**Correlation of Radioactive Waste Treatment
Costs and the Environmental Impact
of Waste Effluents in the Nuclear Fuel Cycle
for Use in Establishing "As Low
as Practicable" Guides—Appendix A.
Preparation of Cost Estimates for Volume 1,
Milling of Uranium Ores**

A. D. Ryon
R. E. Blanco

OAK RIDGE NATIONAL LABORATORY

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CHEMICAL TECHNOLOGY DIVISION

CORRELATION OF RADIOACTIVE WASTE TREATMENT COSTS AND THE ENVIRONMENTAL
IMPACT OF WASTE EFFLUENTS IN THE NUCLEAR FUEL CYCLE FOR USE IN
ESTABLISHING "AS LOW AS PRACTICABLE" GUIDES - APPENDIX A.
PREPARATION OF COST ESTIMATES FOR VOLUME 1,
MILLING OF URANIUM ORES

A. D. Ryon
R. E. Blanco

Project Director: R. E. Blanco

MAY 1975

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Oak Ridge, Tennessee 37830
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PUBLICATION NOTICE

This engineering survey report was developed for the Nuclear Regulatory Commission (NRC) - Office of Standards Development (formerly the Regulatory Office of the Atomic Energy Commission). It is one of a series of draft reports on segments of the nuclear fuel cycle that were prepared in 1973 and 1974 and were made available to the public in December 1974. These draft reports are subject to revision prior to, and subsequent to, their publication by the NRC in conjunction with draft environmental statements for comment by the public and government agencies.

The reports in this series are:

B. C. Finney, R. E. Blanco, R. C. Dahlman, F. G. Kitts, and J. P. Witherspoon, Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As Low As Practicable" Guides - Nuclear Fuel Reprocessing, ORNL-TM-4901 (May 1975).

W. H. Pechin, R. E. Blanco, R. C. Dahlman, B. C. Finney, R. B. Lindauer, and J. P. Witherspoon, Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As Low As Practicable" Guides - Fabrication of Light-Water Reactor Fuel from Enriched Uranium Dioxide, ORNL-TM-4902 (May 1975).

M. B. Sears, R. E. Blanco, R. C. Dahlman, G. S. Hill, A. D. Ryon, and J. P. Witherspoon, Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As Low As Practicable" Guides - Milling of Uranium Ores, ORNL-TM-4903, Vol. 1 (May 1975).

A. D. Ryon and R. E. Blanco, Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As Low As Practicable" Guides - Appendix A. Preparation of Cost Estimates for Volume 1, Milling of Uranium Ores, ORNL-TM-4903, Vol. 2 (May 1975).

W. S. Groenier, R. E. Blanco, R. C. Dahlman, B. C. Finney, A. H. Kibbey, and J. P. Witherspoon, Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As Low As Practicable" Guides - Fabrication of Light-Water Reactor Fuels Containing Plutonium, ORNL-TM-4904 (May 1975).

L. R. McKay (Ed.), A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment, ORNL-4992 (1975). (This report serves as Appendix B for all of the above reports.)

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ABSTRACT

This appendix presents the methodology and detailed calculations used in estimating the costs for treating the radwastes at the model uranium mills.

APPENDIX A. PREPARATION OF COST ESTIMATES FOR VOLUME 1,
MILLING OF URANIUM ORES

A. D. Ryon and R. E. Blanco

This Appendix presents the details of the methods used to estimate the capital and operating costs of the installations required for treating the radwastes at model uranium mills. Two general flowsheets -- acid-leach solvent-extraction and alkaline leach -- at two sites, Wyoming and New Mexico, are estimated. The details of the methods used for estimating the annual fixed charges and contribution to power costs are presented in Sect. 6 of the survey report. In summary, the annual fixed charge is 24% of the capital cost and the contribution to power cost is based on the total U_3O_8 requirement of a power reactor over its life.

The estimates of capital and operating costs were made by A. H. Ross & Associates^a under subcontract from Union Carbide Corporation, Nuclear Division. The costs of major equipment items specified by the flowsheets (Sect. A1) are primarily based on vendor bids and the estimator's files using mid-1973 dollars. In general, the capital costs were derived as shown in Sects. A2 and A3 by using factors to include installation, piping, instruments, utilities, design, engineering, and construction costs. The capital cost totals listed in this Appendix were increased by 20% to allow for interest during construction plus an additional 20% allowance for contingency expenses. These revised totals are used in the survey report. The operating costs were computed by estimating labor, supplies, and maintenance requirements for the waste treatment processes, based on the cost estimator's experience in the uranium milling industry. These costs were increased by 15% to allow for contingency expenses. The revised totals are used in the survey report. Changes in the original estimates were made by ORNL personnel to allow for subsequent revisions of the flowsheets. The changes are shown on the worksheets. The capital costs

^aConsulting chemical and metallurgical engineers, 1505-80 Richmond Street, West Toronto, Canada.

for airborne waste treatment are summarized in Sect. A2.1 and for liquid and solid waste treatment in Sect. A3.1. The derivation of capital costs is presented in Sects. A2.2 and A3.2, and the derivation of operating costs in Sects. A2.3 and A3.3.

A1.0 CHEMICAL AND EQUIPMENT REQUIREMENTS

The general flowsheets for radwaste treatments are shown in the survey report (Figs. 4.1-4.14). The detail equipment requirements for airborne waste treatment are listed in Table 4.2 of the survey. The details of solid-liquid treatment are shown in the following sections (A1.1 and A1.2).

Al.1 Radwaste Treatment Equipment Requirements for Model Acid-
Leach Solvent-Extraction Mill Processing
2000 Tons Ore Per Day

Model Solvent Extraction Mill

2000 Ton/day x 365 days x 20 yr = 14,600,000 Ton Ore processed during
life of mill

14,600,000 Ton x 0.20% U_3O_8 x 2000 lb x 91% Rec. = 53,200,000 lb U_3O_8
concentrate/mill life

$\frac{14,600,000 \text{ T} \times 2000 \text{ lb}}{120 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} = 9,000,000 \text{ yd}^3$ tailings/mill life

$\frac{2000 \text{ T/day} \times 1.5 \text{ T Liq/T ore} \times 2000 \text{ lb/T}}{8.33 \text{ lb/gal} \times 24 \text{ hr} \times 60 \text{ min}} = 500 \text{ gpm waste liquor}$

Pond Area

Wyoming - $\frac{2000 \text{ T/day (1.5-.3 moisture)} \times 2000 \text{ lb} \times 365}{62.4 \text{ lb/ft}^3 \times 4.0 \text{ ft/yr} \times 43,560 \text{ ft}^2} = 161 \text{ acres}$

New Mexico - 161 acres x $\frac{4.0}{87/12} = 89 \text{ Acres}$

Solid-Liquid Solvent Extraction Case 1 at WyomingTailings Pond

1. Assume seepage 10%
2. Area $161 \times 90\% \times 120\% = 174$ Acres
3. Assume square $(174 \times 43,560)^{1/2} = 2753$ -ft-long Dam
4. Ave. solids thickness $\frac{9 \times 10^6 \text{ yd}^3 \times 27}{174 \times 43,560} = 32 \text{ ft}$
5. Assume wedge shape, dam ht = $32 \times 2 + 5$ freeboard = 69 ft
6. Dam, native material, 10 ft ht x 2753 ft x 10 ft crest, slope 2:1
7. Volume of dam = $\frac{(10 \times 10 + 10 \times 20) \times 2753}{27 \text{ ft}^3/\text{yd}^3} = 30,600 \text{ yd}^3$
8. Volume of 6-in. soil cover $\frac{174 \text{ Acre} \times 43,560 \times 1/2 \text{ ft}}{27 \text{ ft}^3/\text{yd}^3} = 140,400 \text{ yd}^3$
9. Stabilize surface
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, 140,400 yd³
10. Diversion dam and ditches = 25,000 yd³

Solid-Liquid Solvent Extraction Case 1 at New MexicoTailings Pond

1. Assume seepage = 10%
2. Area = $89 \times 90\% \times 120\% = 96$ acres
3. Assume square $(96 \times 43,560)^{1/2} = 2046$ ft
4. Ave. solids thickness = $\frac{9 \times 10^6 \text{ yd}^3 \times 27}{96 \times 43,560} = 58$ ft
5. Assume wedge shape, dam ht = $58 \times 2 + 5 = 121$ ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave. solids thickness = $\frac{100-5}{2}$ (freeboard) = 48 ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116$ acres
9. Dam length = $(116 \times 43,560)^{1/2} = 2248$ ft
10. Dam, native material, 10 ft ht x 2248 ft x 10 ft crest
11. Volume of dam = $\frac{(10 \times 10 + 20 \times 10) 2248}{27} = 25,000 \text{ yd}^3$
12. Volume of 6-in. soil cover = $\frac{116 \text{ acres} \times 43,560 \times 1/2}{27} = 93,600 \text{ yd}^3$
13. Stabilize surface
 - a-1. Plant native shrubs and grasses - irrigate in summer
 - a-2. Maintain - water, etc.
 - b. Cover with coarse rock, 6-in. layer, 93,600 yd³
14. Diversion dam = 25,000 yd³

Solid-Liquid Solvent Extraction Cases 2 and 3^a at Wyoming

Tailings Pond

1. Assume 2% seepage
2. Area = $161 \times 98\% \times 120\% = 189$ acres
3. Assume square $(189 \times 43,560)^{1/2} = 2870$ ft
4. Ave. solids thickness = $\frac{9 \times 10^6 \times 27}{189 \times 43,560} = 30$ ft
5. Assume wedge shape, dam ht = $30 \times 2 + 5 = 65$ ft
6. Dam, native x 10-ft clay core, slope 2:1
7. Volume of Dam
 - a. Clay, $10 \times 65 \times 2872/27 = 69,100$ yd³
 - b. Fill, $(10 \times 65 + 130 \times 65) 2872/27 = 968,000$ yd³
8. Excavation to key clay to base, $10 \times 10 \times 2872/27 = 10,700$ yd³
9. Volume of 2-ft soil cover = $\frac{189 \text{ acres} \times 43,560 \times 2}{27} = 609,800$ yd³
10. Stabilize surface
 - a-1. Plant native shrubs and grasses - irrigate in summer
 - a-2. Maintain - water, etc.
 - b. Cover with coarse rock, 6-in. layer, 152,000 yd³
11. Diversion dam = 25,000 yd³
12. Survey and core drilling

^aSame as Case 2 except earth cover (item 9) is 8 ft instead of 2 ft.

Solid-Liquid Solvent Extraction Cases 2 and 3^a at New Mexico

Tailings Pond

1. Assume 2% seepage
2. Area = $89 \times 98\% \times 120\% = 105$ acres
3. Assume square $(105 \times 43,560)^{1/2} = 2135$ ft
4. Ave.solid-thickness = $\frac{9 \times 10^6 \times 27}{105 \times 43,560} = 53$ ft
5. Assume wedge shape, dam ht = $53 \times 2 + 5 = 111$ ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave.solids thickness = $\frac{100-5}{2} = 48$ ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116$ acres
9. Dam length = $(116 \times 43,560)^{1/2} = 2248$ ft
10. Dam, native + clay core, slope 2:1
11. Volume of dam
 - a. Clay core = $10 \times 100 \times 2248/27 = 83,300$ yd³
 - b. Fill = $(10 \times 100 + 200 \times 100) 2248/27 = 1,748,000$ yd³
12. Volume of 2-ft soil cover = $\frac{116 \text{ acres} \times 43,560 \times 2}{27} = 374,300$ yd³
13. Excavation to key clay to base, $10 \times 10 \times 2248/27 = 8,300$ yd³
14. Stabilize surface
 - a-1. Plant native shrubs and grasses - irrigate in summer
 - a-2. Maintain - water, etc.
 - b. Cover with coarse rock, 6-in. layer, 93,600 yd³
15. Diversion dam = 25,000 yd³
16. Survey and core drilling

^aSame as Case 2 except for earth cover (item 12) is 8 ft instead of 2 ft.

Solid-Liquid Solvent Extraction Cases 4a and 4b at WyomingA. Neutralization

1. Lime - 3000 T/day at pH 2.0 ($.01 \text{ N H}^+$), Fe 0.10 N , Al 0.20 N .

$$3000 \text{ T/day} \times 2000 \text{ lb} \times .454 \text{ l/lb} \times \frac{.31 \text{ N} \times 74/2}{454 \times 2000 \text{ lb}} = \frac{34.4 \text{ T}}{\text{Ca(OH)}_2/\text{day}}$$

2. Equipment

Pneumatic unloader for lime

Lime storage silo, 100 T (7-day supply) + slaker

Gravimetric feeder 0-2 Ton/hr

Mix tank, 2000-gal wood, agitated (3)

Automatic pH control of lime feeder

B. Tailings Pond

1. Assume 0.1% seepage
 2. Area = $161 \times 120\% = 193$ acres
 3. Assume square $(193 \times 43,500)^{1/2} = 2000 \text{ ft}$
 4. Ave. solids thickness $\frac{9 \times 10^6 \times 27}{43,560 \times 193} = 29 \text{ ft}$
 5. Assume wedge shape, dam ht = $29 \times 2 + 5 = 63 \text{ ft}$
 6. Dam, native + 10-ft clay core, slope 2:1
 7. Volume of dam
 - a. Clay = $10 \times 63 \times 2900/27 = 67,700 \text{ yd}^3$
 - b. Fill = $(10 \times 63 + 126 \times 63) 2900/27 = 920,300 \text{ yd}^3$
 8. Excavation to key clay to base - $10 \times 10 \times 2900/27 = 10,700 \text{ yd}^3$
 9. Sealing of pond bottom and sides
- Area: bottom (193 acres) + sides $(\frac{2900 \text{ ft} \times 63 \text{ ft} \times 2}{43,560}) = 201 \text{ acres}$

Amount asphalt: assume 2 in. thick:

$$2/12 \times \frac{201A \times 43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb/T}} = 45,200 \text{ Ton}$$

10. Cover

a. 20-ft dirt $\frac{193 \times 43,560 \times 20}{27} = 6,227,000 \text{ yd}^3$

b. 2-in. asphalt + 2-ft dirt

asphalt $\frac{2/12 \times 193A \times 43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}} = 43,400 \text{ tons}$

2-ft dirt: $\frac{193 \times 43,560 \times 2}{27} = 623,000 \text{ yd}^3$

11. Stabilize

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b. Cover with coarse rock, 6-in. layer, 155,800 yd³

12. Diversion dam = 25,000 yd³

Solid-Liquid Solvent Extraction Cases 4a and 4b at New MexicoA. Neutralization (same as Cases 4a and 4b, Wyoming)B. Tailings Pond

1. Assume 0.1% seepage
2. Area = $89 \times 120\% = 107$ acres
3. Assume square $(107 \times 43,560)^{1/2} = 2157$ ft
4. Ave. solids thickness $\frac{9 \times 10^6 \times 27}{107 \times 43,560} = 52$ ft
5. Assume wedge shape, dam ht = $52 \times 2 + 5 = 109$ ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave. solids thickness = $\frac{100-5}{2} = 48$ ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116$ acres
9. Dam length = $(116 \times 43,560)^{1/2} = 2248$ ft
10. Dam, native + 10-ft clay core, slope = 2:1
11. Volume of dam
 - a. Clay = $10 \times 100 \times 2248/27 = 83,300$ yd³
 - b. Fill = $(10 \times 100 + 200 \times 100) 2248/27 = 1,748,400$ yd³
12. Excavation to key clay to base, $10 \times 10 \times 2248/27 = 8,300$ yd³
13. Sealing of pond bottom and sides

$$\text{Area} = 116A + \frac{2248 \times 100 \times 2}{43,560} = 126 \text{ acres}$$

$$\text{Amount of asphalt (2 in. thick)} = \frac{2}{12} \times 126A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}}$$

$$= 28,400 \text{ tons}$$

14. Cover

a. Volume of 20-ft soil cover 116A x $\frac{43,560 \times 20}{27} = 3,742,900 \text{ yd}^3$

b. 2 in. asphalt + 2 ft dirt

$$\text{Asphalt} = \frac{2/12 \times 116 \times 43,560 \times 62 \text{ lb}}{2000 \text{ lb}} = 26,100 \text{ tons}$$

$$2 \text{ ft dirt} = 374,300 \text{ yd}^3$$

15. Stabilize

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b. Cover with coarse rock, 6-in. layer, $93,600 \text{ yd}^3$

16. Diversion dam = $25,000 \text{ yd}^3$

Solid-Liquid Solvent Extraction Case 5 at WyomingA. Neutralization

1. Liquid Waste

$$a. \frac{1130 \text{ T}}{3000 \text{ T}} \times 597 = 13 \text{ T Ca(OH)}_2/\text{day}$$

b. Equipment

Lime unloader

Lime silo, 3 day, 40 T

Feeder, 0-1 T/hr

Mix tank, 1000-gal, wood, agitated

Thickener

Automatic pH controller

2. Sand-Slime Waste

$$a. \frac{1870 \text{ T}}{3000 \text{ T}} \times 59 \text{ T} = 22 \text{ T Ca(OH)}_2/\text{day}$$

b. Equipment

Lime silo, 3 day, 70 T

Lime feeder, 0-2 T/hr

Mix tank, 2000-gal, wood, agitated

Automatic pH controller

B. Cement Slurry to Open Pit Mine [Can. Mine & Met. Bull. 63 (1970)]

Note: Solids content should be ~70%; therefore, the classifier discharge (~75% solid) and thickener underflow (~30% solid) should be combined without further dilution to give ~60% solids slurry

1. Cement

Use 1 part cement to 20 parts tailings (dry basis)

$$2000 \text{ T/day} \times 1/20 = 100 \text{ T cement/day}$$

2. Equipment (see flowsheet)

Pneumatic unloader

Cement silo, 300 T capacity

Gravimetric feeder, 0-10 T/hr

Mix tank, 1000 gal, rubber-lined, agitated

Slurry pump, 25 HP, 500 gpm

Pipe (5 in.) or hose, 3000 ft

Water flush pump, 400 gpm (diesel powered)

C. Evaporation Pond

Note: The volume of liquid to be evaporated will be essentially the same as for Cases 4a and 4b.

1. Assume 0.1% seepage

2. Area = 161 x 120% = 193 acres

3. Assume square $(193 \times 43,560)^{1/2} = 2900 \text{ ft}$

4. Assume dam ht = 15 ft

5. Dam, native +10-ft clay core, slope 2:1

6. Volume of dam

$$\text{a. Clay} - 10 \times 15 \times 2900/27 = 16,100 \text{ yd}^3$$

$$\text{b. Fill } (10 \times 15 + 30 \times 15) 2900/27 = 64,400 \text{ yd}^3$$

7. Excavation to key clay to base - $10 \times 10 \times 2900/27 = 10,700 \text{ yd}^3$

8. Sealing of pond bottom and sides

$$\begin{aligned} \text{Amount of sealant (2 in. thick)} &= 2/12 \times 193 \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}} \\ &= 43,400 \text{ tons} \end{aligned}$$

9A. Cover

a. 20-ft dirt - $193A \times 43,560 \times 20/27 = 6,227,000 \text{ yd}^3$

b. 2-in. asphalt + 2-ft dirt

$$\text{Asphalt: } 2/12 \times 193A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}} = 43,400 \text{ T}$$

$$\text{Dirt: } 2 \times 193A \times 43,560/27 = 623,000 \text{ yd}^3$$

9B. Alternative is to collect solids in a smaller area before covering.

Volume of solids:

$$\frac{25\text{g/l (T.D.S.)} \times 3000\text{T} \times 2000 \text{ lb} \times .454 \text{ l/lb} \times 365\text{d} \times 20 \text{ yr}}{454\text{g/lb} \times 120 \text{ lb/ft}^3 \times 27 \text{ ft}^2/\text{yd}^3} = 338,000 \text{ yd}^3$$

Assume pile 10 ft thick

$$\text{Area} = \frac{338,000 \times 27}{10 \times 43,560} = 21 \text{ acres}$$

a. 20-ft dirt cover - $21A \times 43,560 \times 20/27 = 678,100 \text{ yd}^3$

b. 2-in. asphalt + 2-ft dirt

$$\text{Asphalt: } 2/12 \times 21A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}} = 4,730 \text{ T}$$

$$\text{Dirt: } 2 \times 21 \times 43,560/27 = 68,000 \text{ yd}^3$$

$$\text{Area of concrete} = \frac{2000\text{T/d} \times 2000 \text{ lb} \times 1.05 \times 365 \times 20 \text{ yr}}{120 \times 100/2 \times 43,560} = 117 \text{ acres}$$

10. Stabilize

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b. Cover with coarse rock, 6-in. layer, 155,600 yd³

10. Alternate

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b. Cover with coarse rock, 6-in. layer, 86,300 yd³

11. Diversion dam = 25,000 yd³

Solid-Liquid Solvent Extraction Case 5 at New Mexico

- A. Neutralization (same as Case 5, Wyoming)
- B. Cement Slurry to Mine (same as Case 5, Wyoming, except underground mine)
- C. Evaporation pond
1. Assume 0.1% seepage
 2. Area = $89 \times 120\% = 107$ acres
 3. Assume square, $(107 \times 43,560)^{1/2} = 2160$ ft
 4. Assume dam ht = 15 ft
 5. Dam, native, 10-ft clay core, slope 2:1
 6. Volume of dam
 - a. Clay - $10 \times 15 \times 2160/27 = 12,000$ yd³
 - b. Fill - $(10 \times 15 + 30 \times 15) 2160/27 = 48,000$ yd³
 7. Excavation to key clay to base - $10 \times 10 \times 2160/27 = 8,000$ yd³
 8. Sealing of pond bottom and sides

Amount of sealant (2 in. thick) -

$$2/12 \times 107A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000} = 24,100 \text{ Ton}$$
 - 9A. Cover
 - a. 20-ft dirt - $107A \times 43,560 \times 20/27 = 3,453,000$ yd³
 - b. 2-in. asphalt + 2-ft dirt

Asphalt: $2/12 \times 107A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000} = 24,100 \text{ Ton}$

Dirt: $2 \times 107A \times 43,560/27 = 345,000$ yd³
 - 9B. Same as Case 5, Wyoming.

10. Stabilize

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b. Cover with coarse rock, 6-in. layer, 86,300 yd³

10. Alternate (same as Case 5, Wyoming)

11. Diversion dam = 25,000 yd³

Stream	Ton/day			Diss. Solids	Sp. Gr.	gpm
	Sand	Slime	Water			
1	--	--	1130	28	1.00	190
2	--	40	1130	--	1.00	190
3	--	--	1040	--	1.00	170
4	1400	600	1870	47	1.5	430
5	--	40	90	--	1.2	15
6	1400	690	1960	--	1.5	450
7	1400	790*	1960	--	1.5	460

* Includes 100 T cement

Solid-Liquid Waste - Solvent Extraction - Case 5

Solid-Liquid Solvent Extraction Cases 6a and 6b at Wyoming or New MexicoA. Neutralization

1. Lime [
- $\text{Ca}(\text{OH})_2$
-], MW = 74

$$2530 \text{ T/day} \times 2000 \text{ lb} \times \frac{.454 \text{ lb/lb} \times .31\text{N}}{2000 \text{ lb} \times 454} \times 74/2 = 29 \text{ T/day}$$

2. Equipment (see flowsheet)

Pneumatic lime unloader

Lime storage silo, 100 ton (3-day supply)

Gravimetric lime feeder

1000-gal mix tank, rubber lined

Automatic pH control of lime feeder

Thickener 8 x 100 ft

Continuous filters, 700 T solids/day, area = 2000 ft²

B. Sand Wash (remove 98% dissolved solids)

1. Water (wash ratio = 2)

$$2000 \text{ T} \times 70\% \text{ sand} \times 2 = 2800 \text{ T water/day}$$

2. Equipment (see flowsheet)

(2) classifiers

Transportation to mine or landfill (distance $\leq$ 2 miles)C. Evaporation

1. Calculation of water load

$$\text{Liquid waste} = 1130 \text{ T/day}$$

$$\text{Filtrate from slime} = 1400 \text{ T} - 30\%/70\% 700 \text{ T} = 1100 \text{ T/day}$$

$$\text{Total water to be evaporated} = 2230 \text{ Ton/day}$$

2. Equipment (see flowsheet)

Evaporator, forced circulation, mild steel

Instrumentation

Condenser

Feed surge tank, 10,000 gal, wood

Feed - concentrate heat exchanger, 600 ft²

Feed rate, 410 gpm, pump size = 600 gpm

Concentrate rate, 41 gpm, pump size = 60 gpm

Condensate receiver, 10,000 gal, wood

D. Asphalt Fixation (0.67 lb/lb solid) (Case 6a)

1. Slime + diss. solids + lime

$$30\% \times 2000 \text{ T} + \frac{25 \text{ g/l} \times 2530 \text{ T} \times 2000 \text{ lb} \times .454 \text{ l/lb}}{454 \text{ g} \times 2000 \text{ lb}} + 29 \text{ T lime} =$$

$$690 \text{ T/day}$$

2. Asphalt: $0.67 \times 690 = 460 \text{ T/day}$ 3. Water load to be evaporated, filter cake, $\frac{30\% \text{ moisture}}{70\% \text{ dry solid}} \times 690 \text{ T} =$
300 T/day

4. Equipment (see flowsheet)

a. Asphalt unloader

b. Asphalt storage, 3-day supply, 1400 T

c. Asphalt pump, 0-300 gpm

d. Wiped-film evaporator (160°C)

(6) 200-ft² units in parallel

e. Condenser, 300 T water/day

f. Associated pumps and instrumentation

g. Transportation of asphalt-slime solids to mine or landfill

(distance $\leq$ 2 miles)

D. Alternate (Cement 1:20) (Case 6b)

1. Slime + diss. solids + lime

$$30\% \times 2000 \text{ T} + \frac{25\text{g/l} \times 2530 \text{ T} \times 2000 \text{ lb} \times .454}{454 \times 2000} + 29 \text{ T} = 690 \text{ T/day}$$

2. Cement:
- $1/20 \times 690 = 35 \text{ T/day}$

3. Equipment (see flowsheet)

- a. Pneumatic cement unloader
- b. Cement, silo, 3 day, 100 T
- c. Gravimetric feeder, 0-3 T/hr
- d. Mix tank, 1000 gal, rubber-lined, agitator
- e. Slurry pump, 20 HP, 200 gpm
- f. Pipe or hose, 3000 ft
- g. Water flush pump, 200 gpm (diesel powered)

E. Solids disposal in landfill or open pit mine:

1. Volume of sand: $\frac{2000 \text{ T} \times 70\% \times 2000 \text{ lb} \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb/ft}^3 \times 27 \text{ ft/yd}^3} =$
 $6,309,000 \text{ yd}^3$

2. a. Volume of asphalt-slime

$$\frac{2000 \text{ T} \times 30\% \times 2000 \text{ lb} \times 1.67 \times 365 \text{ d} \times 20 \text{ yr}}{62.4 \times 1.6 \times 27 \text{ ft/yd}^3} = 5,427,000 \text{ yd}^3$$

- b. Volume of concrete-slime

$$\frac{2000 \text{ T} \times 30\% \times 2000 \text{ lb} \times 1.05 \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} = 2,839,000 \text{ yd}^3$$

3. Assume wedge shape, max. ht. = 100 ft

a. Area for sand + asphalt = $\frac{(6.31 \times 10^6 + 5.43 \times 10^6)27}{100/2 \times 43,560} =$
 146 acres

b. Area for sand + concrete = $\frac{(6.31 \times 10^6 + 2.84 \times 10^6)27}{100/2 \times 43,560} =$

113 acres

4. Cover, 20-ft dirt

$$a. \text{ Volume for asphalt} = \frac{20 \times 146 \times 43,560}{27} = 4,711,000 \text{ yd}^3$$

$$b. \text{ Volume for concrete} = \frac{20 \times 113 \times 43,560}{27} = 3,646,000 \text{ yd}^3$$

5. Stabilize

a-1. Plant native shrubs and grasses - irrigate in summer

a-2. Maintain - water, etc.

b-1. Cover with coarse rock, 6-in. layer, for asphalt 117,800 yd³

b-2. Cover with coarse rock, 6-in. layer, for concrete 91,200 yd³

E. Alternate, disposal in underground mine, New Mexico

$$1. \text{ Volume of sand} = 6.3 \times 10^6 \text{ yd}^3$$

$$2. a. \text{ Volume of asphalt-slime} = 5.4 \times 10^6 \text{ yd}^3$$

$$b. \text{ Volume of concrete-slime} = 2.8 \times 10^6 \text{ yd}^3$$

3. Transportation and placement in mine - 3000 ft (pump)

Stream	Ton/day				Sp. Gr.	gpm
	Sand	Slime	Water	Diss. Solids		
1	--	--	1130	28	1.0	190
2	--	600	1400	35	1.2	280
3	--	690	2530	--	1.1	490
4	--	25	250	--	1.1	41
5	--	--	2500	--	1.0	410
6	--	--	2250	--	1.0	370
7	--	690	1610	--	1.2	320
8	--	690	300	--	1.8	90
9	--	460 ^a	--	--	1.0	80
10	--	--	300	--	1.0	50
11	--	1150 ^b	--	--	1.5	130
12	1400	--	470	10	1.8	--
13	--	--	2550	--	1.0	420
14	--	--	2550	10	1.0	420
15	1400	--	470	--	1.8	--

^aAsphalt^bContains 460 T asphalt/day

Solid-Liquid Waste - Solvent Extraction - Case 6a (asphalt)

ORNL DWG 74-7994

Stream	Ton/day			Diss. Solids	Sp. Gr.	gpm
	Sand	Slime	Water			
1	--	--	1130	28	1.0	190
2	--	600	1400	35	1.2	280
3	--	690	2530	--	1.1	490
4	--	25	250	--	1.1	41
5	--	--	2500	--	1.0	410
6	--	--	2250	--	1.0	370
7	--	690	1610	--	1.2	320
8	--	690	300	--	1.8	90
9	--	725 ^a	300	--	1.8	100
10	1400	--	470	10	1.8	--
11	--	--	2250	--	1.0	380
12	--	--	2250	10	1.0	380
13	1400	--	470	--	1.8	--

^aContains 35 T cement/day

Solid-Liquid Waste - Solvent Extraction - Case 6b (cement)

Solid-Liquid Solvent Extraction Case 6c

- A. HNO_3 leach (3 M HNO_3 at 85°C)
- (8) Leach tanks, stainless steel, agitated, 30,000 gal each
- B. CCD
- (10) thickeners, 100 ft x 8 ft, hard rubber
- C. HNO_3 recycle
1. Evaporator, stainless steel, feed = 1100 gpm
 2. Distillation column, stainless steel, with reboiler
4 trays x 2 sections = 8 trays
$$\frac{6000 \text{ T H}_2\text{O} \times 2000 \text{ lb} \times 454 \text{ g} \times 22.4 \text{ l} \times 1.25 \text{ reflux}}{24 \text{ hr} \times 60 \text{ min} \times 60 \text{ sec} \times 18 \times 28 \text{ l/ft}^3 \times 4 \text{ fps}} = 876 \text{ ft}^2 =$$

area of tower
Diameter ~33 ft
Height = $1.5D = 50 \text{ ft}$
Boilup: $6000 \times 0.125 \times 2000 \text{ lb/24} = 125,000 \text{ lb/hr}$
 3. HNO_3 surge tank, stainless steel, 10,000 gal
 4. Water surge tank, steel epoxy, 100,000 gal
- D. SX (assume same as for small conventional plant feed = 50 gpm)
- Product evaporator, stainless steel, 20 gpm
- E. Liquid Waste
1. Calciner
Rotary kiln (Bartlett-Snow)
 2. Condenser - scrub
 3. Mix tank, 1000 gal

Stream	Ton/day					Sp. Gr.	gpm
	Sand	Slime	Water	HNO ₃	Diss. Solids ^a		
1	--	--	2000	--	--	1.0	315
2	1400	600	--	--	--	1.4	460
3	--	--	350	650	--	1.4	120
4	--	--	6350	650	55	1.1	1070
5	--	--	6000	--	--	1.0	1000
6	1400	600	2000	1	--	1.4	480
7	--	--	6450	650	--	1.1	1080
8	--	--	450	650	--	1.4	130
9	--	--	150	200	55	1.4	50
10	--	--	110	--	--	1.0	20
11	--	--	120	--	--	1.0	20
12	--	--	120	2	4	1.0	20
13	--	--	8	2	4	1.4	2
14	--	--	150	200	--	--	--
15	--	--	8	2	--	gas	--
16	--	--	140	200	--	1.2	50
17	--	--	--	--	51	--	--
18	34 ^b	or 10 ^c	--	--	--	--	--
19	85 ^b	or 61 ^c	--	--	--	1.6	--
20	--	--	2	5	--	1.4	1

^aCalculated as metal oxides^bAsphalt^cCement

Solid-Liquid Waste - Solvent Extraction - Case 6c

Al.2 Radwaste Treatment Equipment Requirements for Model
Alkaline Leach Mill Processing 2000 Tons Ore Per Day

Model Alkaline Mill

$$2000 \text{ Ton/day} \times 365 \text{ d} \times 20 \text{ yr} = 14.6 \times 10^6 \text{ Ton ore during life of mill}$$

$$14.6 \times 10^6 \times 0.20\% \text{ U}_3\text{O}_8 \times 2000 \text{ lb} \times 93\% = 54,300,000 \text{ lb U}_3\text{O}_8 \text{ during life of mill}$$

$$\frac{2000 \text{ T/day} \times 1.05 \text{ T liq/T} \times 2000 \text{ lb}}{8.33 \times 24 \text{ hr} \times 60 \text{ min}} = 350 \text{ gpm waste liquid}$$

Pond Area

$$\text{Wyoming} - \frac{2000 \text{ T/day} (1.05 - .3) \times 2000 \text{ lb} \times 365}{62.4 \times 4.0 \text{ ft/yr} \times 43,560} = 101 \text{ Acres}$$

$$\text{New Mexico} - 101 \text{ acres} \times \frac{4.0}{87/12} = 56 \text{ Acres}$$

Solid-Liquid Alkaline Case 1 at WyomingTailings Pond

1. Assume 10% seepage
2. Area: $101A \times 90\% \times 120\% = 109$ Acres
3. Assume square $(109 \times 43,560)^{1/2} = 2180$ -ft-long dam
4. Ave. solids thickness $\frac{9 \times 10^6 \text{ yd}^3 \times 27}{43,560 \times 109} = 51$ ft
5. Assume wedge shape, dam ht = $51 \times 2 + 5$ (freeboard) = 107 ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave. solids thickness = $\frac{100-5}{2}$ (freeboard) = 48 ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116$ Acres
9. Dam length = $(116 \times 43,560)^{1/2} = 2248$ ft
10. Dam, native material
10 ft ht x 2180 ft x 10 ft crest, slope = 2:1
11. Volume of dam = $\frac{(10 \times 10 + 10 \times 20) \times 2248}{27 \text{ ft}^3/\text{yd}^3} = 25,000 \text{ yd}^3$
12. Volume of 6-in. soil cover = $\frac{116A \times 43,560 \times 1/2 \text{ ft}}{27} = 93,600 \text{ yd}^3$
13. Stabilize surface
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, 93,600 yd³
14. Diversion dams and ditches = volume of dam (25,000 yd³)

Solid-Liquid Alkaline Case 1 at New MexicoTailings Pond

1. Assume seepage = 10%
2. Area = 56 x 90% x 120% = 60 Acres
3. Assume square $(60 \times 43,560)^{1/2} = 1623\text{-ft-long dam}$
4. Ave. solids thickness $\frac{9 \times 10^6 \text{ yd}^3 \times 27}{60 \times 43,560} = 93 \text{ ft}$
5. Assume wedge shape, dam ht = $93 \times 2 + 5$ (freeboard) = 191 ft
6. Arbitrary dam ht $\leq 100 \text{ ft}$
7. Ave. solids thickness = $\frac{100-5}{2}$ (freeboard) = 48 ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116 \text{ Acres}$
9. Dam length = $(116 \times 43,560)^{1/2} = 2248 \text{ ft}$
10. Dam, native material, 10-ft ht x 2248 ft x 10-ft crest
11. Volume of dam: $\frac{(10 \times 10 + 20 \times 10) 2248 \text{ ft}}{27} = 25,000 \text{ yd}^3$
12. Volume of 6-in. soil cover = $\frac{116 \times 43,560 \times 1/2}{27} = 93,600 \text{ yd}^3$
13. Stabilize surface
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, 93,600 yd³
14. Diversion dam = 25,000 yd³

Solid-Liquid Alkaline Cases 2 and 3^a at Wyoming

Tailings Pond

1. Assume 2% seepage
2. Area = 101 x 98% x 120% = 119 acres
3. Assume square $(119 \times 43,560)^{1/2} = 2275\text{-ft-long dam}$
4. Ave. solids thickness - $\frac{9 \times 10^6 \times 27}{110 \times 43,560} = 47 \text{ ft}$
5. Assume wedge shape, dam ht = $47 \times 2 + 5 = 99 \text{ ft}$
6. Dam, native material + 10-ft clay core, slope 2:1
7. Volume of dam
 - a. Clay - $10 \times 99 \times 2275/27 = 83,400 \text{ yd}^3$
 - b. Fill - $(10 \times 99 + 198 \times 99) 2275/27 = 1,735,100 \text{ yd}^3$
8. Excavation to key clay to base - $10 \times 10 \times 2275/27 = 8,400 \text{ yd}^3$
9. Volume of 2-ft soil cover - $119 \times 43,560 \times 2/27 = 384,000 \text{ yd}^3$
10. Stabilize surface
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, $96,000 \text{ yd}^3$
11. Diversion dam = $25,000 \text{ yd}^3$
12. Survey and core drilling

^aCase 3 same as Case 2 except earth cover (item 9) is 8 ft.

Solid-Liquid Alkaline Cases 2 and 3^a at New MexicoTailings Pond

1. Assume 2% seepage
2. Area = 56A x 98% x 120% = 66 Acres
3. Assume square $(66 \times 43,560)^{1/2} = 1694\text{-ft-long dam}$
4. Ave. solids thickness - $\frac{9 \times 10^6 \times 27}{66 \times 43,560} = 85 \text{ ft}$
5. Assume wedge shape, dam ht = $85 \times 2 + 5 = 175 \text{ ft}$
6. Arbitrary dam ht $\leq 100 \text{ ft}$
7. Ave. solids thickness = $\frac{100-5}{2} = 48 \text{ ft}$
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116 \text{ Acres}$
9. Dam length = $(116A \times 43,560)^{1/2} = 2248 \text{ ft}$
10. Dam, native + 10 ft clay core, slope 2:1
11. Volume of dam
 - a. Clay - $10 \times 100 \times 2248/27 = 83,300 \text{ yd}^3$
 - b. Fill - $(10 \times 100 + 200 \times 100) 2248/27 = 1,748,400 \text{ yd}^3$
12. Volume of 2-ft soil cover - $\frac{116 \times 43,560 \times 2}{27} = 374,300 \text{ yd}^3$
13. Excavation to key clay to base - $10 \times 10 \times 2248/27 = 8,300 \text{ yd}^3$
14. Stabilize surface
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, $93,600 \text{ yd}^3$
15. Diversion = $25,000 \text{ yd}^3$
16. Survey and core drill

^a Case 3 same as Case 2 except earth cover (item 12) is 8 ft.

Solid-Liquid Alkaline Cases 4a and 4b at WyomingA. Copperas Treatment

1. Copperas (
- $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
-)

$$\frac{0.2 \text{ g/l} \times .454 \text{ l/lb} \times 2100\text{T} \times 2000 \text{ lb}}{454 \text{ g/lb} \times 2000 \text{ lb}} = .42 \text{ T/day}$$

2. Volume of copperas feed solution for 24 hr

$$\frac{0.42\text{T} \times 2000 \text{ lb} \times 454 \text{ g}}{90 \text{ g/l} \times 3.79 \text{ l/gal}} = 1100 \text{ gal}$$

3. Flow rate of copperas stock solution

$$\frac{1100 \text{ gal}}{24 \text{ hr} \times 60 \text{ min}} = 0.76 \text{ gpm}$$

4. Equipment

Copperas feed tank, 2000 gal, wood, agitated

Metering pump, 1 gpm

Mixer: injection into slurry line to pond

B. Tailings Pond

1. Assume 0.1% seepage

2. Area -
- $101 \times 120\% = 121$
- Acres

3. Assume square
- $(121 \times 43,560)^{1/2} = 2298$
- ft-long dam

4. Ave. solids thickness
- $\frac{9 \times 10^6 \times 27}{121 \times 43,560} = 46$
- ft

5. Assume wedge shape, dam ht =
- $46 \times 2 + 5 = 97$
- ft

6. Dam, native material + 10-ft clay core, slope 2:1

7. Volume of dam

$$\text{a. Clay} - 10 \times 97 \times 2298/27 = 82,600 \text{ yd}^3$$

$$\text{b. Fill} - (10 \times 97 + 194 \times 97) 2298/27 = 1,684,200 \text{ yd}^3$$

8. Excavation to key clay to base -
- $10 \times 10 \times 2298/27 = 8,500 \text{ yd}^3$

9. Sealing of pond bottom and sides

$$\text{Area: } 121 \text{ Acres} + \frac{2298 \times 97 \times 2}{43,560} = 131 \text{ Acres}$$

Amount of sealant (2 in. thick) -

$$2/12 \times \frac{131 \times 43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb/T}} = 29,500 \text{ Ton}$$

10. Cover

$$\text{a. } 20\text{-ft soil} - 121 \times \frac{43,560 \times 20}{27} = 3,904,300 \text{ yd}^3$$

b. 2-in. asphalt + 2-ft dirt

$$\text{Asphalt: } 2/12 \times 121 \times \frac{43,560 \times 62}{2000} = 27,200 \text{ Ton}$$

$$\text{Dirt: } 121 \times 43,560 \times 2/27 = 390,400 \text{ yd}^3$$

11. Stabilize surface

a-1. Plant native shrubs and grasses

a-2. Maintain water, etc.

b. Cover with coarse rock, 6-in. layer, 97,600 yd³

12. Diversion dam = 25,000 yd³

Solid-Liquid Alkaline Cases 4a and 4b at New Mexico

A. Same as Case 4a at Wyoming

B. Tailings Pond

1. Assume 0.1% seepage
2. Area: $56 \times 120\% = 67$ acres
3. Assume square $(67 \times 43,560)^{1/2} = 1711$ -ft-long dam
4. Ave. solids thickness - $\frac{9 \times 10^6 \times 27}{67 \times 43,560} = 83$ ft
5. Assume wedge shape, dam ht = $83 \times 2 + 5 = 171$ ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave. solids thickness = $\frac{100-5}{2} = 48$ ft
8. Area = $\frac{9 \times 10^6 \times 27}{48 \times 43,560} = 116$ Acres
9. Dam length = $(116 \times 43,560)^{1/2} = 2248$ ft
10. Dam, native material + 10-ft clay core, slope 2:1
11. Volume of dam
 - a. Clay - $10 \times 100 \times 2248/27 = 83,300$ yd³
 - b. Fill - $(10 \times 100 + 200 \times 100) 2248/27 = 1,748,400$ yd³
12. Excavation to key clay to base - $10 \times 10 \times 2248/27 = 8,300$ yd³
13. Sealing of pond bottom and sides

Area: 116 acres + $\frac{2248 \times 100 \times 2}{43,560} = 126$ acres

Amount of sealant (2-in. thick)

$$2/12 \times 126 \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb/T}} = 28,400 \text{ Tons}$$
14. Cover
 - a. Volume of 20-ft soil, $116 \times 43,560 \times 20/27 = 3,742,900$ yd³

b. 2-in. asphalt + 2-ft soil

$$\text{Asphalt: } 2/12 \times 116 \times 43,560 \times \frac{62}{2000} = 26,100 \text{ Ton}$$

$$\text{2-ft of soil: } 116 \times 43,560 \times 2/27 = 374,300 \text{ yd}^3$$

15. Stabilize surface

a-1. Plant native shrubs and grasses

a-2. Maintain water, etc.

b. Cover with coarse rock, 6-in. layer, 93,600 yd³

16. Diversion dam = 25,000 yd³

Solid-Liquid Alkaline Case 5 at Wyoming

A. Concrete slurry to open pit mine

1. Cement (1:20)

$$2000 \text{ T} \times 1/20 = 100 \text{ T/day}$$

2. Equipment

Cement unloader

Cement storage silo, 7 day, 700 T

Cement feeder, 0-5 T/hr

Mix tank, 1000 gal, agitated

Slurry pump, 25 HP, 500 gpm

Pipe (5-in.), or hose, 3000 ft

Water flush pump, 400 gpm (diesel powered)

B. Evaporation Pond

Note: The volume of liquid to be evaporated will be essentially the same as for Cases 4a and 4b.

1. Assume 0.1% seepage

$$2. \text{ Area} = 101 \times 120\% = 121 \text{ acres}$$

$$3. \text{ Assume square } (121 \times 43,560)^{1/2} = 2296\text{-ft-long dam}$$

$$4. \text{ Assume dam ht} = 15 \text{ ft}$$

$$5. \text{ Dam, native material} + 10\text{-ft clay core, slope } 2:1$$

6. Volume of dam

$$a. \text{ Clay} - 10 \times 15 \times 2296/27 = 12,800 \text{ yd}^3$$

$$b. \text{ Fill} - (10 \times 15 + 30 \times 15) 2296/27 = 51,000 \text{ yd}^3$$

$$7. \text{ Excavation to key clay to base} - 10 \times 10 \times 2296/27 = 8,500 \text{ yd}^3$$

8. Sealing of pond bottom and sides

Amount of sealant (2 in. thick)

$$2/12 \times 121 \times 43,560 \times \frac{62 \text{ lb/ft}^3}{2000 \text{ lb/T}} = 27,200 \text{ Ton}$$

9A. Cover

$$a. \text{ 20-ft soil} - 121 \times 43,560 \times 20/27 = 3,904,300 \text{ yd}^3$$

$$b. \text{ 2-in. asphalt} + \text{2-ft soil}$$

$$\text{Asphalt: } 2/12 \times 121 \times \frac{43,560 \times 62}{2000} = 27,200 \text{ Ton}$$

$$\text{Soil: } 121 \times 43,560 \times \frac{2}{27} = 390,400 \text{ yd}^3$$

9B. Alternative is to collect solids in a smaller area before covering

Volume of solids

$$\frac{25 \text{ g/l(T.D.S.)} \times 2100 \text{ T} \times 2000 \text{ lb} \times .454 \text{ l/lb} \times 365 \text{ d} \times 20 \text{ yr}}{454 \text{ g/lb} \times 120 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} =$$

$$236,600 \text{ yd}^3$$

Assume pile 10 ft thick

$$\text{Area} = \frac{236,600 \times 27}{10 \times 43,560} = 15 \text{ acres}$$

$$\text{Area for concrete} = \frac{2000 \text{ T/d} \times 2000 \text{ lb} \times 1.05 \times 365 \times 20}{120 \times 100/2 \times 43,560} = 117 \text{ acres}$$

A. 20-ft soil cover

$$\text{Volume: } 15 \times 43,560 \times 20/27 = 484,000 \text{ yd}^3$$

B. 2-in. asphalt + 2-ft soil

$$\text{Asphalt: } 2/12 \times 15 \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}} = 3,380 \text{ T}$$

$$\text{Soil: } 2 \times 15 \times 43,560/27 = 48,400 \text{ yd}^3$$

10. Stabilize surface

a-1. Plant native shrubs and grasses

a-2. Maintain water, etc.

b. Cover with coarse rock, 6-in. layer, 97,600 yd³

10. Alternate

a-1. Plant native shrubs and grasses

a-2. Maintain water, etc.

b. Cover with coarse rock, 6-in. layer, 12,100 yd³11. Diversion dam = 25,000 yd³

Solid-Liquid Alkaline Case 5 at New Mexico

A. Concrete Slurry to Mine

Same as Case 5 at Wyoming except underground mine

B. Evaporation Pond

1. Assume 0.1% seepage

2. Area - $56A \times 120\% = 67$ Acres

3. Assume square $(67 \times 43,560)^{1/2} = 1708$ ft

4. Assume dam ht = 15 ft

5. Dam, native material + 10-ft clay core, slope 2:1

6. Volume of dam

$$a. \text{ Clay} - 10 \times 15 \times 1708/27 = 9,500 \text{ yd}^3$$

$$b. \text{ Fill} - (10 \times 15 + 30 \times 15) 1708/27 = 38,000 \text{ yd}^3$$

7. Excavation to key clay to base - $10 \times 10 \times 1708/27 = 6,300 \text{ yd}^3$

8. Sealing of pond bottom and sides

Amount of sealant (2 in. thick)

$$2/12 \times 67A \times 43,560 \times \frac{62 \text{ lb/ft}^3}{2000} = 15,100 \text{ Ton}$$

9A. Cover

$$a. \text{ 20-ft soil} - 67A \times 43,560 \times 20/27 = 2,161,900 \text{ yd}^3$$

b. 2-in. asphalt + 2-ft soil

$$\text{Asphalt: } 2/12 \times 67 \times 43,560 \times \frac{62 \text{ lb/ft}^3}{2000} = 15,100 \text{ Ton}$$

$$\text{Soil: } 2 \times 67 \times 43,560/27 = 216,200 \text{ yd}^3$$

9B. Same as Case 5 at Wyoming.

10. Stabilize surface

a-1. Plant native shrubs and grasses

a-2. Maintain water, etc.

- b. Cover with coarse rock, 6-in. layer, 54,100 yd³
- 10. Alternate
 - a-1. Plant native shrubs and grasses
 - a-2. Maintain water, etc.
 - b. Cover with coarse rock, 6-in. layer, 12,100 yd³
- 11. Diversion dam = 25,000 yd³

Solid-Liquid Alkaline Cases 6a and 6b at Wyoming or New Mexico

A. Sand-slime separation and sand wash (see flowsheet)

1. Assume 50% sands (+150 mesh) x 2000 T ore = 1000 T/day

2. Use 2:1 wash ratio in classifiers

$$50\% \times 2000 \text{ T} \times 2 = \text{water} = 2000 \text{ T/day}$$

3. Equipment

Hydroclone and pump

(2) classifiers, 1000 T sand/day

B. Slime dewatering (see flowsheet)

1. Assume 50% slime, 50% x 2000 T = 1000 Ton/day

2. Diss. solids in liquor from 3rd-stage filter

$$5 \text{ g/l} \times \frac{2000 \text{ T ore} \times 1.05 \text{ liq} \times 2000 \text{ lb} \times .454 \text{ l/lb}}{454 \text{ g/lb} \times 2000 \text{ lb/Ton}} = 10 \text{ T/day}$$

3. Equipment

$$\text{Thickener, area} = 6 \text{ ft}^2/\text{T/day} \times 1000 \text{ T/day} = 6000 \text{ ft}^2$$

$$\text{Filter continuous, area} = \frac{1000 \text{ T} \times 2000 \text{ lb/T}}{600 \text{ lb/ft}^2/\text{day}} = 3300 \text{ ft}^2$$

C. Evaporator

1. Water load (to give desired wash of sands and balance water in mill) 1700 T/day

2. Equipment

Evaporator, forced circulation, mild steel

Condenser and associated instruments

Feed surge tank, 10,000 gal

Feed-concentrate heat exchanger, 300 ft²

Feed rate, 310 gpm; pump size = 400 gpm

Concentrate rate, 31 gpm; pump size = 40 gpm

Condensate receiver, 10,000 gal

D. Asphalt Fixation (.67 lb/lb solids) (Case 6a)

1. Slime solids = 1000 T/day
2. Asphalt $.67 \times 1000 = 670$ T/day
3. Water load to be evaporated - $\frac{30\%}{70\%} \times 1000 + 200 = 630$ T/day
4. Equipment (see flowsheet)
 - a. Asphalt unloader
 - b. Asphalt storage, 3-day supply = 2000 T
 - c. Wiped-film evaporator (160°C)
(13) 200-ft² units in parallel
 - d. Condenser - 630 T/day
 - e. Associated pumps and instrumentation
 - f. Transportation of asphalt slimes to mine or landfill
(distance ≤ 2 miles)

D. Alternate (Cement 1:20) (Case 6b)

1. Cement = $1/20 \times 1000$ T slime = 50 T/day
2. Equipment (see flowsheet)
 - a. Pneumatic cement unloader
 - b. Cement silo, 3 day, 150 T
 - c. Feeder, 0-5 T/hr
 - d. Mix tank, 1000 gal, rubber-lined
 - e. Slurry pump, 200 gpm
 - f. Water flush pump, 200 gpm, diesel powered

E. Solid Disposal in Landfill

$$1. \text{ Volume of Sand} = \frac{2000 \text{ T} \times 2000 \text{ lb} \times 50\% \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb/ft}^3 \times 27} =$$

$$4.51 \times 10^5 \text{ yd}^3$$

2. Volume of fixed slimes

a. Volume of asphalt-slimes

$$\frac{2000 \text{ T} \times 2000 \text{ lb} \times 50\% \times 1.67 \times 365 \text{ d} \times 20 \text{ yr}}{62.4 \times 1.6 \times 27 \text{ ft}^3/\text{yd}^3} = 9.04 \times 10^6 \text{ yd}^3$$

b. Volume of concrete slimes:

$$\frac{2000 \text{ T} \times 2000 \text{ lb} \times 50\% \times 1.05 \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb}/\text{ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} = 4.73 \times 10^6 \text{ yd}^3$$

3. Area, assume wedge shape, max. ht = 100 ft

a. Area of sand + asphalt slime =

$$\frac{(4.51 \times 10^6 + 9.04 \times 10^6)27}{100/2 \times 43,560} = 168 \text{ Acres}$$

b. Area of sand + concrete-slime =

$$\frac{(4.51 \times 10^6 + 4.73 \times 10^6)27}{100/2 \times 43,560} = 115 \text{ Acres}$$

4. Cover, 20-ft dirt

$$\text{a. Asphalt} - \frac{20 \text{ ft} \times 168 \text{ A} \times 43,560}{27} = 5,421,000 \text{ yd}^3$$

$$\text{b. Concrete} - \frac{20 \times 115 \text{ A} \times 43,560}{27} = 3,711,000 \text{ yd}^3$$

5. Stabilize

a-1. Plant native shrubs and grasses

a-2. Maintain, water, etc.

b. Cover with coarse rock, 6-in. layer

$$1. \text{ Volume for asphalt} = 115,300 \text{ yd}^3$$

$$2. \text{ Volume for concrete} = 92,800 \text{ yd}^3$$

E. Alternate (disposal in underground mine) - New Mexico

$$1. \text{ Volume of sand} = 4.5 \times 10^6 \text{ yd}^3$$

2. Volume of fixed slimes

$$\text{a. Volume of asphalt-slime} = 9.0 \times 10^6 \text{ yd}^3$$

$$\text{b. Volume of concrete-slime} = 4.7 \times 10^6 \text{ yd}^3$$

3. Transportation and placement in mine

Stream	Ton/day				Sp. Gr.	gpm
	Sand	Slime	Water	Diss. Solids		
1	1000	1000	2100	10	1.4	490
2	1000	--	500	2	1.8	140
3	--	--	2500	2	1.0	420
4	--	1000	1000	8	1.2	360
5	--	--	1770	4	1.0	300
6	--	1000	2330	6	1.2	460
7	--	1000	430	1	1.8	130
8	--	--	1900	5	1.0	320
9	--	--	1900	5	1.0	320
10	--	--	200	5	1.1	30
11	--	--	1700	--	1.0	280
12	--	--	630	--	1.0	110
13	--	1670 ^a	--	6	1.5	190
14	--	670 ^b	--	--	1.0	110
15	1000	--	330	--	1.8	--
16	--	--	2330	--	1.0	390

^aContains asphalt^bAsphalt

Solid-Liquid Waste - Alkaline Leach - Case 6a (asphalt)

Stream	Ton/day				Sp. Gr.	gpm
	Sand	Slime	Water	Diss. Solids		
1	1000	1000	2100	10	1.4	490
2	1000	--	500	2	1.8	140
3	--	--	2170	2	1.0	360
4	--	1000	1600	8	1.2	360
5	--	--	1140	3	1.0	190
6	--	1000	2330	7	1.2	460
7	--	1000	430	1	1.8	130
8	--	--	1900	5	1.0	320
9	--	--	2200	6	1.0	370
10	--	--	200	6	1.1	30
11	--	--	2000	--	1.0	330
12	--	1050 ^a	630	7	1.6	180
13	--	--	2000	--	1.0	330
14	1000	--	330	--	1.8	--

^aIncludes cement

Solid-Liquid Waste - Alkaline Leach - Case 6b (cement)

A2.0 AIRBORNE MILL WASTE TREATMENT

A2.1 Summary of Radwaste Treatment Cases for Airborne Emissions From Mill

The main references for cost estimation are:

1. Removal of Grit, Dust, and Fume from Exhaust Gases From Chemical Engineering Processes, C. J. Stairmand, The Chemical Engineer, December 1965.
2. Removal of Dust from Gases in Processes for Air Pollution Control, 2nd Ed., The Chemical Rubber Company, Cleveland, Ohio, 1972.
3. Other references are cited locally.

Summary of Radwaste Treatment Cases for Airborne Emissions from Mill

Case No.	Type of Equipment Used		Capital Cost ^a in Dollars	Operating Costs ^b (\$/Year During Operating Life)
	Ore Dusts	Uranium Concentrates		
1	Orifice	Wet impingement	88,000	10,800
2	Wet impingement	Low-energy venturi	111,000	15,300
3	Low energy venturi	Medium-energy venturi	151,000	27,300
4	Reverse jet bag filter	High-energy venturi	262,000	39,400
5	Reverse jet bag filter	High-energy venturi plus HEPA filter	314,000	42,600
6	Reverse jet bag filter plus HEPA filter	High-energy venturi plus HEPA filter	540,000	67,600
7	Reverse jet bag filter plus charcoal delay trap plus HEPA filter, air flow 10% of Case 6	High-energy venturi plus HEPA filter	3,942,000	59,500

^aDoes not include interest during construction or allowance for contingency.

^bDoes not include fixed charges.

Case 1

Basic Treatment System: Ore Dusts: Orifice (baffle, self-induced spray deduster)

Concentrate Dusts: Wet impingement (irrigated target, perforated plate)

Capital Costs

Ore Dust Collectors: 1 @ 27,200-cfm capacity	\$50,000
1 @ 2,720-cfm capacity	\$13,000
Concentrate Dust Collector: 1 @ 6,100-cfm capacity	\$25,000
Total Estimated Installed Cost of Collection Systems	<u>\$88,000</u>

Annual Operating Costs

Ore Dust Collectors: Power	\$ 6,930
Water	270
Maintenance, Labor, & Supplies	<u>580</u>
Concentrate Dust Collector: Power	\$ 2,320
Water	440
Maintenance, Labor & Supplies	289
Total Estimated Annual Operating Cost	<u>\$10,829</u>

Case 2

Basic Treatment System: Ore Dusts: Wet impingement (irrigated target,
perforated plate)

Concentrate Dusts: Venturi (low energy) plus
mist eliminator

Capital Costs

Ore Dust Collectors: 1 @ 27,200-cfm capacity	\$61,000
1 @ 2,720-cfm capacity	\$15,000
Concentrate Dust Collector: 1 @ 6,100-cfm capacity	\$35,000
Total Estimated Installed Cost of Collection Systems	<u>\$111,000</u>

Annual Operating Costs

Ore Dust Collectors: Power	\$ 7,130
Water	\$ 1,352
Maintenance, labor, & supplies	885
Concentrate Dust Collector: Power	4,690
Water	970
Maintenance, labor, and supplies	327
Total Estimated Annual Operating Cost	<u>\$15,354</u>

Case 3

Basic Treatment System: Ore Dusts: Venturi (low energy) plus mist
eliminator

Concentrate Dusts: Venturi (medium energy)
plus mist eliminator

Capital Costs

Ore Dust Collectors: 1 @ 27,200-cfm capacity	\$93,000
1 @ 2,720-cfm capacity	\$21,000
Concentrate Dust Collector: 1 @ 6,100-cfm capacity	<u>\$37,000</u>
Total Estimated Installed Cost of Collection Systems	<u>\$151,000</u>

Annual Operating Costs

Ore Dust Collectors: Power	\$14,390
Water	2,976
Maintenance, labor, & supplies	1,068
Concentrate Dust Collector: Power	7,550
Water	969
Maintenance, labor, & supplies	324
Total Estimated Annual Operating Cost	<u>\$27,277</u>

Case 4

Basic Treatment System: Windbreak around ore pile

Ore Dusts: Reverse jet bag filter

Concentrate Dusts: Venturi (high energy) plus
mist eliminatorCapital Costs

Ore Pile Windbreak	\$ 7,000
Ore Dust Collectors: 1 @ 27,200-cfm capacity	\$172,000
1 @ 2,720-cfm capacity	\$43,000
Concentrate Dust Collector: 1 @ 6,100-cfm capacity	<u>\$40,000</u>
Total Estimated Installed Cost of Collection Systems	<u>\$262,000</u>

Annual Operating Costs

Ore Dust Collectors: Power	\$ 9,747
Water	0
Maintenance, labor, & supplies	16,510
Concentrate Dust Collector: Power	11,900
Water	970
Maintenance, labor, & supplies	<u>322</u>
Total Estimated Annual Operating Cost	\$39,449

Case 5

Basic Treatment System: Windbreak around ore pile

Ore Dusts: As for Case 4

Concentrate Dusts: As for Case 4 plus HEPA
filters

Capital Costs

Ore Pile Windbreak	\$ 7,000
Ore Dust Collectors: As for Case 4	\$215,000
Concentrate Dust Collector: As for Case 4	\$40,000
HEPA Filter	\$52,000
Total Estimated Installed Cost of Collection Systems	<u>\$314,000</u>

Annual Operating Costs

Ore Dust Collectors: Power	\$ 9,747
Maintenance, labor, and supplies	\$16,510
Concentrate Dust Collector: Power	\$11,900
Water	970
Maintenance, labor, & supplies	3,473
Total Estimated Annual Operating Cost	<u>\$42,600</u>

Case 6

Basic Treatment System: Windbreak around ore pile

Ore Dusts: As for Case 5 plus HEPA filters

Concentrate Dusts: As for Case 5

Capital Costs

Ore Pile Windbreak	\$ 7,000
Ore Dust Collectors: As for Case 5	\$215,000
HEPA Filters	\$226,000
Concentrate Dust Collector: As for Case 5	40,000
HEPA Filter	52,000
Total Estimated Cost of Collection Systems	<u>\$540,000</u>

Operating Costs

Ore Dust (Case 5 + HEPA scaled up from Case 7)	\$51,257
Concentrate Dust Collector (Same as Case 5)	\$16,343
Total Estimated Annual Operating Cost	<u>\$67,600</u>

Case 7

Basic Treatment System: Windbreak around ore pile

Ore Dusts: As for Case 6 plus charcoal delay
trap at lower air flow

Concentrate Dusts: Same as Case 6

Capital Costs

Ore Pile Windbreak	\$ 7,000
Ore Dust Collectors: Jet bag filter, 4280-cfm capacity	\$57,000
Jet bag filter, 476-cfm capacity	\$15,000
Charcoal delay trap	\$3,742,000
Air Heaters	1,000
HEPA filter	36,000
Concentrate Dust Collectors: Same as Case 5	<u>\$92,000</u>
Total Estimated Cost of Collection Systems	\$3,950,000

Operating Costs

Ore Dust Collectors: Gas	280
Power	\$ 3,758
Maintenance, labor, and supplies	39,144
Concentrate dust collectors: Same as Case 5	<u>16,343</u>
Total Estimated Annual Operating Cost	\$59,525

A2.2 Derivation of Capital Costs for Airborne Waste Treatment

Case 1

<u>Material</u>	<u>%</u>	<u>Average Pressure Drop (in. H₂O)</u>	<u>Approximate 1965 Cost (\$/10⁶ cu ft)</u>
Ore Dusts	Orifice (baffle, self- induced spray deduster) 93.6	6.1	0.51
Conc. Dusts	Wet impingement (irrigated, target, perforated plate) 97.9	6.1	0.62

Ore Dusts

Air flow from crusher and screens = 20,000 cfm

Air flow from bins = 2,000 cfm

Combined max. air flow to scrubbers = 22,000 cfm

Dust load to collector = 400 lb/day

Daily volume of air from crusher and screens = 20,000 cfm x 16 hr/day
x 60 = 19.2×10^6 cu ft

Daily volume of air from bins = 2,000 cfm x 24 hr/day x 60 =
 2.88×10^6 cu ft

∴ Total volume of air to collector per day = 22.08×10^6 cu ft

∴ Average daily dust load to collector =

$$\frac{400 \text{ lb} \times 7,000 \text{ grains/lb}}{22.08 \times 10^6 \text{ cu. ft}} = 0.127 \text{ grains/cu ft}$$

Average daily dust load in collector exhaust = $0.127 - (0.127 \times 0.936)$

$$= 0.127 - 0.119$$

$$= 0.008 \text{ grains/cu ft}$$

The indicated minimum scrubber size is 22,000 cfm. This does not allow any safety factor. Therefore, a 30,000-cfm unit would be acceptable (36% safety factor).

From the reference given (Power, February 1971, p. 63), the 1965 capital cost of the orifice scrubber was \$58,900 installed for a 60,000-cfm unit.

$$\therefore \text{Installed cost of a 30,000-cfm unit, 1965} = \left(\frac{30,000}{60,000}\right)^{0.6} \times \$58,900 \\ = \$38,900$$

Chem. Eng. June 11, 1973 - CE Plant Cost Index, Prelim. March 1973, Index 141.0 (1957-52 = 100)

The annual CE Plant Cost Index for 1965 was 104.2.

$$\therefore \text{Escalation factor from 1965 to March 1973} = \frac{141.0 - 104.2}{104.2} = \frac{36.8}{104.2} = 35.3\%$$

$\therefore$ Use escalation factor of 1.353 to go from 1965 to March 1973 costs.

$$\therefore \text{Installed cost 1973 (March)} = \$38,900 \times 1.353 = \$52,600$$

Concentrate Dusts

Air flow = 4,500 cfm

$$\therefore \text{Indicated scrubber size, using 36\% safety factor} = 4,500 \text{ cfm} \times 1.36 = \\ 6,100 \text{ cfm}$$

From references given (Power, February 1971, p. 63), the 1965 capital cost of the irrigated target scrubber was \$72,800 installed for a 60,000-cfm unit.

$$\therefore \text{Installed cost of a 6100-cfm unit, 1965} = \left(\frac{6,100}{60,000}\right)^{0.6} \times \$72,800 = \$18,500$$

$$\therefore \text{Installed cost, 1973 (March)} = \$18,500 \times 1.353 = \$25,000$$

Summary of Capital Costs

1 @ 30,000-cfm Ore Dust Collector	\$52,500
1 @ 6,100-cfm Concentrate Dust Collector	\$25,000

The foregoing assumed that the plant geometry permitted one collecting unit to treat all ore dusts. It is, however, more likely that two units would be installed in order that a more flexible system with shorter duct runs be available.

Estimated size of unit to handle ore dust from crushing and screening section = 20,000-cfm air flow x 1.36 (safety factor) = 27,200 cfm

$$\therefore \text{Estimated cost of this size unit} = \left(\frac{27,200}{60,000}\right)^{0.6} \times \$58,900 \times 1.353 = \$49,600$$

Estimated size of unit to handle dust from bins = 2000-cfm air flow x 1.36
(safety factor) = 2,720 cfm

$$\therefore \text{Estimated cost of this size unit} = \left(\frac{2,720}{60,000}\right)^{0.6} \times \$58,900 \times 1.353 = \$12,500$$

Case 2

<u>Material</u>		<u>Eff. (%)</u>	<u>Average Pressure Drop (in. H₂O)</u>	<u>Approximate 1965 Cost (\$/10⁶ cu ft)</u>
Ore Dusts	Wet impingement (irrigated target, perforated plate)	97.9	6.1	0.62
Conc. Dusts	Venturi; low energy (followed by a separator to remove entrained water droplets)	99.5	12.5	1.03

Using the premise that two collector units to treat the ore dust is most feasible, the air flow safety factor of 1.36 and the cost escalation factor of 1.353, all discussed in Case 1, we have:

As in Case 1, Capacity of crushing and screening dust collector = 27,200 cfm

Capacity of ore bin dust collector = 2,720 cfm

Capacity of concentrate dust collector = 6,100 cfm

The 1965 estimated installed cost of a wet impingement type unit was \$72,800 for a 60,000-cfm unit (Ref: Power, February 1971, p. 63).

$$\therefore \text{Estimated installed cost of a 27,200-cfm unit} = \left(\frac{27,200}{60,000}\right)^{0.6} \times \$72,800$$

$$\times 1.353 = \$61,400$$

$$\therefore \text{Estimated installed cost of a 2,720-cfm unit} = \left(\frac{2,720}{60,000}\right)^{0.6} \times \$72,800$$

$$\times 1.353 = \$15,400$$

The 1965 estimated installed cost of a low-energy venturi unit was \$89,500 for a 60,000-cfm unit (Ref: Power, February 1971, p. 63).

$$\therefore \text{Estimated installed cost of a 6100-cfm unit} = \left(\frac{6,100}{60,000}\right)^{0.6} \times \$89,500$$
$$\times 1.353 = \$30,800$$

Note: The subsequent separator to remove entrained droplets from the exhaust gas stream is a necessary adjunct for the venturi scrubber (see Ceilcote Air Pollution Control Equipment Bulletin 12-1, Revised June 1968, pp. 11 - Equip. Catalogs, Dust and Fume Collection).

Case 3

<u>Material</u>	<u>Treatment</u>	<u>Eff. (%)</u>	<u>Average Pressure Drop (in. H₂O)</u>	<u>Approximate 1965 Cost (\$/10⁶ cu ft)</u>
Ore Dusts	Venturi; low energy (followed by a separator to remove entrained water droplets)	99.5	12.5	1.03
Conc. Dusts	Venturi; med. energy (followed by mist eliminator)	99.7	20.0	1.39

As in Case 1, Capacity of crushing and screening dust collector = 27,200 cfm

Capacity of ore bin dust collector = 2,700 cfm

Capacity of concentrate dust collector = 6,100 cfm

The 1965 estimated installed cost of a low energy venturi-type unit was \$89,500 for a 60,000-cfm unit (assumed to not include the mist eliminator) (Ref: Power, February 1971, p. 63).

$$\therefore \text{Estimated installed cost of a 27,200-cfm unit} = \left(\frac{27,200}{60,000}\right)^{0.6} \times \$89,500 \\ \times 1.353 = \$75,400$$

$$\therefore \text{Cost of mist eliminator @ \$0.65 per cfm} = 27,200 \times \$0.65 = \$17,700$$

$$\therefore \text{Estimated installed cost of venturi and eliminator} = \$75,400 + \$17,700 \\ = \$93,100$$

$$\text{Estimated installed cost of 2720-cfm unit} = \left(\frac{2,720}{60,000}\right)^{0.6} \times \$89,500 \\ \times 1.353 = \$18,900$$

$$\text{Cost of mist eliminator @ \$0.65 per cfm} = 2,720 \times \$0.65 = \$1,800$$

$$\text{Estimated installed cost of venturi and eliminator} = \$18,900 + \$1,800 \\ = \$20,700$$

The 1965 estimated installed cost of a medium-energy venturi-type unit was \$95,100 for a 60,000-cfm unit (assumed to not include the mist eliminator) (Ref. Power, February 1971, p. 63).

$$\begin{aligned} \text{Estimated installed cost of a 6100-cfm unit} &= \left(\frac{6,100}{60,000}\right)^{0.6} \times \$95,100 \\ &\times 1.353 = \$32,700 \end{aligned}$$

$$\text{Cost of mist eliminator @ \$0.65 per cfm} = 6,100 \times \$0.65 = \$4,000$$

However, according to notes of telephone call to Mr. Darrah, Ceilcote, Canada, on August 9, 1973 (Union Carbide - ORNL), the mist eliminator may not be included. Assuming this is so, and assuming that the installation cost is already covered in the installed cost of the venturi, then to the venturi installed cost of \$30,800 must be added that of the eliminator.

Using Ceilcote's "ball park" figure of \$0.65 per cfm, then an equipment cost of an eliminator to handle 6100 cfm of air = $6100 \times \$0.65 = \$4,000$.

∴ Estimated installed cost of venturi plus mist eliminator =

$$\$32,700 + \$4,000 = \$36,700$$

Case 4

<u>Material</u>	<u>Treatment</u>	<u>Eff. (%)</u>	<u>Average Pressure Drop (in. H₂O)</u>	<u>Approximate 1965 Cost \$/10³ cu ft)</u>
Ore dusts	Reverse jet bag filter	99.9	3.0	1.69
Conc. dusts	Venturi; high energy (followed by mist eliminator)	99.9	31.5	1.90

As in Case 1, Capacity of crushing and screening dust collector = 27,200 cfm
 Capacity of ore bin dust collector = 2,720 cfm
 Capacity of concentrate dust collector = 6,100 cfm

The 1965 estimated installed cost of a reverse jet bag filter was \$73,000, which at \$2.80/\$ is equivalent to \$204,000. (Table IX, Stairmand's paper, The Chemical Engineer, December 1965.)

$$\therefore \text{Estimated installed cost of a 27,200-cfm unit} = \left(\frac{27,200}{60,000}\right)^{0.6} \times \$204,000 \\ \times 1.353 = \$172,000$$

$$\text{Estimated installed cost of a 2720-cfm unit} = \left(\frac{2,720}{60,000}\right)^{0.6} \times \$204,000 \\ \times 1.353 = \$43,100$$

The 1965 estimated installed cost of a high-energy venturi-type unit was \$104,000 for a 60,000-cfm unit (assumed to not include the mist eliminator) (Ref: Power, February 1971, p. 63).

$$\therefore \text{Estimated installed cost of a 6100 per cfm} = \left(\frac{6,100}{60,000}\right)^{0.6} \times \$104,000 \\ \times 1.353 = \$35,700$$

$$\text{Cost of mist eliminator @ \$0.65 per cfm} = 6100 \times \$0.65 = \$4,000$$

$$\therefore \text{Estimated installed cost of venturi and eliminator} = \$35,700 + \$4,000 \\ = \$39,700$$

Case 5

<u>Material</u>	<u>Treatment</u>
Ore dusts	Same as Case 4
Concentrate dusts	Case 4 + HEPA filter

Ore Dusts

Air flow from crushing and screening = 20,000 cfm.

Unit capacity = 27,200 cfm

Air flow from ore bins = 2,000 cfm

Unit capacity = 2,720 cfm

Concentrate Dusts

Air flow from drier = 1,500 cfm

Unit capacity = 2,040 cfm

Air flow from packaging = 1,200 cfm

Unit capacity = 1,630 cfm

Total = 3,670 cfm

Concentrate Dusts

Assume that air exiting scrubber is at 60°F and 100% humidity.

Assume that air is heated to 40% humidity to prevent freezing during winter.

60°F Enthalpy, BTU/lb dry air = 26.46; Vol. = 13.329 cu ft/lb dry air; 40% RH, temp. = 88°F; Enthalpy, BTU/lb dry air = 33.5; Vol. = 14.448 cu ft/lb dry air. (Ref: Psychrometric chart - Perry, Chemical Engineering Handbook, p. 765).

∴ Heat added per lb dry air = 33.5 - 26.46 = 7.04 BTU

Density of air at 0°C - 1 atm = 0.0808 lb/cu ft or 12.38 cu ft/lb dry air. From psychrometric chart at 60°F, wet bulb moisture content = 0.0115 lb H₂O/lb dry air.

$$\text{Amount of moisture in air flow} = \frac{3,670 \text{ cfm}}{12.38 \text{ cu ft/lb}} \times \frac{0.0115 \text{ lb H}_2\text{O}}{1 \text{ lb dry air}} = 3.41 \text{ lb H}_2\text{O}$$

$$\text{Weight of dry air} = \frac{3,670 \text{ cfm}}{13.329 \text{ cu ft/lb dry air}} = 275 \text{ lb/min}$$

$$\therefore \text{Amount of heat to be provided} = 7.04 \text{ BTU/lb} \times 275 \text{ lb/min} = 1935 \text{ BTU/min}$$

Assuming a natural gas burner inserted in duct; heat capacity = 1,000 BTU/cu ft. Rule of thumb indicates 1 cu ft of gas requires 10 cu ft of air for combustion (Hauck, Ind. Comb. Data, p. 55).

$$\therefore \text{To provide 1,900 BTU/min, burn } 2 \text{ cu ft/min gas} + 20 \text{ cu ft of air/min}$$

$$\text{Gas volumes to heater} = 3,670 + 2 + 20 = 3,692 \text{ cu ft/min}$$

From note of Aug. 13, 1973.

Estimated installed cost of heating unit = \$500

From above, the gas volume fed to heater = 3672 cfm

$$\text{From gas law relationship } V_2 = \frac{V_1 T_2}{T_1} \text{ or } \frac{3,692 \times (460 + 83)}{(460 + 60)} = 3,890 \text{ cfm}$$

From data provided, a standard unit has a nominal capacity of 1,000 cfm per sq ft of area.

$\therefore$ To handle 3,890 cfm, a unit offering 4.0 sq ft of area is required; i.e., 4 standard HEPA filters in parallel could be used if desired.

Estimated cost of HEPA filter to handle 8,000 cfm = \$17,750 (note from A. D. Ryon, ORNL, August 20).

$$\begin{aligned}\therefore \text{Estimated cost of HEPA filter to handle 3,890 cfm} &= \left(\frac{3,890}{8,000}\right)^{0.6} \times \$17,750 \\ &= \$11,500\end{aligned}$$

$$\therefore \text{Installed cost} = \$11,500 \times 2.70 = \$31,000$$

Venturi, high-energy unit, to handle a total of 3670-cfm air flow from concentrate section

$$\therefore \text{Estimated installed cost} = \left(\frac{3,670}{60,000}\right)^{0.6} \times \$104,000 \times 1.353 = \$26,300$$

$$\text{Cost of mist eliminator @ } \$0.65 \text{ cfm} = 3,670 \times \$0.65 = \$2,386$$

$$\text{Estimated cost of venturi and eliminator} = \$28,686$$

$$\text{Heater} = \$ \underline{500}$$

$$\text{Total estimated cost of units} = \$29,186$$

Case 6

Ore Dusts: Same as Case 4 + HEPA filter

Concentrate Dusts: Same as Case 5

HEPA capital and operating costs were proportioned from Case 7.

$$\$36,000 \times \frac{29,920 \text{ cfm}}{4,756 \text{ cfm}} = \$226,000$$

Cases 5 and 6Windbreaks

Assume ore haulage from mine on a 16-hour-per-day, 5-days-per-week basis, i.e., 125 tons/hr as given.

16 hours per day at 125 tons/hr = 2,000 tons per day.

Assume ore storage pile for 4 days operation (to allow for long weekends) = 8,000 tons

Assume bulk density of ROM ore = 100 lb/cu ft or 20 cu ft/ton

∴ Volume of ore pile = 8,000 tons x 20 cu ft/ton = 160,000 cu ft

Assuming an angle of repose = 45° and a height of ore pile = 8 ft

Volume of toe per ft of width = $\frac{8 \times 8}{2} \times 1 = 32$ cu ft

Volume of side toes per ft of length = 32 cu ft

Assume block 140 ft x 140 ft x 8 ft plus toe and sides.

Volume of toe = 4,480 cu ft

Volume of sides = 2 x 4,480 cu ft

Volume of block = 157,000 cu ft

∴ Total volume = 4,480 + 8,960 + 157,000 = 170,440 cu ft

Assume windbreak is located 20 ft out from toes of pile to allow for access, and full length of pile.

∴ Length of windbreak = (20 ft x 10 ft + 28 ft) x 2 + (28 ft x 140 ft + 28 ft) = 376 ft + 196 ft = 572 ft

As pile is 8 ft high, windbreak should be about 12 ft to contain dust evolved during dumping process.

Using set data contained in memos of August 15, 1973 (Notes of Cost Data 624.1)

∴ Assuming steel sheeting construction, then number of sheets required =

$$\frac{572 \text{ ft}}{3 \text{ ft/sheet}} = 191$$

At 42.6 sq ft per sheet and \$25 per 100 sq ft, then material cost =

$$191 \times 42.6 \text{ sq ft} \times \frac{\$25}{100 \text{ sq ft}}$$

∴ Sheeting cost = \$2,035

Screws cost \$60/1,000 and 60 screws/100 sq ft are required.

$$\therefore \text{Cost of screw requirements} = 191 \text{ sheets} \times 42.6 \text{ sq ft} \times \frac{\$60}{1,000 \text{ screws}}$$

$$\times \frac{60 \text{ screws}}{100 \text{ sq ft}} = \$300$$

Using the suggested factor of 2 times + 40%

$$\begin{aligned} \therefore \text{Estimated installed cost} &= (2,035 + 300)2 + 40\% \\ &= 4,670 + 1,870 = \$6,540 \end{aligned}$$

Using the information supplied by Hult Fence Limited, then

$$\begin{aligned} \text{Estimated cost of an installed wooden fence} &= 572 \text{ ft} \times \$12/\text{linear ft} = \\ &= \$6,870 \end{aligned}$$

The costs so derived are comparable; suggest use of a cost of \$7,000 to cover materials freight.

Case 7

<u>Material</u>	<u>Treatment</u>
Ore Dusts	Case 4 + charcoal delay trap = HEPA filter at lower air flow
Concentrate Dusts	Same as Case 5

Ore Dusts

Total air flow from crusher and ore bins = 3,500 cfm

From other cases, air flow from ore bins = 10% of total flow

∴ Air flow from crusher = 3,150 cfm + angles from ore bins = 350 cfm

Case 5 used a jet bag filter for ore dusts.

Allowing for equipment to handle flow plus 36% safety factor

Design air flow from crusher = $3,150 \times 1.36 = 4,280$ cfm

Design air flow from ore bins = $350 \times 1.36 = 476$ cfm

For 4,280-cfm unit, estimated cost = $\left(\frac{4,280}{60,000}\right)^{0.6} \times \$204,000 \times 1.353 = \$56,500$

For 476-cfm unit, estimated cost = $\left(\frac{476}{60,000}\right)^{0.6} \times \$204,000 \times 1.353 = \$15,190$

Design air flow to charcoal radon decay trap = $4,280 + 476 = 4,756$ cfm

Using data from Case 5: Heat to be added to go from 60°F to 88°F
 = 7.04 BTU/lb

Weight of dry air in 4,756 cfm = $\frac{4,756 \text{ cfm}}{13,329 \text{ cu ft/lb}} = 357 \text{ lb/min}$

∴ Amount of heat to be added to prevent icing = $357 \text{ lb/min} \times 7.04 \text{ BTU/lb}$
 = 2,510 BTU/min

At 1,000 BTU/cu ft gas, then 2.51-cfm gas required plus 25.1 cfm of combustion air.

∴ Gas volume to heater = $4,756 + 2.51 + 25.1 = 4,783.61$ cfm

Estimated installed cost of heater based on Case 5 = $\left(\frac{4,783.61}{3,692}\right)^{0.6} \times 500 =$
\$600

Volume of heater gas = $\frac{V_1 T_2}{T_1}$ or $\frac{4,783.61 \times (460 + 88)}{(460 + 60)} = 5,040 \text{ cfm}$

Assume gas velocity through trap = 1.0 ft/min

Cross-sectional area = $\frac{5,040}{1} = 5,040 \text{ sq ft}$

Considering traps of 1,000-cu ft capacity, 8 ft diameter x 20 ft long,
then cross-sectional area of each trap = 16π or 50.25 sq ft

$\therefore$ No. of traps to provide minimum area of 5,040 sq ft = $\frac{5,040}{50.25} = 101$

$\therefore$ Amount of charcoal to fill units at 14 lb per cu ft = 101 units

$\times 1,000 \text{ cu ft} \times 14 \text{ lb/cu ft} = 1.4 \text{ million lb}$

$\therefore$ Estimated cost of charcoal at \$0.36 per lb = $1,400,000 \times \$0.36 = \$504,000$

However, the client has indicated that he wishes to consider the use of
150 units.

$\therefore$ Amount of charcoal required = $150 \times 1,000 \text{ cu ft} \times 14 \text{ lb/cu ft} =$
2.1 million lb

$\therefore$ Estimated cost of charcoal @ \$0.36 per lb = $2,100,000 \times \$0.36 =$
\$755,000

Consider the 150 units packed into an area 132 ft x 126 ft, 12 rows of
12 units plus a short row of 6 units with 2-ft clearance between tanks.
Consider the tanks to be on 4-ft legs to facilitate piping access.

Consider grading a site $132 \text{ ft} \times 126 \text{ ft} \times 0.5 \text{ ft} = 308 \text{ cu yd}$

Estimated cost of grading at \$0.90/cu yd = \$300

Assume wall erected around trap area, 30 ft high, 1 foot thick

$\therefore$ Wall volume = $(2 \times 126 \text{ ft} \times 30 \text{ ft} \times 1 \text{ ft}) + (2 \times 134 \text{ ft} \times 30 \text{ ft} \times 1 \text{ ft})$
 $= 7,550 \text{ cu ft} + 8,040 \text{ cu ft} = 15,590 \text{ cu ft} (576 \text{ cu yd})$

Allowing for a doorway into area, use 573 cu yd of wall volume.

Assuming that concrete floor and walls are constructed using \$120/cu yd to replace reinforced concrete.

Estimated cost of concrete work = 573 cu yd x 120 = \$68,700
(The reinforced concrete cost in April 1971 was quoted at \$100/cu yd.)

Assuming the volume of each tank is 8,000 gallons (3 ft diam x 20 ft high

$$= 16 \pi \times 20 = 7,520 \text{ gallons})$$

Assuming domed ends, allow 8,000 gallons.

Using an estimated cost of \$0.90/gallon for tanks (see Notes of telephone call from Tony Woods, Alcore Fabricating, Ltd., August 20, 1973, Cost Data 624.5).

Estimated fabricated cost per tank = 8,000 x \$0.90 x \$7,200

Using an installation factor of 2.70 (McDavid and Snelgrove) (fill tanks with charcoal located on legs and pipe.)

Total estimated installed cost of 150 tanks = 150 x \$7,200 x 2.70 =

$$\$2,918,000$$

Estimated cost of charcoal trap system = concrete work + tanks + charcoal

$$= \$300 + \$68,700 + \$2,918,000 +$$

$$\$755,000 = \$3,742,000$$

Assume that, after passing through decay traps, air volume is reheated to maintain 5,040 cfm; i.e., second heater required at \$600 installed.

Estimated cost for HEPA filter to handle 8,000 cfm air = \$17,750
(Information received from A. D. Ryon, August 20, 1973)

$\therefore$ Estimated cost of unit for 4,756 cfm = $\left(\frac{5,040}{8,000}\right)^{0.6} \times \$17,750 = \$13,400$

$\therefore$ Estimated installed cost of HEPA filter = \$13,400 x 2.70 = \$36,200

A2.3 Derivation of Operating Cost for Airborne Waste Treatment

From Power, February 1971, p. 63, the following operating costs are given:

<u>Orifice Scrubber</u> (60,000-cfm capacity)	Capital Cost	\$58,900	100.0%
	Power Cost/yr	7,900	13.4%
	Water Cost/yr	308	0.52%
	Maintenance/yr	590	1.00%
	Total Operating/yr	8,800	14.92%

Of these components, assume the following (based on factors derived from DFL):

Maintenance is comprised of 60% labor and 40% materials.

Labor is escalated from 1968 to 1972 by 5.9%/yr; 1972-73 by 5%.

Water and power are escalated at rate of 2.4% per annum.

Materials are escalated from 1968 to 1972 by 3.4%/yr; 1972-73 by 3%.

Case 1

Ore dust orifice scrubber, 27,200-cfm capacity.

$$\begin{aligned} \text{Power cost per year} &= \left(\frac{27,200 \text{ cfm}}{60,000 \text{ cfm}} \right)^{0.6} \times \$7,900 \times (1.024)^5 \\ &= \frac{1}{1.609} \times \$7,900 \times 1.128 = \$5,540/\text{yr} \end{aligned}$$

$$\text{Water cost} = \frac{1}{1.609} \times 308 \times 1.128 = \$216/\text{yr}$$

$$\text{Maintenance - Labor} = \frac{1}{1.609} \times 590 \times 0.60 \times (1.059)^4 \times 1.050 = \$290$$

$$\text{Materials} = \frac{1}{1.609} \times 590 \times 0.40 \times (1.034)^4 \times 1.05 = \$173$$

$$\text{Estimated maintenance cost} = \$293 + 173 = \$463/\text{yr}.$$

$$\therefore \text{Estimated total operating cost/yr} = \$5,540 + 216 + 463 = \$6,219$$

Ore Dust Orifice Scrubber, 2720-cfm capacity

$$\text{Power cost per year} = \left(\frac{2,720 \text{ cfm}}{60,000 \text{ cfm}} \right)^{0.6} \times 7,900 \times (1.024)^5$$

$$= \frac{1}{6.4} \times 7,900 \times 1.128 = \$1,390/\text{yr}$$

$$\text{Water cost} = \frac{1}{6.4} \times \$308 \times 1.128 = \$54/\text{yr}$$

$$\text{Maintenance - Labor} = \frac{1}{6.4} \times \$590 \times 0.60 \times (1.059)^4 \times 1.050 = \$73/\text{yr}$$

$$\text{Materials} = \frac{1}{6.4} \times \$590 \times 0.40 \times (1.034)^4 \times 1.03 = \$44/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$73 + 44 = \$117/\text{yr}$$

$$\text{Estimated total operating cost/yr} = \$1,390 + 54 + 117 = \$1,461$$

Concentrate dust irrigated target scrubber (60,000-cfm capacity)

$$\text{Power cost/yr} \quad \$ 8,120$$

$$\text{Water cost/yr} \quad 1,540$$

$$\text{Maintenance cost/yr} \quad \underline{900}$$

$$\text{Total maintenance cost/yr} \quad \$10,600$$

$$\text{Power cost per year} = \left(\frac{6,100 \text{ cfm}}{60,000 \text{ cfm}} \right)^{0.6} \times \$8,120 \times (1.024)^5$$

$$= \frac{1}{3.94} \times \$8,120 \times 1.128 = \$2,320/\text{yr}$$

$$\text{Water cost per year} = \frac{1}{3.94} \times \$1,540 \times 1.128 = \$440/\text{yr}$$

$$\text{Maintenance - Labor} = \frac{1}{3.94} \times \$900 \times 0.60 \times (1.059)^4 \times 1.050 = \$181/\text{yr}$$

$$\text{Materials} = \frac{1}{3.94} \times \$900 \times 0.40 \times (1.034)^4 \times 1.03 = \$108/\text{yr}$$

$$\therefore \text{Estimated total maintenance cost} = \$181 + 108 = \$289/\text{yr}$$

$$\therefore \text{Estimated total operating cost/yr} = \$2320 + 440 + 289 = \$3049$$

Case 2

Ore dust irrigated target scrubbers - using operating costs from Case 1.

$$27,200\text{-cfm unit} - \text{Power} = 1/1.608 \times \$8,120 \times 1.128 = \$5,700/\text{yr}$$

$$\text{Water} = 1/1.608 \times \$1,540 \times 1.128 = \$1,080/\text{yr}$$

$$\text{Maintenance, Labor} = 1/1.608 \times \$900 \times 0.60 \times 1.258 \times 1.050 = \$444/\text{yr}$$

$$\text{Materials} = 1/1.608 \times \$900 \times 0.40 \times 1.145 \times 1.03 = \$264/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$708/\text{yr}$$

$$\begin{aligned} \therefore \text{Estimated total operating cost for this unit} &= \$5,700 + 1,080 \\ &+ 708 = \$7,488/\text{yr} \end{aligned}$$

$$2,720\text{-cfm unit} - \text{Power} = 1/6.4 \times \$8,120 \times 1.128 = \$1,430/\text{yr}$$

$$\text{Water} = 1/6.4 \times \$1,540 \times 1.128 = \$272/\text{yr}$$

$$\text{Maintenance, Labor} = 1/6.4 \times \$900 \times 0.60 \times 1.258 \times 1.050 = \$111/\text{yr}$$

$$\text{Materials} = 1/6.4 \times \$900 \times 0.40 \times 1.145 \times 1.03 = \$66/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$177/\text{yr}$$

$$\begin{aligned} \therefore \text{Estimated total operating cost for this unit} &= \$1,430 + 272 \\ &+ 177 = \$1,879/\text{yr} \end{aligned}$$

Concentrate dust low-energy venturi scrubber; operating costs given in

$$\text{Power, February 1971, p. 63:} \quad \text{Power} = \$16,400/\text{yr}$$

$$\text{Water} = \$3,390/\text{yr}$$

$$\text{Maintenance} = \underline{900/\text{yr}}$$

$$\text{Total} = \$20,690/\text{yr}$$

$$6,100\text{-cfm unit} - \text{Power} = \left(\frac{6,100 \text{ cfm}}{60,000 \text{ cfm}} \right)^{0.6} \times \$16,400 \times 1.128$$

$$= 0.254 \times \$16,400 \times 1.128 = \$4,699/\text{yr}$$

$$\text{Water} = 0.254 \times \$3,390 \times 1.128 = \$970/\text{yr}$$

$$\text{Maintenance, Labor} = 0.254 \times \$1,018 \times 0.60 \times 1.258 \times 1.050 = \$205/\text{yr}$$

$$\text{Materials} = 0.254 \times \$1,018 \times 0.40 \times 1.145 \times 1.03 = \$122/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$327/\text{yr}$$

$$\begin{aligned} \text{Estimated total operating cost for this unit} &= \$4,699 + 970 + 327 = \\ & \$5,996/\text{yr} \end{aligned}$$

Mist eliminator cost is 13% of venturi cost. Therefore, maintenance cost increased by same amount.

Case 3

Ore dust low-energy venturi scrubber, 27,200-cfm unit

$$\text{Power cost} = 1/1.608 \times \$16,400 \times 1.128 = \$11,500/\text{yr}$$

$$\text{Water cost} = 1/1.608 \times \$3,390 \times 1.128 = \$2,380/\text{yr}$$

In this case, the cost of the mist eliminator is 23.5% of the venturi; therefore, assume maintenance cost of whole unit would be increased by same amount, i.e., $\$900 \times 1.235 = \$1,110/\text{yr}$.

$$\text{Maintenance, Labor} = 1/1.608 \times \$1,110 \times 1.60 \times 1.258 \times 1.050 = \$547/\text{yr}$$

$$\text{Materials} = 1/1.608 \times \$1,110 \times 0.40 \times 1.145 \times 1.03 = \$326/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$873/\text{yr}$$

$$\therefore \text{Estimated total operating cost for this unit} = \$11,500 + 2,380$$

$$+ 873 = \$14,753/\text{yr}$$

Ore dust low-energy venturi scrubber, 2,720-cfm unit

$$\text{Power cost} = 1/6.4 \times \$16,400 \times 1.128 = \$2,890$$

$$\text{Water cost} = 1/6.4 \times \$3,390 \times 1.128 = \$596$$

In this case, the cost of the mist eliminator is 9.53% of the venturi cost; therefore, assume maintenance cost of the whole unit would be increased by same amount, i.e., $\$900 \times 1.095 = \$985/\text{yr}$.

$$\text{Maintenance, Labor} = 1/6.4 \times \$985 \times 0.60 \times 1.258 \times 1.050 = \$122/\text{yr}$$

$$\text{Materials} = 1/6.4 \times \$985 \times 0.40 \times 1.145 \times 1.03 = \$73/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$195/\text{yr}$$

Concentrate dust medium-energy venturi scrubber, 6100-cfm unit.

From Power, February 1971, p. 63

$$\text{Operating costs - Power, cost/yr} = \$26,400$$

$$\text{Water, cost/yr} = \$3,390$$

$$\text{Maintenance, cost/yr} = \$900$$

$$\text{Power} = 1/3.94 \times \$26,400 \times 1.128 = \$7,550/\text{yr}$$

$$\text{Water} = 1/3.94 \times \$3,390 \times 1.128 = \$969/\text{yr}$$

In this case, the cost of the mist eliminator is 12.25% of the venturi cost; therefore, assume maintenance cost of whole unit would be increased by same amount, i.e., $\$900 \times 1.1225 = \$1,010/\text{yr}$.

$$\text{Maintenance, Labor} = 1/3.94 \times \$1,010 \times 0.60 \times 1.258 \times 1.050 = \$203/\text{yr}$$

$$\text{Materials} = 1/3.94 \times \$1,010 \times 0.40 \times 1.145 \times 1.03 = \$121/\text{yr}$$

$$\text{Estimated total maintenance cost} = \$324/\text{yr}$$

Case 4

Ore dusts are treated by reverse jet bag filter; the operating costs are quoted in Table IX of Stairmand's paper, The Chemical Engineer, December 1965.

60,000-cfm unit - Annual Operating Costs

Power	$\cancel{\text{£}} 3,960 \times \$2.80/\cancel{\text{£}}$	= \$11,100
Maintenance	$\cancel{\text{£}} 6,000 \times \$2.80/\cancel{\text{£}}$	= \$16,800 (bags changed twice/yr)

Consider 27,200-cfm unit:

Power	$= 1/1.608 \times \$11,000 \times 1.128 = \$7,787/\text{yr}$
Maintenance-Labor	$= 1/1.608 \times \$16,800 \times 0.60 \times 1.258 \times 1.05 =$ \$8,260/yr
Materials	$= 1/1.608 \times \$16,800 \times 0.40 \times 1.145 \times 1.03 =$ \$4,930/yr

Estimated total maintenance cost = \$13,190/yr

Consider 2,720-cfm unit:

Power	$= 1/6.4 \times \$11,100 \times 1.128 = \$1,960/\text{yr}$
Maintenance-Labor	$= 1/6.4 \times \$16,800 \times 0.60 \times 1.258 \times 1.05 =$ \$2,080/yr
Materials	$= 1/6.4 \times \$16,800 \times 0.40 \times 1.145 \times 1.0 =$ \$1,240/yr

Estimated total maintenance cost = \$3,320/yr

The concentrate dusts are treated in a high-energy venturi equipped with mist eliminator.

The operating costs of such a venturi (60,000 cfm) (without eliminator) are as follows: (Power, February 1971, p. 63).

Power, cost/yr	\$41,600
Water, cost/yr	\$ 3,390
Maintenance, cost/yr	\$ 900

∴ Operating costs for a 6,100-cfm unit are as follows:

$$\text{Power} - 1/3.94 \times \$41,600 \times 1.128 = \$11,900/\text{yr}$$

$$\text{Water} - 1/3.94 \times \$3,390 \times 1.128 = \$970/\text{yr}$$

In this case, the cost of the mist eliminator was 11.4% of the venturi; therefore, maintenance cost increased by same amount, i.e., $\$900 \times 1.114 = \$1,005/\text{yr}$

$$\begin{aligned} \text{Maintenance - Labor} &= 1/3.94 \times \$1,005 \times 0.60 \times 1.258 \times 1.05 = \\ &\$1,005/\text{yr} \end{aligned}$$

$$\begin{aligned} \text{Materials} &= 1/3.94 \times \$1,005 \times 0.40 \times 1.145 \times 1.03 = \\ &\$120/\text{yr} \end{aligned}$$

$$\text{Estimated total maintenance cost} = \$322/\text{yr}$$

Case 5

Same as Case 4 except HEPA filter on concentrate dust.

Gas: Assume heater ahead of HEPA filter operated for 180 days/yr

$$\begin{aligned}\therefore \text{Gas consumption} &= 180 \text{ days} \times 1,440 \text{ min/day} \times 2\text{-cfm gas} \\ &= 518,000 \text{ cu ft}\end{aligned}$$

Cost of gas (ML Industries-Tungsten) in 1971 = \$0.25 per 1000 cu ft

Assuming an escalation of 2.4% per unit

$$\therefore \text{Estimated Annual Cost of Gas} = 518 \times \$0.205 \times (1.024)^2 = \$111$$

Assign an allowance for heater maintenance at \$100/yr.

From Case 5 the ore dust collecting system has an annual operating cost of \$27,257, which includes stack maintenance.

From Case 4 the concentrate dust collecting system has an annual operating cost of \$13,192 for a 6,100-cfm-capacity unit. See p. 81 for derivation of 3,670-cfm-capacity filter cost.

To this cost of \$13,192 must be added the heater fuel and maintenance cost of \$211 plus the operating costs associated with the HEPA filter.

HEPA filter - Installed power = 20 hp for 8,000-cfm unit, assume 10 hp required for 3,890-cfm unit.

Assuming a power cost of \$40/yr per installed horsepower and 85% efficiency.

$$\text{Estimated Annual Power Cost of HEPA filter} = 10 \times \$40 \times 0.85 = \$340$$

Filters: 9 prefilters + 9 HEPA cost \$800 (Note from A. D. Ryon, ORNL, August 20, 1973).

$$\therefore \text{Assume 1 prefilter + 1 HEPA cost } \$800/9 = \$89.$$

The unit in question uses 4 filters, i.e., cost per set = \$356.

Allow for three changes per year. $\therefore$ Annual Material Cost = $\$356 \times 3 = \$1,068$

Assuming that the material cost is 40% of total maintenance cost, then

labor at 60% of total maintenance cost = $\$1,068 \times 0.60/0.40 = \$1,600$.

Allow \$100 per year for lubrication and checking of motor and checking and cleaning of instruments.

$\therefore$ Estimated operating cost of HEPA filter - Power = \$ 340

Labor, Materials = \$2,763
\$3,103

From p. 69, the operating costs of a 3,670-cfm-capacity high-energy venturi are as follows:

$$\text{Power: } \frac{1}{5.35} (\text{size factor, p65}) \times \$41,600 \times 1.128 = \$8,750$$

$$\text{Water: } \frac{1}{5.35} \times \$3,390 \times 1.128 = \$715$$

In this case, the cost of the mist eliminator was 9.45% of the venturi cost; therefore, initial maintenance cost increased by same amount, i.e., $\$900 \times 1.0945 = \$985/\text{yr}$

$$\text{Maintenance - Labor} = \frac{1}{5.35} \times \$985 \times 0.60 \times 1.258 \times 1.05 = \$146/\text{yr}$$

$$\text{Materials} = \frac{1}{5.35} \times \$985 \times 0.40 \times 1.145 \times 1.03 = \$87/\text{yr}$$

$\therefore$ Estimated total maintenance cost = \$233/yr

Summarizing, for concentrate dust collecting system, the operating costs are:

Venturi:	Power	\$8,750		
	Water	715		
	Maintenance	<u>233</u>		
		\$9,698		
Air Heater:	Gas	\$ 111	Power	\$9,090
	Maintenance	<u>100</u>	Water	715
		\$ 211	Gas	111
HEPA Filter:	Power	\$ 340	Maintenance	3,101
	Maintenance	<u>2,768</u>		
		\$3,108		

Case 6

Same as Case 5 except HEPA filters on ore dust collectors. Operating cost for HEPA proportioned from Case 7

$$\$3,945 \times \frac{29,920 \text{ cfm}}{4,756 \text{ cfm}} = \$25,000$$

Case 7

The ore dust collection system operating costs are those associated with the 5 collection system appropriate for this case plus the costs associated with the delay trap and HEPA filter.

Reverse jet bag filter, cfm capacity - Power =

$$\frac{1}{4.89} (\text{size factor}) \times 11,100 \times 1.128 = \$2,560$$

Maintenance - Labor =

$$\frac{1}{4.89} \times \$16,800 \times 0.60 \times 1.258 \times 1.05 = \$2,722$$

Maintenance - Materials =

$$\frac{1}{4.89} \times \$16,800 \times 0.40 \times 1.145 \times 1.03 = \$1,620$$

Estimated maintenance cost = \$4,342

∴ Estimated total operating cost/yr = \$2,560 + \$4,342 = \$6,902

Reverse jet bag filter, 476-cfm capacity - Power =

$$\frac{1}{18.2} \times \$11,100 \times 1.128 = \$688$$

Maintenance - Labor =

$$\frac{1}{18.2} \times \$16,800 \times 0.60 \times 1.258 \times 1.05 = \$731$$

Maintenance - Materials =

$$\frac{1}{18.2} \times \$16,800 \times 0.40 \times 1.145 \times 1.03 = \$436$$

Estimated Maintenance Cost = \$731 + \$436 = \$1,167

∴ Estimated jet bag filter operating cost/yr = \$688 + \$1,167 = \$1,855

Gas Heater, ahead of delay trap - Assume 180 days/yr operation

Gas consumption = 180 days x 1,440 min/day x 2.51 cfm = 650,000 cu ft

From p. 80, gas cost in 1971 was \$0.205/1,000 cu ft.

∴ Estimated gas cost = 650,000 x \$0.205/1,000 cu ft x (1.024) = \$140

Heater maintenance allowance = \$100/yr

Assume operating cost associated with decay traps is negligible.

Assume that gas cost for post-trap heater is as derived, i.e.,

\$140 + \$100 allowance for maintenance.

HEPA filter for 4756 cfm, allow 5 filters.

From p. 80, a set of 5 filters costs 5 x \$89 = \$445

Annual material cost @ 3 changes/yr = \$445 x 3 = \$1,335

Annual Labor cost of maintenance = \$1,335 x 0.60/0.40 = \$2,000

Allow \$100 per year for lubrication and checking of motor and checking and cleaning of instruments.

The installed motor size for an 8,000-cfm unit is 20 hp; therefore, assume 15 hp for 4,756 cfm.

4,756-cfm HEPA unit:

∴ Estimated power cost per year = 15 hp x \$40 hp x 0.85 = \$510

∴ HEPA annual operating cost = Power \$510

Labor and materials \$3,435

\$3,945

Concentrate dust treatment operating costs are same as Case 5.

A3.0 LIQUID AND SOLID WASTE TREATMENT

A3.1 Summary of Radwaste Treatment Cases for Solid
and Liquid Emissions From Mill

Summary of Costs for Treatment of Liquid and Solid Mill Effluents

Case No.	Flowsheet	Wyoming		New Mexico	
		Capital ^a (\$1000)	Operating ^b (\$1000/yr)	Capital ^a (\$1000)	Operating ^b (\$1000/yr)
1	Acid	341	61	284	61
1	Alkaline	279	61	279	61
2	Acid	1384	61	1977	61
2	Alkaline	1968	61	1974	61
3	Acid	1658	61	2145	61
3	Alkaline	2140	61	2142	61
4a	Acid	5590	338	4044	338
4a	Alkaline	3510	66	3604	66
4b	Acid	5538	338	4013	338
4b	Alkaline	3477	66	3573	66
5	Acid	3565	1686	3139	1686
5	Alkaline	2882	1376	2097	1376
6a	Acid	5390	4809	5390	4809
6a	Alkaline	7538	6302	7538	6302
6b	Acid	4735	1526	4735	1526
6b	Alkaline	4470	1346	4470	1346
6c	Acid	20257	800	20257	800
7	Acid	7272	338	5055	338
7	Alkaline	4564	66	4615	66

^aDoes not include interest during construction or allowance for contingency.

^bDoes not include allowance for contingency or fixed charges.

Summary - Case 1 - Wyoming - Solvent ExtractionI. Capital Costs

1. Tailings pump and pipeline	\$96,000
2. Removing top soil from area	21,000
3. Initial earth dam construction	29,000
4. Rehabilitation of area	
(a) Incl. covering with 6-in. earth	77,000
(b) Alternative - 6-in. earth and 6-in. rock cover	(151,000)
5. Installation of water spray system	75,000
6. Diversion dams - 25,000 cu yd at \$0.15	4,000
7. Cyclone installation	<u>40,000</u>
Total estimated capital cost	\$342,000 (\$341,000)

II. Operating Cost - Per Year

Supervision	\$ 2,000
Operating labour - 4 men at \$12,000	50,000
Maintenance labour and supplies	
$10\% \times \frac{95,765 + 40,000}{3.5} = 3,879$	4,000
Power - 80 hp	
$80 \times 0.746 \times 0.90 \times 24 \times 365 \times \0.01	<u>5,000</u>
	\$61,000/yr

III. Maintenance Cost After Rehabilitation - Per Year (Seeded Case Only)

Power	\$ 1,000
Fertilizer	5,000
Labour - operating	37,000
Maintenance supplies and labour	<u>8,000</u>
Total	\$51,000

Summary - Case 1 - New Mexico - Solvent ExtractionI. Capital Costs (installed)

1. Tailings pumps and pipeline	\$96,000
2. Removing top soil from area	14,000
3. Initial earth dam construction	24,000
4. Rehabilitation of area	
(a) Based on covering with 6-in. earth	55,000
(b) Alternative with 6-in. earth and 6-in. rock	(106,000)
5. Installation of water spray system	50,000
6. Diversion dams	4,000
7. Cyclones	<u>40,000</u>
Total estimated capital cost	\$283,000 (\$284,000)

II. Operating Cost - Per Year

Same as Case 1, Wyoming, Solvent Extraction \$61,000

III. Maintenance Cost After Rehabilitation - Per Year (Seeded Case Only)

Same as Case 1, Wyoming, Solvent Extraction \$47,000

Summary - Case 1 - Alkaline - Wyoming and New MexicoI. Capital Costs (installed)

1. Tailings pump and pipeline	\$93,000
2. Removing top soil from area	14,000
3. Initial earth dam construction	22,000
4. Rehabilitation of area	
(a) Based on covering with 6-in. earth	54,000
(b) Alternative with 6-in. earth and 6-in. rock	(106,000)
5. Installation of water spray system	50,000
6. Diversion dams	4,000
7. Cyclones	40,000
Total estimated capital cost	\$277,000 (\$279,000)

II. Operating Cost - Per Year

Same as Case 1, New Mexico, Solvent Extraction	\$61,000
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III. Maintenance Cost After Rehabilitation - Per Year (seeded case only)

Same as Case 1, New Mexico, Solvent Extraction	\$47,000
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Summary - Cases 2 and 3 - Wyoming - Alkaline

I. Capital Costs - Installed

1. Tailings pump and pipeline	\$93,000
2. Surveying for pond site	9,000
3. Removing the top soil from area	58,000
4. Tailings dam construction	1,662,000
5. Rehabilitation of area	
(a) Based on covering with 2-ft earth and seeding	88,000
(b) Based on covering with 2-ft earth and 6-in. rock	(142,000) ^a
6. Installation of water spray system	51,000
7. Diversion dams	<u>4,000</u>
Total estimated capital cost	\$1,965,000 (\$1,968,000)

II. Operating Cost Per Year

Same as Case 1 \$61,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Same as Case 1, New Mexico, Solvent Extraction \$47,000

^aCase 3, Wyoming, Alkaline, same as Case 2, except 5(b) cover with 8-ft earth and 6-in. rock $(4 \times \$484 + \$706) 119A = (\$314,000)$

Summary - Cases 2 and 3 - New Mexico - AlkalineI. Capital Costs - Installed

1. Tailings pump and pipeline	\$93,000
2. Surveying for pond site	9,000
3. Removing top soil from area	56,000
4. Tailings dam construction	1,674,000
5. Rehabilitation of area	
(a) Based on covering with 2-ft earth and seeding	86,000
(b) Based on covering with 2-ft earth and 6-in. rock	(138,000) ^a
6. Installation of water spray system	50,000
7. Diversion dams	<u>4,000</u>
Total estimated capital cost	\$1,972,000 (\$1,974,000)

II. Operating Cost Per Year Before Rehabilitation

Same as Case 2, Wyoming, Alkaline \$61,000

III. Maintenance Cost Per Year After Rehabilitation (Seeded Case Only)

Same as Case 1, New Mexico, Solvent Extraction \$47,000

^aCase 3, New Mexico, Alkaline, same as Case 2 except 5(b) cover with 8-ft earth + 6-in. rock (4 x \$484 + \$706) 116A = (\$306,000)

Summary - Cases 2 and 3 - Wyoming - Solvent Extraction

I. Capital Costs - Installed

1. Tailings pump and pipeline	\$96,000
2. Surveying for pond site	9,000
3. Removing top soil from area	91,000
4. Tailings dam construction	959,000
5. Rehabilitation of area	
(a) Based on 2-ft earth cover and seeding	144,000
(b) Based on 2-ft earth cover and 6-in. rock cover	(225,000) ^a
6. Installation of water spray system	82,000
7. Diversion dams	4,000
	<u>\$1,385,000</u>
	(\$1,384,000)

II. Operating Cost Per Year

Same as Case 2, Wyoming, Alkaline	\$61,000
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III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Operating labour	\$37,000
Maintenance labour and supplies, 10% x 81,500	8,000
Fertilizer, 189/174 x 5220	6,000
Power	<u>1,000</u>
Total	\$52,000

^aCase 3, Wyoming, Solvent Extraction, same as Case 2 except 5(b) cover with 8-ft earth + 6-in. rock (4 x \$484 + \$706) 189A = (\$499,000)

Summary - Cases 2 and 3 - New Mexico - Solvent Extraction

I. Capital Costs - Installed

1. Tailings pump and pipeline	\$96,000
2. Surveying for pond site	9,000
3. Removing top soil from area	56,000
4. Tailings dam construction	1,674,000
5. Rehabilitation of area	
(a) Based on covering with 2-ft earth and seeding	89,000
(b) Based on covering with 2-ft earth and 6-in. rock	(138,000) ^a
6. Installation of water spray system	50,000
7. Diversion dams	<u>4,000</u>
Total estimated capital cost	\$1,978,000 (\$1,977,000)

II. Operating Cost Per Year

Same as Case 2, New Mexico, alkaline \$61,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Same as Case 2, New Mexico, Alkaline \$47,000

^aCase 3, New Mexico, Solvent Extraction, same as Case 2 except 5(b)
cover with 8-ft earth + 6-in. rock (4 x \$484 + \$706) 116A = (\$306,000)

Summary - Cases 4a, 4b, and 7 - Wyoming - AlkalineI. Capital Costs - Installed

1. Copperas treatment equipment	\$15,000
2. Tailings pump and pipeline	93,000
3. Surveying for pond site	Omit
4. Removing topsoil from area	59,000
5. Tailings dam construction	1,968,000
6. Sealing tailings area with asphalt, 1/4 in.	575,000
7. Rehabilitation of tailings area (based on covering with 20-ft earth, asphalt, dirt, and seeding)	1,071,000
(Alternative 6-in. rock in lieu of seeding)	(1,125,000)
8. Installation of water spray system 121/174 x 75,000	52,000
9. Diversion dams	4,000

Corrections and AdditionsCase No.

4a, 4b, 7	Sealing area - 5/16 in. asphalt instead of 1/4 in. asphalt $\$575,000 / \$3,750 = 153.3 \text{ A}$ $[(3267 \times 1.25) + 484] 153.3 \text{ A} =$	\$700,000
4a	20 ft earth + 6 in. rock $(10 \times \$484 + \$706) 121 \text{ A} =$	\$671,000
4b	2 ft earth + 5/16 in. asphalt + 6 in. rock $(484 + 1.25 \times \$3267 + 706) 121 \text{ A} =$	\$638,000
7	2 ft earth + 1 in. asphalt + 6 in. rock $(484 + 4 \times 3267 + 706) 121 \text{ A} =$	\$1,725,000

II. Operating Cost Per Year

A. Copperas treatment (operating supplies)

Consumption - $0.42 \times 365 = 153.3$ tons

Quotation 1970 - "Oil, Paint and Drug Reporter" \$24.00/2000 lb

Escalate at 5% year = \$27.60/ton

Estimate freight rate = \$10/ton

Total - \$37.60/ton

Total estimated cost of copperas per year = $153.3 \times 37.60 = \$5,764$

B. Operating Labour - 1 man/shift \$50,000

Supervision \$ 2,000

C. Maintenance labour and supplies per year

$$\frac{10}{100} \times \frac{(15,491 + 93,065)}{3.5} = \$3102$$

D. Power - $91 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$5,352$

Total estimated costs \$66,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Same as Case 2, New Mexico, alkaline \$47,000

Summary - Cases 4a, 4b, and 7 - New Mexico - AlkalineI. Capital Costs - Installed

1. Copperas treatment	\$15,000
2. Tailings pump and pipeline	93,000
3. Surveying for pond site	Omit
4. Removing top soil from area	56,000
5. Tailings dam construction	2,115,000
6. Sealing tailings dam with asphalt, 1/4 in.	557,000
7. Rehabilitation of tailings area	1,026,000
(based on covering with 20 ft earth, asphalt, dirt, and seeding)	
(Alternative, 2 ft rock in lieu of seeding)	(1,078,000)
8. Installation of water spray system	50,000
9. Diversion dams	4,000

Corrections and AdditionsCase No.

4a, 4b, 7	Sealing area - 5/16 in. asphalt	
	$557,000/3,750 = 148.5 \text{ A}$	
	$(\$3267 \times 1.25 + \$484) 148.5 \text{ A} =$	\$678,000
4a	20 ft earth + 6 in. rock	
	$(10 \times \$484 + \$706) 116 =$	\$643,000
4b	2 ft earth + 5/16-in. asphalt + 6 in. rock	
	$(\$484 + \$3267 \times 1.25 + \$706) 116 =$	\$612,000
7	2 ft earth + 1 in. asphalt + 6 in. rock	
	$(\$484 + \$3267 \times 4 + \$706) 116 =$	\$1,654,000

II. Operating Cost Per Year

Same as Case 4a, Wyoming, Alkaline	\$66,000
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III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Same as Case 4a, Wyoming, Alkaline

\$47,000

Summary - Cases 4a, 4b, and 7 - Wyoming - Solvent ExtractionI. Capital Costs Installed

1. Neutralization	\$452,000
2. Tailings pump and pipeline	96,000
3. Surveying for pond site	Omit
4. Removing top soil from area	93,000
5. Tailings dam construction	1,163,000
6. Sealing tailings dam with asphalt, 1/4 in.	824,000
7. Rehabilitation of tailings area	1,708,000
(based on covering with 20 ft earth, asphalt and 2 ft dirt)	
(based on 6 in. rock cover in lieu of seeding)	(1,794,000)
8. Installation of water spray system	83,000
9. Diversion dams	4,000

Corrections and AdditionsCase No.

4a, 4b, 7	Sealing Area - 5/16-in. asphalt 824,000/3750 = 219.7 A (\$3267 x 1.25 + 484) 219.7 A	\$1,004,000
4a	20 ft earth + 6 in. rock (10 x \$484 + \$706) 193 A	\$1,070,000
4b	2 ft earth + 5/16-in. asphalt + 6 in. rock (\$484 + \$3267 x 1.25 + \$706) 193 A	\$1,018,000
7	2 ft earth + 1 in. asphalt + 6 in. rock (\$484 + \$3267 x 4 + \$706) 193 A	\$2,752,000

II. Operating Cost Per Year

A. Operating labour

1 man per shift + 1 extra man on dayshift = 28 manshifts = 6 men

6 men at \$12,000/year = \$72,000

Supervision, est. $1/3 \times \$15,000 = \$5,000$

B. Operating Supplies

Quicklime consumption = $25.4 \times 365 = 9,271$ tons

Est. cost delivered in bin = $9,271 \times \$25 = \$231,775$

C. Maintenance labour and supplies

Estimate 10% of equipment cost = $\frac{10}{100} \times \frac{(451,692 + 95,765)}{3.5} = \$15,642$

D. Power - 230 hp

Power cost = $230 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$13,527$

Total operating costs per year = \$337,944

III. Maintenance Cost Per Year After Rehabilitation (seeded area only)

Same as Case 2, Wyoming, Solvent Extraction \$52,000/yr

Summary - Cases 4a, 4b, and 7 - New Mexico - Solvent ExtractionI. Capital Costs

1. Neutralization	\$452,000
2. Tailings pump and pipeline	96,000
3. Surveying for pond site	Omit
4. Removing topsoil from area	56,000
5. Tailings dam construction	2,115,000
6. Sealing tailings dam with asphalt, 1/4 in.	557,000
7. Rehabilitation of tailings area	
(a) Based on cover of 20 ft earth, asphalt, and 2 ft dirt	1,026,000
(b) Based on 6-in. rock cover in lieu of seeding	(1,078,000)
8. Installation of water spray system	50,000
9. Diversion dams	4,000

Corrections and AdditionsCase No.

4a, 4b, 7	Sealing area - 5/16-in. asphalt $557,000/3750 = 148.5 \text{ A}$ $(3267 \times 1.25 + 484) 148.5 \text{ A}$	\$678,000
4a	20 ft earth + 6 in. rock $(10 \times \$484 + \$706) 116 \text{ A}$	\$643,000
4b	2 ft earth + 5/16 in. asphalt + 6 in. rock $(\$454 + \$3267 \times 1.25 + \$706) 116 \text{ A}$	\$612,000
7	2 ft earth + 1 in. asphalt + 6 in. rock $(\$484 + \$3267 \times 4 + \$706) 116 \text{ A}$	\$1,654,000

II. Operating Costs Per Year

Same as Cases 4a, 4b, and 7 - Wyoming - Solvent Extraction \$338,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Same as Case 2, New Mexico, solvent extraction \$47,000

Summary - Case 5 - Wyoming - AlkalineI. Capital Costs - Installed

1. Cement and concrete slurry equipment	\$396,000
2. Concrete slurry pumps and pipeline	71,000
3. Removing 2 ft topsoil from evaporation pond	59,000
4. Evaporation pond dam construction	77,000
5. Sealing evaporation pond with 1/4 in. asphalt	470,000
6. Diversion dams	8,000
7. Rehabilitation of tailings areas	
(a) 20 ft earth cover, asphalt and seeding	1,531,000
(b) 6 in. rock cover in lieu of seeding	(1,598,000)
8. Water spray system	64,000

Corrections

1. Sealing evaporation pond - 5/16-in. asphalt	
$470,000/3750 = 125.3 \text{ A}$	
$(\$3267 \times 1.25 + \$484) 125.3 \text{ A}$	\$572,000
2. Sealing bottom and sides concrete pile	
$(\$3267 \times 1.25 + \$484)(117 \text{ A} + 10 \text{ A})$	\$580,000
3. 20 ft earth + 6 in. rock	
$(10 \times \$484 + \$706) 117 \text{ A}$	\$649,000

II. Operating Costs Per Year

A. Operating labour	
Same as Case 4 - solvent extraction	\$72,000
Supervision	\$ 5,000
B. Operating Supplies	
Cement cost = $100 \times 365 \times \$35$	\$1,277,000
C. Maintenance labour and supplies	
$10\% \times \frac{(396,256 + 71,322)}{3.5} =$	\$13,359

D. Power, 130 hp

$$\text{Power cost} = 130 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$ 7,646$$

Total operating costs per year \$1,375,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Based on (134 + 15) acres \$49,000

Summary - Case 5 - New Mexico - AlkalineI. Capital Costs - Installed

1. Cement and concrete slurry equipment	\$396,000
2. Concrete slurry pumps and pipeline	54,000
3. Removing 2 ft topsoil from evaporation pond	32,000
4. Evaporation pond dam construction	57,000
5. Sealing evaporation pond with 1/4-inch asphalt	264,000
6. Diversion dams	8,000
7. Rehabilitation of tailings areas	
(a) 20-ft earth cover, asphalt and seeding	862,000
(b) 6-in. rock cover in lieu of seeding	(896,000)
8. Water spray system	33,000

Corrections

1. Sealing evaporation pond, 5/16-in. asphalt	
$264,000/3,750 = 70.4 \text{ A}$	
$(\$3267 \times 1.25 + \$484) 70.4 \text{ A}$	\$321,000
2. Sealing concrete pile	
See Case 5, Alkaline, Wyoming	\$580,000
3. 20-ft earth + 6-in. rock	
See Case 5, Alkaline, Wyoming	\$649,000

II. Operating Cost Per Year

Same as Case 5, Alkaline, Wyoming	\$1,375,000
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III. Maintenance Cost per Year After Rehabilitation (seeded case only)

$(61 + 15) \text{ acres} =$	\$43,846
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Summary - Case 5 - Wyoming - Solvent ExtractionI. Capital Costs - Installed

1. Equipment for neutralization and pumping liquid waste	\$786,000
2. Cement and concrete slurry equipment	396,000
3. Concrete slurry pumps and pipeline	61,000
4. Removing 2-ft topsoil from evaporation pond	58,000
5. Evaporation pond dam construction	77,000
6. Sealing evaporation pond with 1/4-in. asphalt	470,000
7. Diversion dams	8,000
8. Rehabilitation of tailings areas	
(a) 20-ft earth cover, asphalt, and seeding	1,840,000
(b) 6-in. rock cover in lieu of seeding	(1,916,000)
9. Water spray system	73,000

Corrections

1. Sealing evaporation pond, 5/16-in. asphalt (\$3267 x 1.25 + \$484)(193 A + 15 A)	\$950,000
2. Sealing concrete pile Same as Case 5, Alkaline, Wyoming	\$580,000
3. 20-ft earth + 6-in. rock Same as Case 5, Alkaline, Wyoming	\$649,000

II. Operating Cost Per Year

A. Operating labour - est. 2 men/shift = 42 manshifts/week This will require $42/5 = 9$ men Cost = $9 \times 12,000 =$ Supervision - 1 man =	\$108,000 \$ 15,000
B. Operating Supplies	
(a) Quicklime - $25.5 \times 365 \times \$25 =$	\$232,675
(b) Cement - $100 \times 365 \times \$35 =$	\$1,277,500

C. Maintenance labour and supplies

$$\frac{10}{100} \times \frac{(785,985 + 396,256 + 60,822)}{35} = \$ 35,516$$

D. Power - 280 hp

$$\text{Power cost} = 280 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 \quad \$ 16,468$$

Total operating costs per year = \$1,685,000

III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

(148 + 21) acres \$ 51,000

Summary - Case 5 - New Mexico - Solvent ExtractionI. Capital Costs - Installed

1. Equipment for neutralization and pumping liquid waste	\$786,000
2. Cement and concrete slurry equipment	396,000
3. Concrete slurry and mine water pumps and pipelines	88,000
4. Removing 2-ft topsoil from evaporation pond	52,000
5. Evaporation pond dam construction	72,000
6. Sealing evaporation pond with 1/4-in. asphalt	417,000
7. Diversion dams	8,000
8. Rehabilitation of tailings area	
(a) 20-ft earth cover, asphalt, and seeding	1,030,000
(b) 6-in. rock cover in lieu of seeding	(1,067,000)
9. Water spray system	35,000

Corrections

1. Sealing evaporation pond, 5/16-in. asphalt	
$417,000/3750 = 111.2 \text{ A}$	
$(\$3267 \times 1.25 + \$484) 111.2 \text{ A}$	\$508,000
2. Sealing concrete	
Same as Case 5, Alkaline, Wyoming	\$580,000
3. 20-ft earth + 6-in. rock	
Same as Case 5, Alkaline, Wyoming	\$649,000

II. Operating Cost Per Year

Same as Case 5, Wyoming, Solvent Extraction	\$1,686,000
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III. Maintenance Cost Per Year After Rehabilitation (seeded case only)

Based on (61 + 21) acres	\$44,000
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Summary - Case 6a - Wyoming or New Mexico - Alkaline
Asphalt-Slime Fixation

I. Capital Costs - Installed

Conditions: (A) Sand and asphalt-fixed slime trucked to landfill.

(B) Sand pumped to underground; asphalt-fixed slime trucked to landfill.

	<u>A</u>	<u>B</u>
1. Sand-slime separation equipment	64,000	64,000
2. Slime dewatering equipment	833,000	833,000
3. Evaporation equipment	1,408,000	1,408,000
4. Asphalt fixation equipment	3,618,000	3,618,000
5. Instrumentation	70,000	70,000
6. Boiler	640,000	640,000
7. Loadout and landfill and sand disposal	141,000	120,000
8. Rehabilitation of landfill area		
(a) 20-ft earth cover, seeding	683,000	341,000
(b) 6-in. rock cover in lieu of seeding	(743,000)	(372,000)
9. Water spray equipment	58,000	29,000
10. Road to landfill	<u>21,000</u>	<u>21,000</u>
Total	\$7,536,000 (\$7,538,000)	\$7,144,000 (\$7,146,000)

II. Operating Cost Per Year

Labor	123,000	123,000
Supplies	4,891,000	4,891,000
Maintenance	190,000	190,000
Steam and power	1,001,000	1,001,000
Trucking	<u>97,000</u>	<u>61,000</u>
	\$6,302,000	\$6,266,000

III. Maintenance After Rehabilitation (seeded case only)

Cost per year	\$48,000	\$43,000
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Summary - Case 6b - Wyoming or New Mexico - Alkaline
Cement-Slime Fixation

I. Capital Costs Installed

Conditions: (A) Concrete slurry made from the slimes fraction, pumped to combined landfill and evaporation pond area; the sand fraction trucked to the same area and distributed on the concrete.

(B) Sand fraction and as much of the concrete slurry as can be accommodated to be pumped to bore holes for transfer underground; the balance of the concrete slurry (843 tons slime per day) will be pumped to a combined landfill-evaporation pond. Mine water from the fill sent underground will be returned to surface and pumped to the evaporation pond.

	<u>A</u>	<u>B</u>
1. Sand-slime separation equipment	64,000	64,000
2. Slime dewatering equipment	833,000	833,000
3. Evaporation equipment	1,408,000	1,408,000
4. Cement and concrete slurry equip.	234,000	234,000
5. Sand, cement slurry, and mine water pumping	61,000	164,000
6. Removing 2-ft topsoil from evap. pond	80,000	53,000
7. Dam construction	77,000	77,000
8. Sealing impounding area with 1/4-in. asphalt	633,000	422,000
9. Boiler	431,000	431,000
10. Loadout for sand	48,000	
11. Diversion dams	4,000	4,000
12. Rehabilitation of impounding area		
(a) 20-ft earth cover; seeding	846,000	558,000
(b) 6-in. rock cover in lieu of seeding	(921,000)	(607,000)

13. Water spray equipment	72,000	47,000
14. Road to landfill	21,000	nil

Corrections

1. Sealing area, 5/16-in. asphalt (\$3267 x 1.25 + \$484)(115 A + 10A)	\$571,000	
2. 20-ft earth + 6-in. rock (10 x \$484 + \$706) 115 A	\$638,000	

II. Operating Cost Per Year

Labor	123,000	123,000
Supplies	639,000	639,000
Maintenance	87,000	90,000
Steam and power	460,000	460,000
Trucking	<u>37,000</u>	<u>-</u>
	\$1,346,000	\$1,312,000

III. Maintenance After Rehabilitation (seeded case only)

Cost per year	\$50,000	\$46,000
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Cost Summary for Solvent Extraction Mills in Wyoming
or New Mexico - Cases 6a and 6b

I. Capital Cost

Flowsheet and equipment according to the Terms of Reference supplied but with the following exceptions:

Burnt lime for neutralization rather than slaked lime.

Lime storage silo for 10 days' supply rather than 3 days.

Three 34,000-gallon neutralization vessels instead of one 1000-gallon mixer.

<u>Item</u>	<u>Equipment Cost</u>
Neutralization:	
Pneumatic lime unloader	\$20,000
Storage silo and gravimetric feeder	26,000
Ball mill and belt feeder	26,000
Lime slurry circulation tank and pumps	8,000
Neutralization vessels with agitators	36,000
Instrumentation for neutralization	8,000
Air compressor	5,000
Thickener and pumps	110,000
Filters	95,000
Filtrate surge tank and pump	<u>3,400</u>
Subtotal	\$337,400
Sand Wash:	
Classifiers and pumps	\$19,000
Load-out bin	11,000
Dump truck	<u>34,000</u>
Subtotal	\$64,000

<u>Item</u>	<u>Equipment Cost</u>
Evaporation:	
Evaporator with preheater and condenser	\$436,000
Instrumentation	10,000
Condensate receiver and pump	3,600
Evaporator concentrate pump	<u>1,300</u>
Subtotal	\$450,900

Case 6a

Asphalt Fixation Alternative:

Asphalt unloading and transfer pumps	\$ 6,800
Asphalt storage (heated)	75,000
Wiped-film evaporators	413,000
Condenser	25,000
Instrumentation	15,000
Filter cake surge tank and pumps	8,700
Load-out surge bin	17,600
Dump trucks with heated bodies	78,000
Boiler for entire plant	<u>174,000</u>
Subtotal	\$813,100

Case 6b

Cement Fixation Alternative:

Pneumatic cement unloader	\$ 20,000
Storage silo and gravimetric feeder	24,000
Mixing tank	11,700
Slurry pumps	8,200
Flush pump (diesel)	5,900
Pipe to disposal area	6,000
Filter cake surge tank and pumps	13,600
Boiler for entire plant	<u>135,000</u>
Subtotal	\$224,400

Total Plant: Installation factor: 3.5 except on trucks

Plant CostCase 6a

Asphalt alternative:

Total equipment cost	\$1,665,000
Total installed cost	\$5,436,000

Case 6b

Cement alternative:

Total equipment cost	\$1,076,700
Total installed cost	\$3,650,000

Plant Plus Disposal CostCase 6a

Asphalt alternative:

Sand and slime to landfill	
Earth cover and seeding	\$6,198,000
Earth and rock cover	\$6,200,000 ^a
Sand to mine, slime to landfill	
Earth cover and seeding	\$5,711,000
Earth cover and rock cover	\$5,712,000

Case 6b

Cement alternative:

Sand and slime to landfill	
Earth cover and seeding	\$5,259,000
Earth and rock cover	\$5,261,000 ^b
Sand to mine, slime to landfill	
Earth cover and seeding	\$4,864,000
Earth cover and rock cover	\$4,866,000

^aSee correction a) on p. 116.

^bSee correction b) on p. 116.

Corrections:

a) Case 6a, asphalt fixation

20 ft earth + 6 in. rock

$$(10 \times \$484 + \$706) 146 A = \$810,000$$

$$\text{Total } \$6,200,000 - \$810,000 = \$5,390,000$$

b) Case 6b, cement fixation

Sealing concrete area

$$(\$3267 \times 1.25 + \$484)(113 A + 10 A) = \$562,000$$

$$(\$3267 + \$484)(113 A + 10 A) = \underline{\$461,000}$$

$$\text{Net increase} = \$101,000$$

20 ft earth + 6 in. rock

$$(10 \times \$484 + \$706) 113 A = \$627,000$$

$$\text{Total} = \$5,261,000 + \$101,000 - \$627,000 = \$4,735,000$$

II. Operating Cost Summary

<u>Item</u>	<u>Annual Cost</u>
Common Items:	
Supervision	\$ 15,000
Operating labor	156,000
Lime	220,000
Power	37,000
Steam	490,000
Maintenance	<u>85,000</u>
Subtotal	\$1,003,000

Case 6a

Asphalt Alternative:

Asphalt	\$3,358,000
Power	6,300
Steam	272,000
Maintenance	<u>77,000</u>
Subtotal	\$3,713,000
Trucking to landfill - sand and slimes to landfill	93,000
- when sand going to mine	49,000

Case 6b

Cement Alternative:

Cement	\$ 447,000
Maintenance	<u>21,000</u>
Subtotal	\$ 468,000
Power - sand and slimes to landfill	3,700
- when sand going to mine	4,800
Trucking to landfill	51,000

Case 6a

Asphalt

Sand and slimes to landfill

Common items	\$1,003,000
Asphalt items	3,713,000
Trucking	<u>93,000</u>
	\$4,809,000

Most of sand to mine

Common items	1,003,000
Asphalt items	3,713,000
Trucking	<u>49,000</u>
	\$4,765,000

Case 6b

Cement

Sand and slime to landfill

Common items	\$1,003,000
Cement items	468,000
Power	3,700
Trucking	<u>51,000</u>
	\$1,525,700

Most of sand to mine

Common items	\$1,003,000
Cement items	468,000
Power	4,800
Trucking	<u>Nil</u>
	\$1,475,800

Cost Summary for Case 6c - Nitric Leach at Wyoming and New MexicoI. Capital Cost

<u>Item</u>	<u>Equipment Cost</u>
Leach tanks	\$ 270,000
C.C.D. thickeners and pumps	1,992,000
Evaporator	2,246,000
Distillation	1,051,000
Nitric acid surge tank	11,300
Water surge tank	25,000
Solvent extraction	516,000
Product evaporator	121,000
Calciner	400,000
Condenser - scrubber	42,000
Mix tank	1,700
Storage before mix tank	3,500
Boiler	<u>348,000</u>
Subtotal	\$7,027,500
Asphalt alternative:	
Asphalt unloading	\$ 3,400
Asphalt storage and pumps	<u>27,000</u>
Subtotal	\$ 30,000
Cement alternative:	
Cement unloading	\$ 20,000
Cement storage and feeder	<u>16,600</u>
Subtotal	\$ 36,000

Total Plant: Installation factor 3.5

Asphalt alternative

Total equipment cost	\$ 7,058,000
Total installed cost	\$24,703,000

Cement alternative

Total equipment cost	\$ 7,064,000
Total installed cost	\$24,724,000

Corrections:

Rehabilitation

2 ft earth + 6 in. rock
 (\$484 + \$106) 116 A = \$138,000

20 ft earth + 6 in. rock
 (10 x \$484 + \$706) 6 A = \$33,000

Total = \$171,000

II. Operating Cost

<u>Item</u>	<u>Annual Cost</u>
Supervision	\$ 15,000
Operating labour	252,000
Nitric acid	73,000
Flocculant	88,000
TBP	537,000
Kerosene	91,000
Natural gas	79,000
Steam	135,000
Power	42,000
Maintenance	<u>703,000</u>
Subtotal	\$2,015,000

Asphalt alternative:

Asphalt	\$ 248,000
Maintenance	<u>3,000</u>
Subtotal	\$ 251,000

Cement alternative:

Cement	\$ 128,000
Maintenance	<u>3,700</u>
Subtotal	\$ 131,700

Total Annual Operating Cost

Asphalt alternative	\$2,266,000
Cement alternative	\$2,146,700

Cost Summary for Case 6c - Sulfuric Leach at Wyoming and New Mexico

I. Capital Cost

Conventional sulfuric acid leach flowsheet with 8 18-ft-diameter by 18-ft-high mechanically agitated leach vessels, 5 100-ft-diameter CCD thickeners, solvent extraction, precipitation, drying and packaging. Equivalent equipment was costed in the same manner as for Case 6c - nitric leach and to the same degree of detail to maintain comparability.

<u>Item</u>	<u>Equipment Cost</u>
Leach tanks with agitators	\$ 132,000
C.C.D. thickeners and pumps	790,000
Solvent extraction and precipitation	341,000
Drying and packaging	<u>56,000</u>
Total equipment cost	\$1,319,000
Installation factor - 3.5	
Total installed cost	\$4,617,000

II. Operating Cost

Consumption of chemicals according to the Terms of Reference.

<u>Item</u>	<u>Annual Cost</u>
Supervision	\$ 15,000
Operating labor	168,000
Materials	
Sulfuric acid	722,700
Ammonia	53,700
Sodium chlorate	197,200
Flocculant	87,600
Amine	16,400
Alcohol	13,200
Kerosene	27,600

Power	\$ 33,500
Maintenance	<u>131,800</u>
Total	\$1,466,700

Disposal of leach tailings is excluded in order to maintain comparability with Case 6c - nitric leach.

A3.2 Derivation of Capital Costs for Liquid and Solid Waste Treatment

Data from "Environmental Report August 1971 and November 1971"

A. Rio Algom - Moab, Utah

Mining rate - 750 tpd

Total air volume - 250,000 cfm or 80,000 per mining panel

Dam Construction - Initial

- (a) All top soil was removed from the area and then a core trench was excavated to either bed rock or to highly impervious silty sand at the center of the valley. The trench was excavated to a depth of 8 ft into the subsoil to the clay formation; at the abutments into the rock 6 to 8 ft. This core trench was then backfilled with selected clay material and compacted to a high density. The dam was then raised with natural soils using a clay core 10 to 20 ft wide - all well compacted. Coarse sands were placed on the downstream side. At start of milling, tailings will be discharged against the upstream face of the dam through spigot hoses. When the bank reaches the top of the initial dam, the main dam will be raised using local sand and gravel.

Final height of dam - 65 ft

Min. freeboard - 10 ft

Downstream slope - 2-1/2 to 1; upstream 2:1

Evaporation rate - 55 in. per year

No effluent discharge

Solution

<u>Summary</u> - Mill discharge	100 gpm
Evaporation	35 gpm
Recycled water	80 gpm
Fresh water make-up to balance.	

Monitor well lower in valley; if necessary, a cut-off trench for seepage. All mill discharge must flow to tailings.

Evaporation - Est. 9 acres required for evaporation of the 41 gpm of tailings solution separated from the settled tailings.

Ventilation

1. Crusher plant and conveyor transfer design - discharge through roofs - 13,000 cfm and 7,500 cfm.
Air exhausted will be filtered in a cloth bag filter and discharge will contain less than 0.03 grain of dust per ft³ of air.

Air changes in building - 20 per hour.
2. Concentrator Building
Yellow cake barrel loading enclosed, 1 in. draft provided by exhaust from drying furnace.
Venturi scrubber and centrifugal eliminator - discharged by stack to 20 ft above mill roof.
Volume - 1000 cfm at high velocity at 170°F.
Air changes in Concentrator Building - 4 to 5 per hour

Labor - Rio Algom, Moab (Projected)

	<u>Staff</u>	<u>Hourly Rated</u>
1972	20	100
Maximum	33	126

Detailed Work Force

	<u>Day Shift</u>	<u>Afternoon Shift</u>	<u>Night Shift</u>
Conc. Supt.	1		
Metallurgist	1		
Conc. Foreman	1	1	1
Crusher operator	1	1	
Conc. operators	3	3	3
Conc. helper	1	1	1
Lab. Tech.	2		
Clerk	1		
Mechanics	2	1	1
Electricians	<u>1</u>	<u> </u>	<u> </u>
	14	7	6

Emergency Sumps

No spillage of ore or solution from mill building possible.

Filter sump - 100,000-gal capacity - grinding and filter

SDU sump - 90,000-gal capacity

ADU sump - 6,000-gal capacity

Buildings

1. Warehouse, machine shops, changehouse, and mine offices -
142 ft x 73 ft x 25 ft
2. Main office - 77 ft x 30 ft, single story with basement
3. Assay office and laboratory - 80 ft x 30 ft, single story

General Data (1971)Water Supply

Requirement - 80 gpm

Pipeline from Colorado River est. as alternative to well water

Pipeline (size not stated), 35 miles at \$5/ft	\$924,000
1 pumphouse and 2 booster stations	175,000
Transmission lines	<u>125,000</u>
	\$1,224,000

This cost est. 6-1/2 times present installation.

Rehabilitation of the Tailings Area

- (a) Provide sufficient soil depth to give radiation readings at the surface of the soil below 170 millirem per year continuous exposure (recommended by the National Commission on Radiation Protection).
- (b) Seeding the area.
- (c) Using some method of preventing rodents from bringing tailings to surface.

Estimated Costs: (45-acre area)

1. Preparation of tailings area	\$ 5,500
2. Soil cover: 145,000 cu yd at \$0.50	72,500
3. Seeding: 45 acres at \$400	<u>18,000</u>
Total	\$96,000

Radioactivity

Radium is dissolved in the tailings solution to the extent of about 0.1% of the ore grade.

Seepage Through and Under Tailings Dam

Production - 4,000 lb/day U_3O_8

Assume soluble loss = 0.2% = 8 lb/day

Also assume 50 gpm total solution to tailings and 5 gpm seepage.

Seepage contains $5/50 \times 8 = 0.8$ lb U_3O_8 /day

$0.8 \times 0.85 \times 454 = 309$ grams U/day

$\times 0.333 = 103 \mu\text{Ci/day } U_{\text{nat}}$

B. Highland Uranium Mill - Humble - Exxon Converse County, Wyoming

"Environmental Report, July 1971"

2000 T.P.D. of 0.2% U_3O_8 ore

Leaching 50% solids; 95°F; 40 lb/ton H_2SO_4 ;
1 lb/ton $NaClO_3$; 8 hours agitation

C.C.D. 5 stages
8-in. diaphragm pumps; counterflow of
solution and advance of solids by centrifugal
pumps

Clarification Sand clarifiers

Solvent Extraction

4 extraction stages using mixer-settler units, 20 ft x 65 ft
settlers

4 stripping units use 10 ft x 65 ft settlers

Precipitation (NH_3)

2 - 6 ft x 8 ft agitated tanks

34 ft thickener

20 ft thickener

18 in. x 42 in. continuous solid bowl centrifuge

Dryer - 8-1/2 ft x 6-ft hearth roaster - 600°F

Roaster gas to wet dust collector, fan-powered - capacity

2,730 cfm of dryer gas at 800°F and 1,000 cfm of other air.

Because of cooling the discharge, volume is reduced to 2,244

cfm. Dried yellow cake pulverized using a single impactor

hammer mill and stored in a 320-cu-ft hopper.

Floor Sumps

Leaching Area - 15,000 gallon, but floor can contain 100,000
gallons before any spillage outside, i.e., = volume of 2
leach tanks + 30,000 to spare.

C.C.D. Pump House Floor - can contain 325,000 gallons.

Tailings Disposal - Tailings will deposit at an average slope of 1% above water and 15% below water.

A 5-ft minimum freeboard height will be maintained at the initial height. The pond area is about 125 acres and the volume afforded by this freeboard is 625 acre-feet. The drainage area above the dam is about 640 acres, but cutoff dams around the pond area will intercept and divert most of the runoff water.

Evaporation rate for area - estimated - 4.2 ft/year.

Water entering basin, estimated = 400 gpm

Entrained water, estimated = 70 gpm

Seepage loss, estimated = 100 gpm

Net amount of water that must evaporate = 230 gpm

Rehabilitation of the Tailings Area

When operations cease, Humble will cover the tailings pond with soil and replant with grasses. The soil cover thickness will be the greater of the amount required: (1) to reduce the radiation accumulative dose for an individual in 24-hour residence above the dam to less than 170 millirem, or (2) to allow the perennial growth of natural vegetation.

It is anticipated that 1 to 2 feet of soil and barren sandstone will accomplish both objectives.

Process Dust Control

- (1) Crushers - 2 dust collectors with combined capacity of 22,000 cfm of air; rated to discharge less than 50 lb of dust per hour - 0.2% U_3O_8 content. Dust loading will be less than 0.26 grain of dust per cubic foot of air.

(2) Yellow Cake Area

Discharge will contain less than 0.005 grain of solids per cubic foot of air in 2,244-cfm discharge. The dust will be 85% U_3O_8 .

Process Vapours

- (1) Leaching - tanks vented.
- (2) Solvent extraction building ventilators will produce exhaust gas at 27,000 cfm for 6 air changes per hour. Vaporized organic reagents are the principal contaminant.

C. Utah International

"Supplement to Environmental Reports," June 1972.

Tailings Dam

The dam was built to AEC specifications from compacted earth-fill material with an impervious clay keyway. The bottom of the tailings basin was also sealed with a compacted clay blanket to control seepage.

A minimum of 3 ft of freeboard will be maintained. Area of the pond and tailings at the final water elevation will be 232 acres.

Stabilization and Reclamation

A cover of 18 to 20 inches of waste material will be used to cover the tailings. The area and the dam will be seeded with native grasses.

Estimated cost of providing cover for the tailings and establishing vegetation is as follows:

$$\text{Minimum cover} = \frac{2 \text{ ft} \times 43,560}{27} = 3,227 \text{ cubic yards per acre}$$

3,227 cu yd at \$0.15 (established for scrapers with short haul) = \$484 per acre

Preparation and seeding cost = \$30 per acre

Estimated total per acre = \$514 per acre

For final tailings area of 232 acres, total cost is estimated at \$120,000.

Tailings area is now protected by an animal-tight fence, and this must be maintained after operations cease. Also radiation monitoring must be continued.

D. Mine Tailings Reclamation Program

Approximate schedule

June 1 - 3 tons/acre feed grade limestone applied and disced in.

July 10 - 2 tons/acre agricultural limestone (400 lbs/acre)
5-20-20 fertilizer. Ground harrowed.

July 22 - 300 lbs/acre 5-20-20 fertilizer

1-1/2 bu/acre fall rye

12-1/2 lbs/acre Canada bluegrass

12-1/2 lbs/acre mixed seed

1 part Timothy

2 parts Redtop

1 part Kentucky Blue

1 part Crested wheat

1 part Creeping red fescue

10 lbs/acre Brome grass

Annual Maintenance

100 lbs/acre urea per year

200 lbs/acre 5-20-20 fertilizer

E. "The Hydraulic Construction of Mine Tailings Dams"

Construction Materials

(1) Natural earth - 20¢ to \$1.42/cu yd in place on the dam

(2) Tailings material - 15¢ to 70¢/cu yd in place on the dam

<u>Costs Assumed</u>	<u>Per yd³</u>
(a) Earth (scraping and short haul)	\$0.15
(b) Dam building (i) without clay core	0.74
(ii) with clay core	0.90 for both earth and clay
(c) Rock covering	0.675
(d) Excavating for clay soil trench	0.24

CASE 1 - WYOMING
SOLVENT EXTRACTION MILL

2000 tons/day ore

2000 x 1.5 = 3,000 tons/day solution

Area = 174 acres

Assume square - dam length = 2,753 ft

Average depth of solids, assuming wedge shape = 32 ft

Dam height, allowing 5 ft freeboard = 69 ft

Starter dam, native material, 10 ft high x 2753 ft long x 10 ft
across crest; Slope 2:1

Volume of starter dam = $\frac{10 \times 30 \times 2753}{27} = 30,600 \text{ yd}^3$

Volume of 6-in. soil cover = 140,000 yd³

1. Tailings Pump

Assume tailings dam base at same elevation as tailings pump
and distance = 3000 ft.

Discharge of tailings to be by spigot against the upstream
bank of dam.

Pump and pipeline to be designed for ultimate dam height
of 69 ft.

Tailings comprises:

2000 T.P.D. (No. 5 thickener underflow) at 60% solids =

$$\frac{33.75 \times 2000 \times 7.48}{1440} = 350 \text{ gpm}$$

Waste liquor = 500 gpm

Total flow = 850 gpm

% solids = 31.6

Head:

Vertical lift - ultimate = 69 ft

Assume friction loss = 90 ft (including pressure drop in
spigotting)

2 - 8-in. x 6-in. SRL-C pumps in series, 40-hp motors
 Pipeline - 8-in., Velocity = 5.43 fps

Estimated Cost

2 - 8-in. x 6-in. SRL-C pumps and drives	\$ 5,200
2 - 40-hp, 1760-rpm motors and controls	2,460
1 - 14-ft x 14-ft pump suction tank	2,530
5800 ft 8-in.-diam Class 150, ABS pipe at (288.51/100 x 1.07)	17,900
500 ft - 2-in. spigotting hose and valving	1,000
Rubber lining pump suction tank, 772 ft ² at 3.50	2,700
Total, Excluding Pipe	\$13,890

Installation (not including tailings pipe) =

$$2.5 \times 13,890 = \$34,725$$

Trestle for tailings pipe

Assume average height of 10 ft to dam

Posts (8 in. x 8 in. x 10 ft) x 2 x 3000/8 = 40,000 BD ft

Stringers - top (2 in. x 6 in./12 x 3000 ft) x 2 = 6000 BD ft

Cross members - (2 x 6/12 x 6) x 4 x 3000/8 = 9000 BD ft

Bracing = $\frac{1 \times 6}{12} \times 40 \times \frac{3000}{8} = 7,500$ BD ft

Pipe support = $\frac{2 \times 4}{12} \times 6 \times \frac{3000}{8} = 1500$ BD ft

Total - 64,000 BD ft

Spigotting Pipe Support - Assume a similar structure to above

Allow 130,000 BD ft at \$150/1000 = \$19,500

Labour - assumed 50% 9,750

Total estimated installed cost \$29,250
 (5800 ft)

Summary of Tailings Pumping Installed - Capital Costs

Pumps - 2 - 8-in. x 6-in. SRL-C	\$ 5,200
Motors - 2 - 40-hp, 1,750-rpm	2,460
Pump suction tank, 14-ft x 14-ft, rubber-lined	5,230
Tailings pipe, 3000 ft, 8 in. ABS	17,900
Spigotting hose and valving	1,000
Tailings and spigotting line trestles	29,250
Installation	<u>34,725</u>
Total Estimated Cost	\$95,765

2. Removal of Top Soil for Eventual Use in Rehabilitation

Assume 6 in. average depth.

$$\text{Volume} = \frac{174 \times 43,560 \times 0.5}{27} = 140,500 \text{ cu yd}$$

$$\text{Cost at } \$0.15/\text{cu yd} = \$21,075$$

Tailings Dam Construction

Length of dam = 2,753 ft

Height of dam = 69 ft (eventual)
= 10 ft (initial)

- (1) Removal of top soil to bedrock or impervious silty sand from the area under the starter dam. Estimating an average depth of 2 ft (additional to 6 in. of top soil already removed), the volume to be removed = $\frac{2753 \times 50 \times 2}{27} = 10,200 \text{ cu yd}$

$$\text{Estimated cost} = 10,200 \times \$0.15 = \$1,530$$

- (2) Initial Dam - Native Material

Volume of dam - 30,600 cu yd

$$\text{Estimated laid-down cost for native material} = 30,600 \times 0.75 = \$22,950$$

$$\text{Compacting cost, estimated } 30,600 \times \$0.15 = \$4,590$$

Total estimated cost for dam construction = \$29,070.

- (3) Diversion dams - est. 25,000 cu yd to be moved.
 25,000 cu yds at \$0.15 = \$3,750

Rehabilitation of Tailings Area

Preparation of Surface

With an acid circuit and no neutralization of tailings during operation, it will be necessary to lime the surface as a first step in reclamation. Based on practice, 5 tons of agricultural limestone per acre is disced into the tailings well in advance of seeding. The following are approximate costs for liming and seeding.

Limestone, 5 tons per acre at \$7	\$ 35
Fertilizer, 700 lbs per acre at \$10/cwt	70
Seed, rye or oats, 1-1/2 bu per acre	5
35 lbs grass seed at \$3	<u>105</u>
Total estimated cost of supplies	\$215/acre

Estimated labour cost:

4 men - 2 months = \$10,000

Per acre = $10,000/174 = \$58$

Rental of equipment (see below), est. $\frac{30 \times 40}{174} = \7

Total estimated cost per acre = \$280

Soil cover per acre = $\frac{0.5 \times 43,560}{27} = 807 \text{ cu yd}$

807 cu yd at \$0.15 (scraper with short haul) \$121

Total est. cost per acre \$401

Total cost for 174 acres = $174 \times 401 = \$69,774$

Including riprapping dam slope = \$77,046

Summary List of Equipment as Used by Inco

1. Farm disc
2. Farm harrow
3. Massey-Ferguson Model 26A, 13 run seed drill
4. Alvan Blanch seeder
5. Lely fertilizer spreader
6. Farm tractor
7. Cultipacker

Rental, estimated = \$30/day for 2-month period

Maintaining Vegetationa-1 Water

Assume a water requirement of 2 in. per month =

$$\frac{43,560 \times 174 \times 2}{30 \times 1440 \times 12} = 29 \text{ cfm}$$

Design for 100 cfm (750 USGPM), so as to be able to do all watering on day shift. Distribution of this water will require four 4-in. header pipes running the length of the area and 2-in. cross hoses at 200-ft intervals from the headers. The piping requirement will be about as follows:

8-in. delivery pipe - assume from mill area, using tailings pipeline

4-in. pipe - $4 \times 2750 + 2 \times 2100 = 15,200 \text{ ft}$

2-in. pipe - $28 \times 2300 = 64,400 \text{ ft}$

Use 4-in. ABS header pipes with insert tees.

Cost:

4-in. ABS Class 80 (\$68.21 x 1.07) per 100 ft = \$73.00

4-in. tee	<u>11.70</u>
	\$84.70

$152 \times 84.70 = \$12,900$

2-in. polyethylene hose (\$54.51 x 1.07) per 100 ft = \$58.40

$644 \times 58.40 = \$37,600$

Alternative to 4, Case 1, Wyoming, Solvent Extraction

Cover with coarse rock, 6-in. layer - $140,400 \text{ yd}^3 = 190,000 \text{ tons}$

Total est. cost = $\$706 \times 174 = \$123,000$

See Case 1, alkaline, Wyoming, for derivation.

a-2 Pump for Irrigation

Capacity - 900 US gpm against an estimated 100 ft T.D.H.

$$2670 \times 1.07 = \$2860$$

a-3 Assume 3000 ft 8-in. ABS pipe

$$\$288.51 \times 1.07 \times 30 = \$9270$$

Total estimated installation costs for pipe (10% of cost) = \$6000

Miscellaneous spray nozzles, valves, etc. = \$6370

Total cost for water distribution piping

$$12,900 + 37,600 + 9270 + 2860 + 6000 + 6370 = \$75,000$$

Preliminary Summary Case 1 - Wyoming

Removal of top soil	\$21,075
Tailings pumps and pipeline	95,765
Tailings dam construction - initial	29,070
Rehabilitation of tailings area	77,046
Maintaining vegetation (spray pipes)	75,000
Raising dam with tailings (see addendum)	70,500/yr
Diversion dams	3,750

ADDENDUM

Calculation of cost for building dam from initial 10 ft to final 69 ft.

Ultimate volume of dam = $[(20 \times 69) + (69 \times 2 \times 69)] \times 2753/27 =$

$$1,112,000 \text{ cu yd}$$

Volume of coarse fraction of tailings required = $1,112,000 - 30,600 =$

$$1,081,400 \text{ cu yd} = \frac{1,081,400 \times 27 \times 120}{2,000} = 1,750,000 \text{ tons.}$$

Assuming 60% sand recovery, the tons of tailings that must be cycloned to build the dam = $1,750,000/0.60 = 2,910,000$.

Based on 20 years' operation, 145,500 tons of tailings will be required per year. Therefore, the tailings dam will be raised each summer over a 5-month period, operating 12 hours per day.

Equipment required:

2 - 20-in. hydrocyclones mounted on a carriage with flexible rubber hose connection to the tailings line (est. replacement every 5 years) - $\$10,000 \times 4 = \$40,000$
 $\therefore$ per year = $40,000/20 = 2,000$

Estimated labour required per year:

4-1/2 men for 12 months = $\$12,000 \times 45 = \$54,000$
 Supplies, est. 20% of labor = 10,800
 Total estimated cost per year = 66,800

Maintenance After Rehabilitation:

Yearly fertilizer - $\$30/\text{acre} \times 174 = \$5220/\text{year}$
 Total = $\$51,010/\text{year}$

Re-rehabilitation of Dam Embankment

$$\text{Area} = [\sqrt{69^2 + 138^2} + 20] \frac{2753}{43,560} = 10.3 \text{ acres}$$

Estimated cost for covering surface with 6-in. coarse rock =

$$\$706 \times 10.3 = \$7272$$

Estimated cost for covering total area + embankment with 6-in. coarse rock = $\$706 \times 184.3 = \$130,000$

CASE 1 - NEW MEXICO
SOLVENT EXTRACTION MILL

2000 tons/day ore

3000 tons/day solution

Area = 116 acres

Assume square - dam length = 2248 ft

Height of dam - 100 ft

Initial dam - native material = 25,000 cu yds

Volume of 6-in. soil cover for rehabilitation = 93,600 cu yd

1. Tailings Pump and Pipeline

Average flow = 850 USGPM; design 900 USGPM

Vertical lift (ultimate) = 100 ft

Friction loss = 90 ft (as in Case 1, Wyoming)

Total dynamic head = 190 ft

Use 2 - 8 in. x 6 in. SRL-C pumps - H.P. = $29 \times 1.24 = 36$

Use 40-hp motors as before.

Tailings pumps and pipeline installed cost - Same as Case 1 -
Wyoming = \$95,765

2. Removing Top Soil From Area

Volume = $\frac{116 \times 43,560 \times 0.5}{27} = 93,750$ cu yd

Cost at \$0.15/cu yd = \$14,100

3. Tailings Dam Construction

(1) Removal of top soil from the area under the starter dam, again assuming an average depth of 2 ft.

Volume to be removed = $\frac{2248 \times 50 \times 2}{27} = 8326$ cu yd

Estimated cost = $8326 \times \$0.15 = \1235

Additional to 6-in. topsoil already removed.

(2) Initial dam construction

Volume of dam = 25,000 cu yd

Estimated delivered cost for native material = $25,000 \times 0.75 =$
 $\$18,750$

Compacting (bulldozer) est., $25,000 \times 0.15 = \$3,750$

Total Est. Cost for Dam Construction = \$23,735

4. Building Dam to Ultimate 100-ft Height Using Hydrocyclones

Volume of completed dam = $(40 \times 100 + 100 \times 200) \times \frac{2248}{27} = 2,000,000$ cu yd

Volume of coarse fraction of tailing required = $2,000,000 - 25,000 =$
 $1,975,000$ cu yd

$$= \frac{1,975,000 \times 27 \times 120}{2,000} = 3,200,000 \text{ tons}$$

Assuming 60% sand recovery, the tons of tailings that must be cycloned to build the dam = $3,200,000 / 0.60 = 5,330,000$

Tons tailings to be cycloned per year = $5,330,000 / 20 = 266,500$

If the cyclones are operated 12 hours per day, 8 months per year will be required for building the dam.

Equipment required - as in Case 1, Wyoming = \$40,000

Estimated labour required per year

3 men for 8 months = $4500 \times 8 = \$36,000$

Equipment cost = $40,000 / 20 =$ 2,000
 $\$38,000$

5. Rehabilitation of the Tailings Area

(a) Preparation of surface, soil cover, and seeding - ref. Case 1, Wyoming

Total cost for 116 acres = $\$394 \times 116 = \$45,700$

Total cost including riprapping dam slope $(45,700 + 9602) =$
 $\$55,302$

(b) Maintaining vegetation (water distribution piping) factor directly on area = $116 / 174 \times 75,000 = \$50,000$

Preliminary Summary - Case 1 Solvent Extraction - New Mexico

Removing top soil from area	\$14,100
Tailings pumps and pipeline	95,765
Tailings dam construction - initial	23,735
Raising dam with tailings to ultimate level	38,000
Rehabilitation of tailings area	45,700
Maintaining vegetation (spray pipes)	50,000

Rehabilitation of Dam Embankment

$$\text{Area} = [\sqrt{100^2 + 200^2} + 40] \frac{2,248}{43,560} = 13.6 \text{ acres}$$

$$\begin{aligned} \text{Estimated cost for covering surface with 6-in. coarse rock} &= 706 \times 13.6 \\ &= \$9602 \end{aligned}$$

CASE 1 - WYOMING OR NEW MEXICOALKALINE

2000 tons per day ore

2000 x 1.05 = 2100 tons per day solution

Area = 116 acres

Length of dam = 2248 ft

Height = 100 ft

Initial dam - native material = 24,200 cu yd

Volume of 6-in. soil cover for rehabilitation

$$\frac{116 \times 43,560 \times 0.5}{27} = 93,600 \text{ cu yd}$$

1. Tailings Pump and Pipeline

2000 T.P.D. at 60% solids 350 USGPM

Waste liquor (2100 tons/6) 350 USGPM

Total flow 700 USGPM

$$\% \text{ solids} = \frac{2000 \times 100}{(1333 + 2000 + 2100)} = 36.8$$

Head - vertical lift (ultimate) - 100 ft

Friction loss - 90 ft

2 - 8 in. x 6 in. SRL-C pumps in series, 40-hp motors

Pipeline - 8-in. velocity, 45 fps

Tailings pumping installed capital costs - same as for solvent extraction less rubber lining of pump

Suction tank (\$2700) = 95,765 - 2700 = \$93,065

2. Removing top soil from area - same as for New Mexico solvent extraction - \$14,100

3. Tailings Dam Construction

Length of dam = 2248 ft

Height of dam = 100 ft

10 ft initial

- (1) Removal of top soil under initial dam

$$\text{Volume} = \frac{2248 \times 50 \times 2}{27} = 8326 \text{ cu yds}$$

$$\text{Est. cost} = 8326 \times \$0.15 = \$1249$$

- (2) Initial dam

$$\text{Volume} = 25,000 \text{ cu yds}$$

$$\text{Est. cost for native material} = 25,000 \times 0.75 = \$18,750$$

$$\text{Compacting cost} = 25,000 \times 0.15 = \$3750$$

$$\text{Total estimated cost for dam construction} = \$22,500$$

- (3) Building Dam to Ultimate Height with Tailings

$$\text{Ultimate volume of dam} = (40 \times 100 + 100 \times 200) \times \frac{2248}{27} = 2,000,000 \text{ cu yd}$$

$$\begin{aligned} \text{Volume of coarse fraction of tailings required} &= 2,000,000 - 25,000 \\ &= 1,975,000 \text{ cu yd} \end{aligned}$$

$$= \frac{1,975,000 \times 27 \times 120}{2000} = 3,200,000 \text{ tons}$$

$$\begin{aligned} \text{Assuming 60\% sand recovery, the tons of tailings that must be} \\ \text{cycloned} &= \frac{3,200,000}{0.60} = 5,330,000 \end{aligned}$$

$$\text{Tons tailings required per year} = \frac{5,330,000}{20} = 266,500$$

The cyclones will operate 12 hours per day, 8 months per year.

Equipment: as in Case 1 - solvent extraction \$40,000

4. Rehabilitation of the Tailings Area

Preparation of Surface:

With an alkaline circuit, liming will not be required. Costs are revised as follows:

Fertilizer, 700 lb per acre at \$10/cwt	\$ 70
Seed	110
Labour - 3 men, 2 months = \$9000	
Per acre = 9000/116 =	78
Total estimated cost/acre	258

Soil cover (0.5 ft)/acre	\$121
Total est. cost/acre	379
Total cost for 116 acres = 116×379	= \$40,000
Plus riprapping cost of \$9602	= \$53,602
Water distribution piping	
Factor directly on area = $116/174 \times 75,000$	\$50,000

Alternative to No. 4, Case 1, Alkaline, Wyoming

Cover with coarse rock, 6-in. layer: 93,600 cu yd = 126,500 tons.

It is assumed that the rock would be quarried, crushed in the crushing plant, transported by truck, and distributed on the frozen tailings. Assuming that satisfactory shale or other easily broken rock is located near the site, the estimated cost for supplying the rock to the crushing plant is \$0.109 per ton. Operating the crushing plant will cost \$0.15 per ton and hauling and spreading an estimated \$0.20 per ton.

Estimated cost per ton = \$0.459

Estimated cost for 126,500 tons = $126,500 \times \$0.459$ = \$58,000

The above estimate assumes that the area is accessible by truck at its ultimate height.

Equipment required for handling rock:

1 mobile drill	\$31,000
1 mobile compressor	31,000
1 load, haul, dump unit	<u>40,000</u>
	\$102,000

This equipment as well as the trucks could probably be rented. It would probably take 4 or 5 months to complete the project.

Estimated rental of equipment - \$200/day or 200×120 = \$24,000 for the project.

Total estimated cost = \$58,000 + 24,000 = \$82,000 or \$706 per acre.

Summary Case 1, Alkaline, Wyoming
(Based on rock-facing area)

Tailings pump and pipeline	\$93,065
Tailings dam construction - initial	22,500
Rehabilitation of tailings area	82,000

CASES 2 AND 3^a - WYOMING
ALKALINE MILL

Area = 119 acres

Length of dam = 2275 ft

Height of dam = 99 ft

1. Tailings pump and pipeline - Same as Case 1

2. Removal all top soil (estimated 2 ft) from impoundment area, and retain for final cover.

Area = 119 x 43,560 sq ft.

Volume of top soil to be removed = $\frac{119 \times 43,560 \times 2}{27} = 384,000$ cu yd

Cost = 384,000 x 0.15 = \$57,600

3. Tailings Dam Construction

(1) Excavate core trench into bed rock or impervious soil.

Estimate average depth of 10 ft and width of 10 ft for key; continue width to 10 ft to the top of dam. It is assumed that portable batter boards will be used to contain the clay before compaction. Native material will be piled against the clay core face.

Excavation for clay core = $\frac{8 \times 10 \times 2275}{27} = 6720$ cu yd

Estimated cost at \$0.24/cu yd = \$1613

(2) Estimated Cost Placing and Compacting Clay

(83,417 + 8400) cu yd x 0.90 = \$82,635

(3) Estimated Cost Placing and Compacting Native Material

(coarser material on the downstream face to provide drainage)

1,735,100 cu yd x 0.90 = \$1,561,590

^aSee Summary, p. 91.

- (4) Riprapping downstream and upstream slopes (2:1 slopes)
with 6-in. rock cover

$$\text{Volume required} = \frac{2 \times 221 \times 2275 \times 0.5}{27} = 18,600 \text{ cu yd}$$

$$\text{Estimated cost at } \$0.875/\text{cu yd} = 18,600 \times 0.875 = \$16,275$$

CASES 2 AND 3 - WYOMING - ALKALINE
ADDITIONAL COST

Well-sited pond - allow for surveying and core drilling.

- (a) Area survey to locate a suitable pond site and the desirable location
for the dam - assumed \$1000
- (b) Drilling to rock or impervious earth material at 10-ft intervals
along the length of the dam.

Assume 250 holes, 3-ft average depth - 750 ft

Estimated cost at \$10/ft \$7500

Total cost estimate \$8500

4. Rehabilitation of the Tailings Area

- (a) Preparation of surface - cost per acre = \$258
Total cost for 119 acres = $119 \times 258 = \$30,700$
- (b) Soil cover, 2 ft, volume = 384,000 cu yd
Estimated cost of reclaiming and spreading =
 $384,000 \times \$0.15 = \$57,600$
- (c) Water distribution piping = $119/174 \times 75,000 = \$51,200$

CASES 2 AND 3^a - NEW MEXICO - ALKALINE

Area = 116 acres

1. Tailings pump and pipeline \$93,065
2. Tailings dam construction
 - (a) Remove 2 ft top soil from area and retain for final cover

$$\text{Volume} = \frac{116 \times 43,560 \times 2}{27} = 374,300 \text{ cu yd}$$

$$\text{Cost} = 374,300 \times \$0.15 = \$56,145$$
 - (b) Clay core trench excavation

$$8300 \text{ cu yd} \times \$0.24 = \$1990$$
 - (c) Estimated cost placing and compacting clay

$$83,300 + 8300 \times \$0.90 = \$82,440$$
 - (d) Estimated cost placing and compacting native material

$$1,748,400 \text{ cu yd} \times \$0.90 = \$1,573,560$$
 - (e) Riprapping downstream and upstream slopes with 6-in. rock cover

$$\text{Volume required} = 18,600 \text{ cu yd}$$

$$\text{Estimated cost at } \$0.875/\text{cu yd} = \$16,275$$

Total dam construction cost = \$1,674,265
3. Rehabilitation of the Tailings Area
 - (a) Preparation of surface = $116 \times \$258 = \$29,928$
 - (b) Soil cover, 2 ft = $374,300 \times \$0.15 = \$56,145$
 - (c) Water distribution piping = $116/174 \times 75,000 = \$50,000$
 - (d) Diversion dams = \$3,750

^aSee Summary, p. 92.

CASES 2 AND 3^a - WYOMING
SOLVENT EXTRACTION

Area = 189 acres

Height of dam = 65 ft; length = 2872 ft

1. Tailings pump and pipeline \$95,765

2. Remove 2 ft topsoil from entire area and retain for final cover

$$\frac{189 \times 43,560 \times 2}{27} = 609,840 \text{ cu yd}$$

$$\text{Cost} = 609,840 \times \$0.15 = \text{\$91,476}$$

3. Tailings Dam Construction

(1) Excavate core trench as in Case 2, Wyoming, Alkaline

$$\frac{8 \times 10 \times 2872}{27} = 8,510 \text{ cu yd}$$

$$\text{Estimated cost at } \$0.24/\text{cu yd} = \$2042$$

(2) Placing and compacting clay

$$\frac{10 \times 65 \times 2872}{27} + 10,637 = 78,778 \text{ cu yd}$$

$$\text{Estimated cost} = 79,778 \times 0.90 = \$71,800$$

(3) Estimated cost of placing and compacting native materials

$$968,000 \times 0.90 = \$871,200$$

(4) Riprapping downstream and upstream slopes with 6-in. rock cover

$$\text{Volume required} = \frac{2 \times 145 \times 2872 \times 0.5}{27} = 15,424 \text{ cu yd}$$

$$\text{Estimated cost at } \$706/\text{acre or } \$0.875/\text{cu yd} = 15,424 \times 0.875 = \text{\$13,496}$$

$$\text{Total tailings dam construction} = \$958,538$$

^aSee Summary, p. 93.

4. Rehabilitation of the tailings area

(a) Preparation of surface

Ref. revised estimated cost per acre, not including soil cover
= \$280; total cost = $\$280 \times 189 = \$52,920$

(b) Soil cover

609,840 cu yd at \$0.15 = \$91,476

(c) Water distribution piping = $189/174 \times 75,000 = \$81,500$

CASES 2 AND 3^a - NEW MEXICO - SOLVENT EXTRACTION

Area = 116 acres

Dam length = 2248 ft

Dam height = 100 ft

1. Tailings pump and pipeline	\$95,765
2. Remove 2 ft topsoil from area and retain for final cover =
374,300 cu yd
Cost = 374,300 x \$0.15 =	\$56,145
3. Tailings dam construction
Same as Case 2, New Mexico, Alkaline	\$1,674,265
4. Rehabilitation of the tailings area	
(a) Preparation of surface - 116 x 280	\$32,480
(b) Soil cover - 2 ft (as 2 above)	56,145
(c) Water distribution piping	50,000
(d) Diversion dams	3,750

^aSee Summary, p. 94.

CASES 4a, 4b AND 7 - WYOMING - ALKALINEA. Copperas Treatment

- (a) Copperas feed tank - 2000 gal., wood, agitated
 Use 8-ft-diam x 8-ft tank
 Approx. cost 8-ft x 8-ft agitator, 10-hp motor \$3500
- (b) Metering pump, 1 gpm \$926
 Pump through a loop line with a bleed to the
 tailings pump box
 Installed cost = $4426 \times 3.5 =$ \$15,491

B. Tailings Pond

Area = 121 acres

Height of dam = 97 ft; length = 2298 ft

1. Tailings pump and pipeline installed \$93,065

2. Remove 2 ft topsoil from area and retain for
 final cover

$$\text{Cost} = \frac{121 \times 43,560 \times 2}{27} \times \$0.15 = \$58,564$$

3. Tailings dam construction

- (1) Excavate core trench

$$\text{Cost} = \frac{8 \times 10 \times 2298}{27} \times \$0.24 = \$1634$$

- (2) Placing and compacting clay

$$\text{Volume} = \frac{10 \times 97 \times 2298}{27} + \frac{10 \times 10 \times 2298}{27} = 91,069 \text{ cu yd}$$

$$\text{Est. cost} = 91,069 \times \$0.90 = \$81,962$$

- (3) Placing and compacting native material (using 3:1
 upstream, slope; 2:1 downstream)

$$\text{Volume} = 2,084,541 \text{ cu yd}$$

$$\text{Cost} = 2,084,541 \times \$0.90 = \$1,876,087$$

(4) Riprapping downstream slope with 6-in. rock cover

$$\text{Volume required} = \frac{217 \times 2298 \times 0.5}{27} = 9,234 \text{ cu yd}$$

$$\text{Cost} = \$706/\text{acre or } \$0.875/\text{cu yd}$$

$$\text{Total cost} = 9234 \times 0.875 = \$8,080$$

$$\text{Total tailings dam construction} = \$1,967,763$$

4. Sealing tailings area with asphalt

$$\text{Average height of sides} = 48\text{-}1/2 \text{ ft}$$

Assume sidewalls are sloped 3 to 1.

$$\text{Area of sides to be sealed} = \frac{2 \times 153.5 \times 2298}{43,560} \text{ acres} = 16.2 \text{ acres}$$

$$\text{Area of dam to be sealed} = \frac{307 \times 2298}{43,560} = 16.2 \text{ acres}$$

$$\text{Area of bottom of pond} = 12.1 \text{ acres}$$

$$\text{Total area to be sealed} = 153.4 \text{ acres}$$

$$\text{Amount of sealant (1/4 in. thick)} = \frac{2 \times 153.4 \times 43,560 \times 62\#/ft^3}{12 \times 2000 \times 8}$$

$$= 4315.5 \text{ tons}$$

Procedure - ref. Inspiration Consol. Copper Company
Ox-Hide Mine
April 10, 1969

(1) Apply a stabilizing prime coat (SP-1) at the rate of 1/2 gallon per square yard. A water sprinkling truck was used to dampen the surface and was followed by the asphalt distributor truck. The prime coat was allowed 48 hours to cure.

(2) Apply 1-1/4 gallons per square yard "Cat-Blown" asphalt.

Note: In our case 1/4-in. asphalt and 2-ft dirt is specified.

$$\text{Cost for installed asphalt} = 48.5\phi \text{ per sq yd.}$$

$$\text{Cost for installed asphalt } \$.50 \text{ in } 1966 = 50 \times 1.35 = \$.675 \text{ per square yard at } 1/4\text{-in. thickness.}$$

$$(a) \text{ Cost installed} = \frac{153.4 \times 43,560}{9} \times \$0.675 = \$501,158$$

Note: This is a 1/4-in. coating as recommended by Anaconda as an economic maximum "Leach Dump Operations in Butte, Montana," by Geo. W. Parker, April 1966.

$$(b) \text{ Dirt cover, 2 ft} = \frac{153.4 \times 43,560 \times 2}{27} = 494,971 \text{ cu yd}$$

$$\text{Cost} = 494,971 \times \$0.15 = \$74,246$$

5. Rehabilitation of tailings area

$$(a) \text{ Soil cover, 20 ft}$$

$$3,904,300 \text{ cu yd at } \$0.15 = \$585,645$$

(b) Asphalt and dirt cover

$$\text{Cost of asphalt installed} = \frac{121 \times 43,560}{9} \times 0.675 = \$395,307$$

$$\text{Cost of 2-ft dirt} = 390,400 \text{ cu yd}$$

$$390,400 \times \$0.15 = \$58,560$$

(c) Preparation of surface and seeding

$$121 \times \$258 = \$31,218$$

(d) Water distribution piping

$$121/174 \times \$75,000 = \$52,100$$

$$(e) \text{ Diversion dams} = \$3,750$$

(f) Alternative to (c) 6-in. rock cover

$$121 \times \$706 = \$85,426$$

CASES 4a, 4b, AND 7 - NEW MEXICO - ALKALINEA. Copperas Treatment

Same as Case 4a, Wyoming, Alkaline \$15,491

B. Tailings Pond

Area = 116 acres; height of dam = 100 ft; length = 2248 ft

1. Tailings pump and pipeline \$93,065

2. Remove 2 ft of topsoil and retain for final cover
Cost - $374,000 \times \$0.15 =$ \$56,145

3. Tailings dam construction

(1) Excavate core trench

Cost = $\frac{8 \times 10 \times 2248}{27} \times \$0.24 =$ \$1,598

(2) Placing and compacting clay

Volume = $\frac{10 \times 100 \times 2248}{27} + \frac{10 \times 10 \times 2248}{27} = 91,575$ cu yd

Cost = $91,575 \times \$0.90 =$ \$82,417

(3) Placing and compacting native material (3:1 upstream;
2:1 downstream)

Volume = 2,248,000 cu yd

Cost = $2,248,000 \times \$0.90 =$ \$2,023,200

(4) Riprapping downstream slope with 6-in. rock cover

Volume required = $\frac{224 \times 2248 \times 0.5}{27} = 9324$ cu yd

Cost = $9324 \times \$0.875 =$ \$8159

Total tailings dam construction = \$2,115,374

4. Sealing tailings area with asphalt

Average height of sidewalls - 50 ft

Assume sidewalls are sloped 3:1

Area of sides to be sealed = $\frac{2 \times 158 \times 2248}{43,560} = 16.3$ acres

$$\text{Area of dam to be sealed} = \frac{316 \times 2248}{43,560} = 16.3 \text{ acres}$$

$$\text{Area of bottom of pond} = 116 \text{ acres}$$

$$\text{Total area to be sealed} = 148.6 \text{ acres}$$

$$\text{Amount of sealant (2 in. thick)} = \frac{2 \times 148.6 \times 43,560 \times 62}{12 \times 2,000}$$

$$= 33,444 \text{ tons}$$

$$(a) \text{ Asphalt cost installed} = \frac{148.6 \times 43,560}{9} \times \$0.675 = \$485,476$$

$$(b) \text{ Dirt cover - 2 ft} = \frac{148.6 \times 43,560 \times 2 \times \$0.15}{27} = \$71,922$$

5. Rehabilitation of tailings area

(a) Soil cover, 20 ft

$$3,742,900 \text{ cu yd at } \$0.15 = \$561,435$$

(b) Asphalt and dirt cover

$$\text{Cost of asphalt applied} = \frac{116 \times 43,560 \times \$0.675}{9} = \$378,972$$

$$\text{Cost of 2-ft dirt} = 374,300 \times \$0.15 = \$56,145$$

$$(c) \text{ Preparation of surface and seeding} - 116 \times \$258 = \$29,928$$

$$6. \text{ Water distribution piping} = 116/174 \times \$5,000 = \$50,000$$

$$7. \text{ Diversion dams} = \$3,750$$

$$5(d). \text{ Alternative to (c) - 6-in. rock cover} = 116 \times \$706 = \$81,896$$

CASES 4a, 4b, AND 7 - WYOMING
SOLVENT EXTRACTION

A. Neutralization

Lime requirement based on 100% reactivity = $34.4 \text{ T Ca(OH)}_2/\text{day}$
= approx. $2/3 \times 34.4 = 22.9 \text{ T CaO/day}$

Assuming 90% reactivity = $22.9/0.9 = 25.4 \text{ CaO/day}$

Requirement for 7 days supply = 177.8

Assuming 25% deadload storage capacity required = $177.8/0.75$
= 237 tons CaO

Cost estimates, ref. Case 6a

(a) Pneumatic lime unloader	\$20,000
(b) Lime storage silo, 20 ft x 30 ft	\$20,000
(c) Gravimetric feeder (0-2 T/h)	\$ 6,040

- (d) 3 wood-stave agitator tanks to give 2 hours retention time

Feed to neutralization

2000 T/day solids at 60% solids

3000 T/day raffinate

31.6% solids

Tank volume required = $\frac{81.75 \times 2000}{12} = 13,625 \text{ cu ft}$

or 3 tanks each of 4,542 cu ft

Use 3 - 18-ft x 20-ft wood-stave tanks with air and mechanical agitation at \$11,925

\$35,775

(e) Ball mill belt feeder	\$ 1,000
(f) Ball mill, 4 ft x 6 ft, 40-hp motor	\$25,000
(g) 2 x 2 SRL pump, pump box and piping	\$ 850

Note: Est. USGPM at 20% solids in slurry =

$0.80 \times 25.4 = 20.3 \text{ (consumption)}$

(h) 12-ft x 12-ft lime storage agitator, 15 hp	\$ 6,090
(i) 2 - 2 x 2 SRL pumps	\$ 1,300
(j) pH control equipment	\$ 8,000
(k) Compressor (50 hp)	\$ 5,000

Total neutralization equipment cost =	\$129,055
Total installed cost = \$129,055 x 3.5 =	\$451,692

Air Requirement for Neutralization

Agitation

A 30-ft-diam dorr agitator requires 300 cfm.

An 18-ft-diam agitator will require $18^2/30^2 \times 300 = 108$ cfm.

The 3 agitators will require 324 cfm.

Total compressor capacity required = 400 cfm.

Cost - 400 cfm, 40-psi compressor

Ref. 541 cfm at 100 psi incl. 125-hp motor - \$10,852

Assume 50 hp for 30-40 psi air

$(50/125)^{0.8} \times 10.852 \times 400/541 = \$4,630$ \$5,000

B. Tailings Pond

Area = 193 acres; dam height = 63 ft; length = 2900 ft.

1. Tailings pump and pipeline \$95,765

2. Remove 2 ft of topsoil and retain for final cover
Cost = 62,300 cu yd at \$0.15 = \$93,450

3. Tailings dam construction

(1) Excavate core trench

Cost = $\frac{8 \times 10 \times 2900 \times \$0.24}{27} =$ \$2062

(2) Placing and compacting clay

Volume = $\frac{10 \times 63 \times 2900}{27} + \frac{10 \times 10 \times 2900}{27} = 78,406$ cu yd

Cost = 78,406 x 0.90 = \$70,565

(3) Placing and compacting native material (3:1 upstream;
2:1 downstream)

Volume = 1,201,030 cu yd

Cost = 1,201,030 x 0.90 = \$1,080,927

(4) Riprapping downstream slope with 6-in. rock cover

$$\text{Volume required} = \frac{199 \times 2900 \times 0.5}{27} = 10,687 \text{ cu yd}$$

$$\text{Cost} = 10,687 \times 0.875 = \$9,351$$

$$\text{Total tailings dam construction} = \$1,162,905$$

4. Sealing Tailings Area with Asphalt

Ave. height of sides = 31.5 ft; assume 3:1 slope.

$$\text{Area of sides to be sealed} = \frac{2 \times 99.6 \times 2900}{43,560} = 13.3 \text{ acres}$$

Area of dam upstream face = 13.3 acres

Area of bottom of pond = 193.0 acres

Total area to be sealed = 219.6 acres

$$\text{Amount of sealant (1/4-in. thick)} = \frac{0.25 \times 219.6 \times 43,560 \times 62}{12 \times 2000}$$

$$= 6177.9 \text{ tons}$$

$$(a) \text{ Cost of asphalt installed} = \frac{219.6 \times 43,560}{9} \times \$0.675$$

$$= \$717,433$$

$$(b) \text{ Dirt cover} = \frac{219.6 \times 43,560 \times 2}{27} \times \$0.15 = \$53,143 \times 2$$

$$= \$106,286$$

$$\therefore \text{cost of asphalt and dirt cover} = \$823,719$$

5. Rehabilitation of Tailings Area

(a) Soil cover - 20 ft

$$6,227,000 \text{ cu yd at } \$0.15 = \$934,050$$

(b) Asphalt and dirt cover

$$\text{Cost of asphalt installed} = \frac{193 \times 43,560}{9} \times 0.675 = \$630,531$$

$$\text{Cost of 2-ft dirt, } 623,000 \text{ cu yd} \times \$0.15 = \$93,450$$

$$(c) \text{ Preparation of surface and seeding} = 193 \times \$258 = \$49,794$$

$$(d) \text{ Water distribution piping} = 193/174 \times 75,000 = \$83,200$$

(e) Diversion dams =	\$3750
(f) Alternative to (c) - 6-in. rock cover =	
193 x \$706 =	\$136,258

CASES 4a, 4b, AND 7 - NEW MEXICOSOLVENT EXTRACTIONCapital CostsA. Neutralization

Same as Case 4a, Wyoming, Solvent Extraction \$451,692

B. Tailings Pond

Area = 116 acres; dam height = 100 ft; length = 2248 ft.

1. Tailings pump and pipeline \$95,765

2. Remove 2 ft of topsoil and retain for final cover
Cost = 374,300 cu yd at \$0.15 = \$56,145

3. Tailings dam construction

(1) Excavate core trench = $\frac{8 \times 10 \times 2248 \times \$0.24}{27}$ = \$1599

(2) Placing and compacting clay

Vol. = $\frac{10 \times 100 \times 2248}{27} + \frac{10 \times 10 \times 2248}{27}$ = 91,585 cu yd

Cost = 91,585 x 0.90 = \$82,426

(3) Placing and compacting native material (3:1 upstream,
2:1 downstream)

Vol. = 2,248,000 cu yd

Cost = 2,248,000 x \$0.90 = \$2,023,000

(4) Riprapping downstream slope with 6-in. rock cover

Volume required (ref. p. 29) = 9,324 cu yd

Cost = 9,324 x 0.875 = \$8159

Total cost tailings dam construction \$2,115,384

4. Sealing Tailings Area with Asphalt

Average height of sidewalls = 50 ft

Assume side walls are sloped 3:1

Area of sides to be sealed = 16.3 acres

Area of dam to be sealed = 16.3 acres

Area of bottom of pond = 116.0 acres

Total area to be sealed = 148.6 acres

(a) Asphalt cost installed = \$485,476

(b) Dirt cover (2 ft) = \$ 71,922

5. Rehabilitation of Tailings Area

Total cost = \$1,026,480

6. Water Distribution Piping = \$50,000

7. Diversion Dams = \$3,750

CASE 5 - WYOMINGALKALINE

NOTE: In the two Case 5 alkaline installations, there is no provision for equipment cost for providing the 65% pulp density.

A. Concrete slurry to open pit mine or landfill

1. With ore S.G. = 2.7, the volume mined per day =

$$\frac{2000 \times 2000}{62.4 \times 2.7} = 23,742 \text{ cu ft}$$

∴ tons of fill at 100 lbs/cu ft required = $23,742/20 = 1187$

As fill could probably not be used during the mining cycle in an open pit mine, landfill disposal is selected. Reference is made to the sand backfill plant, the flowsheet for which is as follows:

Fill delivered underground at 68% solids (actually 63%).

Landfill area required - assume piling 50 ft high.

$$\text{Area required for 20 years} = \frac{2000 \times 7300 \times 20}{50 \times 43,560} = 134 \text{ acres}$$

$$\text{Evaporation rate required} = \frac{35 \times 2000 \times 31.5 \times 32}{45 \times 134 \times 43,560} = 2.15 \text{ ft/year}$$

Evaporation will keep solution level low.

2. Equipment for Handling Cement and Slurry

Equipment will permit discharging tailings on two shifts per day.

(a) Pneumatic cement unloader \$20,000

(b) Cement storage silo, 30-ft diam x 26-ft hopper bottom,
700-ton capacity.

Price ref. August 10, 1973

35-ft diam x 41 ft is \$60,267.

Factor directly on area of plate:

$$\frac{\pi \times 30 \times 26 + \pi \times 15^2}{\pi \times 35 \times 41 + \pi \times 47.5^2} \times 60,267 = \$34,774$$

(c) Gravimetric feeder

(d) Fine ore storage bins - 32-ft diam x 36 ft with 60°
conical bottom = \$22,400

Factor directly on area of plate:

$$\frac{\pi \times 17 \times 28 + \pi \times 8.5 \times 16.4}{\pi \times 32 \times 36 + \pi \times 16 \times 32} \times 22,400 = \$8,284$$

Rubber lining est. at \$4/sq ft = 1933 x 4 = \$7,732

Total est. cost each tank = \$16,016

(e) 5 x 4 SRL-C pump with 30-hp motor = \$2,810

(f) Mixing tank, 14 ft x 14 ft with 40-hp motor

Quotation 10 x 10 ft H.D. agitator (Denver) = \$4,400

Factor on plate area

$$\frac{\pi \times 14^2 + \pi \times 49}{\pi \times 10^2 + \pi \times 25} \times 4400 = \$8,624$$

Rubber lining, 770 sq ft at \$4 =	\$3,080
Total cost of mixing tank	\$11,704
(g) Water flush pump (diesel-powered)	\$5,856
Price ref. 1956 Can. Fairbanks-Morse 5-in.	
1000-USGPM pump at 175 psi = \$6,343	
Escalate at 60% = 6343 x 1.6 = \$10,149	
Factor on size for 400-USGPM pump:	

$$\left(\frac{400}{1000}\right)^{0.6} \times 10,149 = 0.577 \times 10,149 = \$5,856$$

Total est. equipment cost for cement-slurry plant = \$113,216
 Estimated installed cost = 113,215 x 3.5 = \$396,256

Assume pumping cement slurry to landfill area on 2 shifts per day and at a density of 65% solids.

Pumping rate $0.15 \times 3000 = 450$ USGPM. Distance to dam assumed = 3000 ft; pump and pipe size based on ultimate vertical lift of 50 ft. Length of pipe to allow for distribution in landfill est. = 4000 ft (NOTE: It is assumed that the pump discharge would form a dam to impound the water for evaporation in the 134-acre area.) Use 6-inch-diameter pipe (velocity, 5.1 fps). Friction loss = $(2.7 \times 0.71 \times 1.70) \times 40 = 130$ ft. T.D.H. $130 + 50 = 180$ ft. Use two 5-in. x 4-in. SRL-C pumps with 30-hp motors. Cost of four 5-in. x 4-in. SRL-C pumps = 11,200 x 3.5 = \$39,200
 Cost of 4000 ft 6-in. ABS pipe at \$2.39 = \$9,560
 Cost of 4000 ft trestle = \$20,172
 Installation of pipe at 25% = \$2,390
 Total installed cost = \$71,322

(h) Diversion dams	\$3,750
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3. Evaporation Pond

Area = 121 acres

Dam height = 15 ft; length = 2,296 ft.

- (a) Remove 2 ft of topsoil and retain for final cover

$$\text{Cost} = 390,400 \text{ cu yd at } 0.15 = \$58,560$$

- (b) Tailings Dam Construction

- (1) Excavate core trench

$$\text{Cost} = \frac{8 \times 10 \times 2296 \times \$0.24}{27} = \$1633$$

- (2) Placing and compacting clay

$$\text{Cost} = \frac{10 \times 25 \times 2296}{27} \times 0.90 = \$19,133$$

- (3) Placing and compacting native material (3:1 upstream; 2:1 downstream)

$$60,559 \text{ cu yd at } \$0.90 = \$54,503$$

- (4) Riprapping downstream slope with 6-in. rock cover.

$$\text{Volume required} = \frac{33.5 \times 2296 \times 0.5}{27} = 1424 \text{ cu yd}$$

$$\text{Cost} = 1,424 \times 0.875 = \$1,246$$

$$\text{Total tailings dam construction} = \$76,515$$

- (c) Sealing Pond With Asphalt

Average height of sides = 7.5 ft; assume 3:1 slope.

$$\text{Area of sides to be sealed} = \frac{2 \times 23.7 \times 2296}{43,560} = 2.5 \text{ acres}$$

Area of dam upstream face = 2.5 acres

Area of bottom of pond = 121.0 acres

Total area to be sealed = 126 acres

Amount of sealant (1/4 in. thick) =

$$\frac{0.25 \times 126 \times 43,560 \times 62}{12 \times 2000} = 3,545 \text{ tons}$$

$$\text{Cost of asphalt installed} = \frac{126 \times 43,560}{9} \times \$0.675 = \$411,642$$

$$\text{Dirt cover} = 390,400 \times \$0.15 = \$58,560$$

Cost of asphalt and dirt cover = \$470,202

(d) Rehabilitation of Tailings Areas (134 + 121)

(1) Soil cover, 20 ft

8,228,000 cu yd at \$0.15 = \$1,234,200

(2) Asphalt and dirt cover

Cost of asphalt installed = $\frac{255 \times 43,560}{9} \times 0.675 =$
\$833,085

Cost of 2-ft dirt = 822,800 cu yd at \$0.15 = \$123,420

(3) Preparation of surface and seeding

255 x \$258 = \$65,790

(4) Water distribution piping

255/174 x 75,000 = \$109,914

(5) Diversion dams = \$3,750

(6) Alternative to (3) 6-in. rock cover

255 x \$706 = \$180,030

(7) Alternative to (d)(1) and (d)(2)

Assume bulldozing the solids (236,600 cu yd) into a 15-acre area with a resultant depth of solids of 10 ft.

Estimated cost of bulldozing = 0.90 per cu yd
= 236,600 x 0.90 = \$212,940

Estimated cost of soil cover (134 + 15 acres)

8228,000 x 149/255 at \$0.15 = \$721,160

Estimated cost of asphalt = $\frac{149 \times 43,560}{9} \times 0.675 =$
\$486,783

Estimated cost of dirt cover = 721,160/10 = \$72,116

Total estimated cost alternative to (d)(1) and (2)

= \$1,492,999

Then $(d)(3) = 149 \times \$258 = \$38,442$

$(d)(6) = 149 \times \$706 = \$105,194$

$(d)(4) = 149/174 \times \$75,000 = \$65,224$

$(d)(1) + (d)(2) + (d)(3) = \$1,531,441$

CASE 5 - NEW MEXICOALKALINEA. Concrete Slurry to Mine

1. (a) As grind is coarse, removal of slimes is assumed unnecessary.

Tons solids in cement slurry = $2000 + 100 = 2100$.

Tons to be pumped to mine = 1187 per day.

Tons to be pumped to landfill = 913 per day.

Total estimated installed equipment cost for cement-slurry
plant = \$396,256

(b) Pumping Concrete Slurry

- (1) Pumping to mine (2 shifts per day)

It is assumed that the mine requires backfill and will
drill 3-in. D.D. holes to receive the slurry and convey
it underground.Volume = $0.15 \times 1187 \times 3/2 = 267$ USGPM

Assume horizontal distance = 500 ft.

Use 4-in. pipeline; 5-in. x 4-in. SRL pump; 7-1/2-hp
motor

- (2) Pumping to landfill.

Landfill area required - assume piling 50 ft high

Area required for 20 years = $\frac{913 \times 7300 \times 20}{50 \times 43,560} = 61$ acresTons solution per year = $35/65 \times 1187 \times 365 = 233,284$ Volume = $0.15 \times 913 \times 3/2 = 205$ USGPMAssume horizontal distance = 4000 ft; vertical lift =
50 ft.Use 4-in. pipeline; 2 - 5-in. x 4-in. SRL-C pumps in
series; 25 hp motors

(c) Pumping costs

1 - 5-in. x 4-in. SRL-C pumps with 7-1/2-hp motors	\$2122
2 - 5-in. x 4-in. SRL-C pumps with 25-hp motors	\$4430
4500 ft 4 in. ABS pipe at \$1.50	\$6750
4500 ft trestle = \$20,172 x 4500/4000	\$22,693
Pipe installation at 25%	\$1687
Pump installation = 2.5 x \$6552	\$16,380
Total installed cost	\$54,062

(d) Diversion dams \$3750

2. Evaporation Pond

Area = 67 acres; dam height = 15 ft; length = 1708 ft

(a) Remove 2 ft of topsoil and retain for final cover

Cost - 216,200 cu yd at \$0.15 \$32,430

(b) Tailings dam construction

(1) Excavate core trench = $\frac{8 \times 10 \times 1708 \times \$0.24}{27} = \$1,215$

(2) Placing and compacting clay

Cost = $\frac{10 \times 25 \times 1708 \times 0.90}{27} = \$14,233$

(3) Placing and compacting native material (3:1 upstream; 2:1 downstream)

$(15 \times 10 + \frac{15 \times 75}{2}) \times \frac{1708}{27}$ at 0.90 = \$40,565

(4) Riprapping downstream slope with 6-in. rock cover

Cost = $\frac{33.5 \times 1708 \times 0.5}{27} \times 0.875 = \927

Total tailings dam construction = \$56,940

(c) Sealing Pond with Asphalt

Area of sides (3:1 slope) = $\frac{2 \times 23.7 \times 1708}{43,560} = 1.9$ acres

Area of dam upstream face = 1.9 acres

Area of bottom of pond = 67.0 acres

Total area to be sealed = 70.8 acres

$$\text{Cost of asphalt installed} = \frac{70.8 \times 43,560 \times \$0.675}{9} = \$231,304$$

Dirt cover = 216,200 cu yd at \$0.15 = \$32,430

Cost of asphalt and dirt cover = \$253,734

(d) Rehabilitation of tailings area (61 + 67 acres)

(1) Soil cover - 20 ft

4,130,000 cu yd at \$0.15 = \$619,520

(2) Asphalt and dirt cover

$$\text{Cost of asphalt installed} = \frac{128 \times 43,560 \times 0.675}{9} = \$418,176$$

Cost of 2-ft dirt, 413,010 at \$0.15 = \$61,952

(3) Preparation of surface and seeding

128 x \$258 = \$33,024

(4) Water distribution piping = $128/174 \times 75,000 = \$55,172$

(5) Diversion dams \$3,750

(6) Alternative to (3) = 6-in. rock cover

128 x \$706 = \$90,368

(7) Alternative to (d-1) and (d-2)

Bulldoze the solids into a 15-acre area with a resultant 10-ft depth.

Cost of bulldozing - 0.80 per cu yd with smaller initial area = $236,600 \times 0.80 = \$189,280$

Cost of 20-ft soil cover (61 + 15 acres) -
2,452,270 at 0.15 = \$367,840

Cost of asphalt seal = $\frac{76 \times 43,560}{9} \times 0.675 = \$248,292$

Cost of dirt cover = $367,840/10 = \$36,784$

Total est. cost of alternative = \$842,196

Then (d-3) = $76 \times 258 = \$19,608$

(d-6) = $76 \times 706 = \$53,656$

(d-4) = $76/174 \times 75,000 = \$32,759$

Calculation of capital costs if landfill and evaporation pond areas are consolidated.

Total combined area = $61 + 67 = 128$ acres

Revised costs will be as follows:

1. Remove 2-ft topsoil from area
 $\text{Cost} = 128/255 \times 123,420 = \$61,952$
2. Sealing pond with asphalt - extend to include bottom of total area $(3.8 + 128) + 131.8$ acres
 $\text{Cost} = 131.8/260 \times (849,420 + 123,420) = \$493,155$
3. Rehabilitation
 - (a) Soil cover - 20 ft
 $\text{Cost} = 128/255 \times 1,234,200 = \$619,520$
 - (b) Asphalt seal and dirt cover
 $\text{Cost} = 128/255 \times 956,505 = \$480,128$
 - (c) Preparation for seeding = $128 \times 258 = \$33,024$
4. Water distribution piping = $128/174 \times 75,000 = \$55,172$
5. Diversion dams = \$3,750

Alternative to 3-c:

6-in. rock cover = $706 \times 128 = \$90,368$

CASE 5 - WYOMING
SOLVENT EXTRACTION

A. Neutralization

1. Liquid Waste - 1130 tons/day
 Lime required - ref. Case 4a, Wyoming, Solvent Extraction
 $= 1130/3000 \times 34.4 = 13.0 \text{ tons Ca(OH)}_2$
 Quicklime required (90% reactivity) =
 approx. $2/3 \times 13.0/0.9 = 9.6 \text{ T.P.D.}$

2. Sand-Slime Waste - 1870 T.P.D. liquid and 2000 T.P.D. solids
 Lime required $= 1870/3000 \times 34.4 = 21.4 \text{ tons Ca(OH)}_2$
 Quicklime required (90% reactivity) =
 approx. $2/3 \times 21.4/0.9 = 15.9 \text{ T.P.D.}$
 Using quicklime, a central slaking station is indicated.

3. Equipment (See p. 157)

(a) Lime unloader	\$20,000
(b) Lime storage silo, 20 ft diam x 30 ft	20,000
(c) Gravimetric feeder	6,040
(d) 3 - 12 ft x 12 ft and 3 - 14 ft x 18 ft wood stave agitators	40,998
(e) Ball mill belt feeder	1,000
(f) 4 ft x 6 ft ball mill, 40-hp motor	25,000
(g) 2 in. x 2 in. SRL pump	850
(h) 12 ft diam x 12 ft lime storage agitator, 15 hp	6,090
(i) 2 - 2 x 2 SRL pumps	1,300
(j) pH control equipment	8,000
(k) Compressor, 50-hp motor	5,000
(l) Thickener and pumps	83,119
(m) Pipeline to evaporation pond	7,170
Total neutralization equipment	\$224,567
Installed cost (x 3.5)	\$785,985

(1) Thickener

Feed = $1130 + (85/15 \times 13) = 1204$ tons solution/day

Size on upflow velocity of 0.7 fph

Then $0.7 \times A = \frac{1204 \times 32}{24}$ and $A = 2293 \text{ ft}^2$

Whence $D = 54 \text{ ft}$

Cost of thickener factored from data, March 1973

$(54^2/40^2)^{0.6} \times 35,000 =$ \$50,295

(2) pH control equipment = \$ 8,000

(3) Thickener Overflow Pump

Tonnage $(1204 - \frac{70}{30} \times 28) = 1139 \text{ TPD} = 190 \text{ USGPM}$

Distance to pump to evaporation pond assumed = 3000 ft

Use 4-in. pipe; T.D.H. = $132 + 15 = 147 \text{ ft}$

Worthington quotation August 22, 1973

3-in. x 2-in. single-stage mild-steel solution pump with
15-hp motor = \$858

(4) Diaphragm Pump

Capacity required = 12.6 USGPM for 28 TPD at 30%

solids = 2,200

Cost - 1-in. duplex

(5) Thickener overflow pump discharge pipeline

3000 ft ABS 4-in. 150 pipe at \$1.50 \$4,500

(6) Calculation of Mixing Tanks required

(a) Liquid waste neutralization

Feed = 1204 tons solution per day

Volume required for 2 hours retention =

$$\frac{1204 \times 32}{12} = 3211 \text{ ft}^3$$

Use 3 tanks in series - 12 ft diam x 12 ft

(b) Sand-slime neutralization

$$\text{Feed} = (2000 + 47 + 28) = 2075 \text{ tons solids}$$

$$(1870 + 19 + 90) = 1979 \text{ tons solution}$$

$$\% \text{ solids} = 51.2\%$$

$$\text{Volume of pulp/2 hrs} = \frac{42.57 \times 2075}{12} = 7361 \text{ ft}^3$$

Use 3 tanks in series, 14-ft diameter x 18 ft

Neut. Mixing Tank Costs

Factor on volume from 18 ft x 20 ft wood-stave tanks - Case 4a,
Wyoming, Solvent Extraction

(a) 12 ft diameter x 12 ft

$$\left(\frac{\pi \times 36 \times 12}{\pi \times 81 \times 20} \right)^{0.6} \times \$11,925 = \$5,390 \times 3 = \$16,170$$

(b) 14 ft diameter x 18 ft

$$\left(\frac{\pi \times 49 \times 18}{\pi \times 81 \times 20} \right)^{0.6} \times \$11,925 = \$8,276 \times 3 = \$24,828$$

Total -

\$40,998

B. Cement Slurry to Landfill

From the flowsheet, and assuming that the dissolved solids are precipitated by lime, the feed to the cement slurry mixing tank will be:

Slime - 600 T.P.D.

Sand - 1400 T.P.D.

Dissolved solids - 75 T.P.D.

Lime - 35 T.P.D.

Total tons solids = 2110

Solution tons = $(1870 + 198 + 65) = 2133$

Note: The above assumes that the thickener overflow is precipitated solids. % solids = 49.7

In order to increase the density, the sand-slime separation classifier should be operated to deliver 70% solids in the rack product; the slime portion, comprising 600 tons slime in a 32% solids pulp can be thickened.

1. Calculation of Thickener for Slime Portion

Feed = 600 tons solids; 1270 tons water

Size on upflow rate of 0.7 ft/hr

$$\text{Then } 0.7A = \frac{1270 \times 32}{24}; A = 2419 \text{ ft}^2 \text{ and } D = 56 \text{ ft}$$

Combining the two thickeners - $A = 4712$ and $D = 78 \text{ ft}$.

$$\text{Factoring } (78^2/40^2)^{0.6} \times \$35,000 = \$78,050$$

Thickener Overflow Pump

Assume 50% solids in underflow

628 tons solids; 628 tons solution

Then overflow = $(1139 + 670) = 1809 \text{ T.P.D.} = 300 \text{ USGPM}$

$$(300/190)^{0.6} \times 858 = \$1131$$

Diaphragm Pump - 144 USGPM

1 - 6-in. duplex \$3,938

Thickener Overflow Pump Discharge Pipeline

3000 ft ABS-150 - 6-in. pipe at \$2.39 = \$7,170

2. Cement Slurry

(a) Feed to cement slurry mixing tank

Sand - 1400 T.P.D. at 70% solids

Lime - 35 T.P.D.

Slime - 675 T.P.D. at 50% solids

Total - 2110 T.P.D. at 62% solids

with the addition of 100 T.P.D. cement, the slurry density becomes 63% solids.

(b) Total estimated installed equipment costs \$396,256

(c) Pumping cement slurry to landfill

Assume pumping on 3 shifts per day and at 63% solids.

Pumping rate = $2210 \times 0.16 = 354$ USGPM.

Distance to landfill assumed = 3000 ft with ultimate
vertical lift of 50 ft (est. 4000 ft pipe)

Using 6-in. pipeline, friction loss = $40 \times (1.8 \times 0.71 \times 1.70) = 87$ ft

T.D.H. = $87 + 50 = 137$ ft

Use 2 - 5-in. x 4-in. SRL-C pumps in series with 15-hp
motors.

Area of landfill based on average depth of 50 ft

$$= \frac{2210 \times 20 \times 365 \times 20}{50 \times 43,560} = 148 \text{ acres}$$

Note: Duplicate pumps required since it is a 3 shift/day
operation.

Cost of 4 - 5 in. x 4 in. SRL pumps with 15-hp motors

(installed) = $8200 \times 3.5 =$ \$28,700

Cost of 4000 ft 6-in. ABS pipe at \$2.39 = \$9,560

Cost of 4000 ft trestle = \$20,172

Installation of pipe at 25% = \$2,390

Total installed cost = \$60,822

(d) Diversion dams - \$3,750

C. Evaporation Pond

Volume of water to be evaporated = 1809 T.P.D.

Area required = $\frac{1809 \times 365 \times 32}{4.0 \times 43,560} = 121$ acres

Dam height = 15 ft; length = 2296 ft.

(a) Removing 2-ft topsoil (121 acres) \$58,560

(b) Tailings dam construction \$76,515

(c) Cost of asphalt installed \$411,642

Dirt cover \$58,560

D. Rehabilitation of Tailings Areas

(1) Soil cover = $\frac{269 \times 43,560 \times 20 \times 0.15}{27} =$	\$1,301,960
(2) Asphalt and dirt cover = $269/255 \times 956,505$	\$1,009,019
(3) Preparation of surface and seeding = 269×258	<u>69,402</u>
	\$2,380,381
(4) Water distribution piping = $269/174 \times 75,000$	115,948
(5) Diversion dams	3,750
(6) Alternative to (d-1) and (d-2)	

Assume bulldozing the 338,000 cu yd solids into a 21-acre area.

Cost of bulldozing = $338,000 \times \$0.90$ \$304,200

Cost of soil cover = $\frac{(148 + 21)}{269} \times 1,301,960$ \$817,960

Cost of 1/4-in. asphalt and dirt

$\frac{169 \times 43,560 \times (0.675 + 0.15)}{9} =$ \$674,817

Total estimated cost alternative to (d-1) and (d-2) \$1,796,977

Then (d-3) = $169 \times \$258$ 43,602

Then (d-6) = $169 \times \$706$ 119,314

(d-4) = $169/174 \times 75,000$ 72,845

Total cost of alternative of (d-1) + (d-2) + (d-3) \$1,840,579

Total cost of alternative of (d-1) + (d-2) + (d-6) \$1,916,291

Calculation of capital costs if landfill and evaporation pond areas consolidated

Total combined area = $(148 + 121) = 269$ acres

Revised costs will be as follows:

1. Remove 2-in. topsoil from area
 $\text{Cost} = 269/121 \times 58,560 =$ \$130,187
2. Sealing pond with asphalt - extend to include bottom of total area
 $\text{Area to be sealed} = 5.0 + 269 = 274$ acres
 $\text{Cost} = 274/126 \times (411,642 + 58,560) =$ \$1,022,503
3. Rehabilitation
 - (a) Soil cover - 20 ft
 $\text{Cost} = 269/255 \times 1,234,200 =$ \$1,301,960
 - (b) Asphalt seal and dirt cover
 $\text{Cost} = 269/255 \times 956,505 =$ \$1,009,019
 - (c) Preparation for seeding, etc.
 $269 \times 258 =$ \$69,402
 - (d) Water distribution piping =
 $269/174 \times 75,000 =$ \$115,948
 - (e) Diversion dams = \$3,750

CASE 5 - NEW MEXICO
SOLVENT EXTRACTION

A. Neutralization

Same as Case 5, Wyoming, Solvent Extraction

Capital costs = \$785,985

B. Concrete Slurry

Same as Case 5, Wyoming, Solvent Extraction

Capital costs = \$396,256

Pumping Concrete - Slurry to Underground Bore Holes

Assume pumping on 2 shifts per day at 63% solids

Tons required by mine = 1187 T.P.D.

Volume = $0.15 \times 1187 = 178$ USGPMOn a 2-shift-per-day basis, the pumping rate will be $178 \times 3/2 =$
267 USGPMUse 4-in.-diam pipe - T.D.H. = $7.0 \times 5 = 35$ ft

Use 5 in. x 4 in. SRL-C pump with 7-1/2-hp motor.

Landfill area required = 61 acres

Pumping Underground Water to Evaporation Pond(a) Water from backfill = $37/63 \times 1187 \times 1/6 = 116.5$ USGPMIt is planned to collect this water in a sump and pump to surface
to join the thickener overflow to the evaporation pond.

Assume 1000-ft depth of mine.

Cost - 4-stage pump, 1000 hp = \$8,700

1500 ft 4-in. pipe at \$2.00 = \$3,000

Thickener Overflow Pump - allow 40 hpIncrease capacity to $300 + 116.5 = 416.5$ USGPMPrice factored = $(416.5/190)^{0.6} \times 858 =$ \$1,375

Thickener Overflow Discharge Pipeline

3000 ft ABS - 150 - 6-in. pipe at \$2.39 \$7,170

Pumping Concrete Slurry to Landfill

Area required = 61 acres

Pumping Costs - (B)

1 - 5 in. x 4 in. SRL-C pump with 7-1/2-hp motor	\$2,122
2 - 5 in. x 4 in. SRL-C pumps with 25-hp motors	4,430
4500 ft 4-in. ABS pipe at \$1.50	6,750
4500 ft trestle	22,693
4-stage solution pump	8,700
1500 ft 4-in. steel pipe at \$2.00	3,000
Pipe installation at 25%	2,437
Pump installation, 2.5 x 15,252 ft	<u>38,130</u>
Total installed cost	\$88,262

C. Evaporation Pond

Area = 107 acres; dam height = 15 ft; length = 2160 ft

- (a) Removing 2 ft topsoil
 345,000 cu yd at \$0.15 = \$51,750
- (b) Tailings Dam Construction
- (1) Excavating core trench

$$\text{Cost} = \frac{8 \times 10 \times 2160 \times \$0.24}{27} = \$1,536$$
- (2) Placing and compacting clay

$$\text{Cost} = \frac{10 \times 25 \times 2160 \times 0.90}{27} = \$18,000$$
- (3) Placing and compacting native material
 (3:1 upstream; 2:1 downstream)
 57,000 cu yd at \$0.90 = \$51,300

- (4) Riprapping downstream slope with 6-in. rock

$$\text{Cost} = \frac{33.5 \times 2160 \times 0.5}{27} \times 0.875 = \$11,173$$

$$\text{Total tailings dam construction} = \$72,009$$

- (c) Sealing Pond with Asphalt

$$\text{Area of sides} = \frac{2 \times 23.7 \times 2160}{43,560} = 2.35 \text{ acres}$$

$$\text{Area of upstream face of dam} = 2.35 \text{ acres}$$

$$\text{Area of bottom} = 107 \text{ acres}$$

$$\text{Total area to be sealed} = 111.7 \text{ acres}$$

$$\text{Cost of asphalt installed} = \frac{111.7 \times 43,560}{9} \times 0.675 = \$364,924$$

$$\text{Dirt cover} = 345,000 \times 0.15 = \$51,750$$

$$\text{Total} = \$416,674$$

- (d) Rehabilitation of Tailings Areas (61 + 107 acres)

$$(1) \text{ Soil cover} = \frac{168 \times 43,560 \times 20 \times \$0.15}{27} = \$813,120$$

$$(2) \text{ Asphalt cover} = \frac{168 \times 43,560 \times 0.675}{9} = \$548,856$$

$$\text{Dirt cover} = \frac{168 \times 43,560 \times 2 \times 0.15}{27} = \$81,312$$

$$(3) \text{ Preparation of surface and seeding} \\ 168 \times 258 = \$43,344$$

$$(4) \text{ Water distribution piping} \\ 168/174 \times 75,000 = \$72,414$$

$$(5) \text{ Diversion dams} = \$3,750$$

- (6) Alternative A to (d-1) and (d-2)

Assume bulldozing the 338,000 cu yds solid into a 21-acre area (total area = 61 + 21 = 82)

$$\text{Cost of bulldozing} = 338,000 \times \$0.90 = \$304,200$$

$$\text{Cost of soil cover} = 82/168 \times 813,120 = \$396,880$$

Cost of asphalt and dirt cover = $82/168 \times 630,168 = \$307,582$

Total cost Alternative A = \$1,008,662

Then d-3 = $82 \times 258 = \$21,156$

d-6 = $82 \times 706 = \$57,892$

d-4 = $82/174 \times 75,000 = \$35,345$

(7) Alternative to seeding 168-acre areas

6-in. rock cover

Cost = $\$706 \times 168 = \$118,608$

Calculation of capital costs if landfill and evaporation pond areas are consolidated. Total combined area = $(61 + 107 = 168 \text{ acres})$

Revised costs will be as follows:

1. Removing 2-ft topsoil from combined area
 $\text{Cost} = 168/121 \times 58,560 = \$81,306$
2. Sealing pond with asphalt - extend to include bottom of combined area
 $\text{Area to be sealed} = 5 + 168 = 173 \text{ acres}$
 $\text{Cost} = 173/126 \times (411,642 + 58,560) = \$645,595$
3. Rehabilitation
 - (a) Soil cover - 20 ft
 $\text{Cost} = 168/255 \times 1,234,200 = \$813,120$
 - (b) Asphalt seal and dirt cover
 $\text{Cost} = 168/255 \times 956,505 = \$630,168$
 - (c) Preparation for seeding, etc.
 $168 \times 258 = \$43,344$
 - (d) Water distribution piping
 $168/174 \times 75,000 = \$72,414$
 - (e) Diversion dams = \$3,750

Alternative - 6-in. rock cover in lieu of seeding
 $706 \times 168 = \$118,608$

CASE 6a - WYOMING OR NEW MEXICO - ALKALINE (ASPHALT)1. Cyclone

Feed = 2000 tons solids and 2100 tons solution/day =

$$0.23 \times 2000 = 460 \text{ USGPM at } 48.8\% \text{ solids}$$

Spigot discharge = 1000 tons solids and 500 tons solution/day =

$$0.14 \times 1000 = 140 \text{ USGPM at } 66.7\% \text{ solids}$$

Overflow = 1000 tons solids and 1600 tons solution/day =

$$0.32 \times 1000 = 320 \text{ USGPM at } 38.5\% \text{ solids}$$

Use two 15-in. cyclones approx. cost - \$1580 each

(cost reference - March 1973 Worksheets)

$$\text{Cost} = 2 \times 1580 = \$3160$$

2. Classifiers

Two - 48-in. single pitch

Cost reference Case 6a solvent extraction

$$7500 \times 2 = \$15,000$$

3. Thickener

Size on upflow rate of 0.7 ft/hr

$$\text{Then } 0.7 A = \frac{4100 \times 32}{24} \text{ and } A = 7810 \text{ sq ft, } D = 100 \text{ ft}$$

Specifications are for 6 sq ft/ton/24 hr = 6000 ft²

$$D = 88 \text{ ft}$$

Cost reference Case 6a solvent extraction - 100 ft thick - \$90,000

$$(88^2/100^2)^{0.6} \times 90,000 = \$77,220$$

4. Diaphragm Pumps

Thickener underflow = 30% solids

$$\text{USGPM} = 0.45 \times 1000 = 450$$

Price reference Case 6a solvent extraction

$$\text{Three - 8-in. simplex pumps} = \$18,172$$

5. Filter

Assume 3.0 sq ft/ton/24 hr

Area required = 3000 sq ft

Use three 8-ft 10-in.-diam x 10 disc filters

Cost reference Case 6a solvent extraction

Cost = 3 x 47,500 incl. auxiliaries = \$142,500

6. Surge Tanks (2) Woodstave

10,000-gallon capacity

Cost (ref. cost data 624.5) = $1824 \times 2 = \$3648$

Wallace and Associates

7. Evaporator (including preheater and condenser) - 1900 TPD

Ref. Case 6a SX $(1900/2230)^{0.6} \times \$435,864 = \$396,200$

8. Wiped-Film Evaporator

Slime = 1000 tons at 61% solids

Asphalt = 670 tons/day

Ref. Case 6a SX - $639/300 \times 6 = 13$ units; $13 \times \$68,826 = \$894,738$

Condenser - $(639/300)^{0.6} \times \$25,000 = \$39,250$

9. Asphalt Storage Tank - 2000 T capacity

Cost (ref. Case 6a SX) = $(2000/1400)^{0.6} \times 75,000 = \$93,000$

10. Pumps

(a) Evaporator feed surge = $(1900/6 = 317 \text{ USGPM})$

Cost ref. Case 6a SX - \$1131

(b) Condenser surge = $(2330/6 = 388 \text{ USGPM})$

$(388/300)^{0.6} \times 1131 = \1323

(c) Asphalt - approx. 110 USGPM

Cost (2) at \$1700 = \$3400

(d) Asphalt unloading pump (2) at \$1700 = \$3400

11. Instrumentation

Cost ref. Case 6a SX = \$20,000

12. Loadout Bins (2)

Cost ref. Case 6a SX = \$28,950

13. 2 - 20-ton heated body trucks at \$39,000 = \$78,000

1 - 20-ton truck at \$34,000 = \$34,000

Total equipment cost = \$1,853,092

Installed cost (1-11) - 1,712,142 x 2.5 = \$4,280,355

Installed cost = \$6,133,447

Rehabilitation, seeding, and water sprays = \$740,891

CALCULATION OF LANDFILL AREA AND COSTS (ASPHALT)

(a) With all slime and sand to landfill

Tons tailings = 2000/day

Tons asphalt = 670/day

Assuming S.G. of ore = 2.7 and asphalt = 1.0

$$\frac{2000 \times 2.7 + 670 \times 1.0}{2670} = 2.27 \text{ S.G. of mixture}$$

However, it is assumed that the asphalt would merely fill the voids and not greatly change the weight of solids per cubic foot.

∴ If we assume an average landfill height of 50 ft in a draw 2298 ft wide, then $(2000 \times 365 \times 20 \times 20) / (50 \times 43,560) = 134$ acres.

Rehabilitation cost, seeding, and provision of water

$$\text{Spray pipes} = \frac{134}{166} (803,440 + 42,828 + 71,552) = \$740,891$$

$$\text{Note: Water spray pipes} = 134/174 \times 75,000 = \$57,758$$

(b) With all of sand to underground

Tons tailings = 1000/day

Tons asphalt = 670/day

Area of landfill required = 67 acres

Rehabilitation cost, seeding, and provision of water

Spray pipes = \$370,445

Seeding = $258 \times 67 = \$17,286$

Water spray pipes = $67/174 \times 75,000 = \$28,879$

Rehabilitation = \$341,566

<u>Alternative to seeding</u>	<u>134 acres</u>	<u>67 acres</u>
6-in. rock cover		
706 x 134	\$94,604	\$47,302
Prep. seeding, etc.		
258 x 134	\$34,572	\$17,286

CASE 6b - WYOMING (ALKALINE) - WYOMING OR NEW MEXICO (CEMENT)

No change from Case 6a in the following items:

1. Cyclones	3,160
2. Classifiers	15,000
3. Thickener	77,220
4. Diaphragm pumps	18,172
5. Filters	142,500
6. Surge tanks (2)	3,648
7. Evaporator	396,200
8. Pumps (a) and (b)	<u>2,454</u>
	658,354

(a) Concrete slurry plant

- (1) Pneumatic cement unloader \$20,000
- (2) Cement storage silo - 7 days = 350 tons
 1 tank same as used on p. 164 provides capacity of 685 tons
 and cost \$34,774.
 Factor on capacity = $(350/685)^{0.6} \times 34,774 = \$23,298$

- (3) Gravimetric feeder \$6,040
- (4) Mixing tank - 14 ft x 14 ft - 40 hp
 Rubber lined \$11,704
- (5) Water flush pump (diesel) \$5,856
- (6) Concrete slurry disposal area

It is assumed that the concrete slurry will be pumped at 65% solids to landfill. It is also assumed that an evaporation pond will be located in a wedge-shaped draw similar to that assumed for previous cases. It is now proposed to build the 15-ft-high dam for the sealed evaporation pond far enough down the draw to permit using the upper part for landfill. The sealing of the floor but not the sides of the draw would be extended beyond the evaporation pond area and under the landfill.

Equipment cost 1 to 8 + concrete slurry plant = \$725,252

Installed cost = $725,252 \times 3.5 = \$2,538,382$

In Case 4a, Wyoming, alkaline, with 97-ft height of dam, the length of dam and of the tailings disposal area = 2298 ft. Thus, the slope of the draw was $97/2298 \times 100 = 4.22\%$.

- (a) Tailings (cement slurry) tonnage to be stored = 1050 x 365 x 20 in 20 years.

Assume weight of concrete = 110 lb/ft³.

$$\therefore \text{cu ft of storage required} = \frac{1050 \times 365 \times 20 \times 2000}{110}$$

If L = length of landfill, then average depth =

$$L \times .0422/2 \text{ and } L \times 0.0211 \quad L \times 2298 = \frac{1050 \times 365 \times 20 \times 2000}{110}$$

$$= 139,363,636$$

Whence $L^2 = 2,873,900$ and $L = 1700$ ft.

$$\text{Area} = \frac{1700 \times 2298}{43,560} = 89 \text{ acres}$$

Volume of water per year to evaporation pond = $35/65 \times 1050 \times 365$ tons = 206,365.

Assuming an evaporation rate of 4.0 ft/year

$$\text{Area of pond required} = 35/65 \times 1050 \times 365 \times 32/4 \times 1/43,560 = 38 \text{ acres}$$

Total area required = 127 acres

- (b) Now if sand also is sent to landfill - It would be trucked to the same area and distributed on the concrete. This would require a larger landfill area, calculated as follows:
Assume combined sand and concrete = 105 lb/ft³

$$\therefore \text{cu ft of storage required} = \frac{2050 \times 365 \times 20 \times 2000}{105}$$

If L = length of landfill, average depth = $L \times .0422/2$

$$\text{and } L \times 0.0211 \quad L \times 2298 = \frac{2050 \times 365 \times 20 \times 2000}{105}$$

$L^2 = 5,878,749$ and $L = 2424$ ft.

$$\text{Area} = \frac{2424 \times 2298}{43,560} = 128 \text{ acres}$$

Total area (landfill + evaporation pond) = 166 acres

(7) Concrete slurry pump and pipeline

1050 tons solids/day at 65% solids = $0.15 \times 1050 = 157.5$ USGPM

Design pump rate = $157.5 \times 1.25 = \sim 200$ USGPM

Use 5 in. x 4 in. SRL-C pump; vertical lift = ~ 75 ft

Use 5-in. pipe; friction loss = $1.5 \times 0.71 \times 1.70 = 1.81$ ft/100 ft

Assume 4000 ft pipeline

TDH = $40 \times 1.81 + 75 = 147.4$ ft.

Use 2 - 5 in. x 4 in. SRL-C pumps in series = 15-hp motors

Cost of pumps (duplicate installations from a single pump box)

4 - 5 in. x 4 in. SRL-C pumps with 15-hp motors (installed)

$\$8200 \times 3.5 = \$28,700$

4000 ft 5-in. pipe (use price for 6-in. ABS) at $\$2.39 = \$9,560$

4000 ft trestle = $\$20,172$

Installation of pipe at 25% = $\$2,390$

Total installed cost = $\$60,822$

(8) Evaporation Pond

It will be necessary to build a dam 15 ft high x 2298 ft long and to seal it with asphalt. The sealing of the bottom would be extended to include the landfill area, i.e., a total of 166 acres.

(a) Removing 2-ft topsoil from area to be sealed

$$\text{Cost} = \frac{166 \times 43,560 \times 2}{27} \times \$0.15 = \$80,344$$

(b) Tailings dam construction

$$(2298/2296) \times 76,515 = \$76,576$$

(c) Cost of asphalt

Area of sides to be sealed

(1) 7.5 ft average vertical height

$$(2) \text{ Length of pool only} = \frac{43,560 \times 38}{2298} = 720 \text{ ft}$$

$$\text{At 3:1 slope, } A = \frac{23.7 \times 720 \times 2}{43,560} = 0.8 \text{ acre}$$

- (3) Upstream face of dam

$$A = \frac{47.4 \times 2298}{43,560} = 2.5 \text{ acres}$$

- (4) Bottom of complete area = 166 acres

Total area to be sealed = 169.3 acres

$$\text{Cost} = \frac{169.3 \times 43,560 \times 0.675}{9} = \$553,100$$

2-ft dirt for bottom, 535,626 cu yd at \$0.15 = \$80,344

- (d) Rehabilitation - 20-ft earth cover

$$\text{Volume} = \frac{20 \times 166 \times 43,560}{27} = 5,356,260 \text{ cu yd}$$

$$\text{Cost} = 5,356,260 \text{ at } \$0.15 = \$803,440$$

- (e) Preparation of surface and seeding

$$166 \times 258 = \$42,828$$

- (f) Water Distribution Piping

$$166/174 \times 75,000 = \$71,552$$

- (g) Diversion dams = \$3,750

- (h) Alternative to (e) - cover with 6-in. rock

$$\text{Cost} - 166 \times 706 = \$117,196$$

Additional Costs

- (a) Two 20-ton trucks at \$34,000 = \$68,000

- (b) Truck load to landfill

Est. 3000 ft x 40 ft wide

$$(1) \text{ Removal of 2 ft of topsoil } \frac{3000 \times 40 \times 2}{27} = 8889 \text{ cu yd}$$

$$(2) \text{ Ditching - est. } \frac{6 \times 4 \times 3000 \times 2}{27} = 5333 \text{ cu yd}$$

Estimated cost at \$0.90/cu yd = \$13,000

- (3) Filling with 2 ft gravel at \$0.90/cu yd =

$$\frac{3000 \times 40 \times 2}{27} \times \$0.90 = \$8000$$

Total cost = \$21,000

(b) Disposal in Underground Mine (Cement)

It is assumed that waste removal would be mainly for the purpose of providing access and haulage facilities and that ore removal only would provide space for tailings disposal.

Cu ft occupied by ore mined per day = $\frac{2000 \times 2000}{62.4 \times 2.7} = 23,742$ cu ft

Assuming a dry sand product weight of 100 lbs/ft³. The 1000 tons per day of sand can be stored underground in $(1000 \times 2000)/100 = 20,000$ cu ft.

In addition, and assuming that the concrete will weigh 110 lb/cu ft $(3742 \times 110)/2000 = 206$ tons of concrete.

Slurry (solids) can be used for mine backfill.

(a) Pumping mine backfill to underground bore holes

Distance assumed = 500 ft; % solids = 65

Assume - 2-shift disposal to underground.

Volume (65% solids) = $0.15 \times 1206 \times 3/2 = 271$ USGPM

Design volume = $271 \times 1.25 = 339$ USGPM

Pump through 5-in. pipeline, velocity = 5.7 FPS

Friction loss = $(4.2 \times 0.71 \times 1.70) \times 5 = 25$ ft

Use 5 in. x 4 in. SRL-C pump with 15-hp motor

(1) Pump cost - 5 in. x 4 in. SRL-C, 15-hp motor \$1711

(2) 500 ft 5-in. pipe at \$2.39 \$1195

(3) Sand storage tank

Required storage - minimum 8 hours - 333 tons at 70%

solids. Tank to be equipped with high-pressure sprays.

Conical bottom tank, 17 ft diam x 28 ft x (14 ft - 60° cone)

Capacity at 70% solids = 241 tons solids

Cost including rubber lining \$16,016

Factoring $(333/241)^{0.6} \times 16,016$ \$19,459

- (b) Pumping balance of cement slurry to landfill - evaporation pond
It is assumed that all the cement slurry will be diverted to underground for a period of $206/1050 \times 24 = 4.7$ hours per day. During the remainder of the day the pumping set-up will apply.

Cost including pumps and pipeline - \$60,822

Including pump to underground landfill $(2906 \times 3.5 + 60,822) =$
\$70,993

- (c) Pumping water from underground backfill

Tonnage = $35/65 \times 1243 = 670$ tons per day = $670/6 = 112$ USGPM

Pump design tonnage = $112 \times 1.25 = 140$ USGPM

Assume vertical lift = 1050 ft and H. Dist. = 3000 ft

With 4-in. pipe, friction loss = $2.6 \times 40.5 = 105$ ft

T.D.H. = 1155 ft

Installed cost - estimate supplied by Worthington, August 28, 1973 - (125 hp) = $\$9100 \times 3.5 = \$31,850$

- (d) Area of combined landfill and evaporation pond

$(844/1050 \times 89) + 38 = 109.5$ acres

- (e) Diversion dams - \$3,750

- (f) Evaporation pond

This will require a dam 15 ft high x 2298 ft, sealing of the evaporation pond sides and upstream dam face and the bottom of the combined 109.5 acres.

- (a) Removing 2-ft topsoil from area to be sealed

$$\text{Cost} = \frac{109.5 \times 43,560 \times 2 \times 0.15}{27} = \$53,000$$

- (b) Tailings dam construction = \$76,576

- (c) Cost of asphalt

Area to be sealed = $0.8 + 2.5 + 109.5 = 112.8$ acres

$$\text{Cost} = \frac{112.8 \times 43,560 \times 0.675}{9} = \$368,518$$

- (d) Covering with 2-ft dirt

$$\frac{109.5 \times 43,560 \times 2}{27} \times 0.15 = \$53,000$$

Rehabilitation

- (a) 20-ft earth cover

$$\text{Cost} = \frac{20 \times 109.5 \times 43,560}{27} \times 0.15 = \$530,000$$

- (b) Preparation of surface and seeding

$$109.5 \times 258 = \$28,300$$

- (c) Water distribution piping

$$109.5/174 \times 75,000 = \$47,200$$

- (d) Diversion dams = \$3,750

Alternative: 6-in. rock in lieu of seeding

$$706 \times 109.5 = \$77,307$$

(c) Disposal in Underground Mine (Asphalt)

In this case only the sand fraction can be used in the mine because of the necessity for maintaining permeability in the fill.

Tons of sand = 1000 per day

- (a) Pumping mine backfill to underground boreholes

(1) Sand storage (1 shift) - $\$19,459 \times 3.5 = \$68,106$

(2) Assume solids 65%; distance 500 ft

Pump cost - $1711 \times 3.5 = \$5,988$

(3) Pipe cost - $1195 \times 3.5 = \$4,182$

Loadout bin $\$14,475$

Two 20-ton heated trucks $\$78,000$

Total equipment costs (installed) - $\$170,751$

Rehabilitation, etc.

Assume 50 ft average height of landfill

Tons solids per day = 1000

Volume in 20 years = $\frac{1000 \times 2000 \times 365 \times 20}{100}$ cu ft

Area required = $\frac{1000 \times 2000 \times 365 \times 20}{50 \times 100 \times 43.560} = 67$ acres

Rehabilitation and seeding

$67/109.5 \times 558,300 = \$341,608$

Water distribution piping

$67/174 \times 75,000 = \$28,879$

Conditions and specifications:

In order to seal the landfill and eliminate seepage, the slime: cement ratio is decreased from 20:1 to 5:1. It is not considered practicable to pump a slurry of this strength over 4000 ft horizontal distance and with a 50-ft vertical lift. The average rate of flow through the 5-in. pipe (Case 6a) = 157.5 USGPM and the calculated time to travel through the pipe = 26 minutes. It is thought that the pipe would build up, especially with any delays in the flow of feed to the pumps. The alternative is to build the concrete slurry plant adjacent to the landfill. The thickener underflow would then be pumped to the filters, now located in the landfill plant.

Costs additional to Case 6b - Cement-Slime Fixation

1. Thickener underflow transfer pump
 Service - 1000 TPD at 30% solids = 450 USGPM
 Design volume = $450 \times 1.15 = 517$ USGPM
 Use 6-in. pipe; and two 8-in. x 6-in. SRL-C pumps in series, with 30-hp motors.
 Pump installed = $13,852 \times 3.5 = \$48,482$
2. Filtrate return to thickener
 1900 T.P.D. = 317 USGPM
 Design volume = $317 \times 1.15 = 365$ USGPM
 5-in. discharge pipe
 Cost of pump est. $1131 \times 3.5 = \$3958$
 Cost of 4000 ft 5-in. pipe = $4000 \times 2.39 = \$9,560$
3. Power line, 3000 ft long with Power Distribution Equipment
 Assume \$5/ft = \$15,000

Total Estimated Additional Cost = \$77,000

CASE 6a AND 6b - CAPITAL COSTS FOR SOLVENT EXTRACTION
AT WYOMING OR NEW MEXICO

A. Neutralization - lime handling

Lime unloading

GATX - Fuller-Traylor system, vacuum unloading to silo, 13 tph, \$20,000. Ref: notes of telephone call to Mr. Britton, May 3, 1973.

Case 1 - hydrated lime - 10 days (300 tons)

Storage in a 20' ϕ x 60' high silo adjacent to rail or truck off-loading. Gravimetric feeder to 5' ϕ x 5' agitated pulping vessel, pulp at 20% solids overflows to pump. Pump to 7' ϕ x 7' vessel in mill with closed loop circulation and pH control to 3 vessels in series. 15' ϕ x 25' high. Via Kent Norlantic feeders actuated by pneumatic valves controlled by pH meters.

$$\text{Case 2 - Burnt lime - 10 days} = \frac{\text{CaO}}{\text{Ca(OH)}_2} = \frac{56}{74} \times 300 \text{ t} = 227 \text{ T.}$$

$$\text{at } 60\#/ft^3 = \frac{227 \times 2000}{60} = 7566 \text{ ft}^3 = 20' \phi \times 25' \text{ high or } = 15' \phi \times 43' \text{ high}$$

Gravimetric (screw) feeder to ball mill = 1 tph CaO, 20% solids

Use 5' x 8' ball mill, 75 hp, 105 tpd CaO.

$\therefore$ 4 ft x 6 ft mill $\sim$ 48% of volume, say 40 hp should be ample.

Pump slurry maximum rate 2 tph CaO at 20% $\approx$ 8 tph water. Say 40 gpm slurry to 7' ϕ x 7' vessel in mill as for Case 1 above. Circulate lime slurry at 40 gpm also (approx. double the consumption).

Comparison of CaOH₂ vs CaO Neutralization

	<u>CaOH₂</u>	<u>CaO</u>
Pneumatic unloader	\$20,000	\$20,000
Silo	20'x60'+17'cone \$ 37,000	15'x43'x13'cone \$20,000
Feeder - vertical gravimetric	\$6,000	\$6,040
Ball mill		\$25,000
Belt feeder (for ball mill)		\$1,000
	<u>\$ 63,425</u>	<u>\$ 72,040</u>

With a consumption of 30 tpd, a saving of \$1/ton would pay back the difference in less than a year. $\therefore$ Use the CaO system.

Gravimetric feeder - ref. cost data 661.22 - June 12, 1972 \$5695

Escalate 6% = \$6040

Steel vessels

Cost data 624.5 - Denver Equipment, March 16, 1973

4' x 4' = \$265

10' x 12' = \$1700

Factor for 5x5 = $5^2/4^2 \times 265 = \$414$ Say \$425

7x7 = $7^2/4^2 \times 265 = \$812$ Say \$825

Agitators

Cost data 661.05 Denver Equipment, March 16, 1973

For 4' x 4' tank-mechanism = \$659 w/motor, 3 hp

Wood vessels - neutralization

Cost data 624.5 - Simpson Wood Products, March 1971

18' x 18' = 5397 - 510 freight = \$4887

Say that 15' x 25' is the same and escalate 12% = \$5473 Say \$5500

Ball Mill - see Case 2

Cost data 661.49 - Denver Equipment, March 15, 1973

3' x 5' = \$13,217

For 4' x 6' factor on 0.6 power of volume

$\left(\frac{4^2 \times 6}{3^2 \times 5}\right)^{.6} \times \$13,217 = \$23,130$ Say \$25,000

Pumps - lime slurry - 2 tph maximum, say 40 gpm

Cost data 661.73, Denver Equipment, August 21, 1969

1-1/2 x 1-1/4 SRL = \$525 (rated 15-70 gpm)

Escalate 24% = \$651

Power - 40 gpm waterhead 40' = 1 hp

Silo - Pl - 20' x 60' for Ca(OH)_2 or 15' x 43' for CaO

Cost data 624.5 - Denver Equipment, March 16, 1973

Steel tanks - 20' ϕ x 20' = \$6500

Cost data 624.5 - Dominion Bridge, Dec. 14, 1970

Steel tank - 24' ϕ x 24' = 5100 + 9300 erection = \$14,400

(wt 24,000 lb - total = 60¢/lb)

For 20' x 60' use $20/24 \times 60/24 \times 14,400 \times 1.18$ esc. = 35,400 + conc.

Say 37,000

For 15 x 43 use $15/24 \times 43/24 \times 14,400 \times 1.18$ = 19,000 + conc.

Say \$20,000

Instrumentation

Cost data 621.36 - Honeywell, May 4, 1973

4 point circular chart recorder \$1500

Foxboro - Dec. 21, 1971

Recording controller with pneumatic output - \$1725 x 12% escalation =

\$1932

Total instrumentation 4-8% of total plant cost

Estimate for neutralization = \$8,000

(agreed with B.R.M.)

Thickener - 8' x 100'

Cost data 624.5 - March 22, 1973

20' ϕ x 12' steel tank only \$56,500 erected

Feb. 16, 1972

90' ϕ x 14' - wood tank only \$58,995 + \$10,000 erection

Cost data 661.97 - May 24, 1973

Mechanism - 105' in carbon steel = \$34,000

March 16, 1973

Mechanism - 80' ϕ = \$24,000

For 100' ϕ x 8' tank - say \$56,000

Mechanism - say \$34,000

Total - \$90,000

Power - 5 hp

Overflow Pumps - SRL - 5 x 5

Cost data 661.73 - Allis Chalmers, Feb. 13, 1969

5 x 5 open frame \$1010

Escalate 24% = \$1300

2500 tpd solution = 416 gpm - 45' head = 8 hp Say 10 hp

Motor with drive - say \$300

Filters - 2000 ft²

Cost data 661.43 - Dorr-Oliver, March 21, 1973

Mild steel - 8'6" ϕ x 6 disc filter Complete \$35,000

133 hp

Require 20 discs - say 2 filters 8'6" x 10 disc each

Factor $(10/6)^{.6} \times \$35,000 = \$47,500 \times 2 \text{ filters} = \$95,000$

Total hp = 20 disc/6 x 133 hp = 443 hp Say 400 hp

Surge Tank - filtrate - 10,000 gal, Say 10' ϕ x 17'

Mild steel

Cost data 624.5 - Denver Equipment, March 16, 1973

10' ϕ x 12' = \$1700

16' ϕ x 16' = \$3200

Steel area - bottom and sides - 10 x 12 = 78.5 + 377 = 455 ft²

10 x 17 = 78.5 + 534 = 613 ft²

Factor by steel area = 613/455 x 1700 = \$2288

Thickener Overflow Pumps - 320 gpm

Use 3 (one space) Denver 8-in. Simplex Model E diagonal

Rated 165-330 gpm each, 5 hp

Cost data 661.73 - Denver Equipment Co., Aug. 18, 1973 - \$4885 each

3 pumps x 4885 x 1.24 esc. = \$18,172

Filter Cake Surge Tank (8 hours for cement)

43,000 gal = 5760 ft³ = 18 ϕ x 22' high Say 10 hp

(a) For asphalt case at 4 hours, say \$7,000

(b) Cost - use BRM leach vessels = \$1,925 c/w agitation

B. Sand Wash: 700 tpd +65 mesh
 2 classifiers required in series
 Denver Equipment Bull. No. C5-B4 - rake classifiers
 Denver Model C - 6'0" x 14'8" duplex
 Rated 650 tpd + 100 mesh
 Rated 900 tpd - 48 mesh
 Denver Equipment Bull. No. C5C-B10 - spiral classifier
 48 in., single pitch model, sand raking
 Capacity of 8.7 tpd rpm = 6.7 rpm = 58 tpd
 Cost Data 661.9 - Denver Equipment Co., August 21, 1969
 48-in. single pitch spiral - \$5960 + 5-hp motor
 Escalate 4 years, say 24% = \$7390 + motor, Say \$150 = \$7540
 Use \$7500 each

Pump - Overflow to mill - 2200 tpd - 367 gpm

Trucks for sand - 1400 tpd - 2 miles

Round trip - fill 2 min., run 8 min., dump 2 min. = 12 min. + 25% =
 15 min.

Operate 7 hours/shift = 3 shift/day = 54 trips = 16.7 tons/trip
 $\therefore$ require 1 - 20-ton dump truck

Trucks for slime-asphalt - 690 + 460 = 1150 tpd = 13.7 tons/trip
 Allow 1 - 20-ton dump truck

Truck for slime-cement - 690 + 35 + 18 (water of hydration) =
 743 tpd = 8.8 ton/trip

Bin for sand - say 4 hours = 233 say 250 tons

Volume at 120 lb/ft³ = $\frac{250 \times 2000}{120} = 4167 \text{ ft}^3$

Straight cylinder - 15' ϕ x 23.5 high (1)

60-in. cone for (1) = 13' high

$\therefore$ straight = 23.5 - 13/3 = 19.17 ft

Total height = 13 + 19.17 = 32.17 ft

Cost data 624.5 - Denver Equipment, March 20, 1973

20' ϕ x 20' = \$6500 steel

16 ϕ x 16/ - O'Connor Tanks, Dec. 11, 1970

24 x 24' steel tank - \$12,500 erected + foundations

For 15' ϕ x 20' straight + 13' cone - Say \$6500

Pneumatic chute gate - Say 1500 (guess)

Total - \$8,000

For 8-hour storage $(8/4)^{.6} \times \$6500 + \$1500 = \$11,354$

Evaporation of liquid waste

11,000 lb/hr steam (5.5 tph) for 510 gal/ton liquid = 88.5 tph
(impossible)

If supernate is to be discarded, then waste liquor = 87 T/T ore _
.87 x 41.67 = 36 tph (also impossibly high)

If waste solution from precipitation (10 gpt) = $\frac{10 \times 8.33}{2000}$

x 41.67 tph = 1.7 tph (too low)

Steam for asphalt - 35,000 lb/hr (17.5 tph)

for 104 gal/T ore

$\frac{104 \times 8.33 \times 41.67}{2000} = 18.06 \text{ tph} - \text{OK}$

C. Evaporation Circuit

Evaporator - 2230 tpd water = $\frac{2230 \times 2000}{24} = 186,000 \text{ lb/hr}$

Steam required - triple effect, forward feed (Perry, p. 518)

186,000/1.95 = 95,400 lb/hr

Ref. April 26, 1963, and April 24, 1963

4-stage evaporator and feed preheater - 2 SS hoods 2 rubber-lined
steel - to evaporate 55,130 lb H₂O, consume 16,700 lb steam, 28 psia
(evap:steam = 3.3)

Cost \$137,000

For steel construction say \$127,000

Factor - $(186,010/55,130)^{.6} \times 127,000 = \$272,415$

Escalate 10 years at 6% = 1.60 = \$435,864

Steam

Requires $186,000/55,100 \times 16,700$ lb steam = 56,343 lb/hr

Includes all pumps

Instruments (same letter, April 24, 1963)

\$7000 for evaporator + crystallizer

Evaporator - 1973 - Say \$12,000

D. Asphalt Fixation (Case 6a, Solvent Extraction)

(a) Asphalt unloader

Emulsified asphalt (35% water)

Say 62.4 lb/ft³

$\therefore 1 \text{ tpm} = 240 \text{ gpm} = \text{say } 300 \text{ gpm } 40 \text{ psi}$

Precipitating steam - direct acting (Chem. Eng. Mar. 24/69, p. 127)

$\text{gpm} \times \text{psi} = 12,000$

Base cost, 1968 = \$850

For cast steel - 1.55

1973 cost = $850 \times 1.55 \times 1.30 \text{ esc} = \1713

(b) Asphalt storage 3 day - 1400 ton

Volume = $(1400 \times 2000)/62.4 = 44,872 \text{ ft}^3$

= $35' \text{ } \phi \times 40' \text{ high} = 32,420 \text{ ft}^3$ ($35' \text{ } \phi \times 40' = 45,200 \text{ ft}^2$)

Area for insulation sides and top

$\pi \times 35' \times 40' + \pi 17.5^2 = 5360 \text{ ft}^2$

Cost of insulation = $4.56/\text{sq ft} \times 5360 \text{ ft}^2 = \$24,440$

Cost data 624.5 - May 1973

Cost of tank - Cost data 624.5 - December 1970

$24' \text{ } \phi \times 24' \text{ high open top, steel} = \$12,555 \text{ erected}$

Factor on steel area and escalate

$5360 \text{ ft}^2/1509 \text{ ft}^2 \times 1.15 \times \$12,555 = \$42,779$

Total insulated tank = \$67,223

Check cost data 624.5 - caustic storage tank

For 4500/2 tons 50% caustic, erected, insulated, heated

= \$72,000 x 1.12 esc = \$80,640

Use \$75,000

(c) Asphalt pump - 0-300 gpm

See asphalt unloader

(d) Wiped-film evaporator - 160°C

6 - 200-ft² units in parallel

(Blanco, Godbee, Frederick paper, 1970)

100 ft² unit = \$38,500 in 1970

50 ft² unit = \$24,800

so 0.6 power should be o.k.

$(200/110)^{.6} \times 38,500 \times 1.18 \text{ esc} = 68,826 \text{ each} \times 6 = \$413,000 \text{ for } 6$

20 hp each

Steam required for 300 tpd evaporation (25,000#/hr)

(Perry, p. 518, Table 4, single effect = .869#/lb steam)

25,000/.869 = 28,770 lb steam/hr

But atmospheric pressure say 30,000 lb/hr

(e) Condenser - 300 tpd = 25,000#/hr

Case B - condensate from evaporator -

2 x 7290 = 14,580#/hr

Condenser cost = \$10,700

Scale - $(25,000/14,580)^{.6} \text{ lb/hr} \times \$10,700 \times 1.60 \text{ esc} = \$23,694$

Say \$25,000

Water required - temp rise, say 160°F - 60°F = 100°F

$\frac{\text{BTU required}}{\text{temp rise}} = \frac{25,000\# \times 1100 \text{ BTU}}{100} = 275,000\#/\text{hr} = \frac{275,000}{60 \times 8.33}$

= 550 gpm

(f) Pumps and Instrumentation(g) Transport of asphalt-slimes $690 + 460 = 1150$ tpd

See page 202 - One 20-ton truck

Rear dump with heated body

Cost data: 661.22 - Mack trucks June 8, 1971

10 ton, 2 axle dump truck = \$20,000

Heated body = \$3,000

 $(20T/10T)^{.6} \times 23,000 \times 1.12 \text{ esc} = \$39,052$

2 required = \$78,000

Unheated $(20/10)^{.6} \times 20,000 \times 1.12 = \$33,958$ Say \$34,000Boiler - 56,000#/hr evaporator

30,000#/hr wiped-film evaporator

86,000#/hr Say 100,000#/hr

Cost data 621.1 April 1971

2 package boilers 30,000 lb/hr 300 psig saturated No. 5

diesel for \$146,000

2 stacks - \$5,000

Chem. Eng. March 24, 1969 - "Capital Cost Estimating" for mid-68

15 psig = 400 unit $\times 320$ (linear) = \$128,000 $\times 1.30 \text{ esc} = \$166,400$ 150 psig = 440 $\times 320 = \$140,000 \times 1.30 \text{ esc} = \$182,000$

Avg. = \$174,200

Surge Loadout Bin for Mixed Asphalt-SlimesSay 4 hours $1/2$ size of sands surge bin $(1/2)^{.6} \times \$6,500 = \4333

Pneumatic chute gate = \$1500

Insulation - see p.204 - asphalt storage = \$4.56/ft²Say 12' ϕ $\times$ 16' straight $\times$ 10' coneTop = $\pi \times 6^2 = 113 \text{ ft}^2$ Straight = $\pi \times 12 \times 16 = 603 \text{ ft}^2$ Cone area = $\pi r \sqrt{r^2 + h^2} + \pi \times 6 \times \sqrt{36 + 100} = 220 =$ $936 \times \$4.56 = \4268

Steam heating - say \$2,000

Total - \$12,101

For 8 hours = $(8/4)^{.6} \times (4333 + 4268 + 2000) + 1500 = \$17,571$

Boiler for cement case (no thin film evaporation)

req. 56,000#/hr = say 65,000#/hr boiler

Factor previous case

$(65/100)^{.6} \times 174,200 = \$134,482$

D. Alternate - Cement-Slimes (Case 6b - Solvent Extraction)

Cement unloader - same as lime unloader = \$20,000

Bulk density 65-85#/ft³

Storage Silo - 7 days, 245 tons - bulk density 75#/ft³

Volume = $245 \times 2000/75 = 6533 \text{ ft}^3$

Say 20 ft x 20 ft or equivalent - hopper bottomed but factor as if flat bottomed on B.R.M. worksheets on area of plate.

$\frac{\pi \times 20 \times 20 + \pi \frac{10^2}{4}}{\pi \times 35 \times 41 + \pi \frac{15^2}{4}} \times \$60,267 = \frac{1571}{5215} \times 60,267 = \$18,155$

Gravimetric feeder - as for lime = \$6040

Cement Alternative Disposal

To conform with Case 6 - BGM worksheets,

Mixing tank 14 x 14, 40 hp \$11,704

Wash flush pump (Dresd) 5,856

Slurry pumps (4), 200 gpm

5 x 5 SRL C (2 in service) 8,200

Pipe (725 tpd instead of 1050) 6,000

E. Solids Disposal - Landfill

As per ORNL notes

For sand and asphalt-slime - 146 acres (square) wedge-shaped to 100 ft high

Find slope:

$$146 \text{ acres} = 146 \times 43,560 \text{ ft}^2 = 6,359,760 \text{ ft}^2$$

$$\therefore \text{length of side} = 56.36 \times 10^3 \text{ ft} = 2520 \text{ ft}$$

$$\therefore \text{slope} = 100/2520 = 1.252 = 3.97\% \quad \text{No problem}$$

For sand and cement-slime = Find slope - 113 acres wedge to 100 ft

$$113 \text{ acres} = 113 \times 43,560 \text{ ft}^2 = 4,922,280 \text{ ft}^2$$

$$\text{Length of side} = \sqrt{4.92} \times 10^3 = 2220 \text{ ft}$$

$$\therefore \text{slope} = 100/2220 = 1 = 22.2 = 4.50\% \quad \text{No problem}$$

Pipe or hose for cement slurry

Mix and pump 2 shifts/day = $24/16 \times 100 \text{ gpm} = 150 \text{ gpm}$

Assume velocity of 4 fps (slime material only)

$$150/7.5 \times 1/4 \times 60 = 0.0833 \text{ ft}^2 = 12.0 \text{ in.}^2 = 3'9" \text{ } \phi \quad \text{Say 4-in. pipe}$$

Cost \$1.50/ft ABS (BRM worksheets)

$3000 \text{ ft} \times 1.50 = \$4,500$ x 1000 ft x 150 = 1500 for distribution over the area

Total = \$6000

Calculation of Landfill Area - Asphalt (Case 6a)

- (a) With asphalted slime + sand to landfill
 - (1) With earth cover + seeding
 - (2) With rock cover
- (b) With sand to underground and asphalted slime to landfill
 - (1) With earth cover + seeding
 - (2) With rock cover

Ref. p. 64(a) B.G.M. worksheets

Tons tailings = 2000/day

Tons slime = 600/day + 90 T/D (gypsum) = 690 T/D

Tons asphalt = 460/day

Tons sand = 1400/day

Assume landfill area same as reference = 134 acres.

Then:

- (1) Rehabilitation cost (20-ft earth cover + seeding)
 - (ref. p. 67, BGM worksheets)
 - $134/166 (803,440 + 42,828) = \$683,132$
 - Water spray pipes = \$57,758
- (2) Alternative to seeding
 - 6-in. rock cover = $\$706 \times 134 = \$94,604$
 - Tons slime 690/day + 460/day asphalt
 - Landfill area = $\frac{690 \times 365 \times 20 \times 20}{50 \times 43,560} = 46 \text{ acres}$
 - (1) Rehabilitation cost = $46/134 \times 683,132 = \$234,508$
 - Water spray pipes = $46/174 \times 75,000 = \$19,827$
 - (2) Alternative to seeding
 - 6-in. rock cover = $\$706 \times 46 = \$32,476$
 - Road to landfill - p. 68 - BGM worksheets - \$21,000

Summary - Rehabilitation + water pipes

(a) (1)	\$740,890	(b) (1)	\$254,335
(2)	\$743,164	(2)	\$255,116

Note a(1) = 683,132 + 57,758

a(2) = 683,132 - 134 x 258 + 94,608

b(1) = 234,508 + 19,827

b(2) = 234,508 - 46 x 258 + 32,476

Loadout and landfill

28,950 + 78,000 + 34,000 = \$140,950

Calculation of Landfill Area - Cement Fixation of Slime (Case 6b)

- (a) With sand and slime sent to landfill - sand by truck and 20:1 slurry by pump.
- (b) With sand and part of slime slurry sent underground; balance of slurry to landfill

Ref. p. 66 - BGM worksheets

- (a) Tons slime + cement - 725 T.P.D. at 65% solids
Area of pond required = $725/1050 \times 38 = 26$ acres

Area of landfill sand as in reference = 128 acres

Total area (landfill and evaporation pond) = 154 acres

Tailings slurry pumps - already included

- (a) Remove 2-ft topsoil from area to be sealed

Cost = $154/166 \times 80,344 = \$74,536$

- (b) Tailings dam construction = \$76,576

- (c) Asphalt sealing

Length of pool = $\frac{43,560 \times 26}{2298} = 493$ ft

At 3:1 slope - $A = \frac{23.7 \times 493 \times 2}{43,560} = 0.54$ acre

Upstream slope of dam also = 0.54 acre

Bottom of area = 154 acres

Total area to seal 155.08 acres

$$\text{Cost} = \frac{155.08 \times 43,560}{9} \times 0.675 = \$506,645$$

$$\text{2-ft dirt cover for bottom} = \frac{154 \times 43,560 \times 2}{27} \times 0.15 = \$74,536$$

Total - \$581,181

Rehabilitation

(a) 20-ft earth cover

$$\text{Cost} = 154/166 \times 803,440 = \$745,360$$

(b) Prep. of surface and seeding = $154 \times 258 = \$39,732$

(c) Water distribution piping = $154/174 \times 75,000 = \$66,379$

(d) Diversion dams = \$3750

(e) Alternative to (b) cover with 6-in. rock

$$\text{Cost} = 154 \times 706 = \$108,724$$

Additional costs

2 - 20-ton trucks at \$34,000 = \$68,000

Truck road to landfill = \$21,000

F. Disposal in Underground Mine (Cement)

Ref. p. 69 BGM

Mine capacity for backfill = 1206 T.P.D.

Hence $1400 - 1206 = 194$ tons of sand must be pumped to landfill with the concrete slurry.

Assume distance to mine boreholes - 500 ft

% solids of sand slurry = 65

(1) Pumping sand to mine - assume 2 shifts/day

$$\text{Pumping rate} = 0.15 \times 1206 \times 3/2 = 271 \text{ USGPM}$$

Design volume - ref. p. 69 BGM = 339 USGPM

Pump equipment cost as shown in reference = \$2906

Sand storage tank - \$19,459

(2) Pumping slurry to landfill

Landfill Size

Use same area as in reference, i.e., 109.5 acres for landfill + evaporation pond

Pumping cost including pump to underground =

$$(2906 \times 3.5 \times 60,822) = \$70,993$$

Pumping water from underground = $(9100 \times 3.5) = \$31,850$

Diversion dams = \$3750

Evaporation Pond

Ref. p. 70-71 BGM worksheets

(a) Remove topsoil	\$53,000
(b) Tailings dam construction	\$76,576
(c) Asphalt sealing	\$421,518
(d) Rehabilitation	
Earth cover	\$530,000
Seeding	\$28,300
Water distribution	\$47,200
Diversion dams	\$3,750
(e) Alternative - 6-in. rock in lieu of seeding	\$77,307

CASE 6c - NITRIC ACID - SOLVENT EXTRACTION
IN WYOMING OR NEW MEXICO

3 M HNO_3 at 85°C = 231 g/liter HNO_3

8 leach tanks x 30,000 gal = 240,000 gal

$\therefore$ total residence = $\frac{240,000}{460 + 120} = 413 \text{ min} = 6 \text{ hr } 53 \text{ min}$

Material Type 304L stainless steel - 15' ϕ x 23' or 17' x 17.5'

10 ccd thickeners with a 3:1 wash ratio, 50% solids

Underflow gives a theoretical wash efficiency of 99.997%

i.e., - loss = 1 part in 29,524 parts $\div 4 = 1:7000$

Material - steel, lined with rubber or epoxy

Solvent Extraction - Feed = 50 gpm; H_2O equiv. = 300 tpd
 containing 4 tpd U_3O_8 = 13.33 g/liter U_3O_8

Ref:

For extraction - 15.15 tpd U_3O_8 (1969 cost)

Purchased equipment = \$365,800

Total direct = \$847,000 (ratio = 2.32)

Factor on U_3O_8 $(4/15.15)^{.6} \times 365,800 = \$164,610$

Escalate at 24% = \$204,116

If factored in raffinate flow to .6 power,

$(50 \text{ gpm}/14.3 \text{ gpm})^{.6} \times 365,800 \times 1.24 \text{ esc.} = \$959,347$

If factored in strip liquor,

$(10,000/14,000)^{.6} \times 365,800 \times 1.24 = \$374,300$

If factored in total raffinate + strip,

$(70 \text{ gpm}/42.4)^{.6} \times 365,800 \times 1.24 = \$612,350$

If factored in raffinate + organic,

$(50 + 4/15.15 \times 33.1 \text{ gpm}/14.3 + 33.1)^{.6} \times 365,800 \times 1.24 = \$515,734$

Note: $\frac{\text{Total Direct}}{\text{Equipment}} = 2.32$

Leach Tanks - 30,000-gal, Type 347 or 304L stainless

15,000 gal digest check tank - Type 304L = \$11,600

Digestion, 15-hp agitators - Type 316SS = \$11,200/3

3,500-gal digestion tanks, w/cooling coils, 347SS = \$31,500/3

10,000-gal nitric acid tank, Type 304L = \$10,300

Based on digestion check tank - scale on volume

$(30,010/15,000)^{.8} \times \$11,600 \times 1.24 \text{ esc} = \$21,800$

Agitator - 17 ft x 17 ft 6 in. tank Say 40 hp

Scale on hp from above, use .8 power

$(40/15)^{.8} \times 11,200/3 \times 1.24 \text{ esc} = \$10,138$

Cost data 661.05 May 1973

= \$9600 with rubber covered including motor

For stainless steel wetted parts, say \$12,000

Total tank and agitator = \$33,800 each

Thickeners - 100' x 8'

For Case 6a - steel tank = \$56,000

Mechanism = \$34,000

Cost data 661.97 - Eimco - May 1973

Similar mechanisms - wetted parts stainless steel = \$82,000

Rubber covering for tank at 4.00/ft²

Tank area = $\pi \times 100 \times 8 + \pi \times 50^2 = 2513 + 7854 = 10,367 \text{ ft}^2$
 $\times \$4 = \$41,468$

Total cost = \$179,468 each

Pumps - overflow (low head) as for 6a but 5 hp = \$1500

Underflow as for 6a but 10 hp = \$18,172

Say 15 hp per thickener

Evaporator - stainless steel - feed 1100 gpm

To evaporate 6450 tpd H₂O x 650 tpd HNO₃ = 537,500 lb/hr +
 54,167 lb/hr

From Chem. Eng. March 24, 1968 - "Capital Cost Estimating"

Vertical tube unit cost = \$1200/ft²

From worksheets Case 6a

Area for 186,000#/hr = 1283 ft²

∴ 537,500 + 54,167 (treat HNO₃ as water)

= 591,667/186,000 x 1283 ft² = 4081 ft²

From Chem. Eng. unit cost = \$1200/ft² (vertical tube) single stage

Size exponent = 0.53

From Fig. 9, linear factor = 4081 at .53 = 80

∴ cost = 1200 x 80 x 1.30 esc = \$124,800 for steel

For stainless steel - pressure vessel factor = 3.67 = \$458,016

Heat exchanger factor = 4.50 + \$561,600 per stage

Use 4 stages = \$2,246,400

Another method (forced circulation - 4 stage) - take the 6a Case

Factor for size and apply s.s. factor

(591,667/186,000)^{.6} x \$435,864 x 4.50 = \$3,922,776

This looks high - Case 6a is already scaled up from 55,130#/hr.

Steam would be 591,667/181,000 x 56,343#/hr = 179,227#/hr

Distillation - 33' ∅ x 50' high given

or 2 columns - 23' ∅ x 35' high

or 4 columns - 16.5' ∅ x 25' high

or 11 columns - 10' ∅ x 15' high

Make 2 columns 23' ∅ x 35' high - Use steel tank cost and stainless steel factor 3.67 (from Chem. Eng. March 24, 1969).

23' ∅ x 35' = π x 11.5² x 35 = 14,542 ft³ = 109,000 gal

Cost Data 624.5 December 1970

24' x 24' steel open top = \$12,555

For 23' x 35' closed top, say + 50% = \$18,833

x 3.67 for stainless steel x 1.15 esc = \$79,483 each

Trays - (Chem. Eng. March 24, 1969) 16.5' ϕ 24" spacing, 8 trays
 Extrapolated - 16-ft stack height = \$20,000 base cost
 $(1.0 + 1.8 + 1.7) \times 1.30 \text{ esc} \times \$20,000 = \$117,000$ each column

Reboiler and Condenser

Reboil 25% = $.25 \times 537,500 \# \text{ H}_2\text{O/hr} = 134,375 \#/\text{hr}$
 Condense 6000 tpd = $500,000 \#/\text{hr} + 134,375 = 634,375 \#/\text{hr}$

Reboil - use two evaporators

$1250 \text{ ft}^2 + 554 \text{ ft}^2$ to evaporate = 13,102# water
 $\therefore$ we require $134,375/13,102 \times (1250 + 554) = 18,502 \text{ ft}^2$ total =
 9000 ft^2 each

From Chem. Eng. March 1969 - heat exchangers

Base cost for 9000 ft^2 = \$33,000

Assume cheapest type - factor 0.8 and escalate 30% = \$34,320

From the materials table, the tubes represent $302/450 = 78\%$ of the
 cost = \$26,770 in carbon steel $\times 4.50$ for s. steel = \$120,463 each

Condenser - 925 ft^2 for 13,100 lbs/hr

Stainless steel shell - s. steel (304L) tubes = \$11,000 in 1969.

$\therefore$ we require $634,375/13,100 \times 925 \text{ ft}^2 = 44,793 \text{ ft}^2$ total

Say \$22,400 each (for 2)

By Chem. Eng. March 1969, 9000 ft^2 cs/ss costs

$33,000 \times .80 \times 3.52 \times 1.30 \text{ esc} = \$120,806$

Factor by area $(22,400/9000)^{.6} \times \$120,806 = \$208,511$ each (1973)

HNO₃ Surge Tank - 10,000-gal, stainless steel

15,000-gal, stainless steel, 304L - condensate tank = \$11,600
 (mid-1969)

Factor on volume $(10,000/15,000)^{.6} \times \$11,600 \times 1.24 \text{ esc} = \$11,277$

Water Surge Tank - 100,000-gal - Wood = 30' ϕ $\times$ 18' high

Cost data 624.5 (October 1968)

$30' \phi \times 12' = 3,945 + 1188 \text{ erection} = 5133$

Factor on area of wood

$$\frac{\pi \times 15^2 + 30 \pi \times 18}{\pi \times 15^2 + 30 \pi \times 12} = \frac{2403.3}{1836.8} \times 5.133 = \$6716 \times 1.30 \text{ esc} = \$8730 \quad (1973)$$

or steel tank - Cost data 624.5 - O'Connor (December 1970)

24' x 24' steel tank = \$12,555 (81,400 gal)

$$(100,000/91,400)^{.6} \times \$12,555 \times 1.15 \text{ esc} = \$16,344$$

Rubber lining at \$4/ft²

$$(\pi \times 12^2 + \pi \times 24 \times 24) \times \$4 = \$9,048$$

Total - \$25,302

Product Evaporator - 20 gpm = 10,000#/hr H₂O

$$2 \text{ evaporators at } 13,100\#/hr = 76,000 + 33,800 = \$109,800$$

$$\text{Factor on capacity} = (10,000/13,100)^{.6} \times \$109,800 \times 1.30 \text{ esc} = \\ \$121,329$$

No condenser required.

Calciner - 10' ϕ x 90' s.s.kiln = indirect heated -

Not installed = \$400,000 (given by ORNL)

Condenser Scrub

Gas to be condensed and scrubbed = H₂O + HNO₃

$$= 150 \text{ H}_2\text{O} + 200 \text{ HNO}_3 = 50 \text{ gpm} = 29,166\#/hr$$

Condenser

Shell and tube - 304L s.s. condenser for 13,100#/hr

Cost - \$11,000 in 1968

$$(29,166/13,100)^{.6} \times \$11,000 \times 1.30 \text{ esc} = \$23,095$$

Scrubber - Some air will leak into the calciner.

To scrub air from condenser - say 20% by weight of the H₂O + HNO₃ =

$$5833\#/hr = \frac{5833 \times 13.5 \text{ ft}^3/\text{lb}}{60} = 1312 \text{ cfm}$$

Ventura scrubber for 125 cfm = \$2000 in 1965

$$(1312/125)^{.6} \times \$2000 \times 1.30 \text{ esc} = \$10,660$$

Condenser + scrubber + 25% for leach tank fumes = \$42,194

Mix Tank - 1000 gal - Say 6' ϕ x 6' (+1272 gal)

Make it wood and use cement which will neutralize any acid salts.

Cost data 624.5 - Wallace & Assoc., March 1971

8 x 8 wood tank - \$512.00 + 17 hours - Say \$600 x 1.14 esc = \$684

Agitator - \$1016

Total \$1700

Solids Storage Before Mix Tank - 1 day - dry solids

51 tons at s.g. 2.0 equiv. to 25 T H₂O = 400 ft³ = 8' ϕ x 8' high
(3018 gal)

Cost Data 624.5 - Denver Equip. Co. (March 20, 1973)

10' x 12' tank = \$1700 - steel

For 8 x 8 - Say \$1500 + \$500 for cone bottom + \$1000 for feeder =
\$3000

For 2 days - Say \$3500

Boiler for evaporator and still reboiler

Evaporator - steam = 179,227#/hr

Reboiler - steam (1.1#/lb H₂O, 147,812#/hr

Total 327,039#/hr

Heat to leach pulp from 60°F $\rightarrow$ 185°F = 125°F

Water + HNO₃ = 1890 + 350 + 650 = 2870 tpd

2000/24 = 240,833#/hr

Solids = $\frac{2000 \text{ tons} \times 2000 \text{ lb}}{24}$ x 25 spht = 41,667# equiv/hr

Steam required = $\frac{240,833 + 41,067}{960 \text{ Btu/lb steam}}$ x 125°F = 36,784#/hr

Total steam = 327,039 + 36,784 = 363,823#/hr

+ product evaporation and asphalt heating

Use 400,000#/hr

From 6a - 100,000# boiler - \$174,200

Chem Eng. March 24, 1969 - Uses 0.5 power for boilers

$$(400,000/110,000)^{0.6} \times \$174,200 = \$348,400$$

Asphalt Storage and Handling - mixing 1 shift/day

Consumption = 34 tpd

Say 200 tons storage

Unloading - as for 6a (2 recirculating steam) - \$3400

Storage silo - factor on 6a (insulated and heated)

$$(200/1400)^{0.6} \times \$75,000 = \$23,325$$

Feed pumps to mixer - as for 6a = \$3400

Cement Storage and Handling - Mixing 1 shift/day

Consumption - 10 tpd

Say 100 tons storage

Unloading - as for 6a = \$20,000

Storage silo - factor on 6a

$$(100/245)^{0.6} \times \$18,155 = \$10,620$$

Feeder - as for 6a - \$6,040

CASE 6c - H₂SO₄ ALTERNATIVE - CAPITAL

8 Leach tanks - 18' x 18' Wood

Cost data - 624.5 - Wallace and Associates, March 15, 1971

18' x 18' leach vessels, \$5397 + 130 hours erection

\$5397 x 1.14 esc + 130 hours x \$6 = \$6933 each

8 Agitators (leach) - 40 hp

Cost data - 661.05 - Denver Equipment - March 4, 1973

40 hp - 72' propeller rubber-covered shaft and propeller

c/w motor = \$9,600 each

Tank and agitator = \$16,533 each

5 Thickeners - 100' x 8' - Same as Case 6c nitric but wooden tanks

Cost data - 624.5 - Wallace & Associates, March 15, 1971

120' x 16' = \$83,448 + 1785 hours erection

Tank factor on area of wood

$$\frac{\pi \times 100^2}{4} + 100 \pi \times 8 = \frac{10,367}{17,342} \times 83,448 = \$49,886$$

$$+ \text{erection } \frac{10,367}{17,342} \times 1785 \text{ hours} \times \$6/\text{hr} = \$6,403$$

Total tank cost = \$56,289

Mechanism as for Case 6c nitric = \$82,000

Total thickener tank and mechanism = \$138,289 each

Power - 20 hp total thickener (as for 6c nitric)

Pumps for thickeners as for 6c - nitric = \$19,700 each

Solvent Extraction and Precipitation

KRC Notes - Nov. 28, 1972

Total direct costs, S-X and precipitation = \$912,688

Escalate from 1971 x 1.12 = \$1,022,210 Total Direct (except concrete)

Total equipment cost, $\div 3.0$ = \$340,736

Drying and Packaging

From KRC notes - as above

$148,800 \times 1.12 = \$166,656$ Total Direct (except concrete)

For equipment cost, $\div 3.0 = \$55,552$

Concrete cost $\sim 1/7$ of total direct. $\therefore$ use 3.0 instead of 3.5, which will be used later to get total installed cost.

A3.3 Derivation of Operating Cost Estimates for
Solid and Liquid Emissions from Mill

OPERATING COSTS - CASES 1 AND 2 - WYOMING AND NEW MEXICO
SOLVENT EXTRACTION AND ALKALINE MILLS

I. Operating Labour

Tailings pump and pipeline

Tailings disposal

Tailings dam construction

Estimate 1 man per shift = 21 man-shifts/week

4 men at \$12,000 = \$48,000; say \$50,000 per year

Supervision - Allow \$2,000 per year

II. Maintenance Labour and Supplies

Estimate 10% of equipment cost = $10\% \times \frac{95,765 + 40,000}{3.5} = \4000

III. Power - 80 hp

Power cost - $80 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$4,705$

Total estimated costs = \$60,705 per year.

OPERATING COSTS - CASES 4a, 4b, AND 7 - WYOMING AND NEW MEXICOALKALINEI. Operating Labour

Copperas treatment

Tailings pump and pipeline

Tailings area supervision

Estimate 1 man per shift = 21 man-shifts per week

Say \$50,000 per year

Supervision - Allow \$2000 per year

II. Operating Supplies

Copperas

Consumption = $0.42 \times 365 = 153.3$ tons per yearPrice ref. 1970 - Oil, Paint and Drug Reporter - \$24.00/2000 lbs

Escalate at 5% per year = 27.60/ton

Estimate freight = 10.00

\$37.60

Estimated cost per year = $153.3 \times 37.60 = \$5764$ III. Maintenance Labour and SuppliesEstimate 10% of equipment cost = $10/100 \times \frac{(15,491 + 93,065)}{3.5} = \3107 IV. Power - 91 hpPower cost = $91 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$5352$

Total operating costs per year = \$66,218

OPERATING COSTS - CASES 4a, 4b, AND 7 - WYOMING OR NEW MEXICOSOLVENT EXTRACTIONI. Operating Labour

Lime slaking

Neutralization

Tailings pump and pipeline

Tailings area supervision

Estimate 1 man per shift + 1 extra man on day shift =

28 man-shifts/week = $28/5 = 6$ menEstimate cost = $6 \times 12,000 = \$72,000/\text{year}$ Supervision - Est. $1/3 \times 15,000 = \$5,000$ II. Operating SuppliesQuicklime consumption = $25.4 \times 365 = 9271$ tonsEst. cost delivered to bin = $9271 \times \$25 = \$231,775/\text{year}$ III. Maintenance Labour and SuppliesEstimate 10% of equipment cost = $10/100 \times \frac{(451,692 + 95,765)}{3.5}$ = $\$15,642/\text{year}$ IV. Power - 230 hpPower cost = $230 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$13,527$ Total operating costs per year = $\$337,944$

OPERATING COSTS - CASE 5 - WYOMING AND NEW MEXICOALKALINEI. Operating Labour

Concrete slurry plant

Tailings and solution pumps and pipelines

Tailings areas supervision

1 man per shift + 1 man extra on day shift = 6 men at 12,000 =
\$72,000/year

Supervision - Est. $1/3 \times 15,000 = \$5,000$ II. Operating Supplies

Cement consumption = 100 T.P.D. = 36,500 tons per year

Cost at \$35 per ton = \$1,277,500

III. Maintenance Labour and Supplies

Estimate 10% of equipment cost = $10/100 \times \frac{(396,256 + 71,322)}{3.5}$
= \$13,359

IV. Power - 130 hpPower cost = $130 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$7646$

Total operating costs per year = \$1,375,505

OPERATING COSTS - CASE 5 - WYOMING OR NEW MEXICOSOLVENT EXTRACTIONI. Operating Labour

Lime slaking

Neutralization - solids

Neutralization - solution

Concrete slurry plant

Tailings and solution pumps and pipelines

Tailings areas supervision

Estimate 2 men per shift = 42 man-shifts per week

This will require 9 men.

Cost = $9 \times 12,000 = \$108,000$ per year

Supervision - estimate 1 man - \$15,000 per year

II. Operating Supplies(a) Quicklime consumption = $25.5 \times 365 = 9307$ tonsEstimated cost delivered to bin = $9307 \times \$25 = \$232,675$ (b) Cement consumption = $100 \times 365 = 36,500$ tonsEstimated cost = $36,500 \times 35 = \$1,277,500$ III. Maintenance Labour and Supplies

Estimate 10% of equipment cost = $10/100 \times \frac{(785,985 + 396,256 + 60,822)}{3.5}$
 $= \$35,516$ per year

IV. Power - 280 hpPower cost = $280 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$16,468$

Total operating costs per year = \$1,685,159

OPERATING COSTS - CASE 6a - WYOMING AND NEW MEXICOALKALINE MILL

- Asphalt (a) Sand and asphalt-treated slime to landfill
 (b) Sand to mine; asphalt-treated slime to landfill

<u>Operating Labour</u>		<u>Per Year</u>
Sand-slime separation	} 1 man per shift	42 man-shifts per week
Slime dewatering		
Load-out		
Asphalt fixation	1 man per shift	
Evaporation	9 men at \$12,000 =	\$108,000
	1 supervision at \$15,000 =	15,000
		<u>\$123,000</u>

Operating Supplies

Asphalt $670 \times 365 = 244,550$ T.P.Y.

Cost at \$20.00/ton = \$4,891,000

Steam - at \$1/1000 lb = $110 \times 24 \times 365 = \$963,000$

Power - est.

Classifiers - 10 hp

Thickener and pumps - 10

Filters } 400
 Vacuum pumps }

Pumps - 6

Wiped-film evaporators (11) 220

Total H.P. = 646

Power cost = $646 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$37,994$

Maintenance Cost - Labour + Supplies

Assumed = 10% of equipment capital cost

Equipment Capital Cost x 10%

- Ia. $10\% \times 1000/3.5 (64 + 833 + 1408 + 3618 + 640) = \$189,514$
 Ib. $10\% \times 1000/3.5 (64 + 833 + 1408 + 3618 + 70 + 640) = \$189,514$
 IIa. $10\% \times 1000/3.5 (64 + 833 + 1408 + 234 + 61 + 431) = \$86,600$
 IIb. $10\% \times 1000/3.5 (64 + 833 + 1408 + 234 + 164 + 431) = \$89,543$

Trucking Cost

Based on a 2-mile return distance at \$0.05 per ton mile.

$\therefore$ Cost per ton hauled to landfill = \$0.10

(a) Asphalt-treated slime + sand

Tonnage = $(1000 + 670) + 1000 = 2670$ tons per day

Trucking cost per year = $2670 \times 365 \times \$0.10 = \$97,455$

(b) Asphalt-treated slime only

Trucking cost per year = $1670 \times 365 \times 0.10 = \$60,955$

Summary - Operating Costs Asphalt Fixation Plant (a)

	Per Year (\$)	Per ton Milled (\$)
Operating labour	123,000	0.17
Operating supplies	4,891,000	6.70
Maintenance labour and supplies	189,514	0.26
Steam	963,600	1.32
Power	37,994	0.05
Trucking	97,455	0.13
	<u>\$6,302,563</u>	<u>\$8.63</u>

Summary - Operating Costs Asphalt Fixation Plant (b)

	Per Year (\$)	Per Ton Milled (\$)
Operating labour	123,000	0.17
Operating supplies	4,891,000	6.70
Maintenance labour and supplies	189,514	0.26
Steam	963,600	1.32
Power	33,773	0.05
Trucking	<u>60,955</u>	<u>0.08</u>
	\$6,259,842	\$8.58

Cement

Operating labour - same as Case 6a \$123,000 per year
 Steam = $\$1 \times 50 \times 24 \times 365 =$ \$438,000 per year
 Power = $(646 - 220 = 426 \text{ hp})$
 $426 \times 0.746 \times 0.80 \times 24 \times 365 \times \$0.01 = \$22,270 \text{ per year}$

Trucking

a. 1000 T.P.D. sand trucked to landfill

Trucking cost per year = $1000 \times 365 \times 0.10 = \$36,500$

Operating Supplies

Price received by telephone (Canada Cement)

Cement = $50 \times 365 \times \$35 = \$638,750$

Summary - Cement Slurry and Sand
(a) Cement Slurry and Sand to Landfill*

	Per Year (\$)	Per Ton Milled (\$)
Operating labour	123,000	0.17
Operating supplies	638,750	0.87
Maintenance labour and supplies	86,600	0.12
Steam	438,000	0.60
Power	22,270	0.03
Trucking	<u>36,500</u>	<u>0.05</u>
Total	\$1,345,120	\$1.84

(b) Sand and Part of Concrete Slurry to Underground Mine,
Balance of Slurry to Landfill*

	<u>Per Year</u> <u>(\$)</u>	<u>Per Ton Milled</u> <u>(\$)</u>
Operating labour	123,000	0.17
Operating supplies	638,750	0.88
Maintenance labour and supplies	89,543	0.12
Steam	438,000	0.60
Power	22,270	0.03
Trucking	-	-
Total	\$1,311,563	\$1.80

a. Cement - 5:1 Mix

Conditions: Slime-cement ratio in slurry decreased from 20:1 to 5:1.
 Both sand and slime-concrete slurry to landfill.

Operating Labour

Increase to 3 men per shift because of the two separate plants.
 This is equivalent to 63 man-shifts per week and will require $63/5 = 13$ men.

13 men at \$12,000 = \$156,000/year

1 supervisor = \$15,000

Operating Supplies

Cement - daily consumption will be $50 \times 4 = 200$ tons

Cost = $200 \times 365 \times \$35 = \$2,555,000$

Maintenance Labour and supplies

$10\% \times 77,000 + 86,600 = \$94,300$

Steam - Same as I = \$438,000

Power

(Additional - 75 hp) = $(426 + 75) = 501$ hp

*Landfill and evaporation pond consolidated.

$$\text{Cost} = 501 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$29,466$$

$$\text{Trucking} - 1000 \text{ T.P.D. sand} \quad \text{Cost} = \$36,500$$

Summary of Operating Costs

	Per Year (\$)	Per Ton Milled (\$)
Operating labour	171,000	0.23
Operating supplies	2,555,000	3.50
Maintenance labour and supplies	94,300	0.13
Steam	438,000	0.60
Power	29,466	0.04
Trucking	<u>36,500</u>	<u>0.05</u>
Total	\$3,324,266	\$4.55

b. Cement - 5:1 Mix

Conditions: The sand and as much slime slurry as the mine can accommodate are pumped underground; the remainder of the slime-concrete slurry - 844 tons - will be pumped to landfill.

Note: With the concrete slurry plant located at the landfill, 2500 to 3000 ft from the underground boreholes, it may not be feasible to send concrete underground. If it is sent underground, the slime-cement ratio would have to be increased to 20:1.

Operating Labour - as in II-a \$171,000/year

Operating Supplies

$$\text{Cement} = \frac{206 \times 24}{1050} \text{ at } 50 \text{ T.P.D.} = 235.4$$

$$\frac{844 \times 24}{1050} \text{ at } 200 \text{ T.P.D.} = 3858.4$$

$$24 \text{ hours at } 170.6 = 4093.8$$

$$\text{Cost per year} = 170.6 \times 365 \times \$35 = \$2,179,415$$

Maintenance Labour and Supplies

$$10\% \text{ of equipment cost} = 10\% \times \frac{3134,000}{3.5} = 89,543$$

$$\text{Steam} = \$38,000$$

$$\text{Power} = \$22,270$$

Summary of Operating Costs

	Per Year (\$)	Per Ton Milled (\$)
Operating labour	171,000	0.23
Operating supplies	2,179,415	2.99
Maintenance labour and supplies	89,543	0.12
Steam	438,000	0.60
Power	<u>22,270</u>	<u>0.03</u>
Total	\$2,900,228	\$3.97

CASES 6a AND 6b - SOLVENT EXTRACTION - WYOMING AND NEW MEXICO

<u>Operating Labour</u>	<u>Man</u>	<u>Shifts x days</u>	<u>Total</u>
Lime pulping and neutralization	1	3 x 7	4
Thickener of filters, evaporator, classification	1	3 x 7	4
Asphalt fixation - evaporator of cement fixation	1	3 x 7	4
		Say 13 men	
General foreman	1	1 x 5	1

Materials

Lime = 29 tpd Ca(OH)_2 x 56/75 $[\text{CaO}/\text{Ca(OH)}_2]$ x 1/.9 = 24.05 tpd
at \$25.00 delivered

24.06 x 365 days x \$25.00 = \$219,540 per year

(a) Asphalt = 460 tpd; \$0.08/gal = \$20.00/ton
460 x 365 days x \$20.00 = \$3,358,000 per year

(b) Cement = 35 tpd, \$35.00/ton
35 x 365 days x \$35.00 = \$447,125/year

<u>Power</u>	<u>Installed hp</u>
Ball mill	40
Ball pump	1
Mill pump	1
Agitator-mill cone tank	15
Agitator 3, neutralization vessels	30
Compressor	50
Thickener	5
Thickener overflow pumps (1 operating)	10
Thickener underflow pumps (2 operating)	10
Filters with pumps and vacuum	400
Filter cake surge tank	10

Filter cake surge tank pumps (2)	4
2 classifiers	10
Pump, classifier to mill	5
Pump, between classifiers	2
Evaporator pump condensate to storage	3
Concentrate pump	<u>1</u>
Total	597 hp
Plus 15% contingency	<u>103</u>
	700 hp

$$700 \times .746 \times .80 \text{ (load factor)} \times 24 \times 365 \times \$0.01 = \$36,596$$

(a) Wiped-film evaporators (6) 120 hp
 $120 \times .746 \times 180 \times 24 \times 365 \times \$0.01 = \$6,274$

(b) Cement mix tank and feeder 5 hp
 Slurry pump 20 hp
 $25 \times .746 \times 60 \times 24 \times 365 \times \$0.01 = \$1,307$

Steam (includes fuel, labour, maintenance)

6b. Cement alternative = $56,000\#/hr$ at $\$1/1000\#$ = $56,000 \times \frac{1.00}{1000} \times 24 \times 365 = \$490,560/yr$

6a. Asphalt alternative = $56,000 + 30,000 + 1000$ miscellaneous
 Heating and pumping
 $\$87,000 \times \frac{1.00}{1000} \times 24 \times 365 = \$762,120/yr$

$$\text{Increment due to asphalt} = \$762,120 - \$490,560 = \$271,560$$

Trucking Cost - includes drivers

Sand transport to mine - charged to mine

6a. Asphalt-slime - 1 mile to landfill - 1150 tpd
 Say $\$0.05/\text{ton mile}$ = $.05 \times 2 \times 1150 \times 365 = \$41,975/yr$

6b. Cement-slime - 1025 tpd (wet)

$$\$0.05 \times 2 \times 1025 \times 365 = \$37,413/\text{yr}$$

Maintenance - 10% of equipment cost

$$\text{Common items} = \$852,312 \times .10 = \$85,200$$

$$\text{Asphalt alternate} = \$774,300 \times .10 = \$77,400$$

$$\text{Cement alternate} = \$206,596 \times .10 = \$20,700$$

Operating Costs Associated with Disposal Area

6a. Asphalt - sand and slime to landfill

Earth (seed cover):

No operating costs at landfill area

Costs after rehabilitation - same as Case 6 - \$48,100/yr

Earth and rock cover - nil

Sand to mine - slimes to landfill

Earth and seed cover -

As for Case 6 - no operating costs

Till after rehabilitation = \$43,200/yr

6b. Cement

Sand and slime to landfill

Earth and seed cover

As for Case 6 - no operating costs until after rehabilitation

Adjusted for area

$$\frac{154 \text{ acres}}{166 \text{ acres (Case 6)}} \times \$50,400 = \$46,800$$

Earth and rock cover - no cost

Sand underground - slime to landfill

Earth and seed cover as for Case 6 - \$46,300

Earth and rock cover - nil

Savings in operating cost when sand is going to the mine rather than to landfill.

6a. Asphalt Case

Sand to mine - 1206 tpd

Remainder trucked to landfill = $1400 - 1206 = 194$ tpd sands

600 tpd slime

90 tpd CaSO_4 460 tpd asphalt

Total

1344

All to landfill = $1206 + 1344 = 2550$ tpd

Trucking cost - 2-mile round trip

 $\$0.05 \times 2 \times 2550 \times 365 \text{ days} = \$93,075/\text{yr}$ When sand going to mine - $\$0.05 \times 2 \times 1344 \times 365 = \$49,056/\text{yr}$ 6b. Cement Case

Sand to mine - 1206 tpd

Remainder 194 sand

1024 slime-cement

1218

All sand to landfill.

Trucking - $\$0.05 \times 2 \times 1400 \times 365 = \$51,100/\text{yr}$

When sand going to mine, mix with slime-cement.

Increase slurring and pumping cost in proportion.

 $\frac{194 + 35/65 \times 194}{1024} \times \$3663 = \$1067/\text{yr}$

Maintenance Costs After RehabilitationCase 1 - Wyoming - Solvent Extraction

Maintenance costs are based on the following premises:

(a) Power for water supply

Irrigation pump

Capacity 900 USGPM against 10 ft T.D.H.

$$\text{Est. H.P.} = \frac{900 \times 8.34 \times 100}{33,000 \times 0.60} = 38 - \text{say } 40 \text{ hp}$$

Power cost for 8 months in year =

$$40 \times 0.746 \times 0.90 \times 24 \times 30 \times 8 \times \$0.01 = \$1290$$

(b) Fertilizer = \$5,220(c) Operating Labour

3 men per day over 8 months per year = 4 men

$$\text{Cost} = 4 \times 2/3 \times \$12,000 = \$32,000$$

$$\text{Supervision} - \text{allow } 1/3 \times 15,000 = \$5000$$

(d) Maintenance Labour and Supplies

10% of equipment cost

$$\text{Water spray piping including pump} = \$75,000$$

$$10\% \times \$75,000 = \$7500$$

Total Estimated cost = \$51,010

Cases 1 and 2 - Solvent Extraction at New Mexico and Cases 1 and 2 - Alkaline at New Mexico and Wyoming

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 50,000	5,000
(c) Fertilizer - 116/174 x 5220	3,480
(d) Power	<u>1,290</u>
Total	\$46,770

Case 2 - Wyoming - Solvent Extraction

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 81,500 =	8,150
(c) Fertilizer	
189/174 x 5220 =	5,670
(d) Power	<u>1,290</u>
Total	\$52,110

Case 4 - Wyoming and New Mexico - AlkalineCase 4 - New Mexico - Solvent Extraction

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 52,100	5,210
(c) Fertilizer	
121/174 x 5220	3,630
(d) Power	<u>1,290</u>
Total	\$47,130

Case 4 - Wyoming - Solvent Extraction

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 83,200	8,320
(c) Fertilizer	
193/174 x 5220	5,790
(d) Power	<u>1,290</u>
Total	\$52,400

Case 5 - Wyoming - AlkalineFor Base Case and Landfill and Pond Area Consolidated

Based on (134 + 121 acres)

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 109,914	10,991
(c) Fertilizer	
255/174 x 5220 =	7,650
(d) Power	<u>1,290</u>
Total (A, A-2)	\$56,931

For Reduced Pond Area

Based on (134 + 15 acres)

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 64,224	6,422
(c) Fertilizer	
149/174 x 5220	4,470
(d) Power	<u>1,290</u>
Total (A-1)	\$49,182

Case 5 - New Mexico - AlkalineFor Base Case and Landfill and Pond Area Consolidated

Based on (61 + 67) acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 55,172	5,517
(c) Fertilizer	
128/174 x 5220	3,840
(d) Power	<u>1,290</u>
Total (B, B-2)	\$47,647

For Reduced Pond Area

Based on (61 + 15 acres)

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 32,759	3,276
(c) Fertilizer	
76/174 x 5220	2,280
(d) Power	<u>1,290</u>
Total (B-1)	\$43,846

Case 5 - Wyoming - Solvent ExtractionFor Base Case and Landfill and Pond Area Consolidated

Based on (148 + 121) acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 115,948	11,595
(c) Fertilizer	
269/174 x 5220	8,070
(d) Power	<u>1,290</u>
Total (A, A-2)	\$57,955

For Reduced Pond Area

Based on (148 + 21) acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 72,845	7,285
(c) Fertilizer	
169/174 x 5220 =	5,070
(d) Power	<u>1,290</u>
Total (A-1)	\$50,645

Case 5 - New Mexico - Solvent ExtractionFor Base Case and Landfill and Pond Area Consolidated

Based on (61 + 107) acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 72,414	7,241
(c) Fertilizer	
168/174 x 5220	5,040
(d) Power	<u>1,290</u>
Total (B, B-2)	\$50,571

For Reduced Pond Area

Based on (61 + 21) acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 35,345	3,535
(c) Fertilizer	
82/174 x 5220	2,460
(d) Power	<u>1,290</u>
Total (B-1)	\$44,285

Case 6a - Wyoming and New Mexico - Alkalinea. Asphalt slime fixation - 134 acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 57,758 =	5,776
(c) Fertilizer	
134/174 x 5220	4,020
(d) Power	<u>1,290</u>
Total	\$48,086

b. Asphalt-Slime Fixation - 67 acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 28,879	2,888
(c) Fertilizer	
67/174 x 5220	2,010
(d) Power	<u>1,290</u>
Total	\$43,188

Case 6b - Wyoming and New Mexico - Alkalinea. Cement-Slime Fixation - 166 acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 71,552	7,155
(c) Fertilizer	
166/174 x 5220	4,980
(d) Power	<u>1,290</u>
Total	\$50,425

b. Cement-Slime Fixation - 109.5 acres

(a) Operating labour	\$37,000
(b) Maintenance labour and supplies	
10% x 47,198	4,720
(c) Fertilizer	
109.5/174 x 5220 =	3,285
(d) Power	<u>1,290</u>
Total	\$46,295

CASE 6c - NITRIC ACID - SOLVENT EXTRACTION

<u>Operating Labour</u>	<u>Men</u>	<u>Shifts x Days</u>
Leaching	1	3 x 7
CCD	1	3 x 7
Evaporation - distillation	1	3 x 7
S-X	1	3 x 7
Product evap. and drumming		
Calciner		
Asphalt or cement mixing	<u>1</u>	
	5	x
		21 = 105 man-shifts
		= 21 men

Supervision

General foreman	1	1 x 5
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Operating Materials

HNO₃ - 5 tpd = 1825 tpy

Cost: \$ 35/T in 1968 - Say \$40/T in 1973 = \$73,000 for 1 yr

Flocculants - 0.12#/ton ore

0.12 x 2000 x 365 = 87,600#/yr

At \$1.00/lb (Separan, etc.) = \$87,600/yr

Tributyl Phosphate

67 tpy at \$1200/T for 5000 stpy of U

Raffinate H₂O = 7172#/hr

Our raffinate = 500 tpd H₂O = $\frac{500 \times 2000}{24}$ = 41,667#/hr

TBP loss = proportional to raffinate = $\frac{41,667}{7172}$ x 67 tpy = 389 tpy

Unit cost - (Kaiser UF₆ = \$1200/T in 1968)

\$1200 x 1.15 esc = \$1380 x 389 = \$536,820/yr

Kerosene - factor as for TBP

$$\frac{41,667}{7172} \times 56,000 \text{ gal} \times \$0.28 = \$91,096/\text{yr}$$

Fuel

Given $0.5 \times 10^6 \text{ ft}^3$ nat gas/day for calciner = $197.1 \times 10^6 \text{ ft}^3/\text{yr}$
 at say $\$0.40/1000 \text{ ft}^3 = \$78,840/\text{yr}$

Steam

$$370,000\#/ \text{hr} \text{ at } \$1 \text{ per } 1000 = \frac{370,000}{1000} \times \$1.00 \times 365 = \$135,050/\text{yr}$$

Power

8 leach tanks at 40 hp = 320 hp
 10 thickeners at 5 hp (mechanism) = 50 hp
 Pumps at 15 hp/thickener = 150 hp

Miscellaneous Pumps in evaporator system, say 30 hp

S-X

Pulse generators (3) = 30 hp
 Pumps = 33 hp (installed)
 Say 46 working
 Scale on capital cost in 1973 = $775,189/365,800 \times 1.24 \times 46 \text{ hp} = 80$

Calciner

Drive - 10 hp
 Fan - 50 hp
 Miscellaneous and contingencies (~16%) = 110
 Total 800 hp

Allow 80% load factor at $\$0.01/\text{kwh} = 800 \times .746 \times .80 \times 24 \times 365 \text{ days} \times$
 $\$0.01 = \$41,823/\text{yr}$

Alternative (a) - Asphalt

34 tpd = 12,410 tpy at \$20.00/ton (Case 6a) = \$248,288

Alternative (b) - Cement

10 tpd = 3650 tpy at \$35.00 = \$127,750

Maintenance - 10% of equipment cost

Common items = 7,029,300 x .1 = \$702,900

Asphalt alt. = 31,100 x .1 = \$3,000

Cement alt. = 36,000 x .1 = \$3,700

CASE 6c - SULFATE - OPERATING COST

<u>Operating Labour</u>	<u>Men</u>	<u>Shifts x Days</u>
Leaching	1	3 x 7
CCD		
S-X and precipitation	2	3 x 7
Drying and packaging	1	1 x 5
$63 + 5 = 68 \text{ man-shifts/week} \div 5 = 13.6 - 14 \text{ men}$		

Supervisors

General foreman	1	1 x 6
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Operating Materials - Consumption given by Union Carbide

	<u>\$/yr</u>
H ₂ SO ₄ - 90#/ton	
2000 tpd x 365 days x 90#/2000 = 32,850 tpy x \$22	722,700
NH ₃ - 2.1#/ton	
730,000 tpy x 2.1/2000 = 767 tpy x \$70	53,700
NaClO ₃ - 2.7#/ton	
730,000 x 2.7/2000 = 986 tpy x \$200	197,200
Flocculant - 0.12#/ton	
730,000 x 0.12 = 87,600#/yr x \$1	87,600
Amine - 0.03#/ton	
730,000 x 0.03 = 21,900#/yr x \$0.75	76,400
Alcohol - 0.07#/T	
730,000 x 0.07 = 51,100#/yr x \$0.26	13,200
Kerosene - 0.90#/T	
730,000 x 0.90 = 657,000#/yr $\div$ 6.67#/gal =	
98,500 gal x \$0.28 =	27,580

Power

8 leach tanks at 40 hp	320 hp
5 thickeners at 20 hp	100 hp
S-X	<u>hp</u>
Extraction mixers, 15 ea x 4	60
Raffinate pump	25
Raffinate pump	25
Preg Organic pump	5
Barren organic pump	5
Barren organic pump	5
Preg Organic pump	<u>10</u>
	555
Misc. and contingencies (~15%)	<u>85</u>
	640

Allow 80% load factor at 0.01/kwh

$$640 \times .746 \times .80 \times 24 \times 365 \times \$0.01 = \$33,459$$

Maintenance - 10% of equipment cost

$$(922,000 + 1,188,900/3) \times .10 = \$131,830$$

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