

**DRAFT ENVIRONMENTAL BASELINE STUDIES  
2005 STUDY PLANS**

**CHAPTER 8. GEOCHEMICAL CHARACTERIZATION  
AND ARD/ML**

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## ACRONYMS

AA	Atomic adsorption
AASHTO	American Association of State and Highway Transportation Officials
ABA	acid-base accounting
ACHP	Advisory Council on Historic Preservation
ACL	alternative cleanup level
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
agl	above ground level
AHRS	Alaska Heritage Resource Survey
AKNHP	Alaska Natural Heritage Program
APE	area of potential effect
ASCI	Alaska Stream Condition Index
ASTM	American Society for Testing and Materials
BEESC	Bristol Environmental & Engineering Services Corporation
BMR	baseline monitoring report
CAD	computer-aided drafting
CC	comprehensive stations with continuous-stage monitoring
CIR	color infrared
CQ	continuous discharge
CWOC	comprehensive stations without continuous-stage monitoring
DECD	Alaska Department of Economic and Community Development
DEM	digital elevation model
DNR	Alaska Department of Natural Resources
DO	dissolved oxygen
DOT&PF	Alaska Department of Transportation & Public Facilities
DQOs	data quality objectives
EC	environmental consequences
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EBD	environmental baseline document
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FSP	field sampling plan
GIS	geographic information system
GPS	global positioning system
HGM	hydrogeomorphic
ICP	Inductively coupled plasma

IEE	Initial Environmental Evaluation
IM	initial monitoring station
LCNPP	Lake Clark National Park and Preserve
LDN	Land Design North
MCHTWG	Mulchatna Caribou Herd Technical Working Group
MDC	mine development concept
mg/L	milligrams per liter
ML/ARD	metal leaching/acid rock leaching
mm	millimeters
MRL	method reporting limit
NASA	National Aeronautics and Space Administration
NDM	Northern Dynasty Mines Inc.
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOAA	National Oceanic & Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
ORP	oxidation reduction potential
PJD	preliminary jurisdictional determination
PSD	prevention of significant deterioration
psi	pounds per square inch
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
SHPO	State Historic Preservation Officer
SOP	standard operating procedure
SRB&A	Stephen R. Braund & Associates
SRK	SRK Consulting (Canada) Inc.
SWE	snow/water equivalent
TIN	triangulated irregular network
TPH	total petroleum hydrocarbons
USACE	United States Army Corp of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMC	Water Management Consultants
WMP	water monitoring plan
WQ	water quality

## 8. GEOCHEMICAL CHARACTERIZATION AND ML/ARD

The component of the study plan for geochemical characterization and metal leaching/acid rock drainage (ML/ARD) addresses the geochemical characterization of tailings and the mine-rock facilities for the mine site. The term “mine rock” includes waste rock, waste rock to be used for construction, the walls and floor of the open pit, and the stockpiles. SRK Consulting (Canada) Inc. (SRK) will lead the geochemical and ML/ARD work for the mine site.

### 8.1 Objectives of Study

This study program is designed to characterize the materials that will be produced from the mining and milling process with respect to geochemistry and, particularly, water chemistry. The data produced from the geochemical testing program will be used for prediction of tailings and mine-rock water chemistry, and for evaluation of alternative mine-waste deposition plans for operation and closure. Thus, the overall objective of the geochemical characterization program is to provide data for assessment of environmental impact and for development of design and mitigation measures to minimize potential for adverse environmental impact from mine-rock (or mine-waste) management facilities. It is well recognized in the mining industry that designing for sound environmental management can significantly reduce the potential for adverse environmental impacts and long-term environmental liabilities.

This overall objective will be accomplished through the sequences of activities summarized in Figures 8-1 and 8-2 (below) and discussed in more detail in the following sections. The specific tasks to accomplish the overall objectives are as follows:

- Define the conceptual project description and project alternatives with respect to waste management in order to design a representative sampling and testing program.
- Determine the amount and types of mine rock and ore that can be anticipated over the mine life based on the ultimate resource (potential pit limits).
- Develop a sampling program for existing drill core and for the 2004 drilling program for mine rock and similarly for tailings from the metallurgical testing program.
- Characterize the geochemistry and potential variability of the tailings solids and tailings water chemistry.
- Characterize the geochemistry and potential variability of the mine rock from the open pit through laboratory testing.
- Quantify the potential rate and extent of the geochemical reactions controlling drainage water chemistry for mine rock and tailings.
- Apply quantitative mathematical modeling techniques to these data to predict water chemistry from waste-rock, open-pit, and tailings facilities both during operation and at closure.
- Develop, and evaluate with respect to water chemistry and environmental impact, alternative waste/water-management options for the waste-rock and tailings facilities and for the open pit.

## 8.2 Proposed Work Plan

### 8.2.1 Study Area/Scope

The assessment of project geology for environmental geochemistry and mine-waste management is focused on the Pebble Deposit geology, with a lesser emphasis on the regional setting and geology. The sampling and characterization testwork will be completed in detail for the mineable reserve that is defined as the basis for the feasibility study. This is currently defined as a resource of 2.5 billion tonnes.

The environmental geochemical characterization program includes:

- Waste rock (including construction rock),
- Ore stockpiles,
- Process tailings,
- Open pit walls and floor rock, and
- Surficial materials in the vicinity of tailings- and mine-rock-storage areas

This chapter of the baseline study program describes activities that are in part a baseline environmental program and in part an engineering program. The environmental aspects—namely the sampling and testing for the characterization of the mine rock and tailings—are emphasized in this study plan. This characterization is then combined with the engineering design, and the mine plan and the site water balance are developed within the project engineering scope-of-work in order to predict the water chemistry throughout the site.

A critical element linking the two is the preparation of the conceptual model of site surface and groundwater flow and the site water balance. The baseline data collected herein are used to calculate the conceptual site surface/groundwater flow model and the site baseline water balance. This balance is then used to develop the chemistry loading balance for operations and closure. The interaction of these components is shown in Figure 8-1 and Figure 8-2 (below).

#### 8.2.1.1 Mine Rock

The exploration work to date has been used to define a preliminary geologic model for the deposit, which provided the basis for the 2004 infill drilling program. Similarly, this geologic model has and continues to be used as the basis for specific sample selection for mine rock for the preliminary-design open-pit limits. In addition to the detailed sampling for this design pit, the geologic model and resource estimation has been used to define the drilling and sampling required to characterize the mine rock for the potential ultimate open-pit limits.

The actual pit limits, and therefore the amount/types of mine rock and tailings, will depend on the detailed exploration drilling program and feasibility analyses currently in progress. It is recognized that as drilling and resource modeling proceed, the defined reserve (i.e., the economic pit limits) may be different than the deposit size considered herein.

While it is recognized to be potentially conservative, it is considered reasonable to sample and test the maximum potential range of geologic materials, and therefore mine-waste geochemistry, that may be encountered from the open pit over the mine life. Within this larger database, the study limits used for the water chemistry prediction and environmental impact assessments can be defined to address either the defined maximum mine plan and resource or various interim pit development stages.

### 8.2.1.2 Tailings

The tailings geochemical characterization program will be done in parallel with the metallurgical program. Thus, as various alternatives for the milling process and ore types are evaluated in the metallurgical laboratory, samples of tailings solids and process water will be characterized with respect to environmental geochemistry. As a consequence, the scope of the tailings characterization program also may include a variety of tailings that are not representative of the final process flowsheet. However, as for the mine rock, this more comprehensive geochemical characterization program provides an additional benefit for project design, allowing environmental considerations to be included in selection of the preferred alternatives for both mine-rock and tailings disposal.

## 8.2.2 Methods and Approach

The approach to the geochemical characterization programs is based on best-practice industry methods for mine-rock characterization comprising the following sequence of major activities:

- Definition of project description and geologic model to identify range of geologic units for sampling.
- Representative sampling and testing of pre-2004 and 2004 drill core and metallurgical tailings samples.
- Staged geochemical testing comprising static and kinetic testing.
- Calculation of oxidation, neutralization, and metal production for each sample/material type in kinetic testing.
- Modeling of water chemistry for each of the mine facilities (i.e., mine-waste storage pile, tailings pond, tailings dams, open-pit walls) using loading calculations and geochemical equilibrium modeling where appropriate.
- Incorporation of water-chemistry predictions for each of the mine facilities into the overall site water balance and loading balance.
- Preparation of design, monitoring and mitigation plans, and environmental impact assessment.

This methodology is summarized in Figure 8-1 for tailings characterization and in Figure 8-2 for mine rock characterization. The central portion of each flowsheet shows the activities that are part of the mine rock geochemical characterization program. The other tasks, shown on the sides and in black, are those for which the input of other project team disciplines is required. The following section discusses the approach to each of the sampling, testing, and water quality prediction activities.

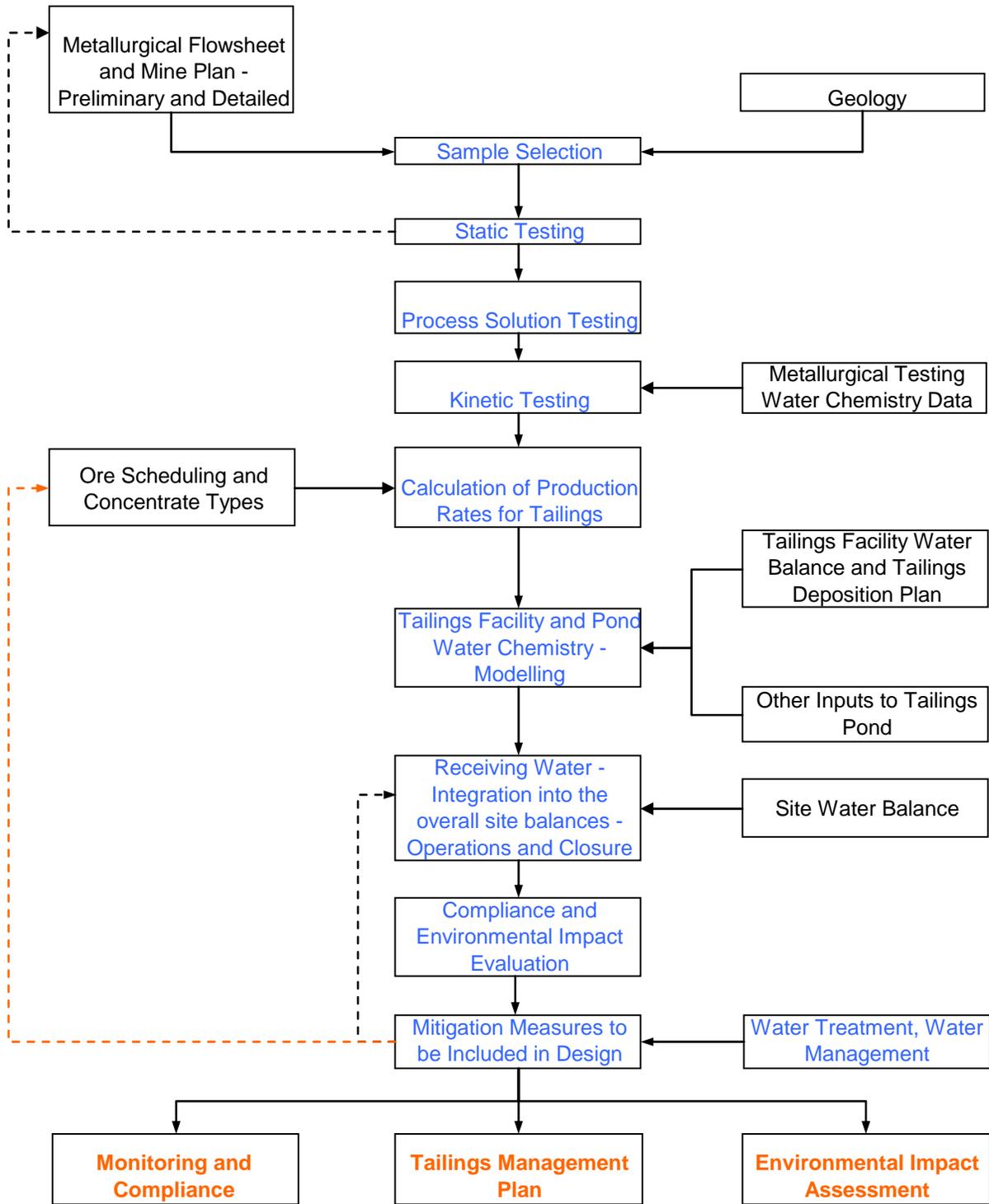


FIGURE 8-1  
Characterization Program Flowsheet — Tailings

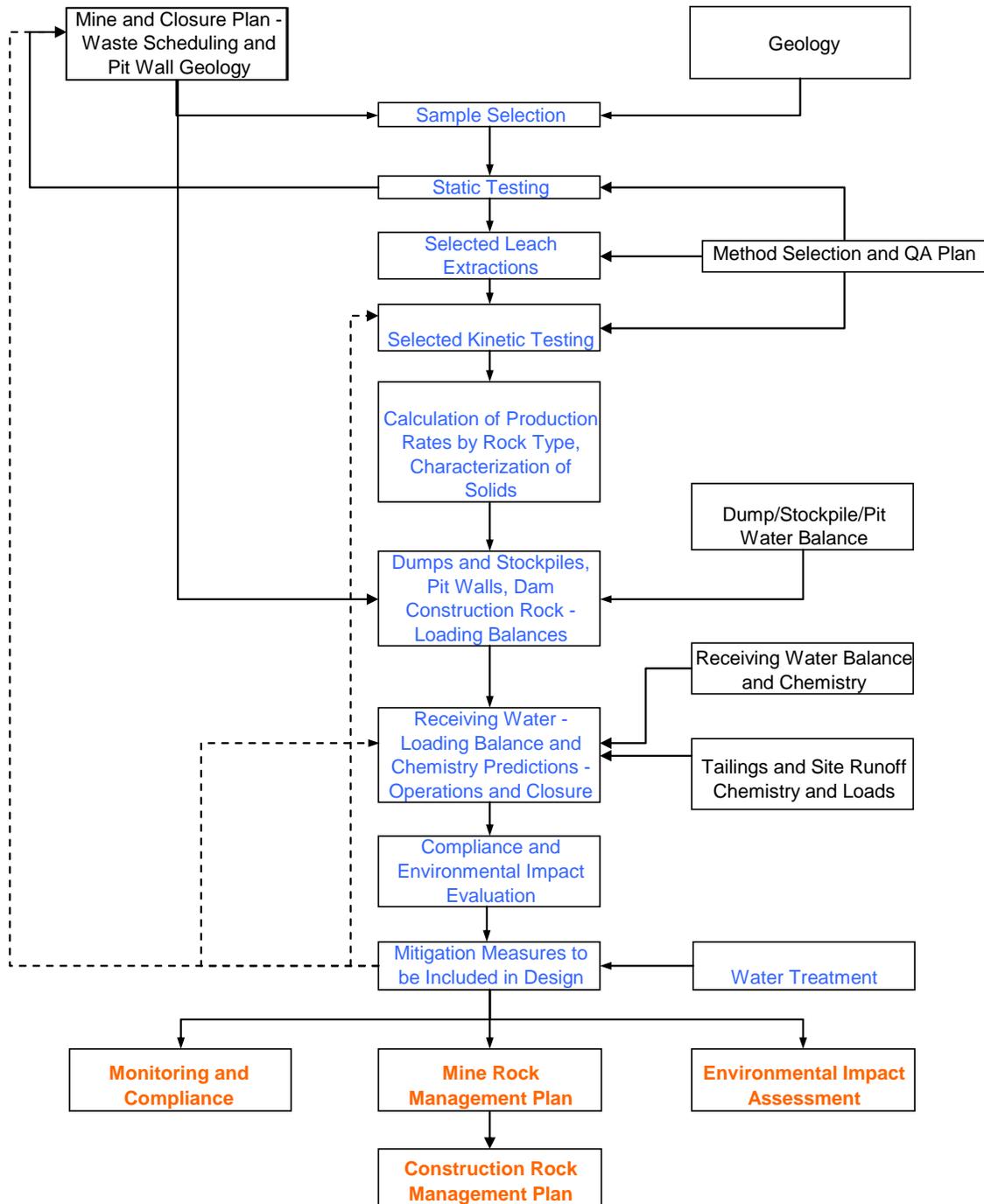


FIGURE 8-2  
Characterization Program Flowsheet — Mine Rock

## 8.2.3 Major Activities

### 8.2.3.1 Activity 1: Sample Selection and Collection

Selection of representative samples for both mine and tailings is the most critical component of a technically sound and practical geochemical characterization program. Samples have and will be selected for testing mine rock and tailings of ore to quantitatively characterize the deposit in terms of the variables that can affect geochemistry:

- Geologic controls and resulting variations in geology/lithology/mineralogy and metal content.
- Spatial distribution in deposit (aerial extent and depth).
- In situ weathering, oxidation, or mineral enrichment as a result of geologic processes.
- Open-pit design parameters including reserve estimate, total tonnages by rock type, strip ratio, and pit-wall geology.
- Production schedule.
- Processing alternatives.
- Deposition alternatives.

Site baseline sampling and testing also include native soils and rock from the areas of tailings and mine-rock storage to assess potential for attenuation of seepage from these facilities. These will be collected from the geotechnical test pit sampling program.

The initial phase of waste-rock sampling and static testing was based on the distribution of rock types indicated by pre-2004 diamond drilling. This phase provided definition of waste-rock characteristics within the extensively drilled central part of the mineralized zone. Specific drilling in 2004 and testing of drill core was completed to geochemically characterize the waste rock near the eventual open-pit walls.

A total of 600 mine-rock samples are expected to be collected and tested during both phases. About 400 samples have been tested to-date for static geochemical characteristics. In 2005, 28 humidity cells and five column tests will be conducted on waste-rock samples.

Additional samples will be selected for analysis in 2005 as required to resolve any uncertainties or gaps in sampling to fulfill the criteria for representative sampling listed in the preceding section. Addressing the potential variability in the geology/geochemistry of the deposit as described earlier is the key to a representative sampling program. For this reason, a large number of samples are collected and tested in a staged approach to ensure that there are no information gaps.

Tailings samples will be collected from each stage of metallurgical testing (including batch testing and locked-cycle testing) and each ore sample/composite for both static and kinetic testing. Up to 15 kinetic tests (humidity cells and columns) are expected to be conducted on tailings samples, depending on the disposal alternatives to be tested and the number of feed/tailings streams that are maintained throughout the metallurgical testing program. In addition, process-water samples from within the milling process and of the final tailings solutions will be collected for detailed environmental analyses.

Sample selection and collection comprise the following ongoing activities in 2005:

- Information Review
  - Project description with respect to quantities of waste rock, sizes of mine-waste piles/stockpile, requirements for construction rock, pit-wall geology, and mineralogy.
  - Geostatistical analyses of drill-hole data with respect to environmental parameters.
  - Metallurgical program and geology with respect to tailings testing.
  - Regulatory requirements and guidelines.
  - Definition of deposit geology and mine plan.
  - Incorporation of environmental geochemistry parameters and rock-management criteria into geologic database (initial for sampling, revised for final design and operational management).
  - Evaluation of surrogates and analyses for rock management (initial for sampling, revised for final design and operational management).
  - Definition of pit-wall geology for pit-lake geochemistry.
- Sample Collection
  - Tailings sampling including selection of samples from batch metallurgical testing and from detailed/design metallurgical testing. Samples provided by metallurgical testing laboratory.
  - Selection of samples from 2004 drilling program. Samples collected by site geologists using rigorous, agreed protocols consistent with geological sampling.

### 8.2.3.2 Activity 2: Geochemical Testing

Static and kinetic testing programs are designed to provide a complete and detailed characterization of the range of mine-rock geology and mineralogy in the deposit. In addition, the test programs provide information for design and closure planning including assessment of mine-waste management options (e.g., use of rock for construction, potential for co-disposal with tailings), pit-wall geochemistry over time, and stockpile management.

A detailed geochemical testing plan, complete with specific methods, number of samples, and laboratory procedures has been prepared for each of the static and kinetic phases of testing. The methods used for geochemical characterization of both mine rock and tailings are consistent with international industry standards and protocols. There are additional procedures, or modifications to procedures, that provide important information for assessment of water chemistry and water-management programs. The approach and principles described in *EPA and Hardrock Mining, A Source Book for Industry in the Northwest and Alaska* provide the basis for the testing program. The test procedures will follow documented procedures from the American Society for Testing and Materials (ASTM), the U.S. Environmental Protection Agency (EPA), or MEND.

The major activities in the mine rock testing program in 2005 are as follows:

- Mine-Rock Static Testing
  - Characterization of waste rock in the vicinity of the pit walls.
  - Testing procedures include solids analysis by inductively coupled plasma (ICP), atomic adsorption (AA), and acid-base accounting (ABA) using standard and modified procedures, short-term leach extraction or contact testing.
- Mine-Rock Kinetic Testing
  - Phase 1—Initiation of tests based primarily on rock type.
  - Phase 2—Test program to address specific mine-design questions and water-quality prediction needs.

Testing procedures include humidity cells (ASTM), humidity columns for waste rock, and as required, saturated columns or sequential kinetic tests for evaluation of disposal options such as underwater disposal of mine rock.

The tailings characterization program is determined by the range of options evaluated in the metallurgical testing. Priorities for this program are to sample and test a representative range of tailings samples, including both solids chemistry and tailings (process) water chemistry within the tailings pond and for the tailings to be used for dam construction.

The same staged approach will be used for tailings characterization, with the exception that samples will be selected from the batch metallurgical testing on a large variety of ore types, composites, or processing methods. This will be followed by a second phase of testing on the products of the locked-cycle tests that are expected to be conducted on a fewer number of ore samples that are considered by metallurgists and mine planning/geology to be representative of the deposit. The results of this approach will provide the data to assess alternatives for tailings deposition (number and type of facilities), tailings water-management constraints, requirements for water treatment, and construction rock.

The major activities in the tailings-testing program in 2005 will be as follows:

- Tailings Static Testing—ongoing testing of tailings products from flowsheet design testing.
- Tailings Kinetic Testing
  - Testing of tailings samples from scoping testing.
  - Testing of tailings products from flowsheet as testing is completed, and modifications, if required, to address tailings-management options.

Static and kinetic test results will be used to define the geochemical units that determine drainage-water chemistry. These geochemical units may be the same as the lithologic definitions or may also include factors such as alteration, metal content, location in pit, etc. From these definitions of the distinct geochemical units, the block model and pit designs will be used to quantify the amount of each unit in the pit walls and waste rock.

Data from the static and kinetic testing programs will be reviewed on a regular basis for quality management and to evaluate the geochemical behavior of the materials.

Bench-scale testing of aquifer materials from the Pebble site will be conducted. This will allow an estimate of the natural attenuation properties of these materials along potential groundwater flow paths downgradient from key facilities such as the tailings impoundment, mine-rock storage areas, and the open pit. The results of this testing will be incorporated in the fate-and-transport model developed for the site.

### **8.2.3.3 Activity 3: Water-Chemistry Prediction**

The prediction of water chemistry will comprise three steps:

- Prediction of drainage-water chemistry by rock type and then, using this, for each of the mine--rock piles, tailings facility(ies) including the beaches, dams and the saturated tailings mass, and open-pit walls.
- Geochemical modeling using commercially available or publicly available software.
- Incorporation of the predicted drainage-water chemistry for each mine facility into the overall site water balance and loading balance.

For the open pit, water-chemistry predictions will be made for various pit limits periodically throughout operation and to the ultimate pit limits. Drainage-water chemistry predictions will be made for waste rock to assess disposal requirements. Tailings-pond water chemistry will depend on both the geochemical characteristics identified in the kinetic testing and the process-water characteristics identified in the metallurgical and static testing. Once the water-chemistry modeling predictions for each of the mine components are completed, these predictions will be incorporated into an overall site water and loading balance to assess the potential impacts on water chemistry from alternative facility designs.

The water-chemistry modeling will use standard spreadsheets for calculations of loading, combined with geochemical modeling packages to address geochemical controls on water chemistry. The laboratory testing protocols will be selected to allow calibration and quantitative extrapolation of laboratory data to field conditions, based on both theoretical and empirical factors. Specific site calibration factors will be developed, where possible, from planned testing on existing older core samples as compared to comparable “fresh” core samples.

Protection of water quality both within the mine site and in the downstream receiving environment is a key consideration for project design. An initial assessment of water chemistry will be done in 2005, using kinetic testing data as it becomes available. As the project design is refined and the geologic model is revised to include the 2004 exploration drilling, the specific quantities of ore/waste rock/pit-wall rock can be defined and input to the water-chemistry prediction models.

### **8.2.3.4 Activity 4: Design and Mitigation Alternatives**

The water-chemistry predictions will be done in two stages to allow incorporation of water chemistry into the assessment of project-design alternatives as the project proceeds. This is, of course, an iterative process—estimates are made of potential water chemistry for various milling/design alternatives, and then the alternatives are refined to optimize water chemistry where possible.

A key component of the mine-rock testing program is the development of this geochemical sampling and testing program in close conjunction with the exploration geology and resource modeling. This allows the development of a mine-rock management program in the same way as the ore is modeled and scheduled for production. These activities are initiated from the start of the sampling program (as discussed earlier) and are finalized with the results of the geochemical testing and water-chemistry modeling to enable the facilities to be designed so as to minimize the potential for oxidation and metal leaching. The specific additional activities that are necessary to link the geochemical testing programs with the mine design and environmental management include:

- Definition of material quantities and alternative mine-rock and tailings designs,
- Development of waste-rock (tailings) management criteria, and
- Integration with water management and tailings-deposition plan.

#### **8.2.3.5 Activity 5: Evaluation of Environmental Effects**

The results of the water-chemistry modeling will be used as the basis to evaluate potential environmental effects from project development. The evaluation will be done in conjunction with the results of the environmental baseline study programs that characterize the existing environment. This evaluation includes not only water chemistry but also the related uses of the water in the project area. This task is an iterative task, as shown in Figures 8-1 and 8-2, so that the project design can benefit from the information on environmental geochemistry.

### **8.3 Deliverables**

The main deliverables from these activities in 2005 will be:

- Geochemical Characterization Report. This report will contain a description of sampling methodology, analytical methods, and initial interpretation of results. The report will provide the basis for water-chemistry predictions
- Progress Report. This report will be prepared at the end of 2005 to compile results obtained through the year.
- Input to Initial Environmental Evaluation. Initial water-chemistry predictions will be provided for mine-planning purposes.
- Input to Closure Plan and Plan of Operations. Criteria for environmental management will be provided, including the following:
  - Mine-rock management program for construction and operations.
  - Operation and closure with respect to tailings solids/water chemistry.
  - Parameters to incorporate into geologic database and, where possible, block modeling for environmental geochemistry.
  - Potential surrogate parameters for mine-rock management criteria and program for operations.

- Final geochemical mine-rock characterization report, containing above draft reports and predictions, suitable for use in environmental impact assessment and permitting documentation.

As the project proceeds, interim technical memos will be produced at key project stages for discussion with the project team, consistent with the approach shown in Figure 8-1 and Figure 8-2.