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222 West 7th Avenue, #13
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Economic Prefeasibility Studies of Mining in the Stikine Area, Southeast Alaska

James R. Coldwell

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Cover Photo

Geologist investigating quartz vein swarm in Coast Range Mountain, Stikine Area, Southeast Alaska, photo by P. Bittenbender

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UNIT OF MEASURE ABBREVIATIONS

dpy	days per year
ft	foot, feet
kst	thousand short tons
lb	pound
mi	mile
Mst	million short tons
st	short ton
tr oz	troy ounce
yrs	years

ACRONYMS AND ABBREVIATIONS

ACRS	accelerated cost recovery system
AMICEF	Alaska mineral industry cost escalation factors
ANCSA	Alaska Native Claims Settlement Act
BLM	Bureau of Land Management
CES	cost estimating system
CIL	carbon-in-leach
DCFROR	discounted cash flow rate of return
FEIS	Final Environmental Impact Statement
GIPV	gross in place value
MAS	minerals availability system
MEP	mineral exploration potential
RMV	recoverable metal value
U/G	underground
USBM	U.S. Bureau of Mines
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USGS	U.S. Geological Survey
VMS	volcanogenic massive sulfide

ECONOMIC PREFEASIBILITY STUDIES OF MINING IN THE STIKINE AREA, SOUTHEAST ALASKA

by James R. Coldwell

ABSTRACT

This report is one of a series produced in conjunction with the Bureau of Land Management's (BLM) ongoing mineral assessment program and is authorized under the Alaska National Interest Lands Conservation Act (ANILCA, Section 1010). These studies assist the BLM in its long-term objectives for management of federal lands and mineral assets. Objectives include making available necessary mineral resources to meet national, regional and local needs, considering mineral and non-mineral resource values in decision making, assuring that mineral resource exploration, development, extraction, and reclamation operations are optimized, minimizing disturbances to the environment and other resources, and assuring a fair value return to the government from the development of its mineral resources.

Mining and processing cost analyses were conducted on copper-molybdenum porphyry, polymetallic replacement, vein gold, and volcanogenic massive sulfide deposit types that are found in the Stikine Area. Resources and recoverable metal values (RMV) needed to make these deposits yield a 15% discounted cash flow rate-of-return (DCFROR) were modeled. Methods for estimating ore grades and RMV are presented.

Modeling for copper-molybdenum porphyry deposits indicated the RMV ranged from $29 per short ton (st) for a 31,309 short ton per day (stpd) operation supported by a 2 mile (mi) road to $63/st for a 3,913 stpd operation supported by a 30 mi road.

Modeling for polymetallic replacement deposits indicated the RMV ranged from $169/st for a 2,189 stpd operation to $490/st for a 273 stpd operation.

Modeling for vein gold deposits indicated the RMV ranged from $150/st for a 708 stpd operation to $840/st for an 89 stpd operation.

Modeling for volcanogenic massive sulfide deposits indicated the RMV ranged from $142/st for a 6,700 stpd operation to $316/st for an 837 stpd operation.

INTRODUCTION

This report is one of a series produced in conjunction with the Bureau of Land Management's (BLM) ongoing mineral assessment program and is authorized under the Alaska National Interest Lands Conservation Act (ANILCA, Section 1010) for the assessment of the mineral potential of public lands in Alaska. These studies assist the BLM in its long term objectives for management of Federal lands and mineral assets. Objectives include making available necessary mineral resources to meet national, regional and local needs, considering mineral and non-mineral resource values in decision making, assuring that mineral resource exploration, development, extraction, and reclamation operations are optimized, minimizing disturbances to the environment and other resources, and assuring a fair value return to the government from the development of its mineral resources.

A mineral assessment includes surveying, mapping, and sampling of historic mines, prospects, and mineral occurrences as well as reconnaissance investigations of prospective mineralized areas. The main objective is to determine the type, amount, and distribution of mineral deposits, which assists in evaluating the area's mineral development potential.

Prefeasibility studies are done for various reasons. As suggested by its name, prefeasibility studies are a type of study completed prior to a final feasibility study. For most mineral projects, this occurs during the exploration stage. The results of the prefeasibility study may indicate that the expense of a final feasibility study is not warranted, and many projects do not advance to the final feasibility stage.

Prefeasibility studies are relatively inexpensive as compared to a final feasibility study. Final feasibility studies are often used in conjunction with project financing proposals, making them costly and much more detailed. At this point, feasibility is no longer in doubt. Detailed engineering, design, most drawings, formal specifications, bid documents, and sub contracts are prepared. Vendors may provide firm quotations for all machinery items. The capital cost estimate will be presented in great detail in a large volume. Environmental impact studies will be well underway or completed (Thompson, 1993).

In the private sector, prefeasibility studies are often used to make decisions about exploration projects, such as determining what level of funds may be allocated to each of several projects competing for the exploration budget. Prefeasibility studies may also be useful in determining if properties may be attractive acquisitions, or perhaps which leases may be renewed or terminated.

For the purposes of this report, economic prefeasibility studies were conducted on typical mineral deposit types that are found in the Stikine area (Figure 1). Two factors were addressed in this study: (1) the magnitude of the resource that would have to exist, and (2) the recoverable metal value (RMV) that would be necessary to make a deposit economically feasible to mine. The RMV is the combined dollar value of all saleable products from a given mineral deposit expressed in dollars per short ton ($/st), and is equal to the amount of revenues required before all expenses including royalties, mining and milling capital and operating costs, off-site transportation costs, smelting charges, and taxes are deducted. The interrelation between these factors is shown in tabular and graphical form.

Existing mineral deposit information was used whenever possible to make these economic assessments for the copper-molybdenum porphyry, polymetallic replacement, vein gold, and volcanogenic massive sulfide deposits. The BLM mineral assessment team furnished mineral deposit grades and supporting background information. Additional information was retrieved from the Minerals Availability System (MAS) database. Results of field work and analytical results from the 1997-2000 investigations of the Stikine area were published in two open-file reports (McDonald and others, 1998; Bittenbender and others, 2000). A third and final technical report is currently in progress, and provides a comprehensive summary of results (Still and others, in progress).

Detailed deposit characteristics such as depth, thickness, orientation, and volume have not been determined for the partially explored deposits used as examples in this study, so assumptions were made. These assumptions are discussed at the beginning of each deposit characteristics section.

Four groups of models are included in the report. For the reader's convenience, each group includes an individual stand-alone description of the hypothetical mine and mill models applied to each deposit type. Although repetitious, this style of presentation was selected for the sake of clarity and for ease of use. For the benefit of readers interested in only one of the models, an individual description, which includes a tabular and graphical summary of cash flow analysis, and the accompanying material from the appendices can be copied for separate use from the report.

Location, Access, Land Status

The following descriptions of location, access, and land status were modified from Bittenbender and others (2000). The lands studied in the Stikine mineral assessment are located in central Southeast Alaska and are referred to as the Stikine study area. The area includes the Kupreanof and most of the historic Petersburg mining districts (Ransome and Kearns, 1954).

"Stikine" is derived from a Tlingit name meaning "Great River." The Stikine River, the mouth of which is in the study area, is a historically important transportation route from the coast, through the Coast Mountains to the interior. Encompassing 5.7 million acres, the Stikine study area extends throughout all of the Forest Service's Petersburg and Wrangell Ranger Districts and parts of the Juneau and Thorne Bay Ranger Districts.

From east to west, it stretches from the U.S.-Canadian border to the outboard islands of the Alexander Archipelago-including the islands of Wrangell, Etolin, Zarembo, Mitkof, Kupreanof, Kuiu, and Coronation, as well as the interspersed smaller islets. From north to south, it stretches approximately 100 miles on the mainland, from its northern boundary at the head of Endicott Arm, south to Bradfield Canal.

The geography of the Stikine area is diverse. To the east on the mainland, peaks reach altitudes of 10,000 feet. Ice fields and alpine glaciers predominate; the LeConte Glacier is the southernmost in North America to flow directly into salt water. Although the topography of the islands is generally subdued compared to elsewhere in southeastern Alaska (much of Kupreaof Island consists of extensive, flat, low-lying regions), peaks reach altitudes of approximately 3,700 feet on both Kupreanof and Etolin Islands. The entire study area was glaciated about 12,000-14,000 years ago (U.S.D.A. Forest Service, 1997).

Southeast Alaska is famous for its lush rainforest. The islands of the Alexander Archipelago are typical of this rainforest. Vegetation includes muskegs in poorly drained areas and thick conifer forests of primarily western hemlock, Sitka spruce, and scattered red and yellow cedar. The tree line is variable, but is generally found around an altitude of 2,000 to 2,500 feet.

The towns of Petersburg and Wrangell have the largest populations in the area, approximately 3,600 and 3,100 respectively. Each is served by daily scheduled jet service from the major Southeast cities of Juneau and Ketchikan (connecting to Seattle), scheduled Alaska Marine Highway System ferries, commercial barge companies, and local chartered air service. Smaller air taxi services also provide access between Petersburg and Wrangell, along with scheduled daily flights to other southeastern Alaska communities and charter services to remote areas. Helicopter service is available from Petersburg and on a prearranged basis from elsewhere in the study area. The two municipalities are the main supply centers in the area. Lodging is available from numerous establishments. Car rental is also available to access the network of roads extending from both cities. There are approximately 200 miles of roads extending from Petersburg and 140 miles from Wrangell. These include municipal, state, and Forest Service roads, both paved and unpaved.

Kake (population: 700) is located on western Kupreanof Island approximately 40 miles northwest of Petersburg. It is served daily by scheduled flights from air taxi services and twice weekly by scheduled state ferry and barge service. Overnight accommodations are available. Car rental is negotiable. Generally to the north and east of Kake, an extensive logging road network includes Forest Service and Kake Tribal Corporation roads (the area's Native village corporation as established by the Alaska Native Claims Settlement Act of 1971).

The climate of the Stikine area is moderated by maritime influences; summers are cool and winters are mild. Snow is common during the winter and at higher elevations, but rain falls at all times of the year. Wrangell experiences average summer temperatures ranging from 42°F to 64°F, and average winter temperatures ranging from 21°F to 44°F. Petersburg experiences average summer temperatures ranging from 40°F to 56°F, and average winter temperatures ranging from 27°F to 43°F. The average annual rainfall is higher in Petersburg, at 106.3 inches per year, as compared to 82 inches in Wrangell. Snowfall in Petersburg is 97 inches, and Wrangell is 64 inches. About half of the precipitation in the area falls in October-December (Alaska Department of Community and Economic Development, 2001).

Environmental and Socioeconomic Issues

This preliminary study does not address environmental and socioeconomic concerns in a direct manner. For each model the acquisition cost represents the cost of mine permitting activities, environmental studies such as baseline data collection, water quality sampling and monitoring, wildlife studies, preparation of permit applications to the required local, state, and federal agencies and other related activities.

Environmental issues that may arise during the course of mineral development in the Stikine area may include, but are not limited to: access, aquatic ecosystem integrity, economic impacts, fish habitat, fisheries, heavy metals contamination, hydrologic changes, impact to scenic values, impacts from past mining operations, impacts on subsistence, impacts on visitor use, impacts from access, monitoring and enforcement, reclamation, threatened and endangered species, water quality, wetlands impacts, wilderness, and wildlife habitat.

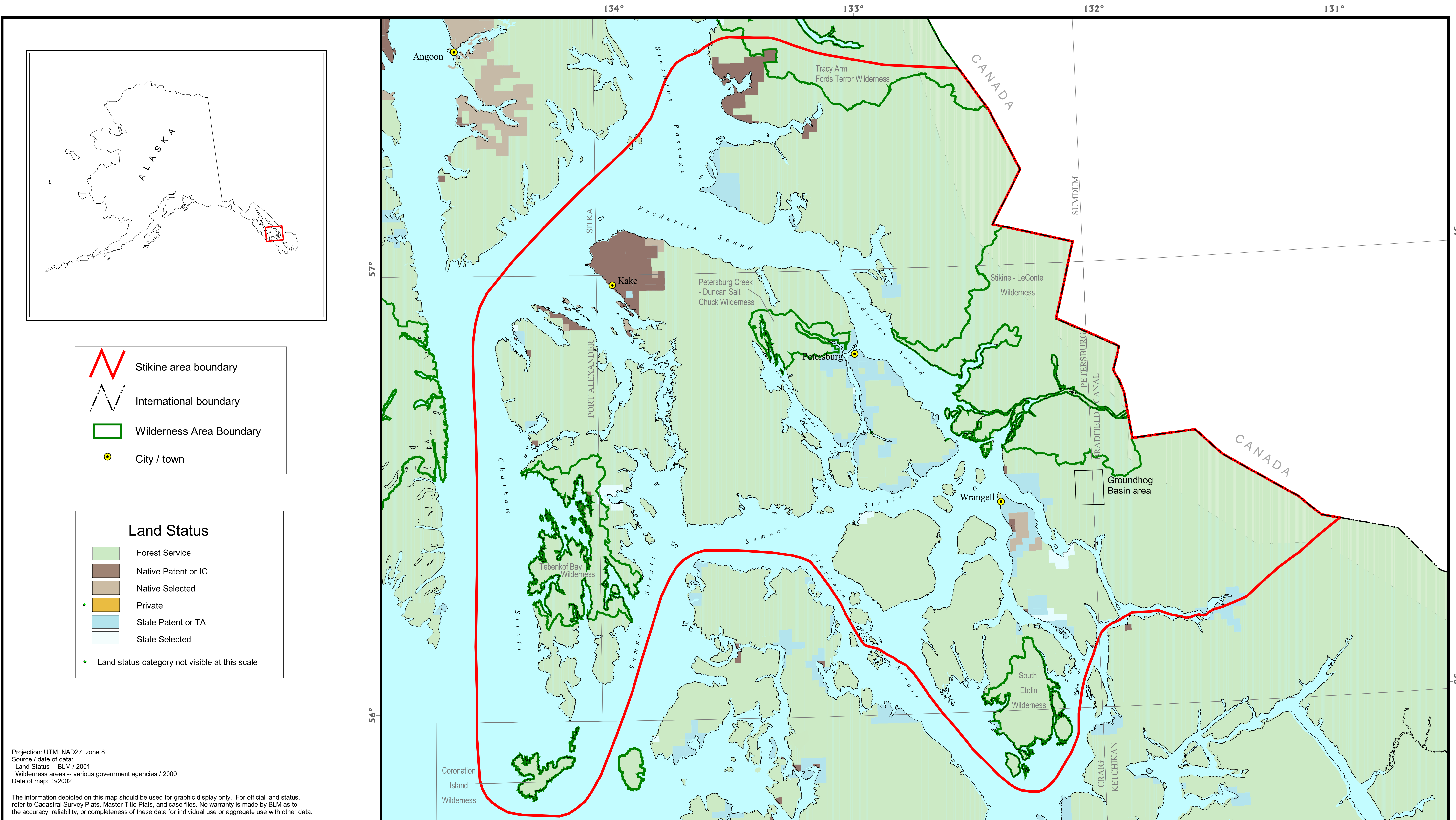

Figure 1. Location map of the Stikine study area, central Southeast Alaska.

Socioeconomic concerns may include but are not limited to potential impacts on the population (population increase, movement, or relocation in response to the project), public services and facilities, housing supply, employment, education (e.g. student population increase), local, state and Federal tax revenues and expenditures, transportation, and quality of life (Berger, 1991).

Mitigation measures and associated costs developed during the permitting process are unique for each mineral development project. It is difficult to estimate these costs without benefit of public scoping and at least a preliminary environmental and socioeconomic assessment for the proposed mineral development project. These issues and the associated costs of mitigation are beyond the scope of this preliminary study, and are not addressed in the economic models.

ECONOMIC MINE PREFEASIBILITY STUDIES

Economic prefeasibility studies for four mineral deposits types were conducted to establish the recoverable metal value (RMV) per short ton necessary to meet a 15% discounted-cash-flow rate-of-return (DCFROR). The definition of RMV from previous feasibility studies performed by the U.S. Bureau of Mines (USBM) was used (Baggs and Sherman, 1987; Sherman and Baggs, 1988).

The RMV is the combined dollar value of all salable products from a given mineral deposit expressed in $/st. The RMV is used to reduce the individual effects of commodity grades, recoveries, and metal prices to a common base so that a single curve relating ore value of the deposit to DCFROR could be created. See Appendix B for further information and a sample calculation of RMV.

This pre-feasibility report considers a number of factors controlling the feasibility of mineral development including physical attributes and geographic location of the deposit, metallurgical attributes of the minerals, metal markets, and infrastructure availability. Results presented here should be considered preliminary. Additional factors such as perceived risk, political and economic climate, environmental constraints, and corporate policy may be relevant but aren’t considered.

These factors are important, but are beyond the scope of this study, and the available information base for this report. These factors receive more in-depth consideration assuming the project advances from the exploration and pre-feasibility stage, into final project feasibility studies, permitting, and development.

Capital and operating costs for the copper-molybdenum porphyry, polymetallic replacement, vein gold, and volcanogenic massive sulfide (VMS) mine models were determined using the USBM Cost Estimation System (CES) version 2.3 (U.S. Bureau of Mines, 1995). These models were supplemented with additional information from Simplified Cost Models for Prefeasibility Mineral Evaluations (Camm, 1991) and PREVAL: Prefeasibility Software Program For Evaluating Mineral Properties (Smith, 1992).

Cost estimates were escalated using the USBM Alaska Mineral Industry Cost Escalation Factors (AMICEF) of 1.51 for operating labor, 1.58 for capital labor, 1.04 for capital costs, and 1.60 for electricity to reflect higher costs in the Stikine area. These factors are a set of calculated values that are used to escalate itemized capital and operating costs for mining and milling operations from the central front range of the Rocky Mountains (Denver vicinity) to any point in Alaska. The Denver vicinity is used as the base for CES (Balen and Allen, 1993)

Published cost information from permitting documents, environmental impact statements, and private reports were also used (U.S.D.A. Forest Service, 1983, 1991; U.S. Environmental Protection Agency and others, 1984). All cost estimates are expressed in 2001 U.S. dollars.

Using the estimated capital and operating costs, economic models were compiled using cash flow analysis techniques. The RMV and DCFROR were computed. See Appendix A for the economic models and Appendix B for 10, 20, and 30 year average commodity prices.

Copper-molybdenum porphyry mine models

The copper-molybdenum porphyry deposit model is based on the geology of mineralized occurrences similar to those found at the Portage Bay Pit on northern Kupreanof Island, and the Black Crag prospect on the mainland (Bittenbender and others, 2000, p. 47, 178). Cox and Singer (1987) describe the deposit model as stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. Primary mineralogy is chalcopyrite, pyrite, and molybdenite. Peripheral vein or replacement deposits may occur with chalcopyrite, sphalerite, galena, and gold mineralogy. Veins of copper-silver-antimony-sulfides, barite, and gold may be located toward the outer zone of the deposit. In general, ore grade is positively correlated with the spacing of veinlets, and mineralized fractures. Country rocks favorable for mineralization include calcareous sediments, diabase, tonalite, and diorite.

The mine models designed for application to the copper porphyry deposit models assume that the deposit is located near surface and the structural characteristics of the orebody are such that open pit mining methods are applicable. Minable resources sizes from 17 to 276 million short tons were modeled to represent the possible size for this deposit type in the Stikine area. Ten models were developed, five assume the deposit would be located 2 mi from tidewater (Portage Bay), and five assume the deposit would be located 30 mi from tidewater (Black Crag).

It is assumed that a work force would be recruited from Petersburg, Wrangell, and Kake. Employees would commute daily to the proposed Portage Bay terminal on north Kupreanof Island. A crew boat would run three round trips per day. Buses would transport each shift from the terminal to the proposed mine over a proposed access road. Tractors on shore would move supplies from incoming barges at the terminal. It is assumed flotation concentrates would be trucked from the mine to the terminal and shipped to a smelter assumed to be located in Japan. Similar arrangements were assumed for Black Crag adjusted for location and road length.

A total of ten open pit mine models were developed for application to this deposit model. In each mine model, the associated mill uses flotation processing. Open pit mine models assume the use of rubber-tired front-end loaders, trucks, and percussion drills. The stripping ratio is assumed to be 1:1. It is assumed that all ten models would use power from the Tyee hydroelectric power grid.

Table 1 summarizes the cash flow analysis of the copper-molybdenum porphyry mine models. The RMV required to achieve a 15% DCFROR ranges from \$29/st for a 31,309 short tons per day (stpd) mine with a 2 mi road to \$63/st for a 3,913 stpd operation with a 30 mi road. Figure 2 graphically presents the results for the ten copper-molybdenum porphyry mine models. Tables A-2 and A-7 in Appendix A list the itemized capital and operating costs of the five copper-molybdenum (2 mi road) mine models respectively. Tables A-3 and A-8 in Appendix A list the itemized capital and operating costs of the five copper-molybdenum (30 mi road) mine models respectively.

Table 1. - Summary of cash flow analysis for copper-molybdenum porphyry mine models

Deposit size (Mst)	Mining rate (stpd)	RMV (2 mi road) 15% DCFROR ($/st)	RMV (30 mi road) 15% DCFROR ($/st)
17	3,913	$56	$63
34	6,582	44	49
68	11,069	37	39
138	18,616	32	34
276	31,309	$29	$30

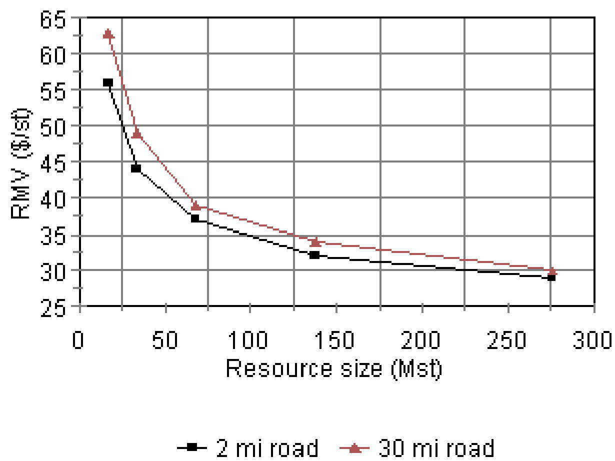

Figure 2. - RMV vs. resource size, copper molybdenum porphyry mine models

Polymetallic replacement mine models

The polymetallic replacement mine model is based on the geology of mineralized occurrences similar to those found at Groundhog Basin (Bittenbender and others, 2000, p. 146). Cox and Singer (1987) describe the deposit model as hydrothermal, epigenetic, silver, lead, zinc, and copper minerals in massive lenses, pipes and veins in limestone, dolomite, or other soluble rock near igneous intrusions.

These deposits usually include an inner zone with higher metal concentrations; with argentite, bournonite, chalcopyrite, digenite, enargite, galena, jordanite, polybasite, proustite, pyrargyrite, sphalerite, stephanite, tetrahedrite, rare bismuthinite, and rare jamesonite mineralogy. Towards the outer zone of the deposit, metal concentrations are lower, and the dominant mineralogy is composed of sphalerite, and rhodochrosite. Quartz, pyrite, marcasite, and barite mineralogy is widespread in the deposit. Sylvanite, calaverite, and rare gold may be locally present in some deposits. Ore controls are described as tabular, podlike, and pipelike ore bodies localized by faults or vertical beds; or ribbonlike or blanketlike ore bodies localized by bedding-plane faults, susceptible beds, preexisting solution channels, caverns, or cave rubble.

The mine models assume ore is mined by shrinkage stoping methods using stopers for drilling and jacklegs for rock bolting. Stopes, stope raises, laterals, and crosscuts necessary for production are developed using drilling and blasting methods. It is assumed that a work force would be recruited from Petersburg, Wrangell, and Kake. Employees would commute daily from Wrangell via the Eastern Passage. A crew boat would run three round trips per day. Buses would transport each shift from the proposed Eastern Passage terminal to the proposed mine site via a proposed 10 mi access road. Tractors on shore would move supplies from incoming barges at the proposed terminal. It is assumed flotation concentrates would be trucked from the mine to the terminal and shipped to a smelter assumed to be located in Japan.

It is assumed that the two smaller models (273 stpd, 460 stpd) would produce their own electric power using diesel powered generators. It is assumed the three larger models (774 stpd, 1,302 stpd, 2,189 stpd) would use power from the Tyee hydroelectric power grid.

Table 2 summarizes the cash flow analysis of the polymetallic replacement mine models. The RMV required to achieve a 15% DCFROR ranges from $169/st for a 2,189 stpd mine to $490/st for a 273 stpd mine. Figure 3 graphically presents the results for the polymetallic replacement mine models. Tables A-4 and A-9 in Appendix A list the itemized capital and operating costs of the five polymetallic replacement mine models respectively.

Table 2. - Summary of cash flow analysis for polymetallic replacement mine models

Deposit size (kst)	Mining rate (stpd)	RMV 15% DCFROR ($/st)
496	273	$490
992	460	345
1,984	774	259
3,968	1,302	203
7,937	2,189	$169

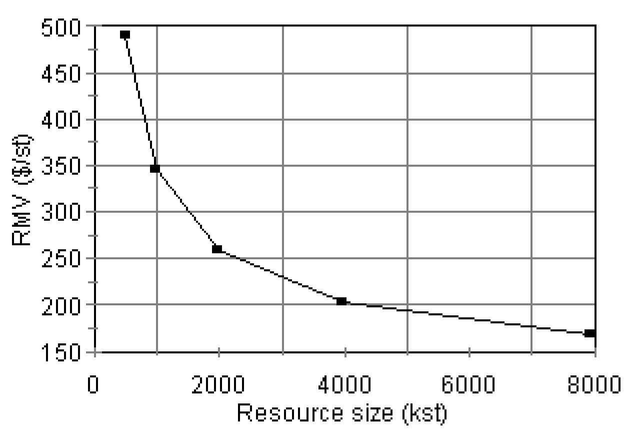

Figure 3. - RMV vs. resource size, polymetallic replacement mine model

Vein gold mine models

The vein gold mine models are based on the geology of mineralized occurrences similar to those found at the Helen S and Maid of Mexico mines, and the Brushy Creek, East of Harvey Lake, Fortune, Harvey Creek, Hattie, Lost Show, Mad Dog 2, and Scott prospects on Woewodski Island (Bittenbender and others, 2000, p. 79 - 94).

Cox and Singer (1987) describe the vein gold deposit model as gold in massive persistent quartz veins mainly in regionally metamorphosed volcanic rocks and sediments. Mineralogy is described as mainly quartz, native gold, pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, and pyrrhotite, but tellurides, scheelite, bismuth, tetrahedrite, stibnite, molybdenite, and fluorite may be present in some deposits. Productive quartz is grayish or bluish in many instances because of fine-grained sulfides. Carbonates of calcium, magnesium, and iron are abundant. Ore controls are described as persistent veins along regional high-angle faults, and joint sets. Best deposits overall occur in areas with greenstone. High-grade ore shoots occur locally at metasediment-serpentine contacts. Disseminated ore bodies occur where veins cut granitic rocks.

The vein gold deposit models are based on the geology and mineralization present at several prospects on Woewodski Island. The models assume ore is mined by shrinkage stoping methods using stopers for drilling and jacklegs for rock bolting. Stopes, stope raises, laterals, and crosscuts necessary for production are developed using drilling and blasting methods. The ore is milled using carbon-in-leach processing.

It is assumed that the local population in Petersburg would be sufficient to recruit a work force. Employees would commute daily via the Mitkof Highway and other improved roads to a proposed parking lot and dock to be built on Mitkof Island. A crew boat would run three round trips per day across Wrangell Narrows. Buses would be scheduled to transport each shift from the proposed Woewodski Island terminal to the hypothetical mine site via a proposed 3 mi access road. Tractors on shore would move supplies from incoming barges at the proposed Woewodski Island terminal.

The models assume that doré bullion is produced from a carbon-in-leach (CIL) mill built on site. It is assumed that the smaller models would produce their own electric power using diesel powered generators. It is assumed the largest model (643 stpd) would use power from the Tyee hydroelectric power grid.

Use of the Westmin Premier Mill located 12 mi north of Hyder, Alaska was investigated for off-site processing of the ore; however, it was found that Boliden Ltd. has no plans to restart production and the mill and other movable infrastructure on site is currently being sold through an asset disposal firm (Jim Jack, Boliden Ltd., email commun., 2001).

Use of the Greens Creek mill located about 18 mi southwest of Juneau or the proposed Kensington mill located about 50 mi north of Juneau were considered, but not evaluated. Greens Creek hasn’t solicited customers for custom milling. Kennecott Minerals Company has steadily expanded the mill’s capacity over the past six years to meet its own needs, and it is unlikely that excess capacity currently exists to serve another mine. The Kensington mill has not been built yet, but Coeur d'Alene Mines has recently re-optimized the project in response to low gold prices. Public scoping for a supplemental environmental impact statement (SEIS) is anticipated in early 2002. Construction may start in about two years after the SEIS and permit amendments are completed.

Table 3 summarizes the cash flow analysis of the vein gold mine models. The RMV needed for a 15% DCFROR ranges from $150/st for a 708 stpd mine to $840/st for an 89 stpd mine. Figure 4 graphically presents the results for the vein gold mine models. Tables A-5 and A-10 in Appendix A list the itemized capital and operating costs of the five vein gold mine models respectively.

Table 3. - Summary of cash flow analysis for vein gold mine models

Deposit size (st)	Mining rate (stpd)	RMV on-site mill 15% DCFROR ($/st)
110,200	89	$840
220,500	149	572
440,900	250	355
881,900	421	236
1,763,700	708	$150

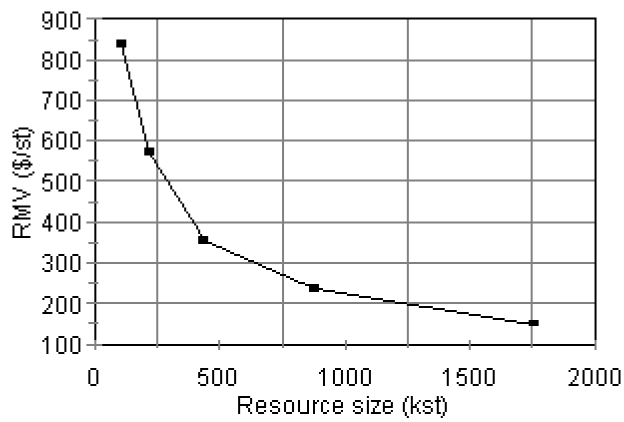

Figure 4. - RMV vs. resource size, vein gold mine models

Volcanogenic massive sulfide mine models

Cox and Singer (1987) describe the massive sulfide deposit model as copper and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition. Mineralogy consists of an upper stratiform massive zone (black ore) with pyrite, sphalerite, chalcopyrite, pyrrhotite, galena, barite, tetrahedrite, tennatite, bornite; a lower stratiform massive zone (yellow ore) with pyrite, chalcopyrite, sphalerite, pyrrhotite, magnetite; and a stringer (stockwork) zone with pyrite, and chalcopyrite (gold and silver). Gahnite occurs in metamorphosed deposits, with gypsum/anhydrite present in some deposits. Ore may be formed or localized near the more felsic top of volcanic or volcanic-sedimentary sequence, and near the center of felsic volcanism. Ore may be locally brecciated or have felsic domes nearby. Pyritic siliceous rock (exhalite) may mark horizons at which deposits occur. Proximity to deposits may be indicated by sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions in the sea floor.

The volcanogenic massive sulfide deposit models are based on the geology and mineralization present in the Alexander terrane extending along both sides of Duncan Canal on Kupreanof Island, south across Zarembo Island, and onto the western side of Etolin Island (Bittenbender and others, 2000). The massive sulfide mine models assume that the structural characteristics of the orebody favor the use of underground cut and fill mining method similar to that used at Kennecott Mineral Company's Greens Creek Mine located about 18 mi southwest of Juneau. It is assumed that the hypothetical volcanogenic massive sulfide deposit is located on Woewodski Island.

It is assumed that the local population in Petersburg would be sufficient to recruit a work force. Employees would commute daily via the Mitkof Highway and other improved roads to a proposed parking lot and dock to be built on Mitkof Island. A crew boat would run three round trips per day across Wrangell Narrows. Buses would be scheduled to transport each shift from the proposed Woewodski Island terminal to the mine site via a proposed 3 mi access road. Tractors on shore would move supplies from incoming barges at the proposed terminal. It is assumed flotation concentrates would be trucked from the mine site to the proposed Woewodski Island terminal and shipped year round to a smelter assumed to be located in Japan.

Five underground cut and fill mine models were developed using an on-site mill. Underground cut and fill mine models incorporate the use of jackleg drills, stopers, and small jumbos. Slushers move ore from the stope to ore chutes, Load-Haul-Dumps (LHDs) move ore from chutes to ore storage pockets. Hydraulic sand fill is used to fill stopes. After processing, approximately half of the daily ore production would be backfilled into the mine, 28% would be sent to the tailings pond for disposal, with the remaining volume constituting the concentrates. It is assumed that all five models would use power from the Tyee hydroelectric power grid.

Table 4 summarizes the cash flow analysis of the massive sulfide models. The RMV required to achieve a 15% DCFROR ranges from $142/st for a 6,700 stpd to $316/st for an 837 stpd mine. Figure 5 graphically presents the results for the massive sulfide mine models. Tables A-6 and A-11 in Appendix A list the itemized capital and operating costs of the five massive sulfide mine models respectively.

Table 4. - Summary of cash flow analysis for volcanogenic massive sulfide (VMS) mine models

Deposit size (Mst)	Mining rate (stpd)	RMV 15% DCFROR ($/st)
2.2	837	$316
4.4	1,408	241
8.8	2,369	194
17.6	3,984	164
35.3	6,700	$142

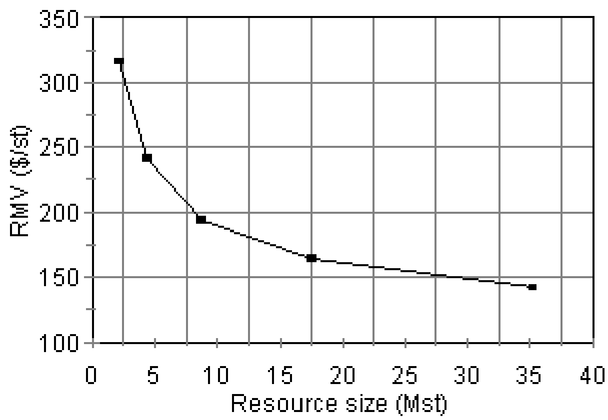

Figure 5. - RMV vs. resource size, volcanogenic massive sulfide mine models

SUMMARY AND CONCLUSIONS

Mining and processing cost analyses were conducted on copper-molybdenum porphyry, polymetallic replacement, vein gold, and volcanogenic massive sulfide deposit types that are found in the Stikine area. Mine models were developed for application to the mineral deposit models. Capital and operating costs for the models were determined. Resource and recoverable metal values (RMV) needed to make these deposits yield a 15% DCFROR were modeled. Methods for estimating ore grades and RMV are presented.

Published cost information drawn from industry publications, permitting documents, and environmental impact statements were also used. All costs were escalated by factors, which reflect the higher cost of labor, transportation, and electricity in Alaska.

Economic modeling for copper-molybdenum porphyry deposits indicated the RMV ranged from $29/st for a 31,309 stpd operation supported by a 2 mi road to $63/st for a 3,913 stpd operation supported by a 30 mi road.

Economic modeling for polymetallic replacement deposits indicated the RMV ranged from $169/st for a 2,189 stpd operation to $490/st for a 273 stpd operation.

Economic modeling for vein gold deposits indicated the RMV ranged from $150/st for a 708 stpd operation to $840/st for an 89 stpd operation.

Economic modeling for volcanogenic massive sulfide deposits indicated the RMV ranged from $142/st for a 6,700 stpd operation to $316/st for an 837 stpd operation.

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APPENDIX A. - CAPITAL AND OPERATING COSTS FOR MINE MODELS

The tables in this appendix give the mineral deposit type and mine model descriptions; and itemized capital and operating costs for the Stikine area models. A four-year preproduction period is assumed for the copper-molybdenum porphyry, polymetallic vein, vein gold, and volcanogenic massive sulfide models. The models assume exploration, permitting, development, mobilization, and construction will take four years. All activities would operate concurrently during the four year period (2002-2005). Production would begin in 2006. Reclamation would commence in the final year of production immediately following depletion of the deposit.

Table A-1. - Mine model descriptions

Deposit type	Deposit size (kst)	Mine model	Mining rate (stpd)	Mine life[1] (yrs)	Mill type
Cu-Mo porphyry	17,224	Surface	3,913	12.6	Flotation
Cu-Mo porphyry	34,447	Surface	6,582	15.0	Flotation
Cu-Mo porphyry	68,894	Surface	11,069	17.8	Flotation
Cu-Mo porphyry	137,789	Surface	18,616	21.1	Flotation
Cu-Mo porphyry	275,578	Surface	31,309	25.1	Flotation
Polymetallic replacement	496	Shrinkage stoping	273	5.2	Flotation
Polymetallic replacement	992	Shrinkage stoping	460	6.2	Flotation
Polymetallic replacement	1,984	Shrinkage stoping	774	7.3	Flotation
Polymetallic replacement	3,968	Shrinkage stoping	1,302	8.7	Flotation
Polymetallic replacement	7,937	Shrinkage stoping	2,189	10.4	Flotation
Vein gold	110	Shrinkage stoping	89	3.6	CIL Plant
Vein gold	220	Shrinkage stoping	149	4.2	CIL Plant
Vein gold	441	Shrinkage stoping	250	5.0	CIL Plant
Vein gold	882	Shrinkage stoping	421	6.0	CIL Plant
Vein gold	1,764	Shrinkage stoping	708	7.1	CIL Plant
Massive sulfide	2,205	Cut and fill	837	7.5	Flotation
Massive sulfide	4,409	Cut and fill	1,408	8.9	Flotation
Massive sulfide	8,818	Cut and fill	2,369	10.6	Flotation
Massive sulfide	17,637	Cut and fill	3,984	12.6	Flotation
Massive sulfide	35,274	Cut and fill	6,700	15.0	Flotation

[1] Mine life estimate is based on 350 days per year.

TABLE A-2. - Itemized capital costs - Cu - Mo porphyry mine model road supported operation (2 mi road)

Model description					
Resource size (Mst)	17	34	69	138	276
Mining rate (stpd)	3,913	6,582	11,069	18,616	31,309
Capital costs ($)					
Total eng. & const. fees	18,506,000	26,775,000	40,227,000	62,974,000	96,099,000
Working capital	8,449,000	12,671,000	19,837,000	30,074,000	47,649,000
Acquisition	5,519,000	7,725,000	11,323,000	20,575,000	28,818,000
Exploration	57,129,000	66,530,000	77,477,000	90,223,000	105,069,000
Reclamation	11,038,000	15,451,000	22,646,000	41,150,000	57,636,000
Access roads	1,670,000	1,670,000	1,670,000	1,670,000	1,670,000
Mine bldg - foundation	488,000	513,000	551,000	609,000	700,000
Mine bldg - offices	870,000	1,762,000	3,570,000	7,232,000	14,652,000
Mine bldg - laboratories	432,000	533,000	658,000	811,000	1,001,000
Mine bldg - shops & warehouses	1,304,000	1,496,000	1,715,000	1,966,000	2,254,000
Mine bldg - general support	626,000	797,000	1,015,000	1,293,000	1,647,000
Mine bldg - foundation	230,000	232,000	236,000	242,000	252,000
Clearing	10,000	23,000	43,000	86,000	174,000
Powerlines - 69kv	6,938,000	6,938,000	6,938,000	6,938,000	6,938,000
Sanitation	4,191,000	4,351,000	4,604,000	4,992,000	5,569,000
Utility substation & distribution	4,413,000	5,524,000	6,912,000	8,652,000	10,833,000
Marine Terminal	3,326,000	3,575,000	3,910,000	4,363,000	4,976,000
Mineral Processing					
Flotation	10,945,000	17,656,000	28,481,000	45,942,000	74,116,000
Tailings dam construction	16,022,000	26,129,000	45,563,000	87,099,000	149,413,000
Transport/place tailings	760,000	1,070,000	1,506,000	2,119,000	2,981,000
Stockpile storage	383,000	523,000	713,000	973,000	1,328,000
Mill bldg - foundation	285,000	408,000	587,000	844,000	1,217,000
Mill bldg - 20 foot eave	374,000	501,000	671,000	899,000	1,205,000
Mill bldg - offices	339,000	688,000	1,393,000	2,821,000	5,716,000
Mill bldg - laboratories	326,000	403,000	497,000	613,000	756,000
Conc storage bldg - mill	173,000	291,000	489,000	822,000	1,383,000
Wastewater-neutralization	1,739,000	4,196,000	7,025,000	10,126,000	13,446,000
Surface mining					
Preproduction capital cost					
Drill & blast	1,937,000	2,683,000	3,735,000	5,225,000	7,339,000
Frontend loader & truck	6,565,000	9,958,000	15,316,000	23,851,000	37,552,000
Equipment					
In-pit primary crushers	5,032,000	5,160,000	5,375,000	5,737,000	6,346,000
Communications system	27,000	34,000	44,000	57,000	73,000
Mill electrical system	3,210,000	4,617,000	6,640,000	10,146,000	17,065,000
Mine electrical system	10,000	14,000	20,000	28,000	39,000
Fuel storage - mill	27,000	45,000	75,000	126,000	211,000
Fueling system	18,000	28,000	44,000	69,000	106,000
Drill & blast	557,000	726,000	946,000	1,233,000	1,608,000
Frontend loader & truck	5,704,000	9,589,000	16,118,000	27,093,000	45,542,000
Total capital cost	179,572,000	241,285,000	338,120,000	509,673,000	753,379,000

TABLE A-3. - Itemized capital costs - Cu - Mo porphyry mine model road supported operation (30 mi road)

Model description					
Resource size (Mst)	17	34	69	138	276
Mining rate (stpd)	3,913	6,582	11,069	18,616	31,309
Capital costs ($)					
Total eng. & const. fees	18,506,000	26,775,000	40,227,000	62,974,000	96,099,000
Working capital	8,745,000	13,003,000	19,666,000	30,308,000	48,044,000
Acquisition	5,519,000	7,725,000	11,323,000	20,575,000	28,818,000
Exploration	57,129,000	66,530,000	77,477,000	90,223,000	105,069,000
Reclamation	11,038,000	15,451,000	22,646,000	41,150,000	57,636,000
Access roads	25,020,000	25,020,000	25,020,000	25,020,000	25,020,000
Mine bldg - foundation	488,000	513,000	551,000	609,000	700,000
Mine bldg - offices	870,000	1,762,000	3,570,000	7,232,000	14,652,000
Mine bldg - laboratories	432,000	533,000	658,000	811,000	1,001,000
Mine shops & warehouses	1,304,000	1,496,000	1,715,000	1,966,000	2,254,000
Mine bldg - general support	626,000	797,000	1,015,000	1,293,000	1,647,000
Mine bldg - foundation	230,000	232,000	236,000	242,000	252,000
Clearing	10,000	23,000	43,000	86,000	174,000
Powerlines - 69 kV	12,282,000	12,282,000	12,282,000	12,282,000	12,282,000
Sanitation	4,191,000	4,351,000	4,604,000	4,992,000	5,569,000
Utility substation & distribution	4,413,000	5,524,000	6,912,000	8,652,000	10,833,000
Marine terminal	3,326,000	3,575,000	3,910,000	4,363,000	4,976,000
Mineral processing					
Flotation	10,945,000	17,656,000	28,481,000	45,942,000	74,116,000
Tailings dam construction	16,022,000	26,129,000	45,563,000	87,099,000	149,413,000
Transport/place tailings	760,000	1,070,000	1,506,000	2,119,000	2,981,000
Stockpile storage	383,000	523,000	713,000	973,000	1,328,000
Mill bldg - foundation	285,000	408,000	587,000	844,000	1,217,000
Mill bldg - 20 foot eave	374,000	501,000	671,000	899,000	1,205,000
Mill bldg - offices	339,000	688,000	1,393,000	2,821,000	5,716,000
Mill Bldg - laboratories	326,000	403,000	497,000	613,000	756,000
Conc storage bldg - Mill	173,000	291,000	489,000	822,000	1,383,000
Wastewater-neutralization	1,739,000	4,196,000	7,025,000	10,126,000	13,446,000
Surface Mining					
Preproduction capital cost					
Drill & blast	1,937,000	2,683,000	3,735,000	5,225,000	7,339,000
Frontend loader & truck	6,565,000	9,958,000	15,316,000	23,851,000	37,552,000
Equipment					
In-pit primary crushers	5,032,000	5,160,000	5,375,000	5,737,000	6,346,000
Communications system	27,000	34,000	44,000	57,000	73,000
Mill electrical system	3,210,000	4,617,000	6,640,000	10,146,000	17,065,000
Mine electrical system	10,000	14,000	20,000	28,000	39,000
Fuel storage - mill	27,000	45,000	75,000	126,000	211,000
Fueling System	18,000	28,000	44,000	69,000	106,000
Drill & blast	557,000	726,000	946,000	1,233,000	1,608,000
Frontend loader & truck	5,704,000	9,589,000	16,118,000	27,093,000	45,542,000
Total Capital Cost	208,562,000	270,311,000	367,093,000	538,601,000	782,468,000

TABLE A-4. - Itemized capital costs - polymetallic replacement mine model

Model description					
Resource size (Mst)	0.45	0.90	1.80	3.60	7.20
Mining rate (stpd)	273	460	774	1302	2189
Capital costs ($)					
Total eng. & const. fees	7,067,000	8,557,000	10,503,000	13,561,000	18,103,000
Working capital	3,910,000	5,820,000	8,887,000	13,809,000	21,758,000
Acquisition	4,474,000	5,346,000	6,356,000	7,888,000	10,087,000
Exploration	26,195,000	30,503,000	35,532,000	41,382,000	48,189,000
Reclamation	5,982,000	7,248,000	9,046,000	11,344,000	14,677,000
Access roads	5,239,000	5,239,000	5,239,000	5,239,000	5,239,000
Mine bldg - foundation	456,000	458,000	461,000	465,000	472,000
Mine bldg - 20 foot eave	357,000	357,000	357,000	358,000	358,000
Mine bldg - offices	9,000	19,000	39,000	79,000	159,000
Mine bldg - laboratories	115,000	142,000	175,000	216,000	266,000
Mine bldg - shops & warehouses	557,000	639,000	733,000	840,000	963,000
Mine bldg - general support	136,000	173,000	220,000	281,000	357,000
Mine bldg - foundation	235,000	235,000	235,000	235,000	235,000
Concentrate storage bldg	393,000	661,000	1,113,000	1,872,000	3,147,000
Clearing	637,000	637,000	637,000	637,000	637,000
Utility substation & distribution			1,714,000	2,347,000	3,210,000
Powerlines - 69 kv	22,000	22,000	7,688,000	7,688,000	7,688,000
Sanitation	2,265,000	2,607,000	3,025,000	3,511,000	4,068,000
Water system	1,033,000	1,047,000	1,096,000	1,155,000	1,225,000
Diesel power generation	4,773,000	6,414,000			
Marine terminal	4,765,000	5,727,000	7,109,000	9,096,000	11,953,000
Flotation	4,341,000	6,644,000	10,179,000	15,587,000	23,858,000
Tailings dam construction	5,720,000	6,207,000	6,976,000	8,157,000	9,924,000
Transport/place tailings	100,000	141,000	198,000	279,000	393,000
Mill bldg - foundation	48,000	68,000	96,000	138,000	197,000
Mill bldg - 20 foot eave	86,000	115,000	155,000	207,000	278,000
Mill bldg - offices	9,000	19,000	39,000	79,000	159,000
Mill bldg - laboratories	115,000	142,000	175,000	216,000	266,000
Conc storage bldg - mill	192,000	323,000	544,000	914,000	1,538,000
Wastewater-neutralization	133,000	258,000	497,000	955,000	1,845,000
Shrinkage stope development	886,000	1,342,000	2,037,000	3,095,000	4,711,000
Communications system	7,000	10,000	12,000	16,000	20,000
Mill electrical system	501,000	720,000	1,037,000	1,492,000	2,145,000
Mine electrical system	1,000	2,000	2,000	3,000	4,000
Fuel storage - mill	1,000	2,000	2,000	3,000	4,000
Fueling system	1,000	2,000	3,000	4,000	7,000
Total Capital Cost	80,761,000	97,846,000	122,117,000	153,148,000	198,140,000

TABLE A-5. - Itemized capital costs - vein gold mine models

Model description					
Resource Size (kst)	110	220	441	882	1,764
Mining rate (stpd)	89	149	250	421	708
Capital Costs ($)					
Total eng. & const. fees	4,632,000	5,333,000	6,287,000	7,743,000	9,867,000
Working capital	832,000	1,180,000	1,693,000	2,479,000	3,498,000
Acquisition	2,807,000	3,281,000	3,885,000	4,722,000	5,877,000
Exploration	18,826,000	21,924,000	25,521,000	29,732,000	34,624,000
Reclamation	3,785,000	4,482,000	5,364,000	6,542,000	7,947,000
Access roads	1,897,000	1,897,000	1,897,000	1,897,000	1,897,000
Mine bldg - foundation	441,000	442,000	444,000	446,000	448,000
Mine bldg - 20 foot eave	348,000	348,000	348,000	348,000	348,000
Mine bldg - offices	2,000	4,000	8,000	17,000	33,000
Mine bldg - laboratories	71,000	88,000	108,000	133,000	165,000
Mine bldg - shops & warehouses	404,000	463,000	530,000	608,000	697,000
Mine bldg - general support	78,000	100,000	127,000	162,000	206,000
Mine bldg - foundation	228,000	228,000	229,000	229,000	229,000
Clearing	637,000	638,000	638,000	638,000	638,000
Powerlines - 69 kv	21,000	21,000	21,000	21,000	4,500,000
Sanitation	1,507,000	1,760,000	2,014,000	2,319,000	2,695,000
Diesel power generation	2,531,000	3,388,000	4,542,000	6,098,000	
Utility substation & distribution					1,628,000
Marine terminal	2,797,000	2,894,000	3,012,000	3,184,000	3,441,000
Carbon in leach processing	1,435,000	2,159,000	3,239,000	4,862,000	7,299,000
Tailings dam construction	5,188,000	5,415,000	5,637,000	6,111,000	6,822,000
Transport/place tailings	65,000	91,000	128,000	180,000	254,000
Mill bldg - foundation	22,000	31,000	44,000	62,000	89,000
Mill bldg - 20 foot eave	44,000	60,000	80,000	107,000	143,000
Mill bldg - offices	2,000	4,000	8,000	17,000	33,000
Mill bldg - laboratories	71,000	88,000	108,000	133,000	165,000
Wastewater-neutralization	638,000	1,539,000	2,577,000	3,715,000	4,933,000
Shrinkage stope development	361,000	546,000	823,000	1,247,000	1,891,000
Communications system	4,000	6,000	7,000	9,000	12,000
Mill electrical system	1,048,000	1,511,000	2,174,000	3,126,000	4,496,000
Mine electrical system	1,000	1,000	1,000	1,000	2,000
Fuel storage - mill	1,000	1,000	1,000	1,000	2,000
Fueling system	1,000	1,000	1,000	2,000	2,000
Total capital cost	50,724,000	59,924,000	71,496,000	86,891,000	104,881,000

TABLE A-6. - Itemized capital costs - volcanogenic massive sulfide models

Model description					
Resource size (Mst)	2.2	4.4	8.8	17.6	35.3
Mining rate (stpd)	837	1,408	2,369	3,984	6,700
Capital Cost ($)					
Access roads	1,897,000	1,897,000	1,897,000	1,897,000	1,897,000
Acquisition	6,651,000	7,990,000	9,886,000	12,298,000	15,618,000
Concentrate storage bldg	822,000	1,382,000	2,324,000	3,908,000	6,572,000
Equipment	9,394,000	15,799,000	26,570,000	44,686,000	75,152,000
Exploration	36,358,000	42,343,000	49,316,000	57,430,000	66,878,000
Marine terminal	4,038,000	4,677,000	5,598,000	6,921,000	8,824,000
Mill	12,879,000	18,603,000	26,874,000	38,824,000	56,091,000
Mine	35,367,000	45,145,000	57,801,000	74,256,000	95,753,000
Mine development	17,674,000	17,674,000	17,674,000	17,674,000	17,674,000
Utility substation & distribution	1,799,000	2,463,000	3,365,000	4,608,000	6,309,000
Powerlines 69 kv	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000
Reclamation	15,434,000	18,500,000	22,927,000	28,847,000	37,312,000
Tailings dam	5,318,000	6,070,000	6,863,000	8,888,000	11,822,000
Total eng. & const. fees	14,797,000	17,881,000	22,074,000	27,702,000	35,446,000
Working capital	12,180,000	18,075,000	27,233,000	41,641,000	64,496,000
Total capital cost	179,108,000	222,999,000	284,902,000	374,080,000	504,344,000

TABLE A-7. - Itemized operating costs - Cu - mo porphyry mine model road supported operation (2 mi road)

Model description					
Resource size (Mst)	17	34	68	138	276
Mining rate (stpd)	3,913	6,582	11,069	18,616	31,309
Operating costs ($/st)					
Office expenses	0.31	0.25	0.20	0.16	0.14
Professional salaries	2.85	2.14	1.61	1.20	0.90
Sanitation	0.03	0.02	0.01	0.00	0.00
Access road maintenance	0.06	0.04	0.02	0.01	0.01
Ocean transportation	0.80	0.80	0.80	0.80	0.80
Truck transportation	0.01	0.01	0.01	0.01	0.01
Flotation	6.36	5.94	5.62	5.35	5.13
Transport/place tailings	0.18	0.16	0.14	0.13	0.11
Wastewater-neutralization	0.65	0.48	0.33	0.21	0.14
Marine terminal	0.27	0.22	0.17	0.14	0.11
Production clearing	0.31	0.18	0.11	0.06	0.05
Drill & blast	1.44	1.22	1.05	0.89	0.77
Frontend loader & truck	2.10	1.86	1.67	1.51	1.40
Stockpile storage	0.49	0.38	0.30	0.24	0.19
Conveyors	0.34	0.25	0.19	0.15	0.13
In-pit primary crushers	2.23	2.20	2.18	2.16	2.15
Restoration	0.79	0.47	0.28	0.16	0.10
Smelting	4.77	4.77	4.77	4.77	4.77
Total operating cost	23.99	21.39	19.46	17.95	16.91

TABLE A-8. - Itemized operating costs - Cu - mo porphyry mine model road supported operation (30 mi road)

Model description					
Resource size (Mst)	17	34	68	138	276
Mining rate (stpd)	3,913	6,582	11,069	18,616	31,309
Operating costs ($/st)					
Office expenses	0.31	0.25	0.20	0.16	0.14
Professional salaries	2.85	2.14	1.61	1.20	0.90
Sanitation	0.03	0.02	0.01	0.01	0.01
Access road maintenance	0.90	0.60	0.30	0.15	0.15
Ocean transportation	0.80	0.80	0.80	0.80	0.80
Truck transportation	0.12	0.12	0.12	0.12	0.12
Flotation	6.36	5.94	5.62	5.35	5.13
Transport/place tailings	0.18	0.16	0.14	0.13	0.11
Wastewater-neutralization	0.65	0.48	0.33	0.21	0.14
Marine terminal	0.27	0.22	0.17	0.14	0.11
Production clearing	0.31	0.18	0.11	0.06	0.05
Drill & blast	1.44	1.22	1.05	0.89	0.77
Front end loader & truck	2.10	1.86	1.67	1.51	1.40
Stockpile storage	0.49	0.38	0.30	0.24	0.19
Conveyors	0.34	0.25	0.19	0.15	0.13
In-pit primary crushers	2.23	2.20	2.18	2.16	2.15
Restoration	0.79	0.47	0.28	0.16	0.10
Smelting	4.77	4.77	4.77	4.77	4.77
Total operating cost	24.94	22.06	19.85	18.21	17.17

TABLE A-9. - Itemized operating costs - polymetallic replacement mine model

Model description					
Resource size (kst)	496	992	1,984	3,968	7,937
Mining rate (stpd)	273	460	774	1,302	2,189
Operating costs ($/st)					
Office expenses	0.62	0.50	0.40	0.33	0.26
Professional salaries	9.43	7.06	5.29	3.96	2.97
Sanitation	0.26	0.17	0.11	0.07	0.05
Water system	0.92	0.63	0.60	0.56	0.53
Employee commuting	12.57	10.74	9.19	7.86	6.73
Access road maintenance	5.43	3.22	1.92	1.14	0.68
Ocean transportation	10.57	10.55	10.56	10.56	10.56
Truck transportation	0.21	0.21	0.21	0.21	0.21
Flotation	26.19	23.03	20.35	18.04	16.04
Transport/place tailings	0.28	0.25	0.21	0.19	0.16
Wastewater-neutralization	5.37	3.74	2.59	1.80	1.25
Marine terminal	0.19	0.19	0.18	0.17	0.15
Shrinkage stope	28.70	27.76	27.00	26.31	25.70
Restoration	11.32	6.72	3.99	2.37	1.41
Smelting	41.39	41.30	41.32	41.32	41.33
Total operating cost	153.45	136.07	123.92	114.89	108.03

TABLE A-10. - Itemized operating costs - small vein gold mine model

Model description					
Resource size (kst)	110	220	441	882	1,764
Mining rate (stpd)	89	149	250	421	708
Operating costs ($/st)					
Office expenses	1.09	0.88	0.71	0.57	0.46
Professional salaries	19.41	14.55	10.90	8.17	6.12
Sanitation	0.70	0.45	0.29	0.19	0.12
Employee commuting	3.79	3.28	2.70	2.24	1.90
Access road maintenance	4.56	2.71	1.61	0.96	0.57
Carbon in leach processing	39.72	33.75	28.88	24.93	21.82
Transport/place tailings	0.60	0.52	0.45	0.39	0.34
Wastewater-neutralization	11.51	8.11	5.60	3.91	2.72
Marine terminal	0.06	0.04	0.03	0.02	0.02
Shrinkage stope	34.12	32.84	31.71	30.74	26.38
Total operating cost	115.56	97.13	82.88	72.12	60.45

TABLE A-11. - Itemized operating costs - volcanogenic massive sulfide mine model

Model description					
Resource size (Mst)	2.2	4.4	8.8	17.6	35.3
Mining rate (stpd)	837	1,408	2,369	3,984	6,700
Operating costs ($/st)					
Access road maintenance	0.81	0.48	0.29	0.17	0.10
Communications system	0.40	0.24	0.14	0.08	0.05
Employee transportation	2.74	2.33	2.00	1.71	1.46
Marine terminal	0.56	0.45	0.36	0.29	0.24
Mill	24.41	18.53	14.45	11.62	9.64
Mine	66.23	56.86	49.00	42.39	36.81
Ocean transportation	7.17	7.17	7.17	7.17	7.17
Tailings Dam	0.40	0.29	0.22	0.18	0.15
Truck transportation	0.06	0.06	0.06	0.06	0.06
Smelting	45.12	45.12	45.12	45.12	45.12
Total operating cost	$147.90	$131.53	$118.81	$108.79	$100.80

APPENDIX B. - ECONOMIC ASSUMPTIONS

This appendix includes information regarding the development of the economic models. It notes all major assumptions for income tax rates, depletion, depreciation, commodity prices, exploration and permitting costs, working capital, salvage value, and reclamation expense.

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires more precise data than that available for this report. The models are based on order-of-magnitude estimates. The American Association of Cost Engineers, an association of cost engineers and related personnel, has established the following classification scheme for cost estimates.

Table B-1. - Estimate Accuracy

Type of estimate	Accuracy
Order-of-magnitude estimate	-30% +50%
Preliminary estimate	-15% +30%
Definitive estimate	- 5% +15%

The models do not include proprietary company data, which if available, would probably change the outcome of the evaluation. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models. Alaska Mineral Industry Cost Escalation Factors (AMICEF) of 1.51 for operating labor, 1.58 for capital labor, 1.04 for capital costs, and 1.60 for electricity were used to reflect higher costs in the Stikine area. These factors are a set of calculated values that are used to escalate itemized capital and operating costs for mining and milling operations from the central front range of the Rocky Mountains (Denver vicinity) to any point in Alaska (Balen and Allen, 1993).

A number of factors control the feasibility of mineral development, including physical attributes of the deposit, metallurgical attributes of the ores, metal markets, infrastructure availability, political climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of these factors.

Cash Flow Assumptions

All RMV ($/st) are equal to the amount of revenues required before all expenses including royalties, mining and milling capital and operating costs, off-site transportation costs, base smelting charges, and taxes are deducted. Base smelter charges are estimated at $200/st for copper concentrate. RMV includes smelter recovery and all price and assay adjustments, which reduce the smelter payment (Schumacher, 2000). It is assumed all concentrates would be sent to Japan.

Federal income tax, Alaska corporate income tax, mining license tax rates and the effects of the exploration incentive credits toward future tax and royalty obligations due the State of Alaska are simulated with a 40% tax rate. All projects were assumed to be equity financed, and Modified Accelerated Cost Recovery System (ACRS) depreciation and percentage depletion were utilized in the cash flow calculations.

Exploration costs were considered for all models. Acquisition capital costs represent the direct cost of permitting, and were estimated at 4% of the total project cost (Sherman, 1990). Reclamation costs were estimated at 8% of total project cost. Mine and mill reinvestment were not considered for models.

Resource size selection

Cox and Singer (1987) compiled 89 mineral deposit models developed by 40 authors. Resource sizes from the following four Cox and Singer mineral deposit models were considered for the economic mine models in this report: 19a - polymetallic replacement deposits, 21a - porphyry copper-molybdenum, 28a - kuroko massive sulfide, and 36a - low-sulfide gold-quartz veins. The BLM mineral assessment team selected these four mineral deposit models as descriptive of mineral deposits having the highest mineral exploration potential (MEP) in the Stikine area (Still and others, in progress).

Cox and Singer (1987) developed these mineral deposit models to assist in identifying and assessing areas favorable for mineral deposits. The individual mineral deposit models were developed through observations of existing mineral deposits around the world. This information was then arranged into a classification system based on common geologic attributes, characteristics, and properties, such as genesis, host rock, geologic setting and others.

Resource size versus proportion of deposits curves are available for most mineral deposit models. The resource size at the 50% proportion is selected for economic mine modeling in this report. Half of the mineral deposits identified and used by Cox and Singer to develop the mineral deposit model are larger than this resource size, and half are smaller. This resource size becomes the middle economic mine model in this report, or the third of five models in the group.

For example, the 50% proportion for 19a - polymetallic replacement deposits is 1,800,000 metric tons (mt) or 1,984,000 st (Cox and Singer, 1987, p. 102, fig. 69). The method for determining the five resource sizes for economic modeling is depicted in Table B-2. Each step to the next resource size increases by a factor of two.

Table B-2. - Resource size determination

Resource size (st)	comment
496,000	½ x 992,000
992,000	½ x 1,984,000
1,984,000	tonnage at 50% proportion from Cox and Singer
3,968,000	2 x 1,984,000
7,937,000	2 x 3,968,000

Cox and Singers' (1987) resource size versus proportion of deposits curve from mineral deposit model 21a - porphyry copper-molybdenum was not used. After discussion with the BLM mineral assessment team, the resource size range was modified. A smaller resource size range appears to be more compatible with the known geology in the Stikine area.

Selection of mining method

Mining methods for the economic models in this report were selected on the basis of the available information for the evaluation and discussions with the BLM mineral assessment team. It is important to note that the available information for most of the models in this report is extremely limited, and opinions may vary with regard to the best mining method for these hypothetical deposits.

Lack of data is a serious limitation of the prefeasibility economic studies. There are no actual drill logs, cross sections, plan views, maps, or dimensions (thickness, strike length, depth) for most of these deposits. The available sample analytical results may indicate the presence of copper-molybdenum porphyry, polymetallic replacement, vein gold, or volcanogenic massive sulfide deposits; however, these have only limited value in determining a mining method.

For the models in this report, several mining methods are considered: 1) surface, 2) room and pillar 3) cut and fill stoping, 4) shrinkage stoping, 5) vertical crater retreat stoping, 6) end slice stoping, 7) room and pillar stoping, and 8) sublevel longhole stoping.

The mining method is selected by a process of elimination after consideration of the Cox and Singer (1987) descriptions from the following four mineral deposit models: 19a - polymetallic replacement deposits, 21a - porphyry copper-molybdenum, 28a - kuroko massive sulfide, and 36a - low-sulfide gold-quartz veins and discussions with the BLM mineral assessment team. The mineral deposit models are compared and matched with mining method descriptions from the Society of Mining Engineers (SME) surface mining (Kennedy, 1990); or SME underground mining methods handbook (Hustrulid, 1982).

Tailings dam assumptions

It is assumed that a tailings pond could be located within half a mile of the mill. Land area requirements were estimated as follows: 5-year mine life - 17 acres per 1,000 stpd mill capacity, for a 10-year mine life - 32 acres per 1,000 stpd mill capacity, and for a 20-year mine life - 62 acres per 1,000 stpd capacity (Ritcey, 1989).

An initial starter dam is constructed that would be an upstream dam design, followed in subsequent years by three raises, added as necessary to meet the mill's requirements. It is assumed that the starter dam and each of the three raises would each hold approximately 25% of the total tailings volume over the life of the mine.

Commodity Prices

Commodity prices provided for individual metals were determined by using an inflation adjusted thirty-year average for the years 1971-2000. Prices for 1971-2000 from various publications were escalated to 2000 dollars using U.S. Department of Commerce Gross National Product implicit price deflators and then averaged. (U.S. Bureau of Mines, 1975, 1980, 1985, 1986, 1993, 1995 and U.S. Geological Survey, 2000, 2001)

Ten (1991-2000), twenty (1981-2000), and thirty year (1971-2000) average prices are shown for the commodities of interest. All prices shown in Table B-3 are given in 2000 U.S. dollars.

Table B-3. - Ten, twenty, and thirty year average commodity prices (1971-2000)

Commodity	10 YR AVG ($)	20 YR AVG ($)	30 YR AVG ($)	units
Copper	1.12	1.22	1.44	lb
Lead	0.44	0.45	0.53	lb
Zinc	0.59	0.67	0.72	lb
Silver	5.33	8.32	10.44	tr oz
Gold	376.56	485.91	478.67	tr oz

Calculation of RMV

Assume mill feed with grades of 0.12 tr oz/st gold, 3% lead, 12.75 tr oz/st silver, and 11% zinc was mined from a deposit. Mill recoveries were estimated at 71% for gold, 81% for lead, 85% for silver, and 90% for zinc. Smelter recoveries were estimated at 55% for gold, 80% for lead, 87% for silver, and 75% for zinc. Prices are assumed at the 10 year average from 1991-2000 from Table B-3. The RMV ($/st) equals $172.

The equation used in calculating RMV for a deposit is:

$$\sum_{I=1}^{n} GiRiSiVi,$$

where

Gi = mill feed grade of commodity I,
Ri = mill recovery of commodity I,
Si = smelter recovery of commodity I,
Vi = $/unit of commodity I,
and n = total number of commodities.

The calculations are shown below in Table B-4.

Table B-4. - Calculation of recoverable metal value

CALCULATION OF RECOVERABLE METAL VALUE							
Commodity	Grade	Unit	Mill recovery (decimal)	Smelter recovery (decimal)	Price ($)	Unit	RMV ($)
	Gi		Ri	Si	Vi		(GiRiSiVi)
Gold	0.12	tr oz/st	0.71	0.55	376.56	tr oz	17
Lead	3.00	percent	0.81	0.80	0.44	lb	17
Silver	12.75	tr oz/st	0.85	0.87	5.33	tr oz	50
Zinc	11.00	percent	0.90	0.75	0.59	lb	88
TOTAL							172

How To Use Worksheet

1. Estimate minable resource size, and resource commodity grades to be evaluated.

2. Refer to Figures 2 to 5; select appropriate graph line representing nearest estimated minable resource size. Read RMV ($/st) from y-axis. This is the minimum value per short ton of minable resource adjusted for mining recovery, dilution, mill and smelter recovery required to yield a 15% DCFROR using the mining and milling scenario described in the report.

3. To translate this value into a gross in place value (GIPV), back calculate value using assumed mill recoveries or pilot testing results if available, and appropriate smelter recoveries. Suggested commodity prices shown in Table B-3 may be used or other prices as desired.

Electrical Power

A preliminary evaluation comparing the cost of diesel generated power versus utility generated power in the Stikine area indicates that utility generated power is the preferred choice for 27 of 40 models examined. Eleven models use diesel power due mainly to their smaller mining rates and shorter mine lifes, and distant location from any potential connection point to the existing power line. Two models are located where the costs of diesel and utility power are approximately equivalent in economic attractiveness. Only the existing power line was evaluated in this report. Predicated power lines, which may be constructed in the future, and are depicted on the map were not evaluated. Construction of these new power lines will affect the evaluation in some cases.

A geographic information system (GIS) spatial analysis of eight hypothetical mineral development locations was completed. These locations range from about 6.5 mi to 29 mi from the existing power line depicted on Figure B-1 on the following page. A power line constructed to connect any of these eight hypothetical mineral development locations to the existing power line will have at least one water crossing. An example of a larger water crossing is Sumner Strait, which would require about a 4 mi submarine power cable.

Power requirements, capital and operating costs for the hypothetical mine models in this report were calculated from O'Hara's formula (O'Hara, 1980). Results ranged from 0.6 megawatts (MW) for the 89 stpd small vein gold model to 24.1 MW for the 31,309 stpd copper-molybdenum porphyry models. All costs were compared with additional information from the Mining Cost Service (Schumacher, 2000).

Power line costs were estimated at $1,500,000/mi for submarine power cables, and $375,000/mi for 69 kV single wood pole power line installation on land. It was assumed that underground burial of power lines on land would not be required. Costs for submarine and land power lines were estimated based on information from Petersburg Municipal Power and Light (Dennis Lewis, Petersburg Municipal Power and Light, oral commun., 2002).

Diesel capital costs ranged from $2.5 million for the 89 stpd small vein gold model to $48 million for the 31,309 stpd copper-molybdenum porphyry model. Diesel operating costs ranged from $1.14/st for the 31,309 stpd copper-molybdenum porphyry model to $10.42/st for the 89 stpd small vein gold model.

Utility capital costs ranged from $464,000 for the 89 stpd small vein gold model to $10.8 million for the 31,309 stpd copper-molybdenum porphyry model. Utility operating costs ranged from $0.43/st for the 31,309 stpd copper-molybdenum porphyry model to $3.91/st for the 89 stpd small vein gold model.

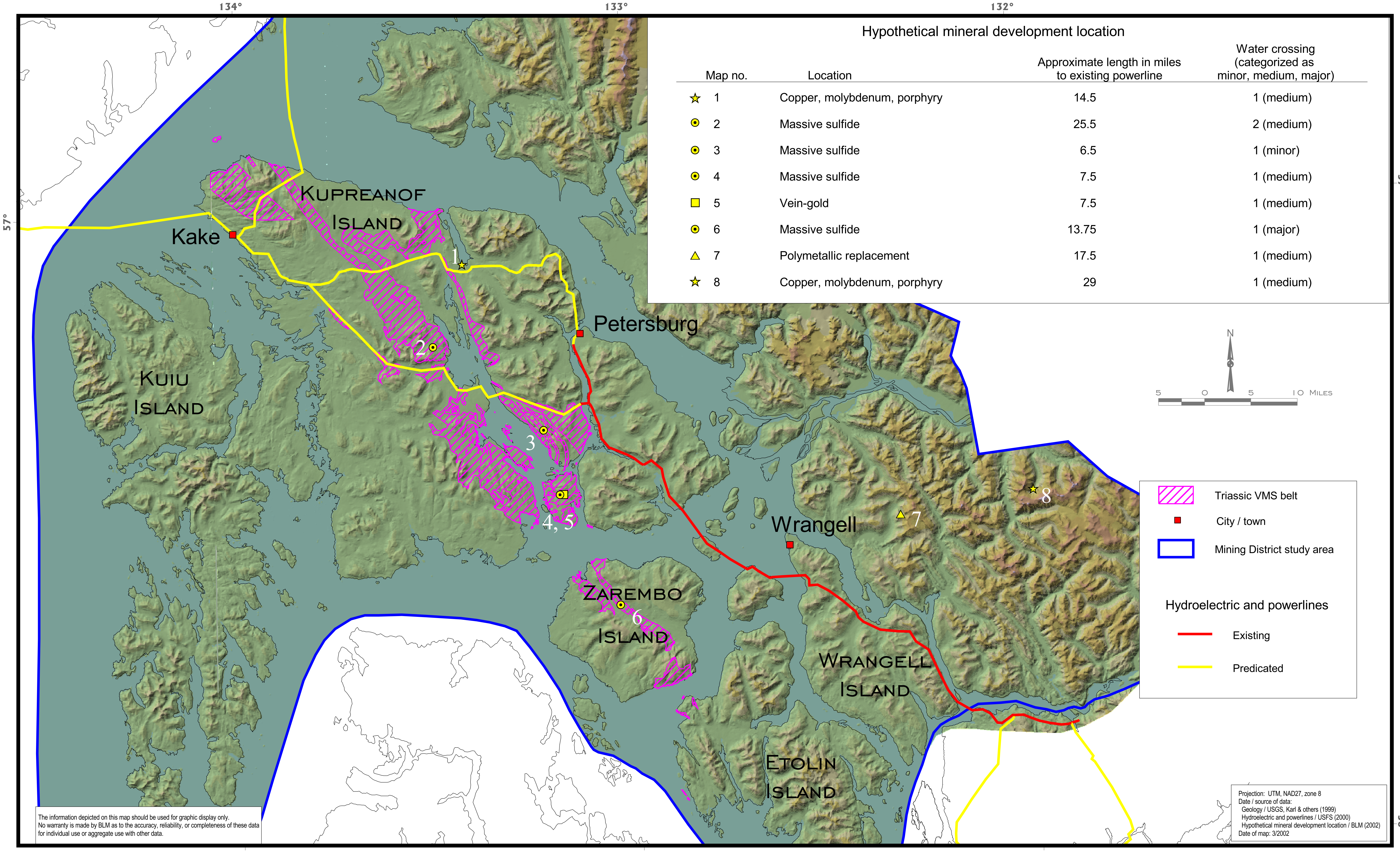
The net present cost of the diesel and utility capital and operating costs over the model's mine life were calculated at a 15% discount rate. Treating the on-land utility power line installation costs as the only variable cost, the net present cost of the utility power alternative including it's associated submarine power cable capital cost was subtracted from the net present cost of the diesel power alternative.

The maximum distance that new power lines could be installed to connect to the existing power line was calculated. If the distance calculated was less than the minimum distance needed to connect, then diesel power is the preferred choice. If the distance calculated was more than the minimum distance needed to connect, then utility power was the preferred choice.

See Table B-5 for the comparison of costs for the 40 models and Figure 6 for a map of the Tyee hydroelectric power grid and the eight hypothetical mineral development locations.

Table B-5. - Comparison of diesel vs. utility electrical power for mine models

Deposit Type	Map no.	stpd	MW	Net present cost diesel ($ thousands)	Capital cost diesel ($ thousands)	Op cost diesel ($/st)	Net present cost utility ($ thousands)	Capital cost utility ($ thousands)	Op cost utility ($/st)	Maximum powerline distance (mi)	Preferred choice
14.5 mi - 1 mi submarine, 13.5 mi land (minimum connection distance)											
Cu-mo porhyry	1	3,913	8.5	39,446	20,893	3.24	39,446	4,413	1.21	34	utility
Cu-mo porhyry	1	6,582	11.0	51,670	25,778	2.50	51,670	5,524	0.93	43	utility
Cu-mo porhyry	1	11,069	14.3	67,182	31,806	1.92	67,182	6,912	0.72	54	utility
Cu-mo porhyry	1	18,616	18.6	87,115	39,245	1.48	87,115	8,652	0.55	67	utility
Cu-mo porhyry	1	31,309	24.1	112,368	48,422	1.14	112,368	10,833	0.43	83	utility
25.5 mi - 3.6 mi submarine, 21.9 mi land (minimum connection distance)											
Massive sulfide	2	837	3.0	13,696	8,998	5.32	7,436	1,799	1.99	2	diesel
Massive sulfide	2	1,408	4.3	19,776	12,077	4.55	11,416	2,463	1.71	8	diesel
Massive sulfide	2	2,369	6.2	28,557	16,213	3.89	17,385	3,365	1.46	15	diesel
Massive sulfide	2	3,984	8.9	41,231	21,757	3.33	26,319	4,608	1.25	25	diesel/utility
Massive sulfide	2	6,700	12.9	59,399	29,199	2.85	39,494	6,309	1.07	39	utility
6.5 mi - 6.5 mi land, power line installed over small creek (minimum connection distance)											
Massive sulfide	3	837	3.0	13,696	8,998	5.32	7,436	1,799	1.99	17	utility
Massive sulfide	3	1,408	4.3	19,776	12,077	4.55	11,416	2,463	1.71	22	utility
Massive sulfide	3	2,369	6.2	28,557	16,213	3.89	17,385	3,365	1.46	30	utility
Massive sulfide	3	3,984	8.9	41,231	21,757	3.33	26,319	4,608	1.25	40	utility
Massive sulfide	3	6,700	12.9	59,399	29,199	2.85	39,494	6,309	1.07	53	utility
9 mi - 1 mi submarine, 8 mi land (minimum connection distance)											
Massive sulfide	4	837	3.0	13,696	8,998	5.32	7,436	1,799	1.99	13	utility
Massive sulfide	4	1,408	4.3	19,776	12,077	4.55	11,416	2,463	1.71	18	utility
Massive sulfide	4	2,369	6.2	28,557	16,213	3.89	17,385	3,365	1.46	26	utility
Massive sulfide	4	3,984	8.9	41,231	21,757	3.33	26,319	4,608	1.25	36	utility
Massive sulfide	4	6,700	12.9	59,399	29,199	2.85	39,494	6,309	1.07	49	utility
9 mi - 1 mi submarine, 8 mi land (minimum connection distance)											
Small vein gold	5	89	0.6	2,931	2,531	10.42	1,134	464	3.91	1	diesel
Small vein gold	5	149	0.9	4,148	3,388	8.93	1,755	636	3.35	2	diesel
Small vein gold	5	250	1.3	5,909	4,542	7.64	2,717	871	2.87	5	diesel
Small vein gold	5	421	1.9	8,469	6,098	6.54	4,201	1,190	2.45	7	diesel
Small vein gold	5	708	2.7	12,175	8,184	5.59	6,475	1,628	2.10	11	utility
13.75 mi - 4 mi submarine, 9.75 mi land (minimum connection distance)											
Massive sulfide	6	837	3.0	13,696	8,998	5.32	7,436	1,799	1.99	1	diesel
Massive sulfide	6	1,408	4.3	19,776	12,077	4.55	11,416	2,463	1.71	6	diesel
Massive sulfide	6	2,369	6.2	28,557	16,213	3.89	17,385	3,365	1.46	14	diesel/utility
Massive sulfide	6	3,984	8.9	41,231	21,757	3.33	26,319	4,608	1.25	24	utility
Massive sulfide	6	6,700	12.9	59,399	29,199	2.85	39,494	6,309	1.07	37	utility
17.5 mi - 1 mi submarine, 16.5 mi land (minimum connection distance)											
Polymetallic replacement	7	273	1.4	6,275	4,773	7.44	1,594	917	2.79	8	diesel
Polymetallic replacement	7	460	2.0	9,000	6,414	6.36	2,375	1,252	2.39	14	diesel
Polymetallic replacement	7	774	2.8	12,953	8,609	5.44	3,540	1,714	2.04	21	utility
Polymetallic replacement	7	1,302	4.1	18,703	11,552	4.66	5,292	2,347	1.75	32	utility
Polymetallic replacement	7	2,189	5.9	27,029	15,504	3.99	7,850	3,210	1.49	47	utility
29 mi - 1.25 mi submarine, 27.75 mi land (minimum connection distance)											
Cu-mo porhyry	8	3,913	8.5	39,446	20,893	3.24	25,115	4,413	1.21	33	utility
Cu-mo porhyry	8	6,582	11.0	51,670	25,778	2.50	34,058	5,524	0.93	42	utility
Cu-mo porhyry	8	11,069	14.3	67,182	31,806	1.92	45,535	6,912	0.72	53	utility
Cu-mo porhyry	8	18,616	18.6	87,115	39,245	1.48	60,512	8,652	0.55	66	utility
Cu-mo porhyry	8	31,309	24.1	112,368	48,422	1.14	79,682	10,833	0.43	82	utility



Map no.	Location	Approximate length in miles to existing powerline	Water crossing (categorized as minor, medium, major)
☆ 1	Copper, molybdenum, porphyry	14.5	1 (medium)
⊙ 2	Massive sulfide	25.5	2 (medium)
⊙ 3	Massive sulfide	6.5	1 (minor)
⊙ 4	Massive sulfide	7.5	1 (medium)
□ 5	Vein-gold	7.5	1 (medium)
⊙ 6	Massive sulfide	13.75	1 (major)
△ 7	Polymetallic replacement	17.5	1 (medium)
☆ 8	Copper, molybdenum, porphyry	29	1 (medium)

Figure 6.- Tyee hydroelectric power grid.