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PROCESS EVALUATION

COST ESTIMATE FOR DEWATERING ALASKAN PLACER EFFLUENTS WITH PEO

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U.S. DEPARTMENT OF THE INTERIOR
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MINERALS AND MATERIALS RESEARCH

Internal Report

COST ESTIMATE FOR DEWATERING ALASKAN PLACER EFFLUENTS WITH PEO

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by

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SUMMARY

This report contains a cost estimate of the Bureau of Mines process for dewatering Alaskan placer effluent streams with polyethylene oxide (PEO). In this process effluent slurry is withdrawn from the placer plant pond system after a primary settling stage. A dilute PEO solution is injected into the slurry line to flocculate the fine, suspended solids. The flocculated solids are dewatered on a stationary screen. Clarified water is returned to the placer operation or discharged, while the 35 percent solids waste is pumped back into the mine cut.

Cost estimates are presented for dewatering plants processing 1,000 gallons per minute of effluent slurry at three representative turbidity levels. Both the placer and the dewatering plants operate on the same 1-shift-per-day, 6-day-per-week schedule for the 100-day Alaskan operating season. Estimated fixed capital costs for these plants processing placer with effluent turbidities of 1,000, 3,000, and 5,000 nephelometric turbidity units (NTU) are approximately $29,000, $31,000, and $34,000, respectively, on a fourth quarter 1986 basis. Operating costs are estimated to be $0.34, $0.37, and $0.40 per thousand gallons of effluent slurry.

INTRODUCTION

In the hydrometallurgical treatment of many ores and concentrates to recover mineral values, slurries of fine particles are generated. Some of these slurries settle slowly and are difficult to dewater, causing environmental and handling problems for the mining industry. Techniques such as impoundment, thickening, and thickening followed by filtration are used to dewater and dispose of waste slurries. In light of new environmental regulations, losses of mineral values and lack of land suitable for impoundment, new technology is needed to handle slurries containing fine particles.[1]

The Bureau of Mines, at its Tuscaloosa Research Center has conducted considerable research on dewatering slurries containing fine particles. During these investigations, PEO was observed to form strong flocs in

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[1]Scheiner, B. J., A. G. Smelley, and D. A. Stanley. Dewatering of Mineral Waste Using the Flocculant Polyethylene Oxide. BuMines B 681, 1985, 18 pp.

many different waste slurries containing clays. These flocs immediately release water, forming a mass that can be mechanically dewatered on static and/or rotary screens.[2] The PEO dewatering technique has been applied to waste slurry streams from the phosphate, coal, potash, talc, mica, and bentonite industries. The resultant dewatered material for many of the slurries has a higher solids content than is obtained using other routine flocculation methods.

In placer mining, gold-bearing gravel is treated in a washing plant to remove boulders, small rocks, sand, and fines. This is usually accomplished by sizing the gravel from 0.5 to 1 inch in a trommel or on vibrating screens, with the undersized material washing into a sluice box. The small rocks, sand, and fines flow off the end of the sluice box into a sump where a majority of the rocks and sand settle out. The water containing the fines and some sand flows out of the sump and into the existing pond system at the mine site. In the pond system, the rest of the settleable material drops out leaving the fine grain silts and clays in suspension.

Some form of treatment of the non-settleable fraction of the gravels is needed. Although most of the fine material will settle with time, the resulting solution contains ultrafine or colloidal particles that remain suspended indefinitely. Large ponds for conventional flocculation and settling can produce acceptable water quality, in the 15 to 65 NTU range, but suitable land is often not available and construction costs are high. In addition, these ponds will fill with solids and require replacement and further reclamation since they will not support landfilling. Dewatering the solids to 30 to 38 percent solids is necessary to allow disposal back in the mine cut.

In the past few years, the effluents from placer mining have received considerable attention from a variety of agencies with regulatory authority, such as the Environmental Protection Agency (EPA), Alaska Department of Environmental Conservation (DEC), Department of the Interior Bureau of Land Management (BLM), and others. EPA has proposed regulations pertaining to water quality and DEC has issued regulations setting a standard for water discharge of 5 NTUs above the background of the receiving stream. BLM is enforcing reclamation standards on federal lands.

The Bureau's PEO dewatering technique was field tested with 500 to 750 gallons per minute of effluents from several Alaskan placer mines. Results showed that PEO requirements increased as the solids content of the feed slurries increased. It was also determined that PEO slurry contact times of 70 to 80 seconds were necessary for good floc formation. Tests achieved 25 to 43 percent dewatered solids and clarified water with a turbidity range of 20 to 200 NTU. This report contains an economic evaluation of the Bureau's process to aid in assessing its potential.

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[2]Smelley, A. G., and B. J. Scheiner. Large-Scale Dewatering of Phosphatic Clay Waste From Northern Florida. BuMines RI 8928, 1985, 9 pp.

Capital and operating costs are included for a commercial-scale plant based on a conceptual flowsheet developed from the Bureau's research.

PROCESS AND PLANT DESCRIPTION

Alaskan placer plants operate 100 days per year, 6 days per week, and 1 shift per day. For the purpose of this analysis the effluent dewatering plants are designed to follow the same schedule. Three dewatering plants have been designed to treat placer effluents with turbidities of 1,000, 3,000, and 5,000 NTU. Based on experimental data these streams were selected as representative of conditions in the plants. Corresponding percent solids and PEO addition rates for the three streams are shown in table 1. Solids capture of essentially 100 percent is assumed.

TABLE 1. - PEO dosage rates

Water turbidity, NTU	Feed, pct solids	PEO dosage, $lb/10^3$ gal
1,000	0.35	0.01
3,000	.6	.015
5,000	.9	.02

Effluent slurry is withdrawn from the plant pond system at 1,000 gallons per minute with a self priming, 6-inch centrifugal pump. The pump is skid mounted, and diesel driven with externally adjustable wear plates. Sections of float mounted, 8-inch, noncollapsing rubber hose are used on the suction side and sections of 8-inch, smooth bore rubber hose on the outlet.

Flocculant concentrate is prepared as a 0.25 percent solution by hand sprinkling a measured amount of PEO powder through a water spray into a stirred tank. This concentrate is diluted to 0.01 percent with water in a tank and allowed a relaxation time of 1 hour for the polymer to uncoil in solution. It is assumed that a portion of the water stream being recycled from the pond system to the sluice box is diverted for these mixing operations.

A variable speed positive displacement pump is used to inject the dilute PEO solution into the placer slurry line following the centrifugal effluent slurry pump. Solids contact and flocculation occur during a 75-second residence time in 500 feet of hose between the centrifugal pump and the dewatering screen.

This mixed stream enters a head box that allows a low-turbulence distribution of the flocculated solids onto the surface of a stationary dewatering screen. The screen consists of two 16-foot by 4-foot sections with the top section at a 58° angle and the lower section at a 50° angle to the horizontal. The surface is formed of window screen over a rigid, 2-inch, hog wire bed supported every 2 feet. Framing is 1-inch by 1.5-inch angle iron with 2-inch by 2-inch angle iron uprights. Dewatered solids move down the screen and drop back into the mine cut. The screen is relocated several times during the season to distribute the dewatered solids. Clarified water passes through the screen into a sump and flows by gravity to a pond for recycle to the plant or discharge to the stream, depending on water quality.

ECONOMICS

The intent of an economic evaluation is to present a capital and operating cost estimate of a commercial-size plant. In the preparation of any economic evaluation, it is necessary to make many assumptions. In general, the assumptions that are made are expected either to apply to the majority of the potential plants or to have only a small effect on the process capital and operating costs. An example of such an assumption is that the plant operates 1 shift per day, 6 days per week for the 100-day Alaska operating season.

If an assumption would be necessary that may not apply to a majority of plants or may have a major effect on capital or operating costs, then it is generally not included in the evaluation. An example of such an exclusion is that land cost and pond construction costs have not been included in the capital or operating cost estimates. When an assumption has been made or deliberately excluded, this fact is documented in the report.

Capital Costs

The capital cost estimate is of the general type called a study estimate by Weaver and Bauman.[3] This type of estimate, prepared from a flowsheet and a minimum of equipment data, can be expected to be within 30 percent of the actual cost for the plant described. The estimated fixed capital costs are based on a fourth quarter 1986 basis (Marshall and Swift (M and S) index of 801.0) for plants processing 480,000 gallons per day of placer effluent slurry. Listed in table 2-A, 2-B, and 2-C are capital costs for three plants operating on feed slurries of 1,000, 3,000, and 5,000 NTU. The only capital cost differences between the plants are for the PEO mixing and dilution tanks, reflecting the variation in PEO dosage with effluent turbidity. Based on an average 100-day operating season, these translate to fixed capital investments per annual thousand gallons of $0.61, $0.66, and $0.71, respectively.

Equipment costs for the process, based on cost-capacity data and manufacturer's quotations, are also shown in tables 2-A, 2-B, and 2-C. Cost data are brought up to date by the use of inflation indexes.

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[3]Weaver, J. B., and H. C. Bauman. Cost and Profitability Estimation. Sec. 25 in Perry's Chemical Engineer's Handbook, ed. by R. H. Perry and C. H. Chilton. McGraw-Hill, 5th ed., 1973, p. 47.

TABLE 2-A. - Equipment cost summary, turbidity 1,000 NTU, dewatering section

Item	Equipment[1]	Labor	Total
PEO Concentrate tank	1,450	200	1,650
PEO Transfer pump	150	630	780
PEO Dilution tank	2,510	680	3,190
PEO Feed pump	840	630	1,470
Placer slurry pump	9,180	2,010	11,190
Sweco cycloid screens	3,010	530	3,540
Total	17,140	4,680	21,820
Foundations			510
Instrumentation			510
Electrical			510
Piping			2,910
Miscellaneous			170
Total			4,610
Total direct cost			26,430
Field indirect, 5 pct of total direct cost			1,320
Total construction cost			27,750
Engineering, 1 pct of total construction cost			280
Administration and overhead, 1 pct of total construction cost			280
Subtotal			28,310
Contingency, 1 pct of above subtotal			280
Subtotal			28,590
Contractor's fee, 1 pct of above subtotal			290
Section cost			28,880
Plant facilities, 1 pct of above section cost			290
Plant utilities, 1 pct of above section cost			290
Total plant cost			29,460

[1]Basis: M and S equipment cost index of 801.0.

TABLE 2-B. - Equipment cost summary, turbidity 3,000 NTU, dewatering section

Item	Equipment[1]	Labor	Total
PEO Concentrate tank	1,660	240	1,900
PEO Transfer pump	150	630	780
PEO Dilution tank	3,710	800	4,510
PEO Feed pump	840	630	1,470
Placer slurry pump	9,180	2,010	11,190
Sweco cycloid screens	3,010	530	3,540
Total	18,550	4,840	23,390
Foundations			560
Instrumentation			560
Electrical			560
Piping			2,970
Miscellaneous			190
Total			4,840
Total direct cost			28,230
Field indirect, 5 pct of total direct cost			1,410
Total construction cost			29,640
Engineering, 1 pct of total construction cost			300
Administration and overhead, 1 pct of total construction cost			300
Subtotal			30,240
Contingency, 1 pct of above subtotal			310
Subtotal			30,540
Contractor's fee, 1 pct of above subtotal			310
Section cost			30,850
Plant facilities, 1 pct of above section cost			310
Plant utilities, 1 pct of above section cost			310
Total plant cost			31,470

[1]Basis: M and S equipment cost index of 801.0.

TABLE 2-C. - Equipment cost summary, turbidity 5,000 NTU, dewatering section

Item	Equipment[1]	Labor	Total
PEO Concentrate tank	1,930	260	2,190
PEO Transfer pump	150	630	780
PEO Dilution tank	5,020	1,360	6,380
PEO Feed pump	840	630	1,470
Placer slurry pump	9,180	2,010	11,190
Sweco cycloid screens	3,010	530	3,540
Total	20,130	5,420	25,550
Foundations			600
Instrumentation			600
Electrical			600
Piping			3,020
Miscellaneous			200
Total			5,020
Total direct cost			30,570
Field indirect, 5 pct of total direct cost			1,530
Total construction cost			32,100
Engineering, 1 pct of total construction cost			320
Administration and overhead, 1 pct of total construction cost			320
Subtotal			32,740
Contingency, 1 pct of above subtotal			330
Subtotal			33,070
Contractor's fee, 1 pct of above subtotal			330
Section cost			33,400
Plant facilities, 1 pct of above section cost			330
Plant utilities, 1 pct of above section cost			330
Total plant cost			34,060

[1]Basis: M and S equipment cost index of 801.0.

Foundations, instrumentation, electrical, and piping factors were separately estimated and added to the erected equipment costs. A miscellaneous item (1 percent of the equipment cost) is added to cover minor equipment and construction costs that are not shown with the equipment listed.

The field indirect cost, which covers field supervision, inspection, temporary construction, equipment rental, and payroll overhead, is estimated at 5 percent of the direct cost. Engineering cost and administration and overhead cost are estimated at 1 percent each of the construction cost. A contingency allowance of 1 percent and a contractor's fee of 1 percent are included.

The costs of plant facilities and plant utilities are estimated as 1 percent each of the total process cost including the field indirect costs, engineering, administration and overhead, contingency allowance, and contractor's fee. Included under plant facilities are the costs of non-process equipment. Also included are labor and material costs for site preparation such as site clearing, grading, drainage, roads, and fences. The cost of water and power distribution systems is included under plant utilities. Land investment is not included in this estimate. Also, cost for the plant owner's supervision is not included in the capital cost of the processed plant.

Operating Costs

The estimated operating costs are based on 100 days per year operation over the life of the plant. Inspection, maintenance, and refurbishing are performed during the off season. The operating costs are divided into direct, indirect, and fixed costs.

Direct costs include raw materials, utilities, direct labor, plant maintenance, payroll overhead, and operating supplies. The raw material costs do not include transportation costs. Electricity is assumed to be generated from available diesel generator capacity at the placer plant. Diesel in addition to that used by the effluent slurry pump is included for generating electricity. Plant water is obtained from streams or recycled from the plant's pond system. Direct cost requirements per thousand gallons of slurry are shown in tables 3-A, 3-B, and 3-C.

Direct labor costs are estimated on the basis of assigning one employee who works 4 hours per day, 6 days per week. No cost of labor supervision is included. Plant maintenance is separately estimated for each piece of equipment and for plant facilities, but no additional labor and supervision are included. Payroll overhead, estimated as 35 percent of direct labor, includes vacation, sick leave, social security, and fringe benefits.

Indirect costs are estimated as 40 percent of the direct labor and maintenance costs. The indirect costs include the expenses of control laboratories, accounting, plant protection and safety, plant administration, marketing, and company overhead. Research and overall company administrative costs outside the plant are not included.

Fixed costs include the cost of taxes (excluding income taxes), insurance, and depreciation. The annual costs of both taxes and insurance are each estimated as 1 percent of the plant construction cost. Depreciation is based on a straight-line, 15-year period.

TABLE 3-A. - Estimated annual operating cost

	Annual cost	Cost per Mgal effluent slurry
Direct cost:		
Raw materials:		
PEO Poly-ox coagulant at $4.60 per pound.....	$2,210	$0.046
Utilities: Diesel fuel at $1 per gallon.......	1,600	.033
Direct labor at $13 per hour..................	5,200	.108
Plant maintenance: Materials..................	630	.013
Payroll overhead, 35 pct of above payroll......	1,820	.038
Total direct cost........................	11,460	.238
Indirect cost, 40 pct of direct labor and maintenance...................................	2,330	.048
Fixed cost:		
Taxes, 1 pct of total plant cost...............	290	.006
Insurance, 1 pct of total plant cost...........	290	.006
Depreciation, 15-yr life.......................	1,960	.141
Total operating cost.....................	16,330	.339

TABLE 3-B. - Estimated annual operating cost

	Annual cost	Cost per Mgal effluent slurry
Direct cost:		
Raw materials:		
PEO Poly-ox coagulant at $4.60 per pound.....	$3,310	$0.069
Utilities: Diesel fuel at $1 per gallon.......	1,600	.033
Direct labor at $13 per hour..................	5,200	.108
Plant maintenance: Materials..................	660	.014
Payroll overhead, 35 pct of above payroll......	1,820	.038
Total direct cost.........................	12,590	.262
Indirect cost, 40 pct of direct labor and maintenance....................................	2,340	.048
Fixed cost:		
Taxes, 1 pct of total plant cost...............	310	.007
Insurance, 1 pct of total plant cost...........	310	.007
Depreciation, 15-yr life.......................	2,100	.044
Total operating cost.....................	17,650	.368

TABLE 3-C. - Estimated annual operating cost

	Annual cost	Cost per Mgal effluent slurry
Direct cost:		
Raw materials:		
PEO Poly-ox coagulant at $4.60 per pound.....	$4,420	$0.092
Utilities: Diesel fuel at $1 per gallon.......	1,600	.033
Direct labor at $13 per hour..................	5,200	.108
Plant maintenance: Materials..................	690	.015
Payroll overhead, 35 pct of above payroll......	1,820	.038
Total direct cost.........................	13,730	.286
Indirect cost, 40 pct of direct labor and maintenance..................................	2,360	.049
Fixed cost:		
Taxes, 1 pct of total plant cost...............	340	.007
Insurance, 1 pct of total plant cost...........	340	.007
Depreciation, 15-yr life.......................	2,270	.047
Total operating cost.....................	19,040	.396

The estimated annual operating costs for the proposed plants are about $16,300, $17,600, and $19,000, as shown in tables 3-A, 3-B, and 3-C, respectively. Based on treatment of 480,000 gallons per day of effluent, 100 days per year, this corresponds to costs of $0.34, $0.37, and $0.40 per thousand gallon.

DISCUSSION

Prior research on dewatering of clay bearing, mineral waste streams with PEO has shown wide variation in separation efficiency. Optimization of the operating parameters of the system appears to be specific to each site and waste stream. Since little research time was available for process optimization at each plant during the Alaskan test program, further improvements in water quality and solids capture may be possible. For example, a shorter residence time and hose length may be possible if in-line mixers are used to achieve PEO/solids contact. Reduced hose breakage from vehicular traffic and line relocation could be a possible benefit along with improved solids separation. However, the distance between the settling pond and the dewatering screen at the mine cut would need to be considered at each plant site.

This estimate is based on research, which yielded a range of values at several Alaskan placer mine sites. Values of 35 percent dewatered solids and 40 NTU clarified water were well within the range of test results and were selected as representative and reproducible. No information was available on the background water quality of the streams but a 40 NTU level was assumed to be satisfactory for recycle to the placer plant. Since the NTU is an optical measurement of water quality and the test readings have shown some variation, interference from factors other than suspended solids may be indicated. This issue should be clarified to provide a reliable basis with which to judge process efficiency and final discharge water quality.

Installation labor accounts for approximately 20 percent of the total direct equipment cost of the dewatering plant. The multi-skilled placer labor force could install the dewatering equipment as part of the significant placer plant maintenance program already performed at the start of each opearting season. As this labor force is traditionally paid by the season, significant reductions in plant capital costs could potentially be realized with little additional cost to the placer operation.

Analysis of the annual operating cost tables show that labor related items account for 48 to 56 percent of the cost per thousand gallons of effluent slurry. The direct labor annual cost reflects one general plant operator being paid 24 hours per week for the 100-day operating season. If plant operation requires more or less attention or if existing labor at the placer plant could be utilized, this cost should be adjusted accordingly.

If the 2 kilowatts needed to operate the dewatering plant's pumps and stirrers cannot be generated by existing placer plant generators, then additional electrical capacity will need to be purchased. Replacement of the diesel drive on the effluent slurry pump with an electric drive may then be feasible. This would realize a capital cost savings of $3,000 on the pump to partially offset the additional generator capacity cost. Availability of electric power from a local utility to drive the plant motors, including the slurry pump, would eliminate the annual diesel fuel cost of approximately $1,600 and add an annual electric power cost of approximately $685 at $0.09 per kilowatt hour to each plant.

A cost of $4.60 per pound PEO is used in this estimate. This figure does not include transportation costs from Charleston, West Virginia, which by motor freight to Alaska are approximately $0.07 per ton-mile. Shipping costs for a years supply of PEO, eight 140-pound fiber drums, shipped 3,500 miles, would be $137 or $0.12 per pound of PEO. However, an increase of $0.50 per pound of PEO increases the estimated operating cost by $0.005 to $0.01 per thousand gallons. Since utilities and maintenance materials costs are also low and taxes, insurance, and depreciation are fixed, any significant improvement in annual operating costs must come in the labor area.