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**Fixed Capital Investments
for the Uranium Soils
Integrated Demonstration
Soil Treatment Technologies**

**Douglas M. Douthat
Robert N. Stewart
Anthony Q. Armstrong**

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1. BACKGROUND

The development of a nuclear industry in the United States required mining, milling, and fabricating a large variety of uranium products. One of these products was purified uranium metal which was used in the Savannah River and Hanford Site reactors. Most of this feed material was produced at the United States Department of Energy (DOE) facility formerly called the Feed Materials Production Center at Fernald, Ohio.

Currently, this facility is called the Fernald Environmental Management Project (FEMP) and is operated by the Fernald Environmental Restoration Management Corporation (FERMCO). The facility consists of 1,050 acres in a rural area that is 18 miles northwest of Cincinnati, Ohio. The manufacturing processes were housed in a 136-acre fenced area and included uranium and thorium metal production and uranium hexafluoride reduction. Production peaked in 1960 with approximately 10,000 tons of uranium processed and began to decline in 1964 to a low of 1,230 tons in 1975. In the mid-1980s, production increased slightly but was terminated in 1989 due to the lack of demand for uranium products.

During operation of this facility, soils became contaminated with uranium from a variety of sources. The sources included deposition of airborne uranium particulates that came from facility stacks as well as leaks and spills of uranium-containing solvents and process effluents generated during nonaqueous extraction/treatment processes. The exact quantity of soil contaminated with uranium is unknown. Some estimates of soil containing unacceptable levels of uranium are as high as 2 million cubic yards. To avoid disposal of these soils in low-level radioactive waste burial sites, increasing emphasis has been placed on the remediating soils contaminated with uranium and other radionuclides.

To address remediation and management of uranium-contaminated soils at sites owned by DOE, the DOE Office of Technology Development (OTD) formed the Uranium Soils Integrated Demonstration (USID) Program to evaluate and compare the versatility, efficiency, and economics of various technologies that may be combined into systems designed to characterize and remediate uranium-contaminated soils. The USID was initiated in 1991 and the FEMP was selected as the host site. The USID Program has five major tasks in developing and demonstrating these technologies. Each must be able to 1) characterize the uranium in soil, 2) decontaminate or remove uranium from soil, 3) treat or dispose of resulting waste streams, 4) meet necessary state and federal regulations, and 5) meet performance assessment objectives. The role of the performance assessment objectives is to provide the information necessary to conduct evaluations of the technologies. These performance assessments provide the basis for selecting the optimum system for remediation of large areas contaminated with uranium. One of the performance assessment tasks is to address the economics of full-scale implementation of soil treatment technologies developed by the USID Program. The cost of treating contaminated soil is one of the criteria used in the decision-making process for selecting remedial alternatives.

2. INTRODUCTION

During the past 2 years, the USID Program has directed various studies throughout the DOE national laboratories, universities, and private industry to determine the best methods to remove uranium from uranium-contaminated soils. The majority of these studies have been conducted in the laboratory at the bench-scale level, and results from these bench-scale studies have been extensively presented and published (Soil Decontamination Task Group 1993, Post and Wacks 1994). The studies have focused on the following seven soil treatment technologies: sodium carbonate soil washing system, sulfuric acid

soil washing system, citric acid soil washing system, tiron soil washing system, heap leaching system, fungal leaching process, and aqueous biphasic extraction.

As the development of these technologies progresses from the bench-scale level to pilot plant testing, the feasibility of operating a full-scale treatment facility using the technologies studied by the USID Program will be evaluated. During the summer of 1994, Halliburton NUS developed engineering flow diagrams for full-scale treatment facilities based on each of the seven technologies. The USID Performance Assessment Group members at the Oak Ridge National Laboratory (ORNL) are responsible for developing cost estimates for the proposed treatment technologies.

Due to the stage of research and the timeframe involved to develop the flow diagrams and cost estimates for the treatment technology options, a number of assumptions and simplifications had to be made. Given the stage of the research work, much of the data used to develop the flow diagrams were preliminary and subject to revision. Therefore, the engineering diagrams and the resulting cost estimates contain a large amount of uncertainty, and they should be viewed as preliminary results only. As further research at the bench-scale and pilot plant levels are completed, the engineering designs will be refined and updated to produce a facility with optimum operating conditions. Once the engineering designs have been revised, the cost estimates will also be refined and updated, thereby eliminating some of the uncertainty.

The objective of this document is to describe the work conducted by the ORNL personnel responsible for developing cost estimates based on the full-scale implementation of the soil treatment technology alternatives being demonstrated by the USID Program. These cost estimates are based on the "best engineering design" for each treatment technology, determined by Halliburton NUS personnel after discussions with the principal investigators conducting the bench-scale studies.

The cost estimates for the treatment technology options will be conducted in three steps. The first step is to estimate the fixed capital investment (FCI), which represents the initial capital expenditure required to design and construct the full-scale treatment facility to operational readiness. The FCI is a one-time project investment cost that occurs at the beginning of the project. The second step is to develop estimates of the operational costs for each of the full-scale facility designs. Operational costs include costs for raw materials involved in processing, operating labor, supervisory labor, utilities, plant maintenance and repairs, and miscellaneous costs such as operating supplies, taxes, and insurance. Unlike FCI costs, operating costs are recurring throughout the life of the project. The third step is to estimate the life-cycle costs for each treatment technology option. The life-cycle costing approach involves projecting the current and future cash flows for soil remediation by each treatment technology over the project life, based on the estimated quantity of contaminated soil at the Fernald site. Non-recurring costs occurring in the first year include the FCI and start-up expenses. Thereafter, operational costs for a full-scale facility based on each treatment technology are projected into future cash flows using an assumed inflation rate. Total costs to build and operate the full-scale treatment facility will then be summed over the life of the project and divided by the amount of soil to be processed to determine which treatment technology is the most cost effective based on their respective values for the treatment cost per ton of soil treated.

This document addresses the FCI for each of the treatment technologies being demonstrated by the USID Program. Future documentation will address the operational costs and the life-cycle costs for the treatment technology options. In addition, this report provides an explanation and description of the FCI,

as well as a list and an explanation of cost ranges for the components used in deriving the FCI for each treatment technology alternative. The FCI for a soil preparation building, required regardless of the soil treatment technology being considered, is also provided. Appendix A contains the engineering flow diagrams of the soil treatment technologies which were developed by personnel at Halliburton NUS. Appendix B provides a detailed cost breakdown of the chemical processing equipment required for full-scale implementation of each soil treatment technology alternative.

3. FIXED CAPITAL INVESTMENT

The FCI is the capital needed to supply the necessary manufacturing and plant facilities for an industrial operation or project. For the USID project, the FCI represents the initial capital expenditure required to construct a full-scale treatment facility based on each of the proposed treatment technologies being demonstrated. The fixed capital investment estimates in this report are defined as study estimates. A study estimate is based on the knowledge of major items of equipment, with an accuracy of over plus or minus 30%. A preliminary estimate is based on sufficient data to permit the estimate to be budgeted, with an accuracy of within plus or minus 20% (Peters and Timmerhaus 1991). Because specifications and design requirements for the equipment as well as the process were preliminary, there is a large probability that the actual cost will be more than the estimated cost where information is incomplete or during inflationary periods. For such estimates, the positive spread is likely to be wider than the negative (Peters and Timmerhaus 1991). Therefore, the plus or minus 30% accuracy rate for a study estimate may in fact be +40% to -20%.

A common method for estimating the FCI is to define it as a function of the purchased equipment costs with each component of the FCI estimated as a percentage of the equipment cost. The method of estimating the FCI by percentage of purchased equipment cost is commonly used for study and preliminary cost estimates. Table 1 presents a checklist of the items used to estimate the FCI for chemical processing plants, along with the range for each item as a percentage of the purchased equipment cost. The cost range for the FCI items shown in Table 1 are based on input from several studies developed by chemical processing cost estimators plus additional data and interpretations from other sources with experience in modern industrial design and construction (Peters and Timmerhaus 1991). The FCI is the sum of the direct and indirect plant costs, contractor's fee, and contingency.

The cost estimator was provided with an equipment parts list for each treatment technology being demonstrated by the USID Program. Once an estimate of the total equipment cost was determined for each treatment technology, percentages of this value were used to calculate the FCI, with the exception of building costs. The percentages of total equipment costs used for FCI calculations were based on many factors, including the type of process involved, design complexity, required materials of construction, as well as discussions with Halliburton NUS representatives experienced in estimating costs for chemical processing equipment. Building costs were determined based on unit costs and estimates of the square footage of building space required for a full-scale treatment facility for each treatment technology alternative. Unit costs for the treatment technologies' building and foundation were provided by cost estimation personnel at Halliburton NUS. Along with surveying and associated closing costs, land costs are normally included in the FCI. However, for this report they were reported as zero for the treatment technology cost estimates, because the facility was assumed to be located on already purchased land at the Fernald site.

Table 1. Fixed capital investment template

Item	Symbol	Description	Range
1	E	Equipment Costs	E
2	L	Cost of Installation Labor	.25E - .55E
3	IC	Instrumentation & Controls	.06E - .30E
4	I	Insulation Costs (equip. & piping)	.05E - .09E
5	P	Piping	.16E - .31E
6	Q	Labor for Installation of Piping	.40P - .50P
7	F	Electrical Installations	.10E - .15E
8	B	Building including Services	.05E - .68E or unit costs, if available
9	Y	Yard Improvements	.10E - .20E
10	S	Service Facilities	.30E - .80E
	D	Direct Plant Cost	Sum 1 - 10
11	ES	Engineering & Supervision	.15E - .80E
12	C	Construction Expenses	.15E - .60E
	IP	Indirect Plant Cost	ES + C
13	CF	Contractor's Fee	.02(D+IP) - .08(D+IP)
14	CO	Contingency	.05(D+IP) - .20(D+IP)
	FCI	Fixed Capital Investment	D+IP+CF+CO

Costs for several pieces of processing equipment were estimated from documents published in previous years. In these cases, cost indexes were used to project these values to present-day costs. A cost index is an index value for a given point in time showing the cost at that time relative to a certain base time. If the cost at some time in the past is known, the equivalent cost at the present time can be determined by multiplying the original cost by the ratio of the present index value to the index value applicable when the original cost was obtained. Many different types of cost indexes exist for estimating items such as processing equipment, labor, construction, materials, and other specialized fields (Peters and Timmerhaus 1991). The Marshall and Swift All-industry and Process-industry Equipment Index was used when costs were obtained from one of the sources containing equipment costs from the past.

The purchased equipment costs (E, referring to Table 1) were obtained from one of the following sources: 1) vendors specializing in the type of chemical processing equipment required for each soil treatment technology, 2) cost estimating personnel at Halliburton NUS, 3) Richardson's Engineering Services *Process Plant Construction Estimating Standards*, 1994 edition, 4) *Mining and Mineral Processing Equipment Costs and Preliminary Capital Cost Estimations*, Volume 25, 1982, 5) *Means Site Work and Landscape Cost Data*, 12th annual edition, 1993, and 6) *Plant Design and Economics for Chemical Engineers*, Max S. Peters and Klaus D. Timmerhaus, 4th edition, 1991. The most accurate method for determining process equipment costs is to obtain firm bids from equipment fabricators or suppliers. Verbal and/or written quotes for the specialized equipment pieces were obtained in as many cases as possible. However, in some cases vendors were unable to provide price quotations because certain design requirements that could significantly affect costs were not available. In cases such as this, as well as for the more common types of processing equipment, costs were estimated from one or more of the above listed reference sources.

The installation of equipment (L) involves costs for labor, foundations, supports, platforms, and other construction expenses related to the erection of purchased equipment. Although different ranges of installation costs exist depending on the type of chemical processing equipment, most fall within the .25E to .55E range specified in Table 1. Instrumentation and controls (IC) costs can vary from 6% to 30% of the purchased equipment costs. For the soil treatment technology alternatives, IC costs were estimated at .13E because this value is normally used for solid-fluid chemical processing plants. The major portion of this category consists of instrument costs, installation labor costs, and expenses for auxiliary equipment and materials.

The estimated cost for piping (P), with a range of 16% to 31% of equipment costs, varies depending on the type of chemical processing plant under consideration (i.e., solid processing, solid-fluid processing, or fluid processing plant). This cost category typically includes valves, fittings, pipe, supports, and other items involved in the complete erection of all piping used directly in the treatment technology process. This includes the piping used for air, steam, water, and other process piping requirements, as well as for the equipment used to treat the contaminated soil. The labor for the installation of piping (Q) ranges from 40% to 50% of the total cost of piping. Insulation costs (I) for equipment and piping normally range from 5% to 9% of purchased equipment costs. Insulation costs vary depending on many factors, including the number of pieces of equipment exposed to very low or high temperatures (i.e., how much of the equipment is enclosed in the building and how much is located outside the building?) and the amount of piping that is required in each full-scale treatment facility design. Electrical installation costs (F) range from 10% to 15% of equipment costs. This cost category consists primarily of installation labor and materials for power wiring, lighting, transformation and service, and instrument and control wiring (Peters and Timmerhaus 1991).

The cost for buildings including services (B) consists of expenses for labor, materials, and supplies involved in the construction of all buildings associated with the treatment facility. The costs for plumbing, heating, lighting, ventilation, and similar building services are also included in this category. The range for this cost varies from 5% to 68% of the purchased equipment cost and is dependent on two factors: 1) the type of process plant (solid, solid-fluid, or fluid processing plant) and 2) whether or not the facility being considered is a new plant at a new site or a plant expansion at an existing site. For solid-fluid processing plants, building costs can range from 29% to 47% of purchased-equipment costs (Peters and Timmerhaus 1991). However, for this report the square footage of building space required for the treatment facility was estimated by Halliburton NUS personnel from the engineering flow diagrams, and costs were estimated from unit costs based on these building size requirements. This provides a more accurate estimate of the building cost rather than estimating the building costs as a percentage of the purchased equipment cost.

After determining the equipment costs for each of the treatment technology options being considered for the USID Program, it appears that basing the building costs solely as a percentage of the equipment cost is not as accurate as using unit costs to estimate building costs because of the wide variation in equipment costs for the treatment technology options. For example, Halliburton NUS personnel recommended that both the sodium carbonate and tiron soil washing facilities can be contained in a 2-story building with 15,000 ft² per floor. Therefore, the building costs for each of the treatment technology cost estimates should be approximately the same because the estimates are based on square footage requirements. However, if the building costs for the two systems had been estimated based on a percentage of the equipment cost, the cost estimates would have been dramatically different, since the equipment cost used to calculate the FCI for the tiron system was estimated at approximately \$14,896,000, whereas the sodium carbonate system equipment cost was much less at \$5,172,000. Using a factor of 25% of the purchased equipment cost to calculate the building costs, the tiron system would have resulted in a \$3,700,000 building cost, while the sodium carbonate soil washing system would have resulted in a \$1,300,000 building cost.

Yard improvements (Y) for the facility include the costs for site clearing and grading, roads and walkways, fencing, lighting, parking areas, landscaping, and other similar improvements. These costs range from approximately 10% to 20% of the purchased equipment cost. The total cost for service facilities (S) ranges from 30% to 80% of equipment costs. These costs include the utilities for supplying and distributing steam, water (i.e., treatment and distribution), power (i.e., electric substation and distribution), compressed air, and fuel to the soil treatment facility. In addition, waste disposal, fire protection, and miscellaneous service items such as communications, first aid, and safety installations require capital investments which fall under the category of service facility costs (Peters and Timmerhaus 1991). Service facilities costs are largely a function of plant physical size and will be present to some degree in most plants. However, there are many service facility cost categories, and for most solid-fluid chemical processing plants, there will not always be a need for each service-facility component. It is anticipated that the water and electricity requirements for each of the full-scale treatment facility options will be fairly high. Therefore, a middle to upper range value was used to estimate service facilities costs for the treatment technologies. The sum of the following items make up the direct plant cost (D) for the facility: 1) equipment, 2) equipment installation labor, 3) instrumentation and controls, 4) equipment and piping insulation, 5) piping, 6) piping installation labor, 7) electrical installations, 8) building including services, 9) yard improvements, and 10) service facilities.

Engineering and supervision costs (ES), ranging from 15% to 80% of equipment costs, are indirect plant costs (IP), because they cannot be directly charged to equipment, materials, or labor. Costs for construction design and engineering, drafting, purchasing, accounting, cost engineering, travel, reproductions, and overhead constitute the capital investment for engineering and supervision (Peters and Timmerhaus 1991). A value close to the upper limit of the cost range was used for all of the treatment technologies, because engineering costs will undoubtedly be high due to the preliminary stage of development for each of the treatment technologies. Another indirect plant cost used in calculating the FCI for each treatment technology option is construction expense (C), ranging from 15% to 60% of equipment costs. This cost item includes temporary construction and operation, construction tools and rentals, construction payroll, insurance, and other construction overhead items. The sum of the engineering and supervision and construction expense items comprise the indirect plant costs for the treatment facility.

A contractor's fee (CF) and contingency (CO) are normally added to the direct and indirect plant costs in calculating the FCI. The CF ranges from 2% to 8% of the sum of the direct and indirect plant costs. Contingency is a project markup factor normally applied to cost estimates to account for any uncertainties or unforeseen occurrences, such as inflationary price trends, bad weather conditions, strikes, small design changes, estimation errors, or possible material shortages associated with a project. Contingency normally ranges from 5% to 20% of the sum of direct and indirect plant costs (Peters and Timmerhaus 1991). Because of the experimental and developmental nature of these treatment technologies, it was determined that the most conservative value (20% of the sum of direct and indirect plant costs) should be used to estimate the contingency for each treatment option. The FCI for each treatment technology is then calculated by summing the direct and indirect plant costs, contractor's fee, and contingency.

4. FCI CALCULATIONS FOR THE TREATMENT TECHNOLOGIES

As stated earlier, the FCI is the initial capital required to provide full-scale implementation of a soil treatment facility. For the FCI calculations, the direct and indirect plant costs for the treatment technology alternatives are based on technical judgement and discussions with cost estimating personnel at Halliburton NUS, as well as comparisons with capital investment requirements for similar facilities. As a joint effort between USID Performance Assessment Group members at ORNL and personnel at Halliburton NUS, equipment costs for each of the treatment technologies were created. ORNL Performance Assessment Group members were responsible for developing the FCI requirements for the treatment technologies and were aided by additional guidance and technical information from personnel at Halliburton NUS experienced in estimating costs for chemical processing equipment.

4.1 SOIL PREPARATION BUILDING

A soil preparation building in which soil is processed before treatment is required for all soil treatment technologies evaluated. A plan view of the proposed soil preparation building developed by Halliburton NUS and an equipment layout are shown in Appendix A. The soil preparation building is a double-bay facility with a total length of 150 ft, a total width of 120 ft (60 ft per bay), and a height of 30 ft. Dump trucks drive into the facility to unload contaminated soil in two soil receiving pits, one in each bay. The building is designed so that work will be conducted in each bay on alternating days. An overhead crane

system will be used to transport the soil from the two 50 ft × 85 ft storage areas (one in each bay) to the storage transfer hoppers which transport the soil to the main conveyor. The equipment in the soil preparation building is primarily composed of enclosed and ventilated conveyor systems and hoppers, a vibrating grizzly for soil separation, and a 60,000 cfm baghouse air pollution control system. The baghouse system controls the dust from soil transport activities as well as the fumes from the trucks and bulldozers transporting the soil.

Discussions concerning the need for a high-efficiency particulate air (HEPA) filter system in addition to the baghouse air pollution control system have been initiated by interested participants of the USID program. One reviewer felt that potential exhaust problems, as well as worker health and safety requirements, associated with a full-scale soil treatment facility may prompt DOE to require a HEPA filter system for the soil preparation building. However, an engineer at Halliburton NUS believed that a sprayer system could be used on the contaminated soil coming into the soil preparation building to wet the soil and alleviate dust control problems. Based on his experience and site visits to soil washing facilities, he believed that the combination of the sprayer system and the 60,000 cfm baghouse system included in the equipment list of the soil preparation building should be more than adequate to control potential dust emissions. The soil in the soil treatment building will be in a slurry, which should eliminate the need for dust control equipment in this facility.

The equipment costs for the soil preparation building, shown in Appendix B, Table B.1, are based primarily on vendor quotes and verbal communication with vendors. The total cost for the equipment in the soil preparation building is approximately \$486,000. The most expensive pieces of equipment are the baghouse air pollution control system and overhead crane system, estimated at \$170,000 and \$120,000, respectively. Table 2 shows an estimated FCI for the soil preparation building. Yard improvement and service facilities costs were estimated at the lower end of the range because the primary concern was for costs associated with the soil preparation building itself and not with the extra costs associated with these items. Building costs, as well as costs for the foundation, storage containment walls, and soil receiving pits are based on unit costs for the construction materials specified by the engineering flow diagram parts list. The total cost for the building, including services (labor, materials, and equipment), is \$1,058,000, approximately one-half of the direct plant cost of \$2,202,000. Engineering and supervision and contingency costs were estimated conservatively because of the developmental nature of this project, along with the requirement for new designs for this building as well as the full-scale soil treatment facility. The indirect plant costs for the soil preparation building are \$413,000. Adding the contractor's fee and contingency of \$131,000 and \$523,000, respectively, to the direct and indirect plant costs results in a FCI of approximately \$3,269,000 for the soil preparation building. In case it is determined that a HEPA filter system is required for the soil preparation building, a cost estimate for this type of equipment is \$25,000 per 1,000 cfm requirement. For a 60,000 cfm baghouse system, the estimated cost for the HEPA filter equipment is \$1,500,000. Therefore, adding the HEPA filter system to the soil preparation building would increase the FCI value by 46% (from \$3,269,000 to \$4,769,000).

4.2 SODIUM CARBONATE SOIL WASHING SYSTEM

The engineering flow diagram for the sodium carbonate soil washing system is shown in Appendix A. The equipment costs for the sodium carbonate system are shown in Appendix B, Table B.2. The total equipment cost (E) is estimated at approximately \$5,172,000. The post-reactor and post-water

Table 2. FCI for soil preparation building

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$485,935
2	L	Cost of Installation Labor	.40E	\$194,374
3	IC	Instrumentation & Controls	.13E	\$63,172
4	I	Insulation Costs (equip. & piping)	.05E	\$24,297
5	P	Piping	.16E	\$77,750
6	Q	Labor for Installation of Piping	.40P	\$31,300
7	F	Electrical Installations	.15E	\$72,890
8	B	Building including Services	---	\$1,058,367
9	Y	Yard Improvements	.10E	\$48,594
10	S	Service Facilities	.30E	\$145,781
	D	Direct Plant Cost	Sum of 1-10	\$2,202,258
11	ES	Engineering & Supervision	.60E	\$291,561
12	C	Construction Expenses	.25E	\$121,484
	IP	Indirect Plant Cost	ES+C	\$413,045
13	CF	Contractor's Fee	.05(D+IP)	\$130,765
14	CO	Contingency	.20(D+IP)	\$523,061
	FCI	Fixed Capital Investment	D+IP+CF+CO	\$3,269,128

rinse vacuum drum filters are by far the most costly pieces of equipment for this system, magnified by the fact that 10 units are required. The total estimated cost for the 10 vacuum drum filters is \$2,700,000, which is approximately 52% of the total equipment cost for the entire sodium carbonate system. Other costly items include six steel soil water rinsing clarifiers at a total cost of \$720,000 and two pre-reactor clarifiers at a total of \$240,000.

Results of the FCI calculation for the sodium carbonate soil washing system are shown in Table 3. Piping and instrumentation costs for all of the technologies fall within the same range, except for the heap leaching system. After a review of piping and instrumentation costs for several of the treatment technologies developed by Halliburton NUS, it was decided that the lower end of the range would be an appropriate factor to use for piping costs (.16E), as well as insulation costs for the equipment and piping (.05E). Another reason the lower end of the range was used for the piping and insulation costs is that a factor for instrumentation and controls, at 13% of equipment costs, is already being considered in the FCI calculations. Piping and instrumentation costs are interrelated and are normally included under the same heading for most FCI cost estimates. Yard improvements for all the technologies were estimated at the lower end of the range because the concern is primarily for the full-scale treatment facility itself and not the extra cost items (i.e., sidewalks and landscaping) normally considered in this cost category. With the exception of the fungal leaching process, the value of 55% of equipment costs for service facilities was used in the FCI calculations, because it represents an average value for a solid-fluid processing plant.

Building costs are based on the assumption of a 2-story building with 15,000 ft² per floor. All of the filters will be located in the top floor. Unit costs based on square footage requirements were used to estimate costs for the treatment building, building foundation, loading/unloading area, and parking area. The total cost for the building (labor, materials, and supplies) and its associated items is \$1,272,000. The direct cost for the sodium carbonate soil washing plant is approximately \$14,741,000. As in the case for the soil preparation building, engineering and supervision and contingency costs for all of the treatment technologies were estimated conservatively because of the experimental nature of this project. Indirect plant costs, consisting of construction expenses and engineering and supervision, for this system are approximately \$4,396,000. Adding the contractor's fee and contingency of \$957,000 and \$3,828,000, respectively, to the direct and indirect plant costs results in a FCI of approximately \$23,922,000 for the sodium carbonate soil washing system.

4.3 SULFURIC ACID SOIL WASHING SYSTEM

Appendix A provides the engineering flow diagram for the sulfuric acid soil washing system. The equipment costs for the sulfuric acid system are shown in Appendix B, Table B.3. Many of the pieces of equipment for the sulfuric acid system are also required for the sodium carbonate soil washing system. In fact, with the exception of a few expensive systems or specialized pieces of equipment, the equipment lists for the sodium carbonate, sulfuric, citric acid, and tiron soil washing systems require many of the same pieces of equipment. However, the requirement for these few specialized pieces of equipment is a major reason why the citric acid and tiron systems' total equipment costs and resulting FCI calculations are so much higher than those of the sodium carbonate and sulfuric acid systems. Also, the additional requirement for lime storage and production and an ion exchange system for the sulfuric acid system is the major difference between this system and the sodium carbonate system. The additional equipment requirements for the sulfuric acid system resulted in the need for a larger building size than that required

Table 3. FCI for sodium carbonate soil washing system

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$5,172,350
2	L	Cost of Installation Labor	.40E	\$2,068,940
3	IC	Instrumentation & Controls	.13E	\$672,406
4	I	Insulation Costs (equip. & piping)	.05E	\$258,618
5	P	Piping	.16E	\$827,576
6	Q	Labor for Installation of Piping	.40P	\$331,030
7	F	Electrical Installations	.15E	\$775,853
8	B	Building including Services	----	\$1,272,400
9	Y	Yard Improvements	.10E	\$517,235
10	S	Service Facilities	.55E	\$2,844,793
	D	Direct Plant Cost	Sum of 1-10	\$14,741,199
11	ES	Engineering & Supervision	.60E	\$3,103,410
12	C	Construction Expenses	.25E	\$1,293,088
	IP	Indirect Plant Cost	ES+C	\$4,396,498
13	CF	Contractor's Fee	.05(D+IP)	\$956,885
14	CO	Contingency	.20(D+IP)	\$3,827,539
	FCI	Fixed Capital Investment	D+IP+CF+CO	\$23,922,121

for the sodium carbonate, citric acid, and tiron soil washing systems.

The total equipment cost (E) for the sulfuric acid system is estimated at approximately \$7,630,000. The post water rinse drum vacuum filters are the most costly pieces of equipment for this system, with a requirement for 10 units. The estimated cost for these filters is \$400,000 each, for a total of \$4,000,000. This is approximately 52% of the total equipment cost for the entire sulfuric acid soil washing system. Other costly items for this system include six rinsing clarifiers at a total cost of \$720,000, seven sulfuric acid storage tanks for a total of \$280,000, two lime storage tanks for a total of \$250,000, two pre-reactor clarifiers for \$240,000, three stainless steel ion exchangers for \$198,000, and two stainless steel pressure sand filters for a total of \$190,000.

The results of the FCI calculation for the sulfuric acid soil washing system are shown in Table 4. Building costs were based on the assumption of a 2-story building with 20,000 ft² per floor. Unit costs (\$/sq. ft or \$/cu. yd) were used to estimate costs for the treatment building, building foundation, loading/unloading area, and parking area. The total cost for the building and its associated items is approximately \$1,479,000. The direct cost for the sulfuric acid soil washing plant is \$21,346,000. Total indirect plant costs, consisting of construction expenses and engineering and supervision, are \$6,485,000. Adding the contractor's fee and contingency of \$1,392,000 and \$5,566,000, respectively, to the direct and indirect plant costs result in a FCI of approximately \$34,789,000 for the sulfuric acid soil washing system.

4.4 CITRIC ACID SOIL WASHING SYSTEM

The engineering flow diagram for the citric acid soil washing system is shown in Appendix A. The equipment list for the citric acid system is given in Appendix B, Table B.4. The total equipment cost (E) for the citric acid system is estimated at \$13,799,000. The citric acid and sulfuric acid soil washing systems are similar in that both require lime storage and production as well as ion exchange equipment. However, the citric acid system requires some additional equipment which has a substantial impact on the total equipment cost for the system. A vendor estimated that a 600 gallons per minute (gpm) vacuum compression evaporation/crystallization system would cost approximately \$8 million. This one piece of equipment represents approximately 58% of the cost for the entire citric acid soil washing system. The vendor stated that a 20-gpm unit was the largest system they had designed and built, at a cost of approximately \$700,000. Other examples of size and cost estimates for a vacuum compression evaporator/crystallizer include: 1) \$375,000 for a 5-gpm unit, 2) \$450,000 for a 10-gpm unit, and 3) \$900,000 for a 35-gpm unit. In addition, an additional pressure sand filter at \$95,000 and an ion exchanger at \$66,000 are required for the citric acid system versus the sulfuric acid system.

As in the sodium carbonate and sulfuric acid systems, 10 post water rinse drum vacuum filters are required for the citric acid system. The total cost for the filters, \$2,700,000, represents approximately 20% of the total equipment cost. Therefore, the vacuum compression evaporator/crystallizer and vacuum drum filters represent 78% of the total equipment cost for the citric acid system. Other costly items for this system include six soil concurrent rinsing clarifiers at a total cost of \$720,000, three pressure sand filters for a total of \$285,000, four ion exchangers at \$264,000, two lime storage silos for \$250,000, and two post-reactor clarifiers for a total of \$240,000.

Table 4. FCI for sulfuric acid soil washing system

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$7,629,650
2	L	Cost of Installation Labor	.40E	\$3,051,860
3	IC	Instrumentation & Controls	.13E	\$991,855
4	I	Insulation Costs (equip. & piping)	.05E	\$381,483
5	P	Piping	.16E	\$1,220,744
6	Q	Labor for Installation of Piping	.40P	\$488,298
7	F	Electrical Installations	.15E	\$1,144,448
8	B	Building including Services	----	\$1,478,500
9	Y	Yard Improvements	.10E	\$762,965
10	S	Service Facilities	.55E	\$4,196,308
D		Direct Plant Cost	Sum of 1-10	\$21,346,109
11	ES	Engineering & Supervision	.60E	\$4,577,790
12	C	Construction Expenses	.25E	\$1,907,413
IP		Indirect Plant Cost	ES+C	\$6,485,203
13	CF	Contractor's Fee	.05(D+IP)	\$1,391,566
14	CO	Contingency	.20(D+IP)	\$5,566,262
FCI		Fixed Capital Investment	D+IP+CF+CO	\$34,789,139

The FCI for the citric acid soil washing system is shown in Table 5. Building costs for this system, estimated at approximately \$1,272,000, are the same as for the sodium carbonate system because both require a two-story building with 15,000 ft² per floor. The direct plant cost for the citric acid system is \$37,206,000. Total indirect plant costs are \$11,729,000. Adding the contractor's fee and contingency of \$2,447,000 and \$9,787,000, respectively, to the direct and indirect plant costs result in a FCI value of approximately \$61,169,000 for the citric acid soil washing system.

4.5 TIRON SOIL WASHING SYSTEM

Appendix A provides the engineering flow diagram for the tiron soil washing system. The equipment costs for the tiron system are shown in Appendix B, Table B.5. The total equipment cost (E) for this system is estimated at \$14,896,000. Except for a few alterations, the tiron system appears to be similar to the citric acid and sulfuric acid systems in terms of process equipment requirements. Although the tiron system requires ion exchangers, it does not require lime storage and production equipment as the citric acid and sulfuric acid systems do. Compared to the citric acid system, the tiron system requires two additional steel water rinse sand filters and two steel ion exchange units. In addition, just as the vacuum compression evaporator/crystallizer is the most costly equipment item for the citric acid system, the requirement for a biological treatment plant at an estimated cost of \$8,870,000 is clearly the largest capital expenditure for the tiron system. This represents approximately 60% of the total equipment cost for the entire tiron soil washing system. Designers of the tiron system engineering flow diagram at Halliburton NUS stated that the 200 gpm biological treatment plant should be sized and costed as a 1600 gpm sewage treatment plant. Unit costs (\$/daily flow rate) were then used to estimate the total cost to build a biological treatment plant, including overhead and profit. As in the sodium carbonate, sulfuric acid, and citric acid systems, 10 vacuum drum filters and 6 soil concurrent rinsing clarifiers at a total cost of \$2,700,000 and \$720,000, respectively, are also required for the tiron system. Other large equipment expenditures include two 40,000-gallon reactors and four 125-horsepower mixers/agitators for a total of \$520,000, two 40-ft diameter stainless steel clarifiers for a total of \$240,000, and five pressure sand filters at a total cost of \$385,000.

The results of the FCI calculation for the tiron soil washing system are shown in Table 6. Building size requirements for the tiron system are the same as those of the sodium carbonate and citric acid systems. Therefore, the building costs for all three systems are the same, estimated at approximately \$1,272,000. The direct plant cost for the tiron system is \$40,062,000. Total indirect plant costs, consisting of construction expenses and engineering and supervision, are \$12,662,000. Adding the contractor's fee and contingency of \$2,636,000 and \$10,545,000, respectively, to the direct and indirect plant costs results in an FCI value of approximately \$65,904,000 for the tiron soil washing system.

4.6 HEAP LEACHING SYSTEM

Due to health and safety requirements as well as regulatory requirements, the removal of uranium from the Fernald soil by the heap leaching system requires the process facilities to be enclosed in a building. The building is a double bay, 60,000 square foot facility with a total length of 500 feet, a total width of 120 feet (60 feet per bay), and a height of 40 feet. The soil is transported from the soil preparation building to the heap leaching building by a system of hoppers, overhead conveyors, and cranes which are interconnected to a main conveyor and track loading hopper. The contaminated soil

Table 5. FCI for citric acid soil washing system

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$13,799,250
2	L	Cost of Installation Labor	.40E	\$5,519,700
3	IC	Instrumentation & Controls	.13E	\$1,793,903
4	I	Insulation Costs (equip. & piping)	.05E	\$689,963
5	P	Piping	.16E	\$2,207,880
6	Q	Labor for Installation of Piping	.40P	\$883,152
7	F	Electrical Installations	.15E	\$2,069,888
8	B	Building including Services	----	\$1,272,400
9	Y	Yard Improvements	.10E	\$1,379,925
10	S	Service Facilities	.55E	\$7,589,588
D		Direct Plant Cost	Sum of 1-10	\$37,205,647
11	ES	Engineering & Supervision	.60E	\$8,279,550
12	C	Construction Expenses	.25E	\$3,449,813
IP		Indirect Plant Cost	ES+C	\$11,729,363
13	CF	Contractor's Fee	.05(D+IP)	\$2,446,750
14	CO	Contingency	.20(D+IP)	\$9,787,002
FCI		Fixed Capital Investment	D+IP+CF+CO	\$61,168,762

Table 6. FCI for tiron soil washing system

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$14,896,050
2	L	Cost of Installation Labor	.40E	\$5,958,420
3	IC	Instrumentation & Controls	.13E	\$1,936,487
4	I	Insulation Costs (equip. & piping)	.05E	\$744,803
5	P	Piping	.16E	\$2,383,368
6	Q	Labor for Installation of Piping	.40P	\$953,347
7	F	Electrical Installations	.15E	\$2,234,408
8	B	Building including Services	----	\$1,272,400
9	Y	Yard Improvements	.10E	\$1,489,605
10	S	Service Facilities	.55E	\$8,192,828
	D	Direct Plant Cost	Sum of 1-10	\$40,061,714
11	ES	Engineering & Supervision	.60E	\$8,937,630
12	C	Construction Expenses	.25E	\$3,724,013
	IP	Indirect Plant Cost	ES+C	\$12,661,643
13	CF	Contractor's Fee	.05(D+IP)	\$2,636,168
14	CO	Contingency	.20(D+IP)	\$10,544,671
	FCI	Fixed Capital Investment	D+IP+CF+CO	\$65,904,196

is placed into one of six leach cells in the heap leaching building. In addition to the hoppers and conveyor systems, chemical processing equipment required for the heap leaching system include a series of storage silos, tanks, reactors, filter presses, clarifiers, mixers, and pumps. The heap leaching building will also contain a 100,000 cfm baghouse air pollution control system.

The engineering flow diagram for the heap leaching system is provided in Appendix A. The equipment list for the heap leaching system is shown in Appendix B, Table B.6. The total equipment cost (E) for this process is estimated at \$2,488,000. The four sodium carbonate/bicarbonate storage silos represent the largest capital expenditure for process equipment at a total cost of \$640,000. Other costly items include two overhead crane conveyors at a total of \$240,000, three 75-horsepower mixers for a total of \$240,000, and three 25,000-gallon steel reactors at a total cost of \$225,000.

The results of the FCI calculation for the heap leaching process are shown in Table 7. Building costs, as well as concrete foundation and compartment wall costs, and parking and loading/unloading area costs, were calculated using unit costs (\$/ft² or \$/yd³) based on size requirements and the materials of construction for each item. Other building costs include a secondary containment system for the heap leaching process, composed of a synthetic membrane liner, gravel and sand drainage bed, and leak detection piping. Unit costs for these material items were also used to determine these cost factors. The total estimated direct cost for the heap leaching building, including foundation, compartment walls, parking and loading/unloading area, is approximately \$4,614,000. This cost includes the material, equipment, and labor for fabrication of the heap leaching building. Due to extensive piping requirements for the heap leaching process, the piping and insulation cost factors (see Table 7) were increased to reflect this change. After a review of the piping requirements in the equipment parts list for the heap leaching process and discussions with Halliburton NUS personnel, it was determined that piping costs for the heap leaching process should be estimated conservatively. Therefore, the upper limit of the ranges shown in Table 1 was used for piping and insulation costs. The direct plant cost for the heap leaching system is \$11,714,000. Total indirect plant costs are \$2,115,000. Adding the contractor's fee and contingency of \$691,000 and \$2,766,000, respectively, to the direct and indirect plant costs results in a FCI value of approximately \$17,286,000 for the heap leaching system.

4.7 FUNGAL LEACHING PROCESS

The fungal leaching process involves the production of a lixiviant created by fermentation of a nutrient broth, removal of the fungus from the lixiviant, and utilization of the lixiviant in conventional soil washing processes. The engineering flow diagrams and equipment parts list are divided into 2 parts: 1) the fungal lixiviant production system and 2) the fungal soil remediation recycle and treatment system. Chemical processing equipment for this system includes tanks, mixers, pumps, fermenters, a cooling tower, and a polymer feed system, as well as specialized equipment such as a sterilizer, ultrafilter, evaporator/crystallizer system, and a reverse osmosis system.

Appendix A provides the engineering flow diagram for the fungal leaching process. The equipment list for the fungal leaching process is shown in Appendix B, Table B.7. The total equipment cost (E) for this system is estimated at \$20,331,000. The wet air oxidation system, at an estimated cost of \$8,000,000, represents the largest capital expenditure for equipment and approximately 39% of the total estimated equipment cost for the entire fungal leaching process. The wet air oxidation system includes an equalization tank, high pressure feed pumps, a heat exchanger, reactor, process cooler, degasser and

Table 7. FCI for heap leaching system

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$2,488,000
2	L	Cost of Installation Labor	.40E	\$995,200
3	IC	Instrumentation & Controls	.13E	\$323,440
4	I	Insulation Costs (equip. & piping)	.09E	\$223,920
5	P	Piping	.31E	\$771,280
6	Q	Labor for Installation of Piping	.40P	\$308,512
7	F	Electrical Installations	.15E	\$373,200
8	B	Building including Services	----	\$4,613,500
9	Y	Yard Improvements	.10E	\$248,800
10	S	Service Facilities	.55E	\$1,368,400
D		Direct Plant Cost	Sum of 1-10	\$11,714,252
11	ES	Engineering & Supervision	.60E	\$1,492,800
12	C	Construction Expenses	.25E	\$622,000
IP		Indirect Plant Cost	ES+C	\$2,114,800
13	CF	Contractor's Fee	.05(D+IP)	\$691,453
14	CO	Contingency	.20(D+IP)	\$2,765,810
FCI		Fixed Capital Investment	D+IP+CF+CO	\$17,286,315

off gas cooler, thermal fluid heat transfer system, and an oxidized wastewater pump. Other costly items include: 1) an externally mounted, vertical tube evaporator/crystallizer system with a 300 gpm feed rate at an estimated cost of \$2,500,000; 2) a reverse osmosis system costing approximately \$2,000,000; 3) five 500-horsepower mixers for the fermenters at an estimated cost of \$2,125,000; 4) a sterilizer estimated at \$1,500,000; 5) five 41,000-gallon stainless steel vertical, cylindrical fermenters estimated at a total cost of \$1,125,000; 6) a 21,000 cfm tandem rotary screw air compression system, with motors included, estimated at \$1,000,000; 7) a wet air oxidation blowdown treatment system, made up of two 50,000-gallon aeration tanks with a clarifier, digester, splitter box, and sludge return pumps, costing approximately \$400,000; and 8) a tube-type membrane ultrafilter with an estimated cost of \$300,000.

The results of the FCI calculation for the fungal leaching process are shown in Table 8. The assumption was made that the fungal leaching building would require approximately the same size building as the sulfuric acid soil washing system. Therefore, building costs are estimated at approximately \$1,479,000 for a 2-story building with 20,000 ft² per floor. Based on discussions with Halliburton NUS personnel, it is anticipated that a greater demand will be placed on supplying the power, compressed air, water, etc., for the fungal leaching process compared to the other treatment technologies. For example, five fermenters mixers, each requiring a 500-horsepower motor, are used for this process. The air compressors also require four 800-horsepower motors. Therefore, the service facilities costs for the fungal leaching process will be higher than that for the other treatment technologies. Because of these additional constraints, the cost factor for the service facilities was increased from .55E to .70E for the fungal leaching process. The direct plant cost for the fungal leaching system is \$57,471,000. Total indirect plant costs are \$17,282,000. Adding the contractor's fee and contingency of \$3,738,000 and \$14,951,000, respectively, results in an FCI value of approximately \$93,441,000 for the fungal leaching process.

4.8 AQUEOUS BIPHASIC EXTRACTION PROCESS

The aqueous biphasic extraction process involves the use of a Karr Column to selectively partition the ultra fine soil particles between two immiscible aqueous phases (Soil Decontamination Task Group 1993). In the aqueous biphasic extraction process, one liquid phase is a solution of polyethylene glycol (PEG) and the other is a sodium carbonate salt solution. The approach taken by the Principal Investigator is to partition the uranium rich solid soil particles into the salt phase leaving the top of the Karr Column. Also in this salt phase is the bulk of the dissolved uranium. The PEG underflow slurry should exit the bottom of the Karr Column containing the uranium-depleted soil.

Appendix A provides the engineering flow diagram for the aqueous biphasic extraction system. The equipment costs for this treatment technology are shown in Appendix B, Table B.8. The total equipment cost (E) for this system is estimated at approximately \$4,501,100. The Karr reciprocating plate columns are by far the most expensive pieces of process equipment required for the aqueous biphasic extraction system. Based on conversations with the principal investigator, a company provided a budget estimate of \$380,000 for each Karr Column. Preliminary sketches from the company indicate that each Karr Column should be 6 feet in diameter, with a 15-ft plate stack height. Due to the requirement for 5 Karr Columns, the total cost for the Karr Columns is \$1,900,000, which represents 42% of the total equipment cost for the aqueous biphasic extraction process. Two belt-type horizontal pressure filters are also required, with a budgeted cost of \$400,000 each. Other large equipment expenditures include a methanol strip column at \$200,000, a PEG thickener at \$150,000, and a drum scrubber with trommel

Table 8. FCI for fungal leaching process

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$20,331,416
2	L	Cost of Installation Labor	.40E	\$8,132,566
3	IC	Instrumentation & Controls	.13E	\$2,643,084
4	I	Insulation Costs (equip. & piping)	.05E	\$1,016,571
5	P	Piping	.16E	\$3,253,027
6	Q	Labor for Installation of Piping	.40P	\$1,301,211
7	F	Electrical Installations	.15E	\$3,049,712
8	B	Building including Services	----	\$1,478,500
9	Y	Yard Improvements	.10E	\$2,033,142
10	S	Service Facilities	.70E	\$14,231,991
	D	Direct Plant Cost	Sum of 1-10	\$57,471,220
11	ES	Engineering & Supervision	.60E	\$12,198,850
12	C	Construction Expenses	.25E	\$5,082,854
	IP	Indirect Plant Cost	ES+C	\$17,281,704
13	CF	Contractor's Fee	.05(D+IP)	\$3,737,646
14	CO	Contingency	.20(D+IP)	\$14,950,585
	FCI	Fixed Capital Investment	D+IP+CF+CO	\$93,441,154

at an estimated cost of \$150,000.

The results of the FCI calculation for the aqueous biphasic extraction process are shown in Table 9. Building size requirements for this system are assumed to be the same as those for the sodium carbonate, citric, and tiron systems. The building cost is estimated at approximately \$1,272,000. The direct plant cost for this process is estimated at \$12,993,000. Indirect plant costs, consisting of construction expenses and engineering and supervision, for this system are \$3,826,000. Adding a contractor's fee and contingency of \$841,000 and \$3,364,000, respectively, to the direct and indirect plant costs results in a FCI of approximately \$21,024,000 for the aqueous biphasic extraction process.

5. SUMMARY

To evaluate the economic feasibility of designing, constructing, and operating a full-scale soil treatment facility, engineering designs and cost estimates for the seven treatment technologies investigated by the USID Program have been prepared. Engineering designs for the following treatment technologies were developed by Halliburton NUS: sodium carbonate soil washing system, sulfuric acid soil washing system, citric acid soil washing system, tiron soil washing system, heap leaching system, fungal leaching process, and aqueous biphasic extraction process. In conjunction with the engineering design development, cost estimates for each system were developed by ORNL.

The cost estimates for these seven technologies are being completed in three steps. The first step is to calculate the FCI, which represents the one-time capital investment needed to supply the necessary full-scale manufacturing and plant facilities for each soil treatment technology alternative being demonstrated by the USID Program. The second step is to develop the operational costs associated with a full-scale treatment facility for each technology. Operating costs occur throughout the life of the project. The third step is to estimate the life-cycle costs for the treatment technology alternatives. It is the first step, FCI calculations, that has been described in this report. A soil preparation building to process and store the soil before treatment is required regardless of the treatment technology being considered. The total equipment cost and the FCI for the soil preparation building and each treatment technology are summarized in Table 10. The operating costs and life-cycle costs for each technology will be documented in future reports.

The estimated equipment cost and the FCI value for the heap leaching system are the lowest of the treatment technologies considered. Although the equipment costs for the heap leaching system are 52% less than equipment costs for the sodium carbonate soil washing system, the FCI for the heap leaching system is only 28% less than the FCI for the sodium carbonate system. This is due to the fact that building costs are projected to be much higher for the heap leaching system than the other technologies. In addition, piping and insulation requirements will be more extensive for the heap leaching system compared to the other treatment technologies. In terms of FCI requirements, the most attractive options from a cost perspective after the heap leaching system are the aqueous biphasic extraction process and the sodium carbonate system, at approximately 21 million and 24 million, respectively. The FCI for the sodium carbonate system is 31% less than its nearest competitor in terms of cost, the sulfuric acid soil washing system. For the citric acid soil washing system, the vacuum compression evaporation/crystallization system with an estimated cost of \$8,000,000 (58% of the systems' total equipment cost) drives up the total equipment cost and the resulting FCI cost when compared to the sodium carbonate and sulfuric acid systems. Likewise, for the tiron soil washing system, the requirement

Table 9. FCI for aqueous biphasic extraction process

Item	Symbol	Description	Formula	Value
1	E	Equipment Costs	E	\$4,501,100
2	L	Cost of Installation Labor	.40E	\$1,800,440
3	IC	Instrumentation & Controls	.13E	\$585,143
4	I	Insulation Costs (equip. & piping)	.05E	\$225,055
5	P	Piping	.16E	\$720,176
6	Q	Labor for Installation of Piping	.40P	\$288,070
7	F	Electrical Installations	.15E	\$675,165
8	B	Building including Services	----	\$1,272,400
9	Y	Yard Improvements	.10E	\$450,110
10	S	Service Facilities	.55E	\$2,475,605
D		Direct Plant Cost	Sum of 1-10	\$12,993,264
11	ES	Engineering & Supervision	.60E	\$2,700,660
12	C	Construction Expenses	.25E	\$1,125,275
IP		Indirect Plant Cost	ES+C	\$3,825,935
13	CF	Contractor's Fee	.05(D+IP)	\$840,960
14	CO	Contingency	.20(D+IP)	\$3,363,840
FCI		Fixed Capital Investment	D+IP+CF+CO	\$21,023,999

Table 10. Summary of equipment costs and FCI calculations

Treatment Technology	Total Equipment Cost	Fixed Capital Investment (FCI)
Soil Preparation Building	\$485,935	\$3,269,128
Heap Leaching System	\$2,488,000	\$17,286,315
Aqueous Biphasic Extraction Process	\$4,501,100	\$21,023,999
Sodium Carbonate Soil Washing System	\$5,172,350	\$23,922,121
Sulfuric Acid Soil Washing System	\$7,629,650	\$34,789,139
Citric Acid Soil Washing System	\$13,799,250	\$61,168,762
Tiron Soil Washing System	\$14,896,050	\$65,904,196
Fungal Leaching Process	\$20,331,416	\$93,441,154

for a biological treatment plant at an estimated cost of \$8,870,000 (60% of the systems' total equipment cost) has a major effect on the systems' total equipment cost and resulting FCI calculation. The fungal leaching process results in the highest estimated total equipment cost and FCI value. The total equipment cost for the fungal leaching process is much higher than the other technologies due to the requirement for many pieces of specialized equipment. Also, service facilities costs are projected to be higher for the fungal leaching process compared to the other treatment technologies, thereby increasing the FCI for this system.

The engineering designs and the FCI cost estimates contained in this report are based on bench-scale study results and are considered preliminary because of the research and developmental nature associated with these seven technologies. Therefore, these costs are considered study estimates with an accuracy of +40% to -20%. With the exception of building costs, the FCI calculations in this report were estimated as a percentage of the process equipment cost for each technology. Building costs were based on unit costs and estimates of square footage requirements provided by Halliburton NUS personnel. As further results become available from bench-scale and pilot plant studies, these engineering designs and cost estimates will be updated to provide the optimum operating conditions to remove uranium from the soil. The operational costs and the life-cycle costs for the treatment technology options being considered by the USID program will be documented in future reports.

6. REFERENCES

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APPENDIX A

Engineering Flow Diagrams for Soil Treatment Technologies

DEVELOPED BY HALLIBURTON NUS

SOIL PREPARATION BUILDING

SOIL PREPARATION BUILDING

SODIUM CARBONATE SOIL WASHING SYSTEM

SULFURIC ACID SOIL WASHING SYSTEM

CITRIC ACID SOIL WASHING SYSTEM

CITRIC ACID
SOIL RINSING AND EXTRACTANT TREATMENT
FLOW DIAGRAM
SHEET 2

TIRON SOIL WASHING SYSTEM

TRION SOIL WASHING
RECYCLED EXTRACTANT TREATMENT
SHEET 3

HEAP LEACHING SYSTEM

61'-A
120'

HEAP LEACHING BUILDING

HEAP LEACHING
SOIL PREPARATION FACILITIES

C:\NC98P008.DWG 6/1/94 MRU

FUNGAL LEACHING SYSTEM

A-23

FIGURE 3-1
PHTHALIC ANHYDRIDE PRODUCTION PROCESS
INTEGRATED ADMINISTRATION PROJECT
REV. 01. 1994

STREAM #	COMPONENT	FLOW	TEMPERATURE	PRESSURE	PHASE	UNIT	TYPE
1	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
2	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
3	Water	100	150	10	Liquid	kg/hr	Feed
4	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
5	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
6	Water	100	150	10	Liquid	kg/hr	Feed
7	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
8	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
9	Water	100	150	10	Liquid	kg/hr	Feed
10	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
11	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
12	Water	100	150	10	Liquid	kg/hr	Feed
13	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
14	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
15	Water	100	150	10	Liquid	kg/hr	Feed
16	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
17	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
18	Water	100	150	10	Liquid	kg/hr	Feed
19	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
20	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
21	Water	100	150	10	Liquid	kg/hr	Feed
22	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
23	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
24	Water	100	150	10	Liquid	kg/hr	Feed
25	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
26	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
27	Water	100	150	10	Liquid	kg/hr	Feed
28	Phthalic Acid	100	150	10	Liquid	kg/hr	Feed
29	Phthalic Anhydride	100	150	10	Liquid	kg/hr	Feed
30	Water	100	150	10	Liquid	kg/hr	Feed

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AQUEOUS BIPHASIC EXTRACTION PROCESS

A-27

ERNALD JD
AQUEOUS BIPHASIC EXTRACTION
SOLUBILIZED URANIUM REMOVAL REAGENT RECYCLE
SHEET 2 OF 2

DATA CARDING AVAILABLE DESK BUG 12/15/94
 REVISION 2

APPENDIX B

Equipment Cost Estimates for Soil Treatment Technologies

Description of source column for the tables in Appendix B:

- 1) Vendor information or quote
- 2) *Process Plant Construction Estimating Standards*, Richardson's Engineering Services, Inc., 1994 Edition.
- 3) *Mining and Mineral Processing Equipment Costs and Preliminary Capital Cost Estimations*, Published by the Canadian Institute of Mining and Metallurgy, Volume 25.
- 4) *Means Site Work and Landscape Cost Data*, R.S. Means Company, Inc., 12th Annual Edition, 1993.
- 5) Cost estimating personnel at Halliburton NUS
- 6) *Plant Design and Economics for Chemical Engineers*, 4th Edition, Max S. Peters and Klaus D. Timmerhaus, 1991.

Table B.1
Soil Preparation Building

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	1	Receiving Pit Bucket Loaders	—	2	—
2	1	Pit Transfer Conveyers	—	2	—
3	1	Main Conveyers	—	2	—
4	1	Transfer Reversing Conveyors	—	2	—
5	1	Coarse Material Conveyors	—	2	—
6	1	Water Wash Trommel Feed Conveyor	—	1	—
7	—	Total for 1 - 6	\$78,650	1	\$78,650
8	1	Storage Transfer Hoppers: 50 tons/hr	\$12,000	2	\$24,000
9	1	Grizzly Transfer Hopper: 80 tons/hr	\$12,000	1	\$12,000
10	1	Stored Soil Receiving Hopper: 30 tons/hr and associated feed regulator	\$10,000	1	\$10,000
11	1	Feed Regulator for Stored Soil Receiving Hopper	\$10,000	1	\$10,000
12	1	Coarse Material Hopper: 1 ton/hr	\$9,000	1	\$9,000
13	1	Main Trommel Feed Transfer Hopper; 30 tons/hr	\$10,000	1	\$10,000
14	1	Coarse Hopper	\$9,000	1	\$9,000
15	1	Vibrating Grizzly: 36 x 60 (in), 6" opening, single deck, 80 tons/hr, mild steel	\$7,985	1	\$7,985
16	1	Coarse Material Trommel and Washer	\$25,300	1	\$25,300
17	5	Overhead Crane System	\$120,000	1	\$120,000
18	1	60,000 CFM Baghouse air pollution control system	\$170,000	1	\$170,000
Total Equipment Cost					\$485,935

Table B.2
Sodium Carbonate Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	1	Trommel Soil Washer	\$42,000	1	\$42,000
2	5	Trommel Pumps	\$12,000	2	\$24,000
3	5	Trommel Sump Tank/Concrete Embedded	\$12,000	1	\$12,000
4	5	Trommel Sump Tank Mixer	\$23,000	1	\$23,000
5	5	Trommel Sump Tank Pumps	\$8,000	2	\$16,000
6	1	Wet Separation Screen	\$18,000	1	\$18,000
7	5	Fast Mix Polymer Tank	\$700	1	\$700
8	5	Fast Mix Polymer Tank Mixer	\$4,000	1	\$4,000
9	5	Slow Mix Polymer Tank	\$1,500	1	\$1,500
10	5	Slow Mix Polymer Tank Mixer	\$20,000	1	\$20,000
11	5	Pre-reactor Clarifier	\$120,000	2	\$240,000
12	5	Clarifier Underflow Pump	\$4,000	4	\$16,000
13	5	Clarifier Overflow Holding Tank	\$22,500	1	\$22,500
14	5	Reactor	\$12,000	3	\$36,000
15	5	Reactor Mixer	\$23,000	3	\$69,000
16	5	Post Reactor Poly Cond. Tank-Fast Mix	\$700	1	\$700
17	5	Post Reactor Poly Cond. Tank Mixer	\$4,000	1	\$4,000
18	5	Post Reactor Poly Cond. Tank-Slow Mix	\$15,000	1	\$15,000
19	5	Post Reactor Poly Cond. Tank-Mixer	\$90,000	1	\$90,000
20	5	Post Reactor Slurry Pumps	\$5,000	3	\$15,000

Table B.2
Sodium Carbonate Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
21	1	Post Water Rinse Drum Vacuum Filter	\$270,000	5	\$1,350,000
22	5	Filter Conveyor - 50'	\$10,000	3	\$30,000
23	1	Coarse Solids Washer - Trommel	\$26,000	1	\$26,000
24	5	Coarse Solids Washer Sump/Conc - Emb.	\$3,000	1	\$3,000
25	5	Coarse Solids Washer Sump Mixer	\$12,000	1	\$12,000
26	5	Coarse Solids Washer Pumps	\$2,500	2	\$5,000
27	5	Coarse Solids Clarifier	\$24,000	1	\$24,000
28	5	Coarse Solids Effluent Holding Tank	\$2,250	1	\$2,250
29	5	Coarse Solids Effluent Pumps	\$2,200	2	\$4,400
30	5	Polymer Feed System	\$12,000	1	\$12,000
31	5	Polymer Feed Pump	\$2,500	2	\$5,000
32	5	Repulping Mixing Tank	\$15,000	2	\$30,000
33	5	Repulping Mixing Tank Mixer	\$35,000	2	\$70,000
34	5	Post Repulping Cond Tank - Fast Mix	\$2,000	1	\$2,000
35	5	Post Repulping Cond Tank Mixer	\$4,000	1	\$4,000
36	5	Post Repulping Cond Tank - Slow Mixer	\$5,000	1	\$5,000
37	5	Post Repulping Cond Tank Mixer	\$20,000	1	\$20,000
38	5	Soil Concurrent Rinsing Clarifiers	\$120,000	6	\$720,000
39	5	Rinse Clarifier Pumps	\$4,000	12	\$48,000
40	5	Rinse Clarifier Eff. Holding Tank	\$22,500	2	\$45,000

Table B.2
Sodium Carbonate Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
41	5	Effluent Holding Tank Pumps	\$8,000	4	\$32,000
42	5	Phosphoric Acid Feed System	\$15,000	1	\$15,000
43	5	Phosphoric Acid Cond. Reactor	\$8,800	2	\$17,600
44	5	Phosphoric Acid Cond Reactor Mixer	\$35,000	2	\$70,000
45	5	Rinse Soil Cond Tank-Fast Mix	\$700	1	\$700
46	5	Rinse Soil Cond Tank Mixer	\$4,000	1	\$4,000
47	5	Rinse Soil Cond Tank-Slow Mix	\$30,000	1	\$30,000
48	5	Rinse Soil Cond Tank Mixer	\$90,000	1	\$90,000
49	5	Rinse Soil Cond Slurry Pumps	\$5,000	3	\$15,000
50	1	Post Water Rinse Drum Vacuum Filter	\$270,000	5	\$1,350,000
51	5	Filter Conveyor - 50'	\$10,000	3	\$30,000
52	5	Extractant Filt Uranium Reactor Tank	\$10,000	1	\$10,000
53	5	Extractant Filt Reactor Tank Mixer	\$3,000	1	\$3,000
54	5	Filtrate Reactor Hold Tank	\$50,000	3	\$150,000
55	5	Filtrate Reactor Hold Tank Mixer	\$50,000	3	\$150,000
56	5	Filtrate Treatment Clarifier	\$45,000	1	\$45,000
57	5	Filtrate Treatment Clarifier Pumps	\$4,500	2	\$9,000
58	5	Filtrate Clarifier P & F Filter	\$30,000	1	\$30,000
59	5	Filtrate Trot Filter Conveyor - 20'	\$5,000	1	\$5,000
60	5	Carbonation Reactor	\$6,000	1	\$6,000

Table B.2
Sodium Carbonate Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
61	5	Carbonation Reactor Mixer	\$4,000	1	\$4,000
62	5	Air Compressor	\$15,000	1	\$15,000
63	5	Sump Pump	\$2,000	2	\$4,000
Total Equipment Cost					\$5,172,350

Table B.3
Sulfuric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	1	Trommel Soil Washer	\$42,000	1	\$42,000
2	5	Trommel Pumps	\$12,000	2	\$24,000
3	5	Trommel Sump Tank/Concrete Embedded	\$12,000	1	\$12,000
4	5	Trommel Sump Tank Mixer	\$23,000	1	\$23,000
5	5	Trommel Sump Tank Pumps	\$8,000	2	\$16,000
6	1	Wet Separation Screen	\$18,000	1	\$18,000
7	5	Fast Mix Polymer Tank	\$700	1	\$700
8	5	Fast Mix Polymer Tank Mixer	\$4,000	1	\$4,000
9	5	Slow Mix Polymer Tank	\$1,500	1	\$1,500
10	5	Slow Mix Polymer Tank Mixer	\$20,000	1	\$20,000
11	5	Pre-Reactor Clarifier	\$120,000	2	\$240,000
12	5	Clarifier Underflow Pump	\$4,000	4	\$16,000
13	5	Clarifier Overflow Holding Tank	\$22,500	1	\$22,500
14	5	Sulfuric Acid Storage Tank	\$40,000	7	\$280,000
15	5	Sulfuric Acid Feed Pump	\$6,000	3	\$18,000
16	5	Reactor	\$12,000	3	\$36,000
17	5	Reactor Mixer	\$23,000	3	\$69,000
18	5	Post Reactor Poly Cond. Tank - Fast Mix	\$700	1	\$700
19	5	Post Reactor Poly Cond. Tank - Mixer	\$4,000	1	\$4,000
20	5	Post Reactor Poly Cond. Tank - Slow Mix	\$15,000	1	\$15,000

Table B.3
Sulfuric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
21	5	Post Reactor Poly Cond. Tank - Mixer	\$90,000	1	\$90,000
22	5	Post Reactor Slurry Pumps	\$5,000	3	\$15,000
23	1	Post Water Rinse Drum Vacuum Filter	\$400,000	5	\$2,000,000
24	5	Filter Conveyor - 50'	\$10,000	3	\$30,000
25	1	Coarse Solids Washer Trommel	\$26,000	1	\$26,000
26	5	Coarse Solids Washer Sump/Conc Emb	\$3,000	1	\$3,000
27	5	Coarse Solids Washer Sump Mixer	\$12,000	1	\$12,000
28	5	Coarse Solids Washer Pumps	\$2,500	2	\$5,000
29	5	Coarse Solids Clarifier	\$24,000	1	\$24,000
30	5	Coarse Solids Effluent Holding Tank	\$2,250	1	\$2,250
31	5	Coarse Solids Effluent Pumps	\$2,200	2	\$4,400
32	5	Polymer Feed System	\$12,000	1	\$12,000
33	5	Polymer Feed Pumps	\$2,500	2	\$5,000
34	5	Repulping Mixing Tank	\$15,000	2	\$30,000
35	5	Repulping Mixing Tank Mixer	\$35,000	2	\$70,000
36	5	Lime Storage Silo	\$125,000	2	\$250,000
37	1	Lime Slaker	\$40,000	1	\$40,000
38	5	Lime Slurry Holding Tank - 10% Slurry	\$1,500	1	\$1,500
39	5	Lime Slurry Holding Tank Mixer	\$3,000	1	\$3,000
40	5	Lime Slurry Feed Pumps	\$2,500	2	\$5,000

Table B.3
Sulfuric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
41	5	Post Repulping Cond. Tank-Fast Mix	\$2,000	1	\$2,000
42	5	Post Repulping Cond. Tank Mixer	\$4,000	1	\$4,000
43	5	Post Repulping Cond. Tank-Slow Mix	\$5,000	1	\$5,000
44	5	Post Repulping Cond. Tank Mixer	\$20,000	1	\$20,000
45	5	Soil Concurrent Rinsing Clarifiers	\$120,000	6	\$720,000
46	5	Rinse Clarifier Pumps	\$4,000	12	\$48,000
47	5	Rinse Clarifier Eff. Holding Tank	\$22,500	2	\$45,000
48	5	Effluent Holding Tank Pumps	\$8,000	4	\$32,000
49	5	Phosphoric Acid Feed System	\$15,000	1	\$15,000
50	5	Phosphoric Acid Cond. Reactor	\$8,800	2	\$17,600
51	5	Phosphoric Acid Cond. Reactor Mixer	\$35,000	2	\$70,000
52	5	Rinse Soil Cond. Tank-Fast Mix	\$700	1	\$700
53	5	Rinse Soil Cond. Tank Mixer	\$4,000	1	\$4,000
54	5	Rinse Soil Cond. Tank-Slow Mix	\$30,000	1	\$30,000
55	5	Rinse Soil Cond. Tank Mixer	\$90,000	1	\$90,000
56	5	Rinse Soil Cond. Slurry Pumps	\$5,000	3	\$15,000
57	1	Post Water Rinse Filter - Vacuum Drum	\$400,000	5	\$2,000,000
58	5	Filter Conveyor - 50'	\$10,000	3	\$30,000
59	5	Acid Treatment System Holding Tank	\$12,000	1	\$12,000
60	5	Acid Extractant Pumps	\$7,000	2	\$14,000

Table B.3
Sulfuric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
61	1	Pressure Sand Filter	\$95,000	2	\$190,000
62	1	Ion Exchange Unit	\$66,000	3	\$198,000
63	5	Ion Exchange Sod. Chloride Mix Tank	\$20,000	1	\$20,000
64	5	Ion Exchange Mix Tank Mixer	\$22,000	1	\$22,000
65	5	Ion Exchange Pumps	\$4,000	2	\$8,000
66	5	Ion Exchange Regenerant Surge Tank	\$20,000	1	\$20,000
67	5	Uranium Prec. Reactor Tank	\$800	1	\$800
68	5	Uranium Prec. Reactor Tank Mixer	\$1,500	1	\$1,500
69	5	Caustic Feed System	\$15,000	1	\$15,000
70	5	Uranium Reactor Hold Tank	\$11,300	1	\$11,300
71	5	Uranium Reactor Hold Tank Mixer	\$12,000	1	\$12,000
72	5	Uranium Prec. Treatment Clarifier	\$15,000	2	\$30,000
73	5	Uranium Treatment Clarifier Pumps	\$2,500	2	\$5,000
74	5	Filter Presses - each 10 cubic feet	\$25,000	2	\$50,000
75	5	Neutralization Tank	\$10,000	1	\$10,000
76	5	Neutralization Tank Mixer	\$6,000	1	\$6,000
77	5	Fast Mix Polymer Tank	\$400	1	\$400
78	5	Fast Mix Polymer Tank Mixer	\$1,000	1	\$1,000
79	5	Slow Mix Polymer Tank	\$800	1	\$800
80	5	Slow Mix Polymer Tank Mixer	\$1,500	1	\$1,500

Table B.3
Sulfuric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
81	5	Clarifier	\$66,000	2	\$132,000
82	5	Clarifier Underflow Pumps	\$7,000	4	\$28,000
83	1	Plate & Frame Filter Press	\$50,000	3	\$150,000
84	5	Filter Cake Conveyor	\$7,500	1	\$7,500
85	5	Air Compressor	\$20,000	2	\$40,000
86	5	Sump Pump	\$2,000	2	\$4,000
Total Equipment Cost					\$7,629,650

Table B.4
Citric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	1	Trommel Soil Washer	\$42,000	1	\$42,000
2	5	Trommel Pumps	\$12,000	2	\$24,000
3	5	Trommel Sump	\$12,000	1	\$12,000
4	5	Trommel Sump Mixer	\$23,000	1	\$23,000
5	5	Trommel Sump Pumps	\$8,000	2	\$16,000
6	1	Wet Separation Screen	\$18,000	1	\$18,000
7	5	Fast Mix Polymer Tank	\$700	1	\$700
8	5	Fast Mix Polymer Tank Mixer	\$4,000	1	\$4,000
9	5	Slow Mix Polymer Tank	\$1,500	1	\$1,500
10	5	Slow Mix Polymer Tank Mixer	\$20,000	1	\$20,000
11	5	Post-Reactor Clarifiers	\$120,000	2	\$240,000
12	5	Clarifier Underflow Pumps	\$4,000	4	\$16,000
13	5	Clarifier Overflow Holding Tank	\$22,500	1	\$22,500
14	5	Reactor	\$40,000	2	\$80,000
15	5	Reactor Mixers	\$50,000	4	\$200,000
16	1	Post-Reactor Filters - Vacuum Drum	\$270,000	5	\$1,350,000
17	5	Filter Conveyor - Open Belt - 50 feet	\$30,000	1	\$30,000
18	1	Coarse Solids Washer	\$26,000	1	\$26,000
19	5	Coarse Solids Washer Sump - Steel Tank Emb.	\$3,000	1	\$3,000
20	5	Coarse Solids Washer Sump Mixer	\$12,000	1	\$12,000

Table B.4
Citric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
21	5	Coarse Solids Washer Sump Pumps	\$2,500	2	\$5,000
22	5	Coarse Solids Clarifier	\$24,000	1	\$24,000
23	5	Coarse Solids Effluent Holding Tank	\$2,250	1	\$2,250
24	5	Coarse Solids Effluent Holding Tank Pumps	\$2,200	2	\$4,400
25	5	Polymer Mix Tank with Bin Feeder	\$6,000	2	\$12,000
26	5	Polymer Mix Tank Pumps	\$2,500	2	\$5,000
27	5	Repulping Mixing Tank	\$15,000	2	\$30,000
28	5	Repulping Mixing Tank Mixer	\$35,000	2	\$70,000
29	5	Lime Storage Silos	\$125,000	2	\$250,000
30	1	Lime Slaker - Max Capacity 2,500lbs/hr ave 1500 lbs/hr	\$44,100	1	\$44,100
31	5	Slurried Lime Holding Tank - 10% Slurry	\$1,500	1	\$1,500
32	5	Slurried Lime Holding Tank - 10% Slurry Mixer	\$3,000	1	\$3,000
33	5	Slurried Lime Holding Tank - 10% Slurry Pump	\$2,500	2	\$5,000
34	5	Post-Repulping Polymer Cond Tank - Fast Mix	\$2,000	1	\$2,000
35	5	Post-Repulping Polymer Cond Tank Mixer - Fast Mix	\$4,000	1	\$4,000
36	5	Post-Repulping Polymer Cond Tank - Slow Mix	\$24,000	1	\$24,000
37	5	Post-Repulping Polymer Cond Tank Mixer - Slow Mix	\$20,000	1	\$20,000
38	5	Soil Concurrent Rinsing Clarifiers	\$120,000	6	\$720,000
39	5	Rinse Clarifier Pumps	\$4,000	12	\$48,000
40	5	Rinse Clarifier Effluent Holding Tanks	\$22,500	2	\$45,000

Table B.4
Citric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
41	5	Effluent Holding Tank Pumps	\$8,000	4	\$32,000
42	5	Rinsed Soil Polymer Conditioning Tank - Fast Mix	\$700	1	\$700
43	5	Rinsed Soil Polymer Conditioning Tank Mixer - Fast Mix	\$4,000	1	\$4,000
44	5	Rinsed Soil Polymer Conditioning Tank - Slow Mix	\$30,000	1	\$30,000
45	5	Rinsed Soil Polymer Conditioning Tank Mixer - Slow Mix	\$90,000	1	\$90,000
46	5	Rinsed Soil Poly. Cond. Tank - Slow Mix Pump	\$5,000	3	\$15,000
47	1	Post-Water Rinse Filters - Vacuum Drum	\$270,000	5	\$1,350,000
48	5	Filter Conveyor - Open Belt	\$10,000	3	\$30,000
49	5	Water Rinse Holding Tank	\$20,000	1	\$20,000
50	5	Hold Tank Pumps	\$7,000	2	\$14,000
51	1	Sand Filters (Pressure)	\$95,000	3	\$285,000
52	1	Ion Exchanger	\$66,000	4	\$264,000
53	5	Ion Exchange Resin Sodium Chloride Mix Tank	\$20,000	1	\$20,000
54	5	Ion Exchange Resin Sodium Chloride Tank Mixer	\$22,000	1	\$22,000
55	5	Ion Exchange Resin Sodium Chloride Tank Pump	\$4,000	2	\$8,000
56	5	Ion Exchange Regenerant Surge Tank	\$20,000	1	\$20,000
57	5	Ion Exchange Regenerant Surge Tank Pump	\$2,500	2	\$5,000
58	5	Uranium Precipitation Reactor Tank	\$800	1	\$800
59	5	Uranium Precipitation Reactor Tank Mixer	\$750	2	\$1,500
60	5	Uranium Reaction Hold Tank	\$11,300	1	\$11,300

Table B.4
Citric Acid Soil Washing System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
61	5	Uranium Reaction Hold Tank Mixer	\$12,000	1	\$12,000
62	5	Uranium Precipitator Clarifier - 10 gpm Avg. Design 20 gpm	\$15,000	2	\$30,000
63	5	Clarifier Underflow Pumps	\$2,500	2	\$5,000
64	5	Filter Presses - each 10 ft ³	\$25,000	2	\$50,000
65	1	Vacuum Compression Evaporator/Crystallizer - 600 gpm	\$8,000,000	1	\$8,000,000
66	5	Air Compressor	\$15,000	1	\$15,000
67	5	Sump Pump	\$2,000	2	\$4,000
Total Equipment Cost					\$13,799,250

Table B.5
Tiron Soil Washing System

Item	Source	Description	Cost/Unit	Quantity	Total
1	1	Trommel Soil Washer	\$42,000	1	\$42,000
2	5	Trommel Pumps	\$12,000	2	\$24,000
3	5	Trommel Sump	\$12,000	1	\$12,000
4	5	Trommel Sump Mixer	\$23,000	1	\$23,000
5	5	Trommel Sump Pumps	\$8,000	2	\$16,000
6	1	Wet Separation Screen	\$18,000	1	\$18,000
7	5	Fast Mix Polymer Tank	\$700	1	\$700
8	5	Fast Mix Polymer Tank Mixer	\$4,000	1	\$4,000
9	5	Slow Mix Polymer Tank	\$1,500	1	\$1,500
10	5	Slow Mix Polymer Tank Mixer	\$20,000	1	\$20,000
11	5	Post Reactor Clarifiers	\$120,000	2	\$240,000
12	5	Clarifier Underflow Pumps	\$4,000	4	\$16,000
13	5	Clarifier Overflow Holding Tank	\$22,500	1	\$22,500
14	5	Reactors	\$80,000	2	\$160,000
15	5	Reactor Mixer	\$90,000	4	\$360,000
16	1	Post-Reactor Filters - Vacuum Drum	\$270,000	5	\$1,350,000
17	5	Filter Conveyor - Open Belt	\$30,000	1	\$30,000
18	1	Coarse Solids Washer Trommel	\$26,000	1	\$26,000
19	5	Coarse Solids Washer Sump - Steel Tank Embedded in Concrete	\$3,000	1	\$3,000
20	5	Coarse Solids Washer Sump Mixer	\$12,000	1	\$12,000

Table B.5
Tiron Soil Washing System

Item	Source	Description	Cost/Unit	Quantity	Total
21	5	Coarse Solids Washer Sump Pumps	\$2,500	2	\$5,000
22	5	Coarse Solids Clarifier	\$24,000	1	\$24,000
23	5	Coarse Solids Effluent Holding Tank	\$2,250	1	\$2,250
24	5	Coarse Solids Effluent Holding Tank Pumps	\$2,200	2	\$4,400
25	5	Polymer Feed System	\$12,000	1	\$12,000
26	5	Polymer Mix Tank Pumps	\$2,500	2	\$5,000
27	5	Repulping Mixing Tank	\$15,000	2	\$30,000
28	5	Repulping Mixing Tank Mixer	\$35,000	2	\$70,000
29	5	Post-Repulping Polymer Conditioning Tank - Fast Mix	\$2,000	1	\$2,000
30	5	Post-Repulping Polymer Cond. Tank - Fast Mixer	\$4,000	1	\$4,000
31	5	Post-Repulping Polymer Conditioning Tank - Slow Mix	\$24,000	1	\$24,000
32	5	Post-Repulping Polymer Conditioning Tank - Slow Mixer	\$20,000	1	\$20,000
33	5	Soil Concurrent Rinsing Clarifiers	\$120,000	6	\$720,000
34	5	Rinse Clarifier Pumps	\$4,000	12	\$48,000
35	5	Rinse Clarifier Effluent Holding Tanks	\$22,500	2	\$45,000
36	5	Effluent Holding Tank Pumps	\$8,000	4	\$32,000
37	5	Rinsed Soil Polymer Conditioning Tank - Fast Mix	\$700	1	\$700
38	5	Rinsed Soil Polymer Conditioning Tank - Fast Mixer	\$4,000	1	\$4,000
39	5	Rinsed Soil Polymer Conditioning Tank - Slow Mix	\$30,000	1	\$30,000
40	5	Rinsed Soil Polymer Conditioning Tank - Slow Mixer	\$90,000	1	\$90,000

Table B.5
Tiron Soil Washing System

Item	Source	Description	Cost/Unit	Quantity	Total
41	5	Rinsed Soil Polymer Cond. Tank - Slow Mixer Pump	\$5,000	3	\$15,000
42	1	Post-Water Rinse Filters - Vacuum Drum	\$270,000	5	\$1,350,000
43	5	Filter Conveyor - Open Belt	\$10,000	3	\$30,000
44	5	Water Rinse Holding Tank	\$20,000	1	\$20,000
45	5	Hold Tank Pumps	\$7,000	2	\$14,000
46	1	Water Rinse Sand Filters	\$50,000	2	\$100,000
47	5	Rinse Filter Surge Tank	\$20,000	1	\$20,000
48	5	Rinse Surge Tank Pumps	\$7,000	2	\$14,000
49	5	Sand Filter Backwash Surge Tank	\$30,000	1	\$30,000
50	5	Sand Filter Backwash Pumps	\$2,500	2	\$5,000
51	1	Ion Exchanger - 6ft diameter, 6ft height	\$66,000	2	\$132,000
52	4	Biological Treatment Plant	\$8,870,400	1	\$8,870,400
53	1	Sand Filters (Pressure)	\$95,000	3	\$285,000
54	1	Ion Exchanger - 5 ft diameter, 6 ft height	\$66,000	4	\$264,000
55	5	Ion Exchange Resin Sodium Chloride Mix Tank	\$20,000	1	\$20,000
56	5	Ion Exchange Resin Sodium Chloride Tank Mixer	\$11,000	1	\$11,000
57	5	Ion Exchange Resin Sodium Chloride Tank Pump	\$4,000	2	\$8,000
58	5	Ion Exchange Regenerant Surge Tank	\$20,000	1	\$20,000
59	5	Ion Exchange Regenerant Surge Tank Pump	\$2,500	2	\$5,000
60	5	Uranium Precipitation Reactor Tank	\$800	1	\$800

Table B.5
Tiron Soil Washing System

Item	Source	Description	Cost/Unit	Quantity	Total
61	5	Uranium Precipitation Reactor Tank Mixer	\$1,500	1	\$1,500
62	5	Uranium Reaction Hold Tank	\$11,300	1	\$11,300
63	5	Uranium Reaction Hold Tank Mixer	\$12,000	1	\$12,000
64	5	Uranium Precipitator Clarifier 10 gpm Avg. Design 20 gpm	\$15,000	2	\$30,000
65	5	Clarifier Underflow Pumps	\$2,500	2	\$5,000
66	5	Filter Presses - each 10 ft ³	\$25,000	2	\$50,000
67	5	Air Compressor	\$15,000	1	\$15,000
68	5	Sump Pump	\$2,000	2	\$4,000
Total Equipment Cost					\$14,896,050

Table B.6
Heap Leaching System

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	5&1	Main Conveyor - 500'	\$200,000	1	\$200,000
2	5	Overhead Crane Conveyor	\$120,000	2	\$240,000
3	1	Hoppers	\$25,000	4	\$100,000
4	5	Acid Feed Tank	\$30,000	1	\$30,000
5	5	Acid Feed Pumps	\$8,000	2	\$16,000
6	5	Sodium Carb/Carbonate Storage Silo	\$160,000	4	\$640,000
7	5	Neat, 1st Cycle, Last Lix. Storage Tank	\$40,000	3	\$120,000
8	5	Neat, 1st Cycle, Last Lix. Pumps	\$10,000	6	\$60,000
9	5	Drainage Sump/Conc Emb	\$12,000	4	\$48,000
10	5	Drainage Sump Pumps	\$9,000	8	\$72,000
11	5	PH Adjustment Tanks	\$16,000	2	\$32,000
12	5	PH Adjustment Tank Mixer	\$4,000	2	\$8,000
13	5	Uranium Precipitation Reactors	\$75,000	3	\$225,000
14	5	Uranium Precipitation Reactor Mixers	\$80,000	3	\$240,000
15	5	Clarifier	\$84,000	2	\$168,000
16	5	Clarifier Underflow Pumps	\$5,000	4	\$20,000
17	5	Filter Press	\$25,000	2	\$50,000
18	5	Air Compressor	\$15,000	1	\$15,000
19	5	Sump Pump	\$2,000	2	\$4,000
20	1	100,000 CFM Baghouse Collection System	\$200,000	1	\$200,000
Total Equipment Cost					\$2,488,000.00

Table B.7
Fungal Leaching Process

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	2	Railcar Corn Syrup Transfer Pumps	\$4,934	2	\$9,868
2	2	Railcar Methanol Transfer Pumps	\$4,821	2	\$9,642
3	5	Urea Transfer Pumps	\$2,500	2	\$5,000
4	5	Phosphoric Acid Transfer Pumps	\$2,500	2	\$5,000
5	5	Corn Syrup Metering Pumps	\$2,500	2	\$5,000
6	2	Methanol Metering Pumps	\$3,500	2	\$7,000
7	2	Urea Metering Pumps	\$3,420	2	\$6,840
8	2	Phosphoric Acid Metering Pumps	\$3,920	2	\$7,840
9	2	Micronutrient Metering Pumps	\$3,420	2	\$6,840
10	2	Feed Pumps	\$4,176	2	\$8,352
11	2	Cooling Water Pumps	\$7,973	2	\$15,946
12	2	Biomass Transfer Pumps	\$6,479	2	\$12,958
13	2	Lixiviant Transfer Pumps	\$5,655	2	\$11,310
14	5	Corn Syrup Tank	\$126,000	1	\$126,000
15	5	Methanol Tank	\$80,000	1	\$80,000
16	1	Urea Tank	\$7,500	1	\$7,500
17	1&3	Phosphoric Acid Tank	\$750	1	\$750
18	1&3	Micronutrients Tank	\$1,300	1	\$1,300
19	5	Blending Tank	\$5,800	1	\$5,800
20	5	Biosolids Tank	\$12,000	1	\$12,000

Table B.7
Fungal Leaching Process

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
21	5	Clarifier	\$84,000	1	\$84,000
22	5	Raw Lixiviant Feed Tank	\$12,000	1	\$12,000
23	3	Coagulation Tank	\$300	1	\$300
24	3	Flocculation Tank	\$600	1	\$600
25	5	Filtered Lixiviant Storage Tank	\$172,000	1	\$172,000
26	5	Seed Fermenter Mixer	\$60,000	2	\$120,000
27	5&2	Fermenter Mixer	\$400,000	5	\$2,000,000
28	5&2	Fermenter Mixer Motor	\$25,000	5	\$125,000
29	6	Micronutrients Mixer	\$2,125	1	\$2,125
30	2	12000 CFM Air Compressor - motor included	\$500,000	2	\$1,000,000
31	6	Blending Mixer	\$2,125	1	\$2,125
32	6	Coagulation Tank Mixer	\$1,500	1	\$1,500
33	5	Flocculation Tank Mixer	\$1,500	1	\$1,500
34	1	Seed Fermenters	\$75,000	2	\$150,000
35	1	Fermenters	\$225,000	5	\$1,125,000
36	1	Cooling Towers	\$71,000	1	\$71,000
37	1	Rotary Microscreen	\$35,000	1	\$35,000
38	1	Ultrafilter	\$300,000	1	\$300,000
39	5	Sterilizers with Preheater	\$1,500,000	1	\$1,500,000
40	1	Biomass Loading Arm	\$6,000	1	\$6,000

Table B.7
Fungal Leaching Process

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
41	5	Polymer Feed System	\$17,000	1	\$17,000
42	1&3	Continuous Ion Exchange System	\$54,000	1	\$54,000
43	5	Reverse Osmosis System	\$2,000,000	1	\$2,000,000
44	5	Evaporator	\$150,000	1	\$150,000
45	5	Evaporator/Crystallizer System	\$2,500,000	1	\$2,500,000
46	5	Wet Air Oxidation System	\$8,000,000	1	\$8,000,000
47	1	Heat Exchanger	\$15,000	1	\$15,000
48	5	WAO Blowdown Treatment System	\$200,000	2	\$400,000
49	1	Brine Feed Tank	\$3,200	1	\$3,200
50	1	Hydrochloric and Storage Tank	\$30,000	1	\$30,000
51	1	Acidification Tank	\$11,000	1	\$11,000
52	1	Permeate Recycle Tank	\$10,500	1	\$10,500
53	1	Condensed Overhead Tank	\$250	1	\$250
54	1	Reject Tank	\$6,500	1	\$6,500
55	5	Caustic Tank	\$12,000	1	\$12,000
56	2	Brine Metering Pumps	\$4,000	2	\$8,000
57	2	Rail Car Acid Transfer Pumps	\$3,018	2	\$6,036
58	2	Acid Metering Pumps	\$4,327	2	\$8,654
59	2	Citric Acid Blowdown Pumps	\$3,358	2	\$6,716
60	2	Lixiviant Recycle Pumps	\$4,312	2	\$8,624

Table B.7
Fungal Leaching Process

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
61	2	Overhead Metering Pumps	\$4,000	2	\$8,000
62	2	Caustic Feed Pumps	\$1,920	2	\$3,840
63	5	Air Compressor	\$15,000	1	\$15,000
64	5	Sump Pump	\$2,000	2	\$4,000
Total Equipment Cost					\$20,331,416

Table B.8
Aqueous Biphasic Extraction

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
1	1	Grizzly Feed Conveyor (@ \$600/ft)	\$60,000	1	\$60,000
2	5	Dry grizzly	\$40,000	1	\$40,000
3	5	Drum Scrubber 1 with trommel screen	\$90,000	1	\$90,000
4	5	Drum Scrubber 2 with trommel screen	\$150,000	1	\$150,000
5	5	O/S Soil Transport Conveyor (@ \$600/ft)	\$60,000	1	\$60,000
6	5	Washing & Dewatering Screen (6' x 8' screen deck)	\$40,000	1	\$40,000
7	5	Slurry Pump and Sump (1 pump & 1 standby, 150 gpm & 50 TDH)	\$7,000	2	\$14,000
8	5	Agitated Holding Tank (15,000 gallon carbon steel shell)	\$30,000	1	\$30,000
9	5	Holding Tank Mixer (15 HP motor, 72 in dia. impellor)	\$14,600	1	\$14,600
10	5	Feed Pumps (centrifugal, 250 gpm max. output, 65 ft TDH, 20 HP)	\$9,000	2	\$18,000
11	5	Vibrating Screen (48 in. x 96 in. with 3.5 HP motor)	\$40,000	1	\$40,000
12	5	Static Mixer 1 (1.5 in. x 18 in., 316 SS shell, 50 gpm)	\$1,500	1	\$1,500
13	5	Static Mixer 2 (4 in. x 24 in., 316 SS, 300 gpm)	\$5,000	1	\$5,000
14	5	Dry Flocculant Hopper/Feeder (.65 lb floc/ton soil solids, 5 cu ft hopper)	\$15,000	1	\$15,000
15	5	Flocculant Mix Tank (1000 gallons, 6' dia. x 6 ft h, 316 SS, mixer bridge)	\$4,000	1	\$4,000
16	5	Flocculant Mix Tank Agitator (5 HP motor, 30 in impellor, variable speed)	\$10,000	1	\$10,000
17	5	Flocculant Metering Pump (dual diaphragm, 0-160 gpm, 2 HP var. motor)	\$17,500	1	\$17,500
18	5	PEG Thickener (250 gpm feed, 28 ft dia., 10 ft high, with rake, 15 HP)	\$150,000	1	\$150,000
19	5	PEG Makeup Tank (6' x 8' cyl. tank, 1000 gal., 316 SS, mixer bridge)	\$4,000	1	\$4,000
20	5	PEG Makeup Tank Agitator (5 HP var. sp. motor, 30 in dia impellor)	\$10,000	1	\$10,000

Table B.8
Aqueous Biphasic Extraction

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
21	5	PEG Makeup Pump (centrifugal, 200 gpm, 65' head, 15 HP)	\$5,000	1	\$5,000
22	5	PEG Recycle Tank (9,000 gallons max., 4,500 gpm WV, 12'D x 12' H)	\$18,000	1	\$18,000
23	5	PEG Recycle Pumps (centrifugal, 225 gpm, 65' head, 15 HP)	\$5,000	2	\$10,000
24	5	PEG Repulp Tank (6' x 8' cyl. tank, 1000 gal. WV, 316 SS, mixer bridge)	\$4,000	1	\$4,000
25	1	Karr Columns (6' D x 10' H, rotating 5 HP drive, 340 gpm net flow)	\$380,000	5	\$1,900,000
26	5	Karr Column PEG U/F Pumps (centrifugal, 350 gpm, 65' head, 20 HP)	\$9,000	2	\$18,000
27	5	Static Mixer 3 (150 gpm max, 316 SS)	\$4,500	1	\$4,500
28	5	Salt Phase Thickener (20' dia., 8' sidewalls, rake, 10 HP)	\$95,000	1	\$95,000
29	5	PEG Thickener Underflow Pumps (dual diaphragm, 0-75 gpm, 100 psig)	\$5,000	2	\$10,000
30	5	Salt Thickener Underflow Pumps (dual diaphragm, 0-20 gpm, 100 psig)	\$2,500	2	\$5,000
31	5	Recessed Plate Concentrate Filter (plate filter press, 27.3 cu ft capacity)	\$20,000	1	\$20,000
32	5	Horizontal Pressure Filters (LAROX PF-16, belt type, 409 sq ft FA, 25 HP)	\$400,000	2	\$800,000
33	5	Washed Soil Conveyor (@ \$600/ft) (24 in x 100 L, 4 in sidewalls)	\$60,000	1	\$60,000
34	5	Salt/Methanol Mix Tank (8' x 8' cyl. tank, 2000 gallon WV, 316SS)	\$8,000	1	\$8,000
35	5	PEG Repulp Tank Agitator (10 HP motor, 42 in dia. impellor)	\$13,500	1	\$13,500
36	5	Salt/Meth. Thickener Feed Pumps (centrifugal, 350 gpm max., 65' head)	\$9,000	2	\$18,000
37	5	Static Mixer 4 (250 gpm max, 316 SS)	\$4,500	1	\$4,500
38	5	Salt/Methanol Thickener (20' dia, 8' sidewalls, rake, 10 HP)	\$95,000	1	\$95,000
39	5	Salt/Methanol Thickener Underflow Pumps (dual diaphragm, 0-20 gpm)	\$2,500	2	\$5,000
40	5	Recessed Plate Precipitate Filters (plate filter press, 54.6 cu ft capacity)	\$18,000	2	\$36,000

Table B.8
Aqueous Biphasic Extraction

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
41	5	Air Compressors (150 psig, 50 HP)	\$48,500	2	\$97,000
42	5	Methanol Feed Tank (cyl. 15000 gallon max, carbon steel)	\$30,000	1	\$30,000
43	5	Methanol Precip. Feed Pumps (centrifugal, 300 gpm, 65' head, 15 HP)	\$6,000	2	\$12,000
44	5	Methanol Makeup Pump (centrifugal, 300 gpm, 65' head, 15 HP)	\$6,000	1	\$6,000
45	5	Methanol Makeup Tank (3000 gallon tank truck trailer, 316 SS)	\$13,000	1	\$13,000
46	5	Salt/Methanol Decant Tank (15000 gallon, 14'D x 16'H, carbon steel)	\$30,000	1	\$30,000
47	5	Methanol Strip Column Feed Pumps (centrifugal, 300 gpm, 65' head)	\$6,000	2	\$12,000
48	5	Methanol Strip Column (10'D x 32' H, 16 trays, 2000 gallon reboiler)	\$200,000	1	\$200,000
49	5	Recycle Salt Pumps (centrifugal, 300 gpm, 100' head, 20 HP)	\$6,000	2	\$12,000
50	5	Recycle Salt Solution Pumps (centrifugal, 300 gpm, 100' head, 20 HP)	\$6,000	2	\$12,000
51	5	High Solution Recycle Pump (centrifugal, 300 gpm, 100' head, 20 HP)	\$6,000	1	\$6,000
52	5	Karr Column Salt Solution Feed Pumps (centrifugal, 300 gpm, 100' head)	\$6,000	2	\$12,000
53	5	Concentrated Carbonate Reagent Pump (centrifugal, 300 gpm, 65' head)	\$6,000	1	\$6,000
54	5	Salt (High-Carbonate) Recycle Tank (12000 gallon max., 14' D x 16' H, CS)	\$25,000	1	\$25,000
55	5	Return Salt (Low-Carbonate) Tank (12000 gallon max., 14'D x 16'H, CS)	\$25,000	1	\$25,000
56	5	Carbonate Makeup Tank (6'D x 8'H cyl, 1000 gallon WV, 316 SS, impellor)	\$4,000	1	\$4,000
57	5	Carbonate Reagent Tank Agitator (5 HP motor, 30 in dia. impellor)	\$10,000	1	\$10,000
58	5	Bulk Carbonate Storage Containers (316 SS, 6 cu yd cap., conical dis.)	\$3,500	12	\$42,000
59	5	Bulk Carbonate Screw Feeder (3.2-160 cu ft/hr, timer, 5 cu ft hopper)	\$15,000	1	\$15,000

Table B.8
Aqueous Biphasic Extraction

Item	Source	Item Description	Cost/Unit	Quantity	Total Cost
60	5	PEG Repulp Tank Agitator (7.5 HP, 30 in dia. impellor)	\$11,000	1	\$11,000
61	5	Repulped Karr Column Feed Pumps (centrifugal, 350 gpm max, 65' head)	\$9,000	2	\$18,000
Total Equipment Cost					\$4,501,100