Quartz Hill Molybdenum Mine:
Would Environmental Protection Price It Out of the Market?

W. Thomas Goerold
Lookout Mountain Analysis
314 Parkview Avenue
Golden, Colorado 80401
(303) 526-2362

and

Joseph R. Mehrkens
2992 Linda Avenue
Juneau, Alaska 99801
(907) 789-3323

Draft of paper presented at the ***Mineral Economics and Management Society***, March 19 - 21, 1992 Washington, D.C. and published in ***Proceedings of the First and Second Annual Meetings of the Mineral Economics and Management Society***, 1993.

Abstract

U.S. Borax, the former owners of the Quartz Hill molybdenum property in southeastern Alaska proposed a mining project that advocates a submarine tailings disposal scheme that would largely fill a nearby fiord--Wilson Arm. Quartz Hill is located in an island of non-wilderness lands completely surrounded by the wilderness lands of the Misty Fiords National Monument, where commercial and sport fishing is the predominant economic activity. Evaluating alternative tailings disposal sites to mitigate the impact on anadromous fish and other marine invertebrates in Wilson Arm, U.S. Borax rejected as too costly dumping tailings at a terrestrial site or an alternative submarine site with a lower fisheries value (Boca de Quadra). After examining the mining alternatives presented in the Environmental Impact Statement (EIS) in the context of molybdenum market conditions, the authors conclude that there is little cost difference between the two submarine tailings disposal alternatives and that none of the Quartz Hill molybdenum production scenarios presented in the EIS are likely to be financially viable in the foreseeable future.

I. Introduction

Located about 45 air miles east of Ketchikan, Alaska, and containing approximately 1.5 billion tons of ore with an average grade of 0.14% MoS_2, Pacific Coast Molybdenum Company, a subsidiary of the U.S. Borax & Chemical Corporation (U.S. Borax), discovered the Quartz Hill molybdenum mineralization in 1974 (USDA Forest Service, 1988, p. 2-1). Late in 1991, after many years of extensive exploration and development, U.S. Borax sold the Quartz Hill workings to Cominco American, Inc., owner and operator of the Red Dog lead-zinc deposit in western Alaska. Epitomizing the conflicts between mineral development and environmental values, Quartz Hill is one of the world's largest known concentrations of molybdenum and it is surrounded by the wilderness lands and commercial-fish laden estuaries of the Misty Fiords National Monument. This paper uses financial and commodity analysis to estimate the operators' costs of production for U.S. Borax's proposed project, and two alternative proposals with higher costs and different economic and environmental impacts than the proposed project. The financial viability of all production scenarios at Quartz Hill are then examined in the context of market conditions.

An inset map of the regional setting of the proposed minesite is shown in the lower right corner of Figure 1. The remainder of Figure 1 depicts a more detailed rendering of the region near the proposed mine showing its location within the Misty Fiords National Monument. Created in 1978, the Misty Fiords National Monument encompasses 2,294,343 acres inside the Tongass National Forest. In 1980, Congress passed the Alaska National Interest Lands Conservation Act (ANILCA) and designated all but 152,610 acres surrounding the Quartz Hill deposit as wilderness. Congress excluded
the lands immediately adjacent to the proposed mine from wilderness to accommodate the development of the Quartz Hill molybdenum mine. At the same time, Congress also established standards to ensure that commercial fisheries and other economic and environmental values would be protected from mining activities. (Section 505(a) of the Alaska National Interest Lands Conservation Act reads, "The Secretary of Agriculture shall...promulgate such reasonable regulations...to maintain the habitats, to the maximum extent feasible, of anadromous fish and other foodfish, and to maintain the present and continued productivity of such habitat when such habitats are affected by mining activities on the national forest lands in Alaska.")

As described in the Forest Service FEIS, initial production from the mine would be about 40,000 tons per day (tpd), increasing to a nominal rate of 80,000 tpd during the fifth year. The open pit created by mining would have ultimate dimensions of approximately 2 miles by 1.3 miles with a depth of up to 1,875 feet, and cover approximately 1,040 acres. The proposed project presented in the FEIS indicates that uncrushed waste rock would be placed in stream valleys adjacent to the deposit and tailings would be transported by pipeline from the ore processing

facilities on Tunnel Creek to be disposed of at a depth of approximately 150 feet into a nearby fiord--the Wilson Arm of

Source: Adapted from USDA-Forest Service, *Quartz Hill Molybdenum Project Mine Development (FEIS)*

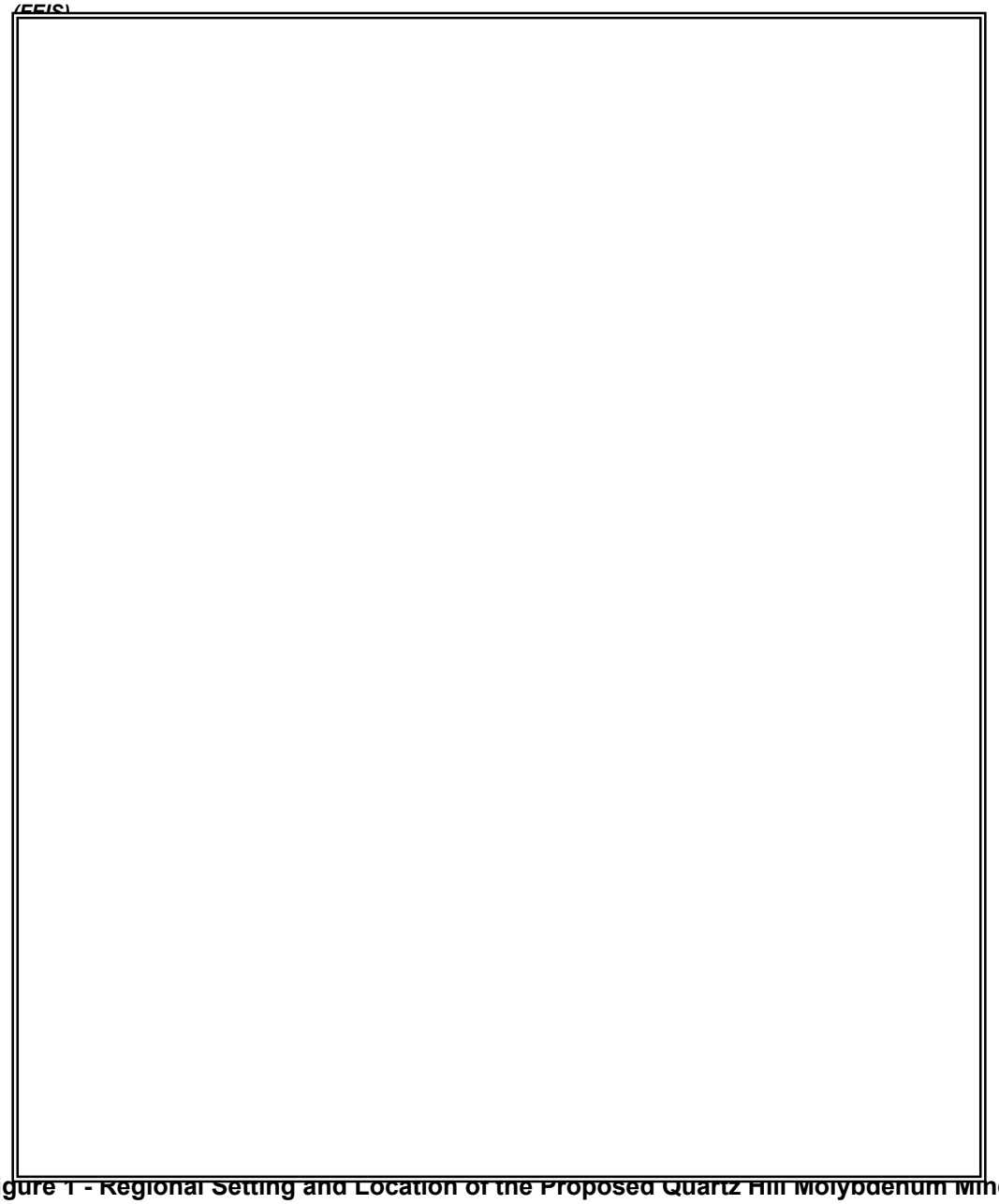

Figure 1 - Regional Setting and Location of the Proposed Quartz Hill Molybdenum Mine.

Smeaton Bay. An alternative tailings disposal site cited in the FEIS is the middle basin of Boca de Quadra, a larger fiord located southeast of the Wilson Arm of Smeaton Bay.

A. Economic and Environmental Impacts of Different Tailings Disposal Sites

The submarine tailings disposal site and method is one of the most controversial environmental impacts of the Quartz Hill Project. During the planned 55-year production of the mine nearly 1.5 billion tons of tailings are expected to be generated. Initial mine development plans called for land disposal of tailings behind impoundments ranging from 700 to 1000 feet in height. However, data reported in the FEIS shows that the capital costs for the least expensive project involving land disposal of tailings are about four times the total capital cost for the lowest cost project with submarine disposal (total capital costs of $2,814 million for land disposal versus

$679 million for submarine disposal into the Wilson Arm of Smeaton Bay [all costs are in mid-year 1984 dollars unless otherwise stated]) (USDA Forest Service, 1988, p. 2-48). The FEIS also indicates that submarine disposal into the middle basin of Boca de Quadra, a basin more distant than the Wilson Arm of Smeaton Bay, would entail total capital costs of about $738 million.

Concerns about differential economic and environmental impacts to the basins from tailings disposal hinge on three factors: (1) impacts to the spawning and rearing habitat for fish important for commercial and sport fishing including several varieties of salmon, trout, and Dolly Varden char, as well as many other species with lesser economic value, (2) changes to economically important marine invertebrates such as dungeness and tanner crabs, shrimp, zooplankton, and others, and (3) effects on marine plants important to the higher animals in the food chain. Commercial and sport fishing is currently the most prevalent form of economic activity in the region. The FEIS mentions that salmon production in the project area streams is higher than in other streams of the SE Alaska region. Especially important is the high production of chinook salmon from streams that would be affected by mining. Less than 20 out of 20,000 streams in southeastern Alaska have chinook salmon runs and most of them are located in the Misty Fiords National Monument (USDA Forest Service, 1988, p. 3-62 - 3-64). Estimates from the FEIS show that the rivers and creeks draining into the Wilson Arm of Smeaton Bay contain spawning or rearing grounds for about 7.60 percent of all salmon harvested annually in the region, compared with 2.27 percent for the rivers and streams flowing into the Boca de Quadra (USDA Forest Service, 1988, p. 3-65). Comments on the EIS by state and federal fish and wildlife agencies contained in and appendix to the FEIS also note the greater importance of Wilson Arm as a fishery than Boca de Quadra. (E.g., U.S. Fish and Wildlife Service, [letter from Nevin D. Holmberg to Colonel Wilber T. Gregory, Jr., June 30, 1987], the National Marine Fisheries Service, [letter from Robert W. McVey to Win Green, June 18, 1987], and the State of Alaska, [letter from Robert L. Grogen to Michael A. Barton, July 2, 1987])(USDA Forest Service, 1988, Appendix Q).

There is a considerable difference in volume between the two alternative tailings disposal basins; 777 million cubic meters below-sill volume in Wilson Arm and 4,300 million cubic meters below-sill volume in the Middle Basin of Boca de Quadra (USDA Forest Service, 1988, p. 3-39). Sills are the higher submarine elevations that serve to control currents, oxygen distribution, sediment transport, and divide the submarine areas into basins. If tailings were discharged into the middle basin of Boca de Quadra, by the end of mining at Quartz Hill the FEIS estimates that 844 million cubic meters of tailings would be deposited, reducing the below-sill volume of Boca de Quadra by about 20 percent. In contrast, the FEIS concludes that between 78 and 82 percent of the below-sill volume of Wilson Arm would be filled by tailings, with some of the finer sediment escaping out into Behm Canal (USDA Forest Service, 1988, p. 4-69). It is clear that the total sedimentation impacts of tailings routed to Wilson Arm are thus likely to far exceed those that could be expected from tailings discharge to the middle basin of Boca de Quadra.

B. Brief Chronology of Quartz Hill Project

Policy issues concerning the Quartz Hill molybdenum deposit have a long and complex history. This section presents a brief chronological history of the Quartz Hill Molybdenum Project highlighting some of the policy events that influenced the development of the project.

- ***Early 1970s:*** U.S. Borax initiates mineral exploration in the Misty Fiords region of the Tongass National Forest.

- ***1974:*** Molybdenum mineralization discovered in the Quartz Hill area.

- ***1978:*** President Carter designates the Misty Fiords region as a National Monument.

- ***1980:*** Congress includes the Quartz Hill locality as a non-wilderness island in the wilderness lands of the Misty Fiords National Monument under Alaska National Interest Lands

Conservation Act (ANILCA) legislation. Provisions in ANILCA allow the development of the Quartz Hill molybdenum deposit provided strict environmental protection provisions are met.

- ***1982:*** The U.S. Environmental Protection Agency (EPA) promulgates effluent limitations under the reauthorized Clean Water Act which apply to new molybdenum mines. The new regulations prohibit the discharge of mine wastewater into navigable waters.

  U.S. Borax argues that the proposed Quartz Hill Mine is significantly different from other molybdenum mines and therefore not subject to new effluent regulations. The EPA largely rejects this assertion, but agrees to postpone a decision on the applicability of the wastewater standards to the proposed mine until the potential environmental impacts could be studied.

  Governor Hammond's administration supports U.S. Borax plan to dump mine tailings into the middle basin of Boca de Quadra.

- ***1983:*** U.S. Borax applies to the EPA for a National Pollutant Discharge Elimination System (NPDES) permit requesting permission to discharge mine tailings into the middle basin of Boca de Quadra.

- ***1984:*** USDA-Forest Service issues a draft Environmental Impact Statement (EIS) on the construction, operation, and postmining operations of the proposed mine and associated facilities. The proposed project calls for disposal of mine tailings into the middle basin of Boca de Quadra.

  U.S. Borax revises the plan for the site of mine tailings disposal from the middle basin of Boca de Quadra to Wilson Arm of Smeaton Bay after gaining the support of Governor Shefield's administration. The stated reason for the change in tailings disposal sites is that further investigation showed that the tailings would be denser than originally estimated, therefore allowing them to fit into the Wilson Arm basin.

  EPA and Alaska Department of Environmental Conservation oppose the conclusions and decisions embodied in the U.S. Borax change in tailings disposal site to Wilson Arm of Smeaton Bay from Boca de Quadra.

- ***1985:*** U.S. Borax officially amends their request for a NPDES permit from EPA, by requesting that the mine tailings disposal site be changed from Boca de Quadra to the Wilson Arm of Smeaton Bay.

- ***1987:*** USDA-Forest Service issues a revised draft of the EIS for the Quartz Hill Project that includes as the proposed project the disposal of mine tailings into Wilson Arm of Smeaton Bay. However, the EPA states that the middle basin of Boca de Quadra is the preferred marine tailings disposal since it minimizes the risk of adverse effects to the marine environment.

- ***1988:*** USDA-Forest Service issues a final EIS for the Quartz Hill molybdenum mine using the Wilson Arm as the proposed tailings disposal site.

  EPA Regional Administrator withdraws his agency's objection to using Wilson Arm of Smeaton Bay as a site for tailings disposal. The EPA releases a draft NPDES permit that authorizes the discharge of mine tailings into Wilson Arm.

- ***1989:*** The Sierra Club Legal Defense Fund (SCLDF) and others appeal the USDA-Forest Service decision approving U.S. Borax's mining plan including the disposal of mine tailings in Wilson Arm.

- ***1990:*** The EPA reevaluates its draft NPDES permit for mine tailings disposal into Wilson Arm/Smeaton Bay and eventually denies the permit primarily on the basis that it would not comply with the Alaska Water Quality Standard Regulations (18 AAC 70).

- ***1991:*** U.S. Borax sells Quartz Hill molybdenum deposit for an undisclosed amount to Cominco American Inc., operator of the Red Dog lead-zinc deposit in western Alaska. Over 17 years U.S. Borax reportedly spent more than $100 million on the deposit (Engineering and Mining Journal, v. 192, p. 14).

No mining project in the United States is currently allowed to dump mine tailings into marine waters. Approval of any of the submarine tailings disposal options for Quartz Hill could set a precedent for future mines. Both the state and federal governments have had extensive involvement with the project, with particularly federal government agencies approving project scenarios and then later overturning them. Many of the policy changes appear to have been caused by the Quartz Hill Project spanning several different state and federal administrations with changing personnel, political support, and objectives.

Initially, in 1983, U. S. Borax planned that the Quartz Hill Project would discharge tailings into the middle basin of Boca de Quadra. By 1984 U. S. Borax had changed the planned tailings disposal site to Wilson Arm/Smeaton Bay and successfully lobbied the Alaska Governor to obtain his support. Notwithstanding prior EPA and USDA-Forest Service tailings disposal site approvals and reversals, in 1991 EPA overturned their draft NPDES permit approval to allow mine tailings to flow into the Wilson Arm of Smeaton Bay.

II. Financial Analysis

Because of restrictions on the disclosure of confidential business data, the authors were not able to acquire year-by-year data on the costs of the alternative Quartz Hill projects. However, the authors obtained material from the USDA-Forest Service under a Freedom of Information Act (FOIA) request that details some of the economic and financial data and arguments used by U.S. Borax, EPA, and the USDA-Forest Service to justify changing the tailings disposal site from Boca de Quadra to the Wilson Arm of Smeaton Bay. The relevant information obtained by FOIA consists of memoranda and studies submitted to the federal government by U.S. Borax, as well as internal documents circulated within the USDA-Forest Service and the EPA.

A letter from U.S. Borax to an official of the EPA puts forth U.S. Borax's case for tailings disposal into Wilson Arm/Smeaton Bay instead of Boca de Quadra;

> "... the $59 million capital cost difference between tailings disposal in the middle basin of Boca de Quadra, as compared with tailings disposal in Wilson Arm/Smeaton Bay, and the operating costs difference between these sites, are of great importance to the project. ...If the Quartz Hill Project's operating costs do not fit into the lower portion of world production costs, the operation will be ill-equipped to withstand future declines in the molybdenum price."

A paper attached to the above letter from U.S. Borax to EPA concludes;

> "A difference of only a few cents in the cost of production per pound of molybdenum will affect the following factors:

- The timing of the start of the project. (The price would have to rise by that much higher in order to attain the same predicted ROI).

- Higher costs and consequent delay in market entry will allow other lower-cost competitive mines to capture the market share needed by Quartz Hill for economic viability, thus casting further doubt upon the project timing.

- Once in operation, the cost burden for a tailings disposal system into the middle basin of Boca de Quadra will be a permanent penalty on the production cost of the project which will make it harder to compete with other world producers.

- Higher operating costs (and the financial burdens of carrying higher capital costs) will affect the project's ability to withstand future price declines after start-up. (Any temporary shutdowns would start earlier and last longer, with consequently greater disruptions to the socioeconomic climate of the Ketchikan area.)

U.S. Borax considers that the minor perceived overall environmental differences in effects of submarine tailings disposal among the three tailings disposal sites under consideration are insufficient to overbalance the real economic penalties placed on the project through requiring tailings disposal in the middle basin of Boca de Quadra. We urge that Pacific Coast Molybdenum Company's NPDES application for tailings disposal in Wilson Arm/Smeaton Bay be approved." (underlining, bullets, and parentheses are original) (Hesse, C.A., February 25, 1986).

Clearly, the project managers at U.S. Borax were trying to make the case that diverting the tailings disposal site from Wilson Arm to Boca de Quadra would raise capital and operating costs to levels that would jeopardize the start-up and continued operation of the mine, especially under conditions of fluctuating and depressed molybdenum prices.

A. Financial Data Sources and Assumptions

The authors constructed discounted cashflow models to investigate the financial effect of disposing of mine tailings into the three areas. While detailed project financial information is scarce, examination of the USDA-Forest Service FEIS reveals the capital cost data presented in Table 1:

Table 1: Estimated Capital Costs for Quartz Hill Project

Facility	Capital Cost (Millions of 2nd Quarter 1984 Dollars)		
	Wilson Arm/ Smeaton Bay	Middle Basin Boca de Quadra	Land Tailings Disposal
Mine	$190	$190	$190
Ore Transport	$60	$60	$17
Concentrator/Ancillaries	$259	$259	$286
Power Supply	$83	$83	$87
Water Supply	$21	$21	$23
Tailings Disposal	$9	$68	$1,844
Subtotal	$622	$681	$2,447
Contingency	$57	$57	$367
TOTAL CAPITAL COSTS	$679	$738	$2,814

Source: USDA-Forest Service FEIS, 1988, p. 2-48.

According to the FEIS, the above capital costs only represent expenditures required for the first 20 years of operation and do not include replacement equipment costs. All capital costs are identical for the two submarine tailings disposal projects with the exception of the tailings disposal system. Piping the tailings to the middle basin of Boca de Quadra would cost $59 million more than tailings disposal to the Wilson Arm of Smeaton Bay. Terrestrial tailings disposal would cost about $2.135 billion more than piping the tailings into Wilson Arm.

Subsequent information derived from the material received from the FOIA request shows some indications of the operating costs for each of the submarine tailings disposal projects. Although no direct statements of operating costs for the projects are shown, a letter and attachment from the Deputy Project Manager for Quartz Hill to the EPA states that tailings disposal in the middle basin of Boca de Quadra would incur $1.63 million more in annual operating costs than disposal in the Wilson Arm of Smeaton Bay. Additionally, the letter states, the $1.63 million rise in operating costs for Boca de Quadra relative to Wilson Arm represents an increase of one percent (Reim, K.M., May 5, 1986). Based on this information the authors project annual operating costs of $163 million for Wilson Arm and about $165 million for Boca de Quadra. No operating cost data for terrestrial tailings disposal were found by the authors.

Another communication obtained under the FOIA request is an internal EPA document containing a financial analysis of the Quartz Hill project using only publicly available data (Coughlin, R., July 28, 1987). This EPA analysis serves as a useful model that the authors have modified, extended, and updated. The EPA study concludes that many factors including the relatively low ore grade, mine distance from suppliers, location in a wilderness area with a consequent need for a self-contained workforce commanding premium wages, the harsh arctic weather, and other factors all combine to produce a proposed molybdenum mine with high fixed costs. EPA's conclusion in this study is that the Quartz Hill mine would be a marginal molybdenum producer with a risky financial future.

The authors modelled the finances of the Quartz Hill Project with three different tailings disposal sites, over a project life of 55 years; (1) land tailings disposal, (2) Wilson Arm tailings disposal, and (3) Middle Basin Boca de Quadra tailings disposal. The objective in these financial models is to portray the *minimum* likely costs of molybdenum production from Quartz Hill by using the lowest possible costs, and most generous assumptions regarding items such as equipment life, annual output, and others. Some of the most important assumptions of the Quartz Hill financial models are shown below:

Production days/year:	320 (Reim, K.M., et al., 1988);
Process Recovery Factor:	82.50% (Hesse, C.A., January 25, 1989);
Depletion Allowance:	22%;
Real Discount Rate:	15%; and
Inflation Rate:	5%.

B. Financial Model Results

Table 2 presents the results from the financial modeling of the different tailings disposal sites for the Quartz Hill project using a 55 year life.

Table 2- Minimum Costs for Selected Quartz Hill Project Scenarios Using 55 Year Life.

Cost Components	Project Cost (1st Quarter 1992 Dollars/lb. of Mo)		
	Wilson Arm/ Smeaton Bay	**Land Tailings Disposal**	**Middle Basin-Boca de Quadra**
Capital Costs	$4.57	$18.93	$4.96
Operating Costs	$6.20	$6.20	$6.26
Federal Taxes	$(1.00)	$(3.19)	$(1.07)
Total	**$9.77**	**$21.94**	**$10.15**

Source: Quartz Hill Financial Model (this study).

Costs in Table 2 are expressed as 1st quarter 1992 dollars per pound of molybdenum produced. Note that the costs displayed in Table 1, representing the capital costs for the first 20 years of operation with no equipment replacement, have been used by the authors to represent total capital expenditures for the entire planned 55 year life of Quartz Hill operations. The result of these assumptions is that the results shown in Table 2 likely understate true project costs.

Wilson Arm/Smeaton Bay tailings disposal has the lowest cost of any of the project scenarios, $9.77 per pound of molybdenum. The second-lowest costs are seen in the tailings disposal to the middle basin of Boca de Quadra, $10.15 per pound. The most expensive project alternative is the land tailings disposal option, $21.94 per pound. The $21.94 per pound cost for land tailings disposal shows a $12.17 (125 percent) cost premium over disposal to Wilson Arm/Smeaton Bay, and represents the value to the project of the contemplated unprecedented approval by the EPA of submarine disposal of tailings. Additionally, the use of the lowest-cost submarine tailings disposal operating costs in the land tailings disposal scenario necessitated by the lack of terrestrial disposal operating cost data likely understates the total costs for land tailings disposal.

Perhaps the most surprising result of the financial analysis presented above is the proximity of the Boca de Quadra costs to Wilson Arm tailings disposal costs. While the capital costs of building a tunnel extension for tailings disposal to the middle basin of Boca de Quadra incurs a $0.39 per pound penalty, $0.07 of that is recouped in greater project tax credits (due to depreciation differences between the projects), resulting in a net capital cost difference of $0.32 per pound. Even more interesting is the small difference in operating costs for the projects--just $0.06 per pound of molybdenum produced. The total cost differential between disposal to Wilson Arm versus Boca de Quadra thus is $0.38 per pound of molybdenum produced.

Using a 20 year project life with the capital costs presented in Table 1, the authors examined the effect of the longer amortization period on total project costs. A 20-year life for the project in lieu of a 55-year period almost uniformly raises costs across all cost components and scenarios. Once again the Wilson Arm scenario is least expensive, with a total project cost of $10.08 per pound of produced molybdenum; followed by Boca de Quadra, $10.47, and the land tailings disposal option, $22.60. The total cost margin between the three scenarios also remains relatively constant, i.e., $0.39 between Wilson Arm and Boca de Quadra, and $12.52 between Wilson Arm and land tailings disposal option (as compared with $0.38 and $12.17 for the analogous measures in the 55 year mine life scenario). The loss of 35 additional years for amortization for the fixed capital costs results in a total unit cost increase of $0.31, $0.32, and $0.66 for Wilson Arm, Boca de Quadra, and land tailings disposal site, respectively. Significantly, the operating cost margin between Wilson Arm and Boca de Quadra remains at $0.06 per pound in the 20-year scenario, same as for the 55-year mine life.

C. Financial Analysis Conclusions

Requiring terrestrial tailings disposal for the Quartz Hill mine would clearly have a huge impact on project profitability. On-land tailings disposal results in total costs more than doubling over similar projects with submarine tailings disposal. Conversely, requiring disposal to the middle basin of Boca de Quadra rather than Wilson Arm incurs a unit cost penalty of $0.38 per pound, a cost margin of less than four percent. Smaller yet is the operating cost differential between the two submarine tailings disposal sites--$0.06 per pound, a difference of less than one percent.

U.S. Borax was concerned that the cost penalty for submarine disposal to Boca de Quadra would result in (1) a delay in the start of the project, (2) loss of market share caused by the delay in Quartz Hill startup, (3) a permanent operating cost surcharge for the mine, and therefore (4) the ability of Quartz Hill to withstand future price declines. Although Boca de Quadra tailings disposal would incur greater costs, the authors maintain that the less than four percent increase in total costs and less than one percent increase in variable costs would have little or no discernable effect on startup times, or the ability of the project to stay up during times of low molybdenum prices. The next section discusses the costs of molybdenum production at Quartz Hill in the context of recent and current molybdenum market conditions.

III. Molybdenum Market Conditions

A. Price, Consumption, and Production

Average annual nominal and real molybdenum prices peaked in 1980 at $9.36 per pound ($14.80 in beginning-of-year 1992 prices). Since that time the trend of real and nominal molybdenum prices has been downward, with average 1991 prices showing an 84 percent decrease to $2.38 per pound, a 23 year low.

Much of the plunge in the molybdenum price can be explained by the recent prices of greater than $1.00 per pound for copper. With the exception of the United States, Canada, and Mexico, all other worldwide molybdenum production is a byproduct of copper output. About two-thirds of worldwide molybdenum reserves are located in copper deposits (U.S. Bureau of Mines, 1987). While the United States is the dominant producer of molybdenum from mainproduct output (as well as a significant contributor from byproduct sources), an increasing share of production is from byproduct production in South America (Chile, Peru) and the centrally planned economies of the former Soviet Union and satellite countries and China.

Molybdenum use by U.S. consumers peaked in the early 1970s and has gradually declined since that time. U.S. production of the metal reached a high in 1980 at about 150,000 pounds, coincident with the molybdenum price peak. After a dramatic plunge in production to approximately 34,000 pounds during 1983 when the majority of mainproduct molybdenum producers were idle, U.S. production recovered to just over 130,000 pounds in 1990. Notwithstanding the production recovery in the latter 1980s, the U.S. share of world production has declined from about 63 percent in 1973 to 53 percent in 1990.

B. Quartz Hill in the Context of World Molybdenum Markets

Source: U.S. Bureau of Mines, Mineral Commodity Summaries, various years, and this study.

Figure 2 depicts the range of minimum total costs for 55-year Quartz Hill Projects with submarine tailings disposal superimposed over the last 23 years of real molybdenum prices.

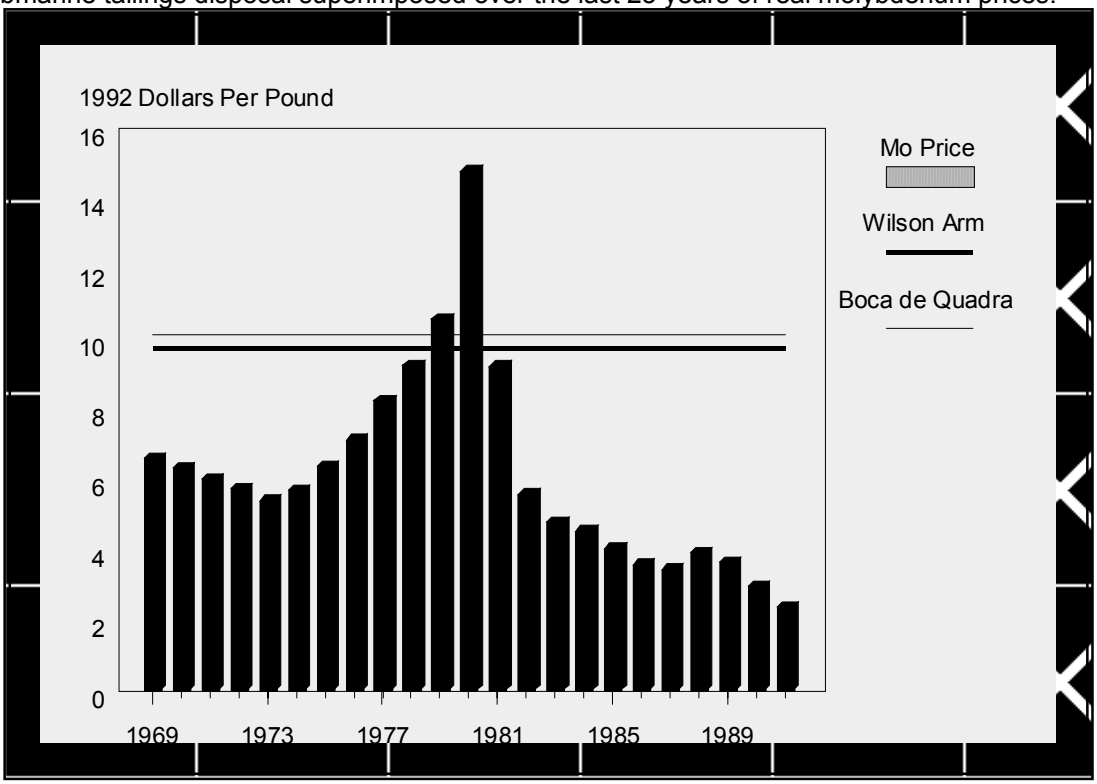

Figure 2-Average Annual Metals Week Dealer Molybdic Oxide Prices and Quartz Hill Breakeven Prices

As shown in Figure 2 in only two of the last twenty-three years has the molybdenum price been as high as any of the Quartz Hill breakeven prices. Also, the average annual change in the average molybdenum price from 1969 to 1991 is about $0.99, almost three times the $0.38 cost difference between the Wilson Arm and Boca de Quadra projects. Even ignoring the capital costs for submarine tailings disposal, the projected minimum operating costs--$6.20 and $6.26--would not be covered by the molybdenum price in 14 of the last 23 years, including none of the last 11.

A comparison of the average costs for U.S. mainproduct molybdenum mines operating in 1987 with the lowest Quartz Hill project cost shows that the total cost for the least expensive Quartz Hill project is almost twice the average cost of operating U.S. mainproduct producers., $9.77 versus $5.01 (U.S. Bureau of Mines, 1987). Much of this cost differential is because operating mines have recovered much or all of their initial capital investment and need only to cover variable costs to continue operation. However, even a comparison of the operating costs of the average U.S. mainproduct mines and the Alaska project shows a marked cost disadvantage for Quartz Hill, $6.20 versus $3.94.

Examination of the distribution and costs of worldwide reserves and resources of molybdenum reveals more disturbing news for Quartz Hill project financial viability. Table 3 depicts the mainproduct and byproduct molybdenum reserves that could be expected at various molybdenum and copper prices, solely in the Market Economy Countries (MEC).

Table 3- Mainproduct and Byproduct Molybdenum Reserves in the Market Economy Countries at

Various Commodity Prices

(Billions of Pounds and BOY 1992 Dollars).

	Mainproduct		**Byproduct**		
	Mo prices< $6.25/lb.	**$6.25/lb.> Mo prices <$12.50/lb.**	**Cu prices <$0.94/lb.**	**$0.94/lb.<Cu prices <$1.25/lb.**	**$1.25/lb.< Cu prices < $2.50/lb.**
Molybdenum Reserves	2.7	4.5	3.5	1.0	2.3

Source: extrapolated from U.S. Bureau of Mines, 1987, *An Appraisal of Minerals Availability for 34 Commodities,* Bulletin 692.

At molybdenum prices below $6.25 per pound (current price is about $2.35 per pound) approximately 2.7 billion pounds of mainproduct molybdenum could be profitably mined, primarily from currently producing deposits. At current annual worldwide production levels that amount represents about 18 years of production. However, an increase in the molybdenum price to about $12.50 per pound would allow an additional 4.5 billion pounds of mainproduct molybdenum to become profitable in currently nonproducing mines--an additional 30 years of production that includes Quartz Hill output. (At molybdenum prices from about $12.50 to approximately $37.50 an additional increment of 2.5 billion pounds of molybdenum would become available from mainproduct molybdenum mines.)

Inspection of byproduct molybdenum relationships shows approximately 3.5 billion pounds of molybdenum reserves available at copper prices of about $0.94 per pound (about 23 years of production at current levels of worldwide output). A modest increase in the copper price

to about $1.25 per pound would change an additional 1.0 billion pounds of molybdenum resources into reserves (current copper price is approximately $1.00 per pound). A further increase in the copper price to $2.50 per pound would place another 2.3 billion pounds in the molybdenum reserves column, totalling 6.8 billion pounds of molybdenum reserves--equivalent to about 45 years of production at the 1991 worldwide production level of approximately 150 million pounds per year.

Note that the above molybdenum reserve figures do not include production from any deposits in the centrally planned economies such as China, the former Soviet Union, nor any of the past Soviet satellite countries. In addition, the reserves shown above include only the deposits known and examined by the U.S. Bureau of Mines prior to 1987 (a total of 92 areas of mineralization in the market economy countries [MEC]). Perhaps the most optimistic future scenario for the Quartz Hill Project would be a significant increase in molybdenum consumption creating a 300-400 percent increase in that commodity's prices coupled with a price decline well below $0.94 per pound for copper. However, even this scenario indicates that output from Quartz Hill would be competing with production from as much as 7 billion pounds of other molybdenum reserves from the MEC.

IV. Conclusions

Citing the grave financial consequences from the additional costs incurred by dumping tailings from the proposed Quartz Hill mine into the middle basin of Boca de Quadra rather than the closer fiord of Wilson Arm, the former owners of the Quartz Hill project rejected the more expensive tailings disposal site with lesser negative environmental effects. This study shows that the difference in operating costs between the two disposal sites is about $0.06 per pound and total cost differences are about $0.38 per pound. These cost differences are quite small compared to the recent average annual variation in molybdenum price of about $1.00 per pound. Unprecedented approval of *any* submarine tailings disposal site by the EPA, rather than requiring terrestrial tailings disposal, for Quartz Hill is worth at least $12 per pound of output and would decrease total project costs by more than half.

Molybdenum prices would have to increase from 300 to 400 percent before any Quartz Hill Project described in the FEIS could become financially viable. Even with dramatic molybdenum price increases, the operators of Quartz Hill would have to compete with production from as much as 7 billion pounds of mainproduct molybdenum reserves and as much as 6.8 billion pounds of molybdenum reserves that may be available as a byproduct of copper mining--equal to almost 100 years of production at current near-record worldwide molybdenum output levels.

REFERENCES

Couglin, Regional Economist of the Environmental Protection Agency memorandum to Robert Courson, et al., Environmental Protection Agency, "Re: financial viability of Quartz Hill Project", July 28, 1987.

Engineering and Mining Journal, December 1991, v. 102, p. 14.

Hesse, C.A., Vice President and Project Manager, Quartz Hill Project letter to Mr. Robert S. Burd, Director, Water Management Division, U.S. Environmental Protection Agency, Region X, "Re: Quartz Hill EIS and NPDES Permit Application No. AK-004043-6, Pacific Coast Molybdenum Company", February 25, 1986

Hesse, C.A., Quartz Hill Project letter to Mr. Robert S. Burd, EPA "Re: EPA Memorandum by Mr. Robert Coughlin on the financial viability of Quartz Hill Project", January 25, 1989.

Reim, K.M., Deputy Project Manager, Engineering, Quartz Hill Project letter to Mr. Robert S. Burd, Director, Water Management Division, U.S. Environmental Protection Agency, Region X, "Re: Economic Evaluation of Tailings Disposal Alternatives, NPDES Permit Application No. AK-004043-6, Pacific Coast Molybdenum Company", May 5, 1986.

Reim, K.M., et al., 1988, *Planning Considerations for Quartz Hill Mine Southeast Alaska*, AIME Preprint 88-53.

U.S. Bureau of Mines, 1987, Bulletin 692, *An Appraisal of Minerals Availability for 34 Commodities*, Molybdenum Chapter.

. USDA Forest Service, 1988, *Quartz Hill Molybdenum Project Mine Development, Final Environmental Impact Statement* (FEIS).