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PRELIMINARY ANALYSIS OF SURFACE MINING OPTIONS
FOR NAVAL OIL SHALE RESERVE 1

July 20, 1981

Work Performed Under Contract No. AC01-78RA32012

TRW
Energy Engineering Division
McLean, Virginia

Technical Information Center
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United States Department of Energy

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NAVAL OIL SHALE RESERVE 1

July 20, 1981

MASTER

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McLean, Virginia 22102

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1. INTRODUCTION

This "Analysis of Surface Mining Options for NOSR 1" report has been prepared by TRW as part of its work under DOE Contract DE-AC01-78RA32012, Management Support and Systems Engineering for the Naval Oil Shale Reserves (NOSR) Predevelopment Project. The surface mining study was conducted as part of an overall assessment of technologies for the development of NOSRs 1 and 3.

The study was undertaken to determine the economic viability of surface mining to exploit the reserves. The study is based on resource information (grade, shale thickness, overburden) already developed for NOSR 1 and conceptual designs of mining systems compatible with this resource. Environmental considerations as they relate to surface mining have been addressed qualitatively.

Kaiser Engineers performed the bulk of this work, while TRW provided study guidelines and technical direction, and had overall responsibility for this study.

2. EXECUTIVE SUMMARY

Previous studies by TRW* on the mining methods applicable to the NOSR 1 development concluded that room-and-pillar mining and vertical modified in situ mining were the two most promising options. Surface mining was briefly evaluated and initially rejected from further considerations based on the potential for serious environmental impacts (aquifer disruptions, high dust and particulate generation, topographic scarring and aesthetics), and poor economics because of high stripping ratios (amount of overburden rock removed to shale recovered). The conclusions on economic viability were based primarily on mining costs projected from other industries (copper, coal, etc.) using surface mining; economic calculations for surface mining NOSR 1 had not been performed.

Because surface mining

- is a technically viable technique for oil shale recovery (just as room-and-pillar mining is)
- offers a high rate of seam recovery, thereby increasing the total resource recovery, and
- provides selective mining, thereby allowing optimization of the retorting process by shale grade,

an analysis of surface mining for the NOSR 1 resource was performed based on its particular overburden thickness, oil shale thickness, oil shale grade, and topography. This evaluation considered reclamation of the

* Conceptual Design of Shale Oil Production Systems for NOSR 1, DOE Contract No. DE-AC01-78RA32012, September 1979 and Supplemental Report August 1980.

surface as part of its design and cost estimate. Had this study demonstrated that surface mining was economically competitive with room-and-pillar mining, mitigation measures for other environmental disruptions would have been addressed.

Conceptual surface mining designs were performed using the northern and northwestern quadrant of NOSR 1 as potential sites. Histogram and lithologic data from eight holes in this region (USBM E, USBM D, Hole 20, Hole 15/16, Hole 18, USBM F, Hole 17, and Hole 19) were examined. Three oil shale grades - 25, 30 and 35 gallons per ton (GPT) - were studied, with stripping ratios varying between 5 and 12. The average overburden thickness in the region of study is approximately 800 feet and the oil shale thickness varied between 70 feet (for 35 GPT shale) and 158 feet (for 25 GPT shale).

The capital costs for mining 25 GPT and 30 GPT shale are presented in Table 2-1. These values do not include costs associated with deferred investments for replacement of machinery and equipment over the life of the project. Other items specifically excluded from the capital costs are:

- Land acquisition
- Facilities located outside of the immediate mining vicinity
- Power transmission, substation, water supplies, etc.
- Infrastructure, mining camp, and related facilities
- Taxes and permits
- Operating and capital and other owner's costs, such as construction interest and finance costs.

All costs are in July 1980 dollars, with no forward escalation.

Table 2-1. Capital Cost Summary
(Dollars in Thousands)

	SHALE GRADE (GALLONS/TON)		
	25	30	35
Preproduction Cost*	\$654,500	\$641,602	\$627,463
Fixed Expenditure (Permanent Mine Structures)	94,645	106,665	144,745
<u>Mine Equipment (Portable)</u>			
• 5 years life	61,387	71,415	109,671
• 10 years life	13,272	16,147	27,422
• 15 years life	56,125	63,495	90,170
Working Capital** (2 month period)	30,545	34,343	50,216
Consumable Inventory*** (parts & materials)	8,720	10,144	15,579
Total Capital Costs	\$191,194	\$943,811	\$1,065,266

*The total amount will be spent in a period of 3.5 years

**Working capital considers total operating expenses for two months of operations

***Spare part and consumable materials for two months of operations

The operating costs for mining 25 GPT, 30 GPT, and 35 GPT shale are presented in Tables 2-2 through 2-4. These operating costs include:

- Operating, maintenance, and supervisory labor and management
- Fringe benefits
- Parts and operating supplies
- Electric power, fuel and lubricants of all kinds
- Operating and maintaining the mining facilities

These operating costs do not include: taxes (income and property), depreciation and interest on borrowed money; royalties, and insurance.

The relationship between operating cost and stripping ratio, and the break-even stripping ratio (BESR) for surface mining to be competitive with room-and-pillar mining, are shown in Figure 2-1. BESR represents the point of transition from underground mining to surface mining, based on the break-even costs for the two mining methods, and is determined by the following equation:

$$\text{BESR} = 1.333 X - 1$$

where X = underground mining costs

Figure 2-1 shows that for surface mining to be competitive with room-and-pillar mining, the stripping ratio should be in the range of 2.5 to 4. There are very few locations on the NOSR 1 reserve with such low stripping ratios.

It should be further noted that mining and materials handling costs only contribute approximately 30 to 35 percent of the total production system capital costs. For low-grade shales (25 GPT), the retorting costs increase substantially (40 to 50 percent greater than for a 35 GPT shale feed) because of the large solids processing requirements. The increase

Table 2-2. Summary - Estimated Direct Operating Cost for Mining Material
of 25 GPT*

Cost Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	1. <u>Mining and Transportation to the Secondary Crusher</u>			
7.2-2	a. Mine, Maintenance Labor & Burden			\$ 56,123,000
7.2-3	b. Office of Mine Manager			33,000
7.2-4	c. Mining Equipment			49,520,000
7.2-5	d. Drilling & Blasting Material			30,770,000
7.2-6	e. Undistributed Mining Dept. Overhead			588,000
	● Subtotal Mining & Transportation	4.72	8.330	\$137,034,000
	2. Engineering, Research & Other Supporting Operation			
7.2-7		\$0.020	\$0.036	\$ 595,000
	3. Secondary Crushing	\$0.370	\$0.653	\$ 10,749,000
	4. Environmental Control & Reclamation	\$0.043	\$0.075	\$ 1,235,000
	5. Spend Shale	\$0.300	\$0.530	\$ 8,715,000
	● Total Estimated Operating Cost	\$5.45	\$9.62	\$158,328,000

*Annual tonnage of oil shale mined = 29,091,000 tons

**Barrel of oil annually produced = 16,450,000

Table 2-3. Summary - Estimated Direct Operating Cost for Mining Material of 30 GPT*

Cross Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	1. <u>Mining & Transportation to the Secondary Crusher</u>			
7.2-8	a. Mine, Maintenance Labor & Burden			\$ 63,330,000
7.2-3	b. Office of Mine Manager			33,000
7.2-9	c. Mining Equipment			56,785,000
7.2-5	d. Drilling & Blasting Material			34,887,000
7.2-6	e. Undistributed Mining Dept. Overhead			659,000
	• Subtotal Mining & Transportation	\$6.42	\$9.46	\$155,694,000
	2. Engineering, Research & other Supporting Operation	\$0.028	\$0.041	\$ 667,000
7.2-7				
	3. Secondary Crushing	\$0.370	\$0.545	\$ 8,970,000
	4. Environmental Control & Reclamation	\$0.057	\$0.084	\$ 1,375,000
	5. Spend Shale	\$0.300	\$0.442	\$ 7,273,000
	• Total Estimated Operating Cost	\$7.18	\$10.58	\$173,979,000

*Annual tonnage of oil shale mined = 24,242,000

**Barrel of oil annually produced = 16,450,000

Table 2-4. Summary - Estimated Direct Operating Cost for Mining Material of 35 GPT*

Cross Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	1. <u>Mining & Transportation to the Secondary Crusher</u>			
7.2-10	a. Mine, Maintenance Labor & Burden			\$ 88,448,000
7.2-3	b. Office of Mine Manager			45,000
7.2-11	c. Mining Equipment			\$ 84,870,000
7.2-5	d. Drilling & Blasting Material			50,101,000
7.2-6	e. Undistributed Mining Dept. Overhead			923,000
	• Subtotal Mining & Transportation	\$10.80	\$13.64	\$224,387,000
7.2-7	2. Engineering, Research & Other Supporting Operation	0.046	0.058	\$ 954,000
	3. Secondary Crushing	0.370	0.467	\$ 7,688,000
	4. Environmental Control & Reclamation	0.095	0.119	\$ 1,964,000
	5. Spend Shale	0.300	0.379	\$ 6,234,000
	• Total Estimated Operating Cost	\$11.61	\$14.66	\$241,227,000

* Annual tonnage of oil shale mined = 20,779,000

**Barrel of oil annually produced = 16,450,000

FIGURE 2-1 OPERATING COST PER TON OF OIL SHALE VS STRIPPING RATIO

in retorting costs will more than offset any decrease in surface mining costs realized for mining low-grade ore.

Identification of potential environmental impacts shows that environmental control procedures for surface mining are more difficult to implement than those for underground mining. The following three areas are of prime concern:

- Maintenance of air quality standards by disruption, movement, and placement of large quantities of overburden
- Disruption or "cutting" of aquifers during the mining process which affect area water supplies
- Potential mineral leaching from spent shales into the aquifers. Although it is an operational benefit to place spent shale in the open pit, leaching of the spent shales and contamination of the water is detrimental

It is therefore concluded that surface mining on NOSR 1 currently is neither economically desirable nor environmentally safe. Stringent (and therefore costly) mitigation measures would have to be implemented to overcome some of the potential environmental hazards.

3. GEOLOGY¹

3.1 PHYSIOGRAPHY

Naval Oil Shale Reserve 1 (NOSR 1) is located on the high southeastern rim of the Piceance Creek physiographic basin. The area is characterized by two topographic forms: the Roan Cliffs and the Roan Plateau.

The Roan Cliffs are generally parallel to the eastern and southern boundaries of the Reserve, and are carved in the resistant oil shales of the Green River Formation. They reach sheer heights of more than 1,000 feet above steep talus-covered slopes which descend as much as 3,000 feet to the valleys of Government Creek and the Colorado River. Above and within the Roan Cliffs is the Roan Plateau topography. This consists of a maturely dissected upland composed of narrow, westward-trending ridges incised by an intricate, dendritic drainage system. The entire area is made up of the slopes of V-shaped valleys and neither extensive level uplands nor valley flood plains are present. The ridges decline unevenly westward with slope between 50 and 200 feet per mile. The main valleys have westward gradients of 100 to 200 feet per mile. A multitude of short, steep tributary valleys, mostly normal to the main valleys, dissect the slopes and make an intricate topographic pattern throughout the Reserve. The upper slopes are relatively gentle, formed in the less resistant silty sands and shales of the Uinta Formation. The inner valleys of the main streams are cut in the marlstones of the Green River Formation and are markedly steeper-sided.

The various forks of Parachute Creek drop into deep canyons where the streams cut through the Mahogany ledge, and the canyon of East Fork extends about one mile into the west side of the Reserve.

¹"Resource Assessment of NOSR 1" Prepared by TRW, Contract No. DE-AC01-78RA32012, September 1979.

Relief from the valley bottom to the adjacent ridge top is 600 to 800 feet. Elevations in the Reserve vary from 9,286 feet above sea level on the southeast rim (the highest point in the Piceance basin) to about 8,200 feet on the ridges and about 7,600 feet in the valleys along the western boundary. The valley of East Fork Parachute Creek drops to 6,640 feet above sea level below the falls.

Most of the larger drainages carry water in the spring during and after snowmelt, but East Fork Parachute and Northwater Creeks are probably the only permanent streams on the Reserve. A number of springs are mapped on the more recent topographic quadrangles and many more undoubtedly exist on other parts of the Reserve, especially along the upper reaches of the permanent streams and along the face of the Roan Cliffs. Most of these are low-volume at best and many probably go dry by mid-summer.

Principal vegetation communities on the Reserve include open grass lands, dense thickets of scrub oak and mountain mahogany, extensive aspen groves, and relatively minor stands of Douglas fir. Each of these communities has a preferred habitat depending on soil, moisture, and slope exposure, among other things.

The only land uses to the present time have been cattle and sheep ranching, and big-game hunting. Experimental oil shale mining has been carried on at the Anvil Points and Rulison facilities on or near the south side of the Reserve.

3.2 STRATIGRAPHY OF NOSR 1

Rocks which crop out on NOSR 1 belong to the Green River and Uinta Formations. The Anvil Points and Parachute Creek Members are the only units of the Green River Formation present on the outcrop or penetrated in coreholes on the Reserve. The Garden Gulch and Douglas Creek Members may be present in the northwestern quarter

of NOSR 1. The Uinta Formation is the surface rock on NOSR 1 over all but the inner parts of the deeper valleys.

The lithology of each of these units is described in the previous reports.

3.3 STRUCTURAL GEOLOGY

The Piceance Creek basin is the Colorado portion of a large structural depression that originated probably in the early Tertiary Paleocene or Eocene and continued as a locus of deposition into late Eocene time. Down-warping was undoubtedly variable in both place and amount, with some areas subsiding more rapidly than others and at rates that varied through time. Deposition at one time or another occurred in all or parts of the Piceance and Sand Wash basins in Colorado, the Uinta basin in Utah, and the Great Divide and Washakie basins, and possibly also the Green River basin in Wyoming. Throughout most of middle Eocene Green River time, the basin area contained a fresh-water lake or lakes in which the oil shales were deposited. The present Piceance Creek basin is bounded by a variety of positive structural features, some of which--such as the White River dome--were uplifted as the basin subsided, whereas others--such as the Douglas Creek arch--postdate most of the depositional period.

The basin trends northwesterly and is asymmetric, with steeper dips on the eastern flank adjacent to the White River uplift. A number of anticlinal and synclinal folds occur within the basin outline. A prominent system of northwesterly trending faults crosses the north central part of the basin, and other faults exist elsewhere in the basin. Dips in the surface rocks are less than 5° in most of the interior of the basin, becoming moderately steeper toward the flanking uplifts. Dips in the Green River Formation steepen markedly adjacent to the White River uplift, and older formations in that area are vertical to overturned. The general dip is

mainly westerly across NOSR 1, and varies between 1° and 2° , increasing to about 5° near the basin margin in the northeast corner.

4. RESOURCES AND RESERVES

4.1 RESOURCES ON NOSR 1

The total resources, based on data obtained from 45 core holes on and adjacent to NOSR 1, have been calculated and are summarized in Table 4-1.

4.2 MINE AREA SELECTION

4.2.1 Area Selected

For the purpose of this study, the northwestern section of the NOSR 1 was selected for analysis upon consideration that the actual data indicate a higher concentration of GPT in this section. This section, shown on Figure 4-1, enclosed eight core drill holes which were evaluated. The main objective of the drill log evaluation was to estimate the tonnage of oil shale and overburden. This estimation was used to form a geological model which will be the base for a mine economical model.

The tonnage estimations of three average grades, namely 25, 30, and 35 GPT, were performed.

To obtain the average grade of the minable oil shale, the following criteria were used:

- The minimum thickness of oil shale at the average grade was established as 25 feet. This is the minimum thickness that can be efficiently mined with the proposed equipment.
- The internal lean oil shale band and waste or overburden less than 25 feet has been included in the overall composite of the oil shale reserves. Again, this is the limit at which separation would be efficiently performed

TABLE 4-1

NOSR 1 RESOURCE SUMMARY

<u>Category</u>	<u>Stratigraphic Interval</u> ^{1/}	<u>Shale Acres</u>	<u>Total In-Place Barrels</u>
10 GPT	Top U-5 to bottom L-2	31 X 10 ³	18 X 10 ⁹
15 GPT	Top U-5 to bottom L-2	31 X 10 ³	15 X 10 ⁹
20 GPT	Top U-5 to bottom L-2	31 X 10 ³	7 X 10 ⁹
25 GPT	Mahogany zone + L-1	33,365	5,107 X 10 ⁶
30 GPT	Mahogany zone only	33,365	4,422 X 10 ⁶
40 GPT	Mahogany zone only	33,365	1,814 X 10 ⁶

^{1/} Zones 15 feet thick or thicker containing 10, 15 and 20 GPT shale exist above the top of the U-5 unit and below the bottom of the L-2 unit, but corehole data in these intervals are so fragmentary that it is impossible to derive even a rough estimate of the resources involved. The 10, 15 and 20 GPT values shown must, therefore, be considered minimum.

FIGURE 4-1 AREA COVERED BY GEOLOGICAL MODEL A

by the large-scale mining equipment. It is assumed that waste thickness greater than 25 feet could be separated during mining operations and would not be a significant factor in further dilution of the oil shale grade.

For the purpose of the tonnage estimation, the following factors were used:

• Overburden	2.15 ton/yd ³
• Oil Shale @ 25 GPT	1.97 ton/yd ³
• Oil Shale @ 30 GPT	1.93 ton/yd ³
• Oil Shale @ 35 GPT	1.90 ton/yd ³

The results of the drill hole evaluation are summarized on Table 4-2.

4.2.2 Preliminary Geologic Model

The results of Table 4-2 were used to form a geological model A of the area shown on Figure 4-1.

The preliminary geological model was developed and led to the use of the concept of resources inventory, which divides the resources body into blocks or zones consistent with the grade of oil shale in GPT per a minimum thickness of 25 feet. This concept permits the determination of the economical cutoff grade to be postponed until the necessary parameters pertinent to selection of a proper economical cut-off grade are better defined.

The model was formed by computing the tonnages of oil shale of the area of influence of the drill holes, shown in Table 4-2, with a minimum thickness of 25 feet for the following average grades: 20, 25, 30 and 35 GPT. The results of the four levels of oil shale grade were plotted on a graph of tons vs gallons per tons of oil shale.

TABLE 4-2

DRILL HOLE EVALUATION

HOLE NO.	COLLAR ELEV. ft.	GALLONS PER TONS								
		25			30			35		
		B ft.	h ft.	Th ft.	B ft.	h ft.	Th ft.	B ft.	h ft.	Th ft.
USBME	7851	7226	430	195	7256	500	95	7256	510	85
USBMD	7805	7295	355	155	7325	380	100	7330	415	60
CC 14X-14 (Hole 20)	8380	7160	1000*	220	7155	1005	210	7285	995	100
CC 23X-1 (15/16)	8600	7305	1175	120	7305	1215	80	7305	1245	50
TRW 41X-13 (18)	8533	7383	990*	160	7383	1015	135	7388	1035	110
USBMF			530	190		600	85		630	45
CC 32X-8 (17)	8815	7605	1085	125	7610	1120	85	7615	1130	70
TRW 12-X (19)	8721	7981	645	95	7989	680	60	7996	680	45
Average		7420	776	158	7430	814	106	7455	830	70
Stripping Ratios										
a) Volume		4.91:1			7.68:1			11.86:1		
b) Weight		5.36:1			8.55:1			13.42:1		
B = Bottom of Mine h = height of overburden Th = Thickness of oil shale										
*Hole 18 Lean seam of 50 ft.					Seam Width = 65			Seam Width = 90		
*Hole 20 50 ft.					= 50			---		

These basic data points were used to obtain the best fitting curve using a "curve fitting program" which calculates the regression coefficients. The logarithmic curves give the best fit; therefore, the curve that estimates the range of tonnage below or above the four levels of average grade originally estimated is given by logarithmic equation as shown on Figure 4-2.

The equation for the estimation of the respective overburden associated for each average grade of oil shale was obtained by the same method.

After the respective regression coefficients were calculated, projects were made based on the curve fit equations. Mathematical calculations yield to the solution of the break-even point which defines where the ratio of overburden over oil shale is equal to one. This relation is known as the stripping ratio. Further calculations established the stripping ratios as a function of the grade in gallons per ton of the oil shale, as shown on Figure 4-2, "Naval Oil Shale Reserve 1 Model A."

TONS OF OIL SHALE & OVERBURDEN VS. GALLONS PER TON

*PARTIAL AREA ONLY AS SHOWN ON FIGURE 4-1

FIGURE 4-2 NAVAL OIL SHALE RESERVE I MODEL* A

5. OPEN PIT MINING

Open pit mining essentially consists of cutting the rock material horizontally by benches and hauling the material selectively either as oil shale or overburden. When the pit gets deeper this takes the form of an amphitheater. For access to the working benches from the surface, it is necessary to design a ramp system descending as a spiral from the rim of the pit to the bottom at a given grade, according to the size of the trucks and the density of the traffic.

In general, the evaluation of any open pit mining alternative involves technical and economical analysis. The selection of the mining scheme is based primarily on economics; however, safety and other factors are also important. Therefore, the method chosen should be as flexible as possible to meet the various factors involved in the overall mining cycle and should satisfy the required rate of production.

The five main factors of open pit mining as listed below will be considered in the following sections:

- General Mine Design Criteria
- Open Pit Design Basics
- Alternate Selection
- Mine Development, Preproduction
- Mining Unit Operation Analysis

5.1 GENERAL MINE DESIGN CRITERIA

Table 5-1 summarizes the general mine design criteria and schedule necessary to obtain the annual oil shale production, at various grades, of 16.45 million barrels of oil per year. These criteria were selected based on the actual property information, production requirements, and general practices of open pit mining operations.

Table 5-1. General Mine Design Criteria

Production Days per Year (Mine)	338
Production Shifts per Day	3
Schedule Hours per Year	Hours 8,112

Production Required

a) Barrel Oil per Year (329 x 50,000)	16.45 x 10 ⁶
b) Retort Recovery	95%

Tonnage Factors

• Shale (Overburden)	Ton/Cu. Yd.	2.15
• Oil-Shale @ 25 GPT	"	1.97
• Oil-Shale @ 30 GPT	"	1.93
• Oil-Shale @ 35 GPT	"	1.90

Swell Factors

• Shale (Overburden)	0.67
• Oil-Shale	0.70

Geotechnical Parameters

a) Overburden	
• Estimated Average Compressive Strength	psi 22,000
• Estimated Average Tensile Strength	psi 1,100
• RQD (Average)	% 91
b) Oil Shale	
• Estimated Average Compressive Strength	psi 15,000
• Estimated Average Tensile Strength	psi 750
• RQD (Average)	% 85

Operation Efficiency

• Job Efficiency (50 min/60 min)	0.83
• Other Losses Factor	0.97
• Overall Efficiency	0.80

Economic Factors

a) Labor	
• Supervisors (Av.)	\$30,000/yr.
• Mine Operators (av.)	\$10.20/hr.
• Mine Labor @ 3 shift/day (7 day/week)	\$ 9.25/hr.
• Maintenance (Mech. & Elec.)	\$10.50/hr.
• Maintenance Helpers	\$ 9.70/hr.
• Labor Burden	40%
b) Electrical Power Cost	\$0.03/kWh
c) Fuel	\$1.0/Gal.

5.2 OPEN PIT DESIGN BASICS

Open pit mine design is a broad subject which interrelates various basic elements. However, the economics of open pit design are dictated by three basic factors: cutoff grade, stripping ratio and pit wall slope angle. Although these basic elements are functions of a number of independent parameters, they are interconnected through their economic relationships. Figure 5-1 illustrates the interrelation of the various elements involved in the open pit design. In preliminary engineering, as shown in Figure 5-1, the first outline of the ultimate pit limit is obtained from assumed conditions. This ultimate pit limit is used to develop the pit design which in turn is the basis for the mining model. From this mining model the capital and operating costs are developed. These costs are then used in a later stage of the design to obtain the definition of the cutoff grade, and consequently to determine a new outline of the ultimate pit limit, pit design, and mining model. As can be seen from Figure 5-1, for example, any change in the parameters used to determine the pit slope angle will lead to a new definition of the outline of the ultimate pit limit.

Generally, the primary objective of open pit mine design is to produce an ultimate pit outline which will maximize profits. This ultimate pit outline is known as the economic pit limit. The economic pit limit defines the pit outline for a given set of economic and technical conditions at a given time.

The relationship of the basic factors in the open pit design could be stated as follows:

- Economic pit limit = f (cutoff grade, stripping ratio, and pit slope angle)

FIGURE 5-1 OPEN PIT MINE DESIGN
INTERRELATION OF
BASIC ELEMENTS

And in turn:

- Cutoff grade = f (market price of commodity, mining cost, stripping ratio, economics, technology)
- Stripping ratio = f (geometry of deposit, pit slope angle, ultimate pit limit, economics, technology)
- Pit slope angle = f (rock properties, geological discontinuities, water table and pore pressure, geometry of deposit, time factors, seismic factors, economics, technology)

5.2.1 Cutoff Grade

Cutoff grade is generally defined as the lowest grade of the recovered product which will pay for the mining and beneficiation costs and yield the minimum acceptable profit. However, in open pit mining there are situations where the cutoff grade of the material that must be removed, either as useful material or waste, is determined by the break-even cost between transporting it to the processing plant or to the waste dump. In these cases, other factors should be considered, such as processing plant capacity, total tons of material recovered, and market and price conditions.

In general, the criteria for selecting the cutoff grade are dictated by several items, including market price of the products, mining and beneficiation costs, annual production rate, and mine life.

A cutoff grade has not been selected in this study since the objective is to develop the preliminary mining capital and operating costs. These costs need to be integrated with the surface

processing costs and the selling price of oil in order to define the economic cutoff grade.

5.2.2 Stripping Ratios

The stripping ratio is a parameter universally used in open pit mining. However, its interpretation is not always the same, and it should be carefully defined to suit a particular mine.

The ratio of overburden removed to expose and efficiently mine the oil shale is called the overall stripping ratio (SR).

$$SR = \frac{\text{Tons of overburden at depth } h}{\text{Tons of oil shale at depth } h}$$

This stripping ratio (SR) is a geometrical relationship. It should be noted that at the beginning of the operation the average SR will have a theoretical value equal to infinity since the oil shale recovered is nil. When the first oil shale is mined the average SR will have its highest value, which will decrease as the oil shale recovered increases with depth, reaching a minimum value at some point. The average SR will begin to increase again as the open pit volume increases and the mine becomes deeper. After the open pit mine has reached a depth h_1 , an incremental volume of overburden must be removed in order to recover the increment of oil shale at depth h_1 .

The ratio of the incremental amount of waste to incremental amount of oil shale is defined as the incremental stripping ratio, generally denoted by $\overline{SR}$.

$$\overline{SR} = \frac{\text{Volume of incremental waste at depth } h_1}{\text{Volume of incremental oil shale at depth } h_1}$$

The incremental stripping ratio, $\overline{SR}$, is also a geometrical relationship. Using the economic parameters involved in the related

operations, the maximum economical $\overline{SR}$ can be obtained. The maximum economical $\overline{SR}$ defines the ultimate pit limit. The maximum economical $\overline{SR}$ represents the last slice of material that can be mined where the value of oil shale recovered pays the costs of mining, beneficiation, and yields the desired minimum profit. Obviously, in each deposit at a given time with an existing set of economic and technical conditions, there is a maximum value of the $\overline{SR}$ which should not be exceeded. This maximum value is called the economic stripping ratio (ESR). The ESR depends primarily on the net value of the recoverable oil shale. Therefore, the ESR varies for different grades of oil shale, costs of production, and market value of the recoverable products.

When the $\overline{SR}$ exceeds the ESR, open pit mining ceases to be profitable and underground methods may be feasible.

The point of transition from open pit mining to underground mining is called the break-even stripping ratio, usually denoted by BESR. The BESR results from the break-even costs for the two mining methods and is determined as follows:

$$BESR = \frac{\text{Underground Mining Cost/Ton} - \text{Open Pit Mining Cost/Ton}}{\text{Open Pit Stripping Cost/Ton Overburden}}$$

*Tons of oil shale.

When underground operations are impossible, the limit of mining is reached when profit per unit is zero or when the profit is equal to the minimum acceptable profit.

5.2.3 Pit Slope Angle

The maximum slope angle for a pit wall at a given depth is provided by the limit which cannot be exceeded without increasing the probability of slope failure over that which is acceptable. On

the other hand, the minimum pit slope angle is limited by the ESR. The lower angle value is defined by the point at which the maximum allowable or ESR is reached. Obviously, beyond this point mining by the open pit method ceases to be profitable.

The optimum pit slope angle should minimize the average SR and provide safe pit walls for the life of the mine. The optimum pit slope angle should be found somewhere between the two limiting angles.

5.2.3.1 Effect of Pit Slope during Evaluation and Operations

During the evaluation stage of a new open pit mine, the accurate determination of an engineered pit slope angle for pit limit is not critical, especially for a large mine with an expected life of 20 years or more. The pit slope engineering should be a continuous process during the life of the mine, which is revised periodically as new, factual geological and geotechnical information is obtained and the volume of statistical data grows.

Obviously, the steeper the ultimate pit slope the greater the amount of oil shale recovered. The working pit slopes should be kept so as to provide ample operating room to perform the mining operations under the safest possible conditions.

5.2.3.2 Working Pit Slopes

Working pit slopes are flat in contrast with the ultimate pit slope. Once the working slope reaches the pit limit, the slopes are steepened to the final pit slope estimation.

Working pit slopes should be designed and arranged to provide ample operating room to permit the most efficient mining operations.

Stripping ratios will be high during the early years of the mine. In order to minimize these SRs, working pit slopes should be kept as steep as possible.

In a truck haulage pit, sufficient bench width is required to provide for passing trucks and easy spotting of the trucks at the loading shovel. Figure 5-2 illustrates the working operating rooms and operating slopes.

5.2.4 Pit Limit

At this point, a preliminary pit limit is established based on general assumptions. This pit outline becomes the basis for the mine operation model.

The analysis should use the capital and operating costs developed from this preliminary mine operation model. The cycle and sequence of the steps in the pit design are illustrated in Figure 5-1.

For this open pit mine model, the dimensions used are given in the following Table 5-2.

5.3 OPEN PIT MINE ALTERNATE SELECTION

In open pit mining, alternatives exist in the selection of excavators and haulage equipment, which represents the larger part of the average mining cost.

5.3.1 Shovel - Conveyor Belt

This alternative is more suitable for shallow deposits and is attractive when the haulage distance (one-way) is over 5 miles. At this point it is believed that this combination by itself is not suitable for the deposit under study.

CREST TO TOE MINIMUM WORK DIMENSION

LEGEND

α = SLOPE ANGLE OF THE FINAL WALL

B = SLOPE OF THE BENCH = 70°

α_e = WORKING SLOPE OF THE MINING FACE
GROUPING TWO BENCHES

= MINIMUM OPERATING ROOM

MINIMUM WORKING OPERATING ROOM AT PIT BOTTOM

FIGURE 5-2 OPERATING SLOPE AT
WORKING OPERATING
ROOM

TABLE 5-2

PRELIMINARY PIT LIMIT DIMENSIONS

Average overburden thickness	=	800 ft.
Average oil shale thickness of 25 GPT	=	150 ft.
Maximum ramp grade	=	8%
Road and ramp width	=	110 ft.
Pit average width for overburden + one bench of oil-shale = $\frac{800 + 50}{2} \times \frac{1}{0.08}$	=	5313 ft.
Slope angle of the side wall	=	45°
Pit bottom width = $5313 - \frac{(950-425)2}{\text{TAN } 45^\circ}$	=	4265 ft.
Minimum work dimension (from figure 4)	=	150 ft.
Number of working rooms = $\frac{4265}{150} = 28.4$ use		29
Actual pit bottom width 29 x 150 ft.	=	<u>4350</u> ft.
Bench high	=	50 ft.
Slope angle of first box cut	=	50°
Slope angle of back filling	=	38°
Working slope of the advance mining face	=	30°

*950 = Bottom elevation

425 = Elevation of average pit width

2 = No. of sides

5.3.2 Inclined Skip Hoisting

This system is essentially a steeply inclined railway utilizing a hoist to pull the skips to the top or to intermediate positions. Inclined skip haulage systems are often justified where high lifts would require long hauls for other haulage systems. However, this system is inflexible and cannot contend with changes in plans.

5.3.3 Shovels and Trucks

This combination is by far the most commonly used in open pit mining operations. It is very flexible and permits changes in the haulage route in accordance with changing conditions. When the haulage distance is within a radius of 2.5 to 3 miles (one-way), it is one of the most economical haulage systems. This alternate has a wide range of possible combinations with regard to the size of the shovels and trucks; however, bigger equipment is preferred for large operations.

For the purposes of this study, the shovel-truck alternate has been selected to perform the operation from the mining places to a primary crusher system located on the pit rim. From that point conveyor belts for both oil shale and overburden will convey the material to either the processing plant or the waste dump.

The selection is predicated on the following factors:

- The material is expected to break into long tubular pieces.
- Operations can be carried out with limited access room.
- Access to and from the working places can be easily changed if unpredictable mining problems develop.

- This haulage combination of truck-conveyor belt utilizes the comparative advantage of each individual system within each radius of optimum average haulage distance.

5.4 MINING UNIT OPERATIONS ANALYSIS

For this study three levels of annual production rates have been analyzed which are the equivalent of mining oil shale of 25, 30, and 35 GPT.

The unit operations in the NOSR 1 model operation are:

- Drilling and blasting
- Loading
- Hauling
- Conveyor belt
- Auxiliary equipment

5.4.1 Drilling and Blasting

The blasting concepts proposed in this study are based on the use of ANFO and 10 percent of slurry.

The primary blast hole drilling patterns are planned to achieve several effects:

- The rock must be broken with acceptable fragmentation and minimized oil shale dilution with waste as a result of the blasting operations.
- The pit floor should not be uneven. Backbreak and vibration from blasting should not lead to instability of the pit walls.

For secondary blasting, self-contained, rubber tire-mounted drills with the capacity to drill holes up to 3-1/2 inches in diameter are proposed.

Tables 5-3, 5-4, and 5-5 summarize the calculations for the rotary drill estimated performances for mining oil shale and stripping for grades of 25, 30 and 35 GPT, respectively.

Tables 5-6, 5-7, and 5-8 summarize the respective calculations for the proposed blasting design.

5.4.2 Loading

In Section 3 we selected shovels as the loading equipment for the loading and transportation schemes.

By considering the site of the operation and the assumed characteristics of the broken materials, we adopted an electric shovel of 28-yd³ capacity as the loader for both oil shale and overburden.

Tables 5-9, 5-10, and 5-11 summarize the estimated performance of the 28-yd³ shovels for mining oil shale and stripping at three levels of mining rate.

5.4.3 Haulage

The basic haulage distances were estimates for the three levels of production under analysis.

Trucks of 170-ton capacity have been adopted to match the 28-yd³ shovels. The performance for the three levels of production are summarized on Tables 5-12, 5-13, and 5-14.

5.4.4 Belt Conveyor System

The trucks from the pit will deliver the runoff materials into a primary crusher located in the rim of the pit.

TABLE 5-3

ROTARY DRILL ESTIMATED PERFORMANCE
FOR MINING MATERIAL OF 25 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden*</u>
Average Tonnage Required per Yr.	Tons x 10 ³	29,091.0	154,180.0
Size Hole	Inches	12 1/4	12 1/4
Bench Height	Ft.	50.0	50
Subdrilling	Ft.	5.0	5
Drill Hole Depth	Ft.	55.0	55
Drill Hole Pattern	Ft.	31 x 31	25 x 25
Estimated Compressive Strength	psi	15,000.0	22,000
Average Estimated Drilling Rate**	Ft./Hr.	65.0	45
Average Tonnage Factor	Ton/Cu. Yd.	1.97	2.15
Tonnage Broken per Hole	Tons	3,506	2,488
Number of Holes Required per Day	Units	25	184
Total Footage to be Drilled per Day	Ft.	1,375	10,120
Effective Drilling per Day at 80%			
Overall Efficiency	Ft.	1,248	864
Number of Drilling Hours Required per Yr. @ 100% Efficiency	Hrs.	7,150	76,012
Number of Drills Required, Average/Day Spare @ 85% Availability and Probability Factor of 95%		(1.1) 2	(11.7) 12
Total Drills Required		$\frac{1}{3}$	$\frac{5}{17}$
Schedule/Shift A		2	12
B		1	12
C		1	11
Average/Day		(1.3)	(11.7)

*Includes: Lean oil shale and waste

**Includes drilling movement, clean hole, etc.
RPM = 70

TABLE 5-4

ROTARY DRILL ESTIMATED PERFORMANCE
FOR MINING MATERIAL OF 30 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden*</u>
Average Tonnage Required per Yr.	Tons x 10 ³	24,242.0	181,815.0
Size Hole	Inches	12 1/4	12 1/4
Bench Height	Ft.	50.0	50
Subdrilling	Ft.	5.0	5
Drill Hole Depth	Ft.	55.0	55
Drill Hole Pattern	Ft.	31 x 31	25 x 25
Estimated Compressive Strength	psi	15,000.0	22,000
Average Estimated Drilling Rate**	Ft./Hr.	65.0	45
Average Tonnage Factor	Ton/Cu. Yd.	1.93	2.15
Tonnage Broken per Hole	Tons	3,435	2,488
Number of Holes Required per Day	Units	21	217
Total Footage to be Drilled per Day	Ft.	1,155	11,935
Effective Drilling per Day at 80%			
Overall Efficiency	Ft.	1,248	864
Number of Drilling Hours Required per Yr. @ 100% Efficiency	Hrs.	6,006	89,645.0
Number of Drills Required		1	(13.8) 14
Spare @ 85% Availability			
and Probability Factor of 95%		<u>1</u>	<u>6</u>
Total Drills Required		2	20
Schedule/Shift A		1	14
B		1	14
C		<u>1</u>	<u>14</u>
Average/Day		1	14

*Includes: Lean oil shale and waste

**Includes drilling movement, clean hole, etc.
 RPM = 70

TABLE 5-5

ROTARY DRILL ESTIMATED PERFORMANCEFOR MINING MATERIAL OF 35 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden*</u>
Average Tonnage Required per Yr.	Tons x 10 ³	20,779	280,517
Size Hole	Inches	12 1/4	12 1/4
Bench Height	Ft.	50.0	50
Subdrilling	Ft.	5.0	5
Drill Hole Depth	Ft.	55.0	55
Drill Hole Pattern	Ft.	31 x 31	25 x 25
Estimated Compressive Strength	psi	15,000.0	22,000
Average Estimated Drilling Rate**	Ft./Hr.	65.0	45
Average Tonnage Factor	Ton/Cu. Yd.	1.90	2.15
Tonnage Broken per Hole	Tons	3,381	2,488
Number of Holes Required per Day	Units	19	334
Total Footage to be Drilled per Day	Ft.	1,045	18,370
Effective Drilling per Day at 80%			
Overall Efficiency	Ft.	1,248	864
Number of Drilling Hours Required per Yr.			
@ 100% Efficiency	Hrs.	5,434	137,979
Number of Drills Required		(0.83) 1	(21.3) 22
Spare @ 85% Availability			
and Probability Factor of 95%		<u>1</u>	<u>8</u>
Total Drills Required		2	30
Schedule/Shift A		1	22
B		1	21
C		<u>1</u>	<u>21</u>
Average/Day		1	21.3

*Includes: Lean oil shale and waste

**Includes drilling movement, clean hole, etc.

RPM = 70

TABLE 5-6

BLASTING DESIGNFOR MINING MATERIAL OF 25 GPTEstimated Conditions

1. Relative Dry Hole Condition	Unit	25 GPT	
		Oil Shale	Overburden
2. Type of Material			
Tonnage Factor	Tons/Cu. Yd.	1.97	2.15
Estimated Tensile Strength	psi	750	1,100
RQD (Average)	%	85	91
JSF = Factor		1.0	1.0
Bench Height	Ft.	50	50
ERQD		0.85	0.91
3. Blast Hole			
Diameter	Inches	12 1/4	12 1/4
Depth	Ft.	50	50
Subdrilling	Ft.	<u>5</u>	<u>5</u>
Total Depth	Ft.	55	55
4. Blasting Agent			
a. Ammonium Nitrate Column Charge + Aluminum Slurry	Ft.	35	37
b. Steaming Dry Rotary Cutting	Ft.	<u>20</u>	<u>18</u>
Total	Ft.	55	55

Basic Calculations

K, Blastability Factor		0.73	0.72
Burden (obtain from curve figure No.	Ft.	22	18
Spacing 2 x Burden @ 45° Echelon		44	36
Tonnage Broken per Bench Hole	Tons	3,506	2,488
Loading Charge Volume			
Loading Charge Weight @ 10% Slurry			
a. ANFO S.C. @ 0.80	Lb.	1,336	1,412
b. Slurry S.G. @ 1.25	Lb.	<u>149</u>	<u>157</u>
Total Weight of Explosive/Hole	Lb.	1,485	1,569
Explosive Factor = Lb./Ton		0.424	0.631

TABLE 5-7

BLASTING DESIGNFOR MINING MATERIAL OF 30 GPTEstimated Conditions

		30 GPT	
		<u>Oil Shale</u>	<u>Overburden</u>
1. Relative Dry Hole Condition	Unit		
2. Type of Material			
Tonnage Factor	Tons/Cu. Yd.	1.97	2.15
Estimated Tensile Strength	psi	750	1,100
RQD (Average)	%	85	91
JSF = Factor		1.0	1.0
Bench Height	Ft.	50	50
ERQD		0.85	0.91
3. Blast Hole			
Diameter	Inches	12 1/4	12 1/4
Depth	Ft.	50	50
Subdrilling	Ft.	<u>5</u>	<u>5</u>
Total Depth	Ft.	55	55
4. Blasting Agent			
a. Ammonium Nitrate Column Charge + Aluminum Slurry	Ft.	35	37
b. Steaming Dry Rotary Cutting	Ft.	<u>20</u>	<u>18</u>
Total	Ft.	55	55
Basic Calculations			
K, Blastability Factor		0.73	0.72
Burden (obtain from curve figure No.	Ft.	22	18
Spacing 2 x Burden @ 45° Echelon		44	36
Tonnage Broken per Bench Hole	Tons	3,435	2,488
Loading Charge Volume			
Loading Charge Weight @ 10% Slurry			
a. ANFO S.G. @ 0.80	Lb.	1,336	1,412
b. Slurry S.G. @ 1.25	Lb.	<u>145</u>	<u>157</u>
Total Weight of Explosive/Hole	Lb.	1,485	1,569
Explosive Factor = Lb./Ton		0.432	0.631

TABLE 5-8

BLASTING DESIGNFOR MINING MATERIAL OF 35 GPTEstimated Conditions

1. Relative Dry Hole Condition

2. Type of Material

Tonnage Factor
 Estimated Tensile Strength
 RQD (Average)
 JSF = Factor
 Bench Height
 ERQD

Unit

35 GPT

Oil ShaleOverburden

Tons/Cu. Yd.

1.90

2.15

psi

750

1,100

%

85

91

1.0

1.0

Ft.

50

50

0.85

0.91

3. Blast Hole

Diameter

Inches

12 1/4

12 1/4

Depth

Ft.

50

50

Subdrilling

Ft.

5

5

Total Depth

Ft.

55

55

4. Blasting Agent

a. Ammonium Nitrate Column Charge +
 Aluminum Slurry

Ft.

35

37

b. Steaming Dry Rotary Cutting

Ft.

20

18

Total

Ft.

55

55

Basic Calculations

K, Blastability Factor

0.73

0.72

Burden (obtain from curve figure No.

Ft.

22

18

Spacing 2 x Burden @ 45° Echelon

44

36

Tonnage Broken per Bench Hole

Tons

3,381

2,488

Loading Charge Volume

Loading Charge Weight @ 10% Slurry

a. ANFO S.G. @ 0.80

Lb.

1,336

1,412

b. Slurry S.G. @ 1.25

Lb.

149

157

Total Weight of Explosive/Hole

Lb.

1,485

1,569

Explosive Factor - Lb./Ton

0.439

0.631

TABLE 5-9

ELECTRIC POWER SHOVEL PRODUCTIONFOR MINING MATERIAL OF 25 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
<u>Shovel - Bucket Capacity</u>	Cu. Yd.	28.0	28.0
Tonnage Required per Year	Tons x 10 ³	29,091.0	154,180.0
Swell Factor Estimated		0.70	0.67
Fill Factor		0.85	0.85
Bucket Factor		0.595	0.595
Rock Tonnage Factor - Insitus	Tons/Cu. Yd.	1.97	2.15
Tons per Shovel Pass		33	36.0
Average Time Cycle	Sec.	30.0	30.0
Effective Time/Hour	Min.	50.0	50.0
Truck Match Factor		0.75	0.75
Other Loss Factor		0.97	0.97
Production Utilization		0.61	0.61
Shovel Passes/Hour @ 100% Efficiency		120.0	120.0
Shovel Capacity/Hour @ 100% Efficiency	Tons/Hrs.	3,960	4,320.0
Average Shovel Tonnage per Day	Ton/Day	57,974	63,240
Number of Hours Shovel Required per Year	Hrs./Yr.	7,347.0	35,690.0
Number of Shovels Required, Average/Day		(1.5) 2	(7.2) 8
Spare		<u>1</u>	<u>2</u>
Total Shovels		3	10
Shovel Schedule			
Shift A		2	8
Shift B		2	7
Shift C		<u>1</u>	<u>7</u>
Average Shovel/Day		1.67	7.33

TABLE 5-10

ELECTRIC POWER SHOVEL PRODUCTIONFOR MINING MATERIAL OF 30 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
<u>Shovel - Bucket Capacity</u>	Cu. Yd.	28.0	28.0
Tonnage Required per Year	Tons x 10 ³	24,242.0	181,815.0
Swell Factor Estimated		0.70	0.67
Fill Factor		0.85	0.85
Bucket Factor		0.595	0.595
Rock Tonnage Factor - Insitus	Tons/Cu. Yd.	1.93	2.15
Tons per Shovel Pass		32.0	36.0
Average Time Cycle	Sec.	30.0	30.0
Effective Time/Hour	Min.	50.0	50.0
Truck Match Factor		0.75	0.75
Other Loss Factor		0.97	0.97
Production Utilization		0.61	0.61
Shovel Passes/Hour @ 100% Efficiency		120.0	120.0
Shovel Capacity/Hour @ 100% Efficiency	Tons/Hrs.	3,840	4,320.0
Average Shovel Tonnage per Day	Ton/Day	56,218	63,240
Number of Hours Shovel Required per Year	Hrs./Yr.	6,313.0	42,087.0
Number of Shovels Required		(1.3) 2	(8.5) 9
Spare		<u>1</u>	<u>3</u>
Total Shovels		3	12
Shovel Schedule			
Shift A		2	9
Shift B		1	9
Shift C		<u>1</u>	<u>8</u>
Average Shovel/Day		1.3	8.7

TABLE 5-11

ELECTRIC POWER SHOVEL PRODUCTIONFOR MINING MATERIAL OF 35 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
<u>Shovel - Bucket Capacity</u>	Cu. Yd.	28.0	28.0
<u>Tonnage Required per Year</u>	Tons x 10 ³	20,779.0	280,517
<u>Swell Factor Estimated</u>		0.70	0.67
<u>Fill Factor</u>		0.85	0.85
<u>Bucket Factor</u>		0.595	0.595
<u>Rock Tonnage Factor - Insitus</u>	Tons/Cu. Yd.	1.90	2.15
<u>Tons per Shovel Pass</u>		31.6	36.0
<u>Average Time Cycle</u>	Sec.	30.0	30.0
<u>Effective Time/Hour</u>	Min.	50.0	50.0
<u>Truck Match Factor</u>		0.75	0.75
<u>Other Loss Factor</u>		0.97	0.97
<u>Production Utilization</u>		0.61	0.61
<u>Shovel Passes/Hour @ 100% Efficiency</u>	-	120.0	120.0
<u>Shovel Capacity/Hour @ 100% Efficiency</u>	Tons/Hrs.	3,798	4,320.0
<u>Average Shovel Tonnage per Day</u>	Ton/Day	55,610	63,240
<u>Number of Hours Shovel Required per Year</u>	Hrs./Yr.	5,471.0	64,935.0
<u>Number of Shovels Required</u>		(1.1) 2	(13.1) 14
<u>Spare</u>		<u>1</u>	<u>5</u>
<u>Total Shovels</u>		3	19
<u>Shovel Schedule</u>			
Shift A		2	14
Shift B		1	13
Shift C		<u>1</u>	<u>13</u>
Average Shovel/Day		1.3	13.3

TABLE 5-12

TRUCK FLEET PRODUCTION REQUIREMENTFOR MINING MATERIAL OF 25 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
Truck Net Capacity	Tons	170	170
Tonnage Required Per Year	Tons x 10 ³	29,091.0	154,180.0
Number of Passes per Load	-	6.0	5.0
Load Time	Min.	3.0	2.5
Dump	Min.	1.0	1.0
Spot	Min.	1.0	1.0
Total Fixed Time	Min.	5.0	4.5
Average Haulage Distance (One Way)	Mile	2.63	1.88
Average Speed	MPH	13.0	16.0
Average Cycle Time	Min.	29.3	18.6
Truck Capacity @ 100% Eff.	Tons/Hr.	340.0	531.0
Haulage Hour Required/Year @ 100% Eff.	Hrs.	85,562.0	290,356
Effective Time/Hour	Min.	50.0	50.0
Other Loss Factor	-	0.97	0.97
Production Utilization	-	0.80	0.80
Average Truck Capacity per Hour	Tons/Hr.	272.0	425.0
Average Truck Capacity per Day	Tons/Day	6,528.0	10,200.0
Number of Trucks Required		(13.1) 14	(44.7) 45
Spare		<u>5</u>	<u>19</u>
Total Fleet		19	63
Truck Schedule			
Shift A		14	45
Shift B		13	45
Shift C		<u>13</u>	<u>45</u>
Average/Day		13.3	45

TABLE 5-13

TRUCK FLEET PRODUCTION REQUIREMENT
FOR MINING MATERIAL OF 30 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
Truck Net Capacity	Tons	170	170
Tonnage Required per Year	Tons x 10 ³	24,242.0	181,815.0
Number of Passes per Load	-	6.0	5.0
Load Time	Min.	3.0	2.5
Dump	Min.	1.0	1.0
Spot	Min.	1.0	1.0
Total Fixed Time	Min.	5.0	4.5
Average Haulage Distance (One Way)	Mile	2.73	2.06
Average Speed	MPH	13.0	16.0
Average Cycle Time	Min.	30.2	20.0
Haulage Capacity @ 100% Eff.	Tons/Hr.	319.0	510.0
Haulage Hour Required/Year @ 100% Eff.	Hrs.	75,994.0	356,500
Effective Time/Hour	Min.	50.0	50.0
Other Loss Factor	-	0.97	0.97
Production Utilization	-	0.80	0.80
Average Truck Capacity per Hour	Tons/Hr.	255.0	408.0
Average Truck Capacity per Day		6,120.0	9,792.0
Number of Trucks Required		(11.7) 12	(54.9) 55
Spare		<u>5</u>	<u>23</u>
Total Fleet		17	78
Truck Schedule			
Shift A		12	55
Shift B		12	55
Shift C		<u>12</u>	<u>55</u>
Average/Day		12	55

TABLE 5-14

TRUCK FLEET PRODUCTION REQUIREMENT
FOR MINING MATERIAL OF 35 GPT

	<u>Unit</u>	<u>Oil Shale</u>	<u>Overburden</u>
Truck Net Capacity	Tons	170	170
Tonnage Required per Year	Tons x 10 ³	20,779.0	280,517
Number of Passes per Load	-	6.0	5.0
Load Time	Min.	3.0	2.5
Dump	Min.	1.0	1.0
Spot	Min.	1.0	1.0
Total Fixed Time	Min.	5.0	4.5
Average Haulage Distance (One Way)	Mile	2.79	2.27
Average Speed	MPH	13.0	15.0
Average Cycle Time	Min.	30.7	21.5
Haulage Capacity @ 100% Eff.	Tons/Hr.	321.0	468.0
Haulage Hour Required/Year @ 100% Eff.	Hrs.	64,732.0	599,396
Effective Time/Hour	Min.	50.0	50.0
Other Loss Factor	-	0.97	0.97
Production Utilization	-	0.80	0.80
Average Truck Capacity per Hour	Tons/Hr.	257.0	374.0
Average Truck Capacity per Day		6,168.0	8,976.0
Number of Trucks Required		10	(92.5) 93
Spare		<u>5</u>	<u>38</u>
Total Fleet		15	131
Truck Schedule			
Shift A		10	93
Shift B		10	93
Shift C		<u>10</u>	<u>92</u>
Average/Day		10	92.66

The crusher arrangement consists of three separate systems, one to convey oil shale to the processing plant and two to convey overburden.

The basic data and assumptions for the estimation of the conveyor belt performance for handling oil shale of 25, 30, and 35 GPT are summarized in Tables 5-15, 5-16, and 5-17, respectively.

The performances of the belt systems for handling overburden material at three levels of mining rate are summarized in Table 5-18.

5.4.5 Auxiliary Operations

In addition to the major mining and stripping equipment, a large amount of support equipment is necessary. This equipment consists of:

motor graders	light trucks
wheel dozers	portable pumps
track dozers	passenger bus
small drills	explosive truck
cranes	front-end loaders
light towers	

Motor graders are used to maintain the road. The graders are used to rework the inclines for the ditches and to maintain a sufficient roadway crown.

Motor graders patrolling the haulage roads on a continuous basis are considered necessary to keep truck operating costs at a reasonable level. Tires deteriorate at an accelerated rate if roads are not kept in excellent condition. Since hauling costs can amount to one-third or more of the total direct mine costs, the maintenance of roads is a priority item.

TABLE 5-15

BELT CONVEYOR PERFORMANCEFOR HANDLING OIL SHALE OF 25 GPT

Tonnage Output per Year	Tons x 10 ³	29,091.0
Scheduled Yearly Operating Hrs.	Hrs.	8,112
Conveyor Utilization of Total Time	%	68
Average Conveyor Capacity Required @ 68%	Tons/Hr.	5,275
Peak Conveyor Capacity Required	Tons/Hr.	6,600
Material Density Insitus	Lb./Ft. ³	146
Swell Factor		0.70
Loose Material Density	Lb./Ft. ³	102.0
Maximum Lump Size	Inches	12.0
Number of Stages of 1,000 ft.		7
Total Length of the System (35° E.R. Idlers)	Ft.	7,000
Vertical Lift		0
Belt Width	Inches	60
Speed	FPM	725
Estimated Belt Capacity	Tons/Hr.	6,850
Required Installed HP per Stage	HP	245
Average Power Consumed per Stage	kWh	155
Total Power Consumed per System	kWh	1,085

TABLE 5-16.

BELT CONVEYOR PERFORMANCEFOR HANDLING OIL SHALE OF 30 GPT

Tonnage Output per Year	Tons x 10 ³	24,742.0
Scheduled Yearly Operating Hrs.	Hrs.	8,112
Conveyor Utilization of Total Time	%	68
Average Conveyor Capacity Required	Tons/Hr.	4,485.0
Peak Conveyor Capacity Required	Tons/Hr.	5,610.0
Material Density Insitus	Lb./Ft. ³	143.0
Swell Factor		0.70
Loose Material Density	Lb./Ft. ³	102
Maximum Lump Size	Inches	12
Number of Stages of 1,000 Ft.		9
Total Length of the System		9,000
Vertical Lift		0
Belt Width	Inches	60
Speed	FPM	600
Estimated Belt Capacity	Tons/Hr.	5,680
Required Installed HP per Stage	HP	205
Average Power Consumed per Stage	kWh	130
Total Power Consumed per System	kWh	1,170

TABLE 5-17

BELT CONVEYOR PERFORMANCEFOR HANDLING OIL SHALE OF 35 GPT

Tonnage Output per Year	Tons x 10 ³	20,779.0
Scheduled Yearly Operating Hrs.	Hrs.	8,112
Conveyor Utilization of Total Time	%	68
Average Conveyor Capacity Required	Tons/Hr.	3,770.0
Peak Conveyor Capacity Required	Tons/Hr.	4,710.0
Material Density Insitus	Lb./Ft. ³	141.0
Swell Factor		0.70
Loose Material Density	Lb./Ft. ³	102.0
Maximum Lump Size	Inches	12
Number of Stages of 1,000 Ft.		12
Total Length of the System (35° E. R. Idlers)	Ft.	12,000
Vertical Lift		0
Belt Width	Inches	60
Speed	FPM	500
Estimated Belt Capacity	Tons/Hr.	4,735.0
Required Installed HP per Stage	HP	172
Average Power Consumed per Stage	kWh	110
Total Power Consumed per System	kWh	1,320

Wheel dozers are used principally as cleanup machines around the power shovels. They continuously sweep the pit floor to remove shovel-to-truck spillage and maintain the loading area. A clean loading area reduces the cutting of tires and conserves tires from premature failures. It also improves the cycle time of the shovel by keeping spillage pushed into the loading face, thus decreasing the need for an inefficient shovel cleanup of the floor.

It is common practice to assign one wheel dozer to each loading shovel. Sometimes if shovels are close to each other they will share one wheel dozer between them.

Front-end loaders could be used for general utility work and to load oil shale or waste into trucks in places where a shovel would be uneconomical. Front-end loaders are also useful as auxiliary lifting devices and for general cleanup around the mine.

Track dozers are most useful on waste dumps to keep newly dumped material pushed outward. There is always a use for track dozers in pioneering mine development and road building. Where continuing exploration is in progress track dozers are good for preparing drill sites and for towing equipment from site to site, depending on the distance between drill holes. Another frequent use for track dozers is working in the blasted muck from the bench top.

The small drills are used in secondary drilling to prepare over-size rocks for blasting, and in mine development pioneering work. The small drill can frequently be employed to correct a hard toe condition or make horizontal holes for blasting or drainage purposes.

Light towers are for night work where power is not normally available. Usually portable light towers are required on waste dumps and for small drills working in isolated areas. Pioneering work

in mine development will also normally require portable lighting. Generators are usually in the range of 2.5 to 7.5 kilowatts depending on the service required.

Special ANFO mixing trucks are proposed to transport both the prilled ammonium nitrate and the fuel oil, mix them, and charge the finished ANFO mixture into the blast hole.

The ammonium nitrate will be mixed automatically with the fuel oil as the meter-controlled mixture is discharged from the truck into the blast holes. Fuel oil can be metered into either an auger-type or a pneumatic mixing and discharge feeder arrangement.

Slurries are water-based mixtures of ammonium nitrate, low-grade explosives and chemicals. The chemicals are used for thickening and gelling the mixture. The slurries are dense mixtures with a specific gravity greater than 1.1. A mixing truck combines the ingredients into the proper density for transportation to and charging of the blast holes. The slurry mixing trucks are insulated to maintain the required temperatures. Slurry solidifying agents are added at the blast hole. As the slurry is being charged into the blast hole, the gelling agent is added, causing the slurry to set or to form a gel shortly after the blast hole is loaded.

All the equipment discussed above is included in the major equipment capital list in Section 7.1, Mine Capital Costs.

5.5 GENERAL STRATEGY FOR OIL SHALE PRODUCTION

For the purposes of this study, a general preliminary long-term mining plan was considered. This is consistent with the time-frame and set of geological, technical and economic conditions known or assumed at this time.

TABLE 5-18

BELT CONVEYOR PERFORMANCE FOR
OVERBURDEN MATERIAL

	OVERBURDEN		
	(Oil Shale) (25 GPT)	(Oil Shale) (30 GPT)	(Oil Shale) (35 GPT)
Total Tonnage Output Required per Year	Tons x 10 ³ 154,180	181,815	280,517
Tonnage Output Required per Year per System (2 System)	Tons x 10 ³ * 77,090	* 90,910	*140,260
Scheduled Yearly Operating Hrs.	Hrs. 8,112	8,112	8,112
Conveyor Utilization of Total Time	% 68	68	68
Average Conveyor Capacity Required/System	Tons/Hr. 13,975	16,480	25,430
Peak Conveyor Capacity Required	Tons/Hr. 17,470	20,600	31,780
Material Density Insitus	Lb./Ft. ³ 159.0	159.0	159.0
Swell Factor	0.67	0.67	0.67
Loose Material Density	Lb./Ft. ³ 107.0	107.0	107.0
Maximum Lump Size	Inches 12.0	12.0	12.0
Number of Stages of 1,000 Ft.	- 10	12	15
Total Length of the System (55 E.R. Idlers)	Ft. 10,000	12,000	15,000
Vertical Lift	Ft. 0	0	0
Belt Width	Inches 90	90	108
Speed	FPM 760	890	940
Estimated Belt Capacity	Tons/Hr. 17,660	20,685	31,785
Required Installed HP per Stage	HP 572	692	1,017
Total Installed HP per System	HP 5,720	8,304	15,255
Average Power Consumed per Stage	kWh 491	582	847
Total Power Consumed per System	kWh 4,910	6,984	12,705
Total Power Consumed	kWh 9,820	13,968	25,410
Total Installed HP	HP 11,440	16,608	30,510

*Using Two Independent Systems

5-35-36

In general, mine planning is a dynamic process continuing throughout the life of the mine, always subject to changes as new information arises. In practice, the mine plans are reviewed periodically. This procedure accounts for the effects of changing economics, new information about the deposit, and improvement in mining technology. The use of computer programs will permit the updating of mine plans to handle several variables so that new plans can be developed in greater detail.

The tentative operation plan for NOSR 1 is based on exploitation of oil shale for 20 years.

Mining strategies are developed to accommodate the conditions and characteristics of the deposit, the basic pit outline, and the proposed mining method for drilling, blasting, loading and transportation of oil shale and overburden.

The location of oil shale and overburden and the quantity to be mined within the first 10 years of operations, were used to determine the mine capital and operating costs. Three levels of annual mining rate were considered, depending on the production from 25, 30, and 35 GPT grade oil shale.

In addition, the geological distribution of the oil shale of the geological model A has an associated SR for each corresponding level of oil shale production.

In summary, the general mining strategy is as follows:

- Mine Development, Production
- Production Mining Plans
- Total Backfilling After Mine Operation Ceases

The general concept of the mine plan is illustrated on Figures 5-3 and 5-4.

FIGURE 5-4 GENERAL LONG TERM MINE PLAN AND TYPICAL WORKING SLOPE ANGLES

Figure 5-5 illustrates the various phases of the mining cycle operation of the property, starting from the undisturbed surface and proceeding to total backfilling and reclamation when the area is completed and mined out.

5.5.1 Mine Development, Preproduction

A preliminary development program should consider the following factors:

- Production rate
- Possible blending requirement
- Average SR

Prior to the start of oil shale production, it is necessary to perform enough preproduction stripping development to expose oil shale to feed the processing plant at the desired production rate for at least three months. It is also advisable to consider only two benches of oil shale exposed (100 feet) in order to have more area exposed to get deeper in the oil shale if blending is required. Table 5-19 shows the preproduction requirements for three levels of annual mining rate. The table also indicates the size of area required for dumping the overburden material. The areas available are tentatively shown on Figure 5-3.

5.5.2 Production Mining Plans

In order to provide the primary crusher with oil shale feed of the tonnage and grade required on a continuous basis, it will be necessary to strip more overburden material in advance and minimize the impact of a possible high stripping ratio during some future period. This should be accomplished by dividing the mine plans into segments to manage the stripping requirements, sometimes called pushbacks or campaigns. A pushback defines the mining of a group of several benches with the following objectives:

5-41-142

FIGURE 5-3
GENERAL MINE PLAN

FIGURE 5-5 IDEALIZED MINING CYCLE

* F.E.L. - FRONT END LOADER

TABLE 5-19
PREPRODUCTION REQUIREMENT

	OIL SHALE GRADE		
	25 GPT	30 GPT	35 GPT
<u>OIL SHALE</u>			
Annual Tonnage Required - Million Tons	29.091	24.242	20.779
Three Month Production	7.273	6.061	5.194
No. of Benches 2 - ft.	100	100	100
Average Bottom Pit Dimension ft.	4500 x 220	4500 x 190	4500 x 165
<u>OVERBURDEN</u>			
Slope Angle High Wall	50°	50°	50°
Slope Angle of Advancing Face	30°	30°	30°
Slope Angle of Side Wall	45°	45°	45°
Average Surface Dimensions	6100 x 2350	6100 x 2305	6100 x 2275
Tonnage to be Removed Million Tons*	374.	363.00	355.0
Av. Dump Height ft.	200	200	200
Size of Sump Area Required ft.	5159 x 5159	5080 x 5080	5026 x 5026

*Average overburden depth of 800 ft.

- To provide enough oil shale for the processing plant until the next pushback reaches the oil shale production stage.
- To keep the SR within the overall average SR if possible (except in the preproduction period).
- To keep the working slope of each pushback as steep as possible consistent with desirable minimum operating space as specified on Figure 5-2.

The mining plans consider the following operations:

- Mining and disposing of overburden
- Mining and delivering the oil shale to the processing plant

5.5.2.1 Overburden Disposal

The overburden disposal will be carried out by a shovel and truck operation, with rear dump diesel-electric trucks hauling on ramps of 8% grade out of the pit to the surface crushers arrangement. The crushers arrangement will feed the conveyor belt systems to the dump area.

During the first two or three years of operation, the overburden material will be disposed of in the same dump areas used in preproduction stripping. This will be necessary to provide enough room to operate efficiently when backfilling operations take place. For the purpose of this study, a clearance distance of 750 feet has been adopted between the toe of the backfilling and the mining face, as shown in Figure 5-4. This figure also shows the group of benches for pushbacks. It is estimated that about 370 million tons of overburden must be disposed outside of the mined-out area.

After the minimum clearance of 750 feet is reached, the overburden will be carried to the mined-out area so the backfilling operation can be performed.

In summary, it will be necessary to dump the following amounts of overburden outside of the mined-out area:

- Preproduction stripping (Table 5-19) = 374 million
(for 25 GPT)

- Production stripping = 370 million
- Total 744 million

5.5.2.2 Oil Shale Production

The proposed mining method for oil shale, as well as for overburden, is the conventional open pit mining technique. Rotary drills and a mixture of ammonium nitrate plus slurry as blasting agents are used to break the oil shale and overburden rock.

The blasted oil shale will be loaded by 28-yd³ electric power shovels into 170-ton rear dump trucks. Based on the average distance of the pit outline shown on Figure 5-3, calculations of the numbers of shovels and trucks required were performed, and are detailed in Section 5.4.

Trucks will haul on a ramp of 8% grade out of the pit to a surface crusher-belt system arrangement. The belt system conveys the oil shale to the processing plant. The conceptual arrangement of the belt systems for both oil shale and overburden is indicated on Figure 5-3.

The totals for material to be mined per year for the three levels of annual production are as follows:

<u>Oil Shale Grade GPT</u>	<u>Overburden Tons</u>	<u>Oil Shale Tons</u>	<u>Total Tons</u>	<u>SR</u>
25	154,180,000	29,091,000	183,271,000	5.3
30	181,815,000	24,242,000	206,057,000	7.5
35	280,517,000	20,779,000	301,296,000	13.5

6. ENVIRONMENTAL REVIEW

6.1 INTRODUCTION

A preliminary environmental overview of the conceptual surface mining plan for NOSR 1 has been completed. Environmental effects and impacts of the mining operation are discussed and recommended environmental controls and reclamation plans are presented. Environmental impacts for surface mining are contrasted with those produced by underground mining.

The scope of this work is limited and considers only the mining operations, primary and secondary crushing, spent shale disposal, material transportation, and storage of ore. The retorting process itself is not addressed.

Since the entire operation is not well defined at this point, potential impacts and generic controls are only identified in this report. During the next phase of the project, an Environmental Assessment will be performed and impact quantification done at that time.

Even though descriptions of the project and the existing environment were not specifically requested for this part of the report, they have nonetheless been included for the sake of completeness. This section, if desired, may be extracted from the rest of the report and used as the framework for the Environmental Assessment and EIS.

6.2 DESCRIPTION OF PROJECT

In order to supply a 50,000-BPD shale oil production operation, approximately 20 to 29 million tons of oil shale would be removed from the mine pit per year. To prepare the site for mining, vegetation would first be cleared. Topsoil and subsoil would be removed

and, as explained in the reclamation plan, may be segregated and stockpiled. Overburden (estimated to be approximately 800 feet thick) would be fractured by drilling and blasting, excavated, hauled by truck out of the mine, then conveyed to an initial waste disposal area. Removal of soils and overburden is completed progressively as greater ore exposure is required. It is estimated that 500 million tons of this material must be removed before mining operations can begin.

Oil shale would be recovered by drilling and blasting, then extracted with electric shovels. Ore would be trucked from the mine pit and then conveyed to the plant site for crushing and eventual retorting. Any waste rock recovered with the ore would be transported to the initial overburden and spent shale disposal areas during the first few years and then to the box cut.

A migrating open pit concept is planned proceeding from west-southwest to east-northeast. When the pit becomes sufficiently large (projected to be after 3-1/2 years of mining), backfilling of the western walls of the pit would begin using overburden, waste rock, and spent (processed) shale. Rehabilitation of back-filled areas would begin as soon as practicable. Crushers would be of the rotary type. The primary crusher would reduce the oil shale to minus 12-inch size. The ore would then be conveyed to a secondary crusher. The operation would be regulated so that minimal reserve and emergency stockpiling would be needed. Any stockpiles would be open rather than enclosed or covered. The secondary crushers would further reduce the ore in size.

Support facilities considered with the surface mining concept include office buildings, shops, a water control dam, water, oil and sewage pipelines, and electric transmission lines. The process water reservoir and other process facilities and products are omitted from this report except for processed shale disposal.

Until the pit is ready to accept waste, the processed (spent) shale will be disposed of with the overburden and waste rock in large disposal areas in natural canyons. Disposal will begin as close to the head of the drainage as possible and progress down-slope. A dam will be constructed at the head of the disposal area, and any water behind the dam will be diverted around the disturbed area.

6.3 DESCRIPTION OF THE EXISTING ENVIRONMENT

6.3.1 Physiography

NOSR 1 is an area of approximately 35,000 acres located in the southeast corner of the Piceance Creek Basin. The Roan Cliffs form the southern and eastern borders with NOSR 3. NOSR 1 is high country with elevations ranging from 7,800 feet to more than 9,300 feet. The terrain is generally rolling, with ridges and valleys. Slopes are moderate to steep.

The surface expression on the Roan Plateau is the result of dissection and erosion of the Tertiary Uinta Formation which is predominantly sandstone with thin beds of marlstone and oil shale. To the east and south, topography is represented by the older Tertiary Green River Formation, whose upper members are predominantly marlstone and contain the principal oil shale units.

The area has a substantial potential for erosion and mass wasting. Sheet wash or rill and gulleying may result on poorly vegetated slopes. The mechanism of rock creep is active in warmer months. Solifluction occurs during colder months. Slumps and mud flows result from rapid melting episodes in spring. Landslides and rock slides are generally restricted to steep valley walls along the lower reaches of Parachute Creek and would not be common on NOSR 1. Seismic activity is low. Epicenters of recorded activity are not in the immediate area. Active faults have not been observed (Energy and Environmental Analysis, Inc., 1978).

6.3.2 Climate

The climate in the Piceance Basin is classified as semiarid. Precipitation is low and the annual averages vary between 12 and 24 inches. The evapotranspiration rate is very high. Most precipitation occurs as winter snows. Characteristic storms are of long duration and low intensity and occur throughout the western Colorado region, while summer thunderstorms are usually short but intense (ARCO Coal Company, 1979).

The mean minimum temperature is 10°F and occurs in January and the mean maximum temperature is 90°F occurring in July. The mountains generally protect the area from severe cold fronts; however, temperatures may drop to -40°F.

6.3.3 Meteorology and Air Quality

During the night or when cloudy daytime conditions prevail, there is generally weak surface layer drainage flow. This results in surface-based inversions of up to 300 meters (which may prohibit pollution dispersion). This condition changes when the sun has sufficiently heated the surface at around 10 or 11 a.m. At this time upslope flow occurs and is generally toward the northeast.

NOSR 1 and the southern Piceance Basin are characterized by usually low concentrations of SO₂, NO_x, CO, total hydrocarbons and ozone. Monitoring indicates that violation of the National Ambient Air Quality Standard (NAAQS) 24-hour averaging time for particulate emissions is not uncommon. These values are attributable to natural fugitive dust sources. Most of the dust particles exceed respirable size. Nonmethane hydrocarbon measurements are also higher than the 24-hour averaging time NAAQS. These levels are believed also to be from natural sources, such as vegetation. Visibility in the Piceance Basin is high. At Tract C-b (an

Occidental Shale development in close proximity), baseline monitoring determined a mean visual range of 79 miles (Occidental Oil Shale Incorporated, 1976).

Located approximately 45 miles to the northeast of NOSR 1 is the Flat Tops Wilderness Area. This is a PSD Class I air quality area.

6.3.4 Water Resources and Quality

NOSR 1 is in the upper Colorado River drainage system. The area is drained in a western direction by the eastern tributaries of Parachute Creek. This drainage direction is dictated by a northwest trending syncline (Energy and Environmental Analysis Incorporated). Streams in the northern portion of NOSR 1 include the Corral Gulch, Trapper, and Northwater Creek. The southern portion is traversed by Ben Good Creek and the Parachute East Fork. Several intermittent streams intercept these creeks. Flow is generally very low in late summer, fall and winter.

Surface and groundwater quality are presently being monitored. Other studies on the Piceance Creek drainages immediately northwest of the Parachute Creek area indicate that the pH is alkaline and ranges from 7.5 to 8.5. Carbonate alkalinity measured as mg CaCO_3 /liter water is high. Salinity increases downstream as low-quality groundwater enters the stream. In summer months, total dissolved solids may be even more concentrated because less water is available due to less precipitation, irrigation and evapotranspiration. Trace element concentrations are generally below the safe drinking water levels set by the U.S. Environmental Protection Agency (Skogerboe et al., 1979 and Weeks and Welder, 1974).

A report on the Parachute Creek drainage that is still in a preliminary stage suggests similar pH and trace metal concentrations. Salinity in Northwater Creek close to headwaters at NOSR 1 was

about 250-350 mg/l total dissolved solids (Patt et al., 1980, in press).

Groundwater aquifer flow and quality studies are not available at this time. Generally in the Piceance Basin, a high alluvial aquifer exists in stream valleys only. Lower aquifers occur in the Green River Formation. They are recharged at the margins of the Piceance Basin where outcrops of the aquifer allow direct infiltration of precipitation and in higher stream valleys by downward percolation through alluvial deposits. Flow is down dip to the northwest toward the basin center (U.S. Department of the Interior, 1973).

Dissolved solids concentration (salinity) in the aquifers of the Green River Formation ranges from 250 mg/l to 63,000 mg/l. Primary ionic constituents are calcium, magnesium and bicarbonate. Generally lower aquifers are more saline and the concentration increases toward the central basin where known nahcolite (NaHCO_3) and halite (NaCl) deposits occur (U.S. Department of the Interior, 1973 and Saulnier, 1978).

6.3.5 Ecology

6.3.5.1 Soils and Vegetation

Soil types and depths vary considerably according to slope exposure and vegetation. Podzolic soils underlie the higher, more forested north and east facing slopes. Chestnut soils have formed on dryer southern exposures. Chernozem soils occur under better developed grasslands.

Vegetation communities on NOSR 1 include some conifer, aspen and juniper forests at the higher elevations, but grasses, mountain shrubs and sagebrush dominate. Ground cover is dependent on topography, water availability and slope exposure. No specific

data are available at this time regarding the occurrence of rare, threatened or endangered plant species on the tract.

6.3.5.2 Terrestrial Wildlife

NOSR 1 is a summer range for elk and an important winter range for deer. The Rocky Mountain mule deer is the most predominant species (Al Whittaker, Colorado Division of Wildlife, pers. comm., 1980). Small game mammals include the cottontail rabbit (Sylvilagus audubonii), snowshoe hare (Lepus americanus), pine (red) squirrel (Tamiasciurus hudsonicus), and white-tailed jackrabbit (Lepus townsendii) (Energy and Environmental Analysis, 1978).

Coyote, beaver, muskrat, weasel, mink, marmot, prairie dog, raccoon, badger, bobcat, spotted and striped skunk, squirrel, chipmunk and fox are also inhabitants of the Naval Reserves. No wild horses have been observed on NOSR 1. The only mammalian endangered species that may be present in the area is the blackfooted ferret (Ron Joseph, U.S. Fish and Wildlife, pers. comm., 1980). Its presence has not been documented.

Game birds may include blue grouse, chukar partridges and some ducks. There may be critical habitats for blue grouse, ringtail cat and chukar partridge. Endangered species in the general area may include the peregrine falcon and the bald eagle (U.S. Fish and Wildlife, pers. comm., 1980 and Division of Wildlife, 1978).

There are no reports of sightings or nests at this time.

6.3.5.3 Aquatic Life

Research is presently underway at NOSR 1 for aquatic organisms, microorganisms, amphibian aquatic life and reptiles. Known fish in the area are native brook trout and mountain suckers. They may occur in Trapper Creek, Northwater Creek, First and Second Anvil Creek, and the East and East Middle Forks of Parachute Creek.

There are unconfirmed reports that native cutthroat trout live in Northwater Creek. The Colorado River cutthroat trout is a likely inhabitant of the area and is on the state threatened species list (Energy and Environmental Analysis, 1978). There are no reports of the state threatened razorback (humpback) sucker or the federally and/or state endangered bony tail chub, humpback chub or the Colorado squawfish in the Parachute Creek drainage (ARCO Coal Company, 1979 and Division of Wildlife, 1978).

6.3.6 Other Characteristics

There are limited fishing and hunting on NOSR 1 because of accessibility. Some livestock grazing occurs on the Naval Reserve. BLM is encouraging grazing on higher slopes by constructing rain catchment basins. This helps to prevent overgrazed areas in the lowlands and valleys.

Presently archaeological and historical surveys are underway by TRW. The results have not yet been released. Socioeconomics are not being addressed in this report.

6.4 OVERVIEW OF ENVIRONMENTAL IMPACTS

The unavoidable negative impacts on the environment from construction, surface mining, materials handling, crushing, and overburden and spent shale disposal operations will be discussed in this section according to the major environmental disciplines of air, water, terrestrial ecology, and aquatic ecology. Other miscellaneous impacts are also identified. The impacts will be described in terms of the nature, scope, magnitude, localization, irreversibility, and cumulative effects of the impact.

6.4.1 Air

In general, air quality impacts are expected to be one of the more significant environmental impacts. In terms of scope, the air pollutants which would be emitted that may affect the environment include particulates, carbon monoxide, NO_x , and hydrocarbons. Negligible amounts of SO_2 are anticipated from the construction, mining, material handling, and crushing activities.

Of the pollutants, the one with the greatest potential for impacts would be particulates. Fugitive dust emissions would be high throughout construction and operation. Controls would significantly reduce the impacts; however, dust controls during dumping of solid wastes into the mine as backfill or into the initial disposal areas would be expensive and complex. Depending on wind patterns and velocity, the main particulate impact is expected to be localized around the project area. This would occur since the relatively large particle size would cause the particulates to settle at a fairly close distance around the operation. At certain times, however, the particulate impact may be more widespread. Modeling would indicate whether and how frequently the Flat Tops Wilderness Area, approximately 45 miles to the northeast, would be affected by NOSR 1 operations. The actual impacts that may be associated with the dust may include reduced visibility, reduced plant photosynthesis, and inhalation by wildlife.

Wind erosion of spent shale disposal areas could increase particulates and associated polycyclic organics, but moisture additions and other controls should minimize this event. The small amounts of CO , NO_x , and hydrocarbons would be produced primarily by vehicular and diesel equipment. These pollutants would be in much smaller quantities and dispersed by the winds into a much larger area than particulates, and their impacts thus minimized.

6.4.2 Water

Construction, mining, stockpiling, and solid waste disposal may have an impact on the water quality of the area. This would include surface and groundwater systems.

Clearing of vegetation for construction and mining would increase the potential for soil and sediment erosion, which is high naturally. Soil would be removed, stockpiled, and stabilized as soon as practical after clearing to prevent soil quantity and quality degradation. Underlying sediments would then be subject to water erosion. This would be particularly severe during rapid melting episodes in early spring and intense rainstorms. Sheet erosion and mud flows could be anticipated. Scheduling earthwork during drier seasons whenever practical, stabilization efforts, and sedimentary traps would reduce the degree of erosion and minimize the potential for stream quality degradation.

Similarly, there is a potential for the leaching of contaminants out of the stockpiles and waste disposal areas into the ground and surface water. Possible leachates may include organic compounds, alkaline elements, boron and fluorine, and other trace elements not volatilized during retorting. These chemicals may cause some degradation in water quality. Safe levels of unwanted substances in water depend on exposure time, organism type and condition, and specific compound associations.

Other sources of water quality degradation would include accidental release of mine waters, which may be high in dissolved solids and certain elements including boron and fluorine, and accidental hydrocarbon spills from equipment, transfer facilities, and storage tanks. With proper controls, impacts would be minimized if these events ever occur.

The potential for leaching of spent shales is dependent on the retort process selected but is considered low. With compaction, oil shale residue, low in carbon or shale ash, undergoes a natural surface cementation process that expedites stabilization of the pile, retards leaching, and reduces infiltration. TOSCO-processed shale has a high carbon content, but the carbon coating tends to prevent water penetration and inhibits percolation-type leaching (U.S. Department of the Interior, 1973). Furthermore, studies on spent shale indicate that permeability decreases with time. One possible explanation for the decrease is the swelling properties of shale resulting from hydration effect of the sodium ion. Another is "progressive interstitial packing of the various sized particles" Ward et al., 1971. High evapo-transpiration and limited precipitation rates further tend to reduce this impact (U.S. Department of the Interior, 1973).

Snow melt penetrates further into the processed shale disposal pile but its actual leaching capability is less than that of rainfall. Snow melt has a greater potential for causing slope instability in the upper few feet of the refuse pile. Slope failure could impact water quality as additional waste material is added. Reclamation and revegetation plans include stabilization of the pile after it has reached its full height.

Mine dewatering operations may affect aquifer flow rates and recharge in other areas of the Piceance Basin. Spring and seep rates could also be reduced in the immediate area, possibly affecting wildlife water availability. Similarly, the groundwater discharge to surface streams may be altered. Water degradation may also result as reduced flow further concentrates constituents in the water, such as total dissolved solids.

These effects will be cumulative as mining continues through the years. The seriousness of these impacts cannot be assessed without the results from the water studies presently being performed.

Mitigating measures may include treatment of some of the mine water and controlled discharge into affected streams. Catchments could be provided for wildlife use to supplement the diminished springs. Subsurface injection into lower highly saline water aquifers may have a long-term beneficial effect.

Mining would alter local surface drainage patterns and possibly aquifer recharge for a considerable period of time. Such large amounts of material would be removed that the impact could be major. Restoration of groundwater flow would be complicated by the fact that spent shale would also be used to backfill the mine pit. Unlike fractured overburden, spent shale would have a low permeability. Research is needed to determine the leachability of spent shale by groundwater contact.

6.4.3 Terrestrial Ecology

During construction and throughout the life of the operation, approximately 180 acres of wildlife habitat would temporarily be disturbed to support the mining and processing facilities, conveyors, and roads. Possibly 200 additional acres would be disturbed per year by mining and waste disposal. The reclamation and revegetation program would progressively restore habitat as mining operations proceed. Thus, the actual area unavailable as wildlife habitat at any one time would be much less than the total area disturbed during the life of the mine.

The degree of impact would depend on actual mine, disposal, and facility sites selected. Terrestrial inhabitants are dependent on relatively localized vegetation community types. The animals impacted would differ if the area to be disturbed supports an aspen forest, a mountain shrub, or a grassland ecosystem.

Disturbance of deer winter habitat may result. Many animals would migrate elsewhere, thus causing slight overcrowding of the remaining habitat.

However, since major construction would occur primarily in the summer months (May to November), the impact would be reduced.

Other impacts on wildlife would include alteration of movement patterns due to obstructions created by the construction and mining activities. Vehicle collisions would increase loss of life. Road construction could also increase public accessibility for hunting and offroad vehicle recreation, further reducing wildlife population numbers. Mine dewatering could reduce surface and spring water flow, thus reducing wildlife water supply. Noise from blasting, mechanical equipment, haul trucks, conveyors, and crushers may have a temporary impact. However, most animals will acclimate to the noise or leave the area. Careful wildlife protection and management plans would minimize the impacts discussed above.

Long-term effects of recontouring, restructuring surface and underground water systems and revegetation are unknown. Consequently, long-term impacts on wildlife cannot be predicted with certainty. However, it is felt they will be minimal.

6.4.4 Aquatic Ecology

Direct impacts on aquatic life during construction may result from increased sedimentation and turbidity. Light penetration reduction could reduce primary productivity of a stream and, if persistent, affect fish populations. High turbidity may cause an increase in water temperatures that could have significant impacts on cold-water species. Increased sedimentation could reduce aquatic insect populations which act as a food source for the fish. Erosion and water quality controls would minimize these impacts.

Stream diversions would alter the existing aquatic habitat and may reduce the habitat somewhat if channel length, depth, or width is

lost. Temporary loss of riparian vegetation due to stream relocation, road encroachment, or other construction would impact the quality of the aquatic habitat. Expedient revegetation efforts would reduce the severity of this effect.

It is possible that accidents involving the release of poor quality water or spills of oil or hazardous substances may occur and impact the aquatic environment. The severity of the effects will be dependent on the nature of the substance spilled, the amount, location, length of time of release, and control and cleanup efficiency. A good Spill Prevention and Countermeasure Contingency Plan (SPCCP) would reduce the potential for serious accidents occurring in the aquatic systems.

Mine dewatering may cause a reduction in surface water flow which could alter the existing aquatic habitat. Flora and fauna may progressively change to more drought-resistant species. An alternative may be to augment the stream flow with mine water treated to attain a water quality comparable to that in the stream, whenever excess mine water is available.

6.4.5 Other Resources

Depending on specific sites selected, there may be some loss of grazing lands, but it may be possible to substitute other areas on tract NOSR 1 outside of the mining disturbance for the area lost.

Some scenic and relatively undisturbed land would be affected. Temporary visual impacts would include the buildings, roads, conveyors, powerlines, and other right-of-way corridors. Permanent alteration of landscape would result from the mine pit and the waste disposal piles. With recontouring and revegetation plans, long-term aesthetic impacts could be minor.

Certain minor historical and archaeological resources may be lost permanently. Appropriate surveys would be conducted to avoid such loss. (See section on Environmental Control.)

Socioeconomics are not discussed within the scope of this report.

6.5 COMPARISON OF SURFACE AND UNDERGROUND MINING ENVIRONMENTAL IMPACTS

Comparison of surface and underground mining does not establish a definite answer as to which is more environmentally favorable. Impacts to different parameters can be compared, but their intensity and "weight" in the overall environmental system are not readily determinable. Subjectivity cannot be avoided when one compares impacts to the water system with impacts to air quality or health and safety.

Table 6-1 presents parameters and a simple statement for each regarding whether or not impacts are greater for surface or for underground mining. As one can see in this table and in the discussions in the text, underground mining results in less impacts to air quality, surface land disturbance, water quality, aesthetics, and cultural resources. However, underground mining would be much less safe for employees. Furthermore, the ultimate effects of subsidence after underground mining may be greater. These parameters have not been sufficiently researched to make valid assessments at this time.

6.5.1 Air Quality

Underground mining would produce significantly less fugitive dust emissions than surface mining. Underground mining requires an extremely efficient ventilation, dust, and gas collection system; thus, particulates could be more readily controlled and federal

Table 6-1. Comparison of Environmental Effects of Underground and Surface Mining

<u>Environmental Aspect</u>	<u>Alternative with Least Adverse Environmental Impact</u>	
	<u>Underground</u>	<u>Surface</u>
● Air Quality	X	
● Water Quality		
- surface	X	
- ground	?	?
● Land		
- surface disturbance	X	
- processed shale disposal		X
- subsidence		X
● Solid Waste	X	
● Terrestrial	X	
● Aquatic	X	
● Safety		X
● Aesthetics	X	

NAAQS more easily attained. The potential for air quality impacts, such as reduced visibility, reduced photosynthesis, and inhalation by wildlife, is thus considerably less in underground than surface mining.

The underground mining and the surface mining concepts both require surface construction of facilities, conveyance of the primary crushed ore product to a plant for fine crushing, and conveyance of spent shale to temporary and permanent disposal areas until backfilling operations begin. These are all sources of particulate emissions. Underground mining, however, would not involve transportation and disposal of large amounts of overburden; therefore, this substantial source of particulate emissions is eliminated.

6.5.2 Water Quality

Underground mining has less impact on surface water than surface mining, but produces more complications and uncertainties with respect to the underground water system.

6.5.2.1 Surface Water

Since no open pit would be developed and since there is essentially no disposal of overburden except for surface facilities, the amount of surface drainage area affected is much less for underground than surface mining. The natural drainage pattern would be less modified. There may be fewer stream relocations and diversions conducted, thus less potential for water resource adjustments and quality degradation.

The potential for sediment erosion is diminished since less area is disturbed and, consequently, impacts on the water quality due to increased sedimentation, turbidity, and chemical leachates may be minimized. The potential for contamination of stream water by accidental hydrocarbon spills or from mine water release is the

same for both mining options in terms of large quantity storage vessels. There is less chance of surface runoff with chemical leachates accidentally entering the surface water system, because less runoff water is collected and impounded.

6.5.2.2 Groundwater

Groundwater recharge impacts during mining operations would be similar for surface and underground mining. Dewatering wells may be required in either case to keep water below the working face. The withdrawal of large quantities of water may have significant impacts on a large area of the Piceance Basin. Disposal problems and impacts would be similar.

The primary difference in the two mining concepts, with respect to groundwater, is that backfilling of an open mine pit may allow some restoration of aquifer flow whereas after underground mining there are areas of very large openings. Water passageways may be large, but often not continuous. Water may collect, stagnate, and become contaminated with leachates because of prolonged exposure to minerals. The unpredictabilities from underground mines are compounded by the occurrence of subsidence. As long as the earth continues to settle, the underground aquifer system would be disrupted.

6.5.3 Land

6.5.3.1 Surface Disturbance

An underground mining operation would demand significantly less surface acreage disturbance because no pit is excavated, and there is little overburden to be disposed. Land requirements for processed shale disposal would be greater for underground mining since a pit would not be available. Land requirements for support facilities and stockpiling would be similar in the surface and

underground concepts. The amount of surface disturbance contributes quantitatively to impacts on air and water quality, terrestrial and aquatic ecology, and aesthetics. Additionally, archaeological and historical resources may be affected.

6.5.3.2 Subsidence

Subsidence refers to the downward movement of overlying sediments as they settle and fill the voids left underground from the excavation of ore. The room-and-pillar method causes less subsidence than other underground mining methods currently practiced. The extent of subsidence from room-and-pillar mining depends on size and spacing of the rooms and pillars, physical properties of the formation, and depth of overburden (U.S. Department of the Interior, 1973). Estimates could be made regarding the probable amount of subsidence, but there is a high level of uncertainty. It should be noted that the area to undergo subsidence may be as large as or larger than the area disturbed with an open pit.

Subsidence could occur over a very long period of time. The land would be unstable for surface development for an indefinite period of time. Cracking as the earth sinks would increase sediment erosion and possibly impact water quality. Vegetation and consequently habitat could be disrupted during movement. The greatest impact may be to the groundwater aquifers. Movement may disrupt the flow systems that may have become established after mine dewatering activities cease.

6.5.4 Solid Waste Disposal

Non-process wastes other than waste rock would be of similar quantities and have similar impacts in surface and underground mining operations. Waste rock disposal differs significantly in that overburden is not removed in underground mining. Thus, surface disturbance is reduced and more aquatic and terrestrial habitat

retained. The potential for air and water erosion decreases. Thus, impacts that cause air and water quality degradation are reduced. Aesthetic and cultural impacts may be decreased.

6.5.5 Terrestrial Ecology.

The fundamental difference between underground and surface mining with regard to terrestrial flora and fauna concerns the amount of vegetation to be cleared and habitat to be temporarily removed from wildlife use. Underground mining would have significantly less short-term and possibly long-term impacts since the effects of recontouring land, restructuring surface drainage patterns, and revegetation over time are unknown.

Additionally, with underground mining there may be flexibility in selecting a location for mine shafts, portals, and related facilities, so certain sensitive habitats that could not be avoided using surface mining could be preserved using underground mining techniques. Wildlife movement patterns would be less affected by underground mining. Fewer surface stream relocations or diversions may be required in underground mining; thus, wildlife habits may require less alteration. Mine dewatering operations could affect the water supply of wildlife regardless of which concept is selected.

Underground mining reduces the potential for air and water quality degradation and the resulting impacts of unfit water for drinking, particulate inhalation, plant toxicity, and reduced photosynthesis. With the mining and primary crushing facilities underground, noise impacts are reduced. Traffic and, therefore, vehicle-wildlife collisions would probably be of the same magnitude with both underground and open pit mining.

6.5.6 Aquatic Ecology

Less surface area disturbance with underground mining may reduce impacts on aquatic ecosystems. Fewer stream relocations or diversions would reduce aquatic habitat loss or alteration. The decreased potential for particulate fall-out, sedimentation, turbidity, and the subsequent light penetration effects would further indicate that underground mining has less impact on aquatic ecology.

The possibility of oil spills impacting the aquatic habitat is approximately the same for both concepts in terms of large quantity storage. Due to less run-off, there may be slightly less chance of accidentally releasing water contaminated with leachate into surface streams. Mine dewatering effects that could reduce stream flow would be similar for both types of mining operations. Long-term effects of groundwater recharge on surface stream flow are largely unknown. It is possible that underground mining may be more disruptive to the recharge system than surface mining.

6.5.7 Health and Safety

In terms of accidents, deaths, exposure to noise, dust, and gases, underground mining would have a greater impact on the human population than surface mining. Since in an underground mine there would be a larger number of workers in confined spaces, the occurrence of accidents and deaths would be greater than in a surface mine. These accidents could include electrical and blasting accidents, roof falls, and equipment accidents. Most of these accidents would occur at a higher frequency in an underground mine as compared to a surface mine.

Exposure to noise, respirable dust, and gases would also be greater in an underground mine. This is largely due to the fact that the ventilation within an underground mine would not disperse the pollutants as well as in an "open-air" surface mine. There is a

possibility that some of the pollutants will become concentrated within an underground mine.

6.5.8 Aesthetics and Cultural Resources

Aesthetically, an underground operation presents less visual impacts. Less land is stripped barren and natural form disturbed. Less waste disposal areas are created and fewer canyon environments altered. Less dust is emitted to affect visibility and cause a nuisance. Aesthetic impacts from surface mining are largely temporary and may be eliminated after abandonment and reclamation. Underground mining may produce postmining and unpredictable aesthetic effects with subsidence. This may continue for an indefinite period of time.

Since less area is affected, historical and archaeological impacts may be less for underground mining. A certain flexibility in locating shafts and facilities may allow avoidance of certain sites that would be eliminated by surface mining operations.

6.6 RECOMMENDED ENVIRONMENTAL CONTROLS

The impact of detrimental environmental effects can be reduced substantially by careful control. Some general controls have been identified as mitigating measures in the previous section on environmental impacts. A more detailed discussion of environmental controls is presented below.

These recommended conceptual controls must be tested for effectiveness throughout every stage of the project. Further baseline data collection may indicate necessary changes in engineering design. Field monitoring of air quality, water quality and habitat during construction would determine whether or not additional controls are required. Throughout mining operations and even after abandonment, certain monitoring and maintenance must continue to assure

that unanticipated impacts or violations of regulations do not occur.

6.6.1 Air Quality Control

Best Available Control Technology (BACT) would be followed for the operation, as necessary. This level of control has been defined by the EPA.

6.6.1.1 Dust (Particulate Emissions)

As discussed in the environmental description, it is not unusual for particulate emissions in the Piceance Basin to exceed the 24-hour NAAQS. The federal EPA contends that the high values are from natural fugitive emissions. The EPA's general policy is that new sources of dust can be constructed in this area if they comply with specified emission limitations and modeling indicates the the sum of the source's emissions, an acceptable background value, and emissions from other stationary sources in the vicinity do not cause violations of the NAAQS (Title 40 Code of the Federal Register Part 51). Thus, acquiring a Prevention of Significant Degradation (PSD) permit would be dependent on establishing adequate dust controls.

A Class I air quality area (the Flat Tops Wilderness Area) is located 45 miles to the northeast of NOSR 1. Modeling would be performed to determine specifically whether that area would be within impact distance. If so, dust control and collection systems must be sufficiently efficient to comply with federal and state PSD Class I particulate incremental standards and visibility standards.

Dust would be the primary potential pollutant controlled during construction, mining, material transport, crushing, and disposal operations.

Controls during construction of roads, conveyors, mine, and plant facilities would include the following:

- Clearing of vegetation and topsoil stripping would be minimized to only that which is absolutely necessary for the operation. The time before the construction activity is scheduled to begin would be minimized.
- Routes would be designated and traffic would be restricted as much as possible to active construction areas and developed roads. Speeds would be controlled.
- Roads and conveyor corridors would be compacted and wetted regularly by trucks or other spray systems.
- Dust palliatives such as polymer or latex solutions would be used where practicable to extend coverage and conserve water.
- Penetration chemicals, such as lignin sulfonate, could be applied on more heavily traveled routes or on parking areas.
- Main access roads and parking areas would be paved.

During overburden removal and mining operations, water for sprays and dust suppressants would be used in the mine to control dust. Equipment operators in the pit could work in enclosed cabs to reduce dust inhalation. Drilling and blasting procedures would be carefully controlled to minimize the disturbance.

Before loading ore, the oil shale piles may be sprayed if the moisture level is low. Haul roads would be compacted as necessary and frequently wetted or treated with dust palliatives. Haul trucks

could pass under a spraybar if the load is very dry. However, the haul to the conveyor may be sufficiently short so that dust emissions are insignificant.

Conveyors to transport overburden, raw shale, waste rock, crushed ore, and spent shale would be covered. Some of the material-handling transfer points could have dust collection hoods leading to a baghouse. At other selected points, water fog-spray equipment would be placed in strategic locations to control dust. Brushing or scraping units would clean the return belts. Dust and fines buildup under transfer points would be periodically cleaned out manually and the accumulated fines possibly put back into the system. The spray systems would use specific proportions of water and wetting agent compounds to extend coverage and conserve water.

Stockpiles would be sprinkled utilizing systems such as oscillating portable sprinkler heads mounted in dusty areas. This system would wet down active stockpiles and utilize pipes, valves, couplings, hose, and heads. Additionally, dust palliatives may be applied to further control fugitive dust. Note that the amount of moisture that can be added to shale stockpiles would be dependent on the retort process selected. If the process is sensitive to moisture, an enclosed stockpile with vents to the baghouse or a covered stockpile may be necessary.

The rotary crushers would be vented to a baghouse to control dust. Method of disposal of the collected dust would depend on the baghouse system selected.

Overburden and spent shale would be conveyed to the disposal area or mine pit and then dumped onto the pile or into the pit. Water-spraying would be used as required. Overburden would be relatively coarse, therefore excessive dust and wind erosion are not anticipated.

6.6.1.2 Vehicle and Equipment Emissions

Diesel and gasoline vehicles, and equipment for construction and operations would be accommodated with regulation exhaust controls. Frequent maintenance would keep emission levels low and performance and fuel efficiency high. At the mine site, electrical equipment such as shovels would be used wherever possible to reduce engine exhaust.

6.6.1.3 Open Burning

Open burning would be discouraged during clearing operations, construction, and mining activities. If unavoidable, permits would be obtained from the appropriate agencies.

6.6.2 Water Quality Control

Water draining into the active mining areas of NOSR 1 would be intercepted and diverted around the disturbed area. Existing perennial or intermittent streams would require relocation for water quality protection during mining and disposal operations. Stream channels would be reconstructed to provide comparable grade and conditions to support an equivalent aquatic ecosystem. Slopes would be revegetated as soon as construction is completed. The new stream channels would be considered permanent in that there is no need to redisturb the new aquatic ecosystem after the mining operation is abandoned.

Surface runoff from the disturbed area, including the mine pit, overburden and shale disposal areas and the building facilities, would be collected through an extensive ditch system and directed to strategically placed retaining ponds. Generally low amounts of runoff would be expected because of low annual precipitation levels and high evapotranspiration rates. Nonetheless the system would be sized to retain at least a 10-year, 24-hour storm for up

to 24 hours to allow settling of suspended solids. The system would also safely pass storms up to and including 100-year frequency. This water could be used without treatment to supplement the process water requirements for dust control, shale disposal compaction, or irrigation of newly revegetated areas.

All collection and diversion ditches would be designed with velocity and sedimentation reduction systems. Ditches and ponds would be cleaned routinely. During construction, when land disturbance is great, additional temporary sediment traps or dams would be added as needed to channels downstream from the construction area.

Flow from aquifers encountered during rock and ore extraction would be controlled by a mine dewatering system. Wells or sumps located strategically at the perimeter of the mining area would pump water through pipes to a retention pond lined with an impermeable material. Clay sources are in the area and this material is recommended. The lining would protect groundwater aquifers that may be lower in salinity than the deeper water encountered in the mining operation. Water seeping into the pit would also be pumped from the pit to the collection pond.

Field work is presently underway to establish underground aquifer and surface water flow rates and quality. All of the results have not yet been made available. Water quality control measures are dependent on these results.

Based on other studies in the Piceance Basin, it is possible that the mine water encountered and collected would need treatment before reuse or discharge. Boron, fluoride, and total dissolved solids (TDS) contents may be higher than in surface streams in the area and may exceed national and state standards. If mine water is ever discharged or is too poor in quality for process use, it may require treatment at least to recover water quality, by defluoridation, deboronization, or a desalting system.

Possibly during the entire mining operation the project could operate on a zero discharge concept using the mine water in processing streams for dust suppression and irrigation. If mine water intercepted ever exceeds quantities required for onsite uses, excess water could then be stored in a reservoir constructed at the head of a drainage. This water could then possibly be used for wildlife, agricultural, or recreational purposes, or other projects in the immediate vicinity.

Potable water sources have not been addressed in this report. A water treatment system would probably be necessary to obtain national and state drinking water standards. The level of treatment required would depend on the water source identified.

A sewage treatment facility would be required. A treatment plant could be designed to comply with the Colorado Department of Health standards.

Process water treatment system design is beyond the scope of this report.

6.6.3 Solid Waste Control

6.6.3.1 Nonprocess Solid Wastes

Nonprocess solid wastes defined in this section include paper, wood, and metal. During construction and operation, these solid wastes would be collected in covered steel containers sized according to the activity area which they service. Collection would be by compaction trucks. Disposal would be in a sanitary landfill in an area protected from flooding. Clay or some other impermeable barrier should form the base layer. The landfill could be located at the processed shale and overburden disposal site to utilize an already disturbed area. The sanitary landfill would be designed and operated in compliance with the Colorado Department of Health

and Garfield County regulations. Recyclable materials could be stored separately and could be collected by vendors or transported to a recycling center.

6.6.3.2 Mining, Sedimentary, and Process Wastes

Process wastes other than spent shale are not considered in this report. Spent shale would be disposed in the same areas as overburden and waste rock. Slopes would be maintained to prevent oversteepening and subsequent slope movement. Controls for preventing wind and water erosion have been discussed previously.

6.6.4 Oil and Hazardous Material Control

Designs and layout of chemical and fuel storage facilities, transfer and dispensing equipment would be selected with emphasis on avoidance of spills. In compliance with the U.S. EPA, a Spill Prevention Control and Countermeasure Plan (SPCCP) would be developed which includes planned measures for spill prevention and procedures for notification, containment of the substance, repair of faulty storage or transfer equipment, and cleanup in the event a spill occurs. Spill containment plans would include berms around storage tanks which would direct flow into the appropriate collection pond where oil separation or appropriate treatment can occur. Backup catchments would be constructed downhill of facilities in case spillage is not contained by the berms.

Pesticide, herbicide, and rodenticide applications would be limited to areas and amounts fundamental for maintaining health and safety standards and eliminating fire hazards. Federal, state, and local regulations would be observed and permits obtained for storage and dispensing of these chemicals.

6.6.5 Fish and Wildlife Management

6.6.5.1 Terrestrial Wildlife

Air quality, water quality, and noise controls discussed previously would contribute to mitigating effects on terrestrial wildlife. Further protection of wildlife could include placing fencing around certain potentially hazardous facilities such as impoundments. Employees could be educated in safe driving techniques to reduce animal-vehicle collisions. Speed limits should be controlled. Off-road vehicle use would be restricted. Depending on migration patterns, underpasses and overpasses may be included in road and conveyor designs.

Mitigation of habitat loss would result from reclamation and revegetation of disturbed areas. This would occur to some extent during the construction, mining, and processing operations but would primarily take place upon abandonment. These plans are discussed in more detail in the Section 6.7, Preliminary Reclamation Plan. Careful planning would assure that slopes of appropriate elevations, steepnesses, and exposures would be planted such that habitats are optimized to support the large variety of wildlife species presently in the area. Migration patterns would also be considered and incorporated into the abandonment plans.

6.6.5.2 Aquatic Life

Aquatic habitat would be protected from the effects of sedimentation and turbidity by the erosion control measures discussed under air and water quality control. Any necessary stream relocations would be completed quickly and a habitat provided which will simulate the former stream channel. Streams would be relocated only once and channel slopes revegetated or stabilized immediately. No further disturbance of the new habitat should occur. Any accidents damaging to water quality should be cleaned up efficiently according to contingency plans.

6.6.6 Noise

Noise generated during the mining operation may at times exceed 90 dBA. Some operators may therefore be encouraged to wear ear protection or reduce exposure time. The noise generated would be well below 90 dBA before it would reach the nonworker community population. The conveyors and crushing facilities would also generate some noise. Noise reduction equipment on the machinery or enclosure would minimize the impact.

6.6.7 Health and Safety

A program of employee protection and accident prevention would be prepared in compliance with the Mine Safety and Health Administration regulations and the Colorado Department of Natural Resources, Division of Mines. Instruction of employees in safety procedures would be performed. Required reports and logs of accidents and damages would be kept. Employees would not be allowed to be exposed to levels of air contaminants or noise that would exceed health and safety standards. Drinking water and sanitation standards would be observed to protect personnel.

Explosives storage, handling and usage would be executed in compliance with federal and state regulations and necessary permits would be acquired. Explosives users would be properly trained, experienced, and licensed.

6.6.8 Fire Prevention and Control

In compliance with the Mine Safety and Health Administration and the Colorado Division of Mines, employees would be trained in fire prevention and safety skills. National Fire Prevention Codes would be followed during the design, construction, and operation of the project. Fire extinguishers and other fire-fighting equipment would be located strategically and workers would be informed

of their locations. Combustible trash would be stored in metal containers. Stockpiles would be located a minimum of 50 feet from buildings and facilities. They would be inspected closely so that spontaneous combustion, if it occurs, is detected and extinguished rapidly.

6.6.9 Aesthetics

A clean and attractive operation is important for public and agency relations, for employee satisfaction, and to avoid accumulating cleanup and unnecessary abandonment tasks.

The project would be designed to be as compatible with the existing landscape as possible. Contours would be rounded to reflect the rolling nature of the terrain. Benches and terraces would interrupt long slopes. Large disposal piles would be constructed with more natural-looking contour lines rather than exhibiting a continuous line.

Colors of buildings and facilities would be earth tones or muted shades of brown, green, red, and gray. Bright colors would not be used. Signals and signs would be easily recognized but not garish. Clearing of vegetation would be minimized. At transmission line corridors, only large vegetation would be removed, i.e., topping of tall trees. A multiple-use corridor would be identified for pipeline and utilities. If possible, the corridor should utilize natural clearings and would transverse ridges in natural depressions.

6.6.10 Archaeological and Historical Resources

Surveys are underway on NOSR 1 to identify cultural resources. Archaeological finds worthy of study would be marked and protected throughout the operation or else fully studied before construction begins. Other archaeological discoveries which indicate only short-period occupancy would be avoided if possible. If not, they

would be further explored prior to mining development and protected if the investigation indicates they are of significant importance.

Paleontological finds would be protected if they are rare or of considerable importance. Significant historical discoveries would also be avoided if they were found. Employees would be advised not to damage any discovery that may be found later, after construction had begun, and would be informed of procedures for notification of finds.

6.7 PRELIMINARY RECLAMATION PLAN

The objective of the reclamation plan for the NOSR surface mining and retorting project is to restore disturbed areas in a timely manner to conditions that are capable of supporting the original land use and readily adaptable to other uses. The primary existing land uses are wildlife habitat and livestock grazing. The surrounding Piceance Basin area has had similar uses but is presently also developing oil shale and oil and gas exploration and recovery operations.

Rehabilitation would be directed toward minimizing or eliminating soil erosion and water pollution. Final contouring and vegetation would be compatible with the surrounding undisturbed or restored areas. Rehabilitation of surface disturbances would, to the highest degree practicable, be concurrent with the mining and retorting operation.

Preliminary plans based on industry practice for reclaiming and revegetating disturbed areas are discussed in the following paragraphs. These plans are the basis for the costs developed in the mining plan. A detailed reclamation and revegetation plan should be prepared when sufficient site-specific data become available.

6.7.1 Preoperational Issues

6.7.1.1 Literature Review

Much research has been published regarding revegetation of western Colorado mining sites. This includes literature specifically concerned with productivity of raw and spent shale piles. A partial bibliography of 64 references has been compiled by Kaiser Engineers. This should be utilized and expanded during the preliminary engineering phase of the surface mining study.

6.7.1.2 Initial Small-Scale Field Testing

Using available literary information, tests of different topsoil, subsoil, overburden, other excavated materials and spent shale combinations should be designed and performed along with neutralization, fertilization, seeding, mulching, irrigation and slope stability tests. These tests would apply baseline data to conditions similar to actual operations and result in a realistic reclamation plan.

6.7.1.3 Post-Mining Comparison Plot

A natural vegetation area should be established prior to any construction. This plot would provide a control area for comparison with revegetated areas at the conclusion of mining.

6.7.2 Heavy Equipment Operations

6.7.2.1 Removal and Stockpile of Topsoils

Soils would be surveyed in areas to be disturbed (including mine site, plant site, waste disposal sites, access construction and other support areas) for identification of soil mapping units, unit boundaries, and establishment of topsoil depths. The field

tests discussed previously would indicate soil and overburden suitability for sustaining vegetation. In accordance with the Colorado Mined Land Reclamation Act, the Colorado Mined Land Reclamation Board would determine whether the topsoil is of sufficient quantity and/or quality to sustain vegetation. If the topsoil is satisfactory, it would be removed prior to surface disturbance and would be segregated from other spoils and stockpiled for reuse as soon as practicable. Removal of usable topsoil would be executed with earthmoving equipment conventionally used on the particular slope and soil conditions encountered. In areas where it is determined that the topsoil is insufficiently productive, it would be removed only if required for construction purposes.

Unless topsoil is 18 inches or thicker at the mine and the overburden and spent shale disposal sites, subsoil would also be removed in those areas immediately following topsoil removal. Subsoil would be segregated and stockpiled for later reuse. Underlying topsoils with subsoils assist in revegetation by supplying more nutrients and moisture than would be available if topsoil is lain directly on overburden or spent shale. Contrarily, if clay subsoils are encountered that may interfere with plant growth, they would be removed but not stockpiled. If possible, the clay would be utilized as lining for sedimentation ponds or sealants for other wastes.

Prior to soil stripping, vegetation that would hinder the removal operation would be cleared and evaluated for possible reuse (transplanting or as cover material). If unusable, vegetation would be burned or disposed of in a manner acceptable to the regulating agencies.

Close monitoring during earthwork activities would be performed (1) so that differences between actual field conditions and data produced during field mapping can be detected, (2) the clearing and stripping area is minimized, and (3) topsoil or material to be stockpiled is handled so as to avoid loss or contamination.

Stockpiled material would be protected from wind and water erosion and from materials, such as clays, which might lessen its capability to support vegetation. This would be done by seeding or planting stockpiles with nonnoxious plants or by other approved methods. Markers would be posted at all predesignated soil stockpiles. Soil stockpiles would not be located in drainage areas. Topsoil and subsoil removal would be performed according to a schedule that would make every effort to minimize time between surface disturbance and construction. This would reduce erosion potential. In the mining area and in the processed shale and overburden disposal area, the initial stripping would be approximately 1,500 acres. To the greatest extent possible, additional stripping would occur only as additional acreage is required. This would reduce number and amount of erosional controls and would preserve the maximum amount of wildlife habitat for the greatest time possible.

6.7.2.2 Replacement of Overburden

Overburden testing would be carried out for trace metals and for materials which may be detrimental to vegetation and water quality. These results may indicate other engineering design that should be done at a later date. Overburden would be disposed in the head of hollows of selected drainages until the pit is ready to be backfilled. Spent shale would be disposed of similarly. When operation of the retort facility begins, overburden and spent shale would probably be combined in the selected disposal areas. As the mine pit becomes sufficiently large to allow recovery equipment to operate efficiently and effectively, backfilling into mined-out areas would begin using overburden removed as the open pit migrates eastward and spent shale from the retorting process.

Replacement of overburden may be more difficult in the final cut area of the operation. It may not be economical or environmentally desirable to move all of the first workings of overburden to the

final cut because of distance and redisturbance of the previously rehabilitated area. It may also not be necessary to return all of the first workings of overburden since spent shale would have at least 12-percent higher volume than raw in-place shale (U.S. Department of the Interior, 1973). Thus, the additional volume of material to be disposed may eliminate a deep depression customarily left at completion of surface mining operations. Regardless of size of the final depression, the contours of the ultimate mine pit area would be graded to slopes less than 3h:1v. Water would be allowed to gradually collect in the hollow and then slope would be revegetated.

6.7.2.3 Reestablishment of Drainages and Contour

The overburden would be placed so that the final drainage and contour would approximate the original as closely as possible. As backfilling is completed, grading would be initiated to return surface contour and drainage according to preconstruction maps and profiles. Grading is also necessary to comply with stipulations such as those of the Colorado Mined Land Reclamation Act, which requires that operators grade to create a final topography appropriate to the final land use selected and return lateral stability of adjacent lands. Where range is the proposed land use, slopes would not be left which are too steep to be traversed by livestock. Long slopes may be benched or terraced with appropriate structures such as ditches or dikes to divert runoff into riprapped channels or erosion-resistant areas. Once the above goals are accomplished, the grading should immediately stop because of possible reduction of vegetative and aquifer quality and quantity due to the following:

- Decreased root penetration due to compaction
- Water pooling due to compaction

- Spread of isolated pockets of materials which may interfere with revegetation

On some slopes steeper than 3h:1v, conditions may be such that revegetation is impossible or impractical. In these areas, a rock cover (using overburden rubble if possible) or a retaining wall may be necessary to control erosion. Seeding may then be attempted on the rock-covered slopes or the slopes may be left for natural invasion (Occidental Oil Shale, Incorporated, 1978).

6.7.2.4 Temporary Erosion Control Measures

Where grading has been completed, but the season is not appropriate for seeding or where seeding episodes have not yet established sufficient vegetation, temporary cover for erosional control would be used as necessary. The need for cover is dependent on exposure, material, surface areas, steepness, and other factors. Cover material to be used would depend on the above conditions and also convenience, cost, ultimate purpose and effectiveness. Possible cover materials are riprap, straw, and emulsions (Gulf Oil Corporation and Standard Oil Company (Indiana), 1979).

6.7.2.5 Scarification of Backfill

Scarification or other treatment would be done before replacement of topsoil to eliminate slippage. This treatment would also promote root penetration and moisture retention.

6.7.2.6 Replacement of Topsoils

In construction cut and fill areas, salvaged topsoil would be spread in uniform layers at least 8 inches thick if sufficient topsoil is available. The topsoil surface would be left in a rough condition until just before seeding to protect against wind and water erosion. Topsoils would be handled in a relatively dry condition.

Where at least 4 feet of overburden material overlies the disposal or backfilled mining areas, 1/2 to 1 foot of subsoil would be replaced and covered with a minimum of 1/2 to 1 foot of topsoil if available.

If overburden is available (without adding to surface disturbance), processed oil shale would be covered with a minimum of 4 feet of overburden. The top 1 to 2 feet should be crushed rock rather than boulders. Subsoil of 1/2 to 1 foot in thickness would be emplaced and overlain with at least 1/2 to 1 foot of topsoil if available.

At the later phases and during final fill of the mining operations, overburden may not be readily available. It is possible to successfully establish vegetation directly on spent shale. This has been demonstrated in the TOSCO II project. The properties of TOSCO II spent shale affecting revegetation include a pH of 7.7 to 8.5, slightly but not excessively alkaline.

Nitrogen, phosphorous and certain minor nutrient concentrations are low. Soluble salt contents are very high. Studies have shown that saturated extract of TOSCO II processed shale gave electrical conductivity measurements ranging from 2.4 to 26 mmhos/cm.

Because of these spent shale characteristics it is recommended that processed shale be covered with at least 18 inches of soil to provide a nontoxic and better moisture-retaining medium. A cover totaling 18 inches of soil, with 1/2 to 1 foot of subsoil and 1/2 to 1 foot of topsoil is recommended. Experiments at Occidental Tract C-6 indicate this to be adequate (Ed Baker, Occidental Reclamation Specialist, personal comm., July, 1980).

6.7.2.7 Scarification of Topsoil

Scarification along graded slope contours may be necessary to loosen replaced topsoils that have been excessively compacted by the operation of reclamation equipment. Replaced topsoil would be tested prior to seeding to determine requirements for ripping.

6.7.3 Revegetation Operations

6.7.3.1 Seedbed Preparation

The preferred time to plant seeds in western Colorado is in late fall (September 15 to November 15), immediately preceding the season of highest precipitation. Timing is critical. If planted too early, seeds may germinate and be killed by the cold. If too late, seeds may not survive. Early spring planting has also been successful (Cook et al., 1974 and Gulf Oil Corporation and Standard Oil Company (Indiana), 1976).

Topsoil replacement would ideally occur in summer prior to fall seeding. If topsoil must be placed at times of the year other than before fall planting, summer fallowing would be performed to remove competitive weeds.

Soils in the NOSR 1 include podzolic, chestnut and chernozem depending on elevation, microclimate and vegetation cover. Thus soils range from slightly acidic to slightly alkaline. Specific conditions of soil removed and stockpiled would be tested and, if needed, conditioners and neutralizers may be added. Probable treatment would include mulching (addition of organic matter) and/or fertilization formulas. Nitrogen and phosphorus fertilizers are especially recommended because levels of these nutrients are low in processed shales. These could be applied with conventional farm-spreading implements or by using a truck designed for spreading sand or other solid materials. Disking would follow to prepare a seedbed suitable for seed germination.

6.7.3.2 Seeding

According to the Colorado Mined Land Reclamation Act, an operator must provide a diverse, effective, and permanent vegetation cover with the seasonal variety, succession, and regeneration capabilities native to the area. Several different vegetation community types presently exist on NOSR 1. Generally shrub communities are located on valley floors and lower slopes. Upland are mixed shrub, pinon-juniper, conifer forest and aspen woodland communities. These vegetation types would be reestablished in appropriate localities. Therefore, it would be necessary to seed a mixture of native and/or introduced species (resident plants) to provide a perennial herbaceous cover and to stabilize soils until the trees are well established.

Due to the high soluble salt level in the spent shale, it may be necessary to plant salt-tolerant plants, especially if considerable topsoil is not present. The U.S. Salinity Laboratory, U.S.D.A. Agricultural Handbook 1S.60, recommends the following forage crop-types which have a high salt tolerance: alkali sacaton, saltgrass, nuttall alkaligrass, bermuda grass, rhodes grass, rescue grass, canada wildrye, western wheatgrass, barley, and birdsfoot trefoil.

The ideal seed mixtures should rapidly provide an effective ground cover, provide nutrients to the soil, and not suppress tree growth. The mixture should include species that establish rapidly but would not over-compete with the trees or other species in the seed mixture. In addition, it should include drought-hardy species so that the herbaceous cover would last through a dry summer. Legumes would be particularly desirable because of their ability to "fix" nitrogen, aiding tree growth.

It is anticipated that where slopes are no steeper than 3h:1v, the mixture would be seeded using drills suited to the soil textures and conditions. It would be desirable to use seed drills rather

than hydroseeders because drills generally obtain a higher germination rate, more uniform distribution and uniform depth. Where terrain is moderately steep, hydroseeders would be used. In these areas, seed would then be covered with soil using harrows, discs or a small sheepsfoot roller. This is necessary to effectively cover the seed. In very steep areas, hydroseeding would be followed by hand raking.

After seeding by drill or broadcasting, mulch suitable for slope steepness and soils would be spread to retain soil moisture and prevent erosion. Light colored mulch would prevent excessive temperatures and retain moisture for seed germination. In certain areas, it might be desirable to utilize chemical binders, cellulose fibers, jute or plastic mats to hold the seed in the soil and preserve moisture.

Irrigation may be required at a rate of 1 acre-foot/acre for the first year, and .5 acre-foot/acre for the second year. After the second year, irrigation would be as needed depending on precipitation in that year.

6.7.3.3 Tree Planting

Junipers, pinon pine, Douglas fir and aspen would be planted in appropriate localities. One-foot seedlings would be planted where desired and may be planted by conventional forestry tree planting equipment or by hand. Seedling supplies would be obtained from state-run tree nurseries or the State Forestry Commission. Tree planting generally would take place between September and November. Fertilization and irrigation would be performed as described previously.

It would be very important for the trees to become established without a great deal of competition from the herbaceous ground cover. For this reason, the trees should be planted soon after the herbaceous ground cover is seeded.

6.7.3.4 Revegetation Maintenance

The revegetation practices discussed above are designed to establish an adequate vegetation ground cover. However, there may be situations where additional effort is required due to drought, erosion, etc. If necessary, additional irrigation, fertilizing, seeding, tree planting, and erosion control measures would be conducted until soils are stabilized and an adequate vegetation ground cover has been established. Weed and animal control may also be necessary for several years after seeding to allow plant establishment. Grazing would be discouraged until vegetation is firmly established.

6.7.4 Final Abandonment

When operations conclude, the preceding reclamation plan would apply to the abandonment of the central operation and support area. The only additions that would be made to cover abandonment are:

- Streams

Restore stream channels to natural, meandering shapes of the original gradient and profile, unless earlier diversion was to be permanent.

- Equipment and Building Removal

All buildings, except those requested to be left by the surface owner, would be removed.

- Foundation Removal

Foundations, blacktop, etc., would be removed down to designated depth.

- Disposal of Materials

Abandonment materials would either be buried or hauled away.

- Scarification

Extensive ripping in compacted areas would be performed.

- Fracturing

Blasting of any concrete underground structure too big or deep for removal would be done to allow percolation. The structure would be filled in, if hollow, and covered with at least 2 feet of soil.

- Fire Lanes

Fire lanes would be constructed in areas to be reforested.

- Access Roads

Roads necessary to provide access for the reestablished land use would be constructed.

6.8 CONCLUSION

Brief descriptions of the project elements in the surface mining plan and the existing environment have been presented. The impacts of surface mining have been identified and contrasted with those of underground mining. Both concepts have advantages and disadvantages. Short-term effects from surface mining appear to be of greater environmental consequence. However, underground mining poses a potentially greater concern for employee health and safety. Long-term effects of both surface and underground mining cannot be predicted with a high level of certainty. The potential

long-term repercussions from underground mining with respect to subsidence and underground water may be of more consequence than the restructuring of surface drainage patterns and revegetation required after surface mining disturbances.

Conceptual environmental controls during surface mining have been recommended. One major area of concern is fugitive particulate emissions. Significant effort would be required to suppress dust. Terrestrial habitat loss would be minimized as much as possible and would be temporary in nature. Reclamation and revegetation would restore the habitats.

Some aquatic habitat may be lost or altered, but stream relocations and diversions would emphasize rapid reestablishment of the ecosystem. Controls presented should effectively reduce water quality degradation, but more research is needed on ways to manage the possible hydrological effects from mine dewatering.

Finally a preliminary reclamation plan was presented which identified some of the more practicable and effective methods currently being used. Much research has been completed that indicates that revegetation efforts can be successful in semiarid western Colorado on both disturbed sediments and processed shale.

6.9 REFERENCES

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7. COST ESTIMATES

7.1 CAPITAL COSTS

The capital cost estimates presented in Tables 7-1 through 7-8 have been determined in general accordance with the parameters of a Type I estimate as described in the Appendix to this report. Some costs have been factored from recent, in-depth studies of a similar nature and some items simply reflect the judgment of project engineers.

This capital cost estimate is based on conceptual mining plans described in Section 5. Additional study work, however, should be done to obtain a better estimate.

7.1.1 Definitions

7.1.1.1 Base Case of Estimates

The cases of estimates are based on average values of three levels of annual production ranging from 25 GPT to 35 GPT, as indicated on Section 5.2.2 of this report.

7.1.1.2 Limits of Estimates of Capital Cost

The capital cost estimates are for the facilities and equipment directly connected with the mining operation, and the transportation of the supplies and products between the mine and processing plant.

TABLE 7-1
SUMMARY OF ALL CAPITAL COST
FOR MINING MATERIAL OF 25 GPT

<u>Cross Ref. Table</u>		<u>Total Cost \$</u>
7.1-2A	Preproduction Cost*	\$654,500,000
7.1-3	Fixed Expenditure (Permanent Mine Structures)	94,645,000
	<u>Mine Equipment, (Portable)</u>	
7.1-4	• 5 years life	61,387,000
7.1-5	• 10 years life	13,272,000
7.1-6	• 15 years life	56,125,000
	Working Capital** (2 month period)	30,545,000
	Consumable Inventory*** (parts & materials)	8,720,000
	<u>Total Capital Costs</u>	<u>\$919,194,000</u>

* The total amount will be spent in a period of 3.5 years.

** Working capital considers, total operating expenses for two months of operations.

*** Spare part and consumable materials for two months of operations.

TABLE 7-2
SUMMARY OF ALL CAPITAL COST
FOR MINING MATERIAL OF 30 GPT

<u>Cross Ref. Table</u>		<u>Total Cost \$</u>
7.1-2B	Preproduction Cost*	\$641,602,000
7.1-3	Fixed Expenditure (permanent Mine Structures)	106,665,000
	<u>Mine Equipment, (Portable)</u>	
7.1-4	• 5 years life	71,415,000
7.1-5	• 10 years life	16,147,000
7.1-6	• 15 years life	63,495,000
	Working Capital** (2 month period)	34,343,000
	Consumable Inventory*** (parts & materials)	10,144,000
	<u>Total Capital Costs</u>	<u>\$943,811,000</u>

* The total amount will be spent in a period of 3.5 years.

** Working capital considers total operating expenses for two months of operations.

*** Spare parts and consumable materials for two months of operations.

TABLE 7-3
SUMMARY OF ALL CAPITAL COST
FOR MINING MATERIAL OF 35 GPT

<u>Cross Ref. Table</u>		<u>Total Cost \$</u>
7.1-2C	Preproduction Cost*	\$627,463,000
7.1-3	Fixed Expenditure (Permanent Mine Structures)	144,745,000
	<u>Mine Equipment, (Portable)</u>	
7.1-4	• 5 years life	109,671,000
7.1-5	• 10 years life	27,422,000
7.1-6	• 15 years life	90,170,000
	Working Capital** (2 month period)	50,216,000
	Consumable Inventory*** (parts & materials)	15,579,000
	<u>Total Capital Costs</u>	<u>\$1,065,266,000</u>

* The total amount will be spent in a period of 3.5 years.

** Working capital considers total operating expenses for two months of operations.

*** Spare parts and consumable materials for two months of operations.

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TABLE 7-4
ESTIMATED CAPITAL COSTS
PREPRODUCTION COSTS IN A PERIOD
OF 3.5 YEARS

	<u>Total Cost \$</u>
A. <u>Mining Material of 25 GPT</u>	
Stripping, 374 million tons @ \$1.75/ton*	\$654,500,000
Eng, Road Construction, etc.,	6,545,000
<u>Total Pre-production</u>	<u>\$661,045,000</u>
B. <u>Mining Material of 30 GPT</u>	
Stripping, 363 million tons @ \$1.75/ton*	\$635,250,000
Eng, Road Construction, etc.,	6,352,000
<u>Total Pre-production</u>	<u>\$641,602,000</u>
C. <u>Mining Material of 35 GPT</u>	
Stripping, 355 million tons @ \$1.75/ton*	\$621,250,000
Eng, Road Construction, etc.,	6,213,000
<u>Total Pre-production</u>	<u>\$627,463,000</u>

*Includes Environmental Control and Reclamation.

TABLE 7-5

ESTIMATED CAPITAL COST-MAJOR
ITEMS OF MINING MACHINERY WITH
ECONOMIC LIFE OF 20 YRS. & OTHER
PERMANENT FACILITIES

ITEM	Unit Cost	25 GPT		30 GPT		35 GPT	
		No. of Units	Total Cost \$	No. of Units	Total Cost \$	No. of Units	Total Cost \$
Primary Crusher Installation	-	-	\$30,000,000	-	\$ 32,500,000	-	\$ 51,205,000
Conveyor Belt System Oil Shale (60") Belts & Structures	\$ 835	7,000 ft.	5,845,000	9,000 ft.	7,515,000	12,000 ft.	10,020,000
Conveyor Belt System Waste (90") Belts & Structures	11,250	2 x 10,000 ft.	25,000,000	2 x 12,000 ft.	30,000,000	2 x 15,000 ft.	37,500,000
Trapper & Stacker	7,400,000	2	14,800,000	2	14,800,000	3	22,200,000
Subtotal mining structures & equipment			\$75,645,000-		\$84,815,000-		\$110,925,000
Maintenance Shop Facilities and warehouse, 268,000 x \$50.-) base			13,000,000		14,950,000		23,140,000
Maintenance Shop Equipment			6,000,000		6,900,000		10,680,000
TOTAL			\$94,645,000		\$106,665,000		\$144,745,000

7-7-4

TABLE 7-6

ESTIMATED CAPITAL COST-MAJOR
ITEMS OF MINING MACHINERY WITH
ECONOMIC LIFE OF 5 YEARS

ITEM	Unit Cost	25 GPT		30 GPT		35 GPT	
		No. of Units	Total Cost \$	No. of Units	Total Cost \$	No. of Units	Total Cost \$
Front End Loader (875 hp)	\$570,000	2	\$ 1,140,000	3	1,710,000	5	\$ 2,850,000
Haulage Trucks 170T	665,000	82	54,530,000	95	63,175,000	146	97,090,000
Rubber Tire Dozer	180,000	6	1,080,000	7	1,260,000	11	1,980,000
Track Dozer	230,000	5	1,150,000	6	1,380,000	9	2,070,000
Passenger Bus	80,000	6	480,000	7	560,000	10	800,000
Front End Loader (1,375 hp)	180,000	3	540,000	3	540,000	5	900,000
Portable Water Pumps	100,000	6	600,000	7	700,000	10	1,000,000
3/4 Ton Truck	14,000	23	322,000	26	364,000	33	462,000
Suburban Truck	25,000	4	100,000	4	100,000	6	150,000
Water Truck 10,000 Gal.	35,000	4	140,000	5	175,000	7	245,000
Portable Welders	6,000	5	30,000	6	36,000	9	54,000
Trailing Cable 1,000 ft.	35,000	33	1,155,000	37	1,295,000	54	1,890,000
Skidder	60,000	2	120,000	2	120,000	3	180,000
TOTAL			\$61,387,000		\$71,415,000		\$109,671,000

7-9-10

TABLE 7-7

ESTIMATED CAPITAL COST-MAJOR
ITEMS OF MINING MACHINERY WITH
ECONOMIC LIFE OF 10 YEARS

ITEM	Unit Price	25 GPT		30 GPT		35 GPT	
		No. of Units	Total Cost \$	No. of Units	Total Cost \$	No. of Units	Total Cost \$
Self Contain Rock Drill	\$165,000	2	\$ 330,000	3	\$ 495,000	5	\$ 825,000
Road Grader - 250 hp	165,000	13	2,145,000	16	2,640,000	24	3,960,000
Backhoe 325 hp	385,000	2	770,000	2	770,000	3	1,155,000
Portable Switch	20,000	35	700,000	40	85,000	56	1,120,000
Primary Substation	175,000	8	1,400,000	9	1,575,000	13	2,275,000
Portable Substation	41,000	8	328,000	9	369,000	13	533,000
AN/FO Mixing Truck	100,000	6	600,000	7	700,000	10	1,000,000
Slurry Mixing Truck	110,000	2	220,000	2	220,000	3	330,000
AN/FO & Slurry Mixing Equipment	-	-	340,000		340,000		500,000
Flat Bed Truck	50,000	2	100,000	2	100,000	3	150,000
Portable Light Towers	12,000	13	156,000	15	180,000	22	264,000
Oil Shale Head Station	470	1,715 hp	806,000	1,845 hp	867,000	2,064 hp	970,000
Waste Head Station	470	11,440 hp	5,377,000	16,608 hp	7,806,000	30,510 hp	14,340,000
TOTAL			\$13,272,000		\$16,147,000		\$27,422,000

7-11-12

TABLE 7-8

ESTIMATED CAPITAL COST-MAJOR ITEMS
OF MINING MACHINERY WITH ECONOMIC
LIFE OF 15 YEARS

ITEM	Unit Price \$	25 GPT		30 GPT		35 GPT	
		No. of Units	Total Cost \$	No. of Units	Total Cost \$	No. of Units	Total Cost \$
Rotary Blast Hole Drill	\$ 935,000	20	\$18,700,000	22	\$20,570,000	32	\$29,920,000
Shovel 28 CB4D	2,650,000	13	34,450,000	15	39,750,000	22	58,300,000
Truck Crane 75 Ton	275,000	1	275,000	1	275,000	2	550,000
Truck Crane 45 Ton	200,000	1	200,000	1	200,000	2	400,000
Mine Power Cable, 5,000 ft. Unit	100,000	25	2,500,000	27	2,700,000	40	1,000,000
TOTAL			\$56,125,000		\$63,495,000		\$90,170,000

2-13-14

7.1.2 Items Specifically Included in Capital Costs

In all locations, capital costs include:

- All process and service machinery for mining, transportation, and other facilities related to mining operations.
- All mining materials and other miscellaneous construction materials for the preproduction period.
- The costs of freight, handling, and warehousing of machinery and materials.
- All costs of construction wages, supervision, payroll additives, and other costs related to preproduction costs.
- The purchase or rental of all construction equipment for preproduction.
- The cost of operating the prime contractor's field office and all of its attendant overheads, including an allowance for various forms of insurance during preproduction.

7.1.3 Items Specifically Excluded from Capital Costs

- Land acquisition, additional exploration and test work.
- Facilities located outside of the immediate mining vicinity.
- Power transmission, substation, water supplies, etc.
- Infrastructure, mining camp and related facilities.

- Import duties where applicable.
- All taxes and permits.
- Operating capital and other owner's costs, such as construction interest and finance cost.

7.1.4 Escalation

These estimates contain no provision for escalation. They are believed to be reasonable as of July 1980.

7.2 OPERATING COSTS

The operating costs presented in Tables 7-9 through 7-21 refer only to the direct cost of managing and operating the mining facilities and the primary and secondary crusher located at the project site.

The direct operating costs developed in this section are for the facility as generally described in Section 5.

7.2.1 Criteria and Methodology

The following are general assumptions pertaining to these estimates:

7.2.1.1 Timeframe and Monetary Units

The calculations have been made in terms of constant dollars projected to July 1, 1980.

7.2.1.2 Establishing the Base Cases

The base cases are the mining of three levels of production, ranging from 25 GPT to 35 GPT, of oil shale with their respective SRs. Section 5 gives the tonnage per year of the base cases to develop the operating mining cost.

7.2.1.3 Contingencies and Escalation

No escalation has been added and all costs are assumed to be in constant July 1980 dollars. No contingencies are added, since a sensitivity analysis to be performed by TRW could add plus or minus contingencies to these costs.

7.2.1.4 Developing Direct Operating Costs

Unit costs from other similar operations are not generally

TABLE 7-9

SUMMARYESTIMATED DIRECT OPERATING COST
FOR MINING MATERIAL OF 25 GPT*

<u>Cross Ref. Table</u>		<u>Cost Per Ton Oil Shale*</u> \$	<u>Cost Per Barrel Oil**</u>	<u>Annual Cost \$</u>
	<u>1.-Mining and Transportation to the Secondary Crusher</u>			
7.2-2	a. Mine, Maintenance Labor & Burden			\$ 56,123,000
7.2-3	b. Office of Mine Manager			33,000
7.2-4	c. Mining Equipment			49,520,000
7.2-5	d. Drilling & Blasting Material			30,770,000
7.2-6	e. Undistributed Mining Dept. Over- head.			588,000
	● Subtotal Mining & Transportation	4.72	8.330	\$137,034,000
7.2-7	2.-Engineering, Research & other Supporting Operation	\$0.020	\$0.036	\$ 595,000
	3.-Secondary Crushing	\$0.370	\$0.653	\$ 10,749,000
	4.-Environmental Control and Recla- mation.	\$0.043	\$0.075	\$ 1,235,000
	5.-Spend Shale	\$0.300	\$0.530	\$ 8,715,000
	● Total Estimated Operating Cost	\$5.45	\$9.62	\$158,328,000

*Tonnage of Oil Shale mined = 29,051,000 Tons

**Barrel of Oil Annually produced = 16,450,000

TABLE 7-10

SUMMARYESTIMATED DIRECT OPERATING COSTFOR MINING MATERIAL OF 30 GPT*

<u>Cross</u> <u>Ref.</u> <u>Table</u>		<u>Cost Per</u> <u>Ton</u> <u>Oil Shale*</u> <u>\$</u>	<u>Cost Per</u> <u>Barrel</u> <u>Oil**</u>	<u>Annual</u> <u>Cost</u> <u>\$</u>
	<u>1.-Mining and Transportation</u> <u>to the Secondary Crusher</u>			
7.2-8	a. Mine, Maintenance Labor & Burden			\$ 63,330,000
7.2-3	b. Office of Mine Manager			33,000
7.2-9	c. Mining Equipment			56,785,000
7.2-5	d. Drilling & Blasting Material			34,887,000
7.2-6	e. Undistributed Mining Dept. Over-head.			659,000
	● Subtotal Mining & Transportation	\$6.42	\$9.46	\$155,694,000
7.2-7	2.-Engineering, Research & other Supporting Operation	\$0.028	\$0.041	\$ 667,000
	3.-Secondary Crushing	\$0.370	\$0.545	\$ 8,970,000
	4.-Environmental Control and Recla- mation	\$0.057	\$0.084	\$ 1,375,000
	5.-Spend Shale	\$0.300	\$0.442	\$ 7,273,000
	● Total Estimated Operating Cost	\$7.18	\$10.58	\$173,979,000

*Tonnage of Oil Shale Mined = 24,242,000

**Barrel of Oil Annually produced = 16,450,000

TABLE 7-11

ESTIMATED DIRECT OPERATING COST
MINE & MAINTENANCE LABOR AND BURDEN
FOR MINING MATERIAL OF 25 GPT

		<u>No.</u>	<u>Average Cost/No.</u>	<u>Total Annual Cost \$</u>
Production	Oil Shale	29,091 x 10 ³		Tons
Production	Overburden	154,180 x 10 ³		
Total Material		183,271 x 10 ³		Tons
<u>A. Mine Management</u>				
	Mine Manager	1		55,000
	Asst. Mine Manager	1		50,000
	Production Superintendent	1		45,000
	Maintenance Superintendent	1		45,000
	Mining Engineering Superintendent	1		45,000
	Secretaries & Clerks	9	15,000	135,000
<u>SUBTOTAL MINE MANAGEMENT</u>		14		375,000
<u>B. Engineering & Safety</u>				
	Engineers, Geologists, Surveyors, Samplers, Draftsmen, Exploration Crew, etc. Safety			
<u>SUBTOTAL ENGINEERING & SAFETY</u>		62	23,500	1,457,000
<u>C. Mine Supervision</u>		55	30,000	1,650,000
<u>D. Maintenance Supervision</u>		30	30,000	900,000
<u>E. Mine Operators</u>				
	Equipment Operators	549	21,250	11,666,000
	Labors	192	19,240	3,694,000
	Conveyor Belt System	145	20,245	2,936,000
<u>SUBTOTAL MINE LABORS</u>		886		18,296,000
<u>F. Maintenance Labor</u>				
	Mechanics & Electricians	333	21,840	7,273,000
	Mechanics & Electricians Helpers	407	20,180	8,213,000
<u>SUBTOTAL MAINTENANCE LABOR</u>		740		15,486,000
<u>G. Mine Support Operations</u>		100	19,240	1,924,000
<u>TOTAL MINING LABOR FORCE</u>		1,887		\$40,088,000
<u>Burden @40%</u>				16,035,000
<u>TOTAL</u>				\$56,123,000

Labor Productivity = 287.35 TPMSH

TABLE 7-12

SUMMARYESTIMATED DIRECT OPERATING COST

<u>Cross Ref. Table</u>		<u>FOR MINING MATERIAL OF 35 GPT*</u>		
		<u>Cost Per Ton Oil Shale*</u> \$	<u>Cost Per Barrel Oil**</u>	<u>Annual Cost \$</u>
	<u>1.-Mining and Transportation to the Secondary Crusher</u>			
7.2-10	a. Mine, Maintenance Labor & Burden			\$ 88,448,000
7.2- 3	b. Office of Mine Manager			45,000
7.2-11	c. Mining Equipment			84,870,000
7.2- 5	d. Drilling & Blasting Material			50,101,000
7.2- 6	e. Undistributed Mining Dept. Over- head.			923,000
	● Subtotal Mining & Transportation	\$10.80	\$13.64	\$224,387,000
7.2-7	2.-Engineering, Research & other Supporting Operation	0.046	0.058	\$ 954,000
	3.-Secondary Crushing	0.370	0.467	\$ 7,688,000
	4.-Environmental Control and Recla- mation	0.095	0.119	\$ 1,964,000
	5.-Spend Shale	0.300	0.379	\$ 6,234,000
	● Total Estimated Operating Cost	\$11.61	\$14.66	\$241,227,000

*Tonnage of Oil Shale mined = 20,779,000

**Barrel of Oil Annually produced = 16,450,000

TABLE 7-13

ESTIMATED DIRECT OPERATING COST
OFFICE OF THE MINE MANAGER IN CHARGE OF PRODUCTION

Goods And Services

Power	14 x 120	\$ 1,680
Water and Sewage	14 x 50	700
Telephone	14 x 300	4,200
Radio Service		3,000
Allowance for Telex and L.O. calls		2,100
Office Supplies		4,200
Repair Office		2,100
Building Maintenance		2,000
Motor Vehicles, 1 Sedan 20,000 mile x 0.30		6,000
Travel and Expenses allowance		<u>7,000</u>

Total Goods & Services (rounded)

● For 25 GPT and 30 GPT \$33,000

● Total Goods & Services for 35 GPP

$\frac{33,000}{14} \times 19$ \$45,000

TABLE 7-15

DRILLING & BLASTING SUPPLIES

		25 GPT	<u>Mining Alternates</u>	
		\$	30 GPT	35 GPT
			\$	\$
1.	<u>Drilling Materials & Supplies</u>			
a)	<u>Oil Shale</u>			
	Bits @ 3,600 ft/bit/\$4,000/Bit	\$ 520,000	\$ 434,000	\$ 392,000
	Drill pipes, collars, tools @ 8% of Bits.	42,000	35,000	31,000
b)	<u>Overburden</u>			
	Bits @ 2,800 ft/Bit/\$4,000/Bit	\$4,887,000	\$5,563,000	\$8,870,000
	Drill pipes, collars, tools @ 8% of Bits.	391,000	461,000	710,000
	Subtotal Drilling Material	\$5,840,000	\$6,493,000	\$10,003,000
2.	<u>Blasting Material & Supplies</u>			
a)	<u>Oil Shale</u>			
	1. AN/FO @ 0.17/lb	\$1,920,000	\$1,612,000	\$1,459,000
	2. Fuel Oil @ U.S.\$1/Gal.	342,000	259,000	234,000
	3. Slurry @ \$0.28/lb.	353,000	288,000	268,000
	4. Other blasting materials	192,000	161,000	146,000
b)	<u>Overburden</u>			
	1. AN/FO @ 0.17/lb.	\$14,929,000	\$17,606,000	\$27,099,000
	2. Fuel Oil @ U.S.\$1/Gal.	2,661,000	3,138,000	4,830,000
	3. Slurry @ \$0.28/lb.	2,734,000	3,224,000	4,963,000
	4. Other blasting materials	1,493,000	1,761,000	2,710,000
	Subtotal blasting material	\$24,624,000	\$28,049,000	\$39,602,000
	Total Drilling & Blasting (Primary)	\$30,464,000	\$34,542,000	\$49,605,000
	Provision for Secondary Blasting	\$ 306,000	\$ 345,000	\$ 496,000
	Grand Total Drilling & Blasting	\$30,770,000	\$34,887,000	\$50,101,000

TABLE 7-16

ESTIMATED OPERATING COST
UNDISTRIBUTED MINING DEPARTMENT COST OVERHEAD

	<u>25 GPT</u>	<u>Mining Alternate</u> <u>30 GPT</u>	<u>35 GPT</u>
Office & Engineering Supplies	\$ 20,000	\$ 22,000	\$ 25,000
Repair office	10,000	10,000	12,000
Offices Power Usage	10,000	11,000	14,000
Shop Power Usage	58,000	66,000	93,000
Telephone	44,000	47,000	62,000
Mobile Radio	51,000	56,000	78,000
Shop Repair Allowance	101,000	115,000	161,000
Repair small equipment & tools	111,000	126,000	177,000
Other undistributed material & miscellaneous	183,000	206,000	301,000
Subtotal	\$588,000	\$659,000	\$923,000

TABLE 7-17

ESTIMATED OPERATING COST
ENGINEERING, RESEARCH & OTHER SUPPORTING OPERATIONS

	<u>Mining Alternate</u>		
	<u>25 GPT</u>	<u>30 GPT</u>	<u>35 GPT</u>
Core Drilling for Mine Planning	\$200,000	\$225,000	\$329,000
Survey & control	30,000	34,000	49,000
Geo-technical studies	100,000	112,000	164,000
Hydrology & Mine Dewatering Allowance	150,000	170,000	250,000
Other Miscellaneous	50,000	56,000	82,000
Laboratory	65,000	70,000	80,000
Subtotal	\$595,000	\$667,000	\$954,000

TABLE 7-18

ESTIMATED DIRECT OPERATING COST
MINE & MAINTENANCE LABOR AND BURDEN
FOR MINING MATERIAL OF 30 GPT

	No.	Average Cost/No.	Total Annual Cost \$
Production Oil Shale 24,242 10 ³ Tons			
Production Overburden 181,815 x 10 ³			
Total Material 206,057 x 10 ³ Tons			
A. <u>Mine Management</u>			
Mine Manager	1		55,000
Asst. Mine Manager	1		50,000
Production Superintendent	1		45,000
Maintenance Superintendent	1		45,000
Mining Engineering Superintendent	1		45,000
Secretaries & Clerks	9	15,000	135,000
SUBTOTAL MINE MANAGEMENT	14		375,000
B. <u>Engineering & Safety</u>			
Engineers, Geologist, Surveyors, Samplers, Draftsmen, Exploration Crew, etc. Safety			
SUBTOTAL ENGINEERING & SAFETY	65	23,500	1,528,000
C. <u>Mine Supervision</u>	60	30,000	1,800,000
D. <u>Maintenance Supervision</u>	33	30,000	990,000
E. <u>Mine Operators</u>			
Equipment Operators	624	21,250	13,260,000
Labors	204	19,240	3,925,000
Conveyor Belt System	175	20,245	3,624,000
SUBTOTAL MINE LABORS	840		20,809,000
F. <u>Maintenance Labor</u>			
Mechanics & Electricians	378	21,840	8,256,000
Mechanics & Electricians Helpers	462	20,180	9,323,000
SUBTOTAL MAINTENANCE LABOR	840		17,579,000
G. <u>Mine Support Operations</u>	112	19,240	2,155,000
TOTAL MINING LABOR FORCE	2,131		\$45,236,000
Burden @ 40%			18,094,000
TOTAL			\$63,330,000

Labor Productivity = 286.08 TPMSH

TABLE 7-14

**ESTIMATED DIRECT OPERATING COST-MINING
EQUIPMENT FOR MINING OIL SHALE OF 25 GPT**

				(A)		(B)		(C)		
	No. of Units	No. of Hr. Per Unit Hrs.	Total Hrs. Per Year Hrs.	No. kWh Per Unit kWh	Total Elect Power Cost @ \$0.03/kWh \$	Fuel Oil Per Unit Gallon/Hr.	Total Fuel Oil Cost \$/Gallon \$	Parts & MAT Cost/Hr \$	Total Costs Parts/MAT \$	Total Annual Operating Cost (A+B+C) \$
Rotary Blast Hole Drills	14	5,940	83,160	520	\$1,297,000	-	-	\$ 13.4	\$ 1,114,000	\$ 2,411,000
Self Contained Rock Drills (Secondary Blasting)	2	4,056	8,112	-	-	7.9	\$ 64,000	3.8	31,000	95,000
Shovel 28 cu.yd.	10	4,304	43,040	1,512	1,952,000	-	-	26.4	1,136,000	3,088,000
Front End Loader (860 hp)	2	4,056	8,112	-	-	28.4	230,000	33.9	275,000	505,000
Haulage Truck 170 tons	59	6,372	375,948	-	-	43.4	16,316,000	36.3	13,647,000	29,963,000
Rubber Tire Dozer 300 hp	5	6,084	30,420	-	-	11.2	341,000	17.9	555,000	896,000
Track Dozers, 410 hp	4	6,084	24,336	-	-	15.1	367,000	17.3	421,000	788,000
Road Grader 250 hp	11	6,084	66,924	-	-	7.9	529,000	12.7	850,000	1,379,000
Backhoe 325 hp	2	4,056	8,112	-	-	11.1	90,000	23.6	191,000	281,000
Passenger Bus (40)	5	3,042	15,210	-	-	1.7	26,000	3.3	50,000	76,000
Truck Crane 75 Ton	1	3,042	3,042	-	-	1.7	5,000	21.5	65,000	70,000
Truck Crane 45 Ton	1	3,042	3,042	-	-	1.7	5,000	16.8	51,000	56,000
Portable Switch house, Allowance	35	-	-	-	-	-	-	-	70,000	70,000
Front End Loader 375 hp	3	4,056	12,168	-	-	22.2	270,000	21.5	262,000	532,000
Portable Water pumps	8	6,084	48,672	-	-	0.6	29,000	0.5	24,000	53,000
AM/FO Mixing Truck	5	3,549	17,745	-	-	2.0	35,000	7.7	137,000	172,000
Slurry Mixing Truck	2	3,549	7,098	-	-	2.0	14,000	9.5	67,000	81,000
Light Truck, 3/4 Ton	20	4,056	81,120	-	-	2.5	203,000	1.6	130,000	333,000
Suburban Truck	4	4,057	16,224	-	-	2.5	41,000	1.6	26,000	67,000
Water Truck	3	3,042	9,126	-	-	2.0	18,000	7.5	68,000	86,000
Portable Welder	4	4,056	16,224	-	-	0.7	11,000	0.4	6,000	17,000
Skidder 175 hp	2	4,056	8,112	-	-	4.0	32,000	4.0	32,000	64,000
Fiat Red Truck	2	4,560	9,120	-	-	1.7	16,000	5.5	50,000	66,000
Primary Crusher System - Oil-Shale	1	5,500	5,500	746	123,000	-	-	24.4	189,000	312,000
Primary Crusher System - Overburden	4	5,017	20,068	746	449,000	-	-	49.9	1,002,000	1,451,000
Belt System Oil Shale, 60 inches	1 system	4,260	4,260	1,085	139,000	-	-	156.1	665,000	804,000
Belt System Overburden, 90 inches	2 system	4,366	8,732	4,910	1,286,000	-	-	517.4	4,518,000	5,804,000
Tripper and Stacker										
TOTAL					\$5,246,000		\$18,642,000		\$25,632,000	\$49,520,000

7-23-24-

TABLE 7-19

ESTIMATED DIRECT OPERATING COST-MINING
EQUIPMENT FOR MINING OIL SHALE OF 30 GPT

	No. of Units	No. of Hr. Per Unit Hrs.	Total Hrs. Per Year Hrs.	No. kWh Per Unit kWh	(A) Total Elect Power Cost @ \$0.03/kWh \$	Fuel Oil Per Unit Gallon/Hr.	(B) Total Fuel Oil Cost \$/Gallon \$	Parts & Met Cost/Hr. \$	(C) Total Costs Parts/MAT \$	Total Annual Operating Cost (A+B+C) \$
Rotary Blast Hole Drills	15	6,377	95,655	520	\$1,492,000	-	-	\$ 13.4	\$ 1,282,000	\$ 2,774,000
Self Contained Rock Drills (Secondary Blasting)	3	4,056	12,168	-	-	7.9	\$ 96,000	3.8	46,000	142,000
Shovel 22 cu. yd.	11	4,400	48,400	1,512	2,195,000	-	-	26.4	1,278,000	3,473,000
Front End Loader (860 hp)	3	4,056	12,168	-	-	28.4	346,000	33.9	412,000	758,000
Haulage Truck 170 Tons	67	6,456	432,552	-	-	43.4	18,773,000	36.3	15,702,000	34,475,000
Rubber Tire Dozer 300 hp	6	6,084	36,504	-	-	11.2	409,000	17.9	653,000	1,062,000
Track Dozers, 410 hp	5	6,084	30,420	-	-	15.1	459,000	17.3	526,000	985,000
Road Grader 250 hp	14	6,034	85,176	-	-	7.9	673,000	12.7	1,082,000	1,755,000
Backhoe 325 hp	2	4,560	9,120	-	-	11.1	101,000	23.6	215,000	316,000
Passenger Bus (40)	6	3,042	18,252	-	-	1.7	31,000	3.3	60,000	91,000
Truck Crane 75 Ton	1	3,410	3,410	-	-	1.7	6,000	21.5	73,000	79,000
Truck Crane 45 Ton	1	3,410	3,410	-	-	1.7	6,000	16.8	57,000	63,000
Portable Switch house, Allowance	40	-	-	-	-	-	-	-	80,000	80,000
Front End Loader 375 hp	3	4,560	13,680	-	-	22.2	304,000	21.5	294,000	598,000
Portable Water Pumps	9	6,684	54,756	-	-	0.6	33,000	0.5	27,000	60,000
AN/FO Mixing Truck	6	3,549	21,294	-	-	2.0	43,000	7.7	164,000	207,000
Slurry Mixing Truck	2	3,975	7,950	-	-	2.0	16,000	9.5	76,000	92,000
Light truck, 3/4 Ton	22	4,056	89,232	-	-	2.5	223,000	1.6	143,000	366,000
Suburban Truck	4	4,560	18,240	-	-	2.5	46,000	1.6	29,000	75,000
Water Truck	4	3,042	12,168	-	-	2.0	24,000	7.5	91,000	115,000
Portable Welder	5	4,056	20,280	-	-	0.7	14,000	0.4	8,000	22,000
Skidder 175 hp	2	4,560	9,120	-	-	4.0	36,000	4.0	36,000	72,000
Flat Bed Truck	2	4,560	9,120	-	-	1.7	16,000	5.5	50,000	66,000
Primary Crusher System - Oil-Shale	1	4,670	4,670	746	105,000	-	-	34.4	161,000	266,000
Primary Crusher System - Overburden	5	4,732	23,660	746	530,000	-	-	49.9	1,039,000	1,569,000
Belt System Oil Shale, 60 inches	1 system	4,360	4,360	1,170	153,000	-	-	156.1	681,000	834,000
Belt System Overburden, 90 inches	2 system	4,395	8,790	6,984	1,842,000	-	-	517.4	4,548,000	6,390,000
Tripper and Stacker										
TOTAL					\$6,317,000		\$21,655,000		\$28,813,000	\$56,785,000

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TABLE 7-20

ESTIMATED DIRECT OPERATING COST
MINE & MAINTENANCE LABOR AND BURDEN
FOR MINING MATERIAL OF 35 GPT

	<u>No.</u>	<u>Average Cost/No.</u>	<u>Total Annual Cost \$</u>
Production Oil Shale 20,779 x 10 ³ Tons			
Production Overburden 280,517 x 10 ³			
Total Material 301,296 x 10 ³ Tons			
A. <u>Mine Management</u>			
Mine Manager	1		55,000
Asst. Mine Manager	1		50,000
Production Superintendents	2	45,000	90,000
Maintenance Superintendent	1		45,000
Mining Engineering Superintendent	1		45,000
Secretaries & Clerks	13	15,000	195,000
SUBTOTAL MINE MANAGEMENT	19		480,000
B. <u>Engineering & Safety</u>			
Engineers, Geologist, Surveyors, Samplers, Draftsmen, Exploration Crew, etc. Safety			
SUBTOTAL ENGINEERING & SAFETY	75	23,500	1,762,000
C. <u>Mine Supervision</u>	84	30,000	2,520,000
D. <u>Maintenance Supervision</u>	46	30,000	1,380,000
E. <u>Mine Operators</u>			
Equipment Operators	886	21,250	18,828,000
Labors	290	19,240	5,580,000
Conveyor Belt System	235	20,245	4,758,000
SUBTOTAL MINE LABORS	1,411		29,166,000
F. <u>Maintenance Labor</u>			
Mechanics & Electricians	531	21,840	11,597,000
Mechanics & Electricians Helpers	650	20,180	13,117,000
SUBTOTAL MAINTENANCE LABOR	1,181		24,714,000
G. <u>Mine Support Operations</u>	164	19,240	3,155,000
TOTAL MINING LABOR FORCE	2,980		\$63,177,000
Burden @ 40%			25,271,000
TOTAL			\$88,448,000

Labor Productivity = 299.13 TPMSH

TABLE 7-21

ESTIMATED DIRECT OPERATING COSTS-MINING
EQUIPMENT FOR MINING OIL SHALE OF 35 GPT

				(A)		(B)		(C)		
	No. of Units	No. of Hr. Per Unit Hrs.	Total Hrs. Per Year Hrs.	No. kWh Per Unit kWh	Total Elect. Power Cost @ \$0.03/kWh \$	Fuel Oil Per Unit Gallon/Hr.	Total Fuel Oil Cost \$1/Gallon \$	Parts & MAT Cost/Hr. \$	Total Costs Parts/MAT \$	Total Annual Operating Cost (A+B+C) \$
Rotary Blast Hole Drills	23	6,236	143,428	520	\$2,237,000	-	-	\$ 13.4	\$ 1,922,000	\$ 4,159,000
Self Contained Rock Drills (Secondary Blasting)	5	4,056	20,280	-	-	7.9	\$ 160,000	3.8	77,000	237,000
Shovel 28 cu. yd.	16	4,401	70,416	1,512	3,194,000	-	-	26.4	1,859,000	5,053,000
Front End Loader (860 hp)	5	4,056	20,280	-	-	28.4	576,000	33.9	687,000	1,263,000
Haulage Truck 170 Tons	103	6,448	664,144	-	-	43.4	28,824,000	36.3	24,108,000	52,932,000
Rubber Tire Dozer 300 hp	10	6,084	60,840	-	-	11.2	681,000	17.9	1,089,000	1,770,000
Track Dozers, 410 hp	8	6,084	48,672	-	-	15.1	735,000	17.3	842,000	1,577,000
Road Grader 250 hp	20	6,084	121,680	-	-	7.9	961,000	12.7	1,545,000	2,056,000
Backhoe 325 hp	3	4,560	13,680	-	-	11.1	152,000	23.6	323,000	475,000
Passenger Bus (40)	9	3,042	27,378	-	-	1.7	47,000	3.3	90,000	137,000
Truck Crane 75 Ton	2	3,410	6,820	-	-	1.7	12,000	21.5	147,000	159,000
Truck Crane 45 Ton	2	3,410	6,820	-	-	1.7	12,000	16.8	115,000	127,000
Portable Switch house, Allowance	-	-	-	-	-	-	-	-	112,000	112,000
Front End Loader 375 hp	5	4,560	22,800	-	-	22.2	506,000	21.5	490,000	996,000
Portable Water Pumps	15	6,084	91,260	-	-	0.6	55,000	0.5	46,000	101,000
AN/FO Mixing Truck	9	3,549	31,941	-	-	2.0	64,000	7.7	246,000	310,000
Slurry Mixing Truck	3	3,975	11,925	-	-	2.0	24,000	9.5	113,000	137,000
Light Truck, 3/4 Ton	28	4,056	113,568	-	-	2.5	284,000	1.6	182,000	466,000
Suburban Truck	5	4,560	22,800	-	-	2.5	46,000	1.6	136,000	182,000
Water Truck	6	3,042	18,252	-	-	2.0	37,000	7.5	137,000	174,000
Portable Welder	8	4,056	32,448	-	-	0.7	23,000	0.4	13,000	36,000
Skidder 175 hp	3	4,560	13,680	-	-	4.0	55,000	4.0	55,000	110,000
Flat Bed Truck	3	4,560	13,680	-	-	1.7	23,000	5.5	75,000	98,000
Primary Crusher System - Oil-Shale	1	4,070	4,070	746	91,000	-	-	34.4	140,000	231,000
Primary Crusher System - Overburden	7	5,215	36,505	746	817,000	-	-	49.9	1,822,000	2,639,000
Belt System Oil Shale, 60 inches	1 system	4,390	4,390	1,320	174,000	-	-	156.1	655,000	850,000
Belt System Overburden, 90 inches	2 system	4,415	8,930	12,705	3,404,000	-	-	517.4	4,620,000	8,024,000
Tripper and Stacker										
TOTAL					\$9,917,000		\$33,277,000		\$41,676,000	\$84,870,000

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employed though they may be used as a credibility check after the fundamental work has been done. The basic ingredients of developed costs are:

- Manning tables and wage rates
- Labor burden and additives, and the establishment of the average number of hours per year that an employee will work
- Energy requirements and the development of the cost thereof
- Wear and replacement parts
- General allowance for services

After the costs have been tabulated they can be subjected to various credibility tests. For example, in the mine, what is the production per man shift? How does this compare with other mines of this size? The tables in this section generally give backup for most items. However, some items are simply allowances to indicate that the item was not overlooked, rather than to signify a high order of accuracy.

7.2.1.5 Definition of Direct Operating Costs

Direct operating costs are defined as the resident costs at the Naval Oil Shale mine site.

7.2.1.6 Items Specifically Included in Direct Operating Costs

- All wages and salaries for operating, maintenance, and supervisory labor and management personnel resident at the operation site

- Wage-related additives and other identifiable cash fringe benefits
- Parts and operating supplies of all kinds and the freight thereon
- Fuel and lubricants of all kinds
- Allowance for travel and subsistence for employees on company business
- Electric power
- Operating and maintaining the mining facilities

7.2.1.7 Items Specifically Excluded from Direct Operating Costs

- Non-resident costs which may be incurred in other parts of the mine site
- All income-related taxes and property taxes
- Depreciation and interest on borrowed funds
- Royalties
- Hazard and public liability insurance

7.2.1.6 Wages

The wages for supervisors and labor have been factored up by an inflation factor from previous labor rates used in other studies, and are consistent with the general mine criteria, Table 5-1.

8. SUMMARY AND REVIEW

The purpose of this study was to investigate the feasibility and desirability of surface (open-pit) mining of oil shale at the NOSR property near Rifle, Colorado. To date, predevelopment planning for this reserve had only considered underground mining of the resource.

Because of the early stage in planning, and the uncertainty inherent in the project, this study is at a conceptual level. Many of the critical operational decisions have yet to be made; a detailed environmental assessment has not yet been performed. The estimates and conclusions in this report, therefore, must be regarded as preliminary and subject to revision when more data become available.

The scope of this report includes the following:

- Executive Summary (Section 2).
- Brief discussions of the geology and resources of the NOSR 1 property (Sections 3 and 4).
- An engineering design study of the use of open-pit mining (Section 5) including:
 - engineering design basis and assumptions (Sections 5.1 and 5.2)
 - analysis of equipment needs (Sections 5.3 and 5.4)
 - strategy for utilization of the mine (Section 5.5)
- An environmental review of the surface mining plan (Section 6), including:
 - description of the environment of NOSR (Section 6.3)
 - potential effects of the project on the environment (Section 6.4)
 - comparison of the environmental impacts of surface and underground mining schemes (Section 6.5)
 - suggested environmental controls for mitigating adverse effects (Sections 6.6 and 6.7)

- Cost estimates of the surface mining plan, including itemized capital and operating cost estimates (Section 7)

8.1 RESOURCES OF NOSR 1

8.1.1 Description of NOSR Property

NOSR 1 is an area of approximately 35,000 acres located in the southeast corner of the Piceance Creek Basin in Northern Colorado. The Roan Cliffs form the southern and eastern borders with NOSR 3. NOSR 1 is high country with elevations ranging from 7,800 feet to more than 9,300 feet. The terrain is generally rolling, with ridges and valleys. Slopes are moderate to steep.

8.1.2 Total Oil Shale Resources in NOSR 1

Using data obtained from 45 core holes on and adjacent to NOSR 1, the total oil shale resources have been estimated. They are summarized in Table 8-1 below, by oil shale grade.

Table 8-1. Total Estimated Resources

<u>Oil Shale Grade (Gallons/ton)</u>	<u>Shale Acres</u>	<u>Total In-place Barrels</u>
10	31,000	18×10^9
15	31,000	15×10^9
20	31,000	7×10^9
25	33,365	5×10^9
30	33,365	4×10^9
40	33,365	2×10^9

8.1.3 Geological Models for Estimating Resources

Using data from eight core holes drilled in the northwestern portion of NOSR 1, Kaiser developed two empirical resource models. One model relates tons of oil shale to the grade of the shale (measured in GPT); the other relates tons of overburden to the grade of the shale. Both models are linear in the logarithm of the shale grade.

With the development of the two models, calculations were then made to determine SRs as a function of the oil shale grade. These calculations will then feed into the economic model for the mine.

8.2 ENGINEERING ANALYSIS OF OPEN PIT MINING

Open pit mining essentially consists of cutting the rock material horizontally (into "benches") and hauling the material selectively as either oil shale or overburden. When the pit gets deeper, this takes the form of an amphitheater. For access to the working benches from the surface, it is necessary to design a ramp system descending as a spiral from the rim of the pit to the bottom at a given grade, according to the size of the trucks and the density of the traffic.

Five aspects of open pit mining were considered in the engineering analysis:

- General Mine Design Basis and Assumptions
- Open Pit Design Factors
- Selection of Excavation and Haulage Equipment
- Unit Operations Analysis—Equipment Sizing
- Mine Development Plan

8.2.1 General Mine Design Basis and Assumptions

A set of design assumptions was specified to assist in the overall design calculations, based on an ultimate yield of 16.45 million barrels of oil per year. These include specifications on:

- Production days
- Tonnage factors
- Swell factors
- Geotechnical parameters (compressive and tensile strength)
- Efficiency factors
- Labor rates

8.2.2 Open Pit Design Factors

The economics of open pit design are dictated by three interrelated factors: cutoff grade, SR and pit wall slope angle.

- Cutoff Grade

Cutoff grade is generally defined as the lowest grade of the recovered product which will pay for the mining and beneficiation costs and yield the minimum acceptable profit. In general, selection of the cutoff grade is influenced by several items, including market price of the products, mining and beneficiation costs, annual production rate, and mine life. A cutoff grade has not been selected in this study.

- Stripping Ratio

The ratio of the incremental amount of waste to incremental amount of oil shale is defined as the incremental stripping ratio, generally denoted by $\overline{SR}$.

$$\overline{SR} = \frac{\text{Volume of incremental waste at depth } h_1}{\text{Volume of incremental oil shale at depth } h_1}$$

The maximum economical $\overline{SR}$ represents the last slice of material that can be mined where the value of oil shale recovered pays the costs of mining, beneficiation, and yields the desired minimum profit. When the $\overline{SR}$ exceeds the economic stripping ratio (ESR), open pit mining ceases to be profitable and underground methods may be feasible.

- Pit Wall Slope Angle

The maximum slope angle for a pit wall at a given depth is provided by the limit which cannot be exceeded without increasing the probability of slope failure over that which is acceptable. The minimum angle is determined from the ESR. The optimum pit slope angle should minimize the average $\overline{SR}$ and provide safe pit walls for the life of the mine. The optimum pit slope angle should be found somewhere between the two limiting angles.

8.2.3 Selection of Excavation and Haulage Equipment

This study chose the shovel-truck combination as the best system to excavate and haul from the mining places to a primary crusher system located on the pit rim. From that point conveyor belts for both oil shale and overburden will convey the material either to the processing plant or to the waste dump.

The selection was determined by the following factors:

- The material is expected to break into long tubular pieces.
- Operations can be carried out with limited access room.
- Access to and from the working places can be easily changed if unpredictable mining problems develop.
- This haulage combination of truck-conveyor belt utilizes the comparative advantage of each individual system within each radius of optimum average haulage distance.

8.2.4 Unit Operations Analysis-Equipment Sizing

Three levels of annual production rates were analyzed, which are the equivalents of mining oil shale of 25, 30 and 35 GPT.

The major unit operations in the NOSR 1 operation are:

- Drilling and blasting
- Loading
- Hauling
- Conveyor belt

Equipment requirements have been summarized in Table 8-2.

8.2.5 Mine Development Plan

Mine development is usually divided up into three stages, namely: preproduction, production and backfill. The tentative operation plan for NOSR 1 is based on exploitation of oil shale for 20 years.

Table 8-2. Estimated Equipment Requirements for Open Pit Mining

<u>OPERATION</u>	<u>OIL SHALE GRADE (GALLONS/TON)</u>		
	<u>25</u>	<u>30</u>	<u>35</u>
• Total drills required			
Oil Shale	3	2	2
Overburden	17	20	30
• Total weight of explosive/hole			
Oil Shale	1485	1485	1485
Overburden	1569	1569	1569
• Total power shovels required			
Oil Shale	3	3	3
Overburden	10	12	19
• Number of trucks required			
Oil Shale	19	17	15
Overburden	63	78	131
• Belt conveyor performance			
- Estimated belt capacity (tons/hr)			
Oil Shale	6850	5680	4735
Overburden	17660	20685	31785
- Total power consumption (Kwh)			
Oil Shale	1085	1170	1320
Overburden	9820	13968	25410

Some statistics from the mine development plan are given in Table 8-3.

Table 8-3. Mine Development Plan

	<u>OIL SHALE GRADE (GALLONS/TON)</u>		
	<u>25</u>	<u>30</u>	<u>35</u>
<u>Preproduction</u>			
Tonnage to be removed ($\times 10^6$)	374	363	355
<u>Production</u>			
Overburden tons ($\times 10^6$)	154	182	281
Oil Shale tons ($\times 10^6$)	29	24	21
Stripping ratio	5.3	7.5	13.5

8.3 ENVIRONMENTAL REVIEW

A preliminary environmental review of the conceptual surface mining plan was performed. Since details of the operation are not yet well defined, only potential impacts and generic controls are identified in this report.

The review performed in this study included characterizations of the environment of the NOSR 1 property, in terms of:

- physiography
- climate
- meteorology and air quality
- water resources and quality
- soils and vegetation
- terrestrial wildlife
- aquatic life

Qualitative impacts of the surface mining project on the NOSR 1 property were outlined and discussed according to the categories listed above. These impacts were then compared to the impact of underground mining on the site, and are summarized in Table 8-4. Overall, the comparison showed that underground mining results in less severe effects on air quality, surface land disturbance, water quality, aesthetics, and cultural resources. However, underground mining would pose greater safety hazards for mining personnel; subsidence from underground mining could also be greater.

Conceptual environmental controls during surface mining were then recommended. One major area of concern is fugitive particulate emissions: significant effort would be required to suppress dust. Terrestrial habitat loss would be minimized as much as possible and would be temporary in nature. Reclamation and revegetation would restore the habitats.

Some aquatic habitat may be lost or altered, but stream relocations and diversions would emphasize rapid reestablishment of the ecosystem. Controls presented should effectively reduce water quality degradation, but more research is needed on ways to manage the possible hydrological effects from mine dewatering.

8.4 COST ESTIMATES

The capital cost estimates developed have been determined in accordance with the parameters of a Kaiser Type I estimate, and are based on the conceptual mining plans described in Section 5 of this report. They are summarized in Table 8-5. The operating costs refer only to the direct cost of managing and operating the mining facilities and the primary and secondary crusher located at the project site; they are summarized in Tables 8-6 through 8-8.

Table 8-4. Comparison of Environmental Effects of Underground and Surface Mining

<u>Environmental Aspect</u>	<u>Alternative with Least Adverse Environmental Impact</u>	
	<u>Underground</u>	<u>Surface</u>
● Air quality	X	
● Water quality		
- surface	X	
- ground	?	?
● Land		
- surface disturbance	X	
- processed shale disposal		X
- subsidence		X
● Solid waste	X	
● Terrestrial	X	
● Aquatic	X	
● Safety		X
● Aesthetics	X	

Table 8-5. Capital Cost Summary
(Dollars in Thousands)

	SHALE GRADE (GALLONS/TON)		
	25	30	35
Preproduction Cost*	\$654,500	\$641,602	\$627,463
Fixed Expenditure (Permanent Mine Structures)	94,645	106,665	144,745
<u>Mine Equipment (Portable)</u>			
• 5 years life	61,387	71,415	109,671
• 10 years life	13,272	16,147	27,422
• 15 years life	56,125	63,495	90,170
Working Capital** (2 month period)	30,545	34,343	50,216
Consumable Inventory*** (parts & materials)	8,720	10,144	15,579
Total Capital Costs	\$191,194	\$943,811	\$1,065,266

*The total amount will be spent in a period of 3.5 years

**Working capital considers total operating expenses for two months of operations

***Spare part and consumable materials for two months of operations

Table 8-6 Summary - Estimated Direct Operating Cost for Mining Material of 25 GPT*

Cost Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	<u>1. Mining and Transportation to the Secondary Crusher</u>			
7.2-2	a. Mine, Maintenance Labor & Burden			\$ 56,123,000
7.2-3	b. Office of Mine Manager			33,000
7.2-4	c. Mining Equipment			49,520,000
7.2-5	d. Drilling & Blasting Material			30,770,000
7.2-6	e. Undistributed Mining Dept. Overhead			588,000
	• Subtotal Mining & Transportation	4.72	8.330	\$137,034,000
	<u>2. Engineering, Research & Other Supporting Operation</u>			
7.2-7		\$0.020	\$0.036	\$ 595,000
	3. Secondary Crushing	\$0.370	\$0.653	\$ 10,749,000
	4. Environmental Control & Reclamation	\$0.043	\$0.075	\$ 1,235,000
	5. Spend Shale	\$0.300	\$0.530	\$ 8,715,000
	• Total Estimated Operating Cost	\$5.45	\$9.62	\$158,328,000

*Annual tonnage of oil shale mined = 29,091,000 tons

**Barrel of oil annually produced = 16,450,000

Table 8-7. Summary - Estimated Direct Operating Cost for Mining
Material of 30 GPT*

Cross Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	<u>1. Mining & Transportation to the Secondary Crusher</u>			
7.2-8	a. Mine, Maintenance Labor & Burden			\$ 63,330,000
7.2-3	b. Office of Mine Manager			33,000
7.2-9	c. Mining Equipment			56,785,000
7.2-5	d. Drilling & Blasting Material			34,887,000
7.2-6	e. Undistributed Mining Dept. Overhead			659,000
	• Subtotal Mining & Transportation	\$6.42	\$9.46	\$155,694,000
	<u>2. Engineering, Research & other Supporting Operation</u>			
7.2-7		\$0.028	\$0.041	\$ 667,000
	<u>3. Secondary Crushing</u>	\$0.370	\$0.545	\$ 8,970,000
	<u>4. Environmental Control & Reclamation</u>	\$0.057	\$0.084	\$ 1,375,000
	<u>5. Spend Shale</u>	\$0.300	\$0.442	\$ 7,273,000
	• Total Estimated Operating Cost	\$7.18	\$10.58	\$173,979,000

*Annual tonnage of oil shale mined = 24,242,000

**Barrel of oil annually produced = 16,450,000

Table 8-8. Summary - Estimated Direct Operating Cost for Mining Material of 35 GPT*

Cross Ref. Table		Cost Per Ton Oil Shale* \$	Cost Per Barrel Oil**	Annual Cost \$
	<u>1. Mining & Transportation to the Secondary Crusher</u>			
7.2-10	a. Mine, Maintenance Labor & Burden			\$ 88,448,000
7.2-3	b. Office of Mine Manager			45,000
7.2-11	c. Mining Equipment			\$ 84,870,000
7.2-5	d. Drilling & Blasting Material			50,101,000
7.2-6	e. Undistributed Mining Dept. Overhead			923,000
	• Subtotal Mining & Transportation	\$10.80	\$13.64	\$224,387,000
7.2-7	2. Engineering, Research & Other Supporting Operation	0.046	0.058	\$ 954,000
	3. Secondary Crushing	0.370	0.467	\$ 7,688,000
	4. Environmental Control & Reclamation	0.095	0.119	\$ 1,964,000
	5. Spend Shale	0.300	0.379	\$ 6,234,000
	• Total Estimated Operating Cost	\$11.61	\$14.66	\$241,227,000

* Annual tonnage of oil shale mined = 20,779,000

**Barrel of oil annually produced = 16,450,000

7.2.1.7 Labor Burden

A total burden of 40% will be provided to allow for a benevolent burden covering retirement and other benefits for employees who remain long enough to qualify for such benefits. Sick leave, vacation, and holiday are not considered to be part of the labor burden. These items are covered by additional employees on the payroll. The average employee will work about 1,758 hours per year but be paid for 2,080 hours per year. For a position that must be staffed 24 hours a day, 7 days a week, or 8,760 hours, 5 employees are required ($8,760 \div 1,758 = 4.98$ employees).

7.2.1.8 Power and Fuel Oil

The cost of power has been estimated at \$0.03/kWh. The cost of fuel oil is at the base price of U.S. \$1.00 per gallon.

7.2.2 Cost Centers

The summary costs of each alternate are organized by center as follows:

- Mining and transportation center
- Engineering, research and other supporting operations
- Secondary crushing
- Environmental control and reclamation
- Spent shale

7.2.3 Type of Estimate

The cost estimate has been developed in accordance with the parameters of a Type I estimate as defined in the Appendix.

APPENDIX

A-1-2-

Type I Estimate

DEFINITION OF TYPE I ESTIMATE For Economic Feasibility Studies

Basis

A Type I estimate can be based on assumed flowsheets and process requirements. Test work is desirable but not an absolute requirement if the process is generally well known. A visit to the actual plant site would be helpful. Design drawings are not prepared beyond sketches made by the project engineer. Equipment lists are prepared from the assumed flowsheets and priced on updated former quotations, telephone quotations from vendors' representatives, and occasionally letter quotes. Equipment specifications are not required, nor are formal vendors' proposals solicited. Total facility costs can be determined by roughly estimating the shelter volume and foundation concrete and applying unit costs. Percentage factors are used for installation of machinery. Electrical costs other than motors and substations are estimated as unit costs per installed horsepower. Percentage factors can be used for contractor's field overhead, construction plant, construction camp, design costs, procurement, and contractor's profit.

Information Required

It is necessary to know the geographical area of the project, the capacity required by the client, and some idea of the gross value of the raw material to be processed. For calculating operating costs, it is helpful to know the range of local labor rates, statu-

tory and union required labor burden, and the approximate cost of basic supplies such as fuel, power, explosives, grinding media, reagents, etc.

Skills Employed

A Type I estimate can usually be made by a project engineer with experience in the industry covered by the feasibility study. Generally, design drawings and specifications are not prepared; however, recent Kaiser Engineers' experience in the construction of industrial facilities is used for updating percentage factors and other unit costs. Often the project engineer depends heavily on his personal acquaintances among vendors and operating companies and on his own experience in the industry.

Use of Estimates

A Type I estimate contains heavy contingencies.* These may range from 20% to 25% on structures and 10% to 15% on machinery. Kaiser Engineers believes that a Type I estimate may frequently be suitable to reject a project, but it is seldom adequate for positive acceptance of a project. A Type I estimate is often used for preliminary comparison of alternates and generally describes a hypothetical installation; it seldom becomes the basis for even conceptual design. It may, however, indicate the desirability of expanding the estimate to a Type II or Type III.

* In this definition the percentage assigned to contingencies is a judgment factor and is not to be interpreted as meaning that estimates are necessarily accurate within this percentage range, nor is there an implied reference to any order of accuracy.

Comparison of Estimates

ITEM	TYPE I	TYPE II	TYPE III	TYPE IV
Site				
Plant capacity	Assumed	Preliminary	Optimized	Finalized
Geographical location	Assumed	General	Approximate	Specific
Maps and surveys	None	If available	Available	Detailed
Soil and foundations tests	None	None	Preliminary	Final
Site visits by project team	Possibly	Recommended	Essential	Essential
Process				
Process flowsheets	Assumed	Preliminary	Optimized	Finalized
Bench-scale tests	If available	Recommended	Essential	Essential
Pilot plant tests	Not needed	Recommended	Recommended	Essential
Energy and material balances	Not essential	Preliminary	Optimized	Finalized
Facilities Design				
Nature of facilities	Conceptual	Possible	Probable	Actual
Equipment selection	Hypothetical	Preliminary	Optimized	Finalized
General arrangements, mechanical	None	Minimum	Preliminary	Complete
General arrangements, structural	None	Outline	Outline	Preliminary
General arrangements, other	None	Minimum	Outline	Preliminary
Piping drawings	None	None	One-line	Some detail
Electrical drawings	None	None	One-line	Some detail
Specifications	None	Performance	General	Detailed
Basis for Capital Cost Estimating				
Estimates prepared by	Project Engr	Sr Estimators	Sr Estimators	Est Dept
Vendor quotations	Previous	Single source	Multiple	Competitive
Civil work	Rough sketch	Drawing estimate	Drawing estimate	Take-offs
Mechanical work	% of machinery	% of machinery	Man-hours/ton	Man-hours/ton ¹
Structural work	Rough sketch	Prelim drawings	Take-off/ton	Take-off/ton ¹
Piping and instrumentation	% of machinery	% of machinery	Take-off	Take-off ¹
Electrical work	\$ per hp	\$ per hp	Take-off	Take-off ¹
Indirect costs	% of total	% of total	Calculated	Calculated
Contingency ²	20-25% ²	15-20% ²	15% ²	10% ²
Operating Cost Determination				
Labor rates	Assumed	Investigate	Get contracts	Get contracts ³
Labor burden	Assumed	Calculated	Calculated	Calculated ³
Power costs	Assumed	Actual	Actual	Contract ³
Fuel costs	Assumed	Verbal quote	Letter quote	Contract ³
Expendable supplies	Assumed	Verbal quote	Letter quote	Contract ³
Reagents	Assumed	Verbal quote	Letter quote	Contract ³
Parts	Assumed	Verbal quote	Letter quote	Letter quote
Economic Analysis D.C.F.	Not meaningful	If requested	If requested	If requested
Use of Estimates	Comparison rejection	Feasibility	Budget	Funding

Notes. 1 Often subject to subcontract bids.

2 In this definition the percentage assigned to contingencies is a judgment factor and is not to be interpreted as meaning that estimates are necessarily accurate within this percentage range, nor is there an implied reference to any order of accuracy.

3 Contracts can be solicited if project is near-term.