APPENDIX 2

NPDES

MARINE WATER and SEDIMENT SAMPLING PROGRAMS

GREENS CREEK MINING COMPANY

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1.0 INTRODUCTION

In 1983, environmental studies of the sill area near the entrance to Hawk Inlet were conducted to aid in selecting a discharge site. Physical studies demonstrated that the sill site had a high tidal velocity and that dispersion and mixing would provide for a small dilution zone. The biological studies at the sill site indicated a resilient intertidal fauna which can be expected to recover quickly from disturbance during pipeline construction. The subtidal area in the region of the outfall terminus is composed of very coarse rocky material sloughed off the fjord walls and of coarse-grained sediments composed of sand and shell material.

Benthic organisms collected in the region were primarily of two types, attached filter feeders such as brachiopods and pelecypods and calcareous tube-building polychaetes with the coarse-grained sediments containing more mobile and sand dwelling forms. The coarse nature of the substrate and the biological characteristics of the endemic fauna clearly indicate a high-energy environment, with little sediment deposition. The lack of fine-grained sediments reduces the potential impacts of heavy metal buildup from the tailings pond effluent. The heterogeneity of the substrate coupled with the resiliency and high diversity of the fauna, precludes the use of general benthic survey techniques in site monitoring. The ambient monitoring program was designed to incorporate knowledge from the previous environmental information collected at Hawk Inlet and follows an experimental design which focuses on the major areas of concern expressed by State and Federal resource agencies during the permit application process. As such, it focuses on chronic changes in the environment and is designed to distinguish between natural variations and possible impacts created by the marine discharge of the tailings pond effluent.

2.0 MARINE WATER SAMPLING PROGRAMS

2.1 SEAWATER

Seawater sampling was started in 1982 in an effort to establish background data regarding heavy metals and cyanide. Test procedures (see Attachment A) incorporated into the study required two samples at each location. One sample is taken at a 5-foot depth and the second is taken at a 20-foot depth. The only exception to this strategy is if a conductivity profile taken at the start of the test indicated stratification after heavy rains. To date, no stratification has been observed, so all seawater results are based on the 5-foot and 20-foot sampling strategy.

Seawater standards were set by the Alaska Department of Environmental Conservation (ADEC) and samples for NPDES compliance are to be collected at the edge of the mixing zone. The mixing zone is defined as an area 500 feet on each side of the outfall line and 300 feet in width. The actual mixing zone then becomes 1,000 feet by 300 feet. Seawater samples are to be collected at the edge of this zone at 5 and 20 feet.

Site descriptions for seawater follow in Attachment A. These descriptions are consistent with

both freshwater and groundwater site descriptions. Site 108 is at the edge of the mixing zone and is used for NPDES compliance.

2.2 HAWK INLET AQUATIC BIOTA PROGRAM

The Hawk Inlet Aquatic Biota Program consists of several major components: sediments, bioaccumulation studies, and toxicity tests performed on wastewater entering Hawk Inlet. These programs are driven by the NPDES permit and the following discussion summarizes the three major components of the program. A site index, site descriptions, and test procedures follow.

Included in this discussion are test protocols for various species and a summary of sampling protocols.

2.2.1 Scope of Ambient Monitoring Studies

Monitoring of the overflow discharge from the tailings pond of the Greens Creek Mine was undertaken to provide early warning should any environmental problems associated with the outfall location or mine operation occur. The monitoring focuses on distinguishing naturally occurring background levels of specific elements from changes resulting from operation of the effluent from the tailings pond during mine operation.

The spatial and temporal heterogeneity of the selected discharge site in Hawk Inlet coupled with the results of pilot studies suggest that the effluent water will contain very low levels of metal and require a relatively small dilution zone. Detection of environmental changes under such conditions will require a high-resolution study with the ability to detect longer-term, subtle changes in specific metal species to determine if they are biomagnifying in the tissues of selected organisms or in the sediments. Based on existing geology and testing for background levels of trace metals, the ambient monitoring examines Cu, Zn, Pb, Hg, Cd, As, Cr, Ni, Se, and Ag.

The monitoring focuses on near-field and far-field concentrations for both surface and mid-depth transported (40 feet) discharge. Transport of contaminants to organisms and sediment is monitored through analysis of fine-grained sediments and sediment-dwelling polychaete annelids.

2.2.2 Sampling

In September 1984, sampling stations were selected to form the basis of the long-term monitoring program. A discussion of each sampling station utilized in the program follows. Corresponding maps are included in Attachment A. Based on the 1984 monitoring program, additional sampling was recommended in 1987. One new site (S5) is a subtidal sediment sampling of the area immediately under the ore-loading berth, the other was the addition of annelid, and pelecypoda (3 species) at station S4. The sampling of suspended fine fraction of the sediments was discontinued at the end of 1987.

Mussel sampling sites are:

East Shoal Light is an intertidal site consisting of mussels attached to a group of dolphin spares at the entrance to Hawk Inlet.

Station 1, a subtidal site lying in 40 feet of water and marks the approximate location of the proposed terminus of the outfall.

Station 2, an intertidal site located on the west bank of the inlet and seaward from the entrance to Hawk Inlet.

Station 3, a subtidal (40 foot) station located on the nearly vertical fjord wall directly west of the outfall terminus. Polychaete annelid sampling stations are identical to sediment sampling stations S-1, S-2 and S-3.

Sediment and annelid and/or pelecypoda sampling sites are:

Station S-1, located on the Greens Creek delta at -1 foot elevation (MLLW).

Station S-2, located in Piledriver Cove and is the southern most station

Station S-3, an intertidal area at the head of Hawk Inlet.

Station S-4, a fourth sediment sampling station added in 1985 in the intertidal area near the old cannery site, and the proposed location of the ore-loading facility. Beginning in the Spring of 1988 annelids and clams have been added to the sediment monitoring program.

Station S-5. After construction of the ore-loading facility, collection of subtidal sediment samples began from the area directly under the ship's berth. Two sediment samples are collected and composited.

The organisms to be analyzed in the program are selected to have as many of the following attributes as possible.

- Naturally occurring in Hawk Inlet.
- Sessile to provide data on duration of exposure.
- Abundant and easily collected.
- At least one species should be a filter-feeding organism.
- Capable of carrying out their entire life history at the depth and under environmental conditions found at the outfall terminus.
- Suitable for culture on artificial substrate and ability to be transplanted for in situ studies.
- When possible, the organisms should have been previously utilized for monitoring and some literature available for comparison.

The bay mussel, Mytilus edulus, is commonly used for monitoring and bioassay. Background levels are well documented by other studies worldwide and comparison with studies in Puget Sound are readily available. Several samples from Hawk Inlet have been analyzed in prior studies. It meets all of the criterion with the exception of being found naturally at the depth (40 feet) and under the environmental conditions found at the outfall site. The bay mussel is not abundant in the subtidal areas of Hawk Inlet due to heavy predation by starfish. Our results suggest that, in its native intertidal habitat, it is an excellent monitoring organism because it will be exposed to any near surface effluents from the outfall discharge. To monitor deeper water levels, such as the mid-depth level (40 feet) in the vicinity of the outfall discharge, it must be transplanted to artificial substrates (cages), and other organisms may be more suitable.

The brachiopod, Terebratalia transversa is one of five species naturally occurring in Hawk Inlet. Although we originally proposed using Lagueus californianus, we have found Terebratalia transversa to be more easily collected, larger in size and better able to be transplanted to the artificial substrate located in Station 1. When originally proposed, brachiopods had no history as a test organism. Our results have indicated they are an excellent mid-depth selection for monitoring. Like the bay mussel, Terebratalia transversa is a filter feeder, and if transplanted without physical damage, excellent survival can be expected. The brachiopods have an additional advantage over mussels. They are rather unpalatable to predators, such as the starfish, whereas the mussels we placed in the caged substrates were heavily preyed upon by starfish.

At the outset of the monitoring program, it was our intention to monitor the same sediment-dwelling polychaete at each station where sediments are collected. However, it soon became apparent that Station S-3, at the head of the inlet was unique and contained somewhat different and more complex faunal dynamics.

Collections of Nephthys sp. were made when present, Nereis vexillosa, a sediment-dwelling predator, and Abarenicola pacifica, a tube-dwelling deposit feeder were routinely analyzed.

Nephthys caeca, an omnivorous, sediment-dwelling polychaete is abundant in the intertidal of

stations S-1, and S-2, but rarely at Station S-3, which has finer sediments.

Abarenicoa pacifica, lives in a U-shaped tube and feeds by passing sediment through its gut. It has been used in both solid-phase bioassay experiments and as a trace metal test organism.

The Littleneck clams and cockles are sediment-dwelling filter/suspension feeders, abundant at the cannery site and have previously been used as test organisms.

2.2.3 Sampling Protocol

Sediment samples for trace metal monitoring are collected using non-metallic collection devices and stored in non-metallic, freezable containers. Samples are frozen within four hours after collection at -2^{o}C.

Sampling frequency:

- Pre-operational - May and September.
- Post-Operational - Monthly for first three months; then semi-annually.
- Grain-size - Sampled a initiation of program. Then, only as required.

Tissue samples are collected using non-metallic collection devices, washed in ambient seawater, taxonomically identified and verified, and stored (water free) in non-metallic freezable containers. Samples are frozen within four hours after collection.

Sampling frequency:

- Pre-operational - May and September.
- Post-operational - Monthly for first three months; then semi-annually.

2.2.4 Analytical Procedures

Sediment Grain Size and Organic Content

On August, 30, 1985, sediments were collected from each of the four intertidal sediment monitoring stations, S-1 through S-4, and analyzed for sediment particle size and organic content (volatile solids). The results indicated stations S-1, S-2, and S-4 were predominately poorly-graded sand while station S-3, at the head of the inlet, 60 percent fines. Organic content ranged between 1.5 and 2.8 at S-1, S-2, and S-4 and was 5.7 percent at station S-3. The results of the sediment analysis using ASTM methodology are shown in Appendix I.

Since trace metals are often associated with the fine sediment fraction, the sediment results suggested that a comparison of metal concentrations between the coarse and fine fraction be undertaken. The results are shown in figure 2 of the first initial pre-operational monitoring report "In Situ Monitoring of Organisms and Sediments in Hawk Inlet (Sept. 1984 through Sept. 1987).

Metal Analysis of Sediments

Sediment samples are freeze-dried, blended in a Spex mixer-mill and a 4-gram aliquot ground in a Spec ceramic ball mill. A 0.5 g subsample is pressed into a 2-cm diameter pellet and analyzed by energy-dispersive x-ray fluorescence to determine As, Cr, Cu, Ni, Pb and Zn. For the metals that were analyzed by atomic absorption, 0.2 g aliquots of the dry homogenate were digested with 4:1 nitric acid/perchloric acid in Teflon digestion bombs. After these samples were allowed to cool, hydrofluoric acid is added and the digestion bombs are returned to the 130^{o}C oven for 8 to 12 hours. The next day, boric acid is added to the solutions stored in polyethylene bottles until analyzed. Mercury is analyzed by cold vapor atomic absorption similar to the method of Bloom and Crecelius 1983. The other three metals (Cd, Se, and Ag) are analyzed by Zeeman graphite furnace with a matrix modifier of ammonium phosphate (Bloom, 1983).

Metal Analysis of Tissue

All samples are sized and shucked prior to tissue processing. Tissue samples are freeze dried to a constant weight and ground to a powder in a plastic mixer-mill. Half-gram aliquots of dry tissue homogenate from each station were reserved for analysis by x-ray fluorescence of As, Cu, Se, and Zn. For all other analyses, half-gram aliquots of dry tissue homogenate from each station sample were weighed in an acid-cleaned, pre-weighed Teflon digesting bomb. Samples are digested with 4:1 nitric acid perchloric acid at 130^{o}C for four hours. After cooling, samples are diluted with deionized-distilled water. Solution volumes were calculated and the sample solutions were transferred to polyethylene bottles for analysis. The methods of analysis used to determine specific metals include cold vapor atomic absorption for Hg and Zeeman graphite furnace for Cd, Cr, Ni, Pb, and Ag.

Effluent Toxicity

The NPDES permit also requires toxicity testing on a quarterly basis. This program requires collecting water directly from the tailings impoundment and run toxicity test on shrimp, salmon, amphipod, and crabs. The effluent is diluted to 50:1, 100:1, and 200:1. The test requires a control test and the survival of organism in the effluent is compared to the survival of the control group, to determine if a statistical difference is observed.

Samples of typical effluent test protocol for each organism are found in Attachment B.

ATTACHMENT A

FIGURES

SEAWATER TEST SITES

SEAWATER TEST PROCEDURES

AQUATIC BIOTA SAMPLING STATIONS

ATTACHMENT B

EFFLUENT TEST PROTOCOLS