T-3664

IMPLICATIONS OF HAZARDOUS WASTE LIABILITIES ON A HYPOTHETICAL MINING INVESTMENT

by

William E. Cobb

T-3664

A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Mineral Economics).

Golden, Colorado

Date December 7, 1988

Signed William E. Cobb
William E. Cobb

Approved Franklin J. Stermole
Franklin J. Stermole
Thesis Advisor

Golden, Colorado

Date Dec. 19, 1988

John E. Tilton
John E. Tilton
Head, Department of
Mineral Economics

ABSTRACT

Large environmental liabilities are motivating companies to carefully select engineering approaches based on both technical and economic perspectives. Firms should be positioning themselves for minimizing present-worth costs; these costs include both front-end capital investment and long-term environmental liabilities.

A hypothetical mining project is used to evaluate the effects on present-worth costs of various engineering approaches to handle two hazardous waste liabilities. The following two basic engineering approaches are evaluated in this study:

1. Allow the pollution-generation activities to continue and subsequently develop into substantial long-term economic liabilities.
2. Adopt a waste-minimizing approach that costs more in the short-term but does not incur future economic liabilities.

Cash-flow analyses have been completed to evaluate the effects of the following variables on the mining project's present-worth costs: sensitivity to variations in mining, milling, general plant, and environmental capital and operating costs; escalation of environmental capital and operating costs; and discount rate.

Based on the assumed conditions for this thesis, the cash-flow analyses indicate that two primary factors affecting the hypothetical investment decision are the escalation rate assumed for the environmental capital and operating costs and discount factor used to calculate present worth. At escalation rates of 11 percent per year and a discount factor of 4 percent, the waste minimization alternative is economically favored over other evaluated alternatives. As the escalation rate increases, the break-even discount rate between the two approaches (waste minimization versus pollution generation) also increases. For instance, at an escalation rate of approximately 15 percent, the waste-minimization alternative is economically preferred over other alternatives if a 9 percent discount rate were used.

The selection of an appropriate engineering approach to long-term environmental liabilities may be based on a firm's risk management philosophy. The procedure for selecting an approach has the following three steps:

1. Develop capital and operating cost estimates for alternate methods of dealing with the identified environmental problem.
2. Determine the projected escalation rates for environmental costs, depending on the firm's long-term views on environmental regulations.

3. Select an appropriate discount rate for the present-worth cost analyses, based on a firm's risk management philosophy. A risk-adverse company would select a smaller factor to emphasize future costs and a risk-seeking company would select a larger factor to de-emphasize future costs.

The three steps listed above, coupled with the assumptions presented in this thesis, indicate that: at relatively low escalation rates, a risk-averse company might select the waste-minimization approach over other alternatives; at the same escalation rate, a risk-loving company might select the pollution-generation alternative, unless prohibited by existing regulations.

Because the costs used in this thesis are based on the specific assumptions presented in this thesis, these conclusions should not be universally applied to real mining projects. However, the methodology used in this thesis can be applied to real projects so that informed decisions can be made regarding the implications of environmental costs to investment decisions. A key assumption in this thesis is that the decisionmaker recognizes that potential environmental liabilities can occur and that costs can be estimated for these liabilities.

TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The work undertaken for this thesis was sponsored by the author's employer, CH2M HILL. Their contributions in terms of financial, technical, and editorial support, are deeply appreciated. The following CH2M HILL staff have contributed substantial effort in producing this report: Rick Marotte, Bill Bluck, Pat Link, Susie Hutchison, and Barb Durland.

My committee members have also provided valuable comments and suggestions during the development of this thesis. I acknowledge the help supplied by my advisor, Dr. Franklin Stermole, and my committee members, Dr. Alfred Petrick and Dr. John Emerick.

Chapter 1

INTRODUCTION

Hazardous waste management has been a growing environmental and economic concern since the passage of the Resource Recovery and Conservation Act of 1976 (RCRA). RCRA was developed to protect human health and the environment from the potential hazards of waste disposal and to ensure that wastes are managed in an environmentally sound manner (EPA 1986). A pre-RCRA concept was that an important way to abate pollution was to reduce air and water discharge and instead discharge residuals to the land (Mills 1978). As our knowledge about the health and environmental impacts of waste disposal increased, the scope of RCRA was significantly expanded (EPA 1986). The RCRA Subtitle C program establishes a system for controlling hazardous waste from generation to disposal, and the Subtitle D program establishes a system for controlling solid waste. The Subtitle C program has procedures for undertaking corrective actions if a waste disposal facility is not in compliance with the regulations.

Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), more commonly known as Superfund, to provide funds for cleanup of uncontrolled hazardous waste sites throughout the country. The Superfund program is implemented through a multistep process of site investigation and characterization; engineering and feasibility studies; remedy selection; remedial design; construction; and ongoing operations, maintenance, and monitoring.

CERCLA also includes a provision for establishing financial claims for damages to natural resources of the United States, such as fish kills or destruction of critical wildlife habitat. These natural resource damage claims extend beyond hazardous waste cleanup costs and can range up to $50 million per incident. These claims can be associated with a facility that is regulated under RCRA, some other environmental program (such as air or water discharges), or a Superfund site.

The minerals industry, unlike other industries, has not been affected by the RCRA Subtitle C program. Mining wastes, although they may be characterized as hazardous wastes, are exempt from regulation under the Subtitle C program. This situation should change in 1989. Mining wastes will be regulated under the Subtitle D program; individual states will be responsible for setting facility design, performance, and corrective action requirements for mining wastes. The types of requirements that will be developed for mining wastes are not known at the time of preparing this thesis. These emerging regulations could result in design, performance, and corrective action requirements that are stricter than some of the requirements assumed in this thesis.

There are no published estimates of the costs for maintaining compliance or undertaking corrective actions to regain compliance with RCRA Subtitle C or D programs. The cost of some CERCLA cleanups has reached the $100-million range with the average site costing $25 million. Because of these large costs, a company now must closely evaluate the potential long-term costs of pollution (Wall Street Journal, 1988). The overall cost of cleaning up the country's CERCLA sites may exceed $100 billion, an amount greater than the combined 1987 profits of the Fortune 500 companies (Wall Street Journal, 1988).

These CERCLA liabilities may have important implications on corporate balance sheets. Major companies are not estimating potential hazardous waste liabilities in 10-K reports filed with the Securities Exchange Commission (SEC). For instance, Allied-Signal states in its 10-K report that it expects to spend $30 to $40 million per year in 1989 and 1990 on environmental cleanups but makes no mention of their 100 CERCLA sites that give rise to unstated liabilities (Wall Street Journal, 1988). These 100 CERCLA sites could represent more than $1 billion in liabilities.

The minerals industry, however, has been affected by CERCLA. Numerous mining sites will be investigated and cleaned up under CERCLA; recent examples include the following:

1. Cleanup of the Uravan uranium mine and mill complex in western Colorado will cost between $40 and $44 million over a 10-year period.
2. Cleanup of the Eagle lead-zinc mine and mill facility in central Colorado has been proposed to cost between $100 and $200 million over a 15-year period.
3. Cleanup of the Yak Tunnel acid-mine-drainage problem near Leadville, Colorado, is estimated to cost between $15 and $20 million between 1988 and 1993.

In 1986, EPA stated that the incentives for waste minimization (the concept of producing less waste or less toxic waste) "are already strong." (Hazardous Waste News, 1986). These incentives included the rising cost of waste management. However, the Natural Resources Defense Council (NRDC) said that a "mandatory regulatory program is essential to force companies to implement source reduction," (Hazardous Waste News, 1986). In this interview, NRDC supported a multimedia approach to force source reduction of various types of releases to air, groundwater, and surface water.

Congress is considering passage of H.R. 2800 (the Waste Reduction Act of 1988) to encourage the concept of "source reduction." The act defines "source reduction" as any practice that reduces the volume of hazardous wastes actually generated before treatment. The treatment of wastes to reduce their volume, mobility, or toxicity (which industry calls waste minimization) would not be considered a form of waste reduction (Hazardous Waste News, 1988). EPA states that "considering the high costs of liability, treatment, storage, and disposal, it is safer not to produce wastes in the first place" (Hazardous Waste News, 1988).

The objective of this thesis is to assess the implications of hazardous waste liabilities on the present-worth costs associated with investment in a hypothetical mineral property. These liabilities will be derived from the generation of hazardous wastes. The hypothesis that will be evaluated is that future environmental costs can alter present engineering decisions and economically justify the reduction in waste generation. This hypothesis will be investigated in the following way:

1. By developing a mining project's cost function using microeconomic theory of the firm.
2. By developing a specific engineering concept and its associated capital and operating costs for a hypothetical mineral project.
3. By developing two potential hazardous waste liability scenarios and their associated capital and operating costs, based on current design and

corrective action criteria established by the RCRA Subtitle C and CERCLA programs.

4. By developing alternative methods of correcting the future environmental liabilities or modifying engineering concepts so that the future environmental problems do not occur.

5. By evaluating the potential economic implications of the present-worth costs for the proposed alternatives on the hypothetical investment decision.

The costs used in this thesis are derived from the specific technical and regulatory assumptions stated in Chapter 3. The costs will change if changes are made in the assumed mining concepts. Changes in the present federal and state regulatory programs, particularly the emerging RCRA Subtitle D regulations for mining wastes, could also dramatically affect the concepts and costs presented in this thesis. As such, the economic conclusions from this study should not be universally applied to real mining projects. However, the methodology used in this thesis can be applied to real projects so that informed decisions can be made regarding the implications of environmental costs to investment decisions. A key assumption is the development of this thesis is that the decisionmaker recognizes that potential environmental liabilities can occur and that costs can be estimated for these liabilities.

Chapter 2

MICROECONOMIC THEORY

In this chapter, the microeconomic theory of the firm is used to develop the cost function for a mining project that has significant environmental costs. Previous work by others that is relevant to this thesis is also presented in this chapter.

2.1 THE TRADITIONAL COST FUNCTION

The traditional long-run cost equation of the firm is in the form of (Henderson and Quandt 1980):

$$C = R_1 X_1 + R_2 X_2 + K \tag{2.1}$$

where R_1 and R_2 are the prices of inputs X_1 and X_2, and K represents fixed costs. There is a direct relationship between inputs and outputs. The long-run marginal cost (MC) curve is the first derivative of total cost with respect to output.

The traditional cost function for this thesis can be modified by changing the inputs X_1 and X_2 (in eq. [2.1]) into traditional cost centers for a mining project:

- o Mining (X_1)
- o Milling (X_2)
- o General and administrative (X_3)
- o Environmental (X_4)

Environmental costs traditionally cover items related to mitigating air quality and water quality impacts. Mine waste disposal costs can be part of the mining costs, while tailings disposal costs are usually part of the milling costs. However, this thesis assumes that these costs are part of the environmental cost center. Costs for each input or cost center (R_1 through R_4) are reported in terms of dollars per unit of throughput (for example, $/ton of ore). Our mining cost function now becomes:

$$C = R_1 X_1 + R_2 X_2 + R_3 X_3 + R_4 X_4 \qquad (2.2)$$

2.2 A MODIFIED COST FUNCTION

As discussed in Chapter 1, mining wastes are currently exempt from the RCRA Subtitle C program for hazardous wastes. However, mining wastes regulations are being developed under the Subtitle D program for solid wastes. Thus, the environmental cost center R_4 will be modified to include RCRA-related costs for design (a capital cost), performance (an operating cost), and any required corrective actions to regain regulatory compliance (also an operating cost). RCRA-related costs are assumed to apply to mining-related solid wastes such as mine waste rock and tailings.

CERCLA liabilities have been experienced by several mining companies, including AMAX, Anaconda, ASARCO, Cotter, Eagle-Picher, Kerr McGee, Newmont, Noranda, Union Carbide, and United Nuclear (Cobb, Bluck, and Hutchison 1988). In practice, the concepts of CERCLA can result in the following scenario for a mining company. Company A, which is a large mining company, acquired a property in 1960 that was mined by a small mining company. The small mining company subsequently went out of business. Company A is evaluating the feasibility of opening a large underground mine in the same location as the previous small mine. The old, small underground mine had an adit that is leaking acidic drainage into a nearby trout stream, and several nearby waste and tailings piles are also leaching metals into the same trout stream. Regardless of the investment decision for the new project, Company A is liable for permanently cleaning up the trout stream, either by stopping the acidic drainages or treating the resulting acidic water. Company A could also be liable for natural resource damages if the trout stream habitat has been severely degraded and fish kills have occurred. In this example, the cost function for the new project should include the natural resource damage and corrective action costs associated with past mining activities.

CERCLA corrective action and natural resource damage costs (Y) are assumed to be a function of output and are included in our modified cost equation (eq. [2.3]).

$$C = R_1 X_1 + R_2 X_2 + R_3 X_3 + R_4 X_4 + Y \qquad (2.3)$$

The new marginal cost equation can be separated into its component pieces: the marginal mining production costs ($R_1 + R_2 + R_3$) and the marginal environmental and hazardous waste compliance costs ($R_4 + dY/dX$).

If a firm with a cost function such as eq. (2.3) wants to minimize its total costs without affecting its production output, the firm can attempt to undertake one of the following steps:

1. Minimize environmental and hazardous waste compliance costs (cost factors $R_4 + Y$) while keeping mining production costs constant.
2. Minimize mining production costs (cost factors $R_1 + R_2 + R_3$) while keeping environmental and hazardous waste compliance costs constant.
3. Increase mining production costs to substantially decrease environmental and hazardous waste compliance costs, resulting in an overall savings.

For a real mining project, all three methods for reducing total costs should be evaluated. It is possible that method 2 can provide substantial short-term cost savings. However, it may be difficult to prove that lower production costs (both capital and operating costs) provide effective long-term environmental safeguards, particularly if mine waste disposal costs are part of the milling cost. Lower capital costs for waste disposal practices typically implies a lower level of environmental protection (for example, no liner to halt metal-laden leachate from entering a groundwater system), although this is not universally true.

For this thesis, mining production costs (cost factors $R_1 + R_2 + R_3$) are assumed to be at the lowest possible level for a given output. This assumption leaves two possible ways (methods 1 and 3 listed previously) for our hypothetical firm to minimize the total costs for its mining project. These two methods form the basis used for developing the environmental alternatives in Chapter 3.

2.3 PREVIOUS WORK

Substantial research has occurred on comparing the various institutional arrangements for controlling pollutant emissions from individual sources--effluent fees, taxes, subsidies, marketable permits, and direct control (regulation).

These studies include: Dales 1968, Mills 1968, Baumol and Oates 1975, Kneese and Schultze 1975, Marin 1978, Mills and White 1978, and Spence and Weitzman 1978. Fisher (1981), in his chapter on Environmental Pollution (Chapter 6), refers to several additional studies: Mishan 1974, Porter 1974, Tietenberg 1974, Portnoy 1978, and Baumol and Oates 1979.

Economic research has concentrated on whether regulations or some other mechanism provide the economically optimal level of pollution output. This thesis differs from these other works because it evaluates the effects of the current and future regulatory framework on a hypothetical cost function and does not discuss whether this results in an optimal level of pollution output.

Two works set the stage for the discussions in this thesis. Linder and McBride (1984) have modeled how a firm responds to enforcement costs by incorporating detection uncertainty and concealment activity. Cobb, Bluck, and Hutchison (1988) briefly analyzed the economic implications of large reclamation and closure costs on Net Present Value. These two works provide background information that will be relied on for evaluating the implications of eq. (2.3) on a hypothetical project. Each work is summarized in the following paragraphs.

2.3.1 Comments on Linder and McBride

Linder and McBride (1984) modeled the firm's response to enforcement. Linder and McBride add one element to a firm's cost function: the amount of concealment effort that the firm undertakes to avoid the detection of any waste emissions exceeding the level permitted by the government.

According to Linder and McBride, the government develops several items that affect the firm. The first is a technology-based control standard that places a limit on the amount of waste the firm is allowed to emit. The second item is the introduction of civil and criminal fines intended to sanction firms whose waste levels exceed the established standards. RCRA and CERCLA both mandate surface and groundwater standards that must be met at pre-established points of compliance. Civil and criminal fines exist for the RCRA Subtitle C and Subtitle D programs. CERCLA allows the government to recover three times the estimated cleanup cost for a given site.

Linder and McBride assume that the firm's decision whether to comply with the government's standards are based, in part, on the expected costs of noncompliance. These expected costs include not only the potential cost of noncompliance but a probability that they will actually be imposed on the company. Linder and McBride subsequently develop a firm's profit function that is equal to revenue minus production costs minus the firm-adjusted penalty minus the expected costs of additional compliance (Linder and McBride, p. 340). The firm then chooses an output level, a level of waste output, and a level of concealment to maximize expected profit. The last two elements of Linder and McBride's profit function are included in cost factors R_4 and Y in eq. (2.3).

The key first-order condition for their profit function is: marginal revenue should equal the marginal cost of output plus the expected costs of output arising from additional compliance efforts. This is the same condition reached using eq. (2.3). Another first-order condition is: the marginal cost of concealment equals its marginal benefit. CERCLA, which is based on the concept of strict and several liabilities (any owner of a property can be legally and financially responsible for the actions of any other past or future owners), makes the marginal benefit of concealment equal to zero. Bankruptcy does not preempt CERCLA liabilities; thus, concealment may only make the long-run liability worse. Therefore, concealment costs are not included in eq. (2.3).

2.3.2. Comments on Cobb, Bluck, and Hutchison

Cobb, Bluck, and Hutchison (1988) evaluated the impacts of reclamation and closure costs on the NPV of two hypothetical mining projects. They assumed these back-end costs were a percentage of initial capital cost rather than site-specific solutions to reclamation problems. This assumption may be questionable because there may not be any direct connection between initial overall investment and reclamation and closure costs. However, the assumption did allow for rapid evaluation of the effect of large, although arbitrary, back-end costs. The results of their analysis are presented in Figure 2-1.

They concluded that the trite expression "an ounce of prevention is worth a pound of cure" is applicable to addressing mine waste management problems. Although long-term projects are less sensitive than short-term projects to large closure costs because of the discounting effect, they suggest two ways of dealing with closure liabilities:

1. Spend some engineering dollars initially to decrease the back-end liability.
2. Invest money up front and use the appreciation to pay for closure.

Cobb, Bluck, and Hutchison (1988) state that "the trade-off between up-front engineering and construction costs and back-end liabilities represents the amount of risk a

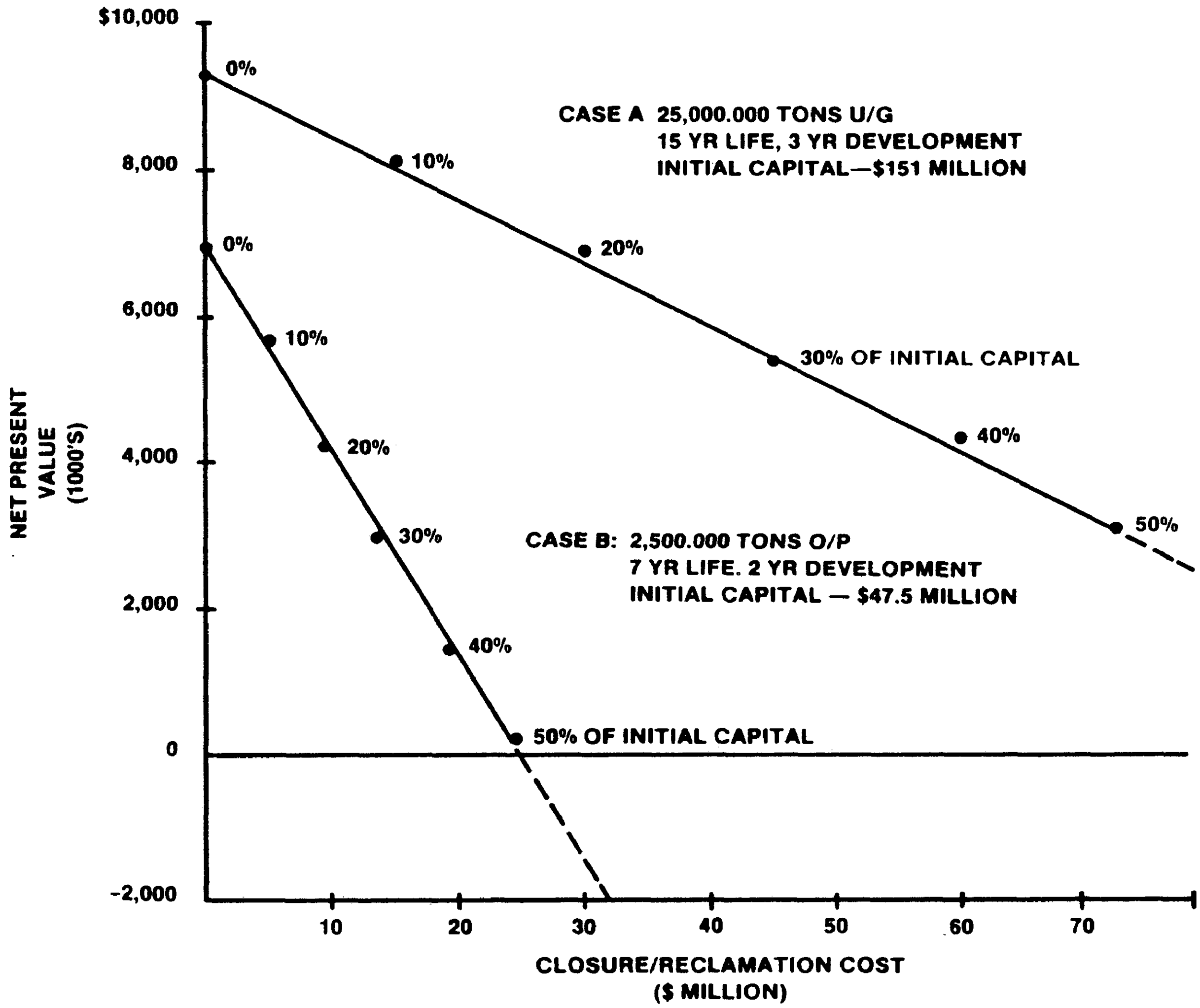

Figure 2-1, Analysis of Closure/Reclamation Costs on NPV mining company is willing to absorb. An important factor in accepting such risks is the importance of inflation or increased regulation on closure liabilities. Intuitively, inflation and/or increased regulation will increase the closure costs resulting in decreased NPV."

2.3.3 Summary

Work undertaken by Linder and McBride generally agrees mathematically with the cost function used as the theoretical basis for this thesis. The only difference between Linder and McBride and eq. (2.3) is that concealment costs are assumed to be zero for this thesis. Both the papers by Linder and McBride, and Cobb, Bluck, and Hutchison concentrate on the effects of expected compliance costs (or liabilities) and how a company may respond to those costs. This thesis goes beyond these two works by developing numerical alternatives that are used to evaluate how a company could respond to hypothetical compliance costs or liabilities.

Chapter 3

ASSUMPTIONS

This chapter presents the assumptions used to test the hypothesis presented in Chapter 1. The hypothetical mining project, its potential environmental problems or liabilities, and alternative solutions are presented below.

3.1 PROJECT DESCRIPTION

The hypothetical mining project that is used for this thesis is assumed to be in the preliminary feasibility study stage. At this stage, several alternative project concepts and approaches can be evaluated to select one or two concepts for detailed engineering feasibility studies. Table 3-1 presents the site-specific characteristics assumed for this project. These characteristics are selected to match the information needed for the capital and operating cost formulas presented in the "Quick Guides to the Evaluation of Orebodies" (O'Hara 1980). This article is further described in Chapter 4.

Table 3-1, General Description of Hypothetical Mining Project

- 25,000,000 ton Zn/Pb orebody containing 10% Zn and 2% Pb
- Underground mine with 2,500 ft adit access
- Adit and underground mine workings will generate an average 2,000 gpm of acidic drainage for discharge into a stream that supports a resident trout fishery
- Three-year project development and construction sequence (years 0, 1, and 2). Fourteen and one-half year production life (years 3 through 17); mine life established using Taylor's rule: mine life = 6.5 x (tonnage in millions)$^{0.25}$
- Blasthole mining method, 25 ft stopes
- Utility power available within 5 miles
- Extensive abundance of water available within 1 mile
- Town nearby for worker housing
- Seven miles of access road needed through steep, difficult terrain
- Project location in cold climate
- Building foundations would be poured onto solid rock
- Selective flotation would be used, with complex thickening and filtration; one would be of medium hardness
- Pb and Zn concentrates produced with mill recovery of 92 percent for Zn and 85 percent for Pb; concentrate would grade 55 percent sulfide
- Environmental aspects associated with tailings disposal are extremely unfavorable, with near surface groundwater

3.2 DISCHARGE OF HAZARDOUS SUBSTANCES

Two methods for minimizing a mining firm's total costs were presented in Chapter 1: (1) minimizing environmental and hazardous waste compliance costs while holding mining production costs constant, and (2) increasing mining production costs to substantially decrease environmental and hazardous waste compliance costs, resulting in an overall savings. The first method implies that environmentally related capital costs are decreased for waste dumps and tailings impoundments. A result of this decrease in environmental capital could be the release of metals to the environment. Metals could be released to the environment, although to a lesser degree, with the second method.

The adit discharge is assumed to flow into a stream that supports a large cold-water fishery; the fishery supports substantial recreation use. The discharge is also assumed to have a low pH and relatively elevated levels of dissolved metals. A sulfide orebody that contains, primarily, lead and zinc could act as a source of cadmium, lead, zinc, iron, manganese, and several other metals that can contaminate groundwater flowing into the underground mine workings.

The liner beneath the tailings impoundment, depending on its design characteristics, could leak metals into the shallow groundwater system. The shallow groundwater system is assumed to discharge into the surface water system. Leachate from the tailings impoundment could also have a low pH and contain relatively elevated levels of dissolved metals. Table 3-2 presents the assumed water quality concentrations for the adit discharge and contaminated groundwater beneath the tailings impoundment.

The surface water and groundwater can act as pathways for the transport of hazardous substances (in this case, metals). This transport mechanism can result in the exposure of living organisms to elevated concentrations of metals. Plants can absorb metals from water, aquatic organisms can consume metals, and humans can be exposed to metals through the ingestion of contaminated water and sediments.

Table 3-2, Criteria Comparison

Element	Assumed Adit Concentration (µg/l)	Assumed Groundwater Concentration (µg/l)	Primary Maximum Contaminant Level (MCL) (µg/l)	Secondary Maximum Contaminant Level (MCL) (µg/l)	Ambient Water Quality Criteria to Aquatic Life[a] (µg/l)	
					Acute	Chronic
Arsenic	10	5	50		360	190
Cadmium	300	25	10		3.9	1.1
Copper	5,500	4,500		1,000	18	12
Iron	20,000	1,900		300		
Lead	2,500	200	50		82	3.2
Manganese	25,000	7,000		50		
Mercury	ND	ND	2		2.4	0.012
Selenium	ND	5	10		260	35
Silver	75	40	50		4.1	0.12
Zinc	100,000	40,000		5,000	120	110

[a]Values assume hardness of 100 mg/l $CaCO_3$.

Note: ND = not detected.

Cadmium, copper, lead, and zinc are assumed to have relatively high concentrations in the adit discharge. The following brief summaries (EPA 1987a) of the toxic effects of these metals is provided to establish the potential problems associated with the adit discharge and contaminated groundwater.

- Cadmium--Chronic exposure to cadmium in animals and humans results in renal dysfunction, hypertension, and altered liver and kidney function. The kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion. Cadmium is toxic to freshwater fish in low concentrations. Cadmium interferes with normal osmoregulation, liver and kidney enzymatic activities, and maturation of reproductive organs. Trout species are sensitive to cadmium and juvenile fish are commonly more sensitive than either eggs or adults.
- Copper--Toxic effects resulting from acute exposure to copper in laboratory animals and humans include gastrointestinal disturbances, hemolytic anemia, renal damage, and liver damage. Copper is one of the most toxic metals for aquatic organisms. Chronic exposure to copper in concentrations greater than 12 ppb reduces growth and rate of reproduction,

may interfere with oxygen transport across gill membranes, and has been reported to reduce the ability of fish to orient themselves properly.

- Lead--The most serious effects in humans associated with markedly elevated blood lead levels are severe neurotoxic effects that include irreversible brain damage. A blood lead level of 15 mg/dl is considered a level of concern. Chronic exposure to lead concentrations of 13 ppb in rainbow trout causes reduced hemoglobin production and changes in red blood cells. Lead concentrations of a few hundred ppb causes spinal deformities in brook trout. Fish that are exposed to chronic and subchronic levels of lead generally show changes in their tissue structure.
- Zinc--Excessive intake of zinc by humans may cause copper deficiencies and result in anemia. Susceptibility of fish to zinc is species-dependent. Rainbow trout and brook trout are fairly susceptible to chronic zinc exposure. Juvenile rainbow trout are about three times more resistant than eggs. Zinc toxicity causes decreased growth, kidney dysfunction, gill damage, and alterations in behavior.

The corrective action provisions of RCRA and Section 121(b) of CERCLA specify cleanup criteria for discharge of hazardous substances. Surface water discharges typically are required to achieve: (1) drinking water standards, more commonly known as maximum contaminant levels (MCLs), established under the Safe Drinking Water Act (40 CFR 141.2 and 40 CFR 143.1); and (2) ambient water quality criteria (AWQC) for acute and chronic toxicity to aquatic life, established under the Clean Water Act (Section 304[a]; 33 USC §1314[a]). Groundwater cleanups are typically required to meet MCLs or state groundwater standards, whichever is more stringent. Table 3-2 also presents both MCL and AWQC criteria.

The assumed data presented in Table 3-2 indicate that the adit discharge exceeds RCRA corrective action and CERCLA criteria for the protection of public health (e.g., MCLs) and the environment (e.g., AWQC). The groundwater also exceeds MCLs. Because the adit discharge and groundwater are beyond the limits, there exists the potential for RCRA corrective action or CERCLA liabilities. If the adit discharge harms the assumed cold-water fishery, the potential CERCLA liabilities could be increased to include natural resource damage claims.

3.3 POTENTIAL REMEDIAL SOLUTIONS

The National Contingency Plan (NCP) specifies potential general response actions (40 CFR 300.70) that must be considered for remediating CERCLA sites. These response actions are also appropriate for evaluating RCRA corrective actions. General response actions are broad categories or measures (e.g., treatment) that can be taken to remediate a hazardous waste problem. Potential general response actions for solving an adit drainage problem and remediating contaminated groundwater have been identified using the NCP list and EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA Office of Solid Waste and Emergency Response [OSWER] Directive 9335.3-01, 1988). These potential general response actions are presented in Table 3-3.

The associated technologies are identified for each general response actions. Technologies are specific categories of measures (e.g., physical or chemical treatment). Technologies that are ineffective or cannot be implemented have been dropped from consideration. Table 3-4 presents the list of technologies that could be used to remediate the adit drainage and groundwater contamination problem.

Table 3-3, Potential General Response Actions

Problem	General Response Actions
<u>Adit Discharge</u>	
No Action	o No action
Source Control (sulfide rock)	o Isolation of Sulfide Rock o Removal of Sulfide Rock o Treatment of Sulfide Rock o In Situ Treatment o Diversion of Groundwater Up-Gradient of Sulfide Rock
Management of Migration (adit discharge)	o Collection of Adit Discharge o Treatment of Adit Drainage o Institutional Controls
<u>Contaminated Groundwater</u>	
No Action	o No Action
Source Control	o Redesign Tailings Impoundment
Management of Migration	o Containment of Groundwater Plume o Removal of Contaminated Groundwater o Treatment of Contaminated Groundwater o Institutional Controls

Table 3-4, Potential Remedial Technologies

General Response Action	Technology
Adit Discharge	
No Action	o None
Isolation of Sulfide Rock	o Encapsulation of Mine Zone with Grout o Backfilling of Mine Voids o Tunnel Plugging
Removal of Sulfide Rock	o Mining
Treatment of Sulfide Rock	o Chemical/Physical Processes
In Situ Treatment of Sulfide Rock	o Ferroxidans Inhibited using Bacteriacides
Collection of Adit Drainage	o Gravity Drainage
Treatment of Acid Drainage	o Physical Processes o Chemical Processes o Biological Processes
Institutional Controls	o Use Restrictions
Contaminated Groundwater	
No Action	o None
Containment	o Vertical Barriers
In Situ Treatment	o Biological Treatment
Removal of Groundwater	o Wells o Drains
Treatment of Groundwater	o Physical Process o Chemical Process o Biological Process
Institutional Controls	o Use Restrictions

Seven components have been used in this thesis to develop alternative solutions for the adit drainage and groundwater contamination problems:

1. Use blasthole stoping to mine the deposit, resulting in underground void spaces.
2. Use perpetual collection and treatment of the adit discharge to meet MCLs and AWQC.
3. Plug the mine voids and adit at strategic locations to flood the workings.
4. Backfill the mine voids by switching to a cut-and -fill mining method.
5. Construct a tailings impoundment liner with a minimum permeability of 10^{-5} cm/second.
6. Construct a tailings impoundment liner with a minimum permeability of 10^{-7} cm/second.
7. Extract and treat contaminated groundwater from beneath the tailings impoundment.

Chapter 1 presents two methods evaluated in this thesis for minimizing a mining firm's total costs:

1. Minimizing environmental and hazardous waste compliance costs while holding mining production costs constant
2. Increasing mining production costs to substantially decrease environmental and hazardous waste compliance costs, resulting in an overall savings

Four alternatives have been developed to represent a reasonable range of alternatives that fit these two categories. Figure 3-1 presents the assembled alternatives. Alternatives 1, 2, and 3 are variations of category one; Alternative 4 fits category two. The four proposed alternatives are briefly described next.

3.3.1 Alternative 1--Leaky Liner

This alternative assumes that the hypothetical mining project would occur as described in Table 3-1. Blasthole mining methods would be used to extract the ore. Conventional flotation milling would be used to generate a zinc concentrate and a lead concentrate. A 6-inch thick tailings impoundment liner would be constructed using onsite materials that are compacted to a permeability of 10^{-5} cm/second. The tailings impoundment liner allows seepage to leak through it creating a plume of contaminated groundwater after 5 years of mining operations; this alternative will be referred to as the "pollution-generation alternative". The contaminated groundwater is assumed to require extraction at a rate of 1,000 gpm for the remainder of the mine's operation and 15 years after the mine closes. The extracted groundwater must be treated to achieve MCLs and AWQC discharge. During mining operations, the adit discharge is collected,

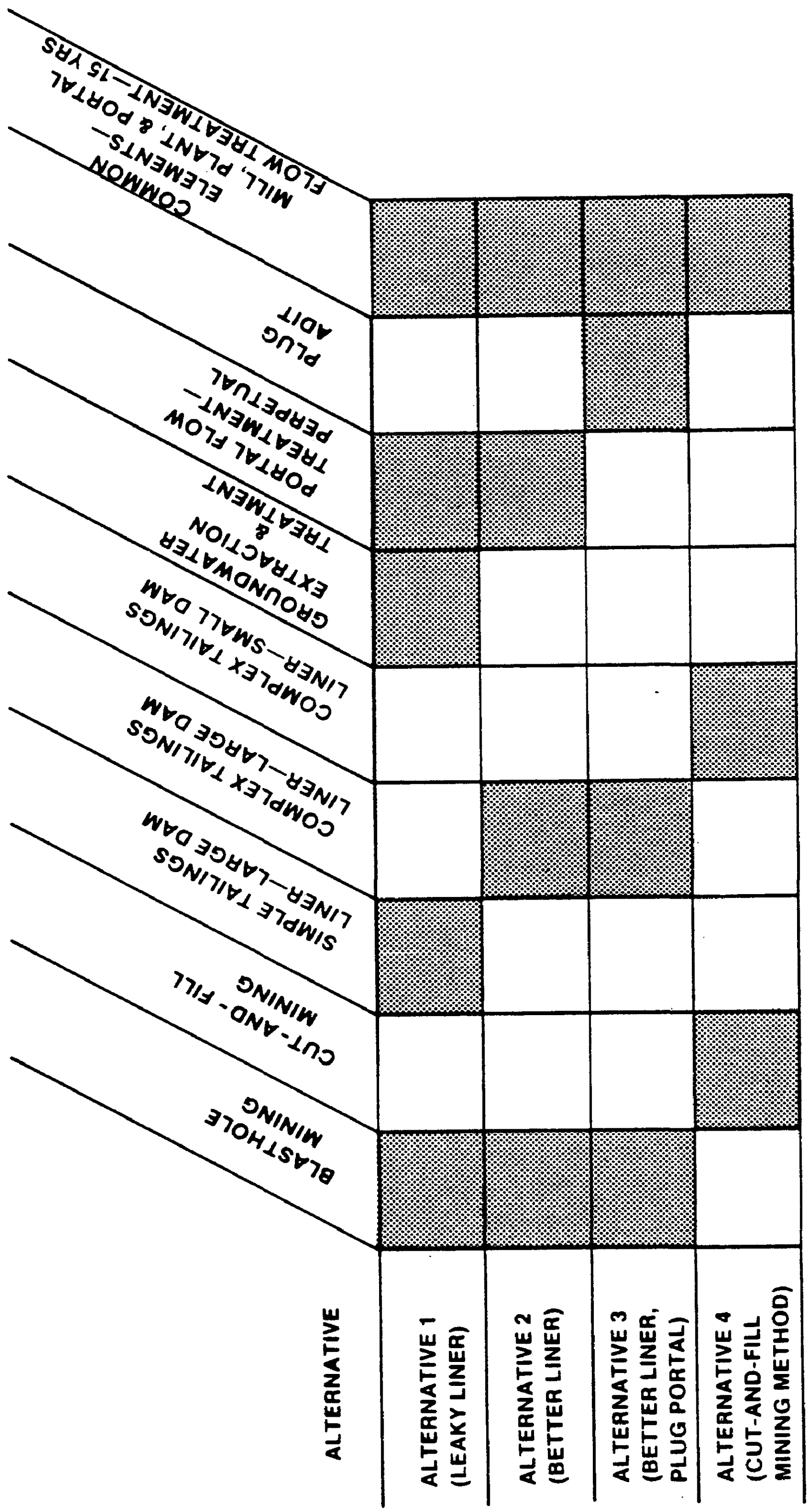

Figure 3-1, Assembly of Alternatives

treated to MCLs and AWQC, and discharged into the stream. Once mine operations cease, the adit flow is treated in perpetuity. The tailings impoundment will be sealed using a RCRA-approved cap. This cap includes a synthetic liner, sand layer, leachate collection pipes, a clay layer, topsoil, and vegetation.

There are several treatment options that may be available to obtain the specified surface water and groundwater cleanup levels from Table 3-2. For this thesis, a lime neutralization, precipitation, and selective ion exchange treatment system will be used to develop cost estimates for this alternative.

The proposed lime neutralization treatment process is presented in Appendix G of the Yak Tunnel Operable Unit Feasibility Study, California Gulch Site (EPA 1987b). Cominco developed a modified version of this process to treat mine drainage in Canada; they termed this process "high density sludge" or HDS. The HDS process is different from conventional lime neutralization in that it produces a lower moisture, filterable sludge of smaller volume than simple lime softening. The sludge can be disposed of in the tailings impoundment.

Secondary treatment may be required to meet the surface water cleanup criteria presented in Table 3-2 that are based on ambient water quality criteria for aquatic life. Ion exchange is the assumed method used to selectively remove transition metals from water.

3.3.2 Alternative 2--Better Liner

Alternative 2 has the same engineering concepts as Alternative 1, except that a double liner system with a minimum permeability of 10^{-7} cm/second is constructed beneath the tailings impoundment. This liner system is assumed to consist of 2 feet of compacted clay on the bottom, a sand layer with leachate collection pipes in the middle, and a 40 mil synthetic liner on the top. There are draft regulations being developed by the State of California (Title 23, Subchapter 15, Article 7) that would require this type of design specifications for a tailings impoundment (Hutchison 1988). This double liner and leachate collection system is assumed to halt the tailings impoundment leakage and no groundwater contamination is assumed to occur.

3.3.3 Alternative 3--Better Liner, Plug Portal

Alternative 3 is the same as Alternative 2, except that tunnel plugging will be considered to remediate the adit discharge rather than perpetual treatment. Steffen, Robertson, and Kirsten (1987) state that plugging is commonly used in the mining industry to control acid-water discharges; there have been many successes as well as failures. The effectiveness of plugging is site-specific.

Concrete plugs could be placed in the adit after the mine is closed in an attempt to halt the flow of water through the adit. This would cause a rise in the groundwater level, potentially flooding the mine voids and stopping the acid-generation process.

The key elements associated with plugging an adit are location and selection of plug design, and potential rehabilitation of drifts to provide access to the plug locations. For cost estimation purposes, three concrete plugs are assumed to be needed. The farthest upgradient would be constructed first, then a middle plug, and then a plug near the adit portal.

Because the plugging scheme may not succeed in halting the acidic drainage, a treatment facility is assumed to be constructed as a contingency plan. This treatment facility is assumed to consist of simple lime neutralization in tanks and settling and precipitation in ponds.

3.3.4 Alternative 4--Cut-and-Fill Mining

The hypothetical mining project will be modified to a cut-and-fill mining method from a blasthole mining method. A cut-and-fill mining method will result in a different extraction pattern within the ore zone, with stopes being opened and subsequently filled. The fill material would consist of coarse slimes from the milling operation mixed with cement. This process of filling void spaces will eliminate void spaces for groundwater to come in contact with oxygen, bacteria, and exposed sulfide ore to form acidic drainage. Backfilling will not eliminate groundwater flow through the natural fractures and fissures that surround the ore deposit.

Switching to cut-and-fill mining would result in no measurable change in mine development, stope width, or mining rate. There should be small modifications to the mill plant, which include the following:

1. Cyclones are required to separate the tailings into coarse and fine fractions.
2. A source of cement is needed to provide material for the backfill system.
3. A mixing and pumping facility is needed to transport the backfill material from the surface to the

underground voids and place the backfill into the voids.

For cost estimating purposes, the mine backfill is assumed to use 70 percent of the generated tailings material from the mill. The remaining 30 percent would be placed in a tailings impoundment that has the same double liner system described for Alternative 2. This liner system is assumed to prevent leakage into the groundwater system. Similar to Alternative 1, the tailings impoundment will be capped on cessation of mining operation. A RCRA-approved cap is assumed.

Because this alternative could prevent long-term water management problems and limits the amount of tailings deposited on land, it will be referred to as the "waste-minimization alternative."

Chapter 4

COST ESTIMATES

The American National Standards Institute (ANSI) and the American Association of Cost Engineers (AACE) define a cost estimate as "an evaluation of all costs of the elements of a project or effort as defined by an agreed-upon scope" (CH2M HILL 1987). This chapter presents an overview of the approaches used to estimate direct capital, direct operating, and indirect costs. Subsequently, cost estimates are developed for the four alternatives.

4.1 COST ESTIMATING SYSTEMS

There is a variety of methods that can be used to develop capital and operating costs for the mining and environmental elements of the four alternatives presented in Chapter 3. Stewart (1982) lists several methods, including: estimating by analogy, parametric estimating, detailed estimating, handbook estimating, and firm quotes.

Costs can be estimated to ±35 to 50 percent using analogous projects (e.g., using factoring and indexing); however, it can be difficult using this method to obtain cost estimates that address specific site conditions.

Computer-assisted parametric estimates can provide additional accuracy (±25 to 30 percent) using cost curves developed from similar projects. Parametric estimates can require a moderate amount of engineering information and some site-specific information. Definitive estimates (detailed estimating, firm quotes, and handbook estimating) are typically based on equipment lists generated from detailed engineering drawings. Definitive estimates can be accurate to ±10 to 15 percent.

The hypothetical mining project that is used for this evaluation is assumed to be in the preliminary feasibility study stage. At this stage, several alternative project concepts and approaches can be evaluated to select one or two concepts for detailed engineering feasibility studies. A parametric cost estimating system can provide an acceptable level of accuracy for preliminary feasibility comparisons between alternatives.

The costs derived from the parametric estimating systems are based on the specific technical and regulatory assumptions presented in Chapter 3. Any change in these assumptions will change the cost estimates. As such, the cost estimates presented in this chapter should not be viewed as absolute or precise estimates. However, because there are common cost elements for the four alternatives, the estimates are suitable for comparative analyses.

The O'Hara estimating system is used to develop mining costs, and factoring and cost indexes are used to develop specific environmental costs. Factored and indexed estimates will be used for remedial alternatives because existing information is readily available. A description of each estimating method follows.

4.1.1 O'Hara System

O'Hara (1980) developed a capital and operating cost estimating system that is based on daily tonnages. The relationships between cost and daily tonnage were determined by computerized statistical analyses to fit an equation of the form $Q=KT^x$. The cost curves presented in his article depend on several site factors, including: underground versus open pit, mining and milling methods, slope at plant site, foundation requirements, climate, ore hardness, power and water availability, and housing requirements. All of the formulas presented in his article were developed using 15 years of Canadian and foreign mining project data. Most of the operating cost data were from Canadian mines.

4.1.2 Cost Indexes

The O'Hara cost curves were published in terms of 1978 Canadian dollars, which had an average 1978 exchange rate of $1 Canadian = $0.877 United States. Several EPA feasibility studies containing remediation information relevant to this thesis were published in terms of 1986 and 1987 U.S. dollars. These capital and operating costs must be updated to current dollars (in this case, second quarter 1988 dollars).

There are several methods of updating costs. A simple method is to use an index that represents a variety of factors. One such index is the Marshall & Swift Equipment Cost Index published in Chemical Engineering. A more complex method is to use indexes that match specific cost items (e.g., producer price, mine wage, construction wage, equipment and parts, bits and steel, timber and lumber, fuel, powder and blasting, tires, construction materials, industrial materials, etc.); this method is used in the Bureau of Mines STRAAM cost estimating system. These indexes are published by the U.S. Labor Department Bureau of Labor Statistics in the two forms: the Producer Price Index data, and the Employment and Earnings data. The U.S. Department of Commerce also publishes the same information in the Survey of Current Business, producer prices and labor sections.

In 1981, Amax Engineering and Management Services (AEMS) did an in-depth analysis of the applicability of cost indexes to the mining industry. Their conclusion was that no one single index was sufficient to cover the wide varieties of capital equipment and operating cost centers in a mining operation. AEMS suggested a composite index, formed by averaging three indexes (equipment, materials, and labor) together (Gallagher 1982).

The AEMS-type approach to averaging indexes is used for developing cost estimates in this thesis. The cost indexes used are from the Survey of Current Business, and include: machinery and equipment, industrial commodities, mine labor, and industrial chemicals. Table 4-1 presents the averaged index for updating the O'Hara cost estimates from 1978 to second-quarter 1988 dollars. Table 4-2 presents the averaged index for updating EPA feasibility study data from second-quarter 1987 to second-quarter 1988 dollars.

4.1.3 Scaling Factors

Scaling factors are commonly used to adjust known or estimated costs from a given size project to different size project. Although specific scaling factors can vary, a commonly used factor for process equipment and plants is 0.6 (Peters & Timmerhaus 1980). Scaling factors for process

Table 4-1, Calculation of Average Cost Index 1978 to 1988

Index	1978 Value	2nd Qtr 1988 Value	Ratio
Machinery/Equipment[a]	232.9	318.9	1.369
Industrial Commodities[b]	209.4	332.6	1.588
Mine Labor[c]	7.67	12.66	1.651
Industrial Chemicals[d]	225.6	322.8	1.431
AVERAGE INDEX			1.510

[a] Producer Price Index Data, U.S. Department of Labor, Bureau of Labor Statistics; Table 6--Code 11.

[b] Producer Price Index Data; Table 6--No Code.

[c] Employment and Earnings Data, U.S. Department of Labor, Bureau of Labor Statistics; Table C-2--No Code.

[d] Producer Price Index Data; Table 6--Code 06.

Table 4-2, Calculation of Average Cost Index 1987 to 1988

Index	2nd Qtr 1987 Value	2nd Qtr 1988 Value	Ratio
Machinery/Equipment[a]	306.1	318.8	1.041
Industrial Commodities[b]	313.5	332.1	1.061
Mine Labor[c]	12.53	12.66	1.010
Industrial Chemicals[d]	301.3	322.8	1.071
AVERAGE INDEX			1.046

[a] Producer Price Index Data, U.S. Department of Labor, Bureau of Labor Statistics; Table 6--Code 11.

[b] Producer Price Index Data; Table 6--No Code.

[c] Employment and Earnings Data, U.S. Department of Labor, Bureau of Labor Statistics; Table C-2--No Code.

[d] Producer Price Index Data; Table 6--Code 06.

equipment can range from 0.3 to 1.2 (Peters & Timmerhaus 1980).

A scaling factor of 0.6 will be used to revise existing remediation equipment costs for developing capital cost estimates.

4.2 INDIRECT CAPITAL COSTS

Indirect costs consist of engineering, financial, supervision, and other services that may be required to construct a project. Indirect capital costs include costs for contingencies, design and engineering, permitting and legal, services during construction, and startup. A discussion of each element follows.

4.2.1 Contingencies

The AACE defines contingencies as "...specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur" (CH2M HILL 1987).

There are two types of contingencies that can be applied to the direct capital cost to reduce the risk of budget overruns from unforeseen events. These include the following:

- Bid contingency--These contingencies may cover unknown costs associated with constructing a given project scope (such as adverse weather conditions, market conditions, strikes, etc). A bid contingency may vary between 10 and 20 percent.
- Scope Contingency--These contingencies cover changes in project scope that invariably occur during final engineering design and construction. Scope change can be substantial in a mining project, particularly if environmental factors are important at the mine site. Scope contingencies may range between 10 and 25 percent of total capital costs for sites with minimum elements of risk or more for state-of-the-art technologies at sites with higher elements of risk.

A bid contingency of 10 percent and a scope contingency of 15 percent applied to the direct capital cost will be used for developing all cost estimates.

4.2.2 Design and Engineering

O'Hara (1980) states that feasibility studies, design engineering, and technical planning may range from 6 to

8 percent of the direct capital cost. Peters and Timmerhaus (1980) state that construction design and engineering should be approximately 8 percent of the direct capital cost. CH2M HILL (1987) provides a range of 6 to 10 percent of the construction cost (direct capital plus contingencies) and includes: design and process development, preparation of specifications and bid documents, drafting, and monitoring and testing, if required.

An 8 percent engineering design cost applied to construction costs will be used for developing all capital cost estimates.

4.2.3 Permitting and Legal

These costs include legal and technical fees necessary to obtain licenses and permits or negotiate contracts. O'Hara (1980) includes permitting and legal with administration and accounting costs; these costs may range from 4 to 7 percent of the direct capital cost. CH2M HILL (1987) suggests that these costs typically range from 2 to 5 percent of the construction cost.

A 3 percent permitting and legal cost applied to construction costs will be used for developing all capital cost estimates.

4.2.4 Services During Construction

O'Hara (1980) includes project supervision, contract management, expediting, and general construction costs in this category. O'Hara (1980) suggests these costs could range from 8 to 10 percent of direct capital costs. CH2M HILL (1987) suggests that engineering expenses during construction can range from 7 to 10 percent of the construction cost. Services during construction could include the following:

- Bidding and contract administration
- Construction management and onsite observation
- Change order negotiations
- Prepurchase of equipment and expediting deliveries
- Submittal review
- Additional design work
- Preparation of operations and maintenance manuals

A 7 percent services-during-construction cost applied to the total construction cost will be used for developing all capital cost estimates.

4.2.5 Startup

O'Hara does not specifically address startup costs in his article. Peters and Timmerhaus (1980) suggest that startup expenses (including equipment changes) may be as high as 12 percent of the fixed-capital investment. CH2M HILL (1987) suggests that startup and shakedown costs can be expected to involve up to 5 percent of the construction cost.

A 2 percent startup cost applied to the construction cost will be used for developing all capital cost estimates.

4.2.6 Summary

Both direct and indirect capital costs are considered in the development of cost estimates. Table 4-3 presents the structure and method for calculating the indirect capital costs.

4.3 INDIRECT OPERATING COSTS

Indirect operating costs are contingencies that cover large, unanticipated operating costs. They may be related to changes in project scope or actual operating conditions being different from planned (similar to bid contingencies).

Table 4-3, Format for Calculating Total Capital Costs

Item		Calculation Method
A	Construction Subtotal	From estimates
B	Bid Contingency	10% of Item A
C	Scope Contingency	15% of Item A
D	Construction Cost Total	Sum of Items A, B, and C
E	Engineering and Design	8% of Item D
F	Permitting and Legal	3% of Item D
G	Services During Construction	7% of Item D
H	Startup	2% of Item D
I	TOTAL CAPITAL COST	Sum of Items D, E, F, G, and H

Operating contingencies may range from 5 to 25 percent (CH2M HILL 1987). An operating cost contingency of 10 percent will be used for developing all cost estimates.

4.4 CAPITAL COST ESTIMATES

The major components that can be part of the alternatives described in Chapter 3 are: blasthole mining or cut-and-fill mining, mill facility, general and administrative facilities, tailings disposal impoundment, portal water treatment, perpetual treatment of portal discharge, RCRA closure (capping) of the tailings impoundment, and 15 years of groundwater treatment. Figure 3-1 presents the components associated with the four alternatives. Capital costs are estimated for each component. Appendix A presents detailed cost estimates for each component including references for unit costs. All costs presented are in second-quarter 1988 U.S. dollars and have an expected accuracy of ±30 percent.

Table 4-4 presents the investment schedule for the components of the hypothetical project. Tables 4-5 through 4-8 present the initial (years 0 through 2) and deferred (years 7, 18, 38, and so on) capital cost estimates for Alternatives 1 through 4, respectively.

4.5 OPERATING COST ESTIMATES

The major operating components that can be part of the alternatives described in Chapter 3 are: mining, milling, general and administrative, portal water treatment, and groundwater treatment. Operating costs were estimated for each operating component; Appendix B presents detailed cost estimates for each operating component. All costs presented are in second-quarter 1988 U.S. dollars and have an expected accuracy of ±30 percent.

Tables 4-9 through 4-12 present the annual estimated operating costs for alternatives 1 through 4, respectively.

Table 4-4, Capital Investment Schedule

Mining--Mill--General Plant--Tailings--Portal Treatment

30% of capital is invested in year 0
40% of capital is invested in year 1
30% of capital is invested in year 2

Groundwater Treatment

100% of capital is invested in year 7
Plant replaced in year 28

Plug

100% of capital is invested in year 18

Perpetual Treatment

100% of capital is invested in year 18
Plant replaced in years 38, 58, and 78

RCRA Cap

100% of capital is invested in year 18

Table 4-5, Capital Cost Summary, Alternative 1--Leaky Dam

	Year 0	Year 1	Year 2	Year 7	Year 18	Year 28	Year 38
Mining	$24,375	$32,500	$24,375	--	--	--	--
Mill	10,441	13,922	10,441	--	--	--	--
General Plant	4,658	6,211	4,658	--	--	--	--
Environment							
Tailings	6,219	8,293	6,219	--	$17,287	--	--
Portal Treatment	3,501	4,668	3,501	--	11,671	--	$11,671
Groundwater Treatment	--	--	--	$7,711	--	7,711	--
Plug	--	--	--	--	--	--	--
Total	$49,195	$65,594	$49,195	$7,711	$28,958	$7,711	$11,671

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-6, Capital Cost Summary, Alternative 2--Better Liner

	Year 0	Year 1	Year 2	Year 18	Year 38
Mining	$24,375	$32,500	$24,375	--	--
Mill	10,441	13,922	10,441	--	--
General Plant	4,658	6,211	4,658	--	--
Environment					
Tailings	11,312	15,083	11,312	$17,287	--
Portal Treatment	3,501	4,668	3,501	11,671	$11,671
Groundwater Treatment	--	--	--	--	--
Plug	--	--	--	--	--
Total	$54,288	$72,384	$54,288	$28,958	$11,671

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-7, Capital Cost Summary, Alternative 3--Better Liner and Portal Plug

	Year 0	Year 1	Year 2	Year 18
Mining	$24,375	$32,500	$24,375	--
Mill	10,441	13,922	10,441	--
General Plant	4,658	6,211	4,658	--
Environment				
Tailings	11,312	15,083	11,312	$17,287
Portal Treatment	3,501	4,668	3,501	--
Groundwater Treatment	--	--	--	--
Plug	--	--	--	21,556
Total	$54,288	$72,384	$54,288	$38,843

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-8, Capital Cost Summary
Alternative 4--Cut-and-Fill Method

	Year 0	Year 1	Year 2	Year 18
Mining	$24,375	$32,500	$24,375	--
Mill	10,441	13,922	10,441	--
General Plant	5,030	6,707	5,030	--
Environment				
Tailings	3,979	5,305	3,979	$5,186
Portal Treatment	3,501	4,668	3,501	--
Groundwater Treatment	--	--	--	--
Plug	--	--	--	--
Total	$47,326	$63,101	$47,326	$5,186

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-9, Operating Cost Summary,
Alternative 1--Leak Liner

	Yrs 3-6[a]	Yr 7	Yrs 8-16	Yr 17	Yr 18	Yrs 19-30[e]	Yr 27
Blasthole Mining	$31,012	$31,012	$31,012	$16,588			
Portal Trmt.	1,296	1,296	1,296	1,296	$6,099[c]	$1,296	$1,296
Groundwater Trmt.		4,180[b]	963	963	963	963	4,180[b]
RCRA Cap					3,381[d]		
Plugging							
TOTAL	$32,308	$36,488	$33,271	$18,847	$10,443	$2,259	$5,476

[a]Three-year project development starts in year 0, then operations start in year 3.

[b]Includes $3,217 of installation expenses for treatment facility (Table A-15).

[c]Includes $4,803 of installation expenses for treatment facility (Table A-15).

[d]Installation expenses (Table A-15).

[e]Year 30 cost in model is $2,259 plus $22,590 (present worth of future operating costs at i=10 percent).

Table 4-10, Operating Cost Summary, Alternative 2--Better Liner

	Years 3 to 16	Year 17	Year 18	Years 19 to 30[a]
Mining	$19,282	$10,313	--	--
Mill	8,239	4,407	--	--
General Plant	3,492	1,868	--	--
Environment				
Tailings	--	--	$3,381[b]	--
Portal Treatment	1,296	1,296	6,099[c]	$1,296
Groundwater Treatment	--	--	--	--
Plug	--	--	--	--
Total	$32,308	$17,884	$9,480	$1,296

[a]Year 30 cost is $1,296 plus $12,960 (Present worth of future operating costs at i = 10%).

[b]Installation expense (Table A-16).

[c]Includes $4,803 of installation expense for treatment facility (Table A-16).

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-11, Operating Cost Summary,
Alternative 3--Better Liner and Plug

	Years 3 to 16	Year 17	Year 18	Years 19 to 30[a]
Mining	$19,282	$10,313	--	--
Mill	8,239	4,407	--	--
General Plant	3,492	1,868	--	--
Environment				
Tailings	--	--	$3,381[b]	--
Portal Treatment	1,296	1,296	--	--
GroundWater Treatment	--	--	--	--
Plug	--	--	6,592[c]	$223
Total	$32,308	$17,884	$9,773	$223

[a]Year 30 cost is $223 plus $2,230 (Present worth of future operating cost at i = 10%).

[b]Installation expenses (Table A-17).

[c]Includes $6,169 of installation expenses (Table A-17).

Notes: All values are in thousands ($000).
Rounding errors may occur.

Table 4-12, Operating Cost Summary,
Alternative 4--Cut-and-Fill Mining

	Years 3 to 16	Year 17	Year 18
Mining	$27,124	$14,508	--
Mill	8,239	4,407	--
General Plant	4,231	2,263	--
Environment			
Tailings	--	--	$1,014[a]
Portal Treatment	1,296	1,296	--
Groundwater Treatment	--	--	--
Plug	--	--	--
Total	$40,890	$22,474	$1,014

[a]Installation expense (Table A-18).

Notes: All values are in thousands ($000).
Rounding errors may occur.

Chapter 5

PRESENT-WORTH COST ANALYSES

After-tax cash flows have been calculated for the four remedial alternatives presented in Chapter 3 and costed in Chapter 4. The methodology used for these evaluations is presented by Stermole and Stermole (1987). All cash flows conducted for this thesis were done using the computer program Software for Economic Evaluation (Investment Evaluations Corporation 1988).

The theoretical basis for this thesis deals with a firm's cost functions; the hypothesis deals with minimizing present-worth costs to the firm. Thus, the after-tax cash flows presented in this chapter were calculated in terms of present-worth costs. Revenue calculations, which would be constant for each remedial alternative (i.e., there are no changes among production rate, grade, recovery, price, or smelting costs), were neglected.

Net Present Value could be calculated if revenues were included for each alternative. However, because the project life and revenues are constant between the various alternatives, present-worth cost analysis is a straightforward method of ranking the alternatives. If revenues are included, a cost-revenue cost situation occurs; this situation generates dual rates of return and requires special techniques to develop a correct analyses.

The initial discussion in this chapter focuses on the cash-flow elements that are part of the cost calculations. Subsequently, the present-worth cost calculations are presented for each alternative.

5.1 ELEMENTS OF THE CASH-FLOW STATEMENT

Table 5-1 presents the format of the cash-flow statements used in this chapter.

The initial element of the cash-flow statement typically is annual revenue. Gross revenue for a mining project is calculated as grade times annual tonnage times mill recovery times smelter recovery times price. Smelter charges are then deducted from gross revenue to yield net smelter revenue. The net smelter revenue for each alternative is the same and is not included in the cash-flow analysis.

The remaining major elements of the cash-flow statement are briefly discussed in the following paragraphs.

Table 5-1, Format of Cash Flow Statement

	Without Revenue
Revenue	
- Smelting Cost	
Net Smelting Revenue	
- Operating Costs	-32,308
- Severance Taxes	
- Development	
- Depreciation	-9,278
- Amortization	
Net Before Depletion	-46,329
- 50 Percent Limit	
- Percent Depletion	
- Cost Depletion	-3,027
Taxable Income	-49,356
- Tax at 42%	+20,730
Net Income	-28,627
+ Depreciation	+9,278
+ Depletion	+3,027
+ Amortization	+4,743
- Capital Costs	-10,204
Cash Flow	$-21,782

Note: All values are in thousands of dollars ($000).

5.1.1 Development Costs

According to Stermole and Stermole (1987), "mineral development costs are defined as expenditures incurred after the determination has been made that an ore body is economically viable..." Development costs for the four alternatives include expenses related to mine development and labor expenses associated with the indirect capital costs that are incurred before mine startup. Seventy percent of a development cost is expensed in the year incurred and the remaining 30 percent is amortized over a 5-year period.

5.1.2 Depreciation

Depreciation is used in this thesis as a tax allowance. Stermole and Stermole (1987) describe the modified Accelerated Cost Recovery System (ACRS) depreciation method for property placed in service after December 31, 1986. ARCS depreciable property is depreciated over one of the following lives: 3 years, 5 years, 7 years, 10 years, 15 years, 20 years, 27.5 years, or 31.5 years. Table A-2 presents the various types of depreciable property used in these evaluations and their associated depreciable lives.

The computer program Software for Economic Evaluation (SEE) used for these cash-flow analyses offers two types of ACRS depreciation methods: 200 percent declining balance or 150 percent declining balance. The former method is used for property with a depreciable life equal to or less than 10 years. SEE automatically switches from declining balance to straight-line depreciation, based on the specified property life. Additional details concerning depreciation methods are found in Stermole and Stermole (1987, pp. 236-242).

5.1.3 Amortization and Write-Offs

Amortization is used to expense mineral development costs. Amortization permits the recovery of these expenditures in a manner similar to straight line depreciation over 5 years (Stermole and Stermole 1987, p. 249).

5.1.4 Depletion

Mineral depletion is computed by two methods (Stermole and Stermole 1987, p. 242): cost depletion and percentage depletion. Cost depletion is based on the mineral rights acquisition cost. In this case, a $1,000,000 acquisition cost incurred in 1985 is assumed. Cost depletion is computed by dividing the total number of mineable tons in the deposit by adjusted depletion basis (cost basis minus cumulative depletion). The adjusted basis takes into account the cumulative depletion, which includes the larger of cost depletion or percentage depletion. Once the adjusted basis equals zero, cost depletion is no longer considered.

Percentage depletion is a specified percentage of gross revenue minus royalties during the tax year, but the deduction for depletion using this method cannot exceed 50 percent of taxable income from the deposit after all deductions except depletion and loss carry forward deductions (Stermole and

Stermole 1987, p. 244). The specified percentage rates for both lead and zinc are 15 percent. However, because gross revenue is neglected for these analyses, percentage depletion and the 50 percent limit are set at zero and only cost depletion is used.

5.1.5 Taxation

There are two types of taxes that are included in the cash-flow analyses: state income tax and federal income tax. Gross-revenue severance taxes are neglected in the calculations.

Stermole and Stermole (1987, p. 269) present a simplifying equation for calculating a combined effective corporate tax rate. This equation applies to the situation where state corporate tax is deductible for purposes of calculating federal corporate tax. However, federal corporate tax is not an allowable deduction when calculating state corporate tax. The assumed incremental federal tax rate is 38 percent and the incremental state tax rate is 7 percent. The effective corporate tax rate thus becomes 42.3 percent (42 percent is used in the cash-flow calculations). A second assumption is that property taxes are included as part of the assumed state tax rate.

5.1.6 Inflation and Escalation

Inflation, which relates to increases in prices for goods, services, and commodities, that is not offset by increased productivity is included in the cash-flow analyses. A 3 percent annual rate of inflation is used.

Escalation refers to the increase in prices of goods, services, and commodities for reasons that include the following:

- o Inflation
- o Supply and demand changes
- o Technological changes
- o Market changes
- o Environmental effects
- o Political effects
- o Miscellaneous effects

Escalation in costs because of environmental regulations is a critical aspect of this thesis. Hazardous waste disposal costs have risen dramatically in the 1970s and 1980s because of increased regulation. An 8 percent escalation rate for capital costs and 5 percent escalation rate for operating costs was assumed. At these rates, current capital costs would double in approximately 9 years, and operating costs would double in approximately 14 years. These rates are reasonable when compared with hazardous waste disposal costs, which have increased 15 fold in approximately 18 years (Hazardous Waste News, 1986).

5.1.7 Evaluation Basis

The cash-flow calculations are completed using the perspective of a major minerals producer and that other income exists to write off losses against. Thus, there is a tax "benefit" in a year when the taxable income is negative.

5.1.8 Discount Rate

A 5, 10, and 15 percent discount factor were used for the initial present-worth cost calculations. A number of mining companies are using a 10 percent discount factor (Antony 1988). A risk-free investment, in late 1988, can return 6 percent after taxes (i.e., a money market account); some high-risk mutual funds can return 15 to 30 percent (Changing Times, 1988).

The Capital Asset Pricing Model (CAPM) could be used to generate an approximate discount rate for a mining company. CAPM uses the risk-free return on government securities, return on the market, and a company's stock beta (measure of riskiness) to calculate the suggested discount rate for analyzing new projects. Because the calculation is dependent on a specific company's stock beta, this method is not used in this study.

The sensitivity of the various alternatives to changes in discount rate will be analyzed in Chapter 6.

5.1.9 Working Capital

Working capital is the money required to operate the mining project on a day-to-day basis until revenues begin to accumulate. For evaluation purposes, working capital is considered to be put into a project at the start of the mine operation and will be fully recovered at the end of the project's expected life. The working capital used in the calculations is equal to approximately 90 days operating costs. Working capital is assumed to be recovered in year 30.

5.1.10 Project Life

The overall life of the various alternatives is greater than 30 years, which is the maximum evaluation period of the software used. Capital and operating costs that would be incurred beyond year 30 were discounted back to year 30 using a 10 percent discount factor.

5.2 INITIAL RESULTS

Appendix C presents the capital and operating cost and tax-related data used to develop a present-worth cost for each alternative. These input data are based on the assumptions described in Chapters 3 and 5. Appendix C also presents a sample cash-flow calculation so that the results presented here can be replicated. The results of the present-worth analysis are dependent on these assumptions.

Table 5-2 presents the present-worth costs at a 5, 10, and 15 percent discount factor for each alternative. Other financial analysis tools such as payback or present-value ratio are not used because of the exclusion of revenue from the analyses.

Based on the assumptions stated in this thesis, the values presented in Table 5-2 indicate that there is no motivation for the company to invest additional dollars in minimizing pollution unless environmental regulations require additional lining of the tailings impoundment (Alternatives 2 and 3). Alternative 1 has a present-worth cost that is approximately $25 million less (at a 10 percent discount factor) than Alternatives 2 and 3. It is more expensive for a company to consider changing mining concepts to cut and

Table 5-2, Initial Present-Worth Cost Analysis

Alternative	Present-Worth Cost i=5%	i=10%	i=15%
1--Leaky Liner	$-373,218	$-275,218	$-221,624
2--Better Liner	-402,108	-300,436	-242,833
3--Better Liner, Plug	-397,719	-300,800	-243,607
4--Cut and Fill	-411,981	-309,921	-247,965

Note: All economic data presented are in terms of escalated dollars; present-worth costs are in thousands of dollars ($000).

fill (Alternative 4); this change results in a waste-minimization program that incurs a $35 million increase in present-worth cost (at a 10 percent discount factor). The trends are the same if the discount factor is increased or decreased, although the absolute differences are changed.

These initial results suggest that under the base case conditions assumed in this thesis, there is no motivation for the hypothetical mining company to change engineering concepts (and its investment strategy) even in the face of future environmental liabilities. Because this conclusion refutes the hypothesis being evaluated in this study, sensitivity calculations completed to determine what types of conditions may be necessary to economically justify modifications to engineering concepts or investment strategy.

5.3 SENSITIVITY CALCULATIONS

The present-worth costs presented in Table 5-2 are a function of the assumptions used in this thesis, which may not be representative of real-life project conditions. If the assumed conditions or real-life conditions were to vary substantially from those used to develop the present-worth costs, the results presented in Table 5-2 could dramatically change. The factors that were evaluated to provide a sensitivity assessment include the following:

- Capital and operating costs for environmental related items
  - tailings impoundment and cap
  - portal water treatment
  - groundwater extraction and treatment
  - plugs
- All capital and operating costs
- Discount factor

The input data associated with modifying these factors are presented in Appendix C; a sample calculation is also included so that the results presented here can be replicated.

5.3.1 Variations in Costs of Environmental Items

A key factor in this thesis is the cost of environmental items that relate to determining the size of potential future CERCLA or RCRA liabilities. It is assumed that the hypothetical mining company is interested in avoiding large future liabilities, if the present-worth cost of those liabilities is more than the present-worth cost of changing engineering concepts.

Three scenarios in environmental capital and operating costs have been analyzed assuming the same inflation and cost escalation rates used for the initial calculations. These scenarios are as follows:

1. A 50 percent increase in the environmental capital cost incurred after production starts and double the ongoing environmental operating costs.
2. Double the environmental capital costs incurred after production starts and quadruple the ongoing environmental operating costs.
3. Quadruple the environmental capital costs incurred after production starts and multiply the ongoing environmental operating costs by eight.

The present-worth costs for both a 10 percent and 15 percent discount factor were calculated for each alternative. Table 5-3 presents the results of scenario 1, Table 5-4 presents the results of scenario 2, and Table 5-5 presents the results of scenario 3.

Table 5-3, Results of Multiplying Environmental Capital by 1.5 and Operating Costs by 2

Alternative	Present-Worth Cost		
	i=5%	i=10%	i=15%
1--Leaky Liner	$-417,606	$-295,856	$-232,620
2--Better Liner	-434,651	-315,666	-250,879
3--Better Liner, Plug	-425,791	-315,512	-251,804
4--Cut and Fill	-423,911	-317,201	-252,674

Note: All economic data presented are in terms of escalated dollars. Present-worth costs are in thousands of dollars ($000).

Table 5-4, Results of Multiplying Environmental Capital Cost by 2 and Operating Costs by 4

Alternative	Present-Worth Cost		
	i=5%	i=10%	i=15%
1--Leaky Liner	$-483,118	$-326,936	$-249,668
2--Better Liner	-482,109	-338,683	-263,657
3--Better Liner, Plug	-464,227	-336,609	-264,261
4--Cut and Fill	-445,385	-330,659	-261,603

Note: All economic data presented are in terms of escalated dollars. Present-worth costs values are in thousands of dollars ($000).

Table 5-5, Results of Multiplying Environmental Capital Cost by 4 and Operating Costs by 8

Alternative	Present-Worth Cost i=5%	i=10%	i=15%
1--Leaky Liner	$-660,666	$-409,486	$-293,653
2--Better Liner	-612,278	-399,602	-295,837
3--Better Liner, Plug	-576,514	-395,455	-297,046
4--Cut and Fill	-493,610	-360,455	-280,668

Note: All economic data presented are in terms of escalated dollars. Present-worth costs are in thousands of dollars ($000).

The present-worth costs in Tables 5-3, 5-4, and 5-5 indicate that increases in the estimated environmental capital costs that occur after production starts and the ongoing environmental operating costs are required to economically motivate the hypothetical mining company to change engineering concepts. Scenario 1 (Table 5-3) has the appropriate level of environmental capital and operating costs to make the waste-minimization alternative (Alternative 4) economically equal (at a discount factor greater than 10 percent) to the more protective tailings impoundment alternatives (Alternatives 2 and 3). If Alternative 1 did not comply with changes in mine waste disposal regulations, then the hypothetical company could select an engineering approach (or alternative) according to discount factor (or risk management philosophy). Alternative 4 would be preferred over Alternatives 2 and 3 at a 5 percent discount factor (this low value represents a risk-averse approach). Alternatives 2 and 3 are equivalent at discount rates greater than 8 percent. This suggests that there is no benefit to plugging over perpetual treatment of the adit discharge. Alternative 4 has the same present-worth cost as Alternative 1 at a 4 percent discount factor. This suggests that a risk-averse philosophy would be needed to select Alternative 4 over the other alternatives, based on the assumed conditions.

In scenario 2 (Table 5-4), the waste-minimization approach has less cost than the more protective tailings disposal alternatives (2 and 3) at all discount factors. At discount rates less than 9 percent, Alternative 4 has less present-worth cost than Alternative 1. This suggests that a risk-neutral philosophy would result in the selection of Alternative 4 over the other alternatives, based on the assumed conditions.

In scenario 3, Alternative 4 has the least cost of the four alternatives up to a discount rate of 21 percent. Alternatives 1 and 4 have the same present-worth cost at this discount rate, and Alternative 1 has a small (less than $3 million) cost advantage at higher discount rates higher than 21 percent.

Escalation of 8 percent (see Chapter 5) is included in the numbers presented in Tables 5-3 and 5-5. This escalation rate would double the environmental capital in approximately 9 years and quadruple it in 18 years. The overall effect of the 8 percent escalation and the assumptions made in scenario 2 would result in a capital cost increase of 8 times over an 18- to 20-year period. The overall effect of the 5 percent escalation and the assumptions made in scenario 2 would result in an operating cost increase of approximately 12 times over the same time period.

Hazardous waste disposal costs for some Denver companies increased as much as 400 percent between early 1986 and early 1987 (Webb 1987). Hazardous wastes disposal costs have increased from $15 per ton in the mid-1970s to more than $300 per ton in 1986 (Hazardous Waste News, 1986). Solid waste disposal costs have increased by 5 to 10 times over the same time period (Hazardous Waste News, 1986). One factor that is responsible for increasing hazardous waste disposal costs is the regulatory compliance costs associated with disposal facilities. Demand for waste disposal capacity is inelastic, and RCRA compliance costs can be passed on to the customers of disposal facilities with high compliance costs.

The increases in capital and operating costs from scenario 2 are less than the 20-fold increase in hazardous waste disposal costs in the last 15 to 20 years and is approximately equal to the increase in disposal cost for nonhazardous solid wastes over the same timeframe. The cost increases associated with scenario 1 are less than the increases associated with solid waste disposal. Although the cost escalation assumptions in scenario 1 and scenario 2 may initially seem ludicrous, they are comparable to cost escalation caused by regulatory restrictions over the past 15 to 20 years.

5.3.2 Variations in All Costs

A secondary sensitivity factor evaluated is variation in the overall capital and operating costs of the alternatives. An early assumption of this thesis was that the mining and milling costs calculated for the hypothetical project were at optimal levels; this assumption is not valid in real-world terms. However, the assumption was made to justify focusing the analysis on the environmental components of the project's cost function.

The effects on the base-case present-worth costs (Table 5-2) from varying the capital costs ±20 percent were evaluated for each alternative. These costs include the mining, milling, general plant, and environmental components of each alternative. The same analyses were performed for varying the operating costs. Table 5-6 presents the results of varying capital or operating costs.

Other than the tailings impoundment capital cost, the initial (first 3 years) capital costs for Alternatives 1 through 3 are the same. Alternative 4 has a slightly higher general plant capital cost associated with the backfill plant. All alternatives have approximately the same sensitivity to capital costs fluctuations. The operating costs of alternatives vary with environmental components in years 18 through 30. Alternative 4 is the most sensitive to changes in operating costs. This is because the cut-and-fill mining method is labor intensive and requires additional materials and power consumption.

The general trends presented in Table 5-6 change if the base present-worth cost is taken from scenario 2 (Table 5-7).

Table 5-6, Present-Worth Cost for Changing Capital and Operating Costs

Alternative	Table 5-2 Present-Worth Cost i=10%	Capital Costs		Operating Costs	
		-20%	+20%	-20%	+20%
1--Leaky Liner	$-275,218	$-242,360	$-308,076	$-247,786	$-302,651
2--Better Liner	-300,436	-265,697	-335,175	-269,867	-331,004
3--Better Liner, Plug	-300,800	-265,563	-336,037	-270,483	-331,117
4--Cut and Fill	-309,921	-280,613	-339,229	-271,843	-347,999

Note: All economic data presented are in escalated dollars. All NPV values are in thousands of dollars ($000).

Table 5-7, Present-Worth Cost--Scenario 2 Changing Capital and Operating Costs

Alternative	Table 5-4 Present-Worth Cost (i=10%)	Capital Costs -20%	Capital Costs +20%	Operating Costs -20%	Operating Costs +20%
1--Leaky Liner	$-326,936	$-289,122	$364,751	$-292,846	$-361,027
2--Better Liner	-338,683	-300,231	-377,134	-303,271	-374,094
3--Better Liner, Plug	-336,609	-297,162	-376,057	-302,262	-370,057
4--Cut and Fill	-330,659	-300,752	-360,566	-288,919	-372,399

Note: All economic data presented are in escalated dollars.
All present-worth costs are in thousands of dollars ($000).

The effects on present-worth cost using the assumptions in scenario 2 and varying the capital and operating costs by ±20 percent have also been evaluated. For these specific conditions, Alternative 4 has the least cost for +20 percent in capital costs and -20 percent in operating costs. This is because Alternative 4 has the same initial mining and milling capital as the other alternatives, but has smaller tailings capital costs and does not have large back-end liabilities. However, the cut-and-fill mining method is labor intensive and has high operating costs. Alternative 1 has the least present-worth cost for -20 percent in capital cost and +20 percent in operating costs. This is because

Alternative 1 has a large front-end capital and back-end liabilities that reflect these sensitivities.

The results of these cost sensitivity calculations verify an original notion for this thesis that the cost estimates cannot be viewed as absolute numbers but as relative numbers. Depending on a particular sensitivity calculation, the least-cost alternative can change. The results presented in Tables 5-2 and 5-4 may not be valid if changes in assumptions or actual conditions result in capital or operating cost fluctuations of ±20 percent or more.

5.3.3 Variations in Discount Rate

A second key sensitivity factor for this thesis is variation in the discount rate used to calculate the present-worth costs. The assumed discount rates for the initial cash-flow calculations were 5, 10, and 15 percent. Sensitivity calculations were completed for the initial project conditions with discount rates between zero and 30 percent. The results of these calculations were used as part of the cost escalation discussion in Chapter 5.

For the base-case scenario (Table 5-2), Alternative 1 has the least present-worth cost for all discount factors between zero and 30 percent. For scenario 1 (Table 5-3), Alternatives 1 and 4 have the same present-worth cost at a discount factor of 4 percent. At discount rates higher than 5 percent, Alternative 1 is the least-cost alternative. For this scenario, Alternatives 2, 3, and 4 have the same present-worth costs at discount factors of 2 and 22 percent (dual rates exist because of the high front-end and high back-end cost structures of the alternatives). Alternative 4 is the least cost alternative at factors less than 2 percent and greater than 22 percent.

In scenario 2, Alternative 1 has the least present-worth cost at discount factor of 10 percent or greater. At a discount rate of 9 percent, Alternatives 1 and 4 have the same present-worth cost. For this scenario, Alternatives 2 and 3 have a higher present-worth cost than Alternative 4 for all discount factors between zero and 30 percent.

In scenario 3, Alternative 1 has the least present-worth cost at discount factors of 22 percent or greater. At discount rates below 21 percent, Alternative 4 has the least present-worth cost.

5.3.4 Fines

The RCRA subtitle C and D programs have civil and criminal fines and penalties. A firm could be fined for daily exceedances of surface water or groundwater quality standards. The effects of these fines may be substantial when they occur, but they may not sufficiently alter present-worth costs to warrant changing investment strategies. For example, a $100,000 per day fine (a substantial fine) is levied for 100 days against the hypothetical mining company in year 5 (the period when groundwater treatment starts). This $10 million fine is a major cost if it occurs, but only adds $6 million to present-worth cost.

A conservative company could incorporate the probability of this fine (maybe estimated at 80 to 100 percent probability of occurrence) in its investment decision-making process. An additional $4.8 to 6 million present-worth cost (including the probability) for Alternative 1 and no fine for Alternative 4 does not change the base-case analysis: Alternative 1 is still favored. However, it would modify the results in scenarios 1, 2, and 3 by decreasing the break-even discount factor between the four alternatives.

A risk-loving company may assign a low probability to this fine (zero to 20 percent). A $1.2 million additional cost (at 20 percent probability) for Alternative 1 would have a limited, if any, effect on the decisionmaking process.

5.4 SUMMARY

The present-worth costs developed in this chapter are derived from the specific technical and regulatory assumptions stated in previous sections. A change in these assumptions could affect the concepts and the costs presented in this thesis.

The cash-flow analysis indicates that, for the base-case conditions (Table 5-2), the hypothetical mining company has no economic incentive to alter its engineering approach for potential environmental problems. There is no economic incentive to minimize the generation of pollution. If the mine waste regulatory program no longer allows the concepts used on Alternative 1, the company could implement a more protective tailings disposal system (Alternative 2 or 3) at a substantial increase in present-worth cost. There does not appear to be an economic incentive to plug rather than treat adit discharge in perpetuity.

However, the hypothetical mining company could change its engineering and investment approach if environmental costs escalate at a rate higher than the assumed base rate of 8 percent. For the scenario 1 conditions (Table 5-3), Alternatives 1 and 4 have the same present-worth cost at a discount factor of 4 percent. For the scenario 2 conditions

(Table 5-4), Alternatives 1 and 4 have the same present-worth cost at a discount factor of 9 percent. Finally, for the scenario 3 conditions (Table 5-5), Alternatives 1 and 4 have the same present-worth cost at a discount factor of 21 percent.

The results presented in Table 5-3, 5-4, and 5-5 indicate that the engineering approach to the environmental problems assumed in this thesis is a function of two key items: escalation rates for environmental capital and operating costs, and discount factor. At low escalation rates (i.e., scenario 1), the hypothetical mining company has substantial latitude in using the discount factor to represent its approach to risk. For instance, Alternative 4 is only economically favorable over Alternative 1 at low discount factors; low discount factors represent a conservative approach in calculating present-worth cost. At high escalation rates (i.e., scenario 2 or 3), the hypothetical mining company has fewer options to assess risk management because Alternative 4 is favored over Alternative 1 at high discount factors. These high discount factors represent a liberal or risk-loving approach in calculating present-worth cost.

Chapter 6

IMPLICATIONS FOR PROJECT INVESTMENT

The present-worth costs presented in Chapter 5 are based on the stated assumptions and conditions in this thesis. The implications from these results to investment in real-life projects may not be directly transferrable. However, the methodology used and the sensitivity calculations that were done certainly can be applied to real-life projects. An objective of this thesis, and presumably for a real-life project, is to assess engineering approaches and investment strategies that result in the expected least present-worth cost.

To assess the selection of one engineering strategy over another (and subsequently determine the expected least present-worth cost), the risk attitude of the hypothetical mining company will be analyzed with escalation rates, discount rates, and accuracy of the capital and operating cost estimates. Each of these three areas are briefly discussed below.

6.1 IMPLICATIONS OF ESCALATION RATES

The cash-flow analyses presented in Chapter 5 identified the escalation rate for environmental capital and operating costs as one of the two key items for determining the choice between engineering approaches. The profit-maximizing firm would be expected to adopt a change in alternatives, or engineering concepts, that promise incremental present-worth gains in excess of initial investment costs. At low escalation rates (scenario 1), there can be gains to the firm, while at high escalation rates (scenario 3) there may be substantial gains. Thus, a hypothetical company's evaluation of the risks associated with environmental cost escalation is an important implication of the results from the present-worth cost analyses.

The environmental escalation rate will be primarily a function of environmental regulations and how those regulations affect the generation and disposal of hazardous and solid waste in this country. The pieces of federal legislation that could increase the regulatory pressures on U.S. business include the following:

- The Clean Water Act Amendments of 1986, which will eventually require biomonitoring of all point-discharge effluents
- The RCRA Reauthorization bill of 1989
- A RCRA Subtitle D bill, which may legislate mining and landfill wastes
- The Waste Reduction Act of 1989, which will support reduction in the generation of hazardous waste

There are three types of approaches to dealing with the potential economic effect of stricter environmental regulations. A company can be risk averse, risk neutral, or risk loving (Henderson and Quandt 1980).

A risk-averse company may consider avoiding potential liabilities even if their cost assumptions do not economically justify it. Companies can ask for hazardous waste disposal designs that meet existing federal and state regulations plus regulations that might someday be imposed (CH2M HILL 1988). This type of company may select Alternative 4 (waste minimization) over other alternatives, even at nonexistent or low projected escalation rates for environmental capital and operating costs. A risk-loving company would accept higher near-term cash flows and bet that the potential downstream environmental liabilities are not a severe as predicted, or that future environmental regulations will not prohibit its activities. A risk-loving company would select Alternative 1 over other alternatives, regardless of the projected escalation rates (assuming that the environmental regulations would still allow the technical approaches assumed for the leaky liner).

However, stricter environmental regulations may prohibit the implementation of Alternative 1; this could occur if the federal government or state governments adopted the types of mining waste regulation being considered in

California (see Chapter 3). In this situation, the risk-averse and risk-loving company have a restricted choice of alternatives (or engineering concepts). A low increase in escalation rate (scenario 1) would make Alternative 4 economically equal to Alternatives 2 and 3. A risk-averse company would still select Alternative 4 over other alternatives; the risk-loving company could select any of the three alternatives.

6.2 IMPLICATIONS OF DISCOUNT FACTOR

The effects of discount rate in determining the choice between pollution generation and waste minimization is the other key item in determining the choice between engineering approaches. At the base-case escalation rates (Table 5-2), variations in the discount rate would not change the selection of Alternative 1 over other alternatives. However, the sensitivity scenarios show that the discount rate is a key factor.

A typical method of incorporating risk into a cash-flow analysis is to vary the discount rate (Brealey and Myers 1984). Traditionally, a risk-averse firm may increase the discount rate to emphasize up-front costs and de-emphasize future revenues. However, for the remedial alternatives that are evaluated in this thesis, a risk-averse firm would be expected to decrease the discount rate. A smaller discount rate would emphasize the future potential environmental liabilities.

The relationship between escalation rates and discount factors for choosing an engineering approach is presented in Figure 6-1. Although this relationship is based on the assumptions used in this thesis, this type of relationship could be developed for a real-life project. The trade-off between escalation rate and discount factor clearly indicates the risk management choice of the hypothetical company. If the company believes that there will be high escalation in environmental costs, it can then select its engineering approach based on a given discount factor or range of discount factors that incorporate the firm's risk management philosophy (that is, a low discount factor represents a risk-averse philosophy).

6.3 IMPLICATIONS OF COST ESTIMATE ACCURACY

The accuracy of the overall capital and operating costs only becomes an issue in determining the choice between pollution generation and waste minimization with the escalation rate and discount factor. For a given escalation rate and discount factor, a 20 percent increase or decrease in capital or operating costs may not alter the selection of a firm's engineering concept.

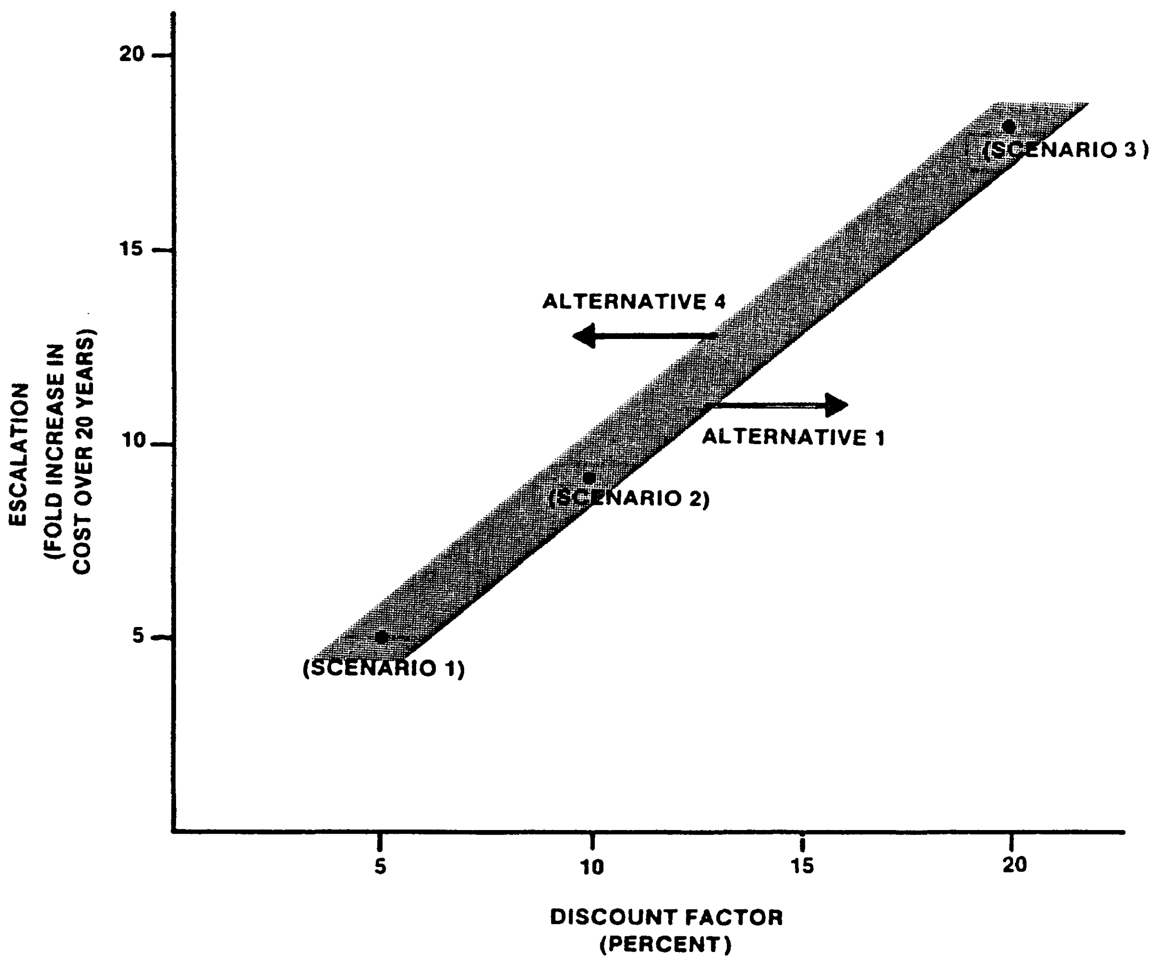

Figure 6-1, Relationship Between Escalation and Discount Factor

6.4 SUMMARY

Thus, the implications of escalation rates to project investment come full circle back to the theoretical basis of this study. The cost function (eq. [2.3]) has two components: mining, milling, and general plant; and environmental compliance. For a company to minimize total cost, one or both of the cost centers must be lowered. The results presented in Chapter 5 suggest that the cost of environmental compliance depends on the projected escalation rate for environmental costs and a chosen discount factor. This study assumes that government regulations are the primary factor that drive the escalation rate and a company's risk management philosophy results in a chosen discount factor.

A risk-averse firm could predict higher escalation rates for environmental costs and lower discount rates than a risk-loving firm. Subsequently, the risk-averse firm would select the waste-minimization alternative (Alternative 4) over other alternatives and the risk-loving firm would select the pollution-generation alternative (Alternative 1) over other alternatives. If environmental regulations prohibit the implementation of Alternative 1, the risk-loving firm could select any of the remaining alternatives.

REFERENCES CITED

Antony, J. 1988. Vice President-Engineering, Coca Mines; Denver. Personal communication.

Baumol, W.J., and W.E. Oates. 1979. Economics, Environmental Policy, and the Quality of Life. Englewood Cliffs, New Jersey: Prentice-Hall.

Baumol, W.J., and W.E. Oates. 1975. The Theory of Environmental Policy. Englewood Cliffs, New Jersey: Prentice-Hall.

Brealey, R., and S. Myers. 1984. Principles of Corporate Finance. New York, McGraw-Hill. Pp. 85-185.

Changing Times. 1988. "Portfolio Monitor." October, Pp. 10-12.

CH2M HILL. 1987. Cost Estimating Guide. Unpublished internal report. Pp. 7-14.

Cobb, W.E., W.V. Bluck, and I.P.G. Hutchison, 1988. "Implications of SARA on Hazardous Waste Liabilities at mining sites." Society of Mining Engineers Preprint Number 88-115.

Dales, J.H. 1968. Pollution, Property, and Prices. University of Toronto Press, Toronto.

Environmental Protection Agency (EPA). 1986. Solving the Hazardous Waste Problem--EPA's RCRA Program. EPA/530-SW-86-037. Office of Solid Waste. Washington D.C. 34 pp.

________. 1987a. Yak Tunnel Operable Unit Feasibility Study--California Gulch Site. Pp. 3-26 to 3-31.

________. 1987b. Yak Tunnel Operable Unit Feasibility Study--California Gulch Site. Technical appendices.

Fisher, A.C. 1981. Resource and Environmental Economics. Cambridge, England: Cambridge University Press. Pp. 164-232.

Gallagher, T.C. 1982. "Developing a Construction Cost Escalation Index for the U.S. Mining and Metals industry." Cost Engineering. 24(3)147-151.

Hazardous Waste News. 1988. "Source Reduction, Recycling Preferred over Treatment of Hazardous Waste." July 25, p. 292.

Hazardous Waste News. 1986. "EPA Backs Non-Regulatory Approach to Spurring Waste Minimization." November 3, p. 424.

Henderson, J.M., and R.E. Quandt. 1980. Microeconomic Theory: A Mathematical Approach, 3rd Edition. New York: McGraw-Hill. Pp. 64-104.

Hutchison, I.P.G. 1988. Corporate Director-Steffen, Robertson & Kirsten; Denver. Personal communication.

Kneese, A.V., and C.L. Schultze. 1975. Pollution, Prices, and Public Policy. Brookings, Washington, D.C.

Linder, S.H., and M.E. McBride. 1984. "Enforcement Costs and Regulatory Reform: The Agency and Firm Response." Journal of Environmental Economics and Management. 11(2):327-346.

Marin, A. 1978. "The Choice of Efficient Pollution Politics: Technologies and Economics in the Control of Sulphur Dioxide." Journal of Environmental Economics and Management. 5(1)44-62.

Mills, E.S. 1968. "Economic Incentives in Air Pollution Control." Economics of Air Pollution (H. Wolozin, Ed.) New York: Norton and Co.

Mills, E.S. 1978. The Economics of Environmental Quality. New York: W.W. Norton & Company.

Mills, E.S., and L.J. White. 1978. "Government Policies Toward Automotive Emissions Control." In Approaches to Controlling Air Pollution (A.F. Freidlander, Ed.). Cambridge, Mass.: MIT Press.

Mishan, E.J. 1974. "What Is the Optimal Level of Pollution?" Journal of Political Economy. 82(6)1287-1299.

O'Hara, T.A. 1980. "Quick Guide to the Evaluation of Ore Bodies." CIM Bulletin. February, pp. 30-42.

Peters, M.S., and K.D. Timmerhaus. 1980. Plant Design & Economics for Chemical Engineers, 3rd Edition. New York: McGraw-Hill. Pp. 166-168; pp. 174-176.

Porter, R.C. 1974. "The Long-Run Asymmetry of Subsidies and Taxes as Anti-Pollution Policies." Water Resources Research. 10(3)415-17.

Portnoy, P.R. 1978. "Toxic Substance Policy and the Protection of Human Health." In Current Issues in U.S. Environmental Policy (P.R. Portnoy, Ed.) Baltimore: Johns Hopkins Press.

Spence, A.M., and M.L. Weitzman. 1978. "Regulatory Strategies for Pollution Control." In Approaches to Controlling Air Pollution (A.F. Friedlander, Ed.). Cambridge, Mass.: MIT Press.

Steffen, Robertson, & Kirsten. 1987. California Gulch Operable Unit Feasibility Study--Yak Tunnel Plug Design. Unpublished report prepared for CH2M HILL. Pp. 1-7.

Stermole, F.J., and J.M. Stermole. 1987. _Economic Evaluation and Investment Decision Methods_. Investment Evaluation Corp., Golden, Colorado.

Stewart, R.D. 1982. _Cost Estimating_. New York: John Wiley & Sons. Pp. 47-56.

Tietenberg, T.H. 1974. "Derived Decision Rules for Pollution Control in a General Equilibrium Space Economy." _Journal of Environmental Economics and Management_. 1(1)3-16.

Wall Street Journal. 1988. "Can $100 Billion Have No Effect on Balance Sheet." May 12, Western Edition, p. 1.

Webb, O. 1987. Former Director of Environmental Affairs-Colorado Association of Commerce and Industry. Personal Communication.

GENERAL BIBLIOGRAPHY

Anderson, C.L. 1987. "The Production Process: Inputs and Wastes." Journal of Environmental Economics and Management. 14(1)1-12.

Davies, III, J.C., and B.S. Davis. 1975. The Politics of Pollution, 2nd Edition. Indianapolis, Indiana: Pegasus, a division of Bobbs-Merill Co. Pp. 175-218.

Downing, P.B., and L.J. White. 1986. Innovation in Pollution Control. Journal of Environmental Economics and Management. 13(1)18-29.

Ketkar, K.M. 1983. Pollution Control and Inputs to Production. Journal of Environmental Economics and Management. 10(1)50-59.

McGartland, A.M., and W.E. Oates. 1985. Marketable Permits for the Prevention of Environmental Degradation. Journal of Environmental Economics and Management. 12(2)207-228.

Mining Engineering. 1988. "EPA Cleanup Order to Cost Mining Companies $17 Million." September, p. 855.

<u>Wall Street Journal</u>. 1988. "Reagan Team Fought Pollution in the Courts." October 5, Western Edition, p. 30.

Appendix A

CAPITAL COST ESTIMATES

This appendix contains the detailed capital cost estimates for the alternatives considered in this thesis. The order-of-magnitude cost estimates presented in this appendix were prepared from the assumed information. Costs are estimated in Second Quarter 1988 dollars. Final costs of the considered alternatives will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final engineering schedule, and other variable factors. Many of these factors are not expected to affect the relative cost differences between alternatives, and therefore, relative cost comparisons between alternatives should remain the same.

Table A-1 presents the inputs required for the O'Hara capital and operating cost estimating system. Table A-2 presents the capital depreciation convention used for the various remedial components. Detailed capital cost estimates for the various remedial components are presented in Table A-3 through A-14. The capital costs for each component are also presented in terms of their depreciable life on each table. Table A-15 through A-18 present summaries of the capital investments, broken down by depreciation category, for each remedial alternative.

There is a cost reference column that provides the basis of the unit cost for Tables A-3 through A-14. The cost references are presented in Table A-19.

Table A-1, Inputs to O'Hara Cost Estimation System

General

Daily Mine Tonnage = 6,880 tpd. 250 dpy
Daily Mill Tonnage = 4,914 tpd, 350 dpy

Depth = 2,500 feet
Slope width = 25 feet

Miles of power line = 5 miles
Miles of water line = 1 mile
Miles of access road = 7 miles
Steep slopes, F_g = 2.5
Solid rock, F_c = 1.0
Cold climate, F_{cl} = 1.8
Medium ore, F_g = 1.5
Selective flotation, F_p = 2.0
Complex Pb-Zn ore, F_t = 2.0
Utility power available

Table A-2, Expenses, Mineral Development, and Depreciation Categories

Expenses

- Revegetation Labor
- Rehabilitation Labor
- Installation Labor
- Engineering Design
- Permitting/Legal
- Services During Construction
- Startup

Mineral Development

- Shafts
- Mine Development

Depreciation--7 Years

- Wells
- Pumps
- Pipes
- Grout
- Diversions
- Control Equipment
- Stacker
- Roads
- General Plant
- Mill Equipment
- Clearing

Depreciation--15 Years

- Water Treatment Plant
- Fences

Depreciation--20 Years

- Power Distribution
- Power Substation
- Water Supply

Depreciation--31 Years

- Buildings
- Tailings Impoundment
- Plugs
- Sludge Disposal
- Housing
- Foundations
- Concentrate Storage

Table A-3, Detailed Mining Capital Cost Estimate
Blasthole or Cut and Fill

	Cost 1978 Dollars (Canadian)	Cost 1978 Dollars (U.S.)	Cost 1988 Dollars (U.S.)	Cost Reference
Concrete Shaft	$ 4,925	$ 4,319	$ 6,522	1
Mine Development	20,955	18,378	27,750	1
Hoist and Headframe				
Hoist Equipment	2,763	2,423	3,659	1
Hoist Installation	404	354	535	1
Hoistroom	1,236	1,084	1,637	1
Headframe	2,654	2,328	3,515	1
Compressor Plant				
Compressor	661	580	875	1
Compressor Installation	123	108	163	1
Underground Equipment	6,021	5,280	7,973	1
Underground Maintenance	1,161	1,081	1,537	1
Subtotal	$40,903	$35,872	$54,167	
Scope Contingency at 15%	6,135	5,281	8,125	
Bid Contingency at 10%	4,090	3,587	5,417	
Subtotal	$51,129	$44,840	$67,708	
Engineering Design at 8%	4,090	3,587	5,417	
Permitting/Legal at 3%	1,534	1,345	2,031	
Service During Construction at 7%	3,579	3,139	4,740	
Startup at 2%	1,023	897	1,354	
TOTAL	$61,355	$53,808	$81,250	

Notes: All values are in thousands of dollars ($000).
Depreciation 7-year = $24,868
Development = $42,840
Expense = $13,542

Table A-4, Detailed Mill Capital Cost Estimate

	Cost 1978 Dollars (Canadian)	Cost 1978 Dollars (U.S.)	Cost 1988 Dollars (U.S.)	Cost Reference
Clearing	$1,281	$1,123	$1,696	1
Foundation	1,402	1,230	1,857	1
Crushing	3,154	2,766	4,177	1
Concrete Building	3,785	3,319	5,012	1
Grind/Ore Storage	4,605	4,039	6,098	1
Processing	1,919	1,683	2,541	1
Thickening	701	615	928	1
Concrete Storage	674	591	893	1
Subtotal	$17,521	$15,366	$23,203	
Scope Contingency at 15%	2,628	2,305	3,280	
Bid Contingency at 10%	1,752	1,537	2,320	
Subtotal	$21,901	$19,207	$29,003	
Engineering Design at 8%	1,752	1,537	2,320	
Permitting/Legal at 3%	657	576	870	
Service During Construction at 7%	1,533	1,345	2,030	
Startup at 2%	438	384	580	
TOTAL	$26,282	$23,049	$34,804	

Notes: All values are in thousands of dollars ($000).
Depreciation 31-year = $9,702
Depreciation 7-year = $19,301
Expense = $5,800

Table A-5, Detailed General/Administrative Capital Cost Estimate, Alternatives 1, 2, and 3

Item	Cost 1978 Dollars (Canadian)	Cost 1978 Dollars (U.S.)	Cost 1988 Dollars (U.S.)	Cost Reference
Power				
Line Cost	$1,549	$1,358	$2,051	1
Distribution Cost	1,000	877	1,324	1
Water Supply				
Pipe	40	35	53	1
Water Reclaim	153	134	203	1
Water Distribution	55	48	73	1
General Plant	1,080	947	1,430	1
Access Roads	2,100	1,842	2,781	1
Housing	1,840	1,614	2,437	1
Subtotal	$7,817	$6,856	$10,352	
Scope Contingency at 15%	1,173	1,028	1,553	
Bid Contingency at 10%	782	686	1,035	
Subtotal	$9,772	$8,570	$12,940	
Engineering Design at 8%	782	686	1,035	
Permitting/Legal at 3%	293	257	388	
Service During Construction at 7%	684	600	906	
Startup at 2%	195	171	259	
TOTAL	$11,726	$10,284	$15,528	

Notes: All values are in thousands of dollars ($000).
Depreciation 31-year = $3,046
Depreciation 20-year = $4,630
Depreciation 7-year = $5,263
Expense = $2,588

Table A-6, Detailed General/Administrative Capital Cost Estimate, Alternative 4--Cut-and-Fill Mining Method

Item	Cost 1978 Dollars (Canadian)	Cost 1978 Dollars (U.S.)	Cost 1988 Dollars (U.S.)	Cost Reference
Power				
Line Cost	$1,549	$1,358	$2,051	1
Distribution Cost	1,000	877	1,324	1
Water Supply				
Pipe	40	35	53	1
Water Reclaim	153	134	203	1
Water Distribution	55	48	73	1
General Plant	1,276	1,119	1,690	1
Access Roads	2,100	1,842	2,781	1
Housing	2,268	1,989	3,003	1
Subtotal	$8,441	$7,403	$11,179	
Scope Contingency at 15%	1,266	1,110	1,677	
Bid Contingency at 10%	844	740	1,118	
Subtotal	$10,551	$9,253	$13,974	
Engineering Design at 8%	844	740	1,118	
Permitting/Legal at 3%	317	278	419	
Service During Construction at 7%	739	648	978	
Startup at 2%	211	185	279	
TOTAL	$12,662	$11,104	$16,769	

Notes: All values are in thousands of dollars ($000).
Depreciation 31-year = $3,753
Depreciation 20-year = $4,630
Depreciation 7-year = $5,588
Expense = $2,794

Table A-7, Tailings Impoundment Capital Cost Estimate, Soil/Clay Liner--400 Acre Impoundment

Item	Quantity	Unit Cost (2nd Qtr 1988 $)	Total Cost (2nd Qtr 1988 $)	Cost Reference
Embankment	10,000,000 yd^3	$ 1.25	$12,500,000	2
Soil Clay Liner--400 Acres --1/2 foot deep	390,000 yd^3	1.75	683,000	3
Synthetic Liner--40 miles				
Leachate Collection Pipes	60,000 feet	2.30	138,000	4
Monitoring Wells--20	2,000 feet	250.00	500,000	5
Subtotal			$13,821,000	
Scope Contingency at 15%			2,073,150	
Bid Contingency at 10%			1,382,100	
Subtotal			$17,276,250	
Engineering Design at 8%			1,382,100	
Permitting/Legal at 3%			518,288	
Services During Construction at 7%			1,209,339	
Startup at 2%			345,525	
TOTAL			$20,731,501	

Depreciation--31 years = $16,478,750
Depreciation--7 years = $797,500
Expenses = $3,455,251

Table A-8, Tailings Impoundment Capital Cost Estimate, Clay Liner + Synthetic Liner--400 Acre Impoundment

Item	Quantity	Unit Cost (2nd Qtr 1988 $)	Total Cost (2nd Qtr 1988 $)	Cost Reference
Embankment	10,000,000 yd^3	$1.25	$12,500,000	2
Clay Liner--400 Acres --2 feet deep	1,351,111 yd^3	2.50	3,377,778	3
Synthetic Liner--40 miles	18,240,000 ft^2	0.45	8,208,000	4
Leachate Collection Pipes	240,000 ft	2.30	552,000	4
Monitoring Wells--20	2,000 ft	250.00	500,000	5
Subtotal			$25,137,777	
Scope Contingency at 15%			3,770,667	
Bid Contingency at 10%			2,513,778	
Subtotal			$31,422,222	
Engineering Design at 8%			2,513,778	
Permitting/Legal at 3%			942,667	
Services During Construction at 7%			2,199,556	
Startup at 2%			628,444	
TOTAL			$37,706,667	

Depreciation--31 years = $30,107,222
Depreciation--7 years = $1,315,000
Expenses = $6,284,445

Table A-9, Tailings Impoundment Capital Cost Estimate, Clay Liner + Synthetic Liner--120 Acre Impoundment

Item	Quantity	Unit Cost (2nd Qtr 1988 $)	Total Cost (2nd Qtr 1988 $)	Cost Reference
Embankment	4,000,000 yd^3	$ 1.25	$5,000,000	2
Clay Liner--120 Acres --2 feet deep	405,333 yd^3	2.50	101,333	3
Synthetic Liner--40 miles	5,472,000 ft^2	0.45	2,462,400	4
Leachate Collection Pipes	72,000 ft	2.30	165,600	4
Monitoring Wells--8	800 ft	250.00	200,000	5
Subtotal			$8,841,333	
Scope Contingency at 15%			1,326,200	
Bid Contingency at 10%			884,133	
Subtotal			$11,051,667	
Engineering Design at 8%			884,133	
Permitting/Legal at 3%			331,550	
Services During Construction at 7%			773,617	
Startup at 2%			221,033	
TOTAL			$13,262,000	

Depreciation--31 years = $10,594,667
Depreciation--7 years = $457,000
Expense = $2,210,333

Table A-10, Capital Cost Estimate for Adit Treatment Plant

Item	Cost at 1,350 gpm (2nd Qtr 1987 $)	Cost at 2,000 gpm (2nd Qtr 1987 $)	Cost at 2,000 gpm (2nd Qtr 1988 $)	Cost Reference
Inlet/Outlet Pipe	$ 197,480	$ 250,000	$ 261,500	6
Headworks	118,000	149,383	156,254	6
Building Facilities	1,796,000	2,273,652	2,378,240	6
Hydraulic Controls	19,748	25,000	26,150	6
Fence	94,790	120,000	125,520	6
Lime System	383,000	484,860	507,164	6
Filtration System	226,000	286,105	299,266	6
Dewatering System	352,000	445,616	466,114	6
IX Tanks	670,000	848,189	887,205	6
Regeneration Unit	470,000	594,998	622,368	6
Installation at 43%	1,860,618	2,355,455	2,463,806	6
Subtotal	$6,987,635	$7,833,258	$7,780,418	
Scope Contingency at 15%	928,145	1,174,989	1,167,063	
Bid Contingency at 10%	618,764	783,326	788,042	
Subtotal	$7,734,544	$9,791,573	$9,725,523	
Engineering Design at 8%	618,764	783,326	778,042	
Permitting/Legal at 3%	232,036	293,747	291,766	
Service During Construction at 7%	541,418	685,410	680,787	
Startup at 2%	154,691	195,831	194,510	
TOTAL	$9,281,453	$11,749,888	$11,670,627	

Notes: Used scaling factor of 0.6.
All costs are lump-sum costs.

Depreciation--31 years = $2,972,800
Depreciation--15 years = $554,881
Depreciation--20 years = $3,340,162
Expense = $4,802,784

Table A-11, Tailings Impoundment Reclamation Cost Estimate
RCRA Cap--400 Acre Impoundment

Item	Quantity	Unit Cost (2 Qtr 1988 $)	Total Cost (2 Qtr 1988 $)	Cost Reference
Fill Material--1 foot	675,556 yd^3	$ 0.75	$ 506,667	3
Synthetic Liner--40 miles	18,240,000 ft^2	0.45	8,208,000	4
Sand Blanket--1 foot	675,556 yd^3	0.25	168,889	3
Leachate Collection Pipes	240,000 ft^2	2.30	552,000	4
Clay Liner--1 foot	675,556 yd^3	2.50	1,688,889	3
Revegetation	400 ac	1,000.00	400,000	2
Subtotal			$11,524,444	
Scope Contingency at 15%			1,728,667	
Bid Contingency at 10%			1,152,444	
Subtotal			$14,405,556	
Engineering Design at 8%			1,152,444	
Permitting/Legal at 3%			432,167	
Services During Construction at 7%			1,008,389	
Startup at 2%			288,111	
TOTAL			$17,286,667	

Depreciation--31 years = $13,155,556
Depreciation--7 years = $690,000
Expenses = $3,381,111

Table A-12, Tailings Impoundment Reclamation Cost Estimate
RCRA Cap--120 Acre Impoundment

Item	Quantity	Unit Cost (2 Qtr 1988 $)	Total Cost (2 Qtr 1988 $)	Cost Reference
Fill Material--1 foot	202,667 yd^3	$ 0.75	$ 152,000	3
Synthetic Liner--40 miles	5,472,000 ft^2	0.45	2,462,400	4
Sand Blanket--1 foot	202,667 yd^3	0.25	50,667	3
Leachate Collection Pipes	72,000 ft^2	2.30	165,600	4
Clay Liner--1 foot	202,667 yd^3	2.50	506,667	3
Revegetation	120 ac	1,000.00	120,000	2
Subtotal			$3,457,333	
Scope Contingency at 15%			518,600	
Bid Contingency at 10%			345,733	
Subtotal			$4,321,667	
Engineering Design at 8%			345,733	
Permitting/Legal at 3%			129,650	
Services During Construction at 7%			302,517	
Startup at 2%			86,433	
TOTAL			$5,186,000	

Depreciation--31 years = $3,964,667
Depreciation--7 years = $207,000
Expense = $1,014,333

Table A-13, Capital Cost Estimate for Groundwater Treatment Plant

Item	Cost at 1,350 gpm (2 Qtr 1987 $)	Cost at 2,000 gpm (2 Qtr 1987 $)	Cost at 2,000 gpm (2 Qtr 1988 $)	Cost at 1,000 gpm (2 Qtr 1988 $)	Cost Reference
Pumps, Pipe	$ 100,000	$ 126,595	$ 132,419	$ 87,364	6
Headworks	118,000	149,383	156,254	103,089	6
Building Facilities	1,796,000	2,273,652	2,378,240	1,569,054	6
Lime System	383,000	484,860	507,164	334,603	6
Filtration System	226,000	286,105	299,266	197,442	6
Dewatering System	352,000	445,616	466,114	306,521	6
IX Tanks	670,000	848,189	887,205	585,337	6
Regeneration Unit	470,000	594,998	622,368	410,610	6
Installation at 43%	1,769,450	2,240,041	2,343,083	1,545,858	6
Subtotal	$5,884,450	$7,449,440	$7,792,114	$5,140,878	
Scope Contingency at 15%	882,668	1,117,416	1,168,817	771,132	
Bid Contingency at 10%	588,445	744,944	779,211	514,088	
Subtotal	$7,355,563	$9,311,800	$9,740,143	$6,426,098	
Engineering Design at 8%	588,445	844,944	779,211	514,088	
Permitting/Legal at 3%	220,667	279,354	292,204	192,783	
Services During Construction at 7%	514,889	651,826	681,810	449,827	
Startup at 2%	147,111	186,236	194,803	128,522	
TOTAL	$8,826,675	$11,164,160	$11,688,171	$7,711,317	

Depreciation--31 years = $1,961,318
Depreciation--7 years = $2,294,390
Expense = $3,217,543

Table A-14, Capital Cost for Tunnel Plugging and Contingency Treatment System

Item	Quantity	Unit Cost (2nd Qtr 1987 $)	Cost at 2,000 gpm (2nd Qtr 1987 $)	Cost at 2,000 gpm (2nd Qtr 1988 $)	Cost Reference
Plugs	3	$116,200	$ 348,600	$ 364,636	6
Temporary Adit Rehabilitation	1,000 ft	75	75,000	78,450	6
Grouting	LS	250,000	250,000	261,500	6
Surface Water Diversion	6 ac	25,000	150,000	156,900	6
Drill Hole Sealing	150 holes	1,000	150,000	156,900	6
Interim Collection Pond	3 ac	150,000	450,000	470,700	6
Collection Piping	5,000 ft	1,000	5,000,000	5,230,000	6
Lime Treatment Equipment	LS	85,000	85,000	88,910	6
Fence	2,000 ft	30	60,000	62,760	6
Power Substation	1,000 kva	35	35,000	36,610	6
Power Distribution	500 hp	300	150,000	156,900	6
Monitor Wells	17,500 ft	150	2,625,000	2,745,750	6
Sampling/Extraction Pumps	45	5,000	225,000	239,207	6
Installation at 43%			4,129,548	4,321,166	6
Subtotal			$13,373,315	$14,370,389	
Scope Contingency at 15%			2,059,972	2,155,558	
Bid Contingency at 10%			1,373,315	1,437,039	
Subtotal			$17,166,435	$17,962,986	
Engineering Design at 8%			1,373,315	1,437,039	
Permitting/Legal at 3%			514,993	538,890	
Service During Construction at 7%			1,201,651	1,257,409	
Startup at 2%			343,329	359,260	
TOTAL			$20,599,723	$21,555,584	

Depreciation--31 years = $ 455,795
Depreciation--20 years = $ 241,888
Depreciation--15 years = $ 2,085,463
Depreciation--7 years = $12,603,593
Expense = $6,168,845

Table A-15, Summary of Capital Investment for Alternative 1--Leaky Liner

Component	Year 0 (30%)	Year 1 (40%)	Year 2 (30%)
Mining			
Depreciation--7 years	$ 7,460,400	$ 9,947,200	$ 7,460,400
Development	12,852,000	17,136,000	12,852,000
Expense	4,062,600	5,416,800	4,062,600
Subtotal	$24,375,000	$32,500,000	$24,375,000
Mill			
Depreciation--31 years	2,910,750	3,881,000	2,910,750
Depreciation--7 years	5,790,450	7,720,600	5,790,450
Expense	1,740,000	2,320,000	1,740,000
Subtotal	$10,441,200	$13,921,600	$10,441,200
General Plant			
Depreciation--31 years	913,875	1,218,500	913,975
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--7 years	1,579,125	2,105,500	1,579,125
Expense	776,400	1,035,200	776,400
Subtotal	$4,658,400	$6,211,200	$4,658,400
Tailings			
Depreciation--31 years	4,943,625	6,591,500	4,943,625
Depreciation--7 years	239,250	319,000	239,250
Expense	1,036,575	1,382,100	1,036,575
Subtotal	$6,219,450	$8,292,600	$6,219,450
Portal Treatment			
Depreciation--31 years	891,840	1,189,120	891,840
Depreciation--15 years	1,002,040	1,336,065	1,002,049
Depreciation--7 years	166,464	221,952	166,464
Expense	1,440,835	1,921,114	1,440,835
Subtotal	$3,501,188	$4,668,251	$3,501,188
Total			
Depreciation--31 years	9,660,090	12,880,120	9,660,090
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	15,235,689	20,314,252	15,235,689
Development	12,852,000	17,136,000	12,852,000
Expense	9,056,350	12,075,214	9,056,350
Subtotal	$49,195,238	$65,593,651	$49,195,238

(continued)

Table A-15, (continued)

	Year 7	Year 18	Year 28	Year 38 and up
RCRA Cap				
Depreciation--31 years		$13,215,556		
Depreciation--7 years		690,000		
Expense		3,381,111		
Subtotal		17,286,667		
Groundwater Treatment				
Depreciation--31 years	$ 1,961,318		$ 1,961,318	
Depreciation--7 years	2,294,390		2,294,390	
Expense	3,217,543		3,217,543	
Subtotal	7,711,317		7,711,317	
Perpetual Treatment				
Depreciation--31 years		2,972,800		2,972,800
Depreciation--15 years		3,340,162		3,340,162
Depreciation--7 years		554,881		554,881
Expense		4,802,784		4,802,784
Subtotal		11,670,627		11,670,627
Plug				
NA				
Total				
Depreciation--31 years	1,961,318	16,188,356	1,961,318	2,972,800
Depreciation--15 years		3,340,162		3,340,162
Depreciation--7 years	2,294,390	1,244,881	2,294,390	554,881
Expense	3,217,543	8,183,895	3,217,543	4,802,784
Total	7,711,317	28,957,294	7,711,317	11,670,627

Table A-16, Summary of Capital Investment for Alternative 2--Better Liner

Component	Year 0 (30%)	Year 1 (40%)	Year 2 (30%)
Mining			
Depreciation--7 years	$ 7,460,400	$ 9,947,200	$ 7,460,400
Development	12,852,000	17,136,000	12,852,000
Expense	4,062,600	5,416,800	4,062,600
Subtotal	$24,375,000	$32,500,000	$24,375,000
Mill			
Depreciation--31 years	2,910,750	3,881,000	2,910,750
Depreciation--7 years	5,790,450	7,720,600	5,790,450
Expense	1,740,000	2,320,000	1,740,000
Subtotal	$10,441,200	$13,921,600	$10,441,200
General Plant			
Depreciation--31 years	913,875	1,218,500	913,975
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--7 years	1,579,125	2,105,500	1,579,125
Expense	776,400	1,035,200	776,400
	$4,658,400	$6,211,200	$4,658,400
Tailings			
Depreciation--31 years	9,032,167	12,042,889	9,032,167
Depreciation--7 years	394,500	526,000	394,500
Expense	1,885,334	2,513,778	1,885,334
Subtotal	$11,312,001	$15,082,667	$11,312,001
Portal Treatment			
Depreciation--31 years	891,840	1,189,120	891,840
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	166,464	221,952	166,464
Expense	1,440,835	1,921,114	1,440,835
Subtotal	$3,501,188	$4,668,251	$3,501,188
Total			
Depreciation--31 years	13,748,632	18,331,509	13,748,632
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	15,390,939	20,521,252	15,390,939
Development	12,852,000	17,136,000	12,852,000
Expense	9,905,169	13,206,892	9,905,169
Total	$54,287,789	$72,383,718	$54,287,789

(continued)

Table A-16, (continued)

	Year 18	Year 38 and up
RCRA Cap		
Depreciation--31 years	13,215,556	
Depreciation--7 years	690,000	
Expense	3,381,111	
Subtotal	$17,286,667	
Groundwater Treatment		
NA		
Perpetual Treatment		
Depreciation--31 years	2,972,800	2,972,800
Depreciation--15 years	3,340,162	3,340,162
Depreciation--7 years	554,881	554,881
Expense	4,802,784	4,802,784
Subtotal	$11,670,627	$11,670,627
Plug		
NA		
Total		
Depreciation--31 years	16,188,356	2,972,800
Depreciation--15 years	3,340,162	3,340,162
Depreciation--7 years	1,244,881	554,881
Expense	8,183,895	4,802,784
Total	$28,957,294	$11,670,627

Table A-17, Summary of Capital Investment for Alternative 3--Better Liner; Plug Portal

Component	Year 0 (30%)	Year 1 (40%)	Year 2 (30%)
Mining			
Depreciation--7 years	$ 7,460,400	$ 9,947,200	$ 7,460,400
Development	12,852,000	17,136,000	12,852,000
Expense	4,062,600	5,416,800	4,062,600
Subtotal	$24,375,000	$32,500,000	$24,375,000
Mill			
Depreciation--31 years	2,910,750	3,881,000	2,910,750
Depreciation--7 years	5,790,450	7,720,600	5,790,450
Expense	1,740,000	2,320,000	1,740,000
Subtotal	$10,441,200	$13,921,600	$10,441,200
General Plant			
Depreciation--31 years	913,875	1,218,500	913,975
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--7 years	1,579,125	2,105,500	1,579,125
Expense	776,400	1,035,200	776,400
Subtotal	$4,658,400	$6,211,200	$4,658,400
Tailings			
Depreciation--31 years	9,032,167	12,042,889	9,032,167
Depreciation--7 years	394,500	526,000	394,500
Expense	1,885,334	2,513,778	1,885,334
Subtotal	$11,312,001	$15,082,667	$11,312,001
Portal Treatment			
Depreciation--31 years	891,840	1,189,120	891,840
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	166,464	221,952	166,464
Expense	1,440,835	1,921,114	1,440,835
Subtotal	$3,501,188	$4,668,251	$3,501,188
Total			
Depreciation--31 years	13,748,632	18,331,509	13,748,632
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--15 years	1,022,049	1,336,065	1,002,049
Depreciation--7 years	15,390,939	20,521,252	15,390,939
Development	12,852,000	17,136,000	12,852,000
Expense	9,905,169	13,206,892	9,905,169
Total	$54,287,789	$72,383,718	$54,287,789

(continued)

Table A-17, (continued)

	Year 18
RCRA Cap	
Depreciation--31 years	$13,215,556
Depreciation--7 years	690,000
Expense	3,381,111
Subtotal	$17,286,667
Groundwater Treatment	
NA	
Perpetual Treatment	
NA	
Plug	
Depreciation--31 years	455,795
Depreciation--20 years	241,888
Depreciation--15 years	2,085,463
Depreciation--7 years	12,604,593
Expense	6,168,845
Subtotal	$21,555,584
Total	
Depreciation--31 years	13,671,351
Depreciation--20 years	241,888
Depreciation--15 years	2,085,463
Depreciation--7 years	13,293,593
Expense	9,549,956
Total	$38,842,251

Table A-18, Summary of Capital Investment for Alternative 4--Cut-and-Fill Mining Method

Component	Year 0 (30%)	Year 1 (40%)	Year 2 (30%)
Mining			
Depreciation--7 years	$ 7,460,400	$ 9,947,200	$ 7,460,400
Development	12,852,000	17,136,000	12,852,000
Expense	4,062,600	5,416,800	4,062,600
Subtotal	$24,375,000	$32,500,000	$24,375,000
Mill			
Depreciation--31 years	2,910,750	3,881,000	2,910,750
Depreciation--7 years	5,790,450	7,720,600	5,790,450
Expense	1,740,000	2,320,000	1,740,000
Subtotal	$10,441,200	$13,921,600	$10,441,200
General Plant			
Depreciation--31 years	1,126,125	1,501,500	1,126,125
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--7 years	1,676,625	2,235,500	1,676,625
Expense	838,200	1,117,600	838,200
Subtotal	$5,029,950	$6,706,600	$5,029,950
Tailings			
Depreciation--31 years	3,178,400	4,237,867	3,178,400
Depreciation--7 years	137,100	182,800	137,100
Expense	663,100	884,133	663,100
Subtotal	$3,978,600	$5,304,800	$3,978,600
Portal Treatment			
Depreciation--31 years	891,840	1,189,120	891,840
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	166,464	221,952	166,464
Expense	1,440,835	1,921,114	1,440,835
Subtotal	$3,501,188	$4,668,251	$3,501,188
Total			
Depreciation--31 years	8,107,115	10,809,487	8,107,115
Depreciation--20 years	1,389,000	1,852,000	1,389,000
Depreciation--15 years	1,002,049	1,336,065	1,002,049
Depreciation--7 years	15,231,039	20,308,052	15,231.039
Development	12,852,000	17,136,000	12,852,000
Expense	8,744,735	11,659,647	8,744,735
Total	$47,325,938	$63,101,251	$47,325,938

(continued)

Table A-18, (continued)

	Year 18
RCRA Cap	
Depreciation--31 years	$3,964,667
Depreciation--7 years	207,000
Expense	1,014,333
Subtotal	$5,186,000
Groundwater Treatment	
NA	
Perpetual Treatment	
NA	
Plug	
NA	
Total	
Depreciation--31 years	3,964,667
Depreciation--7 years	207,000
Expense	1,014,333
Total	$5,186,000

Table A-19, Cost References

1. O'Hara, T.A. 1980. "Quick Guides to the evaluation of ore bodies," in CIM Bulletin. February, pp 30-42.

2. Hutchison, I.P.G. 1988. Corporate Director of Steffen, Robertson & Kirsten-Denver. Personal conversation referencing embankment cost for a 25,000,000 ton tailings impoundment in the Western U.S.

3. Van Zyl, D.J. 1988. Principal of Welsh Engineering-Denver. Personal conversation referencing clay liner costs.

4. Western Mine Engineering. 1988. Mining Cost Service. Supply cost section.

5. EPA. 1988. South Valley SJ-6 Feasibility Study, Albuquerque, New Mexico. Appendix J.

6. EPA. 1987. Yak Tunnel Operable Unit Feasibility Study, California Gulch Superfund Site. Leadville, Colorado. Appendix L.

Appendix B

OPERATING COST ESTIMATES

The operating cost estimates for the blasthole mining, milling, and general plant components of Alternatives 1 through 3 are presented in Table B-1. The operating cost estimate of the cut-and-fill mining, milling, and general plant components of Alternative 4 is presented in Table B-2.

Environmental operating costs for the portal flow treatment plant, groundwater extraction treatment plant, and plugging are presented in Tables B-3, B-4, and B-5, respectively.

Summaries of the annual opearting costs for the four alternatives are presented in Tables B-6 through B-9, respectively.

Table B-1, Operating Cost Estimate
Blasthole Mining

Item	Cost Per Ton 1978 Canadian (Dollars)	Cost Per Ton 1978 U.S. (Dollars)	Cost Per Ton 1988 U.S. (Dollars)	Cost Reference[a]
Mining				
Labor	$ 5.30/T	$ 4.65/T	$ 7.67/T	1
Supplies	2.54	2.23	3.54	1
Milling				
Labor	1.33	1.17	1.93	1
Supplies	1.68	1.47	2.34	1
Power	0.53	0.46	0.52	1
General/Administration				
G&A	0.38	0.33	0.50	1
Wages	0.97	0.85	1.40	1
Supplies	0.09	0.08	0.13	1
TOTAL	$12.82/T	$11.24/T	$18.03/T	

[a]Cost Reference on Table A-19.

Notes: Annual operating cost years 3-17: $31,012,000.
Annual operating cost year 18: $16,588,000.
G&A = general/administration.

Table B-2, Operating Cost Estimate
Cut-and-Fill Mining

Item	Cost Per Ton 1978 Canadian (Dollars)	Cost Per Ton 1978 U.S. (Dollars)	Cost Per Ton 1988 U.S. (Dollars)	Cost[a] Reference
Mining				
Labor	$ 8.05/T	$ 7.06/T	$11.65/T	1
Supplies	2.96	2.60	4.12	1
Milling				
Labor	1.33	1.17	1.93	1
Supplies	1.68	1.47	2.34	1
Power	0.53	0.46	0.52	1
General/Administration				
G&A	0.46	0.40	0.61	1
Wages	1.19	1.04	1.72	1
Supplies	0.09	0.08	0.13	1
TOTAL	$16.29/T	$14.29/T	$23.02/T	

[a]Cost reference on Table A-19.

Notes: Annual operating cost years 3-17: $39,594,000.
Annual operating cost year 18: $21,178,000.
G&A = general/administration.

Table B-3, Annual Portal Treatment Plant Operating And Maintenance Cost

Item	Quantity at 1,350 gpm	Quantity at 2,000 gpm	Unit Cost 1988 Dollars	Cost at 2,000 gpm	Cost[a] Reference
Labor					
HDS Plant	10	10	24,000	$ 240,000	6
IX Units	3	3	24,000	72,000	6
Supervisors	2	2	36,000	72,000	6
Overhead at 35%			134,400	6	
Chemicals					
Lime	730,000 lb	924,146	0.1	92,415	4
A. Polymer	950 lb	1,203	0.75	902	4
C. Polymer	3,140 lb	3,975	0.95	3,776	4
Soda Ash	172,000 lb	217,744	0.1	21,774	4
Sulfuric Acid	228,200 lb	288,891	0.07	20,222	4
Miscellaneous at 10%				13,909	4
Power					
Motors	1,278,000 kWh	1,617,889	0.06	97,073	6
Other	1,278,000 kWh	1,617,889	0.06	97,073	6
Maintenance at 2% of Cap				218,052	
Subtotal				$1,083,598	
Administration at 10%				108,360	
Insurance, Taxes and License at 2%				21,672	
Subtotal				$1,213,629	
Contingency at 15%				182,044	
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,295,674	

[a]Cost references on Table A-19.

Notes: Groundwater treatment plant annual operating cost for 1,000 gpm determined using scaling factor of 0.6.

Table B-4, Annual Operating And Maintenance Cost--Groundwater Treatment Plant

Item	Quantity at 1,350 gpm	Quantity at 1,000 gpm	Unit Cost 1988 Dollars	Cost at 1,000 gpm	Cost[a] Reference
Labor					
HDS Plant	10	10	24,000	$ 240,000	6
IX Units	3	3	24,000	72,000	6
Supervisors	2	2	36,000	72,000	6
Overhead at 35%				134,400	6
Chemicals					
Lime	730,000 lb	609,709	0.1	60,971	4
A. Polymer	950 lb	793	0.75	595	4
C. Polymer	3,140 lb	2,623	0.95	2,491	4
Soda Ash	172,000 lb	143,657	0.1	14,366	4
Sulfuric Acid	228,200 lb	190,597	0.07	13,342	4
Miscellaneous at 10%				9,176	4
Power					
Motors	1,278,000 kWh	1,067,408	0.06	64,045	6
Other	1,278,000 kWh	1,067,408	0.06	64,045	6
Subtotal				$747,430	
Administration at 10%				74,743	
Insurance, Taxes and License at 2%				14,949	
Subtotal				$837,122	
Contingency at 15%				125,568	
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$962,690	

[a]Cost references on Table A-19.

Table B-5, Annual Operating And Maintenance Costs For Plugging And Additional Elements

	Quantity	Cost at 2,000 gpm (2nd Qtr 1987 Dollars)	Cost at 2,000 gpm (2nd Qtr 1988 Dollars)	Cost[a] Reference
Labor				
Maintenance	1	20,000	$20,000	6
Techs	3	12,500	37,500	6
Overhead at 35%			20,000	
Other				
Chemical Analysis	250	250	62,500	6
Chemicals	LS	5,000	5,000	6
Power	200,000	0.06	12,000	6
Miscellaneous	LS	16,500	16,500	6
Subtotal			$173,500	
Administration at 10%			17,350	
Insurance, Taxes, and License at 2%			3,470	
Subtotal			$194,320	
Contingency at 15%			29,148	
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS			$223,468	

[a]Cost reference on Table A-19.

Note: LS = lump sum

Table B-6, Summary of Operating Costs
Alternative 1--Leaky Liner

	Yrs 3-6[a]	Yr 7	Yrs 8-16	Yr 17	Yr 18	Yrs 19-30[e]	Yr 27
Blasthole Mining	$31,012	$31,012	$31,012	$16,588			
Portal Trmt.	1,296	1,296	1,296	1,296	$6,099[c]	$1,296	$1,296
Groundwater Trmt.		4,180[b]	963	963	963	963	4,180[d]
RCRA Cap					3,381[d]		
Plugging							
TOTAL	$32,308	$36,488	$33,271	$18,847	$10,443	$2,259	$5,476

[a]Three-year project development starts in year 0, then operations start in year 3.

[b]Includes $3,217 of installation expenses for treatment facility (Table A-15).

[c]Includes $4,803 of installation expenses for treatment facility (Table A-15).

[d]Installation expenses (Table A-15).

[e]Year 30 cost in model is $2,259 plus $22,590 (present-worth of future operating costs at i=10 percent).

Table B-7, Summary of Operating Costs
Alternative 2--Better Liner

	Yrs 3-16	Yr 17	Yr 18	Yr 19-30[c]
Blasthole Mining	$31,012	$16,588		
Portal Trmt.	1,296	1,296	$6,099[a]	$1,296
Groundwater Trmt.				
RCRA Cap			3,381[b]	
Plugging				
TOTAL	$32,308	$17,884	$9,480	$1,296

[a]Includes $4,803 of installation expenses for treatment facility (Table A-16).

[b]Installation expenses (Table A-16).

[c]Year 30 cost in model is $1,296 plus $12,960 (present worth of future operating costs at i=10 percent).

Table B-8, Summary of Operating Costs
Alternative 3--Better Liner, Plug

	Yrs 3-16	Yr 17	Yr 18	Yrs 19-30[c]
Blasthole Mining	$31,012	$16,588		
Portal Trmt.	1,296	1,296		
Groundwater Trmt.				
RCRA Cap			$3,381[a]	
Plugging			6,392[b]	$223
TOTAL	$32,308	$17,884	$9,773	$223

[a]Installation expenses (Table A-17).

[b]Includes $6,169 of installation expenses (Table A-17).

[c]Year 30 cost in model is $223 plus $2,230 (present-worth of future operating costs at i=10 percent).

Table B-9, Summary of Operating Costs
Alternative 4--Cut-and-Fill Method

	Yrs 3-16	Yr 17	Yr 18
Blasthole Mining	$39,594	$21,178	
Portal Trmt.	1,296	1,296	
Groundwater Trmt.			
RCRA Cap			$1,014[a]
Plugging			
TOTAL	$40,890	$22,474	$9,773

[a]Installation expenses (Table A-18).

Appendix C

Cash-Flow Inputs

Appendix C is divided into two parts. The first past presents the data inputs used for the various scenarios presented in Chapter 5 of the thesis. This information allows a reviewer to duplicate the results presented in this thesis or change input variables to arrive at new results. The second part consists of a sample cash-flows calculation and sample sensitivity calculations.

Tables C-1 through C-4 are the base case scenario inputs for alternatives 1 through 4. Table C-5 through C-8 are the scenario 1 inputs (50 percent increase in back-end environmental capital and doubling of the environmental operating costs) for the four alternatives. Table C-9 through C-12 are the inputs for scenario 2 (two times back-end environmental capital and four times environmental operating costs). Table C-13 through C-16 are the inputs for scenario 3 (four times back-end environmental capital and eight times environmental operating costs). The initial capital costs listed in these tables (years 0 [1989], 1 [1990], and 2 [1991]) are taken from the costs presented in Appendix A. Expenses incurred in these 3 years are taken as development costs.

The back-end capital costs are treated differently in that incurred expenses are incorporated into operating costs. However, for the three scenarios, the expenses are multiplied by the capital cost escalation rate and then added into the approximately estimated operating costs.

Table C-17 is the base case cash flow for alternative 1. Table C-18 is the capital cost and operating cost sensitivity calculations, based on the cash flow presented in Table C-17. Table C-19 is the sensitivity of present-worth cost to discount factor, based on the Table C-17 cash flow.

Table C-1, Alternative 1--Leaky Liner; Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	9,660.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,236.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	13,910.40	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,939.12	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	11,267.42	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,771.27	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	64,687.61	ACRS	31.5	0	../..	0	BASE
01/07	13,346.71	ACRS	15.0	0	../..	0	BASE
01/07	4,975.05	ACRS	7.0	0	../..	0	BASE
01/92	10,203.67	WC	0.0	0	../..	0	
01/89	9,069.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	13,058.28	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	10,578.08	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	63,394.81	ACRS	15.0	0	../..	0	PW OF YR38,68 TRMT PLT
01/97	3,629.68	ACRS	31.5	0	../..	0	BASE
01/97	4,246.04	ACRS	7.0	0	../..	0	BASE
01/17	16,917.77	ACRS	31.5	0	../..	0	BASE
01/17	19,790.60	ACRS	7.0	0	../..	0	BASE

Table C-1, Alternative 1--Leaky Liner;
Data Input, Operating Cost

Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	32,308.00	Escalate	5.00
01/96	36,488.00	Escalate	5.00
01/97	33,271.00	Escalate	5.00
01/06	18,847.00	Escalate	5.00
01/07	10,443.00	Escalate	5.00
01/08	2,259.00	Escalate	5.00
01/16	5,476.00	Escalate	5.00
01/17	2,259.00	Escalate	5.00
01/19	24,849.00	Escalate	5.00

Table C-2, Alternative 2--Better Liner;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	64,687.61	ACRS	31.5	0	../..	0	BASE
01/07	13,346.71	ACRS	15.0	0	../..	0	BASE
01/07	4,975.05	ACRS	7.0	0	../..	0	BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	63,394.81	ACRS	15.0	0	../..	0	PW OF YR 38.58 TRMT PLT

Table C-2, Alternative 2--Better Liner;
Data Input, Operating Cost

Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	32,308.00	Escalate	5.00
01/06	17,884.00	Escalate	5.00
01/07	9,480.00	Escalate	5.00
01/08	1,296.00	Escalate	5.00
01/19	14,256.00	Escalate	5.00

Table C-3, Alternative 3--Better Liner, Plug;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	54,629.62	ACRS	31.5	0	../..	0	BASE
01/07	8,331.71	ACRS	15.0	0	../..	0	BASE
01/07	53,123.12	ACRS	7.0	0	../..	0	BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/07	967.04	ACRS	20.0	0	../..	0	BASE
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS

Table C-3, Alternative 3--Better Liner, Plug;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	32,308.00	Escalate	5.00
01/06	17,884.00	Escalate	5.00
01/07	9,773.00	Escalate	5.00
01/08	223.00	Escalate	5.00
01/19	2,453.00	Escalate	5.00

Table C-4, Alternative 4--Base;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	8,107.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,231.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	11,673.72	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,932.64	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	9,456.01	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,765.44	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	15,844.23	ACRS	31.5	0	../..	0	BASE
01/07	827.18	ACRS	7.0	0	../..	0	BASE
01/92	12,849.06	WC	0.0	0	../..	0	
01/89	8,745.00	DEVLP	5.0	0	../..	0	CONTINGENCY COST
01/90	12,592.80	ACRS	5.0	0	../..	0	CONTINGENCY COST
01/91	10,200.17	ACRS	5.0	0	../..	0	CONTINGENCY COST

Table C-4, Alternative 4--Base; Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	40,908.00	Escalate	5.00
01/06	22,474.00	Escalate	5.00
01/07	1,014.00	Escalate	5.00
01/08	0.00	Constant	0.00

Table C-5, Alternative 1--Scenario 1; Data Input, Capital Cost

Purch Date	Cost	Type	Life	Dpt/ Lag	Date Sold	Amount Received	Cost Description
01/89	9,660.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,236.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	13,910.40	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,939.12	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	11,267.42	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,771.27	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	97,031.41	ACRS	31.5	0	../..	0	1.5X BASE
01/07	20,020.07	ACRS	15.0	0	../..	0	1.5X BASE
01/07	7,464.57	ACRS	7.0	0	../..	0	1.5X BASE
01/92	10,203.67	WC	0.0	0	../..	0	
01/89	9,069.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	13,058.28	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	10,578.08	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	95,092.22	ACRS	15.0	0	../..	0	1.5X BASE, PW TRMT PLT
01/97	5,445.44	ACRS	31.5	0	../..	0	1.5X BASE
01/97	6,369.05	ACRS	7.0	0	../..	0	1.5X BASE
01/17	25,380.97	ACRS	31.5	0	../..	0	1.5X BASE
01/17	29,685.90	ACRS	7.0	0	../..	0	1.5X BASE

Table C-5, Alternative 1--Scenario 1;
Data Input, Operating Cost

Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	33,604.00	Escalate	5.00
01/96	40,356.00	Escalate	5.00
01/97	35,530.00	Escalate	5.00
01/06	21,106.00	Escalate	5.00
01/07	16,794.00	Escalate	5.00
01/08	4,518.00	Escalate	5.00
01/16	9,344.00	Escalate	5.00
01/17	4,518.00	Escalate	5.00
01/19	49,698.00	Escalate	5.00

Table C-6, Alternative 2--Scenario 1;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Dpt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	97,031.41	ACRS	31.5	0	../..	0	1.5X BASE
01/07	20,020.07	ACRS	15.0	0	../..	0	1.5X BASE
01/07	7,464.57	ACRS	7.0	0	../..	0	1.5X BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	95,092.22	ACRS	15.0	0	../..	0	1.5X BASE, PW TRMT PLT

Table C-6, Alternative 2--Scenario 1;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	33,604.00	Escalate	5.00
01/06	19,180.00	Escalate	5.00
01/07	14,868.00	Escalate	5.00
01/08	2,592.00	Escalate	5.00
01/19	28,512.00	Escalate	5.00

Table C-7, Alternative 3--Scenario 1;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	81,946.43	ACRS	31.5	0	../..	0	1.5X BASE
01/07	12,499.56	ACRS	15.0	0	../..	0	1.5X BASE
01/07	79,684.68	ACRS	7.0	0	../..	0	1.5X BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/07	1,450.56	ACRS	20.0	0	../..	0	1.5X BASE
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS

Table C-7, Alternative 3--Scenario 1;
Data Input, Operating Cost

Operating Cost

Date	Amount	Command	Incr/Esc
01/92	33,604.00	Escalate	5.00
01/06	19,180.00	Escalate	5.00
01/07	14,771.00	Escalate	5.00
01/08	446.00	Escalate	5.00
01/19	4,906.00	Escalate	5.00

Table C-8, Alternative 4--Scenario 1;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	8,107.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,231.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	11,673.72	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,932.64	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	9,456.01	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,765.44	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	23,768.34	ACRS	31.5	0	../..	0	1.5X BASE
01/07	1,242.76	ACRS	7.0	0	../..	0	1.5X BASE
01/92	12,849.06	WC	0.0	0	../..	0	
01/89	8,745.00	DEVLP	5.0	0	../..	0	CONTINGENCY COST
01/90	12,592.80	ACRS	5.0	0	../..	0	CONTINGENCY COST
01/91	10,200.17	ACRS	5.0	0	../..	0	CONTINGENCY COST

Table C-8, Alternative 4, Scenario 1;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	42,186.00	Escalate	5.00
01/06	23,770.00	Escalate	5.00
01/07	1,521.00	Escalate	5.00
01/08	0.00	Constant	0.00

Table C-9, Alternative 2, Scenario 2;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	9,660.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,236.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	13,910.40	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,939.12	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	11,267.42	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,771.27	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	129,375.20	ACRS	31.5	0	../..	0	2X BASE
01/07	26,693.43	ACRS	15.0	0	../..	0	2X BASE
01/07	9,950.10	ACRS	7.0	0	../..	0	2X BASE
01/92	10,203.67	WC	0.0	0	../..	0	
01/89	9,069.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	13,058.28	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	10,578.08	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	126,789.60	ACRS	15.0	0	../..	0	2X BASE, FW TRMT PLT
01/97	7,259.35	ACRS	31.5	0	../..	0	2X BASE
01/97	8,492.07	ACRS	7.0	0	../..	0	2X BASE
01/17	33,835.54	ACRS	31.5	0	../..	0	2X BASE
01/17	39,581.20	ACRS	7.0	0	../..	0	2X BASE

Table C-9, Alternative 1, Scenario 2;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	36,196.00	Escalate	5.00
01/96	46,482.00	Escalate	5.00
01/97	40.048.00	Escalate	5.00
01/06	25,624.00	Escalate	5.00
01/07	25,404.00	Escalate	5.00
01/08	9,036.00	Escalate	5.00
01/16	15,470.00	Escalate	5.00
01/17	9,036.00	Escalate	5.00
01/19	99,396.00	Escalate	5.00

Table C-10, Alternative 2, Scenario 2;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22.162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	129.375.20	ACRS	31.5	0	../..	0	2X BASE
01/07	26,693.43	ACRS	15.0	0	../..	0	2X BASE
01/07	9,950.10	ACRS	7.0	0	../..	0	2X BAASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	126,789.60	ACRS	15.0	0	../..	0	2X BASE, PW TRMT PLT

Table C-10, Alternative 2, Scenario 2;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	36,196.00	Escalate	5.00
01/06	21,772.00	Escalate	5.00
01/07	21,552.00	Escalate	5.00
01/08	5,184.00	Escalate	5.00
01/19	57,024.00	Escalate	5.00

Table C-11, Alternative 3, Scenario 2;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	109,259.20	ACRS	31.5	0	../..	0	2X BASE
01/07	16,663.41	ACRS	15.0	0	../..	0	2X BASE
01/07	106,246.20	ACRS	7.0	0	../..	0	2X BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/07	1,934.07	ACRS	20.0	0	../..	0	2X BASE
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS

Table C-11, Alternative 3, Scenario 2; Data Input, Operating Cost

Operating Cost

Date	Amount	Command	Incr/Esc
01/92	36,196.00	Escalate	5.00
01/06	21,772.00	Escalate	5.00
01/07	19,992.00	Escalate	5.00
01/08	892.00	Escalate	5.00
01/19	9,812.00	Escalate	5.00

Table C-12, Alternative 4, Scenario 2; Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	8,107.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,231.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	11,673.72	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,932.64	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	9,456.01	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,765.44	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	31,688.46	ACRS	31.5	0	../..	0	2X BASE
01/07	1,654.35	ACRS	7.0	0	../..	0	2X BASE
01/92	12,849.06	WC	0.0	0	../..	0	
01/89	8,745.00	DEVLP	5.0	0	../..	0	CONTINGENCY COST
01/90	12,592.80	ACRS	5.0	0	../..	0	CONTINGENCY COST
01/91	10,200.17	ACRS	5.0	0	../..	0	CONTINGENCY COST

Table C-12, Alternative 4, Scenario 2;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	44,778.00	Escalate	5.00
01/06	26,362.00	Escalate	5.00
01/07	2,028.00	Escalate	5.00
01/08	0.00	Constant	0.00

Table C-13, Alternative 1, Scenario 3;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	9,660.00	ACRS	31.5	36	../..	0	BLDGS. TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,236.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	13,910.40	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,939.12	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	11,267.42	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,771.27	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	258,750.40	ACRS	31.5	0	../..	0	4X BASE
01/07	53,386.86	ACRS	15.0	0	../..	0	4X BASE
01/07	19,900.19	ACRS	7.0	0	../..	0	4X BASE
01/92	10,203.67	WC	0.0	0	../..	0	
01/89	9,069.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	13,058.28	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	10,578.08	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	253,579.30	ACRS	15.0	0	../..	0	4X BASE, PW OF TRMT PLT
01/97	14,518.70	ACRS	31.5	0	../..	0	4X BASE
01/97	16,984.14	ACRS	7.0	0	../..	0	4X BASE
01/17	67,671.09	ACRS	31.5	0	../..	0	4X BASE
01/17	79,162.40	ACRS	7.0	0	../..	0	4X BASE

Table C-13, Alternative 1, Scenario 3; Data Input, Operating Cost

Operating Cost

Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	41,380.00	Escalate	5.00
01/96	61,962.00	Escalate	5.00
01/97	49,084.00	Escalate	5.00
01/06	34,660.00	Escalate	5.00
01/07	50,808.00	Escalate	5.00
01/08	18,072.00	Escalate	5.00
01/16	30,940.00	Escalate	5.00
01/17	18,072.00	Escalate	5.00
01/19	198,792.00	Escalate	5.00

Table C-14, Alternative 2, Scenario 3; Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	258,750.40	ACRS	31.5	0	../..	0	4X BASE
01/07	53,386.86	ACRS	15.0	0	../..	0	4X BASE
01/07	19,900.19	ACRS	7.0	0	../..	0	4X BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/19	253,579.30	ACRS	15.0	0	../..	0	4X BASE, PW TRMT PLT

Table C-14, Alternative 2, Scenario 3;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/89	0.00	Constant	0.00
01/90	0.00	Constant	0.00
01/91	0.00	Constant	0.00
01/92	41,380.00	Escalate	5.00
01/06	26,956.00	Escalate	5.00
01/07	43,104.00	Escalate	5.00
01/08	10,368.00	Escalate	5.00
01/19	114,048.00	Escalate	5.00

Table C-15, Alternative 3, Scenario 3;
Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	13,749.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,391.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	19,798.56	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	22,162.69	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	16,036.84	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,952.06	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	218,518.50	ACRS	31.5	0	../..	0	4X BASE
01/07	33,326.82	ACRS	15.0	0	../..	0	4X BASE
01/07	212,492.50	ACRS	7.0	0	../..	0	4X BASE
01/92	10,329.64	WC	0.0	0	../..	0	
01/07	3,868.15	ACRS	20.0	0	../..	0	4X BASE
01/89	9,905.00	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/90	14,263.56	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS
01/91	11,553.19	DEVLP	5.0	0	../..	0	CONTINGENCY COSTS

Table C-15, Alternative 3, Scenario 3; Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	41,380.00	Escalate	5.00
01/06	26,956.00	Escalate	5.00
01/07	39,984.00	Escalate	5.00
01/08	1,784.00	Escalate	5.00
01/19	19,624.00	Escalate	5.00

Table C-16, Alternative 4, Scenario 3; Data Input, Capital Cost

Purch Date	Cost	Type	Life	Opt/ Lag	Date Sold	Amount Received	Cost Description
01/89	8,107.00	ACRS	31.5	36	../..	0	BLDGS, TAILS
01/89	1,389.00	ACRS	20.0	36	../..	0	POWER
01/89	1,002.00	ACRS	15.0	36	../..	0	WATER TRMT
01/89	15,231.00	ACRS	7.0	36	../..	0	MINE, MILL, G&A EQUIP
01/89	12,852.00	DEVLP	5.0	0	../..	0	MISC COSTS
01/90	11,673.72	ACRS	31.5	24	../..	0	
01/90	2,000.16	ACRS	20.0	24	../..	0	
01/90	1,442.88	ACRS	15.0	24	../..	0	
01/90	21,932.64	ACRS	7.0	24	../..	0	
01/90	18,506.88	DEVLP	5.0	0	../..	0	
01/91	9,456.01	ACRS	31.5	12	../..	0	
01/91	1,620.13	ACRS	20.0	12	../..	0	
01/91	1,168.73	ACRS	15.0	12	../..	0	
01/91	17,765.44	ACRS	7.0	12	../..	0	
01/91	14,990.58	DEVLP	5.0	0	../..	0	
01/07	63,376.91	ACRS	31.5	0	../..	0	4X BASE
01/07	3,308.71	ACRS	7.0	0	../..	0	4X BASE
01/92	12,849.06	WC	0.0	0	../..	0	
01/89	8,745.00	DEVLP	5.0	0	../..	0	CONTINGENCY COST
01/90	12,592.80	ACRS	5.0	0	../..	0	CONTINGENCY COST
01/91	10,200.17	ACRS	5.0	0	../..	0	CONTINGENCY COST

Table C-16, Alternative 4, Scenario 3;
Data Input, Operating Cost

Operating Cost Date	Amount	Command	Incr/Esc
01/92	49,962.00	Escalate	5.00
01/06	31,546.00	Escalate	5.00
01/07	4,056.00	Escalate	5.00
01/08	0.00	Constant	0.00

Table C-17, Alternative 1, Example
Cash Flow

Period Ending	12/89	12/90	12/91	12/92	12/93	12/94	12/95	12/96	12/97	12/98	12/99	12/00
Revenue												
-Oper Costs				-32.308	-33.923	-35.620	-37.401	-36.488	-33.271	-34.935	-36.681	-38.515
-Development	-15.345	-22.096	-17.898									
-Depreciation				-9.278	-15.267	-11.361	-8.559	-7.364	-8.034	-8.452	-2.421	-2.209
-Amortization	-1.315	-3.209	-4.743	-4.743	-4.743	-3.428	-1.534					
-Writeoffs												
Before Depltn	-16.660	-25.305	-22.641	-46.329	-53.934	-50.409	-47.494	-43.852	-41.305	-43.387	-39.103	-40.725
-50% Limit												
-Percent Depl												
-Cost Depltn				-3.027								
Taxable	-16.660	-25.305	-22.641	-49.356	-53.934	-50.409	-47.494	-43.852	-41.305	-43.387	-39.103	-40.725
-Tax @ 42%	6.997	10.628	9.509	20.730	22.652	21.172	19.947	18.418	17.348	18.222	16.423	17.104
Net Income	-9.663	-14.677	-13.132	-28.627	-31.282	-29.237	-27.546	-25.434	-23.957	-25.164	-22.680	-23.620
+Depreciation				9.278	15.267	11.361	8.559	7.364	8.034	8.452	2.421	2.209
+Depletion				3.027								
+Amortization	1.315	3.209	4.743	4.743	4.743	3.428	1.534					
+Writeoffs												
-Capitl Costs	-33.863	-48.762	-39.498	-10.204					-7.876			
Cash Flow	-42.211	-60.230	-47.687	-21.782	-11.271	-14.448	-17.453	-18.070	-23.799	-16.712	-20.258	-21.411

Period Ending	12/01	12/02	12/03	12/04	12/05	12/06	12/07	12/08	12/09	12/10	12/11	12/12
Revenue												
-Oper Costs	-40.441	-42.463	-44.586	-46.816	-49.156	-18.847	-10.443	-2.259	-2.372	-2.491	-2.615	-2.746
-Development												
-Depreciation	-2.121	-2.121	-2.121	-1.679	-1.679	-1.679	-4.800	-5.993	-5.518	-5.156	-4.949	-4.625
-Amortization												
-Writeoffs												
Before Depltn	-42.562	-44.584	-46.707	-48.494	-50.835	-20.526	-15.243	-8.252	-7.890	-7.646	-7.565	-7.371
-50% Limit												
-Percent Depl												
-Cost Depltn												
Taxable	-42.562	-44.584	-46.707	-48.494	-50.835	-20.526	-15.243	-8.252	-7.890	-7.646	-7.565	-7.371
-Tax @ 42%	17.876	18.725	19.617	20.368	21.351	8.621	6.402	3.466	3.314	3.211	3.177	3.096
Net Income	-24.686	-25.859	-27.090	-28.127	-29.484	-11.905	-8.841	-4.786	-4.576	-4.435	-4.387	-4.275
+Depreciation	2.121	2.121	2.121	1.679	1.679	1.679	4.800	5.993	5.518	5.156	4.949	4.625
+Depletion												
+Amortization												
+Writeoffs												
-Capitl Costs							-83.009					
Cash Flow	-22.565	-23.738	-24.969	-26.448	-27.806	-10.226	-87.050	1.207	942	721	562	350

(continued)

Table C-17, Alternative 1, Example
Cash Flow (concluded)

Period Ending	12/13	12/14	12/15	12/16	12/17	12/18	12/19	Salv.
Revenue								10.204
-Oper Costs	-2.883	-3.027	-3.179	-5.476	-2.259	-2.372	-24.849	
-Development								
-Depreciation	-4.625	-4.107	-4.107	-4.107	-7.449	-9.490	-11.275	-128.851
-Amortization								
-Writeoffs								-10.204
Before Depltn	-7.508	-7.134	-7.285	-9.583	-9.708	-11.862	-36.124	-128.851
-50% Limit								
-Percent Depl								
-Cost Depltn								
Taxable	-7.508	-7.134	-7.285	-9.583	-9.708	-11.862	-36.124	-128.851
-Tax @ 42%	3.153	2.996	3.060	4.025	4.077	4.982	15.172	54.117
Net Income	-4.355	-4.138	-4.225	-5.558	-5.630	-6.880	-20.952	-74.733
+Depreciation	4.625	4.107	4.107	4.107	7.449	9.490	11.275	128.851
+Depletion								
+Amortization								
+Writeoffs								10.204
-Capitl Costs					-36.708		-63.395	
Cash Flow	270	-31	-119	-1.451	-34.890	2.610	-73.072	64.321

Table C-18, Alternative 1--Sensitivity Analysis; Capital and Operating Costs

Sensitivity Analysis

Percent Revenue	Percent Op. Cost	Percent Cap Costs	NPV at 10.000
100.00	100.00	80.00	-$242,360
100.00	100.00	90.00	-$258,789
100.00	100.00	100.00	-$275,218
100.00	100.00	110.00	-$291,647
100.00	100.00	120.00	-$308,076

Sensitivity Analysis

Percent Revenue	Percent Op. Cost	Percent Cap Costs	NPV at 10.000
100.00	80.00	100.00	-$247,786
100.00	90.00	100.00	-$261,502
100.00	100.00	100.00	-$275,218
100.00	110.00	100.00	-$288,935
100.00	120.00	100.00	-$302,651

Table C-19, Alternative 1--Sensitivity Analysis;
Discount Factor

Case	ROR	NPV
0	0.00%	-$576,914.40
1	1.00%	-$521,971.30
2	2.00%	-$475,549.90
3	3.00%	-$436,073.60
4	4.00%	-$402,294.20
5	5.00%	-$373,217.50
6	6.00%	-$348,046.30
7	7.00%	-$326,136.80
8	8.00%	-$306,967.40
9	9.00%	-$290,111.30
10	10.00%	-$275,218.50
11	11.00%	-$261,999.80
12	12.00%	-$250,215.40
13	13.00%	-$239,665.40
14	14.00%	-$230,181.90
15	15.00%	-$221,624.10
16	16.00%	-$213,872.50
17	17.00%	-$206,826.20
18	18.00%	-$200,398.70
19	19.00%	-$194,516.20
20	20.00%	-$189,115.40
21	21.00%	-$184,141.70
22	22.00%	-$179,547.90
23	23.00%	-$175,293.00
24	24.00%	-$171,341.40
25	25.00%	-$167,662.00
26	26.00%	-$164,227.60
27	27.00%	-$161,014.30
28	28.00%	-$158,000.90
29	29.00%	-$155,169.00
30	30.00%	-$152,502.20