R. C. CLOUGH
FEASIBILITY REPORTS
WINGDAM AND LIGHTNING CREEK
MINING COMPANY LTD. (N. P. L.)

ROUGH DRAFT OF

FEASIBILITY REPORT

FOR

TESTING AND REHABILITATION, MELVIN MINE, WINGDAM, B.C.

R. C. CLOUGH ENGINEERING LTD.

1264 West Pender Street,

Vancouver 1, B.C. MU 4-5518

INDEX

WINGDAM PROPERTY (FEASIBILITY STUDY)

SCOPE

This report is a study of the feasibility of using some modern construction techniques to assist in rehabilitating the placer mines at Wingdam on Lightning Creek.

A combination of these new techniques together with variations of established mining methods appears to hold very favourable chances of ocercoming the problems previously encountered at Wingdam and which led to its ultimate closure by the Department of Mines in 1938.

Since the mine cannot be reopened without approval from the Inspector of Mines, discussions of the proposed methods have been held with Mr. J.E. Merrett and Mr. A.R.C. James of the Department of Mines. These two gentlemen appeared to consider the proposals as being quite sound and wish to be kept fully informed of results of the test program outlined herein.

INTRODUCTION

This report is prepared at the request of The Wingdam Syndicate which has a lease and option on Placer Mining Leases 5819 and 5820 (consisting of 160 acres, more or less) in the Cariboo District of British Columbia.

Much of the data on which this report is based is the previous recorded history of the property as viewed by many eminent and worthy engineers who were fully conversant with the problems.

The writers have not personally visited the ground at the time of writing this report, but in the event that the test program is inaugurated would wish to fully supervise the field work.

LOCATION

The property is situated near Wingdam on Lightning Creek in the Cariboo District. Its location is about 32 miles east of Quesnel on the main Barkerville Road. Quesnel is about 440 road miles from Vancouver, and is serviced by the Pacific Great Eastern Railway and the Cariboo Highway. An improved, two-lane gravel highway provides access to Wingdam and Barkerville.

HISTORY

The history of this property is well documented in the work of previous engineers and needs no reiteration at this time.

It is sufficient to note that the majority of reports, both written and oral, indicate rich underground deposits on these properties. Extensive efforts have been made over the last 60 years to extract the values at Wingdam, the most promising being in the years 1936, 1937 and 1938.

During this period a deep shaft was sunk in bedrock and a main lead driven for over a mile in solid rock below the old stream-bed.

In March, 1938 a sudden inrush of "slum" into a raise near the Melvin shaft rapidly developed into a "cave" reaching the surface. The waters of Lightning Creek then completely flooded the workings and eventually filled the "cave" with gravel.

As a consequence the Department of Mines has not permitted re-opening of this mine using usual mining methods.

GEOLOGY

The geology of this property is also well documented in previous works, particularly the Geological Survey Report of 1933.

Generally, there is a trough or "gutter", varying in width from 40 to 140 feet, which has been cut into the bedrock in the geologic past.

This gutter has been filled to a depth of approximately 165 feet with highly varied strata of different materials as shown on Sketch No. 1 which is a typical cross-section of the conditions uncovered by drilling.

The glacial "slum" immediately above bedrock and at other zones is a completely saturated mixture of sand and silt with particle size capable of passing a #200 mesh sieve.

The gold occurs as dust to nuggets and is generally coarse in nature.

PROBLEM

The problem presented for consideration at this time is to evaluate three construction techniques which may be applied in order to rehabilitate the Melvin shaft and its workings.

Whichever method is selected must satisfy the Department of Mines as to its ability to stabilize the troublesome "slum" and to allow mining to proceed in a perfectly safe manner.

The three methods to be considered are:-

(1) Cement grouting.

(2) Freezing.

(3) Chemical grouting.

A further alternative is to use combinations of these methods as circumstances arising in the field might dictate.

CHOICE

The principal factors affecting the choice of a suitable technique are as follows:-

(a) Safety.

(b) Cost.

(c) Speed.

(d) Ease of recovering values.

The end result is, of course, safe and economical recovery of the values from the auriferous strata.

TECHNIQUES

A review of the methods of applying each technique will assist in a full understanding of their effects.

1. Cement Grouting

In this method, holes are drilled into the area which it is desired to stabilize. Casing may be set to shut off areas not requiring attention.

A grout of cement and fine sand is then pumped under pressure into the stratum. The grout tends to fill the voids existing between the particles of the stratum and as a result, when the cement sets, there is a solidified mass of ground surrounding the drill hole.

The shape and size of the cemented mass are a function of the permeability of the stratum and the pumping pressure.

In order to completely cement a large area a suitable number and pattern of holes are required.

2. Freezing

Here, large holes, usually about 8", are sunk to the desired depth. Into the holes are inserted double pipes consisting of a large pipe closed at the bottom and a smaller pipe placed inside the larger.

The required number of holes for the complete frozen curtain must be drilled and pipes set in all holes. The small pipes are then connected to a common supply header and the larger pipes to a common return header.

Chilled brine from a refrigeration plant is then circulated down the central pipe and returns up the annular space inside the outer pipe and back to be re-chilled.

In this manner, heat is removed from the ground water and freezing commences from the bottom, upwards to the surface and also radially in all directions. Complete freezing may take from 10 to 50 days.

3. Chemical Grouting

The technique used is similar to that for cement grouting.

After casing is set, pumping tests are conducted with water to determine the rate at which the stratum will accept the grout.

The grout itself is a two-part solution. The two parts are pumped separately and combined at the point of injection.

Initially the viscosity is the same as water and hence the grout is able to penetrate wherever water will go.

At a given time after combining the two solutions a catalytic reaction occurs and the whole mass turns into a stiff gel.

The proportions of the two solutions may be varied to give setting times of from 15 seconds to 2 hours. Hence rapid repair of faults is possible.

It should be noted that two particular chemical grouts are considered here, namely, sodium silicate grout and Cyanamid's AM-9 grout.

MERITS AND LIMITATIONS

Each of the proposed methods has advantages and limitations as follows:

1. Cement Grouting:

The grouted mass is a solidly cemented block of material, and if sufficient cement is used, it would be capable of carrying heavy loads.

If proper techniques are followed, a "curtain" or wall impervious to water can be constructed.

Material cost is moderately high depending on the amount of cement used to establish a satisfactory seal.

Once grouted, the ground may be considered to be permanently solid. Hence recovery of values from the cemented mass is difficult.

MERITS AND LIMITATIONS (cont'd)

2. Freezing:

The frozen mass resulting from use of this method has high compressive strength and normally would be capable of resisting heavy loads.

Using correct spacing of the freezing pipes, (about 4 feet centers), a fully frozen "curtain" or wall may be produced.

Material cost is moderate, but power cost is a continuing factor as the ground must be maintained in a frozen state until all work is completed.

Recovery of values from mined frozen ground presents no problems, the heat of the hand being sufficient to cause a small lump to revert to "slum".

The presence of flowing water would probably render this system completely useless and highly hazardous.

MERITS AND LIMITATIONS (cont'd)

3. Chemical Grouting:

The properly grouted mass is found to have all voids filled with the gel. A significant increase in strength is obtained and moderate load-carrying capacity is realized.

Properly applied, a stiff but resilient gel curtain impervious to water may be established.

Material cost is likely to be highest of the three systems, but closer control of setting time may result in smaller total quantity. Extenders such as bentonite, cement, and sawdust may be added.

Results obtainable in silty materials are superior to those using sand-cement grout.

The stabilized soil mass below the water table has been known to retain its properties for at least six years. There is no reason to expect degradation with additional time.

Recovery of values is not expected to prove difficult.

On the contrary, the gelled mass may discourage pilfering.

COMPARATIVE MERITS

The following table will assist in assessing the relationships of the three systems and the four basic criteria affecting the choice.

	1. Cement Grout	2. Freezing	3. Chemical Grout Sod. Sil.	AM.9
(a) Safety	10	6	8	9
(b) Cost	9	7	9	6
(c) Speed	6	1	7	9
(d) Ease of recovering values	2	10	6	6
Total Rating	27	24	30	30

Ratings:

10 Excellent

9 Very good

8

7 Good

6 Fairly good

5 Fair

4 Fairly poor

3 Poor

2

1 Very poor

COMPARATIVE MERITS (cont'd)

From this table the choice of method favours the chemical grouting system with cement grouting a close second.

Because of the highly variable nature of the ground to be worked, it appears reasonable to assume that both methods may be employed where circumstances dictate it.

In actual operation it may well be that the combination of the two methods will prove superior to either one separately.

PROPOSED PROGRAM

Whilst the selection of a method of operation which has proven satisfactory elsewhere is usually a safe procedure, it is highly desirable that sufficient tests be carried out on the actual ground in order to verify results.

Similarly, a properly laid-out test program is able to accommodate variations from expected results while still pursuing the main objective.

In this case the main objective is to prove to the satisfaction of all concerned that the application of chemical grouting techniques, (possibly supplemented by cement grouting) is capable of stabilizing the glacial "slum" to such an extent that the Department of Mines will permit the Wingdam properties to be re-opened.

PROPOSED PROGRAM (cont'd)

A rational program capable of satisfying all requirements would be as follows:

STAGE ONE

(1) Sink a suitable group of test holes into an area known from previous drill-tests to contain the slum in its undisturbed form. This would be probably on the "C" or "D" line of test-holes. However, detailed examination of the mine records should be made before final placement is decided upon.

(2) Casing should be set from the surface to the known depth of the upper limits of the slum.

(3) Pumping tests using water with the addition of a suitable dye to determine the rate at which the area will accept grout and also the probable extent of penetration.

(4) Following determination of the pumping rate and probable penetration, the proper relationship between the two solutions comprising the grout is established.

(5) The two solutions are then pumped at a controlled rate through separate lines to the injection point where they are combined prior to entering the strata.

PROPOSED PROGRAM (cont'd)

(6) After sufficient time for the catalytic action to be completed, cores should be recovered for examination and appraisal of the results. At this stage, the District Inspector of Mines should be permitted access to the results and core samples in order that he may be completely satisfied as to the success of the treatment.

(7) The next step is to obtain written authority from the Department of Mines that the use of this system would be permitted in the rehabilitation of the Wingdam Property.

PROPOSED PROGRAM (cont'd)

STAGE TWO

This first stage program is an essential pre-requisite to the second stage which is the rehabilitation of the old Melvin shaft and workings.

It is reasonable to assume that at the time of the cave-in, a considerable quantity of slum and gravel was carried down the raise and into the main tunnel, in all probability the raise and tunnel being completely filled at this point.

The general plan for stage two follows these broad general lines:-

1. Seal off troublesome areas by grouting from the the surface.
2. De-water shaft and workings up to points of seal-off.
3. Reduce hydro-static head by pumping.
4. Divert Lightning Creek if necessary.
5. Place new safety bulkheads on all accessible raises.
6. "Raise" into gutter under protection of grouted "dome" ahead of operations.
7. Continue mining under protection of grouted roof and square set timbering.

PROPOSED PROGRAM (cont'd)

In greater detail the proposed program would be as follows:

1. Previous experience has shown that attempts to drain the general area by pumping have always led to trouble with "caving" due to removing fines in suspension in the water.

   Therefore, before attempting to de-water the shaft and tunnel, it is essential that uncontrolled entry of water be stopped.

   The criterion here being, to disturb the ground as little as possible in order to avoid the formation of "caves" with the attendant uncontrollable movement of surrounding ground.

   Using the old mine records, a careful surface plot of the workings should be made to determine:

   (a) the place where the "cave-in" occurred, that is, "the No. 1 Raise Downstream".

   (b) the position of the "No. 1 Raise Upstream".

   Once these two areas are accurately plotted, a sufficient number of holes should be drilled from the surface into the raises and tunnel to allow grout seals to be injected at these two points.

   The objective here is to isolate the shaft and immediate sections of the tunnel from the remainder of the workings, to allow them to be completely drained and rehabilitated.

PROPOSED PROGRAM (cont'd)

2. The actual de-watering of the shaft and tunnel should not be commenced until a thorough examination has been made of the shaft collar down to bedrock.

   This may be accomplished by a "frogman" but an alternative and perhaps safer method would be to use underwater closed-circuit television equipped with floodlights.

   This apparatus can be used to check conditions right down to the bottom of the shaft; a depth of water sufficient to cause discomfort to frogmen.

   Providing no unforeseen difficulties are encountered, de-watering may then proceed using deep-well turbine pumps of adequate capacity.

   It would appear desirable to have not less than two pumps each capable of handling at least 1,000 g.p.m. from a depth of 280 feet.

3. Past practice has been to reduce the hydro static pressure existing in the stratum by providing drain holes from the tunnel into the "gutter" and by pumping out the water thus drained. However, chemical grouting offers a new tool which may assist in tackling this problem differently.

   The formation of a grouted dome or roof over the areas being worked should be effective in preventing the slum from running. From there on it is principally a matter of using mining methods suitable for soft non-running ground.

PROPOSED PROGRAM (cont'd)

Loads to be carried by timbering should be no more severe than normally encountered in soft ground of this equivalent depth. However, should this proposal be ineffective, the opportunity of de-watering by draining and pumping will still remain, and this operation will be greatly assisted by the judicious use of grouting techniques.

4. The diversion of Lightning Creek away from the working area by use of a flume has been strongly advocated in the past. This proposal has many merits if the practice of draining and pumping is followed.
   However, should the use of a grouted roof prove effective, there would probably be no necessity to disturb Lightning Creek.

5. Once the de-watering of the shaft and tunnel has been accomplished, prudence requires the immediate installation of safety bulkheads on all accessible raises and at suitable intervals in the main drive.
   Inspection of the mine records may show sufficient information to allow steel doors, etc., to be fabricated ahead of time so that no unnecessary delay is encountered.

PROPOSED PROGRAM (cont'd)

6. Following the successful rehabilitation of the shaft and tunnels, re-entering the "gutter" should not be too difficult. With confidence established in the grouting techniques, holes should be drilled from the raise and grout injected to form a "dome" of gelled material completely protecting the area of break-through.

   Again, prudence requires careful testing of each stage of this first attempt.

   Presuming a successful entry, the job of timbering and making secure is routine.

7. The construction of a suitable drift along the floor of the gutter should follow normal practice except that grout injections are required to stabilize the ground ahead and around the drift as it advances.

   Once again the criterion is to disturb the ground as little as possible by keeping all workings to the smallest possible size and fully timbered up to the working face. Thus any tendency of the ground to move may be controlled.

   It must be strongly emphasized that this phase of the operations MUST be closely supervised and directed by a competent mining engineer.

SUMMARY

1. Existing, well documented cases support the belief that chemical gel grouting will probably be successful in stabilizing the slum encountered on this property.
2. In order to prove this to the satisfaction of the Inspectors of the Department of Mines an adequate test program is first necessary.
3. If tests are successful then written authority from the Department of Mines should be obtained.
4. The known areas of cave-in should be sealed off by grouting.
5. The shaft and tunnels should be de-watered and rehabilitated.
6. All workings should be rendered "safe".
7. Mining and recovery of values should be commenced under protection of grouted roof and adequate timbering.
8. Should costs of production exceed $26.00 per ounce governmental subsidies should be obtained.

(Note: The costs of the chemical grouting around the drift appear to be chargeable as an expense of production.)

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May 10, 1961

Wingdam & Lightning Creek Mining Co. Ltd.
204-569 Howe Street
VANCOUVER 1, B. C.

Dear Sirs: <u>Feasibility Report on Wingdam Property</u>

This report is a summary of studies of the feasibility of utilizing modern construction techniques to make possible the rehabilitation of the placer workings at Lightning Creek in the Barkerville area, British Columbia.

A combination of these new techniques together with variations of established mining methods appears to create favorable possibilities of overcoming the problems previously encountered at Wingdam, and which led to its ultimate closure by the Department of Mines in 1938.

<u>LOCATION</u>

The property is situated near Wingdam on Lightning Creek in the Cariboo District. Its location is about 32 miles east of Quesnel on the main Barkerville Road. Quesnel is about 440 road miles from Vancouver, and is serviced by the Pacific Great Eastern Railway and the Cariboo Highway. An improved, two lane gravel highway provides access to Wingdam and Barkerville.

<u>HISTORY</u>

The history of this property is well documented in the work of previous engineers and needs no reiteration at this time.

It is sufficient to note that the majority of reports, both written and oral, indicate rich underground deposits on these properties. Extensive efforts have been made over the last 60 years to extract the values at Wingdam, the most promising being in the years 1936, 1937 and 1938.

During this period a deep shaft was sunk in bedrock and a main lead driven for over a mile in solid rock below the old stream-bed.

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PROBLEM

The problem presented for consideration at this time is to evaluate three construction techniques which may be applied in order to rehabilitate the Melvin shaft and its workings.

Whichever method is selected must satisfy the Department of Mines as to its ability to stabilize the troublesome "slum" and to allow mining to proceed in a perfectly safe manner.

The three methods to be considered are:-

(1) Cement grouting

(2) Freezing

(3) Chemical grouting.

A further alternative is to use combinations of these methods as circumstances arising in the field might dictate.

We have given careful consideration to the three available methods and the final analysis, based on safety, cost, speed, recovering values, points to chemical grouting techniques similar to cement grouting. Possibly this system is described as follows:

After casing is set, pumping tests are conducted with water to determine the rate at which the stratum will accept the grout.

The grout itself is a two-part solution. The two parts are pumped separately and combined at the point of injection.

Initially the viscosity is the same as water and hence the grout is able to penetrate wherever water will go.

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It should be noted that two particular chemical grouts are considered here, namely, sodium silicate grout and Cyanamid's AM-9 grout.

The merits of chemical grouting are as follows:

The properly grouted mass is found to have all voids filled with the gel. A significant increase in strength is obtained and moderate load-carrying capacity is realized.

Properly applied, a stiff but resilient gel curtain impervious to water may be established.

Material cost is likely to be highest of the three systems, but closer control of setting time may result in smaller total quantity.

Extenders such as bentonite, cement, and sawdust may be added. Results obtainable in silty materials are superior to those using sand-cement grout.

The stabilized soil mass below the water table has been known to retain its properties for at least six years. There is no reason to expect degradation with additional time.

Recovery of values is not expected to prove difficult.

On the contrary, the gelled mass may discourage pilfering.

It is proposed that testwork be carried out in the "slum" area to prove the function of the various grouts and their behavior in the slum area. This is described in our report of October, 1960 and is briefly summarized as:

A rational program capable of satisfying all requirements would be as follows:

STAGE ONE

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<u>STAGE TWO</u>

This first stage program is an essential pre-requisite to the second stage which is the rehabilitation of the old Melvin shaft and workings.

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5. Place new safety bulkheads on all accessible raises.
6. "Raise" into gutter under protection of grouted "dome" ahead of operations.
7. Continue mining under protection of grouted roof and square set timbering.

With the data obtained during this grouting test program, decisions can be made as to the method that could be employed to exploit the placer deposit.

It may be interesting to note the success that has already been achieved using the grouting system to provide "curtains" in river sediments. Quoting from Engineering News-Record, May 4,1961,

"MORE ON ASWAN

Sir--I have read the article on the Aswan High Dam (ENR Feb.23, p.32) with great interest and found it quite informative and adequate. I would only call attention to the fact that an upstream clay-concrete blanket is still included in the design as shown on the cross section on p. 36. Thus, no elimination of the upstream blanket is intended and there will continue to be two lines of defense against leakage--the blanket and the vertical cutoff.

It is also fitting to note that in the original design, made by the group of international consultants, the width, up and downstream, was fixed at 1257.5 meters. After this design was submitted a grout curtain in river sediments to a depth of 150 meters was successfully installed under the Mission Dam in Canada. Equally successful was the grout curtain made across the river sediments beneath the Serre Poncon Dam in France, as the article stated. Encouraged by the efficient performance of these grout curtains, the original designers recommended a substantial shortening of the width of the base to 1007.5 meters, as shown on the drawing, and agreed to move the axis of the dam upstream toward the entrance of the diversion channel to gain a reduction in the length of this channel.

Hassan Zaky
President,
Sadd-el-Aali Executive Organisation
Cairo, Egypt. "

While the projects described are of greater magnitude, the performance of the system has proven itself. It is hoped that a similar result be experienced with the Wingdam tests.

Arrangements have been completed this date for drilling, grouting and core recovery contracts, and for laboratory facilities for the testing of the soil samples and grouted sediments. Your office will be kept fully informed of our daily progress together with results. The mobilized equipment and crews, it is expected, will be in operation within ten days.

Yours very truly

R. C. CLOUGH ENGINEERING LTD.

Per:

"HARVEY COHEN"

P. ENG., M.C.I.M.

(SEAL)