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REPORT on RESEARCH PROJECTS

Funded By

THE ECONOMIC DEVELOPMENT AGREEMENT

Between

THE GOVERNMENT OF CANADA

and

THE YUKON GOVERNMENT

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MINERAL SUBSIDIARY AGREEMENT

PROGRAM 3

PLACER MINING

COMPILED BY C.H. MACDONALD, P. Eng.

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MINERAL SUBSIDARY AGREEMENT, PROGRAM 3

PLACER MINING

In late May 1985 the Economic Development Agreement between the Government of Canada and the Yukon government was signed in the Yukon Legislative Building in Whitehorse. The signing of this agreement initiated a program of research on various topics germane to placer mining, better known as E.D.A. Program 3 Placer Mining.

The funds available for research for Program 3 amounted to $600,000 spread over four years, $436,500 contributed by the Government of Canada and $163,500 contributed by the Yukon Government. The program was managed by the Management Committee of the Mineral Subsidiary Agreement of 4 persons, 2 from each contributor, the Canadian Government representatives being Mr. A. C. Ogilvy, Department of Indian and Northern Affairs, Mr. A. Clarke, Department of Energy Mines and Resources and the Yukon Government representatives Mr. J. Masson, Department of Economic Development, Mines and Small Business and Mr. D. Tran, Committee of Yukon Indians. The management committee received technical guidance from an Advisory Group with representation as follows: Environment Canada, E.P.S., (1) Energy Mines and Resources, Canada (1), Fisheries and Oceans Canada (1), Yukon Government (2) Indian and Northern Canada N.A.P. (2), Klondike Placer Mining Association (1), Yukon Chamber of Mines (1). The representatives of the various agencies changed from time to time during the program.

During the course of the program 15 separate contracts or contribution agreements were awarded and studies, or work programs concluded. This report attempts to capture the salient features of each project in summary form and hopefully has truthfully recorded how the work was performed and the results obtained. The funds available were programmed for expenditure over 3 years with the bulk of the funds allocated to 1985 and 1986. The program has now reached its appointed end and in placer miner terms "the settling pond is full, the purse is empty, the final drive has gone out of the dozer, and the water line is freezing, so it's time to call it a season and take stock of our position."

Hopefully the Program 3 projects will have produced some useful ideas for the industry to improve its profitability, to increase the efficiency of water usage, or to lessen the adverse environmental impact. Those seeking additional information on any of the projects are urged to obtain a copy of the full consultants report.

REPORT on PROGRAM 3 RESEARCH PROJECTS

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INDEX

YEDA - MR - 001 FINE GOLD RECOVERY OF SELECTED SLUICE BOX CONFIGURATIONS

The first research project to be initiated under Program 3, Placer mining of the Economic Development Agreement, Mineral Sub-agreement, was a proposal to undertake studies into sluice box technology to be conducted under the general guidance of the Department of Mining and Mineral Process Engineering at the University of British Columbia. For this program Professor G. W. Poling was the principal investigator and Mr. J. F. Hamilton was the graduate investigator. This study was proposed for E.D.A. funding by the executive of the Klondike Placer Mining association and the project was administered by the Yukon Chamber of Mines.

The major objectives of the study were:

1. To examine how variations in sluice operating conditions affected recovery of gold from different size fractions (down to 150 mesh or 105 microns) during sluicing operations.

2. Based on results of the study, provide recommended operating conditions that yield high over all gold recoveries and low water use in sluicing operations.

CONCLUSIONS:

1. A sluice box should use riffles made from expanded metal, such as 1-10H (thickness 1/4 inch, openings 3/4 inch by 1 1/2 inch) since it is more effective in capturing fine gold than dredge riffles (1 1/4" angle iron). Both riffle systems overlaid a suitable matting material such as 3/8" thick Nomad 3M.

2. Good recovery of gold should be expected at a feed rate of 300 to 400 lb./min. solids per foot of sluice box width accompanied by approximately 200 G.P.M. (U.S.) and a box

slope of 1 5/8 inches to 2 inches per foot. Recovery was not highly sensitive to feed rate variations.

3. Angle iron dredge riffles should be used somewhere in the fine gold area to recover gold particles much coarser than 20 mesh. The ideal location would be at the discharge end of the sluice. This would allow maximum use of the expanded metal riffles to capture the fine gold, also the dredge riffles could be operated at a different gradient.

4. The report recommended gathering data from other selected co-operative sluicing operations. Data on location in the sluice box and sizing of recovered gold in actual placer operations could prove beneficial to the entire placer industry.

5. The recovery of fine gold may be improved by having short sections of smooth, unriffled sluice box interspersed with sections of riffles, for example, 4 feet of riffles followed by 2 feet of smooth box (no matting) and then more riffles, and so on.

6. Further research on sluicing would be beneficial, such as;
   a) using different riffle types
   b) processing different gravel types
   c) using very fine gold

SUPPLIES and TEST FACILITIES:

In order to supply a suitable quantity of gravel identical to the gravel being treated in the placer mines of the Klondike, the researchers decided to gather up a sample of gravel from an operating placer mine, and Tech Corporation kindly consented to allow them to collect a 15 ton sample of representative gravel. The sample was collected in 45 gallon drums from the Granville Joint Venture on Sulphur Creek in July, 1985 by Jim Hamilton, and shipped by truck to Vancouver.

The gold required for seeding the gravel for the various tests was also provided by Tech Corporation from Sulphur Creek. The researchers hand sieved several ounces of gold to provide 3 troy ounces each of three size fractions, Tyler screen -20 +28 mesh, -35 +48 mesh and -65 +100 mesh. The hand screened samples were later re-sieved using Ro-Tap equipment to provide the following size and quantities used for testing:

Coarse	-20 +28 mesh	80.53 gms.
Medium	-35 +48 mesh	80.66 gms.
Fine	-65 +100 mesh	88.29 gms.
Total weight		249.48 gms.

This gold weight distribution is artificial in that the seed gold consists of nearly equal parts of each size fraction. The natural gold in the Sulphur Crek sample contained only 3.4% weight of gold coarser than 20 mesh and only 4.0% finer than 100 mesh. The -65 +100 mesh fraction comprised only 11% of the total weight of natural gold present. Since this particular fine fraction comprises over 35% of the seeded gold used in the pilot sluice tests, results from the pilot tests might be conservative.

Due to space limitations and conflict with undergraduate laboratory usage at the Mineral Processing Laboratory at the University of British Columbia, the Western Canada Hydraulic Laboratory at Port Coquitlam was chosen as a suitable site for construction of the pilot plant scale sluicing facility.

The test sluice was 8 feet long by 12 inches wide with rubber lined 3/4 inch bottom and sides of sheet acrylic. The solid feed to the sluice box entered from a 2 cubic yard feed hopper with variable speed 12 inch wide belt delivering to the sluice box through a 5 foot long launder. The water was added to the launder in advance of the feed so that the initial velocity from the 6 inch diameter supply pipe was dissipated prior to the introduction of the gravel and the short period of travel in the smooth entry launder gave time enough for sorting the feed with coarse gangue particles travelling near the top of the flow and the heavier mineral particles along the bottom of the launder.

The discharge end of the sluice box was so arranged that the discharge from the sluice could be channelled into a series of 45 gallon drums ready for re-seeding and re-use.

The whole pilot plant was arranged to provide sufficient flexibility to vary the operating conditions for individual tests:

Feed	from 0 to 1200 pounds per min.
Water	from 0 to 400 gal. U.S. per min.
Box Slope	from 1 5/8 inch to 2 3/8 inches per foot
Riffles	Expanded metal, 1-10H in 2 foot long sections (4 off) Dredge riffles, 1 1/4 inch angle iron in 2 foot sections (3 off)
Matting	Cocoa matting or Nomad matting 3/8 inch thick, both in 2 foot sections to coincide with riffle sections.

The feed rate could be interrupted during a test to simulate surging conditions.

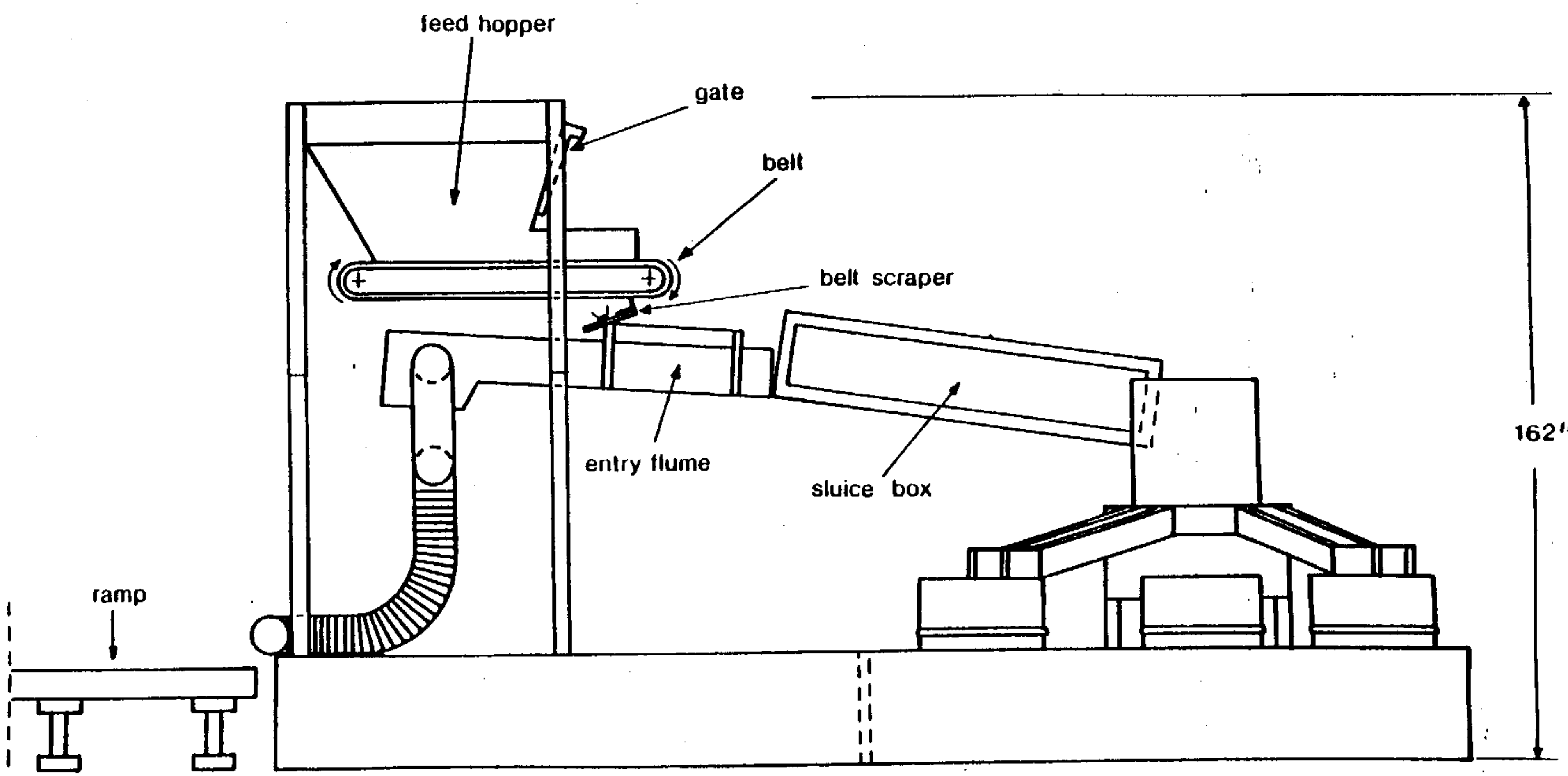
TEST PROCEDURE:

The gravel sample as received from the Yukon was dry screened at 1/4 inch mesh at a screening facility at B.C. Research. This operation provided a 6,500 pound sample of minus 1/4 inch material, or about 22% of the original feed. The screening oversize was later wet screened at 3/4 inch mesh to provide an additional 7,000 pounds of feed which was later combined with the 6,500 pounds to provide material for the minus 3/4 inch size of sluice tests. In order to provide as far as possible a gravel sample free from initial gold for the series of tests the minus 1/4 inch sample was passed through the sluice box 3 times (tests 1,2,3,) to remove the naturally occurring gold. This procedure was also used on the minus 3/4 inch sample.

During each test run the sluice box tails were recovered in the tailings barrels, discharge compartment, and section compartment. Water was decanted from this material and all combined to provide 12 to 14 partially filled barrels of minus 1/4 inch size gravel (later 22 to 24 barrels of minus 3/4 size gravel).

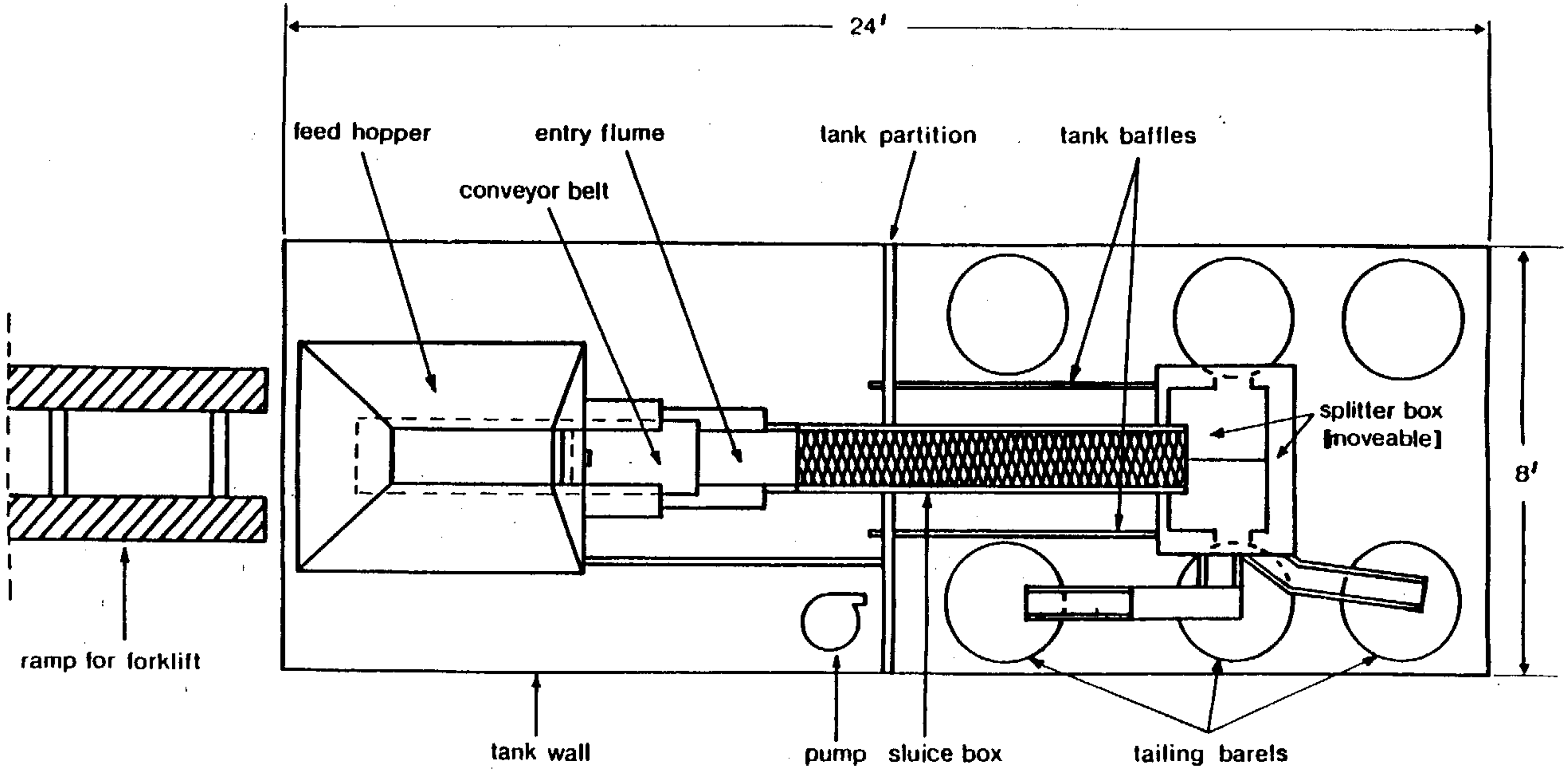
To reconstitute the gravel for each succeeding test the barrels were individually dumped into a small concrete mixer and a carefully measured proportion of the gold recovered from the previous test added to each drum content in the mixer and agitated until the mixture appeared to be homogeneous. After mixing the seeded gravel was discharged into barrels filled nearly to the top, and ready for feeding into the feed hopper for the next test. The barrels were handled by a Baker F.J.D.-040 propane powered forklift with a high lift mast and modified paper roll clamp. The forklift was able to lift the barrels of feed high enough to dump directly into the hopper as each test progressed.

The test procedure developed, and then used throughout the whole project, commenced with setting the sluice box at the desired slope, then installing the matting in 12 inch by 24 inch sections to match the 2 foot riffle sections, 4 in the case of expanded metal and 3 for the dredge riffles, which were then installed and secured. To avoid depleting the sluicing operation of the clay content the water from the sluice operation plus the decant water from the tailings were collected in the process water tank and re-used for each test. The process water pump was started up at approximately 200 gals./min. and subsequently adjusted to the desired flow rate.



SIMPLIFIED SIDE ELEVATION VIEW

FIGURE 4a



SIMPLIFIED PLAN DIAGRAM NOT SHOWING PIPING DETAILS

FIGURE 4b

The feed belt speed was set for the desired solid feed rate and then the test started. During each test it was necessary to close the operation down 2 or 3 times in order to re-charge the feed hopper, but this was done with the minimum of adverse effect by shutting off the water first, and then shutting off the feed as soon as the water flow slackened off.

When nearly all the feed for each particular test had passed through the sluice, the water was shut off approximately 3 seconds before the gravel feed ended. A short period allowed the water to drain off from the sluice box and when the flow had decreased to a few drops per second, recovery of the heavy metal concentrate commenced.

The concentrate was recovered from the sluice box by removing the discharge splitter box and placing a plastic tub under the sluice discharge. The number four section of the expanded metal riffles was then raised, and carefully washed off into the concentrate bucket, the matting raised and placed in the bucket and then the sluice bottom of the sluice washed down into the bucket, taking care not to interfere with the concentrate in the number 3 section. This process was repeated for the other 3 sections.

The matting sections were carefully washed off to remove all solids which were combined with the concentrate. The four individual samples were first screened separately at 18 mesh and the screen oversize checked for possible erratic gold, then discarded to the tails stock pile. The screen undersize was screened at Tyler 32 mesh, and Tyler 60 mesh, yielding finally for each of the four riffle sections 3 samples (-18 +32 mesh, -32 +60 mesh and -60 mesh) for later treatment for gold recovery.

A Goldhound spiral bowl concentrator was used for cleaning up the screened concentrate. The concentrate from the bowl concentrator was then cleaned by using a hand magnet to remove strongly magnetic minerals, followed by careful panning to remove any other included heavy minerals, e.g. haematite or scheelite. This process was continued until the concentrate was virtually free of impurities and then placed in beakers, carefully washed and then dried and weighed.

For the tests using dredge riffles the box was equipped with three 2 foot riffle sections starting at the feed end and one 12 inch section at the discharge end. Due to the large quantity of concentrate from each section of the dredge riffles, the concentrate treatment used for the expanded metal riffles was impractical. The concentrate from each section was processed first in the Goldhound concentrator to reject most of the gangue material after which this concentrate was hand sieved at 32 mesh and 60 mesh. The process from then on was identical to the process used for the expanded metal concentrate.

TEST RESULTS:

In all, 29 pilot scale sluicing tests were performed, 4 of these being to clean the test gravel of contained gold before the gold seeding took place. Of the remaining 25 tests, 18 were performed using expanded metal riffles and 7 using dredge riffles; 8 tests were done at a slope of 1 5/8 inch per foot, 1 test at 2 inch per foot and 16 at 2 3/8 inch per foot; 21 tests were made on minus 1/4 inch feed and 4 tests on minus 3/4 inch feed.

The test results are reported in full in tabular form in the published report in one complete composite table. In this synopsis of the project the tests are grouped according to similar operating conditions and the results reported as percentages of gold recovered in the various box sections as well as gold passing into the tails.

The investigators report that over the course of the 25 tests, 13 grams out of the total 275 grams initially present were not recovered. The lost gold has been apportioned out equally to each test in order to calculate gold recoveries. The gold loss amounts to 4.7% of the total gold, so in effect, by proportioning this loss equally across all the tests it must be realized that the gold recoveries for 25 tests are within the margin of 4.7%

A word of explanation regarding the tables accompanying this report:

TABLE 1:

This grouping puts together all the tests performed at a box slope of 1 5/8 inch per foot, using minus 1/4 inch feed. Tests 26 and 29 had the same slope using minus 3/4 inch feed and in the case of no. 29 using gold -100 mesh +150 mesh. For test no. 21 the expanded metal was reversed with little effect on gold recovery and in test no. 14 the sluice ran clear for 2 hours at the end, which has increased gold loss by 2%.

TABLE 11:

The top group combines all tests with expanded metal riffles and the box slope of 2 3/8 inch per foot and using minus 1/4 inch feed. The bottom 3 tests indicate that under surging conditions and also with minus 3/4 inch feed the gold recovery was not affected adversely.

TABLE 111:

Five test results all shown using dredge riffles with a box slope of 2 3/8 inch per foot and using minus 1/4 inch feed. The other two tests, no's. 24 and 18, indicate that with the dredge riffles, surging feed does affect recovery adversely. In the tests with dredge riffles, 3 sections of riffles show a recovery from 72.06% to 88.69% compared to 86.00% to 97.32% for expanded metal riffles and similar conditions. The expanded metal riffles had 4 sections but the last section only recovered from 4.07% to 1.50% of the gold.

TABLE 1V:

The main objective of this study was to examine the effect on fine gold recovery in a sluice box under varying operating conditions. In Table 1V only the recovery of the fine gold fraction (-65, +100 mesh) in the various tests is considered for comparison, and all tests used were with expanded metal riffles. The first 3 tests listed had the best recoveries at a slope of 1 5/8 inch per foot and minus 1/4 inch feed, while test no. 26 using -3/4 inch feed is included for comparison. The next 3 tests had the best recovery at 2 3/8 inch per foot, minus 1/4 inch feed and normal operation while test 27 is the same except under surging conditions.

It will be noted that the recovery at the box slope of 1 5/8 inch per foot is better than recovery at the steeper slope by more than 5%. It is interesting to compare the results in table 1V with the results of test no. 29 using -100 +150 mesh gold.

DISCUSSION:

1. Flow Pattern:

The use of plexiglass side walls on the sluice box afforded the ability to observe the behaviour of the slurry in the vicinity of the riffles. This is graphically represented in the accompanying drawing reproduced from the full report. A video tape was made to record many observed flow patterns.

The performance of the sluice box was related to the scour patterns developed behind the riffle, and this characteristic was different for each type of riffle and the depth of scour pattern varied depending on operating variables. The energy gained by the flow from the box gradient is dissipated by;

a) - resistance against the flow by aggregate particles.

b) - frictional losses due to flow over the riffles.

TABLE 1
EXPANDED METAL RIFFLES BOX SLOPE 1 5/8" per FOOT

Test No.	Water G.P.M. U.S.	Solids Lbs/Min	Ratio By wgt.	Au. in Feed (est) gms	Au. Recov'rd Grams	Au. recovered per Box Section in %				Au in Tails %	Au Recov'rd %	Remarks
						0'-2'	2'-4'	4'-6'	6'-8'			
4	160	325	1:4.12	249.48	248.79	86.37	10.71	2.24	0.40	0.28	99.72	Normal operation
8	160	225	1:5.94	247.73	244.69	91.41	6.36	0.85	0.15	1.23	98.77	" " "
6	290	325	1:7.46	248.60	245.19	86.37	9.24	2.20	0.79	1.40	98.60	" " "
21	160	385	1:3.47	241.81	239.18	85.81	11.45	1.38	0.24	1.09	98.88	Reverse ex.Metal
14	290Y	325	1:7.46	245.12	236.94	76.66	13.54	4.49	1.97	3.34	96.66	Run Clear 2 hrs.
26	290	400	1:6.06	240.33	237.55	88.00	8.58	1.74	0.52	1.17	98.84	-3/4" Feed
29	160	325	1:4.12	25.38	21.30	62.52	15.01	4.89	1.50	16.08	83.92	-3/4" feed. Au.-100 Mesh

Table 11
EXPANDED METAL RIFFLES BOX SLOPE 2 3/8" per FOOT

Test No.	Water G.P.M. U.S.	Solids Lbs/Min	Ratio By Wgt. Sol/Wtr	Au. in Feed (est) gms	Au. Recov'rd Grams	Au. recovered per Box Section in %				Au. in Tails %	Au. Recov'rd %	Remarks
						0'-2'	2'-4'	4'-6'	6'-8'			
13	400	1260	1:2.56	245.56	211.18	44.93	20.63	13.37	7.07	14.00	86.00	Normal Operation 1/4 inch feed
12	400	700	1:4.78	245.99	229.42	59.52	20.62	9.05	4.07	6.74	93.26	" " "
9	400	625	1:5.35	247.30	233.37	69.58	16.38	5.87	2.54	5.63	94.37	" " "
7	290	325	1:7.46	248.17	241.53	79.93	12.24	3.65	1.50	2.68	97.32	" " "
20	400	325	1:10.29	242.50	232.24	77.51	12.34	4.14	1.78	4.23	95.77	" " "
11	225	90	1:20.90	246.44	243.39	75.19	13.27	4.54	2.11	4.89	95.11	" " "
10	225	325	1:5.79	246.87	239.33	82.89	9.86	2.96	1.24	3.05	96.95	Surging feed -1/4 " feed
22	225	325	1:5.79	241.39	234.	83.09	10.24	2.88	0.90	2.89	97.11	" " "
27	400	400	1:8.36	239.90	231.43	77.99	12.55	4.12	1.81	3.53	96.47	-3/4" Surging

TABLE 111

DREDGE RIFFLES BOX SLOPE 2 3/8 " per FOOT

Test No.	Water G.P.M. U.S.	Solids Lbs/Min	Ratio by Wgt. Sol:H2O	Au. in Feed (est)gms	Au. Recov'rd Grams	Au.recovered per Box Section in %			Au. in Tails %	Au. Recov'rd %	Remarks
						0'-2'	2'-4'	4'-6'			
16	400	625	1:5.35	244.25	176.02	21.81	33.07	17.19	27.93	72.06	Normal 1/4" feed
17	400	625	1:5.35	244.07	178.08	38.62	21.93	12.41	27.04	72.96	" "
15	290	325	1:7.46	244.69	217.01	57.69	23.81	7.19	11.31	88.69	" "
23	400	400	1:8.36	241.20	200.36	56.49	18.40	8.18	16.93	83.07	" "
19	400	325	1:10.29	242.91	201.31	53.98	20.52	8.37	17.13	82.87	" "
24	400	650	1:5.14	240,78	166.87	37.71	21.19	10,40	30.70	69.30	Surging 1/4" feed
18	400	625	1:5.35	243.63	165.40	35.76	21.73	10.40	32.11	67.89	" "

TABLE 1V

EXPANDED METAL RIFFLES-RECOVERY of MINUS 65 MESH SIZE Au.

Test No.	Water G.P.M. U.S.	Solids Lbs/Min	Ratio By Wgt. Sol:H2O	-65 mesh Au. in feed grams	-65 mesh Au. Recov'rd grams	Au. recovered per Box Section in %				Au. in Tails %	Au. Recov'rd %	Box Slope in/ft	Remarks
						0'-2'	2'-4'	4'-6'	6'-8'				
4	160	325	1:4.12	88.29	87.60	73.92	18.98	5.32	1.00	0.78	99.22	1 5/8	Normal 1/4" feed
8	160	225	1:5.94	87.29	84.71	84.28	10.46	1.94	0.36	2.96	97.04	"	" "
6	290	325	1:7.46	87.79	84.64	72.50	17.02	5.07	1.82	3.59	96.41	"	" "
26	290	400	1:6.06	83.06	81.98	76.51	16.64	4.18	1.37	1.30	98.70	"	Normal 3/4" feed
7	290	325	1:7.46	87.54	81.89	63.59	19.29	7.36	3.31	6.45	93.55	2 3/8	Normal 1/4" feed
20	400	325	1:10.29	84.30	76.66	60.39	18.70	8.02	3.83	9.06	90.94	"	" "
11	225	90	1:20.90	86.54	78.01	57.53	19.59	8.56	4.46	9.86	90.14	"	" "
27	400	400	1:8.36	82.81	76.75	59.50	20.52	8.55	4.11	7.32	96.68	"	Surging

The typical slurry exhibited 3 phases of flow:

(i) rotational flow between riffles - size proportional to velocity - low velocity shallow scour.

(ii) immediately above the tops of the riffles a high percentage of solids.

(iii) at the top of the flow low solids concentration, mostly silt and clay.

A range of scour patterns could be observed, with a set water flow of 150 gals./min. U.S., then starting with a low feed rate, and as the feed rate increased the scour pattern grew smaller until a point was reached when the space between the riffles packed and eddying ceased.

2. Riffles:

The scour pattern behind the riffles was oval in shape with the long axis horizontal in the case of the expanded metal riffles and vertical in the case of the dredge riffles. For the expanded metal the most effective scour depth was from 1/2 to 3/4 of the maximum possible, while for the dredge riffles the most effective depth was 1/4 to 1/3 of the maximum possible. For the dredge riffles, when scour pattern approached 1/2 of the maximum possible, the gold recovery dropped to 80% from 85% to 90% at the lower pattern.

3. Solid Feed Rate:

The gold recovery is more dependent on scour pattern than on solid feed rate. Decline in recovery was small as solid flow increased, as long as the proper scour pattern was maintained.

4. Water Flow Rate:

Good gold recoveries were obtained over a fairly wide range of water flows. The limiting conditions were low water flows which tended to bury the riffles, to high flows which produced excessive scour.

5. Sluice Gradient:

Increased slope showed an increase in scour pattern, consequently at a higher slope less water was required to process a given feed rate. Over the range of slopes tested (1 5/8 inch to 2 3/8 inch per foot) there was not a significant change in gold recovery.

6. Surging of Solid Feed Rate:

Surging of the solid feed reduced the gold recovery but only slightly, with the gold being distributed further down the sluice.

7. Matting:

The Nomad matting was very effective in retaining the gold when the surface of the matting was exposed to the slurry flow. There was little difference in gold retention between the Nomad Matting and Cocoa Matting, however as already noted, the Nomad matting was far easier to clean.

8. Upper Feed Size:

There was very little difference in recovery between minus 1/4 inch size feed and minus 3/4 inch size.

9. Test With Fine Gold (-100 +150 mesh):

One test was conducted using fine gold and at optimum conditions outlined by earlier tests. The gold recovery was 85%, however it was noted that recovery in the no. 4 section was very low compared with the gold in the tails.

10. Suspended Solids:

Prior to each test the fines in the water supply tank were agitated, consequently the suspended solids in the process water was in the order of 10,000 p.p.m. High gold recoveries were achieved, even at this concentration.

11. **Packing of Riffles:**

The short duration of each of the laboratory tests did not produce packing of riffles such as would be experienced in actual operations with at times over 50 hours between clean-ups. In actual operations more frequent clean-up may decrease the loss of gold caused by interruptions of feed or from angular sharp bed rock, particularly in the case of dredge riffles.

Y E D A - MR - 006 - 86

TEST PROGRAM on MODIFIED PAN-AMERICAN PULSATOR JIGS

FOREWORD:

Mineral concentrating jigs of various designs have been in use in the mineral processing industry over many years and were in general use in concentrators treating ores where the recovered minerals had a specific gravity sufficiently higher than the specific gravity of the gangue mineral (e.g. galina S.G. 7.5 gangue minerals S.G. 2.2 +/-) during the last century before the advent of flotation. Jigs have also been used extensively in the recovery systems for placer tin, (S.G.7.0) and up to the present in gold milling plants where the ore is free milling. Jigs have been used extensively in the processing equipment on dredges used for the recovery of gold.

In the Yukon in recent years jigs were used by Queenstake Resources at their operation on Preido Hill, and according to the operators of that project recovered gold finer than -100 mesh quite well. For this test project the equipment was owned and operated by Kozak Mining, the equipment having been proven very effective in recovering fine gold elsewhere before coming to the Yukon. The test project described in the field test Program was performed on Barlau Creek at the property of Suskwa Contracting Limited.

Regrettably the test program started very late in the season, and an unfortunate break down of the back-hoe being used to feed the jig plant before the test program was 50% completed necessitated terminating the test prematurely and putting together a report based on treating 725 cubic yards of gravel rather than 1,500 yards as originally planned.

OBJECTIVE:

1. To compare Modified Pan-American Pulsator Jigs to other gold recovery methods with regard to recovery and sizing.
2. To monitor and estimate Modified Pan-American Pulsator Jigs cost of operation and water consumption.

TEST PROCEDURE:

The jig plant was of pilot plant size and consisted of a 1 cubic yard feed hopper equipped with a 6 inch grizzly. A 20 inch wide by 5 foot long feeder conveyor fed a 2 foot wide by 4 foot long single deck vibrating screen equipped with 1/4 inch size screen cloth and driven by a 1 h.p. electric motor. The screen deck was equipped with a nugget trap and the screen operated with wash water. The minus 1/4 inch screen undersize material was washed through eight 12 inch by 12 inch modified Pan-American Pulsator Jigs arranged in a 2 wide by 4 long configuration.

These jigs are normally operated under a head pressure of 14 feet of water but in this test plant head pressure was reduced to 5 1/2 feet giving a water pressure of 2.4 p.s.i. with modifications to the diaphragm and spring to provide the proper action. The plant had a capacity of 15 to 20 yards per hour.

For this test pit run gravel was stock piled with a 966D front-end loader and fed to the feed hopper by a 235 back-hoe. the test program was broken down into 3 catagories:

1. Processing 300 cubic yards of black gravel.
2. Processing 125 cubic yards of sluice box tailings.
3. Processing 300 cubic yards of lower channel gravels.

The sluicing plant on Barlow Creek being operated by Suskwa Contracting Ltd. against which the jig operation would be compared was a well constructed modern looking plant. The gravel was loaded into the feed box by the front-end loader and from the feed box the gravel was washed through twin scrubbers with the discharge end equipped with punch plate with 1 1/2 inch diameter holes through which minus 1 1/2 inch material fed through a 4 foot wide by 12 foot long sluice equipped with 4 inch riffles and nomad matting. From the primary sluice the feed passed over a 4 foot by 8 foot 1/4 inch slotted punch plate, with oversize going to a 4 foot wide by 30 foot riffle equipped centre sluice and minus 1/4 inch feed passing to two side runs 4 foot wide by 30 foot equipped with astro turf and expanded metal.

To evaluate the sluice plant operation four different types of clean-up were performed.

1. Clean-up on side runs every 400 yards and centre run left for 1,000 yards.

2. Clean-up on side runs every 400 yards and centre run left for 2,000 yards.

3. Clean-up both centre and side runs after 1,000 yards.

4. Clean-up both centre and side runs after 2,000 yards.

Results of tests 1 and 2 indicated that the side runs collected 27% and 17% respectively of the gold.

Results of tests 3 and 4 indicated that 33.8% and 35.5% respectively of the total gold collected was of -28 mesh.

TEST RESULTS:

For the test comparing the recovery of gold from the black gravel the results were as follows:

Percentage of Gold Recovery

	Sluice Box	Jig plant
Plus 16 mesh	4.30	2.00
-16 mesh +28 mesh	52.29	36.50
-28 mesh +65 mesh	39.12	46.80
-65 mesh +150 mesh	2.26	7.90
-150 mesh	1.42	6.80

The jig plant had a 76.8% higher recovery overall and a 43.7% higher recovery of the minus 28 mesh size of gold than the sluice plant.

For test number 3 of the jig operation processing lower channel gravels the recoveries were as follows:

Screen size		% of Gold Recovered
+16 mesh		5.00
-16 mesh	+28 mesh	33.15
-28 mesh	+65 mesh	43.60
-65 mesh	+120 mesh	7.64
-120 mesh	+170 mesh	2.61
-170 mesh	+230 mesh	2.32
-230 mesh	+325 mesh	1.90
-325 mesh	+400 mesh	0.98
-400 mesh		2.80

Jig test number 2 was inconclusive as it was determined that the fine gold lost in the sluicing operations was travelling by floatation through the primary settling pond due to the high volume of water.

During the test program for the jigs this plant required 185 G.P.M. with gravel treatment being 15 cubic yards per hour. This water consumption works out at a rate of 1:1.99 solids to water ratio. The sluicing operation required 2,300 G.P.M. to treat 100 cubic yards per hour of gravel; this is a ratio of 1:3.70 solids to water ratio by weight.

For this pilot plant scale test the cost of operating the jig plant was $7.00 per yard of gravel processed.

Y E D A - 09 HEAP LEACHING - GRADE AND METALLURGICAL EVALUATION OF WHITE CHANNEL GRAVELS

FOREWORD:

At the last meeting of the Joint Government and Industry Committee for Placer Mining Research, held in April, 1985, two proposals for heap leaching as a possible means of recovering gold from placer gravels were submitted for discussion. One proposal of a general nature was submitted by the Yukon Chamber of Mines and a second proposal for some research work on the White Channel Gravels where the hydrothermally altered gravels had been shown to contain fine gold. This proposal was supported by the University of Alberta, Geology Department, and submitted to the Committee by the Geology Division of Indian and Northern Affairs Canada.

The Joint Committee was in agreement that this proposal had merit and so the recommendation was passed on to the Management Committee of the E. D. A. Mineral Sub-agreement that if E. D. A. funding was available, the heap leaching research should be considered. At the advisory group level there was general agreement that the best place to start would be some research into the possibility of recovering fine gold from the White Channel Gravels.

During the field season of 1985, field personnel of the Geology Division gathered representative samples of White Channel Gravel from exposures on Dago Hill, Hunker Creek, and also samples of tailings from a sluicing operation treating White Channel gravel.

In the fall of 1985 the Department of Northern Affairs solicited proposals from a select bidders list of laboratories that might have the facilities to conduct the heap leaching research and in due course a contract was awarded to Witteck Development Inc.

OBJECTIVE:

The project was divided into two separate phases:

Phase 1:

One half of each sample submitted would be very carefully evaluated for gold content utilizing a variety of concentrating and analyzing techniques.

Phase 11:

Based on the results of Phase 1, the gold content of the samples would be reviewed and selected samples recommended for cyanide and heap leaching assessment.

PHASE 1:

Twenty-five White Channel gravel samples, each 30 to 40 kg in weight were packaged and shipped to Witteck Development Inc. in late 1985.

The evaluation for head grade is best shown by reference to the copy of Figure 1 from the Witteck Phase 1 report, reproduced herewith. The gold recovered in the various steps was ultimately combined to provide an original head grade for the half sample.

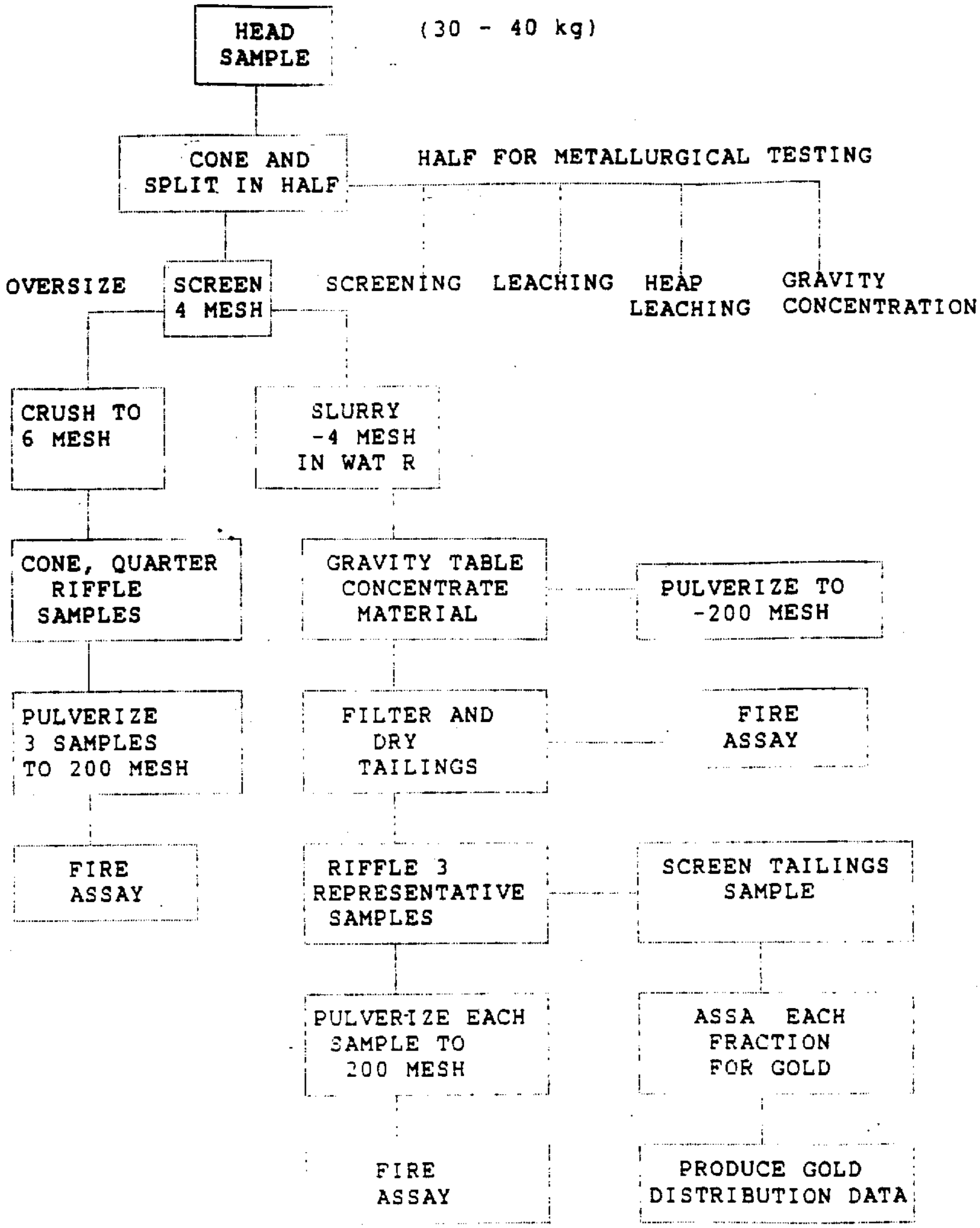
TEST RESULTS:

The Phase 1 report provides mass balance calculations for 25 samples. The results ranged as follows:

Nugget Hill	3 samples	0.03	-	0.23	grams/ton
Dago Hill	16 samples	0.03	-	0.30	grams/ton
Tailings	6 samples	0.02	-	0.20	grams/ton

The test work indicated that the +4 mesh fraction contained very little or no gold so the researchers suggest that the deposit might be upgraded to commercial levels by a simple screening process. Calculating the grade of the samples after discarding the +4 mesh fraction gives values up to 0.63 grams per ton, at which grade heap leaching might be viable.

EVALUATION OF HEAD GRADE



The researchers had suggested that for a heap leach operation to be economically viable a grade of 0.015 oz. per ton (0.467 grams/ton) was considered necessary. In the case of the present project it was decided to proceed with Phase 11 Heap Leach Assessment for 2 reasons:

(a) The White Channel might be a special case since the probable feed was being mined already to uncover the rich pay streak right adjacent to bedrock, therefore mining costs would be minimal

(b) there was no way that the samples obtained for this project could be considered representative of all the White Channel gravel.

It was therefore recommended that the leaching tests outlined in the proposal should be conducted on selected samples.

PHASE 11:

The work outlined in the contractor's proposal for phase 11 was to consist of 3 procedures:

a) mineralogical examination of a representative sample of each of the 5 samples chosen for phase 11.
b) bottle roll tests on representative portions of the 5 samples to determine lime and cyanide requirements.
c) column leaching tests on sufficiently large samples.

TEST RESULTS:

(1) Mineralogical examination:

From each of the 5 composite samples a 1 kg. sample was riffled out and ground to minus 48 mesh and each sample panned to produce a concentrate from which a 25 mm. polished ore mount was made. Stereobinocular microscopic examination of the remaining concentrate identified 14 particles of gold. The particles formed irregular, flattened, elongate to equant particles with localized greyish discolouration and/or white inclusions, possibly silica or clay. Gold particles were 50 - 700 microns in size, with flattened particles 10 - 50 microns in thickness. The microscopic examinations of the 5 polished mounts identified a single free particle of gold.

(2) Bottle Roll Tests:

The 5 bottle roll tests indicated a sodium cyanide consumption of 0.085 to 0.43 kg. per ton and lime consumption ranged from 1.83 to 3.16 kg. per ton. Gold extraction ranged from 0 to 100% against calculated heads. The bottle roll tests were performed on samples of less than 1 kg. each, so due to the nugget effect, recovery figures are meaningless.

(3) Heap Leach Tests:

The first column leaching tests using pit run material had to be abandoned due to the fact that the clay content of the White Channel gravel prevented acceptable percolation of the leachant. Consequently a column leach test was performed on agglomerated material. This test was done on a 7 kilogram sample after agglomeration and the test was successful with a calculated gold extraction of 65.29%.

In this project the laboratory work by the consultant was disappointing. The performance of the work suffered in two aspects:

a) during the project the senior researcher left the project and it, as a result, suffered from lack of continuity.

b) the long distance between the location of the research facilities (Mississauga, Ont.) and the administrative office for the project (Whitehorse, Yukon) prevented good dialogue as the project progressed and unforseen difficulties arose.

YEDA - 07 MATERIAL HANDLING TECHNOLOGY

BACKGROUND:

Another research program that had its inception at the last meeting of the Joint Government Industry Committee for Placer Mining research was research into the subject of material handling in the placer mining industry. At that time it was introduced in a fairly general way but was warmly supported by the industry representatives (Yukon Chamber of Mines and Klondike Placer Mining Association) on the committee. At the same time representatives of the Yukon Government were proposing a fairly ambitious program for the operation of a demonstration placer mining operation at which material handling, sluice box technology and wastewater treatment could all be researched. The Joint Committee recommended that the subject of research into the question of material handling should be considered for funding by the Management Committee, Mineral Subsidiary Agreement.

The original proposal from the Yukon Government was costed out at over a million dollars, and would go on for several years, however when the subject of research into material handling came before the E.D.A. Management Committee the Yukon Government had scaled down their original project, and now put forth 2 proposals, one for research into the whole subject of material handling, including an outline for a demonstration project and the second proposal for a study into the "state of the art" in matters of wastewater treatment. The proposal for material handling became the basis for YEDA-07 Material Handling Technology.

The contract documents were developed during mid summer 1985 and submitted to a number of consulting firms with experience in this matter. The contract was awarded to Wright Engineers Limited in late summer.

OBJECTIVE:

The objective of the study was to develop what is termed "Best Practical Technology" for all phases of material handling at placer mines, including stripping vegetation and black muck, disposing of waste gravels, mining and processing pay gravels, disposing of sluice tailings and settling pond sediment and reclamation of mined areas. The scope of the work would require research a search of available literature and site visits to placer operations and other similar industrial establishments such as gravel plants, coal strip mines etc. The second stage of this contract required the consultant to draw up a work plan for a "Demonstration Project".

MATERIAL HANDLING METHODS - REPORT:

SUMMARY: The report addresses the subject under 5 main headings: Classification of Deposits, Present Material Handling Methods, Material Handling Methods Used Elsewhere, Conceptual Design of Alternative Systems and Reclamation. These 5 main topics are summarized under their respective headings. Operators and others interested in the full discussion are urged to refer to the original Wright Engineers Limited report.

1: **Classification of Deposits:**

The Yukon placer deposits are grouped into 4 classifications on the basis of topography. The four classes, their distinctive characteristics, and distribution of Yukon placer operations in the classes are shown below:

Gulch Deposits -	Valley bottom 10 to 65 feet wide Stream gradient average 9.5%	23%
Narrow Valley -	Valley bottom up to 200 feet wide Stream gradient average 2.0%	55%
Broad Valley -	Broad flat valleys over 200' wide Stream gradient average 0.5%	11%
High Bench -	Plateaux 250 feet wide, 50 feet above valley bottom	11%

The material present in placer deposits is grouped into 5 categories.

Vegetable Cover	Trees, bushes, plants and moss
Black Muck	Decomposed organic material
	Wind blown dust
	Contains plant and animal remains
	Always frozen
Waste Gravel	Colluvium glacial and glacial fluvial material, and alluvial. Mixture of clay, sand, angular fragments and boulders
Pay Gravel	Alluvial or any of above with gold content
Tailings	- Size and type depending on type of processing

The grain size is summarized from available information for feed gravel, coarse tailings and settling pond sediment. Partial figures are as follows:

Feed Gravel +3"	0 to 50%	100 mesh up to 24%
Coarse Tailings +3"	0 to 20%	100 mesh up to 14%
Settling Pond sed. +1"	0 to 10%	100 mesh up to 90%

II: Present Material Handling Methods:

Stripping operations in many cases requires the removal of several feet of frozen black muck as well as a thickness of barren gravel, colluvium or glacial material. The black muck may be removed early in the season, in the frozen condition by mechanical means or in other cases by hydraulic means in a thawed condition. Waste gravel is generally removed by mechanical means.

Mechanical equipment, predominantly tracked dozers, are employed by 79% of all operations while 23% use hydraulicing generally in conjunction with mechanical means. In gulches and narrow valleys lack of space to store stripped material is the greatest problem, inbroad valleys the large distances to transport stripped material makes for a costly undertaking while for high bench deposits at times very great thickness of waste material and lack of water for hydraulicing are problems often encountered.

The mining of pay gravel is performed by some mechanical means in nearly all cases, with 87% of operations employing bulldozers, frontend loaders or backhoes. Other mining methods in use include the use of scrapers, draglines, dredges or hand methods. The main difficulty encountered in most operations is the distance between the cut and the sluicing plant. For sluicing operations 53% of all operators used no system of pre-sluice classification, while 17% used some form of grizzly and 29% used screens or trommels.

The coarse waste products from sluicing are disposed of by dozers or frontend loaders, however the long distances required to move this material and also the excessive wear on track parts from working in slurry at times are problems encountered. The fine sized waste material is handled in settling ponds by 78% of operations with 22% being recirculation ponds, in other cases fines are disposed of in dredge tailings. A common problem in settling ponds is having sufficient room and an effective means of cleaning out the pond. Some typical equipment costs are listed below:

Equipment	Weight	Power	Cost	Total cost/Hr.
Dozer	#	H.P.	$000	$lhr.
Cat D8K	70,500	300	340 (new)	149.93
Komatsu D355	100,150	410	298 (used)	197.00
Track Loader				
Cat 963	39,760	150	185	98.43
Wheel Loader				
Cat 966	43,000	200	254	119.23
Cat 988	89,000	375	477	194.68
Hydraulic Excavator				
Cat 235	86,700	195	331	185.30

Operating costs at placer mines cover a wide range depending on site conditions, equipment used etc. Some very general figures are:

Stripping black-muck	0.52 - 1.85	per yard
Stripping barren gravel	0.50 - 0.90	" "
Feeding Sluice	0.41 - 1.56	" "
Dispose of Tailings	0.65 - 1.89	" "

(figures are Canadiam dollars)

III: Material Handling Methods Used Elsewhere

Material handling methods presently employed in placer mining in other areas were researched by site visits, search of literature or by contact with individuals familiar with practice in other areas.

In Alaska the material handling methods are generally similar to those in use in the Yukon. There has been some increase in the use of screens for pre-sizing sluice box feed in order to reduce water requirement and improve fine gold recovery, and the use of conveyors for stacking dry tailings. In one area a high-tech plant (I.H.C.) uses trommels, jigs, stacker, pumps and hydrocyclone.

The placer mining industry of B.C. also uses pretty well the same techniques as the Yukon operators except for a greater use of backhoes and loaders for sluice feeding. Two operators are using pumps, one for moving screened pay gravel and one for sized tailings. One mining operation in the U.S.A. Southwest makes use of pumps, transporting -3/8" size pay gravel to a fixed plant and getting rid of tailings by pumping to a classifier.

In the far East, pumps are used extensively in the tin industry, both on dredges and in hydraulic mining of terrestrial deposits where pumps are used both to transport feed to treatment plants and to remove tailings. Vertical submersible pumps are in general usage.

Other industries with similar material handling problems to gold placer mining are sand and gravel operations, the china clay industry and dredging. In gravel processing plants, conveyors are used extensively for moving material, with pumps and hydroclones at times for dewatering fine sand products. Hydraulic transport is common in the U.S.A. mid-west, also used at 2 sites in Eastern Canada. Pumps are used extensively in the china clay industry both for transporting feed from pit to plant and tailings to classifiers and screens for dewatering. Dredges depend largely on pumps for moving gravel, one operation in B.C. handles 1000 yards per hour of material up to 8" on size by pumps and an operation in South Africa handles 2,200 tons per hour of material containing boulders up to 13 inch size.

1V: Conceptual Designs of Alternate Systems:

Before examining alternative mining systems some characteristics and possible use of various equipment items will be reviewed briefly:

Pumps are available in a wide range of models and the type recommended will depend on the size of material to be handled. in general terms:

Material	>5 mm.	dredge pumps
"	1 mm - 10 mm	sand and gravel pumps
"	0.25 mm - 2 mm	slurry pumps

pumping operations require pre-sizing and recommended features of pumps:

low R.P.M.

abrasion resistant lining - 1/4" rubber
+ 1/4" hard metal

dry gland seals

belt drive

Conveyors: The recommended type are 24 inch wide with 3 roll troughing idlers. Drive can be electric, gas, or diesel. Can be used in modules of say 100 feet. Large selection available.

Dewatering Equipment:

Hydrocyclones give good separation down to 200 mesh size producing an underflow of 70% solids. Recommend a hydrocyclone with easily replaceable wear parts. Price range for new hydrocyclones 10,000 to 18,000 dollars.

Spiral classifiers will remove solids from 65 mesh to 200 mesh size. Available in a range of sizes - much bulkier than a hydrocyclone. Price 16,000 to 20,000 dollars.

Dewatering screens with rubber decks are available. Not very suitable for sluice tailings. Price 10,000 to 20,000 dollars.

Classifying Equipment:

A wide range of grizzlies, screens and trommels are available. Generally a screen requires a grizzly ahead in the circuit. The trommel will break up clay ahead of the sluice. Vibrating grizzly cost 25,000 to 70,000 dollars, derocker 70,000 dollars.

Piping:

Good performance from high density polyethylene pipe (H.D.P.). For 8" diam. cost approx $7.50 per ft. vs. #13.00 for schedule 40 steel, $26.60 for carbon steel and $124.10 for polyurethane lined pipe.

Alternative Material Handling Methods:

1. A possible alternate system for removing black muck could be, liquify the material, flow by gravity to a pump box or sump, then pump to cover old tailings. It would be necessary to equip the pump with a fairly large intake screen.

2. Any changes in handling pay gravel would be site specific. The objective is to avoid unnecessary handling of "no value"

oversize material. Where oversize material (+3inch) can be removed in a dry condition at the face of the cut the undersize might be transported by conveyor from the cut to the sluice plant. For wet or sticky feed this could be classified at the face by wet means and the resulting undersize slurry pumped to the sluice.

3. For sluice plants handling classified feeds the tailings could be pumped to the disposal site, with or without a hydrocyclone stage. The pump box should be prevented from running dry by a continuous small overflow weir.

4. Settling pond clean out is a costly item and any measure that will reduce the input to the pond will be useful. Some improvement may be achieved by pumping black muck to old tailings.. By pumping sluice tailings to a hydrocyclone so the +200 mesh material may be prevented from entering the settling pond.

Present methods of pond clean out involve mobile equipment or drag lines. Pumping may be a viable alternative using submersible pumps. Installing and moving the pump in the pond are difficult operations however.

The appendices volume that accompanies the Wright Engineers Report provides a number of layouts of theoretical existing operations and examples of layouts utilizing conveying and/or pumping systems. Cost projections have been developed for these various alternatives as indicated below. The cost comparisons shown are purely theoretical and cannot be assumed to represent the total costs of placer mining at any type of deposit.

Guidelines for reclamation of mined areas should be developed, but these should be realistic and should take into account end land use of disturbed areas not forgetting possible future placer mining.

REPORT ON DEMONSTRATION PROJECTS:

INTRODUCTION:

The E.D.A. contract on Material Handling Technology awarded to Wright Engineers Limited consisted of 2 parts. (1) "Material Handling Technology" and (2) "Recommendations for Field Trials on Material Handling Technology". Initially, it is recommended that of the alternate systems recommended in Part 1, only gravel pumping should be tested at this time, with the first priority pumping of sluice tailings followed by pumping feed gravels. A narrow valley site is recommended for pumping tailings while a broad valley would be the preferred type of operation for feed gravel pumping.

METHODS OF CONDUCTING WORK:

To conduct a field trial of the rec mendation for gravel pumping, 4 options are considered:

Option 1.

The Government runs trials at a gravel quarry, or new placer mine.

Comment: Costly $354,200. est.
Only tests single site

Not Recommended

Option 2.

The Government runs trials at a leased private placer operation. Compensation to miner for use of equipment.

Comment: Still costly $ 163,900. est.
Only tests a single site.

Not Recommended

Option 3.

The Government purchases gravel pumping equipment and test at several sites.

Comment: Reasonable cost $ 78,900.

Test more sites.

Recommended approach

Option 4.

The Government monitors trials at a placer mine where the operator has purchased pumping equipment.

Comment: Very little cost involved.

Only tests at one site.

Government provides technical advice.

Also recommended

RECOMMENDED APPROACH:

The recommended approach for the 1986 field season is:

1. Monitor the operations of two placer mines using pumping.

2. Purchase suitable gravel pumping e ipment with Government funds.

3. Appoint a Study Co-ordinator.

4. Collect data on gravel size distributions and rates of natural vegetation.

5. Design and implement an operating cost tracking system.

ESTIMATED COST (1 SEASON):

Equipment and manpower	$ 126,500.
Expenses	$ 18,000.
Contingencies	$ 15,500.
Total cost	$ 160,000.

YEDA - 08 WASTEWATER TREATMENT TECHNOLOGY

FOREWARD:

This research project, like the previous one (YEDA 07) was brought before the Management Committee of the Mineral Subsidiary Agreement of the E.D.A. by representatives of the Yukon Government as part of the previous plan for a Placer Mining Demonstration Project. A proposal for research on the topic of settling pond operation had been introduced in a general way at the Joint Government Industry Meeting in April 1985 and at that meeting research on this phase of placer mining was supported by the representatives of industry. This research was approved for funding by the Management Committee, contract documents were developed by the Administering Agency and submitted for tender to a number of consulting firms. Sigma Resource Consultants Limited was the successful bidder, and a contract was awarded in late summer 1985.

SECTION I:

INTRODUCTION:

Passage of the Northern Inland Waters Act in 1970 provided for regulation of discharge of effluent from Yukon Placer Mines. In 1983, regulations proposed by the Interdepartment Committee on Placer Mining for effluent standards from 0 discharge to 1000 mg. per litre were debated at a public review but were never adopted. Water licences issued by the Yukon Territory Water Board generally require effluent treatment in a settling pond with an effluent objective of 0.2 ml. per litre of settleable solids. During 1984, 40% of the samples gathered by inspectors of the Water Resources Division, I.N.A.C. were equal or less than the 0.2 ml./l objective.

The objectives of this study are:

1. to provide appropriate design criteria for placer mine settling pond systems.
2. to develop a method for sizing ponds and for roughly estimating pond effluent suspended sediment concentrations.

3. to examine methods of improving pond performance.
4. to prepare a methodology for a settling pond demonstration project.

SECTION II:
WASTEWATER CHARACTERIZATION AND MINESITE CONSTRAINTS

The primary focus of wastewater treatment for placer mines is the reduction of sediment discharge. The sources of sediment in placer mining are sluicing, hydraulic stripping, stream diversions, ground sluicing and surface runoff.

The parameters used in measuring effluent quality are:

(1) settleable solids - ml/L (millilitres per litre)
the volume of sediment that settles in 1 hour in a 1 litre Imhoff cone.

(2) suspended solids - mg/L (milligrams per litre)
the weight of sediments in a given volume of water as determined by filtration.

(3) turbidity - interference with passage of light through water caused by suspended material.

(4) sediment loading - the daily sediment loading is the average suspended solids concentration multiplied by the volume of effluent.

For this report, settleable solids and suspended solids will be the only parameters considered, although ideally the effectiveness of a wastewater treatment system should be judged against environmental impact on receiving waters.

The major settling pond variables are surface area and volume. The factors affecting pond operation are (1) pay gravel size distribution, (2) feed rate and (3) pond influent flow rate.

effectiveness of a wastewater treatment system should be judged against environmental impact on receiving waters.

The major settling pond variables are surface area and volume. The factors affecting pond operation are (1) pay gravel size distribution, (2) feed rate and (3) pond influent flow rate. The sizing of a settling pond system can be completed with basic data as follows:

(1) representative grain size distribution and knowledge of settling characteristics

(2) realistic estimate of feed rate.

(3) realistic estimate of water flow rate.

For wastewater treatment, the material of primary interest is fine sand, silt and the clay fraction (material less than 0.5 mm. in diameter). Limited data indicat a wide variation in the proportion of this size of material ound in Yukon placer mines, and little data on the settling haracteristics. One report gives a figure for minus 0.5 mm material varying from 8% to 64% based on 26 samples from 15 mines.

Using the mine classification system proposed by Wright Englineers Limited, space limitations adversely affect the development of adequate settling ponds for gulch, narrow valley and low bench deposits. This problem does not apply to broad valley deposits, but these, however, make up only 11% of the total number of deposits.

SECTION III:
REVIEW OF SEDIMENTATION THEORY AND POND DESIGN METHODS:

The quiescent settling velocity for silt and clay depends on temperature, particle shape, aggregation/flocculation and interference with other particles. The theoretical velocity is, however, strongly influenced by various other factors, for instance turbulence and currents, dead space in pond etc.

The ideal settling pond analysis, modified by empirical factors to account for non-ideal conditions is:

$$Vc = \frac{K1QH.}{V-K2V.}$$

where: Vc = critical velocity

K1 = non-ideal settling factor (to account for turbulence and current)

K2 = dead space factor (to account for pond space and short circuiting.)

Q = flow rate through pond

H = average depth of pond

V = pond volume

The greater the length to width ratio, the smaller the dead space fraction (ratio 1:1 fraction = 0.30, ratio 5:1 fraction = 0.10) There is uncertainty as to the accuracy of the theoretical method for settling pond sizing, however the system may be useful for initial pond sizing.

A review of previous studies and literature on settling ponds and effluent treatment confirmed that this is a complex problem with no universal easy solution. The literature on settling pond technology in other industries had little relevance since effluent treatment processes include the use of chemical coagulants. Twenty-nine reports on the treatment of placer mining effluent were reviewed and excerpts from fourteen of these have been included in this report, and have assisted in developing a recommended design approach.

Alternative 1. Ponds can be sized by an arbitrary retention time. A time of 18 hours has been suggested to provide an effluent standard of 1000 mg/L.

Alternative 2. Ponds could be sized in accordance with pay gravel grain size, and/or settling test data and the basic theoretical settling pond model.

PROPOSED SETTLING POND SIZING METHOD:

1. Determine basic mine operating data.

2. Determine minimum pond volume to provide the required hydraulic retention time.

3. Determine the additional volume for sludge storage

4. Lay out the system within the available space.

5. Estimate the pond removal efficiency.

6. Construct and operate the pond.

SECTION IV:

SEDIMENTATION POND DESIGN:

The accuracy of the pond sizing procedure depends on obtaining accurate operating data. The average grain size of sluice box feed must be obtained by careful sampling of the pay gravel of the deposit and appropriate laboratory procedures for grain size analysis. The material feed rate can be determined from bank surveys or bucket counts, and pond influent rates from flow velocity and cross-section area of channels to the settling pond, over weir flows or from supply pump characteristics. The performance of the pre-settling pond will be determined by grain size, settling characteristics, pond size and cleanout frequency. From these data the volume and size of fine material entering the main pond will be determined. The volume provided in construction of the main pond should allow room for 5 hours retention time plus storage volume for 1 season operation, or less if there is provision for pond cleanout during the season.

Stream diversions should be carefully planned to minimize erosion problems. For gulch operations the settling pond will probably be downstream at the junction with a valley.
However, if the main gulch stream enters the settling pond an overflow spillway should be provided ahead of the pond entry.
The main settling pond may be either one large pond or a series of ponds, in which case the largest should be last in the series. The higher the length to width ratio (L:W) the greater the efficiency.
The ratio should be at least 2:1 and preferably 5:1. The ratio may be improved by baffles but these take up valuable pond volume. The minimum depth should be 5 feet, pond inlet arranged to produce low velocity and pond outlet maximum distance from the inlet and constructed to give erosion protection. There are several cleanout methods, provided equipment is available, drain and excavate with dozer or loader, dig out with dragline or backhoe, portable dredging outfit or use slurry pumps.

This report provides step by step procedur for estimating pond performance using a computer to facilitat calculations. This method of calculating pond performance wa tested against data from 6 actual mining operations, and the theoretical calculations yeilded higher suspended solid levels than the actual field setting tests.

SECTION V

ALTERNATE METHODS of REDUCING EFFLUENT SUSPENDED SOLIDS

Total recirculation of pond effluent is one method of mining that requires far less space for settling ponds. This is used extensively in B.C. Possible problems with total recycle can be too high a build-up of solids in the sluicing water although some tests have shown that recovery of -30 +60 mesh gold was not hindered when sluicing with water containing 200,000 mg/lt. of suspended solids, and excessive pump wear, although this was not noted as a problem in B.C.

Another method sometimes used to improve solid settling rates is the use of flocculents, although to date this method has not been used to any extent in the placer mining operations of B.C., Alaska or Yukon. A test program conducted by E.P.S. in 1984 estimated treatment costs of $0.49 to $0.88 per cubic meter of gravel treated to produce an effluent containing 1,000 mg/lt. suspended solids.

SECTION VI:
WASTEWATER TREATMENT COST ASSESSMENT:

At a significant number of mines well-designed settling ponds at present may not meet effluent standards. Treatment systems may have to be upgraded to meet proposed effluent standards.

The impact of increased costs is a major concern to the industry and regulatory agencies. Reliable cost data for systems designed to meet specifications are essential. Cost estimates from previous studies are highly site specific.

A comprehensive government funded program to provide design layouts and obtain cost estimates would be expensive. Alternatively a joint industry-government effort might produce sufficient accurate data so miners could prepare realistic cost projections for waste water treastment systems.

DEMONSTRATION PROJECT METHODOLOGY:

Objective:

To refine the settling pond design methods outlined in Volume I.

To demonstrate construction and operation of a settling pond system designed in accordance proposed criteria.

Methodology:

1. Collect 8 regular pay gravel samples, determine grain size, develop statistical analysis of data.

2. Determine volumes for pay gravel coarse tailings and sediment accumulations.

3. Construct and monitor a pre-settling pond.

4. Monitor the settleable solids levels at the primary site and/or a secondary site when the effluent reaches 0.2 ml/lt and determine pond volume.

5. Construct the main settling pond with a length to width ratio of 5:1. Conduct tracer surveys of pond operation.

Objective:

To assess and refine the proposed method for estimating effluent suspended solids.

Methodology:

1. Apply the theororetical approach for estimating suspended levels in effluent.

2. Compare with actual levels observed in tests and develop a correcting factor for hours of continuous operation.

Objective:

Evaluate the accuracy of simulated effluent suspended solids estimates with actual waste water values.

Methodology:

Conduct lab. scale tests with feed samples and plexiglass columns 2 m. high X 150 mm. diameter.

Compare results with actual wastewater samples at primary and secondary sites.

Conduct similar tests on 1,000 ml. cylinders.

Objective:

Operate a total recycly system. Develop criteria for designing a total recycle system.

Methodology:

Operate a total recycle system and gather necessary data.

During the field tests the consultant will gather cost data and develop some operating costs for the wastewater treatment program.

This report sets forth 8 characteristics to be considered when choosing a suitable site for the test project.

The report also provides some ideas on the administration of a demonstration project.

YEDA 86 - 03A SITE SELECTION - PROJECT OFFICER

In order to carry out field trials for the ideas proposed by Wright Engineers Limited in YEDA 07 and Sigma Resource Consultants in YEDA 08 with the resources available for Program 3 work during 1986, it was decided to combine the research proposal into one contract.

Both of these consultants had set forth suggested criteria for suitable sites at which to perform the field trials of the ideas developed in the two reports. A contract was awarded to New Era Engineering Services to conduct a survey of as much of the Yukon placer areas as possible, to find sites which fulfilled the requirements of the researchers and where the placer mine operators would be willing to assist in research projects by having representatives monitoring their operations during the season. The response from industry was not overwhelming, however the following mining operations indicated interest in the program and would be pleased to assist the consultants.

1.	Beron Placers Ltd.	Pumping tailings
2.	Airgold Placers Ltd.	Pumping feed gravel
3.	L. Bleiler Mining	Pumping feed gravel
4.	J. Gould Placers	Settling Pond Operation

This contractor, New Era Engineering, carried out this initial contract very effectively, so the contract was extended for the principal R. Clarkson to act as Project Officer for the field trials, which became contract YEDA-86-03.

YEDA 86-03 PLACER MINING MATERIALS HANDLING AND WASTEWATER TREATMENT FIELD TRIALS

To avoid duplication of project management and technical field personnel it was decided to combine the field trials for YEDA-07 Material Handling and YEDA-08 Wastewater Treatment into one contract and the contract tender call was drawn up accordingly and circulated to a number of consulting firms.

In due course, the tender submitted jointly by Sigma Resource Consultants and Wright Engineers Limited was accepted and work commenced in early summer 1986. On behalf of the consultants, the Project Manager was Mr. Neil Peters of Sigma Resource Consultants with Mr. Jim Leader, Senior Engineer of Wright Engineers Limited, responsible for the material handling segment of the program.

INTRODUCTION:

Objectives:

1. To establish "best practicable technology" for material handling and wastewater treatment for placer mining.

2. To test and demonstrate that technique in the field.

3. To provide placer miners with appropriate operating criteria and cost estimates for material handling and wastewater treatment.

Material handling:

1. To monitor operations at an existing operation using pumps and cyclone to dispose of minus 1/4 inch sluice tailings.

2. To evaluate the technical and economic feasibility of pumping and cycloning minus 1/4 inch material, compared with disposal using conventional earth moving equipment.

3. To provide a summary of appropriate operating criteria and costs for sluice tailings pumping.

Waste water treatment:

1. To complete a program of research to apply and refine the settling pond design methods recommended by Sigma Resource Consultants in YEDA-08.

2. To demonstrate the construction, operation, and costs of a settling pond system in accordance with the proposed criteria.

Field Program:

The sites chosen for the field work were:

1. Beron Placers. The operation had already procured pump and cyclone to handle minus 1/4 inch material.

2. Nugget Hill Placers. Principal site for wastewater treatment.

3. Lucky Lady Placers. Alternate site for wastewater treatment.

4. Site "A" - alternate site for wastewater treatment.

5. Airgold Placers. Site for research in pumping 3/4 inch material.

SECTION I: SLUICE TAILINGS PUMPING FIELD TRIALS:

Site Descriptions:

Beron Placers: This placer mine is situated on Upper Eldorado Creek at Nugget Gulch. The valley here is 200 to 300 feet wide so would be classed as a broad valley, although the gradient is 1% to 2%. The gravel is overlain by 30 feet of frozen black muck and in mining the bedrock is ripped to a depth of 2 feet.

The operation utilizes a modern high-tech plant consisting of vibrating grizzly separating at 3 inch, undersize moved by a vibrating sluice for coarse gold to a single deck wet screen equipped with 1/4 inch diameter punch plate. Minus 1/4 inch material is washed in twin 4 foot wide sluice boxes. To feed the plant a D8K dozer pushes to a stockpile from which a Caterpillar 950 F.E. loader feeds the plant. The plant handles 132 cu. yds. per hour with 1250 to 1300 gals/min. U.S.

The sluice box tailings discharge to a 5 foot high pump box equipped with a Furakawa SPL-150-C open impeller, liner type slurry pump equipped with Hi-Chrome Cast Iron wetted parts. The pump is belt driven by a Deutz F6L-912 air cooled diesel. Tailings are pumped through 250 feet of 8 inch diameter polyethylene pipe to a 24 inch diameter rubber lined Linatex hydrocyclone.

Airgold Placers: This operation is located on lower Dominion Creek where the valley is over 1 mile wide. The overburden is about 40 feet deep with the top 6 feet being black muck. The original plan to pump classified feed material from the cut up to a sluicing plant was later modified to pump minus 3/4 inch tailings approximately 700 feet with an increase in height of 50 feet to a disposal site. The pump selected for this duty by Wright Engineers was a Warman 200 E.L. pump, equipped with closed impeller and Ni-Hard wear parts initially driven by a Mitsubishi 112 H.P. Diesel by direct drive. The discharge pipe chosen was 9.5 inch I.D. series 100 polyethylene pipe with Victaulic fittings.

Beron Placer Operation:
After 74.5 hours of operation the suction liner wore through. The liner was repaired 3 times, first with liquid steel, then with ceramic beads and finally with Devcon putty.

After 148 total hours the suction liner was replaced. The new liner operated for 72 hours at which time the casing holed.

Initially there was very low suction head on the pump but this was rectified after 134 hours of operation. The Warman pump was put into service to replace the Furikawa pump and operated for 74 hours, after which time the liners showed very little wear and the impeller weight loss was 10 pounds off 425 pounds.

Initially the hydrocyclone gave a ropy underflow so the apex valve was changed from 3 1/2 inch diameter to 4 inch and the vortex finder from 8 inch to 6 inch. Thereafter the hydrocyclone operated satisfactorily.

Capital and Operating Costs::

The total cost for the pump box, pumps and diesel drive, pipeline and cyclone was $50,061.

The plant operated for 294 hours during the season treating 38,800 cubic yards with the minus 1/4 inch material being approximately 65%, or 25,225 cubic yards. Based on operating hours the Furikawa pump handled 18,637 cubic yards. The estimated total cost of the pump operation including replacement cost of worn out items is $9,071 or $0.49 per cubic yard of solids pumped. There was very little pipeline or hydrocyclone wear.

Based on a comparison with the performance of the Warman pump, and also pump wear experienced elsewhere, the wear on the Furikawa pump during this test is considered excessive.

The consultants suggest that a different liner material should be expected to give a life of 400 hours. If this should be correct the pumping cost would be reduced to $5,876 for the 220 pump hours, or $0.315 per cubic yard of solids pumped. The report has a detailed breakdown of estimated cost of handling the sluice tails by conventional mechanical means and this figure is $0.436 per yard of minus 1/4 inch tailings.

Comparison of Systems:

The pumping system has several advantages over using diesel equipment.

1. For distances over 250 feet the cost is less for pumping.

2. The mobile diesel equipment can be kept on production tasks.

3. The tailings can be stacked at a higher elevation than the plant.

4. By using a cyclone the tailings can be stacked at a steeper angle than is possible with diesel equipment.

5. By using a hydrocyclone material over 0.1 mm in size will report to the cyclone under flow therefore reducing the volume of material to the settling pond.

Summary of Design Criteria for Pump Operation

In order to have an efficiently operated pumping system it is important that accurate advance information should be available.

Site layout:
- location of sluice plant and cut
- location of tailings disposal area
- requirement for bedrock drains
- type of material, range of size

Production:
- type of plant
- production rate
- material size (preferably -1/4 inch)

Data required:
- static head and total head
- feed size range

- feed rate
- sluice water volume
- hardness factor of feed material

Pipeline Diameter - must be sized to provide critical velocity to prevent solids build up

SECTION 2:

WASTEWATER TREATMENT FIELD TRIALS:

Site descriptions - Study options

Beron Placers:

Located on Eldorado Creek, classed as a broad valley according to Wright Engineers classification. The wastewater treatment facilities included a diversion channel for Eldorado Creek, a hydrocyclone which removed the plus 0.1 mm. size material, effluent drain for hydrocyclone overflow leading to a 0.93 acre settling pond, with pond volume of 5044 cubic yards. The initial pond retention time was 13.1 hours and pond life to reach a level of 0.2 ml/lt effluent discharge was estimated at 110 hours at 150 cu.yds/hour. The pond life exceeded the estimate by 27%.

Nugget Hill Placers Ltd:

This property is a high bench deposit on the left limit ofHunker Creek, 400 feet downstream from the rim of Independence Creek valley. The sluice plant includes a 20 foot by 3 foot diameter trommel with 1 1/4 inch openings feeding the sluice runs. Feed material consists of White Channel gravel 15 to 25 feet thick, which ispushed up by caterpillar D-7 dozer and fed to the trommel by a 930 F.E. loader. Water is obtained from Independence Creek by a 2 mile ditch or pumped up from Hunter Creek.

Wastewater treatment consisted of #1 pre-settling pond 25 feet by 10 feet by 1.5 feet deep, #2 pre-settling pond, volume of 30,000 cu.ft. and 7.5 feet deep and main settling pond, U-shaped and 2,000 feet long, 25 feet wide and 4.5 feet deep.

The main pond had a surface area of 1.02 acres and volume of 6,600 cu. yards, giving retention time of 29.7 hours.

Secondary Sites:

	Site 'A'	Lucky Lady Placers Ltd.
Feed rate cu.yd.s/hr.	75.	50
Water G.P.M. U.S.	2,500	1,600
Settling Pond Volume cu.yds.	1,725	23,272
Retention time - hours	2.3	49
Pond inlet quality ml/lt.	8.3	50
Pond outlet quality ml/lt.	2.9	<0.2

(1) Pay Gravel Sampling:

The following samples were collected: Nugget Hill Placers, 8 samples at weekly intervals, Beron Placers, 7 samples at weekly intervals, Site "A" and Lucky Lady Placers, 1 sample each. Samples were obtained from well mixed sluice feed piles, oversize estimated by bucket count of coarse tailings.

Comparison of proportion of fine grained material.

		Percent Passing	
Sites and Data Source	Number of Samples	0.5 mm Med.Sand	0.002 Silt-Clay
22 Yukon Mines (Weagle 1984)	35	36	1.5
15 Yukon Mines (Reid Crowther 1984)	26	32	1.4
Nugget Hill	8	34	0
Beron Placers	7	29	0
Site "A"	1	26	0
Lucky Lady	1	31	0

Conclusions:

1. A fairly wide range of results for both Nugget Hill and Beron (16.0% to 34.0% for 0.5 mm at Nugget Hill)

2. A thorough understanding of the deposit is necessary in order to develop a sampling strategy.

3. Where a minimum number of samples is unlikely to be representative, use of regional field data is justified.

(2) Sediment Volume Estimates:

The objective of this study is to determine the accuracy of calculating settling pond fines volume using feed rates and particle size. Production and sampling data are compared with settling pond volume surveys.

Beron Placer - Settling Pond

Surveyed sediment volume		4720 cu.m.	
Calculate volume -	average of 7 samples	4160 " "	-12%
" "	maximum fines content	6130 " "	+34%
" "	minimum fines content	2570 " "	-46%

Nugget Hill Placer - Settling Pond

Surveyed sediment volume		3800 cu.m.	
Calculated volume -	average of 8 samples	3880 " "	+ 2%
" "	maximum fines content	5400 " "	+42%
" "	minimum fines content	2790 " "	-27%

Conclusion:

1. A realistic estimate of settling pond volume requirements can be made provided grain size data are representative.

2. On a single soil sample volume estimates could be 50% more or less than actual requirements.

(3) Pre-Settling Pond Evaluation.

The effect on settling pond operations and cost of operating pre-settling ponds is evaluated.

Nugget Hill No. 1 Settling Pond.

A 4 hour test using a 950 F.E. Loader indicated that as much as 72% of the sediment could be removed at this point at a cost of $1.48 per cu. yd.

Nugget Hill No. 2 Settling Pond.

The geometry of the No. 2 pre-settling pond required a backhoe to remove accumulated solids. It was cleaned out twice during the operating season. It is estimated that this pre-settling pond actually removed 37% of the total sludge volume at a cost of $0.92 per cu.yd.

Beron Placer - Hydrocyclone

The hydrocyclone acts as a pre-settling pond. At Beron Placer, the hydrocyclone extended the pond life by 70%

(4) **Retention Time for Settleable Solids Removal:**

An attempt was made to determine the minimum hydraulic retention time for effective removal of settleable solids. The proposal was to monitor the settleable solids in the pond effluent until a level of 0.2 ml./L was reached, then survey and calculate the pond effective volume.

At Beron Placers, the test showed that when the level of 0.2 ml./L was reached, the retention time was 2.8 hours. The figure for Nugget Hill was inconclusive due to the "soupy" nature of the pond sludge. At site "A" the effluent level was 2.9 ml/L and pond retention time estimated at 2.3 hours, however the pond was short circuiting.

Based on this limited data, it is probable that a hydraulic retention time of 3 to 5 hours should achieve a settleable solids level of 0.2 ml./L

(5) Settling Pond Geometry

The objective of these tests was to investigate the effect of length to width ratios and inlet berms on settling pond retention time and performance. Dye tests were made on Nugget Hill presettling pond No. 2 (P.S.2) and main pond and on Beron Placers main pond.

The test results were:

P.S.2 Actual retention time 0.97 hrs. v.s. calculated retention time 2.9 hours. Dead space = 60%

Main Pond Actual retention time 5.4 hrs. v.s. calculated retention time 9.8 hours. Dead Space = 40%

Beron Placer, the test was inconclusive due to changing conditions during the test.

The dead space factors in the Sigma Resources Report may be too low, however the 2 tests performed at Nugget Hill are not sufficient justification to revise the ratios developed in that report.

(6) **Theoretical Estimates of Pond Effluent Quality:**

Volume 1 of the Sigma Resource Consultants report 1986, "Design Principles" developed a computer program, table 4.3, for estimating effluent quality in settling ponds. This calculation was used for the 4 sites and estimated sediment levels are compared with observed levels in the table below:

		Effluent Suspended Solids mg./L	
Sampling location		Estimated	Observed
1. Beron Placers	(a) cyclone o'flow	49,000	57,000
	(b) pond discharge	0	200-400
2. Site "A"	pond discharge	1,100	1,820
3. Lucky Lady	" "	0	47
4. Nugget Hill	(a) P.S.2 "	3,300	7,300-10,400
	(b) pond "	0	100-200

The Nugget Hill main pond discharge (recycle pump) levels 100-200 may have been influenced by make up water pumped from Hunter Creek. The theoretical results are of the same order of magnitude as the observed results, however, the calculated levels are very sensitive to small variations in grain size. For this reason, this method of estimating pond size has limited value.

(7) Settling Tests:

In the 1986 report "Design Principles", section 6.5 and "Technology" 2.7, the consultant Sigma Resource Consultants suggest that settling tests using simulated waste water may provide reasonably accurate estimates of effluent suspended solids. This theory is tested against actual settling pond performance.

For the tests, samples can be either actual sluice box discharge or simulated samples made from carefully taken feed samples (-3") mixed with process water in the proper proportion. Both systems have advantages and disadvantages. Both types of samples were employed in this trial and the following tests completed; Beron Placers 3 tests (1 with actual waste water), Nugget Hill Placers 3 tests (1 with actual waste water) and 1 each at Site "A" and Lucky Lady Placers using simulated wastewater.

The pond discharge effluent prediction for 7 cases had a mean error of 124 mg/L for the simulated effluent compared with actual pond discharge. Using a 2 m.high X 150 mm. diameter plexiglass column provides a useful method of estimating minimum pond volume to achieve a specified suspended solids level. Tests in smaller vessels tend to underestimate the volume requirements.

(8) Water Recycle

The concept of recycling water for sluicing for a placer mining operation has potential benefits: (1) could be a possible method for meeting stringent effluent standards (2) may reduce pumping costs, (3) may result in increased sluicing hours in areas and at times of water shortage; but also has possible constraints and limitations, (1) excessive groundwater inflows may preclude zero discharge (2) build up of fine sediment may interfere with gold recovery (3) may increase pump wear.

The objective of this study was to operate a total recycle system, develop methods and additional criteria for pond design and investigate relative cost. The operation at Nugget Hill Placers was a total recycle system with makeup water pumped up from Hunker Creek to offset pond leakage and water loss in sluice oversize removal.

In this operation the recycle water was always virtually free of suspended solids even with the sluicing plant operating 20 hours per day for 6 straight days. A cost comparison is developed between (a) pumping the total sluice requirement from Hunker Creek with tailings disposed of in a dredge tails area; and (b) recycle system, including write off of pond capital cost of $12,580. For 1000 hours of operation, the costs are equal, however at 2000 hours, there is an indicated savings of $12,000 for the recycle system.

(9) **Wastewater Treatment Costs:**

At Beron Placers, the primary settling pond consistently produced a pond effluent with a settleable solid level less than 0.2 ml./L (suspended solids <500 mg./L) during 160 hours of sluicing during which 21,200 cubic yards were mined. The construction cost of the settling pond was $8,877 which equates to a wastewater treatment cost of $0.42 per cu.yd. mined. It is estimated that without the operation of the hydrocyclone the cost of attaining the same effluent levels would be about double.

The settling pond system at Nugget Hill consistently produced plant feed water with suspended sediment levels less than 200 mg./L from the recycle ponds. The capital cost of pond construction was $12,580 and for an estimated life of 1500 hours the maintenance cost (clean-out) is estimated at $13,410. The overall wastewater treatment cost to produce recycle water is estimated at $0.73 per cu.yd. sluiced over several years operation.

YEDA 86 - 03B EQUIPMENT PURCHASE

One part of the material handling field trials proposed the purchase of pumping equipment, piping and incidentals with E.D.A. funds. The specifications for the equipment were provided by the consultant, Wright Engineers Limited, and purchasing done by the Department of Supply and Services. Unfortunately, the pipe required was not available from stock so that slow delivery prevented starting this test during the 1986 season.

In order to carry out the field test program it was necessary to carry out some site modifications at the sites chosen for this research. These changes required the assistance and co-operation of the operators, and in this program we were fortunate in having the full support of the operators, without which it would have been impossible to conduct the required tests. Some of the modifications required the use of equipment and for providing this service the following 3 contribution agreements were negotiated with the operators with the help of the consultants.

YEDA - MR - 002 SETTLING POND CONSTRUCTION

The test program at Beron Placers required a large enough final settling pond to provide sufficient retention time to provide a final pond effluent substantially below 0.2 ml/L. Space available on the Beron Placer claims at the start of the season was limited for construction of a large enough pond with gravity flow from the cyclone. The down stream claim holder, Mr. Dave Johnson, kindly consented for the settling pond to be located on his claims and Ron and Bernie Johnson constructed the settling pond for Berom Placers under direction from the consultants representative.

YEDA - MR - 003 PRE-SETTLING POND CONSTRUCTION

There was no equipment located at Nugget Hill Placers that would be suitable for the construction of the pre-settling pond designed by the consultants and also to clean out the pre-settling and final pond as the test work progressed. Mr. John Gould kindly arranged for the rental of a suitable backhoe and carried out this work in accordance with the wishes of the consultants.

YEDA - MR - 005 PUMP BOX CONSTRUCTION

For the major pumping test at Airgold Placer the consultants decided that the best procedure for providing a suitable pump box would be to construct this item on site. Mr. John Brown arranged the purchase of the necessary material and retained the services of a journeyman welder and fabricated the box as per the design of the consultants.

YEDA - 06 FLOCCULANT TEST PROGRAM

BACKGROUND:

In 1984 the Government of Canada funded a research program to investigate the use of flocculants as a possible method of reducing the quantity in settling pond effluent, particularly for operations using recirculation where available area for settling ponds was limited. This research was conducted by Stanley Associates Engineering Limited and Canviro Consultants Limited at the Airgold Placer Operation on Lower Dominion Creek. This test program was mainly concerned with the anionic type of flocculants, and the test results proved that these flocculants worked well in reducing the sediment load, produced a good fast settling floc. The anionic flocculants tested in 1984 were supplied in powder form and required a fairly elaborate mixing and feeding system, quite feasible for a large settled operation but beyond the resources of the typical small narrow valley Yukon operator.

As a follow up to the 1984 test project the Environment Protection Service Division of Environment Canada proposed a project to carry on research on this subject, particularly to try out the cationic type of flocculants that are available in liquid form and therefore are far easier to feed. This idea was proposed to the Management Committee and subsequently a contract was awarded to Stanely Associates Engineering Limited to develop a test program.

OBJECTIVES:

The objectives of this contract were:

1. To prepare a short list of placer operations where, for a variety of reasons, the use of flocculants might prove attractive to the operators.

2. To contact property owners of the identified sites who would be interested inparticipating in a full scale demonstration.

3. For operators interested in a test program, to collect details of each operation and to collect representative samples of sluice plant feed.

4. To conduct jar tests to determine effective compounds, doses and mixing conditions.

5. To prepare a full report of such studies and propose a plan and budget for a demonstration project.

Methodology:

1. **Site selection:**

   The criteria upon which the site selection was based was:

   (a) Insufficient water to sluice at full rate.

   (b) insufficient water without costly pumping.

   (c) inadequate room for settling ponds.

   (d) operations using innovative classification methods to reduce water requirements.

   (e) a sensitive receiving water situation restricting the effluent discharge.

2. Jar Test Program:

   The laboratory-scale flocculant test program was designed to perform experiments on a number of polymers to determine the best one for each site. The test work would also determine the dosing rate necessary to produce the required results.

Site Assessment:

It was unfortunate that by the time the search for suitable sites commenced many operators had suspended operations and several had already left their sites for the season.

A study of the available office data indicated 32 placer mining operations in the Klondike area which might satisfy the criteria established for an appropriate test site.

Of these, 9 operators were still in the field and three showed interest in a test project, John Gould (Nugget Hill Placers), Queenstake Resources (Preido Hill Operation), and Miben Mining. The operators who had already left the field were contacted by telephone and King Soloman Mines (Art Fay) and Sigma Resources (Gary Crawford) both showed interest.

Nugget Hill Placers is a high bench operation which seasonally has water supply problems when the flow in Independence Creek slackens off. Water is then obtained from Hunker Creek but at a substantial increase in pumping costs. Pay ground samples were taken at this site and make up water from the settling pond.

Queenstake Mine on Preido Hill was already operating a total recirculation system but were interested in the possible use of flocculants for increased operation later. Samples of the actual sluice water were obtained.

Miben Mining is also mining a White Channel Gravel high bench deposit, about 300 feet vertically above Hunker Creek. The present settling pond is located at the Hunker Creek elevation and sluice water is pumped up from Hunker Creek. Sluicing operations had ceased at the time of the inspection, so samples of pay gravel were obtained and water from the pumping pond.

Polymer Selection and Optimization Program:

Based on previous experience with flocculant treatment of placer mining wastewater 11 different polymers in 4 different types were selected for testing. The mix was 1 anionic solid type, 2 anionic dispersion, 2 anionic emulsion, 1 nonionic solid, 1 nonionic dispersion, 1 nonionic emulsion, 3 cationic liquid.

The raw wastewater from the sluice discharge at Queenstake contained suspended solids approximately 20,000 mg/L. To simulate the removal of the coarse fraction in the pre-settling pond the sample was settled for 20 minutes, then the supernatant decanted off. This solution contained 5,600 mg/L suspended solids. The test samples for Nugget Hill and Miben were made up from pay gravel samples mixed with sluice water at operating concentrations, then allowed to stand 20 minutes before decanting to give test mixtures of 3,000 and 3,500 mg/L suspended solids.

For each property, jar tests were performed under similar conditions of all of the chosen polymers at dosages varying from 0.25 mg/L up to 3 mg/L. In addition to the tests using single polymers the effectiveness of a combination of cationic and anionic polymers was evaluated at each site.

At Queenstake, 2 of the 3 liquid cationic polymers were extremely effective in reducing suspended solids concentration, the 2 products being L.T.35 and D 51181. The tests using these 2 cationic polymers in combination with anionic gave no further improvement and L.T.35 and D-51181 were the most cost effective.

The results at Miben Placers were very similar to the results at Queenstake, with the liquid cationic L.T. 35 and D-51181 performing extremely well at dosages less than 0.5 mg./L. The wastewater at the Nugget Hill Placers performed quite similarly to the wastewater at Airgold when tried with the anionic and nonionic polymers. With dosage in the range of 2.5 to 4.0 mg./L to achieve a suspended solids level of 100 mg./L. The cationic polymer L.T. 35 performed well at this site with a dosage of 0.5 mg./L giving a suspended solids figure of 108 mg./L. This product was also the most cost effective and therefore recommended for more testing.

Conceptual Design:

Before the field test project could be initiated it was decided not to consider a test project at Queenstake since the company planned a very much smaller program for 1986, and at Miben, space limitations made construction of settling ponds at the plant site level difficult. The Nugget Hill operation seemed to be the most suitable.

Mr. Gould expressed a wish to increase his sluicing hours from 400 in 1985 to 650 in 1986 and anticipated a shortage of water after mid-June. The proposed program would utilize existing settling ponds.

The polymer mixing and flocculation chamber could be similar in design to that used in the 1984 demonstration and located between Pohds 2 and 3. The estimated cost of a test program at Nugget Hill Placers would be in the order of $63,800, including $43,000 for pond clean-out, for treatment of 27,225 cubic yards of pay gravel. The basic cost for flocculant treatment, omitting the costs for site modification and pond cleanout is 58 cents per yard sluiced, allowing cost of 3 hours labour per day to monitor the flocculant test.

YEDA - 86-06 FLOCCULANT FIELD TRIAL

BACKGROUND:

In 1985 Stanley Associates Engineering Ltd. with Canviro Consultants Ltd. completed an E.D.A. contract with the objectives (1) to identify placer mines which might benefit from the use of flocculants (2) to test material from those sites to determine suitable flocculants for a test program and (3) to make recommendations for a field trial at a suitable site.

The most suitable test site was the John Gould operation Nugget Hill Placers and since Sigma Resource Consultants were already engaged in a wastewater treatment project at this site, with technicians in the field, it was decided to have Sigma Resource Consultants carry out the field trial recommendations during the 1986 season.

Work Program:

The consultants would carry out the 4 main work items at the Nugget Hill site:

(1) conduct jar tests to update the dosages of Pocol L.T.35 outlined in the Flocculant Test Program report.

(2) arrange a system for metering, diluting, injecting and mixing of flocculant to sluice wastewater.

(3) measure the suspended solids levels upstream and downstream during a 125 hour test program.

(4) observe the effects of flocculants on sludge density.

Jar Test Results:

(1) On discharge from settling pond #2, with an initial suspended sediment load of 5600 mg./L, with an addition of 1.0 mg./L of L.T.35, after 1 hour the suspended sediment load was reduced to 180 mg./L.

(2) On primary settling pond water at measuring point 12+50, the suspended solid level was reduced from 1480 mg./L to 88 mg./L after 10 minutes of mixing and 10 minutes of settling with 1.0 mg./L of L.T.35.

(3) At Beron Placers, sediment levels in simulated hydrocyclone overflow were reduced from 3200 mg./L to 80 mg./L by the addition of 3.0 mg./L of L.T.35 and 10 minutes of mixing and 10 minutes of settling.

Feeding System:

The chemical was fed from a 200 Kg. reagent drum through an electric metering pump to a fresh water supply in 100 m. of 25 m.m. diameter P.V.C.pipe to a dilution of 0.5%. The diluted reagent was fed by a 4 m. garden hose to a spray bar 0.6 m. long with 10 holes. Power was supplied for the electric pump by an 800 watt portable generator. The capital cost for the feeding system was $2,150.

TEST RESULTS:

Test #1.

This test was performed for 3 days September 2 to 5. The plant was operating for 20 hours per day and reagent feeding carried on for 38 1/2 hours.

The suspended solids levels were:

discharge from P.S.#2	19,300 mg./L
station 12+50 at start . . .	3,850 "
" " after 5 hrs. . .	825 "
" " after 20 hrs. . .	623 "
" " after 45 hrs. . .	925 "
" " 22 hours after reagent feeding stopped . . .	6,300 "

<u>Note:</u> station 12+50 represents 10 hours theoretical retention time.

Test #2.

For test #2, the chemicals were added at station #12+50 and the effect monitored at stations #12+00 and #10+70 down stream. The test ran from September 18 until September 25, during which period sluicing was intermittent, totalling 81 hours.

The suspended solids levels were:

station	12+50 at start	446 mg./L.
"	12+00 after 5 hrs.	100 mg./L (2 1/2 hrs. retention)
"	10+80 after 70 hrs.	40 to 60 mg./L (8 1/2 hrs. retention)

Sludge Density:

Two tests were carried out on wastewater from the settling pond. Both were allowed to settle in Imhoff cones after agitation, one raw, and the other treated with 1 mg./L. of Percol L.T.35. After 1 hour the flocculated had a much higher density, but later the sludges had equal density.

CONCLUSIONS:

1. The flocculant Percol LT-35 was easy to use, the feeding system capital cost was low and operating cost low.

2. The flocculant additions at this site gave marginal improvements in sediment treatment.

3. Use of flocculants would have greater potential in situations:

   (a) where there is build up of unsettleable fines even with regular pond maintenance.

   (b) where space for pond construction is limited.