RED DOG MINE

LONG-TERM PERMAFROST AND GROUNDWATER MONITORING PLAN FOR THE TAILING IMPOUNDMENT

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CONTENTS

TABLES

3 OPERATIONS AND MAINTENANCE PLAN

This section presents the operations and maintenance plan for the long-term permafrost and groundwater monitoring system described in Section 2. The main objective of the operations and maintenance plan is to ensure that the equipment and installations monitored as part of the Plan are operated and maintained to collect complete and accurate data over the long term. The key components of this plan include general data collection methods, QA/QC procedures, equipment inspection and calibration, provisions for equipment replacement, provisions to upgrade or modify equipment based on technologic advances, and general reporting requirements.

3.1 General data collection methods

A key consideration in the ongoing operation of the permafrost and groundwater monitoring system is the use of a consistent data collection methodology. Data collection methods for the current installations are outlined below. Standard operating procedures (SOPs) are included as Appendix C.

3.1.1 Temperature data from thermistors

Well construction details for the thermistors on site are provided in various SEP reports, including the Phase I, II, and III Reports (WMCI, 1997, 1999B, and 2001). In general, the thermistor wells consist of a string of thermistors hung within a PVC well. The thermistor strings were constructed by Dryden Instrumentation of Anchorage. The individual thermistors used are YSI 44034 equivalent and are accurate to ± 0.1°C. The cable used to hang the thermistors was manufactured by AT&T (AT&T EJ 2001 025D 25/24 [UL] MPP/CMP). The cable has 25 conductor pairs of 24-gauge solid copper and is jacketed in Teflon®. Each thermistor is protected from abrasion and moisture by heat-shrink tubing. At the surface, each string is terminated with a 50-position connector plug which mates with a connector on the readout box.

Temperature data from the thermistors can be collected by using either of two methods, a switchbox/multimeter setup or an automated datalogger setup. The first method consists of a switchbox and an auto-ranging multimeter. The switchbox was manufactured by Dryden Instrumentation and has a mating female receptacle for the plugs installed on the thermistor string. The raw data are in the form of resistance (k-ohms). Dryden Instrumentation checked and calibrated each thermistor string in an

icebath. Calibration sheets for each thermistor are included in Appendix D. Each string used has a Dryden identification number that relates to the reported icebath calibration. Resistance measurements are converted into temperature readings based on the icebath calibration.

An automated procedure has been developed by Dryden Instrumentation using a datalogger to download resistance measurements directly to an electronic file. The T5KMUX system consists of a Juniper Systems Pro2000 handheld computer (DOS PC-AT compatible), a Dryden Instrumentation T5KMUX analog-to-digital converter and multiplexor, and a program diskette with the appropriate system files. A detailed description of the system is provided in Appendix C.

The Standard Operating Procedure for collecting data from thermistors at the Red Dog site is detailed in Appendix C. Both multimeter and datalogger procedures are valid for use, and both are described in the appendix. Data collected with either collection method may be noted on the form presented with the SOP, or in a log book devoted to data collection for the groundwater monitoring program. Electronic data files produced in the automated procedure will be printed and kept on file at the mine for reference. Data will be transferred to the site database based on procedures outlined in the Data Management Plan, included in Appendix B.

3.1.2 Water level data from piezometers

Piezometers monitoring shallow groundwater and the subpermafrost system have been installed using various designs. Construction details of piezometers on site are summarized in SEP reports, including the Phase I II, and III Reports (WMCI, 1997, 1999B, and 2001). In general, piezometers are completed in one of two ways, with an open well screen or with a vibrating wire transducer. In addition, piezometers installed below the permafrost include a packer assembly that isolates the deep well screen from impacts of the overlying permafrost. Transducers measure the pressure of the overlying water, which is subsequently converted into water elevation.

The Standard Operating Procedure for collecting data from piezometers at the Red Dog site is detailed in Appendix C. Data may be noted on the form presented in Appendix C, or in a log book devoted to data collection for the groundwater monitoring program. Data will be transferred to the site database based on procedures outlined in the Data Management Plan, included in Appendix B.

Open well screens

Piezometer SPP-97-002, completed in the shallow system within the seepage collection dam, was built using standard monitoring well construction methods. The piezometer is completed with 1-inch schedule 80 PVC pipe and well screen. An electronic water level indicator is used to measure water depth in piezometers completed with open well screens. Depths to water in this well will be noted in the log book devoted to data collection for the groundwater monitoring program.

Vibrating wire transducers

All other piezometers that are part of the groundwater monitoring program were constructed with vibrating wire transducers. The transducers used at Red Dog are manufactured by Geokon of Lebanon, New Hampshire. They are vibrating wire transducers and have an internal thermistor because the readings are temperature-dependent. Transducers installed in the dam had a particle filter on the inlet whereas those installed in deep piezometers do not have this filter. Instead, the deep piezometers have ¼-inch NPT threads, which attach the transducers to the packer assembly.

Each transducer was factory calibrated prior to shipment. The resultant calibration sheets are used in the site database to calculate water levels based on the direct pressure readings from the transducers. Transducer calibration sheets are provided in Appendix D. The transducers were checked by WMCI personnel prior to installation for any damage that may have occurred during shipment. This was accomplished by taking a reading using the readout box and adjusting the reading for altitude/barometric and temperature differences. This reading was then compared to the reading taken at the factory. The two readings should be within 20 measurement digits of each other. All transducers installed to date have been within the required limits. Any new transducers installed will also be checked in this fashion.

Transducers installed in subpermafrost piezometers were attached to the top of 1.8-inch diameter inflatable packer assembly manufactured by Baski Inc. of Denver, Colorado. The packers were suspended from a fabricated aluminum wellhead with a 3/32-inch diameter stainless steel cable. Pressure to the packer is supplied through ¼-inch diameter nylon tubing. The wellhead is equipped with a pressure gauge and a Schrader valve. Compressed nitrogen was used to inflate the packers.

Data collected from the vibrating wire transducers will be noted on the form provided in Appendix C or in a field book devoted to groundwater monitoring program data collection.

3.2 Quality assurance and control

The quality control elements traditionally used for groundwater monitoring generally refer to chemical samples, in terms of comparing the results of sampling to known or defined standards, or to test the reproducibility of the sample. These include blank samples, spiked samples, calibration checks, and duplicate samples. For thermistor and water level data collection, only calibration checks and field duplicates are applicable. Calibration checks are described in Section 3.3.

3.2.1 Thermistor readings

At Red Dog, field duplicates are intended to demonstrate that the general collection method will produce the same data, independent of whether the multimeter or datalogger approach is used, and independent of the operator. Duplicate measurements of thermistor resistance will be taken for 5% of the annual total. Duplicate sampling will consist of measuring a thermistor by one operator with the multimeter method and another operator with the datalogger method. These measurements will be made within five minutes of one another to ensure time consistency. Resistance data from the multimeter method will be independently entered into the data management process, with temperatures compared only after data had passed through the entire data management process. Any differences will be noted, and worked back through the process to determine where the difference arose. Table 3.1 summarizes the duplicate thermistor measurements.

In addition to duplicate sampling, the instruments themselves may provide measurement error through electrically induced drift. Thermistors installed at the Red Dog Mine have a resolution of 0.1°C. This requires a resistance reading accurate to within approximately 20Ω (0.02KΩ). Both the multimeter and datalogger techniques provide this resolution. However, multimeter readings that are not stable within this limit (i.e., the reading moves about and does not stay on a single value) will be commented on using the form provided or in the site log book.

3.2.2 Manual water level readings

Manual water level indicators are capable of ±0.01 ft precision and shall be maintained in a condition such that this precision is consistently achieved. All water level measurement points for manual measurement are at the top of the steel protector casing. At the beginning of the program, a permanent mark will be made on the casing of SPP-97-002 at the point to be used for all measurements. The water level measurement should be repeatable within the tolerance specified above.

Similar to thermistors, duplicate measurements have been planned for 5% of the total annual manually measured water levels. Because there is only one piezometer for which manual measurements are necessary, one duplicate reading will be made per year. Duplicate measurements will consist of manual water level measurements by an independent operator within five minutes of the original measurements. Duplicates will be noted in the field log book (or on the form provided in Appendix C). Any differences will be noted and resolved if possible. These measurements will be periodically reviewed by site personnel for consistency. Table 3.1 summarizes the duplicate manual water level measurements.

Table 3.1 Summary of quality control measurements for groundwater monitoring program

Measurement type	QC Sample type	Amount of QC samples	Comments
Thermistor resistances, using multimeter	calibration check	all samples	check TEST value before and after each reading
Thermistor resistances, using datalogger	calibration check	all samples	check error code value in datalogger output file
Thermistor resistances, general	duplicate samples	5% of annual total	duplicate 5% of samples by repeating measurement with alternative methods
Piezometers, hand measurements	calibration check	annual check	calibrate electronic sounder versus new sounder or tape
Piezometers, hand measurements	duplicate samples	5% of annual total	check reproducibility in field with independent operator
Piezometers, transducer readings	calibration check	Annual check	if necessary, return GK-403 readout to Geokon for maintenance, calibration
Piezometers, transducer readings	duplicate samples	5% of annual total	duplicate 5% of measurement by independent operator, check after data entered in database

3.2.3 Transducer measurements

Accuracy of the transducers installed at the Red Dog Mine is ±0.5% of the full-scale range of the transducer. Therefore, accuracy ranges from 0.0125 psi for a 2.5 psi transducer to 1.5 psi for a 300 psi transducer (0.03 ft - 3.46 ft of water). Resolution for the transducers is ±0.025% of the full-scale range (or <0.1 psi for all installed transducers).

Measurement of the Geokon vibrating wire transducers requires recording of the barometric pressure. This can be accomplished by either reading the barometric transducer located at the tailing seepage dam immediately prior to or after reading of the piezometric transducers, or by using barometric readings collected hourly at the site meteorological station. Barometric pressure can be accurately read to two decimal places (in inches of mercury). The barometric transducer reading is required for conversion of the piezometric transducer data to pressures.

Duplicate measurements of vibrating wire transducers will be taken for 5% of the annual total. Duplicate sampling will consist of an additional measurement taken within five minutes of the original measurement to ensure time consistency. Data from the pressure transducers will be compared only after data had passed through the entire data management process. Any differences will be noted, and worked back through the process to determine where the difference arose. Table 3.1 summarizes the duplicate vibrating wire transducer measurements.

3.3 Instrument inspection, calibration, and maintenance

3.3.1 Dryden switchbox and Fluke multimeter

The Dryden switchbox and Fluke multimeter shall be inspected for damage and proper function prior to each use. The switchbox is subject to significant mechanical wear, so a backup unit should be available in case of failure of the primary unit. A record of repairs for all equipment will be maintained in the log books.

Each thermistor string was tested in an icebath by Dryden Instrumentation prior to shipment. The results of the icebath calibrations are included in Appendix D. The calibration data are used in equations to reduce the data to temperatures. Each thermistor string is tested a second time prior to installation to confirm proper function of the string.

A calibration check is required immediately before and after each thermistor string reading. When the Fluke model 23, Series II meter is turned on with the Dryden switch box in the off position, it should give a reading of 0.00. When the switch box is set to the "TEST" position, it should give a reading matching the resistance shown on the switch box (16325 Ω or 16.32 or 16.33 KΩ). After reading all of the thermistor nodes, a "TEST" reading is taken again. If actual readings differ from these values, the thermistor data are invalid. Erroneous readings may be due to excessive cold or a low battery. It is the responsibility of mine personnel to correct the problem and take the readings again. Unstable thermistor readings will be noted in the log book. Unstable readings may be due to poor connections, a faulty switchbox, or shorting of the thermistor string. All corrective actions and repairs will be noted in the log book.

3.3.2 Juniper automated thermistor string reading system

The Dryden Juniper system was designed to automatically read thermistor resistances and log the data in a downloadable computer file. The system is subject to significant mechanical wear, and should be inspected for any damage prior to each use. The automated thermistor string reading system consists of the following components:

- Juniper Systems Pro2000 handheld computer, including CA-2009 serial Pro2000 to PC cable, and PW-110T charger.
- Dryden Instrumentation T5KMUK analog to digital converter and multiplexor.
- Program diskette with executable and configuration files.

Technical specifications of these components are provided in Appendix C. Each of these components is subject to wear during use and will be checked for functionality prior to each use. The Pro2000 system includes a rechargeable battery system that has an approximate maximum charge of 10 to 16 hours. The battery status will be checked prior to each data collection event. If the status light on the instrument indicates that the battery is low, the unit should be recharged prior to additional data collection. The Pro2000 system will be inspected annually to ensure proper functioning of the battery and recharging system.

The T5KMUK uses a standard, 9-volt battery. The battery will be checked for proper functioning prior to each use, and a backup battery should be available at all times during data collection.

3.3.3 Electronic well sounder

Electronic well sounders will be inspected for function and damage prior to each usage and shall be periodically (at least annually) calibrated against a new sounder or tape. Calibration must include a zero and a span check. The correction factor (if any) will be applied to subsequent measurements and indicated as such in the log book. Field conditions that prevent measurement of water levels with the required degree of precision shall be noted in the log and appropriate corrective action taken and recorded in the log. A broken well sounder cable will be calibrated after repair, and the service recorded in the log. An example of a correction for a repaired well sounder with stretch using a linear regression is given below for the data in Table 3.2.

Table 3.2 Example of well sounder calibration data

	New sounder or tape reading (X)	Old sounder reading (Y)
1 (zero)	0.00	2.6
2 (span)	300.00	302.71

Corrected measurement = (Y3-Y1)/(Y2/(X2+Y1)), where Y3 is a new reading

or

Corrected measurement = (Y3-2.6)/(302.71/(300+2.6)) = (Y3-2.6)/1.000364

3.3.4 Geokon GK-403 readout

The GK-403 readout instrument will be inspected for damage prior to each use. The face plate should be cleaned periodically with a soft cloth dampened with soap and water. Do not use solvents of any type. The connector sockets may be cleaned with a small stiff brush moistened with soapy water. The sockets will be thoroughly dried after cleaning. When the unit is not used for a long period of time, it should be left connected to the battery charger. The GK-403 uses lead-acid type batteries and will not develop a memory as is typical of Ni-cad batteries.

The manufacturer recommends that the readout unit be periodically returned for inspection, cleaning, and calibration. This calibration process will be completed on an as-needed basis, based on a review of data consistency recorded from the instrument. All service to the instrument will be recorded in the log book. As previously noted, specific calibration sheets for each individual transducer are included in Appendix D.

3.4 Equipment replacement and technological updates

Over the time period of the monitoring program, it is inevitable that monitoring equipment will wear out and need to be replaced. The thermistor wells were designed such that the thermistor strings can be removed from the PVC well and replaced with new equipment. The piezometers were also designed such that transducers or the transducer/packer assembly can be removed and replaced without drilling a new boring and replacing the entire installation. Some of the piezometers proposed for the long-term monitoring plan, however, were installed beneath the dam fill or had a portion of the transducer assembly buried within trenches and routed to a central access box. These installations may require complete replacement in the event of equipment failure.

If equipment fails and requires replacement, Cominco will make every effort to replace the equipment or the entire thermistor or piezometer installation in a timely fashion to ensure continued data collection. However, difficulties of operating within the Arctic environment, including weather and shipping time for equipment, need to be considered. Replacement within the existing installation will be the preferred method for replacement of defective equipment. However, if it is determined that the equipment cannot be replaced, the entire installation may be replaced or, if appropriate, replaced by another existing installation or removed from the program. If a new installation is considered necessary, the new installation will be located as close to the existing installation as is feasibly possible, and will be designed to collect the same data as the original installation.

Cominco shall communicate a plan for all equipment replacement and new installations to the EPA at the time of their occurrence. Cominco shall perform the following general evaluations when equipment or installations require replacement:

- Importance and necessity of the installation to overall monitoring plan. The Plan allows for modifications to the system, and it may be reasonable in some instances to propose that specific installations be replaced by other existing installations or not be replaced at all.

- Availability and applicability of new technology that may provide more detailed, lower cost data than the existing instrumentation.

- Timing and feasibility of equipment and installation replacement. For example, if equipment fails during winter, it may not be feasible to attempt replacement, or to decide to replace the entire installation, until the following summer.

3.5 Reporting of QA/QC, equipment inspections, and replacement

All QA/QC data and analyses will be reported as part of the annual report described in Section 4. The annual report will also include a description of the current condition of equipment and installations, along with a description of any maintenance or replacement activities.