YUKON PLACER SECRETARIAT

YUKON PLACER MINING INDUSTRY

WATER QUALITY OBJECTIVES

MONITORING PROTOCOL

Created by:
The Yukon Placer
Water Quality Working Group

January 16, 2007
Revised January 11, 2016

Table of Contents

1.0 YUKON PLACER MINING WATER QUALITY OBJECTIVES MONITORING PROTOCOL

1.1 INTRODUCTION AND OBJECTIVES

An integrated regulatory regime for the environmental management of the Yukon placer mining industry has been established by the Yukon Placer Secretariat. Founded on principles of adaptive management and the incorporation of a risk-based approach to regulation, this regime is intended to balance the objectives of a sustainable Yukon placer mining industry with the conservation and protection of fish and fish habitat supporting fisheries.

As part of the regulatory regime, a series of three protocols have been designed: a) Aquatic Health Monitoring; b) Water Quality Objectives (WQO) Monitoring; and c) Economic Health Monitoring. The monitoring protocols facilitate the verification of regime effectiveness and provide a basis for future modifications to the regime. The primary objectives of the WQO Monitoring Protocol are as follows:

To provide ongoing information on the water quality in the various watersheds;
To provide the data required to determine whether the WQO set within the regime are being achieved.[1]
To describe how WQO will be monitored; and
To ensure water quality information supports the adaptive management process.

WQO and a new water quality model were developed as management tools to support the sediment discharge standards for Yukon placer mining. While the WQO are not legally enforceable, they are one of several considerations, (including sediment loading and bed load) taken into account when establishing sediment discharge standards.

The WQO were developed specifically for Yukon placer mining with reference to the European Freshwater Fish Water Quality Criteria and the Canadian Council of Ministers of the Environment Water Quality Guidelines. The WQO are set for all habitat types, regardless of fish species present.

The WQO are risk-based in that the degree of protection or level of acceptable risk varies with habitat sensitivity. WQO in highly sensitive habitats are set to eliminate risk entirely (i.e. no sediment discharges from placer mines), while those in habitats of lower sensitivity will balance the protection of fish and fish habitat with the viability of a sustainable placer mining industry. The WQO have been developed

[1] A Water Quality Objective (WQO) is a measure of the concentration of sediment in fish-bearing waters that is established and monitored in order to prevent unacceptable risk to fish habitats of varying sensitivity (sediment concentrations will be measured as total suspended solids). The location of WQO monitoring sites will vary depending upon the sensitivity of the fish habitat receiving protection.

primarily for juvenile Chinook salmon because this species has the most specific and demanding requirements for suitable habitat. Given that other fish species will thrive in habitat suitable for Chinook salmon, protecting salmon habitat also protects other fish habitat. WQO have also been developed for habitats that are far less likely to support Chinook salmon, but where other species are known to thrive.

Preliminary surveys of water quality were conducted, beginning in 2004. By 2007, these surveys employed the methods described in the original Protocol of January 2007. The preliminary surveys provide an opportunity for monitoring staff to gain hands-on experience and to confirm whether components of the program can be implemented as planned. They also provide an opportunity to assess the sampling network and provide indications of whether more (or possibly fewer) samples are needed in order to gain knowledge of the water quality at various points throughout the watershed.

During the preliminary survey seasons it was important to test assumptions about the mixing of sediment in streams and rivers at selected sampling sites and at specific times during the season in order to determine the degree of dilution and sediment loading that was occurring over time. It was appropriate therefore, to consider variations in water quality through the width and depth of a river or stream at selected sampling sites throughout an annual cycle in order to confirm the number of samples required to produce representative data.

Preliminary surveys also helped to refine the logistical aspects of monitoring. For example, access to sampling stations was tested and helped to determine if refinements were necessary to specific site selections. Some sampling sites were also found to be impractical for a variety of reasons, such as transport difficulties. Similarly, operational approaches were tested during the pilot projects and aspects such as the means of transport, on-site testing techniques or sample preservation and transport methods, were evaluated. Sample volume requirements and preservation methods could also then be refined.

The results of monitoring water quality at specific locations in each watershed together with the results of aquatic health monitoring, will feed into an adaptive management process to evaluate the effectiveness of end-of-pipe sediment discharge standards and WQO in protecting fish and their habitat. Adaptive management has been defined as the process whereby management is initiated and then incrementally evaluated and refined.[2] Unlike traditional management, an adaptive approach recognizes uncertainty and the constraints of knowledge. It provides a process that utilizes new information gathered from monitoring and research to modify management practices. In particular, high-quality monitoring data from both successes and failures should lead to improved decision-making.

Careful annual monitoring forms the basis of any recommendations for change. At least three to five years of monitoring the regime’s performance is required before considering adjustments. In the interim, changes may be considered in response to

[2] Kershner (1997), “Monitoring and Adaptive Management.”

unforeseen circumstances of an exceptional nature. The Yukon Placer Secretariat's Implementation Management Group (IMG) is responsible for evaluating the monitoring results on an annual basis. A final annual monitoring report is completed and provided to the IMG each year. This monitoring report is used in the evaluation and adjustment phases of the adaptive management process and is part of the Secretariat's annual report. Before any change is made, the implications for existing licensed placer operations must be carefully examined. Modifications to the regulatory regime must to be implemented in a manner that is fair and understandable to industry.

1.2 KEY QUESTIONS TO BE ADDRESSED

The strategy for the sampling design, data collection and data analysis methodology outlined within this Protocol focuses on these two key questions:

1) Are the WQO established in the new regime being achieved?

2) If not, is this due to placer mining activity or to other causes?

1.3 SAMPLING DESIGN

It is beyond the scope of any monitoring program to sample for every condition that can be found in a lake or in a stream. This outline discusses lake and stream conditions that make good candidates for monitoring as well as the methods and procedures that should be implemented in order to obtain samples that are representative of these conditions. WQO will be monitored by research staff from various federal and territorial agencies but primarily by the water quality research staff, Yukon Department of Energy, Mines and Resources (EMR), Compliance Monitoring & Inspections (CMI), lay stream samplers and Natural Resource Officers/Mining (Inspectors) also employed by EMR CMI, and by automated sampling equipment deployed by the staff of CMI.

Water quality can be described by a single variable or by any combination of more than 100 variables. The variables chosen in this monitoring program are based on the program objectives and on both existing and anticipated uses of the water. The simplest combination of variables is temperature, electrical conductivity, pH, settleable and total suspended solids (TSS). These give the bare minimum of information on which an assessment of overall water quality can be based. In time, more parameters may be added to the list of variables monitored, (i.e. Dissolved metals, alkalinity, Total Organic Carbon (TOC), nutrient concentrations); if it is determined that the results from these additions have merit and aid in the determination of water quality.

The field work associated with the collection and transport of samples is the most costly element of this monitoring program. Sampling expeditions are therefore planned and carried out in such a way that efforts are not wasted. The sample collection process is co-ordinated with the laboratory so that analysts know how many samples will be arriving, the approximate time of their arrival and the analyses that is to be carried out. Personnel who collect water or sediment samples are fully trained in both sampling techniques and field test procedures. They are also aware of the objectives of the monitoring program since this will have an influence on the sampling procedures. The choice of a representative sampling point and the use of appropriate sampling techniques is of fundamental importance.

Two different types of sample can be taken from rivers, lakes and similar surface waters: *grab* samples and *composite* (integrated) samples. The simplest, a grab sample, is taken at a selected location, depth and time. Normally, the quantity of water taken is sufficient for all of the physical and chemical analyses that are required. All samples obtained by field personnel are grab samples. When automated samplers are employed time-integrated composite samples are taken.

Eighteen watersheds within the Yukon Territory are managed by class authorizations under the new placer regime. Due to logistical constraints however, only some of these watersheds can be focused upon during any given year.

The watersheds chosen for sampling will be subdivided into *Major* watersheds (high frequency, multi-site, mechanized water quality sampling) and *Minor* (low frequency, single site mechanized and multi-site non-mechanized water quality sampling). Mechanized sampling refers to monitoring repeatedly at fixed sites in a watershed using automatic sampling equipment supplemented with grab sampling at various intervals throughout the season. Non-mechanized sampling refers to sampling less frequently at fixed sites in a watershed using grab sampling techniques described within this protocol.

The level of monitoring devoted to each watershed will be based on several factors, including overall habitat sensitivity, the amount of historical and current mining activity, lack of or inconclusive data from previous years monitoring activity, changes in environmental conditions in the watershed i.e. from fire, permafrost degradation and subsequent slope / site instability, and to some extent the financial constraints inherent to environmental monitoring in remote locations.

Monitoring will be focused in areas where comparative data has historically been collected and in new areas where little or no background information is available but the potential for future exploration and mining is high. Initially a snapshot or quick baseline of each watershed will be collected, generally concentrating our equipment and efforts at the mouth of the watershed and at the mouth of major tributary streams entering the watershed. Less equipment and automated monitoring will be deployed. In subsequent year, monitoring will occur in fewer watersheds but utilize the majority of our equipment and efforts, providing a greater amount of more detailed information and data (See Table 1).

Table 1

Watershed	2008	2009	2010	2011	2012	2013	2014
MAJOR Multiple Site Automated & Grab Sampling	Big Creek Indian R.	Big Creek Indian R. Klondike R. Sixty Mile R.	White River Liard River	Klondike R.	Klondike R.	Klondike R.	Big Creek Klondike R.
MINOR Automated Sampling At Mouth Of Main Stem Only	Klondike R. Mayo Lake McQuestion R. Sixty Mile R. Stewart R.	McQuestion R. Stewart R.	Klondike R.	White R.	McQuestion R. Mayo Lake	White R. Indian R.	
Grab Sampling Only	Forty Mile R. White R. Yukon R.	Mayo Lake White R. Yukon R.	Sixty Mile R. Indian R. Yukon R.	Big Creek			

Table 1: This table outlines the yearly progression of the WQO sampling

The monitoring program will concentrate on the main stem of each watershed. It may also cover the watercourse system of the watershed, (i.e. a main river and all its tributaries, streams, creeks, drainage ditches, etc., as well as any lakes or ponds that discharge into the river or tributaries) if it is deemed to be necessary in order to monitor overall watershed health and aquatic habitat.

A description of the catchment area will include its size (in km^2), its geographical location and the identification of each water body in the watercourse system. Environmental conditions in the catchment area will be described as fully as possible, because these have an effect on water quality and it may be useful to refer to this material when data are being evaluated. The natural processes that affect water quality will also be described.

Reference will be made to these processes when the description of environmental conditions is prepared. In particular, stream bank composition, vegetation (both terrestrial and aquatic), land form, climate and mining activities in the catchment area will be reported. Mining activities should be described mainly in terms of claim location, water use, and water use structures and land use. Rivers and streams should be described by their dimensions and their flows whenever possible.

Rainfall and ensuing run-off are of vital importance, especially when the program includes the monitoring of fluxes or suspended loads of eroded materials. For this reason, portable environmental monitoring stations will be deployed in conjunction with automated sampling equipment to monitor rainfall, air and water temperature (see Appendix C and D) in each of the targeted watersheds. Some data interpretation techniques also require reliable hydrological information. If there is a gauging station, operated by Water Survey of Canada or YG Water Resources near a sampling location, reliable data on river flow should be available. If not, estimates of flow can be based on data from the closest stream gauging station or by using portable flow and level gauging equipment to measure the flow at each sampling site. Maps and hydrographs for each watershed will be prepared from any available data and will be adjusted as new information is collected each year.

1.3.1 SPATIAL DISTRIBUTION OF SAMPLING

The selection of sampling sites takes into account such considerations as the habitat suitability classification, actual and potential water uses, actual and potential sources of sediment from natural sources and from human activities, sediment control operations (settling ponds), local geological conditions, and type(s) of water body.

The spatial distribution of water quality sample sites will be the same for both primary and secondary/tertiary watersheds. For each watershed, five sites along the rivers main stem will be chosen to conduct water quality sampling. One site will always be at the mouth of the main stem, and four other sites will be situated along the main stem downstream of habitat class change points (Figure 1). Class change points refer to locations where the habitat suitability classification system (based on the sensitivity of the habitat) changes from one category to another.

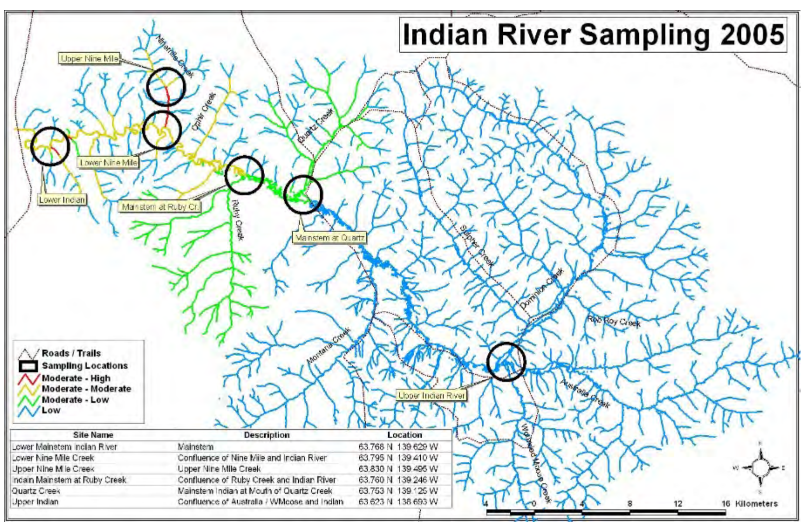


Figure 1: This figure illustrates the proposed spatial distribution of the WQO sampling locations within a watershed. The main stem river will be subdivided into reaches of varying habitat suitability (labelled here as Moderate-High, Moderate-Moderate, Moderate-Low and Low). One sample site will be located at the mouth of the main stem river, while four other sample sites will be located downstream of habitat sensitivity class change points. Additional sampling sites may be added to monitor areas of special interest, like the site shown here on upper Nine Mile.

In addition to the sites mentioned above, water quality samples will be taken at various locations within each watershed during the aquatic health monitoring program (see Aquatic Health Monitoring Protocol), the compliance monitoring program (Appendix A), and the blitz sampling program (Appendix B). The water quality sampling results of all these sampling programs will be considered together in the evaluation phase of the adaptive management process.

In a stream or river, it will be necessary to sample at different points to determine whether water quality can be estimated at a single point or whether the system behaves as a number of separate water bodies with different water quality characteristics. It also will be essential to investigate variation in water quality with depth and especially during precipitation events. Fast flowing, high volume streams and rivers are usually well-mixed and sampling from a single depth or the preparation of a composite sample from two depths may adequately represent the overall water quality.

Sampling sites on rivers and streams will, as a general rule, be established at places where the water is sufficiently well-mixed for only a single sample to be required. The lateral and vertical mixing of wastewater effluent or a tributary stream with the main river can be rather slow, particularly if the flow in the river is laminar and the waters are at different temperatures. Complete mixing of tributary and main stream waters may not take place for a considerable distance, sometimes many kilometres, downstream of the confluence. The zone of complete mixing may be estimated, but if there is any doubt the extent of mixing will be checked by measurements of temperature or some other characteristic variable like electro-conductivity, or by using other handheld instrumentation (i.e. the Partech Model 740 portable suspended solids meter) at several points across the width of the river. If there are rapids or waterfalls in the river, the mixing will be sped up and representative samples may be obtained downstream.

To verify there is complete mixing at a sampling site it will be necessary to take several samples at points across the width and depth of the river and to analyse them. If the results do not vary significantly one from the other, a station will be established at mid-stream or some other convenient point. If the results are significantly different it will be necessary to obtain a composite sample by combining samples taken at several points in the cross-section of the stream. Generally, the more points that are sampled, the more representative the composite sample will be. Sampling at three to five points is usually sufficient and fewer points are needed for narrow and shallow streams.

1.3.2 TEMPORAL DISTRIBUTION OF SAMPLES

Most water quality sampling for the WQO monitoring protocol will take place starting in May and continue until the end of September. Inspectors will routinely sample at WQO monitoring points until the extreme end of the placer mining season (late October in some years).

1.3.2.1 OVERALL APPROACH TO INSPECTIONS

Yearly inspection plans will be designed to prevent or reduce the risk of adverse environmental effects resulting from placer mining activities, and to ensure compliance with all relevant legislation, regulations, and the terms and conditions of permits and licenses. Inspectors will emphasize education and encouragement, and will promote operator-generated solutions to on-site challenges. Inspectors will be prepared to assist with recommendations, and will issue enforceable directions to perform remedial measures when necessary.

In all matters related to fish and fish habitat, inspectors will be guided by "The Protocol Concerning the Inspection and Monitoring of Yukon Placer Mining" between the Government of Yukon and Government of Canada. Water samples will be collected for the purpose of determining compliance with effluent discharge standards, and for the purpose of monitoring WQO.

1.3.2.2 WATER SAMPLING: COMPLIANCE

Samples will be collected for compliance purposes following procedures detailed in the Water Quality Monitoring Protocol.
Grab samples will be taken any time an operation discharges sediment-laden water into a watercourse.
In addition to effluent samples, samples will be taken upstream and downstream of any point of discharge.
All samples will be analyzed for settleable solids, total suspended solids, turbidity, conductivity, and pH.

1.3.2.3 WATER SAMPLING: WATER QUALITY OBJECTIVES

Samples will be collected for the purpose of monitoring WQO following procedures detailed in the Water Quality Monitoring Protocol.
Samples will be collected at locations within the watershed where there is a change in habitat sensitivity. These points will be established by the watershed modeling that has been prepared for the habitat management system.
The WQO sampling sites will be monitored with enough frequency to provide reliable data about the overall water quality in the stream and the watershed during periods of high and low flow.
The sampling will be comprehensive enough to provide representative information about water quality at each site. Additional information regarding channel morphology, flow and water temperature will be gathered whenever it is physically possible.
All samples will be analyzed for settleable solids, total suspended solids, turbidity, conductivity, and pH.

1.3.2.4 FLOW MEASUREMENTS

Flow measurements of effluent discharge streams and receiving waters will be taken whenever practicable by inspectors, in order to provide data related to overall sediment loading in a watershed.

1.3.3 SAMPLING FREQUENCY

Sampling frequency at stations where water quality varies considerably should be higher than at stations where quality remains relatively constant. A new program, however, with no advance information on water quality variation, should be preceded by a preliminary survey and then begin with a fixed sampling schedule that can be revised when the need becomes apparent.

The time interval between the collection of samples depends on the water body and its specific characteristics. An interval of one month between the collection of individual samples at a station is generally acceptable for characterizing water quality over a long time period (e.g. over a year in a river), whereas for control purposes weekly sampling may be necessary. If significant differences are suspected or detected, samples may have to be collected daily or on a continuous basis. In extreme cases, time- integrated, composite samples may have to be made up by mixing equal portions of samples taken at regular intervals over a 24-hour period.

Individual samples taken at a given station will be obtained at approximately the same time of day if possible, because water quality often varies over the course of the day. However, if detection of daily quality variations or of the peak concentration of a contaminant in an effluent is of interest, sampling at regular intervals (e.g. every two or three hours throughout the day) will be necessary. Exceptional conditions of stream flow are frequently of interest because it is at maximum and minimum flow rates that extreme values of water quality are reached. For example, when flowing at its peak rate, a river usually carries its greatest load of suspended material, while sediment will be the least diluted when a river is at minimum flow. For this reason, flow measurements will accompany every water sample collected, when safe stream measuring conditions exist.

The fundamental difference between the sampling programs conducted on Major versus Minor watersheds is the intensity by which they are sampled. At each of the five sites along the mainstem of a Minor watershed (see figure 1), sampling will occur at a minimum of four times per year (capturing 2 high and 2 low flow events). All sampling conducted within Minor watersheds will be grab samples collected by hand, with the exception of samples collected at the mouth of the main stem that will be collected by automated sampling equipment (see APPENDIX F))as these sites are generally less frequently accessible.

In contrast, sampling within Major watersheds will be both automated (ISCO samplers) and collected by field personnel. Due to differences in the timing of the high and low flow events for each of the Major watersheds, water sampling activity will be conducted throughout the season in order to collect data during both events.

1.3.4 DATA COLLECTION

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource. Although the natural ecosystem is in harmony with natural water quality, significant changes to water quality from human activity may be disruptive to the ecosystem.

The results of analyses performed on a single water sample are only valid for the particular location and time at which that sample was taken. One purpose of a monitoring program, therefore, is to gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality.

For each site where personnel collect the water samples, field measurements of pH, conductivity, temperature (see Appendix A) and stream flow (see Appendix B) will be conducted. During installation and upon each field visit to empty the automated samplers, personnel will also conduct pH, conductivity, temperature and stream flow measurements. Automated weather stations capable of collecting rainfall; air and water temperature will be strategically located within each watershed. In addition to field measurements of stream flow, water level measuring stations will be established to monitor changes in stream level (see Appendix E). This data along with rainfall data will be used to assist in determining the correlation between naturally occurring changes in stream flow and effluent discharge.

Laboratory analyzes of each water sample will include, total suspended solids (TSS), settleable solids and turbidity.

1.4 DATA ANALYSIS

The data analysis component of the Water Quality Objective monitoring protocol addresses the two key questions listed in section 1.2. The first step of the assessment process is to determine whether the Water Quality Objectives are being achieved (key question 1). The Water Quality Objectives (above background levels), categorized by habitat sensitivity, will be defined in watershed authorizations.

The next step in the assessment process is to establish whether an exceedance of the Water Quality Objectives is due to placer mining activity (key question 2)

Additional information will be required to determine if placer mining or natural processes cause the exceedance.
This includes:
• Inspection reports on the effluent compliance on upstream placer mines;
• Information on other potential anthropogenic (industrial activities) or natural (landslides) sources of sediment; and
• Local climatic and flow data in efforts to understand the seasonal and inter-annual variations in sediment loading.

ANALYTICAL METHODS

All laboratory analysis and water sample collection will adhere strictly to the methodology described in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, American Water Works Association, and the Water Pollution, Control Federation, 1992).

1.4.3 QUALITY ASSURANCE / QUALITY CONTROL

It is very important to include a field quality assurance/quality control component in a sampling program. It must be well defined and supported by accepted standardized practices. Quality assurance (QA) in the field usually refers to a broad plan for maintaining quality in all phases of a program, including how the samples are to be collected, documented and handled. Possible sources of error and of variation should be listed, as well as quality control (QC) checks for each.

QC checks can include *field replicates, laboratory blanks, travel blanks* and *travel spiked blanks*. Procedures for collecting these samples are described in Appendix A.

Every season's sampling plan will state the number and type of field QA/QC checks to be included in the study. The way to document the results of these QC checks will also be stated.

Field QC procedures are not always performed at the same site. The number of QC locations will provide a general overview from all sections of the watershed being sampled. The total number of QC sites should be no less than 10 percent of the total number of sampling locations. This is a minimum number of QC samples needed to provide meaningful sample results. Up to as many as 30 percent is acceptable, especially at the beginning of a project.

Field QC plans should also list all field observations that are to be made at the time of sampling. These include meteorological conditions and exceptional circumstances, such as debris in a river. Field observations can be important in the interpretation of sample results.

Similar QC samples are also used in the laboratory, as well as the field. Laboratory QA/QC procedures are more elaborate and may use many spiked samples or standards.

Many water quality personnel believe that the collection of two samples from a location is enough for checking the quality of the sampling. This approach presents a problem if the two samples show considerable difference when the laboratory results come back. There is then no way of deciding which sample is right and which is wrong, unless one is so severely contaminated that it is clearly not valid. The collection of three or four samples gives a better indication of how much variation can be expected for a given aspect of water quality. More samples also help indicate how much can be attributed to sampling, handling, storage and analyses. It is also better for any statistical analysis to have more samples.

Please refer to the following document for information regarding field sampling methodology and Quality Assurance / Quality Control procedures:

BRITISH COLUMBIA FIELD SAMPLING MANUAL: For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples **(2003 Edition)**

Prepared and published by:

Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Province of British Columbia, January 2003

Revisions to a program's design may be necessary at any time. From the beginning to the end, it is necessary to examine the various parts of the program to make sure the objectives are being met. It is often necessary to adapt to changing conditions, whether they are environmental, related to a new development, to financial considerations or result from changes in the program's objectives. Recognising when and how to make changes is an important part of a program's success.

2.0 PROGRAM REQUIREMENTS AND RECOMMENDATIONS

Before sample collection can begin, field personnel must take steps to ensure that the samples collected will be representative of the aqueous system under investigation. A representative sample is one that typifies ("represents") in time and space that part of the aqueous system to be studied, and is delineated by the objectives and scope of the study.
Obtaining representative samples is of primary importance for a relevant description of the environment. In order to collect a representative sample that will yield the information required:

(1) Program objectives, including data-quality requirements, must be understood in the context of the water system to be sampled, and
(2) artifacts of the sampling process must be minimized.

Field personnel must be alert to conditions that could compromise the quality of a sample.

What does the data represent?

Data collectors need to know what questions the data being collected is meant to address, and understand the level of accuracy and precision that are needed in the data to answer those questions. The data is no better than the confidence that can be placed in how well the sample represents the aqueous system. Therefore, understand the purpose for which the various types of data will be collected and the aqueous system that each sample should represent.

SAMPLING PERSONNEL
Designated Sampling and Field Staff

Programs that conduct water sampling on a routine basis can benefit from having a core group of personnel highly trained in sample collection. Such personnel produce the most reliable data and can be cost effective because of their familiarity with the needs of sample collection. Especially if the more difficult aspects of sample collection are needed, e.g., field pH, trace metals, and calibration of complex instruments, it may save time to have someone who is more qualified rather than someone who happens to be available but has little or no formal training.

The following requirements are key to ensure the success of the program:
- Having a clear understanding of the programs objectives.
- Use of up to date, state of the art equipment and instrumentation.
- Strict compliance with QA/QC procedures and sampling methodology.
- Use of highly trained, designated field sampling personnel that apply a consistent approach to their work and thus collect the best representative data and information possible.

Failure to follow any of these requirements may lead to data and information errors and nonaccomplishment of the programs intended goals.

If these requirements are met, the first key question of this protocol, "*Are the WQO established in the new regime being achieved?*" will be easier to answer. However, in order to answer the second key question "*If not, is this due to placer mining activity or to other causes?"*, and fully understand the root cause of the WQO **not** being achieved, the following information and data will be required:

a. Extent of placer mining upstream from monitoring sites.
b. The distance between monitoring sites and placer activity
c. The timing, flow volume and duration of effluent discharge from upstream sites.
d. History of forest fire upstream of the monitoring site.
e. Recent flood events / high water at the time of sampling.
f. Natural water quality or background.

Heightened sediment inputs and diminished water quality is thought to be due to rain events in the monitored areas. Surface water runoff and ground water infiltration into a body of water will intensify the sediment-loading while at the same time increase the rate of flow. The increased flow can scour bank and bed material, compounding the loading. These increases are generally well correlated in the frequency and duration to recorded rain events however, not every time. Spikes in solids concentrations have been observed during periods of no precipitation. Why this occurs is yet to be determined. The additional information requirements listed above would assist in answering this and other related questions.

Knowing exactly from where and when these non-point sources of this additional sediment originate or why they occur is a critical question. Are previously or current mined areas more susceptible to ground and surface erosion than primary old growth and regenerated areas? Are there non-mitigated sources of input and could there be better control of these areas? If results indicate that point source effluent discharge appears to have little to no effect when discharge standards are maintained, and generally, compliance has been the norm, then what is the effect of multiple non-point sources on water quality?

Without the monitoring and evaluation of water quality upstream and downstream of stripped, mined and reclaimed sites and without the collection of additional water quality and flow data of mine effluent discharge in a watershed, most of these questions detailed above will remain unanswered. Any causal direct relationship to mining activity versus other natural environmental occurrence cannot be categorically determined if the additional information and data listed above is not collected, a task which is beyond the scope of this protocol and will have to be addressed through another *regime* component within the Fish Habitat Management System.

APPENDIX A

DETAILED SAMPLING METHODS

Sampling is a vital part of studies of natural-water composition and is perhaps the major source of error in the whole process of obtaining water-quality information. This fact is not well enough recognized, and some emphasis on it seems desirable. In any type of study in which only small samples of the whole substance under consideration may be examined, there is inherent uncertainty because of possible sampling error. The extent to which a small sample may be considered reliably representative of a large volume of material depends on several factors. These include, first, the homogeneity of the material being sampled and, second, the number of samples, the manner of collection, and the size of the individual samples. The sampling of a completely homogeneous body is a simple matter, and the sample may be very small.

Because most material is not homogeneous, obtaining truly representative samples depends to a great degree on the sampling technique. A sample integrated by taking small portions of the material at systematically distributed points over the whole body represents the material better than a sample collected from a single point. The more portions taken, the better the sample represents the whole. Sampling error would reach zero when the size of the sample becomes equal to the original volume of material being sampled, but for obvious reasons this method of decreasing sampling error has practical limits.

To determine adequately the instantaneous composition of a flowing stream, the sample, or sets of samples taken simultaneously, must be representative of the entire flow at the sampling point at that instant. Furthermore, the sampling process must be repeated if the results of analysis are to be extrapolated in time, and the sampling interval chosen must represent adequately any changes that might occur. Changes occurring along the length of the stream can be evaluated by adding more sampling points.

The homogeneity of a stream at a cross section is determined by such physical factors as proximity of inflows and turbulence in the channel. Locally, poor lateral or vertical mixing can be observed in most stream systems. Immediately below the confluence of a stream and a tributary there may be a distinct physical separation between the water of the tributary and that of the main stream, and, particularly in large rivers, this separation may persist for many kilometres downstream. The effect is more pronounced if the water of the tributary differs markedly from the water of the main stream in concentration of dissolve or suspended solids or in temperature.

These effects may be of special interest in some studies, but if the average composition of the whole flow of a stream or its changes in composition over a period of time are the factors of principal significance, sampling locations where mixing is incomplete should be avoided.

A composite sample that will represent accurately the water in a vertical cross section of a stream can be obtained by combining appropriate volumes of sample taken at a series of points along the cross section. At each point, samples should be obtained at enough different depths to compensate for vertical homogeneity. Obviously, it is physically impossible to obtain all these samples at one instant. The water in the stream is in motion at different rates in different parts of the cross section, and this further complicates the problem.

Sampling Techniques

There are three commonly used sampling techniques for the collection of stream and river water samples: *Grab, Composite, and Continuous*

A ***grab*** sample is collected at a point in time and space. If you open a tap and fill a sample bottle from it you have collected a grab sample of the tap water, at that moment in time. This is the simplest method of sampling and serves many purposes such as the analysis for bacteria and certain unstable substances like dissolved oxygen and radioactive nuclides. The disadvantage of this method is that, if an event happens before or after the grab sample has been taken, it may go unnoticed and your sample will be of no value.

When fluctuations occur in the system, such as a tailing or effluent outfall, ***composite*** (or pool) sampling is more appropriate. A composite sample is made up of several grab samples, taken at regular intervals of time and space. Consider a tailing line outfall. If every hour on the hour, you collect equal portions of the discharge and pool them into one container, you have collected a composite sample of the tailings effluent over a time element.

When dealing with the three-dimensional space element, there are two ways of collecting a composite sample. Imagine yourself in a boat at a stationary point on a stream. If you collect equal portions of water at various depths, and pool them into one container for analysis, you have collected a composite sample of the water column at that point on the stream. If, however, you are in a boat moving along the stream and every so often collect equal portions of water at the surface of the stream and pool them into one container for analysis, you have collected a composite sample of the surface water of the stream.

A composite sample is a mean sample. It evens out fluctuations in a system. It gives an overview and is a good method to sample a fluctuating or inhomogeneous system like tailing pond discharge. A limitation of this method is that it does not identify the magnitude and duration of a fluctuation.

In some industrial operations, like mining, effluents come as slugs and the composition of the waste effluent changes continuously throughout the day. ***Continuous'*** sampling is used to identify this kind of fluctuation. It is almost invariably done by attaching an automatic sampling device, like an ISCO sampler or floating monitoring device, to the discharge outlet.

CHOICE OF SAMPLING TECHNIQUE

The method of sampling you choose, whether grab, composite, or continuous depends on one or more of the following factors: your objectives; fluctuations in the system; type of water to be sampled (i.e. lake, stream or a discharge pipe); nature and stability of the parameter to be analysed; the wording of licences or authorisation you may be enforcing.

For example, all water licences granted under the Northern Inland Waters Act, specified grab sampling for tailing effluent. It is important to remember that the method of sampling is site specific and depends on the parameter to be analysed. However, some general observations can be made:

For lakes and streams, grab samples may be collected. Composite samples may be used to get an overview;
For effluents, best results are obtained by collecting continuous samples. Composite samples are the next best but if you have no other choice collect grab samples; and,
Samples that are collected for the determination of suspended and settleable solids should be made up from pooled water samples collected at fixed site locations but at various depths.

SAMPLING OF STREAM WATER

Stream and river sampling can be accomplished using a variety of methods. Three cases will be considered:

- sampling a stream from a bridge or overpass;
- sampling a stream shallow enough to wade in; and,
- sampling from a stream bank.

(1) When sampling from a bridge, the following steps should be observed:

- choose a sampling point midway across the stream;
- determine the approximate depth of the stream by lowering the grab sampler to the bottom of the stream;
- retrieve it and wait a few minutes, until all the stirred sediments have been carried away;
- using a swinging motion upstream and parallel to the flow, lower the sampler into the stream;
- retrieve it when it reaches a point perpendicular below you;
- rinse and discard the wash water;
- repeat this procedure until the bottle is filled; and
- transfer the contents into your sample bottle.

Note that an integrated sample can be collected by lowering the sampler to various depths in the stream. A good rule is to sample at 60% of the total depth, 40% of the total depth and, at the water surface.

(2) When sampling a shallow stream, the following steps should be observed:

- Choose a place where the water is flowing freely and is clear of floating debris. Attach safety line if conditions have any significant risk.
- Obtain labeled bottles and wade into the middle of the stream, downstream from the point at which you will collect the samples, then wade upstream to the sample site (this ensures that you will not disturb sediments upstream of the sample point. Wait until all the sediments stirred have been carried away.
- Stand perpendicular to the flow and face upstream.remove the cap of the sample bottle and hold it aside without touching the inner surface. If rinsing is required for the type of bottle, fill and rinse three times[3].
- With your other hand, grasp the bottle well below the neck. Plunge it beneath the surface in front of you with the opening facing directly down, then immediately orient the bottle into the current. Avoid collecting surface scum and film. Point the mouth towards the current and allow it to fill.
- Once the bottle is full, remove it from the water by forcing it forward (into the current) and upwards.
- Replace the cap immediately.

Never sample the edge of the stream from the bank as it usually contains a large portion of stagnant water and always sample upstream and if possible up wind of your position in the water.

Whenever practical, samples should be collected at mid-point rather than near shore. Samples collected from mid-point reduce the possibilities of contamination or alteration (i.e. shores effects, back eddies, seepage from near shore soils). Samples should not be taken in back-eddies or brackish waters. The most important issue to consider when deciding where the sample should be collected from is **SAFETY**.

If the flow is sufficiently slow that you can wade into the stream without risk, then the sample can be collected at a depth that does not pose a threat.

Note: If sample bottles have not been pre-cleaned by the laboratory, then they must be rinsed 3 times with either de-ionized water or sample water. The exception to this is when a sample is to be analyzed for suspended sediments, for contaminants likely associated with the suspended solids, or for oil and grease. In these cases, the bottles should not be rinsed with sample water as suspended particles or grease-like materials are retained on the interior surface of each bottle with each rinsing. For specialized analyses (trace metal, organics) and pre-cleaned bottles, containers should not be rinsed. Rinsing is not a recommended practice. Use of pre-cleaned bottles is recommended, where practical. Where bottles are rinsed, the rinsate should be discarded.

(2) When conditions dictate that the sample is taken from the stream bank, the following steps should be observed;

- secure yourself to a solid object on shore (with a safety harness and line if necessary); remove the lid from the sample bottle and place it into a clean zip lock bag;
- secure the sample bottle to a pole grab sampler;
- reach out as far as possible with the pole sampler and plunge the bottle under the water and immediately orient it into the current;
- when the bottle is full pull it up through the water while forcing it into the current; and,
- immediately recap the bottle

TOTAL SETTLEABLE SOLIDS DETERMINATION

In order to determine total settleable solids in an aqueous solution, a well-mixed sample is placed in a special settling device called an Imhoff cone, and allowed to settle under quiescent conditions for some specified time. The standard method calls for a settling period of one hour and a cone having a volume of one liter. It is necessary to gently rotate the cone, or stir the contents **slowly**, after a period of 45 minutes to prevent the deposition of matter on the inside surface of the cone. At the end of the prescribed settling period, the volume of the settled material is read from a scale etched on the outside of the cone.

Total settleable solids concentrations are usually reported in terms of ml/L. Do not estimate any floating material. The lowest measurable level on the Imhoff cone is 0.1 ml/l. Any settleable material below the 0.1 ml/l mark should be recorded as *trace* or <0.1 ml/l.

SAMPLE HANDLING

Deteriorated samples negate all the efforts and cost expended in obtaining good samples. In general, the shorter the time that elapses between the collection of a sample and its analysis, the more reliable will be the analytical results. For certain constituents and physical values, immediate analysis in the field is required in order to obtain reliable results because the composition of the sample almost certainly will change before it arrives at the laboratory.

Determination of temperature, pH, settleable solids and specific conductance should be made in the field.

Samples must be transferred to sample bottles immediately after collection if they are collected in the container of a pole sampler. If analysis of settleable solids concentration is to be carried out in the field, it should be started as soon as possible.

Sampling staff must have a field notebook in which all details of relevance are recorded at the time. The field book should be hard-bound and not loose-leaf. Full books must not be discarded but stored for future reference because they represent data in original form and are sometimes invaluable for reference purposes.

Details recorded should include: those details noted on the sample bottle, what samples were collected, what measurements were made, how they were made, and the results obtained.

All supporting information (any unusual local features at the site and time of sampling) should also be noted. If there has been any variation from the agreed sampling station, this should be noted, with reasons. Any need for a permanent change in sampling station should be brought to the attention of the program coordinator.

If a standard field record layout is used in place of a plain notebook, adequate space should be available for comments and observations. To facilitate field work, the layout and content of the pages should reflect the sequence in which the various procedures will be carried out.

Each sample bottle must be provided with an identification label on which the following information is legibly and indelibly written:

Name of the study / Reason for sampling
Sample station identification and/or number.
GPS Location of the sampling site
Date and time of sampling.
Name of the individual who collected the sample.

Sample bottles should be placed in a cooler for transport to the laboratory and will protect samples from sunlight, prevent the breakage of sample bottles, and should allow temperatures of < 20 °C to be attained and maintained during transport.

Samples that are to be used for the determination of suspended solids must not be frozen in as much as it is not always possible to reconstitute the original sample exactly as it was before freezing. Freezing can also affect the particle size of some solid constituents in a solution, thus distorting any analysis.

SAMPLE PRESERVATION METHODS FOR SPECIFIC PARAMETERS IN WATER QUALITY SAMPLES

Parameter	**Preservation**	**Maximum holding period**
pH holding	None available	Should be determined on site
Solids	cool to 4°C	7 days
Specific conductance	cool to 4°C	7 days
Turbidity	None available	7 days

APPENDIX B

FLOW MEASUREMENTS

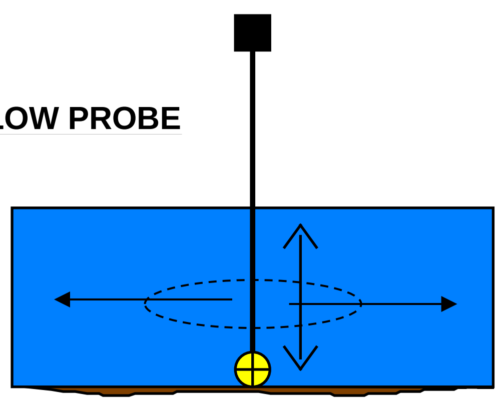
Flow Determination with a Digital Handheld Water Velocity Meter:

The use of an electronic instrument in order to measure flow is similar to other surface speed method but has improved accuracy. This is due to the fact that the velocity of the stream is measured through the entire water column rather than just at the surface.

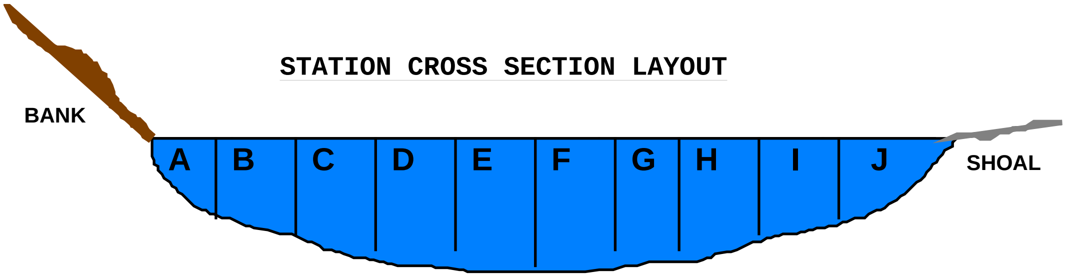
The stream width is measured and then divided into equal width segments (W) or stations for measuring. In this method the flow of the entire stream is determined then the flow calculated at each of the stations is added together. The velocity measurement (V) determined by the instrument is the average of **V** through the water column calculated by the flow meters on board computer. This measurement is obtained by repeatedly raising, lowering and sweeping the head of the instrument up and down, side to side in the water column, for at least one minute, allowing the on board computer to make multiple velocity measurements and compile an average. The instrument displays this calculated average when the head is raised above the water surface and the propeller in the head stops turning.

In order to complete the flow calculation an average depth (D) of the water in each station must be measured, usually at the center of each station, and the depth recorded.

GLOBAL FLOW PROBE



Station 3 – Stream cross-sectional diagram:



Station 3 - Recorded Data:

STATION	WIDTH (m)	AVERAGE DEPTH (m)	AVERAGE V (m/s)
A	1.0	0.20	5.5m/s
B	1.0	0.20	4.9m/s
C	1.0	0.20	6.1m/s
D	1.0	0.24	6.1m/s
E	1.0	0.20	4.9m/s
F	1.0	0.22	6.7m/s
G	1.0	0.25	7.3m/s
H	1.0	0.30	8.2m/s
I	1.0	0.40	6.7m/s
J	1.0	0.33	6.7m/s

Station 3 - Analysis:

Station Discharge (Q_S) = ($V^{m/s}$) (W^m) (D^m)

Where V = Average Velocity

W = Width of station

D = Average depth of station

STATION	A	B	C	D	E	F	G	H	I	J
Q m^3/s	**1.10**	**0.98**	**1.22**	**1.46**	**0.98**	**1.47**	**1.83**	**2.46**	**2.68**	**2.21**

Total Discharge (Q_T) = discharge station A+B+C+D+E+F+G+H+I+J

= 16.38 m^3/s

APPENDIX C

WEATHER MONITORING

An Automatic weather station (AWS) is an automated type of traditional weather station, either to enable measurements from remote areas or to save human labour.

An AWS will typically consist of a weatherproof enclosure containing the data logger, rechargeable battery, telemetry (optional) and the meteorological sensors with an attached solar panel or wind turbine and mounted upon a mast. The specific configuration may vary due to the purpose of the system. The system may report in several different ways. It may be in real time via a local link to a computer system or via telecommunications or satellite systems. GSM mobile phone technology has also been known to be used. An alternative is the storage of the information in local data storage such as flash memory for retrieval at a later stage.

Most automatic weather stations have Thermometer for measuring temperature, Anemometer for measuring wind speed, Hygrometer for measuring humidity, Barometer for measuring pressure. Some of them even have rain gauge for measuring rainfall, ceilometers for measuring cloud height, present weather sensor or visibility sensor.

Early first automatic weather stations needed to be located where there was an availability of electricity and communication lines. In more modern applications of this technology the solar panel, wind turbine and mobile phone technology have made it possible to have wireless AWSs that are not connected to the electrical grid or telecommunications network.

The main power source for an automatic weather station is usually one or more solar panels connected in parallel with a regulator and one or more rechargeable batteries. As a rule of thumb, solar output is at its optimum for only 5 hours each day. As such, mounting angle and position are vital. In the Northern Hemisphere the solar panel should be mounted facing south. The angle of the panel differs from place to place but it should never be mounted with an angle of less than five deg. as dust build up will dramatically decrease the panel's output.

Currently, the WQO Monitoring program uses WatchDog weather station’s in the field for our atmospheric monitoring. This does not mean that alternate instrumentation cannot be used, as there are many comparable manufactures that produce equivalent instrumentation. Each season we deploy up to 24 portable weather stations in areas that we are monitoring.

All WatchDog 2000 Series Weather Stations have the following features:

- Sealed NEMA-4 type IP66 enclosure and weatherproof connectors
- Built-in data logger stores your measurements in fail-safe, non-volatile memory

- Enhanced LCD display; check current conditions and historical high/low readings
- 12-month battery power with four AA lithium batteries. Four AA alkaline batteries included for 10-month life.
- Internal sensors measure air temperature, relative humidity, wind speed and direction, rainfall, and solar radiation (depending on model)
- External sensors (up to 9 sensors) and communication ports
- Wide selection of compatible external sensors and communication options

The stations are completely weatherproof and feature 12-bit resolution for higher accuracy. The stations can be accessed at different times by multiple users because the data is not cleared from memory following a download. The 2000-Series weather stations can communicate via direct-wire, radio or telephone connections. Current weather conditions, historical data, and computed parameters are easily viewed on the station's LCD screen. The arrow keys can be used to program the station's logging interval and assign sensors to the external sensor ports. You can also scroll through the sensor readings, Degree Day/Chill Hour calculations and set your temperature ranges.

The model 2000 station is equipped with nine external sensor ports. It can be connected to any WatchDog external sensor. Although a rain collector is not included as a standard sensor, it can be added as an optional external sensor.

Station Installation

The weather station should be located in an open, unobstructed, grassy area to ensure accurate measurement of wind, rainfall, sunlight, and evapotranspiration. Mounting hardware is provided to attach the weather station to a 4" x 4" treated wooden post or to a mast/pole up to 1.25 inches in diameter. The mounting pole should be securely anchored perpendicular to the ground.

If you are using the mounting tripod, open it and place it where the weather station is to be located. The tripod feet can also serve as mounting brackets if the unit is located on a solid surface. Slide the 3' post through both center screw clamps, adjust the height as desired and tighten the screws such that the post is perpendicular to the ground. Finally, attach the weather station to the post with the U-bolts. Secure the external sensor wires to the mounting pole with a plastic tie. This will ensure that the sensor wires do not become disconnected while recording.

Additional setup information, connection options, program configuration and other instrument options are available on line or can be found in the operating manual that comes with each unit. In addition to the purchase of the unit, a copy of SpecWare software is required to download and graphically interpret the logged data.

APPENDIX D

WATER TEMPERATURE

Introduction

Water temperature is one of the most significant factors in the health of a stream ecosystem (Stevens and others, 1975; U.S. Geological Survey, 2006a). Depending on the type of stream and its location, the natural flora and fauna establish themselves in ranges delineated by temperature. Stream temperature affects various fish species populations by influencing physical, chemical, and biological water properties (Kyle and Brabets, 2001; The Alaska Department of Environmental Conservation, 2012). Water temperature also affects invertebrate and aquatic plant growth and can be subject to environmental regulation and monitoring by Territorial, Federal, and local agencies. Accurate water temperature data is needed to document thermal alterations to the environment caused by natural phenomena and human activities (Kelleher and others, 2012). Anthropogenic or natural alterations may change timing, magnitude, frequency and (or) duration of water-temperature conditions. Additionally, determination of many other important water-quality parameters relies on accurate water temperature data. Temperature affects the density of water, the rate of chemical reactions, biological activity and the solubility of constituents (such as oxygen) in water, pH, and specific conductance (U.S. Geological Survey, 2006b).

Site Selection For In Situ Temperature Measurements

Site selection depends on the purpose of the study. The location of the temperature sensor in the stream channel may be the most important factor in collecting representative water-temperature data.

Sites are ideally located where good mixing characteristics assure an even temperature distribution. If possible, braided channel reaches, backwater or slough areas, and shallow riffles should be avoided. These areas often do not have homogeneous temperature cross-sections or can provide challenges for keeping temperature sensors submerged in the water year round. However, another common purpose of study includes determining the effect of certain points (that is, tributaries, facilities that discharge water, and so on) on stream temperature. For these purposes, the data-quality objective may be to understand how mixing of different water bodies occurs.

Obtaining recorded measurements representative of the water body typically is an important data-collection objective. To achieve this objective, the temperature sensor should be placed in a location that represents the water body being measured. The sensor should be installed in the stream or water body such that recorded water temperature is unaffected by the installation. Cross-section surveys of water temperature should be made to determine the most representative location for placement. A site should not be selected without first determining that the temperature distribution is uniform throughout the cross section. Sufficient measurements must be made at the cross section to determine the degree of mixing at the prospective site under different flow conditions and to verify that cross-sectional temperature variability does not exceed that needed to meet data collection objectives. Cross-sectional temperature variability should be as minimal as possible, but those requirements are ultimately determined by the study's data-quality objectives. Finally, a survey for human, bear, or beaver (or other biotic influence) activity may be an additional consideration when locating a sensor.

Equipment Selection and Deployment

The selection of a water-temperature monitoring instrument to collect water temperature involves three major interrelated elements: (1) the purpose of the data collection, (2) the type of installation, and (3) the duration, accuracy, and precision requirements of the data-collection objectives (U.S. Geological Survey, 2006a; Wagner and others, 2006). Other factors to consider include the use of recording temperature sensors and subsequently their sensor memory capacity, price, battery life, programming versatility, and durability. General calibration procedures for temperature sensors are described in this report. However, because of the large number of manufacturers and models, the manufacturers' instructions and recommendations should be carefully followed. Finally, with each new instrument, it is good practice to record calibrations, maintenance, and history of use in a log book.

Use of Recording Temperature Sensors

There are many manufacturers and models of temperature sensors and data loggers. Many of these configurations are self-contained units that both measure and record temperature data. In some cases, temperature may be measured using a temperature sensor attached to a shore based data logging device that can be used to record various environmental parameters. When selecting a temperature sensor it is important to consider how the device will be installed and if features of the temperature sensor will satisfy data collection objectives. Most manufacturers provide product specifications.

However, the user should verify the accuracy claimed by the manufacturer for the range of application. At a minimum, the data-quality objectives of most temperature-monitoring efforts will likely be met if the instruments have an accuracy of ±0.2 °C or less.

Even durable temperature sensors can be damaged or lost in the harsh environmental conditions encountered in most streams. Flood flows often transport large amounts of sediment and debris and are capable of scouring study reaches or burying sensors. Similarly, in The Yukon's cold climates, ice break-up events can damage or transport sensors that are not suitably secured and protected. Most temperature sensors should be in protective housing and have anchors at sites where there is the possibility of loss or damage. The type of protective housing will depend on the selected temperature sensor and installation method. Because of their greater precision, submersible temperature sensors mounted in durable flow-through housings are preferred over non-submersible temperature sensors installed in sealed waterproof housings.

Programming Recording Intervals

The recording time interval is determined by the data collection objectives, storage capacity of the recorder, time between field visits, and the magnitude of diurnal (daily) temperature fluctuations. Desired recording intervals should be defined in the quality-assurance plan prior to temperature sensor installation. Longer recording intervals result in reduced temporal resolution that may fail to record the actual range of temperature variation at a site. This is particularly important if instantaneous measurements of temperature such as the daily maximum or minimum are critical data collection objectives. In most cases, a recording interval of 30 minutes should provide adequate resolution to determine actual daily maximum and minimum temperature values. A shorter interval of 15 minutes might be necessary to provide suitable resolution on smaller rivers and streams that are subject to large or rapid variations in temperature. Longer intervals of 60 minutes might be appropriate on larger rivers where temperature change could be somewhat slower due to the size of river. In The Yukon, monitoring sites might be remote with limited site visits; therefore, memory capacity available between site visits needs to be sufficient for the data-recording interval.

Field Instruments

Field temperature sensors are used during site visits to verify that recording sensors are operating correctly, to provide an independent check of temperature changes during the site visit, and to make cross-sectional surveys to verify that the recording sensor is providing temperature data representative of the stream cross section. Water temperature should be measured at all sites when collecting water samples. Either thermometers or thermistors may be used; either must be calibrated at two temperatures. Typically, an ice/water mix is used to determine what the reading is at 0 degrees C and a reading from a certified thermometer is compared to the one being calibrated at some higher temperature, e.g., 20 or 25 degrees C. The calibration data are recorded and presented in the project's annual quality assurance report.

Thermistors have become standard and offer a low cost but easily readable and precise measurement. Sufficient time needs to be allowed for equilibration with the water by placing the thermometer or thermistor in the water for several minutes before reading. The reading should be taken with the thermometer or thermistor still in the water because the reading can change quickly once the probe is exposed to air.

Digital readout thermistors are the most commonly used device for collecting field measurements of water temperature. A thermistor is a type of resistor whose resistance varies with temperature. Similar to recording sensors, there are many manufacturers and models of digital field thermistors. A suitable field thermistor should have an accuracy of ± 0.2 °C or less. Most manufacturers of digital thermistors provide detailed information on the accuracy of their instruments.

Thermistors that are traceable to National Institute of Standards and Technology (NIST) standards are available and reliable. Users should verify the accuracy claimed by the manufacturer for the range of application. Regardless of the type of temperature sensor selected for field measurements it should be transported in a protective case designed to reduce shock and vibration.

Field Procedures

Site Selection and Installation Procedures for Continuous Measurement Sensors

Generally, the most important data collection objective for continuous water-temperature monitoring sites is that the temperature sensor records water-temperature data representative of the actual stream temperature. Prior to temperature sensor installation, surveys of the cross-sectional variability of water temperature are needed to determine if the site can readily provide a representative temperature record. Ideally, a number of cross-sectional surveys representing a range of flow and seasonal conditions would be collected to determine if discharges or seasonal changes affect spatial patterns of water temperature variability at the site prior to the installation of a temperature sensor. For reconnaissance purposes, this typically can be done quickly in a small stream by submersing a field thermistor in the stream and noting water temperature as the cross section is traversed. Site reconnaissance and installation should be conducted during low-flow conditions if possible.

In addition to having a homogeneous temperature distribution across the monitoring cross section, a good monitoring reach should be straight and have a uniformly shaped channel (Rantz and others, 1982). There should be no tributaries immediately upstream of the reach unless the purpose of the temperature measurements is to look at mixing from different sources. Mean cross-sectional stream velocities should be uniform temperature across the section. The water-temperature sensor should be located such that it remains submerged under low flow conditions. Ideally, the depth of water over the sensor should be at least 30 cm, although this may not always be practical under all flow conditions or in smaller streams. The sensor should not be located in a position where it could be frequently buried with streambed sediments or have direct exposure to sunlight. If possible, more than one sensor may be installed at each monitoring site to ensure redundancy, to minimize data loss resulting from malfunction or operator error, and to allow for data comparison.

Most water-temperature monitoring sites will not have all of the desired physical characteristics of an ideal site. The methods used to install the temperature sensor will depend on the type of sensor selected and the physical conditions at the monitoring site. For example, positioning the temperature sensor in a deep pool may be the best option to assure it remains submerged during all flow conditions. Under these circumstances, comparative cross-sectional measurements of water temperature might be conducted downstream of the pool across a section that is readily traversed. Field personnel will be required to balance desired site characteristics with practical aspects of site access and field data collection.

Water temperature should be measured and recorded at least once during each site visit to document whether or not a correction to the recorded value is needed. If the sensor appears to be fouled or exposed to air, then additional measurements would be needed after these situations are remedied.

The time and location of the field values should be recorded on the field notes with comparable readings from the temperature monitor. Water temperature can change rapidly over time. If it is not possible to obtain live readings from the recording temperature sensor, it will be necessary to measure and record field values as near as possible to the monitor’s recording intervals. For example, if the monitor records at 15 minute intervals it would be important to synchronize field measurements to these same 15 minute intervals. It is important to note any differences in field personnel watch time and recorder time, as the field values will need to be compared to recorded values to accurately compute the temperature record. Water temperature should always be measured *in situ,* and preferably in a location immediately adjacent to the recording sensor. Field measurements should be conducted with a thermometer that has had its accuracy checked with a NIST thermometer. When measuring the *in situ* field water temperature during sunny conditions, shade the field thermometer from the sun.

<u>Routine Site Visits</u>

After sensors are installed, periodic site visits are recommended to verify that they remain in place, are still underwater, and are working properly. Installation problems often can become apparent shortly after installation. Even at seemingly ideal locations, sensors sometimes become exposed to air or isolated in pools or side channels during low flows. Sensors also may become buried in stream sediment or are lost or damaged during high flows.

The sensor location should be described accurately after installation so that the sensor can be recovered over a range of flow conditions as needed. This may involve GPS coordinates, hand drawn maps, and a description of lateral distance from multiple recognizable reference points on the stream bank. Adequate notes need to be taken to document field conditions. Notes should include sensor movement resulting from channel migration or whether or not the temperature sensor housing is filled with material or covered by streambed material. Photographs from the same point and oriented in the same direction every time may be helpful to detect changes over time and provide an image of siteconditions.

Data loggers should be downloaded frequently to avoid data loss with additional emphasis during autumn flow recessions while they remain easily accessible prior to development of ice cover. Frequent downloading, particularly soon after initial deployment, will minimize gaps in the temporal record and allow an estimation of any issues with the site or the logger before significant time has been wasted. When it is determined that logger is functioning properly and the site is deemed appropriate for the type of measurement being made, site visits may be less frequent, but not longer than 1 month between visits (except at extremely remote sites).

During field servicing the recorder and thermistor may need to be serviced and cleaned following manufacturer's instructions. If self-contained temperature sensors are used, they should be inspected, data retrieved, and cleaned as needed, then returned to the installed location as found.

Record Computation

The record-computation process verifies and validates the water-temperature data and documents water quality. Accurate field notes and calibration logs are essential in processing the record. Ideally, the technician who services the water-temperature monitor computes the data record. The primary steps in processing water-temperature record are an initial data evaluation, removal of erroneous data, application of data corrections, and a final data evaluation (U.S. Geological Survey, 2006a; Wagner and others, 2006). The initial data evaluation should begin immediately upon completion of the field trip to ensure that all necessary information is available and to check for possible instrument malfunctions that may not have been evident in the field. Timely application of data corrections and initial computations are essential and can aid in determining if the sensor is functioning properly or needs to be replaced.

Initial Data Evaluation

Initial data evaluation is used to verify accurate transfer of raw field data to the database, to assess continuity and completion of the data record, and to identify and remove erroneous data.

Standard time-series graphs (temperature/time) of the record should be plotted shortly after field visits to confirm accurate transfer of data and to detect any instrument recording or sensor errors. For example, the beginning or end of a data file may contain air temperature values that were recorded before and after field deployment of the sensor. These values should be deleted. Other values that need to be removed include any periods when the water level was below the sensor level. Erroneous data can result from various problems with sensors, recorders, and hydrologic or environmental conditions.

Common sources and solutions for erroneous data are shown in table 1.

Symptom	Possible problem	Likely solution
Water temperature sensor		
Thermistor does not read accurately	Dirty sensor	Clean sensor.
Erratic readings	Poor connections at monitor or sensor	Tighten connections.
Monitor slow to stabilize	Dirty sensor	Clean sensor.
Readings off scale	Failure in electronics	Replace sensor or monitor.

Table 1. Typical data problems with stream water temperature sensors.

Water temperature data from a properly operating sensor typically yields graphs showing smooth diurnal patterns (fig. 4). These patterns result from water warming and cooling with daily changes in long- and short-wave radiation and the ambient air temperature. Smooth diurnal patterns should be persistent in raw data plots and departures from these patterns should be examined thoroughly. During the summer, the temperature data are likely to contain substantial daily oscillations and seasonally high maximum temperature values.

Comparisons should be made with nearby stream temperature or climate station records when evaluating the data for errors. Deviations or changes in the magnitude of daily variation in these patterns typically result from variations in weather patterns such as prolonged precipitation events, warm sunny weather, or weather patterns resulting in little change in daily air temperature.

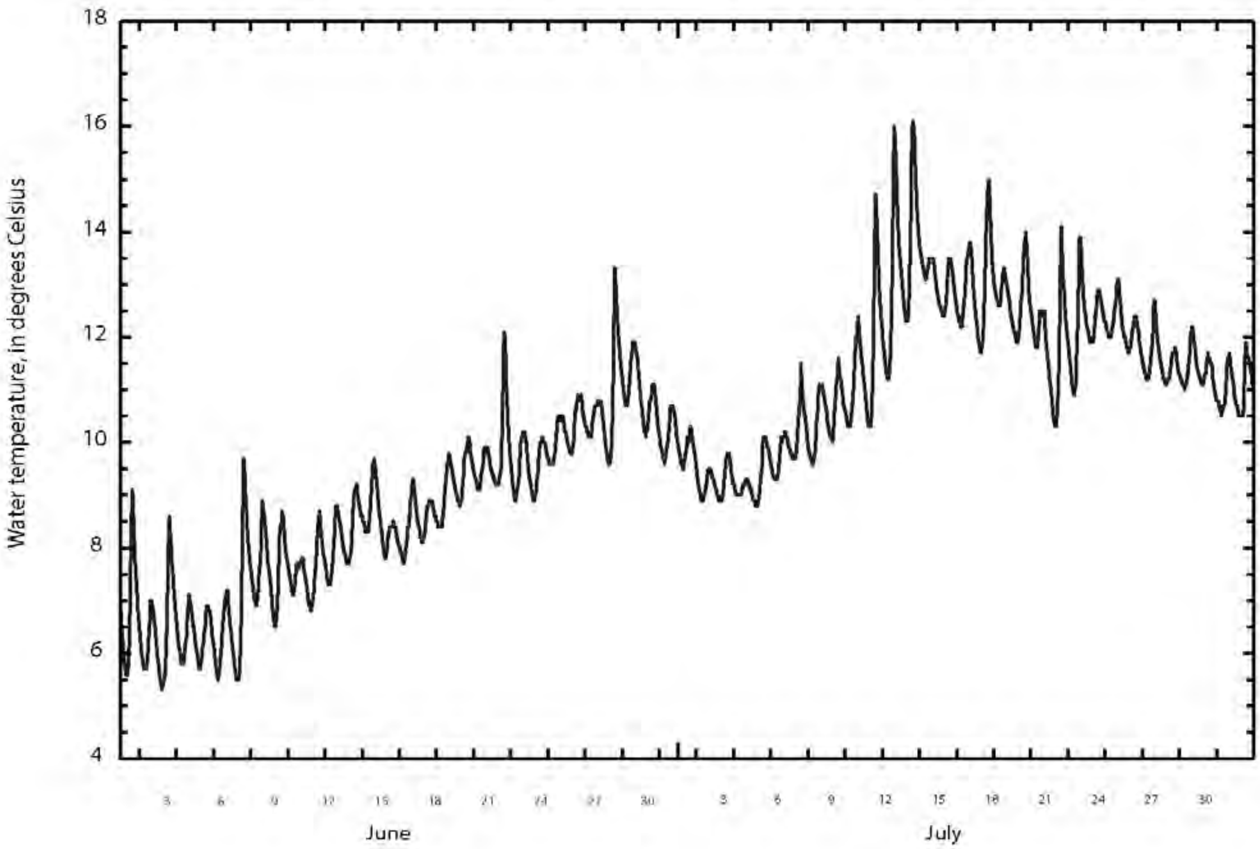


Figure 4. Example of smooth diurnal patters in water temperature as taken from a properly functioning water temperature recording sensor

Yukon Government, Compliance Monitoring & Inspection, Water Quality staff can provide you with examples of erroneous or problematic water temperature data, instrumentation / installation alternatives and protective housing designs. Please contact them directly for more information.

In addition, there are two excellent publications available that address the specifics of water temperature monitoring in the Yukon, both produced by Ta'an Kwäch'än Council;
http://taan.ca/files/uploads/2015/06/WaterTemperatureDataCollectionProgram.pdf

http://taan.ca/files/uploads/2015/06/MeasureWaterTemperatureInSouthWestYukon.pdf

These publications cover equipment, site selection, field deployment, data downloading and management and like our program utilize Onset Tidbit V2 Temp data loggers as part of their ongoing water temperature monitoring program.

TidbiT® v2 Temp (UTBI-001) Manual

onset
HOBO® Data Loggers

The TidbiT v2 Temp logger is Onset's smallest U-Series logger. Its durable, waterproof case is designed for extended deployments measuring temperature in streams, lakes, oceans, coastal habitats, and soils. The logger's small size allows it to be easily mounted and/or hidden in the field. It is waterproof up to 305 m (1000 feet) and rugged enough to withstand years of use. It has enough memory to record over 42,000 12-bit temperature measurements.

The logger uses an optical USB communications interface (via a compatible shuttle or base station) for launching and reading out the logger. The optical interface allows the logger to be offloaded without compromising the electronics. The USB compatibility allows for easy setup and fast downloads. HOBOware® 2.2 or later is required for logger operation. Visit www.onsetcomp.com for compatibility information.

TidbiT v2 Temp

UTBI-001

Required Items:

- HOBOware 2.2 or later
- Coupler (COUPLER2-D)
- Optic USB Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1

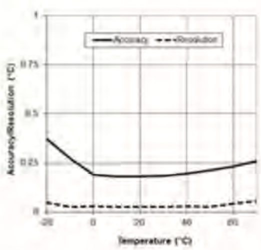
Accessories:

- Black protective boot, 5-pack (BOOT-TIDBIT-BK)
- White protective boot, 5-pack (BOOT-TIDBIT-WH)

Specifications

Temperature Sensor	
Operation Range*	-20° to 70°C (-4° to 158°F) in air; maximum sustained temperature of 30°C (86°F) in water*
Accuracy	±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F), see Plot A
Resolution	0.02°C at 25°C (0.04°F at 77°F), see Plot A
Response Time	5 minutes in water; 12 minutes in air moving 2 m/sec; 20 minutes in air moving 1 m/sec (typical to 90%)
Stability (Drift)	0.1°C (0.18°F) per year
Logger	
Real-time Clock	±1 minute per month 0° to 50°C (32° to 122°F)
Battery	3 Volt lithium, non-replaceable
Battery Life (Typical Use)	5 years with 1 minute or greater logging interval
Memory (Non-volatile)	64K bytes memory (approx. 42,000 12-bit temperature measurements)
Weight	19.6 g (0.69 oz)
Dimensions	3.0 × 4.1 × 1.7 cm (1.2 × 1.6 × 0.68 in.); mounting bail 4.6 mm (3/16 in.) diameter hole
Wetted Materials	Epoxy case
Waterproof	To 305 m (1000 ft.)
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to HOBOware software manual.
Launch Modes	Immediate start, delayed start, triggered start
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery level can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
NIST Certificate	Available for additional charge
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

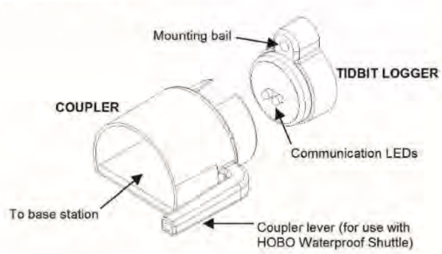
* To guarantee accuracy, the TidbiT v2 Temp must not be used in condensing environments and water temperatures higher than 30C (86F) for more than eight cumulative weeks over the life of the logger. Frequent or prolonged exposure will lead to measurement drift and eventual failure.



Plot A

Connecting the Logger

1. Install the logger software on your computer before proceeding.
2. Follow the instructions that came with your base station or shuttle to attach the base station or shuttle to a USB port on the computer.
3. Wipe the logger with a nonabrasive cloth, if necessary, to ensure that the logger's communication LEDs are clean and dry.
4. Attach the coupler to the base station, then insert the logger into the coupler with the communication LEDs facing into the coupler, as shown in the diagram.



10385-G MAN-UTBI-001

When properly seated, the logger should be nearly flush with the top of the coupler.

5. If you are using the HOBO Waterproof Shuttle, briefly press the coupler lever to put the shuttle into base station mode.
6. If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.
7. Use the logger software to launch the logger, check the logger's status, read it out, stop it manually with the software, or let it record data until the memory is full. Or, use the HOBO Waterproof Shuttle to read out and relaunch the logger in the field.

Refer to the software user's guide for complete details on launching, reading out, and viewing data from the logger.

Important: USB communications may not function properly at temperatures below 0°C (32°F) or above 50°C (122°F).

Note: The logger consumes significantly more battery power when it is "awake" and connected to a base station or shuttle. To conserve power, the logger will go into a low-power (sleep) mode if there has been no communication with your computer for 30 minutes. To wake up the logger, remove the logger from the coupler, wait a moment, then re-insert the logger.

Note: The first time you launch the logger, the deployment number will be greater than zero. Onset launches the loggers to test them prior to shipping.

Operation

An "OK" light (LED) on the front of the logger confirms logger operation. (In brightly lit areas, it may be necessary to shade the logger to see the "OK" light blink.) The following table explains when the "OK" light blinks during logger operation:

When:	The light:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample
The logger is awaiting a start because it was configured to start logging At Interval, On Date/Time, or Using Coupler	Blinks once every eight seconds until logging begins

Triggered Launch

The TidbiT v2 Temp has an optional triggered launch. Launch your logger choosing the Using Coupler option. The magnetically operated reed switch is activated when the Tidbit Coupler is reconnected to the logger for 2 seconds and then removed. The base station and coupler are not necessary to trigger the launch. Any strong magnet placed near the face of the logger will trigger the launch. The TidbiT v2 Temp's red LED light will rapidly flash four times to indicate successful triggered launch.

Sample and Event Logging

The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval (for example, temperature every minute). Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

The logger stores 64K of data, and can record over 42,000 12-bit temperature measurements.

Deploying and Protecting the Logger

- Depending on water conditions and desired measurement location, the logger should be appropriately weighted, secured, and protected.
- The mounting bail on the logger accepts 1/8 inch (4 mm) diameter nylon cord or other strong cable. If wire is used to secure the logger, make sure the wire loop is snug to the bail. Any slack in the loop may cause excessive wear.
- This logger should not be immersed in any liquid other than fresh or salt water. To do so may damage the epoxy case and void the warranty (refer to the Service and Support section). If you have any questions about chemical resistance, call Onset.
- To clean the logger, rinse it in warm water. Use a mild dishwashing detergent if necessary. Do not use harsh chemicals, solvents, or abrasives, especially on the communications LEDs.

Battery

The battery in the TidbiT v2 Temp is a non-replaceable 3-Volt lithium battery. The battery life of the logger should be about five years. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. To obtain a five-year battery life, a logging interval of one minute or greater should be used and the logger should be operated and stored at temperatures between 0° and 25°C (32° and 77°F). Frequent deployments with logging intervals of less than one minute, and continuous storage/operation at temperatures above 35°C, will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

The logger can report and log the battery voltage. If the battery falls below 2.7 V, the logger will record a "bad battery" event in the datafile. If the battery fails, dispose of the logger according to local regulations. Do not attempt to open the logger case. The battery is not replaceable, and the logger does not contain any user-serviceable parts. If you open the case, the logger will be unusable, and the warranty will be voided.

WARNING: Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

APPENDIX E

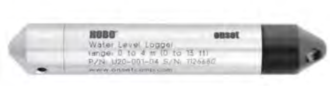
HOBO LEVEL LOGGER, PERENNIAL AND NON-PERENNIAL STREAM, STANDARD OPERATING PROCEDURES AND DEPLOYMENT

Purpose

This APPENDIX describes the procedures for deploying Water Level Data Loggers (HOBOS) in order to study the hydrology of non-perennial streams. Stream discharge will be estimated using HOBO Water Level Data Loggers.

Equipment and Supplies

The HOBO® U20 Water Level Logger consists of a pressure transducer, internal battery, and internal memory for data storage. The logger records pressure, which is translated to water level. Water level information must be corrected to account for barometric pressure differences. Once corrected, a rating curve must be obtained or constructed in order to convert water level (stage) information to discharge. It is preferable to take discharge measurements in sections where flow velocities are greater than 0.15 m/s and most depths are greater than 15 cm, but slower velocities and shallower depths can be used.



Calibration and Pre-deployment Checklist

Calibration of HOBO® U20 Water Level Logger

Each The HOBO® U20 Water Level Logger is calibrated and checked by the manufacturer and certified with a certificate of calibration. The relevant calibration information is stored in the data logger's non-volatile memory. The HOBO® U20 Water Level Logger manual details how each device is checked for accuracy. The HOBO can only be calibrated by the manufacturer, and therefore cannot be calibrated by the field crew. If recalibration is necessary, then the HOBO has to be sent to the manufacturer. Each HOBO is also recalibrated at the factory when the unit is submitted for battery replacement.

During calibration, raw pressure sensor data is collected at multiple pressures and temperatures over the calibrated range of the logger (see the specifications table). This data is used to generate calibration coefficients that are stored in the logger's non-volatile memory. The calibration coefficients are then checked to be sure that the logger meets its stated accuracy over the calibrated range.

Setup

Prior to deployment in the field, each data logger must undergo the following setup procedures (detailed in the manual on page 3).

Before you deploy the HOBO U20 Water Level Logger in the field, perform the following steps in the office:

1. Start HOBOware.
2. Connect the logger to the computer. (See the next section)
3. Verify the status. Click Status on the toolbar and observe that the absolute pressure is near barometric pressure for the location and the temperature is near the actual temperature.

Launch the logger. See the HOBOware User's Guide for details.

- Make sure both Abs. Pressure and Temperature are selected (temperature is required for temperature compensation of pressure).
- Logging Battery Voltage is not essential since you can check the battery voltage using the Status screen at launch or readout of logger.

Measurement Time Step

HOBOs can be set to record data at a range of time steps. Shorter time steps translate to increased battery consumption and shorter deployment periods. The recommended time step for most deployments is 15 min, however a 60 min. time step can be used for extended deployments (i.e. longer than 2 years). Typical deployment duration for this study is 6 months, and therefore the data loggers will use a time step of 60 minutes. The data logging interval must be set before the logger is deployed.

Measurements

Site Selection Criterion

Criteria for site selection for continuous monitoring:

HOBO U20 Data Loggers will be installed at most of the non-perennial stream sites.

The following criteria have been developed to assist in site selection:

- Sample sites for this project are non-perennial Reference sites.
- Sampling sites need to be easily accessible to field crews, however the potential for vandalism needs to be minimized;
- The location of the monitoring station must be recorded with a GPS unit;
- Reconnaissance of sample sites will be conducted before deploying the HOBO.

HOBO U20 Water Level Logger Deployment Procedure

Stilling Well

Data loggers must be installed in a stilling well in order to protect the logger from vibration, shock, and movement. A stilling well typically consists of a perforated, vertical PVC pipe, stabilized by partially burying it in the stream substrate or bolted to a stable object (such as a rock or tree). The manufacturer of the data loggers have developed a “Technical Application Note for Constructing a Stilling Well” which covers in detail the construction and application these devices. Available online: http://www.onsetcomp.com/water_level_stilling_well.html.
Loggers should be deployed either vertically or horizontally at a level where they will remain submerged for as long as possible. The stilling well should be secured with a locking cap to minimize potential for vandalism.
Yukon Government, Compliance Monitoring & Inspection, Water Quality staff can provide installation alternatives to you if using stilling wells prove to be impractical in some applications. Please contact them directly for more information.

Deploying the Data Logger:

A piece of PVC pipe will be installed at each flow monitoring location to serve as a mounting platform for the HOBO. Each mounting platform will have a hole drilled at a specific distance off the bottom of the stream. Record this distance on the data sheet each time you go to service the HOBO.

1. Place the HOBO into the PVC casing. Align the holes on each of the end caps with the holes on the casing and secure them with cable ties. Place a third cable-tie through the holes in the casing, around the HOBO to gently secure it in the center of the casing.

2. Attach the casing to the PVC pipe.

3. Periodically inspect the logger for fouling. Biological growth on the face of the sensor will throw off the sensor's accuracy.

5. The logger can be damaged by shock and may lose accuracy if dropped. If your HOBO is dropped or otherwise damaged, the data logger has to be replaced.

6. To obtain the highest level of accuracy, the logger should be allowed to come to full temperature equilibrium (approximately 30 min) before any reference levels are recorded.

Data Logger Operation:

A light in the communication window of the logger confirms logger operation. The following table explains when the logger blinks during operation:

When:	The Light:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when
The logger is awaiting a start because it is launched in Start At Interval or Delay Start mode	Blinks once every eight seconds until logging begins

Periodic Data Retrieval and Data Logger Maintenance

Data loggers will be retrieved on a monthly basis to perform data retrieval and routine maintenance and inspection of the device. The HOBOs will then be re-deployed at the same location at the site. Following retrieval of data, the following routine maintenance will be performed on each data logger.

- Inspect the logger for evidence of biofouling (growth of organisms on the sensor). If evidence of biofouling is present, the data logger must be cleaned prior to redeployment.

- Review the battery data collected during deployment to confirm the battery is not going bad (see-Battery Maintenance and Replacement).
- The HOBO will then be re-deployed again at the same location at the site (if possible). No field calibration checks are conducted before re-deployment of the HOBO.

Battery Maintenance and Replacement

Under optimal conditions, the stated battery life of the data logger is 5 years. Battery life may be significantly shorter depending on conditions and frequency of deployment and therefore needs to be checked prior to each season's deployment. The data logger logs and reports its battery voltage. Battery voltage information is downloaded when the HOBO is retrieved and evaluated prior to re-deployment. A new battery will record a voltage of 3.6 V. A battery is considered to be bad or in the process of going bad if:

- The battery voltage falls below 3.1 V. If this occurs, the data logger will record a "bad battery" event in the data file.
- The battery voltage repeatedly falls below 3.3 V.

If a data logger's battery is showing signs of failure, the logger must be returned to the manufacturer for battery replacement and recalibration. As an additional precaution, batteries should be replaced by the manufacturer at four year intervals or less.

Quality Assurance / Quality Control

Reporting Limits

The following reporting limits have been provided by the manufacturer:

Absolute Pressure: 0.02 kPa

Temperature: 0.10 °C at 25 °C

Water Level (Calculated): 0.21 cm

Measurement Range and Accuracy

HOBOs can be deployed in up to 10 m of water.

The reported accuracy is ±0.05% FS, 0.5 cm (0.015 ft) water with a maximum error:

±0.1% FS, 1.0 cm (0.03 ft) water.

Reported resolution = < 0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water

Verification of Accuracy and Compensation of Drift

In order to collect information on the accuracy and instrument calibration drift, two loggers to be deployed at the same site and at the same depth. The loggers will be deployed no farther than 1 meter apart. The data collected by the pair of loggers will be evaluated based on comparability of the results. Three sites will be selected for deploying two HOBOs in tandem.

Barometric Correction

The pressure measured by the HOBO needs to be corrected using the barometric pressure data collected from the weather station closest to each site.

Documentation and Records

The following data will be recorded in a data logger logbook before the HOBOs will be deployed for the first time: (1) serial number of HOBO; (2) calibration from manufacturer; (3) GPS location; (4) picture; and (5) day and time of first deployment.

When data is retrieved from the data sondes, the following information will be recorded in the data logger logbook: (1) serial number of HOBO; (2) GPS location, (3) day and time of data retrieval, (4) battery status; (5) any maintenance procedures; (6) GPS location of redeployment; and (7) pictures before retrieval, and after redeployment.

Reporting

Data Download

Continuous data measurements will be collected during this project and downloaded from the moored data loggers monthly (at minimum) using HOBOware Pro software. Original data loggers files will be stored as .hobo files and manipulated data logger data files will be stored as .csv or Microsoft Excel files.

Connecting the logger to a laptop computer

The logger requires an USB-Optic Base Station to connect to the computer. The computer must have the HOBO software installed.

- Plug the base station cable into a USB port on the computer.
- Unscrew the black plastic end from the logger by turning it counter-clockwise.
- Insert the logger with the flat on the logger and the base station aligned. Gently twist to make sure it is fully seated in the base station.
- Use the logger software to launch the logger.
- Program the logger to record a depth measurement every 60 minutes.
- The HOBO pressure gauge records absolute pressure which is converted to water level by the HOBO software. You will need to download barometric pressure from a nearby Meteorological station (within 4.8 Km of the HOBO station). If you do not have a local Met station, we will need to deploy a second HOBO to record the ambient air pressure.
- Use software to upload data as necessary.
- Check the battery voltage; if a battery falls below 3.1 V the logger will record “bad battery” in the data file. If the battery is failing, it will need to be replaced by the manufacturer.

Temperature Compensation Accuracy

HOBOs measurements are accurate between 0 and 40^{o}C without need for post-process compensation.

Data Processing

Data Processing will utilize HOBOware Pro, with Post-Processing done with the HOBOware Barometric Compensation Assistant. The HOBOware Barometric Compensation Assistant utilizes paired data logger, or weather station, barometric pressure readings with water type and temperature to calculate water depth over time.

Need for Barometric Correction

Water level measurements must be corrected for normal variation in barometric pressure. The preferred approach is to install a second HOBO data logger in the stilling well in the ambient air column at a level where it will not be submerged. If there is a local weather stations nearby, and at a similar elevation and setting, barometric pressure data from that station can be used for the correction. The location, elevation, and setting of the weather station relative to the position of the data logger installation should be recorded.

Rating Curve Construction

Specific sites may have site-specific discharge (flow, CFS) rating curves developed in order to determine flow rates. Curves are developed by measuring on-site current velocities for a specified stream cross-section while at the same time measuring corresponding stream water levels. This allows flow to be calculated at sites using water level data collected by the data loggers. Development of rating curves requires multiple trips to each site to capture varying discharge rates. Figure 1 shows an example of a rating curve.

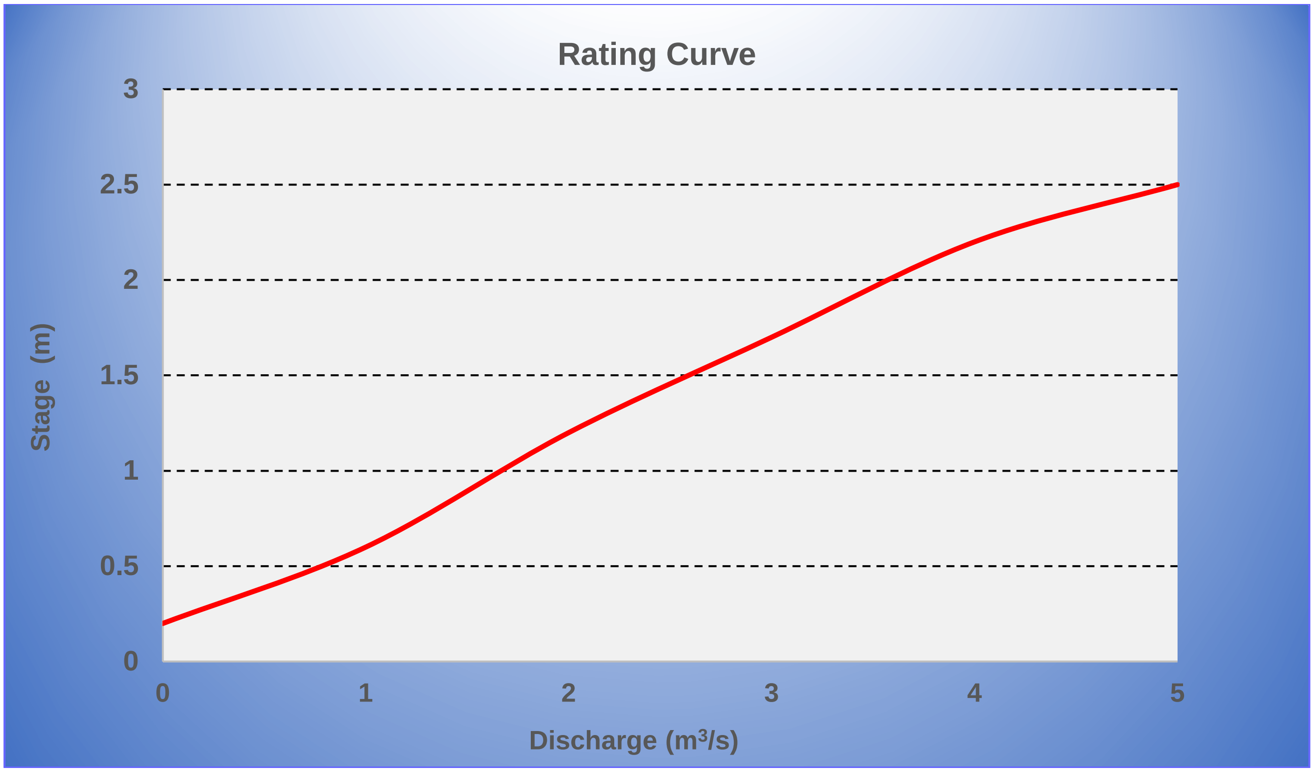


Fig. 1: Example of a rating curve

Flow calculations will follow the SOP detailed in Appendix B

The discharge will be measured as follows:

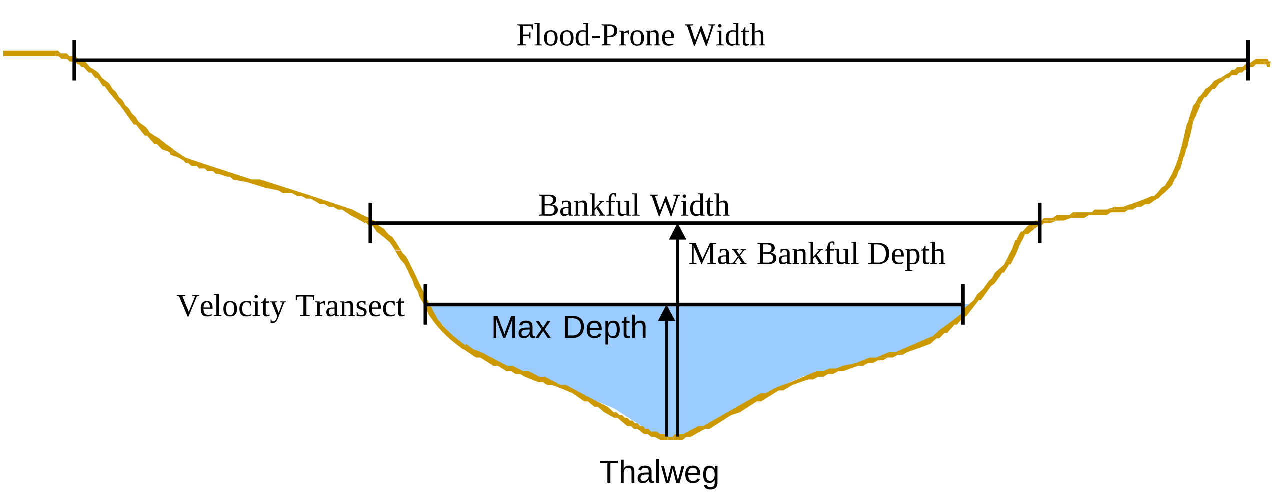


Fig. 2: Diagram of channel cross-section

Channel Profile:

- Place the transect tape across the channel and record the bankful width on the Data Sheet
    - Facing upstream, the left bank should represent the 0 m.
- Keeping the measuring tape tight across the channel at bankful stage, measure and record the bankful depth at the maximum bankful depth at the channel thalweg.
    - Note that this measurement will be necessary each time the site is visited as the channel profile will change over time due to sedimentation or scouring.

APPENDIX F

AUTOMATED WATER SAMPLING

In many environmental monitoring and research programs, water samples are commonly collected, either manually (grab samples) or with automated samplers. An automated sampler is a portable unit that can be programmed to collect discrete sequential samples, time-composite samples or flow-composite samples, in various volumes and at various timed intervals.

Manual sampling in remote areas can be labour intensive and time consuming, whereas the price of automated samplers (around $4,000 Cnd) may be prohibitive to many monitoring programs. Receiving water and effluent discharge water samples can be collected by manual grab or automatic samplers, the latter being more directly expensive, but often superior when conditions fluctuate rapidly or sporadically, or when available personnel are lacking. Automatic samplers are essential for the WQO program when effluents are monitored for permit requirements.

Many types of automatic samplers exist and none are ideally suited for all situations. The following variables must be considered when selecting a sampler:

- Water or effluent variation (flow and constituents)
- Suspended solids concentration, dissolved gases, and specific gravity of effluent
- Vertical lift required
- Maintenance

Automatic Water Sampling Equipment

Automatic water samplers that are commonly used for storm water monitoring are available from ISCO Teledyne and American Sigma, amongst others. These manufactures have samplers that have very flexible programming capabilities specifically designed for storm water sampling and are designed for priority pollutant sampling. Both of these units can be easily adapted for surface water sampling.

ISCO also offers a complete line of automatic water samplers that have been used for storm water sampling for many years. Flow meter and rain gage options are available, along with numerous sample base and sample bottle options.
Sigma and ISCO also have new automatic samplers that interface with continuously recording water quality probes that can be used to control sampling during critical periods, irrespective of time or flow.

American Sigma has many options for using numerous probes (such as conductivity, DO, temperature, ORP, and pH).
The sampler can be programmed to collect a special sample when any of these monitored parameters meets a pre-set criterion.

ISCO has a new sampler series that interfaces with the YSI 6000 water quality probes, allowing specific water quality conditions to also trigger sampling (similar to Sigma’s list, plus turbidity).

Currently, the Water Quality Objective Monitoring program is using ISCO model 6712 samplers exclusively for all automatic sampling. The Yukon Government, Compliance Monitoring & Inspection, Water Quality staff can provide you with examples of installation and deployment alternatives, programing set up and field calibration techniques. Please contact them directly for more information.