canada/yukon subsidiary
agreement on mineral resources

Program 3 Placer Mining

FLOCCULANT TEST PROGRAM

Stanley Associates Engineering Ltd.

and

Canviro Consultants Ltd.

Canada

Yukon

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Stanley Associates Engineering Ltd.
No. 101 - 107 Main Street
Whitehorse, Yukon Y1A 2A7
Telephone (403) 667-2225

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Mr. R. McCandless, Manager
Environmental Assessments and Appraisals
Environmental Protection Service
Environment Canada
Room 225, Federal Building
WHITEHORSE, Yukon Territory
Y1A 2B5

Dear Sir:

Reference: Flocculant Test Program - Final Report
Contract No. YEDA-06

The staff at Stanley Associates and Canviro Consultants have appreciated the opportunity to participate in these flocculant studies for the placer mining industry. We are grateful for the assistance provided by yourself and Mr. D. Vachon of Environment Canada and by the Whitehorse staff of Indian and Northern Affairs Canada. We have appreciated the guidance provided by Mr. N. Ross of the Klondike Placer Miners' Association and we gratefully acknowledge the cooperation of specific mine operators who participated in this study.

As already noted, the attached document has been completed through the joint efforts of Stanley Associates Engineering Ltd. and Canviro Consultants Ltd. Our final report summarizes the study objectives, describes our methodologies, presents data, analyzes the results, and provides specific recommendations and cost estimates for two demonstration projects for the 1986 mining season.

Thank you for the opportunity to participate in this study.

Yours very truly,

STANLEY ASSOCIATES ENGINEERING LTD.

E. Kroeker, M.Sc., P. Eng.
Manager, Environmental Engineering

EK/lp

Enclosure

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1.0 INTRODUCTION

1.1 OBJECTIVES OF THE STUDY

In 1984, the Government of Canada funded preliminary research into anionic flocculants at a Yukon placer mine (Stanley, 1985). This work showed that the compounds were able to clarify effluent waters using small doses of the compound mixed into the flows between settling ponds. Estimated costs of this treatment method suggested that its use could be advantageous in situations where the mine was required to recycle its process water.

The objective of this current study was to search for and identify placer mines which might benefit from the use of flocculants, and by testing materials from those sites, determine if they would be suitable as candidate locations for the full scale demonstration of flocculent use during the 1986 mining season. The principal objective is to narrow the available choices of mining sites on the basis of site characteristicss and the settleability of the treated effluent.

1.2 STUDY TERMS OF REFERENCE

The Terms of Reference have been directly excerpted from the Statement of Work for this project:

"1. Preparation of a short list of candidate sites for the flocculant test program. Candidate sites were to be selected on the basis of the following characteristics:

   a) insufficient water passing the property to sluice at a full daily rate;

   b) insufficient water available without costly pumping to the site;

   c) inadequate room to construct settling facilities large enough to permit recycle;

d) high loadings of fine silts and clays, both of which settle very slowly;

e) a sensitive receiving water situation in which effluent levels of 0 or 100 milligrams per litre of suspended solids above background cannot be attained with settling ponds;

f) reasonably good access by road;

g) use of innovative classification methods at the sluice way or jig which reduce the ratio of water to solids, and which lend themselves to reducing circuit size.

2. Contact the owners/operators of the candidate sites to determine if they are interested in participating in a full-scale demonstration project during the 1986 operating season. Potential benefits of using flocculants at each candidate site were noted.

3. Collect sluicing effluent at mines that are sluicing or collect samples of pay gravels and water used for sluicing where sluicing operations are not underway. Collect details about each operation including existing mode of operation, equipment utilized, problems being encountered and expectations of the flocculant test program.

   The Contractor shall approach the owners or operators or both of selected properties to ask if they wish to participate in tests to determine if flocculants could be of direct benefit to them and their operation.

   Having obtained agreement from any property owner, the Contractor shall obtain screened grab samples of pay dirt or other material apt to contribute to solids in the effluent, and volumes of water from the property sufficient to conduct jar tests; or, volumes of typical effluent sufficient for jar testing.

4. Conduct a program of jar tests to determine effective compounds, doses and mixing conditions to obtain either maximum clarity or settling rate for the optimum dose of the compound selected. Anionic or cationic compounds or both will be examined, depending on the site characteristics and the anticipated delivery method.

5. Prepare a report which lists the sites screened and examined, characteristics of the materials and waters sampled, jar test procedures and results, and any other site observations. Describe the sites where flocculants could be used to the benefit of the miner and the environment. A plan and budget to perform a demonstration project will be recommended for each site, including site modifications and settling pond sizes and locations where necessary."

The following Sections describe the results of these studies.

2.0 REVIEW OF FLOCCULANT-AIDED TREATMENT TECHNOLOGY

The process of coagulation and flocculation is described in detail in the previous Stanley Associates and Canviro (1985) report. The following is a brief summary description of the process related to water treatment for placer mining operations.

In sluicing operations, water is used to wash the gravel and bedrock material. Water use rates vary with the size and type of sluice box that is used. The range of 150 to 375 L/s (200 - 5000 igpm) covers most mining operations in the Yukon.

The effluent from the sluice box is includes coarse tailings that settle out near the end of the box or within a few seconds of entering a settling pond. In a normal placer mining operation, the coarse material is continually removed from the bottom of the sluice by mechanical equipment. The remaining effluent water is discharged into settling ponds to allow the removal of suspended sands, silts and clays.

In operations where water is recyled, at least two ponds are normally provided. In these systems, the sands and coarse silts will usually settle out in the first pond. Even a two pond system may not be sufficient, however to settle out fine silts and clays. Consequently, there is a gradual accumulation of fine suspended sediment in the recycled water.

Coagulants can assist in the treatment process by increasing the settling rate of these fine solids thereby facilitating their removal in settling ponds. Particles in water usually carry electrical charges which prevent natural particle contact and agglomeration. Coagulants neutralize these surface charges, thereby destabilizing the particles and allowing interparticle contact and floc growth.

Synthetic organic compounds called polyelectrolytes or polymers have been developed and widely accepted as coagulants in water and wastewater treatment. Polyelectrolytes are long-chain, high molecular weight compounds which can be positively-charged (cationic), negatively-charged (anionic) or charge neutral (nonionic). Cationic and nonionic polymers function by electrostatic attraction between the negatively-charged particles and the positively-charged sites on the polymer molecule. This attraction results in the initial destabilization of the colloidal particle. Anionic polymers have also been effective despite the fact that the particles in the water also carry negative charges. In this case, a chemical interaction occurs between the polymer molecule and the colloid surface.

The dosages of polyelectrolytes required to achieve coagulation are small compared to the dosages of conventional coagulants such as alum. The typical dosage of cationic and anionic polymers in water and wastewater treatment are 0.1 to 1.0 mg/L. A corresponding dosage of alum would be in the range of 25 mg/L or more.

The effective application of coagulants requires two steps:

1. rapid or flash mixing to distribute the coagulant evenly throughout the fluid and to induce rapid coagulant - particle contact and colloid destabilization; and

2. flocculation or slow mixing to increase the number and frequency of collisions between destabilized particles and to induce particle agglomeration.

Coagulation and flocculation theory is not sufficiently developed to predict optimum coagulant type, dosage requirements or mixing requirements (flash mix or flocculation). Laboratory-scale tests (jar tests) are necessary to determine the optimal design of a coagulation process for a specific application.

The implementation of coagulation processes to increase settling rates and to improve the removal of finely divided particles, such as silt and clay, requires significant changes to the conventional placer mine settling pond.

Most cationic and non-ionic polymers are available in concentrated liquid form. These liquids are highly viscous and must be diluted prior to addition to ensure rapid and uniform mixing with the wastewater. Anionic polymers have traditionally been available as dry materials. Recently, these polymers have also become available in concentrated liquid form (emulsion polymers and dispersion polymers) which can be handled in a similar fashion as cationic polymers. Regardless of the type of coagulant used, a system for solution makeup, storage and feeding to the point of addition is necessary.

Effective polymer use depends on rapid mixing of the polymer with the wastewater at the point of addition. Similarly, effective flocculation depends on adequate inter particle contact to allow floc growth. In conventional water and wastewater treatment systems, mechanical mixing is used. In Yukon placer mining operations, it is most practical to utilize hydraulics to accomplish mixing in order to eliminate the external energy source requirements of mechanical equipment. Thus, a hydraulic structure must be designed to provide the required degree of controlled turbulence to optimize coagulation and flocculation. The design and use of such a structure has been described in the Stanley and Canviro (1985) report.

Polymer efficiency is influenced by the concentration of suspended solids in the wastewater and by their particle size distribution. Dosage requirements typically increase with increasing concentrations of particulate matter. Design of upstream pond(s) is thus more critical in a coagulation process than in the conventional two-pond settling systems currently used.

Flocculation creates particle settling rates considerably higher than those of the unflocculated particles. Therefore, the size of the secondary pond required to achieve removal of the flocculated particles can be reduced proportionally. At the same time, the volume of sediment accumulated in the pond will increase due to higher removal efficiencies and the bulkier nature of the particulate matter. Therefore secondary pond design requires consideration of the requirements both for settling and for sediment storage.

A final consideration is the possible impact, where water is recycled to the sluice, of residual polymer on the gravity separation of gold from the paydirt. The high affinity of the polymer molecules for suspended particulate matter in the wastewater makes it unlikely that detectable quantities of polymer would be present in the clarified water. However, control of excessive polymer dosage and the position of the recycle sluice water pond should both be considered in such situations.

3.0 STUDY METHODOLOGY

The study involved three phases. The first included site selection and data collection. The second involved the jar test program and the third phase was the conceptual design stage detailing the works and cost estimates for the demonstration project. The following is a summary of the methodologies used in completing each phase of the study.

3.1 SITE SELECTION

3.1.1 Selection Criteria

During site selection, we attempted to identify existing placer mining operations that would benefit from the use of flocculants. This included discussing with operators their interest in sponsoring a full-scale flocculant demonstration project on their property during the 1986 mining season. The selection criteria initially considered for this study included the following site characteristics:

1) Insufficient water passing the property to sluice at a full daily rate;

2) Insufficient water available without costly pumping to the sites;

3) Inadequate room to construct settling facilities large enough to permit recycle settling;

5) Use of innovative classification methods at the sluiceway or jig which reduce the ratio of water to solids, and which lend themselves to reducing circuit size;

6) A sensitive receiving water situation in which effluent levels of 0 or 100 milligrams per litre of suspended solids above background cannot be attained with unaided settling;

In addition, these sites had to satisfy the following requirements:

1) Cooperative attitude on the part of the mine owner and operator including a willingness to make certain modifications necessary to accommodate the development project and to conduct test programs for one full season;

2) Accessibility by road so that laboratory and experimental equipment could be moved on-site during 1986;

3) On-site earth moving equipment capable of constructing settling ponds or dams;

4) Topography suitable for pond construction and siting of pilot plant facilities during 1986;

5) Sufficient availability of paydirt to allow full mining operations during the 1986 mining season.

Due to project timing constraints, site visits could not be made until the week of September 22, 1985. As a result, many of the mines had shut down for the season and at least half of the miners had left the area. Because of the time contraints that were then placed on the study, the selection criteria were reduced to the following:

1) Operations in the Klondike Placer area;

2) Operations on the benches which have high pumping costs;

3) Operations in the headwaters which experience water shortage problems;

4) Heavy loads of fine silts and clays limiting the recirculation capabilities;

5) The use of innovative classification methods at the sluiceway or jig.

3.1.2 Sources of Information

The following sources of information were used in the preliminary selection of potential sites:

1) Our own data from the 1984 site selection investigations were used;

2) The 1983-84 INAC mine inspection reports for each placer operation were evaluated; interviews were held with the mining inspectors in order to obtain an update on 1985 activity; and

3) The INAC Water Rights Inspectors for the Dawson City area were interviewed for an operational up date; this included specific information on which miners had already left the area for the season.

3.2 JAR TEST PROGRAM

3.2.1 Introduction

The laboratory-scale flocculant test program involved a series of experiments aimed at developing the conceptual design data and cost information necessary to define the requirements associated with full-scale demonstration of polymer-aided settling at the three sites sampled during the field survey program. The experimentation involved selection of the optimum polymer type for each site, optimization of polymer mixing efficiency and a brief evaluation of the sensitivity of the polymer to the suspended solids concentration in the sluice water being treated. This information was needed to define individual site requirements for full-scale demonstration during the 1986 mining season.

3.2.2 Test Procedures

All jar testing was conducted using a Phipps and Bird multi-position jar test apparatus with rectangular battery jars. To conserve the limited sample available from the sites, testing was done with 500 ml aliquots.

Polymer stock solutions were prepared according to manufacturers' recommendations. Polymers were applied as 0.01% solutions which were prepared daily from the stock solutions. For the polymer screening tests, the standard test procedures involved a 60 second flash mix period at 100 rpm followed by a flocculation period of 10 minutes at 40 rpm. The tested solution was allowed to settle for 10 minutes prior to supernatant sampling. Supernatant samples were analyzed for total suspended solids and residual turbidity, according to standard procedures (Standard Methods, 1985). Time of floc appearance, settling rates and residual sludge volumes were measured and the qualitative floc characteristics were noted. A 'blank' sample without polymer addition was routinely carried through the jar test procedure as a control. Details of the jar testing program and its results are discussed in Section 5.

4.0 SITE ASSESSMENTS

4.1 BACKGROUND

A list of 32 placer mining operations located in the Klondike gold fields were identified as operations that may benefit from the use of flocculants. This list was reviewed with the Project Steering Committee and the Dawson City Water Rights Personnel. In addition, Mr. Norm Ross, President, KPMA, of the Klondike Placer Miners Association (KPMA) was contacted at start-up of the project to discuss the study objectives.

Since the assignment was started near the end of the mining season, the majority of miners on that list had already left the area. Only nine of the original 32 were still available in the field. We, therefore, made attempts to arrange telephone interviews with the remainder to ascertain their interest in direct participation in a field demonstration program. Table 4.1 is a summary of the contacts that were made in the field. Table 4.2 is a summary of results of additional telephone interviews.

TABLE 4.1

LIST OF PLACER MINERS CONTACTED IN THE FIELD

Name	Location	Response
Hakkon Placer	Right Fork of Eureka Creek	They have no room for a large settling pond.
Ballarat/Tatlow Joint Venture	Quartz Creek	They have two operations on the creek. Their problem is too much sediment and finding a place for storage. They do not want to have to handle additional sediments through flocculants.
Tamarac Inc.	80 Pup Hunker Creek	They pump from Hunker Creek and settle sediments in dredge tailings on Hunker Creek. They do not have any room for settling facilities on 80 Pup.
Dave Johnson	French Gulch	He moved from French Gulch to Eldorado Creek during 1985. He is not experiencing any water shortage problems.
Greg Hakonson	Upper Eldorado and Chief Gulch	He recirculates and believes that he can use water with solids concentration up to 35000 ppm before he has to shut down (30 hours of operation). He does not believe that flocculants would help his operation.
Oli Lundi	Gold Bottom Creek	His is a one man operation not experiencing a water shortage. He schedules his work activities around his water availability.
Ron Johnson	Gay Gulch	He is moving from Gay Gulch to Eldorado Creek during 1986. He will be starting up his operation adjacent to the next downstream mine and therefore will not have room for settling ponds.
Murray Crockett	Sulphur Creek	He is below Daryl Morgan and Meadow Gold Placers. The three operations have a joint agreement for coordinating their sluicing and water storage activities. They also employ a joint settling pond in dredge tailings downstream of Tech Corp. A flocculant operation would not assist them.
John Gould	Nugget Hill	He has a gravity feed system with make-up water provided from Hunker Creek. He experiences water recirculation problems and advised that he would be willing to consider the flocculant demonstration program.
Queenstake	Paradise Hill	Queenstake is presently operating a recirculation system on the top of the Hill. They have experienced some handling problems with the fine sediments. They are interested in the demonstration program.
Miben Mining	Dago Hill	They recirculate from Hunker Creek with a static head of over 100 m. They want a higher flow rate at the trommel and are considering pumping from Last Chance Creek to provide the addition. They are interested in the demonstration program.

TABLE 4.2

LIST OF PLACER MINERS CONTACTED BY TELEPHONE

Name	Location	Reference* No.	Comments
Universal Exploration (Jim Simcox)	Jackson Gulch Home Stake Gulch	1	He considers that his water costs are incidental to his overall production costs. He is not interested in the program.
Sigma Properties (Gary Crawford)	Bear Creek	3	The operation includes upstream storage and two settling ponds. He considers that he has 100% recirculation; sluicing starts in June with two 10 hr shifts/day at seven days/week. He is interested in the demonstration program. He plans to be on site by 1 May 1985.
	Hester Creek	21	Ceased operations.
	Bonanza Creek	New	Plan to work next year.
	Home Stake Gulch 49 Pup (Bonanza)	New	Plan to work next year.
J. Hanulik	Hunker Creek	8	He is working in the Hunker Creek Valley and has as a low pumping head. He is not interested in the program.
M. Church	Hunker Creek	9	He is working in the white channel gravels. He does not have room for settling facilities on top of the bench as he already experiences grade problems. He prefers to pump from Miben's lower pond. He is not interested in the program.
D. Sandberg	Hunker Creek	19	He does not have any problems at his operation and therefore, is not interested in the program.
P. Erickson	Gold Bottom Creek	New	He has moved to Upper Gold Bottom near Soap Creek. He has not experienced water shortage and does not believe that his operation is appropriate for the demonstration because he is still setting-up.
I. Hamilton	Dominion Creek	46	He does not agree with the use of flocculants. He does not have room for a recirculation pond.
Tech Corp (Gerry Klien)	Sulphur Creek	64	They operate a closed system as they have enough area to provide sufficient settling for recirculation. They do not require flocculants.
Lucky Lady Placers (Lance Gibson)	Sulphur Creek	65	They do not have any water shortage problems. Their recirculation system works well. They are not interested in the program.
King Solomon Mines (Art Fry)	Bonanza Creek	106 109 111 112	He has three bench operations underway. He usually starts May 1 by clearing snow and then sluicing with spring runoff. He then pumps from Bonanza Creek for the rest of the season. He is interested in the program and is prepared to discuss it further.
C. Nicholson	Sourdough Hill Pure Gold Gulch Lovett Gulch	118	He operates these mines using a gravity feed system for spring runoff. He does not plan to operate in 1986. His problems are associated with too much water. He is not interested in the program.

* Ref. No. from 1983/84 Mining Inspectors report.

Of the operators who were contacted, five of them have indicated an interest in the flocculant demonstration program. Sluicing water or pay dirt and water samples from the water source were collected at the three sites where operators were contacted in the field - John Gould, Queenstake and Miben Mining. The other two sites could not be visited - King Solomon Mines and Sigma Properties. However, these latter operations are scheduled for start-up in May 1986; therefore, sampling and jar testing could be carried out during the month of May if these two operations were considered for the 1986 demonstration program.

4.2 SITE DESCRIPTIONS

The three operations visited are all working the white channel gravels above Hunker Creek. The locations of these operations are shown on Figure 4.1 The following are brief descriptions of each mine.

4.2.1 John Gould - Nugget Hill

The John Gould operation on Nugget Hill is a family type operation. In fact, the property has been in Mr. Gould's family since 1903. The mine, located approximately 100 m above Hunker Creek, sluices white channel gravels. A site plan of the Gould mine is illustrated in Figure 4.2.

The primary source of water is a diversion ditch and storage reservoir from Independance Creek. This source provides the operation with sufficient water for sluicing up until about mid June. At that time, the operator commences to recirculate from the settling pond system and as needed, obtains make-up water from Hunker Creek (Figure 4.2).

When the operator is recirculating, he can only operate for five hours per day because of a sediment build-up in the system which hinders the sluicing operation. The operator anticipates that flocculants could be of assistance to help him sluice for longer periods each day.

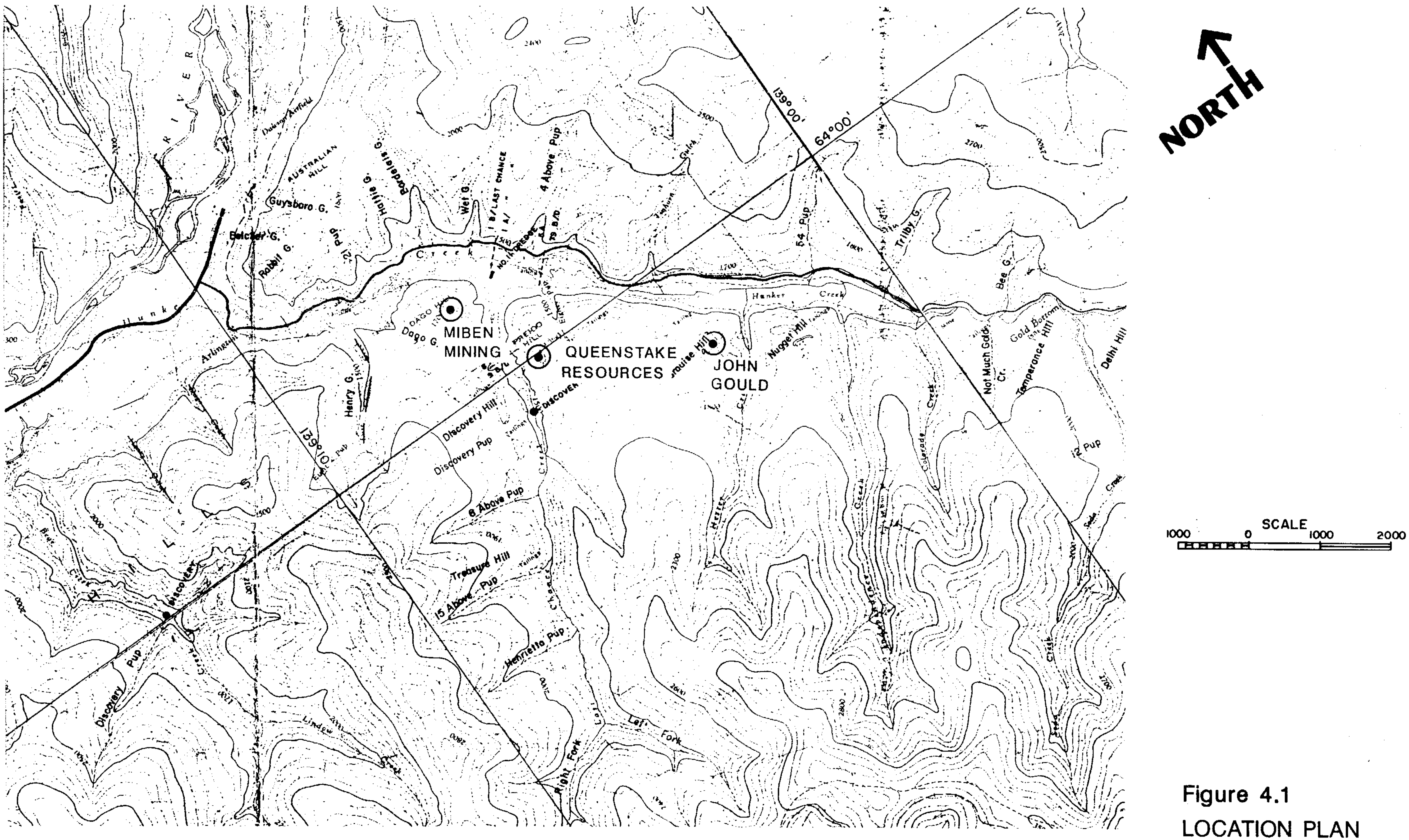


Figure 4.1
LOCATION PLAN

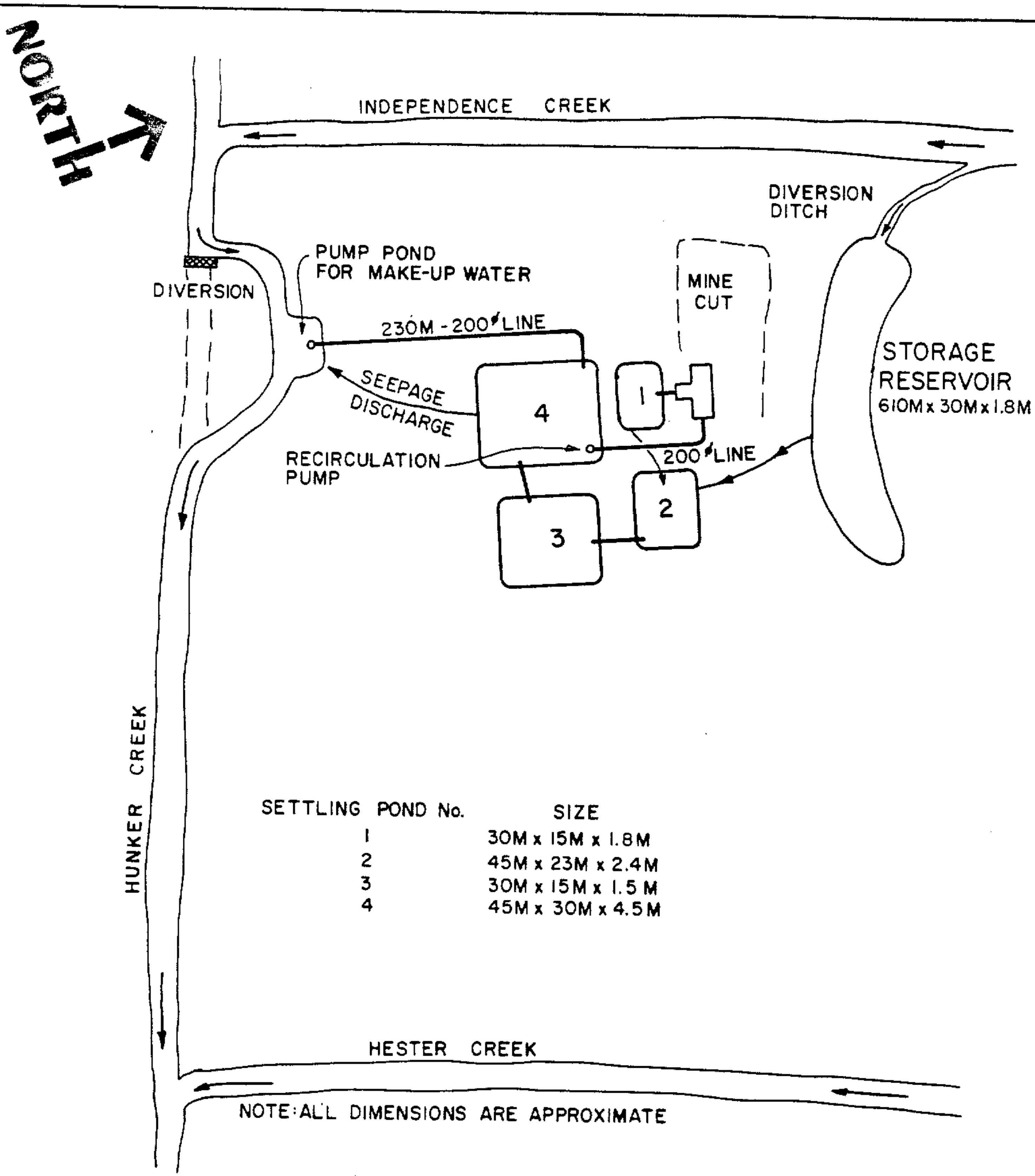


Figure 4.2
JOHN GOULD MINE SITE PLAN

On-site equipment includes a TD 25C bulldozer to strip overburden, a John Deere 350 B loader, and a Cat 930 rubber tired loader to feed the sluice box and to remove tailings. A monitor is also used on site to wash the gravel face and to help segregate the larger material before sluicing. His estimated feed rate is 38 to 45 m^3/hr (50-60 yds^3/hr) of paydirt and a sluice water pumping rate of 16 m^3/min (3500 igpm).

Water samples were taken from the pumping pond. The operation had stopped sluicing four days prior to collection of the sample. Pay gravel samples were taken and a grain size distribution analysis completed (Figure 4.3).

4.2.2 Queenstake - Priedo Hill

The Queenstake mine operated for 90 days during 1985 and an 80-day two-phase operation is planned for 1986. A site plan is illustrated in Figure 4.4. Their operation consists of a trommel with a feed rate of 53 to 91 m^3/hr (70 to 120 yds^3/hr) and a sluice water pumping rate of 4 m^3/min (850 igpm). The trommel separates all gravels above 12.5 mm (0.5 inch). A front end loader operates in the first pond removing the sand sizes. A drag line operates in the second pond removing the finer sands and silts. A third and fourth pond are used for settling of the fines.

A decant system and sludge pumps operate from these ponds to remove the settleable material. This decant and sludge water are deposited into a final settling pond in the Last Chance Creek Valley.

The pump feeding the trommel draws water from the fourth pond. Make-up water is pumped from a storage dam on Last Chance Creek. The operation was sluicing at the time of the visit and samples of sluicing water were collected.

The on-site equipment includes a Hough 100C loader, a Cat 980 B loader, a Lima 1 yd^3 dragline, two sludge pumps and a 120 yd^3/hr trommel which includes a duplex 24 inch Yuka jig.

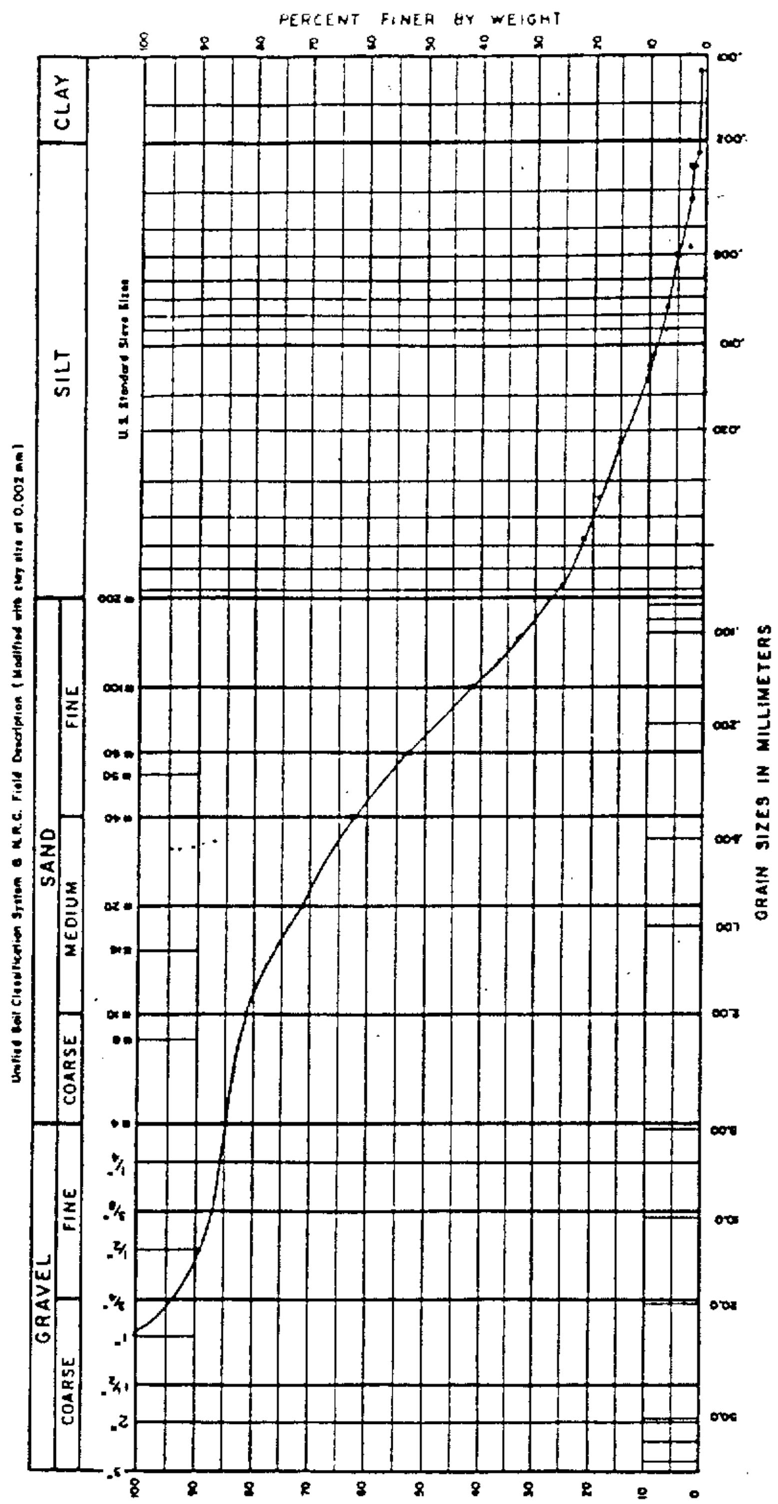
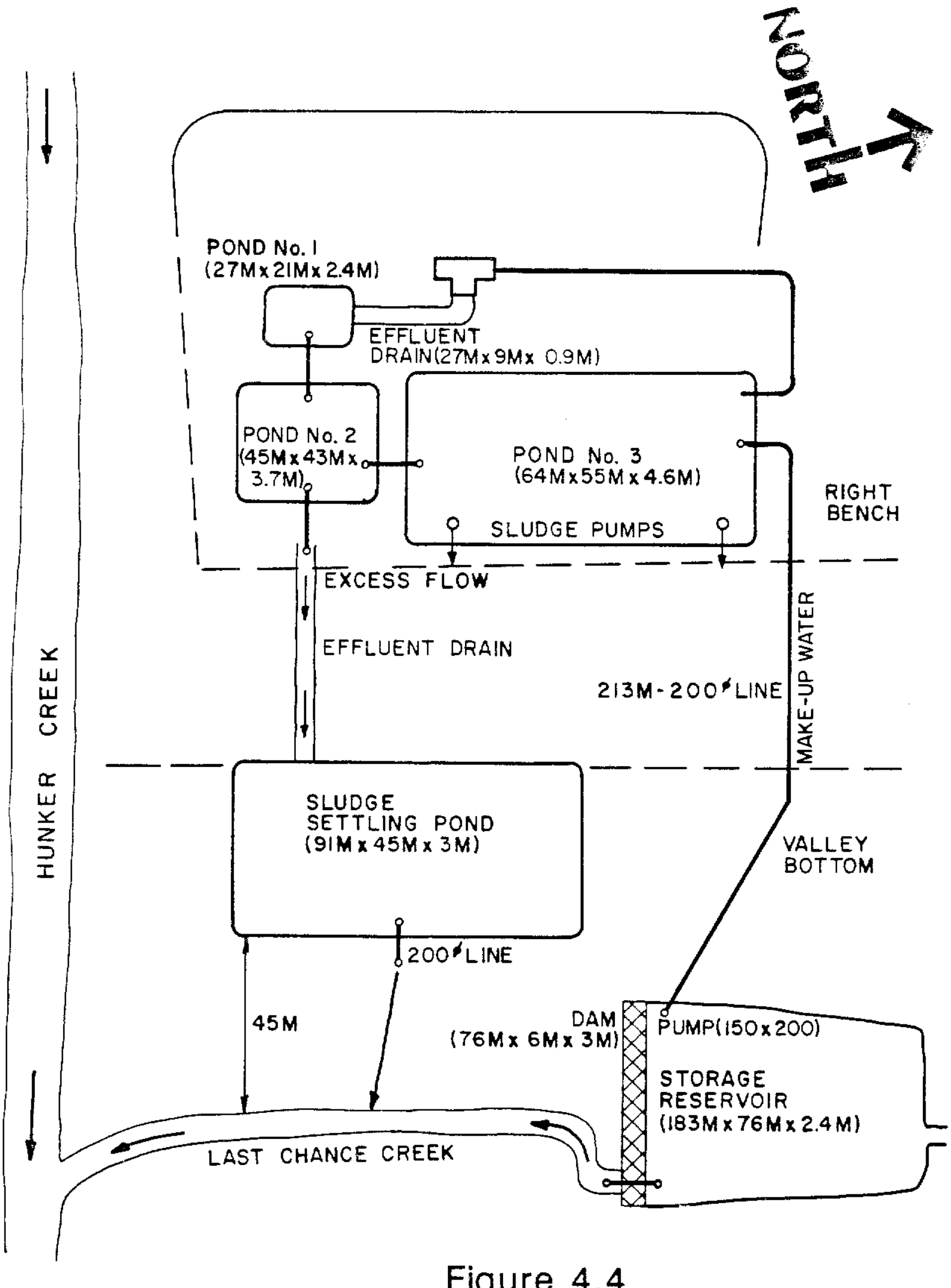


Figure 4.3

JOHN GOULD PAY GRAVEL
GRAIN SIZE DISTRIBUTION



NOTE: ALL DISTANCES ARE APPROXIMATE

Figure 4.4
QUEENSTAKE RESOURSES
LAST CHANCE CREEK

The operators have shown an interest in the demonstration project. Increased recirculation with their existing operating arrangement would be their goal

4.2.3 Miben Mining

The Miben mine is also working the white channel gravels at an elevation of approximately 100 m above Hunker Creek (Figure 4.5). The operation pumps directly from a settling pond on Hunker Creek to a trommel at the site. The water feed rate from this settling pond is 18 m^3/min (4000 igpm). A sand screen at the end of the trommel provides for recirculation of 3 m^3/min (600 igpm) of sluice water. The objective water feed rate for the trommel is 23 min^3/min (5000 igpm). They are presently able to operate only at 21 m^3/min (4600 igpm) and are considering the pumping of water from Last Chance Creek to make up the shortage.

At the current site, there is an estimated paydirt volume of 228,000 m^3 still remaining. This will be sluiced over the next two years. They use a conveyor system to stack any tailings greater than 19 mm (0.75 in) plus a sand screw to collect the sand sizes between 12 mm and 19 mm (0.5 to 0.75 in). They estimate that 55% of the tailings will be handled by the conveyor. Therefore the remaining tailings - 103,000 m^3 (135,000 yds^3) - will be discharged with the sluice water from the trommel.

The operator was interested in reviewing a proposed project because of the possible efficiencies and cost reductions to this operation. The provision of a settling system located on the bench near the trommel would allow for a recirculation system that would have reduced pumping costs while also meeting the total water demands.

The on-site equipment includes a D9 Cat, a 992 B Loader, a D8K Cat, a D824 B rubber tired loader, and a trommel.

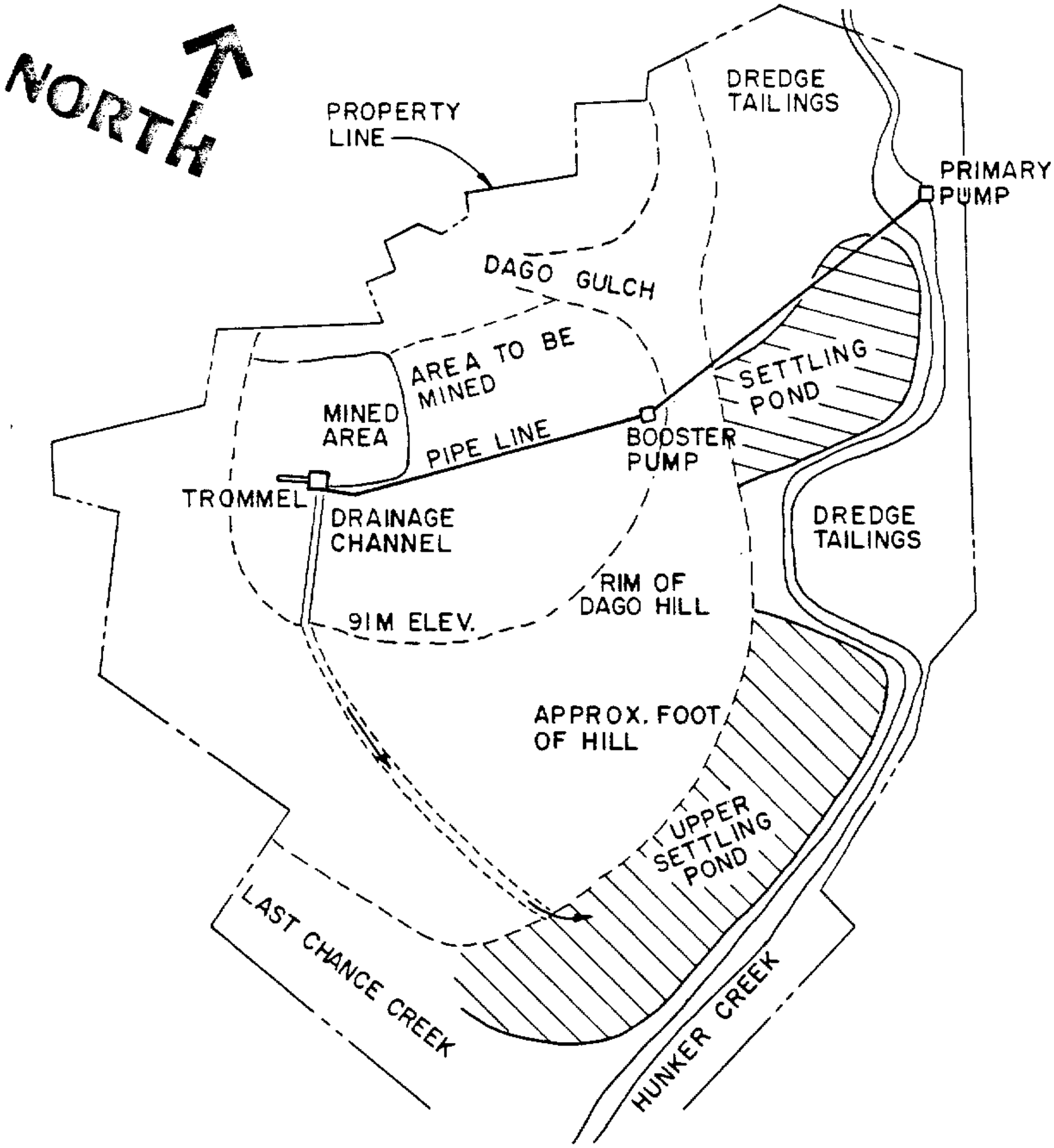


Figure 4.5
MIBEN MINING-HUNKER CREEK

The operation had shut down for the season prior to the site visit. A sample was taken of the pay gravels and the effluent from the pumping pond. A grain size analysis was completed on the pay gravels. (Figure 4.6).

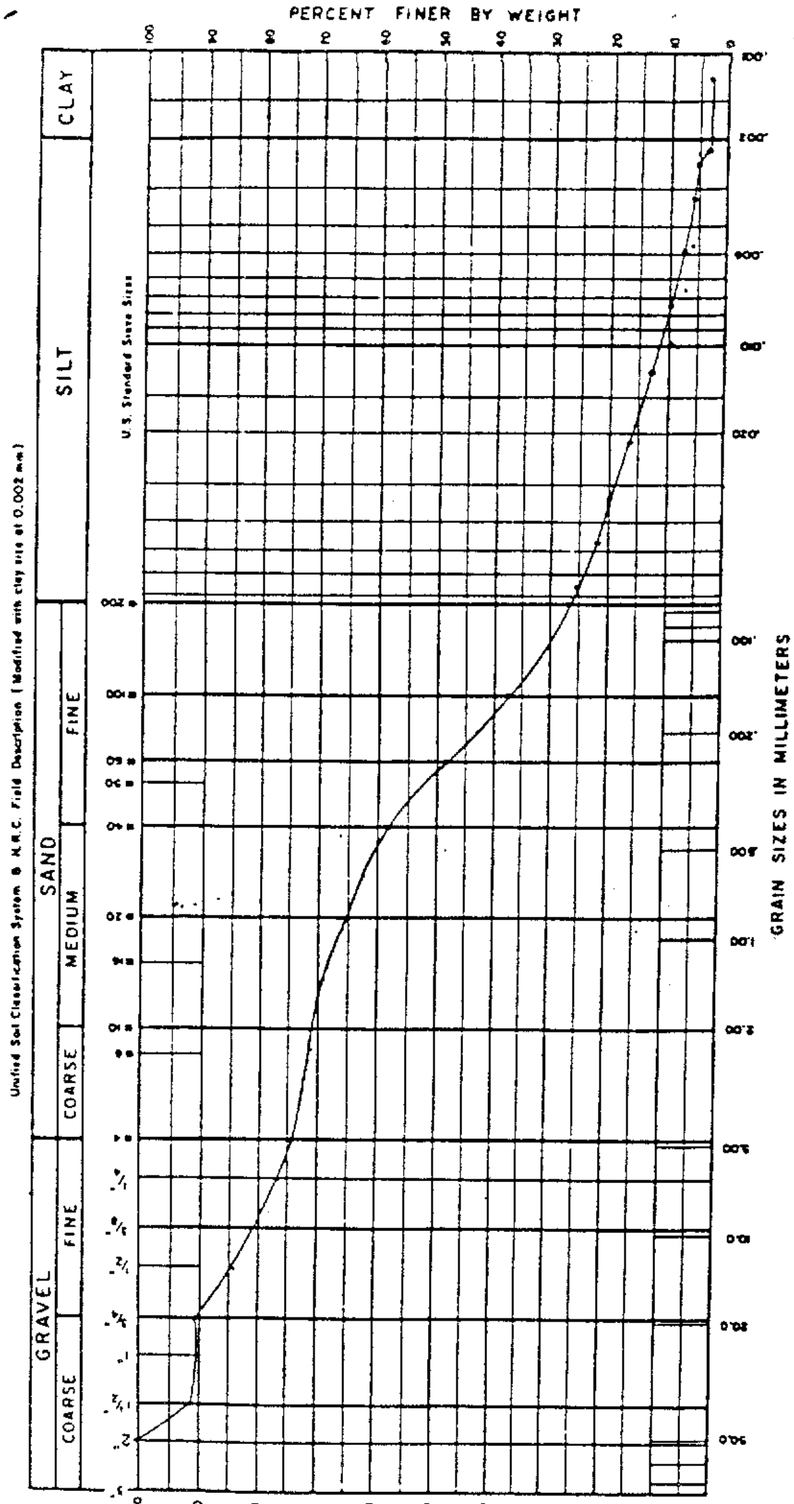


Figure 4.6

MIBEN MINING PAY GRAVEL GRAIN SIZE DISTRIBUTION

5.0 POLYMER SELECTION AND OPTIMIZATION PROGRAM

5.1 INTRODUCTION

A jar test program was used in this study to define the optimum polymer for each wastewater. This was followed by further testing of the optimum polymer to define the effect of mixing conditions and suspended solids concentration on polymer performance. The results of these jar tests are discussed in the following subsections. The actual jar test results are included in Appendix II.

5.2 POLYMERS TESTED

Polymer selection was based on previous experience with flocculant treatment of placer mining wastewaters (Stanley 1985). Four distinct types of polymers were included: solid grade polyacrylamides, liquid dispersion polymers, emulsion polymers and liquid grade cationic polymers. The polymers were supplied by two manufacturers -Allied Colloids (Canada) Ltd. and Alkaril Chemicals Ltd. The use of Allied and Alkaril products does not imply that polymers from other manufacturers would not be equally effective for these applications.

The characteristics of the eleven polymers which were included in the test program are summarized in Table 5.1. Manufacturers' data sheets for each of these products are included in Appendix I of the report.

In the following subsections, a brief description of the characteristics of each type of polymer is presented.

TABLE 5.1

CHARACTERISTICS OF POLYMERS INCLUDED IN TEST PROGRAM

Polymer	Manufacturer	Type	State	Charge Density	Molecular Weight	Cost ($/kg)
PERCOL 351	Allied	Nonionic	Solid	-	High	3.10
PERCOL 155	Allied	Anionic	Solid	Medium	High	3.10
PERCOL 80L	Allied	Nonionic	Dispersion	-	High	2.80
PERCOL 110L	Allied	Anionic	Dispersion	Medium	High	2.80
PERCOL 120L	Allied	Anionic	Dispersion	High	High	2.80
ALKAFLOC EN-503	Alkaril	Nonionic	Emulsion	-	Ultra-High	2.30
ALKAFLOC EA-533	Alkaril	Anionic	Emulsion	Low	Very-High	2.30
ALKAFLOC EA-553	Alkaril	Anionic	Emulsion	Medium	Very-High	2.30
MAGNAFLOC LT31	Allied	Cationic	Liquid	High	Low	2.00
PERCOL LT35	Allied	Cationic	Liquid	High	Low	2.00
ALKAFLOC D-51181	Alkaril	Cationic	Liquid	High	Medium	2.00

*Polymer costs are F.O.B. supplier, as of October 1985. Costs vary depending on lot sizes.

5.2.1 Solid Grade Polyacrylamides

Solid grade polyacrylamides have been most widely evaluated for the treatment of placer mining wastewaters and they were successfully applied during the 1984 full-scale demonstration study conducted in the Yukon (Stanley, 1985). These polymers are marketed as a dry powder and require dissolution, aging and dilution prior to application. The requirement to provide a solid feed system and polymer dissolution/dilution system was identified as an implementation problem during the 1984 demonstration studies and one of the prime goals of the present jar testing program was to identify polymers which could be applied in the field with a simpler delivery system. The solid grade polyacrylamides were included in the test program to allow a comparison of the treatability characteristics of the wastewaters from the three sites selected for this program with those evaluated during the 1984 program.

As indicated in Table 5.1, two solid grade polyacrylamides were included in the polymer testing program. Percol 155 is a medium charge anionic polyacrylamide while Percol 351 is a nonionic polyacrylamide. These two polymers were selected because of their successful performance during the 1984 studies and in other placer mining wastewater treatability investigations conducted by Environment Canada.

5.2.2 Liquid Dispersion Polymers

Dispersion polymers represent a concentrated liquid form of flocculants in the form of micro-bead sized particles of solid polymer dispersed in a mineral oil. These polymers, provided by Allied Colloids, are produced in 50% active form. They have the advantage of eliminating the solid feed system associated with the solid grade polymers; however, since they are not true liquids, they still require dilution and aging prior to application. Therefore, some polymer preparation equipment would be necessary to prepare the polymer solution on site.

Three Allied Colloids liquid-dispersion polymers were included in the test program, as shown in Table 5.1. Percol 80 L is a nonionic polymer similar in characteristics to Percol 351. Percol 110 L is an anionic polymer with a charge density midrange between Percol E10, which was not tested in this program but was found successful during the 1984 program, and Percol 155. Percol 120 L is also an anionic polymer, with a slightly higher charge than Percol 155.

5.2.3 Emulsion Polymers

Emulsion polymers represent a slightly different approach to providing polyacrylamides in concentrated liquid form. In these products, the small particles of solid polymer are dispersed in a water-oil emulsion. The active content of emulsion polymers is lower than that of liquid dispersion polymers, typically in the range from 25 to 35 percent. As with the liquid dispersion polymers, emulsion polymers require dilution and aging prior to application.

Three emulsion polymers, supplied by Alkaril Chemicals Ltd., were included in the test program. Alkafloc EN-503 is a nonionic product, while Alkafloc EA-533 and EA-553 are anionic products of low and medium charge density respectively.

5.2.4 Cationic Polymers

Cationic coagulants can be supplied as true liquids of high active polymer content. These coagulants represent the simplest systems because they can be applied directly to the wastewater as shipped in concentrated liquid form. Some efficiency is lost if the polymer is not diluted prior to application but the loss in polymer efficiency is compensated by the simplicity and low cost of the chemical feed system.

Cationic coagulants have been shown to be toxic to fish in the as-received form. The toxicity is related to the affinity of the polymer for the fish gills. However, in situations where the cationic coagulant is added to a wastewater containing suspended particulate matter, the particulate matter, which has a high affinity for the cationic polymer molecule, readily absorbs the polymer. Cationic coagulants are also typically less expensive than anionic polyacrylamides but produce a less dense, slower settling floc.

Three liquid cationic coagulants were evaluated during the test program. Magnafloc LT31 is a high charge, low toxicity, 50 percent active product approved in the United Kingdom for potable water use. Percol LT35 is a similar high charge, low toxicity 40 percent active product which has been approved for potable water use by the U.S. EPA. Alkafloc D-51181 is a medium molecular weight, high cationic charge density, 20% active polyelectrolyte.

5.3 WASTEWATER SAMPLE PREPARATION

The type of sample which was used for jar testing varied depending on the situation at each site at the time of the site visits. At Queenstake, a sample of actual sluicewater was collected from the sluice tailrace. This raw wastewater sample contained a suspended solid concentration of approximately 20,000 mg/l. To simulate the removal of fine sand and silt which would be expected in a primary settling pond upstream of the point of polymer addition, the sluicewater sample was settled for 20 minutes and the supernatant decanted to provide the wastewater sample for jar testing. The settled sluicewater sample contained approximately 5600 mg/l of suspended solids. At the Miben and Gould sites, sluicing was not being done at the time of the site visit. Therefore, samples of the raw water used for sluicing and of the site paydirt were collected so that simulated sluicewater could be prepared for purposes of jar testing. In these cases, water and paydirt were mixed in proportion to the rates used at the site. For Miben, the water-to-paydirt ratio used was 10:1 by volume while at the Gould site it was 18:1 by volume. To simulate removal of sand and silt in primary ponds, the simulated sluicewater samples were settled for 20 minutes to produce the wastewater sample used for jar testing. In the case of the Miben site, this procedure produced a simulated wastewater containing approximately 3,000 mg/L total suspended solids. The simulated wastewater sample for the Gould site contained approximately 3500 mg/L suspended solids.

Characteristics of the new sluicewaters and settled wastewaters used for jar testing are summarized in Table 5.2.

TABLE 5.2

CHARACTERISTICS OF SITE WASTEWATER SAMPLES

Type	Sample Type	Water: Paydirt Ratio	Total Suspended Solids (mg/l) Unsettled Sample	Settled Sample*
QUEENSTAKE	Actual	-	20,000	5,580
MIBEN	Simulated	10:1	34,300	3,030
GOULD	Simulated	18:1	34,600	3,480

*Settled sample represented the raw wastewater used for jar testing.

5.4 JAR TEST RESULTS

5.4.1 Selection of Optimum Polymer

The polymer selection tests involved a series of jar tests at dosages up to approximately 3 mg/l for each of the eleven polymers included in the selection program. These tests were all conducted under identical conditions of mixing and settling. Final polymer selection for each site was based on the cost-effectiveness of each polymer to achieve a residual suspended solids concentration of 100 mg/L. A cost factor (C.F.) equal to the product of the polymer cost (C, $/kg) and the polymer dosage (D, mg/L) was used to quantify the cost-effectiveness of each polymer tested.

In addition to the individual polymer tests, the effectiveness of a combination of cationic and anionic polymers was evaluated at each site. For these tests, the most cost-effective cationic polymer was combined with the most effective liquid (emulsion or dispersion) anionic polymer over a range of dosages. During these tests, the cationic polymer was added first and the anionic polymer was added after the initial appearance of floc.

5.4.1.1 Queenstake

The results of the jar tests evaluating the individual polymers at the Queenstake site are summarized in Table 5.3. These data are presented graphically in Figure 5.1. For the Queenstake site, two of the three liquid cationic products, LT35 and D-51181 were extremely effective in reducing the wastewater suspended solids concentration to low levels. For some reason, the third cationic product, LT31, was totally ineffective. The liquid dispersion Percol products were more effective than the emulsion Alkafloc products under the test conditions. In order to conserve the sample, Percol 80L was not tested with the Queenstake effluent.

Of the two solid grade polyacrylamides, the anionic product, Percol 155, performed better than the nonionic product, Percol 351. The performance of Percol 155 on the Queenstake wastewater was better than it had been during the 1984 testing at the Airgold site (Stanley, 1995). For the Airgold wastewater, a dosage of 4.5 mg/l of Percol 155 was required to achieve a residual suspended solid concentration of 100 mg/L, compared to a dosage of approximately 1.6 mg/l for the Queenstake sample. The Queenstake sample initially contained a lower suspended solids concentration than the Airgold wastewater. It also settled to a relatively low suspended solid concentration without polymer addition (550 mg/l), possibly indicating the presence of a higher concentration of larger particle sizes in the paydirt.

Polymer efficiency and cost factors for each polymer evaluated on the Queenstake wastewater are summarized in Table 5.4. The two cationic products had significant cost advantages over the other products tested. Of the anionic products, Percol 110L was most cost-effective and out-performed the solid grade polymers on a cost basis despite the lower concentration of active polymers in the product. However, none of the 'liquid' polymers produced as good a floc as the solid grade anionics. The cationic coagulants and emulsion/dispersion flocculants typically produced a smaller, slower settling floc than the solid grade anionics and resulted in a larger volume of settled sludge after jar testing.

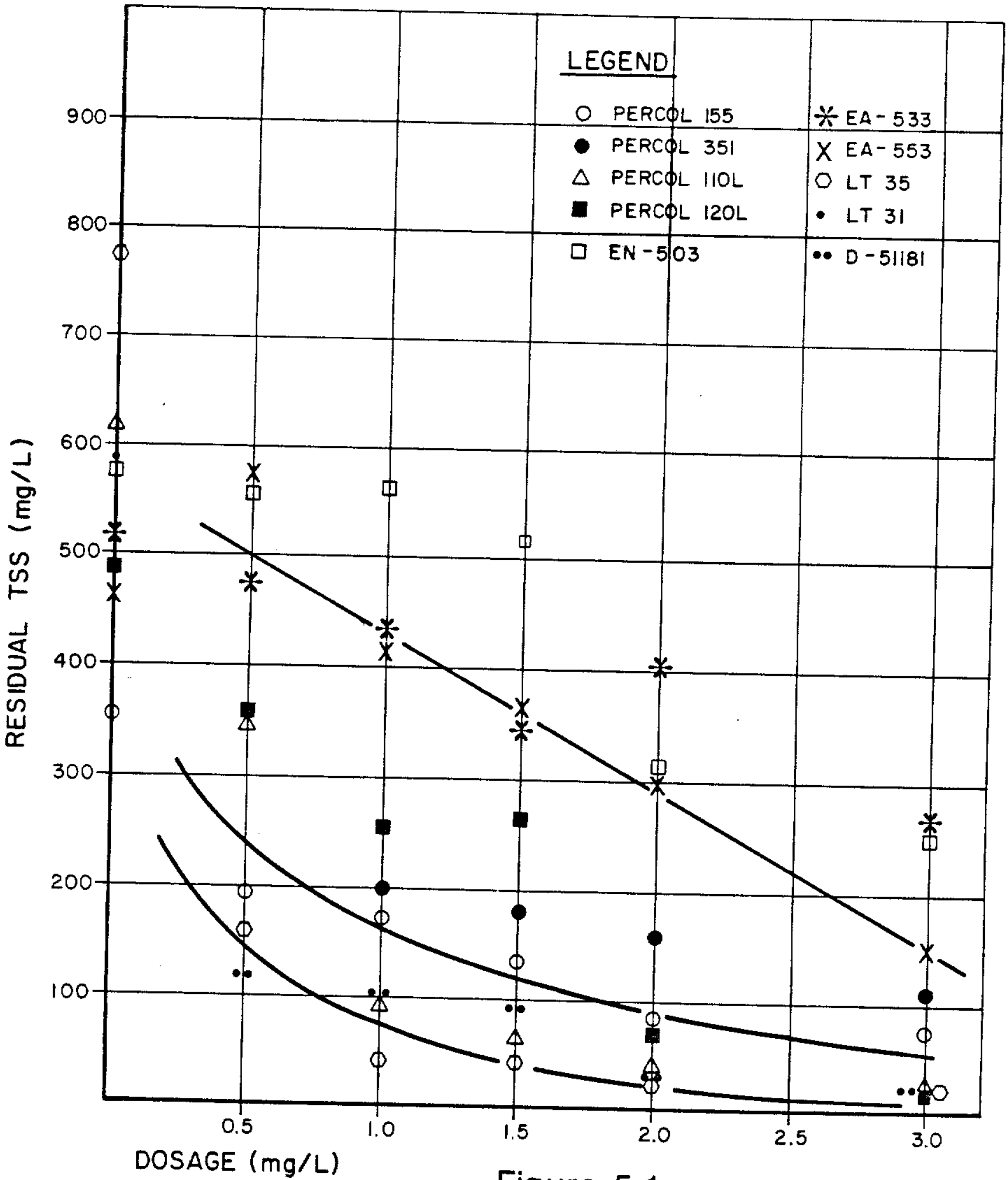
TABLE 5.3

RESULTS OF POLYMER SELECTION TESTS - QUEENSTAKE SITE

Polymer	Residual TSS Concentration at Various Polymer Dosages					
	0.0	0.5	1.0	1.5	2.0	3.0
PERCOL 155	355	195	172	136	80	74
PERCOL 351	-	-	200	180	160	110
PERCOL 80L	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
PERCOL 110L	620	350	95	66	40	26
PERCOL 120L	490	355	256	265	70	20
EN-503	580	560	565	520	310	250
EA-533	520	475	430	350	405	260
EA-553	466	575	415	365	300	150
LT35	780	164	44	44	30	20
LT31	590	700	905	795	685	545
D-51181	-	120	100	95	30	25

Notes:

1) All units in mg/l
2) Average 'blank' concentration = 550 mg/l (± 125)
3) N.T. = Not tested.



NOTE - PERCOL 80L NOT TESTED.
- LT 31 WAS INEFFECTIVE, DATA NOT PRESENTED.

Figure 5.1

RESULTS OF POLYMER SELECTION TESTS - QUEENSTAKE SITE

TABLE 5.4

COMPARISON OF POLYMER EFFICIENCIES - QUEENSTAKE SITE

Polymer	Polymer Type	Approximate Dosage to Achieve 100 mg/l TSS	TSS Concentration at 3.0 mg/l Dosage	Approximate Cost Factor
PERCOL 155	S,A	1.6	74	5.0
PERCOL 351	S,N	3.5	110	10.9
PERCOL 80L	D,N	N.T.	N.T.	N.T.
PERCOL 110L	D,A	0.9	26	2.5
PERCOL 120L	D,A	1.8	20	5.0
EN-503	E,N	4.0	250	9.2
EA-533	E,A	4.0	260	9.2
EA-553	E,A	3.3	150	7.6
LT35	L,C	0.7	20	1.4
LT31	L,C	N.A.	545	N.A.
D-51181	L,C	1.0	25	2.0

Notes:

1) Legend:
   S - Solid Grade   N - Nonionic
   D - Dispersion   A - Anionic
   E - EmulsionC   C - Cation
   L - Liquid

2) Cost Factor (C.F.) = (Dosage to 100 mg/l) x (Cost, $/kg).

3) N.T. = Not Tested

4) N.A. = Not Achieved

Based on the results of the individual polymer tests, the efficiency of the cationic product LT 35 with the liquid dispersion anionic product Percol 110L was evaluated at a range of dosages lower than the individual dosages required to achieve a supernatant quality of 100 mg/l. As summarized in Table 5.5, all conditions produced a supernatant quality of less than 100 mg/l TSS. However, the combined polymer treatment did not improve the floc characteristics in terms of floc size or settling rate and the settled sludge volume actually increased compared to that produced by either polymer individually.

TABLE 5.5
RESULTS OF COMBINED CATIONIC/ANIONIC
COAGULATION OF QUEENSTAKE WASTEWATER

Dosage (mg/l)		Supernatant Quality	
LT35	PERCOL 110L	TSS (mg/l)	Turbidity (NTU)
0.5	0.25	55	35
	0.50	50	29
	0.75	40	24
0.75	0.25	45	25
	0.50	20	16
	0.75	17	20

5.4.1.2 Miben

The results of the jar tests evaluating the individual polymers at the Miben site are summarized in Tables 5.6 and 5.7, and illustrated in Figure 5.2. In an effort to conserve sample volume, the solid grade anionic Percol 155 was not evaluated.

TABLE 5.6

RESULTS OF POLYMER SELECTION TESTS - MIBEN SITE

Polymer	Residual TSS Concentration as Function of Dosage								
	0.0	0.1	0.25	0.50	0.75	1.0	1.5	2.0	3.0
PERCOL 155	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
PERCOL 351	500	-	-	180	-	40	40	12	8
PERCOI 80L	300	-	-	150	-	100	60	20	20
PERCOL 110L	140	120	85	8	4	-	-	-	-
PERCOL 120L	545	232	160	80	12	8	-	-	-
EN-503	-	-	356	250	160	85	80	-	-
EA-533	-	-	392	240	112	52	56	-	-
EA-553	-	-	205	145	110	40	15	-	-
LT35	-	-	128	68	40	28	-	-	-
LT31	572	-	424	364	324	360	320	-	-
D-51181	-	280	175	68	18	10	-	-	-

Notes:

1) Average 'blank' concentration = 479 mg/l (± 123)
2) N.T. = Not Tested.
3) All units are in mg/l.

TABLE 5.7

COMPARISON OF POLYMER EFFICIENCIES - MIBEN SITE

Polymer	Polymer Type	Approximate Dosage to Achieve 100 mg/l TSS	TSS Concentration at 1.0 mg/l Dosage	Approximate Cost Factor
PERCOL 155	S,A	N.T.	N.T.	N.T.
PERCOL 351	S,N	0.7	40	2.2
PERCOL 80L	D,N	1.0	100	2.8
PERCOL 110L	D,A	0.4	4	1.1
PERCOL 120L	D,A	0.4	8	1.1
EN-503	E,N	0.9	85	2.1
EA-533	E,A	0.8	52	1.8
EA-553	E,A	0.8	40	1.8
LT35	L,C	0.4	28	0.8
LT41	L,C	N.A.	360	N.A.
D-51181	L,C	0.4	10	0.8

Notes:

1) Legend:
   S - Solid Grade　N - Nonionic
   D - Dispersion　A - Anionic
   E - Emulsion　C - Cationic
   L - Liquid

2) Cost Factor (C.F.) = (Dosage to 100 mg/l) x (Cost, $/kg).

3) N.T. = Not Tested.

4) N.A. = Not Achieved.

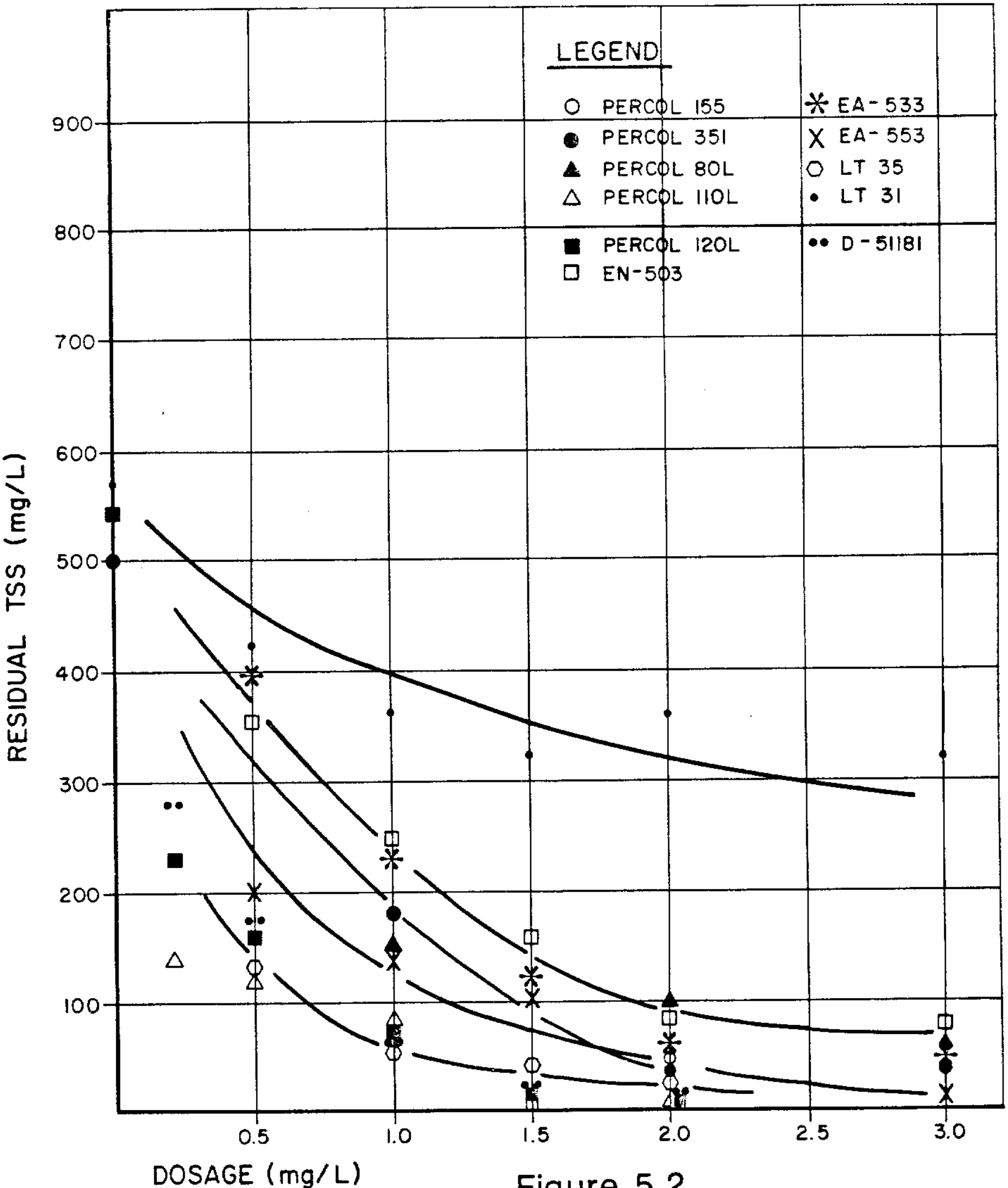


Figure 5.2

RESULTS OF POLYMER SELECTION TESTS – MIBEN SITE

As had been the case for the Queenstake wastewater, two of the liquid cationic products, LT35 and D-51181, performed extremely well while the third product, LT31, was ineffective. The dosage requirements of LT35 and D-51191 to achieve 100 mg/l TSS were less than 0.5 mg/l. All of the anionic/nonionic products also performed well for the Miben site wastewater, achieving the goal of 100 mg/l suspended solids at dosages of 1.0 mg/l or less. Based on the simulated wastewater sample produced, the Miben wastewater was treatable at significantly lower chemical dosages than the Queenstake wastewater despite the similar raw wastewater and blank suspended solid concentrations. Cost factors for each individual polymer evaluated are summarized in Table 5.7. The liquid cationic products had a marginal cost advantage over the emulsion/dispersion flocculants. Of the liquid anionic/nonionic products, the dispersion products Percol 110L and 120L had a slight cost advantage over the best emulsion products EA-533 and EA-553. The nonionic products did not perform as well as the anionic products.

As was the case for the Queenstake wastewater, the solid grade polyacrylamide produced the largest, fastest settling floc. Floc produced by the cationic products tended to be the smallest and slowest settling. The combination of cationic LT35 with dispersion anionic 110L did not improve the settling characteristics of the wastewater significantly over the individual polymers. However, as summarized in Table 5.8, all dosage conditions, down to as low as 0.2 mg/l of LT35 in combination with 0.1 mg/l of 110L, produced a clear supernatant containing 5 mg/l TSS or less.

TABLE 5.8
RESULTS OF COMBINED CATIONIC/ANIONIC
COAGULATION OF MIBEN WASTEWATER

Dosage (mg/l)		Supernatant Quality	
LT35	PERCOL 110L	TSS (mg/l)	Turbidity (NTU)
0.2	0.1	5	3
	0.2	5	4
	0.3	5	3
0.4	0.1	5	3
	0.2	5	2
	0.3	5	1

5.4.1.3 Gould

The results of jar tests on wastewater from the Gould site are summarized in Table 5.9 and shown graphically in Figure 5.3. The treatability characteristics of this wastewater were similar to those of the wastewater from the Airgold site evaluated during the 1984 testing program (Stanley, 1985). Dosages of solid grade polyacrylamides (Percol 155 and Percol 351) required to achieve a residual suspended solids concentration were approximately 2.5 mg/L. The TSS concentration in the blank samples carried through the jar test procedures without polymer addition were significantly higher (1805 mg/L) than the comparative blanks from the Queenstake (550 mg/L) and Miben (479 mg/L) sites.

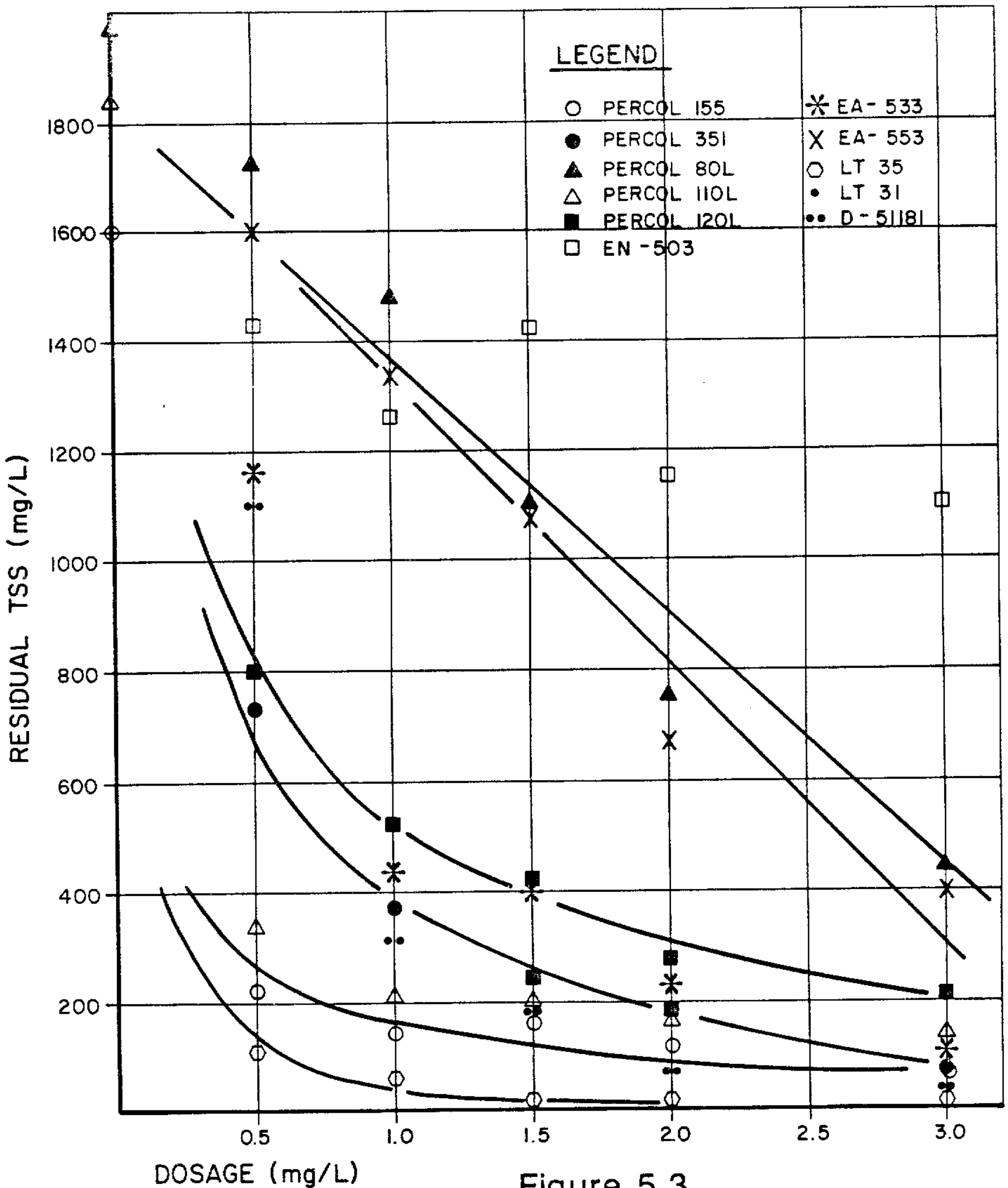
The liquid cationic products LT35 and D-51181 outperformed the solid grade and liquid anionic/nonionic products in terms of dosage requirements to achieve a residual TSS concentration of 100 mg/L. The anionic/nonionic products all required dosages in the range of 2.5 to 4.0 mg/L to achieve this degree of treatment; an exception to this was the nonionic emulsion flocculant EN-503 which was ineffective in coagulating this sample. Liquid cationic LT31 was also ineffective witn this wastewater.

TABLE 5.9
RESULTS OF POLYMER SELECTION TESTS-GOULD SITE

Polymer	Residual TSS Concentration as Fuction of Dosage					
	0.0	0.5	1.0	1.5	2.0	3.0
PERCOL 155	1600	212	144	156	112	65
PERCOL 351	-	730	370	240	180	65
PERCOL 80L	-	1730	1480	1100	750	440
PERCOL 110L	1840	340	210	200	184	145
PERCOL 120L	-	800	520	420	280	210
EN-503	-	1430	1260	1420	1150	1100
EA-533	-	1170	440	410	230	110
EA-553	-	1600	1340	1080	670	400
LT35	-	108	65	20	10	65
LT31	1975	2810	2360	2250	2180	2410
D-51181	-	1100	310	190	70	30

Notes:
1) All units in mg/L
2) Average 'blank' concentration = 1805 mg/L (± 190)

Stanley



NOTE: LT 31 WAS TOTALLY INEFFECTIVE AND IS NOT PRESENTED.

Figure 5.3

RESULTS OF POLYMER SELECTION TESTS - GOULD SITE

The efficiencies of the individual polymers are compared in Table 5.10. Cationic LT35 had a significant dosage and cost advantage over all other products under the test conditions. The dosage requirement of LT35 to achieve a residual TSS of 100 mg/L was only one-third of the dosage of the nearest competitor. As was the case with the wastewaters from the other two sites, the solid grade anionic/nonionic products produced the largest, most rapidly settling floc. The floc produced by the cationic products was small and slow settling and resulted in a significantly higher settled sludge volume than the solid grade products.

The most cost effective anionic product (EA-533) was combined with cationic LT35 to determine if the floc characteristics produced by the cationic product alone could be improved. The results of the combined treatment are presented in Table 5.11. At the lowest dosages evaluated (0.3 mg/L LT35 and 0.4 mg/L EA-533), a supernatant TSS concentration of less than 100 mg/l was achieved. On a qualitative basis, floc size and settling rates were improved by the combined treatment approach.

TABLE 5.10

COMPARISON OF POLYMER EFFICIENCIES - GOULD SITE

Polymer	Polymer Type	Approximate Dosage to Achieve 100 mg/l TSS	TSS Concentration at 3.0 mg/l Dosage	Approximate Cost Factor
PERCOL 155	S,A	2.5	65	7.8
PERCOL 351	S,N	2.6	65	8.1
PERCOL 80L	D,N	3.5	440	9.8
PERCOL 110L	D,A	3.4	145	9.5
PERCOL 120L	D,A	4.0	210	11.2
EN-503	E,N	NA	1100	NA
EA-533	E,A	3.1	110	7.1
EA-553	E,A	3.2	400	7.4
LT35	L,C	0.6	5	1.2
LT31	L,C	NA	2400	NA
D-51181	L,C	1.8	30	3.6

Notes:

1) Legend: S - Solid Grade, D - Dispersion, E - Emulsion, L - Liquid; N - Nonionic, A - Anionic, C - Cationic

2) Cost Factor (C.F.) = (Dosage to 100 mg/l) x (Cost,$/kg).

3) NT = Not Tested.

4) NA = Not Achieved.

TABLE 5.11

RESULTS OF COMBINED CATIONIC/ANIONIC COAGULATION OF GOULD WASTEWATER

Dosage (mg/L)		Supernatant Quality	
LT35	EA-533	TSS (mg/L)	Turbidity (NTU)
0.3	0.5	53	37
	0.75	47	34
	1.0	42	30
0.6	0.5	19	13
	0.75	17	11

5.5 OPTIMIZATION OF POLYMER PERFORMANCE

The polymer optimization tests focussed on the impact of flash mixing conditions (intensity and time) and dosage on polymer efficiency. Based on the results of the polymer screening tests, one polymer product was selected for optimization at each site. A fractional factorial experimental design was prepared which involved the evaluation of these variables in four experimental jar tests for each site. The variables of interest were:

1. Mean Velocity Gradient (G_R) for Flash Mixing;
2. Flash Mix Time (t_R);
3. Polymer Dosage (D);

Sample volume constraints precluded optimization of flocculation conditions (intensity and time); therefore, flocculation conditions were standardized at 20 RPM for 10 minutes for all tests.

Each of the three variables (G_R, t_R and D) was evaluated at an upper and a lower level. In addition, replicate tests were conducted at the mid-level of each variable to establish the error associated with the test procedure. The selected levels of each variable for each site are summarized in Table 5.12. Mixer speed

(RPM) was used as a measure of mean velocity gradient, G_R. This speed was converted to a velocity gradient with calibration curves developed by Lai et al (1975) for Phipps and Bird jar test equipment.

TABLE 5.12
LEVELS OF VARIABLES EVALUATED IN POLYMER OPTIMIZATION TESTS

Variable	Lower Level	Midpoint	Upper Level
Flash Mix Speed (RPM)	50.0	75.0	100.0
Flash Mix Time (seconds)	30.0	45.0	60.0
Dosage (mg/L)			
Queenstake (LT35)	0.5	0.7	0.9
Miben (110L)	0.2	0.4	0.6
Gould (LT35)	0.4	0.6	0.8

For the Queenstake and Gould sites, the Percol LT35, which had a significant dosage and cost advantage over the other products in the polymer screening tests, was selected as the most appropriate coagulant for further testing. In the case of the Miben site, both the cationic product-LT35-and the liquid dispersion product-Percol 110L-provided comparative performance. In order to develop some background information on the sensitivity of the 'liquid' anionic product to mixing conditions, optimization for the Miben site concentrated on the liquid dispersion flocculant Percol 110L. The range of dosages applied in each case was based on the optimum dosage established in the initial polymer screening tests.

Polymer efficiency was assessed by measurement of supernatant TSS and turbidity after ten minutes of quiescent settling. The results of the optimization tests were subjected to detailed analysis to establish the effect of each variable on polymer efficiency.

5.5.1 Queenstake

The results of the optimization jar tests to evaluate the effect of flash mixing conditions and polymer dosage on the performance of the cationic coagulant

LT35 at the Queenstake site are summarized in Table 5.13. The volume of wastewater available to conduct these optimization tests was marginal and the volume constraints may have influenced the results. These tests exhausted the Queenstake wastewater sample.

The effects of changing variables from the low level to the high level are summarized in Table 5.14. The data indicate that flash mix conditions had no significant effect on LT35 performance over the range of conditions evaluated. However, polymer dosage did affect significantly the coagulant efficiency.

Increasing the coagulant dosage from 0.5 mg/L to 0.9 mg/L resulted in a significant improvement in supernatant quality, reducing supernatant TSS by 78 mg/L and supernatant turbidity by 117 NTU.

5.5.2 Miben

The results of the optimization jar tests on Miben site wastewater are summarized in Table 5.15. These data were further analyzed, to assess the effect of each single variable on the supernatant quality. (Table 5.16). Replicate jar tests producted perfect duplication of results. Therefore, the effects of all variables is statistically significant with the exception of flash mix speed. However, the measured effect of variable flash mix speed on supernatant quality (± 8 mg/L TSS) is not of sufficient magnitude to be of concern to system design over the range of the variables tested.

5.5.3 Gould

The results of the optimization tests conducted on the Gould site wastewater are summarized in Table 5.17 and analyzed in Table 5.18. The treatability of the Gould wastewater showed little sensitivity to the flash mix conditions over the range of dosages evaluated. For example, the effect of increasing the dosage of LT35 from 0.4 mg/L to 0.8 mg/L only improved supernatant quality by approximately 13 mg/L TSS. Flash mix intensity and time has a lesser impact than polymer dosage.

TABLE 5.13

SUMMARY OF POLYMER OPTIMIZATION TESTS - QUEENSTAKE SITE

Flash Mix Speed (RPM)	Flash Mix Time(s)	LT35 Dosage (mg/L)	TSS (mg/L)	Turbidity (NTU)
50	30	0.9	55	27
100	30	0.5	220	92
50	60	0.5	200	77
100	60	0.9	55	25
75	45	0.7	215	91
75	45	0.7	230	110

TABLE 5.14

ANALYSIS OF POLYMER OPTIMIZATION TESTS - QUEENSTAKE SITE

	Flash Mix RPM	Flash Mix Time (s)	Percol LT35 Dosage (mg/L)
High Level (+)	100	60	0.9
Low Level (-)	50	30	0.5
Optimum Value	50	60	0.9
Effect[1] on Supernatant TSS (mg/L)	+5	-5	-78
Effect[1] on Supernatant Turbidity (NTU)	+13	-17	-117

Note: (1) "Effect" is the change in the dependent variable (TSS or turbidity) resulting from the change in the independent variable from the low level to the high level. A negative effect indicates that the change in the independent variable produced a decrease in the dependent variable.

TABLE 5.15
SUMMARY OF POLYMER OPTIMIZATION
TESTS - MIBEN SITE

Test Conditions			Supernatant Quality	
Flash Mix RPM	Flash Mix Time (s)	110L Dosage (mg/L)	TSS (mg/L)	Turbidity (NTU)
50	30	0.6	45	15
100	30	0.2	60	25
50	60	0.2	45	17
100	60	0.6	30	12
75	45	0.4	40	18
75	45	0.4	40	18

TABLE 5.16
ANALYSIS OF POLYMER OPTIMIZATION
TESTS - MIBEN SITE

	Flash Mix Speed (RPM)	Flash Mix Time (s)	Percol 110L Dosage (mg/L)
High Level (+)	100	60	0.6
Low Level (-)	50	30	0.2
Optimum Value	-	60	0.6
Effect[1] on Supernatant TSS (mg/L)	0	-8	-8
Effect[1] on Supernatant Turbidity (NTU)	+5	-1	-15

Note: (1) "Effect" is the change in the dependent variable (TSS or turbidity) resulting from the change in the independent variable from the low level to the high level. A negative effect indicates that the change in the independent variable produced a decrease in the dependent variable.

TABLE 5.17

SUMMARY OF POLYMER OPTIMIZATION

TESTS - GOULD SITE

Test Conditions			Supernatant Quality	
Flash Mix RPM	Flash Mix Time (s)	LT35 Dosage (mg/L)	TSS (mg/L)	Turbidity (NTU)
50	30	0.8	70	32
100	30	0.4	80	32
50	60	0.4	105	64
100	60	0.8	65	27
75	45	0.6	65	32
75	45	0.6	75	40

TABLE 5.18

ANALYSIS OF POLYMER OPTIMIZATION

TESTS - GOULD SITE

	Flash Mix Speed (RPM)	Flash Mix Time (s)	Percol LT35 Dosage (mg/L)
High Level (+)	100	60	0.8
Low Level (-)	50	30	0.4
Optimum Value	100	30	0.8
Effect[1] on Supernatant TSS (mg/L)	-8	+5	-13
Effect[1] on Supernatant Turbidity (NTU)	-37	+27	-37

Note: (1) "Effect" is the change in the dependent variable (TSS or turbidity) resulting from the change in the independent variable from the low level to the high level. A negative effect indicates that the change in the independent variable produced a decrease in the dependent variable.

5.6 SENSITIVITY TO SUSPENDED SOLIDS CONCENTRATION

The 1984 full-scale demonstration studies had indicated that the suspended solids content of the raw wastewater at the point of polymer addition had a significant impact on polymer efficiency. The data showed that supernatant quality deteriorated significantly as the suspended solids concentration increased and that polymer dosage had to be increased to maintain a consistent supernatant quality as the suspended solids concentration in the raw wastewater increased. The final step in this jar testing projram involved an assessment of the effect of suspended solids concentration on polymer efficiency. Optimum polymer type, dosage and flash mix conditions were applied in each case. These tests could not be conducted on wastewater from the Queenstate site as the optimization tests had exhausted the available sample volume.

The wastewater samples from the Miben and Gould sites for this testing were produced by increasing the volume of paydirt in the paydirt-sluicewater mixture. In the case of Miben, water-to-paydirt ratios of 5:1 and 3.3:1 were used to generate more concentrated raw wastewater samples compared to the 10:1 ratio used in all other testing. Similarly, Gould samples were produced by settling samples at water-to-paydirt ratios of 9:1 and 6:1 compared to the 18:1 ratio used in the rest of the test program.

Results of these jar tests are presented in Figures 5.4 and 5.5. A deterioration in polymer performance was evident at increasing suspended solids concentrations in the Miben sample. However, despite a three-fold decrease in the water-to-paydirt ratio, the addition of 0.6 mg/L of the liquid dispersion anionic flocculant 110L was still adequate to produce a residual TSS concentration of less than 100 mg/L.

On the Gould sample, the liquid cationic product LT35 was relatively unaffected over the range of conditions tested. At all initial TSS concentrations, a dosage of 0.8 mg/L LT35 produced a supernatant containing less than 100 mg/L TSS. It was noted that floc size decreased and sludge volume increased at lower water-to-paydirt ratios.

Stanley

TEST CONDITIONS:

1) DOSAGE 110L = 0.6 mg/L

2) FLASH MIX SPEED 100 RPM, 60 s.

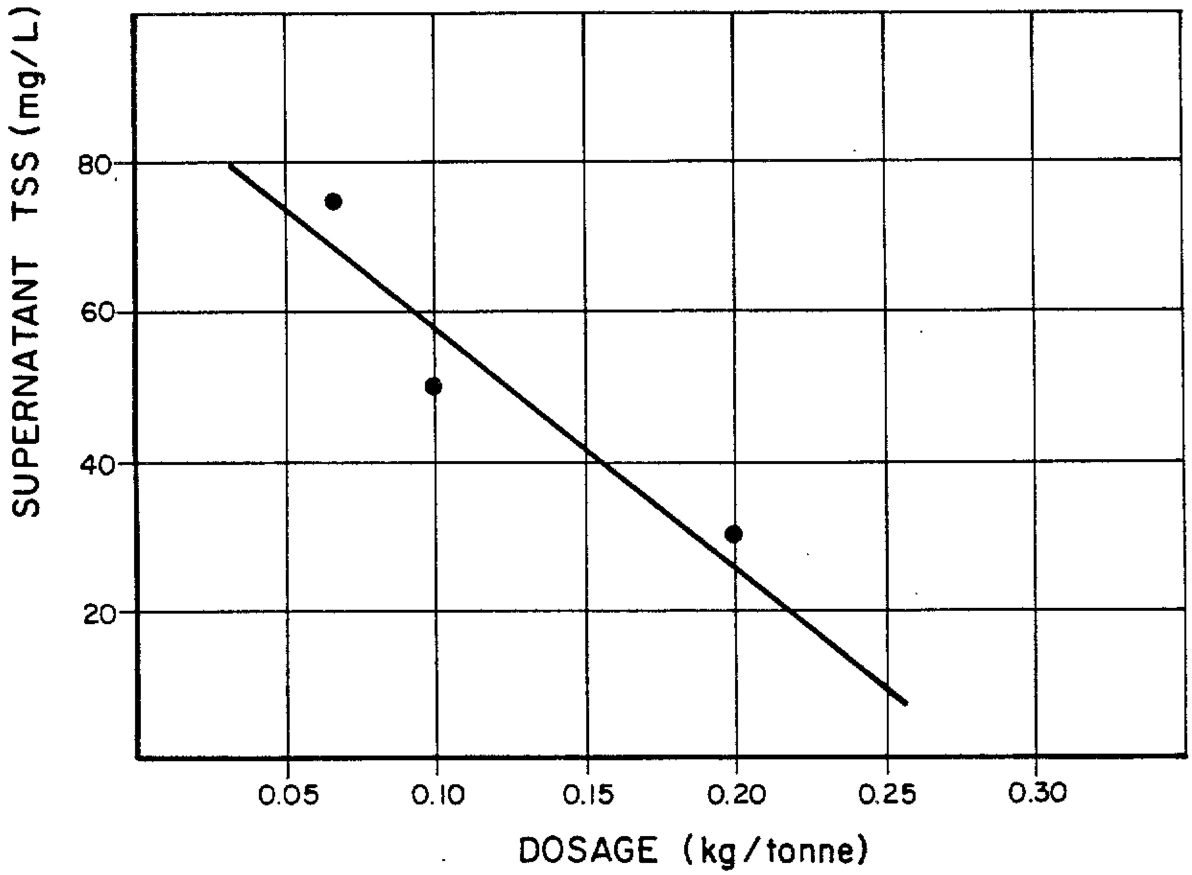


Figure 5.4

SENSITIVITY OF PERCOL 110L TO RAW WASTEWATER TSS CONCENTRATION - MIBEN SITE

TEST CONDITIONS:

1) DOSAGE LT35 = 0.8 mg/L

2) FLASH MIX SPEED
100 RPM, 30 s.

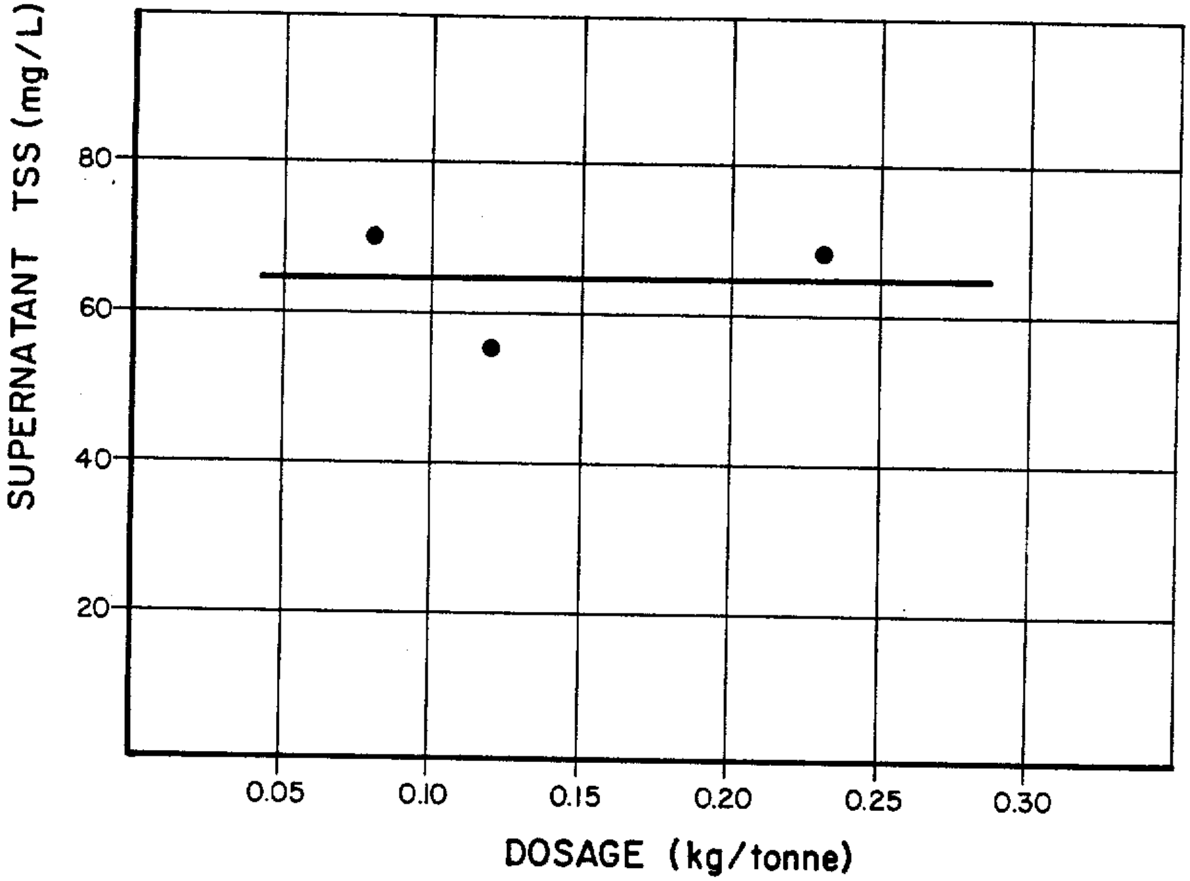


Figure 5.5

SENSITIVITY OF
PEROL LT35 TO RAW WASTEWATER
TSS CONCENTRATION - GOULD SITE

5.7 SUMMARY OF JAR TEST RESULTS

Although solid grade anionic/nonionic products generated the largest, fastest settling floc in all wastewaters evaluated, the liquid cationic products LT35 and D-51181 were consistently the most cost-effective coagulants in terms of the dosage and costs to achieve a supernatant quality of 100 mg/L TSS. Dosage requirements of LT35 ranged from 0.4 to 0.7 mg/L for the three sites evaluated. Dosage requirements for all products evaluated were lowest for the wastewater from the Miben site and highest for the Gould site.

Polymer efficiencies at the Gould and Miben sites were relatively independent of flash mix conditions and polymer dosage. Raw wastewater TSS concentration also had little effect on polymer efficiency. Polymer dosages of less than 1.0 mg/L were capable of maintaining a supernatant TSS concentration of less than 100 mg/L even with significant increases in raw wastewater TSS concentration. Polymer efficiency on the Queenstake wastewater was influenced by polymer dosage but was relatively independent of polymer mixing conditions. Sensitivity to raw wastewater TSS concentration was not evaluated on the Queenstake effluent.

6.0 DEMONSTRATION SITE - CONCEPTUAL DESIGN

6.1 BASIS OF DESIGN

A major study objective was the identification of potential sites for flocculant demonstration projects during the 1986 season and to provide cost estimates to develop such projects. The previous sections in this report include results of the jar tests for three placer mines where an interest has been expressed. This section addresses the adaptation of these existing operations to flocculant demonstration projects.

The following factors were considered in evaluating each site for its suitability and in providing the preliminary design data and cost estimates for each:

1. The waste material handling procedures and storage capacities at each site;

2. The volume of waste likely to be produced in the primary and secondary settling ponds;

3. The existing and potential storage capacities of the primary and secondary settling ponds;

4. Available materials handling procedures for removing settled solids.

5. Suitability of local topography to install a hydraulic mixing structure which relies on a headloss of approximately 1.0 m across the structure;

6. The control of seepage between ponds.

As indicated, the conceptual designs that follow should be considered preliminary for cost estimating and discussion purposes. Final designs will be required in the field to accommodate the 1986 mining plans of the operators.

6.2 JOHN GOULD OPERATION

6.2.1 Background

The existing operation is described in Section 4.4.1. The settling ponds shown in Figure 4.2 were constructed for the 1985 operating season except for Pond 4 which has been operated as a recirculation pond since the 1984 operating season. Ponds 1 and 2 are presently full and current plans include removal of the settled solids by backhoe from these ponds, as well as from Ponds 3 and 4 prior to start-up in 1986.

Mr. Gould plans to sluice for 650 hours in 1986 within the time period starting May 20 and ending September 25. He sluiced for 400 hours in 1985. He anticipates that from 20 May to mid-June, he will have sufficient water from his gravity fed storage reservoir without recirculating. After mid June he will have to recirculate from Pond 4. He has no need to operate the flocculant test program until he starts his recirculation system. As discussed in Section 4.4.1, when he recirculates sluice water, he can only operate five hours a day without the deteriorated water quality affecting his operation. He would like to operate 8 to 10 hours per day and understands that flocculants may enable him to reach this objective.

The mine site does not have sufficient space to provide additional settling ponds or to enlarge the existing ones. Therefore, the flocculant test program would utilize the existing settling ponds. The present operating practice includes the clean out of Pond 1, which contains the coarse tailings, at the start of each day. This daily clean out would continue for the flocculant demonstration project.

6.2.2 Conceptual Design

Figure 4.3 illustrated the particle size distribution for paydirt samples from the Gould site. The following assumptions were used in deriving sludge volume estimates for a demonstration project:

1. All particle sizes greater than fine gravel will settle just below the sluice where they will be removed continuously by a bulldozer or front end loader. This constitutes roughly 20 percent of the total paydirt volume;

2. The sands and silts down to a particle size of 0.01 mm will be settled out prior to the addition of polymer so long as a hydraulic retention time of at least 30 minutes is maintainted in the primary pond(s) (see Table 6.1); this will constitute an estimated 72% by volume of the solids which will be in suspension; and

3. The remaining suspended solids (an estimated 8 percent of the paydirt) will be removed following treatment with polymer.

The proposed operating characteristics at the Gould site for the 1986 mining season are summarized in Table 6.2.

Estimates of the dimensions of the four settling ponds are summarized in Table 6.3. These estimates were derived from measurements taken during the field visit.

TABLE 6.1

RELATIONSHIP BETWEEN PARTICLE SIZE AND PARTICLE SETTLING RATE

(AWWA, 1971)

Particle Diameter (mm)	Particle Description	Settling Rate (mm/s)	Time Required to Settle 0.3 Meters	
10.	Gravel	1,000.	0.3	s
.1	Coarse Sand	100.	3.0	s
0.1	Fine Sand	8.	38.0	s
0.01	Silt	0.154	33.	min
0.001	Clay Upper Limit	0.00154	55.	h
0.0001	Clay	0.0000154	230.	days
0.00001	Colloid	0.000000154	63.	years

TABLE 6.2

SUMMARY OF PROPOSED MINE OPERATION DURING THE 1986 MINING SEASON - GOULD SITE

Parameter	Forecasted Conditions
Paydirt feed rate	42 m^3/hr (55 yd^3/hr)
Sluice water pumping rate	16 m^3/min (3,500 igpm)
Daily Operating Schedule	9 hr/day
Seasonal Operating Schedule	72 days during 1986 with 17 of that total being without effluent recirculation
Total paydirt to be sluiced	27,400 m^3 (35,600 yd^3)
Settling Pond Cleaning Practices	Pond No. 1 cleaned out at the start of each day using front end loader. Ponds 2 through 4 cleaned with a backhoe only as required.

TABLE 6.3

ESTIMATED POND DIMENSIONS - GOULD SITE

Pond	Area (m2 with ft2 in brackets)		Volume Under Clean Conditions[1] (m3 with ft2 in brackets)	
1	460	(5,000)	850	(30,000)
2	1040	(11,250)	2550	(90,000)
3	460	(5,000)	700	(25,000)
4	1380	(15,000)	6400	(225,000)

1 "Clean Conditions" refers to the absence of settled sludges, that is the status of the ponds prior to the onset of sluicing.

As noted earlier, a nominal 30 minute retention time is necessary to achieve gravity settling of all suspended solids above 0.01 mm in size. This will require a minimum primary pond volume of 480 m^3 (17,000 ft^3). In this application, it is more appropriate to apply a safety factor of five to this value to account for hydraulic short-circuiting and for accumulation of sludges. This yields a required primary pond volume of 2400 m^3 (85,000 ft^3). As illustrated by Table 6.3, this requirement can be met by Pond No. 2. There is very little, if any, allowance for storage of sludges, however. In order for Pond No. 2 to operate satisfactorily to remove all particles larger than 0.01 mm, it will have to be cleaned continuously. We estimate that on the basis of sludge production rates, it would have to be cleaned every four or five days.

The jar test results have illustrated that a hydraulic mixing structure similar to that used in the 1984 demonstration project (Stanley 1985) could be utilized to disperse the polymer into the primary pond effluent and to achieve flocculation prior to settling in the secondary pond. This structure would be placed in the berm between Ponds 2 and 3. A head difference of approximately 1.0 m between the two ponds would provide the necessary hydraulic energy for mixing and flocculation. This head loss could be attained simply by raising the liquid level in Ponds 1 and 2.

The jar test results for the Gould site indicated a flocculated solids settling rate of 0.15 mm/s at the optimum polymer dosage. This would require a secondary pond surface area of 1570 m2 (17,000 ft2). As illustrated by Table 6.3, this will require a combination of both Ponds 3 and 4.

The volume of flocculated sludges to be produced during 1986 is estimated to be 3700 m^3 (130,000 ft^3) on the basis of data drom Table 6.2 and Figure 4.3. As noted from Table 6.3, Ponds 3 and 4 should be more than adequate in size, following cleanout, to provide total containment of the flocculated sludges during the 1986 mining season.

In summary, the four existing settling ponds at the Gould site will be cleaned out prior to the start of mining in 1986. These ponds will be sufficient in size to provide the necessary settling of coarse and flocculated solids. Pond 1 serves as temporary storage for coarse gravels which will be removed daily with a front end loader. Pond 2 will function as a primary pond. It will have to be cleaned out on a semi-continuous basis, however. The equipment to do this cleaning is not currently on-site and it would have to be rented or purchased.

The polymer mixing and flocculation chamber could be similar in design to that used in the 1984 demonstration project and described in the Stanley (1985) report. It would be located between Ponds 2 and 3.

Our estimates indicate that Ponds 2 and 3 would be of sufficient size to provide the required settling of flocculated solids. They are also estimated to be of sufficient depth and volume to store all flocculated sludge for the 1986 mining season. Cost estimates for a demonstration project at the Gould site are presented in Section 6.5

6.3 QUEENSTAKE OPERATION

6.3.1 Background

A description of the Queenstake mine operation is contained in Section 4.4.2. The company plans to continue operating as it did in 1985, with the objective of sluicing 120,000 yd.^{3} of pay gravel during 1986.

6.3.2 Conceptual Design

Since we were not able to collect samples of the Queenstake paydirt, gran size distribution tests could not be performed. Because of the similarity in appearance of the Queenstake and Gould paydirts and the proximity of their pay zones, we utilized the Gould particle size distributions (Figure 4.3) for our analysis. A layout of the Queenstake mine was illustrated in Figure 4.4.

The following assumptions were used in deriving sludge volume estimates for a demonstration project:

1. All solids greater than 1.25 mm (0.5 in) in size (an estimated 15 percent by volume of the paydirt) are discharged up the stacker belt;

2. All solids smaller than 1.25 m^3 (0.5 in) but larger than a No. 100 sieve size (all gravel and most sand fractions) will be settled in the drainage channel below the trommel and then removed continuously with a front end loader; this constitutes an estimated 45 percent by volume of the paydirt;

3. The remaining sands and silts down to a particle size of 0.01 mm will be settled out prior to the addition of polymer so long as a hydraulic retention time of at least 30 minutes is maintained in the primary pond; these solids will comprise an estimated 20% by volume of the paydirt; and

4. The remaining suspended solids (an estimated 10 percent of the paydirt) will be removed following treatment with polymer.

The forecasted operating conditions at the Queenstake site for the 1986 mining season are summarized in Table 6.4. Estimates of the dimensions of the drainage channel and settling ponds are summarized in Table 6.5.

In order to provide for unaided gravity settling of all suspended solids of greater than 0.01 mm in size, a hydraulic retention time of 30 minutes is required in the primary pond. In the case of the Queenstake mine, therefore, the pond volume will need to be a minimum of 120 m^3 (4100 ft^3). Pond No. 1 has an estimated volume of 1360 m^3 (48,040 ft^3). In the clean condition, it will be quite adequate as a primary pond. The continuous use of the dragline should ensure that this pond functions adequately throughout the 1986 mining season.

A similar hydraulic mixing structure as that proposed for the Gould site could be used at the Queenstake site to disperse the polymer into the primary pond effluent and to achieve flocculation. This structure would be placed in the berm between Ponds 1 and 2. A head difference of 1.0 m between the two ponds could be attained simply by raising the liquid level in Pond No. 1 and in the drainage channel below the tormmel.

The jar test results for the Queenstake site indicated a flocculated solids settling rate of 0.21 mm/s at the optimum polymer dosage. This would require a secondary pond having a surface area of 320 m^2 (3,500 ft^2). The total estimated flocculated sludge volume to be produced duirng the 1986 mining season is 16,400 m^3 (580,000 ft^3). As illustrated in Table 6.5, the total combined volume of Ponds 2 and 3 is 23,360 m^3. It is therefore apparent that if both ponds are in a relatively clean condition at the start of the season, they should have adequate storage volume to contain all the flocculated sludges produced in the 1986 mining season.

TABLE 6.4
SUMMARY OF PROPOSED MINE OPERATIONS DURING THE 1986 MINING SEASON - OUEENSTAKE SITE

Parameter	Forecasted Conditions
Paydirt feed rate	76 m3/hr (100 yd3/hr)
Sluice water pumping rate	4 m3/min (850 igpm)
Daily operating schedule	15 hr/dav
Seasonal operating schedule	80 days during 1986
Total paydirt to be sluiced during 1986	91,000 m3 (120,000 yd3)
Settling pond cleaning practices	1) Drainage channel cleaned by front end loader. 2) Pond No. 1 cleaned daily with the dragline.

TABLE 6.5
ESTIMATED POND DIMENSIONS - OUEENSTAKE SITE

Pond	Area (m2 with ft2 in brackets)		Volume Under Clean Conditions[1] (m3 with ft2 in brackets)	
Drainage Channel	240	(2,600)	220	(7,720)
1	570	(6,120)	1360	(48,040)
2	1940	(20,950)	7160	(252,700)
3	3520	(38,020)	16,200	(571,600)

During the latter stages of the 1985 season, Queenstake operators used two sludge pumps to transfer settled sludges from Pond No. 3 to the sludge settling pond (refer to Figure 4.4). As an alternative to cleaning out Ponds 2 and 3 prior to seasonal start-up, it may be possible to use a combination of dredging and sludge pumping in Pond 2 to remove sludges on a continuous basis. The floating sludge pumps could be strategically placed at the end of the flocculation zone where most of the solids settling is likely to occur.

In summary, the Queenstake site appears to be easily adaptable to a flocculant demonstration project. If cleaned out prior to start of the 1986 mining season, the existing ponds will be quite adequate to provide the necessary settling times for suspended solids removal. The drainage channel will function to remove gravels and sands while most particles larger than 0.01 mm will settle in Pond 1. The addition of polymer to the effluent from Pond 1 should provide for the removal of most solids in Pond 2 with carryover to Pond 3 as sludges begin to accumulate. Pond 1 will be cleaned continuously with the drag line. Ponds 2 and 3 are sufficiently large to provide seasonal storage of flocculated sludges. An alternative is to use the existing sludge pumps and/or dragline to remove the sludges from Pond 2 as they are produced.

Cost estimates for a demonstration project at the Queenstake site are presented in Section 6.5.

6.4 MIBEN MINING

6.4.1 Background

The Miben mine was described earlier in Section 4.2.3 and illustrated in Figure 4.5. Sluice water is pumped directly from a settling pond on Hunker Creek, approximately 100 m below the benched area being mined. There is no available space to construct settling ponds on the upper bench without interfering with the mine area. Sluice water is discharged into the drainage channel. Settling ponds could be constructed by building berms or dykes across the drainage channel. The drainage channel is in the bottom of a wide gully.

6.4.2 Conceptual Design

Because there is no suitable equipment on site to provide continuous cleaning of ponds, both the primary and secondary ponds would have to be sized to provide total containment of all sludges for two more years of operation - the expected life of the mine at the current location. Our estimates indicate that this would require a primary pond volume of 119,000 m3 (700,000 ft3). These estimates were derived from paydirt characteristics (Figure 4.6) and mine operating plans for 1986 and 1987 (Section 4.2.3).

On the basis of limited available site topographic information, we have estimated that this would require the construction of a high dam below the drainage channel and a minimum dyke length of 215 m (650 ft) for a primary pond and 99 m (300 ft) for the secondary pond.

The costs to complete this construction cannot be justified, particularly since it provides only a two year settling pond capacity. It is apparent, therefore, that the current practice of using the settling ponds adjacent to Hunker Creek is still the most feasible system even with the large pumping horsepower requirements. While a polymer-aided flocculation would provide for more efficient removal of suspended solids, sludge storage constraints overrule any potential benefits.

6.5 DEMONSTRATION PROJECT COST ESTIMATES

The previous sections have described the implementation of flocculant demonstration projects at each of the three sites. The results indicate that both the Gould and Queenstake sites could be readily utilized with minor site modifications. Operation at the Gould site would require the continuous clean-out of Pond 2. The Miben site does not appear to be suitable for a demonstration project because of the extensive site modifications which would be required to construct and operate new ponds. No further consideration has been given, therefore, to a demonstration project at that site.

Tables 6.6 and 6.7 summarize field cost estimates for demonstration projects at the Gould and Queenstake sites. Activities and items included are those which would not normally be incurred at those sites if a flocculant demonstration project was not implemented. The following unit prices were used in the estimates:

1. Backhoe or dragline rental costs of $150/hr including an operator;
2. Bulldozer costs of $80/hour including an operator;
3. Polymer cost of $2.50/kg;
4. Operating labour rate of $40/hr including expenses.

The labour costs were estimated on the basis of minimum actual time required at each site. The results indicate that the field costs for implementation of flocculant demonstration projects would be relatively modest for either site. Pond cleanout costs at the Gould site are the major factor contributing to a higher cost at that site.

TABLE 6.6

ESTIMATED FIELD COSTS FOR FLOCCULANT DEMONSTRATION PROJECT AT GOULD SITE - 1986 MINING SEASON

Item	Cost Estimate
Site Modifications	$ 5,000
Polymer Feed Equipment	2,000
Construction and installation of hydraulic mixing structure	4,000
Semi-Continuous Cleanout of Pond 2	43,000
Chemical flocculants @ 8.6 kg/day	800
Operating and monitoring labour for flocculation system @ 3.0 hr/day	9,000
Total Estimated Field Costs	$63,800

TABLE 6.7

ESTIMATED FIELD COSTS FOR FLOCCULANT DEMONSTRATION PROJECT AT QUEENSTAKE SITE - 1986 MINING SEASON

Item	Cost Estimate
Site Modifications	$ 5,000
Polymer feed equipment	2,000
Construction and installation of hydraulic mixing structure	4,000
Chemical flocculants @ 1.8 kg/day	500
Operating and monitoring labour for flocculation system @ 3 hr/day	10,000
Total Estimated Field Costs	$21,500

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

1. A list of 32 placer mining operations in the Klondike gold fields were identified as potential candidates for a flocculant demonstration project. Nine of these were visited in the field and telephone interviews were conducted with an additional 11 operators. Five operators have indicated an interest in such a project. Effluent, sluice water and paydirt samples were collected from three of these in order to conduct jar tests.

2. Jar tests were conducted on actual sluice water effluent from the Queenstake mine and on simulated effluents from the Gould and Miben mines. Eleven polymers were evaluated for their suitability. Four distinct types of polymers were included: solid grade polyacrylamides, liquid dispersion polymers, emulsion polymers and liquid grade cationic polymers.

3. The solid grade polymers which were evaluated - Percol 155 and Percol 351 - produced floc characteristics which were similar to those observed at the Airgold site in 1984. The flocs formed very quickly and were very dense, thereby settling rapidly.

4. At the Queenstake site the two cationic polymers - Percol LT35 and Alkafloc D-51181 were the most cost effective polymers. In comparison to the solid grade polymers, however, they produced a smaller, slower settling floc. The same was true of the liquid grade anionic polymers tested. A combination of the optimum cationic flocculant (LT 35) with the optimum liquid dispersion (110L) did not improve floc characteristics.

5. At the Miben site the same two liquid cationic polymers were the most cost effective chemicals. They were only marginally more cost effective than the emulsion/dispersion flocculants - Percol 110L and 120L. As was the case at the Queenstake site, the cationic polymers produced the smallest and slowest settling floc particles.

6. At the Gould site, the cationic polymer, Percol LT35, had a significant dosage and cost advantage over all other polymers tested. As with the other two sites, however, floc quality was poor relative to that produced by the solid grade anionic polymers. A combination of cationic polymer (LT35) with the emulsion anionic polymer (EA-533) improved floc size and settling rates.

7. Polymer optimization tests indicated that flash mix conditions had little effect on polymer performance over the range of dosages applied. At the Queenstake and Miben sites, changes in polymer concentration had significant effects on suspended solids removal while on the Gould sample the effect was marginal.

8. Jar test evaluations at various suspended solids levels in the raw wastewater indicated that the dosage requirements for Percol LT35 on the Gould wastewater were relatively unaffected by high TSS levels. While there was a deterioration in the performance of the liquid anioni (Percol 110L) on the Miben wastewater at elevated TSS concentratior only incremental increases in polymer concentration were needed maintain effluent quality.

7.2 RECOMMENDATIONS

1. Both the Gould and Queenstake sites would be suitable for flocculant demonstration projects during the 1986 mining season. Both are currently recirculating some of their sluice water. They could therefore, derive some direct benefits from such a project. Both sites would be suitable for evaluation of either liquid cationic polymers or emulsion/dispersion polymers. In either case, the direct field costs associated with a demonstration project a fairly modest.

2. Two additional operators - Art Fry of King Solomon Mines and Gary Crawford of Sigma Properties - have indicated an interest in hosting

flocculant demonstration projects. Discussions should be held with these operators and jar tests performed at the start of the 1986 mining season. The suitability of each could then be evaluated using the procedures followed in this study.

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