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Dewatering of Alaska Placer Effluent Using PEO

By Sandeep K. Sharma, B. J. Scheiner,
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UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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Manuel Lujan, Jr., Secretary

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cP	centipoise
ft	foot
gal	gallon
gpm	gallon per minute
in	inch
lb	pound
lb/ft^3	pound per cubic foot
lb/st	pound per short ton
mg/L	milligram per liter
min	minute
NTU	nephelometric turbidity unit
pct	percent
s	second
yd^3	cubic yard
yd^3/h	cubic yard per hour

DEWATERING OF ALASKA PLACER EFFLUENT USING PEO

By Sandeep K. Sharma,[1] B. J. Scheiner,[2] and A. G. Smelley[3]

ABSTRACT

The U.S. Bureau of Mines has been investigating new techniques to improve the dewatering of mineral slurries, to recover water lost in the waste slurry, and to produce dewatered solids suitable for disposal. As part of this investigation, a study was undertaken to investigate the feasibility of dewatering Alaska placer effluent. Based on the laboratory tests, preliminary field tests were conducted on three placer mines in Alaska. At these mines, the water recovered from the placer effluent (250 to 23,000 NTU) exhibited turbidities of 20 to 240 NTU. In the second year of the project, a large-scale dewatering unit was set up at a mine located in the Livengood district. The feed, at flow rates up to 935 gpm, was mixed with dilute PEO solution in a flexible plastic hose with and without static mixers. Feed to the dewatering unit generally ranged between 300 and 26,500 NTU and required PEO dosages of 0.02 to 0.14 lb per 1,000 gal to produce water from the screen underflow with turbidities of 20 to 50 NTU. During this period, a small unit was also operated at flow rates of 10 to 25 gpm at seven sites throughout Alaska, with the effluent from four of the sites being dewatered successfully.

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INTRODUCTION

In the placer mining industry, gold-bearing gravels are generally treated in various washing and screening plants to separate the gold particles from small rocks, fines, and sand. In this process, the gravel is first sized from 0.5 to 1 in on a vibratory screen. The undersized material is washed into a sluice box while the small rocks, sand, and fines flow off the end into a sump, where the majority of the rocks and sand settle out. Water for the operation is generally taken from a nearby creek or stream. The rocks and coarser particles are removed from the sump on a regular basis. The water, containing sand and clay, flows into the pond system of the mine. In the pond, the rest of the settleable material drops out, leaving the fine-grain silts and clays. With time, some of this material also settles, leaving water contaminated with ultrafine particles that remain suspended for a long time. Contamination of the creek is possible if this water enters the stream.

In the past few years, the placer mining operations in Alaska 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. The DEC has issued regulations setting a standard for water discharge of 5 NTU above the background of the receiving stream, and BLM has enforced reclamation standards on Federal lands. To meet these regulations with current technology, a large settling pond must be developed. The process involved in the development of a suitable pond system consists of four steps: selection of a site, actual construction, maintenance, and reclamation of the site. All four of these steps could place an economic burden on the placer miner. Although the smaller ponds are less expensive to construct and are easier to reclaim, they do not provide the retention time needed to produce water by natural settling that is acceptable under regulations. Therefore, the regulations requiring low-turbidity water further add to the cost of mining.

Settling in the ponds can be accelerated by the addition of polymers or other flocculants to the sluice discharge. Tests conducted by the U.S. Bureau of Mines in cooperation with EPA have shown that a variety of commercially available flocculants produce flocs that settle rapidly, resulting in water with turbidities of 15 to 65 NTU. Therefore, by using flocculants, a smaller pond system may be used to produce high-quality water. However, the pond will fill with solids and must be cleaned out or a new pond will be needed during the operating season. Eventually, the pond containing flocculated material will have to be reclaimed.

For several years, the Bureau, in support of its goal to minimize the environmental impact of mining, has been investigating a unique dewatering method that removes the solids from the water (*1-2*).[4] The technique consists of flocculating a waste slurry with a polymer and dewatering the resulting flocs on screens. Static screens and rotating trommel screens have been used alone and in combination, depending on the material treated. The solids from the screens can be discharged into a pit or landfill, and the water can be returned to the existing ponds to be recycled to the mining operation or possibly even discharged to the environment. The flocculating agent most commonly used is PEO, a commercially available, nontoxic, water-soluble, nonionic polymer. This technique has been applied to a variety of mineral waste slurries. Laboratory, small-scale continuous, and field tests have been conducted on clay wastes from phosphate, coal, bentonite, and potash operations and the tailings from uranium, talc, copper, gold, silica, and mica mining operations (*1*).

Flocculation of clay-polymer systems depends primarily upon collision of polymer with clay particles, adsorption, polymer reconfiguration, bridging, and minimum redispersion. When the polymer is added to a slurry, it comes in contact with the clay surface because of agitation and forms bonds with the active sites. After adsorption, the tails and loops of polymer coil extend into solution and can bridge with other particles. The flocculation process is very complicated, and all of the aforementioned steps may be going on simultaneously, rather than in succession.

The first tests were conducted on Alaskan placer effluent in 1981. The initial test results showed that the Bureau-developed PEO dewatering technique (*2*) had promise for treating effluent from placer mining. In 1985, additional laboratory tests were conducted on eight different samples to reassess the technology, and similar results were obtained for removal of solids.

Consequently, field testing was begun in Alaska during the summer of 1986. A field test unit, mounted on a truck, was taken to three different mining sites to conduct continuous tests to clarify placer mining effluent: Crooked Creek in the Circle mining district, Fairbanks Creek in the Fairbanks mining district, and Olive Creek in the Livengood mining district. The results of this testing program were positive, indicating that field testing should be continued.

Operation of two field test units was conducted in 1987, a large unit to clarify total sluice box discharge and a small unit to operate at various mine sites throughout Alaska.

[4]Italic numbers in parentheses refer to items in the list of references at the end of this report.

DESIGN AND OPERATION OF PLANTS

The flow sheet for the 1986 test unit is shown in figure 1. The unit was mounted on a truck and was designed to handle up to 300 gpm of placer effluent. The waste slurry was pumped to the conditioner-mixer (tank mixer), where it was mixed with a dilute solution of PEO. The water and flocculated solids flowed out of the tank onto the static screen, where the solids moved down the screen, while released water went through the screen and flowed to a pond for either recycling or discharge to a stream. The solids were stored in a pit where they continued to dewater, eventually reaching a solids content high enough to be handled by mining equipment. The static screen was built in two sections of stainless steel wedge wire, each 8 ft wide and 4 ft long. The upper section of the screen had slot openings 2.75 in long and 0.02 in wide and was at an angle of 58° from the horizontal, while the lower section had slot openings 2.75 in long and 0.01 in wide and was at an angle of 50° from the horizontal.

The dry flocculant, PEO, was added in a mixer shown schematically in figure 2. The mixer consisted of a tank equipped with a stirrer, a vibrating feeder to add the dry PEO, and a water spray system to wet the PEO particles as they fell into the tank. The flocculant was prepared as a 0.25-pct solution and was diluted to 0.01- or 0.02-pct solution in a tank for use.

Based upon the data from the previous tests, the flow sheet for the summer 1987 project was altered. A large unit, shown in figure 3, was designed to handle up to 1,000 gpm of placer effluent. The main difference between this unit and the previous unit was the exclusive use of in-line mixing instead of tank mixing. A 6-in pump with a capacity of about 1,100 gpm, at no head pressure, was used to deliver the waste slurry to the unit. PEO pumps with variable-speed drive systems and with capacities of 45 and 20 gpm were used to inject the PEO solution in-line by using 2-in-diam pipe. Placer effluent was delivered to the system by 6-in pipes of various lengths. A Kenics[5] static mixer (2 to 10 elements) was used, when needed, to increase the turbulence in the pipe. The flocculated slurry was emptied into a trough at the top of the screens and overflowed onto the screens. The water went through the screen into a trough and was allowed to flow by gravity into the secondary pond. The dewatered solids rolled down the screen and discharged into a pit. The screen comprised two sections: The top section was set up at an angle of 47° from the horizontal and the bottom section was set at an angle of 38° from the horizontal. A common aluminum window screen, 16 by 18 mesh, was used as the screening device for the flocculated solids.

Turbidity is a method of measuring the clarity of solution, and it is generally a good indicator of the effectiveness of the flocculation process. For this investigation, the clarity of the supernate in terms of particle content as well as coloring was measured using the Hach turbidity meter. The turbidity unit used was the nephelometric turbidity unit (NTU).

The same mixer was used to prepare the PEO solution as was used in 1986 (fig. 2). However, PEO stock solution was made as 0.33 pct rather than 0.25 pct, and it required

[5]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

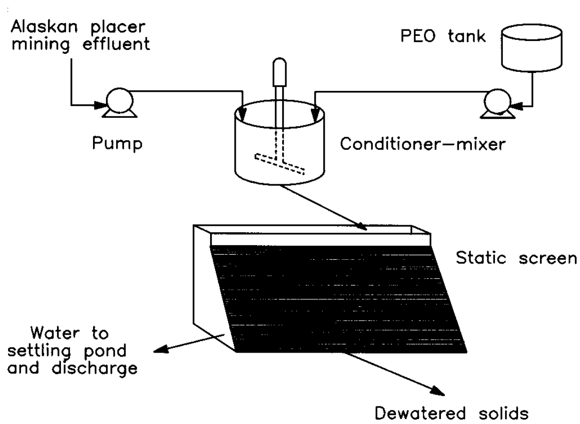

Figure 1.—General layout of small field test unit for first three field tests in 1986.

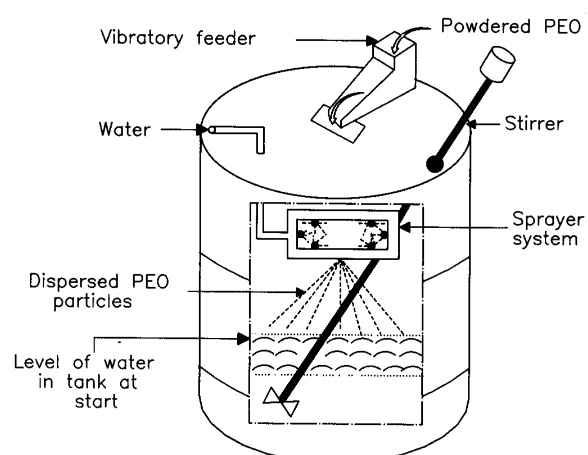

Figure 2.—Schematic of PEO mixer.

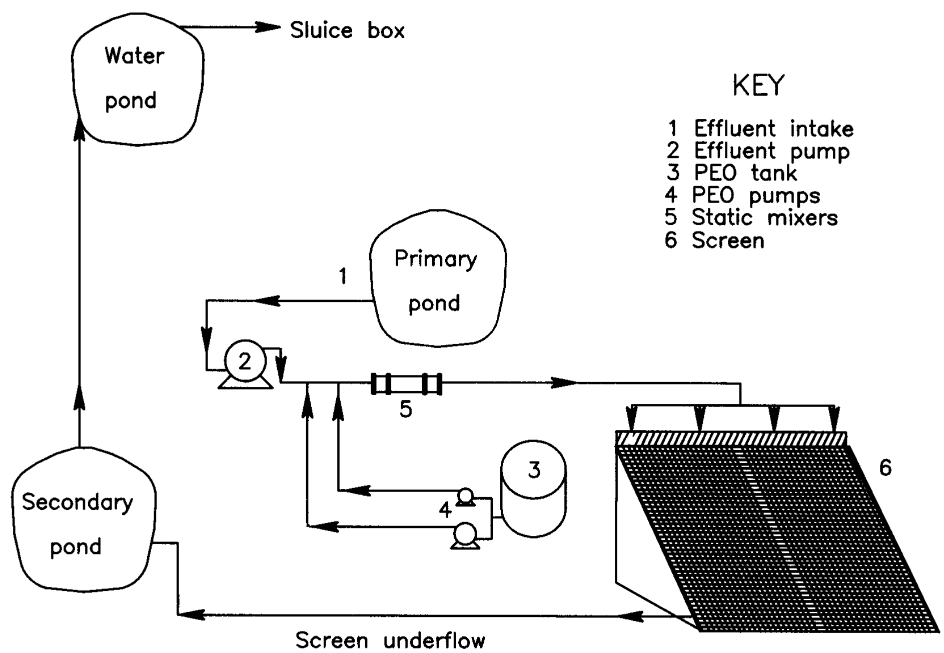

Figure 3.—General layout of large field test unit with capacity to handle 1,000 gpm of placer effluent.

almost 60 min to make 90 gal. This solution was diluted to 0.01 pct in a 3,000-gal tank. The concentrated PEO, 0.33 pct, was stored in a 1,000-gal tank for several days' operation.

A smaller mobile unit was also operated at slurry flow rates of 10 to 25 gpm at the various mine sites throughout Alaska. This unit was composed of smaller components of similar design to the larger unit.

DESCRIPTION OF MINE OPERATIONS

CROOKED CREEK

The first test site was at the Gelvin Mine, located on Crooked Creek near the town of Central, AK. At this mine, 90 to 100 yd^3 of gravel was treated per hour with a water usage of 1,000 gpm. The mine was using a solids removal system whereby the material coming out from the sluice box flowed to a sump, where most of the sand and gravel settled and were removed periodically by a front end loader. The waste stream continued to flow into a large pond, where the rest of the settleables dropped out. The nonsettleable slurry then flowed into an extensive tundra filter and was finally recycled back to the sluice box.

The waste slurry was fairly constant in terms of solids content (0.8 to 1.0 pct solids) and had turbidities of 4,000 to 6,000 NTU. The water recovered from the waste stream, after dewatering, flowed into a pond 54 by 93 ft and about 3 ft deep. The overflow from this pond reentered the mine's water system.

FAIRBANKS CREEK

The second test site was the Cook Mine, located on Fairbanks Creek. This mine was treating 60 to 70 yd^3/h using about 1,200 gpm of water. The material was moved with a drag line, fed into a trommel to remove rocks, and then fed to a sluice box through a hydraulic lift. Water from the sluice box flowed into a primary pond, where some of the water was recycled back to the sluice for reuse. Overflow from the primary pond flowed into various pond systems before it was discharged into an overburden drain system. The dewatering unit was set up at the secondary pond. A water pond about 60 by 60 ft with an average depth of 3 ft was constructed to impound the supernate produced during the experiment. Water from this pond overflowed back into the mine's pond system.

OLIVE CREEK

The third and final site selected for this project was the Geraghty Mine, located on Olive Creek near the Livengood district. At this site, the miner was treating 60 yd^3 of gravel per hour with 1,000 gpm of water. This mine had a series of settling ponds, and it recycled all of its water. In fact, because of the lack of water flow in Olive Creek, water was usually in short supply. The pond system consisted of a primary pond approximately 120 by 130 by 3 ft deep, where most of the sand and gravel settled out. This pond overflowed into a secondary pond, 165 by 125 by 4 ft deep, where some settling of the fines occurred. The water, after flowing through a third pond, was reused for the mining operation. This elaborate system had been used by the miner for the past 8 years.

The placer effluent for the test unit was taken from the second pond. The clean water produced by the dewatering system was put back into the second pond near the pumps used for pumping water to the third pond.

RESULTS AND DISCUSSION

LABORATORY TESTS

Eight samples of the Alaskan placer mining effluent, representing different mining operations and taken at various points in the effluent discharge system, were received during the period of July through October 1985. These samples were collected by the Alaska Field Office of the Bureau. The eight mining operations (table 1) were not necessarily located in the aforementioned districts and were operated independently by different miners. In addition to the flocculation tests, settling tests were also conducted using the procedure from "Standard Methods for Examination of Water and Waste Water" (*3*). The results showed that, although the samples varied widely, only the samples from Gold Dust Creek, Gilmore Creek, and Mammoth Creek contained relatively low percentages of nonsettleable matter (table 1). Batch dewatering tests were conducted using the procedure developed by the Bureau, and the results from these tests are shown in table 2 (*1*). The initial solids of the placer effluent used in the dewatering tests varied from 0.03 to 1.27 pct. A PEO dosage of 0.01 to 0.08 lb per 1,000 gal of effluent was required to produce water with turbidities of 45 to 105 NTU. A PEO dilution test series was also conducted on all of the samples to determine the best polymer concentration to use in the dewatering tests. For this test, six different concentrations of polymers, representing a wide range, were used. The results of these tests showed that when PEO concentration was decreased from 0.25 to 0.001 pct, the optimum dosage of PEO required to produce flocculation also decreased (table 3). Similar results were obtained with other samples. Although decreasing the concentration also decreased the solids in the dewatered product and increased the turbidity of supernate, the dewatered product was still strong enough to be handled.

Table 1.—Results of settling tests on placer effluent sampled in 1985

Location	Initial solids content, pct	Total suspended matter, mg/L	Nonsettleable matter, mg/L	Settleable matter, mg/L
Crooked Creek	0.13	1,300	1,200	100
Deadwood Creek:				
Site 1	1.27	9,850	1,230	8,620
Site 2	.35	3,093	2,247	846
Dredge Pond:				
Number 6	.93	4,680	4,502	178
Eagle Creek	.25	2,000	1,380	620
Gilmore Creek	.49	4,320	160	4,160
Gold Dust Creek	.03	136	48	88
Mammoth Creek	.14	1,280	280	1,000

Table 2.—Results of dewatering tests on placer effluent sampled in 1985

Location	Initial solids content, pct	PEO conc., pct	PEO dosage, lb per 1,000 gal	Turbidity of supernate, NTU
Crooked Creek	0.13	0.001	0.02	66
Deadwood Creek:				
Site 1	1.27	.001	.02	105
Site 2	.35	.005	.03	45
Eagle Creek	.25	.005	.02	87
Gilmore Creek	.49	.05	.08	102
Gold Dust Creek	.03	.005	.02	78
Mammoth Creek	.14	.001	.01	48

Table 3.—Results of dewatering dilution test series on sample from Deadwood Creek, site 1, 1985

PEO addition		Turbidity of supernate, NTU	Final solids content, pct
Concentration, pct	Dosage, lb per 1,000 gal		
0.001	0.02	105	44
.005	.03	153	47
.01	.03	132	48
.05	.07	129	52
.10	.10	79	51
.25	.17	72	53

FIELD TESTS OF SUMMER 1986

After successful completion of the laboratory tests, a field testing program was conducted during the summer of 1986 to test the applicability of the dewatering technology on a larger scale. Tests were conducted at three sites during 12 weeks. Because of the shortage of time, it was difficult to optimize the dewatering operation at any one site. Therefore, it was only possible to record the data on polymer dosage, water quality (turbidity), and screen efficiency at each site.

Crooked Creek

Initial tests showed that the nonsettleable solids could be removed readily from the slurry on the unit with a PEO dosage of 0.05 to 0.10 lb per 1,000 gal of the effluent treated. The turbidity of the underflow water received from the screen was 200 to 400 NTU. At the end of the day and again in the morning before starting tests, the turbidity of the pond water remained in this range. It was observed during initial testing that additional contact time between the PEO and the slurry was required to obtain strong flocs. To accomplish this, the conditioner-mixer was redesigned so that dewatered slurry came out at the middle of the mixer instead of the bottom. Tests conducted using this mixer showed that a PEO dosage of 0.03 to 0.05 lb per 1,000 gal of the slurry was required to produce a screen capture rate of 70 to 80 pct. Screen capture is defined as percent of intact solids recovered from the screen. The rest of the solids passed through the screen, but settled immediately in the pond to produce water with a turbidity of 200 to 240 NTU.

Better results were obtained when a polymer additive, Catfloc T polymer, was added prior to the addition of PEO to the conditioner-mixer. The results in table 4 show that the addition of Catfloc T polymer (a cationic polymer) at a dosage of 0.008 lb per 1,000 gal before PEO addition reduced the PEO dosage from 0.05 to 0.016 lb per 1,000 gal. This combination produced a screen underflow with a turbidity of 280 NTU and the highest screen capture rate, 80 pct. These tests were conducted at flow rates of 200 to 300 gpm, but increasing the flow rates to about 500 gpm reduced the screen capture rate from 80 to 60 pct. Although the field tests conducted at Crooked Creek were preliminary and were conducted for a very short time, the results indicated that the PEO dewatering technique could be applied to the placer effluent. It was also found that proper mixing of the waste slurry with PEO was critical to the operation.

Table 4.—Field test results at Crooked Creek, 1986

Additive dosage, lb per 1,000 gal		Turbidity of supernate, NTU
PEO	Catfloc T polymer	
0.002	0.29	240
.010	.59	155
.012	.59	155
.016	.08	220
.016	.008	280
.026	0	240
.056	.59	160
.058	0	215
.114	1.17	105

Fairbanks Creek

Preliminary tests at this site showed that the tank mixer would not produce strong flocs, even after 16- by 18-mesh wire was added on top of the screen. Laboratory tests of this slurry, conducted on site, showed that an in-line mixer would produce better results than the tank mixer. Tests conducted using flexible plastic hose as an in-line mixer produced strong flocs, and increasing the length of the hose increased the floc size and percentage of solids captured on the screen. It was also determined during the initial testing that different retention times were required for different concentrations of PEO. The retention time is defined as the duration of mixing of polymer and slurry in the hose. For 0.01 pct PEO, optimum retention time was 70 to 80 s, while for 0.02 pct PEO, it was only 60 to 70 s. A further increase in the PEO concentration to 0.05 pct reduced the retention time to almost 10 s.

During the testing program, placer effluent with turbidities ranging from 150 to 3,100 NTU was treated. Placer effluent with higher turbidity was obtained from the primary pond, and the less turbid water was obtained from the secondary pond. The results of the tests done on the effect of turbidity on polymer dosage showed that the PEO consumption increased as the solids content of the placer effluent increased. For example, when waste water with a

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During the testing program, placer effluent with turbidities ranging from 150 to 3,100 NTU was treated. Placer effluent with higher turbidity was obtained from the primary pond, and the less turbid water was obtained from the secondary pond. The results of the tests done on the effect of turbidity on polymer dosage showed that the PEO consumption increased as the solids content of the placer effluent increased. For example, when waste water with a turbidity of 1,000 NTU was treated, a PEO dosage of 0.01 lb per 1,000 gal was required to produce almost 98 pct screen capture and a screen underflow with a turbidity of 30 to 40 NTU. However, when the turbidity of the sample was increased from 1,000 to 3,000 NTU, the PEO dosage required to obtain 98 pct screen capture increased to 0.045 lb per 1,000 gal. Reducing the PEO dosage to 0.03 lb per 1,000 gal decreased the screen capture to 70 pct and increased the turbidity of the supernate to 130 NTU. Again, as was found at Crooked Creek, the PEO dewatering technology showed promising results in the short time it was applied to this site.

Olive Creek

At Olive Creek, initial dewatering tests were conducted using the redesigned conditioner-mixer instead of the in-line mixer. Results from these tests showed that a PEO dosage of 0.042 lb per 1,000 gal was required to produce water with a turbidity of 88 NTU and a screen capture of 90 pct. Lowering the PEO dosage to 0.031 lb per 1,000 gal resulted in an increase of the supernate turbidity to almost 200 NTU and decreased the screen capture to only 34 pct. Therefore, based on the preliminary results, it was decided that the tank mixer was not very effective in providing the best mixing conditions to produce high-quality water at low polymer dosage, so the in-line mixer was used in subsequent tests.

In the in-line mixing setup, PEO was injected in the slurry line about 15 ft from the slurry pump. The mixing of polymer and slurry was accomplished by the turbulence created by a very high flow rate in the hose as previously described at the Fairbanks site. This type of mixing produced better flocs at lower polymer dosage than the tank mixer did. As shown in table 5, a PEO dosage of 0.01 lb per 1,000 gal produced a supernate with a turbidity of 44 NTU and screen capture of almost 98 pct. The feed solids varied from 0.38 to 0.55 pct because of development of a concentration gradient during sedimentation that increases the slurry concentration in the pond with increasing depth. This variation was observed throughout the testing program. Raising and lowering the intake hose in the second pond produced a wide range of solids concentrations and turbidities ranging from 350 to 23,000 NTU. The optimum mixing time for polymer and slurry was between 60 and 70 s. At this mixing time, the effect of PEO concentration on dosage requirement and screen capture was compared. The data show (table 6) that a 0.01-pct PEO concentration gave better performance than 0.02 pct PEO. For 0.01 pct PEO, the dosage requirement was approximately 0.02 lb per 1,000 gal, while for 0.02 pct PEO it was close to 0.03 lb per 1,000 gal. As previously done at Fairbanks Creek, a 16- by 18-mesh screen was overlaid on the top section of the wedge wire screen. This screen functioned very well, resulting in good-quality water and high screen capture.

Table 5.—Effect of PEO addition on unit performance at Olive Creek, 1986

PEO dosage, lb per 1,000 gal	Feed		Turbidity of supernate, NTU	Screen capture, pct
	Solids, pct	Water turbidity, NTU		
0.004	0.40	1,600	245	10
0.008	.38	1,450	62	4
0.010	.53	1,900	44	98
0.016	.45	1,550	35	99
0.016	.55	2,000	25	99

Table 6.—Effect of PEO concentration on dewatering efficiency, Olive Creek, 1986

PEO addition		Feed, pct	Turbidity of supernate, NTU	Capture, pct
Concentration, pct	Dosage, lb per 1,000 gal			
0.01	0.016	1.01	32	81
.01	.023	1.09	18	99
.02	.026	1.05	33	77
.02	.034	.93	60	99

FIELD TESTS OF SUMMER 1987

Based upon the data from summer 1986, the flow sheet for solids removal was altered; this is discussed in the "Design and Operation of Plants" section and shown in figure 3. Also, it was decided to conduct the test at Olive Creek. At this site, the mine production rate was about 50 to 60 yd^3/h and the water consumption increased from 1,000 gpm in 1986 to about 1,600 gpm in 1987. The mining operation at this site is described in the "Description of Mine Operations" section of this report; the tests were conducted at both primary and secondary ponds.

Placer effluent was treated at rates of 300 to 935 gpm. In-line mixing through 400 to 1,000 ft of pipe combined with a wide range of Kenics static mixers (2 to 10 elements) was tested. During initial testing on the primary pond, 600 ft of 6-in pipe and a two-element static mixer produced the best results. However, when the unit was transferred to the secondary pond, 600 ft of pipe alone produced good flocs. In both tests, treated water was recycled back to the secondary pond. The feed, which varied widely in solids content, from 0.09 to 6.0 pct, was dewatered using 0.01-pct PEO solution. Analysis of the solids in the placer effluent showed that there was a direct relationship between the feed water turbidity and initial solids (fig. 4). This relationship was more pronounced for the data from the secondary pond because it had finer particles in the effluent than the primary pond did (discussed in the introduction of this report). An increase in the initial solids from 0.75 to 5.5 pct increased turbidity of the feed water from 5,000 NTU to about 25,000 NTU.

The PEO dosage required to dewater placer effluent, using 0.01-pct PEO solution, varied with the initial solids; the dosage was calculated in pounds per short ton or pounds per 1,000 gallons treated. For example, as shown in figure 5, when the terminology of pounds per 1,000 gallons was used, the PEO dosage increased from 0.06 to 0.15 lb per 1,000 gal with an increase in initial solids from 1 to 4 pct. However, when the dosage was designated in terms of pounds per short ton of dry solids as shown in figure 6, the PEO dosage decreased from 1.5 to 0.25 lb/st of solids treated with an increase in initial solids from 1 to 4 pct.

It was also found that the PEO dosage depended not only on the initial percent solids but also depended on agitation as characterized by the Reynolds number, which is directly proportional to the slurry flow rate. The Reynolds number for the in-line mixer was calculated by the equation (*4*):

$$N_{Re} = 50.6\,(Q\rho)/(\mu D)$$

where N_{Re} = Reynolds number in the pipe,

Q = slurry flow rate, gpm,

ρ = slurry density, lb/ft^3,

μ = slurry viscosity, cP,

and D = inside diameter of mixer, in.

To use the equation, the specific gravity and viscosity of the slurry must be known. The question arises as to what changes in viscosity occur when polymer is added. For this study, it was assumed that, since a small volume of very dilute polymer was added, the overall effect on viscosity would be minimal. Measurements of viscosity taken before and after polymer addition showed that the increase in viscosity was not significant. It was also assumed that the specific gravity of the total slurry (polymer and slurry) did not change during flocculation (i.e., total amount of solids before and after flocculation remained constant). For pipes, flow is laminar when N_{Re} is less than 1,900 and turbulent when N_{Re} is greater than 3,000. Reynolds numbers between 1,900 to 3,000 are called the transition zone (*5*). The results shown in figure 7 indicate

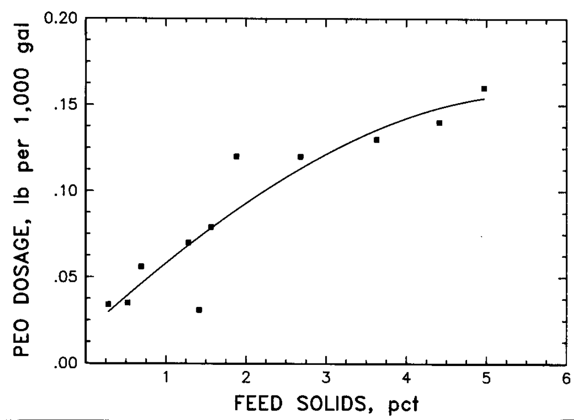

Figure 5.—Relationship between feed solids and PEO dosage, in pounds per 1,000 gal, at Olive Creek.

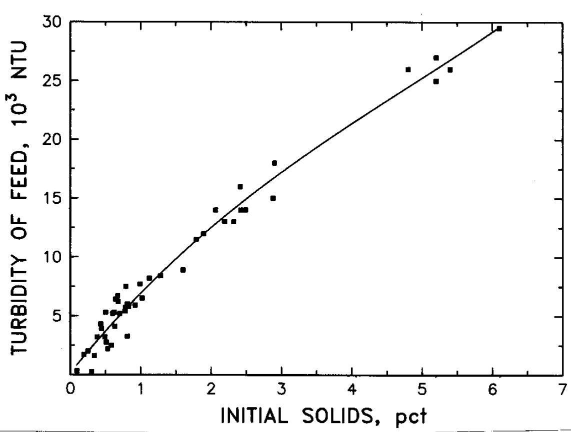

Figure 4.—Relationship between initial solids and turbidity of feed for Alaska placer effluent at Olive Creek.

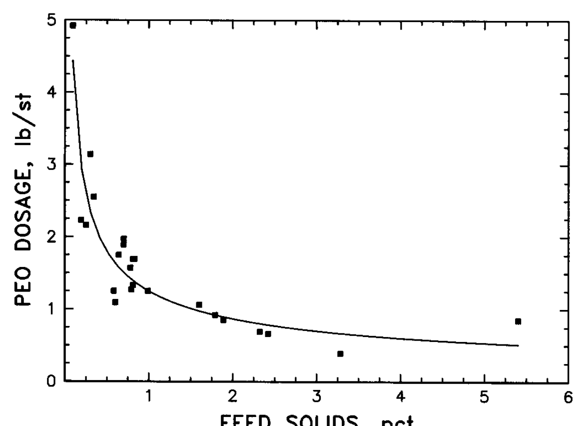

Figure 6.—Relationship between feed solids and PEO dosage, in pounds per ton, at Olive Creek.

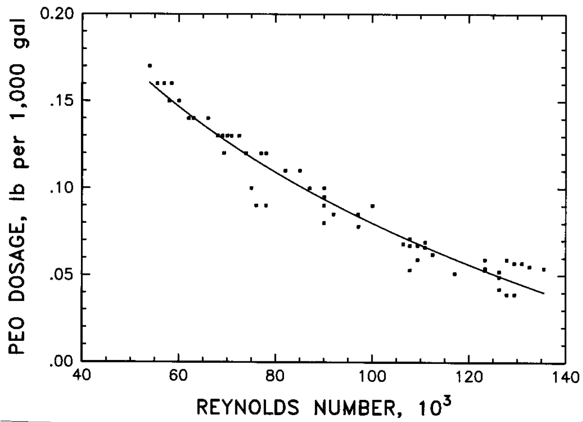

Figure 7.—Effect of Reynolds number on PEO dosage for large field test unit.

that when the Reynolds number increased from 60,000 to 130,000, the PEO dosage decreased from 0.15 to 0.04 lb per 1,000 gal. Finally, taking all the variables into consideration, it was found that a PEO dosage of 0.02 to 0.14 lb per 1,000 gal was required to produce a dewatered product of 33 to 43 pct solids and screen underflow with turbidity of 20 to 50 NTU (table 7). Despite the good results, a settling pond was still necessary to meet the discharge standards.

Table 7.—Results of field test at Olive Creek, 1987

PEO dosage, lb per 1,000 gal	Mixer length, ft	Feed turbidity, NTU	Initial solids, pct	Final solids content, pct	Turbidity of supernate, NTU
0.02	600	2,000	0.25	35.6	32
0.02	600	300	.09	33.2	26
0.04	[1]600	6,300	.52	33.2	20
0.05	600	5,400	.78	42.5	31
0.06	800	6,200	.68	39.7	39
0.07	600	14,000	2.42	33.8	47
0.12	[1]800	15,000	2.68	41.3	50
0.14	[1]600	26,500	4.41	42.9	46

[1]2-element static mixer was used with pipe.

The smaller mobile unit was operated at seven mine sites throughout Alaska. The purpose of this unit was to test the applicability of the Bureau-developed PEO dewatering method on various placer effluents from different areas of Alaska. No attempt was made to optimize the performance at each site. Dewatering was achieved at six of the seven mine sites. However, clear water that could be reused was produced at only four mine sites. At the Ketchem Creek Mine in Circle, 850 or 1,150 ft of in-line mixing was used to dewater a placer effluent ranging from 0.22 to 0.43 pct solids. PEO dosages of 0.06 to 0.17 lb per 1,000 gal produced a screen underflow of 49 to 160 NTU and a dewatered product of 24 to 28.9 pct solids. As shown in table 8, increasing the pipe length from 850 to 1,150 ft did not improve the results. At the Deadwood Creek Mine, effluents with initial solids of 0.53 to 0.60 pct were dewatered to 20 to 25 pct using 0.24 to 0.33 lb per 1,000 gal of PEO, producing a screen underflow with a turbidity of 106 to 198 NTU. At the Willow and the Cache Creeks in Circle, PEO dosages of 0.03 to 0.15 lb per 1,000 gal were required to produce a screen underflow with turbidities of 66 to 196 NTU, and to increase the percent solids from beginning values of 0.08 to 0.53 pct to final values of 20.0 to 34.6 pct.

Table 8.—Field test results of small-scale dewatering unit, 1987

Mine	Initial solids, pct	Initial turbidity, NTU	PEO dosage, lb per 1,000 gal	Solids content, pct	Turbidity of supernate, NTU
Cache Creek:					
1,150-ft mixer ..	0.17	1,147	0.05	27.0	66
	.08	840	.04	29.5	71
	.10	833	.03	34.6	86
Deadwood Creek:					
1,150-ft mixer ..	.60	7,200	.28	25.0	198
	.54	8,300	.24	23.0	196
	.53	10,200	.33	20.0	106
Ketchum Creek:					
850-ft mixer	.27	1,650	.11	28.9	49
	.33	2,970	.17	27.2	49
	.25	4,070	.06	26.3	NA
1,150-ft mixer ..	.43	2,200	.12	24.2	160
	.32	1,420	.08	24.0	154
	.22	2,120	.17	25.0	150
Willow Creek:					
1,050-ft mixer ..	.47	9,100	.06	28.3	156
	.53	9,800	.15	34.0	136
	.53	4,350	.04	20.0	196

NA Not available.

No flocs were produced at Portage Creek because of what was thought to be tannic acid in the water. At another small creek in the Circle mining district, 850 ft of in-line mixing was used to produce a screen underflow with a turbidity of 475 NTU requiring a PEO dosage of 0.13 to 0.28 lb per 1,000 gal. Similar tests conducted at the Crow Creek Mine produced a screen underflow with high turbidities (300 to 400 NTU). The PEO dewatering technique did not produce good results at the last three sites. This may be due to the presence of some type of organic material in the ground that inhibited the flocculation process. Because of the shortage of time, the system was not optimized at any one of the sites; therefore, polymer dosages were very high for most of the sites.

CONCLUSIONS

The results of laboratory and field tests have shown that the Bureau-developed dewatering technique can be applied to Alaskan placer mining effluent. Since the results showed that this technique was site specific, apparently because of the different geology of mine sites, the mixing requirement and polymer or combination of polymers used also depended on the mine site. For example, at the Crooked Creek operation not only a tank mixer but also a combination of PEO and Catfloc T polymer was required to produce a clear supernate and a strong dewatered product. However, both the Fairbanks Creek and the Olive Creek Mines required in-line mixing and PEO to produce clear water and concentrated solids. It was also found that the PEO dosage was dependent on the concentration of PEO solution, the solids content of the effluent, and the mixing equipment used. The results from Olive Creek (1987) showed that the turbidity of the slurry was directly proportional to the solids content and that the Reynolds number significantly affected the polymer dosage when an in-line mixer was used.

Tests conducted using the small mobile dewatering unit also supported the findings of the 1986 field tests—that the quality of water varied with the mine sites—and some of the sites did not respond to PEO treatment at all. Finally, it was found from the field tests that most of the solids were removed from the effluent using a screen as shown by the screen capture during the 1986 field tests. This testing program also showed that the effectiveness of the technique depended significantly on the mine sites. Whether the technique can be used economically will have to be decided on a mine-by-mine basis.

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