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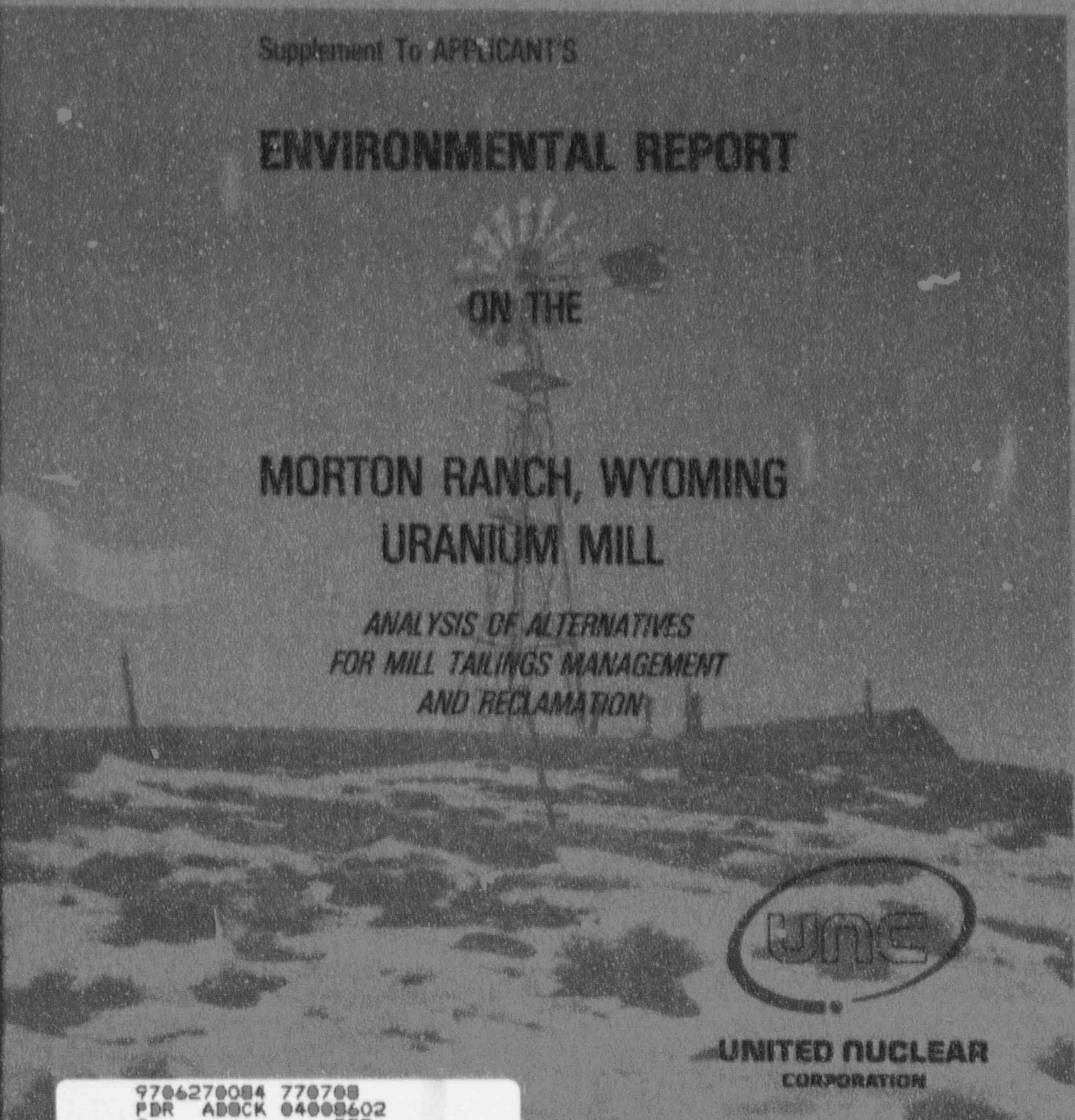

Supplement To APPLICANT'S

ENVIRONMENTAL REPORT

ON THE

MORTON RANCH, WYOMING URANIUM MILL

ANALYSIS OF ALTERNATIVES FOR MILL TAILINGS MANAGEMENT AND RECLAMATION

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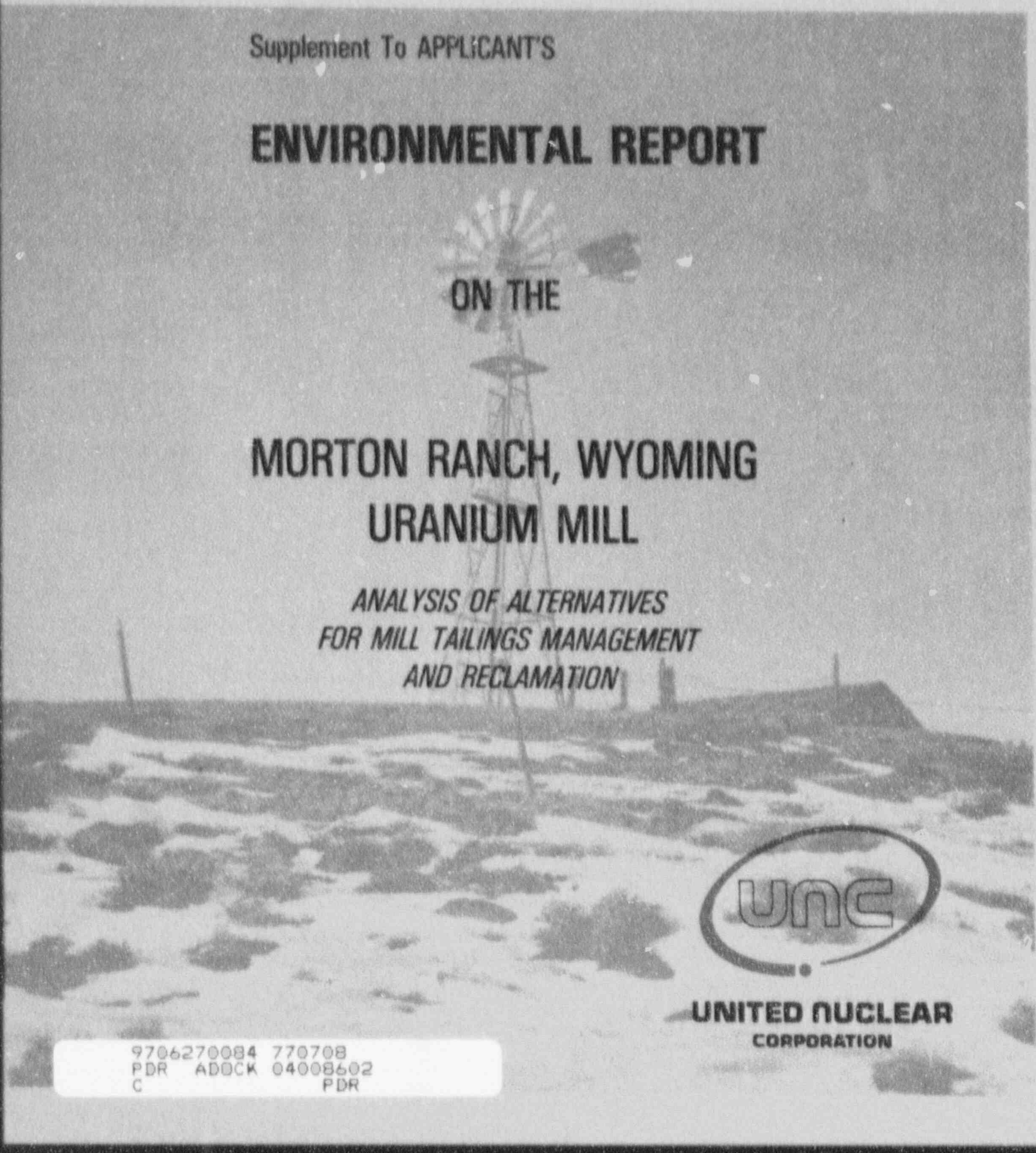

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SUPPLEMENT TO APPLICANT'S ENVIRONMENTAL REPORT ON THE MORTON RANCH, WYOMING URANIUM MILL

ANALYSIS OF ALTERNATIVES FOR MILL TAILINGS MANAGEMENT AND RECLAMATION

DOCKET NO. 40-8602

JULY 1977

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1.0 INTRODUCTION

This report is a supplement to the Morton Ranch Environmental Report, Volumes I and II. It contains an evaluation of viable alternatives on tailings stabilization and reclamation for UNC's Morton Ranch site. Through thorough analysis, the optimum method and location for disposal of mill tailings have been determined. Considerations in determining this method were potential environmental impacts, technical feasibility and confidence of performance, immediate and long-term costs, monitoring and long-term isolation of tailings.

The evaluation includes performance objectives of the tailings management program, Section 2.0. Section 3.0 contains a description of the available options in each phase of tailings treatment, i.e., physical/chemical treatment, retention systems and disposal sites, fugitive dust control, and reclamation.

Those options which appear to be feasible under certain conditions are grouped into alternative tailings management systems and discussed and evaluated in Section 4.0. Section 5.0 contains the plans for tailings management and an assessment of how the performance objectives will be met by the planned system.

2.0 PERFORMANCE OBJECTIVES FOR MORTON RANCH TAILINGS MANAGEMENT AND RECLAMATION PROGRAM

This evaluation addresses objectives for the Morton Ranch tailings management system. Considerations are derived from the Nuclear Regulatory Commission (NRC) and company concerns; these considerations serve as the basis against which tailings management programs are evaluated in other sections of this report.

Siting and Design

1. Locate the tailings isolation area remote from people such that population exposures would be reduced to the maximum extent reasonably achievable.

2. Locate the tailings isolation area such that disruption and dispersion by natural forces is eliminated or reduced to the maximum extent reasonably achievable.

3. Design the isolation area such that seepage of toxic materials into the groundwater system would be eliminated or reduced to the maximum extent reasonably achievable.

4. Design the isolation area so that occupational exposure to radionuclides and hazardous chemicals would be reduced to the maximum extent reasonably achievable.

5. Design the isolation area and opeations so that a minimum of natural resources will be consumed.

During Operations

6. Eliminate the blowing of tailings to unrestricted areas during normal operating conditions.

7. Minimize exposure of plant operating personnel to airborne tailings and radon.

Post Reclamation

8. Reduce direct gamma radiation from the impoundment area to essentially background.

9. Reduce the radon emanation rate from the impoundment area to about twice the emanation rate in the surrounding environs.

10. Minimize or eliminate the need for an ongoing monitoring and maintenance program following successful reclamation.

11. Reclaim the topography in an aesthetically satisfactory manner by establishing ground contours and replanting vegetation.

12. Restore land to its original productivity.

3.0 PHASES OF TAILINGS MANAGEMENT

The tailings management program has been divided into four phases and particular options evaluated for each phase. Phase I, Physical/Chemical Treatment, deals with processes which might be used to change the nature of the tailings independent of the storage or reclamation method. Phase II, Retention Systems and Disposal Sites, deals with the various methods and locations for onsite disposal. Phase III, Fugitive Dust Control, deals with methods which may be used to prevent tailings dispersion during operation and before reclamation. Phase IV deals with methods of ultimate reclamation of the land.

3.1 PHYSICAL/CHEMICAL TREATMENT OF TAILINGS FOR DISPOSAL

The ideal tailings management program would render tailings which are non-polluting both chemically and radiologically. There is no known way to accomplish this. There are, however, several treatment options which may have an environmentally beneficial effect on the long-term storage of tailings when compared to the current industry practice of no additional treatment beyond that required for milling (as discussed in Option A). Treatment options are discussed below.

3.1.1 Description of Options

Option A - No Treatment

The typical acid leach uranium mill produces tailings in slurry at a pH of about 2.0 and radionuclides concentrations in the liquid, coarse sands and fine slimes portions of the tailings similar to those shown in Table 3.1-1.

TABLE 3.1-1

CONCENTRATIONS OF RADIONUCLIDES IN URANIUM MILL TAILINGS[1]

Radionuclide	Liquid Fraction Cover pCi/l	Sands > 200 Mesh pCi/g	Slime[2] < 200 Mesh pCi/g
U-nat	6.7 E+3	1.0 E+1	1.5 E+2
Ra-226	5.0 E+2	1.2 E+2	1.61 E+3
Th-230	1.9 E+5	6.0 E+1	1.75 E+3
Th-234	--	1.0 E+1	1.5 E+2
Pb-210	5.0 E+2	1.2 E+2	1.61 E+3
Po-210	5.0 E+2	1.2 E+2	1.61 E+3
Bi-210	5.0 E+2	1.2 E+2	1.61 E+3

Implementing Option A for the Morton Ranch project would mean discharging a slurry of this composition directly to the tailings impoundment area. The slurry would then be subject to solar evaporation prior to reclamation.

Option B - Neutralization

Acidic tailings can be treated with various bases to yield a neutral solution. This eliminates the adverse effect acid has if it comes into contact with plant or animal life. In Canada, wastes from acid leach anium mills are routinely neutralized prior to discharge to natural waterways. Neutralization reportedly requires about 16 pounds of limestone ($CaCO_3$) and 10 to 48 pounds of lime ($Ca(OH)_2$) per ton of ore.[3] A theoretical value of 34.4 tons/day of lime ($Ca(OH)_2$) for a 2000 tons per day (TPD) mill (34.4 lbs tons of ore) has been reported.[4]

Adjustment to pH 8 also has a beneficial effect on dissolved radionuclides, including precipitation of 90 percent of the radium and at least 90 percent of the thorium.[5]

Option C - Thorium Precipitation

The most efficient method of thorium precipitation is lime neutralization, which is discussed in Option B, above.

Option D - Radium Precipitation

Barium chloride is used in mine water treatment in the U.S., in mill effluent treatment in Canada, and in various laboratory procedures for the precipitation of radium. The procedure involves the formation of insoluble barium sulfate, which incorporates radium sulfate, causing radium to precipitate along with the barium. Barium chloride consumption rates for mill effluents vary from 0.1 to 0.4 pounds per 1000 gallons (0.3 to 1.2 pounds/ton of ore for the proposed facility) to 0.008 to 0.6 pounds/ton of effluent[7] (0.01 to 0.75 pounds/ton of ore for the proposed facility).

Option E - Solid Separation

In the past, uranium mills have performed a rough separation of the sands from slimes and liquids in cyclone separation in order to use the sand portion for dam construction. Although construction of embankments from tailings is no longer considered environmentally acceptable, other benefits may be derived from the separation of sand and slime. Tests performed by National Lead[8] indicate that 78 percent of the radium is contained in the -400 mesh tailings fraction. This fraction comprises 18.5 percent of the total tailings weight. ORNL, in tests run on tailings from three mills, has shown between 82.8 and 86.5 percent of the gamma activity is contained in the -325 mesh fraction, which is 20 to 26.6 percent of the total tailings weight. See also Table 3.1-1.

Separation of sands from liquids and slimes can be accomplished in several ways. Cycloning is the most common; filtration is also a possibility; and depositing the entire effluent on a slope will cause the sands to remain and most of the liquid and slimes to run downgradient.

Option F - Solidification

In this option, mill wastes like wastes from other portions of the uranium fuel cycle are fixed with portland cement, asphalt or urea formaldehyde to form a solid, less leachable product for disposal. Portland cement may be used to fix either the entire tailings solids or the slimes only. Neutralization is required. ORNL reports at least 1 part cement to 20 parts tailings is required for solidification; strength and leaching behavior improve with more cement. Solidification of all sands and slimes from the proposed 3000 TPD mill would require about 150 tons of cement per day. Solidification of slimes only for the proposed mill would require at least 50 tons of cement per day.

Asphalt is proposed only for dewatered slimes, which may comprise up to 60 percent of the solid product.[11] A 3000 TPD mill would require 1200 tons per day of asphalt (assuming 35 percent of the ore is slimes).

Where urea formaldehyde is used, the solid product normally incorporates about 60 percent waste. If used for slime only, about 1200 tons per day would be required.

3.1.2 Physical/Chemical Treatment Evaluation Factors

Table 3.1-2 summarizes the evaluation of the five options presented in Section 3.1.1 in terms of the six evaluation factors given below.

Technical Feasibility: For processes which have not been demonstrated on the scale being considered, engineering and development costs are likely to be greater. Each of the processes being considered has been demonstrated under certain conditions, but not necessarily those of a 2000 or 3000 TPD mill.

Leachability of Products: Although final placement of tailings will be designed to minimize or eliminate the chances of tailings coming into contact with ground or surface water, it is highly desirable that the tailings be in a physical and/or chemical form that prevents their entering drinking water or the human food chain. Radium, thorium and chemicals are considered separately for this purpose.

Effect on Monitoring Requirements: Because of the extremely long half life of the radionuclides stored in the tailings pond, it is important that any migration or condition which might lead to migration is promptly detected and corrected. Long-term monitoring and maintenance represent a significant burden since income from the project will have ceased and those persons responsible for the project may no longer be available. Therefore, any process which minimizes the frequency of monitoring or inspecting the disposal area is also considered highly advantageous.

Consumption of Resources: As we are rapidly becoming aware, we live in a world with limited quantities of natural resources. Energy resources and petroleum products are in particular demand. We consider it beneficial to minimize the consumption of natural resources to the extent practicable while maintaining the desired protection of the public and the environment.

TABLE 3.1-2

EVALUATION OF PHYSICAL/CHEMICAL TREATMENT OPTIONS

Case	Technical Feasibility	Leachability of Product[2] Ra	Th	Chemicals	Effect on Monitoring Requirements	Consumption of Resources[2]	Effect on Mill Operation	Treatment Cost - Estimated: Base Reagent Cost	Reagent Cost Per Ton of Ore	Capital Cost
Option A No Treatment	Yes	✓	✓	✓	✓	✓	✓	0	0	0
Options B and C Neutralization (Th Precip)	Yes	✓+	+	+[3]	?	-[6]	-[6]	$Ca(OH)_2$ $60/ton	$1.03	$200,000
Option D Radium Precip	Yes	+	✓	✓-[4]	?	-	✓-	$BaCl_2$ $28.42/100 lbs	$ .08	$200,000
Option E Solid Separation	Yes	✓	✓	✓	+[5]	✓-	✓-	0	0	$100,000
Option F Solidification Sands/slime Portland cement	Probable[1]	+	+	+	+	-	✓-	$Ca(OH)_2$ $60/ton Cement 6.8¢/lb	$1.03 $8.50	$200,000 $200,000
Slimes only Portland cement	Probable[1]	+	+	+	+	-	✓-	$Ca(OH)_2$ $60/ton Cement 6.8¢/lb	$1.03 $3.00	$200,000 $150,000
Asphalt	Probable[1]	+	+	+	+	-	✓-	$22/ton	$11.55	$100,000
Urea formaldehyde	Probable[1]	+	+	+	+	-	✓-	13¢/lb	$60.50	$250,000

[1]Not demonstrated for a project the size of the proposed mill (3000 TPD); however, laboratory and/or pilot plant tests indicate feasibility.

[2] ✓ Base case or no effect ✓+ Slightly better than base case + Improvement over base case
✓- Slightly worse than base case - Worse than base case ? Effect unknown

[3]Solubility is not decreased, but environmental impact of leachate is reduced.

[4]Although only slightly soluble, barium sulfate is somewhat toxic.

[5]The frequency of monitoring would probably be unaffected, but the area to be monitored might be significantly reduced.

[6]If tailings solution was neutralized as it came from the mill and then recycled, it would increase acid consumption and eliminate reclamation of any uranium in solution.

[7]Costs associated with separating slimes and water are not included.

Effect on Mill Operation: The efficient operation of the mill should not be hampered by tailings treatment and disposal. When the only effect is the operation and maintenance of additional equipment, a check-minus indicates minor effect.

Treatment Cost: Cost figures are given as one-time capital costs, and costs per ton of ore processed. Estimates are based on current dollars.

3.1.3 Evaluation of Physical/Chemical Treatment Options

Option A - No Treatment

The practice of not treating uranium mill tailings for disposal is common in the industry at present. As such, this option serves as the base case against which other treatment options are measured. Radium, thorium, uranium and sulfuric acid are present in a dissolved state until operations close and the retention area is allowed to dry. Option A represents a minimal commitment of resources, and the treatment cost is negligible. A major drawback is that radionuclides remain subject to leaching. Some regular monitoring and/or inspection will probably be required.

Options B and C - Neutralization and Thorium Precipitation

Neutralization with lime or limestone will decrease the solubility of thorium and, to some extent, radium. It will also decrease the environmental effect of tailings leachate if the dried salt cake remaining after operations should come into contact with ground or surface water. We are not able to assess what effect this might have on the need for continuous monitoring after reclamation, but any effect should be toward decreasing the monitoring required. Neutralization could consume in excess of 11,000 tons/year of lime. While this is not a substantial amount in terms of the total resource, it does represent a significant quantity.

The primary drawback of neutralization is its effect on recycle of water from the tailings pond. Water used in the leaching and thickening circuits must be maintained at pH 2.0 or less in order to keep the uranium in solution. Neutralization of tailings effluent would require addition of acid to the recycle stream. In addition, any uranium discharged to the tailings pond (approximately 0.02 gram/liter) would precipitate in the tailings pond rather than return to the mill in the recycle stream. Neutralization would, therefore, decrease the uranium extraction efficiency. A one-time capital cost of about $200,000 for equipment and instrumentation and operating costs of about $1 per ton of ore are the anticipated costs. Lost uranium may amount to $800,000 per year.

If thorium in groundwater is expected to result in a significant population dose, or if tailings pond acids are affecting water supplies or vegetation, neutralization of the tailings pond might represent a justifiable expense. Neutralization should only be considered at the close of mill operation when it will not affect recycle of tailings pond solution.

Option D - Radium Precipitation

Radium precipitation is an established technology; however, because of differences in processes, the quanity of Barium Chloride required is not known. Barium Chloride is generally ineffective for radium removal in the presence of suspended solids; thus, flocculation may be necessary as well. Barium is a potential water pollutant with a recommended maximum drinking water concentration of 1 mg/l. Because of the low solubility of barium sulfate, this limit is not likely to be exceeded in leachate. Bioaccumulation in fish and in some plants has been reported.[12]

If barium chloride can be metered into the pond effluent line at 0.3 pound/ton of ore without prior settling or flocculation, radium precipitation could be accomplished at a fairly modest capital cost of perhaps $200,000 for tests, equipment procurement and instrumentation. Other costs would be about $0.08/ton of ore for reagents.

Option E - Solid Separation

Solid separation by cycloning or gravity separation is technically feasible and fairly inexpensive. Cycloning of tailings increases the pressure on the tailings distribution system and therefore increases the chance of line failure. If tailings are cycloned, additional line inspection and more frequent replacement may be required.

Separation by filtration is not a well established technology and shows relatively few advantages over the other two methods.

Potential benefits are derived from sand-slime separation only if (1) slimes and liquids can be stored in a more environmentally acceptable manner than unseparated tailings, or (2) partial reclamation can be achieved during the life of the mill. Solid separation will be considered further in connection with other treatment options.

Option F - Solidification

Although technologically feasible and environmentally desirable, solidification represents relatively high development and capital costs. In addition the cost of reagents is high, ranging from more than $2.73 per ton for portland cement solidification of slimes to more than $34.58 per ton for urea formaldehyde.

3.2 RETENTION SYSTEMS AND DISPOSAL SITES

To satisfy the siting and design criteria for tailings disposal, two methods of disposal currently warrant consideration: (1) the building of a retention dam in a natural drainage basin to contain the tailings, and (2) disposal in a pit or in mined out underground workings. Several options exist for either method or a combination of both methods at various feasible locations. These are described below.

3.2.1 Descriptions of Options

Option A - State of the Art Tailings Pond - Constructed in 5-Year Increments in North Basin

As originally described in the Morton Ranch Environmental Report[1], a tailings dam could be constructed in the drainage basin to the north of the proposed plant site. An initial embankment would provide storage capacity for approximately 5 years operation of the mill and would have a pond surface area of approximately 110 acres. Later successive increases in the embankment height to accommodate the tailings for the full projected life of the mill would require construction to a height of 90 feet and would provide a surface area of 246 acres. The planned dam location and resulting pond areas are shown in Figure 3.2-1.

Topsoil would be removed and stockpiled from the entire pond surface so that it will be available for reclamation after mill shutdown.

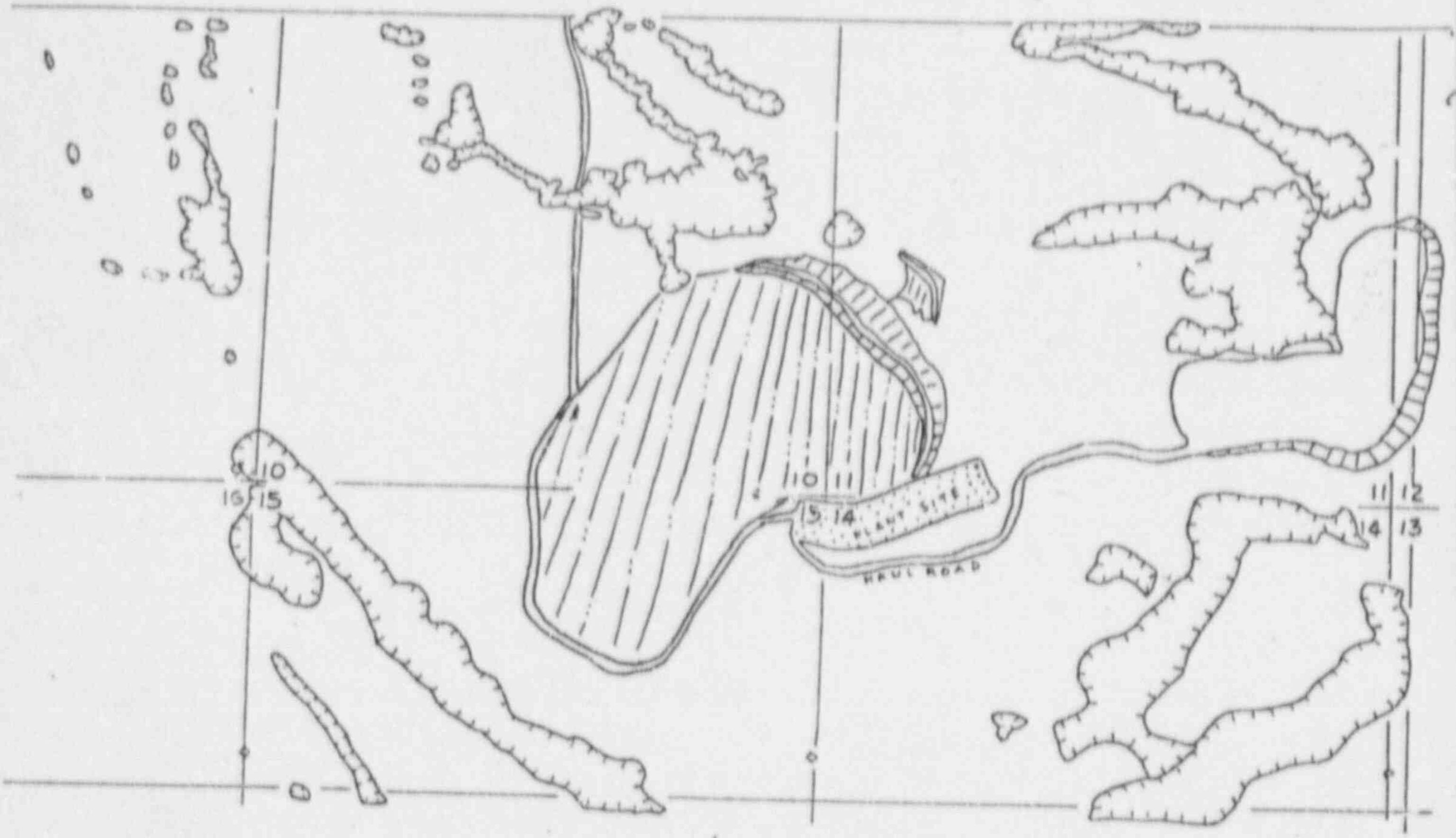
The clay present onsite and if necessary additional clay from stripping the open pit areas would be compacted to provide an impermeable barrier to pond water seepage. Clay would be prepared and compacted for the initial pond before mill operation and additional area prepared as needed during the life of the project.

A narrow finger of ore at the northernmost part of the proposed pond lies approximately 200 feet beneath the surface. This ore pod is not considered economically minable by open pit methods as a separate mining area, but may be recoverable economically by underground methods from the wall of a pit further to the north. Another small pod of ore lying approximately 50 feet beneath the surface at the western side of the pond could be recovered by open pit mining methods. This ore body would not be affected by the initial 5-year pond.

Construction of the initial 5-year dam could be done in one of two ways compatible with the current regulatory thinking. Either the downstream method, illustrated in Figure 3.2-2, or a modification of the centerline method, illustrated in Figure 3.2-3, could be used. Using the downstream method, the centerline of the dam moves away from the pond and the base of the dam is widened as construction progresses. In the modified centerline design, the base of the dam initially is constructed to its final width but a reduced height.

Although there are small ore bodies within the north retention area, these are not expected to preclude its use. The ore bearing horizons are above the water table. The floor of the pits created from open pit mining of the ore will be underlain by 50 feet or more of impermeable clays. The pit walls, on an average slope of 1/2 to 1 (60^{0}) will contain some sections of permeable sandstones. Proposals for sealing these permeable horizons are described in later options involving disposing of tailings in open pits.

If a cost effective sealing material cannot be found or if state regulatory requirements will not allow tailings disposal in pits, the pit may be backfilled and covered with a compacted clay cap similar to the pond bottom.



LEGEND

Ore Bodies

Plant Site

Tailings Area

FIG. 3.2-1 Northern Tailings Pond Site

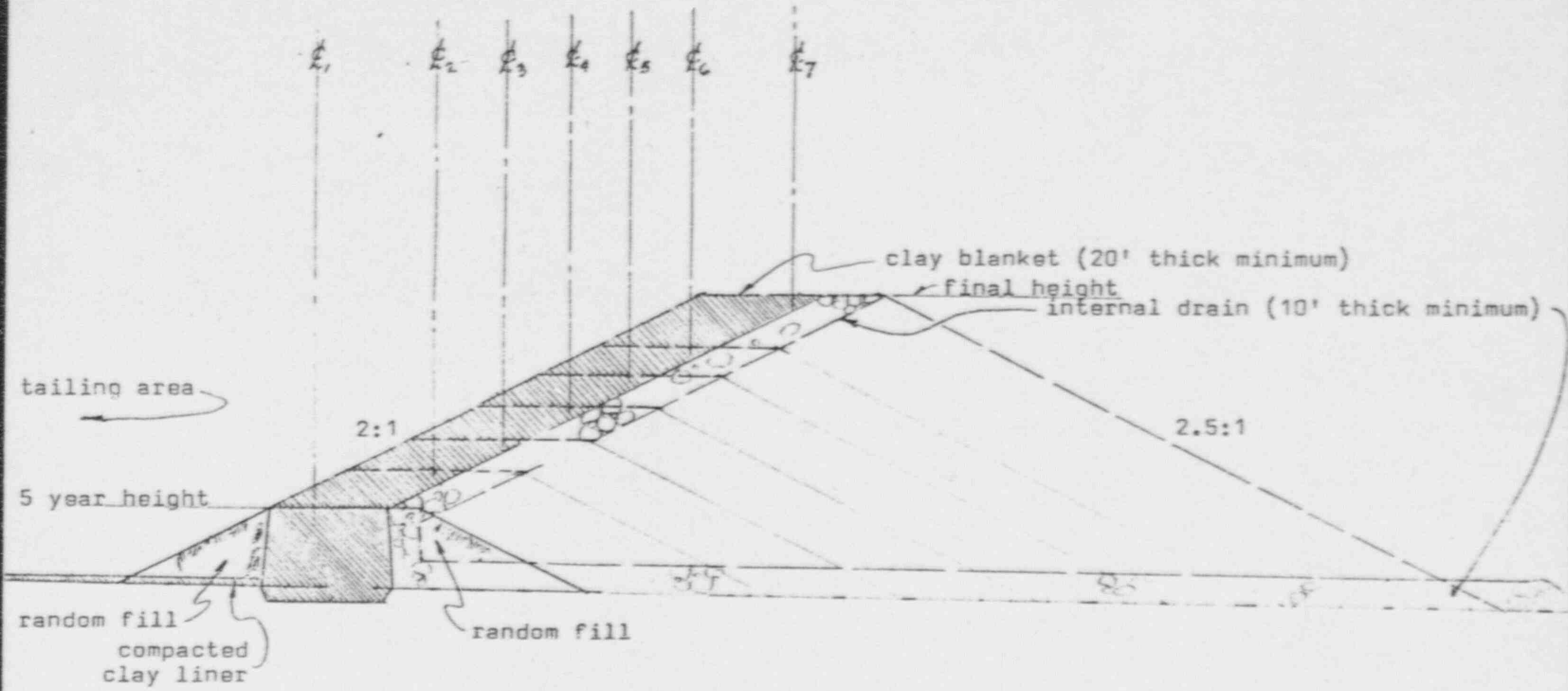


FIG. 3.2-2 Five Year Tailing Dam Proposal
Control by Downstream Method

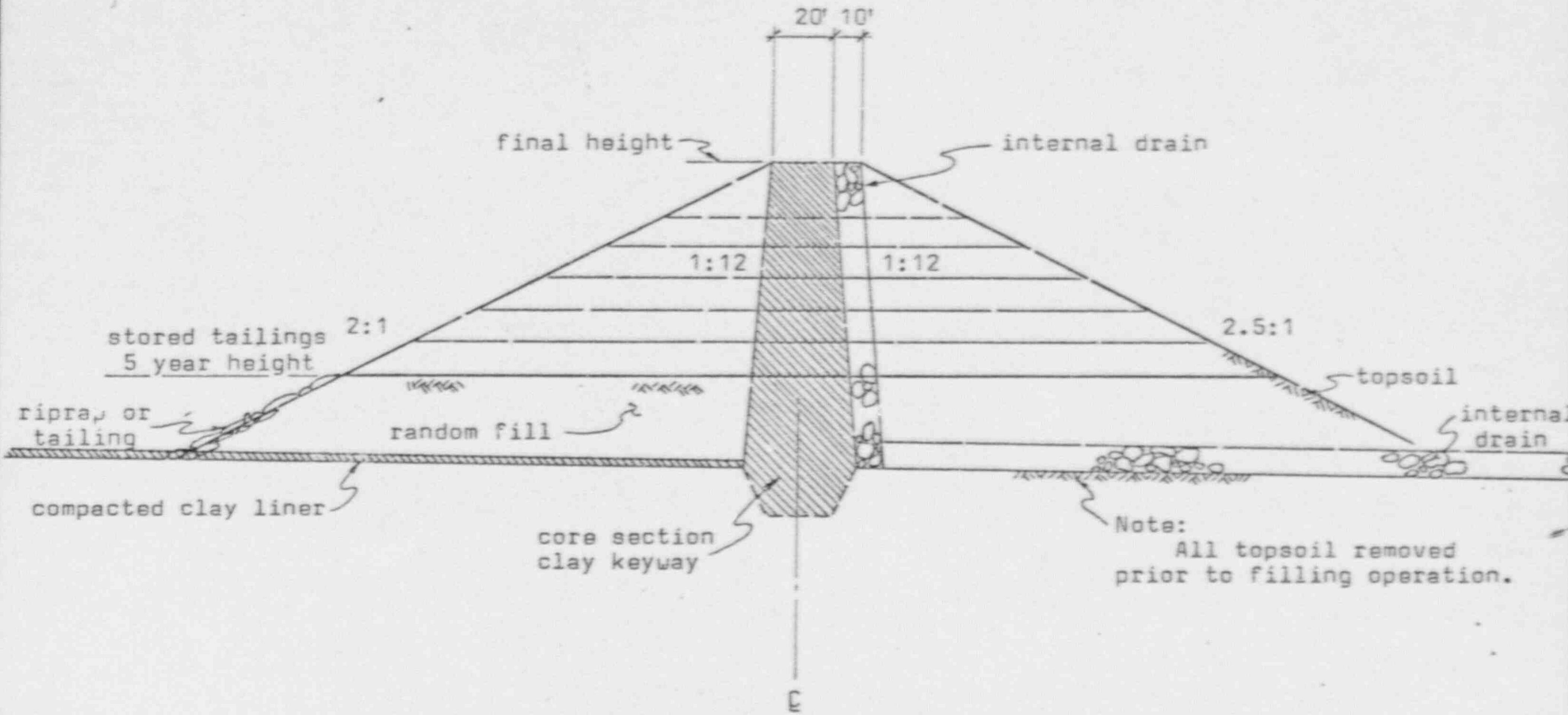


FIG. 3.2-3 Five Year Tailings Dam - Modified Centerline Method
Lifetime Tailings Dam - Centerline Method

Option B - State of the Art Tailings Pond - Constructed in 5-Year Increments in South Basin

A tailings pond similar to the one discussed for Option A could be constructed in the southern drainage basin as shown in Figure 3.2-4.

The ultimate dam height of approximately 100 feet would retain the lifetime tailings pond in the southern drainage basin. The area of the ultimate tailings pond would be approximately 178 acres.

One ore body lies within this pond area about 160 feet deep. This ore would have to be mined and the pit sealed or backfilled and capped with compact clay before the start of the mill operation.

Site preparation and dam construction would be similar to that proposed for Option A.

Option C - State of the Art Tailings Pond - Constructed for Total Project Life in North Basin

This option is identical to Option A except that the final centerline dam illustrated in Figures 3.2-1 and 3.2-3 would be constructed entirely before mill operation began and the entire pond area prepared with compacted clay.

Option D - State of the Art Tailings Pond - Constructed for Total Project Life in South Basin

This option is identical to Option B except that the final centerline dam illustrated in Figures 3.2-4 and 3.2-3 would be constructed entirely before mill operation began and the entire pond area prepared with compacted clay.

Option E - Depleted Open Pits Backfilled Above the Water Table - Compacted Clay Liner

The mill has been sited central to the south Morton ore bodies. The four pits adjacent to the mill will be among the first mined. Figure 3.2-5 shows the location of these pits. Table 3.2-1 below summarizes their design.

TABLE 3.2-1

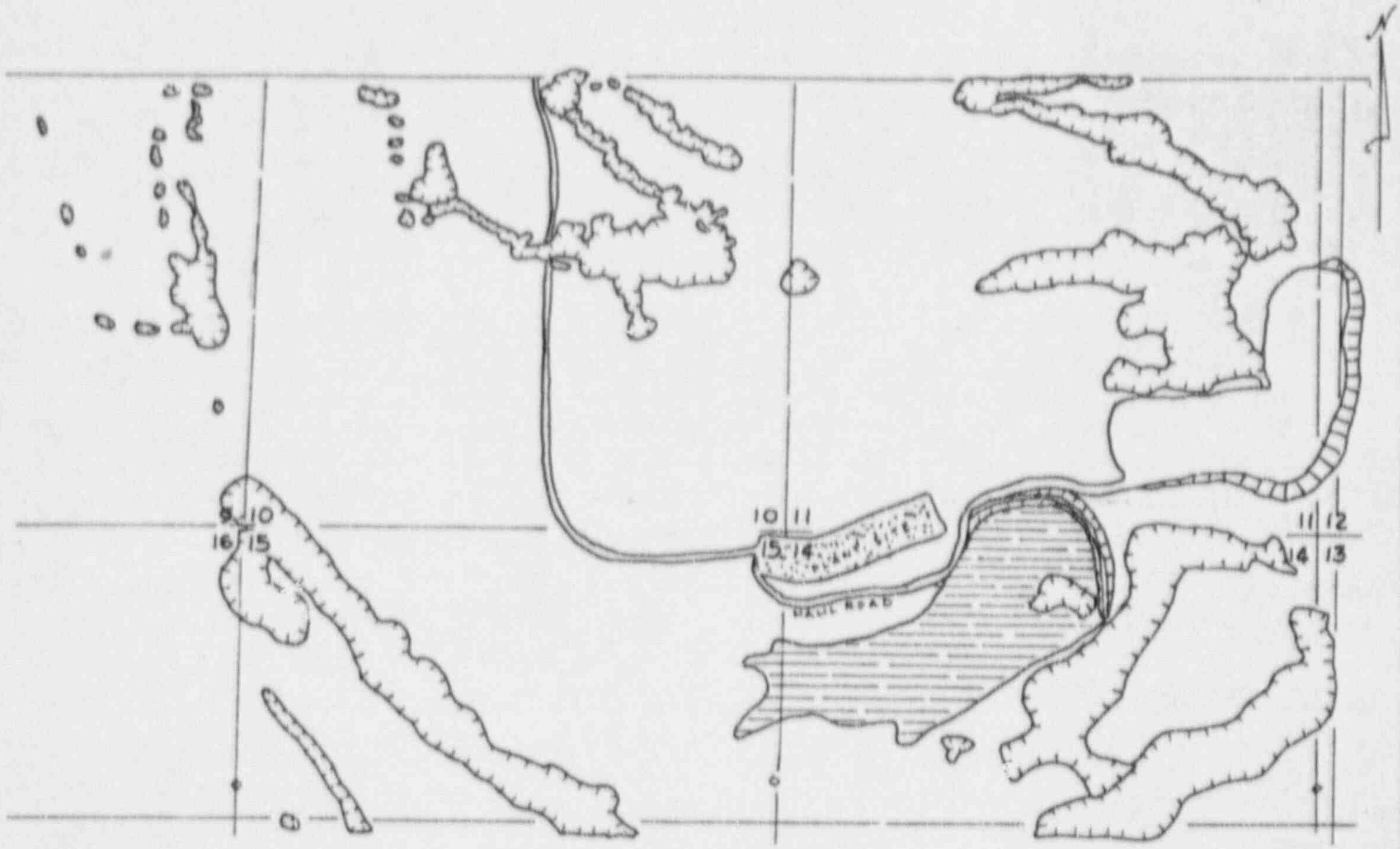
ADJACENT PITS

Pit No.	Usable Depth	Area of Pit (acres) Top	Area of Pit (acres) Bottom	Distance from Proposed Mill	Approximate Tailings Capacity (a)
1704	30	34	24	0.8 mile	2.1×10^6 tons
1705 (b)	50	47	34	0.8 mile	4.1×10^6 tons
1707	20	10	6	0.5 mile	0.4×10^6 tons
1802-1803 (b)(c)	40	63	50	1.1 mile	6.8×10^6 tons

(a) After backfilling above water table, and allowing for cover.

(b) Preliminary estimates.

(c) Ordinarily these would be mined as adjacent pits with 1802 backfilled with overburden from 1803.



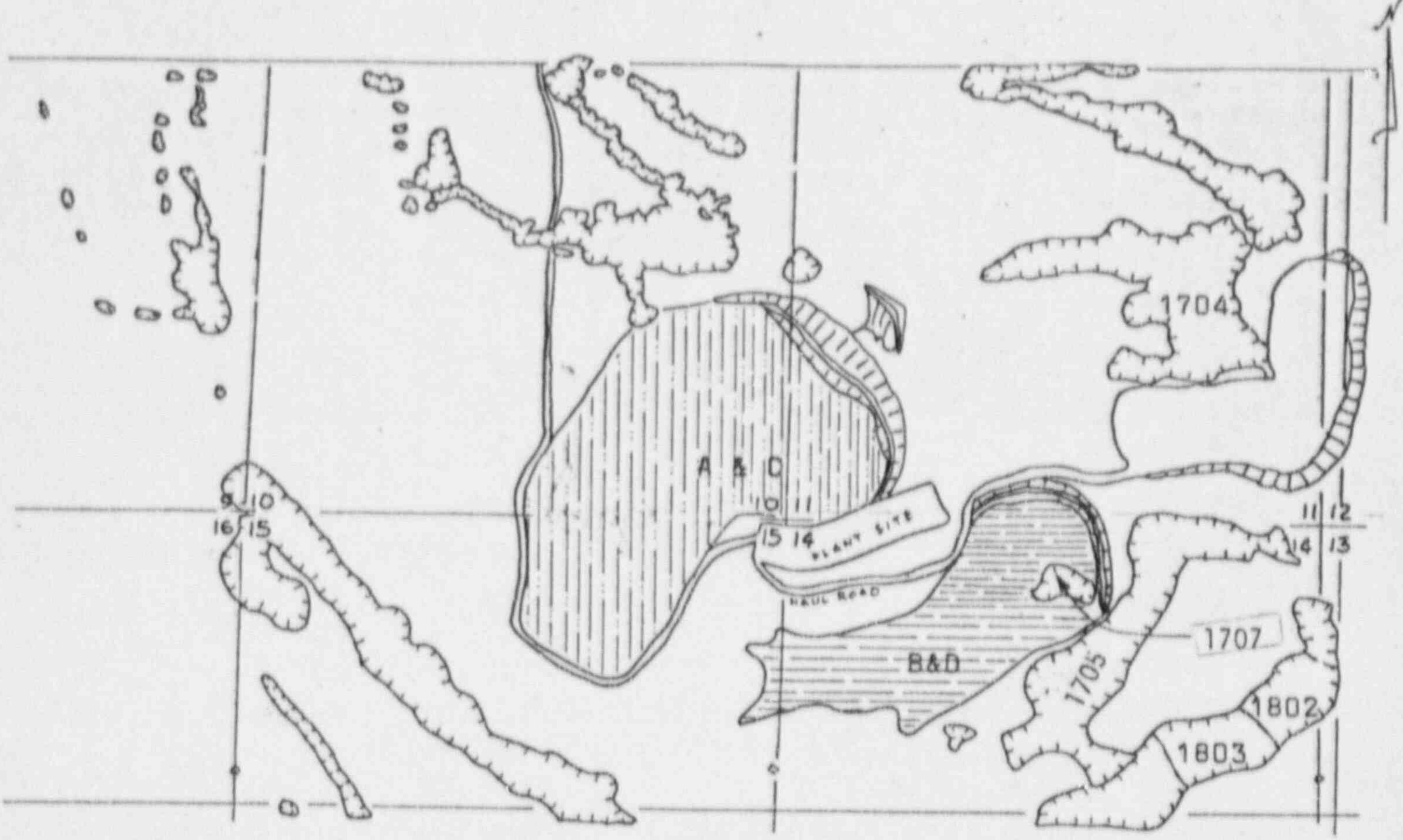
LEGEND

Ore Bodies

Plant Site

Tailings Area

FIG. 3.2-4 Southern Tailings Impoundment Area



LEGEND

Open Pits	1704, 1705, 1707, 1802 and 1803
North Tailings Pond	A & C
South Tailings Pond	B & D

FIG. 3.2-5 Adjacent Open Pit Mines

All pits will be mined at a 1/2 to 1 slope (60% angle) without benches.

The concept of using one or more of these pits for tailings disposal has been considered. The principal requirements for pit selection would be that the exposed strata be above the water table and that the pit be located downgradient from the mill for ease of tailings transport.

Excavation has already been accomplished and mining is under way in the 1704 pit which lies approximately 0.8 mile to the northeast of the plant bench. This pit is downgradient of the mill and on the same ridge between drainages. This pit will be mined out completely before the start of mill operation.

The use of a pit for tailings retention would require the sealing of the floor and of the permeable rock strata exposed in the pit walls. The ore sand is underlain by an impermeable clay but would be backfilled above the water table and lined with compacted clay.

To seal the walls with clay is much more difficult. To reduce the side slopes enough to work, about a 3 to 1 slope, would require considerable earth moving. An alternative is laying of a clay blanket along the wall by use of scrapers. Side slopes would be 1:1.

Successive increases in height would require stabilization by filling the pit with solids most of the way up the clay wall. Coarse tailings might be used for this. Use of a clay lined open pit mine would then require that liquids and slimes be confined to the center of the pit. Further investigation of the stability of such a pit liner would be required to assure the safety of personnel and equipment working on placement of additional clay. A conceptual design of such a tailings retention pit is shown in Figure 3.2-6.

Option F - Depleted Open Pits, Backfilled Above the Water Table, Compacted Clay Liner on Horizontal Surfaces, Membrane on Vertical and Near Vertical Surfaces

Under this concept, the pit bottom, above the water table, would be lined with compacted clay. A membrane such as polyethylene, hypalon or other commercially available lining material would be laid over the wall faces to seal permeable strata. The means of emplacing the membrane has not been fully investigated, but would probably necessitate the cutting of benches at regular intervals on the walls as the pit is being excavated to provide a means of access and anchoring of the membrane. The 1704 pit was not excavated with benched walls.

The placement of the membrane could be accomplished in successive stages, as the increased height of the tailings impoundment required.

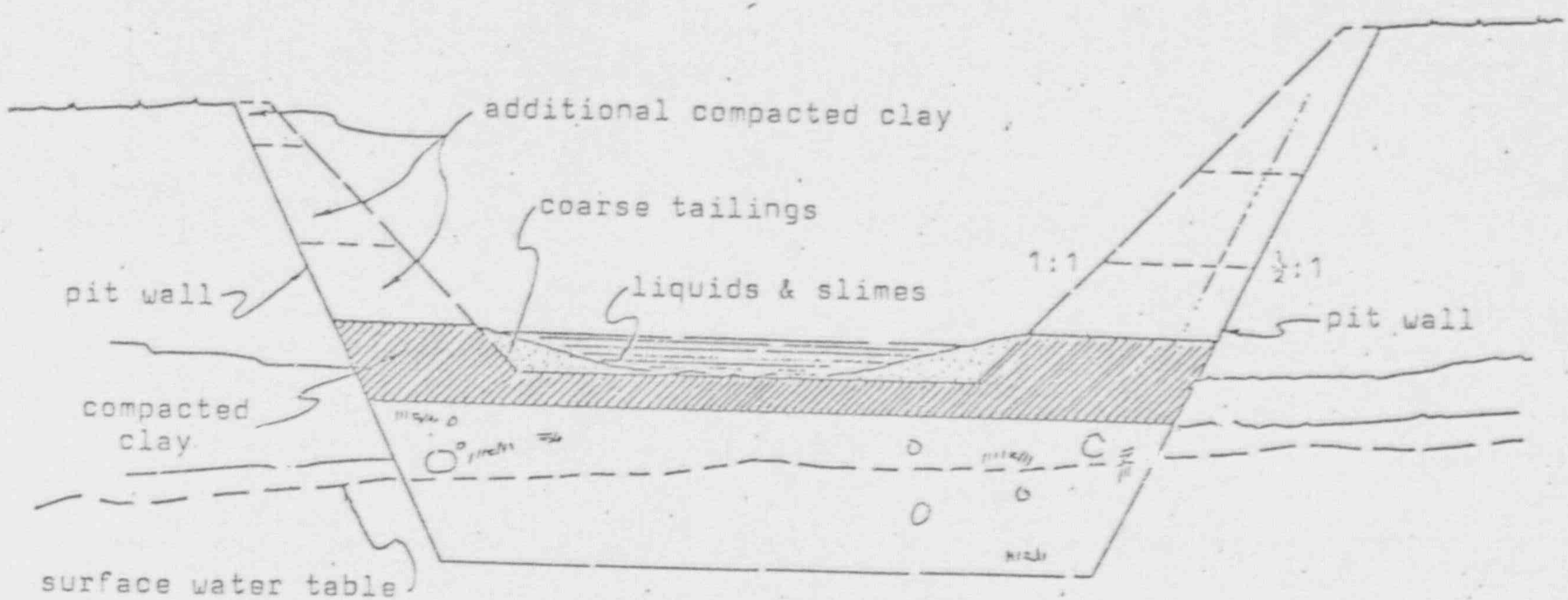


FIG. 3.2-6 Conceptual Design of a Clay-lined Pit Used for Tailings Retention

Option G - Depleted Open Pit, Backfilled Above the Water Table, Compacted Clay Liner on Horizontal Surfaces, Gunnite or Equivalent on Vertical Surfaces

Under this option, gunnite or other sprayed sealant material would be sprayed on the pit walls. Waste would have to be neutralized to avoid decomposing the concrete-like gunnite. Benches cut in the sides might be required for application.

Option H - Depleted Open Pit, Above the Water Table, Compacted Clay Liner on Horizontal Surfaces, Sprayed Asphalt on Vertical Surfaces

This option is identical to Option G except for the material used.

Option I - Expansion of Depleted Pit for Tailings Retention (Utilizing Optimum Seepage Barriers)

Under this concept a mined out pit would be enlarged by removing material from the pit walls to provide a shallower slope for effective sealing and additional volume to confine the tailings to one location. Material would be removed from the walls of one of the shallower pits to provide a slope that earthmoving equipment could negotiate. The pit walls and bottom could then be covered with compacted clay to create an impermeable basin.

An optimum location for such a pit has not been identified but would probably involve use of one of the pits shown in Figure 3.2-5.

Option J - New Pit Constructed for Tailings Disposal (Utilizing Optimum Seepage Barriers)

A pit would be dug especially for the disposal and burial of tailings. Again, the pit walls would have to be excavated to provide a means of sealing them to prevent the escape of captive or percolated water into the containing lithologic units.

To meet the requirements of proximity to the mill and an easy means of transport to the pit, the logical location of the pit would be in one of the adjacent drainages discussed in Options A and B.

Option K - Tailings Storage in Underground Mine

In this option, the underground mine on the north property would be mined and filled with tailings during mill operation or after interim storage or drying at another location. Transportation to the mine site, about 8.5 miles, would be by truck or pipeline.

3.2.2 Evaluation Factors

Table 3.2-2 summarizes the evaluation of each optional retention system/disposal site in terms of the evaluation factors discussed below.

TABLE 3.2-2

EVALUATION OF RETENTION SYSTEMS AND DISPOSAL SITES[1]

	Effect on Groundwater	Monitoring Requirements	Aesthetics	Exposure of Mill Personnel, %	Failure Potential	Airborne Tailings Potential	Transport Failure	Acreage: Disturbed	Acreage: Limited Use	Acreage: Land Acquisition	Economics: Preoperation Construction, Dollars	Economics: Operational Construction, Dollars
Option A, State of the Art Pond. 5-year increments; north basin.	+	√	-	38	√	√	√	246	2100	660	788,000	1,047,000
Option B, State of the Art Pond. 5-year increments; south basin.	+	√	-	14	√	+	√	178	1420	560	567,000	2,246,000
Option C, State of the Art Pond. Total project life; north basin	+	√	-	38	√	√	√	246	2100	660	1,785,000	0
Option D, State of the Art Pond Total project life; south basin	+	√	-	14	√	+	√	178	1420	560	2,813,000	0
Option E, Depleted Pits. Clay lined[4]	+	+	+	9[2]	+	+	-	154	640	750	335,000	1,913,000
Option F, Depleted Pits. Clay and membrane lined.[4]	o	-	+	9[2]	+	+	-	154	700	750	229,000	828,500
Option G, Depleted Pits. Clay and gunnite lined.[3,4]	o	-	+	9[2]	+	+	-	154	640	750	179,000	718,000
Option H, Depleted Pits. Clay and asphalt lined.[4]	o	-	+	9[2]	+	+	-	154	640	750	93,000	371,000
Option I, Expand Existing Pit. Clay lined.	+	+	+	o	+	+	+	95	1036	200	5,880,000	0
Option J, Construct New Pit.	+	+	+	o	+	+	+	95	1036	200	9,476,000	0
Option K, Underground Mine Storage.	-	-	+	8[2]	+	o	-	0	0	10	-	-

1 Symbols used: + Minimal adverse effect; o Effect unknown; - Some adverse effect expected; √ Base case or negligible difference from base case
2 Distance is significantly increased.
3 Neutralization would result in $1,887,000/year additional operating cost.
4 Cost of damming off connecting pits or the value of ore lost from leaving embankments not included.

Chemical or Radiological Effects on Groundwater

The best retention system would allow no seepage or leachate to migrate from the storage site under any foreseeable conditions. An acceptable alternative, although not as desirable, is a retention system which precludes contamination of any aquifer which may be used for potable, agricultural or industrial use above the maximum allowable concentration at any foreseeable point of use.

Monitoring Requirements

Retention systems must be chosen and investigated so that the need for longer-term monitoring and inspection is minimized. Sites should be chosen so that wind and water erosion are minimized. Potential for impact on groundwater should be slight so that extensive groundwater monitoring is not required And the site should permit sufficient cover so that gamma radiation need not be a concern.

Aesthetics of Reclaimed Area

Although the area is remote and nearly inaccessible to the general public at the present time, the retention system should be designed so that, after reclamation, it will harmonize with the surrounding terrain.

Exposure of Personnel to Tailings Dust

The retention system should minimize exposure to plant personnel by its location and exposed surface area. The percent of time the wind blows from the tailings to the mill is listed for comparison. Distance, wind speed and atmospheric stability are also factors, but they are evaluated only qualitatively to determine the lowest exposure reasonably achievable.

Retention System Failure Potential

The retention system must be designed to withstand all earthquakes, winds and floods considered probable. Beyond that, the ability to withstand unexpected combinations of events or deliberate sabotage is considered to be a significant advantage although not a dominant selection criteria.

Potential for Tailings Becoming Airborne

Airborne tailings present both a source of radiation exposure to personnel and a potential for spread of low level radioactive materials. Airborne tailings should be minimized. The potential for airborne tailings is a function of three parameters: the area of tailings exposed, i.e., the area of the tailings beach; the length of time tailings are exposed to the air; and the method used to stabilize tailings. The latter parameter is considered as a separate phase of tailings management and addressed under 3.3, Fugitive Dust.

Potential for Transport Failure

Failure of a tailings transport line could result in an uncontrolled release of radioactive materials, a cause of erosion (including erosion of the retention system barrier), and an unplanned mill shutdown. For these reasons, tailings transport lines should be as short as possible. In addition, the retention system should be designed and located so that the environmental impact of a transport failure is minimized.

Disturbed Acreage

It is desirable from both environmental and economic considerations to minimize the amount of land on which tailings are stored. The acreage on which tailings are stored is tabulated as "disturbed acreage." The buffer zone of 1/2 mile surrounding tailings storage is tabulated as "limited use acreage."

Economics

Economic considerations of tailings disposal are tabulated in the following categories. All values are present dollars.

Land Acquisition Required: Total acreage is listed. It is assumed that per acre cost of all parcels will be comparable.

Preoperation Construction Cost: This includes topsoil removal, facility construction and clay compaction cost based on the following unit cost estimates:

o Topsoil and overburden removal; assuming these materials are stockpiled nearby	$0.80/yd^3$
o Removal and selected placement of topsoil or overburden	$1.25/yd^3$
o Placement and compaction (to95+%) of clay or overburden	$1.25/yd^3$
o Compacting clay which is already in place	$700/acre
o Membrane installed on 100' vertical surfaces	$30,000/acre
o Asphalt sealant (1/2 inch thick)	$0.33/ft
o Gunite	$0.70/ft^2$

Operational Construction Cost: Those construction activities begun after mill operation are listed separately although based on the same preoperational construction values given above.

Operation Cost: This includes transport cost, man-hours of operation, inspection and maintenance required.

Other costs not estimated include the cost of reclamation which is a direct function of the acreage involved, except where construction maintenance of diversion ditches, fences and the like are required.

3.2.3 Evaluation of Retention Systems and Disposal Sites

Option A - State of the Art Tailings Pond - Constructed in 5-Year Increments in North Basin

As the original plan, Option A represents the base case against which other options are evaluated. The effect on groundwater is expected to be negligible and post reclamation monitoring at a minimum. Periodic inspections after heavy rains or other abnormal events are expected to be required. A fence with posted warnings against tailings removal will be required.

Option A would change the land contour somewhat, although once reclaimed, the effect is expected to be slight. A diversion ditch riprapped to prevent erosion and the retention dam are expected to be the most prominant features of the reclaimed area.

Although not in the prevailing wind direction, the wind is expected to blow from some part of the tailings pond to the mill nearly 38 percent of the time.

Current dam design technology makes failure unlikely although possible. The distance from the mill to the pond is an extremely short distance entirely downgradient making transport failures highly unlikely and assuring that spilled tailings would drain into the pond.

At certain times of the year, evaporation may exceed mill discharge such that a beach may be exposed. Water sprinkling may be used to limit the amount of dust. The beach may be as much as 200 feet wide toward the west side of the pond at certain times of the year.

The pond will ultimately occupy almost 246 acres and a 1/2 mile buffer zone around it about 1150 acres.

Cost Analysis - Option A

Preoperational Construction

Pond construction would include:

- Stripping approximately 2 feet of topsoil from the 110 acre initial pond

$$110 \text{ acres } 43{,}560 \text{ ft}^2/\text{acre} \times 2 \text{ ft} \times \frac{\text{yd}^3}{27 \text{ ft}^3} \times \$0.80/\text{yd}^3 = \$280{,}000$$

- Compacting clay in place

$$55 \text{ acres} \times \$700/\text{acre} = \$38{,}500$$

- Placing and compacting clay on permeable strata

$$55 \times 43{,}560 \times 2 \times \frac{1}{27} \times 1.25 = \$222{,}000$$

- Placing and compacting clay and unclassified overburden for the starter dam

For the downstream method:	198,000 yd x $1.25/yd =	$247,500
For modified centerline method:	246,600 yd x $1.25/yd =	$308,250
	Downstream Method Total=	$788,000

Operational Construction

Additional p--d construction during operation would include:

- Stripping approximately 2 feet of topsoil fromthe remaining 136 acres of tailings pond

  $136 \times 43{,}560 \times 2 \times \frac{1}{27} \times \$0.80 = \$350{,}000$

- Compacting clay in place

  $68 \times \$700/\text{acre} = \$48{,}000$

- Placing and compacting clay on permeable strata

  $68 \times 43{,}560 \times 2 \times \frac{1}{27} \times \$1.25 = \$274{,}000$

- Placing and compacting clay and unclassified overburden for raising the dam

For the downstream method:	300,000 yd^3 x $1.25/$yd^3$ =	$375,000
For modified centerline method:	370,000 yd x $1.25/yd =	$462,000
	Downstream Method Total=	$1,047,000

Operation

Transportation, monitoring and dust control costs only.

Option B - State of the Art Tailings Pond - Constructed in 5-Year Increments in the South Basin

The only significant differences between Option B and Option A occur in the following areas:

- Exposure of mill personnel to tailings pond effluents is decreased to less than half of the Option A value because of the prevailing winds.

- The total acreage disturbed is less. The ultimate pond will occupy only 178 acres compared to 246 acres for Option A.

Cost Analysis - Option B

Preoperational Construction

- Topsoil removal: 75 acres x 43,560 x 2 x $\frac{1}{27}$ x \$0.80/yd^3 = \$194,000
- Plac..ng and compacting clay: 38 acres x $\frac{2}{27}$ x 43,560 x \$1.25 = \$154,000
- Compacting clay in place: 37 acres x \$700/acre = \$26,000
- Placing and compacting clay and unclassified overburden for starter dam

For the downstream method:	154,000 yd^3 x \$1.25/yd^3	= \$193,000
For the modified centerline method:	628,000 yd^3 x \$1.25/yd^3	= \$785,000
	Total	= \$567,000

Operational Construction

Additional construction during operation would include:

- Stripping topsoil from remaining pond area

  96 acres x 43,560 x 2 x $\frac{1}{27}$ x \$0.80 = \$248,000

- Placing and compacting clay: 48 x $\frac{2}{27}$ x 43,560 x 1.25 = \$194,000
- Compacting clay in place: 48 acres x \$700/acre = \$34,000
- Placing and compacting clay and unclassified overburden to raise the dam

For the downstream method:	1,416,000 yd^3 x \$1.25/yd^3	= \$1,770,000
For the modified centerline method:	942,000 yd^3 x \$1.25/yd^3	= \$1,177,000
	Total	= \$2,246,000

Operation

Transportation, monitoring and dust control.

Option C - State of the Art Tailings Pond - Constructed for the Total Project Life in the North Basin

Option C is identical to Option A in all respects, except for the time that construction costs occur and possibly some as yet undefined differences in failure potential.

Option D - State of the Art Tailings Pond Construction for the Total Project Life in the South Basin

Option D is identical to Option B in all respects, except for the time that construction costs occur and possibly some as yet undefined differences in failure potential.

Option E - Depleted Pits, Clay Lined

Storage of tailings in depleted open pit mines is expected to have a negligible effect on groundwater provided tailings are stored above the water table in pits with compacted clay liners. As tailings will be stored deeper in the ground and with thicker clay liners, long-term monitoring is expected to be lessened although periodic inspections may still be required.

Reclaimed pits are expected to be nearly indistinguishable from the original land contour.

Exposure of plant personnel to tailings effluent will be lessened both because the wind blows from the pits to the mill site only 9 percent of the time and because the pits will be a greater distance from the mill.

The potential for a retention system failure on the order of a dam failure is virtually nonexistent. The possibility of the entire pond contents liquifying under earthquake conditions so that the clay lining leaves the pit walls requires further analysis although this is thought to be highly improbable.

With a 45 percent wall slope, the tailings beach would be extremely small, making it unlikely that a significant quantity of tailings would become airborne.

Transport of tailings to the pit and recycle of water to the mill represents a major drawback in the use of depleted pits for tailings retention. Not only are the pits significantly further from the proposed plant site, but the tailings and recycle lines would have to be rerouted each time pits were changed. Also overburden removed in stripping would remain on the surface complicating reclamation.

A major advantage in the use of pits is the fact that no new acreage is disturbed and the total acreage disturbed is less than for options involving the use of a pond. The perimeter area which may be subject to some use limitations and the land acuisition required are relatively large because of the number and spacing of pits involved.

Cost Analysis - Option E

Preoperational Construction - 1704 Pit

- Compaction of in place clay (ore is underlain by clay - where backfilling is required to be above the water table, backfill costs are not included since pits must be backfilled anyway)

  24 acres x $700/acre = $17,000

o Placement of initial clay lining -

$$\frac{20 + 35 \times 30 \times 7700 \text{ ft. around}}{27 \text{ ft}^3/\text{yd}^3} \times \$1.25/\text{yd}^3 = \$294,000$$

o Top seal 34 x 700 = $ 24,000

Total = $335,000*

Construction Cost during Operations

o 1705 pit

Clay compaction: 34 acres x $700/acre = $24,000 = $ 24,000

Clay placement: $\frac{(70 + 20)}{2} \times 50 \times \frac{9960}{27} \times \$1.25/\text{yd}^3$ = $1038,000

Top seal 47 acres x $700 = $ 33,000

o 1707 pit

Clay compaction: 6 acres x $700/acre = $ 4,000

Clay liner placement: $\frac{(30 + 20)}{2} \times \frac{20 \times 2300 \times \$1.25/\text{yd}^3}{27}$ = $ 53,000

o 1802-1803 pit

Clay compaction: 50 acres x $700/acre = $ 35,000

Clay liner placement: $\frac{(20 + 60)}{2} \times \frac{40 \times 9800 \times \$1.25/\text{yd}}{27}$ = $ 726,000

Total = $1913,000

Operation Cost

Transportation and monitoring costs,

Option F - Depleted Pits - Clay and Membrane Lined

A membrane liner on the vertical surfaces of a pit would serve to protect groundwater from seepage during the life of the mill. Whether a liner material can be found which will keep its integrity almost indefinitely to mitigate the effects seepages and leachate might have on the groundwater aquifer is not known. After dried tailings have been stored in the pit for many years, some membrane failure might be expected although this will probably have only a slight impact if any on groundwater aquifers since in leakage to the tailings will also be small. Some long-term groundwater sampling after shutdown might be required with this system.

In all other respects, except economics, a membrane liner will not differ significantly from the clay lined pit discussed in Option E.

*estimates do not include the cost of damming off connecting pits on the value of the ore lost from leaving embankments.

Cost Analysis - Option F

Preoperational Construction

o Pit 1704

Compact in place clay: 24 acres x $700/acre = $17,000

Cost of membrane

$$40 \text{ ft} \times 7700 \text{ ft} \times \frac{\$30,000/\text{acre}}{43,560 \text{ ft}^2/\text{acre}} = \$212,000$$

Total = $229,000

Operational Construction Costs

o 1705 pit

Clay compaction: 34 acres x $700/acre = $ 24,000

Liner: $60 \text{ ft} \times 9960 \text{ ft} \, \frac{30,000}{43,560}$ = $412,000

o 1707 pit

Clay compaction: 6 acres x $700/acre = $ 4,000

Liner: $30 \text{ ft} \times 2300 \text{ ft} \, \frac{30,000}{43,560}$ = $ 47,500 o 1802-1803 pits

Compact clay:	50 acres x \$700/acre	=	\$ 35,000
Liner:	50 ft x 9800 ft $\frac{30,000}{43,560}$	=	\$ 338,000

Total = \$828,500

Operation Cost

Transport cost and monitoring only

Option G - Depleted Pits - Clay and Gunite Lined

Gunite is expected to prevent seepage into aquifers of neutralized waste. Some additional work would be required to determine the seepage rate under the expected 60 to 80' plus head of water in some pits. The sluffing problems which may be encountered with clay and the need to construct benches as required with membranes may be eliminated. Neutralization of the waste represents an additional operating cost as discussed previously. In all other respects, gunite should be equivalent.

Cost Analysis - Option G

Preoperational Construction

o Compact existing clay 1704 pit: 24 acres x \$700/acre = \$17,000
o Line 1704 pit: 30 ft x 7700 ft x \$0.70/ft^2 = \$162,000

Operational Construction

Pit No.	Clay Compaction	Liner
1705	34 x \$700/acre = \$24,000	50 x 9960 x \$0.70/ft^2 = \$ 349,000
1707	6 x \$700/acre = \$ 4,000	20 x 2300 x \$0.70/ft^2 = \$ 32,000
1802-1803	50 x \$700/acre = \$35,000	40 x 9800 x \$0.70/ft^2 = \$ 274,000
		Total \$718,000

Operation Cost

o Neutralization cost: \$1,000,000/year

o Recycle acid losses:

$$\frac{2\ g}{gal} \times \frac{250\ gal}{min} \times \frac{4.7 \times 10^5\ min}{yr}\ \frac{lb}{450\ g} \times \frac{\$0.166}{lb} = \$87,000$$

o Uranium losses

$$\frac{\$40/\text{lb} \times .02\ \text{g/l} \times 3.8\ \text{l/gal} \times 250\ \text{gal/min} \times 4.7 \times 10^5\ \text{min/yr}^*}{450\ \text{g/lb}} =$$

$800,000 plus transport and monitoring costs

Total = $1,887,000/yr

Option H - Depleted Pits, Clay and Asphalt Lined

This option, like Option G, could probably be done without significant modification of the pit walls. Asphalt could be spray applied to permeable strata and is known to provide a good sealant. Most asphalt tends to flow in warm weather, making reapplication necessary. Catalytically blown asphalt provides a better barrier and is therefore the product being considered. Calculations are based on a 1/2 inch thick barrier.

Asphalt is expected to protect groundwater adquately both during operation and after restoration. In other respects, it is expected to be similar to other options involving pits (Options E, F and G).

Cost Analysis - Option H

Preoperational Construction - 17[illegible] Pit

o Asphalt lining: 30 x 7700 x $0.33/ft² = $76,000

o Compacting clay: $17,000

Total = $93,000

Operational Construction

o 1705 pit: 50 x 9960 x $0.33/ft² = $164,000
o 1707 pit: 20 x 2300 x $0.33/ft² = $ 15,000
o 1703 pit: 40 x 9800 x $0.33/ft² = $129,000

o Clay compaction: $63,000

Total = $ 371,000

Operation

Transport and monitoring.

*Operating year.

Option I - Expand an Existing Pit

The alternative of expanding an existing pit for tailings would keep radiation in one loation, provide less wall area to line and less surface area to cover than options involving multiple pits. In other respects, this option is similar to other options involving pits. We have assumed a 30^{o} slope and 2 foot compacted clay liner, and 100 foot deep round pit, 2300 feet in diameter at the top.

Cost Analysis - Option I

Construction Costs

- Excavation: (11,600,000 yd^3 - 4,500,000) x 0.80 = $5,680,000
- Clay base: 16.6 acres x $700 = $ 12,000
- Clay liner: $\frac{316 \times \pi 200 \times 2 \times 1.25}{27}$ = $ 184,000

Total = $5,880,000

Operation Cost

Maintenance and tailing transport only.

Option J - Expand Existing Pit

Option J does not differ significantly from Option I, except that the pit could be placed closer to the mill, making tailings transport much easier.

Cost Analysis - Option J

- Excavation: 11,600,000 yd^3 x 0.80 = $9,280,000
- Clay base 12,000
- Clay liner 184,000

Total = $9,476,000

Option K - Underground Mine Storage

Storage of tailings in the mined out underground workings of the mine on the north property has numerous inherent problems. The most significant of these are protection of the aquifer and radiation exposure of miners. Solidification of the stored radionuclides and chemicals would be a minimum requirement and retention of radionuclides in the solidified product has not been assured.

As this alternative was not considered environmentally satisfactory, cost estimates were not made.

3.3 FUGITIVE DUST CONTROL

This section discusses methods of controlling fugitive dust that potentially could be released from uranium tailings. Radon control is not considered in this section since a dust palliative would not be sufficient to minimize such releases. (See Section 3.4, Reclamation for a discussion of ground covers for radon control.)

Techniques for dust control can be valuable as interim controls until reclamation and total stabilization is complete. Numerous tailings cover techniques for the control of fugitive dust have been examined. Table 3.3-1 gives a summary of some dust control chemicals currently available and their approximate costs.

Other temporary stabilization techniques examined include sprinkling with water or tailings solution, mulching, or matting, which range in cost from \$40 to \$750 per acre.

Quantitative data on the effectiveness of these measures for the Morton Ranch tailings are not available.

3.4 RECLAMATION

Upon completion of operations, the UNC Morton Ranch uranium mill will have processed approximately 15 million tons of ore. This will result in approximately 10 million cubic yards of tailings which contain 7,725 curies of radium-226 and thorium-230 along with their short lived daughters. This section discusses the possible long-term tailings stabilization methods for protection of the environment and return of the land to productive use.

3.4.1 Description of the Options

With the exception of placing tailings in an underground mine, reclamation options have the following common features:

- o Tailings are allowed to dry. Interim treatment to reduce radon emanation and wind blown dust is evaluated on a case-by-case basis.
- o Reduce airborne emanations by covering or burying tailings.
- o Protect groundwater by placing tailings above water table with an impervious liner or suitable soil layer between tailings and water table.
- o Protect surface water by establishing the proper drainage patterns.
- o Re-establish normal ground contours.
- o Return land to unrestricted use.

TABLE 3.3-1

DUST PALLIATIVES

Palliative	Application Rate Per Acre	Annual Cost Per Acre	Comments
Coherex	24 to 2400 gal	$65 to $650	Good wind/water resistance
Lignosulfanates	2400 lb	$130 to $170	Effective
Elastomeric polymers	50 to 90 lb	~$130	Good results on either acid or alkaline, sandy tailings
Cement or milk of lime	--	$190	Effective
Paracol TC 1842 (resin emulsion)	--	$250	Effective
Pamak WTP	--	$250	Effective
Petroset SB-1	--	$250	Effective
Potassium silicate	--	$450 to $950	Effective
PB-4601	--	$500	Effective
Dresinol TC1843	--	$500	Effective
Soil Seal-13	--	$2000	Effective

All options can be placed into two categories: in-place stabilization and relocated stabilization. In-place stabilization is usually preferred because of lower costs, less handling of tailings, and already established groundwater protection. However, relocation is necessary when the mill tailings slurry cannot be piped to a suitable location during operation.

Specific reclamation options are discussed below.

<u>Option A - Bury Tailings in Place Using Empirically Determined Amount of Compacted Clay and Unspecified Overburden, 6 Inches of Topsoil and Revegetated</u>

The radon emanation rates would be measured onsite for both tailings and the surrounding area. Sufficient measurements would be made to map emanation rates for the impounded area and also determine an accurate average emanation rate for the surrounding area.

Diffusion parameters for compacted clays and unclassified overburden would be experimentally determined and used to calculate necessary thickness to reduce radon emanation from tailings to not more than twice the surrounding area's rate, and the tailings would be covered with the thickness. Emanation rates would be checked and additional overburden added if necessary. The site would be contoured, covered with topsoil, and revegetated.

<u>Option B - Bury Tailings In Place Using 2 Feet of Compacted Clay, 6 Feet of Unclassified Overburden</u>

Area would be contoured, covered with 6 inches of topsoil and revegeated.

This option is very similar to Option A; the values of clay and overburden are based on the theoretical calculation of .2 percent ore emanation rates and diffusion characteristics of varved clay.[13,14,15]

<u>Option C - Cover Tailing In Place Using 2 Inches of Concrete</u>

This option would require significant contouring and compaction of tailing in order to provide a suitable surface for the concrete.

<u>Option D - Cover Tailing In Place Using 2 Inches of Asphalt</u>

This option would also require significant contouring and compaction of tailings in order to provide a suitable surface for the asphalt.

<u>Option E - Relocate Tailings to an Existing Open Pit, Cover or Bury Using Options A, B, C or D</u>

Pit would need to be made impervious to prevent seepage from reaching groundwater.

Option F - Relocate Tailings to a Specially Prepared Pit, Cover or Bury Using Options A, B, C or D

Pit would need to be made impervious to prevent seepage from reaching groundwater.

Option G - Relocate Tailings into Underground Mine

Tailings would need to be treated to prevent contamination of groundwater. The technical feasibility of this option has not been demonstrated.

3.4.2 Evaluation of Reclamation Options

The selection of the proper option must consider the following factors:

- Reduction of radon concentrations
- Reduction of direct gamma radiation
- Prevention of tailing spreading to the environment
- Prevention of groundwater contamination
- Prevention of surface water contamination
- Long-term stability with minimization of monitoring requirements
- Economics

Table 3.4-1 summarizes the evaluation of the various reclamation options relative to the above criteria. A brief discussion of each of the criteria is given below.

Reduction of Radon Concentrations

Radon-222 from the tailings will be the principal source of radiation exposure from the shut-down mill. Uncovered, semidry tailings will result in ambient radon concentrations that are above background levels for distances up to 1/2 mile from the tailings. Figure 3.4-1 gives outdoor radon concentrations as a function of distance from the tailings impoundment area. Reduction of these radon concentrations is necessary to allow unrestricted use of the surface of the retention area and to assure that nonoccupational radiation doses remain as low as is reasonably achievable even if local population distribution or land occupancy rates should significantly increase.

All of the reclamation options utilize some form of diffusion barrier. The diffusion of radon through a barrier is dependent upon the thickness of the barrier, the percent of void spaces (nonsolids) in the barrier material, and the fluid (air, water, oil, etc.) in the barrier voids. Equation (1) gives the formula for determining the emanation rate through a barrier from a plane source of radon:

$$C_{(X)} = C_p \, e^{-\sqrt{\lambda v / D_e}\, x} \qquad (1)$$

TABLE 3.4-1

RECLAMATION EVALUATION

	Radon Reduction	Direct Gamma Reduction	Prevention of Tailings Spread	Prevention of Groundwater Contamination	Long-Term Stability with Minimum Maintenance and Monitoring	Economics	Pond	Pit
Option A: Bury tailings in place using emperically determined amount of compacted clay and unspecified overburden	S	S	S	S	S	Soil and clay burial	$3,227,000	$1,613,500
						Revegetation	24,000	12,000
						20-yr monitoring and maintenance	100,000	100,000
Option B: Bury tailings in place using 2 feet of compacted clay, 6 feet of unclassified overburden	S	S	S	S	S	Soil and clay burial	3,227,000	1,613,500
						Empirical tests	60,000	60,000
						Revegetation	24,000	6,000
						20-yr monitoring and maintenance	100,000	10,000
Option C: Cover tailings in place using 2 inches of concrete	U	U	S	S	U	Concrete cover	2,151,040	1,076,000
						Loss of land use	150,000	75,000
						Continuing maintenance and monitoring	4,400,000	2,251,040
Option D: Cover tailings in place using 2 inches of asphalt	S	U	S	S	U	Asphalt cover	1,452,000	726,000
						Loss of land use	150,000	75,000
						Maintenance and monitoring	3,000,000	1,552,000
Option E: Relocate tailings to an existing open pit; cover or bury	S	S	S	S	S	Burial	NA	1,613,500
						Groundwater protection	NA	4,790,000
						Relocation	NA	12,500,000
Option F: Relocate tailings to a specially prepared pit; cover or bury	S	S	S	S	S	Burial	3,237,000	1,613,500
						Groundwater protection and area pump	140,000	4,790,000
						Area pump	640,000	8,000,000
						Pump relocation	12,500,000	12,500,000
Option G: Relocate tailings into underground mine	S	S	S	U	S	Treatment	30,000,000	
						Transportation	12,500,000	

S = Satisfactory; meets criteria.
U = Does not meet criteria.

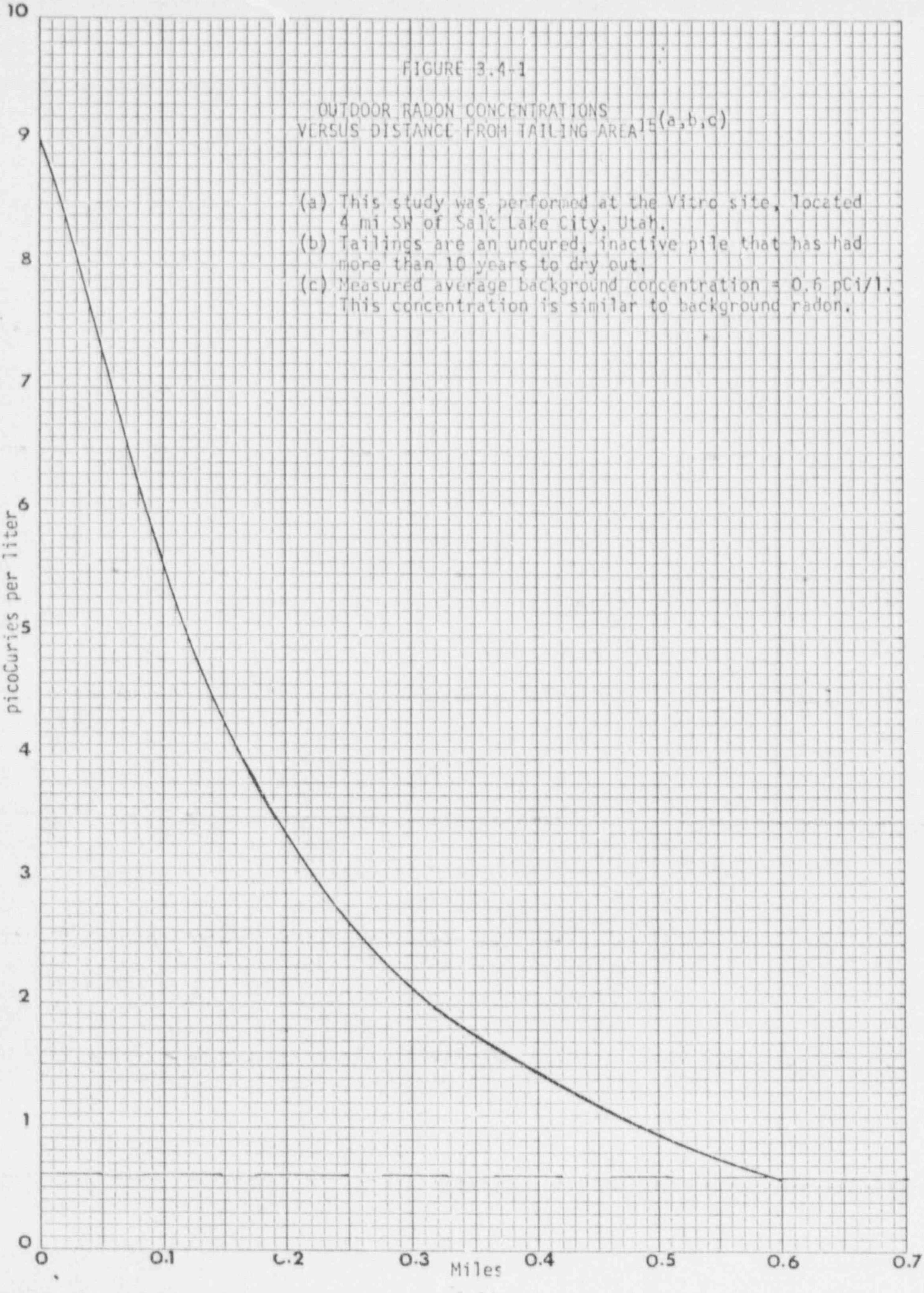


FIGURE 3.4-1

OUTDOOR RADON CONCENTRATIONS
VERSUS DISTANCE FROM TAILING AREA[15(a,b,c)]

(a) This study was performed at the Vitro site, located 4 mi SW of Salt Lake City, Utah.
(b) Tailings are an uncured, inactive pile that has had more than 10 years to dry out.
(c) Measured average background concentration = 0.6 pCi/l. This concentration is similar to background radon.

$C_{(X)}$ = radon emanation rate through the barrier.

C_p = radon emanation rate from plane source.

x = thickness of the barrier.

D_e = effective barrier diffusion coefficient for radon through the fluid (air, water, etc.) in the void spaces between the solid particles.

λ = decay constant of radon-222 = 0.692/half-life = 2.1×10^{-6} sec.

v = barrier void fraction; the fraction of the total volume which is not occupied by solid particles (this is often called the porosity and should not be confused with the porosity of an individual particle).

The calculated attenuation factors $C_{(X)}$ for various thickness and materials are given in Table 3.4-2. Comparing the calculated attenuation factors with the measured concentration (Figure 3.4-1) shows that, except for 2 inches of concrete, all of the proposed diffusion barriers will reduce radon concentrations to background levels.

TABLE 3.4-2

DIFFUSION BARRIER ATTENUATION FACTORS $\left(\frac{C_{(X)}}{C_p} = \exp^{-} \sqrt{\lambda v/D_e}\, x\right)$[14]

Depth	Overburden $e^{-}0.4x$	Clay[a] $e^{-}0.6x$	Asphalt[b] $e^{-}100x$	Concrete $e^{-}2.9x$
2"	.94	.90	E-4	62
1'	.67	.55	E-4	.06
2'	.45	.30	E-4	3.6 E-3
6'	.09	.03	E-4	E-4
10'	.02	2.5 E-3	E-4	E-4
20'	3.3 E-4	1.6 E-5	E-4	E-4

(a) This value is for varved clay. The clay utilized onsite will be compacted bentonitic clay, which should be a more effective diffusion barrier.

(b) Asphalt is theoretically the best diffusion barrier; however, asphalt tends to crack, and deteriorate, which seriously limits its potential for providing an effective, long-term diffusion barrier.

Reduction of Direct Gamma Radiation

Gamma radiation from the tailings is not expected to cau above background radiation levels except for directly over the tailing. The gamma dose rate 3 feet above uncovered tailings would be 1-2 mR/hr[a], which is approximately 50 times greater than background. Options that utilize a clay and

(a) Separation and deep burial of slimes would reduce dose rates to 0.2-0.4 mR/hr.

soil radon diffusion barrier also reduce the direct gamma radiations to essentially background. Options that utilize an asphalt or concrete diffusion barrier would require soil as well to reduce direct gamma radiation to acceptable levels[a].

Prevention of Tailings Spreading to the Environment

All of the proposed reclamation options will prevent tailings from spreading to the environment. In the event that tailings are inadvertently spilled during mill operation or restoration activities, they will be cleaned up and returned to the impoundment area prior to final restoration and reclamation.

Protection of Groundwater

All of the options which utilize a tailings pond or pit for storage place the tailings above groundwater with an impermeable soil or man-made barrier between the tailings and permeable strata. Pit storage will require elimination of seepage to groundwater from the sides of the pit as well as the pit bottom, and may require some reduction of the pit wall slope.

In-place reclamation options will utilize the operational retention system with associated groundwater protection. These methods will provide the necessary long-term groundwater protection. The site's small rainfall and high evaporation rate will further assure that tailings are not subjected to erosion or leaching by runoff from air or melting snow.

Options that involve relocation of tailings will receive identical groundwater protection as the in-place options. This will result in additional costs but will not create any additional technical difficulties.

Returning tailings to the underground mine would place the tailings in direct contact with an aquifer. This would necessitate treatment and/or solidification of tailings to prevent migration of radionuclides and chemicals to groundwater. The technical feasibility of this method for long-term stability has not been demonstrated.

Long-Term Stability with Minimum Monitoring and Maintenance

Long-term stability with minimum monitoring and maintenance is one of the primary criteria for the reclamation of a uranium mill site. Ideally, a satisfactory reclamation option should become self sustaining within a relatively short time period (approximately 20 years) and maintenance and monitoring should not be necessary after this time. Man-made membranes and covers provide excellent short-term protection but, by themselves, cannot be expected to provide long-term stability. Options which utilize stable geological and hydrological conditions, suitable soil (clay) layers, and a naturally contoured, properly drained, and revegetated soil cover will provide the best long-term stability.

(a) The Office of the US Surgeon General, Department of Health, Education and Welfare, recommends that residential external gamma dose rates be less than 40 $\mu R/hr$.

Economics

The various costs associated with each option were estimated based on the following factors:

- Total volume of tailings is 10 million cubic yards.
- Tailings pond covers 200 acres.
- The total area of pit surfaces capable of holding all the tailings is 100 acres.
- All overburden and clay is available onsite.
- Concrete costs $60/yard applied on site.
- Asphalt costs $27/yard applied onsite.
- Clay and overburden costs $1.25/cubic yard to apply.
- Transportation of tailings for relocation costs $1.25/cubic yard.
- Revegation costs $125/acre.
- Value of land is $300/acre.
- Treatment of tailings for placement in underground mine is $2/ton.
- Monitoring and maintenance costs for burial are $5000/year for 20 years.
- Monitoring and maintenance of man-made covers are twice the original cost.

4.0 ALTERNATIVE MANAGEMENT SYSTEMS

The purpose of this section is to summarize viable options for each phase of tailings management and to combine those options into alternative systems which are technically feasible, environmentally sound and economically justified. Any of the systems presented here represent workable alternatives.

From Section 3.0 the following options have been determined to be viable.

PHYSICAL/CHEMICAL TREATMENT

No treatment -- providing groundwater protection is adequate.

Barium chloride precipitation -- if there is sufficient likelihood for seepage during operation or leaching after reclamation to justify the additional cost.

Sand slime separation by cycloning or gravity separation -- provided slimes can be disposed of in a more acceptable manner than sands alone.

RETENTION SYSTEMS AND DISPOSAL SITES

The best of three dam designs in the south basin after sealing the 1704 pit with bentonitic clay or a combination of clay and a sprayed sealant.

Depleted open pit mines backfilled above the water table with a compacted clay liner on the bottom and sprayed sealant on the sides -- provided a sealant can be found with the following properties:

1. Good adherence to pit walls.

2. Low permeability under a pressure of about 200 feet of solution.

3. Resistant to acids, oxidizing agents and small amounts of kerosene over extended time periods.

4. Economic cost.

Depleted open pits sealed with a 20-foot thickness of compacted bentonitic clay, provided thorough engineering analysis indicates the structural stability of the clay walls.

FUGITIVE DUST CONTROL

If the alternative selected will result in significant tailings beaches water sprinkling or chemical sealants will be applied for dust control.

RECLAMATION

Reclamation of the tailings area with 2 feet of compacted clay, 6 feet of unclassified overburden, 6 inches of topsoil, replant and assure revegetation.

Reclamation of the tailings area with a thin (1/2 to 1/4 inch) asphalt cover plus at least 2 feet of unclassified overburden, 6 inches of topsoil and replant to assure productivity is returned, provided studies show plant root systems will not disrupt the radon attenuation properties of the asphalt.

Alternative I

Prepare the south basin areas by topsoil removal and clay placement and compaction. Excavate and spray line the 1707 pit. Construct retention dam from overburden from this and other pits.

Place unsorted tailings in the pond area near the down stream end, allowing the pond to begin filling and spill into the pit. Periodic changes in the discharge location would be used to distribute tailings relatively uniformly in the basin and to fill the pit with solids.

During periods of high evaporation when losses exceed net discharge dust would be controlled by sprinkling with water, or in cases where tailings may be exposed for several months chemical dust control would be employed.

As the pond dries after close of operation very thin layers of tailings material would be bulldozed toward the center of the pond to lessen the tailings storage area. As the pond dries from the edges inward, select clay, stockpiled during stripping operations, would be placed two feet deep and compacted to prevent blowing and achieve the first portions of reclamation. As soon as possible and once the pond is covered, unclassified overburden would be added over the clay to a depth of six feet, six inches of topsoil added and the area seeded at the appropriate time of year.

Monitoring during operation would consist of a series of high volume air samples, to detect blowing dust and to measure radon production. Water samples would be taken from specially drilled wells to detect seepage.

In addition survey points on the dam would be used to detect settlement and piezometers would be used to measure the phreatic water level.

This system is expected to provide maximum surface area for evaporation and adequate control of tailings solution. Control of fugitive dust is entirely by operational procedures which allows some room for error. This procedure should be adequate for the relatively small hazard involved.

The result of a tailings line failure with this system would be almost unconsequential since any spillage would go directly to the retention basin.

Alternative II

Alternative II is a modification of Alternative I which utilizes the same site preparation, pit excavation and preparation and dam construction. This system is designed to utilize gravity separation of the liquids and slimes to deposit sands where they can be reclaimed in part prior to mill shutdown. This system also uses the lined pit, 1707, to concentrate slimes for deeper burial.

The retention facility would be operated as follows: The tailings line would initially be directed toward the upstream (west) end of the pond area where the effluent would be deposited on a 10% grade where the sands would remain. A system of shallow channels within the pond would collect the water and slimes and divert them to the pit. Slimes would settle and the supernate would be recycled to the mill.

As the pit filled a weir would be installed to allow excess supernate to flow into the area behind the dam. Eventually the recycle return pump would be moved to this area.

As dewatered tailings accumulated at the upstream end of the pond they would be leveled, covered with compacted clay, overburden and topsoil, and reseeded.

Runoff from the tailings would continue to be diverted to the pit as long as volume for slimes remained and as long as the pit was sufficiently downgradient from the tailings deposition area.

At the close of operation the upstream portion of the basin would already be reclaimed and would have an extremely low radon emanation rate and gamma dose rate due to the low specific activity of the coarse sands. The slimes would be concentrated in two areas, the pit would contain the majority and the lowest portion of the pond would also contain a significant quantity. Extreme care would be taken to assure dust control of these areas as drying occurred. Once dry, this area would be covered with an oil or asphalt sealant prior to overburden cover and revegetation.

The problems inherent with this system are the necessity for adequate sealing of pit walls. Erosion control in channeling slimes and water to the pit. And, the decreasing evaporation area of the pond as operation progresses.

Advantages of the system include: the concentration of more radioactive portions of the tailings where more costly controls are justified. On-going reclamation which reduces dust potential and provides a significant savings in earth moving costs since overburden can be placed as it is removed from the pits without stockpiling and rehandling, and, a considerably reduced tailings beach area and its associated dust potential during most of the project life.

Alternative III.

This alternative unlike Alternative I and II does not require the construction of a tailings retention dam. The 1704, 1705, 1707, 1802 and 1803 pits would each be mined in turn and backfilled above the water table (only the 1707 pit will be above the water table at the close of mining). The last backfill to be placed will be clay which will be compacted to greater than 95% using water and sheepsfoot rollers. A sprayer will then be used to coat the bottom 20 to 50 feet of the pit wall with an impermeable coating. Asphalt base, plastic base and rubberized coatings may be used. See Table 4.0-1.

The tailings line would then be run to the pit and unsorted tailings deposited. Additional sealant would be added to increase the usable depth of the pit.

While the 1704 pit was filled the 1705 and 1707 pits would be prepared. Each of the pits would be partially filled with tailings, solids and liquid. This would allow for maximum evaporation. The mill recycle stream would be pumped from the active pit back to the mill.

If evaporating liquid leaves a residue on the pit walls which has a tendency to become airborne the walls will be washed with water or sprayed with a chemical sealant. This is not expected to be a major problem.

Once a pit was filled with semi-dry solids it would be reclaimed by covering with clay, overburden and topsoil as in Alternative I.

The major advantages of Alternative III are the reduced acreage for tailings storage and reclamation, the impossibility of a major tailings release from the impoundment area either during operation or from erosion after reclamation, and the relatively low construction cost compared with the dam construction and topsoil removal required for Alternatives I or II.

Table 4.0-1

SPRAY ON SEALANT MATERIALS

Product	Cost/ft^2 installed	Recommended Thickness	Comments
Chevron Suco[illegible]t 101	$2.00	1/8 to 1/2"	excellent resistance to acids & oxidants
C-190; P-205 Catalytic blown asphalt	0.33	1/4 to 1/2"	does not flow at normal temperatures
Rapid Curing Oil (emulsified oil)	0.08	1/4" - 1/2"	
Neoprene m[illegible]fied asphalt	0.09	1/2"	will flow - used for road surface & bridge deck
Gunite	0.70	3/4"	not acid resistant

The major drawbacks of Alternative III are: the relatively high tailings transport costs and increased potential for line failure; the relatively large number of monitoring wells required; the increased studies and justifications required in pioneering a new approach to tailings disposal; the need for a sealant which is impermeable, permanent, adheres to pit walls, and is relatively inexpensive; and the reclamation of overburden piles remaining on the surface.

Alternative IV.

Alternative IV represents a combination of Alternatives I and III and is designed to meet the rigorous schedule required by the applicant for mill startup while assuring adequate time for studies of seepage barriers for use in the pits.

Under this alternative applicant would construct the initial five year starter dam and proceed with stripping and mining the 1707 pit. At the same time a rigorous program of seepage barrier testing would be conducted. Commercially available, sprayable sealants would be tested for the permeability and adherence when applied to sandstone, for their resistance to pond chemicals, for their response to freezing and thawing and for deterioration from heat, ultraviolet radiation (effect of sunshine) and alpha and gamma radiation of levels expected from tailings.

If a material proves successful in these studies it will be used to line the 1707 pit within the tailings basin. If no suitable material is found the pit will be lined with bentonitic clay in successive lifts as described in Section 3.0 under Retention Systems and Disposal Sites Option E or backfilled. Additional tailings storage would then be provided by raising the starter dam in successive lifts and preparing additional pond areas.

Major advantages in this system are that it is responsive to applicant's commitments to supply uranium and allows adequate time for study of the pit disposal option both by the applicant and regulatory agencies.

Major drawbacks are the fact that the alternative does not greatly reduce the area covered by tailings, does not eliminate the need for dam construction and is likely to result in somewhat increased cost over Alternatives I, II or III.

Other identified tailings management alternatives which represent more than a minor deviation from these stated alternatives have not been considered feasible.

5.0 SUMMARY AND TAILING MANAGEMENT PLANS

After careful evaluation of viable alternatives, Applicant has selected Alternative II as most responsive to the objective established and most workable.

Although some design and engineering details are still under study, specific project plans are outlined below and illustrated in Figure 5.0-1.

The natural north-eastward draining basin lying to the south of the plant bench will be dammed for initial deposition and ultimate burial of all the mill tailings expected to be accumulated during the life of the mill. The entire storage area will be stripped of topsoil in conformance with the State of Wyoming Department of Environmental Quality Rules and Regulations. The average stripping depth will be about two feet. Topsoil will be stockpiled and vegetated for use in reclamation after the close of operations. Exposed lithologic sandstone units will be covered to a depth of two feet with bentonitic clays obtained from pit openings or excavated within the basin. Sands may be excavated to obtain a relatively smooth floor in the basin. The removed sands might be used as "unclassified fill" material for the drain construction. All clay, whether found in place or brought in to seal the pond bottom will be compacted with water and a sheepsfoot roller to a minimum of 95% compaction.

Three embankments are being designed and evaluated for the tailings dam. A "downstream" dam to be constructed in five year increments is the first consideration. For this design the compacted clay pond bottom will be extended into the core from the face of the dam. Unclassified fill, compacted in place, will form the structural support. The downstream slope, toward the pond will be 2 to 1 and the upstream slope will be 2.5 to 1. (See Figure 3.2-2).

The second choice for dam construction is a centerline dam constructed to its ultimate width initially and raised in 5-year increments. As a third choice this centerline dam might be constructed initially for the total project life. (See Figure 3.2-3).

The selection of the tailings dam design will be based upon embankment stability, projected seepage rate and availability of construction material from stripping operations.

Diversion ditches at the upper end of the pond will divert runoff from the upper 230 acres of the valley. Only precipitation falling within the impoundment area will be retained in the pond.

The 1707 ore body lies on the south slope of the retention basin a short distance from the planned embankment. This ore body is not fully explored, but is expected to be economically mineable by open pit mining methods. The resulting pit will be approximately 20 feet deep at the lower pit wall, and will require an excavation of 0.4 million cubic yards of overburden and ore. The overburden material removed from the pit will be utilized in construction of the retention dam.

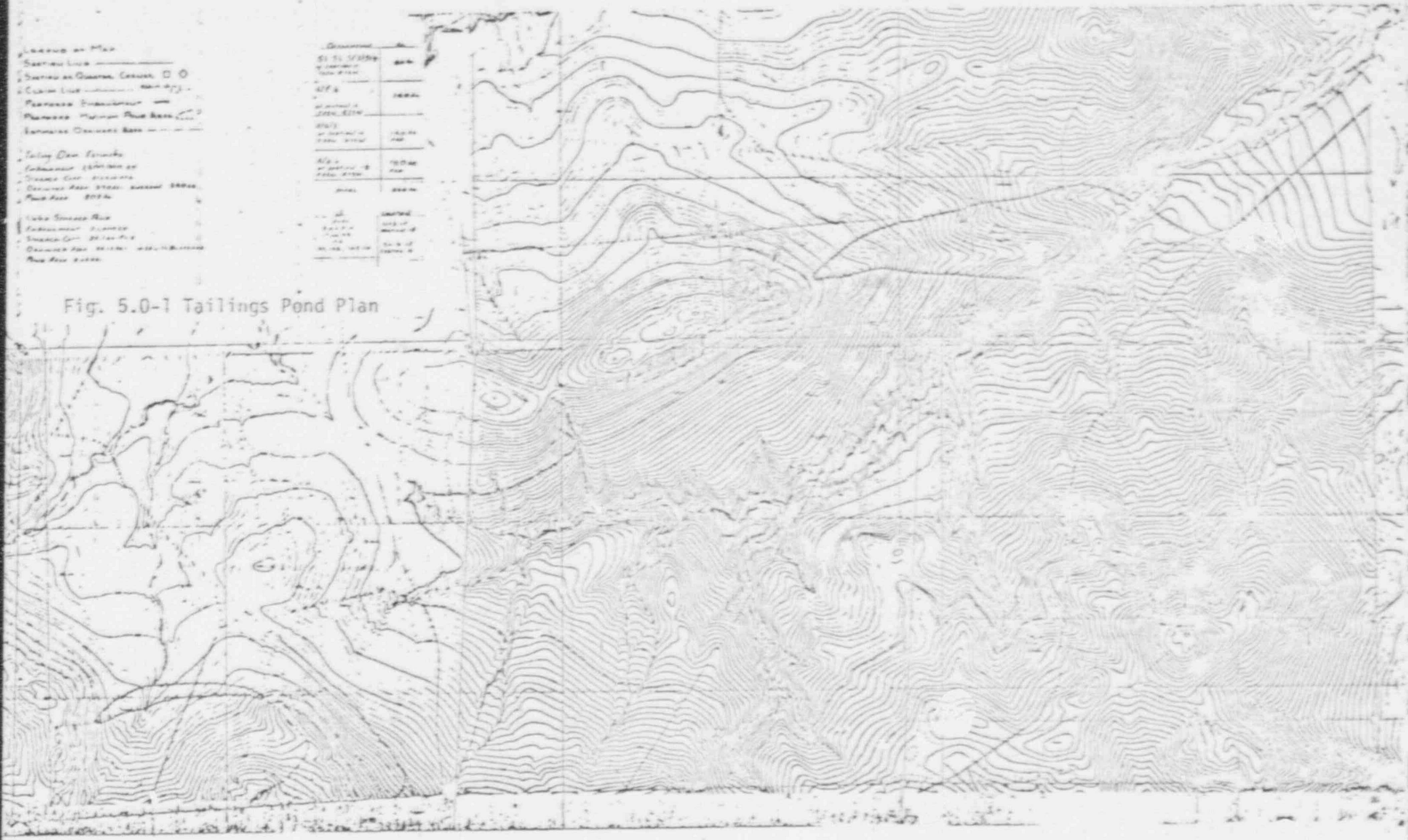


Fig. 5.0-1 Tailings Pond Plan

Although the pit resulting from mining the 1707 ore body lies above the water table, the pit will be backfilled and clay capped to provide an impermeable barrier to seepage.

Under the current concept, tailings would be introduced into the tailings disposal area at the upstream reaches. The sands would be allowed to build up to the final burial depth while the slimes and liquids would flow downstream toward the dam.

Reclamation of the disposal area would be done progressively as the sands build up to ultimate burial depth.

A graph presenting the storage capacity and the resulting surface area for the pond exclusive of the pit is shown in Figure 5.0-2. The storage capacity to be provided by a dam at various points in the project life are shown in Table 5.0-1.

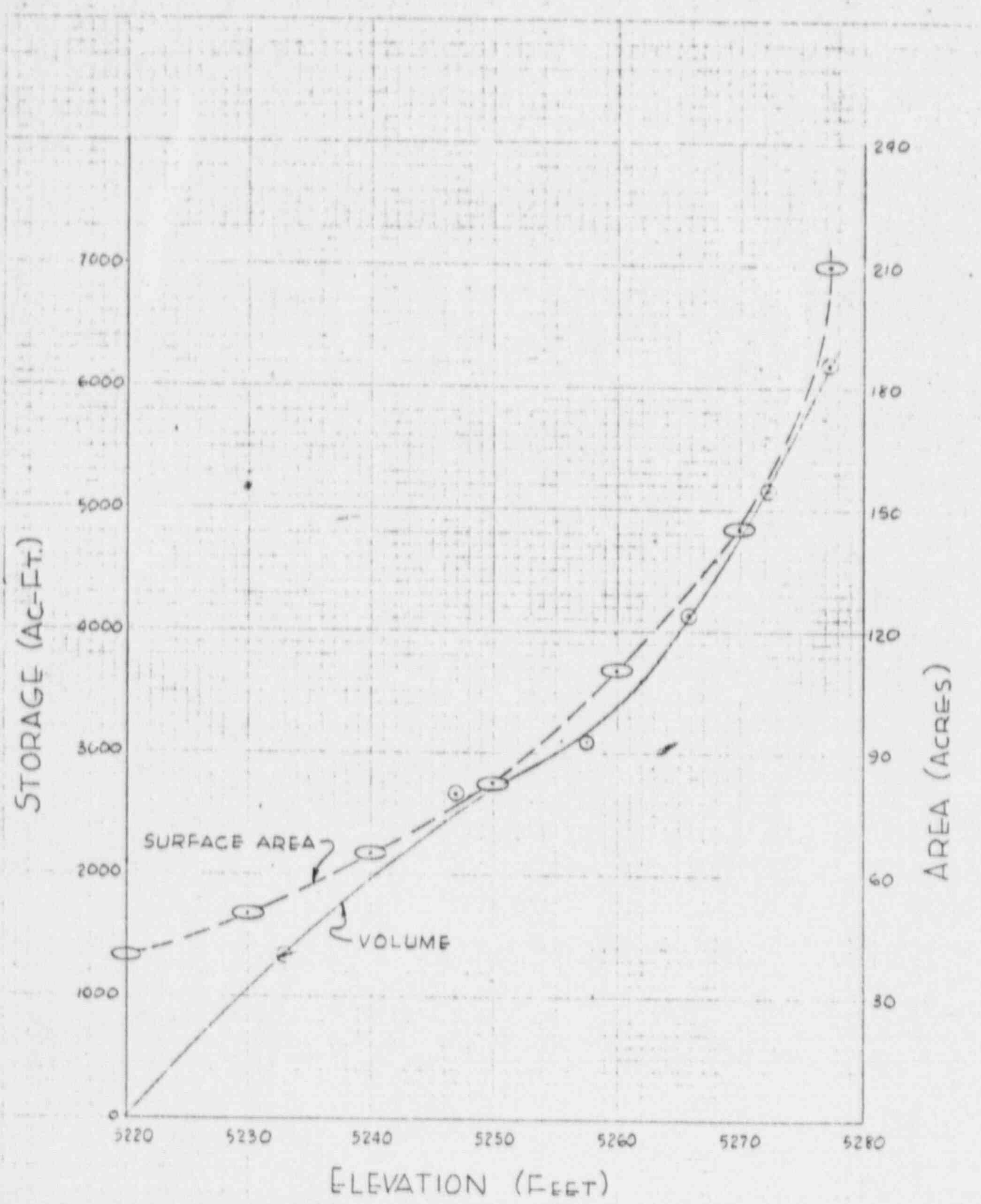
Table 5.0-1

TAILINGS DESIGN PERAMETERS

Years of 3,000 ton/day operation	Surface Area Acres	Volume of Solids	Pool Area Min. Acreage of Liq. Surface	Pool Area Average Depth in Feet	Total Volume in Acre Feet
5	74	1033.33	26.54	10.3	2400
10	107	2066.67	32.4	9.16	3550
15	160	3100.00	44.40	10.34	5400
Final Capacity	171	4133.40	31.33	10.0	5700

Figure 5.0-2

Tailings Disposal Storage Capacity



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