Pebble Project

NORTHERN DYNASTY MINES INC.

ENVIRONMENTAL BASELINE STUDIES

PRELIMINARY SUMMARY
STUDIES PERFORMED BY WATER MANAGEMENT CONSULTANTS
HYDROGEOLOGY, MINE STUDY AREA

1. INTRODUCTION

The hydrogeological characterization for the Pebble Project uses an integrated approach that includes an extensive field program, input to and from team members performing other tasks relevant to hydrogeological characterization, compilation and interpretation of the data being collected, and quantitative analysis of groundwater/surface water interaction.

2. FIELD WORK

A multi-phased field program was developed to characterize the baseline hydrogeological conditions for the Pebble Project. The program was developed by Water Management Consultants (WMC) and is being executed by SLR Alaska (SLR) during 2004, 2005, and 2006. The field program includes the following components:

- Installation of monitoring wells for collecting groundwater samples and monitoring water levels.
- Installation of piezometers for monitoring water levels.
- Development and response testing of all monitoring wells and piezometers to maximize the quality of groundwater samples and to measure the hydraulic conductivity, respectively.
- Installation of pumping wells for the purpose of conducting pumping tests.
- Execution of cross-hole pumping tests to estimate hydraulic conductivity.
- Collection of samples from groundwater monitoring wells.
- Measurement of water levels in monitoring wells and piezometers.

The locations of all monitoring wells, piezometers (including piezometers installed as part of the geotechnical program), and pumping wells are shown on Figure WMC-1 (attached). As part of the wetland program, additional shallow piezometers and staff gages were installed (see summary from Three Parameters Plus, section on small pools study). The locations of these installations are shown in Figure WMC-2 (attached).

The monitoring wells and piezometers installed as part of the hydrogeology program were typically installed in nests of two or three to determine vertical gradients. Groundwater sampling started in 2004 with quarterly samples at 19 wells at eight locations. Groundwater samples are currently being collected quarterly from 33 monitoring wells at 17 locations. Field parameters (temperature, dissolved oxygen, specific electrical conductance, pH, and ferrous iron) are measured at the time of sampling. The samples are analyzed in the laboratory for total and dissolved metals, pH, specific conductance, alkalinity, acidity, ammonia, sulphate, chloride, fluoride, nitrate and nitrite, and total phosphorous.

Water levels have been monitored monthly since 2004, and monitoring currently includes 211 locations. Water levels are also currently being recorded at six-hour intervals with transducers installed in eight wells or piezometers. Barometric pressure is also being recorded.

Pumping wells were installed at three locations in 2004 and four locations in 2005. In all, seven pumping tests have been executed with durations that ranged from 4 to 26 hours.

3. INPUT TO TASKS BY OTHERS

WMC is providing input to and obtaining data from team members involved in other tasks pertaining to the groundwater system and the interaction between surface water and groundwater. These tasks include the following:

- Continuous streamflow monitoring.
- Periodic low-flow streamflow measurements.
- Meteorological data collection.
- Reconnaissance surveys of seeps.
- Ongoing sampling and flow measurement of 24 priority seeps.
- Installation of a Westbay monitoring system in a deep bedrock exploration drill hole.
- Mine design.

4. DATA REVIEW

The data being collected have been reviewed and compiled using a variety of methods. The geological data from the hydrogeological drilling investigations have been integrated into geological sections across the entire mine study area. These sections have been drawn in north-south and east-west directions to develop a set of intersections that themselves become additional data points for infilling the geological interpretation. A total of 34 geologic sections have been developed.

The measured water levels have been plotted on plans and in time series. To see the correlation between hydrologic conditions and groundwater levels, the time series of precipitation and streamflow have been plotted contemporaneously with groundwater levels. Multiple snapshots of groundwater levels have been plotted in plan view.

The groundwater sampling results have been plotted in a variety of ways to determine any trends or patterns that might be evident. These plots include time series of field and analyzed parameters to determine temporal trends, Piper plots of major ions to distinguish types of water, box and whisker plots of all sampling events to obtain a graphical summary of parameter concentration statistics, Stiff diagrams to interpret geographical trends in water types and total dissolved solids, and tables of comparisons to water-quality standards.

5. QUANTITATIVE ANALYSIS

Groundwater flow and the interaction of groundwater with surface water are being analyzed using two quantitative models:

- A water balance model developed using a spreadsheet.
- A groundwater flow model using modeling software.

The water balance model covers the entire study area and divides the watershed into 13 sub-watersheds. The model incorporates the following components:

- Precipitation.
- Evapotranspiration.
- Sublimation.
- Runoff.
- Groundwater storage.
- Groundwater recharge.
- Groundwater discharge to streams.
- Groundwater flow between sub-watersheds.

The strength of this model is its consideration of groundwater in the context of the overall site water balance. The model is calibrated to measured monthly streamflows within each of the 13 sub-watersheds over the course of an entire year for a total of 156 calibration points.

The numerical groundwater model covers the same area as the water balance model and is being used to truth the groundwater component of the water balance model. In turn, the groundwater model is being calibrated to be consistent with the flows estimated in the water balance model. The following components are included in the groundwater model:

- A representation of the hydrostratigraphic units across the entire site.
- Three-dimensional groundwater levels.

- Groundwater recharge.
- Leakage from and discharge to rivers, lakes, and streams.
- Discharge from groundwater seeps.
- Flow between sub-watersheds within the study area.

The groundwater model is distinguished from the water balance model by its more detailed treatment of the physics of groundwater flow. The groundwater model is being calibrated to the following:

- Up to 12 measurements from each of 13 piezometers for a total of 134 water-level measurements.
- Estimates of monthly groundwater discharges to streams within each of the 13 sub-watersheds for a total of 143 calibration points.
- Estimates of monthly inter-watershed flows between each of the 13 sub-watersheds for a total of another 143 calibration points.
- Low-flow streamflow profiles along the three primary drainages within the study area.

This integrated approach to quantitative analysis is being used to make the groundwater analysis consistent with both the hydrologic conditions and the groundwater characteristics, thereby increasing the credibility of the analysis. The short-term goal of this integrated modeling analysis is to simulate baseline conditions for groundwater and surface water interaction. The long-term goal is to estimate potential impacts on surface water and groundwater flows and temperatures after the mine is developed and to help design mitigative measures to minimize or eliminate impacts.