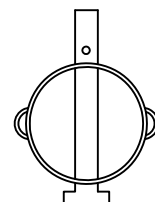
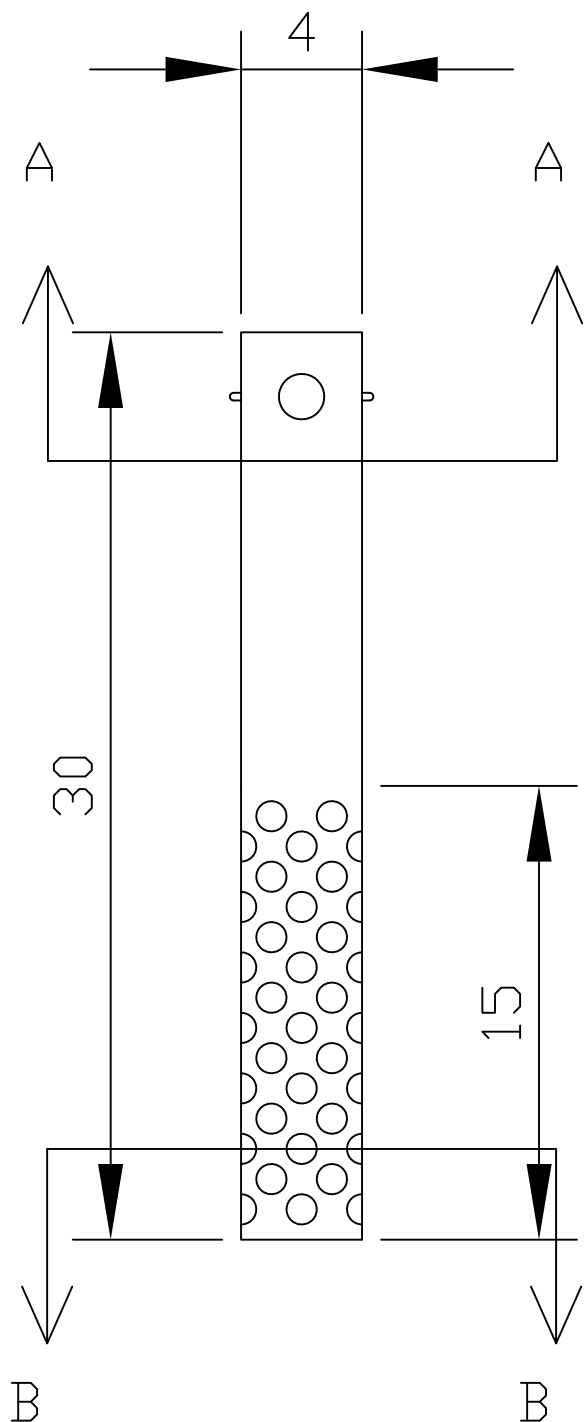
PRESSURE TREATED.

Appendix B

RTWQ Instrument Protective Casing Design

Note:

1. All measurements in inches.
2. Standard thickness stainless steel pipe.
3. Lower section has 1" holes, each row is offset.
4. A fine stainless steel screen must be welded to lower section, covering the 1" holes.
5. In section A-A, a 6" stainless steel bolt is passes through casing, the hole at the end allows a cotter pin to pass through, keeping the bolt in place.
6. In section B-B, two stainless steel pieces are welded perpendicular to each other, covering open section of casing.



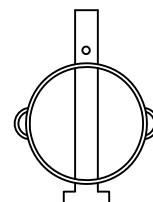
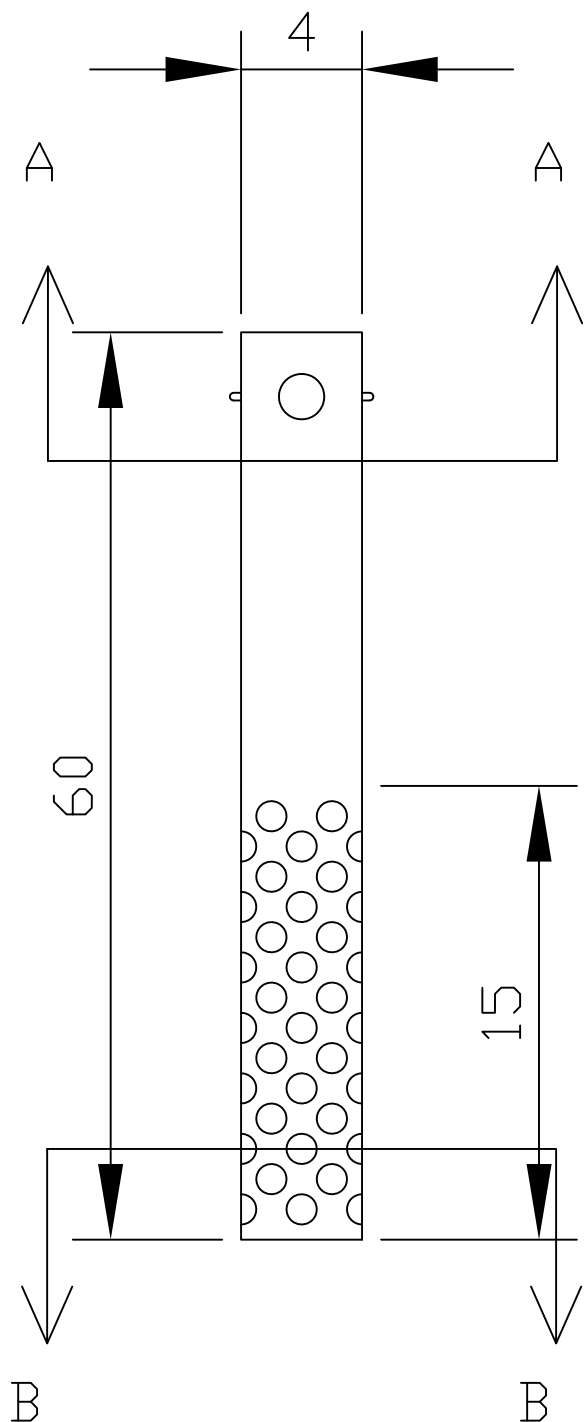
SECTION A-A



SECTION B-B

Note:

1. All measurements in inches.
2. Standard thickness stainless steel pipe.
3. Lower section has 1" holes, each row is offset.
4. A fine stainless steel screen must be welded to lower section, covering the 1" holes.
5. In section A-A, a 6" stainless steel bolt is passes through casing, the hole at the end allows a cotter pin to pass through, keeping the bolt in place.
6. In section B-B, two stainless steel pieces are welded perpendicular to each other, covering open section of casing.
7. Dimesions are not to scale.



SECTION A-A



SECTION B-B

Appendix C

RTWQ Checklist

RTWQ Site Visit Checklist

Travel and Personnel Logistics

- ☐ Transportation arrangements (boat, helicopter, truck, ATV, snowmobile)
- ☐ Appropriate transportation safety gear (see specific policies for transportation by ATV, snowmobile, etc.)
- ☐ Accommodations
- ☐ Field assistant arrangements
- ☐ Industry partners notified
- ☐ Outlook Calendar marked for sampling period
- ☐ _____
- ☐ _____
- ☐ _____

Document Preparation

- ☐ Deployment Field Sheet
- ☐ Grab Sample Field Sheet
- ☐ Grab Sample Numbers & Labels
- ☐ Grab Sample Chain of Custody
- ☐ Shipping account information
- ☐ GPS coordinates, location instructions
- ☐ RTWQ Manual
- ☐ Industry Contact List
- ☐ Waterproof pen/marker
- ☐ _____

Instrument Removal/Deployment

- ☐ Field computer (with charged battery)
- ☐ Hand held display unit
- ☐ QAQC instrument with guard
- ☐ Field instrument with guard (for deployment)
- ☐ Field cable (short, for QAQC instrument)
- ☐ Silicone grease
- ☐ Electrical tape
- ☐ Grab samples bottle sets (6 with TSS bottle)
- ☐ Cooler with ice packs
- ☐ _____

Other

- ☐ Batteries (all types)
- ☐ GPS (programmed with location coordinates)
- ☐ Satellite phone (with phone number)
- ☐ Cell phone (vehicle and outlet charger)
- ☐ SPOT tracker
- ☐ Zip-ties
- ☐ Duct tape
- ☐ Plastic bags
- ☐ Camera (with charged battery)
- ☐ Station key
- ☐ Plumbers putty
- ☐ Desiccant packs for data logger/camera
- ☐ Toothbrush/toilet brush/cloths for cleaning
- ☐ Ice auger (seasonal)
- ☐ Flagging tape
- ☐ Utility knife (box cutter)
- ☐ Lock de-icer
- ☐ 30m Measuring tape

Personal Gear & Safety

- ☐ Hip or Chest waders
- ☐ PFD (CCG approved) with whistle
- ☐ Hard hat
- ☐ Safety Glasses
- ☐ Reflective safety vest
- ☐ Complete change of clothes
- ☐ Long waterproof gloves
- ☐ Rubber boots
- ☐ Rainwear
- ☐ Sunscreen/hat
- ☐ Bug repellent/bug jacket
- ☐ Warm hat and gloves
- ☐ Bear spray and/or bear bangers
- ☐ First aid kit
- ☐ Throw bag/rope
- ☐ Rescue kit
- ☐ Hatchet/axe
- ☐ Waterproof matches or fire starter
- ☐ Waterproof bag
- ☐ Emergency food and water for 24 hours
- ☐ Towel
- ☐ Sleeping bag
- ☐ Emergency flares
- ☐ Heat packs
- ☐ Ice picks (seasonal)
- ☐ _____

Tools

- ☐ Pocket Knife/Multi Tool
- ☐ Adjustable wrench/wrench set
- ☐ Pruning shears
- ☐ Ratchet set
- ☐ Screwdriver set or multi-head screwdriver
- ☐ Fine work screwdriver set
- ☐ Hack saw
- ☐ Cable cutters
- ☐ Hammer
- ☐ Vice grips (small and large)
- ☐ Cordless drill with drill bits and spare battery
- ☐ Hole saw (sized to fit conduit diameter)
- ☐ Spare parts (screws, muffler clamps, hose clamp, U-bolts, quick links etc.)
- ☐ Fish tape
- ☐ Allan key set (metric and imperial)
- ☐ Wire cutters
- ☐ Digital multi-meter
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

Name: _____

Trip Date: _____

Trip Destination: _____

Appendix D

RTWQ Field Sheet

Deployment

▪ Date: _____
Time Zone: NST/NDT/AST/ADT (yyyy - mm - dd hh:mm)

Location	
Staff on site	
Weather Observations	
Aquatic Conditions	
Additional Observations	

Parameter	Field Sonde	QAQC Sonde
	S/n:	S/n:
Temperature (oC)		
pH		
Specific Conductivity (μS/cm)		
TDS (g/l)		
DO %-Sat		
DO mg/l		
Turbidity (NTU)		

QAQC Grab Sample

Grab Sample ID	
----------------	--

Grab Sample Results

Parameter	Value
pH	
Specific Conductivity (μS/cm)	
Turbidity (NTU)	

Parameter		Rank				
		Excellent	Good	Fair	Marginal	Poor
Temperature (°C)		± 0.2	± 0.2 - 0.5	± 0.5 - 0.8	± 0.8 - 1.0	± 1.0
pH (units)		± 0.2	± 0.2 - 0.3	± 0.3 - 0.4	± 0.4 - 1.0	± 1.0
Specific Conductivity	< 35 μS/cm	± 0.3	± 3 - 10	± 10 - 15	± 15 - 20	± 20
	> 35 μS/cm	± 0.3 %	± 3 - 10 %	± 10 - 15 %	± 15 - 20 %	± 20 %
Dissolved Oxygen (mg/l)		± 0.3	± 0.3 - 0.4	± 0.4 - 0.6	± 0.6 - 1.0	± 1.0
Turbidity	< 40 NTU	± 2	± 2 - 5	± 5 - 8	± 8 - 10	± 10
	> 40 NTU	± 5%	± 5 - 10%	± 10 - 15%	± 15 - 20%	± 20

Removal

▪ Date: _____
Time Zone: NST/NDT/AST/ADT (yyyy - mm - dd hh:mm)

Location	
Staff on site	
Weather Observations	
Aquatic Conditions	
Additional Observations	

Parameter	Field Sonde	QAQC Sonde
	S/n:	S/n:
Temperature (oC)		
pH		
Specific Conductivity (µS/cm)		
TDS (g/l)		
DO %-Sat		
DO mg/l		
Turbidity (NTU)		

Deployment Notes

--

Appendix E

RTWQ Laboratory Calibration Form

Laboratory Calibration Form

Type of Sonde (Hydrolab, YSI, etc.)		
Serial Number		
Software Used		
Location of Sonde/Instrument ID Number		
Date Calibrated		
Calibrated By		
Parameters	Before	After
Sp. Conductivity 0 $\mu\text{S/cm}$		
Sp. Conductivity ____ $\mu\text{S/cm}$		
(L)DO% (% Sat)		
pH 7 (yellow)		
pH 4 (red)		
Turbidity 0 NTU		
Turbidity ____ NTU		
Temperature ($^{\circ}\text{C}$)	Thermometer:	Sonde:
<input type="checkbox"/> Downloaded Log File: _____	<input type="checkbox"/> Set Clock	
<input type="checkbox"/> Checked settings (SDI enabled, address, delay, etc.)	<input type="checkbox"/> Checked Parameter Order	
<input type="checkbox"/> Created Log File: _____	<input type="checkbox"/> Log File Enabled	
<input type="checkbox"/> Changed KCl on pH probe	<input type="checkbox"/> Clark Cell (Changed DO electrolyte solution/membrane)	
Internal Battery Power (% or V): _____	<input type="checkbox"/> Changed Batteries within Sonde	
<input type="checkbox"/> Checked Circulator	<input type="checkbox"/> Checked Turbidity brush and wiper	
Comments:		

Appendix F

RTWQ Data Variance Form

Type of Sonde (Hydrolab, YSI, etc.)	
Serial Number	
Station Name	
Station Number	
Date	
Personnel	
Affected Parameter	Tick Applicable box
Temperature	<input type="checkbox"/>
pH	<input type="checkbox"/>
Sp. Conductivity	<input type="checkbox"/>
TDS	<input type="checkbox"/>
LDO% (% Sat)	<input type="checkbox"/>
DO (mg/L)	<input type="checkbox"/>
Turbidity	<input type="checkbox"/>
Affected Time Series	Date/Time
Period Start	
Period End	
Comments:	
Corrective Action Required:	

Appendix G

RTWQ Deployment Spreadsheet

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help Adobe PDF

Type a question for help

Arial 10 B I U

F7

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
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34																			
35																			
36																			
37																			
38																			
39																			
40																			
41																			
42																			
43																			

Print the tab titled Field Sheet for use during the regular 30 day maintenance outings. Recording each sheet in full ensures that a complete record for the deployment interval is available.

Upon deployment, a fully cleaned and calibrated QAQC Sonde is placed in situ with a fully cleaned and calibrated Field Sonde. Once the probes have stabilized -- which may take up to five minutes in some cases -- record the readings for all parameters in the appropriate tables on the Field Sheet. Assuming the readings are in close agreement (consult the Ranking Table included on the Field Sheet), the QAQC Sonde can then be removed. If the readings are not in close agreement, attempt to reconcile the problem on site (bubbles or wiper stuck over the probe, for instance). If no fix is made, consider removing the Field Sonde for recalibration.

During the removal process, a fully cleaned and calibrated QAQC Sonde is once again deployed in situ with the Field Sonde that has been left for a month. Once the QAQC Sonde stabilizes, record measurements from both sondes on the Field Sheet.

Groom the data for the month's deployment by removing any glaring errors (3000 NTU, 0 mg/l DO, etc.) and filling in gaps of > 6 hours using internally logged data. Ensure that every communication dropout is accounted for in the Data tab to ensure the automatic graphing works. ranking will be performed automatically when all the necessary data in the Field Sheet is available. Basic statistics are carried out in the Statistics tab.

Instructions Field Sheet QAQC Rankings Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flow

Draw AutoShapes

Ready NUM

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help Adobe PDF

Type a question for help

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\$ %

NUM

D16

Newfoundland
Labrador

Real-Time Water Quality Network
Deployment Field Sheet

Deployment

Date: _____
Time Zone: NST/NDT/AST/ADT yyyy - mm - dd hh:mm

Location	
Staff on site	
Weather Observations	
Aquatic Conditions	
Additional Observations	

Parameter	Field Sonde S/n:	QAQC Sonde S/n:
Temperature (oC)		
pH		
Specific Conductivity ($\mu S/cm$)		
TDS (g/l)		
DO % Sat		
DO mg/l		
Turbidity (NTU)		

QAQC Grab Sample

Grab Sample ID	
----------------	--

Grab Sample Results

Parameter	Value
pH	
Specific Conductivity ($\mu S/cm$)	
Turbidity (NTU)	

Instructions Field Sheet QAQC Rankings Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flo

Ready

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help Adobe PDF

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Times New Roman 10

B I U

\$ %

NUM

D16

Removal

Date: _____

Time Zone: NST/NDT/AST/ADT yyyy - mm - dd hh:mm

Location	
Staff on site	
Weather Observations	
Aquatic Conditions	
Additional Observations	

Parameter	Field Sonde S/n:	QAQC Sonde S/n:
Temperature (oC)		
pH		
Specific Conductivity (µS/cm)		
TDS (g/l)		
DO %-Sat		
DO mg/l		
Turbidity (NTU)		

Deployment Notes

Instructions Field Sheet QAQC Rankings Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flo

Ready

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

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B5

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Deployment												
2	Field Sonde to QAQC Sonde Comparisons												
3	Parameter	Field Sonde	QAQC Sonde	Difference / % Difference	Ranking								
4	Temperature (°C)				Cannot Rank								
5	pH				Cannot Rank								
6	Specific Conductivity (µS/cm)				Cannot Rank								
7	Total Dissolved Solids (g/l)												
8	Dissolved Oxygen (%-Sat)												
9	Dissolved Oxygen (mg/l)				Cannot Rank								
10	Turbidity (NTU)				Cannot Rank								
11													
12	Field Sonde to Grab Sample Comparisons												
13	Parameter	Field Sonde	Grab Sample	Difference / % Difference	Ranking								
14	pH				Cannot Rank								
15	Specific Conductivity (µS/cm)				Cannot Rank								
16	Turbidity (NTU)				Cannot Rank								
17													
18	Removal												
19	Field Sonde to QAQC Sonde Comparisons												
20	Parameter	Field Sonde	QAQC Sonde	Difference / % Difference	Ranking								
21	Temperature (°C)				Cannot Rank								
22	pH				Cannot Rank								
23	Specific Conductivity (µS/cm)				Cannot Rank								
24	Total Dissolved Solids (g/l)												
25	Dissolved Oxygen (%-Sat)												
26	Dissolved Oxygen (mg/l)				Cannot Rank								
27	Turbidity (NTU)				Cannot Rank								
28													
29													
30													
31													
32													

Instructions Field Sheet **QAQC Rankings** Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flow

Draw AutoShapes

Ready NUM

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

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Arial 10 B I U

A1 Record Count

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Record Count												
2	5000				Uncorrected Data								
3	Record Number	Date/Time	Temp (oC)	pH	Specific Conductivity (uS/cm)	DO (mg/l)	DO-% Sat	Turbidity (NTU)	TDS (g/l)	Stage (m)	Flow (m3/s)		
4	1												
5	2												
6	3												
7	4												
8	5												
9	6												
10	7												
11	8												
12	9												
13	10												
14	11												
15	12												
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32	29												
33	30												
34	31												

Instructions Field Sheet QAQC Rankings Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flow

Draw AutoShapes

Ready NUM

Microsoft Excel - Deployment Spreadsheet.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help Adobe PDF

Type a question for help

Arial 10 B I U

H24

Days Deployed

Please input Deployment and Removal Dates

Parameter Statistics

Parameter	Max	Min	Median	Mean
Temperature(°C)	0.00	0.00	#NUM!	#DIV/0!
pH	#REF!	#REF!	#REF!	#REF!
Specific Conductivity (µS/cm)	#REF!	#REF!	#REF!	#REF!
TDS (g/ml)	#REF!	#REF!	#REF!	#REF!
Dissolved Oxygen (%-Sat)	#REF!	#REF!	#REF!	#REF!
Dissolved Oxygen (mg/l)	#REF!	#REF!	#REF!	#REF!
Turbidity (NTU)	#REF!	#REF!	#REF!	#REF!
Stage (m)	#REF!	#REF!	#REF!	#REF!
Flow (m)				

Instructions Field Sheet QAQC Rankings Data Statistics Temp pH Specific Conductivity TDS DO Turbidity Stage & Flow

Ready NUM

