CAPSTONE MINING CORP.

MINTO MINE

MINTO MINE
SURFACE WATER HYDROLOGY
STANDARD OPERATING PROCEDURES

Prepared by:

Minto Explorations Ltd

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1. Purpose

The standard operating procedures (SOP) in this document serve as a guideline for the collection of water quantity (flow, discharge) data from water bodies at Minto Mine (Minto) specified by Water Use Licence QZ96-006. Water quantity data is critical for a variety of assessment and planning purposes at Minto and is used to interpret water quality data, prepare site water balances, create operating plans, etc. The Minto Mine Hydrology SOP follows methods and procedures described in Guidance Document for Flow Measurement of Metal Mining Effluents (Environment Canada, 2001) and Manual of British Columbia Hydrometric Standards (RISC, 2009). This document is intended for Minto Mine employees familiar with the location of hydrology stations and the data collection methods outlined in this document. Along with on the job training, this SOP will to ensure that surface water hydrology data at Minto Mine is collected consistently and the data produced is reliable and representative.

2. Responsibilities

The quality of flow measurements and water quantity data collected at Minto Mine is dependent on the staff involved and the attention given to field procedures, field equipment, and quality control protocols. It is crucial that flow measurements be carried out in a consistent manner with the appropriate equipment to generate the most accurate results.

The following is a typical allocation of responsibilities associated with the collection of surface water hydrology data at Minto:

Field Staff

Field staff must have the appropriate knowledge and training to take precise flow measurements and collect representative data while minimizing field error as much as possible. This includes following all procedures correctly and consistently, correct use of field equipment, and completion of detailed field notes.

Field staff are responsible for coordinating all station visits in accordance with the requirements of the current WUL, including sampling locations, sampling frequency, etc. Staff performing station visits shall ensure that all site conditions and other required information are clearly documented, and that all quality assurance and quality control (QA/QC) protocols are being followed.

Field staff must be experienced in the operation and maintenance of all field instruments and the equipment used for measuring water quantity data. They are responsible for maintaining equipment and identifying equipment malfunction.

Field staff are also responsible for performing data entry related to surface water hydrology on site.

Supervisors

Supervisors are responsible for ensuring field staff understand the requirements of the WUL and that all procedures and protocols are being followed and documented. Supervisors are responsible for ensuring data collection and data management procedures are being carried out consistently and identifying variance from standard procedures.

Supervisors are responsible for providing appropriate levels of training to all field staff and ensuring that all field staff are proficient to carry out their responsibilities or are adequately supervised. This is especially important when field staff are processing data and completing field activities such as station installs and surveying.

It is the responsibility of supervisors to compare water quantity data collected throughout the year and review trends, outliers, etc. This is often completed with input from external professionals.

Supervisors must also periodically review data collection procedures including the content of this SOP to ensure the best methods are being used and that adequate QA/QC is being incorporated into the program.

3. Hydrometric Station Installation

There are many factors to consider when selecting and installing a hydrometric station in an open channel. Hydrometric stations at Minto typically consist of a pressure sensor and data logger installed in a perforated PVC tube. This instrumentation is accompanied by a staff gauge. All components are attached to a wooden frame and anchored to shore. Minto currently consults with external professionals regarding the establishment of new stations, however the following guidelines will be considered by trained Minto staff when selecting and installing hydrometric stations:

- Site can be accessed safely by field staff through the full range of stage;
- Site is located where the stream cross-section is stable, typically in a pool or run, avoiding turbulent riffle or cascade sections;
- The staff gauge and pressure sensor are able to record accurate water levels through the full range of stage and discharge can be accurately measured at all stages using acceptable flow measurement methods;
- All station components are structurally sound and will not move in any direction;
- Install staff gauges so they are protected from damage by floating debris and ice and are not affected by drawdown or pileup of water. It is typically easiest to read the staff gauge with the face parallel to the current;

- Ideally the depth and velocity of the stream should be fairly uniform with good cross-sections for flow measurements using a flow meter (e.g. single channel, no undercut banks, minimal obstructions, no backwater eddies); and
- No tributaries exist between the hydrometric station and wading cross-sections.

4. Field Instruments

All instruments used for collecting water quantity data are used and maintained according to the manufacturer's specifications. Prior to departure for sampling, staff will ensure that all field equipment is checked for functionality.

Minto currently uses a Hach FH950 Electromagnetic Velocity Meter (current meter) with a top-setting wading rod to perform manual discharge measurements whenever possible. Electromagnetic current meters are factory calibrated and require little maintenance. The Hach FH950 current meter performs a diagnostic self-test each time it is powered on and instructions for checking zero velocity settings are provided in the user manual. Records of all checks and maintenance are stored on site.

Continuous water level readings and barometric pressure are recorded using Solinst data loggers for open channels and inline flow meters for pipe flows. These instruments are received factory tested and calibrated, and are installed, programmed and maintained according to the manufacturer. All information provided with the flow measurement equipment is kept and stored on site.

5. Safety

Wading is the most common method for taking flow measurements at Minto and can also be one of the most dangerous. It is strongly recommended that two people conduct flow measurements, particularly during high flows. Waders with wading belts, safety lines and life vests are available for all staff. Always explore the streambed for large obstacles or holes while wading carefully into the stream. Stream substrates are often slippery. If it is safe to wade the stream then the measurement can begin. Always assess and mitigate safety risks.

When the stream is too high and/or too swift for wading, then either an alternative method should be used or the measurement should not be taken. If conditions do not seem safe or you are unsure, do not attempt to wade the stream. If it is possible to take a measurement from shore, always ensure safe footing and solid points of contact.

6. Field Notes and Photographic Record

Detailed documentation of conditions and observations during station visits is necessary to ensure the quality and accuracy of the data collected. Field staff are responsible for thoroughly documenting site conditions including staff stage readings, stream characteristics up and downstream of the flow measurement site, weather conditions, deviation from standard procedures, and any other significant details about the visit. Standard field forms are used to ensure all the required information is collected. A current copy of the Minto Mine Hydrology Field Form is provided in Appendix 1.

All field notes should be completed at the station immediately following the observations. Field notes must be clear, concise, and include the station name, date and time. It is good practice to refrain from erasing mistakes when recording field notes. Crossing out the error and rerecording the data is preferred. Field notes are entered into the Minto Water Quantity Database upon return from the field and all field notes and field forms are stored on site.

Data logger files downloaded from the pressure sensors should be transferred immediately from the field laptop or Solinst handheld and saved with the correct file names to the appropriate location on the server.

Photographs should be taken to document current conditions at each station. At a minimum, photos must be taken to show changes in physical conditions around the station. Photos from one station visit will typically include one upstream and one downstream facing shot. Aerial photos should also be taken when the opportunity is available. Photographs are stored in digital format and must be accurately labelled by field staff upon return from the field.

7. Water Quantity Data Collection Methods

An explanation of the water quantity data collection methods carried out at Minto Mine and detailed procedures for each method are described in this section.

Staff Gauges

Staff gauges are used to record the stage (water level) of a water body. All discharge measurements and continuous water level readings are referenced to the staff gauge, therefore it is extremely important to read the staff gauge carefully and correctly each visit. Taking a photograph of the water level on the staff gauge is a useful reference in the field for ensuring accurate readings. Staff gauge readings should be taken before and after flow measurements as water levels can change in a small amount of time. Always record stage to three decimal places and document the exact time the reading was taken.

Depending on the orientation of the staff gauge, high flow conditions may sometimes result in water stacking up on the gauge. Readings should be taken at the downstream side of the gauge where the water is calmer.

It is also possible to have no surface flow when the station is visited. These conditions are very important to developing accurate discharge records. Zero flow conditions must be thoroughly documented and photographed. It is also possible to read a water level on a staff gauge when there is no visible flow. This must also be thoroughly documented if encountered.

Surveying and Tracking Staff Gauge Drift

Due to ice movement and natural freeze-thaw cycles, staff gauges are subject to move or drift over time. If a staff gauge moves the reference elevation to which all other measurements and records at that site are compared to changes. Always document conditions that may suggest the staff gauge moved in any direction. Photos and any estimates of amount and direction of drift are very useful when correcting data records and planning repairs.

Annual surveying of staff gauge elevation (typically in the spring) tracks changes in staff gauge location and allows for correction of water level records if needed. Detailed procedures for level surveys are not provided in this SOP; however the following elevation points must be collected:

- Elevation of 0.000m on the staff gauge (should be relative to an arbitrary elevation assigned to a benchmark in the area, typically a spike in the base of a large nearby tree);
- Elevations of at least two benchmarks; and
- Elevation of the water surface at the gauge;

Bench marks are permanent reference points with known elevations. They are established at each station in a stable location close enough to the gauge to allow for efficient surveying, anchored where they are not likely to move or be damaged. The ability of the benchmark to maintain its position in the local environment is essential. At Minto, benchmarks are typically a spike or lag bolt in a mature tree.

Discharge Measurement using a Current Meter

Minto uses the mid-section method for measuring flows using a current meter. This is a standard discharge measurement technique where the depth and velocity are measured at a number of verticals along a cross-section. Velocity measurements at a percentage of the stream depth are assumed to represent the average velocity through the vertical water column. Accurate current metering is critical to the accuracy of the discharge measurement.

Preparation

Upon arrival at the site, field staff will conduct an overall station inspection. Observing and documenting the overall channel conditions will help identify conditions that may affect the measurement and the stage-discharge relationship. Assessing channel conditions is also important in deciding whether or not it is safe to complete the measurement. This includes the presence of aquatic plants and floating debris, any obstructions in the stream, and signs of channel bank erosion and deposition in vicinity of the station.

Field staff are responsible for selecting the best cross-section to carry out discharge measurements during each station visit. The location of the cross-section often varies with changes in water levels or channel conditions.

The best sections for low, medium, and high flow measurements should be established and used as much as possible.

Make a preliminary crossing before stringing the tagline. Try to obtain an overall impression of the depths and velocities while wading. Select an appropriate cross-section where the bed and banks of the watercourse are straight and uniform and the channel bed is free from vegetation, immovable rocks, and other obstructions. Avoid muddy and sandy bottoms, backwater eddies, obstacles, etc. as much as possible.

Improve the cross-section by removing boulders and debris from the section and the area immediately above it. Remove significant vegetation from the area upstream and downstream from the section. On smaller watercourses it may be possible to construct small dikes to cut off sections of shallow flows and dead water. Once complete, allow sufficient time for conditions to stabilize before proceeding with the measurement. Improvements should not affect the staff gauge reading. Do not make changes to the cross-section during the course of the discharge measurement.

Performing the measurement

Proceed with the measurement as follows:

1. Note the date and time and record the staff gauge reading. This step is absolutely essential for plotting the results of the discharge measurement.

2. Secure the tagline (measuring tape) on either shore and string it across channel perpendicular to the direction of flow. Determine the overall width of the metering section. Assess the approximate spacing of the verticals, according to the channel width and flow pattern.

3. Record the distance along the tagline of the left or right bank. Left and right bank are determined facing downstream. If there is a steep drop at the edge of the stream, the first "vertical" depth and velocity observation should be taken as close to the edge as possible.

4. Begin the measurement at the first vertical along the tagline. Record the distance of the reading along the tagline then measure and record the water depth at each location using the wading rod. The water depth is the point where the water surface intersects the rod. Observations should be made to the nearest centimeter. This is used to calculate the total cross-sectional area.

5. Where water depth in the vertical is <1.0 m, observations are made at 0.6 depth from the water surface. To position the current meter sensor correctly, adjust the sliding rod to line up the scale on the rod to the value of the observed depth. Detailed instructions on how to adjust the rod are provided by the manufacturer.

6. Where water depth in the vertical is >1.0 m, the velocity is measured at both 0.2 and 0.8 depth from the water surface and the mean velocity is calculated. To set the current meter on 0.2 depth position, double

the value of the observed depth and adjust the sliding rod to line up the scale to read this value. For 0.8 depth position the scale to read half of the observed depth.

Note: The 0.2-0.8 method is not entirely satisfactory if the channel bed is very rough, irregular, or covered with aquatic growth. These conditions will often produce erratic results for the observation at the 0.8 depth. In some situations, more reliable results will be obtained by computing the average velocity on the basis of the 0.2 and 0.8 depths and averaging the computed value with the velocity from the 0.6 depth. This is known as the three-point method.

7. Allow sufficient time for the current meter to adjust to water conditions. Observe velocities for a minimum of forty seconds. The adjustment time will be a relatively short at high velocities and significantly longer at low velocities.

8. Continue the measurements across the stream until you reach the opposite bank and record the distance on the tagline. After taking the discharge measurement record the second staff gauge reading and the time.

9. After the measurement, download data logger readings, record real time data from the Solinst data logger, and service the instrument by checking the battery voltage and inspecting all of the cables and connections. During every visit to a hydrometric station, a complete inspection of the data logger and all related components should be conducted. Any sign of malfunction or deterioration of the station components must be recorded and repaired as soon as possible.

To obtain accurate measurements by wading, field staff must pay attention to detail and technique. There are many things to consider and numerous opportunities for error. The following guidelines will help obtain reliable results:

Number and Spacing of Verticals

All discharge measurements should include 20 verticals with no less than 10 observations of both depth and velocity for most cross-sections. The distance between verticals must be at least 5 cm when using the Hach FH950 current meter (equal to or greater than the width of the current meter).

The spacing of verticals along the metering section is not usually uniform. Where the water is shallow and/or slow moving, the spacing will be greater than where the water is deep and swift. Spacing depends largely on the several factors including overall width of the stream, unevenness of the channel bed, and variation in velocity across the channel.

Position of Field Staff

Field staff should stand to the side and downstream of the current meter to prevent any interference or effect on velocity readings. In very small channels the presence of a person in the water may significantly affect the flow measurement. In this case a plank can be placed across the stream for field staff to stand on.

Position of the current meter

Hold the wading rod in a vertical position and the current meter parallel to the direction of flow while measuring velocity.

Uneven Channel Bed

Measuring depths in a channel bed that is extremely soft or scattered with boulders requires extra attention. Be careful not to allow the bottom of the wading rod to sink into soft channel bed material. If the channel bed is very rough, take time to adjust the width of verticals so the observed depths so reflect the tops of the boulders and the depths between them.

Rated Structure

Minto currently has a prefabricated flume combined with a pressure sensor constructed in a four season shelter at W3. Water levels are read off an embedded staff gauge on the flume during each visit.

For optimal performance the flume floor and walls should be kept clean and free of sediment and algae growth and upstream of the structure should be kept free of sediment accumulation and debris.

Volumetric Measurements

Volumetric measurements are taken at the outlets of elevated pipes and culverts, and periodically at select stations when appropriate. This method involves collecting water in a container of known volume and recording the time it takes to fill in seconds. There must be a minimum of three trials to produce an average time. Volumetric containers should be calibrated and stopwatches should be water resistant.

8. Data Processing

Hydrology data is compiled by Minto Mine staff on a monthly and yearly basis, including discharge calculations and water level record corrections. Processing data into stage discharge curves, hydrographs, and other discharge records is presently completed or largely supported by a third party (Access Consulting Group) and is not included in this SOP.

Discharge Calculations

Discharge is defined as the volume of water flowing through a given cross-section of a stream over a given period of time. Discharge is typically expressed in L/s or m3/s. For any stream location there is a correlation between water level and discharge called the stage-discharge relationship. Once this is established, discharge can be estimated from recorded water levels and staff gauge readings to create a continuous discharge record. To develop this relationship, manual discharge measurements are obtained at the hydrometric station over the maximum range of stage possible. These corresponding points are graphed, then a stage-discharge curve can be drawn that best represents these points.

All field data from station visits is entered into the Minto Water Quantity Database and processed into discharge values using a template and standard formulas in Excel. Care must be taken to ensure the formulas are not modified during data entry.

Current Meter Measurements

The mid-section method allows for mean discharge (Q) to be calculated by multiplying the mean stream velocity (V) and the cross-sectional area (A); thus Q=VA. In this method the stream is divided into a number of panels. The flow in each panel is calculated by multiplying the mean velocity measured at each vertical by the corresponding width measured along the surface tape or cord. This width should be equal to the sum of half the distance between adjacent verticals. The velocity in the two half widths next to the banks can be estimated. For a detailed description of the mid-section method of computing discharge measurements, please refer to the Manual of British Columbia Hydrometric Standards (RISC, 2009).

Table 1 illustrates an example of a completed discharge calculation for a current meter measurement.

Table 1 Discharge Calculation

Site:	MC1	Start Time:		Staff Gauge:	0.249
Date:	8-Aug-12	End Time:	16:50	Staff Gauge:	0.249
Observations		Calculations		Samplers:	CB/PE
Tape Distance (m)	Depth (m)	Width (m)	Area (m^2)	Velocity (m/sec)	Discharge (m^3/s)
0.46	0	LB			
0.60	0.06	0.12	0.01	0.062	0.000
0.70	0.10	0.10	0.01	0.150	0.002
0.80	0.14	0.10	0.01	0.131	0.002
0.90	0.11	0.10	0.01	0.186	0.002
1.00	0.10	0.10	0.01	0.216	0.002
1.10	0.12	0.10	0.01	0.282	0.003
1.20	0.08	0.10	0.01	0.278	0.002
1.30	0.14	0.10	0.01	0.271	0.004
1.40	0.15	0.10	0.02	0.203	0.003
1.50	0.14	0.10	0.01	0.141	0.002
1.60	0.15	0.10	0.02	0.262	0.004
1.70	0.13	0.10	0.01	0.226	0.003
1.80	0.13	0.10	0.01	0.182	0.002
1.90	0.08	0.10	0.01	0.050	0.000
2.00	0.00	RB			
		Total Discharge (m^3/s)			0.0320

Continuous Water Level and Inline Pipe Flow Meter Data

Continuous water level readings from pressure sensors and inline flow meters are downloaded and compensated as needed using the manufacturer's software. At this time, instructions for compensating this data are not included in this SOP.

All continuous water level readings from pressure sensors require reference to the water level during station visits. Therefore, staff gauge readings must be accurate and always documented including the time of the observation. Basically, water level data is compensated by calculating the difference between the pressure sensor water depth and staff gauge reading for each point in time and the average of all these differences can be applied to the entire data record as a single offset adjustment.

Volumetric Measurements

To calculate discharge from a volumetric measurement the following formula is used:

Discharge = Volume of container (litres) / Average time to fill (seconds)

9. Quality Assurance and Quality Control

The Minto Quality Assurance and Quality Control plan has been created to provide confidence in the data collected for all environmental monitoring and sampling programs. QA/QC is an integral component to quality surface water hydrology data.

Quality Control

Quality control protocols are the set of routine procedures and methods designed to achieve and maintain a recognized level of quality. Therefore, the collection of reliable surface water hydrology data at Minto is accomplished by following the procedures described in this document.

For current meter measurements, errors in the measurement of width, depth, and velocity as well as the lack of care in choosing the number of verticals and observations in a vertical, all combine to reduce the overall accuracy of water quantity data. To a large extent, human errors can be avoided by careful attention to detail and by adhering to established and proven techniques and routines. Systematic errors can be reduced significantly by proper maintenance and calibration of instruments and equipment, and by adequate training. However, random errors will always occur. A significant reduction in these errors can be achieved if field staff performing the measurement can recognize the potential problem areas and can take the appropriate precautionary measures to avoid or minimize them. For a detailed description of common factors that lead to inaccuracies in current meter discharge measurements, please refer to the Manual of British Columbia Hydrometric Standards (RISC, 2009).

Quality Assurance

Quality assurance includes the procedures that provide a check on the quality of the data produced. Minto Mine is continuously involved in consultation with professionals and technical experts regarding program design, standard operating procedures, and data review. Ongoing staff training and inspections of staff (especially new hires) performing data collection activities help to ensure the results are consistent, representative and high quality.

Standardized management of data collected in the field is important in hydrological monitoring programs. Standard protocols and systems make the task of data processing easier and less likely prone to error. Processing of data often involves returning to the original field notes to cross check suspicious values or to analyze site conditions that might have been responsible for anomalies in the logger records. Therefore, it is easiest to evaluate the quality of water quantity data successfully when supportive values and observations have been well documented.

The steady improvement of quality assurance protocols involves developing more detailed and program specific verification processes and automated checks, as well as peer reviews and audits by external professionals on a regular basis. Effective quality assurance will identify potential problem areas and necessary corrections to procedures and data management, and facilitates evaluation and improvement of the monitoring program.

Quality Assurance on Data

Examination and evaluation of field data and data entry is an integral part of quality control. All data should be reviewed to determine if it is comparable to past recordings. While it is not possible to check all aspects of input data, calculations, and interpretations, checks can be performed on selected sets of data at appropriate intervals. A review of work procedures and data collection methods will identify potential sources of error.

All water quantity data including field notes, photographs and datalogger download files are carefully handled, organized and stored to ensure the information can be located for future use. Corrections or adjustments to abnormal or inaccurate data logger records rely on the availability of complete documentation.

10. References

Guidance Document for Flow Measurement of Metal Mining Effluents, Environment Canada, 2001

Manual of British Columbia Hydrometric Standards, Resources Information Standards Committee (RISC), 2009

Standard Operating Protocol Surface Water Hydrology Data Collection and Management, Access Consulting Group, 2010.

Appendix 1: Minto Environment Mine Hydrology Field Form

Minto Hydrology Field Form

Site:	Date:	Initials:	
Start Time:		Start Staff Gauge:	
End Time:		End Staff Gauge:	
Datalogger download: Y / N		Photos Taken: Y / N	

Notes (**precipitation**, changes to site conditions, datalogger info, etc):

Left & right banks chosen looking downstream

Left Bank Measurement:	Left Bank Depth:
Right Bank Measurement:	Right Bank Depth:

Section	Tape Distance (m)	Depth (m)	Velocity (m/s)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			