# Automated Water Quality Monitoring

## Field Manual

Prepared by
Ministry of Environment Lands, and Parks
Water Management Branch
for the Aquatic Inventory Task Force
Resources Inventory Committee

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

## Aquatic Inventory Task Force

The procedures outlined in this manual represent a compilation of material from various agencies and individuals working in the area of automated water quality monitoring. Information in this document was compiled by Ted White of the Ministry of Environment, Lands and Parks Water Management Branch. Technical support was provided by numerous Ministry staff in Regions and Victoria, Environment Canada staff, and non-government proponents. Contributors from the Ministry of Environment, Lands and Parks, Water Quality Section include: R. Nordin, L. Pommen, R. Rochinni, L. Swain, H. Singleton, B. Truelson, S. Andersson, R. Preston, and from the Resources Inventory Branch: M. Clark and W. Mason. Contributors from Ministry of Environment Regions include: D. Einarson (Vernon), V. Jensen (Penticton), D. Boyer (Nelson), J. Denisenger (Nanaimo), P. Doyle (Kamloops), and K. Andrews (Williams Lake). Contributors from the Ministry of Forests include: P. Beaudry (Prince George), P. Jordan (Nelson), D. Maloney (Smithers), and P. Teti (Williams Lake). Contributions from Water Survey of Canada and Environment Canada came from: E. Mayert, N. Wade, and P. Whitfield. Non-government contributors include: E. Quilty, J. Harper, S. Rysavy, Forest Technology Systems (Victoria), Frank van der Have (Hoskins Scientific), S. Biduk (Geneq, Vancouver), B. Carson (Sechelt), and J. Termeunde (Gibsons).

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# 1. Introduction

This field manual addresses the minimum requirements for the establishing and operating a reliable automated water quality monitoring program. The challenge associated with automated monitoring programs is to collect data that consistently represent environmental conditions. This requires clear planning and the field staff to have a full understanding of the equipment and the necessary protocols for data collection, and quality assurance and quality control. To meet the challenge, this manual has been developed and organized to present the basics of implementing and maintaining an automated monitoring station. The procedures outlined in this field manual provide the standards to ensure quality and consistency in automated data collection.

The intent of this manual is to aid field staff in developing an automated monitoring station and collecting reliable, representative data. Discrete sampling protocols for ambient freshwater are not addressed in this manual. The Resource Inventory Committee (RIC) approved manual, *Ambient Freshwater and Effluent Sampling* (Cavenagh *et al.* 1994), is the reference document for ambient freshwater sampling procedures and protocols. Associated subjects such as sample containers, preservation techniques, safety measures, etc. are only briefly discussed in this manual. Appropriate documents listing specific protocols have been referenced accordingly. Protocols for hydrometric data collection can be attained in RIC *Standard Methods for Hydrometric Surveys* (RIC 1998) and protocols for climatic data collection can be found in *AES guidelines for Co-operative Climatilogical Autostations* (1992).

The procedures presented here are the most acceptable ones used at present. It should be emphasized that experienced professional judgment is a necessary component of method choice and application.

# 2. Quality Assurance and Quality Control

The quality assurance program is a systematic process integrated into laboratory and field procedures as well as data storage protocols to ensure a specified degree of confidence in the data collected for an environmental monitoring survey. Planning for quality assurance should occur for all steps of a project through implementation and operation (Figure 1). It is essential that all the phases of a project be documented thoroughly and supplemented by detailed field notes. The following section outline the elements of quality assurance and quality control (QA/QC) for an automated water quality monitoring program as presented in Figure 1.

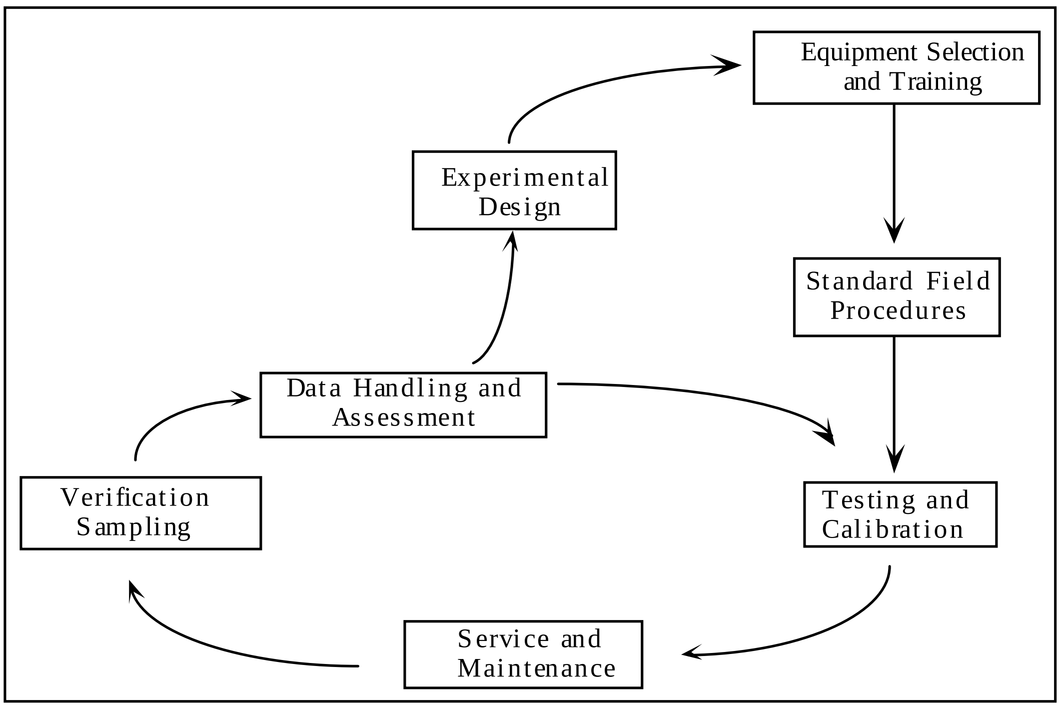


**Figure 1. Incorporating QA/QC into an automated water quality monitoring program.**

## 2.1 Elements of Quality Assurance and Quality Control For Automated Monitoring Programs

### 2.1.1 Standard Field Procedures

The quality of data collected by automated monitoring equipment is dependent on the methods used to handle, assemble, operate, and maintain the equipment. For each station field procedures must be standardized and documented. Detailed notes from each field visit must be recorded and maintained on standardized forms (Appendix 2), any deviation from standard protocol must also be recorded.

### 2.1.2 Training

Training is required to operate any automated water quality monitoring equipment. Improper training may result in lost data, improper site set-up, and poor quality data.

### 2.1.3 Testing and Calibration

All automated sampling equipment must be calibrated and bench tested prior to field deployment. Calibration ensures that readings from instruments will be representative of environmental conditions. Bench testing prior to deployment provides the assurance that all components of the system are functional. Each instrument will have a duty cycle that defines the period between calibrations for which there should be confidence in the data. The duty cycle which is dependent on instrument type and deployment environment, must be determined for each monitoring program. For each instrument, a log of the calibration date and the date of next calibration should be maintained and entered into the Water Quality Data Management System (WQDMS).

### 2.1.4 Service and Maintenance

Each installation will have a specific service cycle or the period between required maintenance. The service cycle must be adhered to in order to maintain the functionality of instrumentation. All information regarding maintenance should be recorded on standard field forms (Appendix 2) and entered into the WQDMS.

### 2.1.5 Verification Sampling

To verify the data generated by the automated monitoring equipment, it is essential that instruments be tested against a standard to check performance and independent samples, or measurements, of the water column be taken. Instrument verification provides confidence in the performance of the instrument while water column tests provide confidence that the instrument is returning an environmentally representative sample. Results from verification sampling should be transferred to the appropriate Ministry of Environment, Lands and Parks' data bases, WQDMS and Environmental Monitoring System (EMS).

Field verification programs by wet sampling must include quality control samples including replicates and blanks. Replicate samples allow the precision of the measurement process to be estimated, and are an additional check on sample contamination. Field or travel blanks to test for contamination in sample containers, collection, handling, and to detect other systematic and random errors occurring from sampling through analysis.

Field verification programs employing portable field meters must include the calibration of the field meter, referencing to standard solutions, and replicate samples. Calibration provides confidence in the output of the portable meter. Standard solutions tested in the field provide an estimate of accuracy of the field measurements. If the meter reads outside instrument specific tolerances, the instrument must be considered inaccurate, and removed from service and sent to a qualified technician for repair, recalibration, and certification. Replicate samples allow the precision of the measurement process to be estimated, and provide an additional check on sample contamination.

### 2.1.6 Data Handling and Assessment

Data from automated monitoring equipment must be downloaded from the data source, entered into WQDMS, and viewed and edited frequently. To maintain continuity in the data handling process data approval should be conducted by field personnel. All steps in data handling, from downloading, screening, editing, and verification must be documented. Viewing data graphically may aid in detection of obvious errors in the data and allow corrective measures to be taken. It is important that when data are edited the original data set not be altered or destroyed, and that detailed notes be maintained and entered into WQDMS. It is imperative that all steps in data handling be documented. Figure 2 shows the flow of data, and meta-data (field notes, calibration logs, and maintenance logs), through the steps of data assessment and approval in WQDMS. Guidelines for each step, as well as proper documentation, are outlined in sections 3.2 and 8.3. Detailed discussion of data approval can be found in *Data Approval Guidelines for Automated Water Quality Monitoring* (Stallard and Clare 1998).

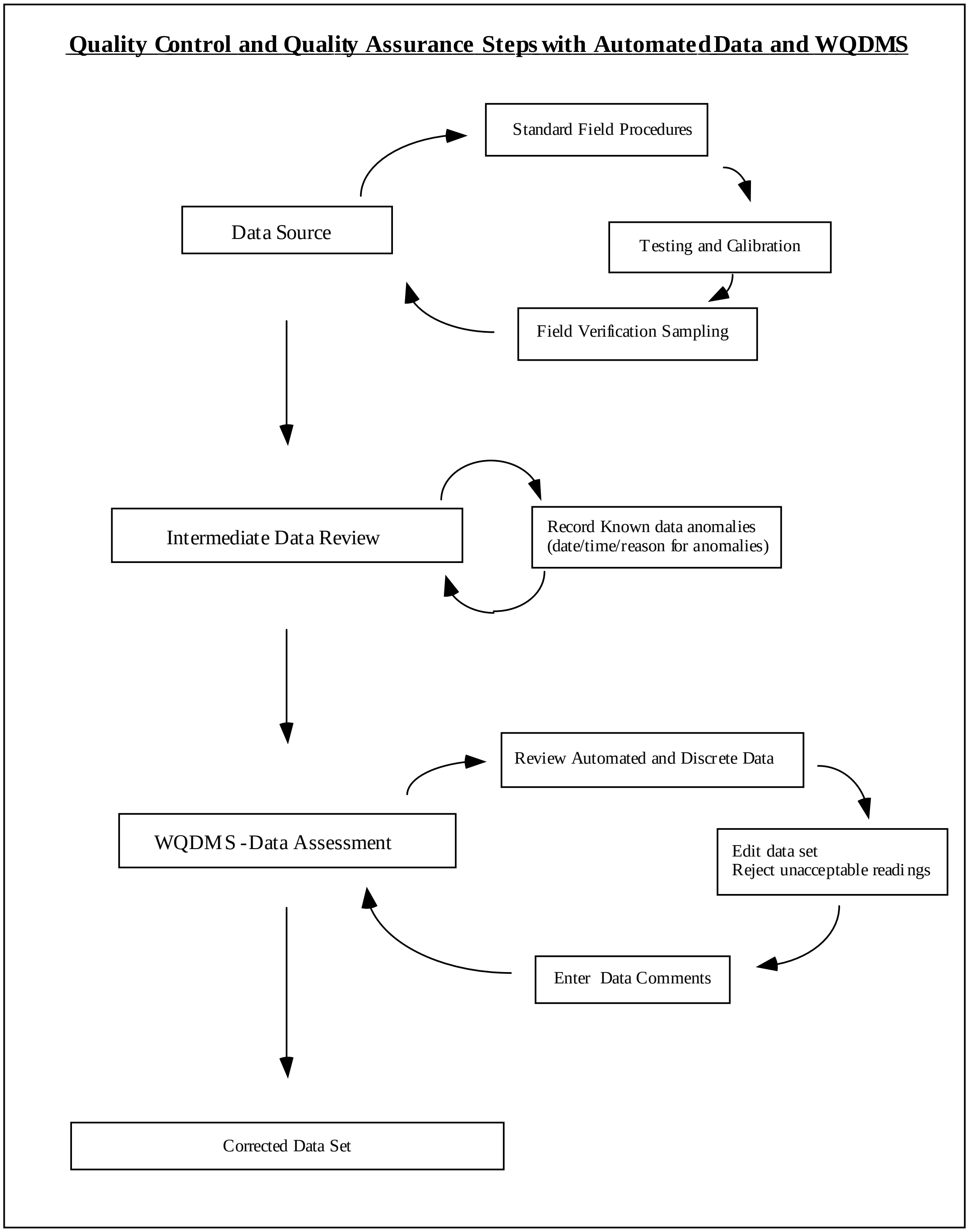


**Figure 2. Flow of automated monitoring data from raw to corrected data set.**

## 2.2 Data Grading Scheme

The application of the QA/QC measures described in this section and the procedures described in subsequent sections are critical for the production of credible data. To summarize the requirements for data collection as described in this manual a data grading scheme has been developed (Table 1). This table should be used to describe the quality of data coming from the site on an annual basis. The data category designation applies only to the potential quality of the raw data stream. Data Category ‘C’ is generally the minimum acceptable level of data quality. Data Category ‘D’ is unacceptable, considered to have inadequate level of confidence. Individual project objectives may indicate that alternate data category levels are required, therefore changing the minimum acceptable data category (e.g., a project may require ‘A’ grade data).

Once assigned a data grade data may not be promoted, however, data may be downgraded if review of data and field information dictate. From one site segments of data may be designated different data grades. For example a two month block of data may have ‘A’ category designation, six months ‘C’ category designation, and the remaining four months ‘D’ category.

It is intended that this grading system be used as a means of developing project work plans and, in conjunction with the *Data Approval Guidelines* (Stallard and Clare 1998) , evaluating confidence in raw data quality. Data approval procedures will be required to assess and correct data sets (Sections 3.2 and 8.3, and Stallard and Clare 1998).

**Table 1. Data Grading Scheme. To be used as a means of evaluating confidence in raw data.**

| Element | A | B | C | D |
|---|---|---|---|---|
| **Instrument Certification** | • Annual | • Annual | • Annual | • Annual calibration and certification not maintained |
| **Field Visit** (1 completed automated monitoring field form is required for a visit to be considered ) | • Monthly (or more frequent)<br>• >3 visits under High (storm event), Medium, and Low flows | • Monthly (or more frequent)<br>• At least 3 visits under High (storm event), Medium, and Low flows | • Monthly<br>• At least 1 visit under High (storm event), Medium, and Low flows | • Bi-monthly, or less frequent |
| **Instrument Verification*** (tested against a known standard as per manufacturer's specifications) | • With each site visit (minimum monthly)<br>• If out of calibration re-calibration and certification initiated.<br>• Procedures for verification are documented and followed | • Monthly<br>• If out of calibration re-calibration and certification initiated.<br>• Procedures for verification are documented and followed | • Monthly<br>• If out of calibration re-calibration and certification initiated.<br>• Procedures for verification are documented and followed | • Bi-monthly (or less frequent)<br>• If shown to be out of calibration and no action is taken.<br>• Procedures for verification are not documented or followed |
| **Water Column Sample** (Using either a portable meter, or lab samples, with appropriate QA/QC) | • With each site visit (minimum monthly)<br>• > 3 samples under High (storm event), Medium, and Low flows<br>• Portable meter or wet sample QA/QC procedures are documented and followed | • Monthly<br>• At least 3 samples under High (storm event), Medium, and Low flows<br>• Portable meter or wet sample QA/QC procedures are documented and followed | • Monthly<br>• At least 1 sample under High (storm event), Medium, and Low flow<br>• Portable meter or wet sample QA/QC procedures are documented and followed | • Bi-monthly (or less frequent)<br>• No storm events sampled. Only mid-flow or low flow samples.<br>• Portable meter, or wet sample, QA/QC procedures not documented, or not followed |
| **Station Log** | • Completed | • Completed | • Completed | • Incomplete |
| **Data Captured Confirmed** | • Data Present for date range. (No unexplained data gaps) | • Data present for date range. (No unexplained data gaps) | • Data Present for Date Range. (No unexplained data gaps) | • Unexplained Data Gaps over date range. |

* Where it is not possible to test against a known standard (e.g., a temperature probe) efforts should be made to check performance under controlled conditions.

# 3. Selection of Monitoring Method (Automatic vs. Manual)

Automated monitoring is not appropriate for all situations. The selection of automated monitoring must be made on the basis of specific monitoring objectives, program resources, and suitability of sites. The method selected must be appropriate for program goals and be technically feasible.

Automated methods may be more appropriate than manual methods in situations where:

- highly variable water quality occurs on an hourly-daily time frame;
- infrequent transient events occur and affect water quality; or
- it is not possible to sample manually or difficult to maintain the required sampling frequency.

For direction on experimental design refer to Cavanagh *et al*. 1997a.

## 3.1 Variables

Variable selection is a critical step in program design. Careful research should be conducted so the chosen variables are:

- representative indicators of stream processes;
- quick to respond to environmental stress; and
- they link to the program objectives.

A list of available and reliable variables, suitable for incorporation into an automated water quality monitoring program is provided in Table 2.

**Table 2. Selected environmental variables that can be automatically monitored.**

| WATER | AIR |
|---|---|
| • Stage/ Water Level/ Streamflow | • Wind Speed and Direction |
| • pH | • Precipitation (Amount/Rate) |
| • Specific Conductance | • Relative Humidity |
| • Temperature | • Temperature |
| • Total Dissolved Solids | **SOLAR** |
| • Specific Ions | • Solar Insolation |
| • Turbidity | |
| • Flow Velocity | |
| • Dissolved Oxygen | |
| • Redox / Oxidation Reduction Potential (ORP) | |

Detailed descriptions of selected variables can be found in Appendix 1. The specific standards for each are described as they pertain to an automated monitoring program.

## 3.2 Data Assessment

Data assessment can be divided into two steps, approval and validation, and synoptic assessment. Steps used in data validation will be common to most automated monitoring programs, and will be discussed in Section 8.3, Data Storage and Management. Methods of Synoptic assessment must be based on the specific objectives of the monitoring program. Information regarding data approval can be found in Stallard and Clare (1998). While further information on experimental design and data assessment can be found in Cavenagh *et al.* 1997b.

# 4. Site Selection Factors

The following section provides guidance on the criteria for site selection. The importance of selecting an appropriate site cannot be over-emphasized. All of the criteria described below must be considered and the site must be evaluated under a variety of flow conditions.

The site selection process for a continuous water quality monitoring program includes an assessment of stream characteristics. Factors to be assessed include: channel stability, sources of turbulence, water depth, protection from natural forces, accessibility, safety, protection from vandalism, and exposure to sunlight. Sites should be chosen based on program objectives and field reconnaissance, preferably under several flow conditions. The following is a discussion of these factors and considerations during the site selection process.

If the site is to be used for stream gauging please refer to the *RIC Standard Methods for Hydrometric Surveys* (RIC 1998) for appropriate site criteria.

## 4.1 Selection Factors

Depending on the objectives of the monitoring project, automated equipment may be installed in a range of channel types, each demonstrating varying degrees of stability. In a typical stream, automated equipment may be situated in small headwater gullies, high energy boulder cascade reaches, or alluvial pool riffle sequences. The inherent stability of each morphology and water column characteristics will dictate appropriate measures for equipment specification, protection, and identify the relevant considerations when dealing with a particular morphology. Morphological features, and factors for site selection are shown in Table 3.

### 4.1.1 Gully Morphology

Gully channels are steep-gradient channels on hillslopes, often characterized by steep sidewalls with unstable banks. Direct relation to hillslope sources of debris, the incidence of debris torrents, and both vertical aggradation and degradation constitute the major sources of instability in gullies (Church 1992). The inherent instability of gully channels are often result in very geomorphically active condition which require special consideration for instrumentation.

### 4.1.2 Boulder Cascade Morphology

Boulder cascade morphologies are less susceptible to channel stability issues due to the nature of channel constituents. These channels consist of large boulders (lag deposits) and smaller keystones which form the step-pool profile. Boulder step channel units are highly stable and rarely reform. Estimated return periods for channel shaping events for boulder cascade morphologies have been estimated at approximately 50 years (Grant *et al*. 1990), thus stability of channel units is unlikely to be an issue for installation. However, the highly turbulent flows characteristic of this morphology are likely to complicate monitoring.

### 4.1.3 Pool Riffle Morphology

Pool riffle sequences are the dominant low-gradient morphology in coastal British Columbia. These alluvial channels are significantly larger than upstream gullies or boulder step channels increasing in size as the drainage area and channel size increases through a river system (Church 1992). Channel materials often consist of smaller gravel and sands with deposits forming bars and infilling pools. Channel banks of alluvial channels are subject to erosion from high energy flows, with the magnitude of erosion dependent on material characteristics. As materials from the stream banks and bed of pool riffle sequences are readily entrained during high discharge events, the stability of such channels becomes an issue for installation of automated monitoring equipment. If project objectives dictate installation in alluvial channels, look for stable areas of bedrock outcroppings where the influences of erosion and deposition are reduced.

**Table 3. Morphology and factors for site selection consideration.**

| Morphology | Considerations |
|---|---|
| Gully | • Small woody debris loading in channel<br>• Potential torrent hazard<br>• Evidence of past torrents<br>• Gully headwall erosion or failures |
| Boulder Step | • Embedded smaller channel constituents (may indicate bedload transport potential)<br>• Potential for high energy flows to damage instruments<br>• Cascading flows create unwanted turbulence and bubbles |
| Pool Riffle | • Stability and mobility of channel materials (bedload transport)<br>• Stream bank stability<br>• Deposits of fine sediments<br>• Magnitude of high energy flows |

## 4.2 Minimal Sources of Bubbles

Attempts should be made to locate the sensors, particularly optical turbidity sensors, away from sources of bubbles (e.g., rocks, boulders, riffles, abutments, piles, spillways, piers, or large woody debris). Sites that are subject to minimal turbulence will have increased consistency in measurements (Jordan 1996). Although it is not always feasible, areas of laminar flow are preferred for more accurate instrument readings. Additionally excessive water velocity can introduce error, where possible attempts should be made to locate instruments in waters moving less than 1 m/s.

Areas protected from turbulent flows by bedrock outcroppings or boulders may protect equipment from bubbles, however it must be assured that higher flows do not lead to water cascading onto the sensors.

## 4.3 Chance of Damage or Destruction by Natural Forces Is Minimal

Consideration of potential natural hazards from upstream activity or channel units is important in the set up of automated equipment. Hazards may include debris torrents, extreme flow magnitude, bedload transport, failure of in-channel debris structures, streamside treethrow, and sediment accumulations. Attempts should be made to protect instruments from breakage and displacement due to collisions with debris under normal and high flow conditions through appropriate choice of deployment location and deployment method (see Table 6 for in-stream deployment options).

Physical observation and investigation upstream should indicate site-specific concerns. Areas of obvious hazards should be avoided. If it is not possible to avoid hazard areas, measures to ensure instrument integrity must be undertaken. Natural hazards will be most prevalent under extreme discharges an assessment of potential hazards should consider extreme conditions.

## 4.4 Safe and Accessible Under All Conditions

The site should be safe for the individual conducting regular maintenance visits, for the equipment and the station enclosure. Seasonal weather and flow conditions should be considered in site selection as they may create hazardous situations in an otherwise safe location. The site accessibility should be assessed over a series of reconnaissance surveys under a variety of flow conditions. Cautious estimates of bankfull height and danger of treethrow, snowpack, and ice must be employed when judging site safety. Winter conditions may require the removal of equipment.

## 4.5 Meets Minimum Stream Depth Requirements for Instruments

Sufficient water depth for accurate sensor readings is crucial. This requires that seasonal flow patterns, manufacturer specifications and accessibility need to be accounted for when calculating the depth for deployment.

Assessments of minimal stream depth are best done through field observations at low flow periods when stream flow is maintained by baseflow. If observations of minimum stream depths are not possible, conservative estimates may be interpolated from longitudinal profiles of streams based on the assumption that pool depth will be maintained in perennial streams. Discussion with local persons familiar with a given stream may also be helpful in determining the extent to which stream flow drops.

Once estimates of minimum stream depth have been determined, the sensors and chosen deployment option must be assessed together to ensure that the deployment structure will meet minimum stream depth requirements under low flow conditions. A monitoring program must be designed to incorporate both summer low flows and extreme discharges; however, not all programs will be able to continue throughout low flow or winter periods, depending on sensor placement and deployment option in use. In such cases, different deployment options may be utilized during times of low risk summer low flows or under winter conditions, including discontinued sampling.

## 4.6 Located to avoid the danger of vandalism

The safety of equipment is an important consideration in site selection. Natural channel characteristics that camouflage the station and equipment can offer some means of protection from vandalism.

# 5. Operational Considerations

## 5.1 Participants/Personnel

### 5.1.1 Dedicated Project Contact

A continuous monitoring program can only be successful if a dedicated project contact and an alternate are identified. Once equipment is deployed, it is essential that equipment receives regular service and maintenance.

The project contact and alternate must be familiar with the operation of all equipment, be able to perform minor repairs and react to critical conditions.

### 5.1.2 Regional Support

Regions will provide support to both non-government and government proponents with automated monitoring programs. This includes:

- technical support;
- specify required abilities of contractors;
- monitoring of proponents to ensure QA/QC procedures are implemented in data collection; and
- evaluation of data for regional needs.

Contact the Environmental Section Head of Pollution Prevention in your region to locate the regional support person for automated water quality monitoring programs.

Alternately, contact the Water Inventory Section of the Resources Inventory Branch, in Victoria at (250) 387-9483 for information regarding regional support.

## 5.2 Responsibility Matrix

To ensure that all duties are performed at each monitoring station, an agreement on responsibilities between partners should be determined and a responsibility matrix similar to Table 4 should be developed.

**Table 4. Sample responsibility matrix for the operation of an automated water quality monitoring station.**

| Responsibility | Participant |
|---|---|
| Prepare proposal for review | Project Proponent |
| Proposal review | Ministry of Environment, Lands and Parks |
| Technical advice on establishing monitoring | Ministry of Environment, Lands and Parks |
| Methods and standards | Ministry of Environment, Lands and Parks |
| Ensure local contact is able to conduct duties | Ministry of Environment, Lands and Parks |
| Equipment installation | Project Proponent |
| Calibration of equipment | Project Proponent |
| Service and maintenance | Project Proponent |
| Collect field verification samples | Local Site Contact |
| Collect QA/QC audit samples | Ministry of Environment, Lands and Parks |
| Data assessment | Project Proponent |
| Ensure data and field notes are in WQDMS | Ministry of Environment, Lands, and Parks |



When developing a responsibility matrix it is essential to:

- identify all duties;
- outline emergency responses; and
- determine what to do if personnel change and new responsibilities are added/subtracted.

## 5.3 Training

All participants in a monitoring project should be adequately trained to perform those duties described in a responsibility matrix. Project contacts and support personnel should receive training in equipment service and maintenance, software operation, and proper sampling protocols.

# 6. Project Preparation

## 6.1 Timing

Successful program implementation can only be achieved after adequate planning and preparation. Time must be allocated for: locating and preparing an appropriate site; ordering, receiving, and testing equipment; as well as installing and trouble shooting once the equipment is installed.

At a minimum, allow three months to have a functional system in the field from the time that agreement in principle has been reached, monitoring objectives have been set and funding is secured. This will provide a realistic time frame to operate under.

## 6.2 Equipment Selection and Purchase

The process of selecting and purchasing equipment for an automated monitoring program requires that the system as a whole be considered. The required data accuracy, available budgets, operational environment, and projected life of the project must be considered when selecting equipment. Together the data logger, instruments, software, power supply, deployment structures, and housing constitute a complete system (Figure 3). The following section provides an overview of options that exist for deployment methods and housing. For specific information on the features of data loggers, software, and power, please refer to *Guidelines for Automated Water Quality Monitoring Equipment*, by White (1997). Information that will guide the selection of instruments can be found in *Guidelines for Automated Water Quality Monitoring Equipment* (White 1997), and Appendix 1 provides information specific to the measurement of selected variables.

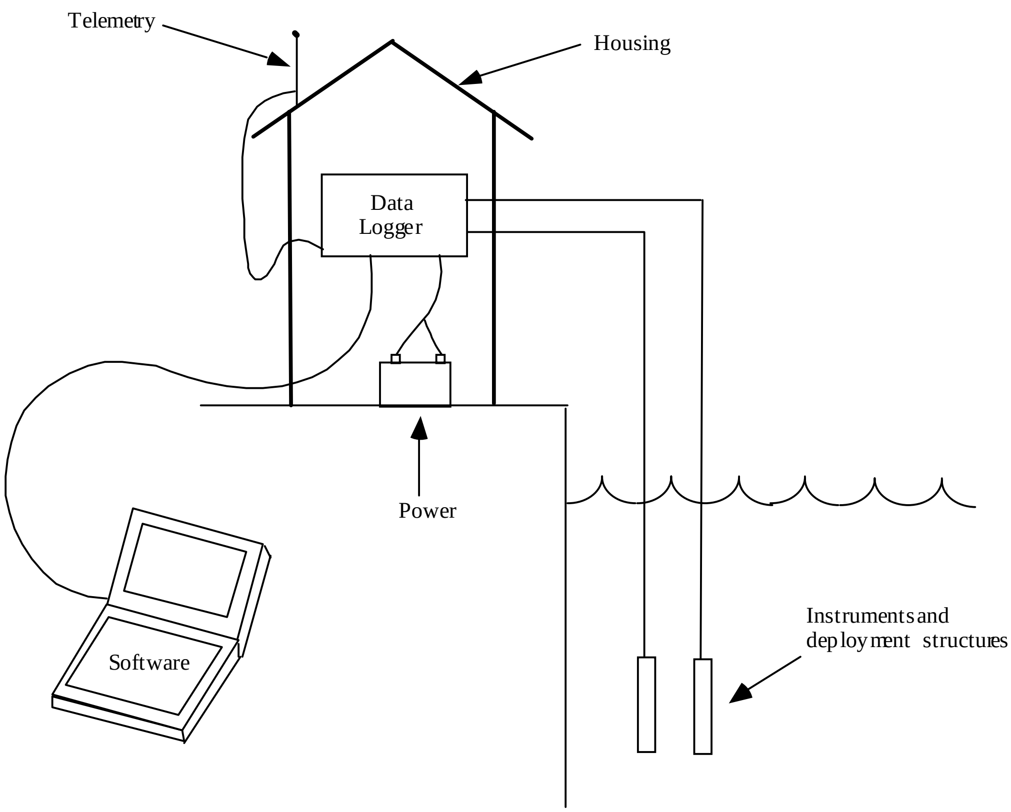


**Figure 3. Components of an automated monitoring system.**

The following specific considerations should be made to approach the purchase as a system:

- What parameters are to be monitored;
- What is the duty cycle, or the length of time the instrument(s) can remain deployed in the field before requiring re-calibration;
- What is the maintenance cycle or the length of time the instrument(s) can remain deployed in the field before requiring maintenance;
- What is the operational environment;
- How will the system be powered;
- How will the data be accessed and manipulated;
- What options exist at the site for housing equipment and deploying instruments; and
- Who will be operating the system and what level of training is required?

The emphasis on the purchase of a **whole system** stems from the fact that there are many pieces of equipment available with a wide array of options. With units of variable quality, it is important to carefully select instruments and equipment that will function together as part of the overall monitoring system. This will ensure program compatibility and minimize potential deficiencies in the monitoring system.

## 6.3 Professional Calibration

Instruments must be calibrated, and certified, by a professional laboratory. This ensures that proper procedures are followed and consistency in calibration, thereby increasing data confidence. Qualified calibration facilities include manufacturers and contracted laboratories.

A record of each instrument's calibrations must be maintained in a paper format as well as on WQDMS.

## 6.4 Bench Testing Equipment

Bench-testing is generally the most time-consuming component of the deployment routine. However, this is an essential step to ensure that all programming and connections are functioning prior to moving to the field. Bench testing equipment:

- checks that the equipment is properly connected;
- tests for equipment functionality; and
- assesses the operation of software programming.

It is imperative that all hardware is appropriately programmed, wired and prepared. The time taken to ensure the functionality of equipment and software will save time and frustration in the field.

**DO NOT TAKE EQUIPMENT TO THE FIELD PRIOR TO BENCH TESTING**

## 6.5 Duty Cycle

A duty cycle defines the period that an instrument is used in the field between calibrations. Each instrument type will have different duty cycle requirements that are determined by manufacturer's specifications, environmental conditions, and experience. Unless otherwise directed by manufacturers or experience:

- assign an annual duty cycle to instruments known to have stable calibration; and
- assign a shorter duty cycle to instruments known to have unstable calibration based on manufacturer specifications and/or field experience.

As instruments are to be re-calibrated in laboratory the purchase of replacement instruments that can be used while the others are being re-calibrated should be considered during project planning.

## 6.6 Service and Maintenance Cycle

A maintenance schedule should be planned from the monitoring program's conception. Establishing a schedule for regular station and instrument service as part of the planned quality assurance and quality control measures is essential. Exact timing depends on site-specific factors, but it is recommended that plans initially be based on a weekly service schedule. Difficult sites could require daily service, while trouble-free sites should be visited at least monthly. Service functions include:

- physical cleaning of instruments;
- inspection for fouling, corrosion or damage;
- replacing instruments for recalibration; and
- replacement of components such as batteries.

For those sites being polled by telemetry, check the database to ensure successful transfer of data.

A comprehensive and consistent service schedule will:

- prevent loss, or lengthy gaps, of data resulting from equipment failures;
- improve data credibility; and
- improve anecdotal understanding of site processes.

Duties to be carried out by the selected local site contact include:

- routine sensor inspection, cleaning, and servicing;
- downloading data (to lap-top computer for sites without telecommunications); and
- alerting the designated project coordinator when critical conditions exist.

The maintenance cycle defines the period between required service functions. Maintenance needs will vary with the seasons and between streams. The schedule provided in Table 5 should be used as a template and modified to suit local stream conditions. Timing will be determined by instrument type and environmental conditions.

**Table 5. Sample of a maintenance schedule.**

| Variable | Maintenance Activity Required | Frequency of Maintenance | Documentation and Reporting |
|---|---|---|---|
| **Battery/Solar Panels/AC** | Check battery voltage, replace if below 11.75 V | Monthly | Standard Reporting Form (Appendix 2) |
| **Time** | Adjust to Local Standard Time | Monthly | Standard Reporting Form (Appendix 2) |
| **Turbidity** | Clean sensor windows | Monthly | Standard Reporting Form (Appendix 2) |
| **Conductivity** | Inspect for signs of corrosion or damage | Monthly | Standard Reporting Form (Appendix 2) |
| **Temperature** | Clean probe of fouling | Monthly | Standard Reporting Form (Appendix 2) |
| **Data Telemetry** | Check database to ensure successful upload of data. View graphically | Once every two weeks (min.) | Record in database under Data Source Comments. |



**Note:** this table should be developed to meet specific monitoring program requirements.

## 6.7 Deployment Method

### 6.7.1 In-stream

The selected in-stream deployment method should protect the sensors from damage and maintain the sensors in a suitable location in the stream. Various options for in-stream deployment are listed in Table 6; other techniques may be devised as required.

**Table 6. In-stream deployment methods.**

| Deployment Method | Advantages | Disadvantages |
|---|---|---|
| **Bottom Plate Deployment (Figure 4)** | • protects sensors from damage<br>• equipment is below the regular influence of bubbles | • difficult to access under high flow conditions and winter ice conditions<br>• influence of saltating particles |
| **Deployment Tube:**<br>• Aluminum<br>• PVC<br>• High Density Poly **(Figure 5)** | • easy to retrieve and clean probes<br>• locking mechanism ensures consistent orientation of sensors and improves data consistency<br>• cables protected by tube<br>• access under high flow conditions | • attractive to vandals<br>• more easily hit by boulders/logs; sensor is subject to freezing in tube<br>• foam<br>• pressure transducer must to be located separately<br>• freezing (with aluminum structures) |
| **Mounted to Angle Iron In-stream** | • variable depending on<br>• construction | • difficult to access under high flow conditions and winter ice conditions;<br>• does not provide protection against abrasion or debris |
| **Surface Deployment (anchored and floating on surface of water)** | • protected from bedload<br>• access under all flow<br>• conditions | • exposed to bubbles<br>• susceptible to damage from floating debris and ice<br>• attractive to vandals |

Electrical cables connected to instruments and data loggers must be adequately protected. One option to reduce damage is to wrap electrical cables in steel cable, PVC tubing, or metal pipe. This makes the cable very resistant to damage. Other options are acceptable as long as they protect the cable and systems.

**Figure 4. Bottom deployment plate at Gray Creek pilot station - Sechelt, BC (1995).**

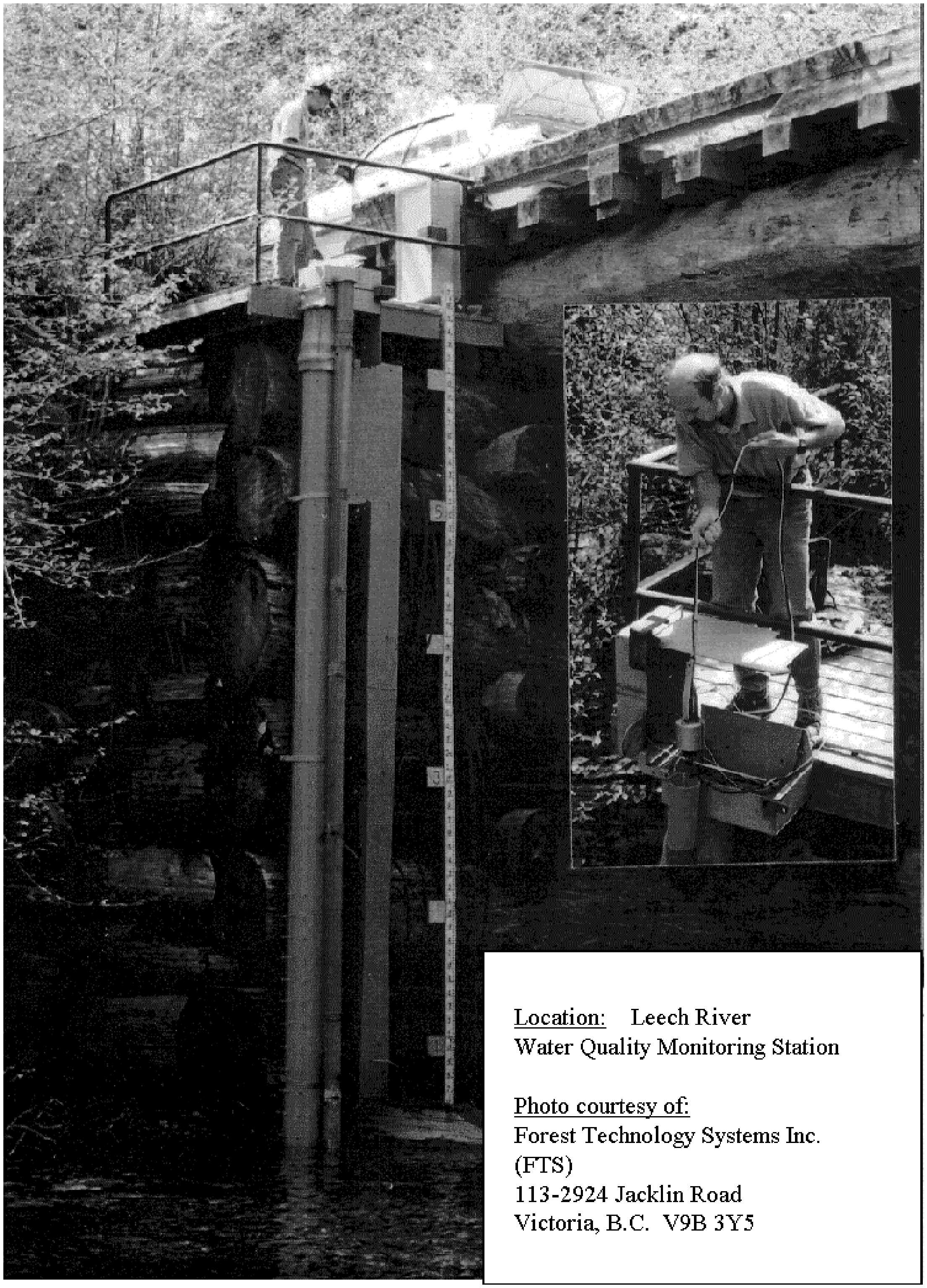


**Figure 5. PVC tube anchored onto the streambank (alternatively, a metal pipe may be used).**

### 6.7.2 Side-Stream Deployment Method

Stream conditions may dictate that instruments cannot be installed in the stream channel. In such cases, side-stream deployment may be required. Conditions that may necessitate the use of side stream deployment include:

- excessive turbulence and bubbles;
- extreme danger of instrument damage from floating debris or bedload;
- insufficient water depth to meet operational requirements; and
- unsuitable deployment site on stream bank.

Two methods of side stream deployment exist, gravity fed and pump fed (Figure 6).

Gravity fed system works by drawing water from the stream channel, through a length of pipe, to a sample chamber and then discharging water back to the stream. Figure 6a shows a typical side-stream deployment system. Intake hoses must be deployed to avoid airlocks this requires that the system is gravity fed, not siphoned. It may be required to dig a trench to lay the intake pipe. At heads greater than 1.5 m a pressure reducing system should be used. Appendix 4 provides schematics of side-stream deployment devices and head reducing systems.

Pump fed systems use a peristaltic pump, or other type, to move water out of the stream channel to a sample chamber and then discharges by gravity to the stream channel. Pumped samplers require a reliable power supply to operate and may require more maintenance and repair than a gravity fed sampler.

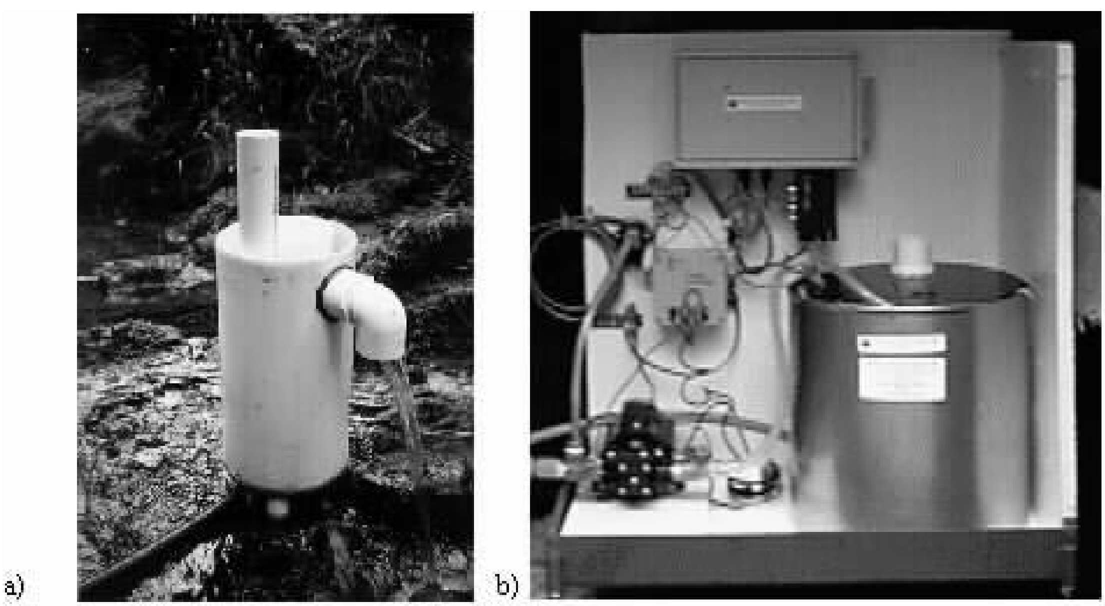


**Figure 6. Example of gravity fed (a) and pumped (b) side-stream samplers.**

Other considerations for side-stream monitoring are discussed below:

- Side-stream samplers will require site-specific calibration to correlate the measurement in the sampling chamber to that of the stream.
- An effective intake device for both gravity-fed and pump-fed samplers will have a large surface-area meshed intake that is securely anchored in place. This will increase the period

of time between required intake servicing. Certain variables, such as dissolved oxygen are not conducive to side-stream monitoring as the mixing in the intake pipe may effect the distribution of constituents in the water.

- Full year deployments will require special considerations to prevent freezing. Measures should include the use of a submerged and buried intake hoses, minimize metal components used in the sampling chamber, and providing insulated housings for the sampling chamber.

With this in mind side-stream systems should only be used when in-stream deployment is not operationally feasible.

## 6.8 Station Enclosure Requirements

The data logger and supporting equipment must be stored in a secure enclosure above the bank-full width, or the high water mark. Enclosures such as Water Survey of Canada hydrometric sheds and used BC Hydro kiosks have been used (Figure 7). Other fabricated enclosures are acceptable so long as the unit is secured from vandals and out of danger from flooding. The enclosure must be located in an area free from electronic interference (e.g., overhead or buried power lines).

The following is a list of general requirements for monitoring station enclosures:

- station should be secure (locked) and provide sufficient storage space for equipment;
- vented, yet still provide protection from wind, rain, and snow;
- prevent direct contact of equipment components with floor of the enclosure and allow for ventilation under components to avoid condensation;
- a point of attachment to clamp cables to the interior of the enclosure;
- a point to bolt down/anchor the enclosure to ground (e.g., an existing structure, cement pad or stakes driven into the ground); and
- a point to secure cables at their point of entry to the enclosure.

********

**Remember: Vandals can be very curious and determined. Protect the monitoring station with adequate deterrent and safety measures.**

********

Note: Advance contact(s) should be made with private landowners, provincial agencies, regional districts, etc. who may be involved with or affected by a monitoring station erected alongside a stream. Agreements must match the proposed duration of the monitoring program.

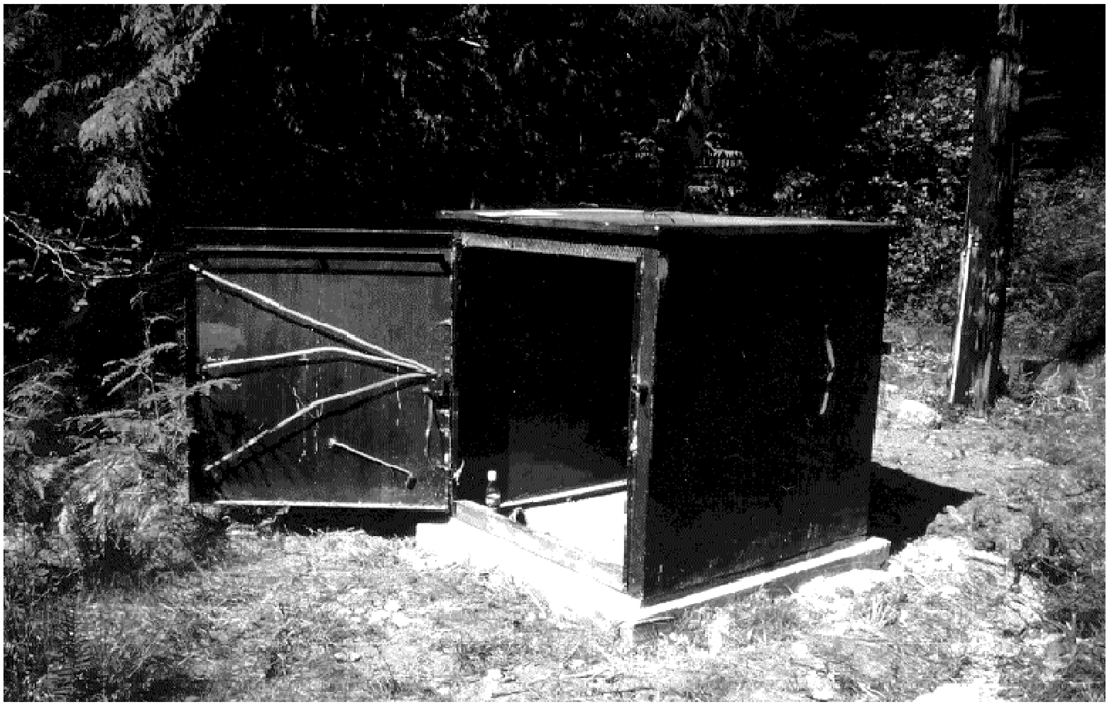

**Figure 7. Hydrometric shed constructed on cement pad - Gray Creek pilot monitoring station.**

# 7. Verification (QA/QC) Sampling

## 7.1 Field Verification

Sensor calibrations can change over time as a result of fouling, breakage, electrolytic drift, and aging of electrodes. The effect will be unreliable and erroneous data. For example, a sensor may consistently produce negative readings where positive values are expected, indicating that the sensor has drifted. Conscientious application of duty and maintenance cycles will minimize the potential for error from calibration drift, however it will not eliminate it.

Verification sampling consists of instrument performance testing and independent sampling of the water column. Each is discussed below.

**Instrument performance testing**

Instrument performance testing is conducted where it is possible to check an instrument against a standard solution. Instruments are first taken off-line, removed from the water, and inserted into a standard solution. The instrument is scanned and the reading recorded. Again, if the instrument reading is within the Data Quality Objective (DQO, see example Table 6), the instrument is considered to pass and not require re-calibration. Examples of instruments that can be tested in this way include, pH, conductivity, and turbidity. If the instrument is not reading within the DQO field adjustment or laboratory re-calibration is required.

**Independent sampling or measurements of the water column**

Independent sampling or measurements of the water column will provide a quality assurance check to verify that the data produced by the electronic sensors are providing a representative sample of the water column. If the reading is within DQO, the instrument is considered to pass, not requiring calibration. If it does not pass, however has passed the instrument performance test, steps should be taken to examine the data to see if calibration is required or an off-set factor applied to the data. It is preferable to ensure that the deployment and instrument set-up is configured so as not to require an off-set.

For each site a schedule of verification sampling is required with protocols described. Table 7 provides an example of a verification sampling schedule. For each site a sampling schedule must be developed based on required data grade, site characteristics and equipment used.

**Table 7. Sample verification schedule.**

********

**This table is a sample only. A sample verification schedule will have to be developed for each site.**

********

| Variable | Sample Method | Sampling Frequency | Data Quality Objectives | Documentation |
|---|---|---|---|---|
| **Time** | • comparison to Local Standard Time (LST)<br>• do not switch to day light savings time | Monthly | • ±1 minute from Local Standard Time (LST) | • record deviation from LST<br>• record date/ time of adjustment to LST<br>• document verification of laptop clock |
| **Turbidity** | • wet sample to laboratory or measure with portable meter<br>• Scan instrument in distilled water. | Monthly | • ± 2 NTU, if < 20 NTU<br>• + 5 % from standards solution<br>• + 10% of wet sample or portable meter, if > 20 NTU | Refer to Standard Reporting Form (Appendix 2) for:<br><br>Turbidity, Temperature and Conductivity<br><br>Record:<br>• date/ time sample/measurement collected<br>• sample/measurement results<br>• deviation from automated sensor readings<br>• action taken if DQO's not achieved |
| **Water Temperature** | • check sensor temperature against thermometer reading | Monthly | • + 1° C from portable meter value | |
| **Air Temperature** | • thermometer or portable meter | Monthly | • + 1° C from thermometer or portable meter value | |
| **Specific Conductance** | • wet sample to laboratory or measure with portable meter<br>• scan instrument when immersed in standard solution | Monthly | • +3% from standard solution<br>• +3% of wet sample or portable meter value | |
| **Flow** | RIC Provincial Hydrometric Standards | | | |



- Check laptop clock prior to field visit.
- Use Standard Time. Do not switch laptop clock to Daylight Savings Time.
- Ensure field replicates and blanks are collected as required - refer to Cavanagh *et al.* (1994), for detail on QA\QC for discrete measurements.
- Note: Documentation of sampling conditions is critical to quality assurance. Any deviations from standard collection procedures need to be recorded. This will aid in achieving a comprehensive interpretation and analysis of the data (see section 8.0 for Field Preparation, Observations and Notes).

## 7.2 Sample Frequency

The frequency of field verification or QA/QC sampling of measurements depends on several factors, including:

- Instrument history or experience. Sampling should be more frequent when monitoring first begins or when changes are made, and then become less frequent if stable operating conditions emerge (e.g., three days in first week, then monthly thereafter).
- Variability of the stream. More frequent sampling is needed for variable conditions than for stable conditions, to verify the results over a wider range.
- Achieving data quality objectives. Failure to achieve the objectives should prompt more frequent sampling, whereas achieving the objectives consistently may allow decreasing the frequency.
- It is thus difficult to recommend frequencies to cover all circumstances, but it is recommend that the minimum frequency be monthly (see Table 1), with subsequent increases based on experience. QA/QC samples or measurements should be made whenever the station is visited for maintenance or the deployment of new equipment.

## 7.3 Field Sampling

As part of the automated water quality monitoring program, wet samples are required to be taken on a regular basis and sent to an accredited laboratory for analysis and/or measurements made with portable meters. The results of the analyses should be recorded and entered on a database with, or linked, to automatic sensor results (see Section 8.4 on Data Storage).

### 7.3.1 Wet Sample Collection

The appropriate protocol for manual collection of samples in rivers and streams are outlined in Cavanagh *et al.* (1994), *Ambient Fresh Water and Effluent Sampling Manual.*

### 7.3.2 Portable Meter Measurements

The requirements for measuring with portable meters are discussed in part by Cavanagh *et al.* (1994) in the *Ambient Fresh Water and Effluent Sampling Manual*. Refer to the operator's manual for specific instructions on the meter you are using. Portable meters must be certified by an accredited laboratory annually.

**Note:** Personal safety is the greatest consideration when deciding where, when and how a sample should be collected from a stream. Caution is the key - never jeopardize personal safety when sampling.

## 7.4 Shipping

The day's sampling schedule must be designed to ensure that the samples arrive at the shipping agency's terminal well before the end of business hours. Since some variables have very limited hold times (e.g., 48-72 hours), every effort must be made to avoid delays in shipping. Protocols to maintain the integrity of the samples during transit are outlined in Cavanagh *et al.* (1994), *Ambient Fresh Water and Effluent Sampling Manual* pp. 59-60.

## 7.5 Analytical Laboratory Requirements

For water quality analyses, only those laboratories registered under the Ministry of Environment, Lands and Parks' Environmental Data Quality Assurance (EDQA) program and are capable of downloading to EMS are acceptable.

Note: Laboratories are certified only for specific parameters. Contact your Regional Quality Assurance (QA) Officer or Laboratory Services and Systems Management Section (250) 387-5214 for a list of EDQA registered laboratories and their certified parameters.

# 8. Documentation and Data Management

Quality assurance and quality control of automated data is dependent to a large degree on the quality of the documentation surrounding calibration logs, procedures, field notes, and area events. The following section provides an outline of the basic information that should be kept on file and the methods for data management and storage. For a more detailed discussion of data approval protocols the reader is referred to *Data Approval Guidelines for Automated Water Quality Monitoring* (Stallard and Clare 1998).

## 8.1 Documentation

For each site a file must be maintained that provides information on the equipment at the site and the maintenance and service records. At a minimum for each site the following must be kept on file.

- Equipment and Sensors Catalogue. At the time of set-up complete the equipment and sensors catalogue forms, update as required.
- Modification or damage form. If any modifications are made to a site or damage is noted complete and file one of these forms (e.g., if a sensor is added or the enclosure is changed, or if vandalism has occurred).

  Note: if the modification includes equipment changes ensure that the equipment and sensors catalogue is updated.

- Station log. The log is kept at the site, each visit must be recorded.
- Field Form. With each site visit complete one of the automated field forms and file the original or a copy of the original.
- Other Notes. Ensure any other relevant notes are included in the file.

## 8.2 Downloading Frequency

Downloading frequently is an integral part of the QA/QC program, because it allows you to identify data gaps, unusual readings and unusual patterns of one or more variables. If gross errors in the data exist they may be apparent when plotted, and subsequently problems within the system can be identified. For example, if the resulting data are not meeting the *Data Quality Objectives* (sample in Table 7), sensors may need field recalibration or manufacturer/laboratory calibration, or the software may need to undergo calibration.

Data downloading should be done at least weekly to ensure that high standards of operation and data collection are maintained. This will allow for appropriate corrective measures to be taken before any lengthy data losses occur. Regular downloading will complement the field verification program.

## 8.3 Data Management

All data captured by automated monitoring systems must be stored in the Water Quality Data Management System (WQDMS). This includes sensor readings, as well as all notes, comments, and calibration logs from a site. The following provides a summary of some of the steps required for data management and assessment in WQDMS detailed methods for data approval are described in Stallard and Clare (1998).

If data are downloaded to an intermediate storage system prior to importing into WQDMS the following procedures must be followed.

- Review data graphically - either within a proprietary data management system (e.g., Weather Plus or PDL) or in a spreadsheet program such as EXCEL.
- Note all date and time ranges that are considered to be anomalous data and reasons why. Enter comments into Sensor Comments in WQDMS. Reasons to consider data anomalous include:
  - periods when it was known that sensors were obstructed, or operational requirements were not met, and therefore were returning incorrect data
  - data spikes caused by the operator not taking instruments off line prior to servicing or instrument performance testing.
  - periods that instruments are known to be out of calibration
- Do <u>not</u> remove data from the data set

Data Capture and Editing in the Water Quality Data Management System (WQDMS)

- Import data into WQDMS.
- View data to ensure all readings have been imported.
- Enter information from field forms and intermediate data review including:
  - field calibrations - Calibration Log
  - maintenance of field site - Data Source Comments, and
  - conditions at site - Data Source Comments or Monitoring Location Notes
- Graphically view data (prior to the development of a viewer for WQDMS this will require the export of data to EXCEL or similar system for viewing). Overlay all automated data, including flow and precipitation.
- Overlay discrete data from EMS.
- Reject data that are not acceptable (this includes data noted as anomalous above) - Note date and time ranges under Sensor Comments.
- Edit data, individually under Sensor Readings or batch update using the Adjust For Drift function.
- Note all modifications under appropriate Sensor Comments.

## 8.4 Storage

All data and information collected must be stored on the appropriate data management system. For information regarding the storage and format of data use the following contacts:

- Automated water quality data, field notes, and calibration information, Water Quality Data Management System (WQDMS) - contact Water Inventory Section, Resources Inventory Branch (250) 387-9483;
- Discrete water quality data, EMS - contact the regional EMS coordinator;
- Storage of flow data, contact the Water Inventory Section, Resources Inventory Branch (250) 387-9474; and
- Station program configuration - maintain hard copy and electronic copy with site contact.

Responsibility matrix, station maintenance schedule, verification sampling schedule, field forms and notes, completed station logs - maintain hard copy with site contact.

# 9. Field Preparation, Observations and Notes

## 9.1 Preparing to go to the Field

### 9.1.1 Field Log Book

Good sampling practices always involve the use of detailed field notes. Specific information about seemingly unimportant facts such as the time of day or weather conditions are often important when interpreting data.

A field log book, with standard field forms, for each project is mandatory. All procedures, field measurements, and observations should be entered directly into this field log book. All information recorded in the log book should be entered into the database immediately upon return from the field.

In addition to documenting standard conditions and measurements, field staff are responsible for noting any unusual occurrences. Any deviations from standard protocols (such as different methods used for field verification, calibration or procedures that differ from those outlined here) must be recorded in the database. Detailed notes of all procedures and observations are required, including notes indicating that there is reason to believe that the data are valid. Sparse notes may be intended to indicate that there were no deviations from protocol or problems encountered they add little value to data when approving or subject to an audit.

The Field Log book for automated monitoring station must contain:

- Standard Field Form for Automated Monitoring Stations, several copies on waterproof paper (minimum of one copy per site to be visited, and five extra copies);
- Modification or Damage Form, minimum one copy per site to be visited;
- Equipment Catalogue, minimum of one copy per site to be visited; and
- Water proof paper, several copies for making notes (minimum of 10).

### 9.1.2 Checklist

Preparation for each sampling trip is critical since oversights are not usually noticed until staff reach the field sampling station. A checklist designed to meet the requirements of each project is an essential tool for the water purveyor or group intending to collect data and provide maintenance to monitoring equipment. This will prevent wasted time due to simple oversights.

In addition to specifying site-specific instructions, the checklist should identify the following:

- type and number of (labeled) sample bottles, including extras;
- field equipment such as meters (with adequate equipment for small repairs), sampling tools, and sample bottles;
- equipment requirements (i.e., checked and calibrated, properly loaded to avoid damage during transport, batteries charged, probes not damaged or dried, etc.);
- appropriate quantity of ice packs and coolers;
- Field Log book and reporting forms (Appendix 2);

- laboratory requisition forms (partially filled out);
- personal gear (for all possible weather conditions, such as raincoats, protective footwear, etc.);
- first aid kit, and
- camera or video equipment as required.

It is suggested that a general operating procedure would be to have the essential equipment in a box or plastic “tote” which is dedicated to field visits (see Appendix 3, for a sample general field checklist).

# Literature Cited

AES Guidelines for Co-operative Climatological Autostations, Version 2. 1992. Climate Information Branch, Canadian Climate Centre, Atmospheric Environment Service.

Binkley, D., and T.C. Brown. 1993. Management Impacts on Water Quality of Forests and Rangelands. USDA For. Serv., Gen. Tech. Rep. RM-239. Nov. 1993. pp. 729-740.

Cavanagh, N., L.W. Pommen, L.G. Swain and R.N. Nordin. 1997a. Guidelines for Designing and Implementing a Water Quality Monitoring Program. Water Quality Br., Min. Environ., Lands and Parks, Victoria, BC.

Cavanagh, N., L.W. Pommen, L.G. Swain and R.N. Nordin. 1997b. Guidelines for Interpreting Water Quality Data. Water Quality Br., Min. Environ., Lands and Parks, Victoria, BC.

Cavanagh, N., R.N. Nordin, L.G. Swain and L.W. Pommen. 1994. Ambient Fresh Water and Effluent Sampling Manual (Field Test Edition). Water Quality Br., Environmental Protection, BC Environment, Victoria, BC.

Church, M. 1992. Channel Morphology and Typology. *In* G.E. Petts and P. Calow (eds). The Rivers Handbook: hydrological and ecological principles: Vol. 1.

D & A Instrument Company. 1991. Instruction Manual: OBS-1 and 3 Suspended Solids and Turbidity Monitor. Port Townsend, WA.

Environmental Management Act, Environmental Data Quality Assurance Regulation. BC Reg. 301/90, M188/90.

Fisher, N. (ed). 1992. The Monitor's Handbook. LaMotte Company, Chesterton MD., USA.

Golterman, H., R. Clymo and M. Ohnstad. 1978. Methods for physical and chemical analysis of freshwaters. Blackwell Scientific Press, Oxford.

Grant, G.E., F.J. Swanson and M.G. Wolman. 1990. Pattern and origin of stepped-bed morphology in high-gradient streams, Western Cascades, OR. Geol. Soc. Am. Bull., Vol.102:340-352.

Hornbeck, J.W., E. Corbett, P. Duffy and J. Lynch. 1984. Forest hydrology and watershed management. Wenger, K., ed. Forestry Handb. Wiley and Sons, NY.

Jordan, P. 1996. Turbidity and suspended sediment measurements using OBS Meters, West Arm Demonstration Forest sediment budget survey. BC Min. For., Nelson Forest Region. pp. 15.

MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams on the Pacific Northwest and Alaska. US EPA. pp. 24-25.

Resource Inventory Committee. 1998. Standard Methods for Hydrometric Surveys. Water Inventory Br., Min. Environ., Lands, and Parks, Victoria, BC.

Singleton, H.J. 1985. Water Quality Criteria for Particulate Matter. Executive summary 7 p. Technical Appendix 82 pp.

Stallard, S.S., and K., Clare. 1998 *Draft.* Data Approval Guidelines for Automated Water Quality Monitoring. Min. Environ., Lands, and Parks, Victoria, BC.

Teti, P. 1996. An Experimental Turbidity Probe Installation. Proceedings from the Second Automated Water Quality Monitoring Workshop. Richmond BC, February 12-13, 1996.

White, E.T. 1997. Guidelines for Automated Water Quality Monitoring Equipment. Min. Environ., Lands, and Parks, Victoria, BC.

# Appendix 1A. Turbidity

Turbidity refers to the relative clarity of water. It is a measure of the absorption and scattering of light in water by suspended matter (e.g., clay, silt, finely-divided organic and inorganic matter, soluble coloured organic compounds, plankton and other microscopic organisms). Turbidity is reported in terms of the amount of light scattered (Nephelometric Turbidity Units, NTU; or Formazin Turbidity Units, FTU). Suspended sediments or solids or non-filterable residue are the suspended particles that scatter light, and their quantity is measured as the weight of particles retained on a filter paper after the water has been filtered (milligrams of sediment per litre of water), (Binkley and Brown 1993).

Turbidity can be used as a surrogate for suspended sediment. The rapid response of turbidity to changes in sediment levels indicate it is sensitive to land-use activities such as forestry (Binkley and Brown 1993, MacDonald *et al*. 1991). Sediments introduced to a stream will be detected immediately in the turbidity values; however, there is not a direct relationship between the two variables. The relationship varies with particle size, climate, time, and discharge as the variability in streamflow directly affects the concentrations of materials in a stream (MacDonald *et al*. 1991).

Fish have a fairly high tolerance level for turbidity for short periods. Long term, high turbidity levels can effect visibility for sight-feeding fish and reduce algae photosynthesis. High sediment loads have the potential to induce anaerobic conditions which are unsuitable for spawning and prevent alevins from emerging from the gravel. In addition, sediment transport aids in the removal of nutrients such as phosphorous from the stream (Singleton 1985, Binkley and Brown 1993).

## Standards (Turbidity probe)

A variety of probes may deliver effective results under specific program application. Until experimental results determine one turbidimeter to have the greatest capabilities in automated monitoring applications, different options exist. The following are the specifications which provide general guidance for equipment standards (see Table 8). Instruments that meet the specifications outlined in this document and site-specific criteria may be suitable.

**Table 8. Specifications for turbidity probes.**

| Characteristic | Requirement |
|---|---|
| Parameter Name and Units | • turbidity (NTU or FTU) |
| Conforms to EPA/ISO Standard[1] | • ISO-7027 (IR light source) |
| Dynamic Range | • minimum: 0.2 - 200 NTU linear response |
| Resolution[2] | • 0.1 NTU |
| Accuracy | • +/- 2 NTU at turbidities < 5, 2.0% full scale |
| Temperature Compensation | • drift $\leq$ 0.05%/°C<br>• Settling time to 25 °C change in water temp $\leq$ 15 s |
| Power Requirements[3] | • + 7 - 15V/14 mA, or<br>• 9-12V/27-74 mA for 4-20 mA current loop |
| Output format[4] | • 0-5 V, or SDI-12, preferred<br>• 4-20 mA current loop acceptable |
| Calibration | • minimum two point calibration with turbidity standard (Fromazin) or source sediments<br>• calibration to be stable for a period no less than 90 days |
| Operating Depth | • $\geq$ 100 m |
| **Desirable Features** | • automated self cleaning of optical surfaces<br>• small sample volume, to allow use in shallow streams<br>• minimum required operational depth: $\leq$10 cm<br>• minimum supplied cable length 8 m (25 feet) |

## Potential Sources of Error

Several environmental and electronic factors may introduce error into turbidity measurement. Understanding these sources is important for siting instruments, maintenance, and data interpretation. Recommendations to prevent their influence on the turbidity signal are provided.

### Biofouling

Biogrowth on turbidimeters is one of the most significant problems. After a turbidimeter is deployed or cleaned, accumulation of periphyton on the optical surface causes readings to increase, gradually at first and then rapidly, demonstrating almost an exponential increase in readings. This has been referred to as the ramping effect (Figure 8).

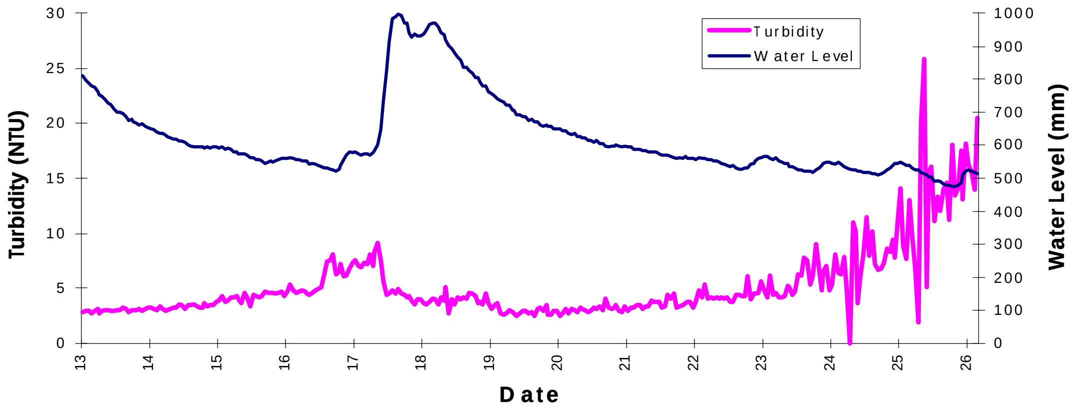


**Figure 8. Water level and turbidity data from Gray Creek, June 13-26, 1995. The ramping effect (June 23 and following) due to biogrowth on the turbidimeter's optical window is evident.**

Frequent cleaning of the optical surfaces is required to minimize error introduced by biofouling. An initial cleaning schedule of once a week is recommended and should be amended with experience. The rate of periphyton growth may force a more frequent schedule. Positioning of the instrument out of direct sunlight will reduce potential rates of growth. Application of anti-foulant to the optical surfaces is not recommended. Sensors with devices to wipe the optical surface should be considered where high periphyton growth is a concern.

## Physical Fouling

Obstruction by debris such as sediments, animals (e.g., amphipods), leaves or branches, can incur significantly high readings. This occurs frequently under high flow conditions (Jordan 1996). Bedload movement may cover instruments (Figure 9), debris may catch on the instrument, invertebrates may position themselves over the optics, and fish may position themselves in front of the instrument. Bedload obstruction can be minimized by proper siting, regular site visits, and clearing the area around the instrument as required. Minimizing the influence of animals can only be done by recognizing patterns in the sensor outputs and field observations. The influence of debris such as leaves and sticks may be minimized by regular site visits, however outliers in the data may also be the result of a piece of debris covering the optics for a short period of time.

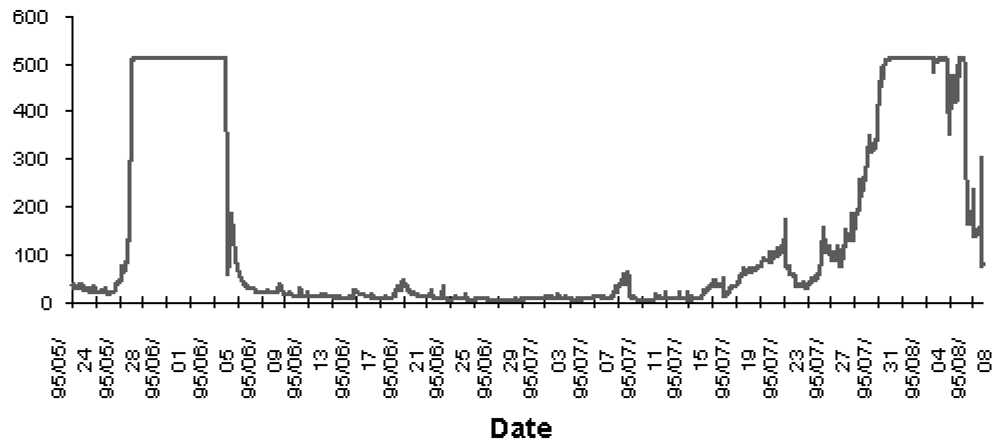


**Figure 9. Chase Creek turbidity data (1995), origin of large turbidity peaks May 28 to June 7 and July 29 to August 8 may be a result of bedload interference with turbidity probe.**

## Noise in Sensor Outputs

There are sources of “noise” that affect turbidity sensor measurements . These include bubbles, direct exposure to sunlight, surface reflections, hydrodynamic noise, and electrical interference. As turbidity meters are optical instruments, sediment scouring on the optical surfaces of the instrument, creating irregularities that may interfere with readings, must also be explored.

### Bubbles

Bubbles in the water column will reflect light emitted from the turbidity probe and may result in increased sensor outputs. Errors due to bubbles can occur at velocities of one meter per second or more (Teti 1996), near obstructions to flow (e.g., rocks, bridge abutments, and large woody debris), or below riffles or plunges. Action to minimize the influence of bubbles on turbidity readings include increasing the depth of the sensor, as bubbles are more abundant near the water surface, and positioning instruments away from obstructions to flow that may cause bubbles.

### Direct sunlight

Direct sunlight on the photoreceptors of the instrument will cause increased sensor outputs; this has been termed a sunlight spike (Figure 10). Actions to reduce the impact of sunlight include positioning instruments out of direct exposure to sunlight and observing recommended minimum sensor depths.

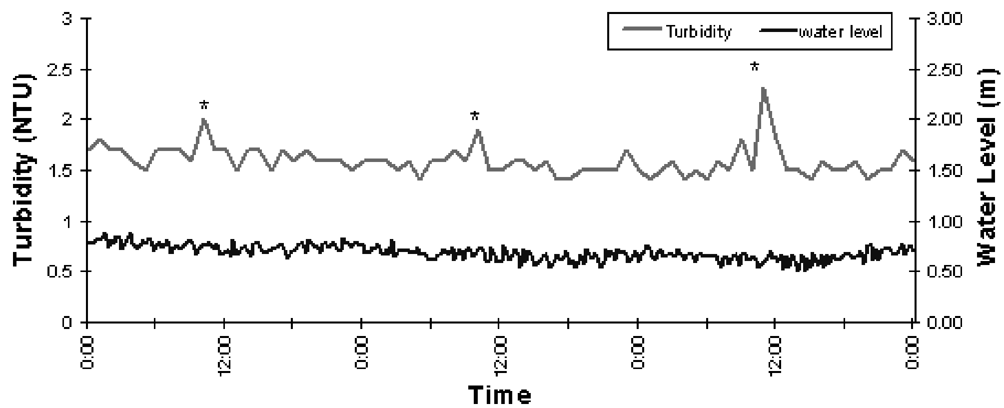


**Figure 10. Suspected sunshine effects on turbidity data at Gray Creek, May 17-19, 1995. An "*" indicates an event believed to be generated by incident sunlight.**

### Surface Reflections

Light emitted from turbidity instruments will reflect off of the bottom of the surface of the water, which may result in an increased output from the sensor. Observation of minimum sensor depth should reduce the influence of reflections from the water surface (Figure 11).

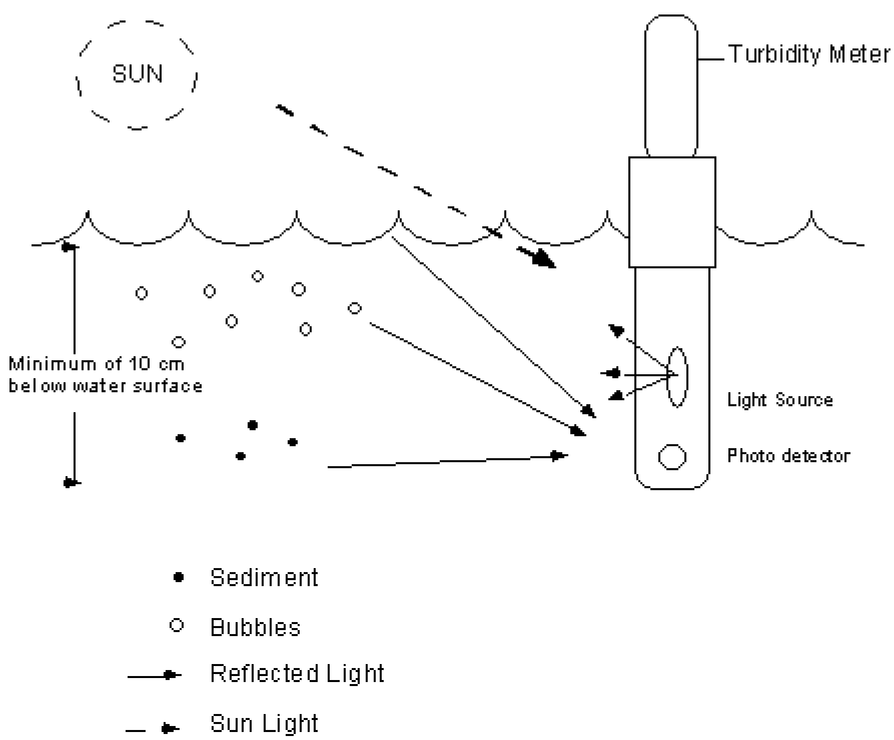


**Figure 11. Sources of noise in the turbidity signal from bubbles, water surface reflections and sunlight.**

### Hydrodynamic noise

Results from turbulent flows redistributing sediment particles around the sensor, which causes a sediment concentration above actual levels. Because the volume sampled by the sensors depends on how far the light beam penetrates into the water, increased and fluctuating sediment concentrations cause the sample volume to constantly change (D & A Instrument Co. 1991) and this can lead to sampling errors. This is noticeable in the data by a large degree of variation in the data. To compensate for this effect, the turbidity signal be may be reported as an average, with an estimate of variation included.

### Electrical interference

Magnetic fields from nearby electrical sources can create erratic fluctuations in the readings.

## Calibration Drift

Calibration drift of turbidity probes can vary significantly with each instrument. Figure 12 illustrates the effect of calibration drift on turbidity data. The signal wanders randomly with no substantiating change in the stream water level (e.g., ± 40 NTU wandering on descending limb of the hydrograph). To prevent calibration drift a 90-day duty cycle is recommended. This is a preliminary duty cycle and should be modified on the basis of experience and recommendations from the manufacturer.

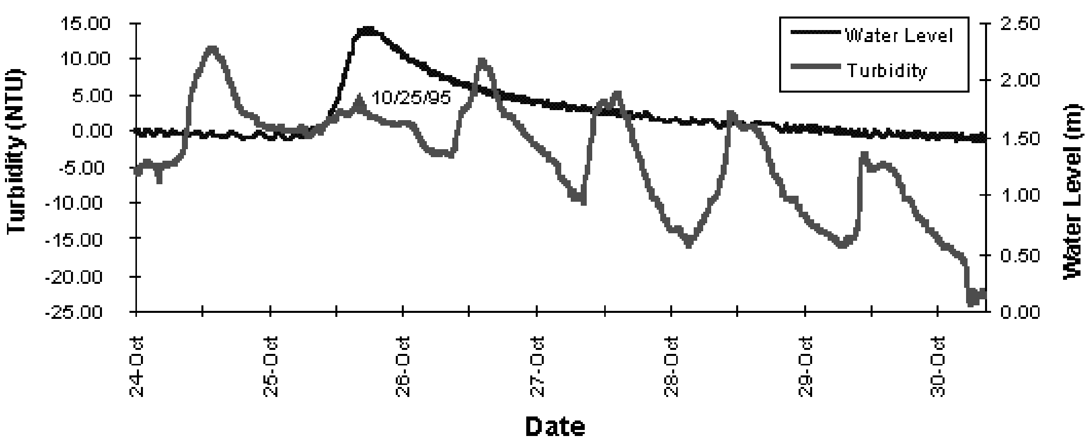


**Figure 12. Example of turbidity data showing drift. The point labeled 10/25/95 is a field verification sample.**

## Power-up Transients

Significant errors can be encountered in the first 1 - 10 seconds after power-up. The internal temperature of the turbidity meter needs to stabilize, and the temperature transducer has to track and compensate for heat from the emitter after power up. It is recommended to delay 10 seconds after power-up prior to making a measurement (D & A Instruments 1991). Data logger programming will tend to minimize the influence of power up transients on output signals.

## Water temperature change

Rapid changes in water temperature can affect turbidity readings. It takes approximately 15 - 30 seconds for the OBS3 turbidity probe readings to stabilize to temperature changes. When water temperatures change by more than 6°C/hour the turbidity readings are considered unreliable (D & A Instruments 1991).

Table 9 summarizes potential sources of error when automatically monitoring turbidity. Recommended actions to remedy the problems are also provided.

**Table 9. Summary of problems encountered with turbidity measurements and recommended actions.**

| Potential Sources of Error | Problem | Recommended Action |
|---|---|---|
| **Biofouling** | • periphyton on the optical surface of the sensor increasing the turbidity readings | • place out of direct sunlight<br>• regular maintenance and cleaning of the sensors<br>• use sensor with automatic self-cleaning mechanism |
| **Physical Fouling** | • floating/in-stream debris<br>• bedload<br>• animals or other obstructions | • careful site selection<br>• regular site visits to check for and remove obstructions |
| **Noise**<br>• **bubbles** | • increased sensor outputs as a result of bubbles in the water column reflecting light emitted from the turbidity probe | • increase operating depth, as bubbles are more abundant near the water surface<br>• position instruments away from obstructions to flow that may cause bubbles |
| • **hydrodynamic** | • turbulent flows redistributing sediment particles around the sensor causing variation of sediment concentration above actual levels<br>• potential errors in sensor readings due to fluctuating sediment level | • regular validation sampling to ensure actual sediment levels are being recorded |
| • **direct sunlight/ reflectance** | • direct light on photoreceptors of instrument increasing the turbidity readings | • positioning instruments out of direct exposure to sunlight<br>• observing recommended minimum sensor depths |
| • **electronic interference** | • electrical interference by local magnetic fields; can create erratic fluctuations in readings | • proper assessment of site before deployment (e.g., locate station away from overhead or buried powerlines) |
| **Calibration Drift** | • instruments drift over time<br>• signal wanders randomly with no substantiating change in the stream | • use a 90-day duty cycle to recalibrate instruments |

| Potential Sources of Error | Problem | Recommended Action |
|---|---|---|
| **Power-up Transients** | • internal temperature of the turbidity meter increases with start-up<br>• sensor errors occur until temperature transducer compensates for heat from the emitter after a power up | • delay 10 seconds after power-up before making a measurement |
| **Water Temperature Changes** | • rapid changes in water temperature affect turbidity readings | • if the change in temperature is greater than or equal to 6°C/hour, disregard readings |

# Appendix 1B. Conductivity

Conductivity of water refers to its ability to conduct an electric current. It is a function of the water temperature and the total number of dissolved ions in a water sample (MacDonald *et al*. 1991). The measured units are µS/cm (microSiemens per centimetre). Conductivity is generally reported as specific conductance, which is conductivity corrected to 25°C (Standard Methods 1992) An empirical relationship between total dissolved solids (filterable residue) and conductivity can be derived for a stream on a site-specific basis. Total dissolved solids (mg/L) is usually equal to 0.55 to 0.9 times conductivity (µS/cm), with 0.67 being typical (Fisher 1992).

Conductivity is an important indicator of the chemical and physical conditions of the water. An inverse relationship exists between conductivity and the variables flow, precipitation, and turbidity. Water that is slowly transmitted to the stream (baseflow or groundwater flow) has more opportunities to pick up dissolved ions through weathering and other chemical reactions. Water that is quickly transformed from precipitation to runoff (surface run-off) tends to have fewer dissolved ions, thus causing a corresponding decline in conductivity at high discharges. Therefore a measure of streamflow or discharge is required for the interpretation of conductivity measurements (MacDonald *et al*. 1991).

## Standards (Conductivity Probe)

The following are considerations for selecting conductivity probes. It is important that the conductivity probe:

- has a suitable range of water temperature (e.g., 0-30°C) and an accuracy of ± 1 µS/cm;
- has internal or external automatic temperature compensation for electrodes (conductivity measurements are temperature dependent - it is essential to temperature compensate conductivity measurements to 25° C and report as specific conductance);
- interfaces readily with the data logger (outputs of 0-5 V, 4-20 mA, or SDI-12);
- has considerable longevity (approximately 2-5 yr.);
- has a protective enclosure for the probe; and
- is calibrated according to known standards.

# Appendix 1C. Water Temperature

Water temperature is sensitive to modifications of the riparian zone and channel morphology. Increased sunlight from a cleared riparian zone and/or a shift in channel morphology to a wider and shallower channel can significantly affect the temperature regime of a stream, dissolved oxygen content and consequently drinking water aesthetics (palatability) and aquatic life (Golterman *et al*. 1978, Hornbeck *et al*. 1984).

## Standards (Thermistor)

Measurement of water temperature is made with a thermistor. The selection of an appropriate thermistor is dictated by the type of data logger used and the data quality objectives. For automatic monitoring programs the following requirements must be satisfied:

- Units: degrees Celsius (°C)
- Accuracy: ±1.0°C
- Range: -5°C to 30°C

# Appendix 2. Standard Field and Reporting Forms

- Automated Monitoring Station Form
- Modification or Damage Form
- Equipment Catalogue
- Station Log

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## Automated Monitoring Station Form

| | | |
|---|---|---|
| | **Date** (YYYY/MM/DD) | |
| **Monitoring Location** | | |
| **EMS Id** | | |
| **Data Source Name** | | |
| **Recorder's Name** | | |
| **Time** (Arrive/Leave) | | |
| **Weather/Stream Stage** | | |

| **Prior to cleaning or handling instruments** | **Prior to departure** |
|---|---|
| Force scan instruments, record readings | Power sources are connected |
| Download source data | Probes are secure and sensors are submerged in water |
| | Force scan instruments, record readings |
| | Instruments and program are on-line |
| | Station locked |

| | |
|---|---|
| **Power Source Reading V** | **(Check with voltmeter prior to accessing data logger)** |

| | |
|---|---|
| **Data Logger Clock Time Checked: Y / N** | **Adjustment Required Y / N (If Yes note below)** |

**NOTES (Maintenance activities performed, field calibrations performed, other)**

**If site set-up is modified or damage to the station is noted complete use Modification or Damage Form.**

| | | | |
|---|---|---|---|
| **Source Data Downloaded** | **Y / N** | **Samples Taken** | **Y / N** |
| **Download File Name: _________________** | | **Lab Requisition # : _________** | |
| **Data entered into WQDMS** | **Y / N** | | |
| **Date entered: _________________________** | | | |

**Page 1 of 2**

| Parameter | Sensor Reading | | Instrument Performance [†] | | Field Cal. [‡] | Water Column Verification | Comments[*] |
|---|---|---|---|---|---|---|---|
| | **Arrival** | **Departure** | **Reading** | **Standard** | | | |
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[†] Record when testing instrument against a standard. Note standard used and instrument reading. If not tested enter N/A.
[‡] Independent sample of water column. Note reading and type of instrument used.
[*] Note method of field calibration, including standards used.

**Page 2 of 2**

## Modification or Damage Form

| | | |
|---|---|---|
| | | **Date** (YYYY/MM/DD) |
| **Monitoring Location** | | |
| **EMS Id** | | |
| **Data Source Name** | | |
| **Recorder's Name** | | |
| **Time** (Arrive/Leave) | | |
| **Weather/Stream Stage** | | |

**DAMAGES**

**HOUSING OR DEPLOYMENT STRUCTURES Y / N EQUIPMENT Y / N ______**

Description of damage (leaks, obstructions, any type of damages incurred due to vandalism or natural forces, etc.):

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______

Picture(s) or drawing(s) of damage to station and/or equipment (use backside of form if more space required)

**Page 1 of 2**

**MODIFICATIONS**

Describe repairs/modifications made to housing or deployment structures:

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______

Describe repairs/modifications to monitoring equipment: (e.g., instrument exchange for re-calibration)

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______

Repairs/Modifications completed by:

______________________________________________________________________

______________________________________________________________________

Contact Number(s) to alert if equipment is damaged or in need of repair

( ____ ) ___________ - ___________ ( ____ ) ____________ - ____________

( ____ ) ___________ - ___________ ( ____ ) ____________ - ____________

**Page 2 of 2**

## Equipment Catalogue

| | | |
|---|---|---|
| | | **Date** (YYYY/MM/DD) |
| **Monitoring Location** | | |
| **EMS Id** | | |
| **Data Source Name** | | |
| **Recorder's Name** | | |
| **Time** (Arrive/Leave) | | |
| **Weather/Stream Stage** | | |

**Data Source:**

| | |
|---|---|
| **Make/model** | |
| **Serial number** | |
| **Telemetry Mode** | |
| **Phone Number** | |
| **Baud Rate** | |
| **Parity** | |
| **Data Bits** | |
| **Stop Bits** | |

**Battery:**

Critical Battery Voltage: ________________________
(If voltage is allowed to go below this level damage may occur or data may be lost)

**Data Entered into WQDMS _____ Date: ___________** **Page __ of __**

**Sensors:**

**Date** (YYYY/MM/DD)

| | | | | |
|---|---|---|---|---|
| **Sensor Type** | | | | |
| **Channel No.** | | | | |
| **Sensor Class** | | | | |
| **Serial No.** | | | | |
| **Start Date** | | | | |
| **Sampling Interval** | | | | |
| **Calibration Interval** | | | | |
| **Media Type** | | | | |
| **Preservation** | | | | |
| **Parameters Monitored** | | | | |
| **Parameter Abbreviation** | | | | |
| **End Date** | | | | |

**Data Entered into WQDMS _____ Date: ___________**

**Page __ of __**

## Station Log

**Date** (YYYY/MM/DD)

| Date/Time | Recorder | Weather Conditions | Stream Condition | Instrument Readings | Notes (maintenance performed) |
|---|---|---|---|---|---|
| | | | | | |
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**Page __ of __**

# Appendix 3. General Checklist for Field Visits

**General**

| | | | |
|---|---|---|---|
| Log Book | ___ | Waterproof Markers | ___ |
| Cooler(with ice packs) | ___ | Tape | ___ |
| Deionized Water | ___ | Requisition Forms | ___ |
| Zip Lock Bags | ___ | Shipping Labels | ___ |
| Squirt Bottle | ___ | Pencils | ___ |
| Rope | ___ | | |

**Labeled Sample Bottles**

| | | | |
|---|---|---|---|
| Turbidity/Conductivity | ___ | Replicate | ___ |
| Fecal Coliforms | ___ | Blank | ___ |

**Field Measurements (Equipment)**

| | | | |
|---|---|---|---|
| Conductivity Meter | ___ | Thermometer | ___ |
| Turbidimeter | ___ | Thermistor | ___ |
| Spare Battery/or Charger | ___ | | ___ |

**Personal Gear**

| | | | |
|---|---|---|---|
| Rain Gear | ___ | Waders (hip or chest) | ___ |
| Gum Boots | ___ | Lunch | ___ |

**Safety**

| | |
|---|---|
| First Aid Kit | ___ |
| Personal Flotation Device | ___ |
| Safety Harness | ___ |

# Appendix 4. Side Stream Sampling Device

## Detail of Gravity Feed Side Stream Sampler Design

The following descriptions detail the design elements of the side stream sampler. Figures 13-17 illustrate the sampling system.

### Intake

- a 1 inch PVC elbow. Feed pipe is coupled with this connector

### Debubbler unit

- designed to remove bubbles that are present in the incoming water
- 10 cm long 1 inch PVC pipe inserted directly into the water intake elbow pipe (the length of this section can be varied based in rate of inflow and number of bubbles encountered)
- 2 inch PVC pipe approximately 55 cm long with holes in the bottom to allow water to enter the main reservoir is surrounding the 1 inch PVC
- the 2 inch PVC pipe is held in place by a fitting that is welded to the plastic base of the unit

### Main reservoir

- consists of 8 inch PVC pipe 40 cm in height
- a plastic bottom plate attached to the 8 inch PVC (the inflow elbow is inserted through this plate)
- a plastic plate is inserted vertically into the reservoir blocking dead space behind the deployment tube and debubbler, this is referred to as the baffle. The void space behind the plate is filled with an expanding foam. Note the position of this plate will effect the total volume of the unit, typical configuration reduces one litre of void space.
- a 40 cm long 4 inch PVC pipe, of which the bottom 10 cm has three large notches cut out, one is a large notch oriented towards the middle of the unit. This provides a view window for the sensors. A notch is cut into the top of the tube to provide water flow this notch is approximately 3cm wide and extends a minimum of 1 cm below the level of the top drain. The tube is attached to the plastic bottom plate and fastened to the main reservoir by a nylon bolt.

### Deployment unit

- designed to hold the probes and it is inserted into the 4 inch PVC pipe. The holder may be constructed of aluminium or PVC.
- aluminium holder made of three half pipes, to hold the sensors
- aluminium top and base (attached to the half pipes), to anchor the sensors, (the top and bottom both contain 3 holes to allow the sensors to pass through and the aluminium bottom has high density foam beneath it in which the probes can be embedded)

- a hose clamp attaching the sensors to the half pipes in order to assure that the sensors have a snug fit
- a 45 cm metal rod that has been inserted into the top to allow easy insertion and removal of the deployment unit
- a notch in the base (correlates with a vinyl bolt on the side of the PVC pipe) to hold the deployment system in place within the 4 inch PVC pipe

## Drains

- a top drain (to ensure overflowing does not occur) consisting of a 2 inch elbow pipe attached to a fitting, (the fitting is welded to the edge of a opening in the outer body approximately 1 inch from the unit's top (at a height of 30 cm))
- a bottom drain consisting of a ¾ inch elbow pipe 3 inches long inserted through the plastic bottom plate

## Unit Supports

- three 1 inch PVC couplers with 1 inch PVC pipe legs approximately 2 inches long

## Pressure Reduction System

This system is designed to reduce pressure when large head or flow rates are encountered. The system breaks the flow into two streams, one to the sample chamber and the other as overflow, with an air vent.

- 6 elbows same size as inflow line
- 2 tees same size as inflow line
- 6 lengths of pipe same size as inflow line

The pipe and fittings are arranged as in Figure 17. The system is operated vertically. The length of pipe sections used will vary depending on incoming flow rate.

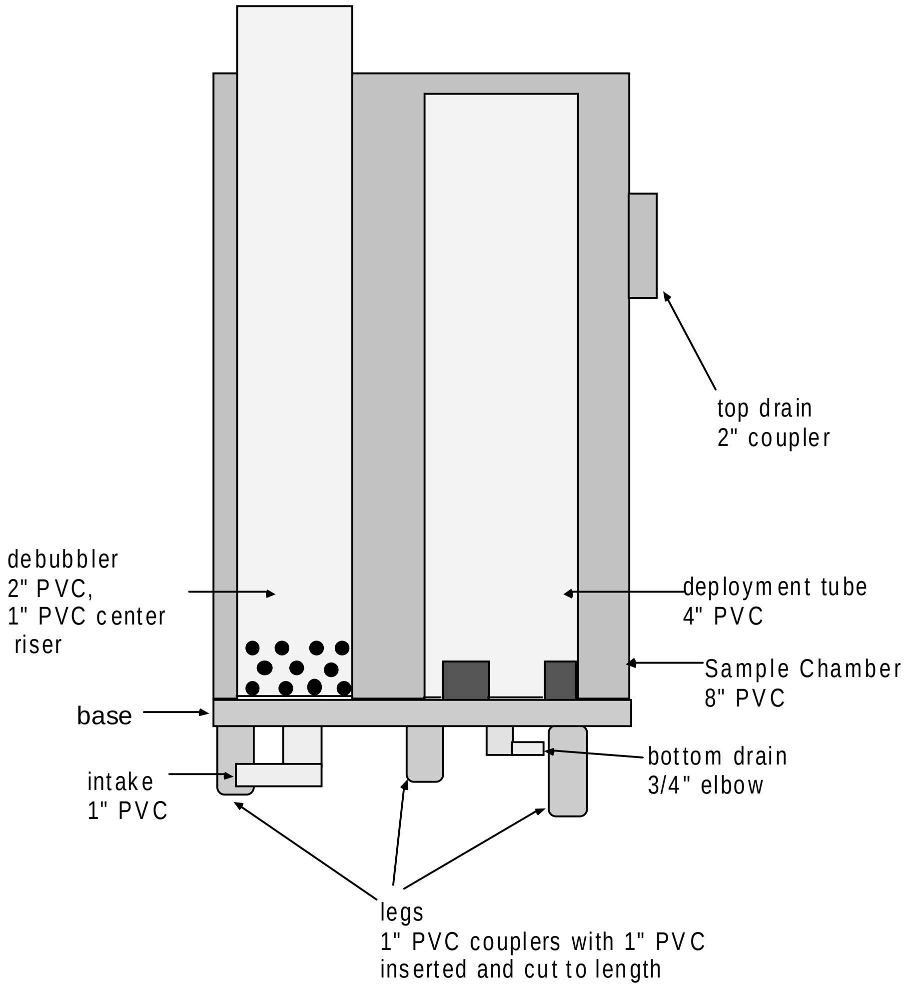


**Figure 13. Side cut away view of side stream sampling chamber.**

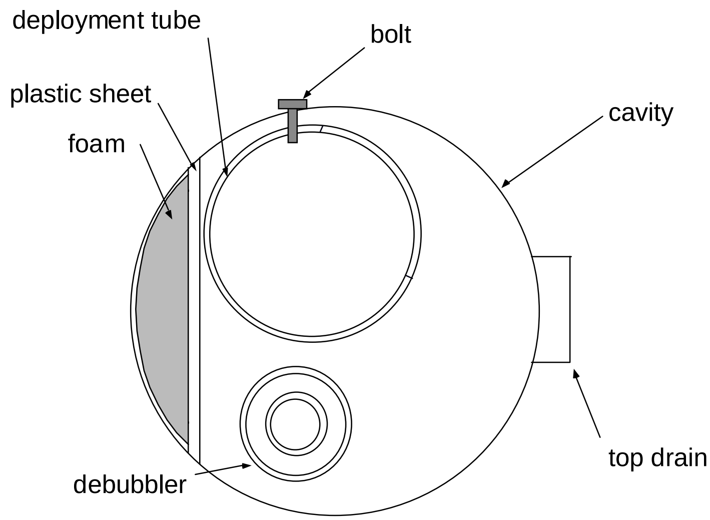


**Figure 14. Plan view of side stream sampling device.**

**Figure 15. Side stream sampling device being tested.**

**Figure 16. Top view of side stream sampling device. Note the location of the baffle and bottom drain in relation to the debubbler and instrument deployment tube.**

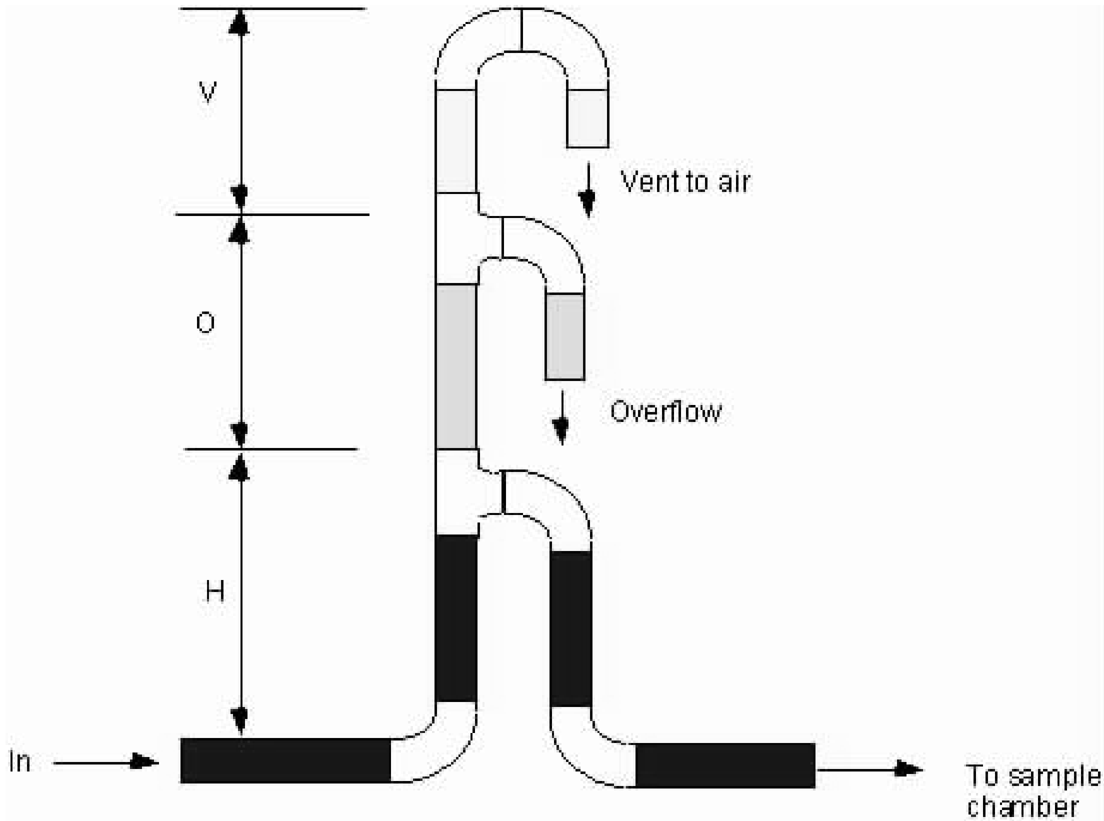


**Figure 17. Pressure reduction system. Heights H,O, and V need to be varied depending on required pressure reduction.**