
A. D. Ryon
R. E. Blanco
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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

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NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

OAK RIDGE NATIONAL LABORATORY
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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:


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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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

\(^a\)Consulting 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

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

Pond Area

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

New Mexico - 161 acres x $\frac{4.0}{87/12} = 89$ Acres
Solid-Liquid Solvent Extraction Case 1 at Wyoming Tailings Pond

1. Assume seepage 10%

2. Area 161 x 90% x 120% = 174 Acres

3. Assume square \((174 \times 43,560)^{1/2} = 2753\)-ft-long Dam

4. Ave. solids thickness \(\frac{2 \times 10^6 \text{ yd}^3 \times 27}{174 \times 43,560} = 32 \text{ ft}\)

5. Assume wedge shape, dam ht = 32 x 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 \(\text{yd}^3\)

10. Diversion dam and ditches = 25,000 \(\text{yd}^3\)
Solid-Liquid Solvent Extraction Case 1 at New Mexico

Tailings Pond

1. Assume seepage = 10%
2. Area = 89 x 90% x 120% = 96 acres
3. Assume square \((96 \times 43,560)^{1/2} = 2046\) ft
4. Ave. solids thickness = \(\frac{9 \times 10^3 \text{ yd}^3 \times 27}{96 \times 43,560} = 58\) ft
5. Assume wedge shape, dam ht = 58 x 2 + 5 = 121 ft
6. Arbitrary dam ht ≤ 100 ft
7. Ave. solids thickness = \(\frac{100-5}{2}\) (freeboard) = 48 ft
8. Area = \(\frac{9 \times 10^3 \times 27}{48 \times 43,560} = 116\) 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 = \(\frac{(10 \times 10 + 20 \times 10) \times 2248}{27} = 25,000\) yd³
12. Volume of 6-in. soil cover = \(\frac{116 \text{ acres} \times 43,560 \times 1/2}{27} = 93,600\) yd³
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 at Wyoming

Tailings Pond
1. Assume 2% seepage
2. Area = 161 x 98% x 120% = 189 acres
3. Assume square \((189 \times 43,560)^{1/2} = 2870\) ft
4. Ave. solids thickness = \(\frac{2 \times 10^6 \times 27}{189 \times 43,560} = 30\) ft
5. Assume wedge shape, dam ht = 30 x 2 + 5 = 65 ft
6. Dam, native x 10-ft clay core, slopes 2:1
7. Volume of Dam
   a. Clay, \(10 \times 65 \times 2872/27 = 69,100\) yd\(^3\)
   b. Fill, \((10 \times 65 + 130 \times 65) \times 2872/27 = 968,000\) yd\(^3\)
8. Excavation to key clay to base, \(10 \times 10 \times 2872/27 = 10,700\) yd\(^3\)
9. Volume of 2-ft soil cover = \(\frac{189 \text{ acres} \times 43,560 \times 2}{27} = 609,800\) yd\(^3\)
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 yd\(^3\)
11. Diversion dam = 25,000 yd\(^3\)
12. Survey and core drilling

\[^a\] Same as Case 2 except earth cover (item 9) is 8 ft instead of 2 ft.
Solid-Liquid Solvent Extraction Cases 2 and 3\textsuperscript{a} at New Mexico

Tailings Pond

1. Assume 2\% seepage
2. Area = 89 x 98\% x 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 x 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 = \(10 \times 100 \times 2248/27 = 83,300\) yd\(^3\)
   b. Fill = \((10 \times 100 + 200 \times 100) 2248/27 = 1,748,000\) yd\(^3\)
12. Volume of 2-ft soil cover = \(\frac{116 \text{ acres} \times 43,560 \times 2}{27} = 374,300\) yd\(^3\)
13. Excavation to key clay to base, \(10 \times 10 \times 2248/27 = 8,300\) yd\(^3\)
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 yd\(^3\)
15. Diversion dam = 25,000 yd\(^3\)
16. Survey and core drilling

\textsuperscript{a}Same 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 Wyoming

A. Neutralization

1. Lime - 3000 T/day at pH 2.0 (0.01 N H⁺), Fe 0.10 N, Al 0.20 N.
   
   \[
   3000 \text{T/day} \times 2000 \text{ lb} \times \frac{.454}{\text{lb}} \times \frac{.31N \times 74/2}{454 \times 2000 \text{ lb}} = 34.4 \text{T Ca(OH)₂/day}
   \]

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 x 120% = 193 acres

3. Assume square \((193 \times 43,500)^{1/2} = 2000 \text{ ft}\)

4. Ave. solids thickness \(\frac{0 \times 10^6 \times 27}{43,560 \times 193} = 29 \text{ ft}\)

5. Assume wedge shape, dam ht = 29 x 2 + 5 = 63 ft

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

7. Volume of dam
   
   a. Clay = 10 x 63 x 2900/27 = 67,700 yd³
   
   b. Fill = (10 x 63 + 126 x 63) 2900/27 = 920,300 yd³

8. Excavation to key clay to base - 10 x 10 x 2900/27 = 10,700 yd³

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:

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

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

   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 \text{ yd}^3

12. Diversion dam = 25,000 \text{ yd}^3
Solid-Liquid Solvent Extraction Cases 4a and 4b at New Mexico

A. Neutralization (same as Cases 4a and 4b, Wyoming)

B. Tailings Pond

1. Assume 0.1% seepage
2. Area = 89 x 120% = 107 acres
3. Assume square \((107 \times 43,560)^{1/2} = 2157 \text{ ft}\)
4. Ave. solids thickness \(\frac{9 \times 10^6 \times 27}{107 \times 43,560} = 52 \text{ ft}\)
5. Assume wedge shape, dam ht = 52 x 2 + 5 = 109 ft
6. Arbitrary dam ht ≤ 100 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 = \((116 \times 43,560)^{1/2} = 2248 \text{ ft}\)
10. Dam, native + 10-ft clay core, slope = 2:1
11. Volume of dam
   a. Clay = 10 x 100 x \(2248/27 = 83,300 \text{ yd}^3\)
   b. Fill = \((10 \times 100 + 200 \times 100) \times 2248/27 = 1,748,400 \text{ yd}^3\)
12. Excavation to key clay to base, \(10 \times 10 \times 2248/27 = 8,300 \text{ yd}^3\)
13. Sealing of pond bottom and sides
   Area = \(116A + \frac{2248 \times 100 \times 2}{43,560} = 126 \text{ acres}\)
   Amount of asphalt (2 in. thick) \(2/12 \times 126A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}}\)
   \(= 28,400 \text{ tons}\)
14. Cover
   a. Volume of 20-ft soil cover $116A \times \frac{43,560 \times 20}{27} = 3,742,900 \text{ yd}^3$
   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 yd$^3$

16. Diversion dam = 25,000 yd$^3$
Solid-Liquid Solvent Extraction Case 5 at Wyoming

A. Neutralization

1. Liquid Waste
   a. \( \frac{1130 \text{T}}{3000 \text{T}} \times 597 = 13 \text{T} \ \text{Ca(OH)}_2/\text{day} \)
   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. \( \frac{1870 \text{T}}{3000 \text{T}} \times 59 \text{T} = 22 \text{T} \ \text{Ca(OH)}_2/\text{day} \)
   b. Equipment
      Lime silo, 3 day, 70 T
      Lime feeder, 0-2 T/hr
      Mix tank, 2000-gal, wood, agitated
      Automatic pH controller


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 T/day x 1/20 = 100 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 \((193 \times 43,560)^{1/2} = 2900\) ft
4. Assume dam ht = 15 ft
5. Dam, native +10-ft clay core, slope 2:1
6. Volume of dam
   a. Clay \(-10 \times 15 \times 2900/27 = 16,100\) yd\(^3\)
   b. Fill \((10 \times 15 + 30 \times 15) 2900/27 = 64,400\) yd\(^3\)
7. Excavation to key clay to base \(-10 \times 10 \times 2900/27 = 10,700\) yd\(^3\)
8. Sealing of pond bottom and sides

Amount of sealant (2 in. thick) \(-2/12 \times 193A \times \frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}}\)

\[= 43,400 \text{ tons} \]
9a. Cover
   a. 20-ft dirt - 193A x 43,560 x 20/27 = 6,227,000 yd³
   b. 2-in. asphalt + 2-ft dirt
       Asphalt: 2/12 x 193A x \(\frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}}\) = 43,400 T
       Dirt: 2 x 193A x \(\frac{43,560}{27}\) = 623,000 yd³

9B. Alternative is to collect solids in a smaller area before covering.
   Volume of solids:
   \[\frac{25 \text{g/l (T.D.S.)} \times 3000 \text{T} \times 2000 \text{ lb} \times 0.454 \text{ lb/lb} \times 365 \text{d} \times 20 \text{ yr}}{43,560 \times 27 \frac{\text{ft}^3}{\text{yd}^3}}\] = 338,000 yd³
   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 x 43,560 x 20/27 = 678,100 yd³
   b. 2-in. asphalt + 2-ft dirt
       Asphalt: 2/12 x 21A x \(\frac{43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb}}\) = 4,730 T
       Dirt: 2 x 21 x \(\frac{43,560}{27}\) = 68,000 yd³
       \[\text{Area of concrete} = \frac{2000 \text{T/d} \times 2000 \text{ lb} \times 1.05 \times 365 \times 20 \text{ yr}}{120 \times 100/2 \times 43,560} = 117 \text{ acres}\]

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 x 120% = 107 acres
3. Assume square, \((107 \times 143,560)^{1/2} = 2160 \text{ ft}\)
4. Assume dam ht = 15 ft
5. Dam, native, 10-ft clay core, slope 2:1
6. Volume of dam
   a. Clay - \(10 \times 15 \times 2160/27 = 12,000 \text{ yd}^3\)
   b. Fill - \((10 \times 15 + 30 \times 15) \times 2160/27 = 48,000 \text{ yd}^3\)
7. Excavation to key clay to base - \(10 \times 10 \times 2160/27 = 8,000 \text{ yd}^3\)
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 - \(107A \times 43,560 \times 20/27 = 3,453,000 \text{ yd}^3\)
   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: \(2 \times 107A \times 43,560/27 = 345,000 \text{ yd}^3\)
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
CEMENT 100T

LIME 13T

LIQUID WASTE 1130T
DISS. SOLID 28T

THICKENER

7''

SLIME 600T
SAND 1400T
WATER 1870T
DISS. SOLID 47T

CONCRETE TO MINE OR LAND FILL
WATER TO SEALED POND

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*Includes 100T cement

Solid-Liquid Waste - Solvent Extraction - Case 5
Solid-Liquid Solvent Extraction Cases 6a and 6b at Wyoming or New Mexico

A. Neutralization

1. Lime [Ca(OH)$_2$], MW = 74
   \[
   2530 \text{ T/day} \times 2000 \text{ lb} \times \frac{0.454 \text{ lb/lb} \times 0.31 \text{IN}}{2000 \text{ lb} \times 454} \times 74/2 = 29 \text{ T/day}
   \]

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 ft$^2$

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 ≤ 2 miles)

C. Evaporation

1. Calculation of water load
   - Liquid waste = 1130 T/day
   - Filtrate from slime = 1400 T - 30%/70% 700 T = 1100 T/day
   - Total water to be evaporated = 2230 T/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

\[
30\% \times 2000 \ T + \frac{25 \ g/l \times 2530 \ T \times 2000 \ lb \times 0.454 \ T/lb}{454 \ g \times 2000 \ lb} + 29 \ T \ lime = 690 \ T/day
\]

2. Asphalt: 0.67 \times 690 = 460 T/day

3. Water load to be evaporated, filter cake, \(\frac{30\% \ moisture}{70\% \ dry \ solid}\) \times 690 \ 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 ≤ 2 miles)
D. Alternate (Cement 1:20) (Case 6b)

1. Slime + diss. solids + lime
   \[30\% \times 2000 \text{T} + \frac{2530 \text{T} \times 2000 \text{lb} \times 0.454}{454 \times 2000} + 29 \text{T} = 690 \text{T/day}\]

2. Cement: \(\frac{1}{20} \times 690 = 35 \text{T/day}\)

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

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

   a. Area for sand + asphalt
   \[\frac{(6.31 \times 10^8 + 5.43 \times 10^8)27}{100/2 \times 43,560} = 146 \text{ acres}\]

   b. Area for sand + concrete
   \[\frac{(6.31 \times 10^8 + 2.84 \times 10^8)27}{100/2 \times 43,560} = 113 \text{ acres}\]
4. **Cover, 20-ft dirt**
   
   a. Volume for asphalt = \( \frac{20 \times 146 \times 43,560}{27} \) = 4,711,000 yd³
   
   b. Volume for concrete = \( \frac{20 \times 113 \times 43,560}{27} \) = 3,646,000 yd³

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. Volume of sand = 6.3 x 10⁸ yd³
   
   2. a. Volume of asphalt-slime = 5.4 x 10⁸ yd³
   
      b. Volume of concrete-slime = 2.8 x 10⁸ yd³
   
   3. Transportation and placement in mine - 3000 ft (pump)
Solid-Liquid Waste - Solvent Extraction - Case 6a (asphalt)
Solid-Liquid Waste - Solvent Extraction - Case 6b (cement)
Solid-Liquid Solvent Extraction Case 6c

A. HNO₃ leach (3 M HNO₃ 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. HNO₃ recycle
   1. Evaporator, stainless steel, feed = 1100 gpm
   2. Distillation column, stainless steel, with reboiler
      4 trays x 2 sections = 8 trays
      \[
      \frac{6000 \times 18 \times 28 \times 22.4 \times 1.25 \times 24 \times 60 \times 60 \times L}{4 \times \text{fps}} = 876 \text{ ft}^2 = \text{area of tower}
      \]
      Diameter = 33 ft
      Height = 1.5D = 50 ft
      Boilup: 6000 x 0.125 x 2000 lb/24 = 125,000 lb/hr
   3. HNO₃ 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
Solid-Liquid Waste - Solvent Extraction - Case 6c
Radwaste Treatment Equipment Requirements for Model Alkaline Leach Mill Processing 2000 Tons Ore Per Day

**Model Alkaline Mill**

- **2000 Ton/day x 365 d x 20 yr = 14.6 x 10^8 Ton ore during life of mill**
- **14.6 x 10^8 x 0.20% U_3O_8 x 2000 lb x 93% = 54,300,000 lb U_3O_8 during life of mill**
- **2000 T/day x 1.05 T liq/T x 2000 lb**
  \[ \frac{8.33 \times 24 \text{ hr} \times 60 \text{ min}}{} = 350 \text{ gpm waste liquid} \]

**Pond Area**

- **Wyoming**
  \[ \frac{2000 \text{ T/day} (1.05 - .3) \times 2000 \text{ lb} \times 365}{62.4 \times 4.0 \text{ ft/yr} \times 43,560} = 101 \text{ Acres} \]
- **New Mexico**
  \[ 101 \text{ acres} \times \frac{4.0}{87/12} = 56 \text{ Acres} \]
Solid-Liquid Alkaline Case 1 at Wyoming

Tailings 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 \(\leq 100\) 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 \(\times 2180\) ft \(\times 10\) ft crest, slope = 2:1

11. Volume of dam = \(\frac{(10 \times 10 + 10 \times 20) \times 2248}{27 \text{ ft}^3/\text{yd}^3} = 25,000\) yd\(^3\)

12. Volume of 6-in. soil cover = \(\frac{116A \times 43,560 \times 1/2 \text{ ft}}{27} = 93,600\) 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 yd\(^3\)

14. Diversion dams and ditches = volume of dam (25,000 yd\(^3\))
Solid-Liquid Alkaline Case 1 at New Mexico

Tailings Pond

1. Assume seepage = 10%

2. Area = 56 x 90% x 120% = 60 Acres

3. Assume square \((60 \times 43,560)^{1/2} = 1623\)-ft-long dam

4. Ave. solids thickness \(\frac{9 \times 10^6 \text{ yd}^3 \times 27}{60 \times 43,560} = 93\) ft

5. Assume wedge shape, dam ht = \(93 \times 2 + 5 \) (freeboard) = 191 ft

6. Arbitrary dam ht \(\leq 100\) 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 = \((116A \times 43,560)^{1/2} = 2248\) ft

10. Dam, native material, 10-ft ht x 2248 ft x 10-ft crest

11. Volume of dam: \(\frac{(10 \times 10 + 20 \times 10) \times 2248\text{ ft}}{27} = 25,000\) yd³

12. Volume of 6-in. soil cover = \(\frac{116 \times 43,560 \times 1/2}{27} = 93,600\) yd³

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\textsuperscript{a} at Wyoming

Tailings Pond

1. Assume 2\% seepage

2. Area = 101 x 98\% x 120\% = 119 acres

3. Assume square \((119 \times 43,560)\textsuperscript{2} = 2275\)-ft-long dam

4. Ave. solids thickness \(-\frac{2 \times 10^8 \times 27}{110 \times 43,560} = 47\) ft

5. Assume wedge shape, dam ht = 47 x 2 + 5 = 99 ft

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

7. Volume of dam
   a. Clay - \(10 \times 99 \times \frac{2275}{27} = 83,400\) yd\textsuperscript{3}
   b. Fill - \((10 \times 99 + 198 \times 99) \frac{2275}{27} = 1,735,100\) yd\textsuperscript{3}

8. Excavation to key clay to base - \(10 \times 10 \times \frac{2275}{27} = 8,400\) yd\textsuperscript{3}

9. Volume of 2-ft soil cover - \(119 \times 43,560 \times \frac{2}{27} = 384,000\) yd\textsuperscript{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 yd\textsuperscript{3}

11. Diversion dam = 25,000 yd\textsuperscript{3}

12. Survey and core drilling

\textsuperscript{a}Case 3 same as Case 2 except earth cover (item 9) is 8 ft.
Solid-Liquid Alkaline Cases 2 and 3a at New Mexico

Tailings Pond

1. Assume 2% seepage

2. Area = $56 \times 98 \times 120 = 66$ Acres

3. Assume square $(66 \times 43,560)^{1/2} = 1694$-ft-long dam

4. Ave. solids thickness $= \frac{9 \times 10^8 \times 27}{66 \times 43,560} = 85$ ft

5. Assume wedge shape, dam ht = $85 \times 2 + 5 = 175$ ft

6. Arbitrary dam ht ≤100 ft

7. Ave. solids thickness $= \frac{100 - 5}{2} = 48$ ft

8. Area $= \frac{9 \times 10^8 \times 27}{48 \times 43,560} = 116$ Acres

9. Dam length $= (116A \times 43,560)^{1/2} = 2248$ ft

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

11. Volume of dam
   a. Clay $= 10 \times 100 \times 2248/27 = 83,300$ yd$^3$
   b. Fill $= (10 \times 100 + 200 \times 100) \times 2248/27 = 1,748,400$ yd$^3$

12. Volume of 2-ft soil cover $= \frac{116 \times 43,560 \times 2}{27} = 374,300$ yd$^3$

13. Excavation to key clay to base $= 10 \times 10 \times 2248/27 = 8,300$ 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, $93,600$ yd$^3$

15. Diversion $= 25,000$ 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 Wyoming

A. Copperas Treatment

1. Copperas (FeSO₄ · 7H₂O)

\[
\frac{0.2 \text{ g/l} \times 0.454 \text{ lb/g} \times 2100 \text{ lb} \times 2000 \text{ lb}}{454 \text{ g/lb} \times 2000 \text{ lb}} = 0.42 \text{ T/day}
\]

2. Volume of copperas feed solution for 24 hr

\[
\frac{0.42 \text{T} \times 2000 \text{ lb} \times 0.454 \text{ g}}{90 \text{ g/l} \times 3.79 \text{ T/gal}} = 1100 \text{ gal}
\]

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 x 120% = 121 Acres

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

4. Ave. solids thickness \(\frac{2 \times 10^{6} \times 27}{121 \times 43,560} = 46 \text{ ft}\)

5. Assume wedge shape, dam ht = \(46 \times 2 + 5 = 97 \text{ ft}\)

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

7. Volume of dam

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

   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

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

Amount of sealant (2 in. thick) -
\[\frac{2}{12} \times \frac{131 \times 43,560 \times 62 \text{ lb/ft}^3}{2000 \text{ lb/T}} = 29,500 \text{ Ton}\]

10. Cover
   a. 20-ft soil - \(121 \times \frac{43,560 \times 20}{27} = 3,904,300 \text{ yd}^3\)
   b. 2-in. asphalt + 2-ft dirt
      Asphalt: \(\frac{2}{12} \times 121 \times \frac{43,560 \times 62}{2000} = 27,200 \text{ Ton}\)
      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 x 2 + 5 = 171 ft
6. Arbitrary dam ht \(\leq 100\) 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 = \((116A \times 43,560)^{1/2} = 2248\) ft
10. Dam, native material + 10-ft clay core, slope 2:1
11. Volume of dam
   a. Clay - \(10 \times 100 \times \frac{2248}{27} = 83,300\) yd\(^3\)
   b. Fill - \((10 \times 100 + 200 \times 100) \frac{2248}{27} = 1,748,400\) yd\(^3\)
12. Excavation to key clay to base - \(10 \times 10 \times \frac{2248}{27} = 8,300\) yd\(^3\)
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)
   \(2/12 \times 126 \times \frac{43,560 \times 62}{2000} \text{ lb/ft}^3 = 28,400\) Tons
14. Cover
   a. Volume of 20-ft soil, \(116 \times 43,560 \times \frac{20}{27} = 3,742,900\) yd\(^3\)
b. 2-in. asphalt + 2-ft soil

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

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

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 yd\(^3\)

16. Diversion dam = 25,000 yd\(^3\)
Solid-Liquid Alkaline Case 5 at Wyoming

A. Concrete slurry to open pit mine

1. Cement (1:20)
   
   \[2000 \text{ T} \times \frac{1}{20} = 100 \text{ T/day}\]

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. Area = 101 x 120\% = 121 acres

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

4. Assume dam ht = 15 ft

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

6. Volume of dam
   
   a. Clay - \(10 \times 15 \times \frac{2296}{27} = 12,800 \text{ yd}^3\)
   
   b. Fill - \((10 \times 15 + 30 \times 15) \frac{2296}{27} = 51,000 \text{ yd}^3\)

7. Excavation to key clay to base - \(10 \times 10 \times \frac{2296}{27} = 8,500 \text{ yd}^3\)
8. Sealing of pond bottom and sides

Amount of sealant (2 in. thick)

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

9A. Cover

a. 20-ft soil - 121 x 43,560 x 20/27 = 3,904,300 yd³

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

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

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

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

Volume of solids

\[
\frac{25 \text{ g/l}(T.D.S.) \times 2100 \text{ T} \times 2000 \text{ lb} \times \frac{1.454 \text{ lb/g}}{\text{lb} \times 365 \text{ d} \times 20 \text{ yr}}}{454 \text{ g/lb} \times 120 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} = 236,600 \text{ yd}^3
\]

Assume pile 10 ft thick

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

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

A. 20-ft soil cover

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

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

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

Soil: \(2 \times 15 \times \frac{43,560}{27} = 48,400 \text{ yd}^3\)
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 yd³

11. 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 x 120% = 67 Acres

3. Assume square \((67 \times 43,560)\)^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. Clay - \(10 \times 15 \times 1708/27 = 9,500 \text{ yd}^3\)
   b. 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. 20-ft soil - \(67 \times 43,560 \times 20/27 = 2,161,900 \text{ yd}^3\)
   b. 2-in. asphalt + 2-ft soil

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

   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 yd$^3$

10. Alternate
   a-1. Plant native shrubs and grasses
   a-2. Maintain water, etc.
   b. Cover with coarse rock, 6-in. layer, 12,100 yd$^3$

11. Diversion dam = 25,000 yd$^3$
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% x 2000 T x 2 = water = 2000 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
      \[ \frac{5 \text{ g/l} \times \frac{2000 \text{ T ore} \times 1.05 \text{ lb} \times 2000 \text{ lb}}{454 \text{ lb/ton}}} {454 \text{ g/lb} \times 2000 \text{ lb/ton}} = 10 \text{ T/day} \]
   3. Equipment
      Thickener, area = 6 ft\(^2\)/T/day x 1000 T/day = 6000 ft\(^2\)
      Filter continuous, area = \[ \frac{1000 \text{ T} \times 2000 \text{ lb/T}}{600 \text{ lb/ft}^2/\text{day}} \approx 3300 \text{ ft}^2 \]

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 ft\(^2\)
      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 x 1000 = 670 T/day
3. Water load to be evaporated - \( \frac{30\%}{70\%} \times 1000 + 200 = 630 \text{T/day} \)
4. Equipment (see flowsheet)
   a. Asphalt unloader
   b. Asphalt storage, 3-day supply = 2000 T
   c. Wiped-film evaporator (160°C)
      (13) 200-ft\(^2\) 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 x 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. Volume of Sand = \( \frac{2000 \text{T} \times 2000 \text{ lb} \times 50\% \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb/ft}^3 \times 27} \)
   \[ = 4.51 \times 10^9 \text{ yd}^3 \]
2. Volume of fixed slimes
   a. Volume of asphalt-slimes
      \[
      \frac{2000 \text{ T} \times 2000 \text{ lb} \times 50\% \times 1.67 \times 365 \text{ d} \times 20 \text{ yr}}{62.4 \times 1.6 \times 27 \text{ ft}^3/\text{yd}^3 \times 20 \text{ yr}} = 9.04 \times 10^6 \text{ yd}^3
      \]
   b. Volume of concrete slimes:
      \[
      \frac{2000 \text{ T} \times 2000 \text{ lb} \times 50\% \times 1.05 \times 365 \text{ d} \times 20 \text{ yr}}{120 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3} = 4.73 \times 10^6 \text{ yd}^3
      \]
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
   a. Asphalt - \[
      \frac{20 \text{ ft} \times 168A \times 43,560}{27} = 5,421,000 \text{ yd}^3
      \]
   b. Concrete - \[
      \frac{20 \times 115A \times 43,560}{27} = 3,711,000 \text{ yd}^3
      \]
5. Stabilize
   a-1. Plant native shrubs and grasses
   a-2. Maintain, water, etc.
   b. Cover with coarse rock, 6-in. layer
      1. Volume for asphalt = 115,300 \text{ yd}^3
      2. Volume for concrete = 92,800 \text{ yd}^3

E. Alternate (disposal in underground mine) - New Mexico
1. Volume of sand = \(4.5 \times 10^6 \text{ yd}^3\)
2. Volume of fixed slimes
   a. Volume of asphalt-slime = \(9.0 \times 10^6 \text{ yd}^3\)
   b. Volume of concrete-slime = \(4.7 \times 10^6 \text{ yd}^3\)
3. Transportation and placement in mine
### Table: Tony/day

<table>
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<sup>a</sup>Contains asphalt
<sup>b</sup>Asphalt

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


3. Other references are cited locally.
## Summary of Radwaste Treatment Cases for Airborne Emissions from Mill

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Type of Equipment Used</th>
<th>Capital Cost&lt;sup&gt;a&lt;/sup&gt; (in Dollars)</th>
<th>Operating Costs&lt;sup&gt;b&lt;/sup&gt; ($/Year During Operating Life)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Orifice Wet impingement</td>
<td>88,000</td>
<td>10,800</td>
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<td>2</td>
<td>Wet impingement Low-energy venturi</td>
<td>111,000</td>
<td>15,300</td>
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<tr>
<td>3</td>
<td>Low energy venturi Medium-energy venturi</td>
<td>151,000</td>
<td>27,300</td>
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<td>4</td>
<td>Reverse jet bag filter High-energy venturi</td>
<td>262,000</td>
<td>39,400</td>
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<tr>
<td>5</td>
<td>Reverse jet bag filter High-energy venturi plus HEPA filter</td>
<td>314,000</td>
<td>42,600</td>
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<tr>
<td>6</td>
<td>Reverse jet bag filter High-energy venturi plus HEPA filter</td>
<td>540,000</td>
<td>67,600</td>
</tr>
<tr>
<td>7</td>
<td>Reverse jet bag filter High-energy venturi plus HEPA filter, plus HEPAC filter, plus charcoal delay, trap plus HEPAC filter, air flow 10% of Case 6</td>
<td>3,942,000</td>
<td>59,500</td>
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</tbody>
</table>

<sup>a</sup>Does not include interest during construction or allowance for contingency.

<sup>b</sup>Does 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 $88,000

Annual Operating Costs

Ore Dust Collectors: Power $6,930
Water 270
Maintenance, Labor, & Supplies 580

Concentrate Dust Collector: Power $2,320
Water 440
Maintenance, Labor & Supplies 289

Total Estimated Annual Operating Cost $10,829
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

1 @ 2,720-cfm capacity

Concentrate Dust Collector: 1 @ 6,100-cfm capacity

Total Estimated Installed Cost of Collection Systems

Annual Operating Costs

Ore Dust Collectors: Power

Water

Maintenance, labor, & supplies

Concentrate Dust Collector: Power

Water

Maintenance, labor, and supplies

Total Estimated Annual Operating Cost

$15,354
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 $37,000

Total Estimated Installed Cost of Collection Systems $151,000

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 $27,277
Case 4

Basic Treatment System: Windbreak around ore pile

Ore Dusts: Reverse jet bag filter
Concentrate Dusts: Venturi (high energy) plus mist eliminator

Capital Costs

<table>
<thead>
<tr>
<th>System</th>
<th>Capacity</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Ore Pile Windbreak</td>
<td></td>
<td>$7,000</td>
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<tr>
<td>Ore Dust Collectors:</td>
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</tr>
<tr>
<td>1 @ 27,200-cfm capacity</td>
<td></td>
<td>$172,000</td>
</tr>
<tr>
<td>1 @ 2,720-cfm capacity</td>
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<td>$43,000</td>
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<td>Concentrate Dust Collector:</td>
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<td>$40,000</td>
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<tr>
<td>Total Estimated Installed Cost of Collection Systems</td>
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<td>$262,000</td>
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Annual Operating Costs

<table>
<thead>
<tr>
<th>Collector Type</th>
<th>Power</th>
<th>Water</th>
<th>Maintenance, labor, &amp; supplies</th>
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<tbody>
<tr>
<td>Ore Dust Collectors:</td>
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<td>9,747</td>
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<tr>
<td>Water</td>
<td>0</td>
<td></td>
<td>16,510</td>
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<tr>
<td>Maintenance, labor, &amp; supplies</td>
<td>11,900</td>
<td>970</td>
<td>322</td>
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<tr>
<td>Concentrate Dust Collector:</td>
<td></td>
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</tr>
<tr>
<td>Water</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td>Maintenance, labor, &amp; supplies</td>
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<td></td>
<td>0</td>
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</table>

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 $314,000

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 $42,600
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

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Pile Windbreak</td>
<td>$7,000</td>
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<tr>
<td>Ore Dust Collectors: As for Case 5</td>
<td>$215,000</td>
</tr>
<tr>
<td>HEPA Filters</td>
<td>$226,000</td>
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<tr>
<td>Concentrate Dust Collector: As for Case 5</td>
<td>$40,000</td>
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<tr>
<td>HEPA Filter</td>
<td>$52,000</td>
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<tr>
<td><strong>Total Estimated Cost of Collection Systems</strong></td>
<td>$540,000</td>
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Operating Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
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<tr>
<td>Ore Dust (Case 5 + HEPA scaled up from Case 7)</td>
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<tr>
<td>Concentrate Dust Collector (Same as Case 5)</td>
<td>$16,343</td>
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<tr>
<td><strong>Total Estimated Annual Operating Cost</strong></td>
<td>$67,600</td>
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</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Pile Windbreak</td>
<td>$7,000</td>
</tr>
<tr>
<td>Ore Dust Collectors: Jet bag filter, 4280-cfm capacity</td>
<td>$57,000</td>
</tr>
<tr>
<td>Jet bag filter, 476-cfm capacity</td>
<td>$15,000</td>
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<tr>
<td>Charcoal delay trap</td>
<td>$3,742,000</td>
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<tr>
<td>Air Heaters</td>
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<tr>
<td>HEPA filter</td>
<td>36,000</td>
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<tr>
<td>Concentrate Dust Collectors: Same as Case 5</td>
<td>$92,000</td>
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<tr>
<td>Total Estimated Cost of Collection Systems</td>
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Operating Costs

<table>
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<th>Description</th>
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<tr>
<td>Ore Dust Collectors: Gas</td>
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<tr>
<td>Power</td>
<td>$3,758</td>
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<tr>
<td>Maintenance, labor, and supplies</td>
<td>39,144</td>
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<tr>
<td>Concentrate dust collectors: Same as Case 5</td>
<td>16,343</td>
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<tr>
<td>Total Estimated Annual Operating Cost</td>
<td>$59,525</td>
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A2.2 Derivation of Capital Costs for Airborne Waste Treatment

Case 1

<table>
<thead>
<tr>
<th>Material</th>
<th>Average Pressure Drop (in. H₂O)</th>
<th>Approximate 1965 Cost ($/10⁶ cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Dusts</td>
<td>Orifice (baffle, self-induced spray deduster)</td>
<td>93.6</td>
</tr>
<tr>
<td>Conc. Dusts</td>
<td>Wet impingement (irrigated, target, perforated plate)</td>
<td>97.9</td>
</tr>
</tbody>
</table>

**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 x 10⁶ cu ft

Daily volume of air from bins = 2,000 cfm x 24 hr/day x 60 = 2.88 x 10⁶ cu ft

:. Total volume of air to collector per day = 22.08 x 10⁶ 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 x 0.936)

= 0.127 - 0.119

= 0.008 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.

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


The annual CE Plant Cost Index for 1965 was 104.2.

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

\[ \text{Use escalation factor of 1.353 to go from 1965 to March 1973 costs.} \]

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

**Concentrate Dusts**

Air flow = 4,500 cfm

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

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.

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

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

\[ \text{Estimated cost of this size unit} = \left( \frac{27,200}{60,000} \right)^{0.8} \times $58,900 \times 1.353 = $49,600 \]

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

\[ \text{Estimated cost of this size unit} = \left( \frac{2,720}{60,000} \right)^{0.8} \times $58,900 \times 1.353 = $12,500 \]
Case 2

<table>
<thead>
<tr>
<th>Material</th>
<th>Average Pressure Drop (H₂O)</th>
<th>Approximate 1965 Cost ($/10^6 cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Dusts Wet impingement (irrigated target, perforated plate)</td>
<td>97.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Cone. Dusts Venturi; low energy (followed by a separator to remove entrained water droplets)</td>
<td>99.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>

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).

\[ \text{Estimated installed cost of a } 27,200\text{-cfm unit} = \left(\frac{27,200}{60,000}\right)^{0.66} \times 72,800 \times 1.353 = 61,400 \]

\[ \text{Estimated installed cost of a } 2,720\text{-cfm unit} = \left(\frac{2,720}{60,000}\right)^{0.66} \times 72,800 \times 1.353 = 15,400 \]

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).
\[ \text{Estimated installed cost of a 6100-cfm unit} = \left( \frac{6100}{60000} \right)^{0.6} \times 89500 \times 1.353 = 30800 \]

Note: The subsequent separator to remove entrained droplets from the exhaust gas stream is a necessary adjunct for the venturi scrubber (see Celcote Air Pollution Control Equipment Bulletin 12-1, Revised June 1968, pp. 11 - Equip. Catalogs, Dust and Fume Collection).
Case 3

<table>
<thead>
<tr>
<th>Material</th>
<th>Treatment</th>
<th>Average Pressure Drop (in. H₂O)</th>
<th>Eff. (%)</th>
<th>Approximate 1965 Cost ($/10^6 cu ft)</th>
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<tbody>
<tr>
<td>Ore Dusts</td>
<td>Venturi; low energy (followed by a separator to remove entrained water droplets)</td>
<td>99.5</td>
<td>12.5</td>
<td>1.03</td>
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<tr>
<td>Conc. Dusts</td>
<td>Venturi; med. energy (followed by mist eliminator)</td>
<td>99.7</td>
<td>20.0</td>
<td>1.39</td>
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</tbody>
</table>

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).

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

Cost of mist eliminator @ $0.65 per cfm = 27,200 x $0.65 = 17,700

Estimated installed cost of venturi and eliminator = 75,400 + 17,700 = $93,100

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

Cost of mist eliminator @ $0.65 per cfm = 2,720 x $0.65 = 1,800

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).

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

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.

\[ \therefore \text{Estimated installed cost of venturi plus mist eliminator} = \]$32,700 + $4,000 = $36,700
Case 4

<table>
<thead>
<tr>
<th>Material</th>
<th>Treatment</th>
<th>Eff. (%)</th>
<th>Pressure Drop (in H₂O)</th>
<th>Average 1965 Cost ($/10⁶ cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore dusts</td>
<td>Reverse jet bag filter</td>
<td>99.9</td>
<td>3.0</td>
<td>1.69</td>
</tr>
<tr>
<td>Conc. dusts</td>
<td>Venturi; high energy (followed by mist eliminator)</td>
<td>99.9</td>
<td>31.5</td>
<td>1.90</td>
</tr>
</tbody>
</table>

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.)

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

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

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

\[
\text{Estimated installed cost of venturi and eliminator} = 35,700 + 4,000 = 39,700
\]
Case 5

<table>
<thead>
<tr>
<th>Material</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore dusts</td>
<td>Same as Case 4</td>
</tr>
<tr>
<td>Concentrate dusts</td>
<td>Case 4 + HEPA filter</td>
</tr>
</tbody>
</table>

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.

Amount of moisture in air flow = \( \frac{3,670 \text{ cfm}}{12.38 \text{ cu ft/lb dry air}} \times \frac{0.0115 \text{ lb H₂O}}{\text{lb dry air}} = 3.41 \text{ lb H₂O} \)

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

∴ Amount of heat to be provided = 7.04 BTU/lb x 275 lb/min = 1,935 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).

∴ To provide 1,900 BTU/min, burn 2 cu ft/min gas + 20 cu ft of air/min

Gas volumes to heater = 3,670 + 2 + 20 = 3,692 cu ft/min


Estimated installed cost of heating unit = $500

From above, the gas volume fed to heater = 3,672 cfm

From gas law relationship \( V_2 = \frac{V_1 T_2}{T_1} \) 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.

∴ 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).
Estimated cost of HEPA filter to handle 3,890 cfm = \( \left( \frac{3,890}{5,000} \right)^{0.6} \times 17,750 \)

\[ = 11,500 \]

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

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

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

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

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

Heater

\[ = 500 \]

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.

\[
\frac{36,000 \times \frac{22,920 \text{ cfm}}{4,756 \text{ cfm}}}{4,756 \text{ cfm}} = 226,000
\]
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

\[ \text{Volume of ore pile} = 8,000 \text{ tons} \times 20 \text{ cu ft/ton} = 160,000 \text{ cu ft} \]

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

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

\[ \text{Volume of side toes per ft of length} = 32 \text{ cu ft} \]

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

\[ \therefore \text{Total volume} = 4,480 + 8,960 + 157,000 = 170,440 \text{ cu ft} \]

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

\[ \therefore \text{Length of windbreak} = (20 \text{ ft} \times 10 \text{ ft} + 28 \text{ ft}) \times 2 + (28 \text{ ft} \times 140 \text{ ft} + 28 \text{ ft}) = 376 \text{ ft} + 196 \text{ ft} = 572 \text{ ft} \]

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)

\[ \therefore \text{Assuming steel sheeting construction, then number of sheets required} = \frac{572 \text{ ft}}{3 \text{ ft/sheet}} = 191 \]
At 42.6 sq ft per sheet and $25 per 100 sq ft, then material cost =
191 x 42.6 sq ft x \frac{$25}{100 \text{ sq ft}}

\therefore \text{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%

\therefore \text{Estimated installed cost} = (2,035 + 300) \times 2 + 40\%

= 4,670 + 1,870 = $6,540

Using the information supplied by Hult Fence Limited, then

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

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

<table>
<thead>
<tr>
<th>Material</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Dusts</td>
<td>Case 4 + charcoal delay trap = HEPA filter at lower air flow</td>
</tr>
<tr>
<td>Concentrate Dusts</td>
<td>Same as Case 5</td>
</tr>
</tbody>
</table>

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.

\[ \therefore \text{Air flow from crusher} = 3,150 \text{ cfm} + \text{angles from ore bins} = 350 \text{ cfm} \]

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 = \( 3,150 \times 1.36 = 4,280 \text{ cfm} \)

Design air flow from ore bins = \( 350 \times 1.36 = 476 \text{ cfm} \)

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

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

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

\[ = 7.04 \text{ BTU/lb} \]

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

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

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

\[ \therefore \text{Gas volume to heater} = 4,756 + 2.51 + 25.1 = 4,783.61 \text{ cfm} \]
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 = \( \frac{V_1 T_1}{T_2} \) 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 = 16 π or 50.25 sq ft

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

:. Amount of charcoal to fill units at 14 lb per cu ft = 101 units \( \times 1,000 \text{ cu ft} \times 14 \text{ lb/cu ft} = 1.4 \text{ million lb} \)

:. 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.

:. Amount of charcoal required = 150 \( \times 1,000 \text{ cu ft} \times 14 \text{ lb/cu ft} = 2.1 \text{ million lb} \)

:. 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 ft x 126 ft x 0.5 ft = 308 cu yd

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

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

:. 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 π x 20 = 7,520 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)

. Estimated cost of unit for 4,756 cfm = \( \frac{5,040}{8,000} \times 6 \times 6 \times 8,000 \) x $17,750 = $13,400

. 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:

<table>
<thead>
<tr>
<th>Component</th>
<th>Capital Cost</th>
<th>Power Cost/yr</th>
<th>Water Cost/yr</th>
<th>Maintenance/yr</th>
<th>Total Operating/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice Scrubber (60,000-cfm capacity)</td>
<td>$58,900</td>
<td>$7,900</td>
<td>$308</td>
<td>$590</td>
<td>$8,800</td>
</tr>
</tbody>
</table>

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.

Power cost per year = \( \left( \frac{27,200 \text{ cfm}}{60,000 \text{ cfm}} \right)^{0.6} \times 7,900 \times (1.024)^6 \)

\[ = \frac{1}{1.609} \times 7,900 \times 1.128 = $5,540/yr \]

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

Maintenance - Labor = \( \frac{1}{1.609} \times 590 \times 0.60 \times (1.05^4) \times 1.050 = $290 \)

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

Estimated maintenance cost = $293 + $173 = $463/yr.

\[ \therefore \text{Estimated total operating cost/yr} = $5,540 + 216 + 463 = $6,219 \]
Ore Dust Orifice Scrubber, 2720-cfm capacity

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

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

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

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

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

Estimated total maintenance cost = $73 + $44 = $117/yr

Estimated total operating cost/yr = $1,390 + $54 + $117 = $1,461

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

Power cost/yr = $8,120

Water cost/yr = $1,540

Maintenance cost/yr = $900

Total maintenance cost/yr = $10,600

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

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

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

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

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

Estimated total maintenance cost = $181 + $108 = $289/yr

Estimated total operating cost/yr = $2,320 + $440 + $289 = $3,049
Case 2

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

27,200-cfm unit - Power = $8,120 x 1.128 = $9,139.04
Water = $1,540 x 1.128 = $1,738.08
Maintenance, Labor = $900 x 0.60 x 1.258 x 1.050 = $671.70
Materials = $900 x 0.40 x 1.145 x 1.03 = $470.22
Estimated total maintenance cost = $708/yr

.: Estimated total operating cost for this unit = $9,139.04 + $1,738.08 + $708 = $11,605.12/yr

2,720-cfm unit - Power = $8,120 x 1.128 = $9,139.04
Water = $1,540 x 1.128 = $1,738.08
Maintenance, Labor = $900 x 0.60 x 1.258 x 1.050 = $671.70
Materials = $900 x 0.40 x 1.145 x 1.03 = $470.22
Estimated total maintenance cost = $177/yr

.: Estimated total operating cost for this unit = $9,139.04 + $1,738.08 + $177 = $11,034.19/yr

Concentrate dust low-energy venturi scrubber; operating costs given in Power, February 1971, p. 63:

Power = $16,400/yr
Water = $3,390/yr
Maintenance = $900/yr
Total = $20,690/yr

6,100-cfm unit - Power = \frac{6,100}{60,000} \times 16,400 \times 1.128 \approx 0.25 \times 16,400 \times 1.128 = $4,699/yr
Water = 0.25 \times 3,390 \times 1.128 = $970/yr
Maintenance, Labor = 0.254 x $1,018 x 0.60 x 1.258 x 1.050 = $205/yr

Materials = 0.254 x $1,018 x 0.40 x 1.145 x 1.03 = $122/yr

Estimated total maintenance cost = $327/yr

Estimated total operating cost for this unit = $4,699 + 970 + 327 = $5,996/yr

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

Power cost = \( \frac{1}{1.608} \times 16,400 \times 1.128 = 11,500/yr \)

Water cost = \( \frac{1}{1.608} \times 3,390 \times 1.128 = 2,380/yr \)

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/yr.

Maintenance, Labor = \( \frac{1}{1.608} \times 1,110 \times 1.60 \times 1.258 \times 1.050 = 547/yr \)

Materials = \( \frac{1}{1.608} \times 1,110 \times 0.40 \times 1.145 \times 1.03 = 326/yr \)

Estimated total maintenance cost = $873/yr

\[ \therefore \text{Estimated total operating cost for this unit} = 11,500 + 2,380 + 873 = 14,753/yr \]

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

Power cost = \( \frac{1}{6.4} \times 16,400 \times 1.128 = 2,890 \)

Water cost = \( \frac{1}{6.4} \times 3,390 \times 1.128 = 596 \)

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/yr.

Maintenance, Labor = \( \frac{1}{6.4} \times 985 \times 0.60 \times 1.258 \times 1.050 = 122/yr \)

Materials = \( \frac{1}{6.4} \times 985 \times 0.40 \times 1.145 \times 1.03 = 73/yr \)

Estimated total maintenance cost = $195/yr

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

From Power, February 1971, p. 63

Operating costs - Power, cost/yr = $26,400

Water, cost/yr = $3,390

Maintenance, cost/yr = $900
Power = \( \frac{1}{3.94} \times 26,400 \times 1.128 = 7,550/yr \)

Water = \( \frac{1}{3.94} \times 3,390 \times 1.128 = 969/yr \)

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/yr.

Maintenance, Labor = \( \frac{1}{3.94} \times 1,010 \times 0.60 \times 1.258 \times 1.050 = 203/yr \)

Materials = \( \frac{1}{3.94} \times 1,010 \times 0.40 \times 1.145 \times 1.03 = 12/yr \)

Estimated total maintenance cost = $324/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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>$3,960 x $2.89/ft³ = $11,100</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$6,000 x $2.80/ft³ = $16,800 (bags changed twice/yr)</td>
</tr>
</tbody>
</table>

Consider 27,200-cfm unit:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>1/1.608 x $11,000 x 1.128 = $7,787/yr</td>
</tr>
<tr>
<td>Maintenance-Labor</td>
<td>1/1.608 x $16,800 x 0.60 x 1.258 x 1.05 = $8,260/yr</td>
</tr>
<tr>
<td>Materials</td>
<td>1/1.608 x $16,800 x 0.40 x 1.145 x 1.03 = $4,930/yr</td>
</tr>
</tbody>
</table>

Estimated total maintenance cost = $13,190/yr

Consider 2,720-cfm unit:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>1/6.4 x $11,100 x 1.128 = $1,960/yr</td>
</tr>
<tr>
<td>Maintenance-Labor</td>
<td>1/6.4 x $16,800 x 0.60 x 1.258 x 1.05 = $2,080/yr</td>
</tr>
<tr>
<td>Materials</td>
<td>1/6.4 x $16,800 x 0.40 x 1.145 x 1.0 = $1,240/yr</td>
</tr>
</tbody>
</table>

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:

- Power - $41,600 \times \frac{1}{3.94} \times 1.128 = $11,900/yr
- Water - $3,390 \times \frac{1}{3.94} \times 1.128 = $970/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/yr

- Maintenance - Labor = $1,005 \times 0.60 \times 1.258 \times 1.05 = $1,005/yr
- Materials = $1,005 \times 0.40 \times 1.145 \times 1.03 = $120/yr

Estimated total maintenance cost = $322/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

\[ \text{Gas consumption} = 180 \text{ days} \times 1,440 \text{ min/day} \times 2 \text{ cfm gas} \]

\[ = 518,000 \text{ cu ft} \]

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

Assuming an escalation of 2.4% per unit

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

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.

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).

\[ \therefore \text{Assume 1 prefilt}er + 1 \text{ HEPA cost} \$800 / 9 = \$89. \]
The unit in question uses 4 filters, i.e., cost per set = $356.

Allow for three changes per year. ' Annual Material Cost = $356 x 3 = $1,068

Assuming that the material cost is 40% of total maintenance cost, then labor at 60% of total maintenance cost = $1,068 x 0.60/0.40 = $1,600.

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

\[ \text{Estimated operating cost of HEPA filter - Power} = \$340 \]
\[ \text{Labor, Materials} = \$2,763 \]
\[ \$3,103 \]

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

\[ \text{Power: } \frac{1}{5.35} (\text{size factor, 165}) \times \$41,600 \times 1.128 = \$8,750 \]

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

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 x 1.0945 = $985/yr

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

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

' Estimated total maintenance cost = $233/yr

Summarizing, for concentrate dust collecting system, the operating costs are:
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Power</th>
<th>Water</th>
<th>Gas</th>
<th>Maintenance</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Venturi:</td>
<td>$8,750</td>
<td>715</td>
<td>$111</td>
<td>233</td>
<td>$9,698</td>
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<tr>
<td>Air Heater:</td>
<td>$111</td>
<td>100</td>
<td>111</td>
<td>211</td>
<td>$211</td>
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<tr>
<td>HEPA Filter:</td>
<td>$340</td>
<td></td>
<td></td>
<td>2,768</td>
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<tr>
<td></td>
<td>Power</td>
<td>Water</td>
<td>Gas</td>
<td>Maintenance</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>$9,090</td>
<td>715</td>
<td>111</td>
<td>3,101</td>
<td>$9,991</td>
</tr>
</tbody>
</table>
Case 6

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

\[
\frac{\$3,945 \times 29,920 \text{ cfm}}{4,756 \text{ cfm}} = \$25,000
\]
Case 7.

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

Reverse jet bag filter, cfm capacity - Power =

\[
\frac{1}{\text{size factor}} \times 11,100 \times 1.128 = \$2,560
\]

Maintenance - Labor =

\[
\frac{1}{4.89} \times 11,800 \times 0.60 \times 1.258 \times 1.05 = 2,722
\]

Maintenance - Materials =

\[
\frac{1}{4.89} \times 11,800 \times 0.40 \times 1.145 \times 1.03 = \$1,620
\]

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 =

\[
\frac{1}{18.2} \times 11,800 \times 0.60 \times 1.258 \times 1.05 = \$731
\]

Maintenance - Materials =

\[
\frac{1}{18.2} \times 11,800 \times 0.40 \times 1.145 \times 1.03 = \$436
\]

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

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Flowsheet</th>
<th>Wyoming Capital(^a) ($1000)</th>
<th>Wyoming Operating(^b) ($1000/yr)</th>
<th>New Mexico Capital(^a) ($1000)</th>
<th>New Mexico Operating(^b) ($1000/yr)</th>
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<tr>
<td>1</td>
<td>Acid</td>
<td>341</td>
<td>61</td>
<td>284</td>
<td>61</td>
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<td>279</td>
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<td>1977</td>
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<td>1974</td>
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<td>4564</td>
<td>66</td>
<td>4615</td>
<td>66</td>
</tr>
</tbody>
</table>

\(^a\) Does not include interest during construction or allowance for contingency.

\(^b\) Does not include allowance for contingency or fixed charges.
Summary - Case 1 - Wyoming - Solvent Extraction

I. 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 40,000

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
\[80 \times 0.746 \times 0.90 \times 24 \times 365 \times 0.01\] 5,000

$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 8,000

Total $51,000
Summary - Case 1 - New Mexico - Solvent Extraction

I. 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 40,000

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
I. 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

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

Same as Case 1, New Mexico, Solvent Extraction $47,000
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 4,000

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

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

I. 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 4,000

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

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

$1,385,000 ($1,384,000)

II. Operating Cost Per Year

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

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>$37,000</td>
</tr>
<tr>
<td>Maintenance labour</td>
<td>8,000</td>
</tr>
<tr>
<td>and supplies, 10% x 81,500</td>
<td></td>
</tr>
<tr>
<td>Fertilizer, 189/174 x 5220</td>
<td>6,000</td>
</tr>
<tr>
<td>Power</td>
<td>1,000</td>
</tr>
<tr>
<td>Total</td>
<td>$52,000</td>
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</table>

aCase 3, Wyoming, Solvent Extraction, same as Case 2 except 5(b) cover with 8-ft earth + 6-in. rock (4 x $484 + $706) $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 4,000 ($1,977,000)

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

\(^a\) Case 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 - Alkaline

I. 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 Additions

Case No.

4a, 4b, 7

Sealing area - 5/16 in. asphalt instead of 1/4 in. asphalt
$575,000/$3,750 = 153.3 A
[(3267 x 1.25) + 484] 153.3 A = $700,000

4a
20 ft earth + 6 in. rock
(10 x $484 + $706) 121 A = $671,000

4b
2 ft earth + 5/16 in. asphalt + 6 in. rock
(484 + 1.25 x $3267 + 706) 121 A = $638,000

7
2 ft earth + 1 in. asphalt + 6 in. rock
(484 + 4 x 3267 + 706) 121 A = $1,725,000
II. **Operating Cost Per Year**

A. Copperas treatment (operating supplies)
   Consumption - 0.42 x 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 x 37.60 = $5,764

B. Operating Labour - 1 man/shift
   Supervision
   $50,000
   $2,000

C. Maintenance labour and supplies per year
   \[
   \frac{10}{100} \times \frac{(15,491 + 93,065)}{3.5} = \$3102
   \]

D. Power - 91 x 0.746 x 0.90 x 24 x 365 x $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 - Alkaline

I. 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 Additions

Case No.
4a, 4b, 7

Sealing area - 5/16 in. asphalt
557,000/3,750 = 148.5 A
($3267 x 1.25 + $484) 148.5 A = $678,000

4a
20 ft earth + 6 in. rock
(10 x $484 + $706) 116 = $643,000

4b
2 ft earth + 5/16-in. asphalt + 6 in. rock
($484 + $3267 x 1.25 + $706) 116 = $612,000

7
2 ft earth + 1 in. asphalt + 6 in. rock
($484 + $3267 x 4 + $706) 116 = $1,654,000

II. Operating Cost Per Year

Same as Case 4a, Wyoming, Alkaline $66,000
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 Extraction

I. 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 Additions

Case 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 $2,000/year = $72,000
   Supervision, est. 1/3 x $15,000 = $5,000

B. Operating Supplies
   Quicklime consumption = 25.4 x 365 = 9,271 tons
   Est. cost delivered in bin = 9,271 x $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 x 0.746 x 0.90 x 24 x 365 x $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
I. **Capital Costs**

1. Neutralization  
   - Cases 4a, 4b, and 7 - New Mexico - Solvent Extraction  
   - $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 Additions**

**Case No.**

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<tr>
<th>Case No.</th>
<th>Sealing area - 5/16-in. asphalt</th>
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<td>(3267 x 1.25 + 484) 148.5 A</td>
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<td>20 ft earth + 6 in. rock</td>
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<td>(10 x $484 + $706) 116 A</td>
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<td>2 ft earth + 5/16 in. asphalt + 6 in. rock</td>
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<td>($454 + $3267 x 1.25 + $706) 116 A</td>
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<td>$612,000</td>
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<td>7</td>
<td>2 ft earth + 1 in. asphalt + 6 in. rock</td>
</tr>
<tr>
<td></td>
<td>($484 + $3267 x 4 + $706) 116 A</td>
</tr>
<tr>
<td></td>
<td>$1,654,000</td>
</tr>
</tbody>
</table>
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 - Alkaline

I. 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 A
   ($3267 x 1.25 + $484) 125.3 A
   $572,000
2. Sealing bottom and sides concrete pile
   ($3267 x 1.25 + $484)(117 A + 10 A)
   $580,000
3. 20 ft earth + 6 in. rock
   (10 x $484 + $706) 117 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 x 365 x $35 $1,277,000

C. Maintenance labour and supplies
   10% x \(\frac{(396,256 + 71,322)}{3.5}\) $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 - Alkaline

I. 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 A
   ($3267 x 1.25 + $484) 70.4 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

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

(61 + 15) acres = $43,846
Summary - Case 5 - Wyoming - Solvent Extraction

I. 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 x 12,000 = $108,000
   Supervision - 1 man = $15,000

B. Operating Supplies
   (a) Quicklime - 25.5 x 365 x $25 = $232,675
   (b) Cement - 100 x 365 x $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
Power cost = 280 \times 0.746 \times 0.90 \times 24 \times 365 \times \$0.01 = \$\ 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 Extraction

I. 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
   \[ \frac{417,000}{3750} = 111.2 \text{ A} \]
   \[ (\$3267 \times 1.25 + \$484) 111.2 \text{ A} \] $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

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

Based on (61 + 21) acres $44,000
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.

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

II. Operating Cost Per Year

<table>
<thead>
<tr>
<th>Item</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>123,000</td>
<td>123,000</td>
</tr>
<tr>
<td>Supplies</td>
<td>4,891,000</td>
<td>4,891,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>190,000</td>
<td>190,000</td>
</tr>
<tr>
<td>Steam and power</td>
<td>1,001,000</td>
<td>1,001,000</td>
</tr>
<tr>
<td>Trucking</td>
<td>97,000</td>
<td>61,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$6,302,000</strong></td>
<td><strong>$6,266,000</strong></td>
</tr>
</tbody>
</table>

III. Maintenance After Rehabilitation (seeded case only)

<table>
<thead>
<tr>
<th>Item</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per year</td>
<td>$48,000</td>
<td>$43,000</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Item</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sand slime separation equipment</td>
<td>64,000</td>
<td>64,000</td>
</tr>
<tr>
<td>2. Slime dewatering equipment</td>
<td>833,000</td>
<td>833,000</td>
</tr>
<tr>
<td>3. Evaporation equipment</td>
<td>1,408,000</td>
<td>1,408,000</td>
</tr>
<tr>
<td>4. Cement and concrete slurry equipment</td>
<td>234,000</td>
<td>234,000</td>
</tr>
<tr>
<td>5. Sand, cement slurry, and mine water pumping</td>
<td>61,000</td>
<td>164,000</td>
</tr>
<tr>
<td>6. Removing 2-ft topsoil from evap. pond</td>
<td>80,000</td>
<td>53,000</td>
</tr>
<tr>
<td>7. Dam construction</td>
<td>77,000</td>
<td>77,000</td>
</tr>
<tr>
<td>8. Sealing impounding area with 1/4-in. asphalt</td>
<td>633,000</td>
<td>422,000</td>
</tr>
<tr>
<td>9. Boiler</td>
<td>431,000</td>
<td>431,000</td>
</tr>
<tr>
<td>10. Loadout for sand</td>
<td>48,000</td>
<td></td>
</tr>
<tr>
<td>11. Diversion dams</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>12. Rehabilitation of impounding area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) 20-ft earth cover; seeding</td>
<td>846,000</td>
<td>558,000</td>
</tr>
<tr>
<td>(b) 6-in. rock cover in lieu of seeding</td>
<td>(921,000)</td>
<td>(607,000)</td>
</tr>
</tbody>
</table>
13. Water spray equipment  72,000  47,000
14. Road to landfill  21,000  nil

Corrections
1. Sealing area, 5/16-in. asphalt
   ($3267 \times 1.25 + $484)(115 \text{ A + 10A})  \$571,000
2. 20-ft earth + 6-in. rock
   (10 \times $484 + $706) 115 \text{ 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  37,000  -
   $1,346,000  $1,312,000

III. Maintenance After Rehabilitation (seeded case only)
   Cost per year  $50,000  $46,000
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.

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutralization:</td>
<td></td>
</tr>
<tr>
<td>Pneumatic lime unloader</td>
<td>$20,000</td>
</tr>
<tr>
<td>Storage silo and gravimetric feeder</td>
<td>26,000</td>
</tr>
<tr>
<td>Ball mill and belt feeder</td>
<td>26,000</td>
</tr>
<tr>
<td>Lime slurry circulation tank and pumps</td>
<td>8,000</td>
</tr>
<tr>
<td>Neutralization vessels with agitators</td>
<td>36,000</td>
</tr>
<tr>
<td>Instrumentation for neutralization</td>
<td>8,000</td>
</tr>
<tr>
<td>Air compressor</td>
<td>5,000</td>
</tr>
<tr>
<td>Thickener and pumps</td>
<td>110,000</td>
</tr>
<tr>
<td>Filters</td>
<td>95,000</td>
</tr>
<tr>
<td>Filtrate surge tank and pump</td>
<td>3,400</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$337,400</strong></td>
</tr>
</tbody>
</table>

| Sand Wash:                              |                |
| Classifiers and pumps                   | $19,000        |
| Load-out bin                            | 11,000         |
| Dump truck                              | 34,000         |
| **Subtotal**                            | **$64,000**    |
### Equipment Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator with preheater and condenser</td>
<td>$436,000</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>10,000</td>
</tr>
<tr>
<td>Condensate receiver and pump</td>
<td>3,600</td>
</tr>
<tr>
<td>Evaporator concentrate pump</td>
<td>1,300</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$450,900</strong></td>
</tr>
</tbody>
</table>

#### 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: 174,000

**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: 135,000

**Subtotal**: $224,400

**Total Plant**: Installation factor: 3.5 except on trucks
Plant Cost
Case 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 Cost
Case 6a
Asphalt alternative:
  Sand and slime to landfill
    Earth cover and seeding $6,198,000
    Earth and rock cover $6,200,000
  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
  Sand to mine, slime to landfill
    Earth cover and seeding $4,864,000
    Earth cover and rock cover $4,866,000

\[a\] See correction a) on p. 116.
\[b\] See correction b) on p. 116.
Corrections:

a) Case 6a, asphalt fixation
   20 ft earth + 6 in. rock
   \((10 \times 484 + 706) \times 146 = 810,000\)
   Total $6,200,000 - $810,000 = $5,390,000

b) Case 6b, cement fixation
   Sealing concrete area
   \(\left(3267 \times 1.25 + 484\right) \times (113 + 10) = 562,000\)
   \(\left(3267 + 484\right) \times (113 + 10) = 461,000\)
   Net increase = $101,000

   20 ft earth + 6 in. rock
   \((10 \times 484 + 706) \times 113 = 627,000\)
   Total = $5,261,000 + $101,000 - $627,000 = $4,735,000

II. Operating Cost Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision</td>
<td>$15,000</td>
</tr>
<tr>
<td>Operating labor</td>
<td>156,000</td>
</tr>
<tr>
<td>Lime</td>
<td>220,000</td>
</tr>
<tr>
<td>Power</td>
<td>37,000</td>
</tr>
<tr>
<td>Steam</td>
<td>490,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>85,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$1,003,000</strong></td>
</tr>
</tbody>
</table>
Case 6a
Asphalt Alternative:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt</td>
<td>$3,358,000</td>
</tr>
<tr>
<td>Power</td>
<td>6,300</td>
</tr>
<tr>
<td>Steam</td>
<td>272,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>77,000</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>$447,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>21,000</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common items</td>
<td>$1,003,000</td>
</tr>
<tr>
<td>Asphalt items</td>
<td>3,713,000</td>
</tr>
<tr>
<td>Trucking</td>
<td>93,000</td>
</tr>
</tbody>
</table>

$4,809,000

Most of sand to mine

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common items</td>
<td>1,003,000</td>
</tr>
<tr>
<td>Asphalt items</td>
<td>3,713,000</td>
</tr>
<tr>
<td>Trucking</td>
<td>49,000</td>
</tr>
</tbody>
</table>

$4,765,000
### Case 6b

**Cement**

**Sand and slime to landfill**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common items</td>
<td>$1,003,000</td>
</tr>
<tr>
<td>Cement items</td>
<td>468,000</td>
</tr>
<tr>
<td>Power</td>
<td>3,700</td>
</tr>
<tr>
<td>Trucking</td>
<td>51,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,525,700</strong></td>
</tr>
</tbody>
</table>

**Most of sand to mine**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common items</td>
<td>$1,003,000</td>
</tr>
<tr>
<td>Cement items</td>
<td>468,000</td>
</tr>
<tr>
<td>Power</td>
<td>4,800</td>
</tr>
<tr>
<td>Trucking</td>
<td><strong>N1L</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,475,800</strong></td>
</tr>
</tbody>
</table>
Cost Summary for Case 6c - Nitric Leach at Wyoming and New Mexico

I. Capital Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leach tanks</td>
<td>$270,000</td>
</tr>
<tr>
<td>C.C.D. thickeners and pumps</td>
<td>1,992,000</td>
</tr>
<tr>
<td>Evaporator</td>
<td>2,246,000</td>
</tr>
<tr>
<td>Distillation</td>
<td>1,051,000</td>
</tr>
<tr>
<td>Nitric acid surge tank</td>
<td>11,300</td>
</tr>
<tr>
<td>Water surge tank</td>
<td>25,000</td>
</tr>
<tr>
<td>Solvent extraction</td>
<td>516,000</td>
</tr>
<tr>
<td>Product evaporator</td>
<td>121,000</td>
</tr>
<tr>
<td>Calciner</td>
<td>400,000</td>
</tr>
<tr>
<td>Condenser - scrubber</td>
<td>42,000</td>
</tr>
<tr>
<td>Mix tank</td>
<td>1,700</td>
</tr>
<tr>
<td>Storage before mix tank</td>
<td>3,500</td>
</tr>
<tr>
<td>Boiler</td>
<td>348,000</td>
</tr>
</tbody>
</table>

Subtotal $7,027,500

Asphalt alternative:

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt unloading</td>
<td>$3,400</td>
</tr>
<tr>
<td>Asphalt storage and pumps</td>
<td>27,000</td>
</tr>
</tbody>
</table>

Subtotal $30,000

Cement alternative:

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement unloading</td>
<td>$20,000</td>
</tr>
<tr>
<td>Cement storage and feeder</td>
<td>16,600</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision</td>
<td>$15,000</td>
</tr>
<tr>
<td>Operating labour</td>
<td>252,000</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>73,000</td>
</tr>
<tr>
<td>Flocculant</td>
<td>88,000</td>
</tr>
<tr>
<td>TBP</td>
<td>537,000</td>
</tr>
<tr>
<td>Kerosene</td>
<td>91,000</td>
</tr>
<tr>
<td>Natural gas</td>
<td>79,000</td>
</tr>
<tr>
<td>Steam</td>
<td>135,000</td>
</tr>
<tr>
<td>Power</td>
<td>42,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>703,000</td>
</tr>
</tbody>
</table>

Subtotal: $2,015,000
Asphalt alternative:
- Asphalt
  - Maintenance $248,000
  - Subtotal $251,000

Cement alternative:
- Cement
  - Maintenance $128,000
  - 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.

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leach tanks with agitators</td>
<td>$132,000</td>
</tr>
<tr>
<td>C.C.D. thickeners and pumps</td>
<td>790,000</td>
</tr>
<tr>
<td>Solvent extraction and precipitation</td>
<td>341,000</td>
</tr>
<tr>
<td>Drying and packaging</td>
<td>56,000</td>
</tr>
<tr>
<td><strong>Total equipment cost</strong></td>
<td><strong>$1,319,000</strong></td>
</tr>
</tbody>
</table>

Installation factor = 3.5

Total installed cost $4,617,000

II. Operating Cost

Consumption of chemicals according to the Terms of Reference.

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision</td>
<td>$15,000</td>
</tr>
<tr>
<td>Operating labor</td>
<td>168,000</td>
</tr>
<tr>
<td>Materials</td>
<td></td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>722,700</td>
</tr>
<tr>
<td>Ammonia</td>
<td>53,700</td>
</tr>
<tr>
<td>Sodium chlorate</td>
<td>197,200</td>
</tr>
<tr>
<td>Flocculant</td>
<td>87,600</td>
</tr>
<tr>
<td>Amine</td>
<td>16,400</td>
</tr>
<tr>
<td>Alcohol</td>
<td>13,200</td>
</tr>
<tr>
<td>Kerosene</td>
<td>27,600</td>
</tr>
</tbody>
</table>
Power Maintenance

$ 33,500 131,800

Total

$1,466,700

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

**Summary** - 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 ft$^3$ 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)

<table>
<thead>
<tr>
<th>Staff</th>
<th>Hourly Rated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>20</td>
</tr>
<tr>
<td>Maximum</td>
<td>33</td>
</tr>
</tbody>
</table>

Detailed Work Force

<table>
<thead>
<tr>
<th></th>
<th>Day Shift</th>
<th>Afternoon Shift</th>
<th>Night Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. Supt.</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metallurgist</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conc. Foreman</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Crusher operator</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Conc. operators</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Conc. helper</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lab. Tech.</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clerk</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanics</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Electricians</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
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  125,000
   $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 18,000
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 U₃O₈
Assume soluble loss = 0.2% = 8 lb/day
Also assume 50 gpm total solution to tailings and 5 gpm seepage.
Seepage contains 5/50 x 8 = 0.8 lb U₃O₈/day
0.8 x 0.85 x 454 = 309 grams U/day
x 0.333 = 103 μCi/day U_{nat}
B. Highland Uranium Mill - Humble - Exxon  Converse County, Wyoming

"Environmental Report, July 1971"

2000 T.P.D. of 0.2% U₃O₈ ore

Leaching  50% solids; 95°F; 40 lb/ton H₂SO₄; 1 lb/ton NaClO₃; 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 (NH₃)

2 - 6 ft x 8 ft agitated tanks
3 ½ 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% U₃O₈ 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% U₃O₈.

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


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:

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

<table>
<thead>
<tr>
<th>Costs Assumed</th>
<th>Per yd³</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Earth (scraping and short haul)</td>
<td>$0.15</td>
</tr>
<tr>
<td>(b) Dam building (i) without clay core</td>
<td>0.74</td>
</tr>
<tr>
<td>(ii) with clay core</td>
<td>0.90 for both earth and clay</td>
</tr>
<tr>
<td>(c) Rock covering</td>
<td>0.675</td>
</tr>
<tr>
<td>(d) Excavating for clay soil trench</td>
<td>0.24</td>
</tr>
</tbody>
</table>
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 2,753 ft long x 10 ft across crest; Slope 2:1

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

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)
Estimated Cost

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 8-in. x 6-in. SRL-C pumps and drives</td>
<td>$5,200</td>
</tr>
<tr>
<td>2 - 40-hp, 1760-rpm motors and controls</td>
<td>2,460</td>
</tr>
<tr>
<td>1 - 14-ft x 14-ft pump suction tank</td>
<td>2,530</td>
</tr>
<tr>
<td>5800 ft 8-in.-diam Class 150, ABS pipe at (288.51/100 x 1.07)</td>
<td>17,900</td>
</tr>
<tr>
<td>500 ft - 2-in. spigotting hose and valving</td>
<td>1,000</td>
</tr>
<tr>
<td>Rubber lining pump suction tank, 772 ft² at 3.50</td>
<td>2,700</td>
</tr>
<tr>
<td>Total, Excluding Pipe</td>
<td>$13,890</td>
</tr>
</tbody>
</table>

Installation (not including tailings pipe) =

2.5 x 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 = \( \frac{1}{12} \times 40 \times \frac{3000}{8} = 7,500 \) BD ft
Pipe support = \( \frac{2}{12} \times 6 \times \frac{3000}{8} = 1500 \) 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 (5800 ft) $29,250
Summary of Tailings Pumping Installed - Capital Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps 2 - 8-in. x 6-in. SRL-C</td>
<td></td>
<td></td>
<td>5,200</td>
</tr>
<tr>
<td>Motors 2 - 40-hp, 1,750-rpm</td>
<td></td>
<td></td>
<td>2,460</td>
</tr>
<tr>
<td>Pump suction tank, 14-ft x 14-ft, rubber-lined</td>
<td></td>
<td></td>
<td>5,230</td>
</tr>
<tr>
<td>Tailings pipe, 3000 ft, 8 in. ABS</td>
<td></td>
<td></td>
<td>17,900</td>
</tr>
<tr>
<td>Spigotting hose and valving</td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Tailings and spigotting line trestles</td>
<td></td>
<td>29,250</td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td></td>
<td></td>
<td>34,725</td>
</tr>
</tbody>
</table>

Total Estimated Cost: $95,765

2. Removal of Top Soil for Eventual Use in Rehabilitation

Assume 6 in. average depth.

Volume = \( \frac{174 \times 43,560 \times 0.5}{27} = 140,500 \text{ cu yd} \)

Cost at $0.15/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 = \( \frac{2753 \times 50 \times 2}{27} = 10,200 \text{ cu yd} \)

Estimated cost = 10,200 x $0.15 = 1,530

(2) Initial Dam - Native Material
Volume of dam = 30,600 cu yd
Estimated laid-down cost for native material = 30,600 x 0.75 = $22,950
Compacting cost, estimated 30,600 x $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
Fertilizer, 700 lbs per acre at $10/cwt
Seed, rye or oats, 1-1/2 bu per acre
35 lbs grass seed at $3

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. $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 Vegetation

a-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 x 2750 + 2 x 2100 = 15,200 ft
- 2-in. pipe - 28 x 2300 = 64,400 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 $11.70
- $84.70

\[
152 \times 84.70 = 12,900
\]

- 2-in. polyethylene hose ($54.51 x 1.07) per 100 ft = $58.40
- 644 x 58.40 = $37,600
Alternative to 4, Case 1, Wyoming, Solvent Extraction

Cover with coarse rock, 6-in. layer - 140,400 yd$^3 = 190,000$ 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 = \[ ((20 \times 69) + (69 \times 2 \times 69)) \times 2753/27 = \]
$1,112,000$ cu yd

Volume of coarse fraction of tailings required $= 1,112,000 - 30,600 =
1,081,400$ cu yd $= \frac{1,081,400 \times 27 \times 120}{2,000} = 1,750,000$ 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 x 4 = $40,000
  \[ \therefore \text{per year} = \frac{40,000}{20} = 2,000 \]

Estimated labour required per year:
- 4-1/2 men for 12 months = $12,000 x 45 = $54,000
- Supplies, est. 20% of labor = 10,800
  \[ \text{Total estimated cost per year} = 66,800 \]

Maintenance After Rehabilitation:
- Yearly fertilizer - $30/acre x 174 = $5220/year
  \[ \therefore \text{Total} = 51,010/\text{year} \]

Re-rehabilitation of Dam Embankment

Area = \[ \frac{\sqrt{69^2 + 138^2 + 20}}{3,560} \times \frac{2753}{14,356} = 10.3 \text{ acres} \]

Estimated cost for covering surface with 6-in. coarse rock = $706 x 10.3 = $7272

Estimated cost for covering total area + embankment with 6-in. coarse rock = $706 x 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 x 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 = 8236 x $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 x 0.75 = $18,750
Compacting (bulldozer) est., 25,000 x 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 x 100 + 100 x 200) x \(\frac{2248}{27}\) = 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 x 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 x 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 x 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

Area = $[\sqrt{100^2 + 200^2} + 40] \frac{2,248}{43,560} = 13.6$ acres

Estimated cost for covering surface with 6-in. coarse rock $= 706 \times 13.6$

= $9602$
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

Volume = \( \frac{2248 \times 50 \times 2}{27} \) = 8326 cu yds

Est. cost = 8326 x $0.15 = $1249

(2) Initial dam

Volume = 25,000 cu yds

Est. cost for native material = 25,000 x 0.75 = $18,750

Compacting cost = 25,000 x 0.15 = $3750

Total estimated cost for dam construction = $22,500

(3) Building Dam to Ultimate Height with Tailings

Ultimate volume of dam = \((40 \times 100 + 100 \times 200)\) x \(\frac{2248}{27}\) = 2,000,000 cu yd

Volume of coarse fraction of tailings required = 2,000,000 - 25,000

= 1,975,000 cu yd

\(= \frac{1,975,000 \times 27 \times 120}{2000} = 3,200,000\) tons

Assuming 60% sand recovery, the tons of tailings that must be cycloned = \(\frac{3,200,000}{0.60}\) = 5,330,000

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 x 379 = $40,000
Plus riprapping cost of $9602 = $53,602
Water distribution piping
Factor directly on area = 116/174 x 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 x $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 40,000
$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 x 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)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailings pump and pipeline</td>
<td>$93,065</td>
</tr>
<tr>
<td>Tailings dam construction - initial</td>
<td>22,500</td>
</tr>
<tr>
<td>Rehabilitation of tailings area</td>
<td>82,000</td>
</tr>
</tbody>
</table>
CASES 2 AND 3* - 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) \text{ cu yd } \times 0.90 = $82,635
   (3) Estimated Cost Placing and Compacting Native Material
       (coarser material on the downstream face to provide drainage)
       \(1,735,100 \text{ cu yd } \times 0.90 = $1,561,590

*See Summary, p. 91.
(4) Riprapping downstream and upstream slopes (2:1 slopes) with 6-in. rock cover

Volume required \[= \frac{2 \times 221 \times 2275 \times 0.5}{27} = 18,600 \text{ cu yd}\]

Estimated cost at $0.875/cu yd = 18,600 x 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 x 258 = $30,700

(b) Soil cover, 2 ft, volume = 384,000 cu yd

Estimated cost of reclaiming and spreading = 384,000 x $0.15 = $57,600

(c) Water distribution piping = 119 \times \frac{174}{174} \times 75,000 = $51,200
CASES 2 AND 3\textsuperscript{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

\textsuperscript{a}See Summary, p. 92.
CASES 2 AND 3<sup>a</sup> - 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

\[
\frac{189 \times 43,560 \times 2}{27} = 609,840 \text{ cu yd}
\]
Cost = 609,840 x $0.15 = $91,476

3. Tailings Dam Construction

(1) Excavate core trench as in Case 2, Wyoming, Alkaline

\[
\frac{8 \times 10 \times 2872}{27} = 8,510 \text{ cu yd}
\]
Estimated cost at $0.24/cu yd = $2042

(2) Placing and compacting clay

\[
\frac{10 \times 65 \times 2872}{27} + 10,637 = 78,778 \text{ cu yd}
\]
Estimated cost = 79,778 x 0.90 = $71,800

(3) Estimated cost of placing and compacting native materials

968,000 x 0.90 = $871,200

(4) Riprapping downstream and upstream slopes with 6-in. rock cover

Volume required = \[
\frac{2 \times 145 \times 2872 \times 0.5}{27} = 15,424 \text{ cu yd}
\]
Estimated cost at $706/acre or $0.875/cu yd = 15,424 x 0.875 = $13,496

Total tailings dam construction = $958,538

<sup>a</sup>See 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 = \frac{189}{174} \times 75,000 = $81,500
CASES 2 AND 3a - 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

a See Summary, p. 94.
CASES 4a, 4b AND 7 - WYOMING - ALKALINE

A. Copperas Treatment

(a) Copperas feed tank - 2000 gal., wood, agitated
   Use 8-ft-dim x 8-ft tank
   Approx. cost 8-ft x 8-ft agitator, 10-hp motor $3500

(b) Metering pump, 1 gpm
   Pump through a loop line with a bleed to the
tailings pump box
   Installed cost = 4426 x 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
   Cost = \( \frac{121 \times 43,560 \times 2}{27} \) x $0.15 = $58,564

3. Tailings dam construction
   (1) Excavate core trench
   Cost = \( \frac{8 \times 10 \times 2298}{27} \) x $0.24 = $1634

   (2) Placing and compacting clay
   Volume = \( \frac{10 \times 97 \times 2298}{27} + \frac{10 \times 10 \times 2298}{27} \) = 91,069 cu yd
   Est. cost = 91,069 x $0.90 = $81,962

   (3) Placing and compacting native material (using 3:1
       upstream, slope; 2:1 downstream)
   Volume = 2,084,541 cu yd
   Cost = 2,084,541 x $0.90 = $1,876,087
4. Sealing tailings area with asphalt

Average height of sides = 48-1/2 ft
Assume sidewalls are sloped 3 to 1.

Area of sides to be sealed = \(\frac{2 \times 153.5 \times 2298}{43,560}\) acres = 16.2 acres

Area of dam to be sealed = \(\frac{307 \times 2298}{43,560}\) = 16.2 acres

Area of bottom of pond = 12.1 acres

Total area to be sealed = 153.4 acres

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 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.

Cost for installed asphalt = 48.5¢ per sq yd.

Cost for installed asphalt $.50 in 1966 = 50 \times 1.35 = $0.675 per square yard at 1/4-in. thickness.
(a) Cost installed = \( \frac{153.4 \times 43,560}{9} \times 0.675 \times 603 = 501,158 \)$

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) Dirt cover, 2 ft = \( \frac{153.4 \times 43,560 \times 2}{27} \) = 494,971 cu yd

Cost = 494,971 x $0.15 = $74,246

5. Rehabilitation of tailings area

(a) Soil cover, 20 ft

3,904,300 cu yd at $0.15 = $585,645

(b) Asphalt and dirt cover

Cost of asphalt installed = \( \frac{121 \times 43,560}{9} \times 0.675 = 395,307 \)$

Cost of 2-ft dirt = 390,400 cu yd

390,400 x $0.15 = $58,560

(c) Preparation of surface and seeding

121 x $258 = $31,218

(d) Water distribution piping

121/174 x $75,000 = $52,100

(e) Diversion dams = $3,750

(f) Alternative to (c) 6-in. rock cover

121 x $706 = $85,426
CASES 4a, 4b, AND 7 - NEW MEXICO - ALKALINE

A. 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 x $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 x $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 x $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 x $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
Area of dam to be sealed = \( \frac{316 \times 2248}{43,560} \) = 16.3 acres
Area of bottom of pond = 116 acres
Total area to be sealed = 148.6 acres
Amount of sealant (2 in. thick) = \( \frac{2 \times 148.6 \times 43,560 \times 62}{12 \times 2,000} \)
= 33,444 tons
(a) Asphalt cost installed = \( \frac{148.6 \times 43,560}{9} \times 0.675 \) = $485,476
(b) 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 cu yd at $0.15 = $561,435
(b) Asphalt and dirt cover
Cost of asphalt applied = \( \frac{116 \times 43,560 \times 0.675}{9} \) = $378,972
Cost of 2-ft dirt = 374,300 x $0.15 = $56,145
(c) Preparation of surface and seeding - 116 x $258 = $29,928

6. Water distribution piping = 116/174 x $5,000 = $50,000

7. Diversion dams
$3,750

5(d). Alternative to (c) - 6-in. rock cover = 116 x $706 = $81,896
A. **Neutralization**

Lime requirement based on 100% reactivity = $34.4 \text{T } \text{Ca(OH)}_2/\text{day}$

$= \text{approx. } 2/3 \times 34.4 = 22.9 \text{T CaO/day}$

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

$= 177.8/0.75 = 237 \text{ tons CaO}$

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 $= 0.80 \times 25.4 = 20.3$ (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 $18^2/30^2 x 300 = 108$ 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

Cost = $4,630

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 = $2062

   (2) Placing and compacting clay
       Volume = $10 x 63 x 2900 + 10 x 10 x 2900 = 78,406$ 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

Volume required = \( \frac{199 \times 2900 \times 0.5}{27} \) = 10,687 cu yd

Cost = 10,687 \times 0.875 = $9,351

Total tailings dam construction = $1,162,905

4. Sealing Tailings Area with Asphalt

Ave. height of sides = 31.5 ft; assume 3:1 slope.

Area of sides to be sealed = \( \frac{2 \times 99.6 \times 2900}{43,560} \) = 13.3 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

Amount of sealant (1/4-in. thick) = \( \frac{0.25 \times 219.6 \times 43,560 \times 62}{12 \times 2000} \) = 6177.9 tons

(a) Cost of asphalt installed = \( \frac{219.6 \times 43,560}{9} \times 0.675 \) = $717,433

(b) Dirt cover = \( \frac{219.6 \times 43,560 \times 2}{27} \times 0.15 \times 2 \) = $106,286

:. cost of asphalt and dirt cover = $823,719

5. Rehabilitation of Tailings Area

(a) Soil cover - 20 ft

6,227,000 cu yd at $0.15 = $934,050

(b) Asphalt and dirt cover

Cost of asphalt installed = \( \frac{193 \times 43,560}{9} \times 0.675 \) = $630,531

Cost of 2-ft dirt, 623,000 cu yd \times 0.15 = $93,450

(c) Preparation of surface and seeding = 193 \times 258 = $49,794

(d) Water distribution piping = 193/174 \times 75,000 = $83,200
(e) Diversion dams = $3750

(f) Alternative to (e) - 6-in. rock cover =
    193 x $706 = $136,258
CASES 4a, 4b, AND 7 - NEW MEXICO
SOLVENT EXTRACTION

Capital Costs

A. 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 $8 \times 10 \times 2248 \times 0.24 = 1599$
   (2) Placing and compacting clay
   \[ \text{Vol.} = \frac{10 \times 100 \times 2248}{27} + \frac{10 \times 10 \times 2248}{27} = 91,585 \text{ cu yd} \]
   \[ \text{Cost} = 91,585 \times 0.90 = 82,426 \]
   (3) Placing and compacting native material (3:1 upstream, 2:1 downstream)
   \[ \text{Vol.} = 2,248,000 \text{ cu yd} \]
   \[ \text{Cost} = 2,248,000 \times 0.90 = 2,023,000 \]
   (4) Riprapping downstream slope with 6-in. rock cover
   \[ \text{Volume required (ref. p. 29)} = 9,324 \text{ cu yd} \]
   \[ \text{Cost} = 9,324 \times 0.875 = 8159 \]
   Total cost tailings dam construction $2,115,384

4. Sealing Tailings Area with Asphalt

Average height of sidewalks = 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
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:

- Pneumatic feeder
- 5 Model D1OB Krebs Cyclones
- Cement silo, 17 ft x 41 ft conical bottom, 250 tons
- 2 tailings storage tanks at 400-ton capacity, 17-ft diam x (28 ft cyl. + 1\(\frac{1}{4}\) ft conical) fitted with 150-psi water nozzles
- Gravimetric feeder, belt type, 20 T/H capacity
- 5-in. x 4-in. SRL-C pump - 20-hp motor
- Mixing tank - rubber-lined steel, 1\(\frac{1}{4}\) ft x 1\(\frac{1}{4}\) ft, 40-hp Lightning mixer
- 5-in. x 4-in. SRL-C pump, 25-hp motor, 160 TPH sand
Fill delivered underground at 68% solids (actually 63%).

Landfill area required - assume piling 50 ft high.

Area required for 20 years = \( \frac{2000 \times 7300 \times 20}{50 \times 43,560} = 134 \text{ acres} \)

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 = \(1933 \times 4 = \$7,732\)

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

\[
\frac{\pi \times 14^2 + \pi \times 49}{\pi \times 15 \times 15 + \pi \times 25} \times 4400 = \$8,624
\]
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 = 113,216 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 x 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 x 0.71 x 1.70) x 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
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
   Cost = $390,400 cu yd at 0.15 = $58,560

(b) Tailings Dam Construction
   (1) Excavate core trench
      Cost = \( \frac{3 \times 10 \times 2296 \times 0.24}{27} = 1633 \)

   (2) Placing and compacting clay
      Cost = \( \frac{10 \times 25 \times 2296 \times 0.90}{27} = 19,133 \)

   (3) Placing and compacting native material (3:1 upstream; 2:1 downstream)
      Volume = \( \frac{33.5 \times 2296 \times 0.5}{27} = 1424 \) cu yd
      Cost = 1,424 \times 0.875 = 1,246
      Total tailings dam construction = $76,515

(c) Sealing Pond With Asphalt
Average height of sides = 7.5 ft; assume 3:1 slope.
Area of sides to be sealed = \( \frac{2 \times 23.7 \times 2296}{43,560} = 2.5 \) 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) =
   \( \frac{0.25 \times 126 \times 43,560 \times 62}{12 \times 2000} = 3,545 \) tons
Cost of asphalt installed = \( \frac{126 \times 43,560}{9} \times 0.675 = 411,642 \)
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 = \( \frac{255 \times 43,560}{9} \) x 0.675 = $333,085
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 = \( \frac{149 \times 43,560}{9} \) x 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 x $258 = $38,442
(d)(6) = 149 x $706 = $105,194
(d)(4) = 149/174 x $75,000 = $65,224
(d)(1) + (d)(2) + (d)(3) = $1,531,441
CASE 5 - NEW MEXICO
ALKALINE

A. 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 x 1187 x 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 = \( \frac{913 \times 7300 \times 20}{50 \times 43,560} = 61 \text{ acres} \)
      Tons solution per year = 35/65 x 1187 x 365 = 233,284
      Volume = 0.15 x 913 x 3/2 = 205 USGPM
      Assume 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
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
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 = \( \frac{128}{174} \times 75,000 \) = $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 x 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 = \( \frac{76 \times 43,560}{9} \) x 0.675 = $248,292
Cost of dirt cover = 367,840/10 = $36,784
Total est. cost of alternative = $842,196

Then (d-3) = 76 x 258 = $19,608
(d-6) = 76 x 706 = $53,656
(d-4) = 76/174 x 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
   Cost = $61,952

2. Sealing pond with asphalt - extend to include bottom of total area (3.8 + 128) + 131.8 acres
   Cost = $493,155

3. Rehabilitation
   (a) Soil cover - 20 ft
       Cost = $619,520
   (b) Asphalt seal and dirt cover
       Cost = $480,128
   (c) Preparation for seeding = $33,024


5. Diversion dams = $3,750

Alternative to 3-c:
6-in. rock cover = $90,368
A. Neutralization

1. Liquid Waste - 1130 tons/day
   Lime required - ref. Case 4a, Wyoming, Solvent Extraction
   = 1130/3000 x 34.4 = 13.0 tons Ca(OH)₂
   Quicklime required (90% reactivity) =
   approx. 2/3 x 13.0/0.9 = 9.6 T.P.D.

   Lime required = 1870/3000 x 34.4 = 21.4 tons Ca(OH)₂
   Quicklime required (90% reactivity) =
   approx. 2/3 x 21.4/0.9 = 15.9 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 x 13) = 1204 tons solution/day

Size on upflow velocity of 0.7 fph

Then 0.7 x A = \( \frac{1204 x 32}{24} \) and A = 2293 ft²

Whence D = 54 ft

Cost of thickener factored from data, March 1973

\( \frac{54^2}{40^2} \cdot 0.8 \times 35,000 = \) $50,295

(2) **pH control equipment** = $8,000

(3) **Thickener Overflow Pump**

Tonnage (1204 - \( \frac{70}{30} \) x 28) = 1139 TPD = 190 USGPM

Distance to pump to evaporation pond assumed = 3000 ft

Use 4-in. pipe; T.D.H. = 132 + 15 = 147 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 =

\( \frac{1204 x 32}{12} = 3211 \) ft³

Use 3 tanks in series - 12 ft diam x 12 ft
(b) Sand-slime neutralization

Feed = \((2000 + 47 + 28) = 2075\) tons solids
\((1870 + 19 + 90) = 1979\) tons solution

\% solids = \(51.2\%\)

Volume of pulp/2 hrs = \(\frac{42.57 \times 2075}{12} = 7361\) 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

\[
\frac{\pi \times 36 \times 12}{\pi \times 81 \times 20}^{0.6} \times 11,925 \times 3 = 16,170
\]

(b) 14 ft diameter x 18 ft

\[
\frac{\pi \times 49 \times 18}{\pi \times 81 \times 20}^{0.6} \times 11,925 \times 3 = 24,828
\]

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

Then \[0.7A = \frac{1270 \times 32}{24}; A = 2419 \text{ ft}^2 \text{ and } D = 56 \text{ ft}\]
Combining the two thickeners - \[A = 4712 \text{ and } D = 78 \text{ ft}\].
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 x 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 x (1.8 x 0.71 x 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

\[ \text{Area} = \frac{2210 \times 20 \times 365 \times 20}{50 \times 43,560} = 148 \text{ acres} \]

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 x 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 = \[ \frac{1809 \times 365 \times 32}{4.0 \times 43,560} = 121 \text{ acres} \]

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 = \( \frac{269}{255} \times 956,505 \) = $1,009,019

(3) Preparation of surface and seeding = \( 269 \times 258 \) = $69,402

(4) Water distribution piping = \( \frac{269}{174} \times 75,000 \) = $115,948

(5) Diversion dams

(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) = \( \frac{269}{174} \times 75,000 \) = 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
   
   \[
   \text{Cost} = \frac{269}{121} \times 58,560 = 130,187
   \]

2. Sealing pond with asphalt - extend to include bottom of total area
   
   Area to be sealed = 5.0 + 269 = 274 acres
   
   \[
   \text{Cost} = \frac{274}{126} \times (411,642 + 58,560) = 1,022,503
   \]

3. Rehabilitation
   
   (a) Soil cover - 20 ft
       
       \[
       \text{Cost} = \frac{269}{255} \times 1,234,200 = 1,301,960
       \]
   
   (b) Asphalt seal and dirt cover
       
       \[
       \text{Cost} = \frac{269}{255} \times 956,505 = 1,009,019
       \]
   
   (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 x 1187 = 178 USGPM
On a 2-shift-per-day basis, the pumping rate will be 178 x 3/2 = 267 USGPM

Use 4-in.-diam pipe - T.D.H. = 7.0 x 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 x 1187 x 1/6 = 116.5 USGPM

It 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 hp
Increase capacity to 300 + 116.5 = 416.5 USGPM
Price factored = (416.5/190)^0.6 x 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. SRI-C pump with 7-1/2-hp motor $2,122
2 - 5 in. x 4 in. SRI-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 38,130

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
Cost = \( \frac{8 \times 10 \times 2160 \times 0.24}{27} = \) $1,536

(2) Placing and compacting clay
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
\[ \text{Cost} = \frac{33.5 \times 2160 \times 0.5}{27} \times 0.875 = \$1173 \]
Total tailings dam construction = \$72,009

(c) Sealing Pond with Asphalt
Area of sides = \[ \frac{2 \times 23.7 \times 2160}{43,560} \] = 2.35 acres
Area of upstream face of dam = 2.35 acres
Area of bottom = 107 acres
Total area to be sealed = 111.7 acres
Cost of asphalt installed = \[ \frac{111.7 \times 43,560}{9} \times 0.675 \] = \$364,924
Dirt cover = 345,000 \times 0.15 = \$51,750
Total = \$416,674

(d) Rehabilitation of Tailings Areas (61 + 107 acres)
(1) Soil cover = \[ \frac{168 \times 43,560 \times 20 \times 0.15}{27} \] = \$813,120
(2) Asphalt cover = \[ \frac{168 \times 43,560 \times 0.675}{9} \] = \$548,856
Dirt cover = \[ \frac{168 \times 43,560 \times 2 \times 0.15}{27} \] = \$81,312
(3) Preparation of surface and seeding
168 \times 258 = \$43,344
(4) Water distribution piping
168/1.74 \times 75,000 = \$72,414
(5) 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)
Cost of bulldozing = 338,000 \times \$0.90 = \$304,200
Cost of soil cover = 82/168 \times 813,120 = \$396,880
Cost of asphalt and dirt cover = \( \frac{82}{168} \times 630,168 \) = $307,582

Total cost Alternative A = $1,008,662

Then d-3 = 82 x 258 = $21,156

d-6 = 82 x 706 = $57,892

d-4 = \frac{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 acres)

Revised costs will be as follows:

1. Removing 2-ft topsoil from combined area
   Cost = \( \frac{168}{121} \times 58,560 = \$81,306 \)

2. Sealing pond with asphalt - extend to include bottom of combined area
   Area to be sealed = 5 + 168 = 173 acres
   Cost = \( \frac{173}{126} \times (411,642 + 58,560) = \$645,595 \)

3. Rehabilitation
   (a) Soil cover - 20 ft
      Cost = \( \frac{168}{255} \times 1,234,200 = \$813,120 \)
   (b) Asphalt seal and dirt cover
      Cost = \( \frac{168}{255} \times 956,505 = \$630,168 \)
   (c) Preparation for seeding, etc.
      168 x 258 = $43,344
   (d) Water distribution piping
      168/174 x 75,000 = $72,414
   (e) Diversion dams = $3,750

Alternative - 6-in. rock cover in lieu of seeding
706 x 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)
   Cost = 2 x 1580 = $3160

2. **Classifiers**

   Two - 48-in. single pitch
   Cost reference Case 6a solvent extraction
   7500 x 2 = $15,000

3. **Thickener**

   Size on upflow rate of 0.7 ft/hr
   Then \[
   0.7 A = \frac{4100 \times 32}{24} \quad \text{and } A = 7810 \text{ sq ft, } D = 100 \text{ ft}
   \]

   Specifications are for 6 sq ft/ton/24 hr = 6000 ft³
   \[D = 88 \text{ ft} \]

   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
   USGPM = 0.45 x 1000 = 450
   Price reference Case 6a solvent extraction
   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 x 2 = $3648
   Wallace and Associates

7. **Evaporator (including preheater and condenser) - 1900 TPD**
   Ref. Case 6a SX (1900/2230)\(^{0.6}\) x $435,864 = $396,200

8. **Wiped-Film Evaporator**
   Slime = 1000 tons at 61% solids
   Asphalt = 670 tons/day
   Ref. Case 6a SX - 639/300 x 6 = 13 units; 13 x $68,826 = $894,738
   Condenser - (639/300)\(^{0.6}\) x $25,000 = $39,250

9. **Asphalt Storage Tank - 2000 T capacity**
   Cost (ref. Case 6a SX) = (2000/1400)\(^{0.6}\) x 75,000 = $93,000

10. **Pumps**
    (a) Evaporator feed surge = (1900/6 = 317 USGPM)
        Cost ref. Case 6a SX - $1131
    (b) Condenser surge = (2330/6 = 388 USGPM)
        (388/300)\(^{0.6}\) x 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 \((2000 \times 365 \times 20 \times 20)/(50 \times 43,560) = 134 \text{ acres.}\)

Rehabilitation cost, seeding, and provision of water

Spray pipes = \(\frac{134}{166} (803,440 + 42,828 + 71,552) = \$740,891\)

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

<table>
<thead>
<tr>
<th>Alternative to seeding</th>
<th>134 acres</th>
<th>67 acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-in. rock cover</td>
<td>$94,604</td>
<td>$47,302</td>
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<tr>
<td>Prep. seeding, etc.</td>
<td>$34,572</td>
<td>$17,286</td>
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</tbody>
</table>

134 acres

67 acres
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) 2,454

(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)^.6 x 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 x 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 x 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.

\[ \text{cu ft of storage required} = \frac{1050 \times 365 \times 20 \times 2000}{110} \]

If \( L \) = length of landfill, then average depth = \( L \times 0.0422/2 \) and \( L \times 0.0211 \) L x 2298 = \( \frac{1050 \times 365 \times 20 \times 2000}{110} \)

\[ = 139,363,636 \]

Whence \( L^2 = 2,873,900 \) and \( L = 1700 \) ft.
Area = \( \frac{1700 \times 2298}{43,560} = 89 \) 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
Area of pond required = \( 35/65 \times 1050 \times 365 \times 32/4 \times \frac{1}{43,560} = 38 \) 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

\[ \text{cu ft of storage required} = \frac{2050 \times 365 \times 20 \times 2000}{105} \]

If \( L \) = length of landfill, average depth = \( L \times 0.0422/2 \) and \( L \times 0.0211 \) L x 2298 = \( \frac{2050 \times 365 \times 20 \times 2000}{105} \)

\[ L^2 = 5,878,749 \] and \( L = 2424 \) ft.
Area = \( \frac{2424 \times 2298}{43,560} = 128 \) acres
Total area (landfill + evaporation pond) = 166 acres
(7) Concrete slurry pump and pipeline

1050 tons solids/day at 65% solids = 0.15 x 1050 = 157.5 USGPM

Design pump rate = 157.5 x 1.25 = ~200 USGPM

Use 5 in. x 4 in. SRL-C pump; vertical lift = ~75 ft

Use 5-in. pipe; friction loss = 1.5 x 0.71 x 1.70 = 1.81 ft/100 ft

Assume 4000 ft pipeline

TDH = 40 x 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 x 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

Cost = \( \frac{166 \times 43,560 \times 2}{27} \times 0.15 = \$80,344 \)

(b) Tailings dam construction

\( \frac{2298}{2296} \times 76,515 = \$76,576 \)

(c) Cost of asphalt

Area of sides to be sealed

(1) 7.5 ft average vertical height

(2) Length of pool only = \( \frac{43,560 \times 38}{2298} = 720 \text{ ft} \)

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
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
Volume = \( \frac{20 \times 166 \times 43,560}{27} = 5,356,260 \text{ cu yd} \)
Cost = 5,356,260 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
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) Removal of 2 ft of topsoil \( \frac{3000 \times 40 \times 2}{27} = 8889 \text{ cu yd} \)

(2) 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/ft\(^3\). 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 \( \frac{206}{1050} \times 24 = 4.7 \) 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 = \( \frac{35}{65} \times 1243 = 670 \) tons per day = \( \frac{670}{6} = 112 \) 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
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
Cost = \( \frac{112.8 \times 43,560 \times 0.675}{9} = \$368,518 \)
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 x 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 x 3.5 = $48,482

2. Filtrate return to thickener
   1900 T.P.D. = 317 USGPM
   Design volume = 317 x 1.15 = 365 USGPM
   5-in. discharge pipe
   Cost of pump est. 1131 x 3.5 = $3958
   Cost of 4000 ft 5-in. pipe = 4000 x 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

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.

Case 2 - Burnt lime - 10 days
\[
\frac{\text{CaO}}{\text{Ca(OH)₂}} = \frac{56}{74} \times 300 \text{ t} = 227 \text{ T.}
\]

at 60#/ft³ = \(\frac{227 \times 2000}{60} = 7566 \text{ ft}³ = 20' \phi \times 25' \) high or = 15' φ x 43' high

Gravimetric (screw) feeder to ball mill = 1 tph CaO, 20% solids
Use 5' x 8' ball mill, 75 hp, 105 tpd CaO.
∴ 4 ft x 6 ft mill ~ 48% of volume, say 40 hp should be ample.

Pump slurry maximum rate 2 tph CaO at 20% ≈ 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

<table>
<thead>
<tr>
<th></th>
<th>CaOH₂</th>
<th>CaO</th>
</tr>
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<tbody>
<tr>
<td>Pneumatic unloader</td>
<td>$20,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>Silo</td>
<td>20'x60'+17'cone $37,000</td>
<td>15'x43'x13'cone $20,000</td>
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<tr>
<td>Feeder - vertical gravimetric</td>
<td>$6,000</td>
<td>$6,040</td>
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<tr>
<td>Ball mill</td>
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<td>$25,000</td>
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<tr>
<td>Belt feeder (for ball mill)</td>
<td></td>
<td>$1,000</td>
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<tr>
<td></td>
<td>$ 63,425</td>
<td>$ 72,040</td>
</tr>
</tbody>
</table>
With a consumption of 30 tpd, a saving of $1/ton would pay back the difference in less than a year. 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 = 5²/4² x 265 = $414 Say $425
7x7 = 7²/4² x 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
\[\left(\frac{4}{3}\right)^2 \times \frac{6}{5} \times 13,217 = 23,130 \text{ Say } 25,000\]

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' ø x 20' = $6500
Cost data 624.5 - Dominion Bridge, Dec. 14, 1970
Steel tank - 24' ø x 24' = 5100 + 9300 erection = $14,400
(wt 24,000 lb - total = 60#/lb)
For 20' x 60' use 20/24 x 60/24 x 14,400 x 1.18 esc. = 35,400 + conc.
Say 37,000
For 15 x 43 use 15/24 x 43/24 x 14,400 x 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
(agree with B.R.M.)

Thickener - 8' x 100'
Cost data 624.5 - March 22, 1973
20' ø x 12' steel tank only $56,500 erected
Feb. 16, 1972
90' ø 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' ø = $24,000
For 100' ø 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" ø 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 x $35,000 = $47,500 x 2 filters = $95,000
Total hp = 20 disc/6 x 133 hp = 443 hp Say 400 hp

Surge Tank - filtrate - 10,000 gal, Say 10' ø x 17'
Mild steel
Cost data 624.5 - Denver Equipment, March 16, 1973
10' ø x 12' = $1700
16' ø 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 ø 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
.: 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' Ø x 23.5 high (l)
60-in. cone for (l) = 13' high
.: 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' Ø x 20' = $6500 steel
16 ø x 16/ - O'Connor Tanks, Dec. 11, 1970
24 x 24' steel tank - $12,500 erected + foundations
For 15' Ø x 20' straight + 13' cone - Say $6500
Pneumatic chute gate - Say 1500 (guess)
Total - $8,000
For 8-hour storage (8/4) x $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
\( \frac{104 \times 8.33 \times 41.67}{2000} = 18.06 \) tph - OK

C. Evaporation Circuit
Evaporator - 2230 tpd water \( \frac{2230 \times 2000}{24} = 186,000 \) 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 - \( \frac{186,010}{55,130} \times 127,000 = \$272,415 \)

Escalate 10 years at 6% = 1.60 = \$435,864

Steam
Requires \( \frac{186,000}{55,100} \times 16,700 \) 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/ft\(^3\)
\[ \text{1 tpm} = 240 \text{ gpm} = \text{say 300 gpm 40 psi} \]
gpm x psi = 12,000
Base cost, 1968 = $850
For cast steel - 1.55
1973 cost = 850 x 1.55 x 1.30 esc = $1713

(b) Asphalt storage  3 day - 1400 ton
Volume = \( \frac{1400 \times 2000}{62.4} = 44,872 \text{ ft}^3 \)
\[ = 35' \phi \times 40' \text{ high} = 32,420 \text{ ft}^3 \]
\[ (35' \phi \times 40' = 45,200 \text{ ft}^2) \]
Area for insulation sides and top
\[ \pi x 35' \times 40' + \pi 17.5^2 = 5360 \text{ ft}^2 \]
Cost of insulation = 4.56/sq ft x 5360 ft\(^2\) = $24,440
Cost data 624.5 - May 1973
Cost of tank - Cost data 624.5 - December 1970
24' \phi \times 24' high open top, steel = $12,555 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 \times 1.12 \text{ 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.

\[(200/110)^* \times 38,500 \times 1.18 \text{ esc} = 68,826 \text{ each} \times 6 = \$413,000 \text{ for 6 each 20 hp each} \]

Steam required for 300 tpd evaporation (25,000#/hr)

(Perry, p. 518, Table 4, single effect = .869#/# 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)* 8 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

\[\text{BTU required} = \frac{25,000\# \times 1100 \text{ BTU}}{100} = 275,000\# / \text{hr} = \frac{275,000}{60 \times 8.33} \]

= 550 gpm
(f) **Pumps and Instrumentation**

(g) **Transport of asphalt-slimes** \( 690 + 460 = 1150 \text{ tpd} \)

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

\( (20T/10T)^{\text{\textsuperscript{6}}} \times 23,000 \times 1.12 \text{ esc} = 39,052 \)

2 required = $78,000

\[ \text{Unheated} \ (20/10)^{\text{\textsuperscript{6}}} \times 20,000 \times 1.12 = 33,958 \quad \text{Say} \ 34,000 \]

**Boiler** - 56,000#/hr evaporator

30,000#/hr wiped-film evaporator

86,000#/hr \quad \text{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


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-Slimes**

Say 4 hours \quad \text{1/2 size of sands surge bin}

\( (1/2)^{\text{\textsuperscript{6}}} \times 6,500 = 4333 \)

Pneumatic chute gate = $1500

**Insulation** - see p.204 - asphalt storage = $4.56/ft\(^2\)

Say 12' \( \phi \) \times 16' straight \times 10' cone

Top = \( \pi \times 6^2 = 113 \text{ ft}^3 \)

Straight = \( \pi \times 12 \times 16 = 603 \text{ ft}^2 \)

Cone area = \( \pi r^2 + h^2 + \pi \times 6 \times \sqrt{36 + 100} = 220 = 936 \times 4.56 = 4268 \)
Steam heating - say $2,000
Total - $12,101

For 8 hours = \( \frac{8}{4} \times (4333 + 4268 + 2000) + 1500 = 17,571 \)

Boiler for cement case (no thin film evaporation)
req. 56,000#/hr = say 65,000#/hr boiler
Factor previous case
\( \frac{65}{100} \times 174,200 = 134,482 \)

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 = \( \frac{245 \times 2000}{75} = 6533 \) ft³

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.
\[
\frac{\pi \times 20 \times 20 + \pi \times 10^2}{\pi \times 35 \times 41 + \pi \times 15^2} \times 60,267 = \frac{1571}{3215} \times 60,267 = 18,155
\]

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 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:

\[
146 \text{ acres} = 146 \times 43,560 \text{ ft}^2 = 6,359,760 \text{ ft}^2
\]

\[
\therefore \text{ length of side} = 56.36 \times 10^3 \text{ ft} = 2520 \text{ ft}
\]

\[
\therefore \text{ slope} = \frac{100}{2520} = 1.252 = 3.97\%
\]

No problem

For sand and cement-slimes - Find slope - 113 acres wedge to 100 ft

113 acres = 113 x 43,560 ft² = 4,922,280 ft²

Length of side = \sqrt{4,922,280} = 2220 ft

\[
\therefore \text{ slope} = \frac{100}{2220} = 1 = 22.2 = 4.50\%
\]

No problem

Pipe or hose for cement slurry

Mix and pump 2 shifts/day = 2 × \frac{16}{100} \times 150 \text{ gpm} = 150 \text{ gpm}

Assume velocity of 4 fps (slime material only)

\[
\frac{150}{7.5} \times \frac{1}{4} \times 60 = 0.0833 \text{ ft}^3 = 12.0 \text{ in.}^3 = 3'9'' \Ø
\]

Say 4-in. pipe

Cost $1.50/ft ABS (BRM worksheets)

3000 ft x 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 x 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 acres

   (1) Rehabilitation cost = 46/134 x 683,132 = $234,508
   Water spray pipes = 46/174 x 75,000 = $19,827

   (2) Alternative to seeding
   6-in. rock cover = $706 x 46 = $32,476
   Road to landfill - p. 68 - BGM worksheets - $21,000
Summary - Rehabilitation + water pipes

(a) (1) $740,890
    (2) $743,164

(b) (1) $254,335
    (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 x 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 x 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

\[ \text{Cost} = \frac{155.08 \times 43,560}{9} \times 0.675 = \$506,645 \]

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

\[ \text{Cost} = \frac{154}{166} \times 803,440 = \$745,360 \]

(b) Prep. of surface and seeding = \( 154 \times 258 = \$39,732 \)

(c) Water distribution piping = \[ \frac{154}{174} \times 75,000 = \$66,379 \]

(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 x 3.5 x 60,822) = $70,993

Pumping water from underground = (9100 x 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

$3 \text{ M } \text{HNO}_3 \text{ at } 85^\circ \text{C} = 231 \text{ g/liter } \text{HNO}_3$

8 leach tanks x 30,000 gal = 240,000 gal

\[
\text{:. total residence} = \frac{240,000}{460 + 120} = 413 \text{ min} = 6 \text{ hr 53 min}
\]

Material Type 304L stainless steel - 15' $\phi$ 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., \[ \text{loss} = 1 \text{ part in } 29,524 \text{ parts} = 4 = 1:7000 \]

Material - steel, lined with rubber or epoxy

Solvent Extraction - Feed = 50 gpm; $\text{H}_2\text{O}$ equiv. = 300 tpd

containing 4 tpd $\text{U}_3\text{O}_8 = 13.33 \text{ g/liter } \text{U}_3\text{O}_8$

Ref:

For extraction - 15.15 tpd $\text{U}_3\text{O}_8$ (1969 cost)

Purchased equipment = $365,800

Total direct = $847,000 (ratio = 2.32)

Factor on $\text{U}_3\text{O}_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) x $11,600 x 1.24 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 x 11,200/3 x 1.24 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 - Bimco - May 1973
Similar mechanisms - wetted parts stainless steel = $82,000
Rubber covering for tank at 4.00/ft^2
Tank area = \pi x 100 x 8 + \pi x 50^2 = 2513 + 7854 = 10,367 ft^2
x $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 H_2O x 650 tpd HNO_3 = 537,500 lb/hr +
54,167 lb/hr

Vertical tube unit cost = $1200/ft\(^2\)

From worksheets Case 6a

Area for 186,000#/hr = 1283 ft\(^2\)

\[ \text{.537,500 + 54,167 (treat HNO_3 as water)} \]
\[ = 591,667/186,000 \times 1283 \text{ ft}^2 = 4081 \text{ ft}^2 \]

From Chem. Eng. unit cost = $1200/ft\(^2\) (vertical tube) single stage

Size exponent = 0.53

From Fig. 9, linear factor = 4081 at .53 = 80

\[ \therefore \text{cost} = 1200 \times 80 \times 1.30 \text{ esc} = $124,800 \text{ for steel} \]

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

\[(591,667/186,000)^{0.6} \times $435,864 \times 4.50 = $3,922,776 \]

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'Ø x 50' high given

or 2 columns - 23'Ø x 35' high

or 4 columns - 16.5' Ø x 25' high

or 11 columns - 10' Ø x 15' high


23' Ø x 35' = \( \pi \times 11.5^2 \times 35 = 14,542 \text{ ft}^3 = 109,000 \text{ gal} \)

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 = $72,483 each
Trays - (Chem. Eng. March 24, 1969) 16.5' ø 24" spacing, 8 trays
Extrapolated - 16-ft stack height = $20,000 base cost
(1.0 + 1.8 + 1.7) x 1.30 esc x $20,000 = $117,000 each column

Reboiler and Condenser
Reboil 25% = .25 x 537,500/# H2O/hr = 134,375#/hr
Condense 6000 tpd = 500,000#/hr + 134,375 = 634,375#/hr

Reboil - use two evaporators
1250 ft² + 554 ft² to evaporate = 13,102# water
∴ we require 134,375/13,102 x (1250 + 554) = 18,502 ft² total =
9000 ft² each

Base cost for 9000 ft² = $33,000
Assume cheapest type - factor 0.8 and escalate 30% = $34,320
From the materials table, the tubes represent 302/450 = 70% of the
cost = $26,770 in carbon steel x 4.50 for s. steel = $120,463 each

Condenser - 925 ft² for 13,100 lbs/hr
Stainless steel shell - s. steel (304L) tubes = $11,000 in 1969.
∴ we require 634,375/13,100 x 925 ft² = 44,793 ft² total
Say $22,400 each (for 2)
By Chem. Eng. March 1969, 9000 ft² cs/ss costs
33,000 x .80 x 3.52 x 1.30 esc = $120,806
Factor by area (22,400/9000)³ x $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)³ x $11,600 x 1.24 esc = $11,277

Water Surge Tank - 100,000-gal - Wood = 30' ø x 18' high
Cost data 624.5 (October 1968)
30'ø x 12' = 3,945 + 1188 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/ft^2
\[\pi \times 12^2 + \pi \times 24 \times 24 \times 4 = \$9,048\]

Total = $25,302

Product Evaporator - 20 gpm = 10,000#/hr H_2O
2 evaporators at 13,100#/hr = 76,000 + 33,800 = $109,800

Factor on capacity = \[(10,000/13,100)^6 \times 109,800 \times 1.30 \text{ esc} = \$121,329\]

No condenser required.

Calciner - 10' \(\Phi \times 90\)' s.s.kiln = indirect heated -
Not installed = $400,000 \quad (given by ORNL)

Condenser Scrub
Gas to be condensed and scrubbed = H_2O + HNO_3
\[150 \ \text{H}_2\text{O} + 200 \ \text{HNO}_3 = 50 \ \text{gpm} = 29,166#/hr\]

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 H_2O + HNO_3 =
\[5833#/hr = \frac{5833 \times 13.5 \text{ ft}^3/\text{lb}}{60} = 1312 \text{ cfm}\]
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' ø 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' ø 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 → 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 = \( \frac{240,833 + 41,667}{960 \text{ Btu/lb steam}} \) 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

ORE 2000T

Leach

CCD

Preg storage

S-X

Precipitation

Dry and package

8 tanks, 18' x 18' - wood 40 hp ea., rubber-lined

5 thickeners 110' x 14' wood 8' stack height, 10-hp each, 8" drylex underflow, 7-1/2 hp; 10' x 8' overflow, 20 hp

335,000 gal (1396 tons)
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  
\[
\frac{\pi \times 100^2}{4} + 100 \pi \times 8 = \frac{10,367}{17,342} \times 83,448 = \$49,886
\]
+ 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, \(\frac{1}{3.0} = \$340,736\)
Drying and Packaging

From KRC notes - as above

148,800 x 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
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 = $40,000

III. Power - 80 hp
Power cost = 80 x 0.746 x 0.90 x 24 x 365 x $0.01 = $4,705

Total estimated costs = $60,705 per year.
Operating Costs - Cases 4a, 4b, and 7 - Wyoming and New Mexico

ALKALINE

I. 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 x 365 = 153.3 tons per year
Escalate at 5% per year = 27.60/ton
Estimate freight = 10.00
$37.60
Estimated cost per year = 153.3 x 37.60 = $5764

III. Maintenance Labour and Supplies
Estimate 10% of equipment cost = 10/100 x \( \frac{15,491 + 93,065}{3.5} \) = $3107

IV. Power - 91 hp
Power cost = 91 x 0.746 x 0.90 x 24 x 365 x $0.01 = $5352

Total operating costs per year = $66,218
OPERATING COSTS - CASES 4a, 4b, AND 7 - WYOMING OR NEW MEXICO

SOLVENT EXTRACTION

I. 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 men
Estimate cost = 6 x 12,000 = $72,000/year
Supervision - Est. 1/3 x 15,000 = $5,000

II. Operating Supplies

Quicklime consumption = 25.4 x 365 = 9271 tons
Est. cost delivered to bin = 9271 x $25 = $231,775/year

III. Maintenance Labour and Supplies

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

IV. Power - 230 hp

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

Total operating costs per year = $337,944
OPERATING COSTS - CASE 5 - WYOMING AND NEW MEXICO

ALKALINE

I. 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 x 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 x \( \frac{396,256 + 71,322}{3.5} \) = $13,359

IV. Power - 130 hp

Power cost = 130 x 0.746 x 0.90 x 24 x 365 x $0.01 = $7646

Total operating costs per year = $1,375,505
I. 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 tons
   Estimated cost delivered to bin = 9307 \times $25 = $232,675

(b) Cement consumption = 100 \times 365 = 36,500 tons
   Estimated cost = 36,500 \times 35 = $1,277,500

III. Maintenance Labour and Supplies

Estimate 10% of equipment cost = \frac{10}{100} \times \frac{(785,985 + 396,256 + 60,822)}{3.5}
   = $35,516 per year

IV. Power - 280 hp

Power 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 MEXICO
ALKALINE MILL

Asphalt  (a) Sand and asphalt-treated slime to landfill
(b) Sand to mine; asphalt-treated slime to landfill

Operating Labour

<table>
<thead>
<tr>
<th>Activity</th>
<th>Labour</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand-slime separation</td>
<td>1 man per shift</td>
<td>42 man-shifts</td>
</tr>
<tr>
<td>Slime dewatering</td>
<td>1 man per shift</td>
<td>42 man-shifts</td>
</tr>
<tr>
<td>Load-out</td>
<td>1 man per shift</td>
<td>42 man-shifts</td>
</tr>
<tr>
<td>Asphalt fixation</td>
<td>9 men at $12,000</td>
<td>$108,000</td>
</tr>
<tr>
<td>Evaporation</td>
<td>1 supervision at $15,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

Operating Supplies

Asphalt 670 x 365 = 244,550 T.P.Y.
Cost at $20.00/ton = $4,891,000
Steam - at $1/1000 lb = 110 x 24 x 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 x 0.746 x 0.90 x 24 x 365 x $0.01 = $37,994

Maintenance Cost - Labour + Supplies
Assumed = 10% of equipment capital cost
Equipment Capital Cost x 10%

Ia. \(10\% \times 1000/3.5 \times (64 + 833 + 1408 + 3618 + 640) = 189,514\)

Ib. \(10\% \times 1000/3.5 \times (64 + 833 + 1408 + 3618 + 70 + 640) = 189,514\)

IIa. \(10\% \times 1000/3.5 \times (64 + 833 + 1408 + 234 + 61 + 431) = 86,600\)

IIb. \(10\% \times 1000/3.5 \times (64 + 833 + 1408 + 234 + 164 + 431) = 89,543\)

Trucking Cost

Based on a 2-mile return distance at $0.05 per ton mile.

\[\text{Cost per ton hauled to landfill} = 0.10\]

(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)

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($)</th>
<th>Per ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>123,000</td>
<td>0.17</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>4,891,000</td>
<td>6.70</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>189,514</td>
<td>0.26</td>
</tr>
<tr>
<td>Steam</td>
<td>963,600</td>
<td>1.32</td>
</tr>
<tr>
<td>Power</td>
<td>37,994</td>
<td>0.05</td>
</tr>
<tr>
<td>Trucking</td>
<td>97,455</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>6,302,563</td>
<td>8.63</td>
</tr>
</tbody>
</table>
Summary - Operating Costs Asphalt Fixation Plant (b)

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($)</th>
<th>Per Ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>123,000</td>
<td>0.17</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>4,891,000</td>
<td>6.70</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>189,514</td>
<td>0.26</td>
</tr>
<tr>
<td>Steam</td>
<td>963,600</td>
<td>1.32</td>
</tr>
<tr>
<td>Power</td>
<td>33,773</td>
<td>0.05</td>
</tr>
<tr>
<td>Trucking</td>
<td>60,955</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td><strong>$6,259,842</strong></td>
<td><strong>$8.58</strong></td>
</tr>
</tbody>
</table>

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 hp)
426 \times 0.746 \times 0.80 \times 24 \times 365 \times $0.01 = $22,270 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*

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($)</th>
<th>Per Ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>123,000</td>
<td>0.17</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>638,750</td>
<td>0.87</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>86,600</td>
<td>0.12</td>
</tr>
<tr>
<td>Steam</td>
<td>438,000</td>
<td>0.60</td>
</tr>
<tr>
<td>Power</td>
<td>22,270</td>
<td>0.03</td>
</tr>
<tr>
<td>Trucking</td>
<td>36,500</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td><strong>$1,345,120</strong></td>
<td><strong>$1.84</strong></td>
</tr>
</tbody>
</table>
(b) Sand and Part of Concrete Slurry to Underground Mine, Balance of Slurry to Landfill*

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($</th>
<th>Per Ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>123,000</td>
<td>0.17</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>638,750</td>
<td>0.88</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>89,543</td>
<td>0.12</td>
</tr>
<tr>
<td>Steam</td>
<td>438,000</td>
<td>0.60</td>
</tr>
<tr>
<td>Power</td>
<td>22,270</td>
<td>0.03</td>
</tr>
<tr>
<td>Trucking</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$1,311,563</td>
<td>$1.80</td>
</tr>
</tbody>
</table>

a. **Cement - 5:1 Mix**


**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.

\[
13 \text{ men at } \$12,000 = \$156,000/\text{year} \\
1 \text{ supervisor} = \$15,000
\]

**Operating Supplies**

Cement - daily consumption will be 50 x 4 = 200 tons

\[
\text{Cost} = 200 \times 365 \times \$35 = \$2,555,000
\]

**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.
Cost = 501 x 0.746 x 0.90 x 24 x 365 x $0.01 = $29,466

Trucking - 1000 T.P.D. sand Cost = $36,500

Summary of Operating Costs

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($)</th>
<th>Per Ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>171,000</td>
<td>0.23</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>2,555,000</td>
<td>3.50</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>94,300</td>
<td>0.13</td>
</tr>
<tr>
<td>Steam</td>
<td>438,000</td>
<td>0.60</td>
</tr>
<tr>
<td>Power</td>
<td>29,466</td>
<td>0.04</td>
</tr>
<tr>
<td>Trucking</td>
<td>36,500</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$3,324,266</strong></td>
<td><strong>$4.55</strong></td>
</tr>
</tbody>
</table>

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

Cement = \( \frac{206 \times 24}{1050} \) at 50 T.P.D. = 235.4

\( \frac{844 \times 24}{1050} \) at 200 T.P.D. = 3858.4

24 hours at 170.6 = 4093.8

Cost per year = 170.6 x 365 x $35 = $2,179,415
Maintenance Labour and Supplies

10% of equipment cost = 10% x \( \frac{3134,000}{3.5} \) = 89,543

Steam = $38,000

Power = $22,270

Summary of Operating Costs

<table>
<thead>
<tr>
<th></th>
<th>Per Year ($)</th>
<th>Per Ton Milled ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating labour</td>
<td>171,000</td>
<td>0.23</td>
</tr>
<tr>
<td>Operating supplies</td>
<td>2,179,415</td>
<td>2.99</td>
</tr>
<tr>
<td>Maintenance labour and supplies</td>
<td>89,543</td>
<td>0.12</td>
</tr>
<tr>
<td>Steam</td>
<td>438,000</td>
<td>0.60</td>
</tr>
<tr>
<td>Power</td>
<td>22,270</td>
<td>0.03</td>
</tr>
<tr>
<td>Total</td>
<td>$2,900,228</td>
<td>$3.97</td>
</tr>
</tbody>
</table>
CASES 6a AND 6b - SOLVENT EXTRACTION - WYOMING AND NEW MEXICO

<table>
<thead>
<tr>
<th>Operating Labour</th>
<th>Man</th>
<th>Shifts x days</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime pulping and neutralization</td>
<td>1</td>
<td>3 x 7</td>
<td>4</td>
</tr>
<tr>
<td>Thickener of filters, evaporator, classification</td>
<td>1</td>
<td>3 x 7</td>
<td>4</td>
</tr>
<tr>
<td>Asphalt fixation - evaporator</td>
<td>1</td>
<td>3 x 7</td>
<td>4</td>
</tr>
<tr>
<td>of cement fixation</td>
<td></td>
<td></td>
<td>Say 13 men</td>
</tr>
<tr>
<td>General foreman</td>
<td>1</td>
<td>1 x 5</td>
<td>1</td>
</tr>
</tbody>
</table>

**Materials**

Lime = 29 tpd Ca(OH)$_2$ x 56/75 [CaO/Ca(OH)$_2$] x 1/.9 = 24.05 tpd at $25.00 delivered
24.05 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

**Power**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Installed hp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball mill</td>
<td>40</td>
</tr>
<tr>
<td>Ball pump</td>
<td>1</td>
</tr>
<tr>
<td>Mill pump</td>
<td>1</td>
</tr>
<tr>
<td>Agitator-mill cone tank</td>
<td>15</td>
</tr>
<tr>
<td>Agitator 3, neutralization vessels</td>
<td>30</td>
</tr>
<tr>
<td>Compressor</td>
<td>50</td>
</tr>
<tr>
<td>Thickener</td>
<td>5</td>
</tr>
<tr>
<td>Thickener overflow pumps (1 operating)</td>
<td>10</td>
</tr>
<tr>
<td>Thickener underflow pumps (2 operating)</td>
<td>10</td>
</tr>
<tr>
<td>Filters with pumps and vacuum</td>
<td>400</td>
</tr>
<tr>
<td>Filter cake surge tank</td>
<td>10</td>
</tr>
</tbody>
</table>
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 1
Total 597 hp

Plus 15% contingency 103
700 hp

700 x .746 x .80 (load factor) x 24 x 365 x $0.01 = $36,596

(a) Wiped-film evaporators (6)
120 x 746 x 180 x 24 x 365 x $0.01 = $6,274

(b) Cement mix tank and feeder 5 hp
Slurry pump 20 hp
25 x .746 x 60 x 24 x 365 x $0.01 = $1,307

Steam (includes fuel, labour, maintenance)
6b. Cement alternative = 56,000#/hr at $1/1000# = 56,000 x $1
x 365 = $490,560/yr

6a. Asphalt alternative = 56,000 + 30,000 + 1000 miscellaneous
Heating and pumping
$87,000 x $1
x 365 = $762,120/yr

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/ton mile = .05 x 2 x 1150 x 365 = $41,975/yr
6b. Cement-slime - 1025 tpd (wet)
$0.05 \times 2 \times 1025 \times 365 = $37,413/yr

**Maintenance** - 10% of equipment cost
- Common items = $852,312 \times 0.10 = $85,231
- Asphalt alternate = $774,300 \times 0.10 = $77,430
- Cement alternate = $206,596 \times 0.10 = $20,659

**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
  \[
  \frac{154}{166 \text{ acres (Case 6)}} \times 50,400 = 46,800
  \]
- 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 CaSO₄
460 tpd asphalt

Total sands = 194

All to landfill = 1206 + 1344 = 2550 tpd
Trucking cost - 2-mile round trip
$0.05 x 2 x 2550 x 365 days = $93,075/yr

When sand going to mine - $0.05 x 2 x 1344 x 365 = $49,056/yr

6b. Cement Case

Sand to mine - 1206 tpd
Remainder 194 sand
1024 slime-cement
1218

All sand to landfill.
Trucking - $0.05 x 2 x 1400 x 365 = $51,100/yr

When sand going to mine, mix with slime-cement.
Increase slurrying and pumping cost in proportion.

\[
\frac{194 + 35/65 \times 194}{1024} \times 3663 = 1067/yr
\]
Maintenance Costs After Rehabilitation

Case 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.
   Est. H.P. = \( \frac{900 \times 8.34 \times 100}{33,000 \times 0.60} \) = 38 - say 40 hp
   Power cost for 8 months in year =
   \[ 40 \times 0.746 \times 0.90 \times 24 \times 30 \times 8 \times 0.01 = 1,290 \]

(b) **Fertilizer** = $5,220

(c) **Operating Labour**
   3 men per day over 8 months per year = 4 men
   Cost = \( 4 \times \frac{2}{3} \times \$12,000 \) = $32,000
   Supervision - allow \( \frac{1}{3} \times 15,000 \) = $5000

(d) **Maintenance Labour and Supplies**
   10% of equipment cost
   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

<table>
<thead>
<tr>
<th>(a) Operating labour</th>
<th>$37,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Maintenance labour and supplies</td>
<td>5,000</td>
</tr>
<tr>
<td>(c) Fertilizer - 116/174 x 5220</td>
<td>3,480</td>
</tr>
<tr>
<td>(d) Power</td>
<td>1,290</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$46,770</strong></td>
</tr>
</tbody>
</table>
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
   Total 1,290
   Total $52,110

Case 4 - Wyoming and New Mexico - Alkaline

Case 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
   Total 1,290
   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
   Total 1,290
   Total $52,400
Case 5 - Wyoming - Alkaline

For Base Case and Landfill and Pond Area Consolidated

Based on (134 + 121 acres)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Operating labour</td>
<td>$37,000</td>
</tr>
<tr>
<td>(b) Maintenance labour and supplies</td>
<td>10% x 109,914</td>
</tr>
<tr>
<td>(c) Fertilizer</td>
<td>255/174 x 5220 = 7,650</td>
</tr>
<tr>
<td>(d) Power</td>
<td>1,290</td>
</tr>
<tr>
<td><strong>Total (A, A-2)</strong></td>
<td><strong>$56,931</strong></td>
</tr>
</tbody>
</table>

For Reduced Pond Area

Based on (134 + 15 acres)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Operating labour</td>
<td>$37,000</td>
</tr>
<tr>
<td>(b) Maintenance labour and supplies</td>
<td>10% x 64,224</td>
</tr>
<tr>
<td>(c) Fertilizer</td>
<td>149/174 x 5220 = 4,470</td>
</tr>
<tr>
<td>(d) Power</td>
<td>1,290</td>
</tr>
<tr>
<td><strong>Total (A-1)</strong></td>
<td><strong>$49,182</strong></td>
</tr>
</tbody>
</table>

Case 5 - New Mexico - Alkaline

For Base Case and Landfill and Pond Area Consolidated

Based on (61 + 67) acres

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Operating labour</td>
<td>$37,000</td>
</tr>
<tr>
<td>(b) Maintenance labour and supplies</td>
<td>10% x 55,172</td>
</tr>
<tr>
<td>(c) Fertilizer</td>
<td>128/174 x 5220 = 3,840</td>
</tr>
<tr>
<td>(d) Power</td>
<td>1,290</td>
</tr>
<tr>
<td><strong>Total (B, B-2)</strong></td>
<td><strong>$47,647</strong></td>
</tr>
</tbody>
</table>
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 1,290
Total (B-1) $43,846

Case 5 - Wyoming - Solvent Extraction

For 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 1,290
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 1,290
Total (A-1) $50,645
Case 5 - New Mexico - Solvent Extraction

For 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 1,290

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 1,290

Total (B-1) $44,285

Case 6a - Wyoming and New Mexico - Alkaline

a. 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 1,290

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  
1,290  
Total $43,188

---

Case 6b - Wyoming and New Mexico - Alkaline

a. **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  
1,290  
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  
1,290  
Total $46,295
CASE 6c - NITRIC ACID - SOLVENT EXTRACTION

Operating Labour

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Shifts x Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching</td>
<td>1</td>
<td>3 x 7</td>
</tr>
<tr>
<td>CCD</td>
<td>1</td>
<td>3 x 7</td>
</tr>
<tr>
<td>Evaporation - distillation</td>
<td>1</td>
<td>3 x 7</td>
</tr>
<tr>
<td>S-X</td>
<td>1</td>
<td>3 x 7</td>
</tr>
<tr>
<td>Product evap. and drumming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calciner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt or cement mixing</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Supervision

General foreman

Operating Materials

$\text{HNO}_3$ - 5 tpd = 1825 tpy

Cost: $35/T in 1968 - Say $40/T in 1973 = $73,000 for 1 yr

Flocculants - 0.12#/ton ore

$0.12 \times 2000 \times 365 = 87,600#/yr$

At $1.00/\text{lb}$ (Separan, etc.) = $87,600/yr

Tributyl Phosphate

67 tpy at $1200/T for 5000 stpy of U

Raffinate $\text{H}_2\text{O} = \frac{500 \times 2000}{24} = 41,667#/hr$

Our raffinate = 500 tpd $\text{H}_2\text{O} = \frac{500 \times 2000}{24} = 41,667#/hr$

TBP loss = proportional to raffinate = $\frac{41,667}{7172} \times 67 \text{ tpy} = 389 \text{ tpy}$

Unit cost - (Kaiser UF$_a$ = $1200/T$ in 1968)

$1200 \times 1.15 \text{ esc} = $1380 \times 389 = $536,820/yr$
Kerosene - factor as for TBP
\[
\frac{41.667}{7172} \times 56,000 \text{ gal} \times \$0.28 = \$91,096/yr
\]

Fuel

Given 0.5 \times 10^8 \text{ ft}^3 \text{ nat gas/day} for calciner = 197.1 \times 10^8 \text{ ft}^3/yr
at say \$0.40/1000 \text{ ft}^3 = \$78,840/yr

Steam

\[
370,000 \text{#/hr} \text{ at } \$1 \text{ per 1000} = \frac{370,000}{1000} \times \$1.00 \times 365 = \$135,050/yr
\]

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 (\sim 16\%) = 110
Total 800 hp

Allow 80\% load factor at $0.01/kwh = 800 \times .746 \times .80 \times 24 \times 365 \text{ days} \times $0.01 = $41,823/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

## Operating Labour

<table>
<thead>
<tr>
<th>Process</th>
<th>Men</th>
<th>Shifts x Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching</td>
<td>1</td>
<td>3 x 7</td>
</tr>
<tr>
<td>CCD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-X and precipitation</td>
<td>2</td>
<td>3 x 7</td>
</tr>
<tr>
<td>Drying and packaging</td>
<td>1</td>
<td>1 x 5</td>
</tr>
</tbody>
</table>

\[
63 + 5 = 68 \text{ man-shifts/week ÷ 5 } = 13.6 - 14 \text{ men}
\]

## Supervisors

<table>
<thead>
<tr>
<th>Role</th>
<th>Men</th>
<th>Shifts x Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>General foreman</td>
<td>1</td>
<td>1 x 6</td>
</tr>
</tbody>
</table>

## Operating Materials - Consumption given by Union Carbide

<table>
<thead>
<tr>
<th>Material</th>
<th>Consumption</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}_2\text{SO}_4$ - 90#/ton</td>
<td>2000 tpd x 365 days x 90#/2000 = 32,850 tpy x $22</td>
<td>722,700</td>
</tr>
<tr>
<td>$\text{NH}_3$ - 2.1#/ton</td>
<td>730,000 tpy x 2.1/2000 = 767 tpy x $70</td>
<td>53,700</td>
</tr>
<tr>
<td>$\text{NaClO}_3$ - 2.7#/ton</td>
<td>730,000 x 2.7/2000 = 986 tpy x $200</td>
<td>197,200</td>
</tr>
<tr>
<td>Flocculant - 0.12#/ton</td>
<td>730,000 x 0.12 = 87,600#/yr x $1</td>
<td>87,600</td>
</tr>
<tr>
<td>Amine - 0.03#/ton</td>
<td>730,000 x 0.03 = 21,900#/yr x $0.75</td>
<td>76,400</td>
</tr>
<tr>
<td>Alcohol - 0.07#/T</td>
<td>730,000 x 0.07 = 51,100#/yr x $0.26</td>
<td>13,200</td>
</tr>
<tr>
<td>Kerosene - 0.90#/T</td>
<td>730,000 x 0.90 = 657,000#/yr ÷ 6.67#/gal = 98,500 gal x $0.28 =</td>
<td>27,580</td>
</tr>
</tbody>
</table>
Power

8 leach tanks at 40 hp 320 hp
5 thickeners at 20 hp 100 hp
S-X

Extraction mixers, 15 ea x 4 60 hp
Raffinate pump 25
Raffinate pump 25
Preg Organic pump 5
Barren organic pump 5
Barren organic pump 5
Preg Organic pump 10

Misc. and contingencies (~15%) 85

640

Allow 80% load factor at 0.01/kwh
640 x .746 x .80 x 24 x 365 x $0.01 = $33,459

Maintenance - 10% of equipment cost

(922,000 + 1,188,900/3) x .10 = $131,830
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